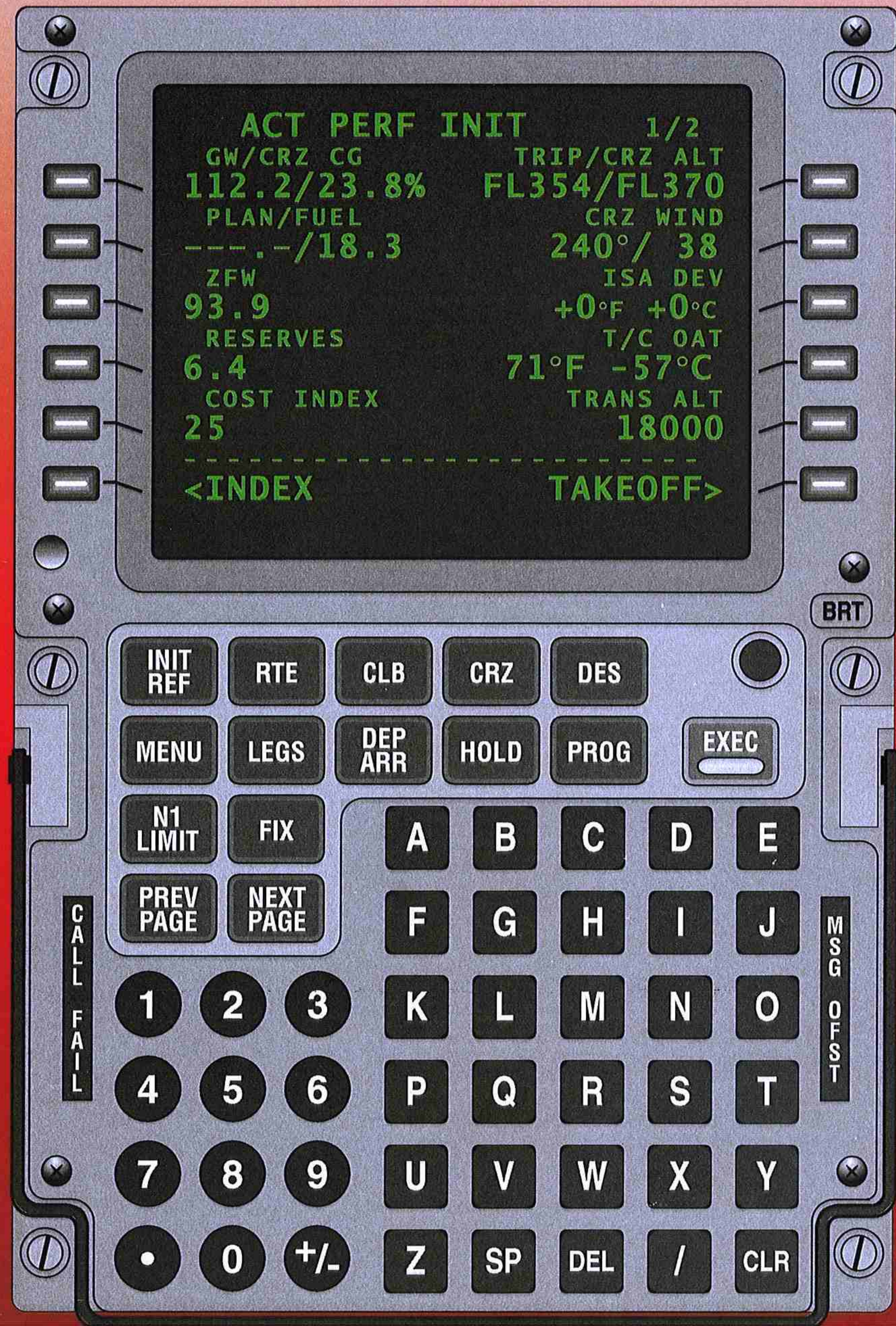
737

FMC USER'S GUIDE

Advanced Guide to the 737 Flight Management Computer



737 FMC GUIDE CONTENTS

Let's skip the haughty phrases normally reserved for book introductions and get right to the point. This manual is about improving your piloting skills through the integration of the Flight Management Computer.

The FMC User's Guide is a collection of data from many sources, including the factory and airline manuals, training material, instructors, line pilots like yourself, and others.

This manual is written for the pilot who has already acquired basic skills of FMC operation.

The guide will be updated by the issuance of revisions. Revisions are necessary to keep up with industry procedures, hardware and software development, to add techniques as I learn them, and to correct mistakes. Send in the registration card so you will be placed in my database. You can also check my web site for revision information. Please ensure that I have your current address so that I may send a notice when the next revision is available. A small fee will be required to keep you manual up to date. I encourage the use of e-mail as it will help to keep my long distance phone bill down.

The Smiths FMC, installed in all Boeing 737-300s through 800s, has been used by the author in preparing this manual.

Here is a word of caution to those operating the Honeywell FMC, used in the Airbus, the F-100, MD-11, and all Big Boeings. These Honeywell FMCs come in two base lines, due to different kickoff customers. I call them the Boeing and the European baselines. The Boeing baseline of Honeywell is quite similar to the Boeing baseline of Smiths. Much of the information in this manual does pertain to the B-757 / 767, the B747-400, and the B777, but many differences do exist. I recommend the BIG BOEING FMC USER'S GUIDE we now produce for users of this equipment.

The Honeywell European baseline (found on the MD-11, Fokker, and Airbus) is quite different and no attempt is made at this time to cover these computers.

The 737 FMC USER'S GUIDE is designed to be used as a reference and as a supplement to the operator's publications. If any suggestions herein conflict with approved procedures in your airplane flight manual, our company's procedures, or the manufacturer's pilot guides, these other sources shall take precedence over these contents.

Due to the variable content and ongoing revisions of each operator's customized navigation database, these page displays are only intended to provide a general description of overall systems capability. They do not necessarily reflect customized data of the specific operator, nor are they intended to reflect valid navigation or performance data.

The layout is such that information is presented in a fashion that is readily available. It is organized by Mode Key sequence. This sequence approximates the chronological use of the FMC during a typical flight. For a quick reference, use the index in the back of the book.

Although thoroughly researched, the information in this handbook is subject to change after publication. I welcome your suggestions for improvements and invite you to send me your real time experiences to include herein. This will tap the experience of may pilots and will be passed on to all revision subscribers. This is a very educational experience.

HISTORY OF LEAR SIEGLER

The Flight Management Computer in the Boeing 737 family is manufactured by the Smith Industries, SLI Avionics Systems Corporation in Grand Rapids, Michigan. The company has quite an interesting history. The FMC is probably not the first instrument you've used from this group.

In 1930, William P. Lear formed a company in Chicago he called Lear Wuerful, Inc. Its first industrial contribution was an automobile radio he invented.

The next year the company name was changed to Lear Development, Inc. and introduced a low-cost light weight aircraft radio transceiver called the Magic Brain. By 1935, the company was almost entirely engaged in design, development, and manufacture of airborne radio transceivers and direction finding equipment, including the Lear-O-Scope radio direction finder.

During WW II, Lear engineers developed the Fastop electromagnetic clutch for accurately stopping devices operated by high speed electric motors. These mechanisms were used in landing gear assemblies on every B-24 and B-29 built.

The Learmatic Navigator, an instrument providing a pilot with straight-track navigation using any radio station available was introduced in 1940 and won Bill Lear the Frank M. Hawks Memorial Award.

During the war, the company was building linear and rotary actuators, power units, and automatic and remote electrical controls.

The headquarters were moved to Grand Rapids in 1945.

In 1950, Bill Lear was awarded the Collier Trophy for the development of the Auto Flight Control System for the F-5. (The Collier Trophy is an annual award for the greatest achievement in aviation in America. Glen Curtis was awarded the first in 1912 by the Aero Club of America for his flying boat.)

By 1958, production of the Flight Director-Attitude Indicator and All-Attitude Two-Gyro Master Reference System for the USAF's Integrated Panel cockpit display established Lear as the USA's first production supplier of this type of equipment for the military.

In 1962, Lear and Siegler Corp of Illinois announced a merger - Lear Siegler. From 1969 through the seventies, the Instrument Division placed a lot of equipment into space: a camera on Gordon Cooper's spacecraft, the pilot's ADI and other instruments on the Gemini program, instruments on the Apollo spacecraft (lunar and command module). LSI had produced the DG for the lunar rover that operated on the moon in 1970. The computer systems moved from the space program to the B 747 in 1970, followed by the Performance Data Computer System (1982), the digital flight control system for the F-15E (1985), weapons management system for the F-14D Tomcat (1985) and the Self-contained Navigation System for the Air Force's C-130 (1985).

Smiths was founded in 1851 by Samuel Smith (1827-1875). The son of a potato merchant, he was a watch and clockmaker, and started his first shop in Newington Causeway, South London, near the Elephant & Castle, "an area crowded with shops interspersed with several splendid gin palaces". The business prospered and expanded under the founder's son, Samuel, Jr (eldest of twelve). In 1871 the business was moved to The Strand. In 1882 additional branches were opened in Piccadilly and Trafalgar Square.

It is not surprising that the skills of watch makers were considered appropriate to the requirements of the emerging motor industry, even though speed limits were as low as 12 mph. Allen Gordon-Smith, Sam Jr.'s fifth child and manager of the Piccadilly shop, joined the pioneers as one of the people credited with the invention of the mileometer. King Edward VII asked, "Why can't you make an instrument to show the speed I am traveling, as well as the distance?" The outcome was the first British speedometer, installed in King Edward's 18/28 hp Mercedes. Three years and several speedometers later, the company was granted a Royal Warrant. By 1908, sales of Smiths Perfect Speedometers exceeded 100 per week. The Goldenlyte headlamp business was acquired and also the car lighting and starting business of Trier and Martin in 1913.

In 1911, a Blackburn B1, equipped with a Smiths tachometer, was the first aircraft to fly with a Smiths instrument.

S. Smith & Sons (Motor Accessories) Ltd., became a public company in 1914. The use of wristwatches grew during W.W.I; the company also made 'tankometers', kite balloon wind indicators, shell fuses, wire rope, lighting sets, signalling lamps, and KLG spark plugs. In 1917, they acquired an airspeed indicator invented by Holcomb Clift, using an oilskin diaphragm. This product became the recognized standard indicator of its day. Such an instrument was fitted to the record-breaking Vickers Vimy bomber in which Alcock and Brown made their historic crossing of the Atlantic in 1919.

The company successfully weathered the depression years of the early twenties.

In 1927, Smiths gained controlling interest in Jaeger Ltd., a speedometer maker, plus Robinhood Engineering Works Ltd. Apparently though, Sir Allen's first love was clock making, to which he devoted himself. In 1928 he formed the All British Escapement Co., Ltd. Previously, all these items had been imported from Switzerland. This proved useful during W.W. II. The clock side of the business was further boosted in 1931 with the introduction of the first synchronous electric clock.

In 1929, Smiths Aircraft Instruments was formed, though Smiths was already supplying instruments and accessories to many manufacturers including the victorious Schneider Trophy airplanes.

Product expansion included the first electrical fuel gauge in 1932, followed by electrical thermometers and oil pressure gauges.

In 1931, Smiths acquired a pneumatic autopilot from Henry Hughes & Son Ltd., marine engineers. The first Smiths autopilot was produced in 1933.

By 1936 the Smiths Desynn System of remote indication became standard equipment on practically every British-built aircraft. Sir Allen headed a team of eight executives who visited the U.S. to conduct a comprehensive survey of American techniques in aviation instrumentation. It is possible that he met Bill Lear. As a result, Smiths acquired a license from Bendix for the production in Britain of aviation instruments, including the altimeter.

With W.W.II imminent, the company moved out of the London area to Bishops Cleeve, Cheltenham. Sir Allen left the company to work in the government's Ministry of Aircraft Production. He returned in 1945 and began to expand, forming Radiomobile Ltd to manufacture car radios. An electric auto-pilot was introduced in 1947. Sir Allen died in 1951.

By 1961 motor accessories still dominated; every one of the one million Morris Minors produced up to that time had Smiths instrumentation.

Smiths' first Boeing contract was for 160 machmeters for the 727. In 1964, the Trident became the first civil airliner to land in fog under fully automatic control with visibility no more that 50 meters - equipped with an autopilot from Smiths.

The last fifteen years has seen the gradual decline and disappearance of the once great automotive and time keeping businesses and the emergence of new electronically based high-technology businesses. The most dramatic has been the appearance of concepts such as the all glass flight deck and other computer-aided systems.

The clock factory was closed in 1979 and the distribution business closed in 1983, severing its link with the company's origins.

In 1983, the automotive group was sold to Lucas Industries, a long time competitor.

Smiths established a U.S. operation in 1958, but it was not until the acquisition of the Instrument and Avionics Systems Division of Lear Siegler, Inc. in 1987 that the U.S. operations took on the importance that they have today.

As B737 pilots, we're linked to destiny through Smiths indicators such as the airspeed, altimeter, fuel, flap, and engine instruments, the clock, and the A/T system.

Principles of FMC (and Autoflight) operation, as viewed by your authors. If the following concepts conflict with your company SOP, then your company SOP must prevail.

1. One pilot always flies the airplane. Sounds obvious, but it is surprising how often both pilots will have their heads down during an FMC modification.
2. Think of the FMC as your "electronic flight bag". Most (but not all) of the information you need in flight can be retrieved from the FMC.
3. Understand the advantages of glass. Performance and navigation are more accurate. Although it takes a few minutes more to preflight the automation and enter the flight plan, many routine operations in flight are easier, quicker and more accurate. Analog flight instruments are expensive to repair. It's cheaper to replace a CRT or LCD.
4. Independent verification is required if initial position is entered by latitude and longitude. This means that the other pilot (either pilot can make the initial entry) independently verifies the initial position using a separate source document. In international operations crossing into East longitudes or the Equator, use caution and avoid transposing E for W or N for S. One pilot does not read the latitude and longitude to the other pilot! It is the authors' opinion that a database entry of the Airport Reference Point is safer to use than a manually entered gate position.
5. If departure time is sneaking up on you, and you don't have time to key the entire route, then don't. Load enough waypoints to get your airplane to TOC and to a point where you will have enough time to load the remainder of the route. After all, rope-start airplanes with INS could only load 9 waypoints at a time. Oh, yes. We like to anchor the end of a partial route with the ICAO four letter identifier of the destination airport. That lets the FMC take a wag at the fuel score until you have time to feed it better information. The ICAO airport will be automatically replaced with the appropriate arrival and runway when you enter it.
6. Use extra time to enter the most complete information into the FMC. On very short flights, there is little practical reason to enter several enroute winds. On long range flights, forecast winds play an important role in fuel predictions. Entering the most likely arrival path, runway and speeds will enable the FMC to most accurately predict time and fuel at destination. Also, entry of the destination runway will permit modifications to be made at the end of the flight plan that do not affect the fuel score.
7. Appreciate the speed and accuracy of the FMC, but be prepared for glitches.
8. At some point during the descent, only the most necessary FMC entries are made. This point may vary, and is the subject of lively debate among standardization weenies. They will advocate points anywhere from TOD to the traffic pattern. Our view is that when you get busy, that's the time to spend less time with the FMC. That point might be TOD at ORD, but 5,000 feet at DSM. At that point, airplane control is changed to LVL CH and HDG SEL when the path and track deviate from that which is programmed in the FMC.
9. Know your airplane and verify FMC calculations. Every number displayed by the FMC should pass your test of reasonableness.
10. The airplane can be operated safely on raw data, just like a 727.
11. If you'reoperating non-GPS equipment, recognize situations where the possibility of map shift exists. Remote areas served by a single VOR, or multiple VORs located close together qualify. Operations over or in the vicinity of the former USSR, North Korea or China are candidates for extra caution, also.
12. If time is critical in flight and one of the pilots is new to glass, it is prudent that the best qualified pilot make the FMC modification. It is important that new captains recognize this and manage their cockpits accordingly. When the urgency has passed, the pilot who made the modification should thoroughly explain the keystrokes used to make the change.
13. Think of Vertical Speed as "Very Special". With the exception of three specific situations, some mode of autoflight other than V/S is probably more appropriate.
14. This is a book about the Flight Management System, but because it is inexorably linked to Autoflight, we would be remiss in not mentioning one more thing. There will be times that the FMC and Autoflight are not appropriate to the situation, and the safest way to operate the airplane is to disconnect the magic and handfly it. Examples of this might be in reacting to a TCAS warning to avoid a potential collision, to side-step to an adjacent runway or to stop your climb in response to an urgent request on the part of ATC.

15. Anytime a crew makes an entry into the FMC that has the potential of changing the flight path, the other crew should be invited to confirm prior to execution. If only one pilot receives a clearance or makes a CDU entry and executes it, the other pilot may be unaware of why the airplane starts a maneuver or the FMS changes modes.
16. Even though the HSI Map is no more accurate than the updated FMC position, we recommend both pilots fly in Map. If in an area that is suspect of inaccurate navaids, occasionally check your FMC position against raw data, but return to the Map mode. This is easily done if flying on an airway. GPS input will solve this problem.
    1) The pilot must understand completely the concept of "Real vs. FMC" position.
    2) The pilot must be proficient in verifying FMC position. Page 4.10 describes one technique. Even on domestic flights, every time you got an IRS NAV ONLY or VERIFY POSITION message, do a quick position check.
    3) This should be a simulator training item during transition; or at least a specific demonstration during IOE.
    4) In the event that map shift is observed, both pilots should change to raw data.
    5) During terrain-critical approaches, one pilot must monitor raw data not later than the Initial Approach Fix (IAF) or the equivalent point. In all cases, one pilot must monitor raw data inside the Final Approach Fix (FAF).

    The author recognizes that the SOP of some airlines require that one pilot monitor raw data under certain circumstances. These typically include high terrain and areas of suspected inaccurate updating.

    The disadvantages to this procedure include:
    1) The possibility of diminished situational awareness on the part of the pilot monitoring raw data.
    2) Difficulty on the part of the pilot monitoring raw data to assess and verify modifications to the route.
    3) Reduced ability to recognize an along-track map shift in a timely manner.
    4) Potential for less-than-optimum FMC updating on some airplanes.
17. Automation should only be a supplement to a pilot's airmanship and not a substitute; automation is only the means to an end. Unfortunately, this philosophy is not always taught and the excessive emphasis on automation can result in the loss of basic flying skills.

    Norm Komich

CONVENTIONS

The *FMC USER'S GUIDE* employs the following conventions to make it easier for you to learn useful information without slogging through a lot of words.

CAUTION

Action that may damage equipment, delay a flight, or cause some other undesireable outcome.

TECHNIQUE

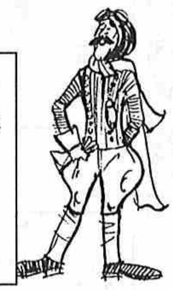
Information considered "technique" will be in this special box. "Technique" is presented for your consideration only. In some cases it may not be an approved procedure for your operation. It is presented for your education, usually to demonstrate capabilities of the FMCS.

U3.0 & up

Specific software will be provided in this special box. The title defines the particular update(U).

CHECKAIRMEN ONLY

Demonstration to be carried out by an instructor pilot or a person familiar and comfortable with the equipment.
If the procedure goes against company precedures, of course company procedures take precedence.



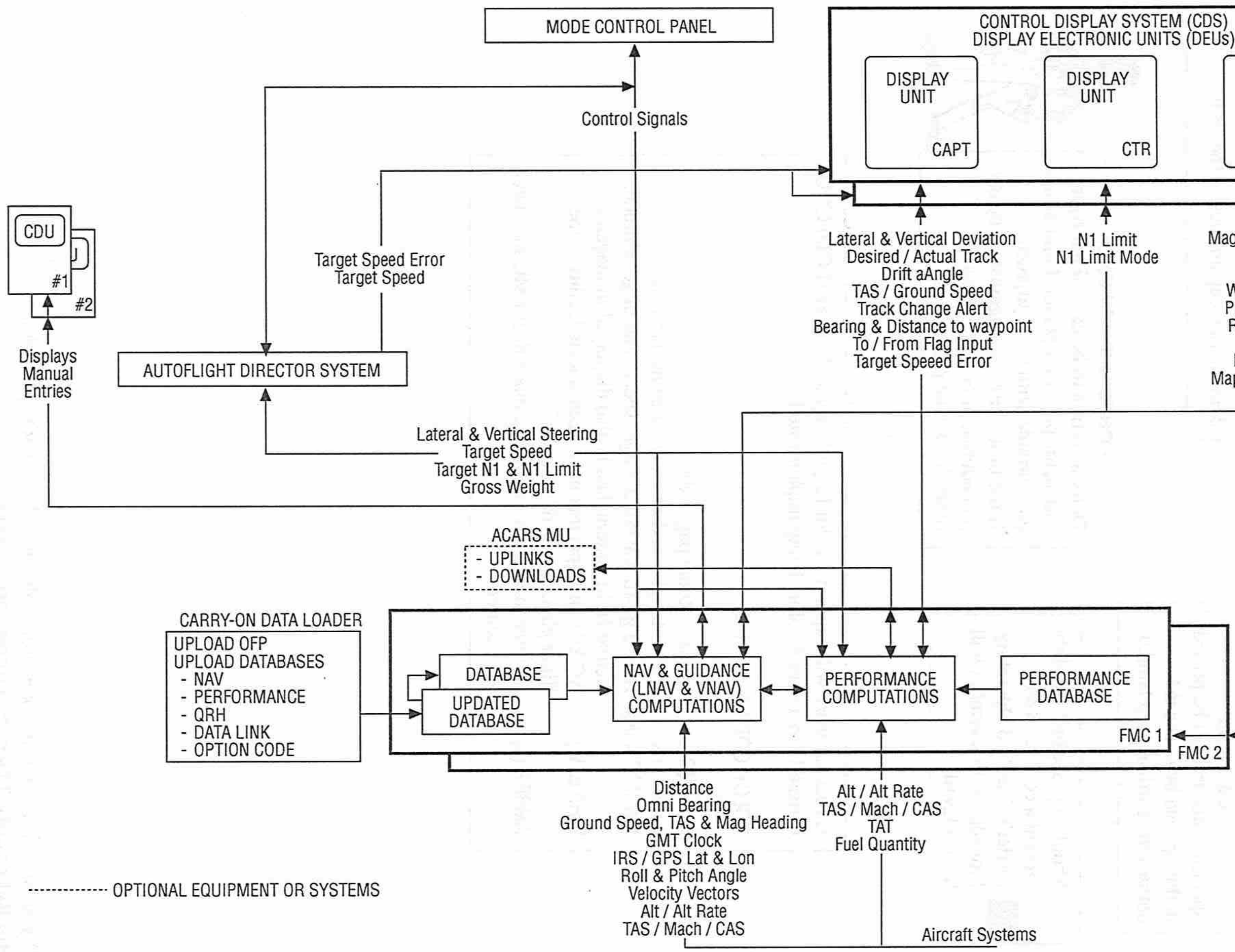
S Should a procedure possibly present a conflict with a carrier's Standard Operating Procedures, this symbol will be displayed.

U10.2 software will support a color Liquid Crystal Display (LCD) CDU. Currently there are 5 colors being implemented:

COLOR CODING OF TEXT

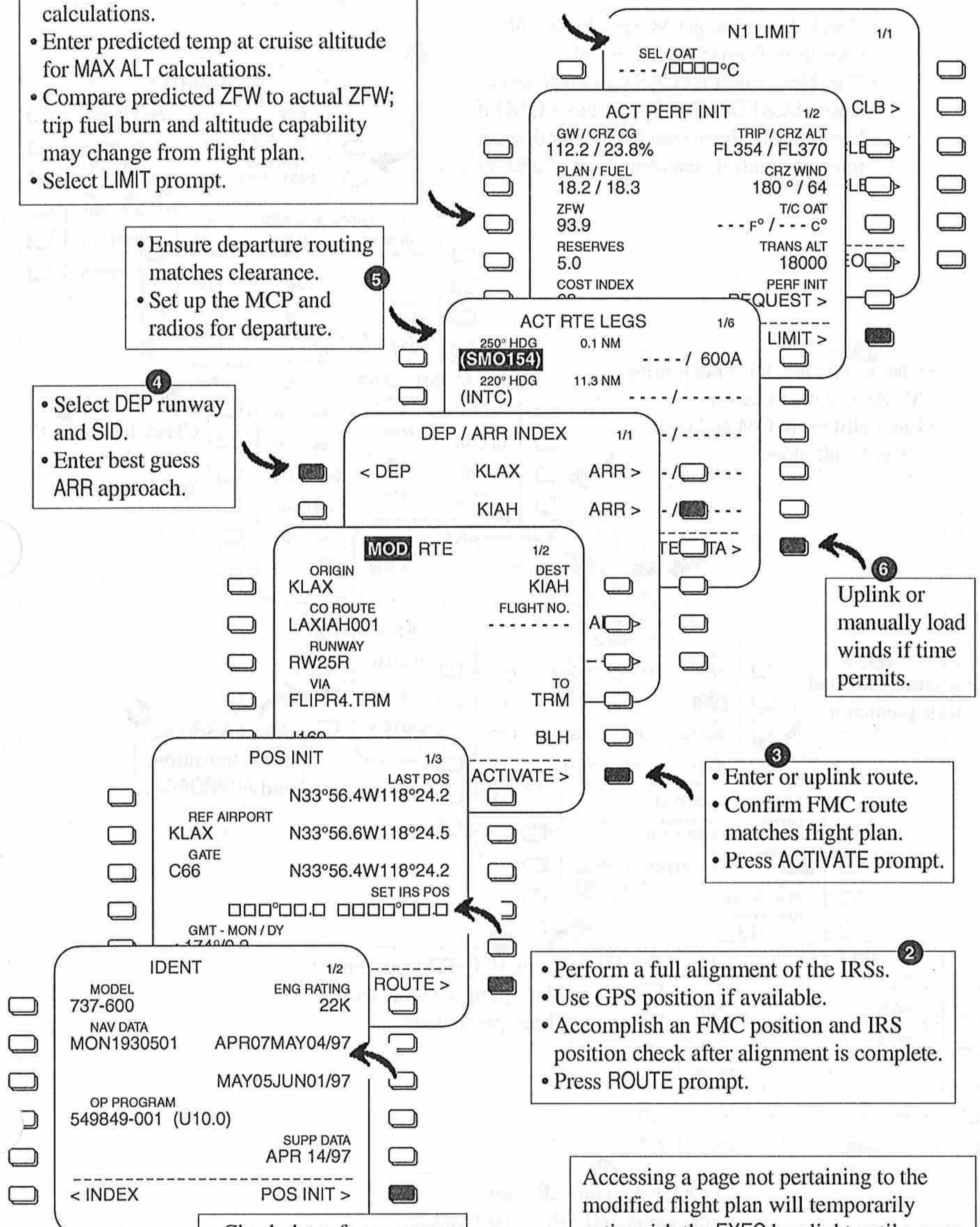
CYAN (C)	Inactive Route page titles.
GREEN (G)	Active toggles and actively tuned navaid data.
MAGENTA (M)	Active go-to waypoint, target speed, and target altitude. Active Hold pattern data is also displayed in magenta.
WHITE (W)	ACARS prompts that have been selected, edits to the flight plan, cruise altitude, etc.
AMBER (A)	Maintenance pages to indicate that a dual FMC mismatch has occured.

If you have questions or suggestions, please call. E-mail is preferred.
Bill Bulfer <bbulfer@firstnethou.com>


MODE CONTROL PANEL
CONTROL DISPLAY SYSTEM (CDS)
DISPLAY ELECTRONIC UNITS (DEUs)
DISPLAY UNIT
CAPT
DISPLAY UNIT
CTR
Control Signals
CDU
#1
#2
Displays
Manual
Entries
Target Speed Error
Target Speed
AUTOFLIGHT DIRECTOR SYSTEM
Lateral & Vertical Deviation
Desired / Actual Track
Drift aAngle
TAS / Ground Speed
Track Change Alert
Bearing & Distance to waypoint
To / From Flag Input
Target Speeed Error
N1 Limit
N1 Limit Mode
Lateral & Vertical Steering
Target Speed
Target N1 & N1 Limit
Gross Weight
ACARS MU
- UPLINKS
- DOWNLOADS
CARRY-ON DATA LOADER
UPLOAD OFP
UPLOAD DATABASES
- NAV
- PERFORMANCE
- QRH
- DATA LINK
- OPTION CODE
DATABASE
UPDATED
DATABASE
NAV & GUIDANCE
(LNAV & VNAV)
COMPUTATIONS
PERFORMANCE
COMPUTATIONS
PERFORMANCE
DATABASE
FMC 1
FMC 2
Distance
Omni Bearing
Ground Speed, TAS & Mag Heading
GMT Clock
IRS / GPS Lat & Lon
Roll & Pitch Angle
Velocity Vectors
Alt / Alt Rate
TAS / Mach / CAS
Alt / Alt Rate
TAS / Mach / CAS
TAT
Fuel Quantity
Aircraft Systems
------------- OPTIONAL EQUIPMENT OR SYSTEMS

CONDENSED PREFLIGHT

The purpose of this page is to give the pilot an overview of the preflight process of the FMC. This page takes the pilot up to the runway for takeoff.



1
- Check dates for currency; interchange if necessary.
- Check software version.
- Press POS INIT prompt.

2
- Perform a full alignment of the IRSs.
- Use GPS position if available.
- Accomplish an FMC position and IRS position check after alignment is complete.
- Press ROUTE prompt.

3
- Enter or uplink route.
- Confirm FMC route matches flight plan.
- Press ACTIVATE prompt.

4
- Select DEP runway and SID.
- Enter best guess ARR approach.

5
- Ensure departure routing matches clearance.
- Set up the MCP and radios for departure.

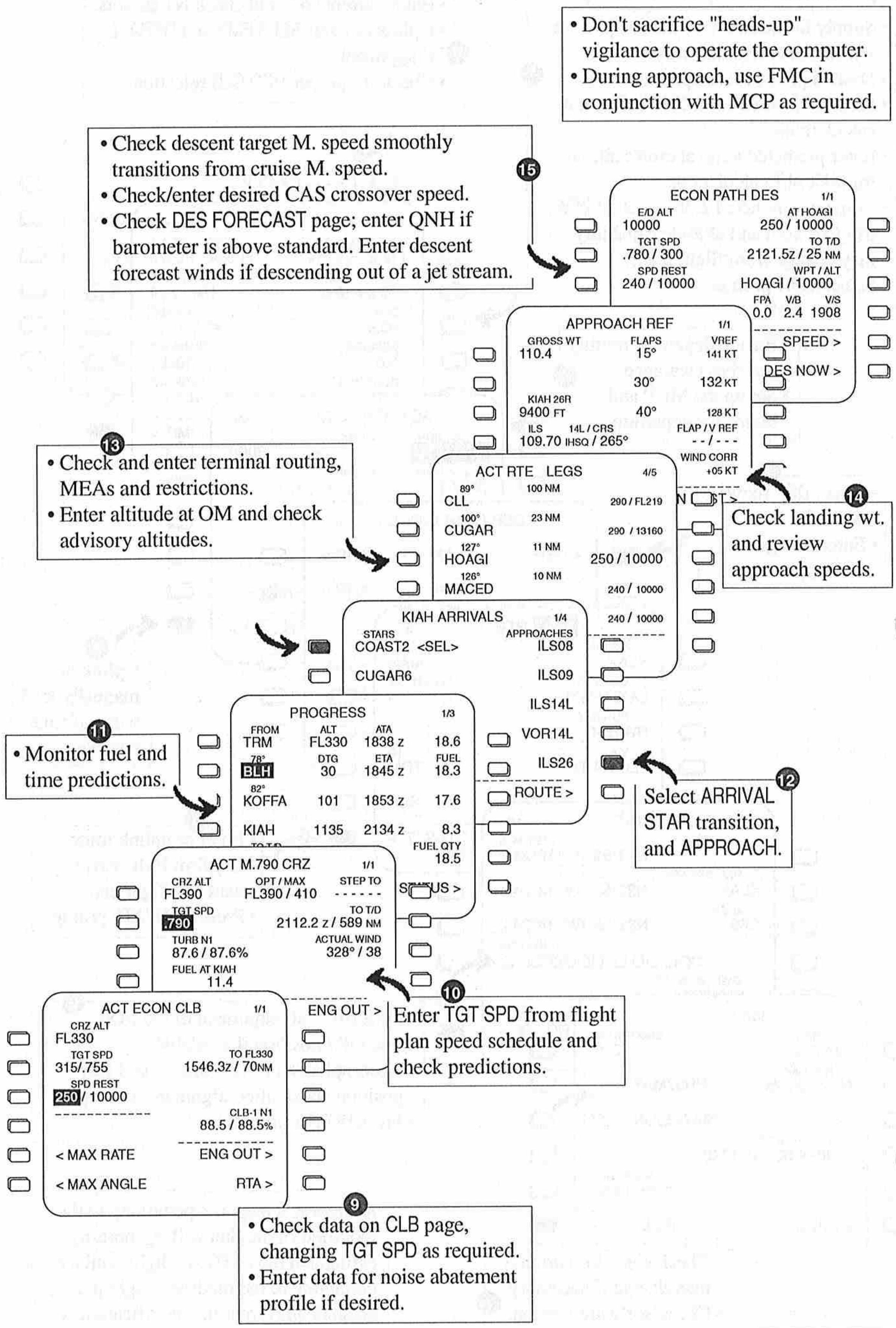
6
Uplink or manually load winds if time permits.

7
- Supply information for all box prompts via uplink or manual entry.
- Dashed prompts are optional.
- Enter CRZ WIND for ECON CLB speed calculations.
- Enter predicted temp at cruise altitude for MAX ALT calculations.
- Compare predicted ZFW to actual ZFW; trip fuel burn and altitude capability may change from flight plan.
- Select LIMIT prompt.

8
- Enter current OAT and check N1 cursors.
- Uplink or enter SEL TEMP and DERATE if applicable.
- Check for proper RED CLB selection.

Accessing a page not pertaining to the modified flight plan will temporarily extinguish the EXEC key light until a page pertaining to the modified flight plan is again displayed or the modification is erased or confirmed on the other CDU.

The purpose of this page is to give the pilot an overview of the enroute process of the FMC. This page takes the pilot from climb to approach.



The Flight Management Computer (FMC) in the Boeing 737 has been developed from the Lear Siegler (LS-54) family of processors. There are four basic models; the smaller the number preceding the Modular Concept Unit (MCU), the smaller the box.

2904A series.
U1.x software base. 8 MCU non EFIS.
2904D series.
U3, U4, U5, or U6 software base. 8 MCU.
2904F series.
U4, U5, or U6 software base. 8 MCU.
2907A series.
U7/8/10 software base. Dual/4 MCU.

A byte is the smallest discrete memory unit which a microprocessor can handle. A *word* is generally the largest discrete unit that a microprocessor can handle *efficiently*. The unit of measure for the database is 16-bit words. On the Motorola 68x family of processors, a *word* is two bytes. A *long-word* is four bytes. 1 meg is 1024 words.

The FMC and the CDU make up the 737 Flight Management Computer System (FMCS).

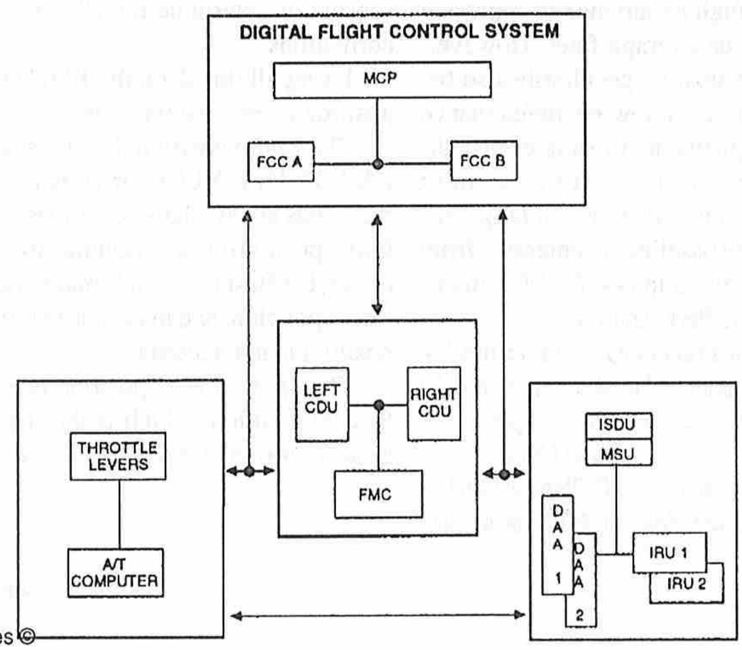
It is convenient to think of the FMC as an electronic Operations Manual. This is a simplification, for the FMC furnishes a great deal more information than can be obtained from the Ops Manual. The cost optimum speed schedules used in climb, cruise, and descent are an excellent example. This is the essential difference between the FMC and a conventional area nav system.

The Flight Management Computer and Control Display Units (FMC/CDU) provide the pilots with a flight management tool which performs navigational and performance computations. Computations related to lateral navigation include items such as courses to be flown, ETA's, and distances-to-go. Route segments may be flown as Great Circle tracks between flight-planned waypoints, as constant heading legs, or as published airways, depending on flight plan criteria. For vertical navigation, computations include items such as fuel-burn data and optimum speeds and altitudes.

In addition, the FMC also provides control and guidance commands which can be coupled to the Autopilot/Flight Director System (AFDS) and Autothrottle (A/T). This allows integrated FMS operation with automatic lateral and vertical navigation. In this way, the FMC unburdens the crew from many routine system integration tasks and allows them to concentrate upon management of the flight.

The crew may select any degree of automation desired. This can mean simply using the CDU for reference during manual flight, or using conventional autopilot functions, or selecting full FMS operation with automatic flight path guidance and performance control.

The basic system configuration consists of a Flight Management Computer and one Control Display Unit. Some installations of the FMCS may include two CDUs, one for each pilot, and an alternate navigation system, called the Alternate Navigation Control/Display Unit (ANCDU). The ANCDU operates independently of any other CDU. It can be used as a standard CDU in a non-nav mode for crew inputs only, to provide an alternate independent source of navigation for cross-checking other systems, or with the FMC inop, the ANCDU can be used to provide back-up IRS navigation by providing lateral guidance information to the (E)HSIs and autopilot.



The FMC storage is made up of three types of memory: erasable programmable read-only memory (EPROM), nonvolatile random access memory (NV RAM), and high-speed volatile random access memory (HS RAM).

Power for the NV RAM memory is provided by the computer power supply whenever power is applied to the FMC. When power is removed, the memory elements are switched to a low-power standby state specially designed for data retention. Power for the standby mode is provided by an internal solid-state dry lithium battery.

The FMC contains storage space for two data bases; they are the Navigation database, of which the Temporary database is a part, and the Performance database.

The Navigation database is stored in the NV RAM memory and in two parts: a main body of active data that is effective until a specified expiration date, and a set of data revisions for the next period of effectivity.

Nav database suppliers as of June 2001 are Jeppesen Sanderson, Swissair, Thales Avionics (Racal), LIDO GmbH, SAS, and NIMA.

The Performance database has the average model of the aircraft and the engines.

The average aircraft model includes high speed drag polars, a buffet limit envelope, certified operating limits, and speed and altitude capability of engine out.

This model is used during computations of fuel flow, thrust, engine limits and target values, and for corrections for the effects of air-conditioning and anti-icing bleeds. Thrust targets for turbulence penetration are also provided for crew advisory.

The aerodynamic and engine models used as the performance database for the FMCS represent the average, in-service model of the 737. This data is from aircraft design information and flight tests and have been shown through experience to represent the characteristics of the average fleet. However, each aircraft may have its own peculiarities so the FMC contains provisions allowing maintenance personnel to make adjustments to suite each individual aircraft. Factors which adjust the aircraft's drag and fuel flow modeling data over a range of -9.9% to +9.9% from the baseline are enterable from the CDU. They are retained in NV RAM memory for continued use. (Ref: Perf Factors)

The Loadable Defaults function provides a mechanism for the carrier to prepare and load a customized list of default parameters. Typical default examples are:

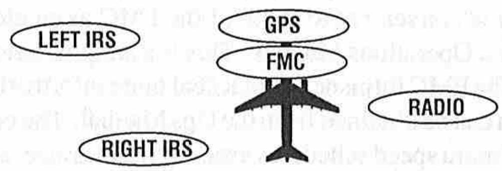
Transition Altitude	Climb Mode
Departure Airport Spd rest.	TO Flap for QRH
Max & min spd in clb, crz, des	ACARS messages
QRH data tables	

There are three independent computing units within the FMC: (1) the Navigation Processor for navigation computations, lateral and vertical steering guidance, and CDU management; (2) the Performance Processor for performance computations, flight envelope protection, and some vertical steering guidance related to target speeds, and (3) the Input/Output Processor, which performs the functions associated with I/O handling and some management of the CDU and management of the Built-In Test (BIT).

The link among the three controlled by the Global RAM, which acts as a common "mailbox" message and data shuttle point. It holds, in a single place, all the information the three processors require.

The FMC is certified to navigate accurately within a VOR/DME and GPS environment.

FMC navigational computations are based upon an FMC System position that is established using radio inputs and/or IRU present position. The FMC position may be based upon IRU data only; however, available GPS, DME or VOR/DME inputs are normally used to refine and update the FMC Position.



We don't actually navigate off the inertial platforms. All they do is provide independent inputs to the FMC(s) which integrate the sensors into a nav solution which is better than any one of the sensors.

In a dual IRU installation, the FMC uses five positions to arrive at navigation solutions:

It obtains basic position and velocity data from the IRU. The left IRU is used unless invalid or deselected. The IRU position is then checked against the data received from ground and/or space based sensors to determine the IRS drift rates and offset corrections.

Using all this data, the FMC generates the Best position every five seconds.

The Radio position data is obtained using GPS, DME-DME, ILS LOC, or VOR/DME updating when radio aids are available. Since the FMC assumes the Radio position is more accurate than the IRS position in use, the Best position is biased heavily toward the Radio position, and may cause problems if the Radio position is not accurate.

The updated Best position is used to correct the System position, which is the navigation position used for airplane guidance in LNAV.

This material is based on a paper writen by Richard Stensland and by correspondence with Stuart Law on the Bluecoat Forum.

STRAPDOWN INERTIAL NAVIGATION

Inertial navigation is the process of determining a vehicle's location using internal inertial sensors rather than external references. Three accelerometers and three gyros are needed because, in a three-dimensional world, an aircraft can simultaneously accelerate and rotate in three axes.

The term strapdown indicates that the gyros and accelerometers are mounted solidly to the aircraft. It eliminates the need for gimbals, bearings, and torque motors to keep the sensors level with the surface of the earth. The accelerometers are mounted such that the input axis of one accelerometer is always in the longitudinal axis, one is in the lateral axis, and one is in the vertical axis. Likewise, the gyros are mounted such that one gyro senses roll, one senses pitch, and the other senses yaw.

The laser gyros allow the microprocessors to maintain a stable platform mathematically, rather than mechanically. This results in an increase in system reliability and accuracy.

The primary source of attitude, velocity, and position information is the Inertial Reference System (IRS). The development of the IRS had to await the advent of the laser and advances in such optical technology as fiber-optic cables and highly reflective mirrors. From this technology there have emerged two classes of optical rotation sensors: fiber-optic gyros and ring-laser gyros.

The laser gyro has caused a technological revolution in the design of inertial reference and navigation systems. Laser gyros are not gyros in the traditional sense of the word. Rather, they are angular rate sensors that operate in one particular axis. This solid-state, high-precision, angular rate sensor is ideally suited for strapdown system configurations. This has been made possible through the advent of the laser gyro and high-speed microprocessors. The microprocessor calculates velocity, position, and attitude from the angular rate measurements and inertial sensors' acceleration.

AIR DATA INERTIAL REFERENCE UNIT

The Air Data Inertial Reference Unit (ADIRU) has three parts; power supply, inertial reference (IR), and the air data reference (ADR). On the 300-400-500, the air data reference is separate.

The ADIRU operates with either power source, 115v ac or 28v dc. The power supply feeds the ADR, the IR, the ISDU and to the air data modules (ADMs).

The IRS includes two ADIRUs, one inertial system display unit (ISDU), and one mode select unit.

The IR is the heart of the IRS. The main function of each IR is to sense and compute linear accelerations and angular turning rates about each of the airplane's axis. This data is used for pitch and roll displays and navigational computations.

The sensed data is resolved to local vertical coordinates and combined with air data inputs to compute attitude (pitch, roll, and yaw), position (latitude and longitude), true and magnetic heading, inertial velocity vectors, linear accelerations, angular rates, track angle, wind speed and direction, inertial altitude, vertical speed and acceleration, ground speed, drift angle, flight path angle and acceleration.

The only other inputs required are initial position, barometric altitude, and true airspeed. Initial position is required because present position is calculated from the distance and direction traveled from the starting point. Barometric altitude stabilizes the vertical navigation, and thereby stabilizes the vertical velocity and inertial altitude outputs.

The ADR supplies altitude, vertical speed, and true airspeed to the IR processor. The IR uses this ADR data as part of its inertial altitude, vertical speed and wind calculations.

Barometric correction comes from the common display system (CDS).

ACCELEROMETER

The three ring laser gyros can accurately measure rotation in any axis, however they give no measurement of the aircraft's movement through space. This is accomplished by three inertial accelerometers. The accelerometer is a mass centered in an outer case by two springs.

When the airplane accelerates or decelerates, the mass moves from the center. A pick-off device is positioned so that it can measure the size of the swing, and generate an electrical signal proportional to the swing. This signal is amplified proportionately into a current, which is used to torque the mass back to the null position. This recentering operation allows the accelerometer to sense very small changes in acceleration over a wide range. The amount of the signal necessary to keep the mass centered is proportional to airplane acceleration.

The current output of the accelerometer is an analog signal. The current is converted to a digital signal and supplied to the IR processor. The IR processor integrates the feedback signal with time to calculate velocity and then integrates the calculated velocity with time to calculate distance flown.

For example, a vehicle accelerating at three feet per second squared would be traveling at a velocity of 30 feet per second after 10 seconds have passed. Note that acceleration was simply multiplied by time to get velocity. The processor also integrates the calculated velocity to determine position. For example, a vehicle traveling at a velocity of 30 feet per second for 10 seconds will have changed position by 300 feet. Velocity was simply multiplied by time to determine the position.

The IR processor then adds distance flown to the initial position to calculate present position.

LASER

The laser gyro operates on the Sagnac effect. (Georges Marc Marie Sagnac - 1913).

The first ring-laser gyro was demonstrated by Sperry Gyroscope Co. (now Honeywell) in 1963.

The laser gyro can have three or more sides. The Honeywell gyro is actually triangular-shaped, cut and drilled from a block of temperature-stable glass.

Each side of the 737 and 757 / 767 gyro is 4.2 inches long. The new series 737 has sides reduced to 2 inches in length.

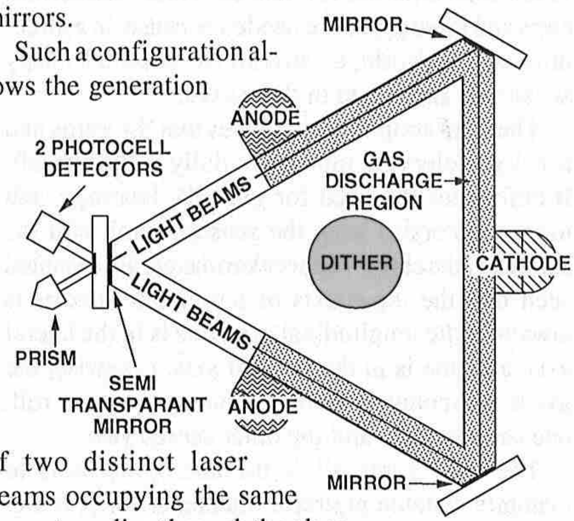
At each corner is a very accurate mirror. One mirror is partially transparant so that some of the light can shine through it.

A small amount of helium-neon gas is sealed into the tunnel. A dc voltage is applied to anodes and a cathode when you turn the MSU switch out of the OFF position. The discharge that develops is similar to that in a neon sign. The discharge excites helium atoms into several energy states. Many of these helium atoms collect in a relatively stable energy state, which is at nearly the same energy level as excited neon atoms. Because these levels are so close to each other, they can easily exchange energy. This happens when an excited helium atom collides with an unexcited neon atom, causing the helium atom to lose its energy while the neon atom becomes excited. This process is known as "pumping", because neon atoms are thereby pumped into a high-energy state.

Light amplification occurs when a photon strikes a neon atom that has been pumped into the excited state, causing the atom to generate an additional photon as it makes a transition into the lower energy state. Pumping is necessary in that it ensures that more neon atoms are at the higher energy level than at the lower level. Lower energy level atoms use up the photons, whereas the higher energy level atoms emit photons. As long as there are more higher level atoms than lower level atoms, there will be more photons emitted than absorbed. This results in a net gain of photons, or an amplification of light also known as "lasing".

In a laser cavity, photons are emitted (or light is radiated) in all directions. However, only the light that radiates in a straight line between the mirrors is reinforced by repeated trips through the gain medium. The mirrors are specially coated to act as both reflectors and optical filters, reflecting the single frequency of light that the system uses and absorbing all others. This repeated amplification of the light reflecting between the mirrors soon reaches saturation, and a steady-state oscillation results. This light oscillating between the mirrors is typically called a laser beam. To obtain useful laser light outside the laser cavity, a small percentage of the laser beam is allowed to pass through one of the mirrors.

Such a configuration allows the generation of two distinct laser beams occupying the same space, traveling through the glass block in opposite directions. One beam travels in a clockwise direction and the other travels in a counter-clockwise direction.



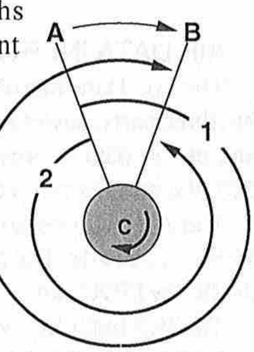
The laser gyro measures rotation by using the properties of these two laser beams rotating in opposite directions.

Now, imagine one laser beam traveling clockwise - we'll call Beam 1, and one traveling counter clockwise - we'll call Beam 2.

Rotate the graphic a few degrees clockwise. Beam 1, which left point A traveling clockwise around the cavity at the speed of light, reaches its starting point, which, due to the slight clockwise rotation, has moved to another point, we'll think of as Point B. Beam 1's path is now longer than it would have been had the picture not been rotated, so the wavelength must lengthen proportionately.

Meanwhile, Beam 2, traveling counter-clockwise, has a shorter path than Beam 1's because its starting point has also moved to point B. Beam 2's shortened path results in shortened wavelengths.

When the wavelengths change there is a concurrent change in the light's frequency. This means that in a rotating gyro one laser beam will exhibit an increase in frequency, whereas the other beam will exhibit a frequency decrease.



It gets easier to understand now. I know you can't wait to get out in the garage and hook up that old Mac or 286 to some fiber-optic cables you've got laying around.

In normal operating conditions, the frequency change of the laser beam is incredibly small; it cannot be measured to such an accuracy, but the frequency difference between the two beams is easily and accurately measured using an optical means.

This is done by combining light from the two beams in a nearly parallel fashion such that the wave fronts of the two beams interfere with each other and form a fringe pattern. If the frequencies of the two beams are equal, the fringe pattern will be stationary. If the frequencies are different, the fringe pattern will move at a rate proportional to the frequency difference.

One of the corners of the gyro contains a partially silvered mirror and a corner prism which lets the two light beams mix together to form a fringe pattern on a detector. Photo diodes sense the fringe pattern rate and direction of movement and change the fringe pattern movement into a signal that is equal to the rotation rate of the gyro. The measured rotation rate is integrated with time to calculate the attitude of the airplane.

Thus, frequency difference between the laser beams becomes a measure of rotation rate. Any difference in frequency is sensed by the photocell detector at the end of the light paths.

When the IRU is static, scatter from the mirrored surfaces can cause the opposing beams to lock together in a dead band around the zero-rate point until rotation of the unit reaches a certain rate. This condition is called laser lock-in or beam coupling. To prevent a loss of information at low rotation rates, a piezo-electric dither motor vibrates the gyro assembly through the lock-in region. The gyro sensed signals that are caused by these vibrations, are decoupled from the gyro output to prevent errors during operation. The dither motor vibration can be felt on the IRU case and produces an audible hum.

INERTIAL NAVIGATION

Although it is used to calculate velocity and position, acceleration is meaningless to the system without additional information. For example, consider an accelerometer strapped down to the longitudinal axis of the aircraft and measuring a forward acceleration. Is the aircraft acceleration north, south, east, west, up, or down? In order to navigate over the surface of the earth, the system must know how this aircraft acceleration is related to the earth's surface. Because accelerations are measured by accelerometers that are mounted to the three axes of the aircraft, the IRS must know the relationship of each axis to the surface of the earth. The laser gyros make the measurements necessary to describe this relationship in terms of pitch, roll, and heading angles. These angles are calculated from the angular rates measured by the gyros through an integration - similar to the manner in which velocity is calculated from measured acceleration.

For example, suppose a gyro measures a yaw rate of 3° per second for 30 seconds. Through integration, the microprocessor calculates that the heading has changed by 90° after 30 seconds.

Given the knowledge of pitch, roll, and heading that the gyros provide, the microprocessor resolves the acceleration signals into earth-related accelerations, and then performs the horizontal and vertical navigation calculations.

Suppose the gyro signals have been integrated to indicate that the aircraft's heading is 45° and the pitch and roll are both zero. The only acceleration measured has been in the longitudinal axis and it has been integrated into a velocity of 500 miles per hour. After flying at a constant heading and attitude for one hour, the microprocessor has integrated the velocity to determine that the aircraft has flown to a latitude and longitude that is 500 miles northeast of the original location. In doing so, the IRS has used the acceleration signals in conjunction with the gyro signals to calculate the present position.

ALIGNMENT

IR alignment basically consists of determination of local vertical and initial heading. Both accelerometer and laser gyro inputs are used for alignment.

The IR has to establish the level (North/East) plane and the direction to True North with extreme accuracy with only 3 inputs: your estimate of location, gravity, and the Earth's rotation. The alignment computations use the premise that the only accelerations during alignment are due to the earth's gravity and the only motion during alignment is due to the earth's rotation.

Leveling of the IR (vertical velocity) and altitude are calculated using the acceleration that is measured perpendicular to the earth's surface. This local vertical is used to erect the attitude data so that it is accurately referenced to vertical.

This is essentially the same as getting the pendulum on your clock to hang perfectly straight down. Every time you move it, the smallest error has it oscillating. Unfortunately the pendulum length for an inertial is to the center of the Earth (thus the natural Schuler frequency of 84 min for pendulum oscillations). However, an inertial accelerometer cannot distinguish between gravitational force and actual aircraft acceleration. Consequently, any accelerometer that is not perfectly parallel to the earth's surface will measure a component of the earth's gravity in addition to the true aircraft acceleration. Therefore, the IRS's microprocessor must subtract the estimated local gravity from the measured vertical acceleration signal. This prevents the system from interpreting gravitational force as upward aircraft acceleration. Since there is always some error, there is always some Schuler oscillation.

Once vertical is established, the laser gyro sensed earth rate components are used to establish the heading of the airplane.

True north and present position latitude is calculated. After the ADIRU has measured these values and the present position (latitude and longitude) is entered, the ADIRU completes its alignment to true north, both the vertical reference and the heading determinations are fine tuned for maximum accuracy and is then ready to navigate.

Earth rate sensing by the laser gyros allows the IRU to determine initial latitude but it cannot calculate its present position longitude.

This gyro-determined latitude is compared to the crew entered latitude to make sure its calculation of latitude is correct. Crew entered longitude is compared to the last stored longitude. These comparisons must be favorable to complete the alignment period.

When both ADIRUs are in ALIGN mode, the position you enter goes to both ADIRUs. If you make a wrong entry, you can enter the data again. The ADIRUs use the last data entry that you make.

NAV MODE

The gyros measure the motion of the aircraft with respect to the earth, plus the motion of the earth with respect to inertial space. The earth rotates with respect to inertial space at a rate of one rotation per 24 hours as it spins from west to east on its own axis, plus one rotation per year as it revolves around the sun. The sum of these two rates is equivalent to an angular rate of about 15 degrees per hour. (North Pole, *earth rate* is zero, azimuth rate of 15°/hr. At the Equator, *earth rate* is 15°/hr and azimuth rate is zero. In the middle *earth rate* varies as the cosine of the latitude.) The microprocessor compensates for this rate by subtracting this value, which is stored in memory, from the signal measured by whichever gyro or gyros are pointed eastward. Without this *earth rate* compensation, an IRS operating at the equator would mistakenly think that it is upside down after 12 hours of navigation. At other places on the earth, the system would develop similar errors in pitch, roll, and heading. If you input the wrong latitude, the IRS will compute the wrong *earth rate* value (deg/hr). The wrong *earth rate* means that the alignment can't ever find True North well, since the Earth rate compensation doesn't work; the ALIGN lights would continue to flash.

The major effect imposed by the earth's spherical shape is somewhat similar to that caused by the earth's rotation. As an aircraft travels across the surface of the earth, its path becomes an arc due to the shape of the earth. Consequently, the gyros - particularly the pitch axis gyro - measure a rotational rate, because traveling in a curved path always involves rotation. This rate, called the *transport rate*, does not describe rotational motion of the aircraft with respect to the earth's surface. Therefore, the IRS must calculate how much *transport rate* is being measured by the gyros, and subtract that value from their measurements.

INS errors continue to diverge with average amplitude increasing exponentially.

A close observation of the individual IRS position on the POS REF page will show that occasionally they will drift slowly apart, and then move back together again over a period of time. This can be due to the Schuler-tuning of the IRSs.

The basic design of any inertial system (INS or IRS) would have it maintain a reference to a fixed point in space. However, in navigating around the Earth, there is a problem that a straight line is not really that; it must constantly curve downward to follow the curvature of the Earth. With the gyroscopically stabilized platform of the INS, the platform tilt is constantly biased to allow for this. With the strapdown IRS, an equivalent bias signal is applied to the readouts of the IRUs.

The Schuler-Tuning signal has an 84 minute sinusoidal cycle and will cause slight position oscillations (around 1 nm) during the cycle. While all IRUs are subject to this effect, individual IRUs will not necessarily be at the same point in their cycles, with the result that they may drift apart at one stage of the cycle and back together again later.

After a full 84 minute cycle, the IRUs have the ability to introduce a bias signal to compensate for Schuler drift and this aspect of IRU performance will be gradually refined on longer flights as the flight progresses.

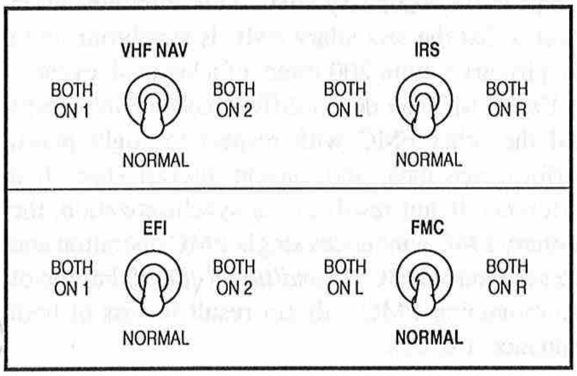
There are many other effects (such as coning, sculling, size effect, Coriolis effect, etc.) that are compensated for in commercial inertial reference systems, and even more in systems used in military applications. These effects have not been considered in this discussion because they get more and more complicated as higher precision is demanded, yet do not appreciably increase understanding of the strapdown nav principles.

DUAL FMC CONFIGURATION - B737

A dual FMC configuration meets the "sole means of navigation" requirement. Redundancy - two FMCs; Integrity - the FMCs can successfully determine how much error exists in the position. The U7.2/8.1 is the first Smiths software certified for "sole means".

A dual configuration will allow use of Precision RNAV airways - 2 nm in width and FMS approaches in a non radar environment.

A dual FMC configured FMCS has the same interfaces as a single FMC system except for the Intersystem Bus (ISB). The operation of these interfaces is different in that the dual FMCS must direct the data to 2 FMC's. This direction is determined by the setting of the 3 position FMC switch. It can be set on NORMAL, BOTH ON L, or BOTH ON R.



FMC switch in NORMAL

In the NORMAL position the FMC switch designates that the left FMC drives FCC-A, the autothrottle, the left EFIS map, the left autopilot, both CDU's, and tunes the left radio receiver. The right FMC drives FCC-B, the right EFIS map, the right autopilot, and tunes the right radio receiver. The guidance / map position and velocity are a weighted average of each FMC's data. CDU keypress events are passed from the left to the right FMC through the ISB. Composite navigation is enabled and N1 limits are provided by the left FMC. A change in the switch results in the disengagement of LNAV and VNAV, and a resynchronization attempt via memory copy if currently in single operation (for dual installation).

The FMCS will select the combination of available sensors that provide the best valid data for updating the estimate of the aircraft state (position and velocity). In the dual configuration with the FMC switch in the NORMAL setting only, a second aircraft state is calculated in each FMC by combining both FMCs error estimates and applying that to the estimated aircraft state. This is called the *composite navigation solution.*

Both single and dual systems select and tune stations based on the current aircraft position and the navaid position obtained from the navigation data base. Dual systems require that at least one navaid is not shared between FMCs so there is navigation independence. This is a requirement for primary means navigation.

FMC switch on BOTH ON L or BOTH ON R

With the FMC switch set to BOTH ON L or BOTH ON R the dual FMCS operates just like a single FMC installation. Both FCCs, EFIS maps, radio receivers, CDUs, and autothrottle are driven by the selected primary FMC. So the primary FMC is providing the guidance commands and map display data. The secondary FMC remains synchronized with the primary FMC. A change in the switch results in the disengagement of LNAV and VNAV.

Intersystem Bus

The dual FMC FMCS includes an Inter-System Bus (ISB) to commmunicate between FMCs.

Ground Start-up

The ISB maintains uniform configurations and synchronization. This is done by comparisons performed at start-up and in flight. At start-up, it does a cross compare of the OFPs and data bases. If an OFP mismatch exists, the primary FMC will display the crossload page. This page provides for the crossloading of OFPs. A different crossload page is displayed for a data base miscompare. The data bases that are compared are contained in the following list: Nav and Performance data bases, QRH takeoff speeds, ACARS datalink configurations, Supp data bases, and software options data base.

If the Supp data base exists and does not compare to the other FMC's Supp data base, the first FMC to be powered-up will automatically crossload its data to the other FMC. If the first FMC has no Supp data base and the second FMC does, the second FMC's data is crossloaded to the first powered-on FMC.

FMC configurations are also compared at startup. If a mismatch exists, the primary FMC displays an appropriate BITE page to help isolate the miscompared data. If the mismatch is not resolved before the BITE pages are exited, the secondary FMC *conditional-fails.* A *conditional-failed* FMC does not transmit valid data on its output channels.

The primary FMC also checks the status of the secondary FMC and automatically crossloads pilot entered data as required to maintain synchronization between the two FMC's. Some of these procedures are performed by maintenance.

Downmode to SINGLE FMC OPS

If the FMC FAIL annunciation displays, do not follow this procedure.

Downmode to SINGLE FMC OPS due to a miscompare or communication bus failure is not an FMC failure. The FMC FAIL annunciation does not display. This gives you independent operation of the FMCs...with one being in the standby mode (hot spare) in case the other one fails. The downmode to single can be caused by miscompares of .5% on N1 targets, small differences in Distance-To-Go to the next waypoint, differences on airspeed targets, altitudes, etc. The FMC is quite capable of predicting the values well within the tolerances given equal inputs. Without equal inputs, or in the case of a spurious input, the outputs vary. If the outputs vary enough for a period of time within which they should have equalized, the master FMC, normally the left, divorces the right FMC; the right FMC is *brickwalled*. The *brickwalled* FMC no longer takes part in guidance or Map position.

Dual integrity is still available but you should verify the other FMC is operating.

If the downmode to single ops occurs during taxi-out, place the FMC switch to BOTH ON RIGHT. If the CDU LEGS pages and the EFIS/ND Maps display correct information, the right FMC is operating. Switch to BOTH ON LEFT and again check the flight plan and EFIS/ND Maps for proper information; continue in the BOTH ON LEFT or BOTH ON RIGHT mode.

If the downmode to single ops occurs while airborne, occassionally accomplish the reasonableness check (BOTH ON RIGHT and LEFT) comparing each waypoint (sequence, course and distance) and cross-track error (PROGRESS 3/3).

Even though one FMC is *brickwalled*, they continue to update. If the FMCs come to an agreement and return to work together the DUAL FMC OP RESTORED message signals that you can return to NORMAL.

The fault is recorded in the maintenance records of the FMC. Maintenance will be able to do a data dump to disc and possibly identify the miscompare.

In-Flight Restarts

If an in flight restart occurs while radio updated navigation is being performed, the normal operation continues. If necessary, the flight plan and performance data may be re-entered and activated. At that point, all guidance commands are output normally after having been NCD (no computed/return data).

Also after an in flight restart, the OFP, data bases, program pins, performance factors and status are compared. Differences in the OFP, data bases, program pins or performance factors cause single FMC operation annunciation and failure of the secondary FMC. The Supp nav data base automatically crossloads the same way as on the ground, if a miscompare exists. The primary status is also automatically crossloaded to the secondary FMC.

On-Going Dual Synchronization

The primary FMC transmits all CDU keypush events to the secondary FMC. This communication insures that the secondary FMC is synchronized to the pirmary within 200 msec. of a keypush event.

Each FMC can detect differences between itself and the other FMC with respect to flight plans, performance data, and current aircraft state. If a difference is not resolved via synchronization, the primary FMC announces single FMC operation and the secondary FMC is *conditional-failed.* Failure of the remaining FMC will not result in loss of both guidance displays.

On Demand Dual Synchornization

When synchronization cannot be maintained in flight, the SINGLE FMC OPERATION message will be displayed in the CDU scratchpad. To restore dual operation, move the position of the FMC switch from NORMAL to BOTH ON L - hesitate momentarily, and move to NORMAL. This will result in a memory copy operation from FMC-L to FMC-R. (A movement of the FMC switch in the other direction will result in a memory copy from FMC-R to FMC-L.) If resynchronization is successful, the message DUAL FMC OP RESTORED will be displayed.

ACARS Operation in a Dual FMC Configuration

In a dual FMC installation the primary FMC receives and originates all FMC ACARS messages. The secondary FMC ignores ACARS messages from the ACARS MU. Uplinks received by the primary FMC are transmitted to the secondary FMC via the ISB. Each FMC processes the uplink information independently.

ALIGNMENT CONDITIONS AND INDICATIONS

The IRU has two power sources; one 115 VAC, and the other a 28 VDC. Either is sufficient for operation but in most installations, 28 VDC is a back-up source.

Three types of errors may build up in the IRU.

1. Present Position displacement error;
2. Velocity errors;
   a. Ground speed error
   b. Acceleration error
3. Attitude errors (pitch, roll, heading).

Quick alignment re-sets the first two errors (if present position is entered). A full alignment corrects all three errors.

Full alignment of the IRS requires approximately 10 minutes.

NG models when above 60° latitude, it is recommended to leave the mode switch in the ALIGN position for 15 minutes to force the most accurate alignment. Note: only Boeing incorporates the ALIGN position.

Some models incorporate a "variable alignment" mode. With this IRU, the farther from the Equator, the longer the alignment takes. Two minutes at the equator to seventeen minutes at 82°N. Business jets and air transports using the advanced IRS have this feature.

During alignment, the system determines: 1) level attitude based on gravity, 2) true north, 3) aircraft heading and, 4) aircraft latitude based on earth rotation. Present position latitude and longitude must be manually entered during alignment, and becomes the navigation starting point as the IRSs determine subsequent airplane position during flight.

There are no IRS outputs during alignment. In NAV mode, the IRS uses a stored magnetic variation table to generate magnetic heading, magnetic track, etc.

After the alignment period, the entered latitude is compared with the IRU computed latitude. A difference exceeding tolerances in latitude sine and cosine will cause the ALIGN annunciator to flash after the ten minute alignment period has elapsed.

Prior to removing power from the airplane, turn the mode selector switch on the MSU to OFF and wait until the ALIGN annunciator extinguishes. Failure to do so will prevent the IRU's from storing the current present postion in nonvolatile memory, and at the next start-up, the ALIGN annunciator will flash when present position is entered. Present position must then be re-entered to stop the ALIGN annunciator from flashing.

When the motion has stoped, the IRS automatically re-starts the alignment. No operator intervention is required.

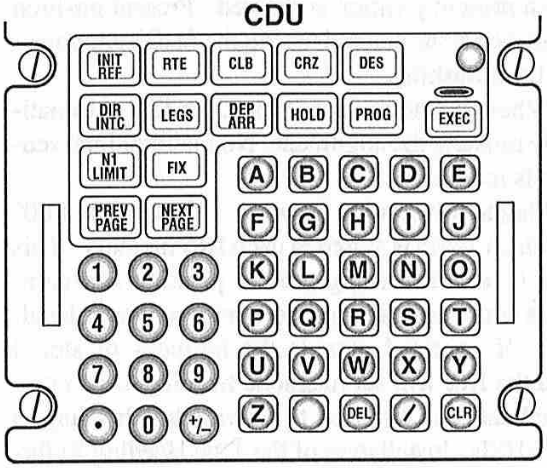
Magnetic variation between 73° North and 60° South latitudes is stored in each IRS memory. This data is accessed using present position and combines with true heading to determine magnetic heading. If operated outside the latitudes of stored data,the IRS will set magnetic heading to **no** computed data and continue to provide true heading to the EHSIs. Installation of the True Heading Reference switch allows the use of the EFIS and autopilot in these regions.

Because it is important that the IRUs have adequate airflow for cooling, the IRS activates the ground crew call horn if the Equipment Cooling Blower fails (light on overhead) on the ground. This most commonly is caused by loss of AC power. The IRS continues to operate on 28 VDC. On aircraft with Honeywell IRSs, the horn is de-activated after the IRS mode select switch is turned OFF and the ALIGN lights extinguish (30 sec.). The IRS can run for hours on no cooling air; cooling is specified because of possible effect on long term component reliability.

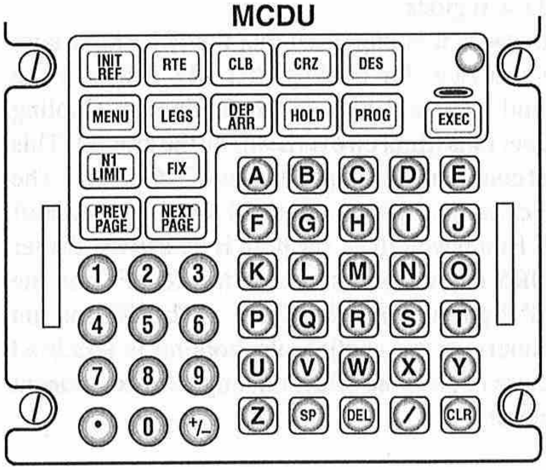
FMS Certification:

FMS Software is certificated to Level C as defined in RTCA DO-178B, based on a safety analysis of the consequences of incorrect/misleading performance or information from a malfunctioning system and it's detectability. Nowadays, as FMSs are dabbling more and more in performance parameters that can be more critical from a safety standpoint (e.g. computation and dispalyof V-speeds on an EFIS airspeed tape) at least some of the software is required to be developed to Level B.

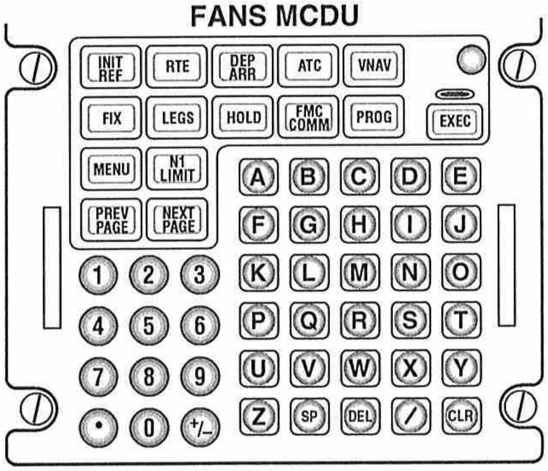
CDU



MCDU



FANS MCDU



CRT Color Gun Failure:

Boeing uses CRT displays that have reversion modes when failed or partially failed. Each basic color has its own gun. When there is the loss of a gun (basic color) in the CRT, the whole display would still be intact with all symbols/annunciation present, except the colors will no longer be true. The display unit will revert to monochorme.

If green were lost, the FMA would still be visible to the pilot, except it will no longer be green.

Three types of CDUs may be utilized in many combinations for any given airplane type.

The CDU, the MCDU (multi-function control display unit) and the FANS MCDU (Future Air Navigatioin System CDU).

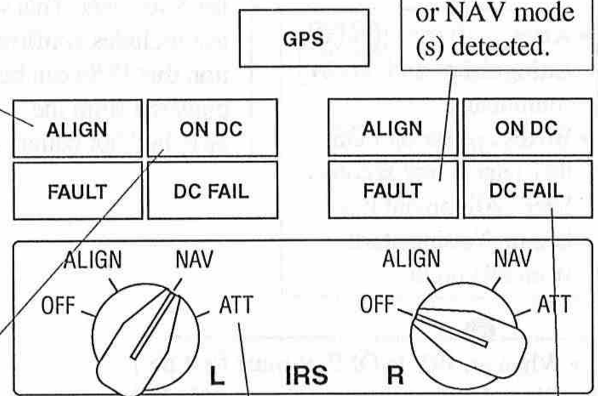
All three CDUs provide a bisic interface to operte the FMCS, while the MCDU and the FANS MCDU provide a broader rnage interface to both the FMCS and connected sub-systems within the FMS.

INERTIAL REFERENCE UNIT OPERATION

MODE SELECT UNIT (MSU)

STEADY: IRS in ALIGN mode, ATT mode, or the shutdown cycle.
FLASHING: Alignment cannot be completed due to a Code 3 (if auto realignment has not started), 4, or 8. Ref: Code Table.
EXTINGUISHED: IRS not in ALIGN mode due to:
- Selector in NAV - Alignment complete.
- Selector in ATT - Attitude info available.
- Heading info also available following entry of initial magnetic heading.
- Selector in OFF.

Fault affecting IRS ATT and/or NAV mode (s) detected.



- IRS operating on DC from BAT bus instead of normal AC.
- Right IRS limited to 5 minutes.
- If on ground, ground-call horn in nose wheel well sounds, providing alert that a battery drain condition may exist.

- Back-up ATT mode. (30 sec.) Provides rapid ATT and HDG info. if the IRS has had a total power shutdown or BITE has detected a failure in the NAV.
- Magnetic heading must be entered using ISDU or CDU.

- DC power for the IRS is not normal.
- If the other lights are extinguished, the IRS is operating normally on AC power.

CAUTION

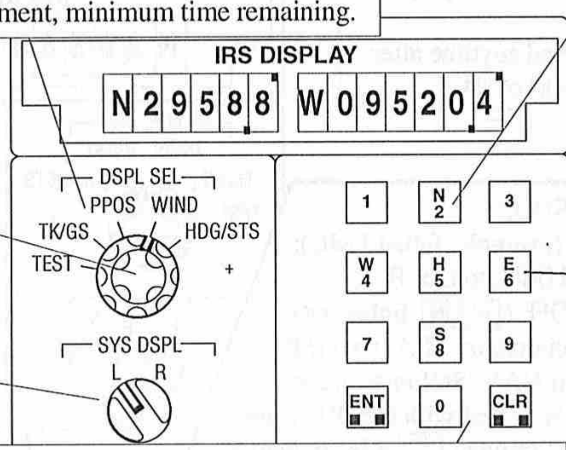
During flight, nav reference is lost if the MSU select switch is set to any position except NAV, even momentarily.

INERTIAL SYSTEM DISPLAY UNIT (ISDU)

TK/GS	True track (course) and g/s.
PPOS	Present position. (Lat/Lon)
WIND	True direction and spd. (Inflight) IRU velocity and attitude errors, and onside air data true airspeed errors will affect the calculated wind.
HDG/STS	True heading and Status codes. During alignment, minimum time remaining.

- ALPHA keys - The data displays are controlled by the keyboard when the N, S, E, or W key is pressed (for Lat/Lon), or the H key is pressed (for heading).
- Arms the keyboard for numeric entries.

Brightness control.



Allows selection of left or right system for display on ISDU.

NUMERIC keys - Permits manual entry of present position (Lat/Lon) when either ALIGN light is illuminated, and permits manual entry of present magnetic heading when either mode selector is in ATT.

CLR key
- The integral cue lights illuminate following an ENT operation if the self-test determines the data to be of an unreasonable value (entry not accepted by the IRSs).
- Pressing extinguishes the cue lights.
- If the cue lights are already extinguished, pressing CLR clears the associated data display of data keyed-in but not yet entered (or not accepted). The data displays are again controlled by the display selector.

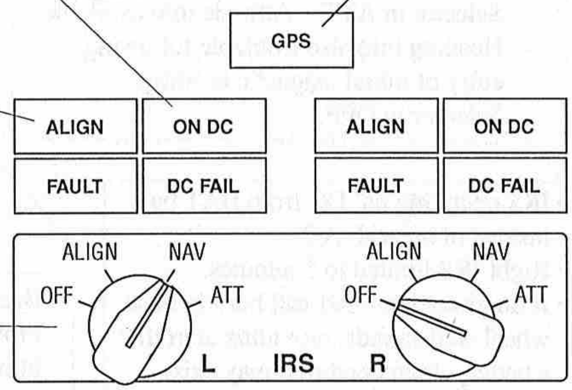
USING THE ISDU

- If repeated attemps to enter the Present Position via the CDU result in RE-ENTER IRS POS, use the ISDU.
- The steps follow:

3
- After ~ 10 sec., ON DC extinguishes and ALIGN illuminates.
- Boxes appear on POS INIT page a few seconds later. Alignment has begun. Timing starts from this point.

2
ON DC light illuminates for 5 seconds This self test includes confirmation that IRSs can be powered from the switched hot battery bus.

GPS light (600-700-800-900)
- Dual GPS installed.
- Dual channel light.
- With a single GPS failure, the light will illuminate when RECALL is pressed.
- With a dual GPS failure, the light will illuminate by itself.



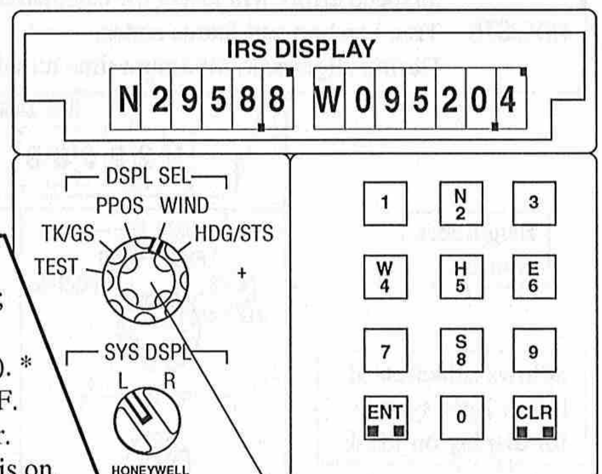
1
- When an IRS is OFF, it must first be aligned before it can enter the NAV mode and aircraft must be parked.
- Set both mode switches from OFF, thru ALIGN, to NAV.
- Initial IRS alignment requires 10 min. after step 3.
- If the position is not entered, ALIGN lights will start flashing.

6
Select HDG/STS and verify no fault codes present on both left and right systems after 2 min.
Ref: Abnormals

8
After the alignment period, IRS's will transition into NAV mode:
- ALIGN lights will extinguish,
- Valid STBY PWR check possible.

5
- Both IRS's will be simultaneously initialized with the lat/lon entered.
- May verify that the IRSs have accepted the initialization by checking the display on the ISDU with PPOS selected.
- If an IRS display unit does not reflect the entered coordinates within 5 seconds after they were entered, the CDU will display ENTER IRS POSITION.
- Local Lat/Lon can be entered anytime after setting MSU switch to ALIGN or NAV.

7
Switch to HDG/STS.
Time-to-nav will countdown from 7 to 0.
7 = 7 to 10 min.
6 thru 0 = 6 to 0 min.



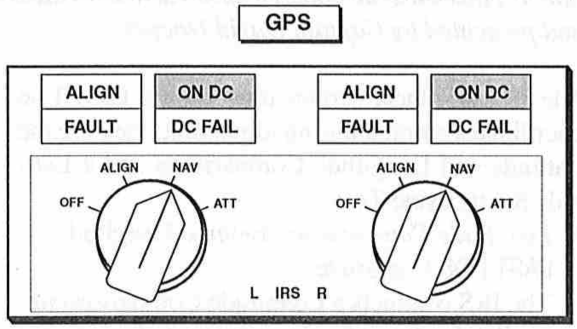
4
Enter lat/lon via CDU or ISDU.
If entry into ISDU is req'd (example, failed FMC);
- Select PPOS and SYS DSPL to L or R.
- Both MSU switches OFF (ALIGN lights out). *
- Check all IRS annunciators on MSU are OFF.
- Place both switches in NAV. Self tests occur.
- Ensure ALIGN light associated with the IRU is on.
- Press N 2, then enter latitude (S 8 if in so. hem.)
- Check entry and press ENT to transmit to both IRUs.
- Press W 4, then enter longitude (E 6 if in ea. hem.)
- Check entry and press ENT to transmit to both IRUs.
- Turn SYS DSPL to other position to check coordinates are same.

* For *Quick* align, enter positions with switches in ALIGN.

- 4 selections permit DR navigation without either FMC or the Standby Nav feature of the MCDU. More redundancy.
- HDG is True.

TYPES OF ALIGNMENT

This material comes from an article presented by David Hooper at the 1995 FMS User's Conference.



FULL ALIGNMENT (10 min)

OFF - thru ALIGN to NAV (enter POS)

A *Full alignment* is recommended for every initialization - time permitting (at least every 18-24 hours) or if the route to be flown is over an area of poor or no radio updating. A *Full alignment* takes approximately 10 minutes.

Item #	Description
1	Defines a new reference for True North
2	Establishes a new starting position to navigate from.
3	Sets internal velocities to zero (define)
4	Flushes all navaid update bias
5	Flushes TOGA FMC Position Update bias
6	Establishes a new leveling or vertical reference.
7	Performs a self-test of system including operational on DC power.
8	Performs the Lat/Lon self tests.

- Do not overshoot to OFF or ATT.
- Wait for both ALIGN annunciators to go OFF before moving aircraft.
- If the airplane is moved during alignment, bring the aircraft to a complete stop; position the MSU select switch to OFF (wait 30 sec. for ALIGN to go out) and reaccomplish alignment.

HIGH LATITUDE ALIGNMENT (17 min) *

OFF - stop at ALIGN (enter POS), wait 17 minutes then - NAV

Same as a *full alignment* but leaving the mode select switch in ALIGN for 17 minutes gives additional time to measure True North due to the speed of earth's rotation at extreme latitudes.

QUICK ALIGNMENT (30 sec)*

NAV - ALIGN (enter POS) - NAV

A *Quick alignment* is not recommended when departing for a route that offers poor updating.

A *Quick alignment* compares the entered Lon to the LAST POS Lon ± one degree and compares the entered Lat to the LAST POS Lat ± one-half degree.

Item #	Description
2	Establishes a new starting position to navigate from.
3	Sets internal velocities to zero.

ABBREVIATED QUICK ALIGNMENT (30 sec)*

NAV - ALIGN - NAV

An *Abbreviated Quick alignment* is accomplished without lat/lon entry. Good when short of time. IRS position is not changed. It starts where it left off.

Item #	Description
3	Sets internal velocities to zero.

MALFUNCTION CODE TABLE (display selector in HDG/STS)

01	ISDU FAIL	02	IRU FAILURE	03	EXCESSIVE MOTION	04	ALIGN FAULT
05	L DAA FAILURE	06	R DAA FAILURE	07	ADC DATA INVLD	08	ENTER PPOS
09	ENTER HEADING	10	ISDU POWER LOSS	18	NO ADR DATA	19	IR PROG PIN INVLD
20	ADR FAIL	21	ADR PROG PIN INVLD	22	TAT PROBE SIGNAL FAIL	23	AOA SIGNAL FAIL
24	NO AOA REF SIGNAL	26	NO BARO 3 REF SIGNAL	27	NO PITOT ADM DATA	28	NO STATIC ADM DATA
29	NO BARO 1 DATA	30	NO BARO 2 DATA	31	NO IR DATA	32	PITOT ADM DATA INVLD
33	STATIC ADM DATA INVLD	34	BARO 1 DATA INVLD	35	BARO 2 DATA INVLD	36	BARO 3 SIGNAL FAIL
37	IRU DATA INVLD	38	AIR/GND LOGIC INVLD				

Much of this material comes from an article written and presented by Captain David Hooper.

The IRS conducts certain tests on the Lat / Lon coordinates entered during alignment; they are the Latitude and Longitude Comparisons and a Latitude Sine/Cosine Test.

1. *Longitude Comparison* - Entered Longitude vs: LAST POS Longitude
   The IRS conducts a Longitude Comparison immediately after it has been entered. To pass, the entered longitude must not be more than one degree different from the LAST POS longitude.
2. *Latitude Comparison* - Entered Latitude vs. LAST POS Latitude
   The entered latitude must be within one degree of the LAST POS latitude.

If either of these comparisons fail, the FMC message ENTER IRS POS will appear and an ALIGN annunciator flashes. Any subsequent entry must also pass or override the comparison. A subsequent entry of correct data passes the comparison test. A subsequent entry of incorrect data identical to that which causes the FMC message to appear overrides the comparison test and causes the flashing ALIGN annunciator to go steady. It is possible to enter a srong longitude, override the warning with a second entry, and suffer severe navigation problems. For this reason, it is recommended to use a nav database starting position such an the ARP or GATE if available rather than manually entering coordinates if operating in DME-DME environment.

A proper entry may fail the *Comparison Test* if a replacement IRS has been installed, though boxes that leave Minneapolis are now nulled out to eliminate this problem.

It is unlikely that an airplane will be moved far enough to a location 1 degree different than the LAST POS; 1 degree latitude change is 60 nm and 1 degree longitude will be 60 nm x cos(lat).

2. *Sine / Cosine Latitude Test*
   At the end of alignment, the entered latitude must pass a *sine/cosine comparison test.*
   If the entered latitude passes the *sine/cosine comparison test*, alignment is completed.

A flashing ALIGN annunciator at the end of alignment indicates that the entered latitude has failed a *sine/cosine comparison test*, and that entry into the NAV mode is inhibited. Additional latitude entries are still allowed until the test passes; however, new latitude entries must also pass the *comparison test.* If two consecutive, identical latitudes are entered and the *sine/cosine comparison test* fails, the flashing ALIGN annunciator goes steady and the FAULT annunciator illuminates.

One correct latitude entry passes the *comparison test* and turns the warning annunciator OFF. If the mode select switch is set to ALIGN, the ALIGN annunciator remains illuminated. If the mode select switch is set to NAV, the ALIGN annunciator goes out, and the IRS enters the NAV mode if the 10 minute align mode is complete.

If the pilot has not entered latitude and longitude by the end of the alignment, the ALIGN annunciator flashes, and the IRS inhibits entry into the NAV mode until data is received.

CAUTION

In the case where two airports are close together with similar ICAO identifiers, take great care in entry of the REF AIRPORT.

Example:

Santa Ana (Orange County, California) is 66 nm northwest of San Diego.

KSNA	N33°40.5	W117°52.1
KSAN	N32°44.0	W117°11.4

Anytime you get a message during alignment, don't "blow" it off. It's a wake up call. The IRS will accept this wrong position if entered a second time.

If you're flying a non-EFIS airplane, the round dial HSI will not supply any hints of a bad position. If you're flying an EFIS airplane and have the habit of always entering the runway or some point around the airport to help with situational awareness, you will notice it is not in the viewable area of the EHSI Map. You may get a second chance when the RTE entry doesn't match the IRS position.

Astronauts and Engineers: Sine / Cosine Comparison Test

Just prior to entering the NAV mode, the sine of the computed latitude is compared to the sine of the entered latitude and must agree within ±.15 and. The cosine of the computed latitude is compared to the cosine of the entered latitude and must agree within ±.012.

CREATED (FIXED) WAYPOINTS

To explain Created waypoints, we'll use part of a route heading east from Los Angeles.

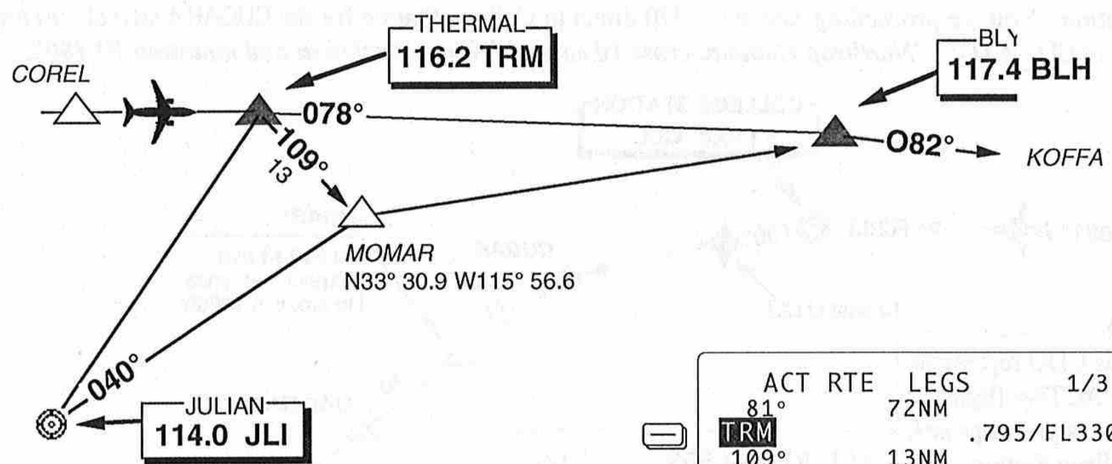
Eastbound on J 169 and approaching Thermal, ATC says, ***"Junkers 13, after Thermal proceed to Momar intersection, then direct Blythe, as filed".***

You type MOMAR into the scratch pad, Line Select Key (LSK) 2L of the LEGS page, (behind Thermal) and the message NOT IN DATA BASE appears. You need to create a waypoint!

Created waypoints can be defined on the REF NAV DATA page or on the RTE or LEGS pages. Both methods have advantages and disadvantages. Both methods store in the Temporary nav data base.

Using the RTE or LEGS pages is the quickest.

On the RTE or RTE LEGS pages, created waypoints (max-20) can be keyed into the scratch pad by any of the following four ways (4th is on the next page).



1

PLACE-BEARING / DISTANCE (PBD)
Example: Type TRM109/13 to s/p. (The bearing entry requires 3 digits). Place after the proper wpt - TRM (LSK 5R). Becomes TRM01 (sequential no.). Close up route discontinuitiy, check headings, and EXECute. Distance entry will take a decimal point.

```
   ACT RTE  LEGS      1/3
  81°       72NM
 TRM             .795/FL330
  109°      13NM
 TRM01           .795/FL330
  THEN
 □□□□□
  --ROUTE DISCONTINUITY--
 BLH             .795/FL330
  82°       44NM
 SALOM           .795/FL330
 RNP/ACTUAL--------------
 2.00/0.05        RTE DATA>
 TRM109/13
```

2

PLACE-BEARING / PLACE-BEARING (Course intersection)
Example: Type TRM109/JLI040 to s/p. (Bearing entries require 3 digits). Place after TRM (LSK 2L). Becomes TRM01 (sequential no.). Close up DISCO, check headings, and EXECute. If specified radials do not cross within 400 nm of first fix ID, INVALID ENTRY message is displayed.

```
   ACT RTE  LEGS      1/3
  81°       72NM
 TRM             .795/FL330
  109°      13NM
 TRM             .795/FL330
  THEN
 □□□□□
  --ROUTE DISCONTINUITY--
 BLH             .795/FL330
  82°       44NM
 SALOM           .795/FL330
 RNP/ACTUAL--------------
 2.00/0.05        RTE DATA>
 TRM109/JLI040
```

3

LATITUDE and LONGITUDE
Example: Type N33309W115566 into s/p (Leading zeros are required; trailing zeros are optional). Place after the proper wpt (TRM). Becomes WPT01 (sequential no.). Close up the route discontinuity, check headings, and EXECute.

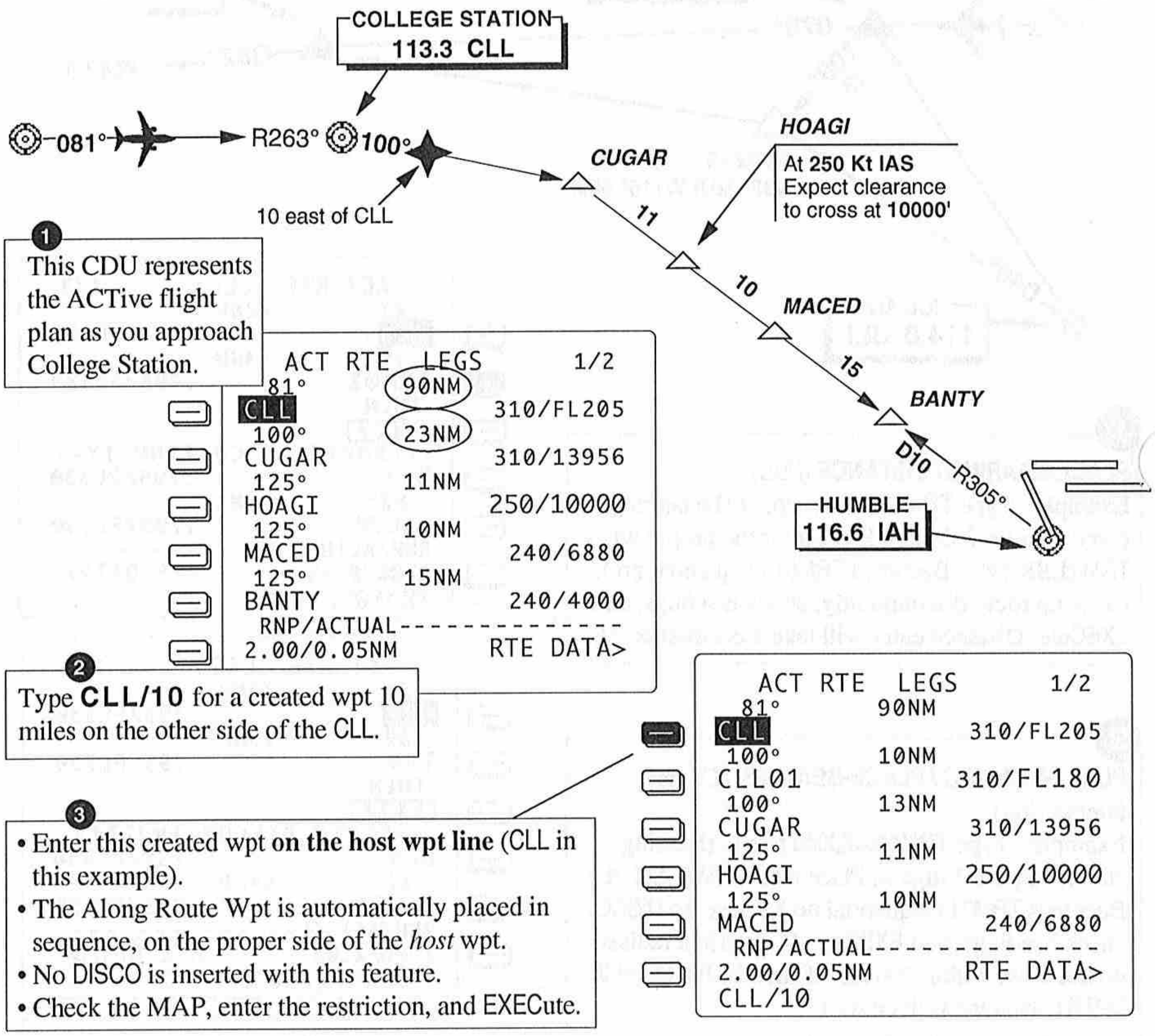
```
   ACT RTE  LEGS      1/3
  81°       72NM
 TRM             .795/FL330
  109°      13NM
 WPT01           .795/FL330
  THEN
 □□□□□
  --ROUTE DISCONTINUITY--
 BLH             .795/FL330
  82°       44NM
 SALOM           .795/FL330
 RNP/ACTUAL--------------
 2.00/0.05        RTE DATA>
 N33309W115566
```

Also known as the Along Track Offset

4

- It is a pilot defined point at a given distance before or after an existing flight plan wpt on the existing flight plan course.
- This example uses the same example found in the Downtrack Fix procedure, except that the arc is gone because the Along Track Offset **must use a waypoint in the flight plan.**
- The distance specified **must be within the distance to the preceding or next wpt.**
- A Conditional wpt may not exist at either end.
- Entries not meeting these criteria result in the INVALID ENTRY message.
- Ref: Advanced Techniques.

Situation: You are proceeding east at FL 370 direct to College Station for the CUGAR 4 arrival. 90 nm west of CLL, ATC : ***"Northrop Gamma, cross 10 east of College Station at and maintain FL180".***



1 This CDU represents the ACTive flight plan as you approach College Station.

2 Type **CLL/10** for a created wpt 10 miles on the other side of the CLL.

3
- Enter this created wpt **on the host wpt line** (CLL in this example).
- The Along Route Wpt is automatically placed in sequence, on the proper side of the *host* wpt.
- No DISCO is inserted with this feature.
- Check the MAP, enter the restriction, and EXECute.

NOTES:
- If the created wpt was to have been on your side of the wpt, you would have used a minus (–) sign.
- Positive values are assumed by the FMC and "+" signs need not be entered.
- There can be no wpts between the reference (host) wpt and the position of the Along Route Wpt. In this case, entries exceeding "-90" or "+23" would result in an INVALID ENTRY message.

HEADING VS TRACK

This material is under development, but important enough that I though it should be included in it's orginal form. Thanks to Captain Andre Berger for researching this topic.

When a flight segment is labeled "hdg", or when a textual description of a published route (SID, STAR, ...) reads to turn to a published "heading", do you have to correct for wind (1)?

ICAO (2):
SID: Yes.
STAR: Yes.
Enroute: Your choice: yes or no.

FAA:
SID: No, must not!
STAR: No (but you are allowed to correct for wind if RNAV equipped)
Enroute: Your choice: yes or no

(1) When ATC instructs you to fly a heading (e.g. runway heading, radar heading) you must not correct for wind.
(2) See Pans-Ops 8168. Not all ICAO states follow these rules exactly, minor variations exist.
Note on Jeppesen charts: if the radar vector symbol is printed on the chart, you must not correct for wind.

FMS heading legs:
The leg can be a track or a heading leg depending the coding done by the NAV database supplier (Jeppesen, Racal, Swiss Air …). The supplier of the database delivers what is requested by the customer. Most legs outside the USA are coded as track.

One of the important things to understand is that Jeppesen accurately produces a standard graphic format of government source information for every country in the world. They will not change the label of "hdg" to "track" until the procedure designer who is responsible for the SID and STAR makes a change to the label on the procedure that he/she designed.

This is important because the person who designed the SID or STAR procedure coordinated the intent with air traffic control. Even though PansOps has revisions, not all countries apply the new specifications at the same time. If the chart says "heading", there is the likelyhood that the controller in that country expects the pilot to fly a heading - not a track.

When Jeppesen receives a revision from the government source that changes the label of "hdg" to "track", Jeppesen does the same.

-- UNDER --
-- DEVELOPMENT --

ARINC 424 PATH TERMINATORS

AF	DME arc to a fix
CA	Course to an altitude
CD	Course to a distance
CF	Course to a fix
CI	Course to an intercept
CR	Course to intercept a radial
DF	Direct to a fix
FA	Course from a fix to an altitude
FC	Course from a fix to a distance
FD	Course from a fix to a DME distance
FM	Course from a fix to a manual termination
HA	Terminate hold automatically at altitude and fix
HF	Terminate hold automatically at fix after one circuit
HM	Terminate hold manually
IF	Initial fix
PI	Procuedure turn
RF	Arc to a fix
TF	Track between two fixes
VA	Heading to an altitude
VD	Heading to a distance
VI	Heading to intercept next leg
VM	Heading to manual termination
VR	Heading to intercept a radial

Conditional (or floating) waypoints are events when a condition occurs and are not at a geographically fixed position. They are dependent upon aircraft operating state and external variables such as wind. Conditional waypoints cannot be entered manually. They are imbedded within stored procedures such as DEPARTURES and ARRIVALS. Speed and/or altitude entries may be DELeted from the right side, but intermediate legs (Smiths only) are not DELetable [i.e. (LAS280) below]. Conditional wpts have ( )

Examples of Conditional waypoints are:

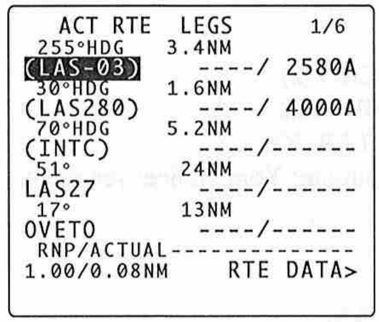
- **A** (LAS280) *Constant heading/course leg intercepts a VOR crossing radial.* See below.
- **B** (INTC) *Intercept heading/course to next waypoint.* See below.
- **C** (LAS-03) *Constant heading/course leg intercepts a DME.* See below.
- **D** (VECTOR) *Maintain heading/course indefinitely*
- **E** (5000) *Climb profile flown on a heading/course until passing a specified altitude.*

The OVETO departure from RW25R at Las Vegas contains 3 Conditional wpts.

C A *constant heading/course intercepts a DME.* "Climb on a 255° hdg to the LAS 3 DME".

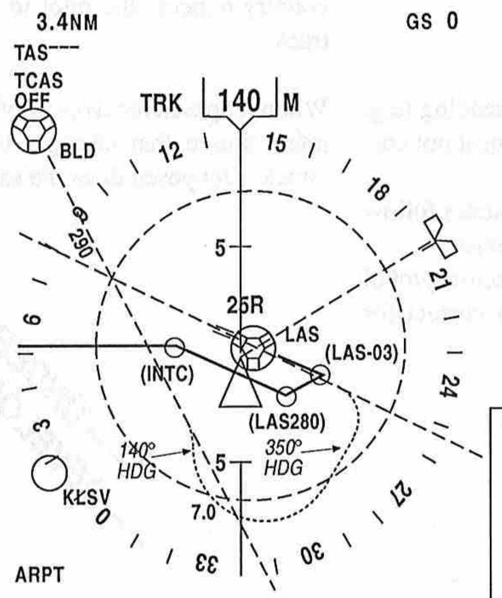
A Then a right turn to a 70° *heading/course* to *intercept* the LAS 280° at or above 4000'. A heading of 030° will be maintained until reaching 4000'. The (LAS 280) cannot be DELeted from the Smiths computer.

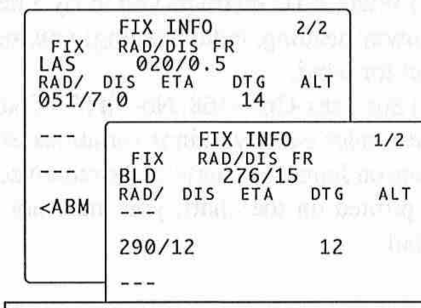
B Continue on a 70° heading to *intercept course to next waypoint* - the LAS 050° radial to the D27 LAS27 to the OVETO intersection.



If a DISCO occurs in a departure that has tight maneuvering enter a slower speed in the LEGS page.

The E/O departure requires a right turn to a heading of 350°. At 7 DME from the LAS VOR, another right turn is required, this time to a heading of 140°. Intercept the BLD VOR R-290. Fly the procedure in HDG SEL using the map as reference.





To construct this E/O procedure:

- Use one FIX page to display the 7 mile circle and.
- Use the second FIX page to display the BLD R-290, or manually tune a VHF nav to BLD VOR with the course bar at 290°.

PHANTOM WAYPOINTS

In addition to the types of waypoints discussed so far, (Fixed and Floating), the system implementation takes into account in its profile predictions, the existence of points of importance to the vertical performance calculations called Phantom waypoints. These points are like floating waypoints in that they occupy positions dependent upon the aircraft operating state and external variables such as wind. Phantom waypoints influence the system only by their "presence" being accounted for in time and distance predictions.

Phantom waypoints	Displayed on Map	Phantom waypoints	Displayed on Map
SPD RESTR on CLB pg	No	SPD RESTR on DES pg	Yes (decel pts)
Crossover CAS-M on clb	No	Crossover M - CAS on des	No
T/C	Yes	T/D	Yes
E/D	Yes	Tropopause breakpoint (U10.5)	No

CONDITIONAL WAYPOINTS (Continued)

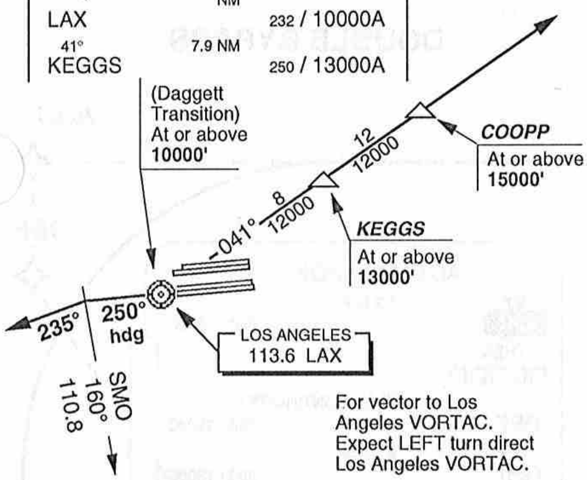
D

This is an example of a **(VECTOR)**. It is a conditional wpt in the LOOP DEP at LAX.

- When (VECTOR) is the ACTive LEG, the FMC **does not** automatically sequence to the next wpt. It *maintains heading indefinitely*. The next wpt becomes ACTive only upon EXECution of the procedure for proceeding direct to a wpt or intercepting a leg to a wpt.
- Time and fuel predictions go straight across a vector, just as with a disco.
- After takeoff and a turn to the north, expect DIR TO or INTC LEG TO KEGGS. Engage VNAV (updates FMC predictions and enables message) and check your CLB page to monitor restrictions.

ACT RTE LEGS 1/5

250° HDG	.6 NM	
(530)		170 / 530A
251°	1.8 NM	
D160E		212 / 1828
235° HDG	NM	
(VECTOR)		----/-----
°	NM	
LAX		232 / 10000A
41°	7.9 NM	
KEGGS		250 / 13000A



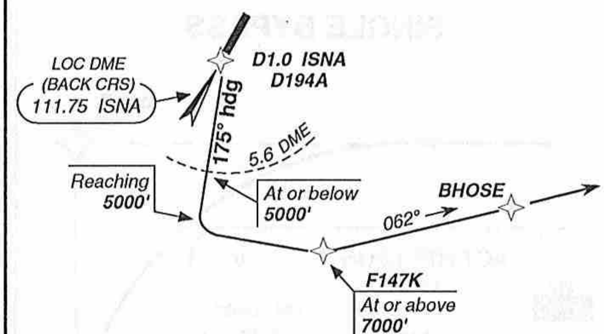
E

Here's an example of an **(ALTITUDE)** Conditional wpt in the BACK BAY DEP from Orange County, Ca.

- With LNAV engaged, guidance from runway 19L will be a heading of 194° until reaching one mile from ISNA. That's D194A.
- Then cross ISNA 5.6 DME at or below 5000 ft. That's the conditional wpt (ISN-06).
- Then a heading of 175° until reaching an altitude of 5000 ft (*climb profile flown on a heading passing thru a specified altitude*).

ACT RTE LEGS 1/5

194° HDG		
D194A		212 / 500A
175° HDG	5 NM	
(ISN-06)		250 /5000B
175° HDG	1 NM	
(5000)		250 /5000A
59°	7.6 NM	
F147K		250 /7000A
62°	8.8 NM	
BHOSE		300 / 13500



A review of how certain waypoints are displayed:

Conditional wpt

(LAS280) *Remember: 3 digits means a radial.*	Defines a heading leg terminated when crossing the 280° R from LAS VOR. If only 2 letters make up the ID, the third character will be a dash.

Conditional wpt

(LAS-04) *Remember: 2 digits means a DME.*	Defines a heading leg terminated when reaching 4 nm from the LAS VOR. If only 2 letters make up the ID, the third character will be a dash.

Pilot created wpt

TRM01	Defines a pilot created wpt, first in sequence and Along Track Offset.

FMC created wpt

SEA-05	A computer created wpt located 5 nm from the stored reference wpt of SEA. The DME portion of this convention is sometimes violated.

Database supplier wpt

TNV21 D194A F096M	A Jeppesen data base entered wpt.

WAYPOINT BYPASS

The flight plan may occasionally contain waypoints connected by a leg of short length and a significant change in direction. This would most likely occur as part of a departure procedure. The *predictions* algorithms of the 737 FMCs prior to U10 use 210 kts as the starting point for climb predictions. That means that all turns are predicted at a minimum of 210 kts. There is then a canned acceleration assumption built into the FMC.

If FMC computations determine that normal turn construction between legs cannot provide a continuous path (combinations of airspeed, short leg length, and a significant change in direction), the FMC will bypass the affected leg (DEF in this example) and use an alternate turn construction to intercept the leg going to the subsequent waypoint. On the CDU, the word BYPASS appears above the speed and altitude for the waypoint.

When the active waypoint is bypassed, the waypoint remains active until passing abeam. For non-EFIS aircraft, with the HSI switch in NAV, the course pointer points to the next leg direction, while the waypoint bearing pointer continues to point to the active waypoint.

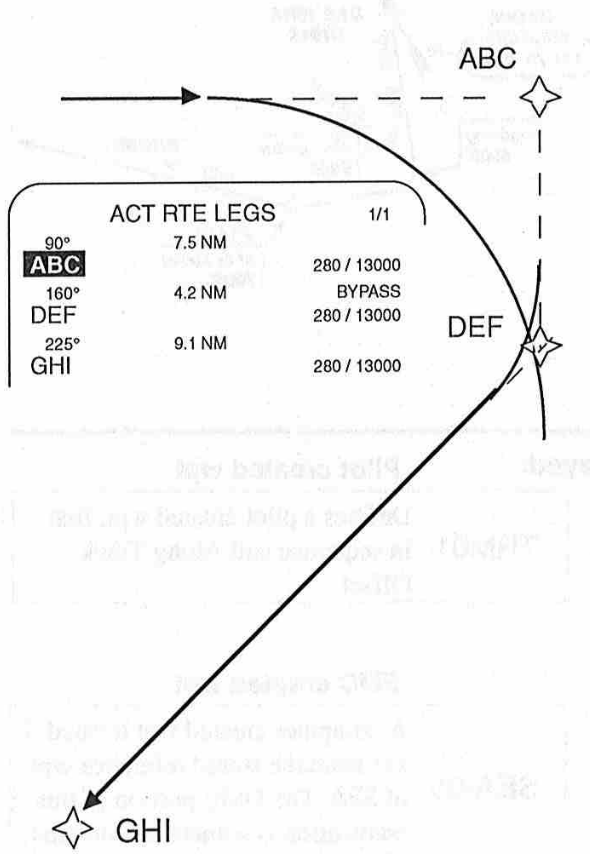
If elimination of the bypass is desired, consider entering a speed restriction at a wpt prior to the BYPASS. 210 kts is the lowest speed U8 and lower will allow. U10 is changed to allow entries (targe speed, SPD REST, and wpt speed restrictions) as low as 100 kts. The slowest speed that predictions will actually use is Vref (40) + 20.

DELeting one of the waypoints, or proceeding DIRECT TO or INTC LEG TO a downpath waypoint will also solve the problem.

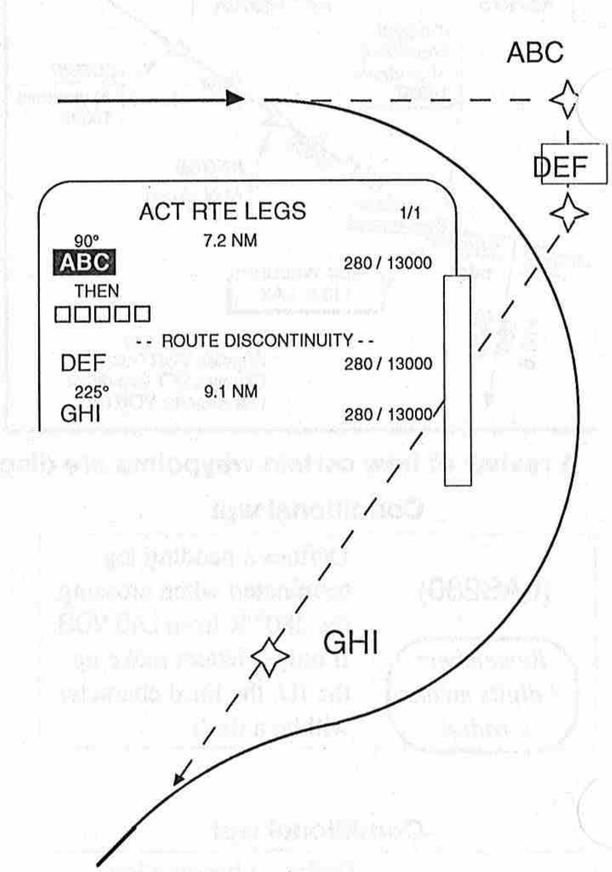
Any mandatory altitude-crossing restriction for the BYPASS waypoint is still observed, based on passing abeam the waypoint.

Prior to U10, if a double BYPASS condition occurs (bypass of two consecutive legs), then a DISCO is inserted just prior to the first by-passed waypoint, DEF in the example. U10 will by-pass three consecutive wpts before a disco is inserted.

SINGLE BYPASS



DOUBLE BYPASS



NOTE: ABC is not a *Flyover* waypoint. *Flyover* transitions require the aircraft to pass directly over the waypoint's geographic position. In general, they occur most often in terminal area procedures (SIDS/STARS), and are rarely encountered in the enroute phase.

FLY-OVER WPT vs FLY-BY WPT

Pilot defined wpts will be *fly-by* wpts.

If a wpt must be flown over, such as D5 SEA in the example below, some adjustment in the definition may be required to meet the clearance.

Note: ICAO charting convention for a *fly-over* wpt is a circle around the fix. Boeing does not presently support this convention.

Example: In the ELMAA 7 Departure from Seattle, Washington, ATC wants you to *fly-over* a point 5 nm south of the SEA VOR on the 158° radial; then, a 92° turn to 250° is required.

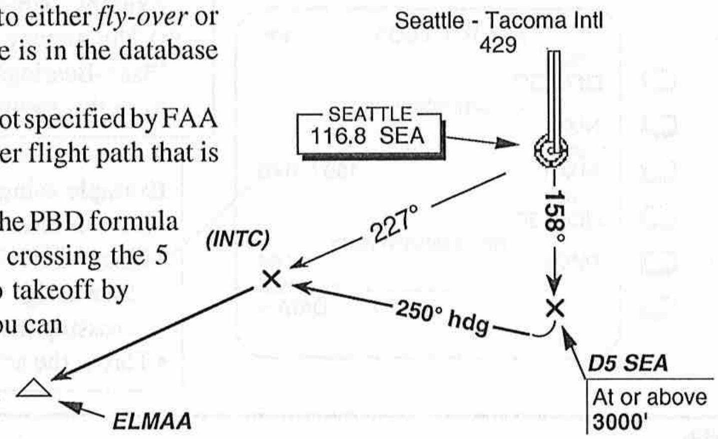
Database defined wpts can be coded to either *fly-over* or *fly-by* a point. In this case, the departure is in the database and D5 SEA is coded as a *fly-over* wpt.

The default is *fly-by* if this attribute is not specified by FAA or other AIS because it results in a shorter flight path that is more economical to fly.

If the pilot defines this wpt using the the PBD formula SEA158/5 the airplane will turn prior to crossing the 5 DME wpt. This can be checked prior to takeoff by viewing the route in the PLAN mode. You can see that the wpt is not going to be crossed.

One work-around is to create the wpt a mile or two further south. The angle of the turn will dictate the size of the adjustment.

On the A320, fly-over waypoints appear with a small triangle symbol on the MCDU, so you know that wpt is different than a fly-by waypoint! "C'est automatique!" Also, there's a triangle key on the MCDU keyboard that may be used to "force" the airplane to fly-over a wpt (if needed) to comply with an ATC clearance. - G. Bleyle

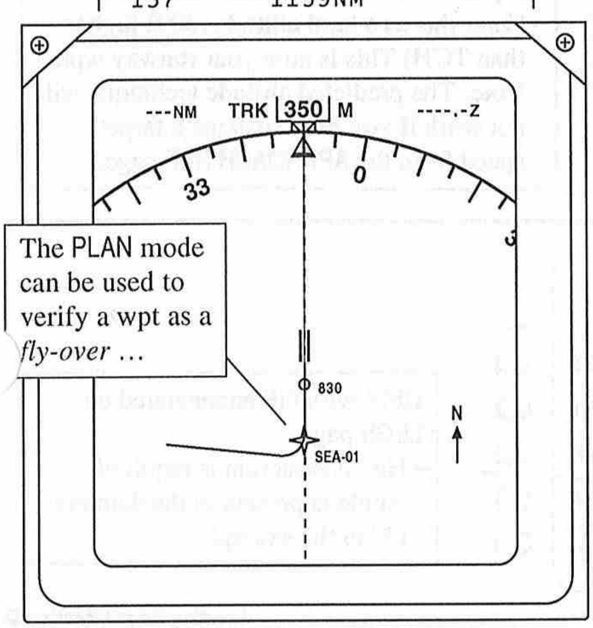


- ELMAA 7 Departure as obtained from the nav database.
- SEA-05 (D5 SEA) is a *fly-over* wpt.

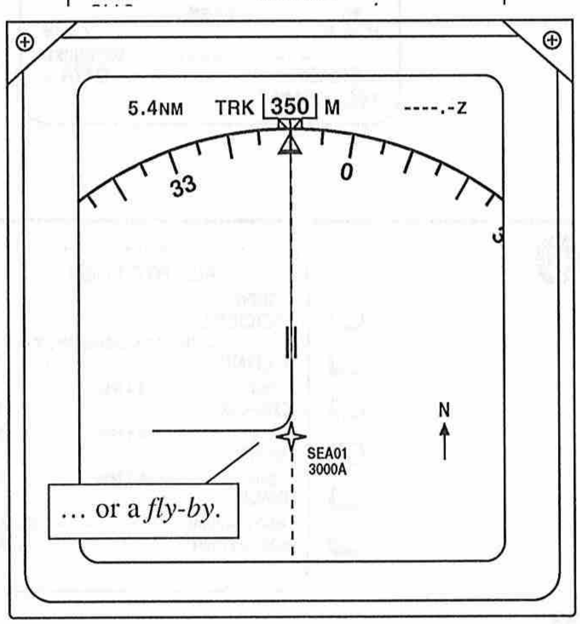
```
 ACT RTE  LEGS        1/5
 161°HDG    5.5NM
(830)           ----/ 830A
 161°       5.6NM
SEA-05          ----/ 3000A
 250°HDG    13NM
(INTC)          ----/------
 230°       34NM
ELMAA           ----/------
 157°      1159NM
```

- ELMAA 7 Departure defined by pilot entries.
- SEA01 (D5 SEA) is a *fly-by* wpt.

```
 ACT RTE   LEGS          1/5
 158°            5.5NM
SEA01                ----/ 3000A
 250°            15NM
SEA02                ----/------
 THEN
□□□□□
 --ROUTE DISCONTINUITY --
ELMAA                ----/------
 157°            159NM
```



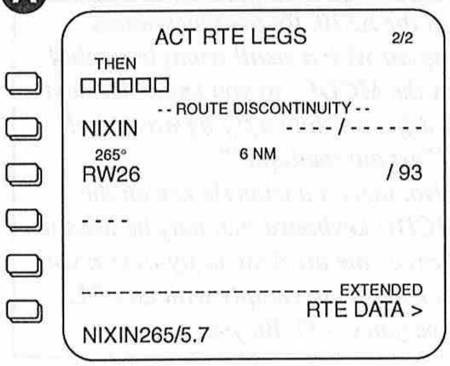
The PLAN mode can be used to verify a wpt as a *fly-over* ...



... or a *fly-by*.

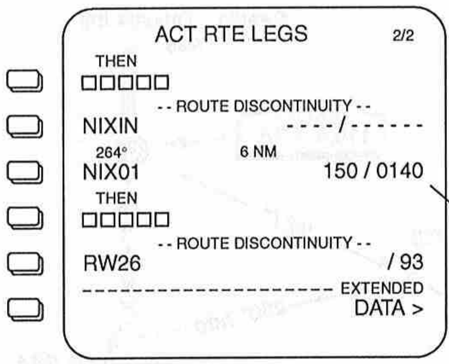
BUILDING A RUNWAY WAYPOINT FOR CONSTANT ANGLE APPROACH

A



Non EFIS.

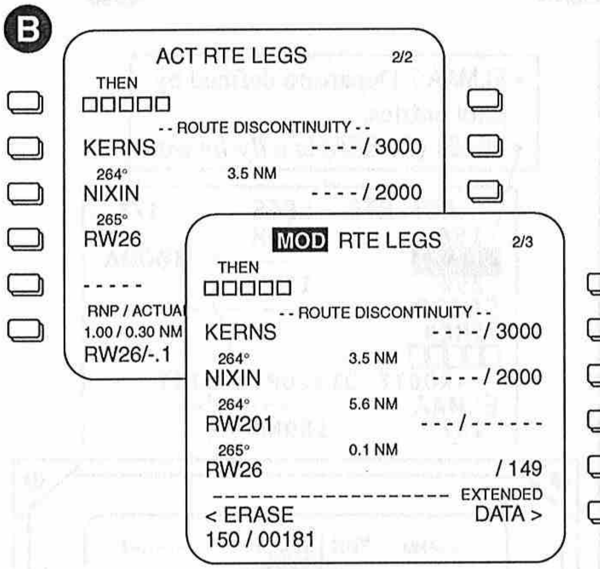
- Must be manually built.
- Your teammate should back you up in constructing this wpt. When inserting the created wpt in front of the runway, ensure the course and distance do not change appreciably.
- Two techniques:
  (a) Retrieve the destination runway's coordinates using the REF NAV DATA page. Write the coordinates down then use the REF NAV DATA again to create a wpt at the threshold using these coordinates. Example name could be R26
  (b) The runway waypoint can also be built using a Place-Bearing/Distance method from the OM/FAF, as in this example.



Example using NDB approach to RW26 at Houston Intercontinental:

- Place NIXIN265/5.7 in front of the runway and then assign an altitude that equals the threshold crossing height (140 ft in example)
- Throw the actual runway wpt away.

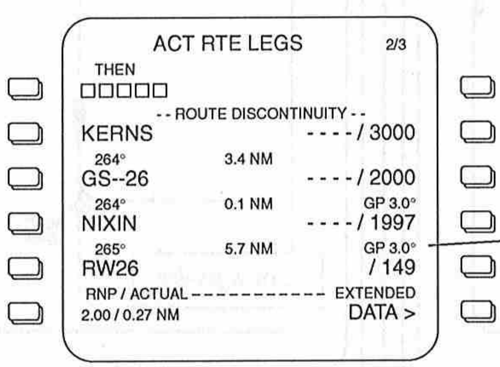
B



EFIS without GP annunciated on LEGS page.

- Using the Along Track Wpt feature, place the runway in the scratchpad, type /-.1 after it, and place back on top of the host wpt - the runway. A wpt one tenth of a mile inside the threshold will appear, with dashes at it's speed / altitude line.
- Press the LSK next to the speed / altitude dashes and a predicted speed and altitude will appear in the scratch pad. Check that it passes your own reasonableness test.
- Enter this as a hard altitude (30 ft higher than TCH) This is now your runway wpt. Note: The predicted altitude technique will not work if you have selected a target speed from the APPROACH REF page.

C



EFIS with GP annunciated on LEGS page.

- No construction is required. Angle is present in the database. (3° in the example)

IDENTIFIERS

The following is provided as background information to improve your understanding of waypoint identifiers used by the FMC. Some of the information only applies to a few areas of the world.

Coded waypoints by Jeppesen (lat/long entries) actually are measured to 100th of a second which is about 1 ft. Consider the coded gate position of N212012.06 W1575530.18.

The FMC displays these coordinates as N2120.2 W15755.5 ; an accuracy of 1/10th of a minute. (To convert, divide the …12.06 and the …30.18 by 60.) If you were to manually build a lat/lon wpt, the closest you can get is to the nearest tenth of a minute, which is about 600 ft.

Standard rules for naming waypoints (except for the SEA-05 format) are defined in the ARINC Specification 424-8 and used industry wide. Computerized nav system software limits wpt names to a maximum of five characters that are assigned according to the following rules.

N2120.2
degrees – minutes – tenth of minute

APPROACH MARKER IDENTIFICATION

If the approach marker is named, the NDB ident now normally used. (Check with your database provider.) If it is unnamed and not an NDB, the letters OM followed by the rwy number are used.

UN-NAMED TERMINAL AREA FIX, or BEARING DISTANCE WAYPOINT (formerly DME ARC WAYPOINT)

This form of wpt naming is very common on SIDS, STARS, arc approaches, and FMS data base departures and arrivals. Jeppesen inserts a "D" as the first character - or an "F" if part of an FMS database procedure. In the case of the "D" format, characters 2 through 4 signify the bearing from a navaid on which the wpt lies; there are no rules as to which navaid. Consult the applicable chart to determine the origin of the bearing. In the "F" format, characters 2 through 4 are the bearing from the Airport Reference Point. The last character is the DME arc radius defining the position of the wpt on the radial. This arc radius is expressed as the equivalent letter of the alphabet, i.e., A=1 nm. B=2 nm. C=3 nm. D=4 nm, and so on. If the wpt includes a fraction of a mile, the letter is rounded up.

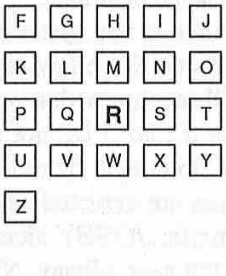
Example: ISNA194/1 = D194A

This convention takes more time to manually construct if not in the database, but is much easier to follow on the CDU than using the Place-Bearing/Distance method.

MUSEL Departure - SNA

FMC Quiet Bridge App - SFO

> ***TECHNIQUE***
>
> Use the keyboard as an aid to convert letters to miles. Each row has 5 keys. See how easily **R** is determined to be the 18th letter/mile.



An unnamed wpt along a DME arc with a radius greater than 26 miles is identified as an unnamed turn point that is not coincidental with a named wpt.

A couple of examples are:

CPR338°/29 becomes CPR29
GEG079°/30 becomes GEG30

When there are multiple un-named wpts along a DME arc with a radius greater than 26 nm, the station identifier is reduced to two characters, followed by the radius, and then a sequence character.

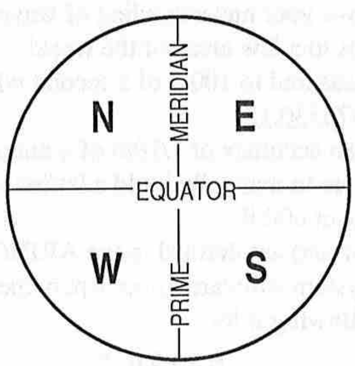
Examples are:

CPR134/29 becomes CP29A
CPR190/29 becomes CP29B

Ref: p 28, 29

CONDITIONAL WAYPOINTS

COORDINATES



Database contained Entry/Exit positions to Oceanic Control Areas are often defined by wpts which are "undesignated", made available as geographical coordinates expressed in full degrees.

The four digits include two for latitude and two for longitude. The first two digits of the ID are the degrees of latitude. The third and fourth digits of the ID are the second and third lon digits. The first lon digit does not appear in the ID.

Examples:

N Lat W Long N46W050 coded as 4650N
N Lat E Long N50E020 coded as 5020E
S Lat E Long S50E020 coded as 5020S
S Lat W Long S52W075 coded as 5275W

Positions in the northern hemisphere use the letters "N" and "E"; the southern hemisphere use the letters "S" and "W".

The letter "N" is used for north latitude and west longitude. The letter "E" is used for north latitude and east longitude.

The letter "S" is used for south latitude and east longitude. The letter "W" is used for south latitude and west longitude.

N Lat W Long N37/W125 coded as 37N25
N Lat E Long N06/E110 coded as 06E10
S Lat W Long S20/W125 coded as 20W25
S Lat E Long S06/E110 coded as 06S10

Placement of the letter in the five character set indicates what the first digit of longitude is published as.

The letter is the last character if the *longitude is less than* 100° (above example).

The letter is the third character if the *longitude is 100° or greater*.

COMPUTER CREATED WAYPOINTS

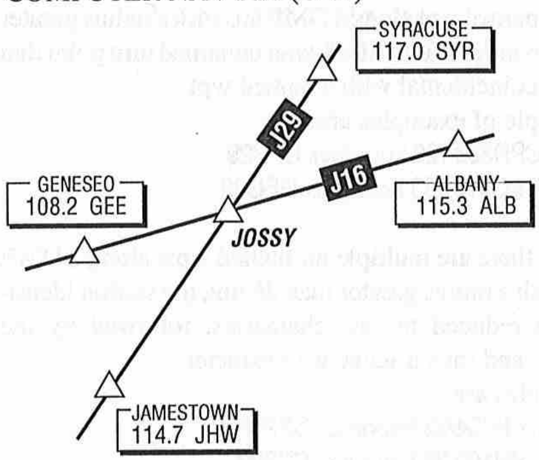
```
CCR          ---/------
 20°      24NM
ISYOH        ---/-----
 354°     5.0NM
ISY-05       ---/-----
  354°    10NM
ELKOE        ---/-----
```

Occasionally a waypoint will exist that has not been assigned a name. The FMC recognizes the need for a *path* and *terminator*, and assigns a name. Since it is 6 characters, the pilot is unable to check its location in the nav database WPT IDENT.

DUPLICATE IDENTIFIERS

Should application of these rules result in more than one wpt having the same identifier, the SELECT DESIRED WPT page appears. This page lists the wpts with the same name, along with information such as the lat/lon, type of facility, frequency, etc.

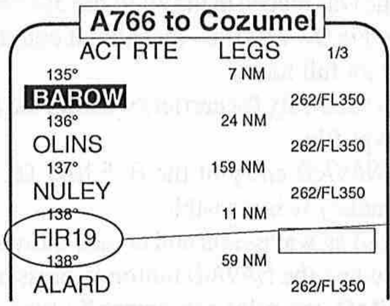
COMPUTER NAV FIX (CNF)



Formerly unnamed positions on airways and terminal procedures in the US will be provided with 5-letter Computer Navigation Fix (CNF) names. Initally CNFs will be designated at unnamed airspace fixes or mileage break points on airways and routes that currently display an "x". Jepp charts currently have navdata identifiers consisting of 5 character alphanumeric names in brackets at these same positions.

CNFs are for reference to nav systems using navdata bases only. CNFs do not have any air traffic control functions. (ATC will not request that you hold at, report at, or otherwise use a CNF.) Do not request routing using a CNF either direct to ATC or in a flight plan. The new CNF names are depicted near the "x" in an italic type. Forexample, *JOSSY* identifies the intersection of J16 and J29 near Albany, NY.

FIR, UIR, CONTROLLED AIRSPACE



For an FIR, FIR plus a numeric from 02 to 99 is used. For a UIR, UIR plus a numeric from 02 to 99 is used. For Controlled Airspace, use the 3 letter character for the type of controlled airspace plus a numeric from 02 to 99. An identifier so developed is unique within the geographic area.

ATZ for Aerodrome Traffic Zone
CTA for Control Area
CTR for Control Zone
FIR for Flight Information Region *[FIR19]* on Jeppesen chart.
TIZ for Traffic Information Zone
TMA for Terminal Control Area
UIR for Upper Flight Information Region

NAMED WAYPOINTS

National Flight Data Center is responsible for naming waypoints.

One Word Names

Full name is used if five or less characters are involved.

Example: LOGAN

More than 5 letters:

Eliminate double letters.

Example: KIMMEL becomes KIMEL

Keep the first letter, first vowel, and last letter. Drop other vowels starting from right to left.

Example: BURWELL becomes BURWL

Drop consonants, starting from right to left.

Example: ANDREWS becomes ANDRS
BRIDGEPORT becomes BRIDT

Multiple Word Names

Use first letter of the first word and abbreviate the last word using the above rules sequentially until a total of five characters remain.

Example: CLEAR LAKE becomes CLAKE

Phonetic Letter Names

When an ICAO phonetic alpha character is used as a wpt name (Alpha, Bravo, Charlie, etc) the rules above are used.

Example: November becomes NOVMR.

When a double phonetic such as Tango India is used as the wpt name, use the rules established above under multiple word names.

When a phonetic alpha character followed by a numeric and/or other alpha characters (A1, A1N, B2, etc.) is used as the wpt name, it will appear the same in the database as shown on charts.

NON DIRECTONAL BEACONS (Marker beacons)

At Jeppesen, most NDBs are identified by the use of the station identifier and loaded in the NDB navaid file. Example: Galveston NDB is GLS. Until recently, where more than one NDB navaid with the same identifier existed, only one was placed in the NDB navaid file; the other was placed in the wpt file - meaning it could only be accessed by its full name.

The suffix NB is used only for carriers wanting the NDB to go into the wpt file.

Entry into the NAVAID entry of the REF NAV DATA to obtain the frequency is impossible.

NDBs are packed as waypoints and do not show up on the EFIS Map when the NAVAID button is pressed.

For the IL96 FMC, the pilot can manually tune them through the FMC (type in the frequency into the MCDU NAV RADIO page) and the FMC will automatically Route tune them.

PILOT DETERMINED WAYPOINTS

Place bearing/distance.
Place bearing/place bearing.
Lat/Lon.
Along Track (Route) Offset.

TERMINAL WAYPOINTS (Procedure Fix Wpts)

These rules are used in developing identifiers for wpts used soley in terminal area procedures. Such wpt identifiers will be unique only for the airport specified. A wpt identifier used in a terminal area cannot be repeated in that terminal area but can be used in an enroute area encompassed by the same geographical area code.

Runway Related - Single Approach Procedure for given runway.

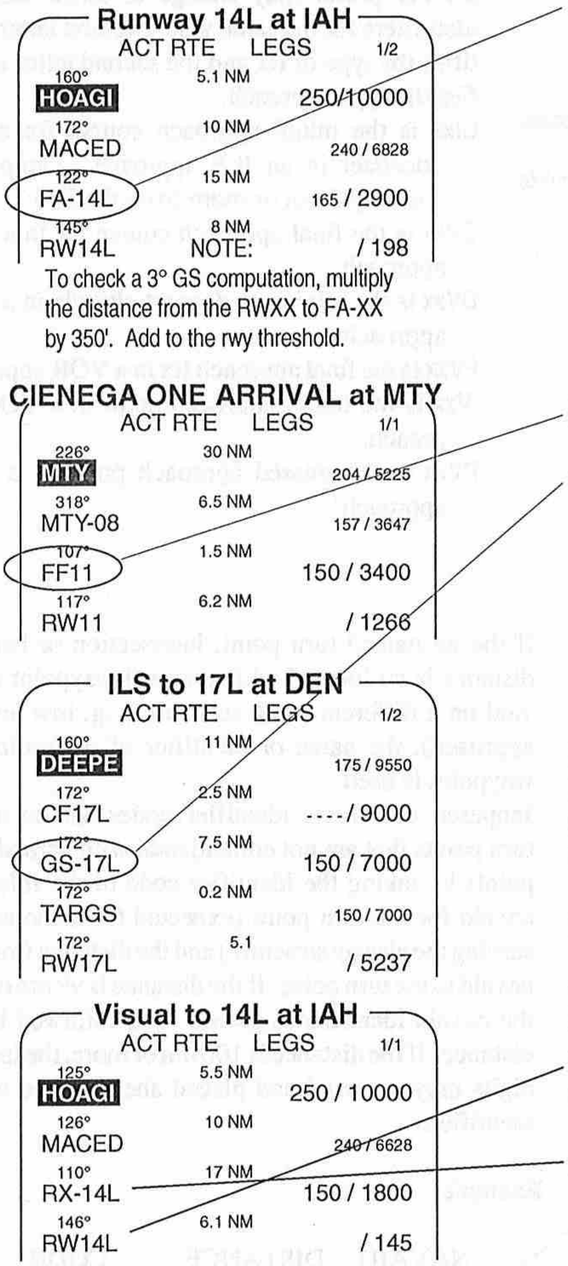
The following 2-letter prefixes are added to the relevant runway number to make up an identifier when no named wpt has been established by the government source for the fix type.

A– (+ an alpha) step down fix.

BMxx is a back course marker.

CFxx is a final approach course fix wpt. Such waypoints are contained in certain ILS procedures to ensure alignment on the final approach course. They are located approximately 9 nm prior to glideslope intercept. Example 17L at old DEN below.

TERMINAL WAYPOINTS (continued)



Runway Related - (Continued)

FA--xx is a VFR final approach fix. Discontinued after U4.0. Six characters, it identifies the computed final approach waypoint for a runway. Such wpts are inserted when a runway is chosen from the ARRIVALS page. The wpt is located 8 nm from the runway threshold on the extended runway centerline. Wpt altitude usually must be specified by crew entry. If an altitude has been assigned, the path has been constructed beginning at a point 50' above the runway threshold extending upward to a point above FA--xx.

FFxx is a final approach fix of an ARRIVAL procedure.

GS-xx identifies the computed glideslope intercept point for an ILS approach. This wpt is generated by the FMC, and in software up to U6 is the end-of-descent point for a VNAV descent. If left in, will cause VNAV to disconnect in all software, but in U7.1 and up, can be re-engaged. Usually advisable to delete this wpt.

IFxx is an intermediate approach fix.

IMxx is an inner marker.

MMxx is a middle marker.

MAxx is a missed approach point other than the runway.

MA24B is a missed approach point on the non-precision approach to RW24.

MDxx is the minimum descent altitude.

OMxx is an outer marker.

RWxx is the runway threshold.

RC-xxx U7 & up: is a computer generated (floating) rwy centerline intercept wpt.

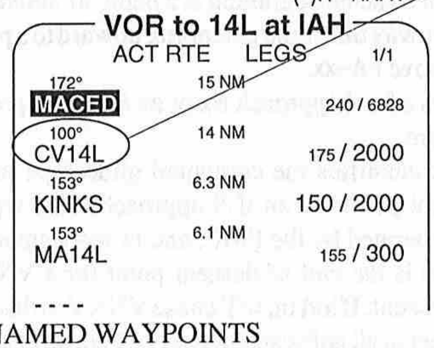
RX-xx U5.0 & up: runway extension. Distance from the runway can be entered up to 25 nm. Computer generated. Access the RWY EXT after choosing a RWY from the ARRIVALS page.

SDxx is a step-down fix.

TDxx is the touchdown point inboard of the threshold.

TERMINAL WAYPOINTS (continued)

TYPE OF FIX	TYPE APPROACH
C( ) - final approach course fix	( )L - localizer only
F ( ) - final approach fix	( )B - backcourse ILS
P( ) - missed approach point	( )D - VOR/DME
I( ) - initial approach fix	( )V - VOR only
D( ) - minimum descent altitude	( )S - VOR with DME points
T( ) - touch down point	( )N - NDB
R( ) - runway centerline intercept	( )Q - NDB with DME points
	( )M - MLS
	( )T - TACAN
	( )I - ILS
	( )R - RNAV



Runway Related - Multiple Approach Procedure for same runway.

2-letter prefix may change to allow different identifiers for the same wpt. The first letter identifies the type of fix and the second letter identifies the type approach.

CIxx is the initial approach course fix on the localizer in an ILS approach. (Jepp wpt) Usually 2 nm or more from the FAF.

CVxx is the final approach course fix in a VOR approach.

DVxx is the minimum descent altitude in a VOR approach.

FVxx is the final approach fix in a VOR approach.

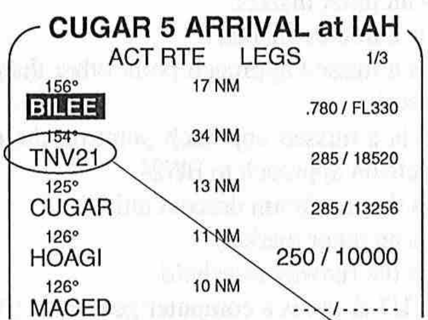
IVxx is the initial approach point in a VOR approach.

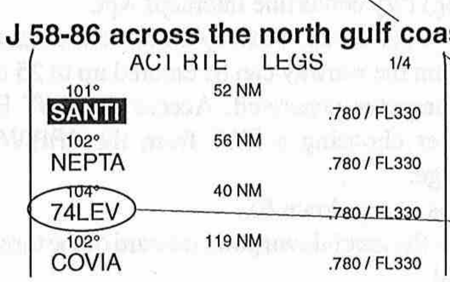
PVxx is the missed approach point in a VOR approach.

UNNAMED WAYPOINTS

If the un-named turn point, intersection or bearing/distance is co-located with a named waypoint or navaid on a different route structure (e.g. low level or approach), the name or identifier of the co-located waypoint is used.

Jeppesen constructs identifier codes for un-named turn points that are not coincidental with named waypoints by taking the identifier code of the reference navaid for the turn point (expected to be the nearest serving the airway structure) and the distance from this navaid to the turn point. If the distance is 99 nm or less, the navaid identifier is placed first, followed by the distance. If the distance is 100 nm or more, the last two digits only are used and placed ahead of the navaid identifier.





Examples:

NAVAID	DISTANCE	CODE
TNV	21	TNV21
LEV	174	74LEV

VHF NAVAIDS

Examples:

Los Angeles VORTAC	LAX
Tyndall TACAN	PAM
Ft. Nelson NDB	YE

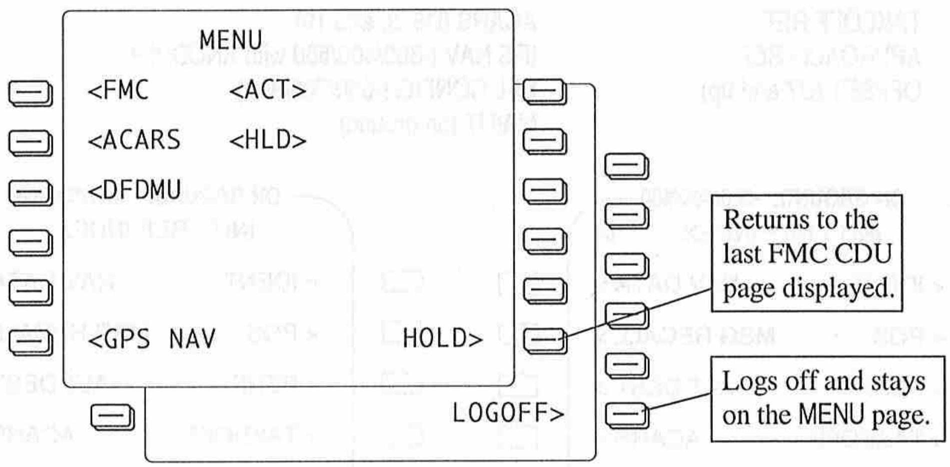
Waypoints located at any of the types of facilities on the left will take on the official identifier of the facility in question.

MENU - U10 and up

You get to this page by:

- Press (MENU) key.

- Allows selection of system for which the MCDU will be active in providing the control / display function.
- Line select system to be made active.
- HOLD - line sleected (LSK 6L) to suspend control of active system.
- LOGOFF - line selected (LSK 6L) to terminate control of an active system.
- Note: HOLD and LOGOFF are operational for a any system except the FMC.



*GPS NAV prompt allows access to IRS LEGS, IRS PROGRESS, and IRS WPT DATA. ANCDU required that is receiving valid IRS data.

You get to this page by:

- Press INIT REF key.
- If on the ground and prior to alignment, POS INIT page appears.
- If on the ground after alignment, PERF INIT page appears.
- After takeoff, information on page 101 applies.
- INDEX prompt (LSK6L) of displayed page.

The FMC will determine which page to display (based on preflight status, flight phase, etc.) when the INIT REF key is pressed.

NO REQUIRED ENTRIES

INIT/REF INDEX page provides access to:

IDENT	NAV DATA (SUPP - U4 and up)
POS INIT	MSG RECALL (U6, 8, and 10)
PERF INIT	ALT DEST (U6, 8, and 10)
TAKEOFF REF	ACARS (U6, 8, and 10)
APPROACH REF	IRS NAV (-300/400/500 with ANCDU) *
OFFSET (U7 and up)	SEL CONFIG (-600/700/800)
	MAINT (on ground)

ON GROUND: -300/400/500

INIT / REF INDEX	1/1
< IDENT	NAV DATA >
< POS	MSG RECALL >
< PERF	ALT DEST >
< TAKEOFF	ACARS >
< APPROACH	IRS NAV >
< OFFSET	MAINT >

ON GROUND: -600/700/800

INIT / REF INDEX	1/1
< IDENT	NAV DATA >
< POS	MSG RECALL >
< PERF	ALT DEST >
< TAKEOFF	ACARS >
< APPROACH	SEL CONFIG>
< OFFSET	MAINT >

- Maintenance Built-In-Test (BIT).
- Displayed on ground only.
- Provides the major test interface for the automatic flight guidance and control systems aboard the a/c. Maintenance pages are provided for recording the inflight history of the systems with which the FMCS interfaces. This recording is maintained in the FMC NVRAM. The data is collected and held for the failure incidents of the past nine flights plus current internal on-ground faults. (A "flight" is defined as the period between squat switch and greater than 20 kts and squat switch and less than 20 kts.) The FMCS records the reason and time of the failure, and the unit in which the failure was detected.

IN THE AIR: -600/700/800

INIT REF / INDEX	1/1
< IDENT	NAV DATA >
< POS	MSG RECALL >
< PERF	ALT DEST >
< TAKEOFF	ACARS >
< APPROACH	
< OFFSET	NAV STATUS>

You get to this page by:

- Displayed automatically on power up if self-test is satisfactory.
- INIT/REF INDEX page IDENT prompt (LSK 1L)
- Displayed automatically after a computer restart. (Flight plan is dumped)

NO REQUIRED ENTRIES

- Verify: Active NAV DATA base selection
- Check: OPerational PROGRAM Update

The FMC will attempt 2 restarts within 1 minute before declaring an FMC FAILure.
- If the first attempt is successful, the LEGS page will appear with a disco and a mesage SELECT ACT WPT.
- If the first restart fails but the second is successful, the IDENT page appears and the flight plan is dumped.

If the second restart fails (within one min.) the FMC is declared failed and the failure annunciator is illuminated and both CDUs display FMC after a 2 second delay.
It is necessary to remove power from the FMC for a minimum of 10 seconds to reset the FMC.

- Inclusive effectivity dates (GMT).
- Blank when internal battery is dead. (U7 computer uses a capacitor instead of a battery.)
- This time sensitive data is applicable to a 28 day time period.
- Maintenance uses a Data Loader Unit (tape cartridge or w/U7, a 3.5" disc loader) to accomplish this updating.
- Most updates are completed in approximately 15 minutes.

POWER UP → PASS SELF TEST ? – NO → FAIL

YES ↓

❷ Press 2R, transfering Alt. data base dates from s/p to active line and moving old dates down.

IDENT	1/1
MODEL	ENGINES
737-300	CFM56-03
NAV DATA	ACTIVE
WPB1900701	MAY31JUN27/90
	JUN28JUL25/90
OP PROGRAM	
548720-05-01	
<INDEX	POS INIT>
JUN28JUL25/90	

❶ Press 3R. This transfers Alt. nav/data dates to the blank s/p.

Identifies the permanent NAV DATA base in use with the airline identifier.

OPerational PROGRAM number. Ref: Updates

- To change ACTIVE nav data follow steps 1 and 2 above.
- This can be accomplished only when on the ground. Doing so clears any previously selected flight plan entries.

Non-EFIS

OP PROGRAM Updates are identifed as follows:

U 1.1 ends in -08-01
U 1.2 ends in -01-01
U 1.3 ends in -05-01
U 1.4 displays U1.4
U 1.5 displays U1.5
U 1.6 displays U1.6

U1.x standard data base is 96k with an option to go to 192k. U3, U4, U5, U6, U7, U8, U10, reference next page.

IDENT	1/1
MODEL	ENGINE RATING
737-300	22K
NAV DATA	ACTIVE
WPB1589501	MAY31JUN27/90
	JUN28JUL25/90
OP PROGRAM	
549100-02-01 (U1.4)	

TECHNIQUE

If you need to delete an entered route, simply cycle the nav databases.

TECHNIQUE

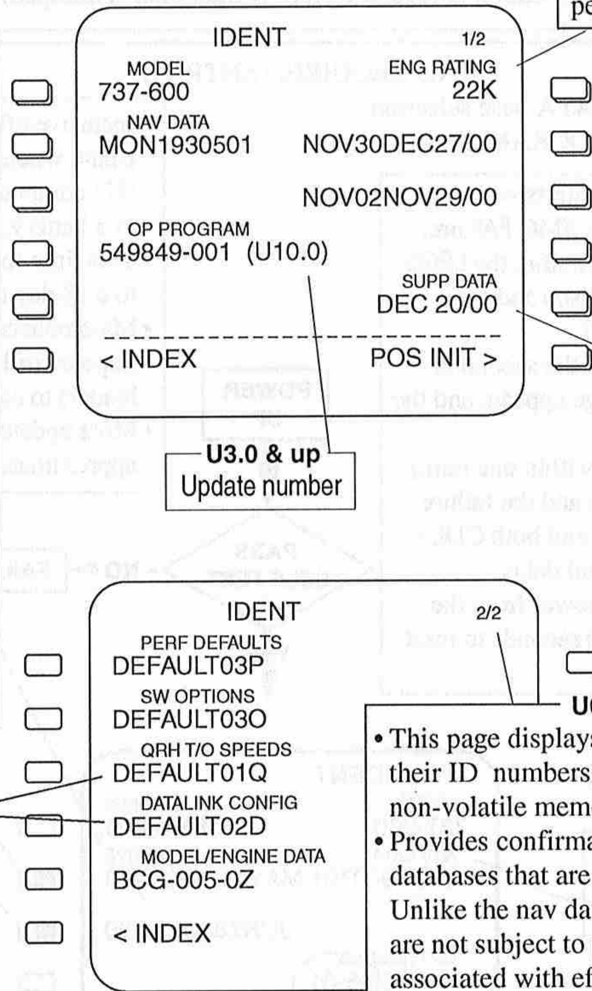
- If both primary and alternate nav data is out of date, check your MEL. Operations may be continued using conventional VOR / Airways navigation.
- Notify dispatch that the aircraft is no longer area nav capable.

Displayed on this page are samples of EFIS IDENT pages.

EFIS capability software.
Single FMC installation:
U3.0
U4.0
U5.0 option to 288k data base.
U6.0 adds .5 or 2 meg data base.
U7.1, 7.2, 7.3, 7.4
U8.0, 8.1, 8.2, 8.3
U10

Dual FMC capability:
U7.1 and up.
Note: U6, U8, and U10 offer ACARS interface and parallel each other.
Note: For more update information, refer to Appendix.

Identifies the airplane model and engine thrust in pounds stored in the performance data base.



U3.0 & up
Update number

U3.0 & up
- Displays the EFFective FRoM date propagated from the SUPP NAV DATA page.
- Blank if nothing in SUPP data base.

Airline selectable options.

U6 & up
- This page displays the databases and their ID numbers; they are stored in the non-volatile memory of the computer.
- Provides confirmation of the optional databases that are loaded into the FMC. Unlike the nav database, these databases are not subject to periodic revisions nor associated with effectivity dates.
- U10 adds QRH T/O SPEEDS and MODEL/ ENGINE DATA.

The FMC needs continuous electrical power to operate. When electrical power is interrupted for *less than 10 seconds:*
- LNAV and VNAV disengage
- all entered data is retained by the FMC
- the FMC resumes normal operation when power is restored.

If power is lost for *10 seconds or more on the ground,* all preflight procedures and entries must be done again when power is restored.

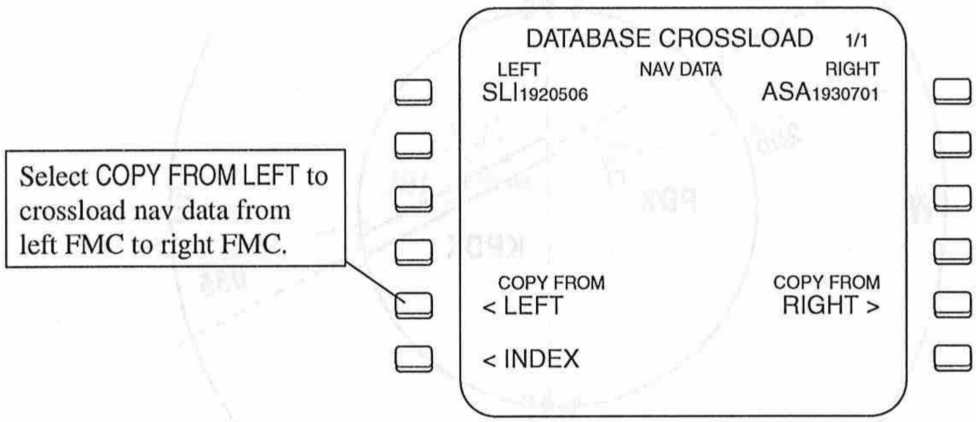
If power is lost for *more than 10 seconds in flight:*
- LNAV and VNAV disengage
- all entered data is retained by the FMC, and when power is restored the MOD RTE LEGS page is displayed with the scratchpad mesage SELECT ACTIVE WPT/LEG.

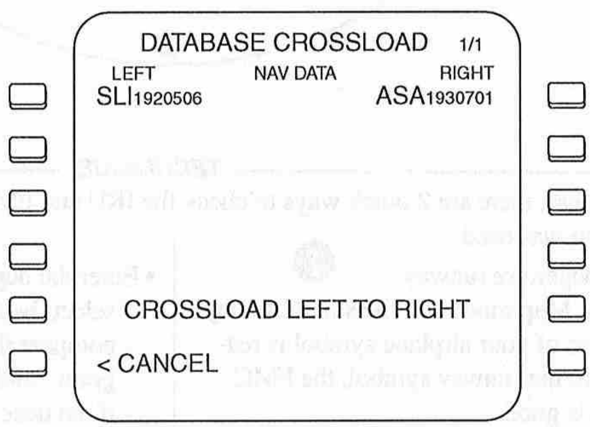
Astronauts and Engineers: Nav Database Management
When maintenance inserts a disc to change the Nav database, the old database is not actually removed. Certain data is "de-selected" and new data is inserted. Of course the sum of the old data and new data cannot exceed the card's capacity. For example, the practical limit of a 96k card is 94k. Some free space is required because the amount of new data is limited by the available free space.

DATABASE CROSSLOAD

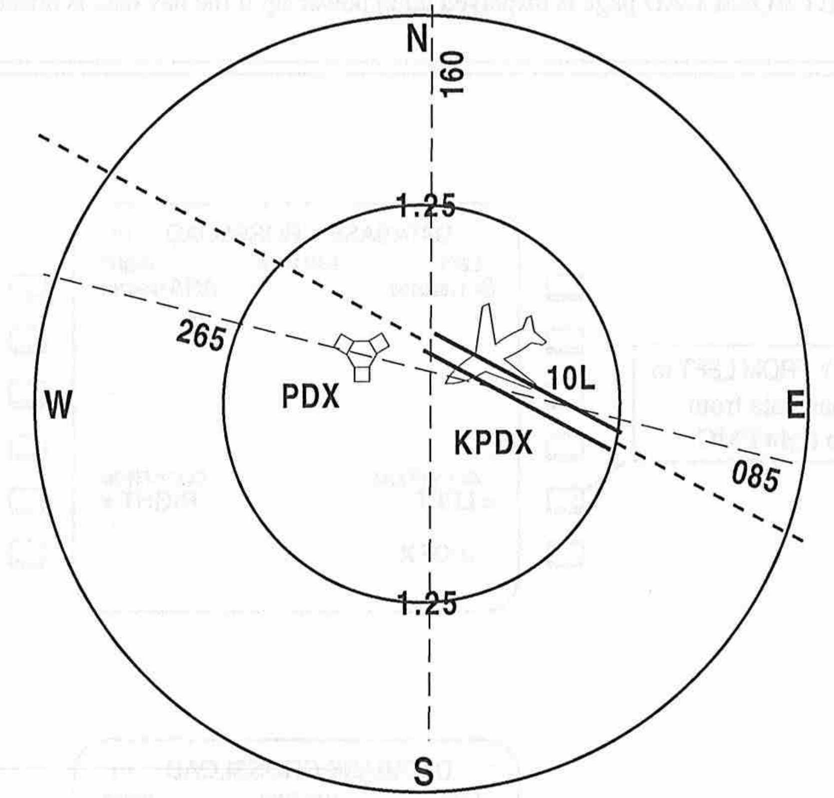
You get to this page by:

– DATABASE CROSSLOAD page is displayed upon power-up if the nav data is different.





VERIFYING POSITION AFTER ALIGNMENT



TECHNIQUE

After alignment, there are 2 quick ways to check the IRU and FMC positions to ensure the correct initial positon was used.

❶
- Enter the departure runway:
  - select the Map mode and the smallest range.
  - if the nose of your airplane symbol is reasonable to the runway symbol, the FMC position is good.
  - EFIS display option only: If you have 2 Position Difference arrows on the lower right of the ND/Map, the IRU position differs from the GPS/FMC position. You entered the wrong lat/lon into the ISDU for alignment and the IRS position is not the same as the GPS position.
  - the ND Map (FMC Position) assumes the GPS position while the IRSs accept your entered position!

❷
- Enter the departure runway (above).
  - select the PLAN mode and the smallest range.
  - compare the Map display to your airport diagram, holding it in the North-up positon.
  - if the nose of your airplane symbol is reasonable to the runway symbol, the FMC position is good. We're parked at gate D1 at Portland International Airport.
  - Ref: Position Difference information (#1)
- If you are unsure of the active runway, press the NAVAID or AIRPORT switch and check the displayed data passes your own reasonableness test.
- Select the POS SHIFT page, and all sensors will lie on top of each other (though difficult to see)

You get to this page by:

- INIT REF key when on the ground and an IRS is in ALIGN mode.
- IDENT page POS INIT prompt (LSK 6R)
- TAKEOFF REF page (LSK 4L) (When POS INIT is not yet accomplished)
- INIT/REF INDEX page POS prompt (LSK 2L)
- POS REF 2/3 then PREV PAGE
- POS SHIFT 3/3 then NEXT PAGE

Box prompts: The IRS's need present position latitude and longitude for initial alignment.

There are 4ways to enter present position. Ranked by most desired.	1 Transfer GPS position from LSK 4 or 5 of POS REF 2/2, 2 Line Select REF AIRPORT (then GATE / ALL if you have that option), 3 Keyboard entry of present position lat/lon into CDU, 4 Keyboard entry of lat/lon into ISDU (overhead).

The example below is the 5 step process to initialize the IRUs by entering the Airport Reference Point (ARP) - contained in the permanent nav database. U1.x note: Consider manual entry of actual position only if LNAV is desired immediately after takeoff since you cannot accomplish the runway update. Manual entry is undesireable because it opens a window for entry error. If a manual entry is made, both pilots should verify the entry.

- Gate position (database) or manual entry to one tenth (.1) minute is desireable if planned route is over an area of poor navaid coverage or over-water with an ANCDU.
- On the ground, the nav mode uses IRS position and taxi accelerations to maintain position. With GPS enabled, updating will occur on the ground.
- On EHSI aircraft with the nav head in AUTO (Non-EFIS a/c, HSI switch in NAV), the FMC will update its position after lift-off (strut switch).

- Displays the LAST FMC POSition anytime both IRS's are not in the NAV mode.
- LAST POS is retained by the FMC even when power is removed (NV RAM).
- This position is not recommended for IRS initialization (unless GPS is enabled) because it will contain accumulated IRS drift error from the previous time in NAV.

4 Press 2R to place ARP in s/p.

1 Set both mode switches from OFF, thru ALIGN, to NAV.
2 Type:KLAX into s/p.
3 Press 2L to retrieve Airport Reference Point (ARP) from nav database.

5
- Press 4R to place ARP in boxes and begin alignment.
- On a dual FMC, the left FMC transmits the initial position to the right.
- Go to next page to verify all IRUs have accepted this position.

- Requires entry of present position (Leading zeros req'd, decimal points and trailing zeros are optional).
- Displays current FMC position when the IRS(s) are in the NAV mode.
- SET IRS POS header and data clear when IRS is in NAV, ATT, or OFF.
- SET IRS POS and box prompts are displayed when either IRS is in ALIGN mode and IRS present position has not been entered (on ground).

U3.0 & up

- GATE used for display of the ORIGIN airport GATE position if it is in the data base.
- GATE coordinates are automatically displayed on line 3R upon entry of the REF AIRPORT (2L) followed by the GATE identifier (3L).
- It is selectable for IRS position initialization using LSK 3R.
- A procedure used by certain airlines is to enter ALL into 3L. This brings up the database concourse coordinate, a position closer to the aircraft than the ARP and saves space in the nav database.
- GPS capability renders this option obsolete.
- The lines clear at lift-off.

5 characters max

```
          POS INIT            1/2
                         LAST POS
        N33°57.2 W118°23.6
REF AIRPORT
KLAX    N33°56.6 W118°24.4
GATE
L4      N33°56.4 W118°24.4
                      SET IRS POS
□□□°□□.□ □□□□°□□.□
GMT-MON/DY          SET IRS HDG
1757.2z 06/20              ---°
------------------------------
<INDEX                  ROUTE>
NAV DATA OUT OF DATE
```

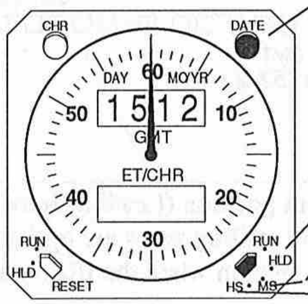
U5.0 & up

- When a clock with a date output is installed, the selected database effectivity is compared automatically with the date input and if out of date, the message NAV DATA OUT OF DATE will appear in the scratchpad.
- MON / DY is set using the Captain's clock.

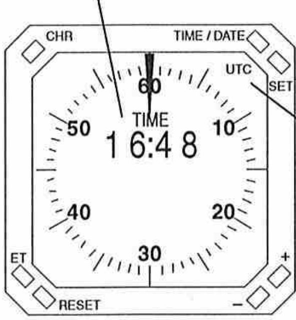
- At power-up: (U8 and down)
  - both CDUs display the Captain's clock time if it is operative.
  - the hour can be changed by entering desired hour via the CDU. The minutes cannot be changed by CDU entry; they are taken from the Captain's clock.
  - manual entry into the FMC may be UTC or local time. The GMT legend and the Z will always be displayed regardless of the time zone used for entry.
  - to ensure the FMC has GMT time, the GMT hours can be entered via CDU even when the Captain's clock is set to a non-GMT time zone.
  - if the Captain's clock is inop the FMC timer will continue to keep track of time. In this case, the POS INIT page will take both hours *and* minutes entry via the CDU. The date will blank.
  - if the Captain's clock is inop at powerup, the time will be blank; a manual entry of hours *and* minutes is allowed.

- SET IRS POS displayed when an IRS is in the ATT mode.
- Used to enter or update magnetic heading for any IRS which is in the ATT mode.
- Any entry clears upon selection on another page.
- This is not a normal mode.

- Operate the clock in UTC. After power-up, it will be in MAN.
- If dashes display in UTC, GPS signal has been lost on that side (left or right)



- Pressing the DATE switch will alternately display the day and month, then the year.
- The DATE can then be set by nimble-fingered use of the Slew switch.
- HoLD Slews the year value.
- MS Slews the Minute, or Month value.
- HS Slews the Hour or day value.



LCD Clock
TIME / DATE (3 position)
- UTC - time comes from GPS satellite and cannot be changed by pilot.
- MAN - time can be set manually using SET button with "+" and "-" buttons.
- DAY MO YR displays date.

ATTITUDE (Not a normal mode)

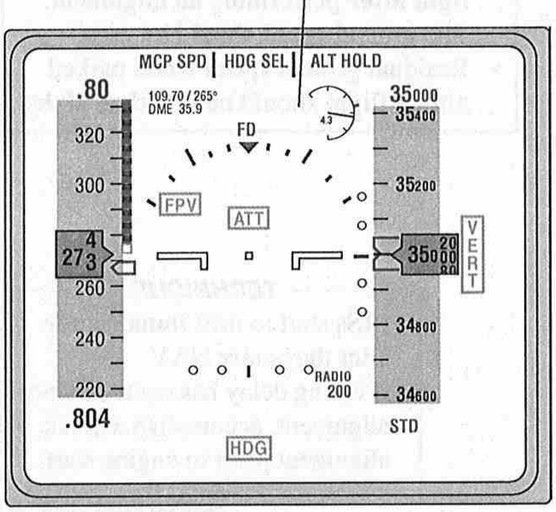
When an IRS enters the ATT mode, ATT and HDG flags appear. The ALIGN light illuminates steady. After approximately 30 seconds, the light extinguishes and the ATT flag retracts from view. In the ILS and VOR modes, the HDG flags remain in view, and in the Map and Plan modes, the doghouse (heading pointer) is not displayed, until magnetic heading has been manually entered into the IRU. Since all navigation parameters are lost for the system in ATT , the ISDU displays are blank when either PPOS, WIND, or TK/GS displays are selected. (Position and ground speed information is lost.)

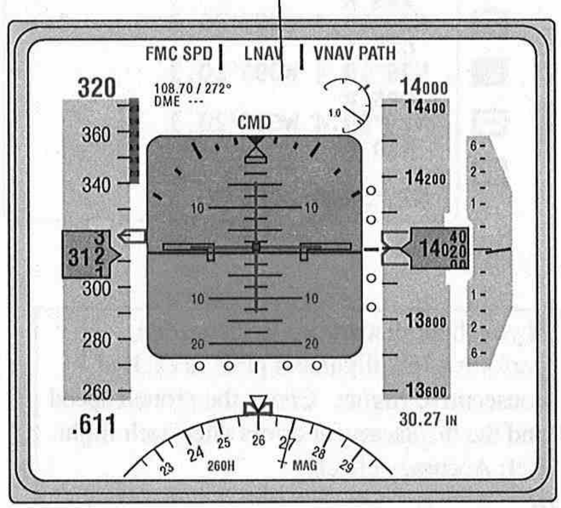
- This is a reversionary attitude mode to provide aircraft attitude and heading information after loss of AC power or certain IRS failures.
- Selectable on ground or in air.
- This "DG" type heading reference processes (drifts). Therefore, new compass headings must be entered manually whenever compass card indications are unacceptable (up to 15°/hr).
- Try this as a demonstration so you'll be comfortable should you ever experience this type of failure. I'd recommend a "good weather day" and only with the IRU in front of the PNF.

- SET IRS HDG and dash prompts are displayed anytime any IRU is in the attitude mode.
- Dash prompts are used to enter or update magnetic heading.
- The ISDU can also be used.
  - Switch the SYS DSPL to the affected IRU.
  - Press H/5 and key in the heading, and press ENT
  - If accomplished before takeoff, it does not remove the POS INIT prompt from TAKEOFF REF page.

- Several flags are present on the PFD with loss of attitude!
- IRS display unit displays for PPOS, WIND, and TK/GS are blank for the IRS in the ATT mode.

PFD after short interval of level flight and entry of heading.





You get to this page by:

- POS INIT 1/2 then NEXT PAGE

NO REQUIRED ENTRIES

- Determines present position and ground speed as calculated by the FMC.
- Used to detect errors in the IRS.
- The example below is the 3 step process to initialize the IRUs using the GPS position. This is how you will normally accomplish the alignment.

1

- Downselect either the left or right GPS position to the scratchpad.
- If you're doing an initial power-up, the GPS will require a couple of minutes to display present position.

```
        POS REF              2/3
  FMC POS                     GS

  IRS L

  IRS R

  GPS L
 N29°59.4 W095°20.3
  GPS R
 N29°59.4 W095°20.3
  RADIO

 N29°59.4 W095°20.3
```

PREV PAGE

2

- Using the POS INIT page, enter the REF AIRPORT.
- Compare the GPS position in the s/p to the LAST POS, and REF AIRPORT. The ARP is sometimes a mile or two from your position.

```
       POS INIT          1/3
                    LAST POS
       N29°59.6 W095°20.2
   REF AIRPORT
 KIAH  N29°58.8 W095°20.4
  GATE
 -----
                 SET IRS POS
          □□□°□□.□ □□□□°□□.□
  GMT-MON/DY
 0026.3z 11/21
 ------------------------
 <INDEX            ROUTE>
 N2959.4W09520.3
```

3

- Enter the GPS position into the boxes by pressing LSK3R.
- SET IRS POS header and lat/lon disappear after initialization is complete.

```
       POS REF           2/3
  FMC POS                 GS

  IRS L
 N29°59.4 W095°20.3      0KT
  IRS R
 N29°59.4 W095°20.3      1KT
  GPS L
 N29°59.4 W095°20.3
  GPS R
 N29°59.4 W095°20.3
  RADIO

 N29°59.4 W095°20.3
```

- A quick way to determine whether or not there are excessive errors in the IRS's is to check the IRS ground speed right **after** performing an alignment. The ground speed should be zero.
- Residual ground speed when parked after a flight should be less than 20 kts.

If you think that an IRS is inaccurate, perform a full alignment prior to each of 2 consecutive flights. Check the ground speed and the displacement errors after each flight. Ref: Accuracy check.

TECHNIQUE

- IRSs start to drift immediately after they enter NAV.
- If a long delay has occured since alignment, accomplish a quick alignment prior to engine start.

- Data lines will be blank if the IRS (s) are not in the NAV mode.
- Current FMC System POSition and ground speed requires that at least one IRS be in the NAV mode, otherwise line 1 will be blank.

The FMC POSition is computed periodically by GPS position updating, radio updating, and inertial updating.

An error in IRS position will probably supercede an attitude error.

U1.4,5 & U5 & up RADIO position.

```
POS REF                          2/3
FMC POS                           GS
N32°27.5 W087°23.9             397KT
IRS L
N32°27.8 W087°23.6             396KT
IRS R
N32°27.3 W087°22.8             396KT
GPS L
N32°27.6 W087°23.9
GPS R
N32°27.6 W087°23.7
RADIO
N32°27.6 W087°23.8
```

- Displays present position and ground speed as computed by the FMC and each IRS.
- In the air: (E)HSI ground speed is generated by the FMC.
- On the ground: (E)HSI ground speed is generated by the left and right respective IRSs.

U7.1 & up

- Global Position System is available (option) and is displayed at 4 and 5L.
- Dual system is required for "sole means" navigation.

```
POS REF                          2/3
FMC POS                           GS
N33°57.2 W118°23.6               0KT
IRS L
N33°56.5 W118°25.4               0KT
IRS R
N33°56.5 W118°25.4               1KT
GPS L
N33°57.2 W118°25.6
GPS R
N33°57.2 W118°25.6
RADIO
N33°57.5 W118°25.3
```

- GPS is useful in position initialization, rendering the optional GATE entry unnecessary (but always enter the REF AIRPORT as a reasonableness check.
- GPS L or GPS R may be selected to the s/p for movement to the POS INIT LSK 4R.

- If an incorrect lat/lon (i.e., REF AIRPORT) is entered during initialization, the FMC(s) will assume the position of the GPS(s). The Map appears normal but the IRUs will assume the entered lat/lon position.
- The Position Difference Display arrows will display if ORIGIN and IRS L and R differ by more than 4 nm so always check for the presence of these little arrows on the Map after alignment.

Astronauts and engineers: RAIM Prediction

RAIM (Receiver Autonomous Integrity Monitoring) prediction checks the availability of satellite coverage at the destination (5° above the horizon) at the predicted time of arrival. RAIM prediction can be done prior to departure or enroute. Systems such as the Universal FMS knows the precession of the GPS satellite constellation and computes the number of satellites that will be available overhead the destination at +/- 15, 10, 5 and 0 minutes. Local terrain can block satellite signals near the airport; RAIM predictions generally do not consider this problem nor does RAIM know if a satellite is out of service. RAIM can be accomplished when at least 5 signals are received and Fault Detection can be accomplished when at least 6 signals are received.

The RAIM and RNP/ANP concepts are quite different and one cannot cover for the other. RAIM is a predictive concept that assesses the future integrity state (not accuracy) of the GPS navigation. RNP/ANP is a real time concept that uses sensor performance characteristics to assess the current accuracy (not integrity) of the state of the navigation.

There is no RAIM prediction in the Boeing system and is unnecessary due to the ability to "coast" inertially if GPS signals are lost temporarily. The Boeing system monitors the GPS and decides how good the ANP can get. All the pilot has to do is monitor ANP.

You get to this page by:

- POS INIT 1/3 go to previous page
- POS REF 2/3 go to next page.
- (U7.0 and up) NAV STATUS page POS SHIFT prompt (6R).

Displays the position differences of each sensor (IRUs, GPS, RADIO) relative to the FMC POSition. A dual configuration includes the left and right FMC positions on line one.

POS SHIFT allows the FMC POSition to be moved to any of the displayed positions by line selection and EXEC.

It is useful to make the POS SHIFT when you are having trouble getting an update and you think an IRS position is more accurate than the FMC POSition. A badly performing radio navaid can corrupt the FMC POSition such that subsequent valid navaid position reports are considered out-of-tolerance and are ignored. The old Circular Error of Probability (CEP) which determined what updates were used, is opened up. If an update from two DME stations falls outside the error allowed by the CEP, which is just a little larger than the ANP, the FMC will not use that update. Opening the CEP will let the updates in to correct the position.

The VERIFY POSITION message or IRS NAV ONLY in a region of normally good radio coverage, typically would be the first alert that the FMC POSition and some other sensor are in substantial disagreement. Use this page to evaluate the situation.

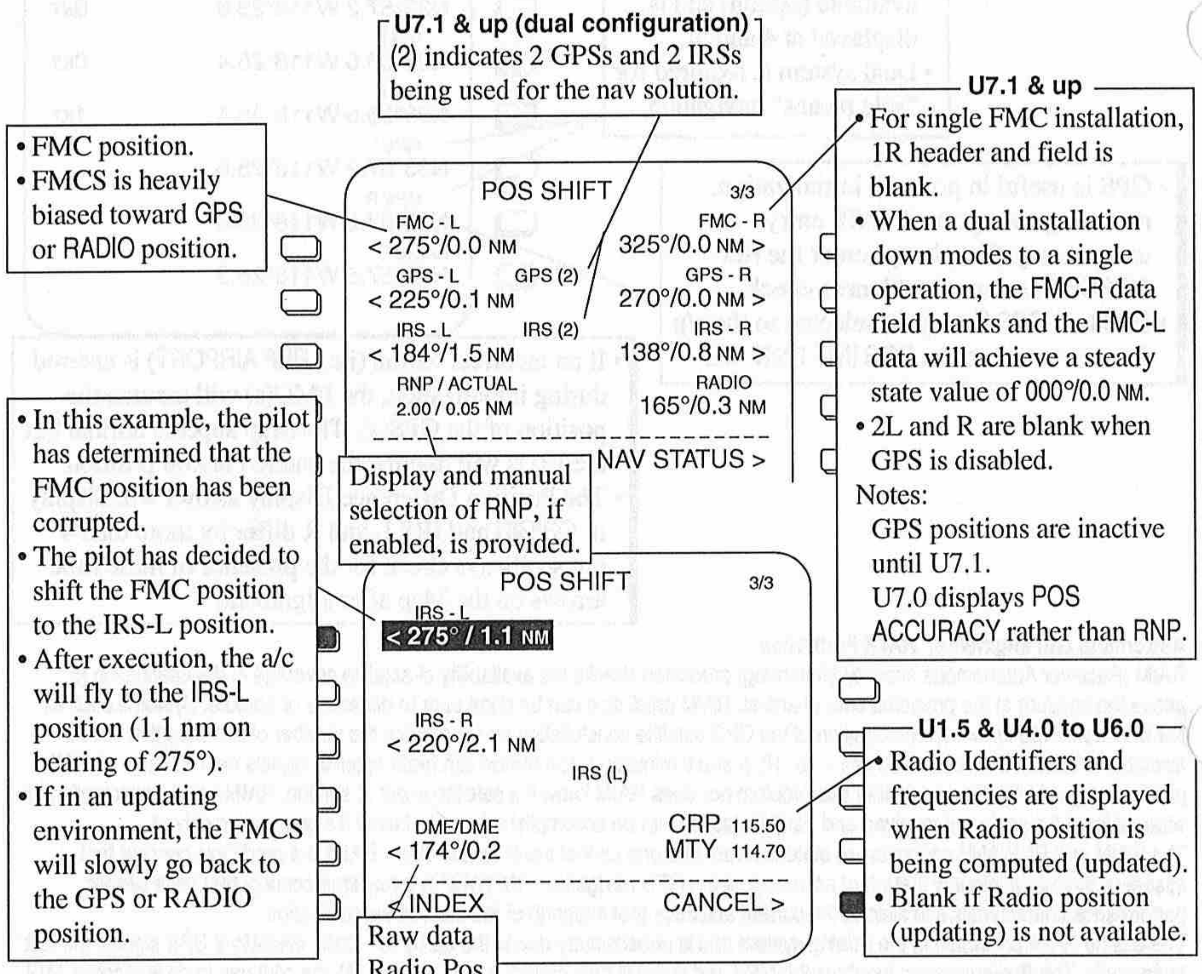
The nav filter is cleared and Ten Best List is rebuilt

Relative Position lines (1-3L and 1-4R) display bearing and range from FMCS position to each available sensor.

Line selection arms the function to shift the FMC POSition to the selected position: highlights and freezes the selected position and illuminates the EXECute key.

EXECution shifts the FMC to the selected position and an UPDATE COMPLETE annunciation appears. Page change clears this message.

If an IRS position is selected, the FMC will use that IRS for reference until changed again or it is determined to be unreasonable.

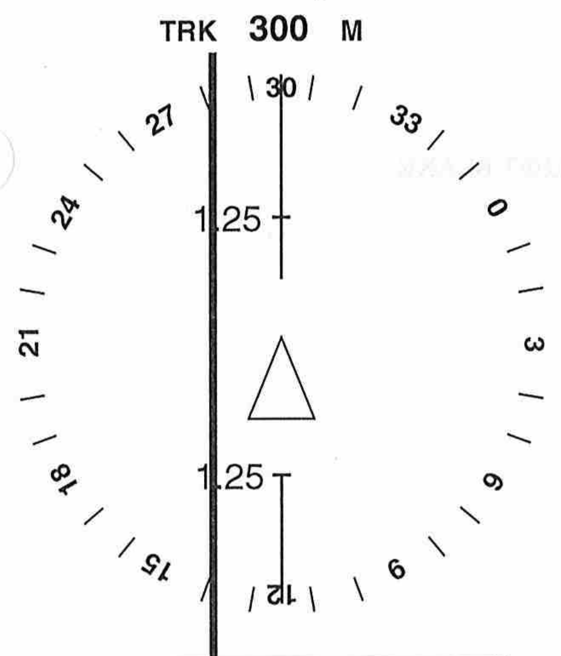


POSITION SHIFT EXERCISE

The following exercise is helpful in understanding how the POS SHIFT feature works and how GPS and radio updating affects FMC position. Accomplish this exercise only when work load is low.
Note for non-EFIS pilots: When the term *magenta line* is used, it is the same thing as the *course bar* when the HSI switch is in NAV.

1. Select the smallest range on the EFIS CP. Notice the magenta line (active route) is centered on the aircraft symbol.
2. Locate the POS SHIFT page.
   INDEX / POS / PREV PAGE
3. Each sensor's position relative to the FMC position(s) is displayed in bearing and distance **from** FMC position. In the CDU below, IRS-L is .9 nm on a bearing of 068° from the FMC (off the right wing tip). IRS-R is 1.1 nm on a bearing of 129° (off the tail).
   Use your center map or RDMI to help visualize this. The following lesson is best demonstrated when the sensor to be shifted to is off a wing tip.

Normally, the FMC POSition is a GPS updated position, not an IRU position. This *updated* position is more accurate than an IRU position.

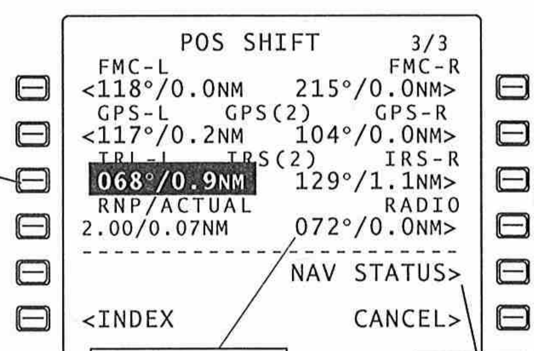


5. To keep the aircraft flying straight, line up the heading bug and press HDG SEL. This will stop the airplane from turning because the next two steps are going to reposition the FMC.
7. Press the LSK adjacent to the left IRSs. Notice you could press CANCEL to back out of this.
8. Press EXECute. Check the EFIS display. The FMC POSition has shifted to the selected IRS. Can you figure out why the magenta route appears off to one side?
9. The FMC will start updating right away because the GPS and/or DME systems are operating. Can you tell what stations the FMC is tuning? (NAV STATUS). Because the FMC POSition is biased to the sensor's position, it immediately starts to shift from the referenced IRS position to the position being calculated by those sensors. The magenta line will move back to where it was previously.
10. After the XTK ERR indicates approximately .2 nm or less, re-engage LNAV.

If all updating fails and the FMC position becomes unuseable (i.e., serious map shift), this is how you shift the FMC POSition to one of the IRSs.

Note: It is normal for the FMS POSition(s) and the positions of the various sensors to be slightly different. However, significant differences in position can be a clue to FMS nav error. For example, if the FMS-to-IRS position vector is significant and the same for *both* IRSs, it is quite possible the FMS has a position error. Why? Because it is usually unlikely that *both* IRSs will have significant drift in the same direction.

- Select the sensor that you believe is most accurate by pressing the adjacent prompt Example: Select the left IRS by pressing LSK 3L. This arms the position shift. An armed shift state may be cancelled by pressing the CANCEL > prompt at 6R.
- Press EXECute. The FMC POSition shifts to the sensor position you selected.
- If in LNAV, The aircraft will turn to the left to get back on the magenta line.
- If in an updating environment, the FMCS will slowly go back to the GPS or RADIO position.



Raw data Radio Position.

Radio Identifiers and frequencies are displayed on NAV STATUS page.

INTENTIONALLY LEFT BLANK

COMPANY RTE

You get to this page by:

- (RTE) key.
- POS INIT page ROUTE prompt (LSK 6R).
- TAKEOFF REF page ROUTE prompt (LSK 4R).
- DEPARTURES / ARRIVALS page ROUTE prompt (LSK 6R).

SELECT A COMPANY ROUTE: (Example below)

- Enter COmpany ROUTE identifier in scratchpad, then on CO ROUTE line (LSK 2L). 3 letter identifier required for each airport.
- Check FMC route matches clearance flight plan.
- Press LSK 6R, ACTIVATE>
- Press (EXEC) key. (First wpt shows zero miles if you do not EXECute.)
- ACT RTE is displayed on the top line.

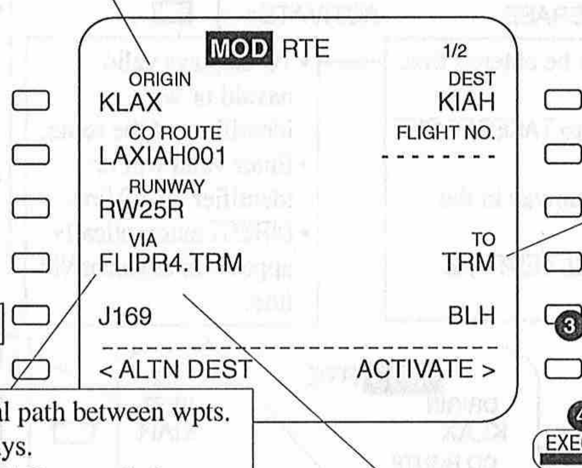
OR

MANUALLY BUILT ROUTE: (Example next page.)

- Required entry and must be in database, but can be created on REF NAV DATA if required.
- Entry from keyboard (4 letter ICAO) or propagated from CO ROUTE or UPLINK.
- Enables selection of DEParture and ARRival procedures from the DEP/ARR INDEX.
- Entry of new ORIGIN erases the previous route and can be accomplished on the active route only while on the ground. Inflight entry is inhibited.
- Note: Entry of route prior to alignment of IRS will display VERIFY POSITION message.

1 Type: LAXIAH into s/p. May need # (i.e. 001,002)

2 Enter into 2L



If a SID with a specified transition route has been entered in the VIA (line 4L), then the last wpt navaid in the SID appears in TO (line 4R).

CAUTION

EXECution of RTE may cause FMC to lock up if done at same time final alignment takes place. Cycle FMC CB.

- VIA field is the lateral path between wpts.
- VIA entries are airways.
- Entry of a SID or STAR can only be made on the DEP/ARR page or propagated from the CO ROUTE.
- Minimum plan to which the FMC can be engaged must have 3 waypoints: ORIGIN, DEST, and one TO wpt.

- If no VIA entry is made, then DIRECT appears.
- The DIRECT identifier may be overwritten.
- DIRECT entries are great circle paths. A great circle course is the shortest distance between two points that lie on the Earth's surface. The True Course formed by a great circle route constantly changes.

Astronauts and engineers: Runway Selection

If the first leg in the flight plan is a DIRECT leg, the FMC will construct a lateral path from the Origin position to the first wpt. This path is more realistic with the takeoff runway entered, since the FMC would not otherwise know what runway heading to use, and may provide a more accurate ETA and FUEL AT DEST.

If a SID is selected, a runway entry is probably necessary to get the proper terminal routing.

Other advantages for entering runway for U1.x:

Other than above, none.

Other advantages for entering runway for U4 and up:

Required for runway position update. During a runway update, the "position uncertainty" is shrunk from .4 nm to .1 nm, and the onset of an update after takeoff is delayed.

Also, the runway symbol will be displayed on the map.

MANUALLY BUILT

- Enter ORIGIN airport and DESTination airport - ICAO identifier required.
- In the dash prompts:
  - It's faster to enter departure runway here unless you need a departure procedure.
  - Enter valid waypoint or identifier on TO line.
  - Enter VIA field with valid airway, or leave DIRECT entry.
- Go to DEP/ARR page for terminal area procedure selection if required.
- Press LSK 6R, ACTIVATE> after all route entries are made.
- Press EXEC key.
- ACT RTE will be displayed on top line.

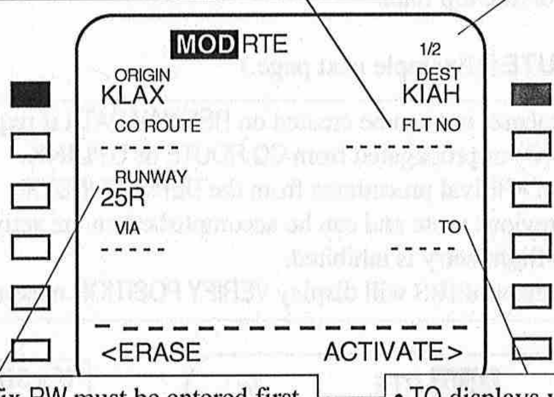
U3.0 & up

FLT NO (4 numbers) may be entered. Propagates to PROGRESS page. With U6/8 it can be downlinked. U7 and up allows entry of up to 8 alpha-numeric characters.

- Required entry and must be in database, but can be created on REF NAV DATA.
- Entry from keyboard (4 letter ICAO) or propagated from CO ROUTE or UPLINK.
- Enables selection of ARRival procedures from the DEP/ARR INDEX.
- Entry and EXECution of a new DEST clears any runway and runway dependent approach procedures of the previous destination. If the active leg is part of the affected procedure, then all subsequent legs are cleared.

TECHNIQUE

If you need to delete an entered route, simply re-enter the origin airport or cycle the nav databases.

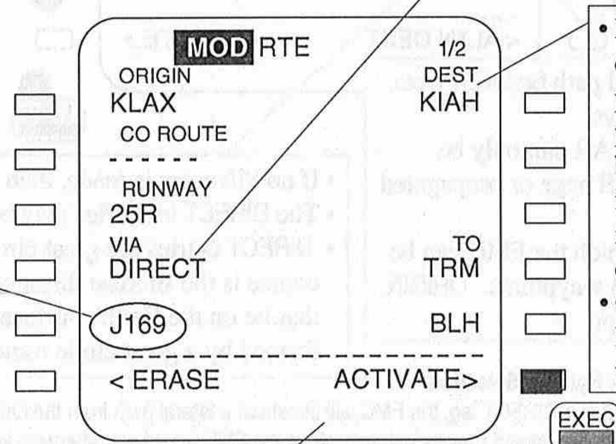


- Prior to U3.0, prefix RW must be entered first. (Example: RW08, RW25R)
- U4 and up: Entry propagates to TAKEOFF REF page for position update.
- RUNWAY header blank if no runway in the data base for that ORIGIN.
- Runway change will blank SEL TEMP and V SPDS.

- TO displays valid navaid or wpt identifiers of the route.
- Enter valid wpt or identifier on TO line.
- DIRECT automatically appears in adjacent VIA line.

- If ACTIVATE prompt does not appear after route entry, check altitude restrictions on the SID.
- DELete the altitude restriction that appears out of place.

- Enter VIA field with valid airway, or leave DIRECT entry.
- When entering an airway, the beginning wpt of interest must be entered before the airway will be accepted.
- In addition, both beginning and ending wpts must be entered before the airway can be displayed on the Map.



- If DEST is changed during climb, performance predictions may be blanked if the new flight plan is incompatible with the entered cruise altitude.
- Correct by entering a lower CRZ altitude on the CLB page.

U6 and U8

In the air, ALT DEST prompt is displayed.

U6 and up

When the missed approach procedure is initiated, the DESTination airport becomes the ORIGIN airport. This allows the selection of a SID after a missed approach to exit the terminal area, for SIDs are only listed on the DEP or left side of the CDU.

RTE - U10

To Manually build a route:
- Enter ORIGIN and DESTination ICAO identifiers.
- Enter departure runway on page 1 unless you need a departure procedure.
- On page 2, enter valid wpts on TO line
  - enter airway(s) in VIA field.
- Select STAR and approach from DEP/ARR.
- Press ACTIVATE> and EXECute.

- Enables selection of ARRival procedures from the DEP/ARR INDEX.
- Entry and EXECution of a new DEST clears any runway and runway dependent approach procedures of the previous destination. If the active leg is part of the affected procedure, then all subsequent legs are cleared.
- When the missed approach procedure is initiated, the DESTination airport becomes the ORIGIN airport. This allows the selection of a SID after a missed approach to exit the terminal area, for SIDs are only listed on the DEP or left side of the CDU.

- Enables selection of DEParture and ARRival procedures from the DEP/ARR INDEX.
- Entry of new ORIGIN erases the previous route and can be accomplished on the active route only while on the ground. Inflight entry is inhibited.

```
ACT RTE                 1/3
ORIGIN                 DEST
KIAH                   KSAN
CO ROUTE            FLT NO.
IAHSANXXX              1033
RUNWAY             FLT PLAN
15L                REQUEST>
---------------------------
```

- TO displays valid navaid or wpt identifiers of the route.
- Enter valid wpt or identifier on TO line.
- DIRECT automatically appears in adjacent VIA line.

```
ACT RTE                 2/3
VIA                      TO
JCT3                    JCT
J86                     FST
J2                      ELP
J50                     GBN
J18                     IPL
---------------------------
                 PERF INIT>
```

- Enter VIA field with valid airway.
- When entering an airway, the anchor wpt must be entered before the airway will be accepted.
- In addition, both beginning and ending wpts must be entered before the airway can be displayed on the ND.

- VIA field is the lateral path between wpts.
- VIA entries are airways.

If a SID with a specified transition route has been entered in the VIA (BARET4), then the last wpt navaid in the SID appears in TO.

```
ACT RTE                 3/3
VIA                      TO
DIRECT                BARET
BARET4                SWATT
LOC27                  RW27
MISSED APPRCH         SARGS
-----                 -----
---------------------------
                 PERF INIT>
VERIFY POSITION
```

- If no VIA entry is made, then DIRECT appears.
- The DIRECT identifier may be overwritten.
- DIRECT entries are great circle paths. A great circle course is the shortest distance between two points that lie on the Earth's surface. The True Course formed by a great circle route constantly changes.

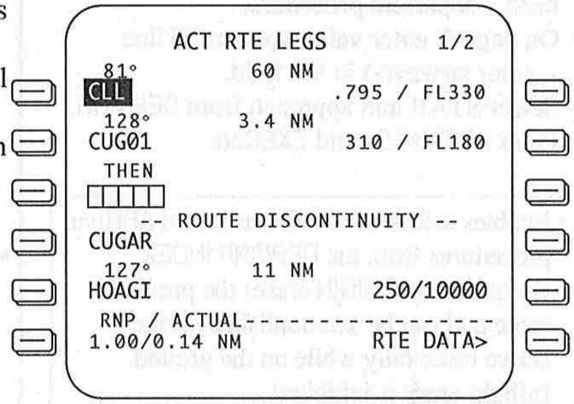
Entry of route prior to alignment of IRS will display VERIFY POSITION message.

- Entry of a SID or STAR can only be made on the DEP/ARR page or propagated from an uplink or the CO ROUTE.
- Minimum plan to which the FMC can be engaged must have 3 waypoints: ORIGIN, DEST, and one TO wpt.

- If ACTIVATE prompt does not appear after route entry, check altitude restrictions on the SID.
- DELete the altitude restriction that appears out of place.

If the entered route does not form a continuous path of linked legs (TO entries) a ROUTE DISCONTINUITY will be inserted. A ROUTE DISCONTINUITY will also be inserted if the end of a leg is indeterminate due to impossible geometry of the path (too tight a turn and / or too high an airspeed), or when an added waypoint is not part of the existing active flight plan.

There are times when a ROUTE DISCONTINUITY is advantageous, such as reaching the end of an ATC clearance, or when manuevering around the terminal area with the runway at the top of the LEGS page, the runway may drop out! Insert a DISCO; then when on the maneuvering side of the runway, accomplish a DIRECT TO or INTERCEPT LEG TO the runway.



An occasional discontinuity may occur in a procedure (DP, STAR or approach), due to the methods used for coding the database.

This example depicts a route entry where the waypoint identifier (CUGAR) is not linked with CUGO1.

A path descent is not available for a point beyond a ROUTE DISCONTINUITY.

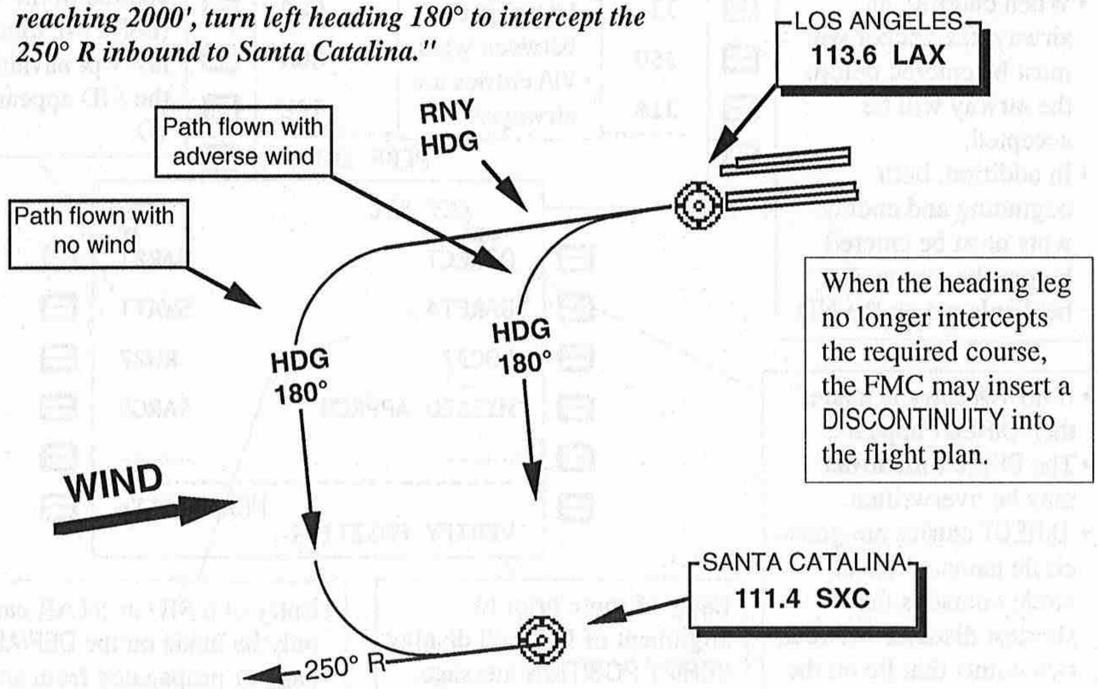
ETA and estimated fuel calculations assume direct flight across the route discontinuity.

If LNAV is allowed to fly into a ROUTE DISCONTINUITY, the AFDS will disengage to CWS (maintains heading).

A ROUTE DISCONTINUITY can also be caused by adverse wind effects on a conditional waypoint, as shown below. If normal procedures for correcting the discontinuity are unsatisfactory, consider DELeting the wpt or proceding DIRECT TO or INTERCEPT LEG TO a downpath wpt.

This example could occur if you selected a SID and runway with conditional waypoints.

ATC: *"Lockheed Air Express, maintain runway heading until reaching 2000', turn left heading 180° to intercept the 250° R inbound to Santa Catalina."*



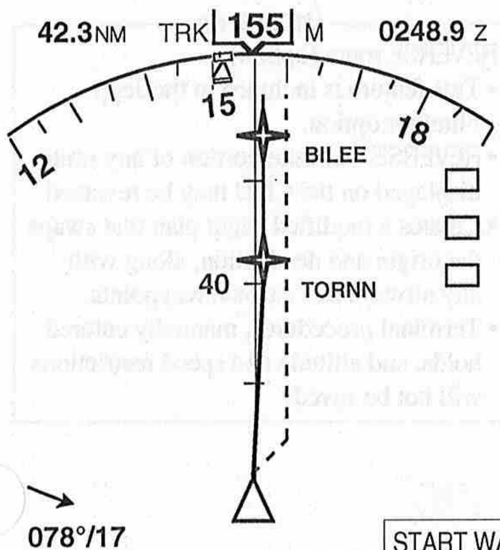
Correct the ROUTE DISCONTINUITY by entering or DELeting wpt (s) in a sequence that provides a continuous flight plan path.

ROUTE OFFSET - U7.1 and up

You get to this page by: (not available for electrical-mechanical instrumented aircraft)

- RTE page OFFSET prompt (LSK 6R) when airborne (On ground, TAKEOFF> is displayed).
- INIT REF INDEX page OFFSET prompt (LSK 6L).

- Used to establish a parallel lateral path offset left or right of the active flight plan.
- An offset can be activated for the present leg or pre-planned to start and end on a downstream leg.
- The following legs are not valid for an offset: end of flight plan wpt, a DISCO, start of a published approach transition, an approach procedure, a data base DME arc, a heading leg, a holding patttern (except PPOS), CF leg with course change greater than 2°, non TF leg or FD/FC leg with course change greater than 10°, a course change greater than 135°, and a pre-planned termination wpt.
- An offset can be built while on the ground by accessing <OFFSET prompt from the INIT REF INDEX.



ATC: ***"Boeing B-1, cleared for 5 nm offset to the right side of course."***

LATERAL OFFSET

OFFSET DIST
- - - . -

❶ Enter direction and distance in 2L. Ex: R5
- Limits of desired offset distance left or right of active flight plan is .1 to 99.9 nm. If no offsettable legs exist in flight plan, no dashes.
- Distance entry results in display of START and END WAYPOINT fields.

❷ Check the Map & EXEC.

MOD LATERAL OFFSET

OFFSET DIST
R5.0
START WAYPOINT

END WAYPOINT

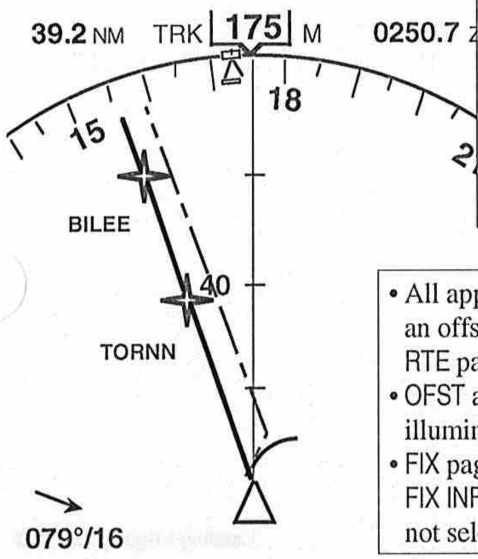
START WAYPOINT
- 6 characters max.
- After OFFSET DIST is entered, dashes display here if current leg is valid for offset (box prompts if current leg is non-offsettable).
- If no START WAYPOINT is specified (or if deleted), the offset will begin immediately or at the first valid offset wpt.
- A 45° intercept entry and exit is constructed, distance permitting.
- After passing the last leg of the offset path for which no automatic termination wpt has been specified, LNAV will disengage.

ACT LATERAL OFFSET

OFFSET DIST
R5.0
START WAYPOINT

END WAYPOINT

END WAYPOINT
- 6 characters max.
- Offset will propagate through flight plan until end wpt is encountered.
- If no END WAYPOINT is specified, the offset will end at the last valid offset wpt.
- To end an offset, enter zero or DELete the OFFSET DIST (2L).
- Use of the DIR / INTC function to a wpt on the offset path or downstream cancels an existing offset.

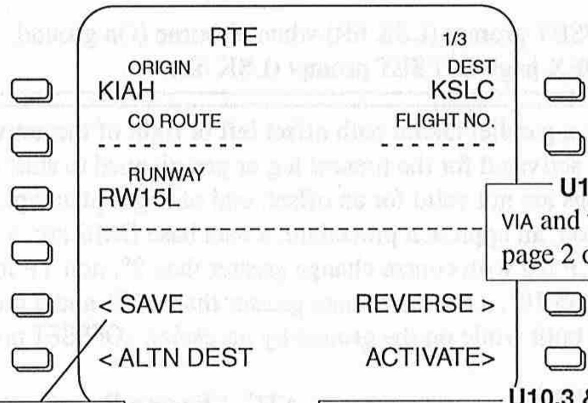


- All applicable wpt legs will have an offset header on the LEGS and RTE pages.
- OFST annunciator light illuminates (on CDU).
- FIX page title changes to OFFSET FIX INFO and RAD/DIS entries are not selectable to the s/p.

MOD OFFSET RTE 1/2

ORIGIN		DEST
KDFW		KIAH
CO ROUTE		FLT NO.
DFWIAH		100
VIA	OFST R5.0	TO
DIRECT		TORNN
	OFST R5.0	
J87		BILEE
	OFST R5.0	
DIRECT		TNV21
<ERASE		OFFSET>

SAVE and REVERSE



U10.3 & up

VIA and TO starts on page 2 of RTE pages.

U10.3 & up

SAVE route (option)

- This feature is included in the Jepp FliteStar option.
- SAVE - saves up to 10 flight plan routes for recall at another time.
- Permanently saved until deleted.
- Terminal procedures, airways and user defined wayponts can be saved.
- Manually entered holds, and altitude and speed restrictions are not retained.

U10.3 & up

REVERSE route (option)

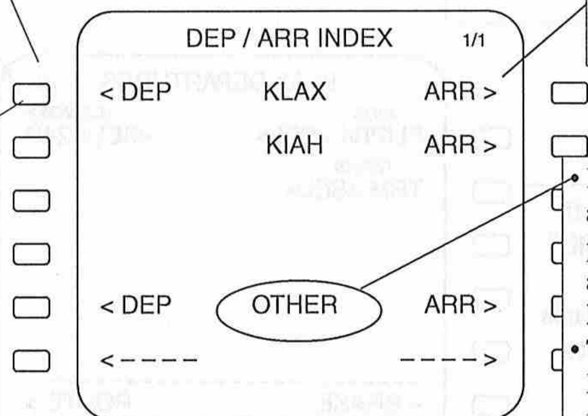
- This feature is included in the Jepp FliteStar option.
- REVERSE - enroute portion of any route displayed on the CDU may be reversed.
- Creates a modified flight plan that swaps the origin and destination, along with any airways and enroute waypoints.
- Terminal procedures, manually entered holds, and altitude and speed restrictions will not be saved.

You get to this page by:

- DEP ARR key.

1 Press LSK 1L for Origin airport.

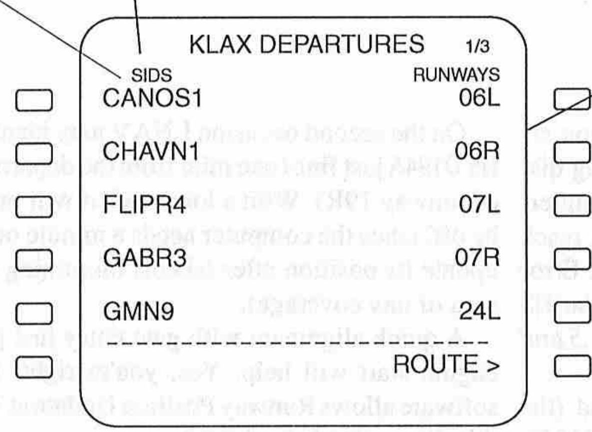
- Quick access to ORIGIN ARRIVALS for air return.
- If a runway or approach is selected from the ARR prompt, the DEST on the RTE page will change to match the ORIGIN.



- If another airport departure/arrival information is needed, press LSK 6L or 6R for OTHER airport **after entering the 4 letter airport designator in s/p.**
- These procedures are only listings and cannot be selected for entry into the flight plan.

- Upon initial page display, an alphabetical listing of all SIDS for the airport is displayed.
- Departures which are radar vectors (i.e. LAXX2 at Los Angeles) will not be displayed.

- RUNWAY coordinates are *thresholds*, – the beginning of that portion of the runway usable for landing. A *threshold* is located at the extreme end of the runway.
- If a runway has a *displaced threshold*, i.e. a threshold not located at the extreme end of the runway, the RUNWAY coordinate will be those of the *displaced threshold*.
- Runways are listed chronologically, the Left listed first.
- Go to page 2 for RUNWAY 25R.



- Selection of a departure runway before selection of a Departure Procedure will cause only the DPs applicable to the selected rwy to be displayed.
- For airports with numerous SIDs, selection of the rwy first can reduce effort in locating a particular SID.

2 ATIS is advertising 25R and the FLPR4 SID.
First SELect the runway. 25R will be on the second page.

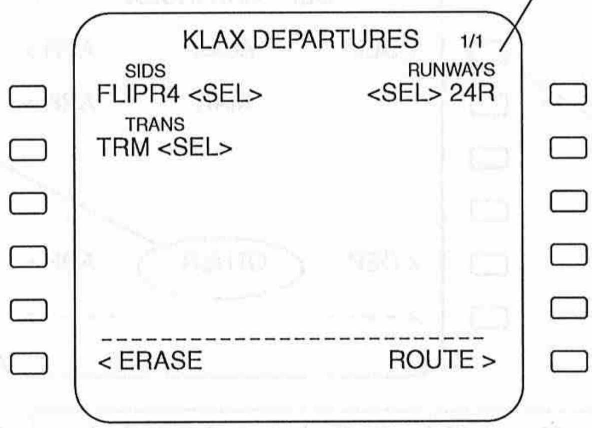
3 Now the SIDS pertinent to 25R are displayed.
SELect FLIPR4. Departure transitions are now displayed that are associated with that SID.

4 SELect the TRM transition.

Note: For most efficient operation, do not select the runway from the DEP page unless a SID is required. Type the runway right into the RTE page at 2L.

- After all choices are made, this is the screen view before EXECution.
- Selections may be EXECuted here or on the RTE or LEGS pages after linking any Route Discontinuities.
- The FMC always attempts to match DPs into the existing route. Departure matching is performed by comparing the last fix on the SID (DP) or SID TRANS with the waypoints in the route until a match is found.

- After EXECuting, only the ACTive SID, TRANSition, and RUNWAY is displayed.
- To view the complete list of DPs and RUNWAYS, simply change pages and return to the DEPARTURES page (both CDUs).



- Takeoff speeds and reduced takeoff setting once set on the TAKEOFF REF page will remain set unless some dependent data for the computation is changed, then the display is reset to the default.
- Dependent data includes Gross Weight, ZFW, OAT, runway, or SID.
- SID is included because it may require a different runway.

Since inertial systems accumulate position errors as a function of time, the position being displayed on the ground is slowly accumulating errors. In other words, as soon as the IRUs reach NAV (lights out), they start to drift slightly. Error rate history (last flight) can be checked on the IRS MONITOR page. It is common to see less than .5 nm/hr. drift.

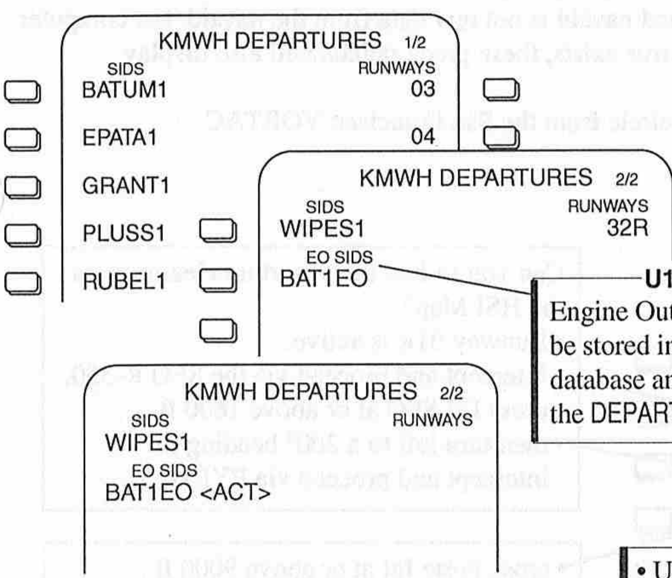
Since no updating occurs on the ground (the FMC System position follows the Referenced IRS), a significant error can build up after a long taxi. For example, being number 10 in line waiting for the Santa Ana, Ca. airport to open early in the morning produces a larger drift than taxiing immediately to the runway.

On the second occasion LNAV may identify the fix D194A just fine (one mile from the departure end of runway 19R). With a long taxi, it will probably be off, since the computer needs a minute or two to update its position after takeoff (assuming a good area of nav coverage).

A quick alignment with gate entry just prior to engine start will help. Yes, you're right. If your software allows Runway Position Update at TOGA, this discussion is irrelevant.

LNAV accuracy is not guaranteed without updating. This presents a problem for U1.x software aircraft immediately after takeoff because of the lack of the Runway Position Update feature. For this reason, LNAV is not recommended for use until updating has begun. Place an HSI switch in NAV and examine the bottom of PROGRESS 1/2 for radio updating status.

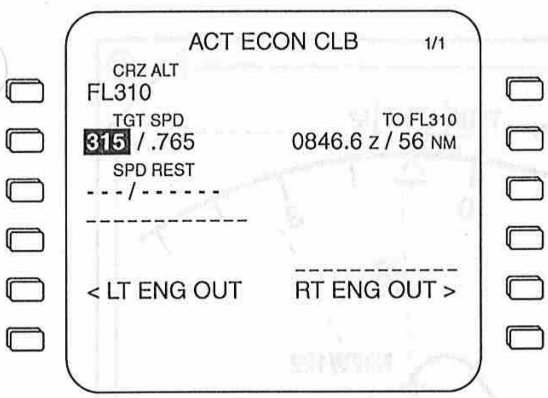
ENG OUT DEPARTURE

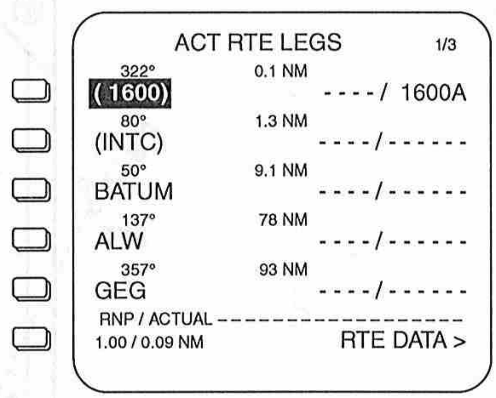


U10.3 & up

Engine Out Departures can be stored in the nav database and selected from the DEPARTURES page.

- U10.0-10.3: The EO SID can also be selected from the ENG OUT prompt on the CLB page when in climb and flaps are extended. It will insert the EO SID into the flight plan where it can be executed or erased.
- U10.4 & up: If flaps are down and an engine failure is detected, EO SID is automatically loaded as a mod plan.





U10.4

Includes a discrete bit from the engines controllers that will get set when an engine out occurs which will cause the engine out SID to be automatically linked into the flight plan.

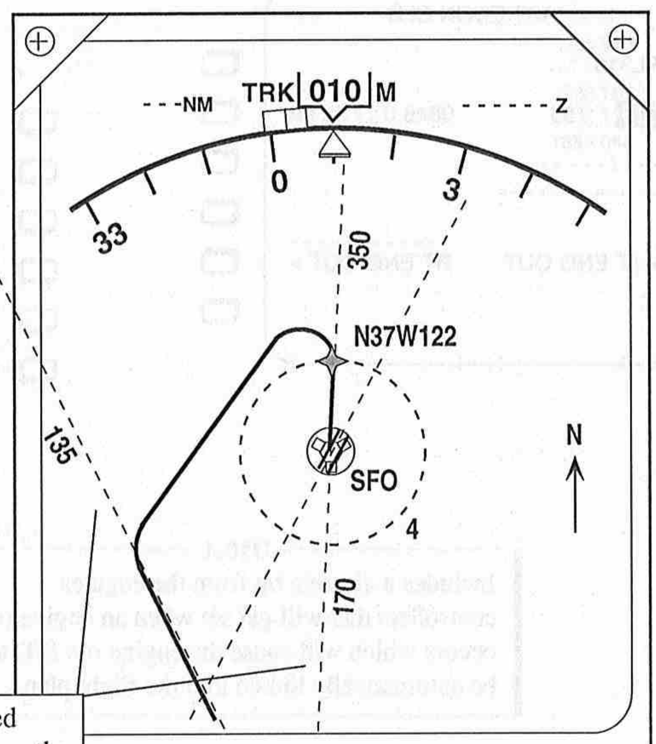
- This is an example of a PLAN mode being used in conjunction with two MANually tuned VORTACs, San Francisco (SFO) and Point Reyes (PYE)
- It is important to note that a manually tuned navaid is not raw data from the navaid, but computer data from the FMC. If an FMC position error exists, these green radials will also display erroneous information.
- The FIX page is used to build the 4 DME circle from the San Francisco VORTAC.

ACT RTE LEGS 1/x

12° HDG		
(410)		--- / 410A
350°	2 NM	
(SFO-04)		--- /1600A
200° HDG	13 NM	
(INTC)		--- / ------
135°	5 NM	
PORTE		--- /9000A
136°	15 NM	
PESCA		--- /13000A
90° HDG	17 NM	
(INTC)		--- / ------
116°	17 NM	
WAGES		--- /FL200A
117°	115 NM	
AVE		--- / ------

Can you follow the departure clearance on the HSI Map?
- Runway 01R is active.
- Intercept and proceed via the SFO R-350, cross D4 SFO at or above 1600 ft, …
- then turn left to a 200° heading to intercept and proceed via PYR-135 …

- cross Porte Int at or above 9000 ft …
- and Pesca Int at or above 13000 ft.
- Then turn left and proceed via OSI R-116 to cross Wages Int at or above FL 200 or at assigned lower altitude/flight level.
- Thence via transition or assigned route.



- These green dashed lines extending from the navaid symbol are not raw data information.
- Use for position awareness only.

PERF INIT

You get to this page by:

- ACT RTE page PERF INIT prompt (LSK 6R) on the ground.
- (INIT REF) key (on the ground and IRS initialized).
- TAKEOFF REF page (prior to PRE-FLIGHT COMPLETE) PERF INIT prompt (LSK 5L) on the ground.
- INIT/REF index page PERF prompt (LSK 3L).

- After a long-term power down, wait 15 seconds after applying power before entering PERF INIT data.
- Box prompts are entries necessary to compute performance targets.
- Dash prompts: The optional temp entry provides important performance enhancement for the MAX ALT calculation on the CRZ page if temps are above ISA.

- Displayed value equals total of ZFW and FUEL
- Entering either GROSS WT or ZFW causes display of the other.
- The FMC will round off decimals for display, but uses the full number if entered.

CAUTION

Don't enter the ZFW in this line!

- Main purpose is to optimize ECON climb computations by adjusting the climb speed (slower in a tailwind, faster in a headwind).
- If no entry, FMC assumes climb winds to be zero while on the ground and actual wind in flight; ECON climb speed will not consider wind component.
- Must be entered on the ground to be effective.
- Propagates to the crz wpts if entered after route entry.
- Does not displace forecast winds.
- Will blank upon reaching cruise altitude.
- Ref: U4 Bug on next page.

- Refer to your specific airline SOP. Usually alternate plus reserves.
- RESERVES represent fuel reserves required at destination after normal flight completion.
- Used by HOLD AVAIL field of HOLD page.

TECHNIQUE

U5 & up: Enter flight plan arrival fuel. Now, message USING RESERVE FUEL will remind you if/when the predicted arrival fuel is less than flight planned.

```
          PERF INIT                  1/1
GROSS WT                   TRIP / CRZ ALT
□□□.□                        /□□□□□
FUEL                            CRZ WIND
18.3                           - - -° / - - -
ZFW                              ISA DEV
□□□.□                            - - -° C
RESERVES                         T/C OAT
□□.□                             - - -° C
COST INDEX                     TRANS ALT
□□□                              18000
- - - - - - - - - - - - - - - - - - - - - -
<INDEX                          TAKEOFF>
```

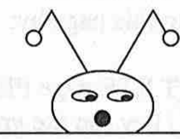
- TRANS ALT may be manually entered.
- Displayed in feet.
- May change with selection of SID.

When passing through the Transition Layer, vertical position shall be expressed in terms of Flight Levels when climbing.

- Ratio of other operating costs compared to the cost of fuel. The lower the index, the more influence fuel price has on the speed schedule. The higher the index, the greater influence time related costs (i.e. maintenance and crew) have on the equation.
- Ref: Cost Index chart, CRZ section.
- 0 causes ECON speed to be Max Specific Range (min fuel) in zero winds. 200/500 results in minimum flight time.
- Adjusting CI to meet operational schedule or ATC requirement defeats cost studies if computed by your engineering department.
- RTA function adjusts Cost Index to meet arrival times.

TECHNIQUE

After entering an estimated ZFW to check arrival time, the PERF INIT page does not offer an ERASE prompt, but the LEGS page does.



U5.0 & up

- Entry of *cruise CG - not takeoff* - can be made at LSK 1L.
- DEL returns to default value.
- Used for calculating max and optimum altitudes and maneuver-margin to buffet. Aft CG provides higher altitudes.
- Defaults:

FAA	-300 is 18.5%	-400 is 15%	-500 is 23%
	-600 is	-700 is 22.2%	-800 is 26.2%
CAA	4% (forward CG)		

CG TECHNIQUE

The net result of fuel burn is that the CG does not generally move more than 4% MAC. Maneuver altitude capability will increase approximately 100' per 2% the CG is aft the default value of 4%.

FAA operators:
Use the default CG.

CAA operators:
Enter the takeoff CG less 4%.

TECHNIQUE

If a fuel qty sensor is inop, add that missing fuel to the ZFW for performance data computations for takeoff.

T/C OAT

- Entry on the ground does not immediately generate a change in the MAX ALT calculation.
- Entry in the air (climb or cruise) may change MAX ALT calculation.

T/C OAT

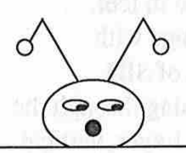
- Entry affects the TRIP, T/C, and MAX ALT calculations.
- Enter cruise OAT during preflight, after CRZ ALT is entered, especially if cruise temp is above ISA, to get an accurate MAX ALT calculation.
- If no entry is made, FMC assumes standard ISA (lapse rate of -1.983°C/1000' to tropopause at 36,089').
- The FMC does not look at air data temps for MAX ALT calculation, only this entry from the PERF INIT page!
- Manual entry of **57** goes in as -57°C
- Don't enter average temp.
- Update this temp in above ISA conditions.

- If a fuel qty. sensor or gauge is inop, maintenance will disconnect the fuel summation unit; the GW and FUEL fields will then reflect the missing fuel qty.
- If blank, the FMC is not receiving the required fuel data and will not provide performance predictions or VNAV guidance.
- In older software, AFDS occassionally drops out of VNAV during a fuel quantity test.

```
ACT PERF INIT                    1/2
GW / CRZ CG          TRIP / CRZ ALT
112.2 / 23.8%         FL354 / FL370
PLAN / FUEL                CRZ WIND
18.2 /18.3                 180° / 24
ZFW                         ISA DEV
93.9                  +18 °F +10 °C
RESERVES                    T/C OAT
4.0                   -26 °F -32 °C
COST INDEX                TRANS ALT
28                            18000
---------------------------------
<INDEX                     TAKEOFF>
```

Assumes 0° if no entry is made.

Stored in nav database.



U1.4 & U4 only

If the top-of-climb wind is entered on the CRZ WIND field of the PERF INIT page, the climb wind is erroneously assumed to be the same as the cruise wind from takeoff to level-off. An EFIS display will actually show a drift to the down wind side, known by some pilots as "la courbe du chien". On U4, top-of-climb wind should not be entered to avoid this problem.

TECHNIQUE

If the flight plan T/C temp is ISA, save Pre-flight time by using the default value.

ISA	
FL 220	-20°F/-29°C
FL 250	-31°F/-35°C
FL 270	-38°F/-39°C
FL 280	-42°F/-41°C
FL 290	-45°F/-43°C
FL 310	-52°F-47°C
FL 330	-60°F-51°C
FL 350	-67°F-55°C
FL 370	-71°F-57°C
FL 410	-55°C

Mathematicians: Temperature Conversion

To calculate ISA at specific altitudes.
ISA at 15,000 is -15°C. It decreases 2° per 1,000 ft.
Example: Calculate ISA at 30,000 ft,
30,000 – 15,000 = 15,000 x 2° per 1,000 = 30°.
-15° + -30° = **-45°**

- U7.5 & 10: FUEL
- Fuel qty may be entered if FQIS fails.
- Dashes appear at 30 min intervals; a manual fuel value entry is then required.
- MAN displayed by fuel wt.
- Use fuel predictions only immediately after a manual entry.

- U6 & up: PLAN
- With dashes displayed, takeoff fuel may be entered to generate predictions before fuel is loaded.
- FMC will use this entered value in place of the data provided by the fuel summation unit.
- Remains in effect until engine start.

```
          PERF INIT          1/2
 GW/CRZ CG               CRZ ALT
 □□□.□/22.2%                □□□□□
 PLAN/FUEL              CRZ WIND
 28.0/ 7.5              080°/ 50
 ZFW
 □□□.□
 RESERVES              TRANS ALT
 8.0                       18000
 COST INDEX            PERF INIT
 50                     REQUEST>
 ------------------------------
 <INDEX                N1 LIMIT>
```

- A short range flight may be limited by the distance required to perform the climb and descent.
- TRIP ALT is designed to be used like the Short Trip Cruise Altitude chart to show the max altitude at which it is possible to cruise for at least one minute in level flight.
- Constrained by the operator's minimum cruise-time criteria Ref: PERF FACTORS. Normally 1 minute.
- TRIP ALT is advisory and provides a reference for selecting the planned CRZ ALT.
- Auto displayed whenever a route is entered with the GROSS WT (or ZFW) and COST INDEX.
- For long flights, it propagates from OPT ALT on CRZ page.
- This feature is very useful, however a little on the optimistic side because it unfortunately it does not consider altitude restrictions on the LEGS page!
- It will look at the wind entry on the PERF INIT page but not the winds on the RTE DATA page.

Situation: AD requires center tank fuel pumps to be immersed in fuel when in use (chafing of wire bundle or potential overheating). 1,000 lbs of unuseable fuel must remain in the center tank.

- Center tank must contain 1,000 lbs of ballast fuel.
- This fuel may also be accounted for in the payload, depending on your takeoff paperwork.
- Since the FMC calculates the weight of the fuel from the fuel gauges, the gross weight may be high by 1,000 lbs.
- If this is the case, reduce the ZFW by 1,000 lbs so the FMC will accurately reflect the actual weight.

```
       ACT PERF INIT         1/2
 GW/CRZ CG          TRIP/CRZ ALT
 117.7/22.2%     FL285/FL220
 PLAN/FUEL              CRZ WIND
 ---.-/12.5              240°/ 38
 ZFW                     T/C OAT
 105.2              -20°F -29°C
 RESERVES              TRANS ALT
 5.0                       18000
 COST INDEX            PERF INIT
 68                     REQUEST>
 ------------------------------
 <INDEX                N1 LIMIT>
```

Technique

Calculate the point on the route where you'll have approximately 1,500-2,000 lbs of fuel remaining in the center tank. Enter this waypoint in a FIX page. You may need to use a distance circle. This will remind you to check the center tank quantity and to turn the pumps off before the quantity is less than 1,000 lbs.

You get to this page by:

- N1 LIMIT key.
- ACT PERF INIT page, N1 LIMIT prompt while on the ground (U10.1 and up)

NO REQUIRED ENTRIES

- Provides manual override of automatically controlled N1 limits.
- N_1 for the individual thrust limits, based on present conditions and bleed air configuration.
- Making a selection in flight causes the cursors to move to the displayed value. That selection is then displayed on the FMA/TMA.
- Current N_1 limit values are displayed for all phases of flight except TO:
  - GA - Go-around
  - CON - Max continuous thrust
  - CLB - Climb
  - CRZ - Cruise
- Normally, N_1 limits are AUTOmatically specified by the FMC. However, a pilot selection of other limits is allowed. If the AFDS commands an N_1 limit, any manually selected limit is automatically replaced by the AUTO selection when the A/P next changes vertical modes.
- The <ACT> prompt indicates which set of N1 values are currently being used by the system.
- The only time a pilot may need to select an N1 limit is during an engine out situation. One could accomplish the same thing on the ENG OUT, CLB or CRZ page. If a manual selection is made, automatic selection resumes when the autopilot changes autothrottle or pitch modes.
- It may also be useful during a situation where you've encountered mountain wave or a hold at cruise altitude; an extra 2% N1 is available by changing to the CLB limit.

N1 LIMIT 1/1
T/R ALT
AUTO <ACT> 1100 FT
GA 91.7 / 91.7%
CON 89.5 / 89.5%
CLB 89.5 / 89.5%
CRZ 87.5 / 87.5%
------- REDUCED CLB -------
< CLB-1 <SEL> CLB-2 >

U3.0 & up

Takeoff Profile option req'd for Thrust Reduction ALTitude (T/R ALT).
- Indicates where the takeoff N_1 automatically transitions to climb N_1.
- Allows entry of the altitude in feet AGL.
- Default is 1500 FT AGL (ICAO "A") for the ORIGIN airport but may be overwritten.
- U10: Moved to TAKEOFF REF 2/2.

Takeoff Bump Thrust (TO-B) is available when increased thrust is needed for takeoff above the normal max takeoff thrust setting. When TO-B is selected, takeoff thrust is increased to the N1 bug. It applies only to takeoff rating; max climb, max continuous and go-around thrust ratings are not affected. TO-B will be displayed on the FMA.

U10.1 & UP - ON THE GROUND

N1 LIMIT 1/1
SEL / OAT
/□□□□°C
< TO CLB >
< TO-1
< TO-2

< PERF INIT
/15

with BUMP OPTION

N1 LIMIT 1/1
SEL / OAT 26K BUMP N1
- - - - / +15°C 102.5 / 102.5
26K
< TO
24K DERATE
< TO-1
22K DERATE
< TO-2
26K BUMP
< TO-B <ACT>

< PERF INIT

Header changes to 26K BUMP N1 when TO-B is selected.

without BUMP OPTION

N1 LIMIT 1/1
SEL / OAT RED 24K N1
+120 / +61°F 89.1 / 88.2
24K
< TO <ACT> CLB >
22K DERATE
< TO-1 CLB-1 >
20K DERATE
< TO-2 <SEL> CLB-2 >

< PERF INIT TAKEOFF >

- Selects Takeoff Bump Thrust limit.
- Header changes to 26K BUMP.
- When TO-B is selected, assumed temp (SEL) thrust reduction is not available.
- Takeoff data uplink may automatically select TO-B.

N1 LIMIT

REDUCED CLIMB

- Two Reduced Climb selections are available.
- Reduced thrust takeoffs lower EGT and extend engine life.
- Since climb power will not be greater than takeoff power, a reduced takeoff thrust may result in a reduced climb thrust. Reduced CLB-1 or CLB-2 is **automatically** selected when a large assumed temp is selected on the TAKEOFF REF page which results in a takeoff N_1 less than the CLB limit. OAT entry on TAKEOFF REF page is required.
- Use of reduced climb thrust reduces engine maintenance costs but increases total trip fuel.
- If CLB-1 or CLB-2 is selected, the N1% for CLB and the N1 cursors still display values for full rated climb.

Identifies ACTive N_1 limit.

Displays the N_1 for individual thrust limits based on present conditions and bleed air configuration.

```
              N1 LIMIT              1/1
                                T/R ALT
AUTO <ACT>                      1100 FT

GA                        91.7 / 91.7%

CON                       89.5 / 89.5%

CLB                       89.5 / 89.5%

CRZ                       87.5 / 87.5%
         ---- REDUCED CLB ----
< CLB-1 <SEL>                  CLB-2 >
```

TECHNIQUE

After a SEL TEMP is entered on TAKEOFF REF, and if RED TO is indicated, check the N1 LIMIT page to see which one of the REDUCED CLBs has been selected **automatically**.

- Select Reduced CLB by LSK 6L or 6R.
- OAT on TAKEOFF REF page is required.

CLB-1 approximates 3% N_1 reduction to 10,000' (± 8% reduction in thrust) and the provides a gradual thrust increase until normal climb N1 limit thrust is reached at 15,000'. After selecting CLB-1, actual N_1 setting can be read on CLB page. N_1 gauge cursors stay at full rated limit.

CLB-2 approximates a 6% N_1 reduction to 5,000' (± 16% thrust reduction) and then provides a gradual thrust increase until normal climb N_1 limit is reached at 15,000'. After selecting CLB-2, the actual N_1 setting can be read on the CLB page. N_1 gauge cursors stay at full rated limit.

```
              N1 LIMIT              1/1
                                T/R ALT
AUTO <ACT>                      1100 FT

GA                        91.7 / 91.7%

CON                       89.5 / 89.5%

CLB                       89.5 / 89.5%

CRZ                       87.5 / 87.5%
------ REDUCED CLB ------
< CLB-1                  <SEL> CLB-2 >
```

TECHNIQUE

Use CLB-2 to avoid high nose-up attitudes in high density traffic areas and for low-altitude level-off.

REDUCED CLB may be deleted by:
- Pressing the DEL and then LSK 6L or 6R to return to full rated climb limit, or
- by DELeteing the SEL TEMP on the TAKEOFF REF page.

If the autothrottles are inop, you need to know what the climb power setting should be after takeoff. Where would you find this, if a reduced power selection has been made? Turn to the CLB page. And at what altitude would you go to the N1 LIMIT page to continue to monitor the climb power? 15,000'

PERF LIMITS

You get to this page by:

- PERF INIT 1/1, go to (NEXT PAGE)
- (INIT REF) key (on the ground and IRS initialized, (NEXT PAGE)).
- RTA PROGRESS page, LIMIT prompt.

The RTA function defaults to flaps-up minimum maneuvering speed and VMO for airspeed limits to meet a specified arrival time. This page allows customization of the operating speed limits to restrict the target speeds the FMC will use in the RTA or ECON mode. Speed restricions may be entered individually for each phase (climb, cruise, descent) of flight.

The values on this page have no effect on a manually entered speed or LRC.

The default settings essentially provide no restrictions on the Cost Index driven flight profile optimizations, which are always constrained by low and high speed performance limitations associated with buffet margin restrictions.

Both CAS and Mach must be entered.The slower of the CAS or Mach entry will command the speed bug. If the slower entry is the CAS entry, it is displayed as Mach.

U4.0 & up

TIME ERROR TOLERANCE

- 15 seconds is the default value (LSK 1L)
- Allowable entry range at 1L is from 6 to 30 sec. The RTA function attempts to arrive at the RTA wpt within a TIME ERROR TOLERANCE of 15 seconds unless another value is entered.
- Default value displayed in small font.
- This tolerance value affects only the number of potential speed adjustments when near the RTA wpt.

TECHNIQUE

To limit the speed that ECON 0 will use in a tailwind, enter the MRC speed (in CAS and Mach).

DELeting manual entries will result in display of default values.

```
       ACT PERF LIMITS         2/2
 TIME ERROR TOLERANCE
   30 SEC AT RTA WPT
 MIN SPD      --CLB--      MAX SPD
210/.400                  340/.820
              --CRZ--
210/.400                  340/.820
              --DES--
210/.400                  340/.820
 PERF LIM                  PERF LIM
<REPORT                   REQUEST>
-------------------------------
<INDEX                        RTA>
```

U4.0 & up

MIN SPD

- Default is:
  (3-4-5) 210/.400, which is lower limit. (Flaps 0 min man.)
  (6-7-8) min is defined in the MODEL/ ENGINE database.
- Default value displayed in small font.

U4.0 & up

MAX SPD

- Establishes upper speed limit for each phase of flight in the RTA or ECON mode.
- Default is:
  (3-4-5) 340/.820, which is upper limit.
  (6-7-8) max is defined in the MODEL/ ENGINE database.
- Both CAS and Mach must be entered.
- Default value displayed in small font.

Astronauts and engineers: Temperature

During the first 5,000' of the climb phase, if no aspirated TAT probe interface exists, pilot-entered information (if available) is used for performance predictions.

Above 5,000', but more than 2,000' below T/C (cruise) altitude, the temperature used for predictions is a linear interpolation between current temperature and the pilot-entered T/C temperature. This often results in a non-standard temperature lapse rate. When the aircraft is within 2,000' of T/C (cruise) altitude, the current temperature and the standard lapse rate are used for predictions.

All other flight phases use current temperature - pilot entered value is not used.

TECHNIQUE

Enter desired descent speed (ex: 300/.78) at LSK 4R to limit ECON or RTA speed. This saves editing the DES page if cruise altitude is changed enroute while flying ECON with a CI entry above 54.

TAKEOFF REF

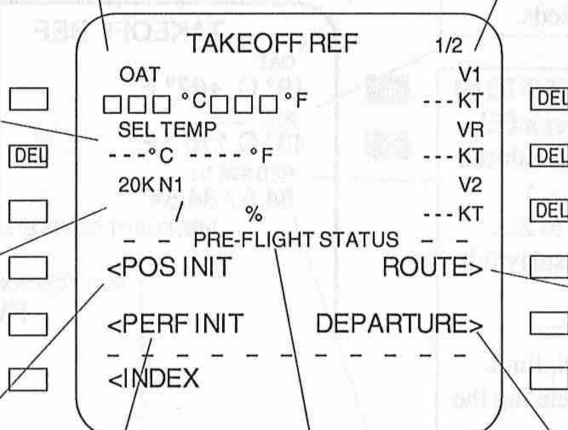
You get to this page by:

- PERF INIT page TAKEOFF prompt (LSK 6R).
- ACT RTE page TAKEOFF prompt (LSK 6R) on ground and PERF INIT completed.
- INIT/REF index page TAKEOFF prompt (LSK 4L).
- TAKEOFF REF page automatically changes to CLB page after takeoff (U10.3 & up)

- Reduced thrust takeoffs lower EGT and extend engine life.
- An assumed temp that is higher than the actual temperature is used to calculate a takeoff thrust that is less than full rated thrust.
- Max thrust reduction authorized is 25 percent below certified rating.
- May result in reduced climb thrust to avoid throttle up at transition to climb.
- Runway change or entry will blank field.
- The assumed temp setting is not considered a limitation. The assumed temp can be removed, and if desired, the crew can manually apply full thrust.

- Enter actual OAT for takeoff N_1 limit calculations.
- N_1 cursors will drive to full TO limits.
- TO is annunciated as the N_1 limit on the FMA.

- U1.x and non-EFIS aircraft: Entry of V speeds is optional and may be used as a reference. They have no effect on other computations in round-dialed aircraft.
- U3.0 and up: EFIS aircraft, V1 and VR may be entered for display on the EADI speed tape. Items are downselectable to the s/p for easier entry.
- Entries clear when airborne.



U1.x: Not DELetable.

- Displays the FMC computed N_1 for takeoff.
- TO N1 indicates full power.

Displayed if a ROUTE is not ACTive.

Displayed if RTE page 1 displays prompts for RUNWAY and VIA.

Displayed if a valid SET IRS POS entry disagrees with the position determined by any IRS in the ALIGN mode.

Displayed if any req'd PERF INIT entries have been omitted.

- PREFLIGHT STATUS - Displays prompts for uncompleted pre-flight entries.
- Discontinued if TAKEOFF SPEEDS option is selected.

TECHNIQUE

On the BEFORE START checklist challenge of "FMC . . . SET", check PRE-FLIGHT STATUS has changed to PRE-FLIGHT COMPLETE.

Mathematicians: Temperature Conversion
To change °C to °F:
(°C x 2) -10% +32
To change °F to °C
°F -32 / 2 + 10%

TEMP CONVERSION °C	°F
-18	0
-15	5
-13	8
-11	12
-9	16
-7	19
-4	25
-1	30
2	36
4	39
7	45
10	50
13	55
16	61
18	64
21	70
24	75
27	81
29	84
32	90
35	95
38	100
40	104
43	109
46	115
49	120

- OAT must be entered before the SEL TEMP and before attempting to arm the A/T on the ground.
- Airplanes with aspirated TAT probes, OAT automatically entered from DADC system (option).
- Entry of °C causes only the °C to display.
- Entry of °F causes the equivalent °C to be displayed.
- If you are trying to convert Celsius to Farenheit, unfortunately you must enter estimated °F first.
- Default temp can be °F (option).

TECHNIQUE
Display this page before takeoff to check power setting.

CAUTION
- The **difference** in the actual temp and the assumed temp is used in computing the RED TO N1.
- The greater the difference, the lower the RED TO N1 computation.
- If you see an unusually low RED TO N1, a temp has been entered incorrectly.

SEL TEMP entry deletes entered V speeds.

TAKEOFF REF 1/2
OAT V1
19° C +67° F 131 KT
SEL TEMP VR
43° C 110 ° F 132 KT
RED 20K N1 V2
84.5 / 84.5% - - - KT
- - - - - - PRE-FLIGHT COMPLETE - - - - -
FMC POSITION UPDATE
RW25R>

- Data line changes to RED-TO N1 (or RED XXK) whenever a SEL TEMP entry results in a reduced N_1 value.
- Same items duplicate to 2/2.
- The N_1 cursors still display full TO N_1 limit.
- FMA/TMA annunciates REDUCED TO as the N_1 limit.
- May be DELeted by deleting the SEL TEMP entry.
- Max reduced is 25%.
- Ref: N1 LIMIT.

U3.0 & up
- V1, VR, and V2 may be entered for reference.
- Only V1 and VR can be displayed on the EADI speed tape/ MASI.
- Entry of V2 has no input; it is set on MCP.

CAUTION
PRE-FLT COMPLETE
- Displayed when all pre-flight entries are completed.
- Does not mean they are correct!

TECHNIQUE
If N_1's differ and <u>both</u> pack switches are OFF or ON, it may help to cycle the PMC control switches. If not, notify maintenance.

TECHNIQUE
Check the N1 or CLB page after a SEL TEMP has been entered to see if / which RED CLB setting has been automatically chosen.

Astronauts and engineers: Runway Update
Runway update reduces Position Uncertainty (PU, now known as Actual Nav Position) from .4 nm (normal Radio PU) to .1 nm. The FMC can do a VOR/DME update after takeoff, however, contaminating a good FMC POSition. This will be fixed in U10.

TAKEOFF SPDS or ACARS option

You get to this page by:

- PERF INIT page TAKEOFF prompt (LSK 6R).
- ACT RTE page TAKEOFF prompt (LSK 6R) on ground and PERF INIT completed.
- INIT/REF index page TAKEOFF prompt (LSK 4L).

U3.0 & up

Option pin TAKEOFF SPEEDS in **bold**.

- V1, VR, and V2 are calculated by the FMC and displayed in the center of the page. Accounts for altitude, temperature, gross weight, and flap setting.
- Takeoff speeds are computed only if the Minimum takeoff weight is in the region determined by the table provided in the Performance databas
- To display V1 and VR on the speed tape, they must be overwritten - press 1R, 2R, and 3R twice.

Option pin FAA/CAA QRH TAKEOFF SPEEDS.

- U6 & U8 and up: V1, VR, and V2 displays will take into account in addition to the above, runway length, slope, wet/dry, wind spd/direction, and CG.
- Don't check the V speeds before the fuel quantity system has caught up with the actual figures.

- OAT entry requires a slash.
- SEL (assumed temp) needs no slash.
- Reference *slash rule* on fold-out page in back.

```
     TAKEOFF REF                 1/2
SEL / OAT           VSPDS         V1
+110° F / +72° F    128 >     128 KT
20K N1                            VR
92.0 / 92.0%        130 >     130 KT
FLAPS                             V2
5°                  138 >     --- KT
GW                      /        TOW
110.5 /                        110.5
INTERSECT             FMC POS UPD
--- / RW25R                RW25R>
------------------------   SELECT
<INDEX                     QRH OFF>
```

U6/U8

Uplink data.

U6 & up

TOW is the gross weight that the line selected QRH speeds were based on or, if takeoff speeds were uplinked, it is the weight associated with the uplinked data.

U6 & up

With TAKEOFF SPEEDS (opt)

- FLAPS and GW are displayed and used (with temp) for V speed calculations.
- FLAPS defaults to 5° or may be entered manually:

-300	1°, 5°, or 15°
-400/500	5° or 15° only.
-600/700/800	possible flap entries are defined in the MODEL/ENGINE database.

- GW propagates from PERF INIT and is used for QRH T/O speed calculations.

U6, U8 & up

6R toggles the QRH takeoff speeds ON and OFF.

U7.0 & up

6R toggles the center VSPDS ON and OFF.

TAKEOFF SPDS and ACARS option: PREFLIGHT STATUS prompts not available. (POS INIT, PERF INIT, ROUTE, DEPARTURE, PREFLIGHT COMPLETE).

RUNWAY POSITION UPDATE

U4 & up

- Several options are available for position updating of the FMC at takeoff. The option is selected via the option code displayed on the PERF FACTORS page.
- Entry of the departure rwy is required and the update command must be issued prior to 60 kts. If the runway is not entered, 5R will be blank. Update is limited to 10 nm.
- GPS update disables TOGA update.

- TO SHIFT design shortcomings. Max limit is 3300 ft; the T10 intersection on RW32L at O'Hare (KORD) is 4200 ft! A negative value is not allowed, so one cannot shift the FMC to position behind a displaced threshold. (KEWR Rwy 4L)
- TO SHIFT and RWY REMAIN: DELeting a mistaken entry is not allowed. You must enter another rwy, re-enter the proper one, then re-enter the V-spds; or enter **1** for 100 ft from the threshold coordinates.

1

```
                FMC POS UPD
                 RW25R>
------------------------------
<INDEX         CANCEL UPD>
```

U4 & up

FMC POS UPD RWXXX
This updates the FMC to the rwy coordinates.

2

```
               TO SHIFT
        RW25R   1500FT
------------------------------
<INDEX
15
```

3

```
               RWY REMAIN
        RW25R  12000FT
------------------------------
<INDEX
120
```

TO SHIFT and **RWY REMAIN** (option depends on pin selection)

- With these two options, you may specify the position of the aircraft as a displacement forward of the beginning of the runway as in example 2, or runway remaining in front of you as in example 3. Enter the offset in hundreds of feet (FT) or meters (M), depending on option code selected.
- Use the default entry of zero for normal takeoff, i.e. from the landing threshold.
- No prompt is displayed. When TOGA is pressed, the FMC position is updated. TOGA update disabled if GPS is available.
- Following TOGA activation, the runway identifier and any entered shift value are highlighted in reverse video.
- The TO SHIFT option requires you to enter the position on the runway as an offset forward of the **landing threshold.** Example: Entry of **15** shifts FMC position 1500 ft forward of landing threshold. Negative values not allowed so cannot shift takeoff to a displaced threshold.
- If the RWY REMAIN option is chosen, then a runway remaining distance from the takeoff end can be entered. (Example: 12000 FT remaining)

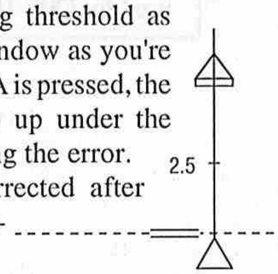
The runway coordinate in the FMC Nav database and EFIS Map runway symbol is the *landing threshold.* This landing threshold may be at the beginning of the prepared surface or at the official displaced threshold as shown on the runway diagram chart.

If you depart from any position that is not coincident with this landing threshold, you will introduce an FMC position error. If the takeoff point is ahead of the landing threshold, a TO SHIFT entry will ensure that the airplane symbol on the EFIS Map updates to the actual aircraft position when TO/GA is pressed. Failure to do this incurs a map error. A negative value cannot be entered in the TO SHIFT field, so a departure from a displaced threshold will induce a map error.

This requirement is more critical where the distance from the landing threshold is large and LNAV is used shortly after takeoff. For takeoffs at max weight in areas of significant terrain and subsequent to engine failure, a map shift error resulting from non-use of the TO SHIFT function may be critical.

The displaced threshold for RW25R at Los Angeles is abeam taxiway F. If departing from the beginning of the prepared surface, you'll introduce a 1000 ft error in the FMC position because you cannot enter minus 1000 into the TO SHIFT field.

At Newark's runway 04L, the displaced threshold is 2500 ft from the landing threshold! This graphic shows the landing threshold as you'd see it out the left window as you're holding short. When TOGA is pressed, the virtual runway will jump up under the airplane symbol, displaying the error.



This error will be corrected after DME-DME updating is established.

TAKEOFF REF - U1.4, U1.5, & U4.0 & up

You get to this page by:

- TAKEOFF REF 1/1, go to NEXT PAGE

- TAKEOFF REF page 2 allows entries to enhance takeoff performance and, selection of reduced takeoff thrust in addition to the assumed temperature method.

U6, U8 & up
- Takeoff CG may be entered to allow the FMC to calculate and display the T/O stab TRIM setting. PERF INIT must have GROSS WT entry.
- Valid entries are 5-32 with resolution to a tenth of a percent.

U6, U8 & up
- Enter rwy wind direction and speed.
- Blanks V-speeds.

Blanks V-speeds.

Displays the trim setting if gross weight is calculated and takeoff CG is entered.

U6, U8 & up
- When QRH SPD is available (opt), the RW COND DRY/WET toggle is also available.
- Valid entries are D (dry) and W (wet).
- Blanks V-Speeds.

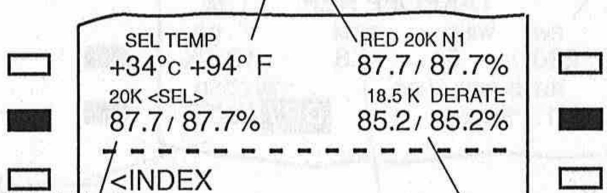
DERATE

- Known users of DERATE:
  Asiana
  KLM
  Sabena
  USAirways

> **CAUTION**
> - If a SEL TEMP is entered to reduce the takeoff thrust and thereafter a derate is selected, the previously entered SEL TEMP will also reduce the selected de-rate thrust.
> - Care must be exercised to avoid an inadvertent reduced thrust takeoff during derated thrust operations.
> - Don't use a derate or "double-up" unless takeoff performance charts allow your selection.

A reduced climb thrust (CLB-1 or CLB-2) is automatically selected if necessary when using a *derated thrust* or a high *assumed temperature* for takeoff to avoid a throttle up when going to climb power.

U1.4, 1.5, & U4 & up
Repeats information shown on TAKEOFF REF 1/2.



U1.4, 1.5, & U4 & up
TAKEOFF DERATE 1
- Selection will derate takeoff thrust to the next lower engine rating. (Example: 23.5 to 22K)
- N1 indicators will display the de-rated N1 values.
- Deletion returns takeoff thrust to full rated value.
- When the derate is selected, the title changes to TO-1 <SEL>.

U1.4, 1.5, & U4 & up
TAKEOFF DERATE 2
- Selection will derate takeoff thrust to the next lower rating below TO-1, providing one exists. (Example: 22K to 20K)
- Deletion returns takeoff thrust to full rated value.
- If no second derate capability exists for the installed engine rating, header and data field will be blank.
- When the derate is selected, the title changes to TO-2 <SEL>.

AIRFRAME	ENGINE THRUST RATING FULL	TO-1	TO-2
737-300	20K	18.5K	NONE
(option)	22K	20K	18.5K
737-400	20K	NONE	NONE
(option)	22K	20K	NONE
(option)	23.5K	22K	20K
737-500	18.5K	NONE	NONE
(option)	20K	18.5K	NONE
737-600	18.5K	NONE	NONE
(option)	20K	18K	NONE
(option)	22K	20K	18K
737-700	20K	18K	NONE
(option)	22K	20K	18K
(option)	24K	22K	20K
737-800	24K	22K	NONE
(option)	26K	24K	22K

U1.4, 1.5, & U4 & up
How to use:
- When a 23.5K engine is installed in your -400, you have the option of de-rating to either a 22K (TO-1) or a 20K (TO-2).
- IDENT page displays your engine size.

> **CAUTION**
> A fixed DERATE is considered a limitation; therefore, thrust levers should not be advanced further except in an emergency.
> You can still push the throttles up for more thrust, but all V-speeds and performance are related to the derate, including minimum control speed.

TAKEOFF REF

U10 and up

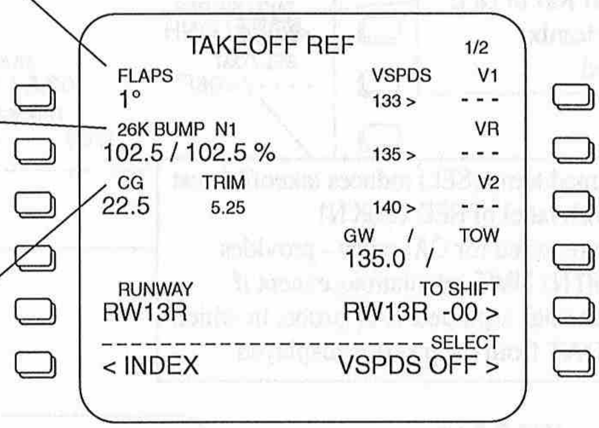
You get to this page by:

- N1 LIMIT page, TAKEOFF prompt
- ACT RTE page, TAKEOFF prompt
  (on the ground and PERF INIT completed)
- INIT REF INDEX page, TAKEOFF prompt

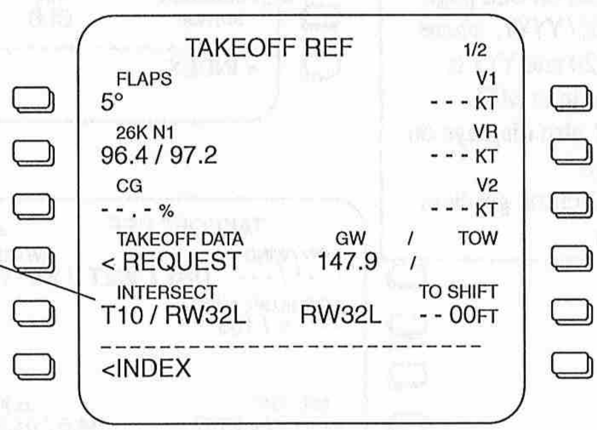
- Field is blank if Takeoff Ref Speeds option is not enabled.
- When displayed, default flap value determined by aircraft model.
- Custom performance database overrides the default setting.
- When box prompts are displayed, manual entry is allowed.

- Header changes to 26K BUMP N1 when TO-B is selected on N1 LIMIT page (option).
- Repeats the same information shown on the preflight version of the N1 LIMIT page.

- CG may be entered to allow the FMCS to calculate the takeoff stab trim setting. Gross weight must be entered.
- Once takeoff CG and FLAPS is entered, TRIM is calculated and displayed.



- Runway intersection can be manually entered or uplinked.



U10 and up

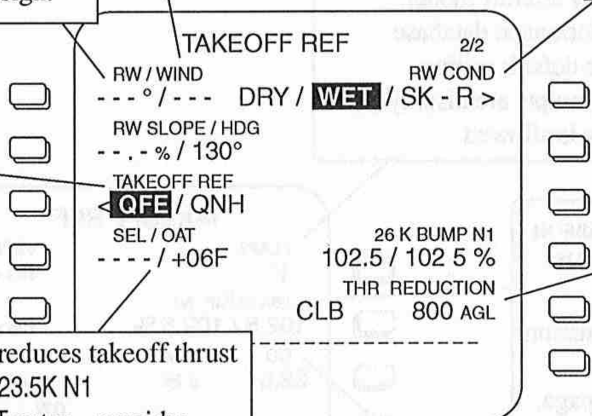
You get to this page by:

- TAKEOFF page, then NEXT PAGE

(QRH SPD Option)
- Runway Slope and Heading may be manually entered.
- Entries are percent gradient.
- Downhill gradients need the prefix D or the minus sign.

(QRH SPD Option)
- Runway Wind may be entered to improve the accuracy of the takeoff speed calculation.
- The direction is entered corresponding to the Mag/True switch position selected.

- Runway Condition toggle is also provided with QRH SPD Option.
- SK-R is skid-resistent.



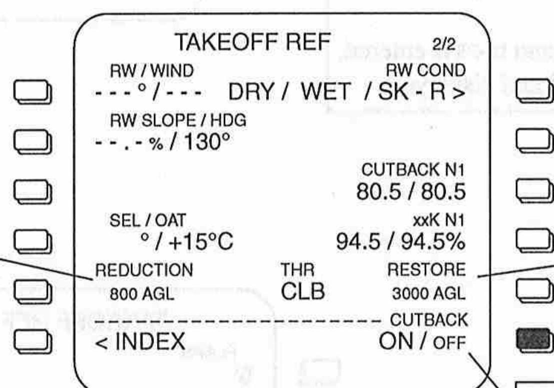
600/700/800 (Option) Takeoff Ref of QFE or QNH can be selected.

(Takeoff Profile option)
- Thrust Reduction altitude may be manually entered in AGL (above airport).
- Default is 1500 ft AGL (ICAO "A") for the ORIGIN airport.
- Automatic thrust reduction to climb power occurs at the specified altitude if in VNAV or if N1 switch is not pushed.

- Assumed temp (SEL) reduces takeoff thrust N1 with label of RED 23.5K N1
- Slash required for OAT entry - provides takeoff N1 LIMIT calculations except if airplane has aspirated TAT probe, in which cast OAT from the probe is displayed.

U10.3 & up

Quiet Climb System (option)
- REDUCTION and RESTORE altitudes at 5L and 5R. (AGL)
- 800 ft AGL is default but will take pilot entry on ground.
- When CUTBACK is selected ON, SPD REST field on CLB page displays XXX / YYYY, where XXX is V2+20 and YYY is restore altitude in MSL.
- Cutback N1 also displays on the CLB page.
- Insures 1.2%climb gradient for E/O ops.

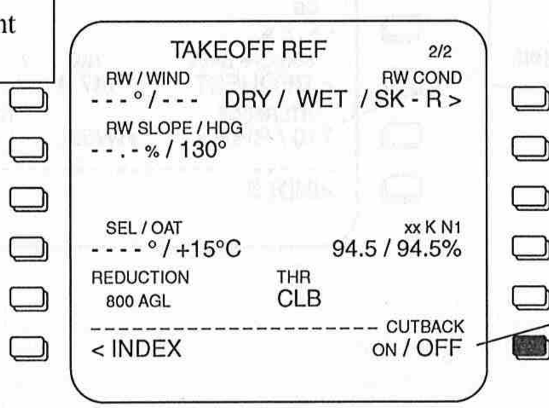


U10.3 & up

Normal or reduced climb power is restored at RESTORE altitude.

U10.3 & up

Quiet Climb System engaged by selecting CUTBACK ON at 6R.



U10.3 & up

If CUTBACK is selected OFF, CUTBACK N1 and RESTORE headers and fields are blanked.

You get to this page by:

- LEGS key.
- RTE DATA page LEGS prompt (LSK 6R).
- SELECT DESIRED WPT page.

TECHNIQUE
Consider having this page displayed during takeoff.

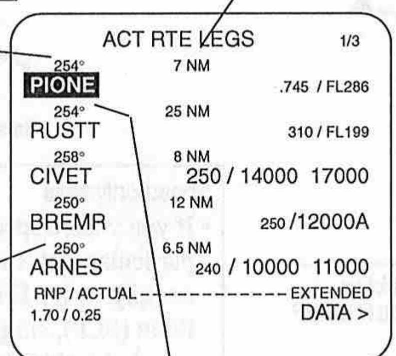
NO REQUIRED ENTRIES

- Modifications to the flight plan can be made which involve only a portion of a route segment or procedure (such as a single leg change).
- Waypoints can be entered or deleted. 10.2 allows max of 99. 10.3 & up allows up to 150
- Speed / Altitude constraints can be entered or altered. (Altitude entries ***may not be allowed*** for waypoints with cruise altitude displayed.
- Box prompts□□□□□ identify Route Discontinuities.
- U10. LNAV can be armed on ground. At 50 ft RA LNAV engages.

- Manual entries enter the flight plan on the LEGS page as DIRECT routing (Great Circle course) between waypoints.
- If an entry requires an airway, (Example: J 2), use the RTE page.

Great Circle distance to go to the active wpt.
U3.0 and up
Leg length in tenths of a mile if the leg length is less than 10 miles.

- The course above the active wpt is the course the airplane needs to fly at that exact location.
- When flying direct to a wpt, the Great Circle track changes due to variation and convergence.



- Page one displays the active wpt in reverse video highlight.
- Prior to U 10, the 737 uses a *raster screen* which allows for reverse video highlighting. After U10, the LCD is an option.
- A *stroke screen* such as on the 757/ 767 produces a slightly sharper character but does not allow reverse video highlighting.

- At normal lat/lons, displayed courses are magnetic.
- If true course/hdg. is displayed, it will have the suffix T (249°T).

All courses displayed after line one are initial tracks outbound - from PIONE in this example.

U10.0 and up
An arc can be flown. Arc distance, followed by ARC, then direction L or R.

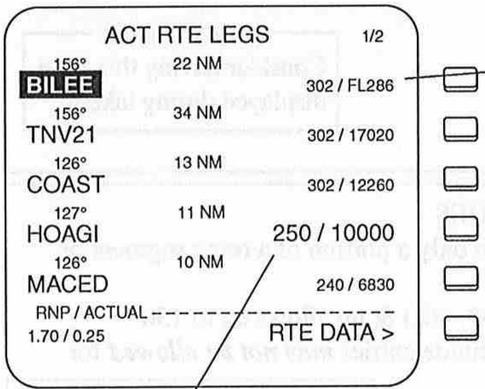
- Entry formats of 200, FL200, or 20000 are all acceptable.
- Altitudes suffixed with the letter "A" are altitudes to be flown *at-or-above.*
- Suffixed with "B" are *at-or-below.*
- While *at-or-above* or *at-or-below* altitudes form restriction for the descent they are not used as the end of descent point. Without an end of descent point there is no path built for the PATH descent mode. The FMC will revert to SPD descent.
- Two altitude values identify an altitude window or block crossing restriction.
- Manual entry of block altitude is not allowed.
- FMC will chose the altitude within the block based on the restriction down-route.
- Two ways to check this advisory altitude: DELete Line 3 - do **not** execute. If the small font altitude is within the window, it is an accurate prediction. If lower than the bottom of the window, then it will cross at the bottom of the window. Same for high side. Or, place CIVET in the FIX page and press the <ABM prompt. Check predicted ALT.

Astronauts and Engineers: Color CDUs

Is one type of screen required to produce color?

Answer: No. Color is a characteristic of the CRT rather than the method used to create the image. Color CRTs can be raster, stroke or hybrid. A hybrid CRT is used in some of applications. This type draws the raster image and then uses the time required for the electron beam to return to the top of the screen (fly-back time) to write characters and symbols. This is, as you can imagine, a short time and capability is usually expressed in terms of the inches of character/symbol that can be drawn. It is used to brighten and highlight symbols for increased daylight readability. With the new LCD displays there is no problem with reverse video or color.

USE OF SPEED and ALTITUDE LINES



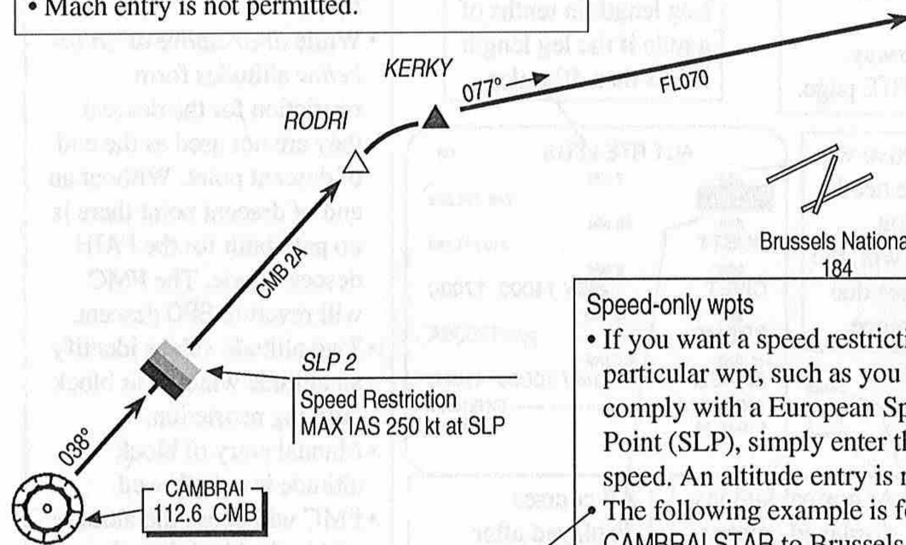
Speed predictions and Altitude predictions:

- Predicted values are displayed in small font.
- Speed and altitude predictions are displayed only if an E/D constraint exists, otherwise dashes are displayed for those fields that fall within the descent phase.
- Predictions in a defined path descent segment are displayed with respect to the computed descent path irrespective of aircraft position.

Speed and Altitude entries:

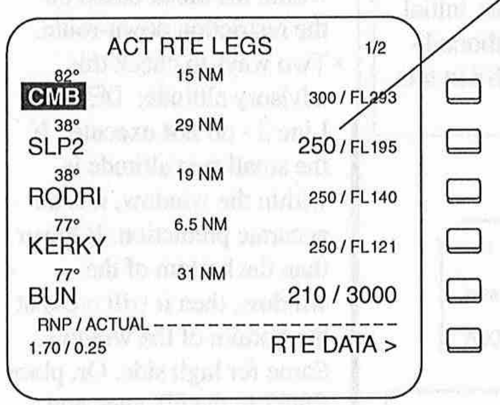
- Mandatory speed or altitude restrictions are displayed in large characters.
- Speed entries alone must terminate with a slash. Altitude entries alone do not need a slash.
- Mach entry is not permitted.

Speed entries are not permitted for cruise wpts on the LEGS page.



Speed-only wpts

- If you want a speed restriction over a particular wpt, such as you might do to comply with a European Speed Limit Point (SLP), simply enter the desired speed. An altitude entry is not required.
- The following example is for a CAMBRAI STAR to Brussels. FL070, the Minimum Enroute Altitude at that point on the STAR. The Transition Altitude for Belgium is 4,500 feet.



TECHNIQUE

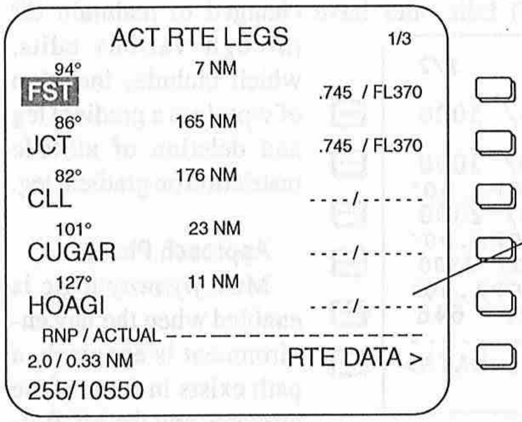
Assume you're in a non-EFIS airplane with the HSI switch in NAV, and SCURRY the active wpt. After takeoff, ATC says, ***"Barnburner 200, fly heading 300 degrees, direct Scurry when able"***. Take a look at the winds. Now, using HDG SEL, place the orange diamond (track indicator) right on top of Scurry, the yellow wpt bearing pointer. In the mean time, the FMC will update it's position in the AUTO mode.

After DME-DME updating has occured for a moment or two, do another Direct-To Scurry and engage LNAV. No hunting will occur, but the technique takes a little practice.

Otherwise, the a/c heading may change as the FMC position changes during the updating process.

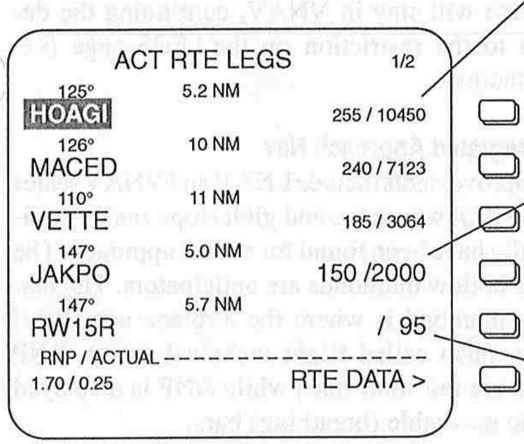
SPEED AND ALTITUDE LINES

- For speed and altitude lines, keyboard entries are permitted for climbs and descents only, not for cruise legs.
- Minimum speed values permitted are 210 knots for climb wpts and 150 knots for descent wpts.
- Speed entries on the LEGS page must be followed by the slash key (/).
- Manual Mach entries are not allowed.



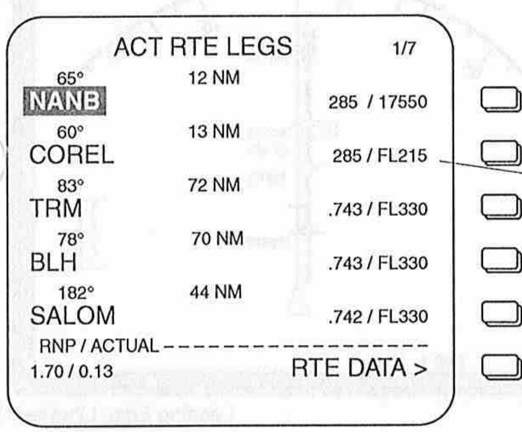
- If no descent restriction is entered, you get only ----/----.
- By line selecting any of the keys next to a dash line, (example, 5R) an advisory speed and altitude will appear in the s/p.
- It's a good tool for descent planning and in creating a restriction. Most accurate if the terminal route and runway is entered.

If an end-of-descent altitude is entered, intermediate speeds and altitudes calculated by FMC are shown in small block characters. They are excellent displays for use in planning climbs and descents.



- Speed only constraints are allowed on the LEGS page for climb and descent wps.
- Entered wpt speed constraints are treated by the FMC as "at or below" speed limitations.
- Only mandatory restrictions may be DELeted. They are replaced by predicted values.

- U1.x: Displays Threshold Elevation for destination runway. (Airport diagram page)
- U3.0 and up: Displays Threshold Crossing Height.
- Displayed as a mandatory "at" altitude restriction.
- Speed restriction is blank.
- Manual entries not allowed.
- VNAV descent **cannot** be flown to this point until U7.1 and up. Ref: Gradient Path on next page.
- Altitude entries of less than 1000' must be preceded with zeroes to at least 4 digits, rounded to the nearest 10 ft. Ex: 80 ft is entered as 0080.



- Note advisory speeds and altitudes.
- Altitudes can be entered on this page during climb-out.
- If FL270A is entered at COREL, the message UNABLE NEXT ALTITUDE will appear.
- Refer to CLB page for ERR AT (error at) COREL.

GRADIENT PATH or VERTICAL ANGLES - U7.1 & UP

VNAV can be used allowing approaches to be flown using vertical angle (Gradient Path) guidance.

The Gradient Path (GP) is defined in the data base and is assigned to a waypoint. It defines a VNAV path between that waypoint and the waypoint preceding it.

A good example is the Gradient Path for an ILS in which the Vertical Angle would typically be around 3°. This angle is displayed on the LEGS page above the speed / altitude line for the associated waypoint. There are three GP legs in this example.

```
      ACT RTE   LEGS       1/2
  133°       2.7NM
MORRY              180/ 3000
  133°       4.9NM
POPPA              180/ 3000
  133°       2.2NM    GP3.00°
GS-13R             180/ 2300
  133°        .1NM    GP3.00°
HODAX              151/ 2300
  133°       5.1NM    GP3.00°
RW13R              132/  646
------------------------------
<INDEX              RTE DATA>
```

A modification to the route such as entering another wpt may destroy the vertical angle by converting the inserted leg to an open idle descent vertical path. (An Along Track entry does not destroy the Gradient Path.) General rule: Don't make changes to a database approach unless you are sure of a mistake.

Vertical Angles may be expected in any approach ending at RWXXX or MAXXX (Missed Approach point). The end of descent point will be RWXXX or MAXXX, and the E/D altitude will be either the Threshold Crossing Height (TCH - typically 50 feet above the touchdown zone elevation) or the altitude specified at MAXXX, the MDA.

Prior to 10.3, VNAV will disconnect when passing the GS-XXX point, but it can be re-engaged.

If VNAV PATH is active when a gradient path leg becomes active, the PATH mode will remain active, but VNAV will follow the vertical angle rather than the idle thrust descent path.

If the gradient path leg becomes active during a VNAV SPD descent, the VNAV mode will change to PATH automatically, and there will be no SPD > prompt on the DES page.

Software 10.3 & up improvements:

(1) VNAV will not disengage at the GS-XXX point unless APP (glideslope) is armed,

(2) GP now displayed to nearest hundredths,

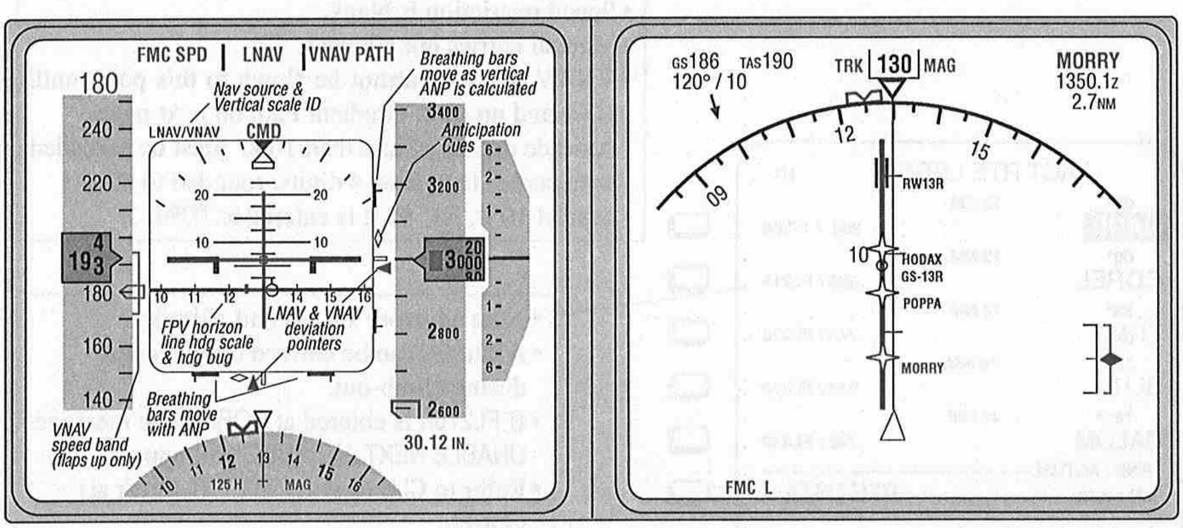
(3) Edit rules have changed to maintain GP through various edits, which includes insertion of wpts into a gradient leg and deletion of altitude restriction on gradient leg.

Approach Phase

MCP *flyaway* logic is enabled when the nav environment is approach, a path exists in front of the airplane, and the MCP altitude is more than 250 ft from the airplane altitude, or has moved within the last 1.5 seconds. The MCP altitude can be dialed above the airplane altitude (i.e., missed approach altitude) and the airplane will stay in VNAV, continuing the descent to the restriction on the LEGS page (i.e. minimums).

Integrated Approach Nav

Improvements include LNAV and VNAV scales on the ADI where loc and glideslope scales traditionally have been found for an ILS approach. The white hollow diamonds are anticipators. The magenta diamond is where the airplane acutally if flying (also called flight technical error). RNP limits are the short lines while ANP is displayed by the moveable (breathing) bars.



RNP and ANP - U7.1 & UP

In the past, navigation has not been an exact science. Just a few years ago celestial nav was sufficient to navigate the North Atlantic. In unconfined airspace, position accuracy can be sacrificed.

A certain amount of error in position has always been accepted. Error is the difference between a specific value and the correct or standard value. As used here, it is related to lack of perfection. RNP/ ANP with GPS updating is "primary navigation".

Greater accuracy can be attained as technology advances, but at a price. Placing satellites in orbit, upgrading FMCs, writing procedures and training flight crews is a major undertaking.

Precision RNAV is under development, which will allow for more tightly controlled airspace – airways ± 2 nm wide. Aircraft capable of Precision RNAV will be allowed preferential treatment such as optimum altitudes and routing. However, Precision RNAV requires a high degree of nav accuracy.

RNP

The concept of Required Nav Performance (RNP) defines the capability necessary for an aircraft to navigate in a particular airspace segment. This value tells the pilot what level of accuracy is required for the particular LEG being flown. The active level of RNP is expressed in nautical miles and is displayed on the ACT LEGS page and the POS SHIFT page. RNP is defined in the nav database according to the present route segmentor can be entered manually. RNP is larger where some navigation error is allowed, such as at cruise altitude, and smaller in the approach environment.

Navigation environments are defined as Oceanic, Enroute, Terminal, and Approach, with increasing accuracy required for each subsequent definition.

Any /E or /F airplane can fly a procedure requiring an RNP of 1.0. The only requirement for a non-GPS system is that radio updating is allowed to continue. Do not place both nav switches in MANUAL. This should be considered in the "radio setup" of your Descent or Approach Checklist. A /G airplane is approved to .3 or less (check you ops specs).

ANP

Actual Nav Performance (ANP) is the degree of current navigated position accuracy, or how good your present position is. It is the degree of accuracy that the FMC will guarantee based on the type and amount of updating that the FMC has experienced (GPS, DME-DME, VOR-DME, or IRS NAV ONLY)

ANP represents an estimate of the 95% containment radius of the FMCS position. You could think of it as representing the Position Uncertainty (PU) of the FMC position, though this term is no longer used. It means that the system is presently unable to verify position any more accurately than that amount - with some level of confidence (95%). If you imagine a circle around the cockpit having the radius of your present ANP, that is where the FMC System position thinks it is located.

ANP has nothing to do with RAIM. It takes four satellites to resolve GPS position. RAIM is an integrity check and needs an additional satellite to provide integrity. If you hold five satellites the system samples four of the five satellites and compares the position with the position it computed with a different set of four satellites. The system cycles through all of the satellites in this manner. If there is an errant satellite it will be discovered and discarded. If the number of satellites gets down to four, integrity is lost, not position. Experience has shown that there are seven plus satellites in view nearly all the time. Even then there is no loss of RAIM annunciation in the cockpit because ANP does not slew immediately to a number in excess of RNP. In the overwater realm one can be without RAIM for nearly an hour and still be within the RNP.

If the ANP exceeds the RNP, a warning is tripped and a message is displayed. VERIFY POSITION in the s/p if the default RNP of .5 is exceeded, or UNABLE REQD NAV PERF-RNP on the EFIS Map if a manually entered RNP such as .3 is exceeded.

With later software RNP values may be entered manually and will appear in large font; this procedure is required if the default RNP does not match the RNP displayed on the approach plate.

Inclusion of this new parameter leads to the necessity of additional CDU messages and are defined in the Message Section. Ref: UNABLE REQD NAV PERF-RNP and VERIFY RNP.

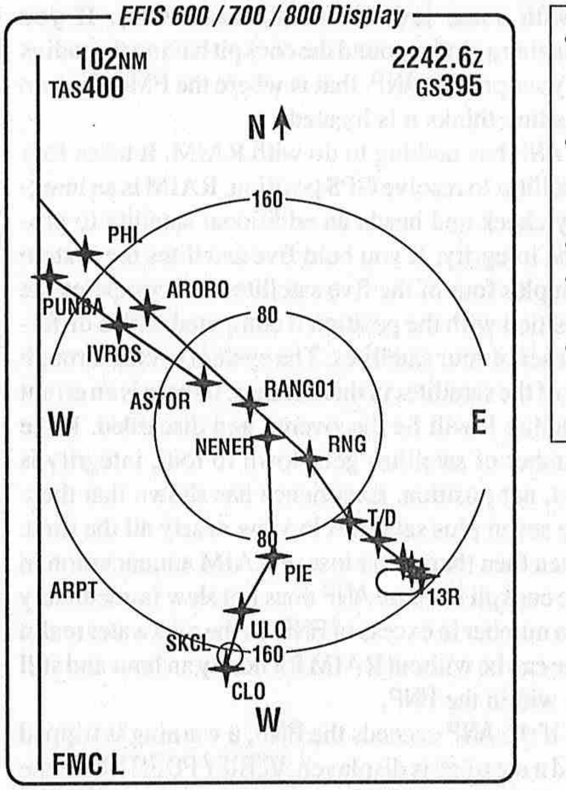
RNP Default Value:

- Enroute Oceanic = 12.0nm/400 ft vertical. Enroute environment and no radio updating; i.e., FMC knows it is in an area where no navaids exist from which to update.
- Enroute Domestic = 2.0nm/400 ft vertical. Not in Approach or Terminal environment but in area of radio updating possibility.
- Terminal = 1.0nm/400 ft vertical: Below 15,000' and not in the Approach environment.
- Approach = 0.5 nm/400 ft vertical: For a/c with GPS and either IAN or NPS the default approach RNP is 0.3nm via SW Options disk (OPC).

ALTERNATE ROUTES

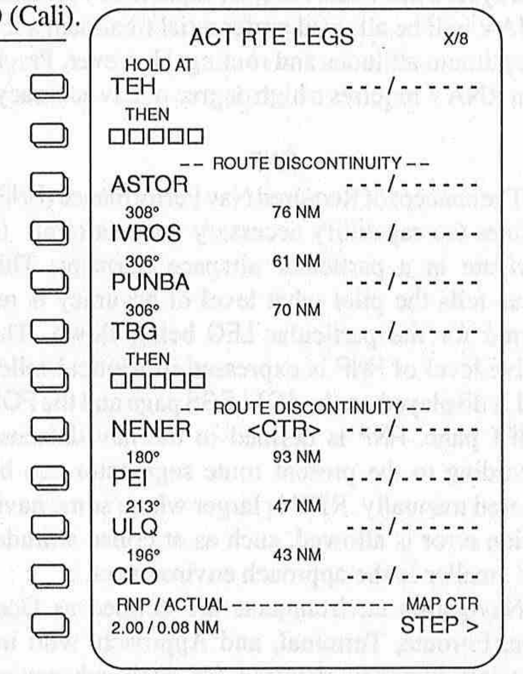
- Alternate routes may be added after the destination runway without changing the FUEL and ETAS.
- Special wpts such as ETPs are very useful when placed in the LEGS page in this manner. The wpt symbol will display on the Map but will not interfere with the flight plan track nor will it take up a line on the PROGRESS page, possibly interfering with position report data.
- The LEGS page and / or the RTE page may be used.

EFIS 600 / 700 / 800 Display

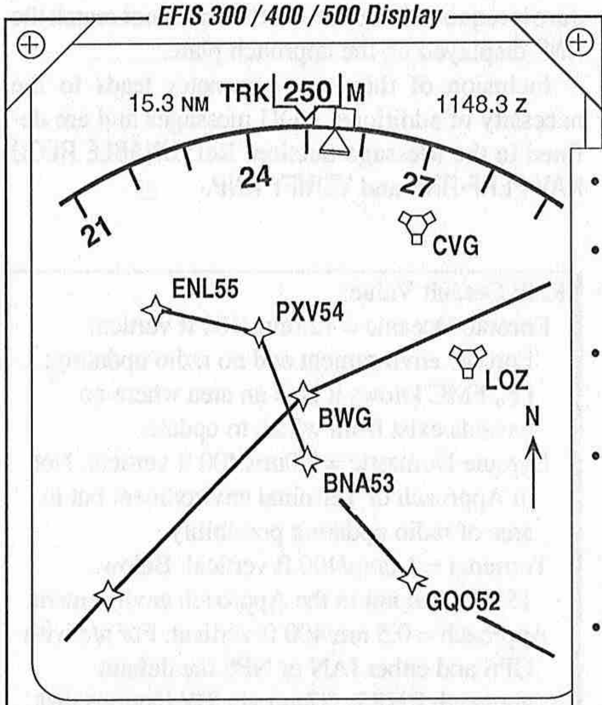


TECHNIQUE

- In this example, two depressurization escape routes have been built after the ILS approach and missed approach procedure at Bogota, Columbia.
- This Map display depicts a NG 737 with the *EFIS* option, though the technique can be used for any glass display.
- The Map is in the PLAN mode.
- After each alternate route, insert a discontinuity by using a throw away wpt.
- See if you can trace the first escape route to TBG (Panama City) - via PUNBA, and the second to CLO (Cali).



EFIS 300 / 400 / 500 Display



TECHNIQUE

- This technique can also be used to display a line of weather that crosses the active flight plan.
- Convective Sigmet 27E, valid until 1055z, reads: From 50 SE RMG - 50 SW GQO - 75 W BNA - 25 SW PXV - 20 SE ENL, moving …
- The pilot has entered each point as a place-bearing / distance (PBD) into the LEGS page after the destination runway.
- Now step through the route using the PLAN mode. Though both routes are magenta, a discontinuity will separate the two, and as long as the destination runway is entered, accurate predictions will not be sacrificed.
- If there are other areas of weather to enter, or other special waypoints to monitor, use a discontinuity to separate them.

MISSED APPROACH - U7.1 / U8 and up

- The guidance function includes the provision to execute Missed Approach (MA) procedures in U7.1, U8, and up. Lateral and vertical guidance is provided throughout the procedure.
- Though U6 may contain MA procedures, speed and altitude assignments on the MA routing do not propagate to the CLB and CRZ page.
- U7.2/U8 and up has the ability to contain Missed Approach procedures in its data base and is able to execute the procedure.

U1.x to U5

- To engage VNAV after a missed approach, you must enter a new destination, route and cruise altitude. This will re-activate FMC performance data for VNAV operation.
- Minimum plan for all software requires Origin, Destination, and one TO waypoint.

ACT RTE LEGS 1/2

83°	5.0 NM	
SAYNO		150 / 3018
82°	0.1 NM	
GS--09		150 / 3000
84°	5.3 NM	GP 3.0°
HIWAY		137 / 1830
84°	5.2 NM	GP 3.0°
RW09		137 / 148
82°	21.8 NM	
COSBI		200 / 2000
RNP / ACTUAL	------	EXTENDED
1.70 / 0.22 NM		DATA>

U7.1 and up

INITIATION OF THE MISS

- The FMCS will initiate a MA procedure automatically under any of the following conditions:
  1. *Go-Around method:* While in descent and a Go-Around is initiated by any of the following:
     a Activation of TOGA,
     b Below MCP altitude, Go-Around Thrust Limit selected (GA on N1 LIMIT page) while in N1 auto throttle mode (typical captured ILS mode);
     c Below MCP altitude, Go-Around Thurst Limit selected, vertical rate exceeds 600 fpm, and flaps retracting from 30-15 or 15-1 (manual throttle push on a Go-Around).

     Predictions for MA wpts will not be generated until the missed approach procedure is initiated.
  2. *DIR TO method:* When a DIR TO a wpt in the Missed Approach (other than the MAP) is selected. Any descent altitude constraints remaining in the approach will be deleted and be replaced with predicted values.
  3. *Sequencing method:* While on approach, the last flight plan wpt prior to the MA is sequenced, that is flown by, and the next wpt is a MA wpt.
- To engage VNAV, the MCP altitude must be reset from the DH/MDA to a higher altitude.

U7.1 and up

- A speed and altitude entered on the MA route LEGS page will propagate to the CLB and CRZ page.
- Down route predictions do not take this speed into account and it does not propagate to cruise wpts that may exist down route.

ACT ECON CLB 1/1

CRZ ALT	AT COSBI
2000	2000
TGT SPD	TO COSBI
210/.740	1836.5 z/ 21 NM
SPD REST	
210 / COSBI	

U7.1 and up

- If the FMC transitions onto the MA via the *Go-Around method*, the new CRZ ALT will be the highest of:
  1. The highest constraint in the missed approach routing;
  2. The default value of 1500' above the ARP;
  3. The MCP altitude.
- If the FMC transitions onto the MA via the *DIR TO* or *Sequencing method*, the new CRZ ALT will be set to the highest of the following:
  1. The highest constraint in the missed approach routing;
  2. The default value of 1500' above the ARP.

U7.1 and up

- In the example below, the original flight plan was DFW to IAH. We've executed the MA at IAH and we are flying direct to COSBI, a wpt in the MA procedure.
- When the missed approach procedure is initiated,the DESTination airport will also be set to the ORIGIN airport.
- This allows the pilot to select a SID to exit the terminal area or another approach.

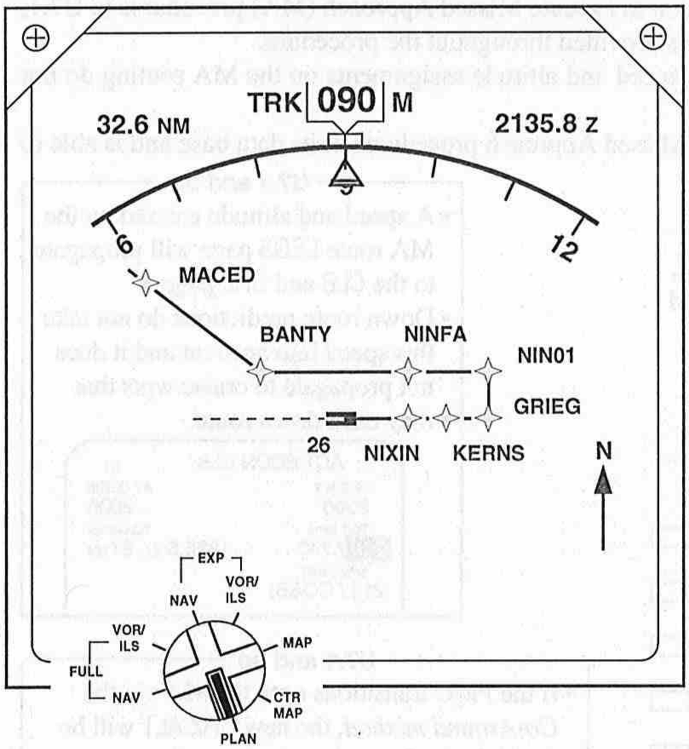
DEP / ARR INDEX 1/1

<DEP	KIAH	ARR>
	KIAH	ARR>

ACT RTE 1/2

ORIGIN	DEST
KIAH	KIAH
CO ROUTE	FLT NO.
------	SA1620
VIA	TO
DIRECT	COSBI

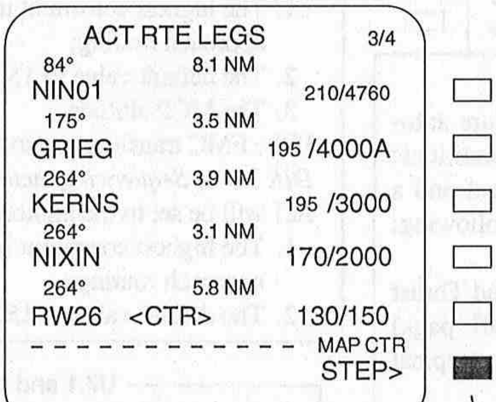
CENTER STEP - EFIS ONLY



EFIS

MAP CENTER LABEL

- Identifies the waypoint centered on the EHSI display.
- Whenever the EHSI Mode Selector is positioned to PLAN, the label is automatically displayed for the first geographically-fixed waypoint on the displayed page.
- Keyed to the FMC System position.

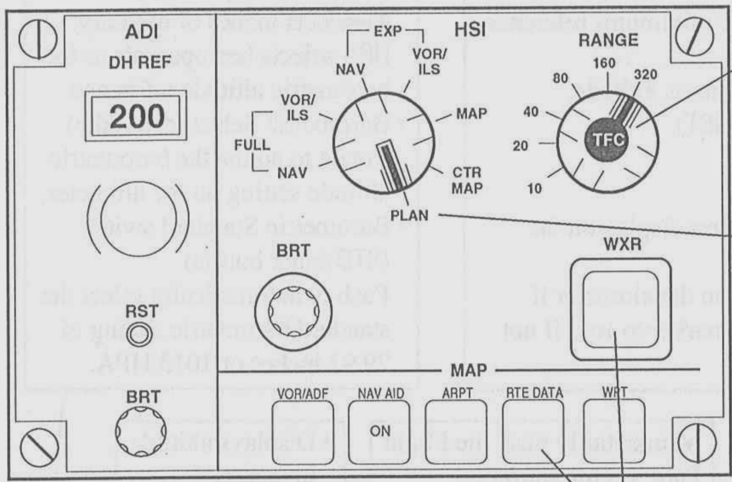


EFIS

- Very useful for checking a SID or STAR. Requires selection of proper RANGE.
- MAP CTR STEP is displayed on a CDU only when PLAN is selected on the associated EHSI Mode Selector. Replaces the EXTENDED DATA or ACTIVATE prompts.
- Line selection steps (moves) the Map Center label <CTR> to the next geographically-fixed waypoint in the route. If the <CTR> is already on line 5, line selection causes the next page to be displayed.
- To step rapidly through the flight plan, press the PREV PAGE or NEXT PAGE key to step the <CTR> to the first geographically-fixed waypoint on the new page.
- If the LEGS page is not displayed when the EFIS PLAN mode is selected, the map center of the EHSI defaults to the active waypoint.
- Use caution when selecting this page in flight, as the PLAN view may not make sense with the Map expanded compass display at the top.

Electronic Flight Instrument Control Panel (EFCP)

-300 / -400 / -500



TFC switch displays TCAS on EHSI Map. (Optional equipment)

EFIS

- PLAN displays a static map which is oriented to true north. The top portion of the EHSI remains the same as in the Map mode.
- Allows the pilot to review the planned route by using the LEGS MAP CTR STEP line select key.
- Weather radar and TCAS display data is inhibited.

If the FMC detects a failure of an EFCP, the FMC will continue to output map data to the respective EHSI at the 40 nm range

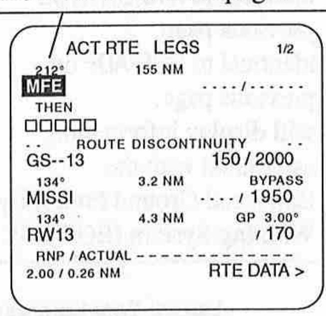
Map switches add background data/symbols to Map and center Map modes, can be displayed simultaneously, and are removed by a second push of the switch.

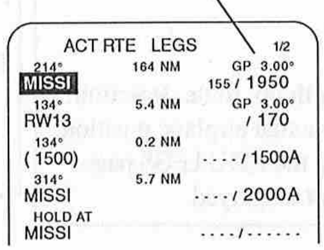
WXR	- energizes radar transmitter and displays weather radar returns in MAP, CTR MAP, expanded VOR and expanded NAV modes.
VOR/ADF	displays VOR and/or ADF bearing vectors extended from the nose of the airplane symbol to the tuned stations. Useful for checking FMC POSition for shorter ranges.
NAVAID	- displays all FMC database navaids if on map scales 10, 20 or 40 nm. - displays FMC database high altitude navaids on map scales 80 nm and above.
ARPT	- displays all airports which are stored in the FMC database and which are within the viewable Map area.
RTE DATA	- displays altitude constraint, if applicable, and ETA for each active route wpt.
WPT	displays the waypoints in the FMC database which are not in the flight plan route if the selected range is 40 nm or less.

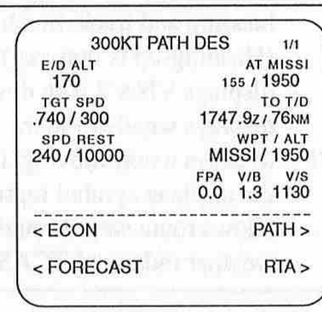
Situation: You are level at cruise altitude and cleared direct to your destination, McAllen, Texas (MFE). The ILS approach to runway 13 has been selected from the ARRIVALS page.

ATC clears you direct-to MISSI. You accomplish a direct-to and execute. The FMC, because the leg inbound to MISSI was a 3° *gradient path*, now builds a 3° path from MISSI to your cruise altitude.

And there is no DES NOW prompt. If VNAV is selected, the airplane will descend at 1000 fpm until it intercepts the 3° path. So what to do? Go direct to the GS--13 wpt for proper descent planning.







Electronic Flight Instrument Control Panel (EFCP)
-600 / -700 / -800 / -900

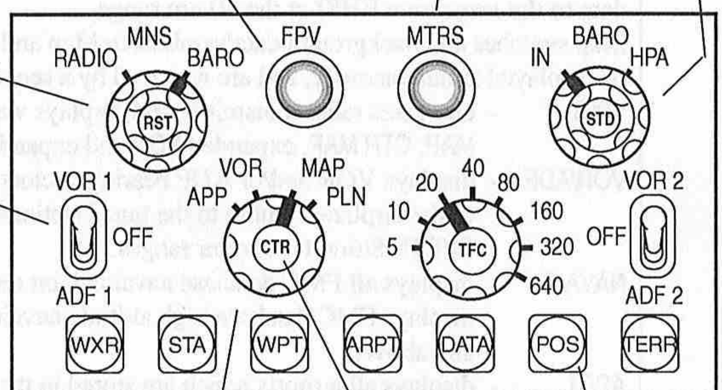
- Minimums Reference Selector (outer knob-2 position)
  RADIO-selects radio altitude as the minimums reference.
  BARO-selects barometric altitude as the minimums reference.
- Minimums Selector (middle)
  Rotate to adjust the radio or baro minimums altitude.
- Minimums Reset push button switch (RST).
  Push: (option - Altitude Alert, ALT)
  - Blanks radio height ALT alert.
  - Resets the radio altitude minimums alert display on the attitude indicator.
  - Blanks the reference altitude marker on the altimeter if displayed; sets the reference altitude marker to zero if not previously displayed.

- Barometric Reference Selector (outer knob-2 position)
  IN-selects inches of mercury.
  HPA-selects hectopascals as the barometric altitude reference.
- Barometric Selector (middle)
  Rotate to adjust the barometric altitude setting on the altimeter.
- Barometric Standard switch (STD)inner button)
  Push to automatically select the standard barometric setting of 29.92 inches or 1013 HPA.

Momentarily push the Flight Path Vector button to display flight path vector on the attitude indicator.

- Displays altitude in meters.
- Not available in compact display.

VOR/ADF switch
- VOR displays the selected VOR bearing pointer and VOR bearing pointer source indicator.
- OFF removes the VOR or ADF displays and displays OFF in place of the bearing pointer source indicators.
- ADF displays the selected ADF pointer and ADF bearing pointer source indicator.



Mode Selector (outer knob-4 position)

APP - displays localizer and glideslope information in heading-up format.
- displays reference ILS receiver, ILS frequency, course and DME.
- weather radar and TCAS are not displayed in center APP mode.

VOR - displays VOR nav information in heading-up format.
- displays reference VOR receiver, frequency, course, DME and TO/FROM information.
- radar and TCAS are not displayed in center VOR mode.

MAP - displays FMC generated route and other information from the nav database, including the airplane position, heading and track, in a track-up format. (Heading-up is optional)
- displays VNAV path deviation.
- displays weather radar.

PLAN displays a non-moving, true north up, route depiction.
- the airplane symbol represents actual airplane position.
- allows route step-through using the CDU LEGS page.
- weather radar and TCAS are not displayed.

Center Map push button displays full compass rose for APP, VOR, and MAP modes.

Map switches are similar to those described on the previous page except for the following name changes:

STA - identical to NAVAID on previous page.

DATA - identical to RTE DATA on previous page.

POS - identical to VOR/ADF on previous page.

TERR - will display information associated with the Enhanced Ground Proximity Warning System (EGPWS).

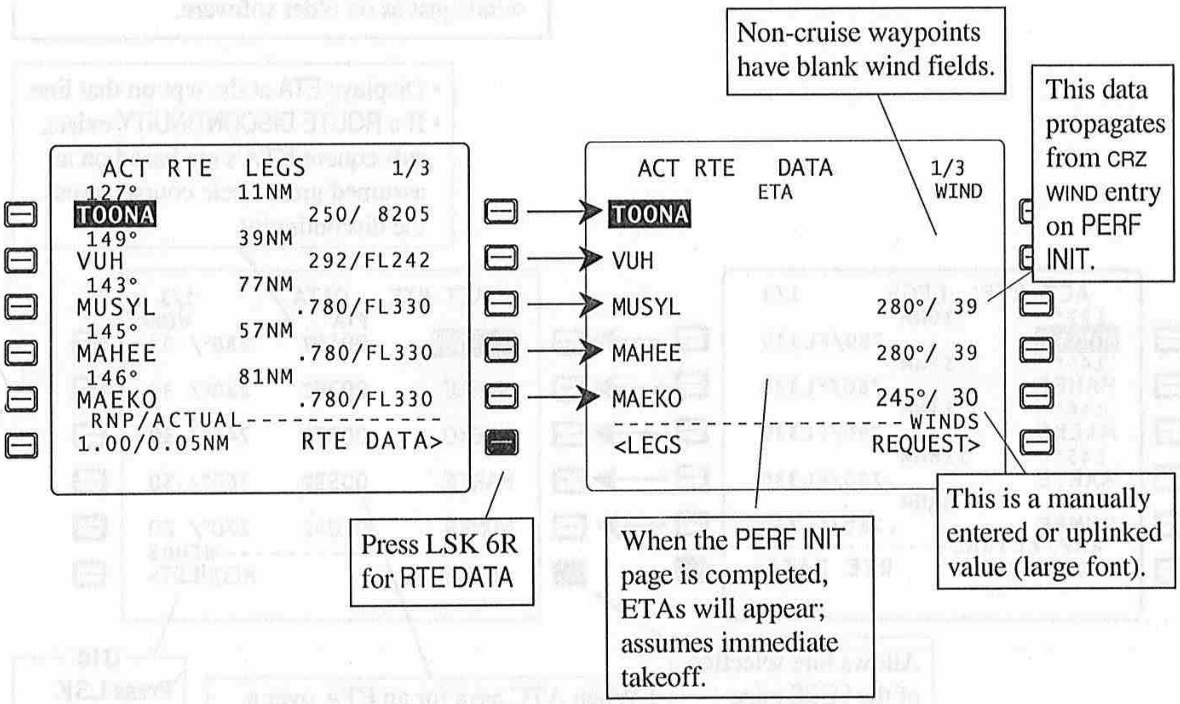
RTE DATA

You get to this page by:

- RTE LEGS page, EXTENDED DATA prompt (LSK 6R)

NO REQUIRED ENTRIES

RTE DATA page displays additional RTE LEGS data for corresponding waypoints.



Astronauts and engineers: Winds - Climb Phase

For pre-flight climb winds, the FMC starts with a zero wind at takeoff and linearly interpolates the climb winds to the top-of-climb (T/C) wind value. The T/C wind value is equal to the CRZ WIND entered on the PERF INIT page or zero if a wind was not entered. It uses this approximation to determine the distance to climb to the cruising altitude and ETAs. Ref: U4 bug on page 7.2. Some computer-based flight plans use an average wind from the last wpt to the T/C wpt. If yours does this, do not enter this averaged climb wind on line 2R of the PERF INIT page, but go to the next cruise fix. (The temperature in this row may be generated in the same way.)

If the pilot loads the winds in the LEGS - EXTENDED DATA page(s), leaving the CRZ WIND on the PERF INIT page blank, the FMC considers the T/C winds to be zero until nearing the planned cruising altitude.

After takeoff, the FMC updates the predicted climb wind profile by using the FMC computed actual wind for the current altitude. The actual wind at the current altitude is linearly interpolated to the T/C wind. The predicted distance and ETA to climb to the cruise altitude are then modified accordingly. Obviously, it is essential that the wind value be as accurate as possible to give you the most accurate ETA's and fuel predictions.

| Improved graphics

This is an example of the RTE DATA page as viewed in flight.
It is useful in entering forecast true winds and carrying out position reports to ATC.

If any or all of the wpts for which a manual wind entry is made are deleted, the corresponding wind entries are also deleted and the wind is propagated from the last entry to forward wpts.

However, current wind is still used for predictions and is blended with the manual entry over a 100 mile distance.

Since doing a direct-to will delete interim wpts that have wind entries, an ABEAM PTS prompt was added to U6, U8, and U10 to preserve the wind entry at abeam points to the original flight plan. If you do not have the ABEAM PTS feature, you will want to create abeam points and re-enter forecasted wind data for correct predictions.

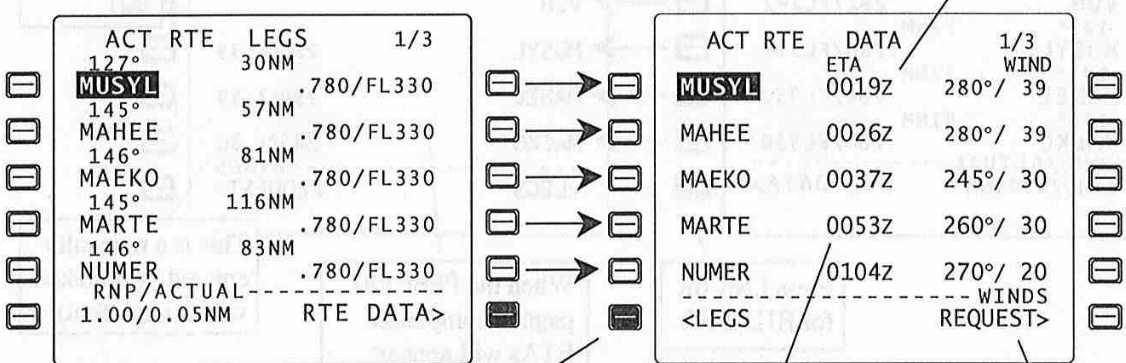
U1.5 and down

- Winds propagated from PERF INIT page are large characters.
- As aircraft nears each wpt, wind prediction display changes to match actual winds.
- Manual entries (272/72)do not propagate down the route. An entry must be made at each cruise wpt.

U4.0 and up

- Winds propagated from PERF INIT page are small characters.
- Manual entries are large.
- All propagated entries are small.
- As aircraft nears each wpt, biased values are not displayed, though the FMC is blending winds just as on older software.

- Displays ETA at the wpt on that line.
- If a ROUTE DISCONTINUITY exists, subsequent ETA's are based on an assumed great circle course across the discontinuity.



Allows line selection of the LEGS page which corresponds to this RTE DATA page.

When ATC asks for an ETA over a particular wpt, the RTE DATA page is very useful.

ATC: "Cessna 1654G, what is your estimate for MARTE?."

Select the LEGS page, press LSK 6R, and read the ETA for MARTE.

U10

Press LSK 6R to initiate the uplink request via ACARS.

TECHNIQUE

U1.x users (no RTA function): If ATC needs you over a wpt at a specific time, enter trial fixed Mach cruise speeds until the desired ETA is displayed.

Astronauts & Engineers: WINDS - CRUISE PHASE

The winds used for predictions during the cruise or RTA phase of flight are the actual winds and the forecast winds assigned to the cruise waypoints. Forecast cruise winds default to the CRZ WIND entered on the PERF INIT page if not entered on the RTE DATA pages. If entry is not made on either the PERF INIT page nor the RTE DATA pages, the actual wind will be used. Entered winds should be periodically checked and updated to ensure accurate predictions.

In flight, the system computes wind from current groundspeed and TAS for its current System winds. For downtrack route predictions, linear interpolation between the present System winds and the next applicable crew entered wind is used. When the aircraft is within 2000' vertically and/or 100 nm laterally from a point at which predicted winds are defined, the System modifies the predicted wind at that point based on current wind and distance to that point. This avoids step change transients in the wind conditions and results in smooth performance predictions.

You get to this page by:

- CLB key.

TECHNIQUE

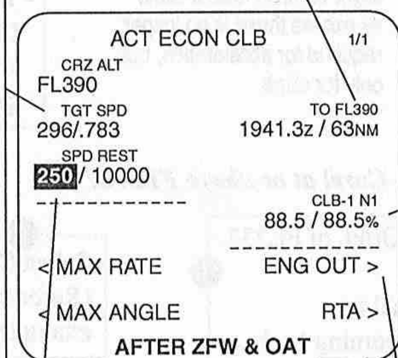
ATC: "Short Silverstreak, how long (or how many miles) will it take you to climb through FL280?"
Enter 280 with LSK 1L. Do not EXECute. Solution will display at 2R.

NO REQUIRED ENTRIES

- CLB page defaults to ECON CLB.
- Climb modes available: ECON, MAX ANGLE, Manually selected speeds, MAX RATE, ENG OUT, RTA with U4.0
- May be used during preflight or climb to evaluate different climb modes.
- Allows crew monitoring of RTA navigation mode and access to RTA PROGRESS page.
- If a fuel quantity gauge is inop, maintenance may disconnect the Fuel Summation Unit, disabling VNAV and blanking 2L. (Fixed in Update 10)

- ECON climb speed is derived as a function of CI, gross wt., temp deviation, and wind.
- TGT SPD is locked in when PERF INIT is executed. If the CRZ ALT is re-entered during an ECON climb, FMC looks up new TGT SPD based on lighter wt. a/c due to fuel burn in the climb.
- Max 335/M.809
- If CRZ WIND entry is made on PERF INIT page, ECON TGT SPD adjusts for winds. Later software: 100 kt headwind will increase climb speed ± 48 kts; 100 kt tailwind decreases climb speed approximately 20 kts.
- Where **both** CAS and Mach can be entered on a line (such as CLB or DES page), simply enter the desired value if only one value is to be entered. Ensure CLB M. ≥ the CRZ target as it is desired that there is no acceleration at TOC.
- Crossover occurs where the M. is faster than the IAS.

- If no wpt restriction exists then the ETA and distance to CRZ ALT are displayed.
- VNAV must be engaged for predictions on lines 2R to be accurate.



AFTER ZFW & OAT ARE ENTERED

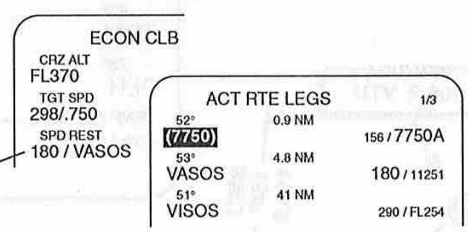
U4.0 & up

- Allows selection of RTA PROGRESS page.
- Displayed only after execution.

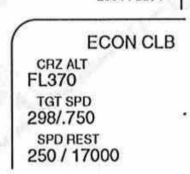
- Full rated climb power indicated by CLB N1.
- CLB-1 N1 or CLB-2 N1 (or engine rating-20K N1) displayed if a reduced climb mode has been selected on N1 LIMIT page.
- FMC may compute a reduced climb N1 when a SEL TEMP or a de-rate or a combination of the two is selected on TAKEOFF REF page.
- Reduced climb power is active until normal climb thrust is reached at 15,000'.
- If cutback mode is selected ON, displays FMC calculated cutback N1.
- If VNAV is inop, CLB N1 is not displayed here, nor any place else.

ENG OUT prompt will display after takeoff.

- FMC assumes 250 kts below 10,000'.
- Displays XXX/FLAPS (XXX being an IAS number) if active speed rest. is lower than min speed at current flaps setting.
- Speed restrictions of lesser value on the LEGS page have precedent, such as the VASOS example.
- Clears above the altitude value displayed.
- (U8 and below) 210 kts is lowest speed computer will fly, even though U1.x does not display INVALID ENTRY.
- May be deleted.
- A departure consideration at Bogata or Quito might require entering the max angle. (Ex: 230/13000)
- When Cutback mode is on, cutback airspeed and RESTORE altitude are displayed. Deletion or modification is not allowed.



Speed restrictions on climbout from 05L/R at Mexico City:
- 180 until VASOS
- 250 kts within 30 nm or below 10,000 ft AGL



Enter:
- 180 on LEGS speed field at VASOS
- 250/17000 in SPD REST field of CLB page

Sample view of a CLB page in flight.

Active only between lift-off (squat switch) and top-of-climb.

- Displays the next wpt which has an altitude constraint, and the associated restriction.
- Propagates from the LEGS page.
- Blank if no restriction.

The commanding speed is reverse video highlighted or magenta on ACT climb pages of the Smiths FMC.

```
ACT ECON CLB                         1/1
 CRZ ALT                      AT COREL
FL330                            FL270
 TGT SPD                      TO COREL
315/.755              1836.5z / 21NM
 SPD REST                 ERR AT COREL
250 / 10000                    1710 LO
------------------------------------

< MAX RATE                  ENG OUT >

< MAX ANGLE                     RTA >
UNABLE NEXT ALT
```

IN FLIGHT VIEW

- If a wpt is displayed on line 1R, displays ETA at and distance to, that waypoint, otherwise, the values are for cruise altitude.
- VNAV must be engaged for accurate predictions.

- Displays a wpt related restriction propagated from the LEGS page if the restriction limits climb speed.
- Example: Lets assume ATC limits you to 250 kts until further advised. You enter 250/37000 so you can use VNAV above 10,000'. Now let's assume you enter 250/12000 at FLIPR on the LEGS page. (See below)
- The SPD REST (line 3L) will display 250/FLIPR until passing FLIPR. It will then display 250/37000.

Astronauts & Engineers: Climb Performance
At crossover, you may get a slight bump in rate-of-climb as excess thrust is no longer required for acceleration, but only for climb.

- If a wpt is displayed on line 1R, any predicted altitude undershoot error will display here.
- Blank if no undershoot error.
- This prediction is based on a Great Circle route (direct) and will not consider altitude to be gained in a turn.

ATC: "Fokker VII, can you cross Corel at or above FL270?"

1

- Notice the advisory altitude at COREL of FL233. Type 270A into s/p and LSK 3R.
- Be sure to include the "A" or you'll be wondering why the throttles are coming back and the airplane is leveling off at FL270.

2

Select CLB page. (Refer to above example.)

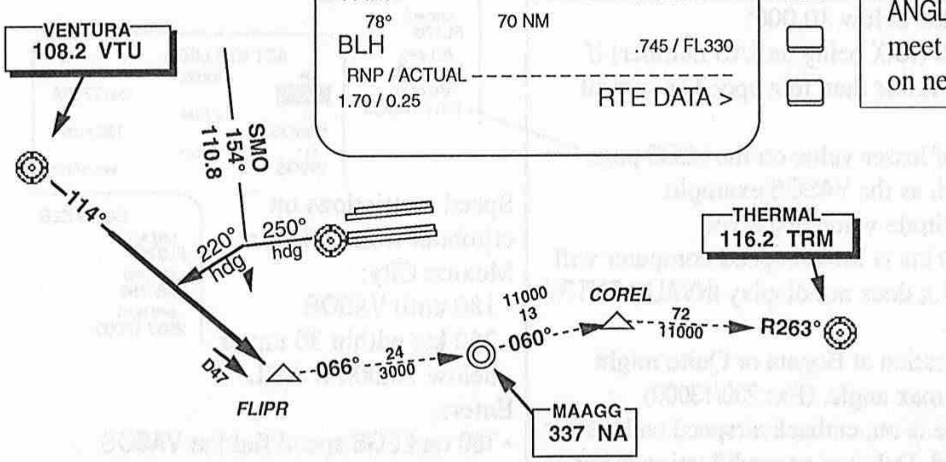
3

ERR AT COREL will be displayed on line 3R if unable to meet restriction.

```
ACT RTE LEGS                         1/5
 115°     7.8 NM
FLIPR                        250/12000
 65°      24 NM
NANB                      292 / 17540
 60°      13 NM
COREL                     292 / FL233
 83°      72 NM
TRM                      .745 / FL330
 78°      70 NM
BLH                      .745 / FL330
 RNP / ACTUAL ----------------------
 1.70 / 0.25                RTE DATA >
```

4

- Delete, from the N1 LIMIT page, the reduced CLB 1 or 2 if any selected, when below 15000 feet.
- Try MAX RATE or MAX ANGLE in the attempt to meet request - samples on next page.



VNAV cannot be engaged if in climb and above an active climb constraint.

Sample views of typical

- MAX RATE CLB,
- MAX ANGLE CLB, a
- 280KT CLB, and an
- RTA CLB (U4.0)

MAX RATE CLIMB - (Vy)
This airspeed produces the maximum gain in altitude per unit of time. (Minimum time to altitude)
-300: At lower altitudes is usually around 70 kts above F. 0 maneuvering but decreases with altitude.
-700: Crossover Mach is approximately .74.

```
ACT MAX RATE CLB              1/1
CRZ ALT
FL330
TGT SPD                    TO T/C
267/.755          1844.5z / 47NM
SPD REST
---/-----
------------
< ECON
                      ----------
                       ENG OUT >
< MAX ANGLE                RTA >
```

MAX ANGLE CLIMB - (Vx)
This airspeed produces the maximum gain in altitude for horizontal distance traveled.
(Minimum ground distance to altitude)
At lower altitudes is usually around 20 kts above F. 0 maneuvering (737-300) but increases with altitude.
-700: Crossover Mach is approximately .74.

```
ACT MAX ANGLE CLB             1/1
CRZ ALT
FL330
TGT SPD                    TO T/C
225/.755          1841.5z / 45 NM
SPD REST
---/-----
------------
< ECON
                      ----------
< MAX RATE             ENG OUT >
                           RTA >
```

TECHNIQUE

When ATC asks for *best rate*, he usually means *best angle*; that is, due to conflict of traffic, he wants you to gain altitude as quickly as possible.

ATC: "Handley Page 8b, cleared to FL310, best rate through FL230."

For a smooth transition to MAX ANGLE then back to high speed climb, select but do not EXECute MAX ANGLE. Select LVL CHG; slowly and in several steps, wind the speed knob back, eventually stopping at max angle speed.
Re-engage VNAV after the clearance is met.
Another method which teaches use of the CWS tool is:
- Deselect VNAV. Puts you in CWS. If AP is in CMD, you have level-off protection.
- Increase pitch a few degrees with control column.
- Adjust pitch using displayed speed as an advisory.
- Above FL230, lower pitch to ±4° and Engage VNAV.
- ERASE MAX ANGLE selection.

The CWS tool is also a useful for climbout in the NG when it starts pitching in VNAV.

```
ACT 280KT CLB                 1/1
CRZ ALT
FL330
TGT SPD                  TO COREL
280/.755          1841.5z / 50NM
SPD REST
---/-----
------------             CLB-1 N1
< ECON               90.5 / 90.5%
                      ----------
< MAX RATE             ENG OUT >
< MAX ANGLE                RTA >
```

U4.0 & up
- Displays the computed time error at the RTA wpt.
- Same display as line 2R on RTA PROGRESS page.
- If error is more than tolerance, amount of time EARLY or LATE will be shown.

```
ACT RTA CLB                   1/1
CRZ ALT                  AT COREL
FL330                       FL270
TGT SPD                TIME ERROR
325/.763                  ON TIME
SPD REST
---/---
------------
< ECON
                      ----------
< MAX RATE             ENG OUT >
< MAX ANGLE                RTA >
```

U4.0 & up
- Displays the computed speed req'd to meet the entered RTA.
- When RTA mode is exited by wpt sequence or DELetion, this speed will become the FMC target speed on a manual speed climb page.

U4.0 & up
Line select will display RTA PROGRESS page where RTA mode can be defined and RTA window displayed.

You get to this page by:

- ENG OUT prompt from ACT CLB page.
- ENG OUT prompt from ACT CRZ page.
- ENG OUT prompt from ACT CRZ CLB page.

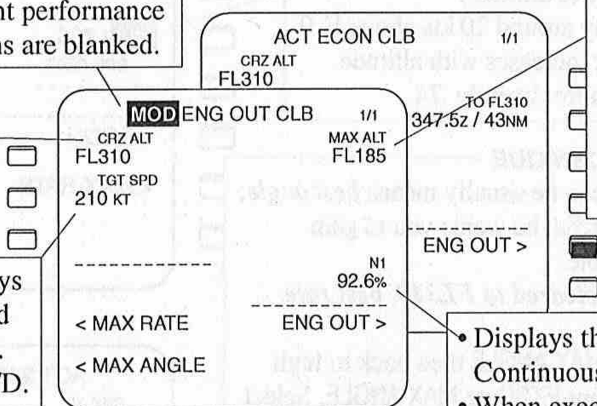
> VNAV cannot be engaged.

NO REQUIRED ENTRIES

- Displays **advisory** data for 1 engine inop.
- There is no single-engine performance data in the FMC database which may be used to predict ETAs or fuel consumption.
- Schedules displayed for engine out conditions are the one engine inop operational speeds defined by Boeing and are valid for climb, cruise, and descent.
- The engine out climb phase automatically transitions to the engine out cruise phase when reaching the cruise altitude.

U1 thru U4
When ACTive, all subsequent performance predictions are blanked.

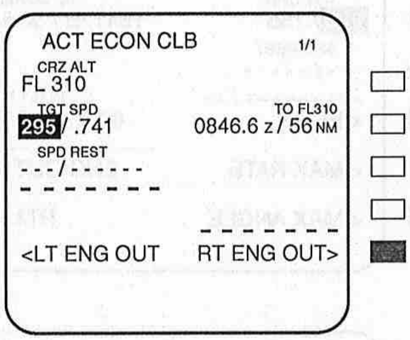
CRZ ALT line is propagated from the PERF INIT or other CLB page.



- Displays the max altitude single engine at which a company-specified rate of climb can be achieved at max continuous thrust.
- Default climb rate is 100 fpm. Ref: Perf Factors.

- TGT SPD line displays the optimum airspeed for engine-out climb.
- It is Flaps up Best L/D.

- Displays the N_1 for Max Continuous thrust.
- When executed, the displayed N_1 value becomes the active N_1 limit.

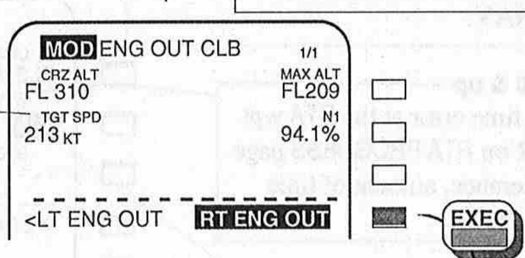


U5.0 & up

- The pilot must select either the LT ENG OUT or the RT ENG OUT prompt.
- This tells the FMC which engine has failed so it can account for the actual bleed configuration. This improves the accuracy of the max altitude calculation.
- The FMC also considers temp lapse rate.

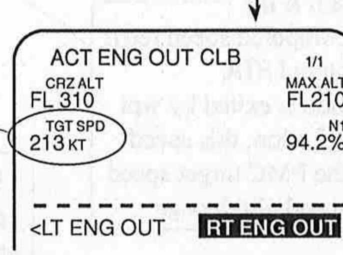
U4.0 & up

- TGT SPD matches the green donut on the speed tape display of the EADI.
- It is Best L/D and about 20 kts above zero minimum maneuvering.



U9 and below

- If executed, VNAV will disconnect without leaving a message.
- Time and fuel predictions on PROGRESS 1/3 will blank.



TGT SPD does not reverse video highlight because VNAV cannot be engaged.

ENG OUT CLB - U10

You get to this page by:

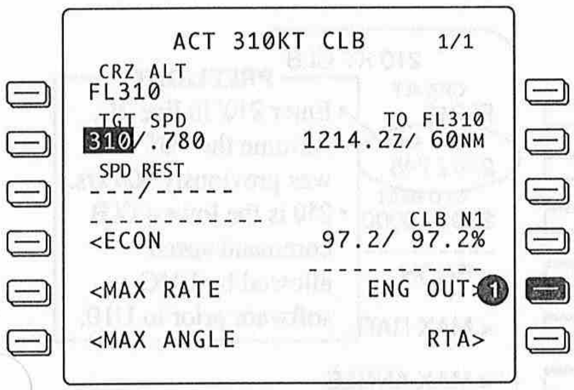
- ENG OUT prompt from ACT CLB page.
- ENG OUT prompt from ACT CRZ page.
- ENG OUT prompt from ACT CRZ CLB page.

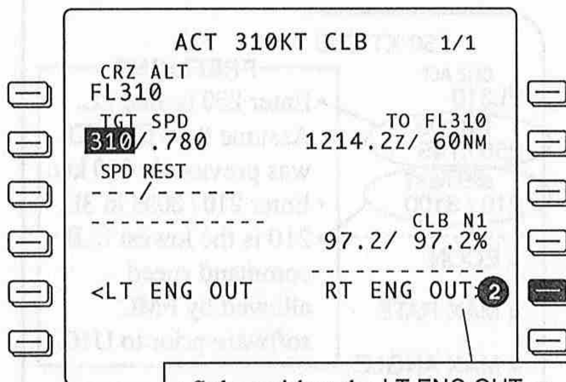
VNAV cannot be engaged.

NO REQUIRED ENTRIES

- Displays **advisory** data for 1 engine inop.
- There is no single-engine performance data in the FMC database which may be used to predict ETAs or fuel consumption.
- Schedules displayed for engine out conditions are the one engine inop operational speeds defined by Boeing and are valid for climb, cruise, and descent.
- The engine out climb phase automatically transitions to the engine out cruise phase when reaching the cruise altitude.

❶ *Ball flags indicate 3 required steps.*



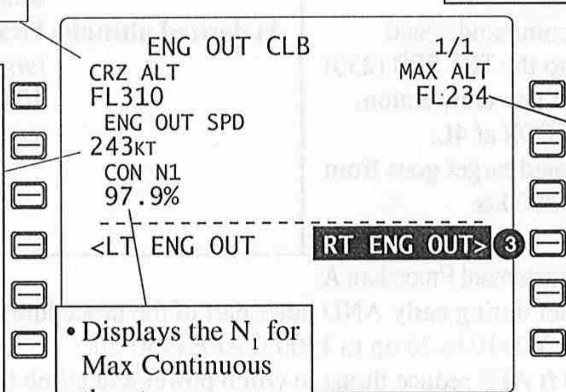


- Select either the LT ENG OUT or the RT ENG OUT prompt.
- This tells the FMC which engine has failed so it can account for the actual bleed configuration.
- The FMC also considers temp lapse rate.

U10.3 & up

Title does not change, i.e. no MOD or ACT, since page cannot be executed.

CRZ ALT line is propagated from the PERF INIT or other CLB page.



- TGT SPD line displays the optimum airspeed for engine-out climb.
- It is MaxL/D.
- TGT SPD does not reverse video highlight because VNAV cannot be engaged.
- U10.3 & up - Headers labeled ENG OUT SPD and CON N1.

- Displays the N_1 for Max Continuous thrust.

- Displays the max altitude single engine at which a company-specified rate of climb can be achieved at max continuous thrust.
- Default climb rate is 100 fpm. Ref: Perf Factors.

TECHNIQUE

This page is for reference only (CRZ ALT and TGT SPD). Return to normal CRZ page, enter the planned E/O speed for time predictions. Fly the L/D Max speed if terrain is a consideration, LRC if range is a consideration, or a normal descent speed if descending directly to an airport, realizing that the fuel figures are going to be in error. CRZ ALT will have to be changed to match-up with the s/e capability of the aircraft at your chosen speed.

737-300 Speed Sample: GW 114.0	
Hold Target (endurance)	234 kts
Max Angle	220 kts
E/O (L/D)	215 kts
Ø Min Maneuvering	194 kts

Noise Abatement Procedure Workaround

As usual, if this or any other workaround or technique in the *737 FMC User's Guide* clashes with your Standard Operating Procedure, your SOP must be used.

- This workaround is due to a poorly designed CLB page.
- This is what the CLB page should look like.
- **Advantages**: Allows early selection of VNAV to meet altitude restrictions during certain departures, such as Ontario, Ca; fewer steps for the MP at a critical phase of flight, the takeoff; slightly less verbal communication during a time when the tower controller is usually handing you off to Departure control.
- **Disadvantages**: Increases the workload on the ground; does not allow programming complete climb, cruise, and descent profile on the ground.
- Whatever the procedure used, brief it during the Preflight.

ECON CLB
CRZ ALT
FL330
TGT SPD
315/.755
SPD TRANS
250 / 10000
SPD REST
210 / 3100

PROCEDURE # 1

Use when the desired climb speed is 250 kts at a specific altitude above the ground. (3000 ft AFE in this example. Field is 98 ft)

250 KT CLB
CRZ ALT
FL310
TGT SPD
250 /.745
SPD REST
210 / 3100

< ECON
< MAX RATE
< MAX ANGLE

PREFLIGHT
- Enter 250 in line 2L. Assume the TGT SPD was previously 300 kts.
- Enter 210 / 3098 in 3L.
- 210 is the lowest CLB command speed allowed by FMC software prior to U10.

At 400': FP calls "Heading Select" or "LNAV".

At 1000' AFE: FP calls "Flaps 1, VNAV". FMC commands climb power. Clean-up on schedule.

At 3000 AFE: FMC command speed resets to the TGT SPD (250) without any crew action.

At 10,000': Press ECON at 4L. Command target goes from 250 to 300 kts.

PROCEDURE # 2

Use when 250 kts is not desired until turned on course - departure runway may be in wrong direction.

210 KT CLB
CRZ ALT
FL310
TGT SPD
210 /.745
SPD REST
250 / 10000

< ECON
< MAX RATE
< MAX ANGLE

PREFLIGHT
- Enter 210/ in line 2L. Assume the TGT SPD was previously 300 kts.
- 210 is the lowest CLB command speed allowed by FMC software prior to U10.

At 400': FP calls "Heading Select" or "LNAV".

At 1000' AFE: FP calls "Flaps 1, VNAV". FMC commands climb power. Clean-up on schedule.

At desired altitude: Press ECON. Command target goes to 250 until 10,000, then 300 kts.

ICAO Noise Abatement Procedure A:

(Noise relief during early AND latter part of the procedure)
- Climb at V2+10 to 20 up to 1500 ft AFE (450 m).
- At 1500 ft AFE reduce thrust to climb power and climb to 3000 ft (900 m) at the same speed.
- At 3000 ft AFE, accelerate and retract flaps on schedule.

ICAO Noise Abatement Procedure B:

(Noise relief only for that part of the procedure close to the airport.)
- Climb at V2+10 to 20 up to 1000 ft. AFE (450 m).
- At 1000 ft AFE, select climb power, accelerate to zero flap maneuvering speed, retracting flaps on schedule, and climb to 3000 ft AFE at zero maneuvering speed.

OPTIMUM ALTITUDE

The FMC displays OPTimum altitude for each of the three normal cruise modes: Constant or Fixed-Mach (ACT M.XXX CRZ), LRC and ECON.

There exists for each weight, an optimum altitude, increasing with decreasing weight.

The *fixed-Mach* and *LRC optimum altitudes* are calculated to yield maximum nautical miles per pound of fuel. These optimum altitudes yield the greatest fuel mileage for the aircraft weight, so always favor higher altitudes. The 737 FMC will display an OPT altitude for a CAS entry, but it does not have a database to support this display.

The ECON OPT altitude is based on minimum *cost* per nautical mile calculated by the entered Cost Index. The OPT ALT will decrease with high CI entries because ECON is looking for higher ground speed (lower altitude equals higher TAS).

Fixed-Mach and *LRC* yield different OPT altitudes than ECON OPT altitude because they do not consider cost optimization calculations found in CI.

Though not a rule, optimum altitude provides at least a 1.4g or better buffet margin. (1.5g equals 47° bank to buffet onset. 1.4g equals 45°)

If one climbs above optimum altitude and remains at best range speed for the lower altitude, L/D is influenced unfavorably and the engines must produce more thrust to support the aircraft at the greater angle of attack (alpha) and accompanying increased drag. There is an added penalty because the airplane is flying slower than required and induced drag has greater influence on total drag than does parasite drag for a limited range of alpha. This effect can be minimized by flying at a faster speed (reducing alpha).

By increasing speed (thereby adjusting alpha) you will minimize these penalties (not always attainable because of transonic drag rise, etc.). To compound the problem, climbing the heavy weight higher than required (higher throttle settings for a longer time) decreases cruise fuel, which decreases range. Bleed requirements also increase at high altitudes.

If one cruises lower than optimum altitude without changing speed, L/D is also unfavorably influenced. However the penalties are somewhat less pronounced because the aircraft is faster than required (lesser alpha) and even though the drag condition is not optimized there is a lesser penalty (parasite drag has a lesser influence than induced drag for a limited range of alpha, which is part of the reason for the greater margin of error below optimum altitude. And since cruising flight has begun prematurely (shorter climb), available cruising fuel is increased, thus increasing range (a condition negated eventually by the penalties of cruising too low). The penalties for cruising too low can be minimized by reducing speed to between MRC and LRC for the new and lower altitude.

A climb above *optimum altitude* may be desirable for more favorable winds or ride comfort as long as you do not exceed Max altitude.

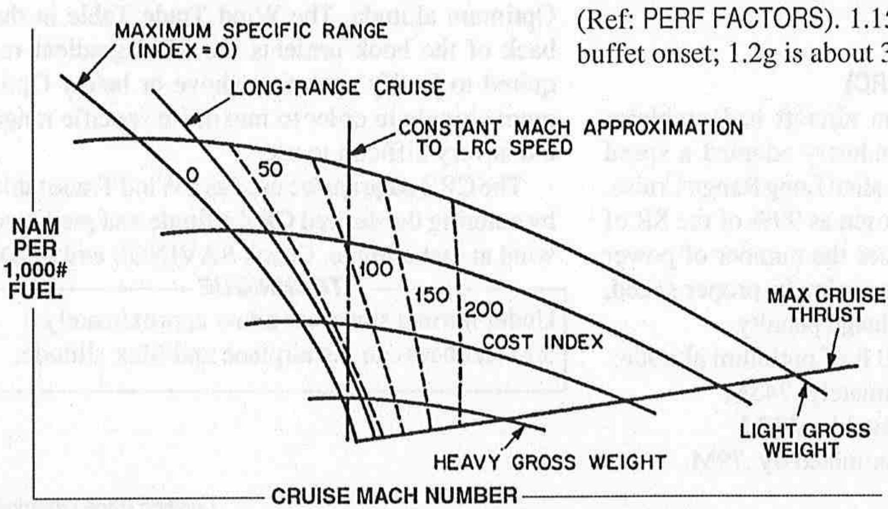
Some approximate cruise fuel penalties are:
2,000' below Opt. alt. - 1% increase in trip fuel.
4,000' below Opt. alt. - 4% increase in trip fuel.
Cruise speed of M.01 above schedule - 1-2% increase in trip fuel.

BUFFET MARGIN

The higher the airplane flies above the Optimum altitude, the more the buffet margin is reduced. This is graphically displayed on the speed tape.

Before accepting a clearance to cruise at MAX ALT, determine that it is, and will continue to be, acceptable as the flight progresses under projected conditions of turbulence and temperature.

The maneuver margin is stipulated by either the FAA, CAA, or Europe's Joint Aviation Authority and is selected by a program logic pin. The value of the FAA maneuver margin to initial buffet is CDU enterable from 1.15g (1.2g in U6.2) to 1.6g. The CAA maneuver margin limits are fixed at 1.3g. (Ref: PERF FACTORS). 1.15g is about 30° bank to buffet onset; 1.2g is about 34° bank to buffet.



Certain factors such as ATC clearance, temperature, weather, or wind conditions may require the crew to operate very near the Max altitude. The most critical situation is a 737-800 or 900 at high altitude in warm air; the airplane is thrust limited.

MAX ALTITUDE

Max altitude is limited by three factors.

1) Max certified altitude - structural capability of the aircraft to withstand the pressure difference between the inside and the outside air.
2) Aerodynamics, or high and low speed buffet limited altitude. High speed buffet is caused by supersonic airflow over parts of the wing. Low speed buffet results from an increase in angle of attack to the point where the airflow separates from the wing.
3) Thrust limited altitude - based on a residual rate of climb of 300 fpm in the climb but changing to 100 fpm at cruise.

MAXIMUM RANGE CRUISE (MRC)

This is the speed at which max fuel mileage occurs. MRC is displayed in the ECON mode when a zero is entered as the Cost Index, but the calculation is affected by winds. You can check your Max Range Cruise speed on the ground - complete the PERF INIT page with a CI entry of zero (no wind); or at cruise altitude with no tailwind (headwind is ok). It will be approximately .02 mach less than LRC.

To fly at max range an airplane must operate continuously at the OPTimum altitude. Older generation aircraft have a hard time operating at MRC in the higher altitudes because of the frequent power changes needed to maintain the target speed. The B737 autothrottle system allows operation at MRC but be careful; when you are near the bottom of the thrust/speed curve you are in the speed instability region. It is also useful to operate at MRC when you are expecting a holding clearance down route or when ATC has requested slowest possible speed.

LONG RANGE CRUISE (LRC)

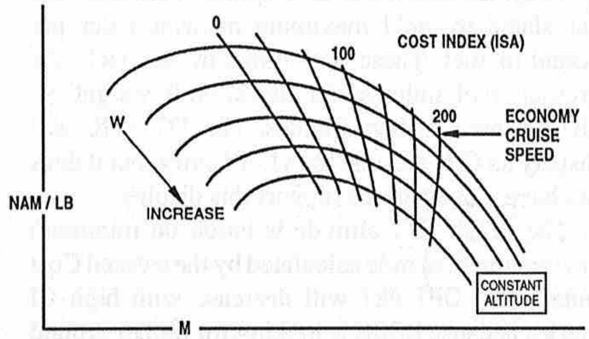
Since older generation aircraft had problems maintaining MRC, the industry adopted a speed slightly faster than MRC called Long Range Cruise. It has been arbitrairly chosen as 99% of the SR of MRC. Flying LRC reduces the number of power adjustments necessary to maintain proper speed, but results in 1% fuel mileage penalty.

For cruise within 2000 ft of optimum altitude:

(3-4-5) LRC approximately .743M
700 LRC approximated by .78M.
800/900 LRC approximated by .79M.

ECONOMY CRUISE (ECON)

ECON takes hourly maintenance and crew costs into consideration and balances them against the cost of fuel. ECON speeds are derived from the Cost Index entered on the PERF INIT page. A low CI entry indicates fuel is the most important variable while a high CI would indicate time is the most important consideration.



AUTOTHROTTLE

The autothrottle uses the FMC gross weight to establish a target N1 for cruise at the selected airspeed. It then checks the FMC gross weight against a weight computed using the angle of attack (AOA) data. If the weights differ significantly, the target N1 setting may be hung up at the wrong value which will result in a slightly different airspeed than selected.

TEMPERATURE

The effect of air temperature on range may be negligible but if the temperature is above ISA the thrust will decrease. To maintain the original Mach number, the thrust must be returned to its original value; this means the throttles must be advanced, increasing the engine RPM and specific fuel consumption. However, by maintaining a given Mach under increased temperature conditions, the TAS has increased due to the higher local speed of sound, counteracting the increased fuel flow.

WINDS

Wind is a factor which may justify operations off Optimum altitude. The Wind Trade Table in the back of the book presents the wind gradient required to justify operation above or below Optimum altitude in order to maximize specific range but is very difficult to use.

The CRZ page can be used as a Wind Trade table by entering the desired CRZ altitude and predicted wind at that altitude. Check SAVINGS and FOD.

TECHNIQUE

Under normal situation, allow approximately 300 feet between the airplane and Max altitude.

CONCEPT OF COST INDEX

TIME ITEMS

Airplane operating costs are affected not only by fuel burn but by flight time. In fact, certain categories of costs are directly related to flight time, so that a reduction in flight time of say, 5% will result in a 5% savings for that cost category. These costs are time related costs and are the key to determining the best speed at which to fly for minimum cost. Cost Index documentation recommends cost considerations that are variable and directly related to flight time. It helps to think of C.I. as a measure of the effect of time on the operating costs. Items such as aircraft ownership, hull insurance and landing fees are considered fixed costs and not time related. Direct operating costs affected by flight time are: crew costs (cockpit and cabin), leasing, and variable maintenance costs (airframe material, engine overhaul, labor), expressed in dollars per flight hour. Fuel used is expressed in cents per hour.

Line AB represents crew and certain maintenance costs decreasing as speed is increased.

FUEL USED

Fuel cost is expressed in cents per pound. It should reflect the price of fuel used on a particular leg or the average price for the routes over which the airplane flies. Determination of fuel price is usually a simple process, but can become complicated when prices change at various airports, or when tankering is used.

Line CD represents fuel consumption increasing as speed is increased.

The method for determining minimum cost speed (called ECONony speed) is to combine the time-related costs and fuel cost for a flight segment.

So Cost Index is defined then, as a ratio between time-related inflight costs and fuel cost.

$$\text{Cost Index} = \frac{\text{Time Related Cost (\$ / flight hr)}}{\text{Fuel in cents / pound}}$$

$$\text{Cost Index} = \frac{\text{Units of currency per flight hr}}{\text{(Units of currency per lb)} \times 100}$$

Cost Index is the relative importance of time cost compared to fuel cost.

TIME + FUEL

The TIME + FUEL line takes into consideration the ratio of these two curves and produces one specific Cost Index or ECON speed for that flight leg. If you fly slower or faster than this *Official Cost Index*, you will increase your cost of operation.

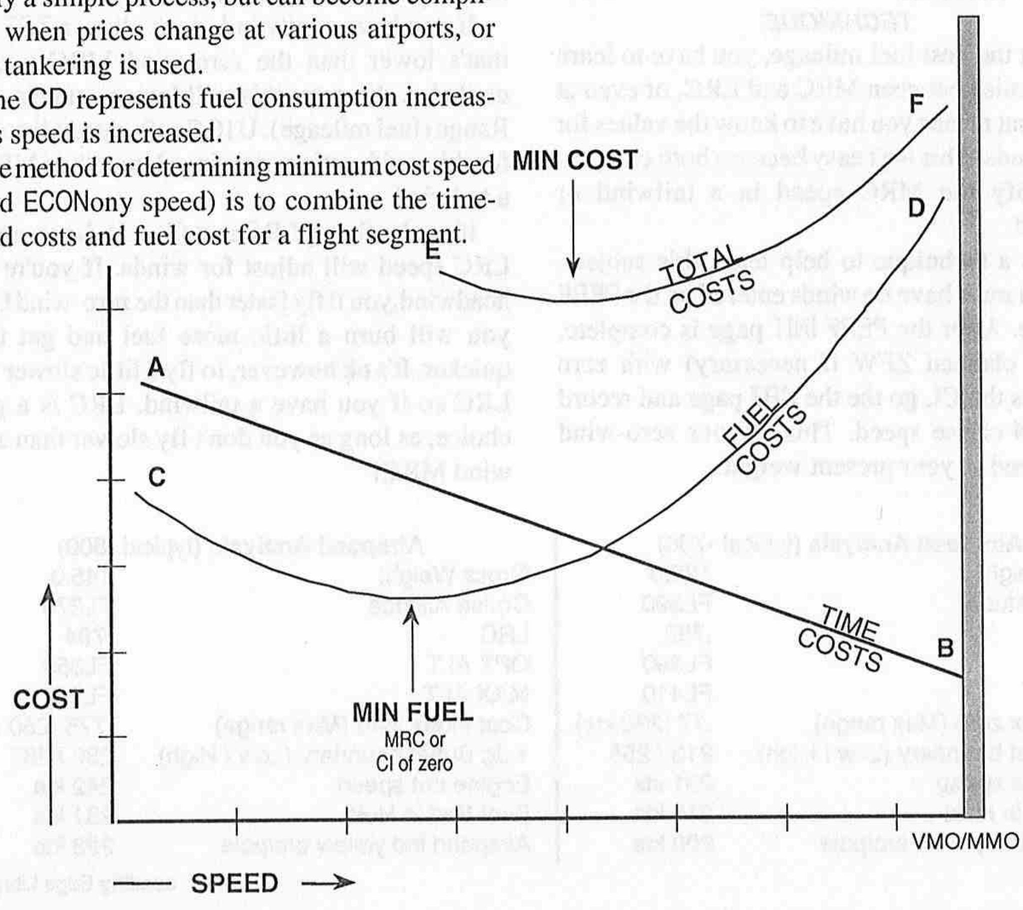
A low Cost Index could mean high fuel costs or the need to increase your RESERVES fuel.

A high Cost Index could mean high time-related costs or a need to get there fast.

Cost Index does not need to be accurate. Using a Cost Index that is reasonably near the correct one is sufficient.

Currently, few airlines actually do the true calculations required to produce an accurate Cost Index.

Will one value of CI approximate LRC for all weights and altitudes? No.



SAMPLES

- Included below are comparisons between ECON, LRC and a Manually entered cruise.
- TGT SPDs, OPT and MAX displays are accurate representations.

Cost Index of 200
(300) / (800)

```
ACT ECON CRZ   (GW104.0)
CRZ ALT   OPT/MAX
FL370  FL327/370
TGT SPD
M.775
```

```
ACT ECON CRZ   (GW137.0)
CRZ ALT   OPT/MAX
FL370  FL369/389
TGT SPD
M.806
```

Cost Index of 0
(300) / (800)

```
ACT ECON CRZ   (GW104.0)
CRZ ALT   OPT/MAX
FL370  FL370/370
TGT SPD
M.729
```

```
ACT ECON CRZ   (GW137.0)
CRZ ALT   OPT/MAX
FL370  FL370/389
TGT SPD
M.764
```

LRC Entry
(300) / (800)

```
ACT LRC CRZ   (GW104.0)
CRZ ALT   OPT/MAX
FL370  FL370/370
TGT SPD
M.743
```

```
ACT LRC CRZ   (GW137.0)
CRZ ALT   OPT/MAX
FL370  FL369/389
TGT SPD
M.789
```

M.760 Entry (300)
M.780 Entry (800)

```
ACT M.760 CRZ   (GW104.0)
CRZ ALT   OPT/MAX
FL370  FL370/370
TGT SPD
M.760
```

```
ACT M.800 CRZ   (GW137.0)
CRZ ALT   OPT/MAX
FL370  FL376/383
TGT SPD
M.800
```

I make two assumptions. The Autothrottles are on and you are ahead of schedule.

(3-4-5) LRC will slow up a little for a tailwind and speed up in a headwind; it's calculatinging ground mi. per lb rather than air mi. per lb.

(NG) LRC does not adjust speed for headwind or tailwind conditions.

TECHNIQUE

To get the best fuel mileage, you have to learn how to cruise between MRC and LRC, or even at MRC. That means you have to know the values for these speeds. This isn't easy because both computers modify the MRC speed in a tailwind or headwind.

Here's a technique to help learn this subject. First, you must have no winds entered on the PERF INIT page. After the PERF INIT page is complete, (use the planned ZFW if necessary) with zero entered as the CI, go the the CRZ page and record the ECON cruise speed. This is your zero-wind MRC speed at your present weight.

If you're sitting in a (3-4-5), press the LRC prompt and record that speed, too. Now you have zero-wind MRC and LRC, at your present weight.

At cruise altitude...

If you're in a headwind, fly MRC; that is, fly ECON with a CI entry of zero. CI zero in a 100 kt headwind is still slower than LRC!

If you have a tailwind, don't allow a TGT SPD that's lower than the zero-wind MRC you recorded at the gate; this will lower your Specific Range (fuel mileage). U10.7 software will correct for this malfunction of flying slower than MRC in a tailwind.

If you're flying LRC in a (3-4-5), be aware the LRC speed will adjust for winds. If you're in a headwind,you'll fly faster than the zero-wind LRC; you will burn a little more fuel and get there quicker. It's ok however, to fly a little slower than LRC so if you have a tailwind, LRC is a good choice, as long as you don't fly slower than zero-wind MRC!

Airspeed Analysis (typical -700)

Gross Weight	126.0
Cruise Altitude	FL390
LRC	.786
OPT ALT	FL390
MAX ALT	FL410
Cost Index zero (Max range)	.77 (238 kts)
1.3g Buffet boundary (Low / High)	213 / 255
Engine out speed	231 kts
Best Spd in Hold	218 kts
Airspeed ind yellow arc/pole	208 kts

Airspeed Analysis (typical -800)

Gross Weight	145.0
Cruise Altitude	FL370
LRC	.794
OPT ALT	FL358
MAX ALT	FL383
Cost Index zero (Max range)	.775 (250 kts)
1.3g Buffet boundary (Low / High)	230 / 267
Engine out speed	242 kts
Best Spd in Hold	231 kts
Airspeed ind yellow arc/pole	223 kts

EFFECT OF WIND ON RANGE

The effect of wind is to change the ground speed, thus changing the time to travel a given ground distance, effectively traveling a different air distance. (Still-air distance equals ground distance.)

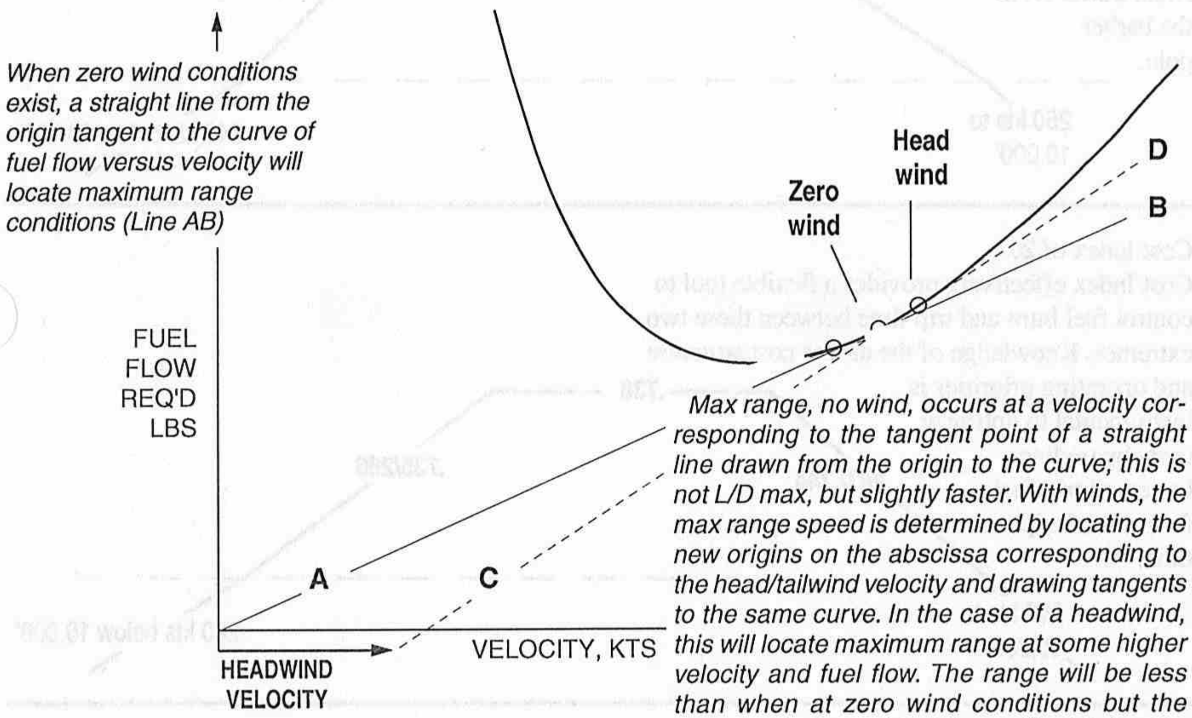
Wind does not influence fuel consumption or altitude, only max range.

Since only max range is influenced by wind, we can adjust MRC airspeed. We minimize the loss in a headwind by increasing the MRC speed by the magnitude of the wind factor. A Cost Index entry of zero will automatically take care of this calculation.

There is no aerodynamic justification for increasing LRC or any other speed in a headwind. There is some justification in reducing LRC slightly in a tailwind, but be careful; if fuel is the main driver, do not fly slower than MRC. Contrary to popular belief, you do NOT want to fly slower than MRC, even in a tailwind.

Specific Range is the measurement of the aircraft's fuel mileage in NAM per lb of fuel. $SR = \frac{TAS}{FF}$

Using different ingredients, SR can be expressed in terms of ground speed. $SR_G = SR\left(1 + \frac{V_W}{a_0 M\sqrt{\theta}}\right)$



You can use Cost Index Zero to calculate a wind-corrected MRC. A headwind increases MRC. The stronger the headwind, the higher the cruise mach.

Because ECON reads the wind and LRC does not, ECON with a CI that approximates LRC (such as 30) may provide a slightly more *fuel* economical cruise mode in a tailwind situation because it's flying slower than LRC.

To pick a CI that approximates LRC, first check the LRC speed after the PERF INIT page is filled out. Don't enter ANY winds, either on the PERF INIT or on the RTE DATA pages. Now, enter a CI that is close to the LRC value. It is not possible for one CI to match LRC under all weights and altitudes. Next, enter the forecast winds. The ECON based cruise speed will change accordingly.

If you use this technique in a headwind you may want to pick a lower CI as the goal in fuel conservation is to fly somewhere between MRC and LRC.

Note: Using ECON is this manner is another way of choosing a cruise speed with fuel mileage being the main driver. It defeats the real purpose of the concept of Cost Index - choosing a cruise speed taking into consideration time related items *and* fuel cost, but is a useful tool in flying close to or at MRC.

TYPICAL COST INDEX

Cost Index of zero = Max Specific Range
Cost Index of 200 (3-4-5)
500 (6-7-8-9) = Minimum Time

As these costs change due to change in fuel, crew or maintenance costs, the operator can change the value of Cost Index accordingly, to optimize the performance of the sytem and the aircraft for current economic conditons.

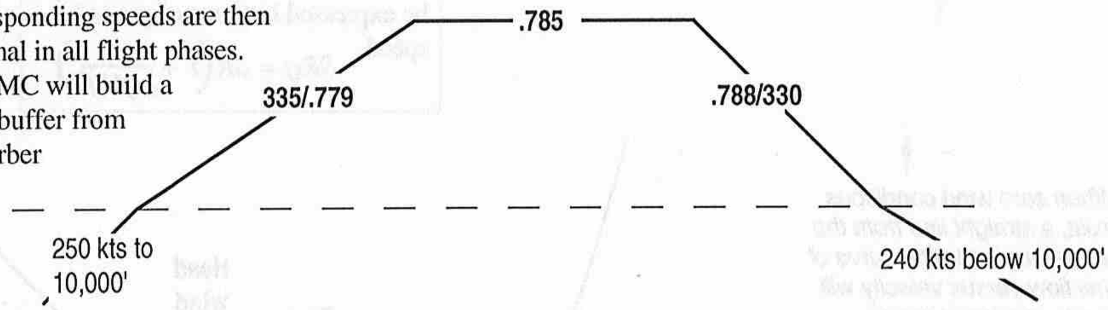
ECON climb trajectories are steeper at low cost index values and flatter at high cost index values.

At a Cost Index of zero, the ECON climb is near the max rate of climb. This decreases the time to climb and minimizes the time spent at climb thrust (high fuel flow).

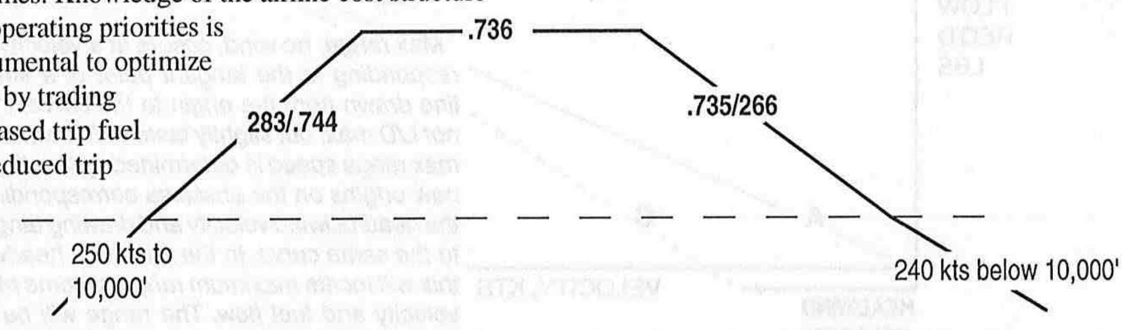
ECON descent trajectories are flatter at low CI (lower speeds) and steeper as CI increases.

To summarize: As Cost Index increases, speed increases to decrease time costs. This results in a shallower climb, steeper descent, less overall time, a higher overall fuel burn, but lower relative cost at the specified CI.

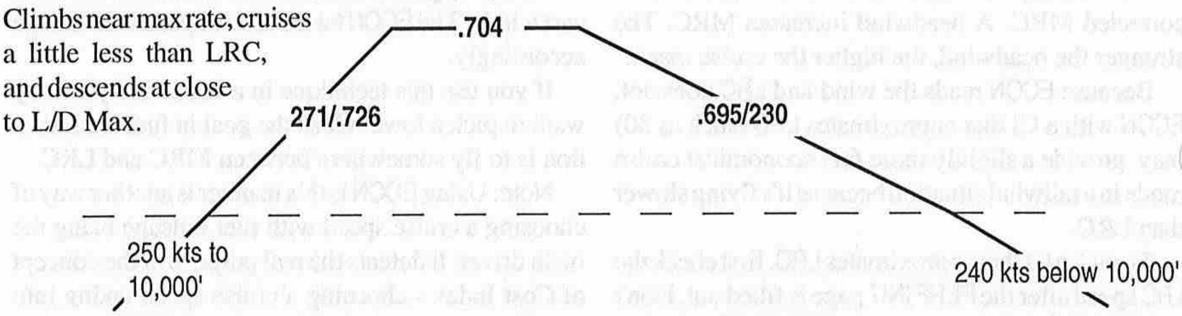
Cost Index of 200
Premium exists on time (arrival). Corresponding speeds are then maximal in all flight phases. The FMC will build a small buffer from the barber pole.



Cost Index of 20
Cost Index effectively provides a flexible tool to control fuel burn and trip time between these two extremes. Knowledge of the airline cost structure and operating priorities is instrumental to optimize costs by trading increased trip fuel for reduced trip time.



Cost Index of 0
This is the case of highest influence of fuel cost in the operating bill, or a requirement for max range. ECON will minimize consumption in all flight phases. Climbs near max rate, cruises a little less than LRC, and descends at close to L/D Max.



HOW TO USE COST INDEX

Many factors need to be considered before choosing a speed schedule.

- Is my company's speed schedule fuel or time constrained?
- Can I meet the schedule requirements?
- Can I maintain the ATC clearance?
- Do I have enough fuel?
- What's my decision going to cost the company?

COMPANY CALCULATED COST INDEX

ECON speeds are computed to minimize the cost factor which is defined as the sum of hourly operating costs and mx costs related to the cost of fuel. True ECON flying means management must do the analysis and compute the actual cost. The CI will change with fuel cost or lease/maintenance variables. I'll call this the *Official Cost Index* or *Official ECON operation.*

If you then change your Cost Index (increase or decrease) the cost of that flight will increase. If you don't fly that OPT ALT, your cost will increase.

If you are on time or early, fly the *Official Cost Index.*

NO COMPANY CALCULATED COST INDEX

Most airline flight plan speed schedules have no correlation to the assigned Cost Index. In these cases, the FMC will match the paper flight plan's fuel burn and ETA data only if the pilot manually enters a speed schedule equal to the paper flight plan speed schedule. Make sure you enter the winds!

If you don't have a Cost Index that was arrived at in a scientific manner, you're simply using Cost Index as a means of choosing climb, cruise, and descent speeds. There's no science to it since you are not taking into consideration all the costs involved.

SUMMARY

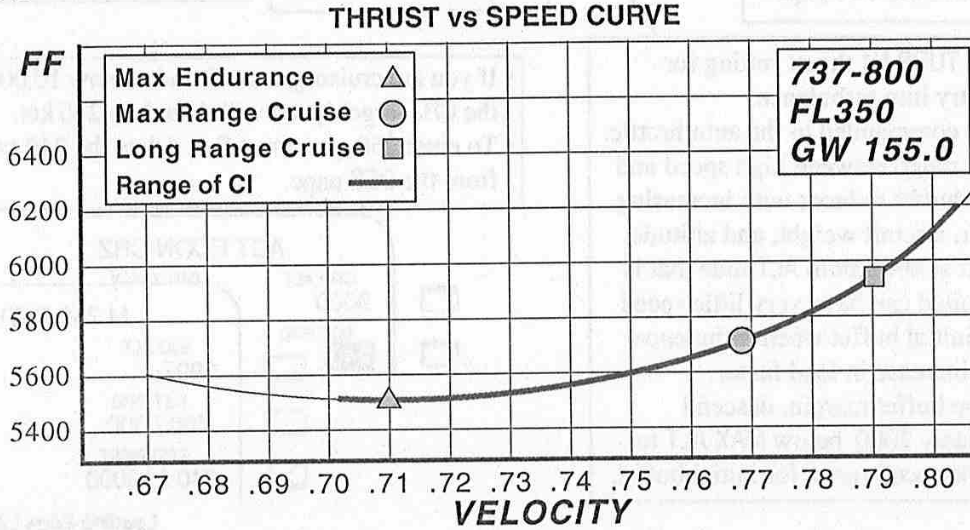
For domestic operation, schedule normally drives choice of cruise speed more than cost of operation. Remember, anytime you get away from an *Official Cost Index,* you're through with the science - i.e. ECON flying based on the ratio of time costs to fuel cost.

TECHNIQUE

If you don't have an *Official ECON operation,* follow these steps.

- During preflight, enter your own personal Cost Index because the boxes must be filled. If fuel mileage is an issue (fuel-over-destination is too low or fuel is expensive), the CI entry should be from 10 to 20. This will put your speed between LRC and MRC (chart below). If time is the issue, use a CI of 40 or above.
- Fill out the RTE and PERF INIT pages to include wind at TOC and temperature.
- Go to the CRZ page and enter a cruise altitude as close as possible to the displayed OPT ALT. (Don't make a temp entry on the N1 LIMIT page yet.)
- Now go to the LEGS RTE DATA and enter the forecast winds from the flight plan. Your flight profile is now just about as efficient as possible!
- Airline ops: prior to takeoff or during climbout, check the ETA. If you are on-time, don't make any changes. If early or late, manually enter speeds sufficient to calculate an ETA to get you there at the desired time. Remember, higher speed or lower altitude requires more fuel!
- This discussion does not address operational factors such as gate problems if too early.

THRUST vs SPEED CURVE



You get to this page by:

- CRZ key.
- Automatically displayed at top of climb when an active climb page is displayed.

OPTIMUM ALTITUDE

– Optimum altitude increases as weight is reduced.
– For an optimum range flight path, an aircraft must climb as it burns off fuel weight.
– Optimum altitude display may be used during preflight, climb, or cruise to evaluate altitude choice.

TECHNIQUE

Change Thrust Mode to CLB
- if you are cruising above OPT alt
- if you are cruising slower than LRC
- if you are cruising in mountain wave or turbulence
- if you are holding at high altitude
- or any other time you feel like it; it's a good idea.

- Fixed mach and LRC optimum altitudes are based on maximum nautical miles per pound of fuel.
- ECON OPT ALT is based on cost. Example: the higher your CI entry, the more important ground speed becomes over range (fuel mileage). So an ECON OPT ALT will decrease as the CI entry is increased (higher TAS). If speed (time) is more important than fuel, you're not interested in stepping, so you should fly the displayed OPT ALT for your CI entry. Does that make sense?
- If you're interested in fuel mileage, OPT ALT calculation is your best tool for evaluating step climb.
- You could consider an LRC derived OPT ALT calculation to be a little inaccurate because of where the calculation comes from in the FMC. To get an accurate OPT altitude for your weight and speed, manually enter a speed equal to LRC, or select ECON with a low CI (<20).
- OPT ALT is not constrained by the minimum cruise time criteria as is TRIP ALT on the PERF INIT page, therefore don't use it for short-trip altitude selection.

- TGT SPD becomes active at level off and is reverse video highlighted or magenta.
- Enter CAS or Mach.
- Trailing zeros not req'd for Mach entry.
- ECON TGT SPD increases in headwind and decreases in tailwind.
- If operating near max altitude, TGT SPD will be reduced with EAI and / or WAI on.
- Limit 340/M.82 less 5 kts.
- Speed Propagation (option) - When a manual speed is entered on the CRZ page, it propagates to the DES page.

```
     ACT M.800 CRZ        1/1
 CRZ ALT      OPT/MAX     STEP
 FL370     FL365/382     -----
 TGT SPD                TO T/D
 .800      1919.1z/ 1313NM
 TURB N1           ACTUAL WIND
 88.4/ 88.4%        277°/ 62
 FUEL AT KEWR
 18.9
 ------------------------------
 <ECON                ENG OUT>

 <LRC                     RTA>
```

- Appears at level off.
- Displayed when more than 100 nm from T/D and no STEP TO altitude is entered.
- Always displayed when less than 100 nm from T/D.

Provides advisory data and cannot be coupled to the AFDS.

U4.0 & up
Line selection will display the RTA PROGRESS page.

- Reference TURB N1 thrust setting for sudden entry into turbulence.
- Cannot be commanded to the autothrottle.
- The speed range between high speed and low speed buffet reduces with increasing load factor, aircraft weight, and altitude. An aircraft at MAXimum ALTitude that is weight limited can have very little speed range for initial buffet when turbulence causes an increase in load factor.
- To increase buffet margin, descend approximately 2000' below MAX ALT to increase the speed range for initial buffet.

- If you are cruising at an altitude below 10,000 ft, the CRZ target speed will default to 240 kts.
- To enter 250, you must first delete the 240 SPD REST from the DES page.

```
      ACT ECON CRZ
 CRZ ALT      OPT / MAX
 9000
 TGT SPD        M.760 PATH DES
 240         E/D ALT
             1997
             TGT SPD
             .760 / 300
             SPD REST
             240 / 10000
```

STEP TO

- As weight is reduced, fuel mileage, or "miles per gal.", increases. At some point, it becomes more economical from a fuel issue, to climb to a higher altitude.
- May help to monitor winds during climb-out and cruise. Compare to flight plan winds.

• The STEP TO prediction differs with the chosen cruise mode - ECON, fixed mach, or LRC.
• % of SAVINGS (or penalty) will be shown along with the ETA and distance to the STEP POINT.
• Fuel at destination reflects STEP TO entry.
• U5.0 and up: When the step altitude cannot be achieved within the cruise segment of flight, UNABLE is displayed in the STEP POINT field.

• In the author's opinion, the STEP TO feature should not be used. It will advise a climb when it is actually too early. The NOW prompt appears when MAX ALT equals entry in 1R.
• It is not impossible or necessarily unsafe to climb to MAX ALT, however it is not normal, and should only be done in certain situations such as when faced with the choice of a very low altitude over a long period of time.

U4 and below

Enter max certified altitude into LSK 1R. MAX ALT FL will appear in s/p. This is the aero limit, i.e., the 1.3g buffet boundary. It is not the thrust limit altitude which may be lower.

• Enter STEP TO altitude.
• If past STEP POINT, it will show NOW as long as savings are positive.
• Blank when within 110 nm of top-of-descent and when RTA mode is active (step evaluation not available) because changes toward the later portion of the flight will have very little effect on economy of operation.
• May be transferred to s/p for entry at 1L.
• STEP POINT changes to T/D when within 110 nm of predicted T/D point.
• To clear entry from 1R, simply DELete.

Arrival fuel predicated on continued flight per the displayed cruise and planned descent modes and the ACTive route, and that the step (if entered) will occur at the point computed.

```
      ACT M.800 CRZ            1/1
  CRZ ALT      OPT/MAX        STEP
 FL330   FL355/370           FL370
   TGT SPD              STEP POINT
 M.800                         NOW
  TURB N1              ACTUAL WIND
 86.4/ 86.4%              277°/ 62
  FUEL AT KEWR             SAVINGS
           15.9               0.5%
 ------------------------------------
 <ECON                    ENG OUT>

 <LRC                            R
```

• Normally displays ACTUAL true WIND.
• If the wind at the STEP TO altitude is known, it can be entered (Flight plan or ask ATC). Changes ACTUAL WIND to EST WIND.

• A step climb performed late in the en-route segment will not have a significant effect on total trip cost or fuel. A step trade for these reasons is more effective earlier on in the cruise segment.
• Other reasons for step-climb such as for ride comfort may still be effective late in the cruise segment.
• On the ND Map, a green donut with S/C will be displayed at this point.

TECHNIQUE

So how do you step-climb the 737?

• Don't use the STEP TO feature.
• (NG) Check the SAT on PROGRESS 2/4. If the ambient temp is ISA + 10 or more, enter that SAT into line 3R of the PERF INIT page.
This may affect the MAX ALT calculation.
• Climb when the MAX ALT is approx. 300 ft above your desired altitude. In this example a climb to FL370 would commence when the MAX ALT is approx. FL373.
• If you climb too soon, the engines will run at a high N1 (high fuel flow) and you'll have less protection from buffet boundary until the weight is reduced
• To predict a step-climb, the MAX ALT will increase 100 ft approximately every 7 min.
• After entering the new altitude on the CRZ page you may also enter the estimated wind and check new ETA and FUEL AT destination before executing.
• If the MAX ALT display is limited by the certified ceiling, climb to the certified ceiling when the OPT ALT is approximately (3-4-5) 1,000 (NG) 700 feet less than the MAX ALT.

(3-4-5)

```
      ACT LRC CRZ          1/1
  CRZ ALT    OPT/MAX      STEP
 FL350   FL360/370       -----
   TGT SPD               TO T/D
 M.743         1648.3z/ 958NM
```

(NG)

```
      ACT ECON CRZ         1/1
  CRZ ALT    OPT/MAX      STEP
 FL390   FL404/410       -----
   TGT SPD               TO T/D
 M.782        1921.6z/1254NM
```

Situation:

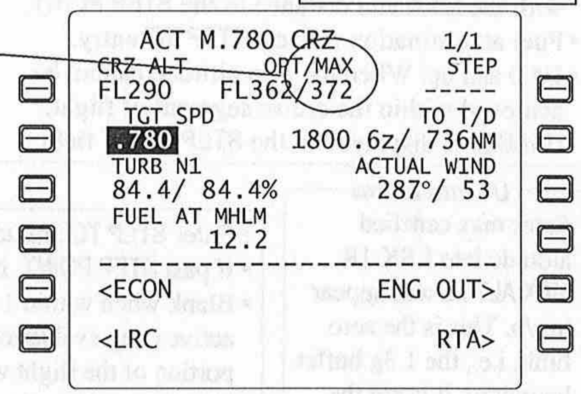
You have just deparated Houston Intercontinental, destination San Pedro Sula, Honduras, in a -900. You are flight planned for FL330 on UB 753.

ATC: "Columbia STS107, climb and maintain FL290, company traffic above you at 330. Can you make FL 370?"

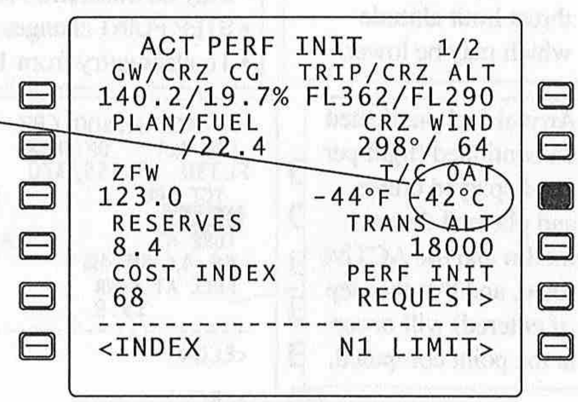
You're interested in arriving over San Pedro Sula with as much fuel as possible; because of the heavy payload, your planned fuel-over-destination is at a minimum.

U5.0 & up
Displays MAX altitude.

Checking the MAX altitude on the CRZ page, you notice FL 370 is possible, but let's do some investigating.



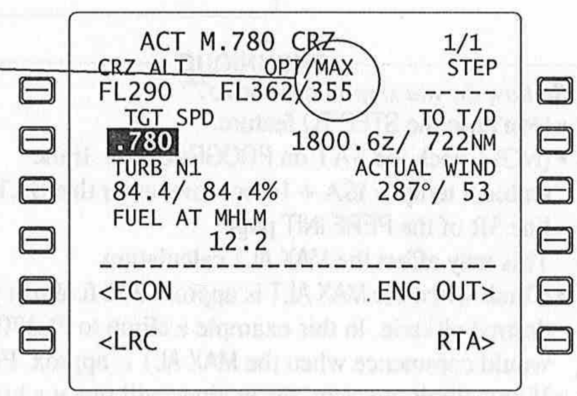
- Check the OAT on PROGRESS page 3, ask ATC if they've got someone at that altitude for a temp report, or check your flight plan for the temp at FL370.
- In this case, it's ISA +15 at FL 290.
- Go the the PERF INIT page and enter the ISA + 15 at FL 370. (It's a good idea to have a temp chart with you at all times.)



ISA

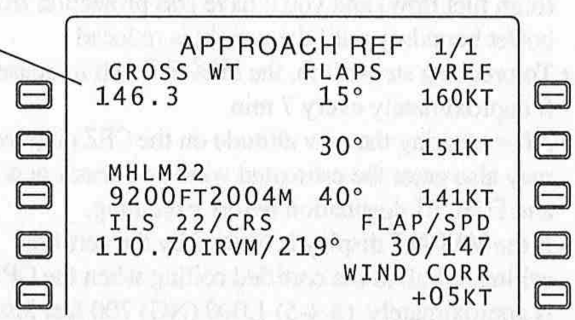
FL 220	-20°F/-29°C
FL 250	-31°F/-35°C
FL 270	-38°F/-39°C
FL 280	-42°F/-41°C
FL 290	-45°F/-43°C
FL 310	-52°F/-47°C
FL 330	-60°F/-51°C
FL 350	-67°F/-55°C
FL 370	-71°F/-57°C

Now go back the the CRZ page and check the MAX altitude. Surprise!



To verify the FMC calculations by using your flight manual:

- Check your weight by turning to the APPROACH REF page.
- Next, check your Altitude Capability chart, specifically, the Cruise Thrust Limit Altitude at ISA + 15.



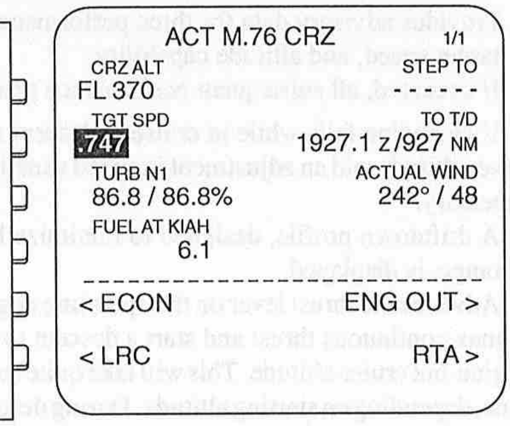
737-900 Altitude Capability **LRC & M.79**

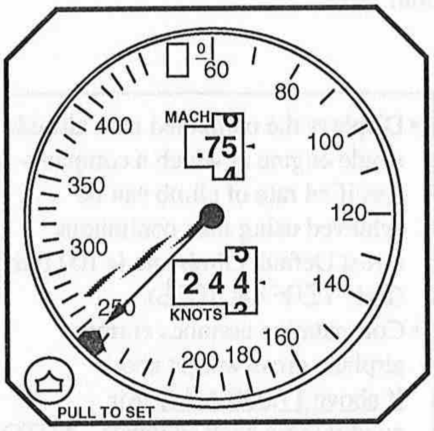
WEIGHT (1000 lb)	OPT ALT (ft)	CRUISE THRUST LIMIT ALT (ft)	
		ISA+10	ISA+15
150	35000	36300	35000
145	35800	37000	35800

TECHNIQUE

FLYING THE HIGH SPEED BUFFET BOUNDARY

If you find yourself behind schedule, try this technique:
- Enter a cruise speed that is unattainable at the moment because of weight, temperature, and/or altitude.
- The title will display the entry, but the FMC will calculate and fly the max allowed airspeed considering the current high speed buffet boundary.
- As fuel is burned off, the TGT SPD will increase, eventually meeting the entry (M.76)
- If you've flying inside the yellow pole without buffet, (EFIS) the weight in the FMC is inaccurate (too heavy).





1.3 G BUFFET BOUNDARY CHART HIGH / LOW

FL LVL	GROSS WT
	110.0 #
370	247 / 220

A check of the Buffet Boundary chart confirms the FMC calculation.

TECHNIQUE

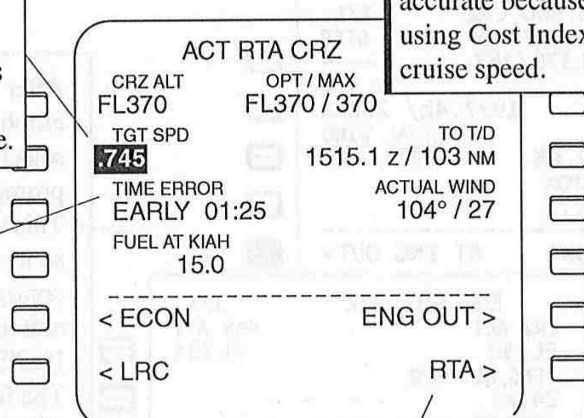
A check of the *low-speed boundary* can be done in a similar way; enter an unrealistic low mach speed.

RTA CRZ - U4 & up

The RTA navigation mode is designed to assist the pilot in complying with a required time of arrival at a designated waypoint such as the final approach fix, holding fix or airport. After the appropriate waypoint and RTA are entered, the FMC will compute a recommended takeoff time and speeds required to comply with the RTA, and progress information as the flight takes place. Speeds are automatically adjusted for inflight winds and route changes by the FMC adjusting the Cost Index. If the RTA is unobtainable under present routing and/or environmental conditions, the FMC will so advise by displaying an appropriate message. For the most economical operation, the recommended takeoff time should be met, as a later takeoff will result in a higher Cost Index than originally planned.

U4.0 & up
- Displays the computed speed required to meet the entered RTA.
- When RTA mode is exited by waypoint sequence or DELetion, this speed will become the FMC target speed on a manual speed climb page.

When flying RTA mode, the OPT ALT calculation may not accurate because the FMC is using Cost Index to select it's cruise speed.



U4.0 & up
- Displays the computed time error at the RTA waypoint.
- Same display as line 2R on RTA PROGRESS page.

U4.0 & up
- Line selecting this prompt will display the RTA PROGRESS page.
- Displays ERASE on a MOD page.

TECHNIQUE

Coordinate cruise speed selections with the M / CAS speeds on the CLB and DES page.

ENG OUT CRZ

CAUTION

VNAV cannot be engaged.

- Provides advisory data for three performance parameters; thrust, target speed, and altitude capability.
- If executed, all subsequent performance predictions are blanked.

If an engine fails while in cruise, a descent to a lower altitude and an adjustment in speed usually is necessary.

A driftdown profile, designed to minimize loss of range, is displayed.

Advance the thrust lever on the operating engine to max continuous thrust and start a descent to the engine-out cruise altitude. This will take quite some time, depending on starting altitude. During descent time is available to consult engine inop cruise data and establish a new plan.

You have some alternatives:

1) Slow to, then descend at and maintain E/O TGT SPD (Max L/D). This results in max altitude capability, max range and minimum driftdown angle.
2) If not range or terrain limited, descend and maintain MAX ALT at single engine LRC. A higher speed will increase the descent angle but shorten the time exposed to single engine operation.

```
ACT ENG OUT CRZ            1/1
CRZ ALT                MAX ALT
FL330                    FL187
TGT SPD
234
N1
91.9%

------------------------------
< ECON

< LRC                    RTA >
```

Propagated from PERF INIT or CRZ page.

- TGT SPD based on minimizing drag and maximizing gradient.
- Approximates max L/D speed at present weight and altitude.
- Does not reverse video highlight because VNAV cannot be engaged with a the ACT ENG OUT page.

Max Continuous Thrust N1. Becomes active limit if EXECuted. Includes current air conditioning and anti-ice bleed adjustments.

- Displays the computed max altitude single engine at which a company-specified rate of climb can be achieved using max continuous thrust Default climb rate is 100 fpm. (Ref: PERF FACTORS).
- Computation assumes current airplane gross weight and:
  <u>If above 17,000' MSL</u>: Air conditioning pack switches - AUTO and Anti-ice switches - OFF.
  <u>If below 17,000' MSL</u>: Engine Bleed Air switches OFF and Anti-ice switches - OFF.
- Cowl anti-ice and 100 fpm residual rate of climb will reduce the max altitude by approximately 1000 ft.
- Wing and cowl anti-ice ON and 300 fpm residual rate of climb will reduce the max altitude by approximately 3600 ft.

Two steps.

1. Select ENG OUT prompt.
2. Select the engine that is out.

U10.3 & up

Title does not change, i.e. no MOD or ACT since page cannot be executed.

```
  ACT M.800 CRZ        1/1
 CRZ ALT   OPT/MAX     STEP
FL350   FL370/387     -----
 TGT SPD               TO T/D
.800        1927.4z/ 230NM
 TURB N1          ACTUAL WIND
 85.4/ 85.4%       031°/ 89
 FUEL AT KPDX
        12.8
---------------------------
<LT ENG OUT     RT ENG OUT>
```

```
        ENG OUT CRZ          1/1
CRZ ALT                  MAX ALT
FL350                      FL234
 ENG OUT SPD
243KT
 CON N1
 97.9%
--------------------------------
<LT ENG OUT          RT ENG OUT>
```

U 5.0 & up

- After selecting the ENG OUT prompt on the climb or cruise page, the pilot must now select either the left or right ENG OUT prompt.
- This tells the FMC which engine has failed so it can account for the actual bleed configuration. Accuracy of the maximum altitude calculation is improved.
- If EXECuted, VNAV will disengage. The fuel and time predictions on the PROGRESS page will blank.
- U10.2 & up: EXECute light does not illuminate.

CRUISE WAYPOINT - U1.x to U6

NOTE: This problem does not pertain to U7.0 and above.

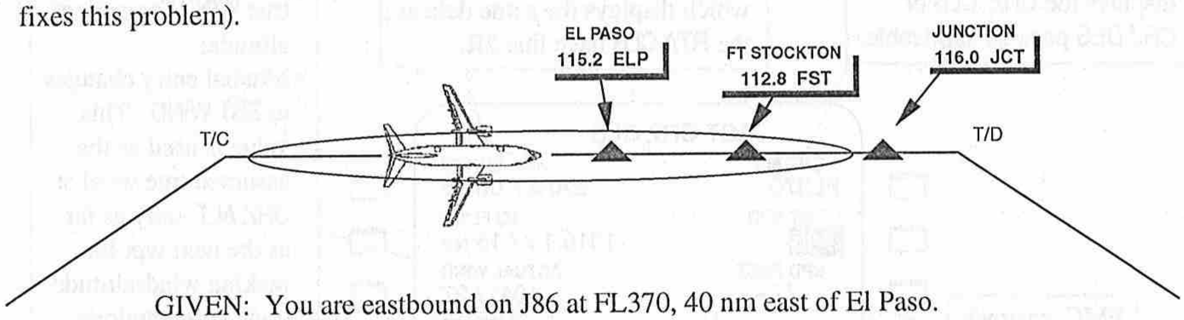
When programmed with route and performance data, the FMC computes predicted route segments for the climb, cruise, and descent phases. This establishes the T/C and T/D points. Each waypoint is then assigned to the proper segment.

Once assigned, the waypoints remain in the respective phases unless basic performance data such as cruise altitude is changed.

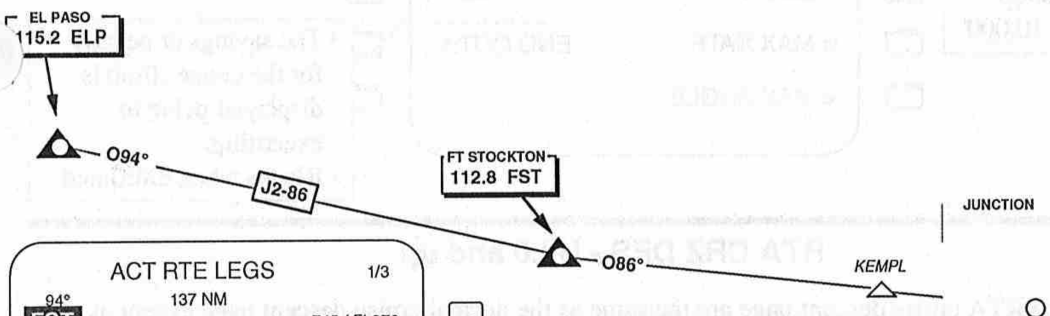
Waypoints that are identified as cruise waypoints in the Smiths FMC are not allowed to have altitude restrictions entered by the pilot unless they are close to the top-of-climb or top-of-descent points. (U7.0 fixes this problem).

On some versions of the Smiths FMC, the lower altitude restriction may be accepted while programming on the ground or early in the climb. Thus, if the pilot knows of probable ATC restrictions for a particular flight leg, attempt entry into the FMC at the gate.

Sometimes entering an altitude restriction on the waypoint before the one in question will allow the altitude restriction to be entered at that waypoint. It may be necessary to make an extra waypoint along the route to do this.



GIVEN: You are eastbound on J86 at FL370, 40 nm east of El Paso.
ATC: ***"Ford Pullman, cross Fort Stockton at and maintain FL330."***




```
ACT RTE LEGS                1/3
94°       137 NM
FST                .745 / FL370
86°       111 NM
KEMPL              .745 / FL370
89°        53 NM
JCT                .745 / FL370
81°        17 NM
CLL                 290 / FL204
100°       23 NM
CUGAR              290 / 13570
--------------------- EXTENDED
                        DATA >
INVALID ENTRY
```

1
- You attempt to enter FL330 in line 1R of the ACTive LEGS page.
- INVALID ENTRY appears because FST is a cruise wpt and will not take a restriction.

```
ECON PATH DES                1/1
E/D ALT                 AT HOAGI
1997                 250 / 10000
TGT SPD                  TO T/D
.740 / 280        2040.5z / 380NM
SPD REST               WPT / ALT
240 / 10000          FST / 33000
                  FPA   V/B   V/S
                  0.0   0.0   850
---------------------------------
                          SPEED >
< FORECAST              CAPTURE >
FST / 33000
```

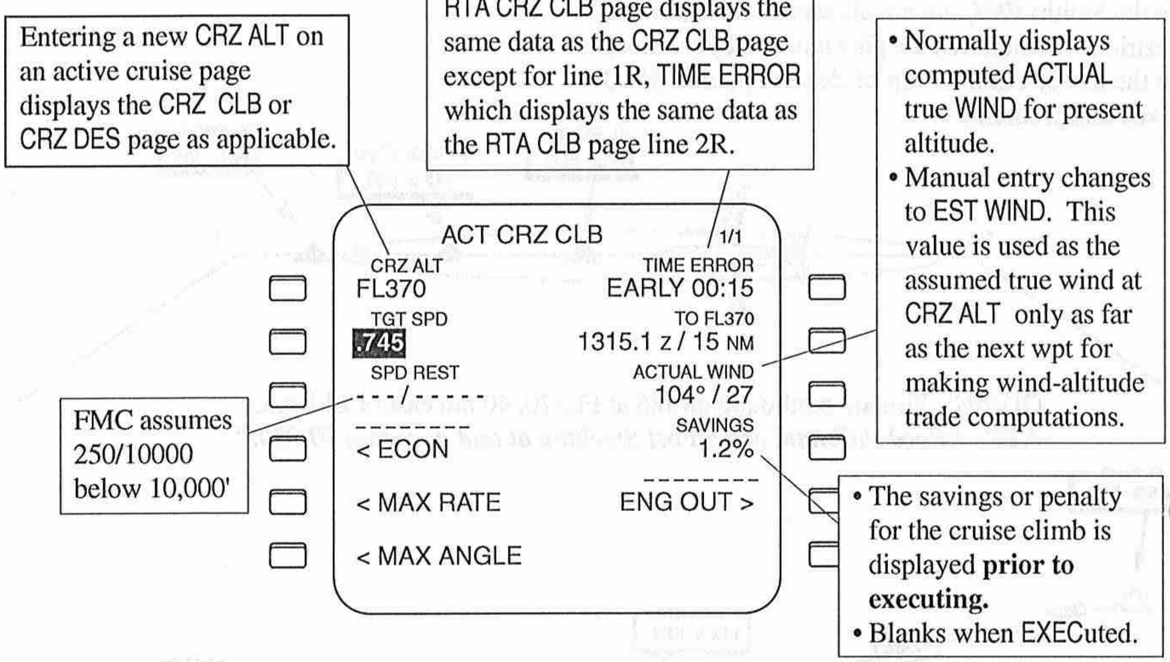
2
- Enter the restriction (FST/33000) in line 3R of the DES page.
- When V/S on line 4R shows ± 800, start a Cruise Descent to the new altitude.
- If the V/S is in excess of 800', use the MCP V/S or LVL CHG with manual calculations.
- DELete this entry after passing, for a manual entry at 3R on this page will not clear automatically until landing!

You get to this page by:

- Entering a higher CRZ ALT on a cruise page during active cruise.
- CLB key when a CRZ CLB is MOD or ACT.

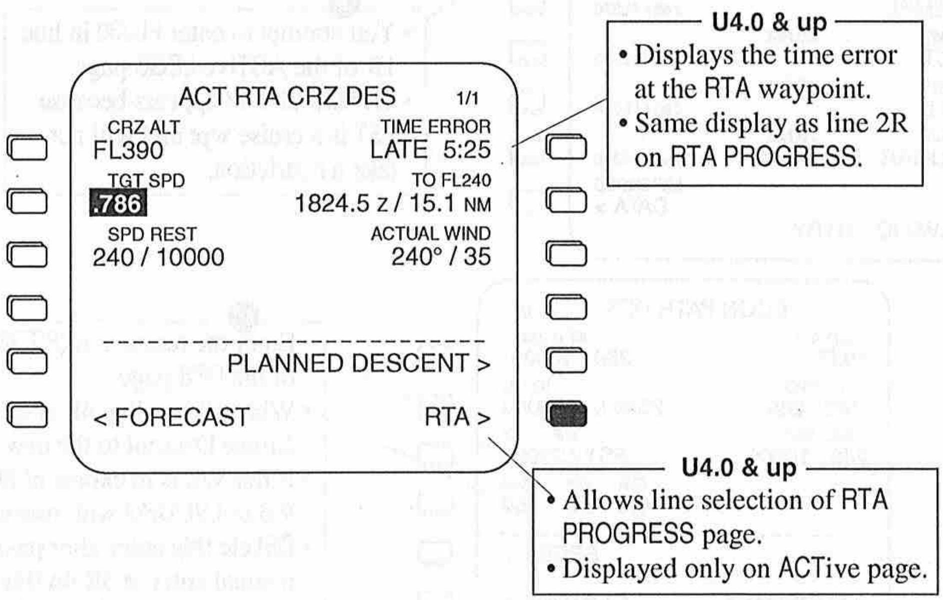
NO REQUIRED ENTRIES

- Provides cruise climb data to entered CRZ ALT.
- During active cruise:
  Enter valid higher CRZ ALT (on CRZ page)
  Press EXEC key. Initiates climb at climb thrust (N1 LIMIT page) and cruise TGT SPD.



RTA CRZ DES - U3.0 and up

Displays on the RTA cruise descent page are the same as the normal cruise descent page except as noted.



CRZ DES

You get to this page by:

- Entering a lower CRZ ALT on an active cruise page during cruise.
- DES key when a CRZ DES is active.

NO REQUIRED ENTRIES

– Provides cruise descent to entered CRZ ALT.
– During active cruise, enter valid lower CRZ ALT (on CRZ page), and press EXEC key.

Cruise descents are performed at the selected cruise mode cruise speed and at a 1000 FPM rate of descent. It is intended to provide a smooth descent for enroute descents made to avoid turbulence/ winds, or upon request by ATC to change cruise altitude. It is not intended to be used as part of an arrival descent profile.

A CRZ DES will capture the computed path if initiated in excess of 50 nm from T/D. Closer than that, you are taking your chances. That is why the DES NOW (CAPTURE) mode is recommended if within 50 nm of T/D point or whenever the descent is made in preparation for the arrival and approach.

When using **CRZ DES**, the pilot must always check the distance to the new T/D point vs. the distance to **CRZ DES** level-off to ensure that the airplane will be level at the new altitude prior to T/D.

A disadvantage to using CRZ DES is that at lower altitudes, new CRZ DES TGT SPDs may exceed planned DES TGT SPD.

Displays the new CRZ ALT entered on the CRZ page.

All values may be modified via keyboard entry.

MOD CRZ DES 1/1

CRZ ALT
FL310

TGT SPD
.734

TO FL310
1318.4 z/28 NM

SPD REST
240/10000

ACTUAL WIND
104°/98

PENALTY
.3%

PLANNED DES>

<FORECAST

ERASE>

- Normally displays computed ACTUAL true WIND for present altitude.
- Manual wind entry has priority. The Data Line Title then changes to EST WIND.
- Used for making wind-altitude trade computations.

- SPD REST normally displays the active default speed restriction (240/10000) unless another value has been manually entered or propagated from the data base.
- Either may be modified.
- DELetion clears both.

PLANNED DES allows line selection of the default ECON PATH DES or other preplanned DES page. (One of the four standard descent modes).

- The SAVINGS or PENALTY for the cruise descent is displayed **prior to executing.**
- Blanks when EXECuted.

TECHNIQUE

Here's a technique to use when ATC is assigning an intermediate cruise altitude.

ATC: ***"Savoia-Marchetti 55, descend so as to cross El Paso at FL330".***

- Enter 330 in 1L of the CRZ page and execute. Press VNAV.
- The throttles will come back to maintain 1,000 f/m descent.
- Enter ELP/330 in 3R of the DES page. The V/S display will indicate immediately, the rate of descent required to meet the clearance.
- The altitude trend vector will lie right on top of ELP if you dial in this rate of descent.

With the help of Dole, Padilla, Hurt, Perkins and others, let's discuss the Basics of Jet Performance.

The problem of efficient range operation appears in two general forms: to extract the maximum flying distance from a given fuel load, or to fly a specified distance with minimum expenditure of fuel. (Hurt)

The common denominator for each is the specific range, NAM/lb of fuel.

Turbojet engines are designed to operate at high rpm and will produce higher specific fuel consumption values at higher altitudes since an increase in altitude requires increased RPM.

Lower inlet temps at altitude results in decreased specific fuel consumption.

An increase in altitude will increase the proportion of velocity (TAS) to thrust and provide a greater TAS for the same thrust. At FL400 the TAS is twice the indicated airspeed!

There exists for each weight, an Optimum Altitude; it continues to climb as weight is decreased. Flying at Optimum Altitude will produce the best Specific Range at that speed.

If the airplane is flown at MRC and OPT ALT, the SR value is maximized. This is called the optimum altitude for max range. This speed is slightly faster than the corresponding speed for max endurance which is only a function of minimum lb/hr and is unchanged by wind.

When considering max range (or max fuel-over-destination) only MRC speed is increased in a headwind (Cost Index zero). From an aerodynamic study, no other speed should be increased in a headwind if max FOD is the objective. This is why flying ECON is not more advantageous than flying LRC from strictly a fuel standpoint.

Max altitude considers 3 things: max certified altitude, the high and low speed buffet boundaries, and the thrust limit.

The preceding paragraphs are important and mean that to operate in a fuel efficient manner, you don't just fly as high as the airplane is capable of reaching for your present weight (service ceiling). At heavy weights, the thrust requirements are such that a lower value of nam/lb will be obtained if flying above Optimum Altitude. The preceding paragraph states that you must operate close to Optimum Altitude for your chosen cruise speed schedule to realize best nam/lb.

The thrust of a turbojet/fan for a given throttle setting is directly proportional to the mass flow rate of the air through the engine. Consequently, as the density of the atmosphere decreases with an increase in altitude, so does the available thrust.

Specific range (SR) is the nautical air miles per pound of fuel (NAM or nam). It is the measure of the fuel required to cover some air distance; the higher the SR, the more distance covered on a given quantity of fuel. SR generally does not include the effects of wind; as a result nam is used instead of nm. SR is a measure of aircraft efficiency, or SR = TAS / ff in pph

Since the gross wt will decrease along the flight path, the best specific range will increase along the flight path and the potential for the best mileage will be at the end of the flight when the aircraft is the lightest. (Hale)

Long Range Cruise (LRC) - corresponds to a flight condition where the SR is 99% of the SR at MRC; no rigorous analytical derivation is associated with this percentage. A 1% reduction of range is traded for 3-10% higher cruise speed and keeps the airplane in a more speed-stable area.

Cruise Schedules or strategies:

1. *Constant Mach-constant lift coefficient.* (cruise climb / block altitude profile). In order to keep the CL constant as the weight decreases, density (rho) must decrease so as to keep the ratio of the weight to the atmospheric density constant. Consequently, the aircraft will be in a continuous climb. Range factor is constant. If LRC is the chosen speed, you're accomplishing 99% max range in a speed stable environment. This is just about as good as you can do.
2. *Constant altitude-constant lift coefficient.* (variable Mach schedule) Ex: LRC flight. Since CL is constant, lift-to-drag ratio will also be constant. Airspeed must be decreased as fuel is used if CL is to be kept constant; thrust must constantly be decreased as the GW decreases.
3. *Constant altitude-constant Mach.* Ex: FL350 M.79. (hard altitude-hard airspeed) The two flight parameters of lift-to-drag ratio and the lift coefficient will decrease along the flight path. Thrust will be reduced along the flight path so as to maintain constant airspeed.
4. *Constant thrust.* The two flight parameters of lift-to-drag ratio and the lift coefficient will decrease along the flight path. Thrust is maintained and speed is increased (to the high speed buffet) as weight decreases. Such a condition might exist when time is more important than fuel.

In order to maximize the specific range at all points along the flight path, the lift coefficient must be kept constant at all times to be equal to the best-range lift coefficient, which is a design characteristic. Therefore, best-range conditions can be applied only to the two constant lift coefficient flight programs, 1 and 2 above. (Hale)

CRUISE DESCENT vs. DESCENT NOW

ATC: *"Ford-Stout, descend to flight level 310."*
Here are two Cruise Descent examples; in the first, the top of descent will be reached prior to the new cruise altitude (poor pilotage); in the second, the new cruise altitude will be reached **before** the top of descent.

```
ACT CRZ DES                    1/1
CRZ ALT
FL310
TGT SPD                     TO T/D
.744              2043.4z / 15.2 NM
SPD REST               ACTUAL WIND
240 / 10000               240° / 35

------------------------------------
                       PLANNED DES >
```

If the new T/D will be reached prior to the new CRZ ALT, the data line title reads TO T/D and the line displays ETA at and distance to the T/D.

Cruise descents occur at a slightly slower speed (the new planned cruise speed) than Capture descents (planned descent speed from original crz altitude).

```
ECON PATH DES                  1/1
E/D ALT                   AT HOAGI
1997                   250 / 10000
TGT SPD                     TO T/D
.742 / 290        2043.4z / 15.2 NM
SPD REST                  WPT / ALT
240 / 10000          HOAGI / 10000
                     FPA  V/B  V/S
                     1.3  2.4  1850
```

- Check descent parameters by pressing LSK 5R.
- Notice both pages display 15 nm TO T/D.
- Monitor your ratio and TO T/D as you approach the computed path.
- Be prepared to intervene with the MCP if the FMC disregards the path.

```
ACT CRZ DES                    1/1
CRZ ALT
FL310
TGT SPD                    TO FL310
.744              2040.2z / 10.5 NM
SPD REST               ACTUAL WIND
240 / 10000               240° / 35

------------------------------------
                       PLANNED DES >
```

If the new CRZ ALT will be reached prior to the new T/D, the data line title reads TO FL310 and the line displays values for reaching new CRZ ALT.

TECHNIQUE

ATC: ***"Tin Goose 4, descend to FL240, pilot's discretion out of FL310."***
Enter 24000 in MCP and 310 in the FMC. Aircraft will stop descent at FL310 and intercept path at new T/D.

```
ECON PATH DES                  1/1
E/D ALT                   AT HOAGI
1997                   250 / 10000
TGT SPD                     TO T/D
.742 / 290          2047.4z / 30 NM
SPD REST                  WPT / ALT
240 / 10000          HOAGI / 10000
                     FPA  V/B  V/S
                     1.3  2.4  1850
```

Notice TO T/D safely beyond level off in this example.

TECHNIQUE

- Descents can always be made using CAPTURE. You then have definite protection from flying through the computed path. Desired speed can be entered at 2L.
- Energy Compensation feature is available at intermediate level-offs, not at CRZ altitudes.

TECHNIQUE

- Consider using DES NOW (CAPTURE) if step-down altitudes are anticipated rather than repeatedly entering new CRZ altitudes because:
  - New CRZ speeds will be at a faster IAS than the old (and still planned) DES IAS, which becomes ACTive at T/D. The lower the new cruise altitude, the greater the discrepancy.
  - If you start your descent at the new T/D, you will be on path but fast.
- If using new CRZ altitudes, match CRZ and DES speeds (CI change works well here) or start your descent early with DES NOW (CAPTURE).

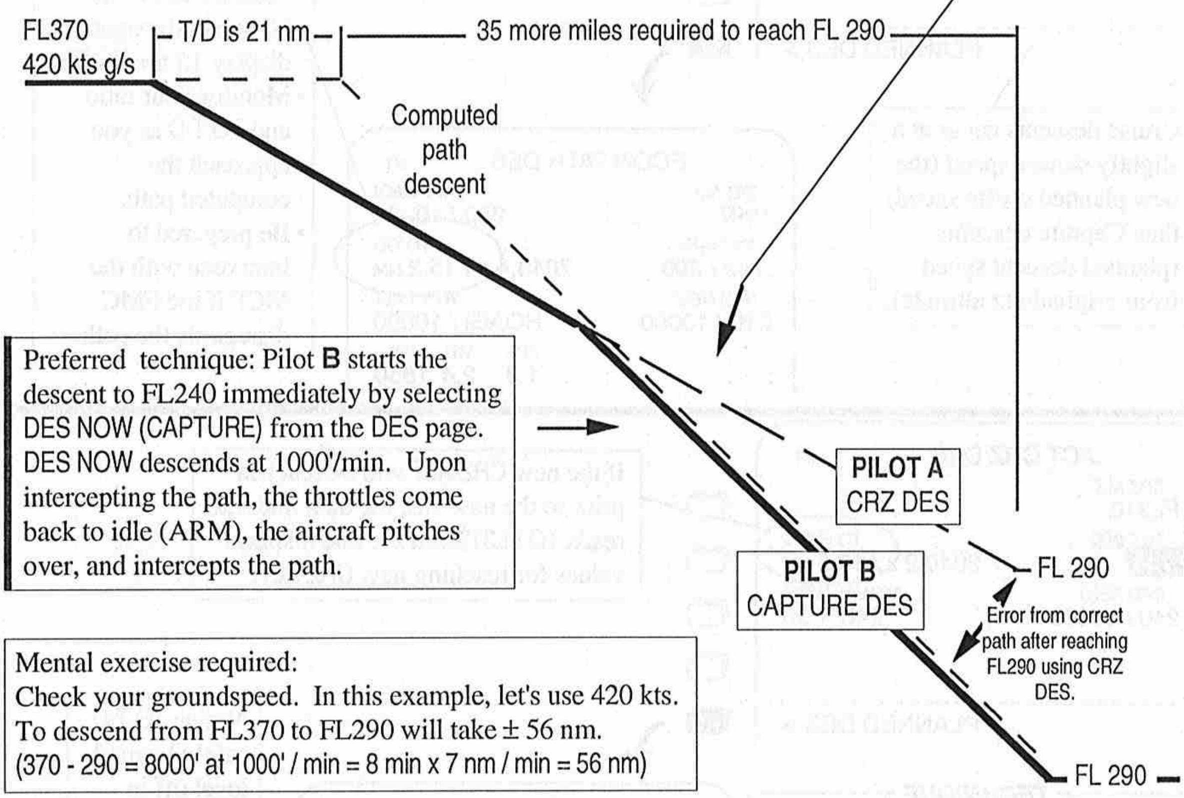
CRUISE DESCENT vs. DESCENT NOW

ATC: ***"Dornier Komet, descend to and maintain FL240, pilot discretion out of FL 290".***

Pilot **A** starts the descent by selecting a new cruise altitude (FL290) inside 50 nm of the top-of-descent. This is a Cruise descent (CRZ DES) and descends at 1000' per minute at cruise speed. If initiated inside 50 nm of top-of-descent, the FMC may:

- actually compute and display a T/D that will be several miles beyond the correct T/D, or
- disregard the computed descent path until level at the new cruise altitude.

Monitor your required ratio closely if using this procedure. Be prepared to intervene with MCP. You could be in for a surprise!



Preferred technique: Pilot **B** starts the descent to FL240 immediately by selecting DES NOW (CAPTURE) from the DES page. DES NOW descends at 1000'/min. Upon intercepting the path, the throttles come back to idle (ARM), the aircraft pitches over, and intercepts the path.

Mental exercise required:
Check your groundspeed. In this example, let's use 420 kts.
To descend from FL370 to FL290 will take ± 56 nm.
(370 - 290 = 8000' at 1000' / min = 8 min x 7 nm / min = 56 nm)

So what must you be particularly aware of when using Cruise Descents?
Do not use Cruise Descent when within approximately 50 nm of top-of-descent.
Use Capture Descent.

ATC: ***"Dornier Komet, pilot's discretion to descend to FL240; maintain 300 kts".***

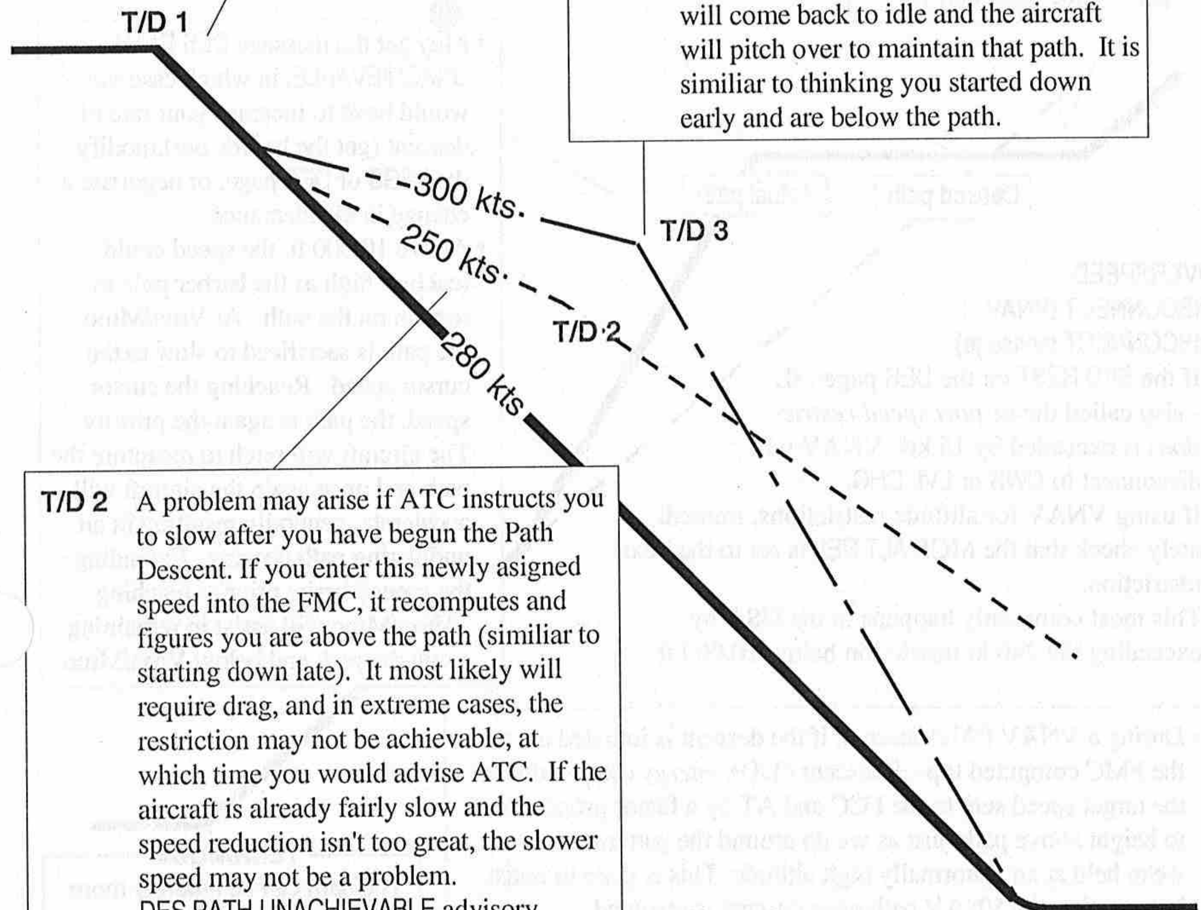
TECHNIQUE

- Set MCP ALT SEL to 240, enter 300 kts in the DEScent page.
- Approximately 15 nm prior to T/D, press DES NOW, or thumbwheel 1000 fpm in the V/S and turn the speed knob to 300.
- When the VERT DEViation indicates about 1,000 ft below the path (you're under the computed path) press LVL CHG.
- This maintains the clearance speed. A VNAV PATH descent is slaved to the path, not the speed.
- LVL CHG will keep you below the path, unless the winds change appreciably.

ATC COMMANDED SPEED INCREASE OR DECREASE

T/D 1 Normal VNAV PATH descent. Example is 280 kt target.

T/D 3 If ATC instructs you to increase speed, this is much easier. Enter the new speed into line 2L of the ACT DES page. The throttles will come out of the ARM position, the aircraft vertical speed will shallow to the DES NOW (CAPTURE) mode of 1000'/minute, and the speed of course will increase. Upon intercepting the newly computed path, the throttles will come back to idle and the aircraft will pitch over to maintain that path. It is similiar to thinking you started down early and are below the path.



T/D 2 A problem may arise if ATC instructs you to slow after you have begun the Path Descent. If you enter this newly asigned speed into the FMC, it recomputes and figures you are above the path (similiar to starting down late). It most likely will require drag, and in extreme cases, the restriction may not be achievable, at which time you would advise ATC. If the aircraft is already fairly slow and the speed reduction isn't too great, the slower speed may not be a problem.
DES PATH UNACHIEVABLE advisory message will appear if FMC predictions show the profile constraints at the next waypoint cannot be made and the path maintained.

ACT RTE LEGS		1/2
297°	10 NM	
SEAGO		250 / 11000
297°	6 NM	
GLADD		250 / 11000
297°	11 NM	
REFIL		210 / 11000
350° HDG	NM	
(VECTOR)		----/
THEN		
□□□□□		
RNP / ACTUAL		
1.70 / 0.25		RTE DATA >

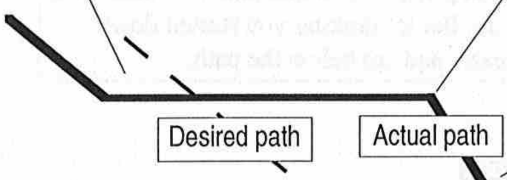
- This example is taken from the CEDAR CREEK Arival to Dallas - Ft Worth.
- You must slow from 250 kts over SEAGO to 210 kts at REFIL.
- In level flight you'll need about 1 to 1.5 nm per 10 kt (adjust for wind and weight) to decelerate. VNAV waits until the last minute to pull the throttles back, and sometimes is a little fast.
- Approximately 5 nm from REFIL, you'll see the throttles start coming back.
- In this example, VNAV will default to ALT HOLD and SPEED at REFIL.

1

- We are approaching an intermediate level-off. (Energy Compensation does not work in CRZ mode.)
- Assume ATC cannot allow us to *continue* descent due to conflicting traffic. If in VNAV, the aircraft will slow to the appropriate speed in the chart below.

2

- Finally, after you are several miles past the T/D point, ATC says, ***"Douglas Cloudster, cross HOAGI at 10,000 ft".*** You dial 10000 into the MCP and press VNAV. The aircraft will dive in its attempt to capture the path.
- Remember, during a PATH DES the computer will disregard the speed to go after the path. This is one reason VNAV PATH does not work well below 10,000'. If necessary, it will exceed SPD REST (3L) on DES page to capture the path.



3

- May get the message DES PATH UNACHIEVABLE, in which case you would have to increase your rate of descent (get the boards out),modify the LEGS or DES page, or negotiate a change in the clearance.
- Above 10,000 ft, the speed could reach as high as the barber pole to remain on the path. At Vmo/Mmo, the path is sacrificed to slow to the cursor speed. Reaching the cursor speed, the path is again the priority. The aircraft will pitch to recapture the path and once again the aircraft will accelerate, generally resulting in an undulating path descent. Extending the speeed brake prior to reaching Vmo/Mmo will assist in remaining on the path and below Vmo/Mmo.

OVERSPEED DISCONNECT (VNAV DISCONNECT message)

- If the SPD REST on the DES page (3L - also called the *airport speed restriction*) is exceeded by 15 kts, VNAV will disconnect to CWS or LVL CHG.
- If using VNAV for altitude restrictions, immediately check that the MCP ALT SEL is set to the next restriction.
- This most commonly happens in the USA by exceeding the 240 kt restriction below 10,000 ft.

- During a VNAV PATH descent, if the descent is initiated after the FMC computed top-of-descent (T/D), *energy comp* reduces the target speed sent to the FCC and AT by a factor proportional to height above path, just as we do around the pattern when we're held at an abnormally high altitude. This is done to assist in regaining the VNAV path once descent is resumed.
- The target speed displayed on the DES page does not change. The DRAG REQUIRED message appears, indicating the need to lower the potential energy of the aircraft.
- Bleeding off speed from the aircraft directly affects the ability of the aircraft to capture the vertical path constraints programmed into the FMC. If the excess energy is not removed it may become impossible to capture the vertical path, a fact annunciated by the DES PATH UNACHIEVABLE message.

TECHNIQUE

The path can be attained more quickly if you start to slow and then dive manually (MCP), rather than waiting for the FMC calculations. VNAV can be re-engaged later.

The energy compensated target speed is not allowed to fall below Block Operating Speeds which are computed as a function of flap position and gross weight.

FLAP POSITION	FMC BLOCK OPERATING SPEEDS			
	< 117.0	117.0 - 138.5	> 138.5	600/700/800
0	210	220	230	VREF 40+70
1	190	200	210	VREF 40+50
5	170/180*	180/190*	190/200*	VREF 40+30
10	160/170*	170/180*	180/190*	VREF 40+30
15	150	160	170	VREF 40+20
25	140	150	160	VREF 40+10
30	Compensated VREF + VREF increment			

* U10.3 Increased Block Operating Speeds

ALTITUDE INTERVENTION - U6, U8, U10 (option)

The Altitude Intervention feature provides the pilot with the ability to perform the following operations using the Altitude Select knob and the Altitude Intervention pushbutton, both on the MCP.

1 **Intervention of FMC Altitude Constraints during VNAV Climb or Descent:**
To delete the next altitude constraint, the MCP altitude is set above/below (for climb/descent respectively) the next altitude constraint and the Altitude Intervention pushbutton is pressed. One constraint is deleted for each push. In climb, lowest constraint is deleted. In descent, highest constraint is deleted. This operation can be performed with or without VNAV engaged. *An altitude constraint on a waypoint which represents a leg terminated at an altitude, cannot be deleted using Altitude Intervention.*

MCP altitude selector .... Set new altitude
New altitude must be higher or lower than the FMC altitude constraint(s) to be deleted.
ALT INTV switch .... Push
Each push of the ALT INTV switch will delete an FMC altitude constraint.
If all FMC altitude constraints are deleted, the descent mode will revert to a VNAV speed descent.

2 **Intervention of FMC Cruise Altitude during VNAV Cruise:**
Set the MCP altitude above the cruise altitude and press the Altitude Intervention pushbutton. To do this in a climb, there must be no altitude constraints remaining in the climb phase. Attempting to raise the cruise altitude above the maximum allowable cruise altitude using Altitude Intervention will not change the cruise altitude and will result in MAX ALT FLXXX message. This operation can be performed with or without VNAV engaged. *Cruise altitude cannot be lowered using Altitude Intervention.*

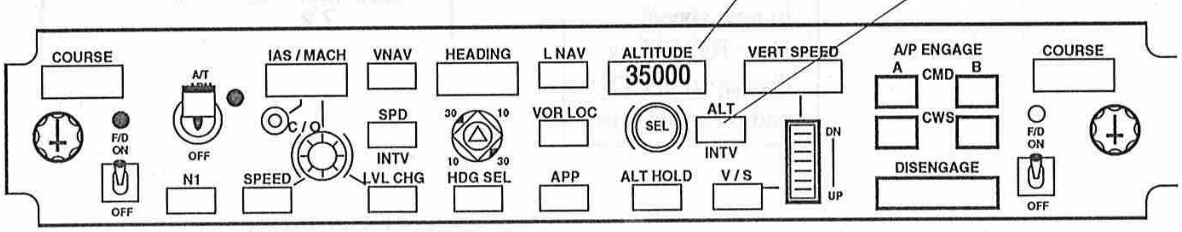
MCP altitude selector .... Set new altitude
ALT INTV switch .... Push
If a higher altitude is selected, a CRZ climb will be initiated.
If a lower altitude is selected, an early descent (DES NOW) will be initiated.

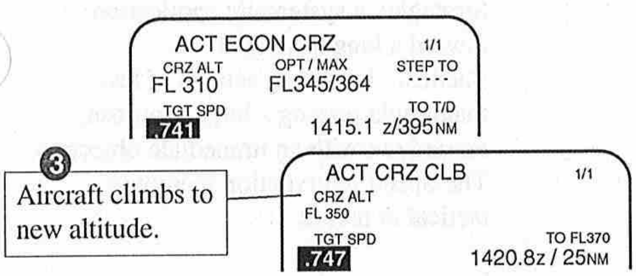
3 If the VNAV ALT option is enabled, resume a climb/descent after holding an MCP altitude while in climb/descent. (VNAV ALT is annunciated by EFIS symbol generator to EADI when level at MCP altitude not equal to FMC altitude.)
To resume a climb/descent (while in climb (or cruise)/descent, respectively) from altitude hold of the MCP altitude, the MCP altitude is set above/below, respectively, the hold altitude, and the Altitude Intervention pushbutton is pressed. This operation can be performed only with VNAV engaged.

Here is an example of the second paragraph.
ATC: ***"Fokker VIIB, climb and maintain FL350 for traffic".***

1 Enter new altitude (35000) in MCP window.

2 Press the Altitude Intervention button.





A couple of definitions:
- Strategic: a systematic application toward a long term goal.
- Tactical: involving actions of less magnitude serving a larger purpose, carried out with an immediate objective.
- The Altitude Intervention feature is tactical in nature.

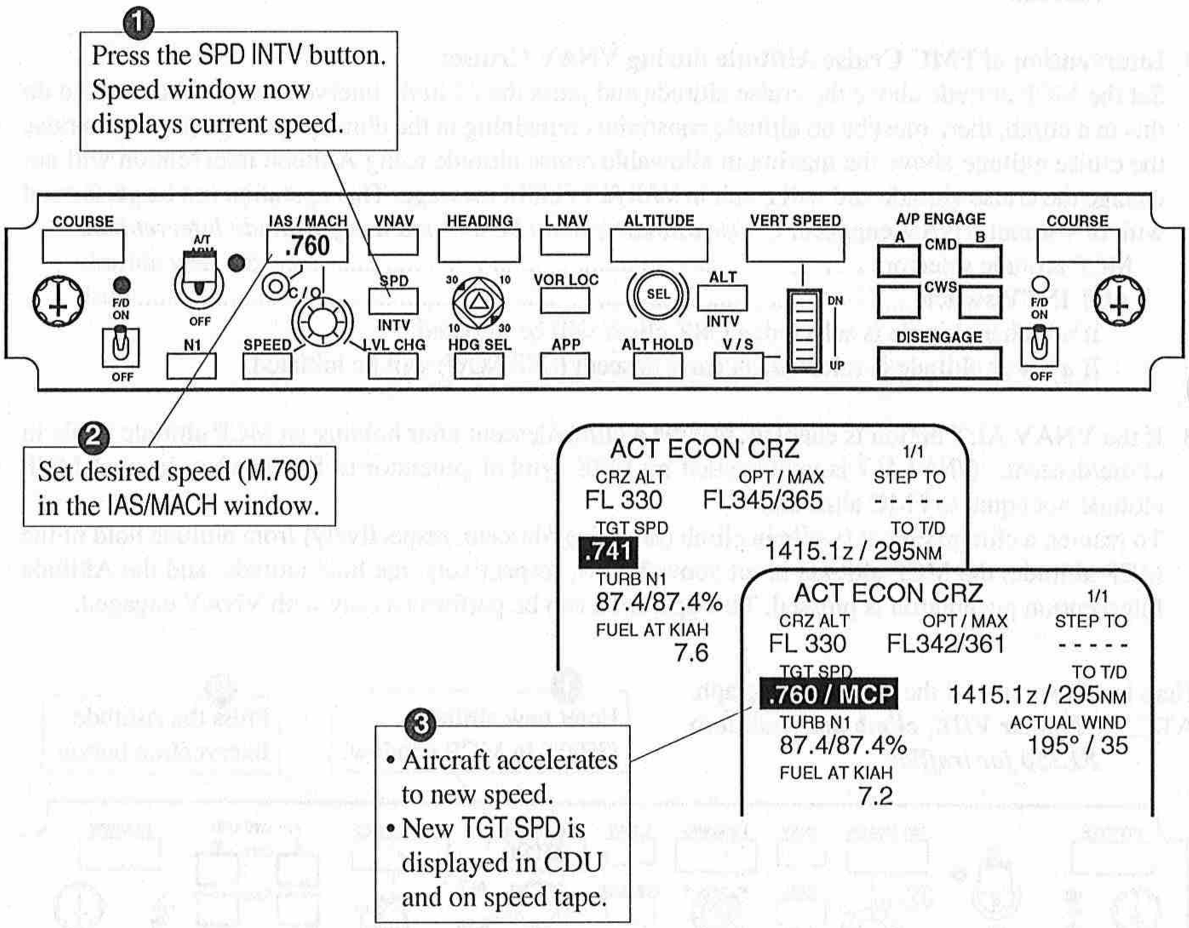
Intervention of FMC Airspeed Constraints during VNAV:

The Speed Intervention function, selectable by pressing the MCP IAS-MACH knob, is provided to allow a means of overriding the FMC's commanded speed. Selection of Speed Intervention mode will display current target speed in the MCP's speed window, automatically setting it to the commanded FMC speed. Changes to the commanded speed can then be made via the MCP IAS-MACH knob.

Pressing the button again blanks the speed window and returns speed to the FMC VNAV path schedule.

SPD INTV switch .... Push
MCP IAS-MACH display shows currect FMC target speed.
MCP Speed selector .... Set desired speed
VNAV remains engaged.
To resume former FMC speed:
SPD INTV switch .... Push
MCP IAS-MACH display blanks and FMC commanded VNAV speed is active.

Here is an example of a Speed Intervention command.
ATC: ***"Boeing 40, I need Mach point seven six for spacing".***



A couple of definitions:

- Strategic: a systematic application toward a long term goal.
- Tactical: involving actions of less magnitude serving a larger purpose, carried out with an immediate objective.
- The Speed Intervention feature is tactical in nature.

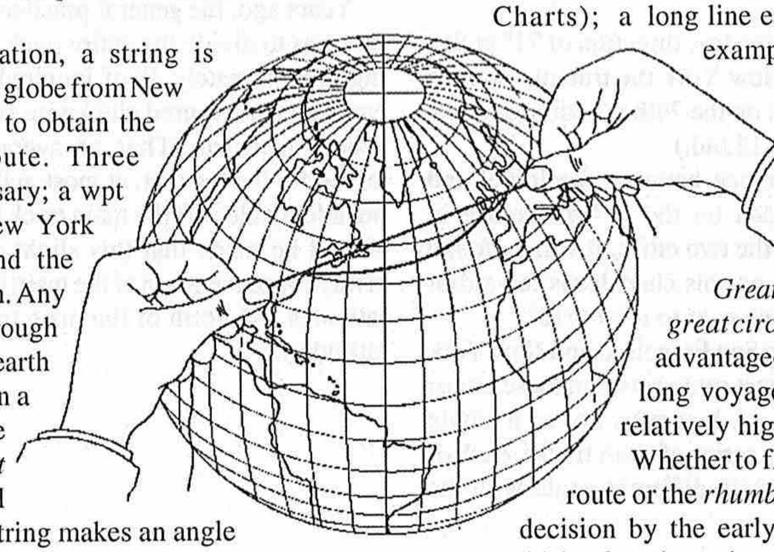
INTRODUCTION: DIRECT-TO

There are two kinds of direction on a sphere; a *great circle* and a *rhumb line.*

The arc of a *great circle* is the most direct route on the surface of the earth, and may be considered the shortest line drawn between two points.

A *great circle* track will appear as a straight line on a gnomonic projection; a chart on which neither meridians nor parallels of latitude appear as parallel lines.

In the illustration, a string is stretched over the globe from New York to London to obtain the *great circle* route. Three points are necessary; a wpt on each end (New York and London) and the center of the earth. Any plane passing through the center of the earth cuts the surface in a *great circle.* The Equator is a *great circle* as are all meridians. The string makes an angle of 54° true at the meridian of New York, about 90° true with the meridian of Iceland, and a greater angle with the meridian of London (112°). The direction of the *great circle* is constantly changing as we progress along the route, except if the two points are on the same meridian or both are on the equator.



A *rhumb line* is defined as a line which crosses all meridians at a constant angle. An aircraft that holds a constant true course of about 80° from New York will arrive at London, but will have to fly an extra 141 miles. A *rhumb line* is represented on the globe under the string and in the Mercator projection at the bottom of the page as the straight line.

At latitudes within an area such as the United States, for distances of less than 1,000 miles, the saving in distance by way of the *great circle* is not a great deal. The advantage of shortest distance may give way to shortest time.

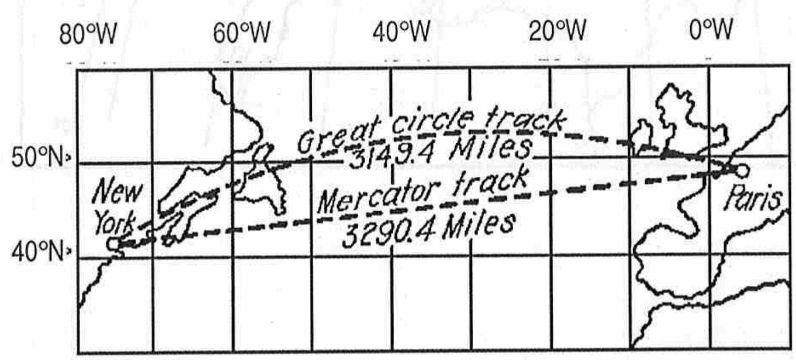
A small portion of the earth's surface may be represented on a plane surface with only slight distortion using Lambert projections (Sectional Charts); a long line east and west, for example along the Canadian border, will display more distortion (WACs and ONCs).

Great circle flying, like *great circle* sailing, is most advantageous when flying a long voyage east or west in relatively high latitudes.

Whether to fly the *great circle* route or the *rhumb line* was a major decision by the early Atlantic racers. Ships could be found on the southerly course, which were used for weather reporting, in case of distress or to relay messages. Lindbergh flew the *great circle* track. He changed compass headings each 100 miles. Kingsford-Smith was the first pilot to conquer the two great oceans and the first to circumnavigate the world via the great circle route.

The FMS has robbed *great circle* flying of it's mathematical mysteries.

By the way, a minute (1') of latitude is considered a nautical mile, but because of the flattening of the earth near the poles, the length of a minute of latitude increases a bit. Minutes of longitude are never a measure of nautical miles except on the equator.



Any straight line on a Mercator chart is a *rhumb line.*
The *great circle* route appears longer due to the fact that the Mercator projection distorts the areas in high latitudes.
(*1569 Gerardus Mercator, Flemish geographer*)

INTRODUCTION: DIRECT-TO

A straight-line track drawn on a Lambert conformal conic projection does not cross all meridians of longitude at the same angle, as may be seen in this drawing.

A line has been drawn from San Francisco to New York. While it may not be apparent to the naked eye, the angle between this track and north is different at San Francisco than it is at New York. A protractor has been used to indicate this fact.

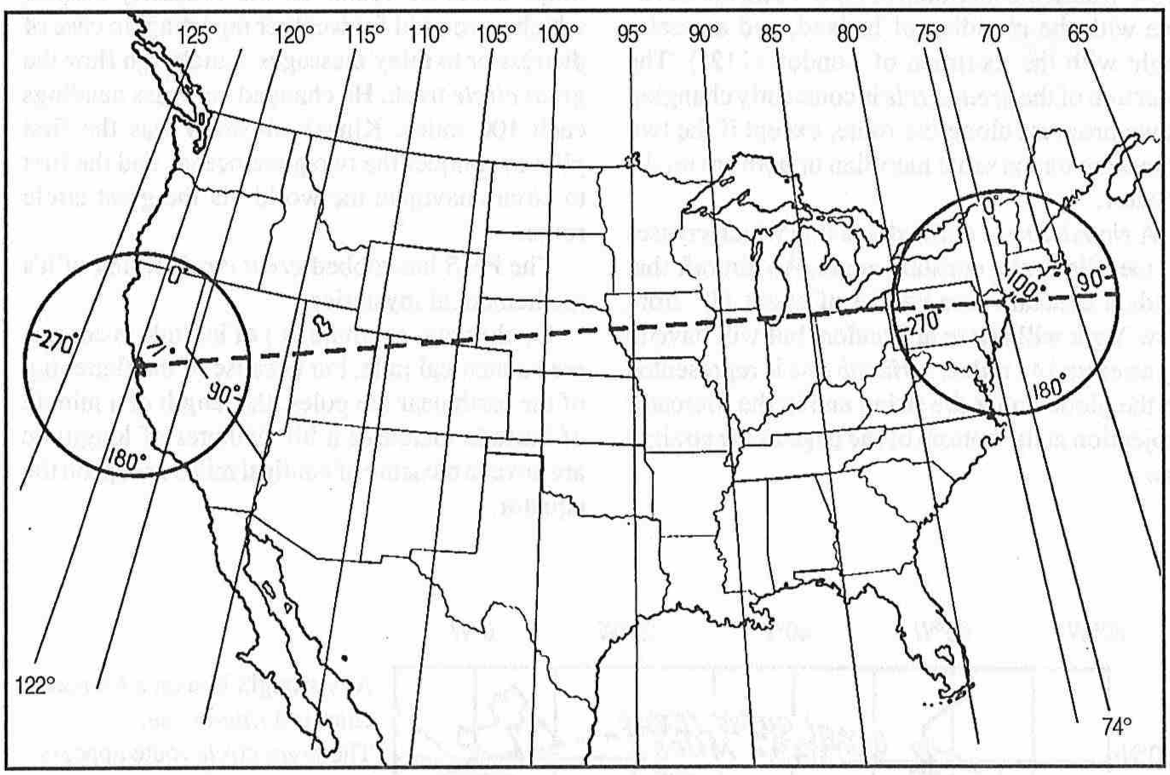
This track takes the true direction of 71° at San Francisco, and at New York the true direction is 100°. (New York is on the 74th meridian and San Francisco is on the 122nd.)

If the 29° difference between the initial and final track is divided by the 48° difference in longitude between the two cities, it will be found that each meridian on this chart leans toward or converges on the one next to it by 6/10°.

The line between San Francisco and New York represents the shortest route between these cities; it is to be thought of, however, not as a single track, but rather as a series of short tracks, each of which makes a slightly different angle with the meridian it crosses.

If a pilot was traversing the country before the advent of RNAV, the navigator would, if there is no wind, shift the true heading of the plane 6/10° every time he crosses a meridian. If he chooses to consider the long track as actually being a series of 16 tracks each crossing 3° of longitude, he may alter the true heading of the plane 3 x 6/10°, or, roughly, 2°, whenever the flight has progressed through 3° of longitude.

Years ago, the general practice among navigators was to divide the entire track into legs covering approximately 4° of longitude; the track for each leg is measured clockwise from north at the central meridian. Thus an average track is obtained for the leg that, at most, will take the plane but a few miles off the main track laid down. Note should be made that this slight divergence will always be to the south of the main track in northern latitudes and north of the main track in southern latitudes.



U1.x (non-EFIS)

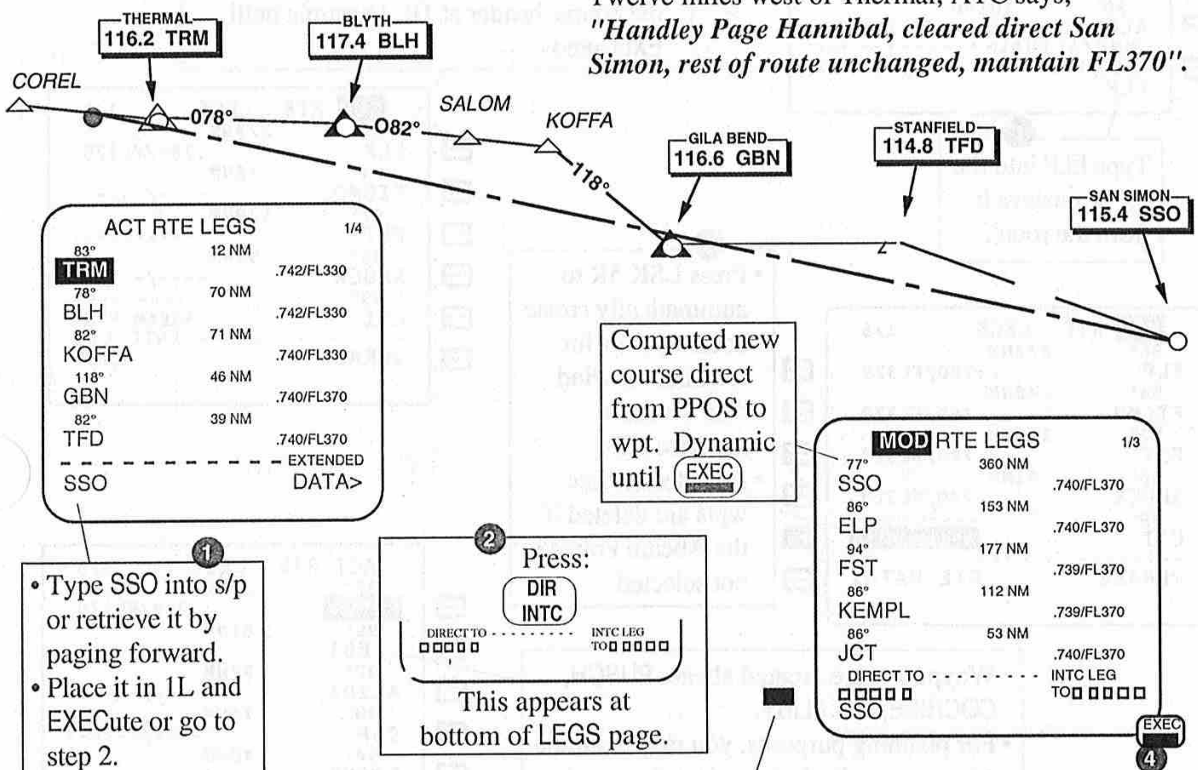
You get to this page by:

- DIR INTC key with route active.
- SELECT DESIRED WPT page.

DIRECT TO a waypoint: Great Circle course between current FMC position and the waypoint.

- 2 ways: First. Line select the waypoint from a page, or type it into the scratchpad. Place it in 1L, close up the route discontinuity, confirm, and EXECute.
  Second: If several pages ahead, copy it to the s/p, press DIR INTC, enter that wpt into line 6L, confirm, and EXECute. In using the DIR INTC key, one does not have to go back to page 1. This key is not available on the CDU that is used for sub-systems such as ACARS. The key is labeled MENU.

Twelve miles west of Thermal, ATC says, ***"Handley Page Hannibal, cleared direct San Simon, rest of route unchanged, maintain FL370".***



3 Enter this waypoint in DIRECT TO line. Examine wpts and headings before executing. For planning purposes, you may examine other pages also before executing, such as PROGRESS, for time/fuel changes. All intermediate waypoints are deleted when proceeding direct to a waypoint in the flight plan.

TECHNIQUE

After DIRECT TO function is complete, enter abeam positions for fuel checks and wind entries for more accurate ETA. U6 and U8 retain pertinent waypoint data (i.e. winds) by means of the ABEAM PTS feature.

TECHNIQUE

Thanks to Capt. Dave Hooper for this technique.

- To turn smoothly to a new wpt, use HDG SEL and position the track line/track indicator above the next wpt/wpt bearing indicator. This takes some practice and a check for a crosswind. After the airplane rolls wings level, accomplish a DIR-TO.
- Be careful. If you use the HDG SEL trick first, then do the DIR-TO and press LNAV before you are on a track direct to the new wpt, the a/c will turn back to capture the curved magenta line. In other words, don't mix the two styles of going direct-to a wpt. Use one or the other.

TECHNIQUE

Use MCP HDG (with 10-15° bank) for initial turn to the wpt to reduce the bank; when the track is on the route press LNAV. LNAV bank angle is a function of TAS and the magnitude of the turn. (Big pilot complaint. Waiting for Boeing order to fix.)

U3.0 and up

You get to this page by:

- DIR INTC key with route active.
- SELECT DESIRED WPT page.

- Direct-to a waypoint uses a Great Circle course between the FMC position and the wpt.
- Line select the waypoint from a page, or type it into the scratchpad. Place it in 1L of the first LEGS page, have your teammate verify the entry, and EXECute.

```
  ACT RTE  LEGS        1/6
 190° HDG     NM
(VECTOR)          ----/------
 160°         NM
TFD              290/FL261
 107°        59NM
PUSCH           .791/FL345
 99°         61NM
CIE             .788/FL370
 80°        101NM
ALBY            .788/FL370
 RNP/ACTUAL--------------
2.00/0.05NM      RTE DATA>
ELP
```

South of Sacramento, over central California, ATC says, ***"Northrop Alpha, cleared direct El Paso, flight plan route, maintain FL330".***

1. Type ELP into the s/p or retrieve it from the route.

2.
- Place ELP in line 1 of the first LEGS page.
- New course from PPOS to ELP appears in the course header at 1R. Dynamic until EXECuted.

```
MOD RTE   LEGS        1/5
 96°    273NM
ELP              .780/FL370
 94°       48NM
FIGMO           ----/------
 97°      129NM
FST             ----/------
 96°       91NM
SHUCK           ----/------
 99°
CSI              ABEAM PTS>
---------------  INTC CRS
<ERASE                 083>
```

```
MOD RTE   LEGS        1/5
 96°    272NM
ELP              .780/FL370
 94°       48NM
FIGMO            .780/FL370
 97°      129NM
FST              .780/FL370
 96°       91NM
SHUCK            .780/FL370
 99°
CSI              ABEAM PTS>
---------------
<ERASE            RTE DATA>
```

3.
- Press LSK 5R to automatically create abeam points for retention of wind data for more accurate ETA.
- All intermediate wpts are deleted if the Abeam Points is not selected.

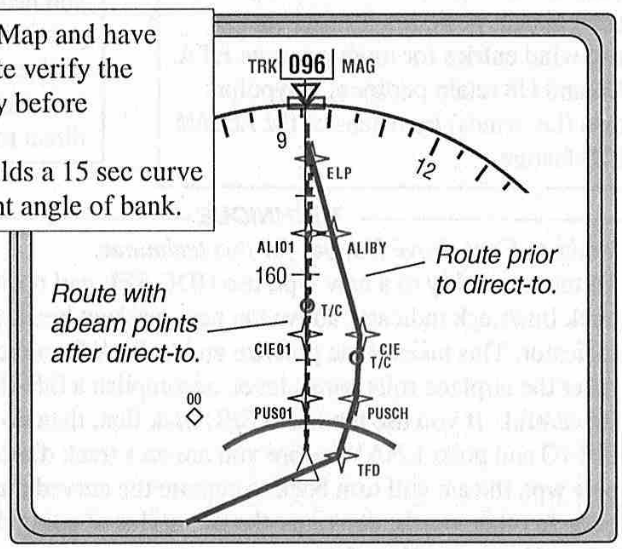
```
  ACT RTE   LEGS        1/6
 96°       37NM
PUS01            299/FL276
 96°       61NM
CIE01           ----/------
 97°       97NM
ALI01           ----/------
 99°       74NM
ELP             ----/------
 94°       40NM
FIGMO           ----/------
 RNP/ACTUAL--------------
2.00/0.05NM      RTE DATA>
```

- Waypoints are created abeam PUSCH, COCHISE, and ALIBY.
- For planning purposes, you may examine other pages also before executing, such as PROGRESS, for time/fuel changes.

EFIS U 6, U8, & up

ABEAM PTS will not be generated for conditional wpts, if the abeam distance exceeds 700 nm, or if the abeam wpt would fall within 10 nm of either the present position or the direct-to wpt.

4.
- Examine the Map and have your teammate verify the direct-to entry before executing.
- The FMC builds a 15 sec curve at your current angle of bank.



TECHNIQUE

Thanks to Dave Hooper for this technique.
To turn smoothly to a new wpt, use HDG SEL and position the track line above the next wpt. This takes some practice and a check for a crosswind. After the airplane rolls wings level, accomplish a DIR-TO and press LNAV.

INTRODUCTION TO INTERCEPTS

This lesson could not have been written without input from Dave Gorrell, Mike DeJonge, Jim Terpstra, and others.

There are a few ways to intercept a leg in the flight plan:

1. Allow the FMC to auto sequence; then engage LNAV - no keyboard action is required.
2. Intercept a leg using the CDU; accept the course at LSK 6R if available, by making it big. The FMC will use the original great circle course between the two waypoints.

Back up the intercept by:

1. Tune a VOR and watch that VOR needle on the RDMI, or set the course bar and monitor the intercept with raw data using a VOR mode or, (EFIS) monitor the computed data by watching the airplane as it intercepts the green MCP course line.
2. Enter the anchor navaid in a FIX page with the outbound bearing; verify the magenta line passes over/near the green dashed FIX bearing line. This is FMC computed data, not raw data.

We used to navigate the airway system by following the outbound radial to the changeover point and then along the inbound radial to the next VOR. The FMC has made our workload much lighter during cruise, but many times, will display a different course than the chart.

The main reason for the difference between the mag courses on the Jepp chart and in the FMS is that Jeppesen publishes the FAA value for the airway which is the true course with the station declination of the VOR applied. The FMS computes the same true course as does the FAA, but the FMS will use the station declination if the intercept is to a navaid, or it will use it's own mag var model if the intercept fix is a waypoint. By the way, the IRU provides the mag heading and track to the HSI/Nav display, using it's own mag var model!

If you put a VHF navaid in LSK 1L, when you do an intercept-leg-to, the declination for conversion from true to mag comes from the nav database and will almost always match the chart, except for the effect of tenths of degrees.

To make the problem worse, the FAA doesn't change the VOR declination until it gets at least 4° different than local magnetic variation. This means you could have a few degrees difference between the Jepp chart course and the FMS computed course.

Great circle effects also enter into the discussion. Consider the following example.

A Fokker VII has just departed Dallas-Ft Worth Intl (KDFW) and is being radar vectored to intercept the 070R from Ranger (FUZ) to Texarkana (TXK), where the inbound radial is 250.

"Fokker VII, fly heading 140 to join J42 to Texarkana".

FUZ is the active waypoint and the anchor for airway J42.

If an airway is loaded, the FMC just connects the waypoints with great circle courses; no declination is needed so none is applied, until the true is converted to mag for the CDU display. (Mag calculations are only for pilot consumption - CDU and EFIS displays)

As you fly on a heading closer and closer to the magenta line, eventually FUZ will drop out and the next wpt (TXK) will become active. It is at this point you engage LNAV. The magenta line remains in the place it was before and keyboard action is not required - you have to monitor the situation very carefully.

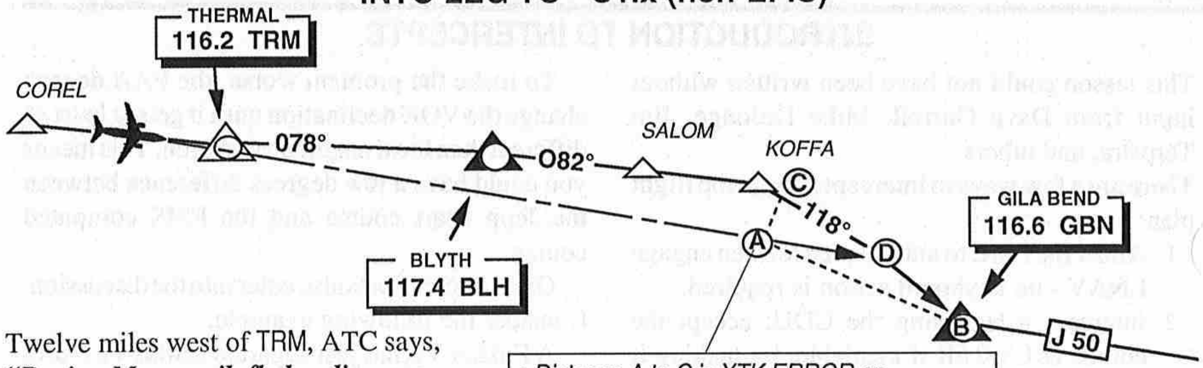
If you do an intercept to a wpt 160 nm down the road the course displayed in 6R may not match the chart because it retains the original course of the leg that connects the two wpts on the airway; press 6R to make it big and you will end up flying the airway.

If an intercept is necessary, use the DIR/INTC key, or for later software, accept the course that is displayed at 6R and make it big. The FMS will fly the shortest line between the two fixes - it's just that the numbers don't match.

Reality check: If you are departing Dallas-Ft Worth Intl you'll get a Departure Procedure that will have short legs (± 35 nm) and the great circle effect mentioned above will not occur.

So we have two reasons why the courses on the chart may not exactly match the CDU, mag var vs station declination, and great circle effects.

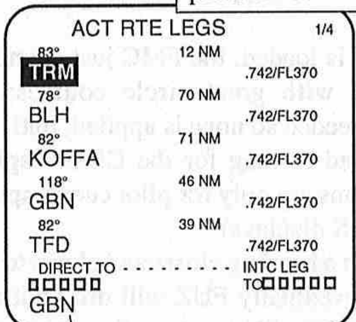
INTC LEG TO - U1.x (non-EFIS)

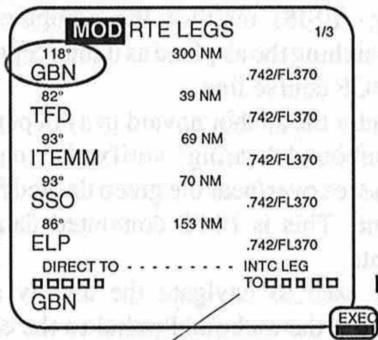


Twelve miles west of TRM, ATC says, ***"Boeing Monomail, fly heading one zero zero to intercept J50 to Gila Bend, then flight planned route."***

- *Distance A to C is XTK ERROR on PROGRESS 2/2.*
- *A to B is on LEGS, PROGRESS 1/1, HSI.*
- *A to D to B, the actual flight path distance, is available on DES page 2R if altitude restriction exists at B and descent is ACTive.*

1. Select 100° HDG on the MCP and press HDG.





2.
- Bring GBN down from 4L.
- Press DIR INTC

3.
- Enter GBN into INTC LEG TO box prompts (LSK 6R). The entered waypont identifier and the **flight planned** course (118°) move to the active wpt line.
- A line is fired over the horizon for 400 miles, just as in the EFIS a/c (next page).
- **Verify the course displayed on the 1L header is the flight plan heading from Koffa.** The great circle heading changes and magnetic variation to the next wpt will be considered.
- For planning purposes, you may examine other pages before executing, such as PROGRESS, for time/fuel changes. This works on the ground also.

4. EXECute. Don't select LNAV until you've rolled out wings level on the intercept heading. Monitor your waypoint bearing pointer and course bar for "lead in". If intercept is greater than four miles, use PROGRESS 2/2 to show approximate distance to the intercept. With U7.2 and up, the XTK ERR will zero out when LNAV is engaged.

If within the LNAV capture criteria, LNAV remains engaged, otherwise LNAV disengages. With LNAV disengaged, manually select any desired heading on the MCP to intercept the flight plan leg to the wpt, then re-engage LNAV.

NOT ON INTERCEPT HEADING is displayed when LNAV engagement is attempted and the present airplane track to the intercept waypoint does not allow for an intercept.

Enroute, it is predicated on course (track).

Only predicated on heading when on a *conditional wpt* HDG leg is active.

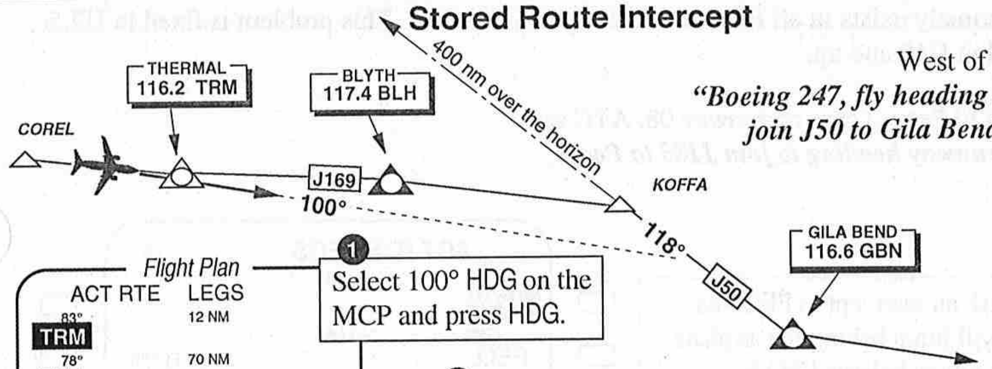
TECHNIQUE

The PNF should back up the PF with raw data when doing an INTC LEG TO function.

INTC LEG TO - U3.0 and up

Stored Route Intercept

West of TRM, ATC says: ***"Boeing 247, fly heading one zero zero to join J50 to Gila Bend, then as filed."***



❶ Select 100° HDG on the MCP and press HDG.

```
Flight Plan
ACT RTE    LEGS
83°
TRM           12 NM
78°
BLH           70 NM
82°
KOFFA         71 NM
118°
GBN           46 NM
82°
TFD           39 NM
- - - - - - - - - -
GBN  ▬
```

❷
- Place GBN in 1L; the direct-to course appears at 1L header (105°).
- The intercept course appears at 6R in small font. 118 >
- If the entered wpt is an *off route* wpt, that is, not in the existing ACTive or MODified route, 6R will display dashes, allowing entry of the desired course. The value displayed in 1L is the direct-to course to the wpt from your present position.

```
MOD RTE    LEGS
105°
GBN          300 NM
82°
TFD           39 NM
          INTC CRS
              118>
```

❸
- Line select 6R and EXECute. This is called *"Making it big"*. It is identical to using the box prompts from the previous page. An intercept course is *fired over the horizon.*
- Check the Map, and after the airplane rolls out of the turn, engage LNAV.

```
MOD RTE LEGS         1/3
118°
GBN          300 NM
82°
TFD           39 NM
93°
ITEMM         69 NM
93°
SSO           70 NM
86°
ELP          153 NM
- - - - - - - - INTC CRS
<ERASE            118
```

Astronauts and Engineers:
U7.2 & up:
When LNAV is engaged a capture path is calculated. A magenta dash-dot line extends from the a/c symbol to the magenta course. An unseen wpt is created at the intersection of the intercept leg and the extension of the a/c's heading. The deviation from this capture path is what is referenced for the availability of VNAV PATH. This deviation is called Lateral Steering Crosstrack.

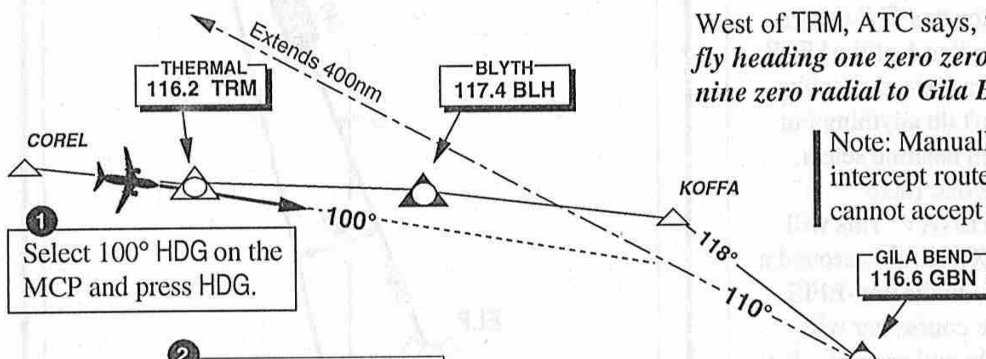
TECHNIQUE

The PNF should back up the PF with raw data when doing an INTC LEG TO function.

Manually Entered Intercept

West of TRM, ATC says, ***"Dewoitine 332, fly heading one zero zero to join the two nine zero radial to Gila Bend, as filed."***

Note: Manually enter the intercept route only when you cannot accept the stored value.



❶ Select 100° HDG on the MCP and press HDG.

❷
- Place GBN in the s/p and place in 1L.
- The direct-to course appears at 1L header and the intercept course from Koffa appears at 6R in small font.

```
MOD RTE
105°
GBN
82°
TFD
93°
ITEMM
93°
SSO
86°           153 NM
ELP         .742/FL370
- - - - - - - - INTC CRS
<ERASE            118>
```

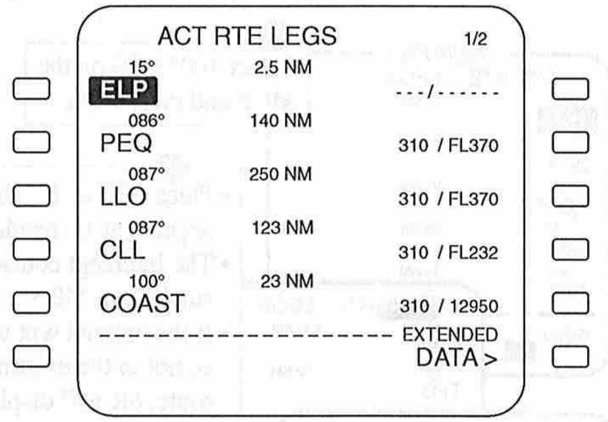
❸
- Type the inbound radial to Gila Bend to the s/p and line select into 6R. Reciprocal of 290 is 110. (It will take a two character entry.)
- Always think of an intercept as INTerCept CouRSe to the wpt.

```
ACT RTE    LEGS
110°
GBN          300 NM
82°
TFD           39 NM
93°
ITEMM         69 NM
93°
SSO           70 NM
86°
ELP          153 NM
            .742/FL370
- - - - - - - - INTC CRS
                  110
110                   ▬
```

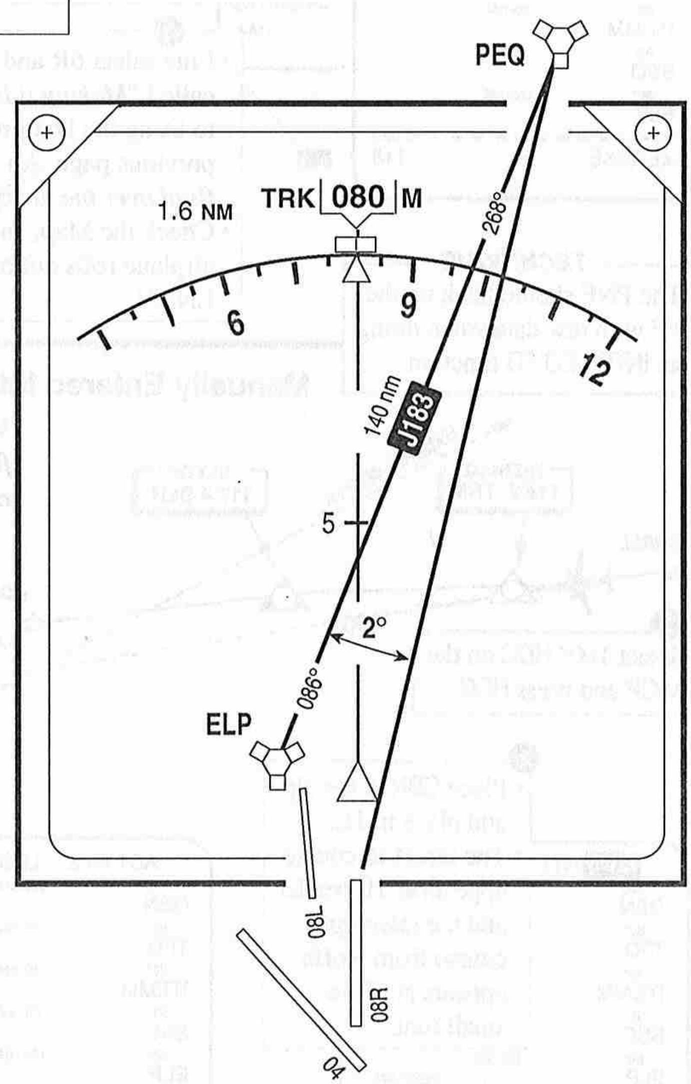
INTC-LEG-TO ANOMALY

– An intercept anomaly exists in all EFIS software up to U7.4 / 8.4. This problem is fixed in U7.5/ 8.5 and is fixed in U10 and up.

After takeoff from El Paso, Texas on runway 08, ATC says:
"Boeing 247, fly runway heading to join J183 to Pecos, then as filed."



- If you accomplish an intercept to PEQ, the magenta route will jump behind the airplane symbol, leading one to believe LNAV should/could not be engaged to capture J183.
- Here's what's going on. If the intercept course lies within 2 degrees of the *history wpt* (RW08 in this case), the magenta route will extend directly to the *history wpt*, jumping behind the airplane in this case.
- If LNAV is engaged, the magenta route will again re-position to appear ahead of the airplane symbol, and LNAV will indeed join the airway, but the EFIS display does not lead one to believe LNAV can be engaged.



- Solution:
- First check to see which wpt is active. If the downroute wpt is active you can arm LNAV as soon as you roll out.
- In this case, notice that ELP is still active. It's still in line 1 of the LEGS page and magenta instead of white on the Map. Don't do anything but fly the airplane in heading select.
- When ELP drops out, (auto sequences), arm LNAV. This will occur when the XTK ERR is around a couple of miles. On the non-EFIS airplane, first the course bar will swing to the outbound course; a few seconds later ELP will drop out.
- The airplane will intercept the airway and no further steps are required.
- The down side to this technique is that you must remember that you are in HDG SEL, and not set up to capture the outbound course in case you are distracted.

PATH CAPTURE, BANK ANGLE & VERTICAL GUIDANCE

Path Capture criteria

If the present aircraft track crosses the leg to be captured at an intercept angle of greater than 15° (8° U5.0) or less than 90°, the track will be maintained until the leg is captured by the lateral steering function. If, however, the predicted intercept point is so close to the leg's termination waypoint that a path cannot be calculated, a new path will be calculated direct to the waypoint (instead of maintaining present track). If the direct path does not allow calculation of an acceptable path, then the path capture will be turned over to the normal FMC steering function to steer to the flight plan path.

If the present aircraft track does not cross the leg to be captured or its backward extension, or crosses at a intercept greater than 45°, (30° U5.0) but the aircraft is within 3 nm of the desired leg, (check XTK ERR) then the path capture will be turned over to the normal FMC steering function to steer to the flight plan path.

If the intercept is less than or equal to 15° (8° U5.0) outside 3 nm, or less than or equal to 45° (30° U5.0) inside 3 nm crosstrack, then lower initial steering gains will be used.

If none of the above criteria is satisfied and an attempt to use the INTC function is made, the advisory message NOT ON INTERCEPT HEADING will be displayed and no MCP engagement of the LNAV will be permitted until a corrective change has been introduced.

U7.2 and up: After an intercept is performed and after LNAV is engaged, a dash-dot magenta line is drawn from the airplane symbol on the EFIS map to the solid magenta line; this is a capture path and the XTK ERROR is referenced to this new path.

Astronauts and engineers:
Why does the course displayed for a DIR TO mod differ from the course displayed after the mod is EXECuted?

Before the mod is EXECuted, the course reflects the Great Circle heading from your current position to the entered waypoint. After the EXECution, the turn radius to the new heading is accounted for which changes the displayed course a few degrees.

Bank Angle

The bank angle is a function of TAS and the magnitude of the turn. If more than 50° of turn is required, the 25° maximum planned bank angle will be used. If only 20° of turn is required, the bank angle will be around 15°. If less than 10° of turn is required, the bank angle will be around 8° as a minimum. If unexpected winds are present, the bank angle may vary up to a max of 30°. This will also happen if LNAV engagement is delayed after the modification is executed.

It is common to see the 737 go to excessive (25°-30°) bank while "at altitude"; this is a major complaint of the line pilot. This problem may have been addressed in U10. Pilot reports are requested.

The bank control must remain under FMC control in order to meet airspace limitations established by the FAA and fly the computed path. Now, the first thing that has to be thought about is that the bank control must be consistent and work for all situations encountered during the flight. Inevitably there will be situations in which the FMC response differs from that which the pilot would have used. One area of frequent comment is roll control at altitude for small turns. The bank control continues to be improved as the designers are aware of the pilot concerns and are trying to make things better.

Vertical Path Control

Prior to U10.5: For path descent operation, the maximum descent flight path angle for predicting interception of the vertical reference path is 7° for aircraft operation above the airport speed restriction altitude plus 1,000' and 6° below this altitude.

10.5 & up: Max descent path angle corresponds to Vmo/Mmo minus 5 kts if above the airport speed restriction altitude and speed restriction plus 10 kts if below the airport speed restriction altitude. It is stil 6° with flaps down.

If the predicted late descent path with these limitations does not intercept the vertical reference path without violating an altitude constraint, a DES PATH UNCACIEVABLE or UNABLE NEXT ALTITUDE message is displayed on the CDU. Longitudinal steering also is constrained by these limits when vertical speed command to the AFDS is being generated.

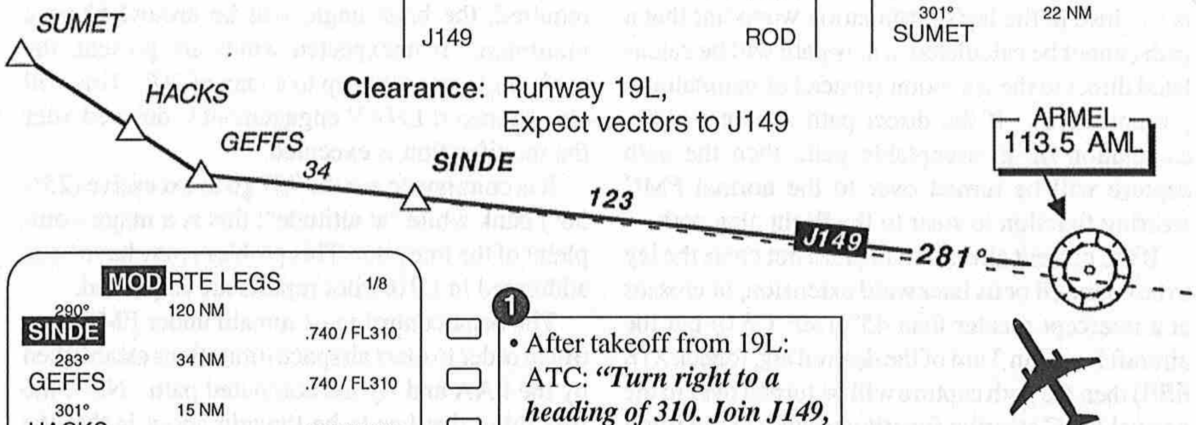
The vertical speed steering commands at path capture or at the vertical flight path transitions are acceleration-limited so as to produce a normal acceleration of not more thao 0.1g.

INTC-LEG-TO (Departure) - U3.0 and up

These are your RTE and LEGS pages.

ACT RTE	1/2
ORIGIN	DEST
KIAD	KSLC
CO ROUTE	FLIGHT NO.
- - - - - - - - - -	- - - - - - - -
RUNWAY	
RW19L	
VIA	TO
- - - - - -	AML
J149	ROD

ACT RTE LEGS	
200°	12 NM
AML	
281°	123 NM
SINDE	
283°	34 NM
GEFFS	
301°	15 NM
HACKS	
301°	22 NM
SUMET	



MOD RTE LEGS		1/8
290°	120 NM	
SINDE	.740 / FL310	☐
283°	34 NM	
GEFFS	.740 / FL310	☐
301°	15 NM	
HACKS	.740 / FL310	☐
301°	22 NM	
SUMET	.740 / FL310	☐
301°	87 NM	
EMPTY	.740 / FL310	☐
	INTC CRS	
<ERASE	281 >	☐
SINDE		

1
- After takeoff from 19L: ATC: ***"Turn right to a heading of 310. Join J149, flight plan course".***
- Notice this clearance is over the route in the FMC.

2
- Bring SINDE to the top,
- Since the entry is a wpt in the route, the *in-course* to SINDE from ARMEL appears at 6R in small font. It sometimes is a bit different than the figure on the chart.

Note - Two other options:
- Allow the FMC to auto sequence, or
- In anticipation of this clearance, perform the intercept while on the ground, reducing "heads down" time at low altitude.

TECHNIQUE

Continue in HDG SEL until AML drops out; then press LNAV. The airplane will intercept the magenta line extending from AML to SINDE.

Note: A design discrepancy of the 737 AFDS is that LNAV cannot be armed, only engaged. By the way, this is not true of the Big Boeings; LNAV can be armed and is displayed in white on the FMA. Heading stays engaged until the course is intercepted.

TECHNIQUE

The MP should back-up the PF with raw data, especially when constructing an intercept to an outbound VOR radial.

MOD RTE LEGS		1/8
290°	120 NM	
SINDE	.740 / FL310	☐
283°	34 NM	
GEFFS	.740 / FL310	☐
301°	15 NM	
HACKS	.740 / FL310	☐
301°	22 NM	
SUMET	.740 / FL310	☐
301°	87 NM	
EMPTY	.740 / FL310	☐
	INTC CRS	
<ERASE	281 >	☐

3
- Press 6R (*Makes 281 big*).
- Check that the white dashed line overlays the magenta route and EXECute. A manual entry into 6R is necessary only if a route anchor point (AML) is not in the route.

Manual entry into LSK 6R is allowed, however **do not overwrite the stored course** (281° in this example) when the stored *in-course* is the desired course. (AML to SINDE) It is accurate to one-tenth degree, whereas a manual entry is only accurate to one degree.

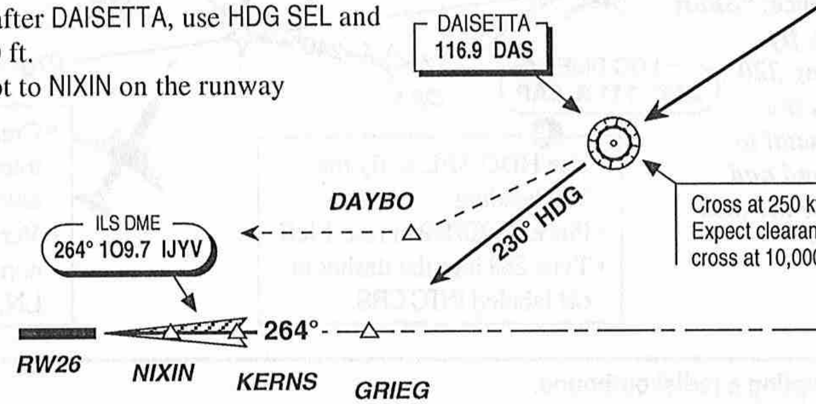
Only 3 conditions require manual entry over the stored value:
- The stored course is not the desired course, or
- The entry in 1L was not part of the route – box prompts appear, or
- A DISCO existing directly in front of the intercept wpt – box prompts appear.

If you are cleared to join an airway, ensure that an *anchor* to the airway is present in the RTE page. This is a sure way to avoid being off the airway, which could lead to a violation.

INTC-LEG-TO (Arrival) - U3.0 and up

ATC: ***"Barnburner 200, after DAISETTA, fly heading 230, vectors for the ILS 26. Descend and maintain 3000 ft."***

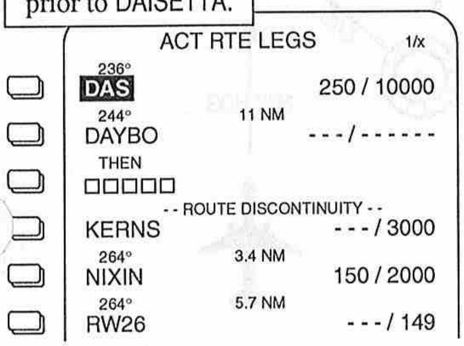
- To meet the clearance after DAISETTA, use HDG SEL and V/S or LVL CHG to 3000 ft.
- Accomplish an intercept to NIXIN on the runway centerline.
- Two examples follow:

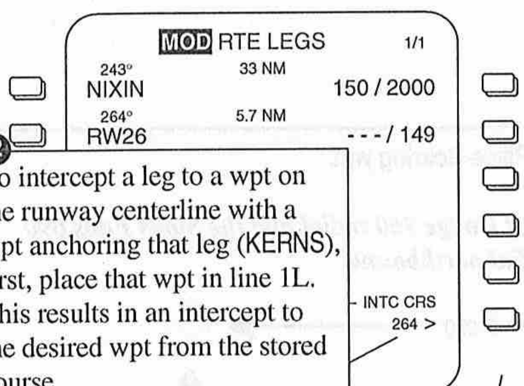


The intercept fires a line over the horizon 500 nm from the fix.on a great circle course.

Example #1: *Default intercept*

1 This is your LEGS prior to DAISETTA.



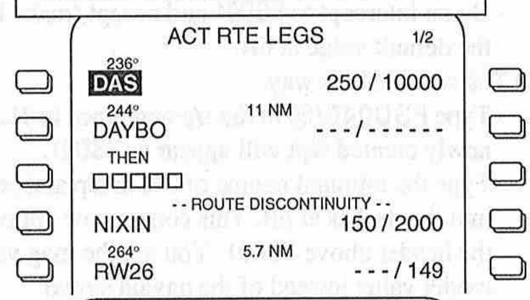


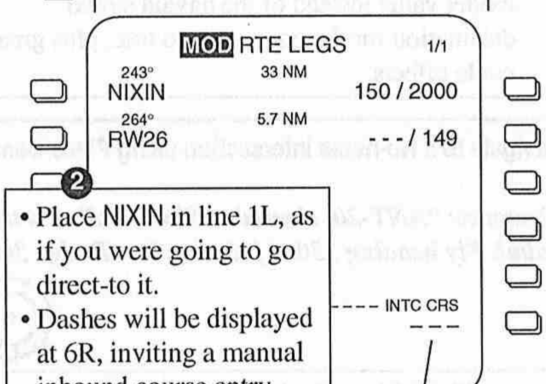
2
- To intercept a leg to a wpt on the runway centerline with a wpt anchoring that leg (KERNS), first, place that wpt in line 1L.
- This results in an intercept to the desired wpt from the stored course.
- Because the course inbound to NIXIN was your desired course, – KERNS to NIXIN was 264° – 264> will show up at 6R.

3
- A manual entry can be made at 6R, but in this case, since it's the course you want, simply press 6R, *Making it big*.
- This ensures you have intercepted the correct course and saves key strokes, a consideration in operating the FMC in the terminal area.
- Check the white dashed line on the Map and execute.

Example #2: *Manual entry intercept*

1
- Notice in this case there is no inbound course to NIXIN because of the DISCO.
- This same technique is used if the inbound course is not the one desired.





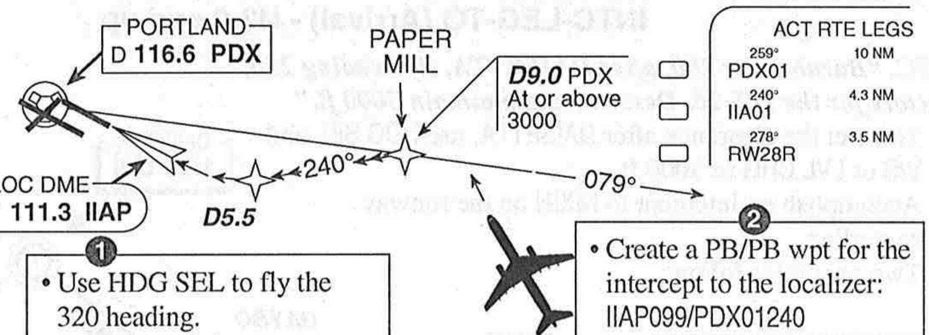
2
- Place NIXIN in line 1L, as if you were going to go direct-to it.
- Dashes will be displayed at 6R, inviting a manual inbound course entry.

3
- Enter the desired inbound course (264) to the s/p then into 6R, the dashes. Accuracy is to 1° whereas accepting the stored course, when possible, is to .1° and does not correct for *round-off error* (.5°)
- Check the white dashed lines on the EHSI Map and execute.
- If the magenta line no longer matches the correct course, the problem is the magnetic variation model being used does not match your geographic area.

INTERCEPT EXERCISES - U3 and up

Intercepting a radial inbound.

Clearance: ***"Short Seylla, fly heading 320 to join the 079 radial to Portland and resume the Mill Visual."***

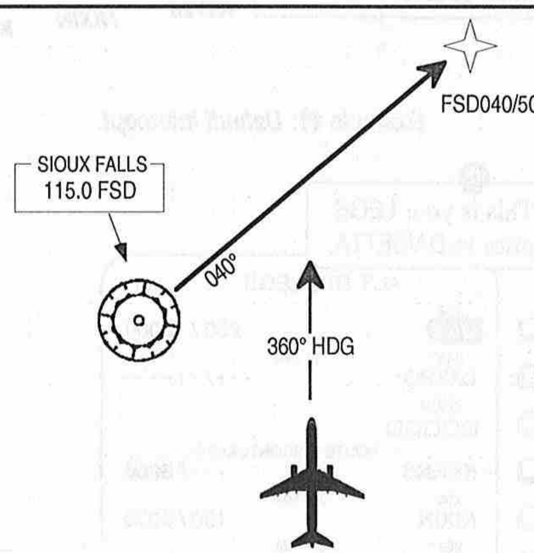


1
- Use HDG SEL to fly the 320 heading.
- Place PDX079/9 in line 1 left.
- Type 259 into the dashes at 6R labeled INTC CRS.

2
- Create a PB/PB wpt for the intercept to the localizer: IIAP099/PDX01240
- Verify MODified route is correct, EXECute, and press LNAV.

Intercepting a radial outbound.

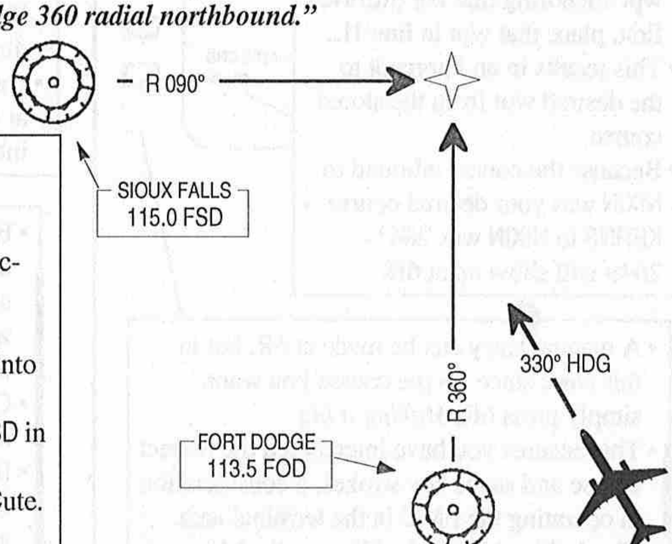
Clearance: ***"Breguet Saigon, fly heading 360 to join the Sioux Falls 040 radial outbound."***



Use HDG SEL to fly the 360 heading.
- The best way...
  - Enter FSD in 1L and FSD040/50 directly below (appears as FSD01).
  - Do an intercept to FSD01 and accept (make it big) the default value at 6R.
- The secomd best way...
  - Type FSD040/50 in the s/p and place in 1L. This newly created wpt will appear as FSD01.
  - Type the inbound course of 040 in s/p and enter into the dashes at 6R. This course now appears in the header above FSD01. You get the mag var model value instead of the navaid stored declination for the converson to true, plus great circle effects.

Navigate to a No-name intersection using Place-Bearing/Place-Bearing wpt.

Clearance: ***"ANT-20, cleared to Sioux Falls via the Fort Dodge 360 radial and the Sious Falls 090 radial. Fly heading 330 to join the Fort Dodge 360 radial northbound."***



- Use HDG SEL to fly the 330 heading.
- In the s/p, define the intersection FOD360/FSD090.
- Place FOD360/FSD090 into 1L. The intersection is displayed in line 1L as FOD01.
- Dashes labeled INTC CRS appear at 6R.
- Enter the inbound course to FOD01 (360), into these dashes at 6R.
- Complete building the route by placing FSD in sequence at 2L.
- Verify MODified route is correct and EXECute.
- Press LNAV.

You get to this page by:

- (PROG) key. Two pages available.

U3 & up 3 pages.

NO REQUIRED ENTRIES

- Wpt identifier, ALTitude and Actual Time of Arrival for last wpt crossed.
- If a waypoint is bypassed, it will not be displayed.

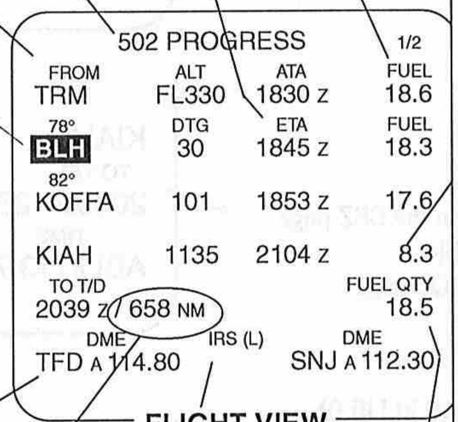
These ETA's will be displayed on the ground with a ZFW entered.

U3 & up Flight number from RTE page.

U5 & up Includes display of fuel at last wpt.

- Predicted fuel remaining at destination - calculated by the FMC Performance function. Uses the cruise altitude, wind profiles, and target speed to perform the integration. It uses the lateral flight plan for the distance and if there are any DISCOS then a direct line distance between the discontinuous parts are used. This probably happens most when you have not entered an arrival. The biggest impact to the fuel at destination is the accuracy of the wind model.
- If APU is running, FMC predictions will be incorrect. It does not include APU burn.

- Identifier of ACTive wpt.
- Flight plan course, Distance To Go from present position to ACTive wpt, Estimated Time of Arrival, and predicted fuel remaining at the active and next wpts.
- The active wpt is highlighted.



FLIGHT VIEW

Monitor these nav stations with the RDMI for position awareness and tuning status.

Current fuel quantity as obtained from the fuel summation unit.

Total of segments from LEGS pages.

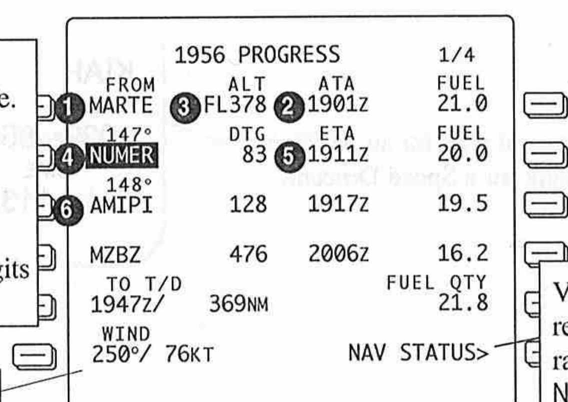
TECHNIQUE

During Preflight, compare this distance with the hard copy flight plan distance. This is especially important if you had to use a SELECT DESIRED WPT page, or if you added a SID or STAR. If this distance is considerably different than the hard copy, you can bet you've got a mistake in the route.

- On initial start-up, the left IRS is referenced, indicating the FMC is using the left IRS as its inertial reference.
- U1.3 and up: The FMC defaults to the left IRS, and switches to the right IRS when it detects that the left IRS is invalid (position has diverged from the Radio position by more than 4 nm for more than 120 seconds), or, for U1.4, 1.5, U4.0 and up: The right IRS has been selected on the POS SHIFT page.
- U5.0 & up: The Left IRS may also be declared invalid if it is diverging from the FMC position by more than 8 nm/hr and from the Right IRS by more than 12 nm/hr.

Ball flags indicate the order in which a Position Report is made.

1 Aircraft position
2 Time over Position - 4 digits
3 Flight Level
4 Next Fix
5 Estimate over Next Fix - 4 digits
6 Name of subsequent Fix



True wind display.

U7.0 & up VHF nav displays are removed. To monitor radio updating, press NAV STATUS prompt.

ALTITUDE CHANGE POINT LINE

PROGRESS			1/2
FROM	ALT	ATA	
TRM	FL 330		
78°	DTG	ETA	FUEL
BLH	50	1845z	18.3
82°			
KOFFA	71	1853z	17.6
MOD			
KIAH	1075	2104z	8.3
TO T/C			FUEL QTY
1840z/ 25NM			18.9
DME	IRS (L)	DME	
TRM A116.20		MZB A117.80	

MOD

Flight plan modification is in progress. Displayed values on the DEST page may not be accurate for the active flight plan.

TO T/C

Top-of-Climb in an ACTive climb mode.

KIAH	245	2104z	8.3
TO T/D			FUEL QTY
2039z/ 135NM			10.7
DME	IRS (L)	DME	
ABI A113.70		LZZ A112.50	

TO T/D

Top-of-Descent
If no STEP TO entry exists on the CRZ page and a path descent is available.
Does not re-compute on a MOD page.

KIAH	135	2104z	8.3
TO T/D ADVISORY			FUEL QTY
2039z/ 135NM			10.7
DME	IRS (L)	DME	
ABI A113.70		LZZ A112.50	

TO T/D ADVSRY (Discontinued in U5.0)

An advisory to top-of-descent if no STEP TO entry exists on the CRZ page and a path descent is not available. Automatic initiation of VNAV descent is not available. Upon reaching T/D, message DES PATH NOT AVAILABLE appears and VNAV disconnects to ALT HOLD. T/D point computed using Spd Des parameters, i.e. 1000' above DEST airport.

KIAH	1135	2104z	8.3
TO STEP POINT			FUEL QTY
1859z/ 180NM			18.7
DME	IRS (L)	DME	
SJN A112.30		TUS A116.00	

TO STEP POINT

To the Step Point if a STEP TO entry exists on the CRZ page.

KIAH	1135	2104z	8.3
TO E/D			FUEL QTY
2039z/ 85NM			10.5
DME	IRS (L)	DME	
CLL A113.30		LOA A110.80	

TO E/D

To the End-of-Descent wpt, for an ACTive Path Descent; blank for a Speed Descent.

RTA PROGRESS - U4.0 & up

This page shows the RTA PROGRESS page before an RTA WPT and time constraint has been chosen.

To use the RTA function, designate a single waypoint in the flight plan and specify a Required Time of Arrival at this waypoint. A speed schedule to achieve an RTA at some waypoint can be activated through this RTA PROGRESS page.

The target speed schedule to meet the RTA is derived by finding the ECON mode Cost Index that results in the desired ETA prediction. The FMC will choose a CI from 200 to a minus 40 in an attempt to meet the RTA. Speed limits are defined by the PERF LIMITS page.

Entry of an RTA WPT and an RTA time at that waypoint activates the RTA mode and overrides the previous performance mode. Supplementary computations also display the earliest and latest arrival times possible at the RTA waypoint - called the RTA WINDOW. If an RTA is entered outside the RTA WINDOW, a message RTA UNACHIEVABLE will be displayed.

The accuracy of the RTA function relies heavily on accurate wind forecasting for the route of flight. Therefore it is recommended that you enter the best wind profile available on the PERF INIT page, if using RTA through the climb phase, and on the RTE DATA pages for RTA calculations in cruise.

On the ground, it advises of pertinent times such as recommended takeoff time to meet the RTA.

In flight, it provides advisory data on progress of flight when in the RTA mode.

After passing the RTA wpt, the message SELECT MODE AFTER RTA appears. Check the CRZ page and make desired speed change.

To get out of the RTA mode, DELete the wpt that you placed in 1L of the RTA PROGRESS page. You may be left with a Manually entered cruise speed, so check the CRZ page for desired speed.

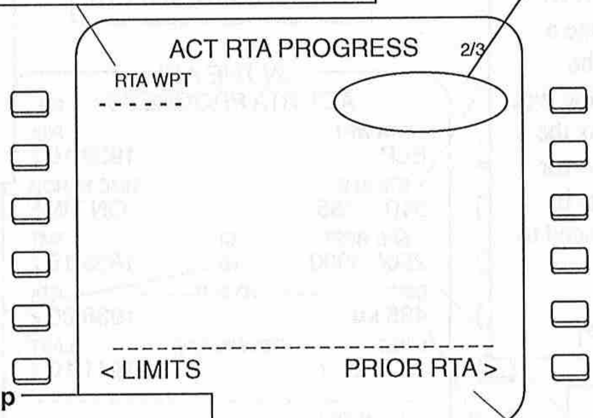
U4.0 & up

- An active flight plan with complete performance information should exist prior to entry of an RTA WPT.
- Access to the RTA PROGRESS page is normally made by pressing the next page key when on PROGRESS 1/1 or by selecting an RTA prompt on the CLB, CRZ, or DES page.
- Wpt entered must be in the flight plan or the message INVALID ENTRY will be displayed in the scratch pad.
- Entering a valid wpt will generate a MOD RTA PROGRESS page and illuminate the EXECute key.

U4.0 & up

- RTA displayed after RTA WPT entry.
- Initially, the RTA will propagate from line 4R, the computed ETA, which is based on the active flight plan and performance parameters at time of RTA WPT entry.
- Desired RTA would be entered manually by overwriting displayed data.

Ref: Next page.



U4.0 & up

DELETION OF RTA WPT

- To exit RTA window, DELete the RTA WPT. It will create a MOD RTA PROGRESS page with all data blanked except for dashes in line 1L and illuminate the EXECute key. The FMC will exit the RTA mode when the EXECute key is pressed.
- DELetion of the RTA WPT does not remove the wpt from the flight plan.
- The RTA WPT clears and the RTA mode is exited after passing the RTA wpt.

U4.0 & up

- PRIOR RTA will be displayed only if a prior active RTA mode was changed to some different performance mode (e.g. a manual climb mode). Otherwise blank.
- Line selecting 6R will recall the RTA waypoint and the RTA time entered previously.

- Will initialize to predicted ETA of flight plan.
- Entry of **A** after RTA specifies arrival time of at or after.
- Entry of **B** after RTA specifies arrival time of at or before.
- Entry can be a 6 digit number with no separators.

19 38	10	19 38	19 38	.2
hr min	sec	hr min	hr min	tenths

Enter RTA WPT and RTA time to define RTA mode.

- Displays the target speed req'd to meet the planned RTA.
- Same as speed displayed on RTA CLB, CRZ or DES pg.
- Based on entered Cost Index.

ON THE GROUND

```
ACT RTA PROGRESS              2/3
RTA WPT                        RTA
ELP                      1938:10 z
RTA SPD                 TIME ERROR
255 / .735         EARLY     05:00
RECMO T/O                      GMT
1820:30 z                1800:45 z
DIST      ----TO ELP----       ETA
648 NM                   1938:00 z
FIRST     ---T/O WINDOW---    LAST
1805:44 z                1833:10 z
----------------------------------
< LIMITS
```

Will be ON TIME if GMT is within the T/O WINDOW; other wise will show EARLY or LATE and the corresponding time.

Current GMT.

- On the ground, displays the recommended takeoff time required to meet the planned RTA at the entered Cost Index.
- Attempt to takeoff as close to this time as possible.

- On the ground, displays the earliest and latest takeoff times which will allow compliance with the planned RTA at speed limits specified on PERF LIMITS page.
- Based on Cost Index of 0 - 200.

Performance prediction for an immediate take-off and will keep advancing along with GMT.

- Will be based on a CI adjusted so that ETA in performance predictions equals enterd RTA.
- Speed adjustments are infrequent far from RTA WPT. Over 2 hrs from the RTA WPT, the FMC does not initiate a speed correction until the predicted time error at the wpt is greater than 2 min. As the wpt is approached, the error req'd to initiate a change in airspeed is linearly reduced to the selected time error tolerance.
- Frozen nearing RTA WPT.

New RTA entry will cause Cost Index adjustment for new speed schedule and ETA.

- Displays the most recent time error in minutes and seconds up to a maximum of 59:59.
- Will be ON TIME if RTA is within the error tolerance on the LIMITS page; otherwise will show LATE or EARLY of achievable ETA, as compared to desired RTA.

IN THE AIR

```
ACT RTA PROGRESS              2/3
RTA WPT                        RTA
ELP                      1938:10 z
RTA SPD                 TIME ERROR
310 / .765                 ON TIME
SPD REST         CI            GMT
250/10000        85      1835:15 z
DIST      ----TO ELP----       ETA
485 NM                   1938:00 z
FIRST     ---RTA WINDOW---    LAST
1934:25 z                1941:10 z
----------------------------------
< LIMITS
```

- If you want to know what Cost Index is being used, enter CI into 3R.
- The current CI will appear in line 3.

Restriction from current flight phase will highlight if actively limiting speed, otherwise blank.

Distance from present position to RTA WPT and ETA based on current flight plan.

- Inflight, displays the earliest and latest achievable arrival times at the RTA WPT.
- Based on present position and the PERF LIMITS speed limits.

- Constantly updated by performance predictions.
- When error between RTA and ETA exceeds tolerance (based on PERF LIMITS page entry), RTA computations will be re-run, and new speed schedule will result.

PROGRESS 3/3 (2/2 for U1.x)

You get to this page by:

- PROG key, press PREV PAGE or NEXT PAGE

Non EFIS TECHNIQUE
This page is very useful in monitoring winds during climb-out, cruise, and while maneuvering for the approach.

- HEADWIND or TAILWIND and CROSSWIND component are relative to aircraft heading.
- De-crab maneuvers on approach (cross-controls) will cause erroneous winds on aircraft without a sideslip sensor.

Present SAT and ISA DEViation.

```
      502 PROGRESS           3/3
HEADWIND               CROSSWIND
27 KT                     R 3 KT
WIND                 SAT/ISA DEV
104°/ 27              -49°c/+1°c
XTK ERROR               VERT DEV
L0.1 NM                    12 HI
GPS - L TRK                  TAS
310°T                     434 KT
PREFLIGHT               PROGRESS
< REPORT                REPORT >
WEATHER                 POSITION
< REQUEST               REPORT >
```

- Displays current vertical deviation from computed vertical guidance in PATH DES only.
- Appears only when descent is ACTive.

- Direction and magnitude of crosstrack error from the "leg".
- Blank if error is greater than 99.9 nm.
- U10.3: From the "path" (magenta line).

WINDS

- FMC winds are relative to True north.
- The following assumptions are made:
  1) The aircraft is flying straight and level with small (cruise) angle of attack,
  2) Sideslip is assumed to be zero,
  3) Vertical direction is assumed to be level - this can be the source of substantial errors when the aircraft is not in level flight.
- FMC velocity errors, IRU attitude errors, and air data (onside to master FCC) true airspeed errors will affect the calculated wind. With Source Select switch in BOTH-L or NORMAL, same value displayed on each CDU.
- If an IRS wind readout (on the ISDU - optional equipment) reads significantly different than the FMC winds, this may be the first indication of failure (IRS system drift or FMC failure).
- The ND winds are relative to the north reference displayed on the map (MAG or TRUE)
- In a dual FMS installation, the Captain's ND displays FMC-L calculated wind and the FO's ND displays FMC-R calculated winds.

U10.5
Approach RNP and VERT RNP are enterable in line 2L and 2R.

```
        RNP PROGRESS          4/4
168°          1.6 NM     GP 2.18°
F3200                    150/2200
RNP / ACTUAL        VERT RNP / ANP
1.00/0.14 NM              400/33FT
XTK ERROR                 VERT DEV
L 0.08NM                     441HI



RNP  -  -  APPROACH  -  -  VERT RNP
0.50NM                       400FT
```

- VERT RNP can be entered on the ground, only.
- Entry defines the height of the VNAV path deviation bar on the ND.
- Default is 400 ft.

```
         ACT RTE LEGS          1/2
168°          1.7 NM      GP 2.18°
F3200                   150 / 2200
128°          3.4 NM
NOLLA                   147 / 2200
132°          6.4 NM      GP 3.00°
RW13R                         / 55
130° HDG      0.2 NM
( 420)                     ----/420A
131°          7.5 NM
F075D                      ----/-----
RNP / ACTUAL  - - - - - - - - - - - -
1.00/0.14 NM              RTE DATA >
```

Radio update mode, navaid ID, freq, and tuning status along with the IRS in use are displayed on the bottom lines. Navaid ID and freq should never be blank under normal conditions. When possible, only DME information is used from each radio. Blank when not being used for updating. Facilities must be co-located (< .1 arc-min.) Best pair is re-evaluated each 2 min. with DME-DME and DME-VOR modes.

DME IRS (L) DME
TFD A114.80 DRK A114.10

DME-DME TUNING (Primary)
Auto-tunes radio #1 and #2 to separate DME capable stations based on geometry (when available). Max 130 nm. U1.4 and 5.0 extends to 200 nm (260 nm sq).
Criteria for auto tuning: Geometry, range, quality, it cannot be blackballed (long term invalid) nor pilot inhibited.

Presence of these titles indicates that the FMC is updating its position.

IRS (R) TUS A116.00
DME-DME RPE A112.10

AGILITY TUNING (Secondary) Not available on NG
Every 5 sec. a single AUTO mode DME interrogator will be tuned alternately to each of two DME stations selected by the FMC. This usually does not have any adverse effects on the FMC position and ANP is not affected. Until U1.4 and U5.0, a single DME may be used, which can contaminate a radio update if the DME is misplaced or badly biased. If scanning DME is installed, agility tuning is inhibited.

TECHNIQUE
At certain locations, the first update is a VOR-DME. This is undesireable. Inhibit VOR-DME updating or use HDG SEL until DME-DME updating occurs.

IRS (L) VOR-DME
SPP A113.30 SPP A113.30

VOR / DME TUNING (Lowest Priority)
Both bearing and DME is used from a single co-located station if required. The FMC does not use VOR information beyond a 25 nm range (40 nm for U1.3 and below) - less accurate due to inherent VOR-bearing errors. Most likely to occur when tuning manually. If the station declination is off significant position error can result.

DME IRS (L) DME
IGHI A 110.90 IGHI M 110.90

LOCALIZER TUNING
All software: A localizer can be auto selected for DME updating. DME header is displayed. U5.0 & up: During final approach, localizer deviation can be used if the rwy is selected on the LEGS page and the localizer is manually tuned.

IRS (L)
108.00 108.00
IRS NAV ONLY

IRS DEAD RECKONING MODE (Inertial Navigation)
When no stations are available for radio updating, the FMC displays 108.00 in AUTO window (or blank if frequency scanning DME is installed).
If the FMC determines that the bearing or DME in not within the "reasonable test limits" for 90 sec or more, it deselects the unreliable radio and will not use it for 8 minutes. 108.00 is displayed in the unreliable VHF nav control panel AUTO frequency indicator.

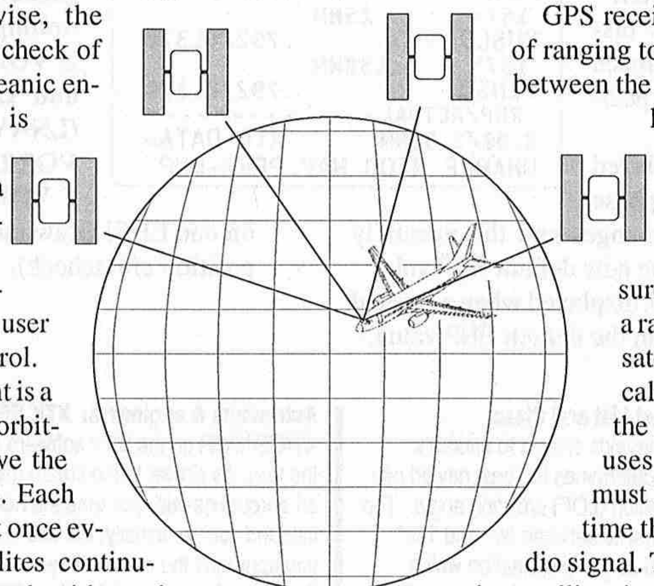
M - Manually tuned
A - Auto tuned via FMC search.
P - Auto tuned by FMC as required by an active procedure.

FMC will search its data base for stations to use for updating only when controls are in proper position. To ensure auto-updating can occur as quickly as possible after takeoff: EFIS - Mode Selector to NAV, MAP, or CTR MAP and a nav selector to AUTO; Non-EFIS - one HSI switch to NAV. Otherwise, a VOR-DME update may occur with manually tuned navaid.

The use of GPS data for navigation depends on the certification level, flight phase, and pilot inhibits (NAV STATUS page). The certification determines the following GPS ratings: Primary, Supplemental, and Advisory.

Primary: The GPS data may be used in all flight modes and on the ground.

Supplemental: GPS data may be used if checked against other sole means certified nav data sources. VHF is the sole means method while enroute domestic and in terminal areas; IRS is the sole means for oceanic. If VHF radio data is unavailable in terminal, approach, or enroute flight, GPS updating is allowed without affecting actual nav performance. Otherwise, the VHF data is used as a check of the GPS data. In an oceanic environment, IRS data is used for the check.



Advisory: GPS data is only displayed for information.

The GPS has 3 segments; the satellite, the user (aircraft), and the control.

The satellite segment is a group of 24 satellites orbiting at 11,000 nm above the earth; three are spares. Each satellite makes an orbit once every 12 hrs. The satellites continuously transmit radio signals with nav data, range code, and the exact time. The GPS sensors require at least 4 satellites to be in view in order to calculate position. Use of a fifth satellite allows the sensors to use different combinations of four to verify the truth of the information. This important integrity check, known as Receiver Autonomous Integrity Monitoring (RAIM) is required in order for the FMC to use the GPS information. As satellite constellation geometry varies, the radius of position accuracy confidence varies also. Given this, the FMC will weigh the GPS information relative to the other available position sensors. Good satellite geometry results in an FMC position that is almost entirely GPS position; poor satellite geometry results in an FMC position that is a blend of radio, IRS and GPS.

The user segment is the GPS receiver unit on the aircraft. It receives of course, the GPS signals.

The control segment has control and monitor stations on earth that continuously monitor and track the satellites. The control segment monitors and corrects satellite's orbits and clocks. The satellites use control rockets to correct their orbits.

The control segment has one master control station and 5 monitor stations (Ascension, Diego Garcia, and Kawajalein Islands, Hawaii, and COS. The master control station is in Colorado Springs, CO and has an atomic clock that is the reference for the GPS.

Verification of the GPS satellite signals is required for any route in which GPS is the only source of navigation sufficiently accurate for the intended route. For RNP operations, availability of adequate navigation aides, or GPS satellite coverage must be assured for the intended route. Your dispatch office will provide you with this GPS prediction.

GPS receivers use the principle of ranging to measure the distance between the receiver and the satellites. The receiver always knows the location of the satellites in their orbits in memory.

The receiver measures the time it takes for a radio signal to go from a satellite to the a/c; it then calculates the distance to the satellite. The receiver uses 1-way ranging and must know exactly at what time the satellite sent the radio signal. The receiver compares the satellite signal to a signal that the receiver makes at the same time as the satellite. The difference between the 2 signals ($\triangle$ t) is the time the satellite signal took to get to the receiver. Each satellite has an atomic clock; all satellites have precisely the same time. The receiver calculates the accurate time from the difference between the receiver time and the GPS time.

To calculate the a/c position (lat, long, altitude) and $\triangle$ tBIAS, the receiver must know the position of at least 4 satellites. The receiver then measures the distances to all the satellites at the same time and computes the nav solution.

The dual GPS sensor units are installed in the upper forward part of the fuselage near the two, nearly flush, GPS antennas. Position information is provided to each unit's onside FMC, just as the other position sensors currently on the aircraft (IRS, DME, VOR/DME, LOC/DME). The result is a very accurate FMCS.

Loss of GPS signal will turn the clock display, if in UTC, to dashes if the clock is in UTC mode. Loss of signal does not illuminate the GPS light on the overhead.

GPS RELATED MESSAGES

GPS Related Messages

IRS NAV ONLY is displayed when the ANP is larger than the default RNP. Default RNP numbers are automatically assigned by the FMC for the phase of flight (Ref: RNP-default values)

UNABLE REQD NAV PERF-RNP is displayed when the ANP is larger than the manually entered RNP (with GPS operations enabled, the FMC allows a manual entry of RNP on the ACT RTE LEGS page 1/x or POS SHIFT 3/3). When on approach this message is also displayed in amber text across the EHSI Map.

```
     ACT RTE  LEGS      1/4
  146°      11NM
AMIPI                .792/FL370
  148°      51NM
LULIS                .792/FL370
  149°      64NM
MID                  .792/FL370
  157°      25NM
DUSLO                .792/FL370
  157°     138NM
PENSO                .792/FL370
 RNP/ACTUAL---------------
2.00/2.51NM       RTE DATA>
UNABLE REQD NAV PERF-RNP
```

Note: Your SOP may not allow manual entry of RNP.

VERIFY POSITION is displayed when the difference between GPS and FMC position exceeds the RNP.

VERIFY RNP is displayed when the default (i.e. phase of flight based) RNP changes and the manually entered RNP exceeds the new default RNP value.

VERIFY RNP VALUE is displayed when a manual RNP entry is greater than the default RNP value.

All of the above messages, with the exception of VERIFY RNP VALUE message, are *alert* messages when issued on the CDU scratch pod. and will be accompanied by an amber FMC annunciator on both pilot instrument panels. VERIFY RNP VALUE message is an *advisory* message and will not be accompanied by the amber FMC annunciator.

These messages can be cleared by the CLEAR key, or the condition being corrected. In addition, to avoid nuisance messages, all of the above messages are inhibited when one of the following is true:

1. VOR/LOC mode is engaged (another system is controlling the lateral path).
2. VOR/LOC mode is armed and LNAV not engaged (LNAV not used to capture VOR/LOC).
3. VOR/ILS mode is selected on one EHSI (Raw radio data displayed for position crosscheck).

Astronauts & engineers: Best List and Class

From the best navaid list (10 navaids closest to aircraft's computed position), the FMC determines the best navaid pair as a function of the line-of-position (LOP) crossing angle. The crossing angle of the LOPs must lie between 30° and 150°. The best navaid pair is defined as the combination which produces a crossing angle closest to the ideal value of 90°. Reselection of a best navaid pair will normally occur after the selected pair no longer meets the range and geometry criteria. The closer to 90° the smaller the ANP. You can witness all this action by viewing the RDMI.

The FMC uses a coordinated search pattern. It constructs a rectangle about the a/c made up of 5 latitude bands – a band is 140 nm in width. It searches the rectangle in this manner – the first band to the north, then first to south, the second band to the north, then the second band going south, etc.

All this searching takes time, and has caused problems with some U1.x computers. U1.6 will limit this search to 3 bands below 15,000'. This will shorten the search time, thereby solving this "restart" problem some operators are experiencing.

Above FL180, only H class navaids are used. Above 12000' and below 18000' MSL, H or L class within 40 nm; 12000' and below, H or L class within 40 nm, or T class within 25 nm. U1.4 and U5.0 and up have increased these distances to 200 nm. On EFIS a/c, they can be identified up to 390 nm. Navaids of unknown class are used at any altitude. DMEs associated with ILS treated as L and used below 12,000'

If one of the two DME receivers has been switched to MANUAL, the FMC will attempt to use the manually tuned DME station to 200 nm regardless of class, and to find a complementary DME station that provides an acceptable LOP crossing angle.

Astronauts & engineers: XTK ERROR

XTK ERROR on the U1.x software references the leg without the turn. It's similar to the steam gauge HSI. As you approach an enroute navaid, you tune the next station and select the inbound course. Initially, the course bar is slightly off center. As you approach the center of the airway, the course bar centers. If you watch the course bar (non EFIS) you will notice that as you sequence fromone leg to the next, as soon as yu start the turn (in NAV), the HSI's course pointer switches to the next leg and moves slightly off center. If you check the XTK ERROR display on PROGRESS 2/2, you'll see it reflects the deviation of the course bar.

EFIS software does not work in this manner. The XTK ERROR will remain at zero because the FMC builds a curved fly-by course as it sequences each wpt. The curved magenta line reflects this design.

Astronauts & engineers: Correction Rates

The Best position is used to slew the System position. The final filter position correction is rate limited based on the phase of flight to insure smooth changes to the system position used for guidance.

These limits are:

Update Type	Phase	Limit In NM / Min
Any update	Enroute	0.5
Any update	Terminal	2.0
Localizer update	Approach	8.0
Manual shift		No limit

NAV STATUS - U7.0 & up

You get to this page by:

- POS SHIFT 3/3 page NAV STATUS prompt (LSK 5R).
- INIT REF page NAV STATUS prompt while in flight.
- PROGRESS 1/3 page NAV STATUS prompt (LSK 6R).
- NAV OPTIONS 2/2 page, then go (PREV PAGE) or (NEXT PAGE).

This information is common to both types of DME interrogators.

- Small font displayed if tuned but not being received (no valid data).
- Large font displayed (no highlighting) if being received but not used in navigation solution.
- Large font with highlighting if being used in navigation solution.
- FAIL is displayed (small font) in the ident field and frequency is blank if no frequency being received or freq status is FAIL WARN.
- Ident field blanked and frequency alone is displayed if no ident for the tuned frequency.

GPS and IRS displays

- GPS display blanked if inhibited.
- (2) Dual FMC installation, indicates that both IRSs(or GPSs) are being used in the nav solution.

NON SCANNING DME

If the tuning mode is agility, then the agility tuned frequencies and their corresponding identifiers are displayed simultaneously.

The data for the nearest station will be displayed above the other station.

For single FMS with standard or agility DME receivers ANP should range from 0.25 up to 0.35 or so, maybe even 0.40. This remains the same for a dual FMS with standard receivers.

For VOR/DME updating, the range will be 0.3 to 0.6 or so depending on distance to the VOR.

DME-DME updating

NAV STATUS	1/2
VOR - L	ILS - R
QED A 113.6	RBL A 115.70
DME - L	DME - R
QED 113.6	RBL 115.70

Agility Tuning

NAV STATUS	1/2
VOR - L	VOR - R
OAK M 116.8	
DME - L	DME - R
OAK 116.80	OED 113.60
	RBL 115.70

SCANNING DME

The FMC will generally be more accurate even if aircraft geometry does not change because the ability to acquire slat ranges for 4 groundstations instead of only 2 can reduce the uncertainty (ANP) by up to 30%. (Multiple observations of similar data reduces the uncertainty.)

A scanning DME receiver can monitor 5 DME stations at the same time. The 737 has two types of installations available, *single* and *dual*.

Single scanning DME is usually installed with the older U3 thru U6 FMCs. This aircraft has 3 DME receivers, one for each pilot radio head and one for the single FMC to use for updating. On this installation, the FMC will use channel 2 and 3 for FMC autotune operation and 1, 4, and 5 are not used.

Expect ANP in the range of 0.17 to 0.25.

The dual scanning installation is normally used with dual FMC installations, U7.2 or 8.1 and up. In this type of installation, there are only 2 DME receivers on the airplane. Channel 1 on each scanner is dedicated to the pilot radios, channel 2, 3, 4, and 5 on each scanner are available to the FMCs for use in radio updating.

Expect ANP in the range of 0.13 to 0.20

Agility tuning and VOR/DME updating are inhibited.

The last 4 channels do not display A, M, or P, since they are always automatic.

Scanning DME

NAV STATUS	1/2
VOR - L	ILS - R
SEA M 116.8	IBFI M
110.90	
DME - L	DME - R
SEA 116.80	IBFI 110.90
GEG 111.50	ELN 113.40
EPH 112.60	PAE 114.20
ALW 116.40	BLI 113.00
HQM 117.70	MWH 115.00

- The first is for the pilot, manually tuned to SEA. Manual tuning does not inhibit scanning DME ops.
- The next 4 are reserved for the scanning DME. Each radio may pick up to 4 stations. The Primary FMC determines which ones to use, and allocates the stations for updating to both FMCs.
- Displayed in order of the directed freq. number.

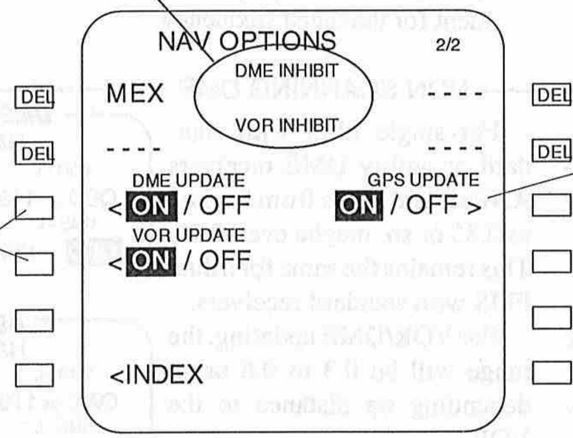
You get to this page by:

- REF NAV DATA page NAV OPTIONS prompt (LSK 6R).
- NAV STATUS page then (NEXT PAGE) or (PREV PAGE)

- Allows inhibiting use of specific navaids in navigation solution.
- Provides a means of selecting which sensors are available for the navigation solution.

- Allows entry of up to four navaids to be inhibited from position updating, (Auto, Procedure, or Manual modes).
- Overwriting or DELeting clears previous entry and removes previous inhibition.
- Selection automatically cleared after landing.
- VOR entries not allowed if VOR updating is OFF.
- The example shows an entry to inhibit the Mexico City DME from updating.
- LOC updating cannot be inhibited.

- Allows de-selection of DME and/or VOR update mode.
- Default is ON.
- Current mode is highlighted.



- 3R header and field is blank when inactive, as in U7.0
- Allows selection of GPS update mode.
- Default is ON at end of flight.
- Current mode is highlighted.
- Certain carriers require GPS UPDATE to be OFF if flying in a country that has not converted to WGS-84

Astronauts & engineers: Localizer Updating

U5.0 and up: During final approach, the FMCS can use a manually tuned front course localizer and DME for updating. Localizer updating has priority over DME-DME updating. Localizer deviation may be applied in addition to the DME update. Note: An LDA cannot be used to update the FMC position.

The following criteria must be satisfied before the FMCS will use localizer deviation:

- The tuned ILS frequency matches the frequency in the nav database for the approach programmed in the LEGS page.
- Aircraft altitude must be less than 6000 above station elevation.
- Aircraft must be within 20 nm of the localizer antenna (Nav Data Base) for a front course approach (12 nm for a back course approach).
- Aircraft must be within 25 degrees of the localizer centerline.
- Aircraft track angle must be within 45 degrees of the localizer inbound course.
- Localizer deviation must be less than 1.25 dots after having been less than 2.0 dots for at least 5 seconds prior to the start of localizer updating.
- LOC updating terminates when crossing over or abeam the runway threshold.

Astronauts & engineers: Bad Navaid List

The first operation in creating the navaid allocation list is identification of the unusable navaids. This is determined by identifying navaids that are giving bad or no data over 4 consecutive update cycles. This bad navaid list is shared by each FMC in the dual configuration. Each time an FMC finds a new unusable navaid, that update to the bad navaid list is transmitted to the other FMC. The bad navaid list is capable of containing the 10 most recent DME stations, or 5 most recent VOR/DME stations.

Under some circumstances, the bad navaid list is purged so that nearby stations may again be selected and their validity rechecked. The bad navaid list is also purged whenever a navaid receiver is determined to be invalid. In addition, the bad navaid list is purged every 2 minutes after an IRS/GPS IRS NAV ONLY mode is entered. The bad navaid list is purged on the ground.

Operating the FMS in areas where navaids have alignment errors can result in lateral navigation errors of significant magnitude. A map shift may be invisible and everything could look fine; it depends on the relative geometry of the aircraft heading vs. the nav error. One indicator of an invisible map shift the display of the IRS indicator arrows both pointing the same way at the same distance. A map shift in a non-EFIS airplane would show up as a jump in the HSI course bar.

Characterization of facilities potentially radiating unvalidated or incorrect information

a. Signals are sometimes radiated for test purposes (prior to completion of flight inspection).
b. A suspect facility can be radiating *out of tolerance* with the ident not yet removed.
c. A facility may be radiating *out of tolerance* during maintenance or installation, with no ident or a T-E-S-T ident. (The FMS does not check for a valid identification before use.) A facility will usually be NOTAMed if in maintenance. It may not be NOTAMed if it is related to a previously decommissioned facility, and the new facility has not yet been promulgated for service.
d. The FMC data base may be incorrect because a facility has been moved to a new location, a frequency has been changed, or discrepancies exist in coordinate reference.
e. The facility may be radiating, but is unmonitored (e.g. monitors have failed or are not attended). Integrity could be lost during this condition.
f. A facility may be radiating bad azimuth information in certain quadrants, or along certain radials, even though commissioned and monitored.
g. A facility may not be colocated. To be used for the nav solution, the VOR and DME facility must be colocated; i.e., the lat/long of the two must not differ by more than 0.1 arc-minute.

Recommendations

a. Ensure a system exists at your carrier where problem navaids are flagged.
b. Check NOTAMS for known navaid problems.
c. When known facility problems exist, use this information to INHIBIT this particular navaid using the REF NAV DATA or the NAV OPTIONS page.
d. If a faulty update has occured just after takeoff (example, VERIFY POSITION message with a map shift), navigate with raw data; you should not direct your attention to the computer while in this phase of flight.
e. If known bad facilities are being automatically selected and used by the FMS, manually tune one side to force the system off a bad facility.
f. The governing body should seek a better way to flag facilities that are radiating for maintenance or test purpose, or are suspect, to aid timely airline and crew response.
g. A search swath for NOTAMS should include navaids within 200 nm of course.
h. Advise the governoring body and your airline immediately when known problems are found.
i. Any time you receive the message VERIFY POSITION, be alert for a possible course deviation.

The IRS NAV ONLY message is quite common and normally indicates a lack of radio updating of the FMC POSition, not that the airplane is off course. The normal flight crew reaction to this message is three-fold. First ensure that both nav radios are in a configuration that will allow the FMC to auto-tune. Second, check the effectiveness of the updating by monitoring the RADIO position on the POS SHIFT page; if the airplane is operating in an unreliable navaid environment, consider shifting the FMCS position to the referenced IRS position - (L) on the PROGRESS, POS SHIFT, or NAV STATUS. An FMS can be forced off a bad facility by manually tuning a different valid facility on one side, thus forcing consideration of a new pair of facilities, but the most effective means of avoiding an unreliable navaid is to INHIBIT that navaid prior to entering its coverage. Finally, compare raw data position to the FMCS position.

If the navaids are questionable and in a radar environment, actual position should be confirmed with the controller. Use the most accurate navigation system available to ensure compliance with the desired/required navigation track. This may require the use of conventional VOR/ADF nav.

If one of the nav heads has been switched to MANUAL, the FMCS will attempt to use the manually tuned DME station and to find a complementary DME station that provides an acceptable crossing angle. **It may result in a less desireable pair than it would have chosen.** When this is not possible, the DME interrogator in the AUTO mode may operate in a frequency-agile submode in order to preserve the primary dual-DME nav solution. This is agility tuning.

Theoretically, agility tuning is as accurate as DME-DME tuning. Latency of data should be considered however, since it is held for five second intervals as the frequencies are cycled. Agility tuning is not desireable when both radios are available for DME-DME tuning, and pilot action may be required to force a radio out of the agility tuning mode and back to the DME-DME mode.

For example: Both nav heads are in AUTO. The First Officer's nav radio has been declared invalid - three consecutively tuned navaids on that receiver all produced invalid data. The Captain's radio now agility tunes.

Action: If in a phase of flight that has a low work load and nav accuracy is not compromised, start your timer to check whether or not the invalid radio is reconsidered as it should be, within 8 minutes. If it is not, you can intervene manually, in two ways. The easiest is to dial a local VOR/DME in the FO's side (consider LOP) and press MANUAL on that side. This forces the FMC to reconsider this reciever. The second procedure is to dial 108.00 in the Captain's radio and press MANUAL. The First Officer's radio should start agility tuning. Press AUTO on the Captain's side. Both radios will now contribute to the nav solution in a DME-DME mode. If a position error existed, you will see the RADIO position on the POS SHIFT page settle down to around .1-.2 nm vector.

Note: It is impossible to manually check the FMC POSition accuracy within the req'd limits for an approach without RNP equipment.

In areas of questionable navaid integrity, check the FMS position for accuracy prior to entry into the teminal area.

Manual position check:

a. Enter a VOR identifier into one of the FIX pages; preferably a navaid that's off to one side.
b. Manually tune the same VOR and press the nav switch to MANUAL. Your SOP may require selecting a VOR mode and centering the course bar.
c. Compare the RDMI pointer (or course bar) and DME to the bearing and distance on the FIX page. The DME of the FIX page will always be a little shorter than the DME on the RDMI due to the fact that RNAV distance is on the earth's surface and not slant range; the bearing should be the same. Practically speaking, the FIX page DME changes to the next lower number at the half mile; that is, when the distance changes from 25 to 24, you're 24.5 from the FIX. With practice you can tell if the error is less than a mile.
d. If you are flying directly to the manually tuned station, as may be the case when using raw data as a back-up in mountainous terrain in South America, the EHIS Map distance may be compared to the raw data DME. You can get a very good accuracy check since both displays are in tenths of a mile. Again, allow for slant range.

The *manual position accuracy check* described above requires that your RDMI needles point to the tuned navaid, and not the active waypoint (an option). Choose a navaid that the FMC is using for updating (displayed on the PROGRESS or NAV STATUS page) and enter its 3 letter ID on a FIX page. Now compare the FIX page bearing *and* distance with the RDMI bearing and distance.

Map check: EFIS pilots have a very quick way of checking Map accuracy, however this method works well only if updating is occuring from navaids close to the aircraft (40 nm range). In the AUTO mode (or MANUAL with an entered VORTAC) press the VOR/ADF Map switch. The strobes radiating from the vertex are raw data. The navaid symbols are computer generated from the nav data base. Strobes penetrating the center of the navaid symbols indicate an accurate Map.

When an FMC navigation error is detected, either assist the computer in correcting the error (POS SHIFT) or continue the flight using conventional VOR/ADF navigation procedures.

The FMC is designed to reject unreliable navaid data during FMCS position updating, even after takoff - one of the most vulnerable times. (The rwy update feature lessens the chance of this occurance). However, in certain conditions, especially during a VOR-DME update, navaids which are in error may satisfy the "reasonableness criteria" and provide the FMC with an inaccurate RADIO position. Trouble shoot by immediately checking the POS SHIFT page and performing a shift to the referenced IRS. Note the navaid that may have caused the problem and inform the proper authorities.

The single FMC is not certified as a *primary* means of navigation. It is certified to navigate accurately only in conjunction with an accurate VOR/DME environment. The dual FMC installation in U7.2/8.1 meets the criteria for sole means of nav.

If radio navaids are available:

a. Ensure that one nav radio is in the AUTO tuning mode so that the FMC can update its position using the DME-DME method. PROGRESS 1/1 (6L and 6R) or NAV STATUS will indicate whether or not auto-updating is in progress.
b. The radio updating that is underway should be of high quality. Using the POS SHIFT page, compare the FMC System position to the RADIO or DME/DME position. A figure less than .2NM is desireable
c. Accomplish a *Manual check* prior to entry into the terminal area.
d. You may compare the FMC System position to the IRS positions, but expect the distance to grow in an updating environment since the IRSs will drift as a function of time. You may use the formula 3 + 3T where T is time since last **full** alignment.

FLYING ROUTES WITH OCCASIONAL LAPSES OF UPDATING

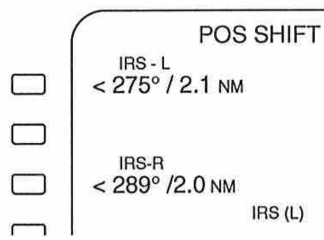
The following procedure is designed for a single FMC installation for the 737 flying a route over an area such as the Gulf of Mexico, where the airplane is outside the range of radio updating for a short period of time.

PREFLIGHT

a. IRS Drift Rate Check:

If IRS drift rates for previous flights have been recorded in the log, verify that no two consecutive flights have a recorded groundspeed of 20 kts or more or that vector distances do not exceed 2 nm. The drift rates for the IRSs can be found by following: INIT REF INDEX / MAINT> / <FMCS / IRS MONITR>. Ref: IRS MONITOR

b. Pre-Departure IRS Checks: Go to POS REF 2/3. Check groundspeeds are less than 2 kts. and ensure that the FMC POSition and IRS positions are *all* the same as the coordinate used for initialization. If not, do another full alignment. The author recommends using the actual gate position prior to flights intended for areas of poor nav coverage because use of the POS SHIFT page may be required. If a manual entry is made the other pilot must verify the entry using a separate doucument.



ISLAND DEPARTURES

In cases such as an island takeoff, where only one navaid is available, there has been a history of problems with a VOR/DME update slinging the FMC off into large errors. In U6 software and below, sometimes these errors were too large for correction at coast-in. During Preflight, either inhibit that navaid or manually tune 108.00 in both receivers until more than 50 nm from the navaid.

PRIOR TO COAST-OUT

a. Check for DME-DME radio updating,

b. Perform a *manual position accuracy check* (described on page 13.12) prior to loss of navaid updating, except repeat the procedure for the other VOR.

c. Verify IRS (L) is the *referenced* IRS - line 4C in the graphic. If it is not, it has drifted out of tolerance and the FMC has chosen the right. The left is the *referenced IRS* at start-up.

d. Record the *offset* distance each IRS is from the FMC POSition. This *offset* is the difference between that IRS and the FMC POSition.This is simply a way to monitor the operation of the IRSs and may assist in determining which IRS is the most accurate. If one IRS is several miles away from the FMC POSition during DME-DME operation, take note. This may be an early indication of an errant IRS. You would not want to shift your FMC POSition to this IRS if the need arose.

e. If you're flying U7 software or above, note the RNP vs. ACTUAL data.

ENROUTE

a. FMC / IRS Comparison Check

When the IRS NAV ONLY message appears, check the *offset* from the *referenced* IRS again. Perform this check and at each subsequent waypoint while in IRS NAV ONLY. This is a quick and easy check and you will get a feel for how the IRSs are performing. With software versions 1.5, 1.6, and 5, the FMC will maintain this *fixed offset* from the *referenced* IRS. This *fixed offset*, (2.1 nm in the graphic) will not change during flight in IRS NAV ONLY. This means that the FMC follows the *referenced* IRS until updating resumes. With versions 1.3 and 3, 4, 7, and up, the velocity errors are still active and the difference may continue to grow.

b. Check the RNP vs. ACTUAL data. ACTUAL error will grow during periods of IRS NAV ONLY.

c. During periods without Radio or GPS nav input, (IRS NAV ONLY), the only true way to perform an accuracy check is to compare the FMC POSition with some identified landmark, i.e., a waypoint you can see out the window. The IRSs are a good next choice, but as we know, they tend to drift.When you compare the FMC POSition to an IRS position, the FMC in LNAV will always pass over the waypoint whether it has a nav error or not. In extreme cases, consider ground mapping with the radar or a position check with ATC.

COAST-IN

a. After the FMC has been auto-updating for a few minutes, go to the POS SHIFT page and note the *offset* that the newly updated FMC POSition is from the *referenced* IRS.

b. Perform a manual position accuracy check as outlined on the previous page.

c. If the offset seems greater than it should be, perform a POS SHIFT to your favorite IRS. The FMC will start updating if good navaids are present. Ref: POS SHIFT Exercise.

POSTFLIGHT

a. IRS Monitor Check

Check the IRS drift rates and groundspeeds. In airplanes that are used for overwater routes or those going to sparse navaid territory, record if SOP.

DUAL FMC - ETOPS QUALIFIED B 737

This section concerns the use of 2 engine aircraft during Long Range Navigation (LRN). This usually means Extended Twin Engine Operation (ETOPS) over water or land in areas where no suitable airports exist.

ETOPS, also referred to as Extended Range Operations (EROPS) is a term to describe Extended Range (ER) flights of twin engine aircraft. An ER flight is conducted over a route that as some point, is further than 60 minutes flying time at single engine cruise speed. The distance to an adequate enroute alternate airport from any point along the intended route must be covered within the approved diversion time using single engine cruise speed (still air and ISA conditions). Diversion times are approved by the governing body and range from a low of 60 minutes to 75, 90, 120, 138, and finally 180 minutes (3 hrs.).

The ETOPS segment of the flight is commenced when the aircraft is more than 60 minutes from a suitable airport. This is called the Extended Range Entry Point and will be defined on your Flight Plan (FP).

A flight leaves the ETOPS portion of the flight when within 60 minutes of an adequate airport. This is called the Extended Range Exit Point, and again, will be defined on the FP.

UNDER DEVELOPMENT

FIX INFO

You get to this page by:

- FIX key. There are 2 pages for use.

- This page is not operable until PERF INIT is complete and is not updated in flight until performance predictions are complete.
- Entry of valid navaid or wpt (LSK 1L) will display the radial and distance **from** (RAD / DIS FR) the FIX to the current FMC position.
- This page is also used to:
  - Create up to 3 downtrack fixes from the entered waypoint.
  - Create an ABEAM position from the entered waypoint.
- When on an OFFSET, entries are not down-selectable and the title changes to OFFSET FIX INFO

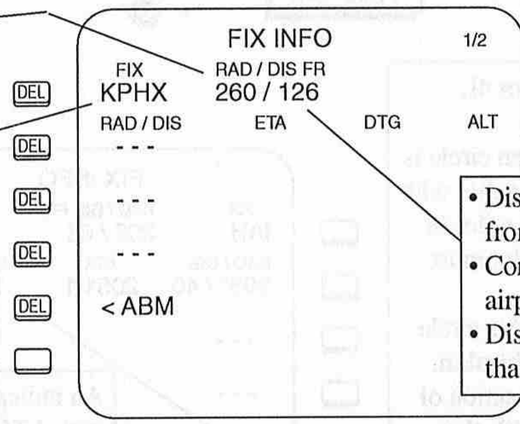
Initial Great Circle course from the fix (KPHX) to the airplane.

EFIS

The fix is displayed inside a green circle on the EHSI map.

U10.5 & up

- Destination runway can be entered on the FIX page and on the WPT/ALT data field of the DES page.
- Can be used to draw lines and circles on the Map but down-selection to LSK 2L through 4L is inhibited.

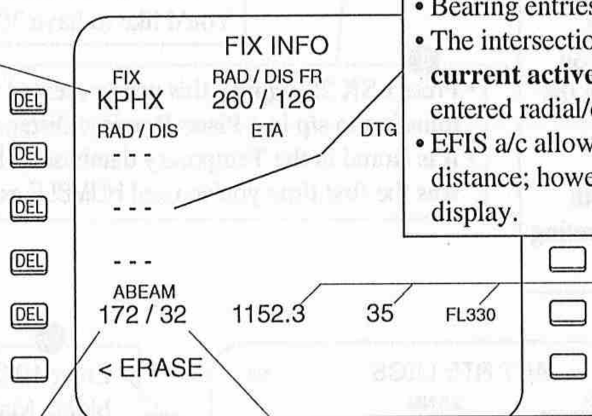


- Displays radial and distance from the fix to the airplane.
- Continually updated as the airplane position changes.
- Distance is blank if more than 999 nm.

- Up to 3 downtrack fixes may be entered based on manually entered bearing or distance from FIX.
- Bearing entries require 3 digits.
- The intersections are the intersections of the **current active flight plan** and the manually entered radial/distances from the FIX.
- EFIS a/c allow entry of both the radial and distance; however, the predictions will not display.

1

- Let's assume we want to see how far our active route will come to the Phoenix airport.
- Enter KPHX into LSK 1L.
- Present position from KPHX will display.



ETA, distance, and advisory altitude to the ABEAM position.

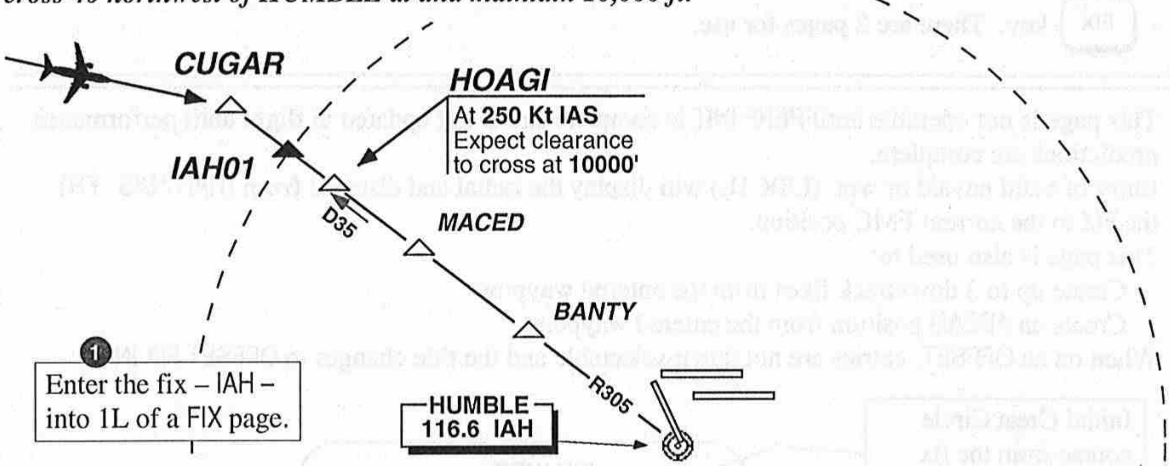
2

- Press the ABEAM key (LSK 5L) to display the calculated RADial / DIStance, ETA, Distance-To-Go and predicted ALTitude for the point along the flight path where the aircraft will be directly abeam the entered FIX if the ACTive flight plan is flown.
- Possible to have more than 1 abeam point in a flight plan.

- Remains blank if the ABEAM fix does not intersect the route or is behind the aircraft, or if PERF INIT is inactive.
- To enter this calculated location as a new waypoint, line select this intersection (LSK5L) into the scratch pad. It will appear as a Place-bearing/Distance waypoint.
- May transfer to desired RTE LEGS page and enter. Insure new waypoint is inserted into correct space (Non-EFIS, check headings).
- A very useful purpose of the abeam position is to check fuel burn against the flight plan if you have been cleared direct to a wpt far down the line, and to re-enter forecast winds for cruise wpts deleted by a DIRECT-TO function.

DISTANCE ENTRY - IN ROUTE

You are proceeding east direct to CUGAR. ATC says : *"Lockheed Electra, cross 40 northwest of HUMBLE at and maintain 10,000 ft."*



1. Enter the fix – IAH – into 1L of a FIX page.

2.
- Type /40 into LSK 2, 3, or 4L (U1.x needs no slash).
- On the EFIS Map, a green circle is formed around the fix symbol with a green dashed circle 40 miles in radius. The non-EFIS pilot must imagine this picture.
- A wpt is created where this circle intersects the **active flight plan.**
- Predictions for the intersection of the **next arc distance with the flight plan** will display after the first one is sequenced (none in this example).
- Before moving to step 3, examine DTG and advisory ALT. Do the mental calculations first, for you may have to start down before the steps discussed below can be carried out.
- Note: Great temptation for both pilots to go *heads-down* in meeting this clearance.

FIX INFO 1/2

FIX	RAD / DIS FR		
IAH	302 / 66		
RAD / DIS	ETA	DTG	ALT
305° / 40	2051.1	26	12435

- - -

- - -

< ABM

IAH305/40.0

An indication that you're above the path ATC now wants you on.

TECHNIQUE

Check the DTG . Assume you're descending through FL200. You have 26 nm to loose 10,000 ft – a little tight. You'd like to have 30. (3:1 ± wind)

3.
- Press LSK 2L **again** - this newly created wpt transfers to s/p in a Place-Bearing/Distance format.
- It is stored in the Temporary database as IAH01 if this was the first time you've used HUMBLE as a FIX host.

4. Return to LEGS page, enter this new position into the proper sequence, close up the DISCO and EXECute.

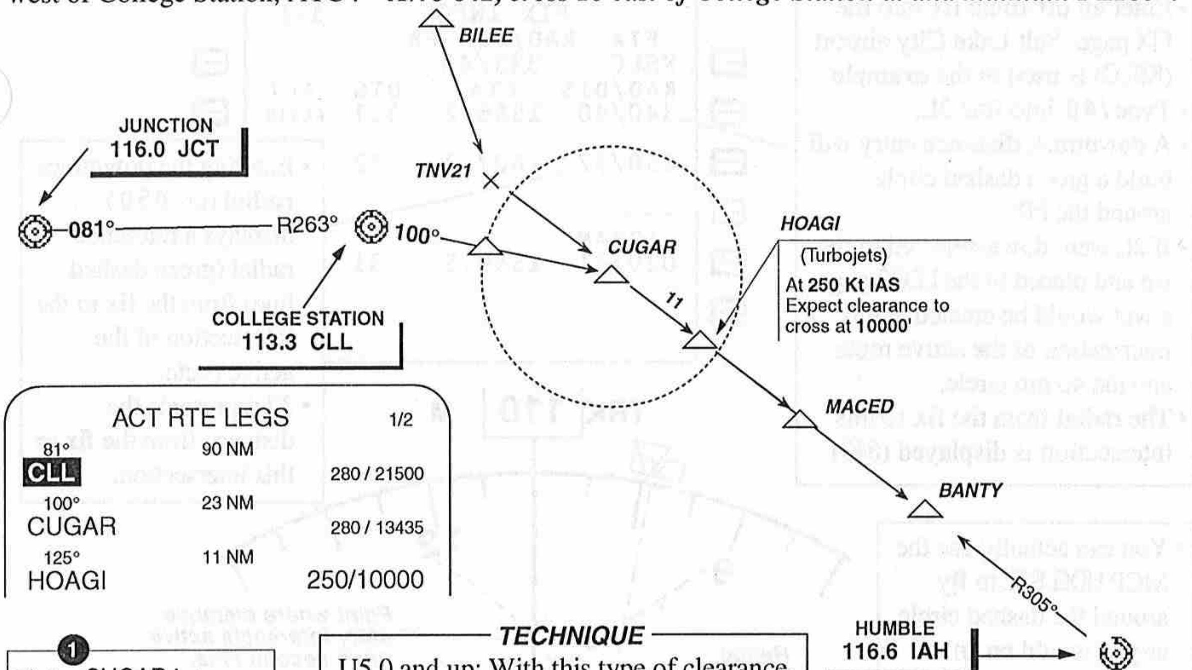
ACT RTE LEGS 1/2

100°	20 NM	
CUGAR		280/13875
125°	6 NM	
IAH01		280 / 10000
125°	5 NM	
HOAGI		250/10000
125°	10 NM	
MACED		240 / 6860
126°	15 NM	
BANTY		240 / 3730
RNP / ACTUAL		
1.70 / 0.28		RTE DATA >

5.
- Enter 10,000' into altitude block. Make sure that the MCP altitude has been selected to 10000.
- If you were previously on a path to cross HOAGI at 10,000, you'd have to increase your descent speed to dissipate the excess energy (possibly get the boards out).
- Ref: Advanced Technique Bradford Arrival to ORD.

DISTANCE ENTRY - BEYOND CLEARANCE REFERENCE
(Not a recommended procedure)

You are proceeding eastward at FL 370 direct to College Station for the CUGAR 4 arrival. 90 nm west of College Station, ATC : *"Avro 642, cross 10 east of College Station at and maintain FL180"*.



ACT RTE LEGS 1/2

81°	90 NM	
CLL		280 / 21500
100°	23 NM	
CUGAR		280 / 13435
125°	11 NM	
HOAGI		250/10000

1 Enter CUGAR into LSK 1L of a FIX page.

2 Type /13 into s/p. (U1.x needs no slash). This is your wpt 10 east of CLL. LSK 2L. This req'd calculation is a good reason not to use this technique.

3 Check DTG and advisory ALT. Back up the FMC with your own calculations. You've got 70 mi. to loose 19000'. Start down ± 13 mi. You've got a little more than a minute to set it up in the computer before T/D.

TECHNIQUE

U5.0 and up: With this type of clearance, use the Along Track Offset feature (CLL/10) from the LEGS page. It is quicker than using the FIX page. U4 and below: Use the P-B/D construction technique - a more logical method.

FIX INFO 1/2

FIX	RAD / DIS FR		
CUGAR	270 / 80		
RAD / DIS	ETA	DTG	ALT
280° / 13	2051.5	73	18435
- - -			
- - -			
< ABM			
< ERASE			
CUGAR280/13.2			

An indication that ATC is going to have you very close to your desired path.

ETA, Distance To Go, and predicted altitude at the first intersection (flt plan route).

4 Press LSK 2L again to transfer this created wpt into s/p.

5 Return to LEGS page, enter this new position into the proper sequence (after CLL), enter 180 into the altitude block. Close up the DISCO and EXECute. Make sure you are in VNAV and that the MCP altitude has been selected to 18000.

MOD RTE LEGS 1/2

81°	60 NM	
CLL		280 / 21200
100°	10 NM	
CUG01		280 / FL180
THEN	NM	
□□□□□		
- - - - ROUTE DISCONTINUITY - - - -		
CUGAR		280 / 13250
127°	11 NM	
HOAGI		250/10000
< ERASE		RTE DATA >

DISTANCE, RADIAL, and ABEAM ENTRIES - OFF-ROUTE

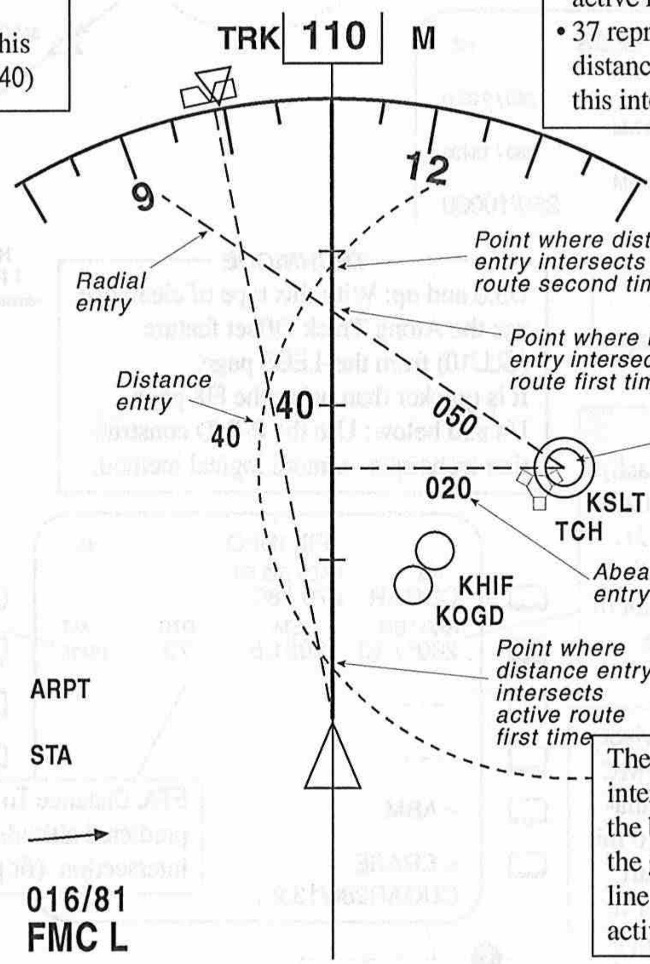
To investigate how the distance entry works, try something like this the next time you have a few minutes to spare while at altitude. In this example, we are eastbound on J50, just passing KOFFA.

- Enter an off-route fix into the FIX page. Salt Lake City airport (KSLC) is used in the example.
- Type **/40** into line 2L.
- A downtrack **distance** entry will build a green dashed circle around the FIX.
- If 2L were down-selected to the s/p and placed in the LEGS page, a wpt would be created at this intersection of the active route and the 40 nm circle.
- The radial from the fix to this intersection is displayed (340)

FIX INFO			1/2
FIX	RAD/DIS FR		
KSLC	335/43		
RAD/DIS	ETA	DTG	ALT
340/40	1556.2	5.1	FL330
050/37	1602.2	52	
- - -			
ABEAM			
020/31	1559.5	31	

- Entering the downtrack **radial** (ex: **050**) displays a reference radial (green dashed line) from the fix to the intersection of the active route.
- 37 represents the distance from the fix to this intersection.

- You can actually use the MCP HDG SEL to fly around the dashed circle as you would on an arc approach.
- The distance, ETA, and predicted altitude at this intersection with the **active flight plan** are displayed until this is behind the aircraft. Then it will display the next intersecton that the circle makes with the active route.
- Radial and distance can be entered at the same time, but no predicted information will appear.



The ABEAM intersection displays the bearing (020); the green dashed line stops at the active route.

When the first DIStance fix is behind the aircraft, data for the second intersection created by the dashed circle will display.

FIX INFO			1/2
FIX	RAD/DIS FR		
KSLC	335/43		
RAD/DIS	ETA	DTG	ALT
060/40	1556.2	54	FL330
050/37	1602.2	46	FL330

FIX INFO

BEARING ENTRY

For a downtrack **bearing** fix in U5 and up, a slash is not req'd.

A bearing entry results in a green dashed radial line being displayed on the EFIS Map.

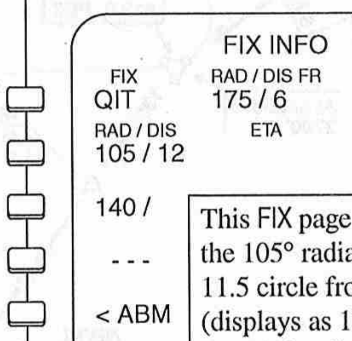
If more than one intercept point exists for a selected radial, the data is displayed for the one nearest the a/c.

The bearing data is magnetic.

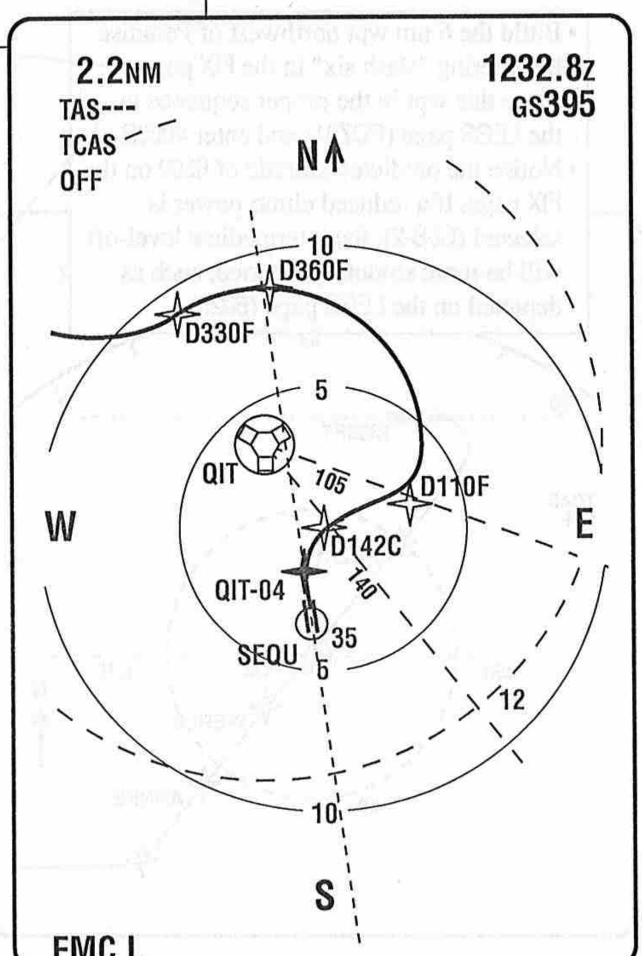
This example depicts use of the FIX page during a takeoff from Runway 35 at Quito, Ecuador

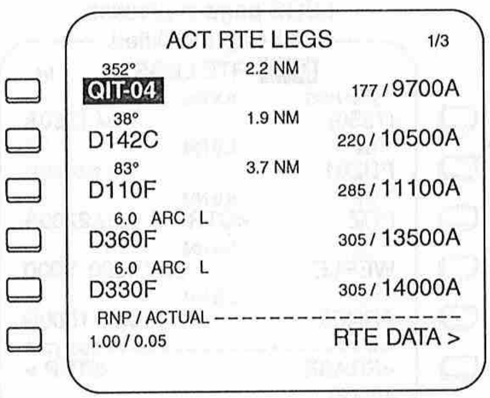
This FIX page is used to display the green dashed bearing lines and the green dashed distance/circle that aid in position awareness for a special procedure - engine failure after takeoff. The engine-out route and hold fix have not been constructed. Can you draw them on the EFIS Map?

- Climb on runway heading to TP marker (QIT-04).
- At TP marker initiate a climbing right turn to a heading of 090° using a 15° bank turn. Do not begin flap retraction nor exceed V2+20 until established on the 090° heading.
- Upon crossing the QIT 105° radial, but no later than D10.3 QIT, initiate an immediate left turn to heading 210°.
- Do not proceed east of D11.5 QIT.
- If IMC, proceed on 210° heading to intercept the QIT 140° radial and proceed outbound to QIT 140° / D13.
- Hold northwest at QIT R-140° / D13, left turns, 8 mile legs. Climb in holding pattern to 16,000 ft MSL. Use 30° bank and clean maneuvering speed.



This FIX page contains the 105° radial, the 11.5 circle from QIT (displays as 12) and the 140° radial.





- The solid line on the HSI Map is the route in the FMC.
- The green dashed lines contrast nicely with the solid magenta line that you will normally follow.

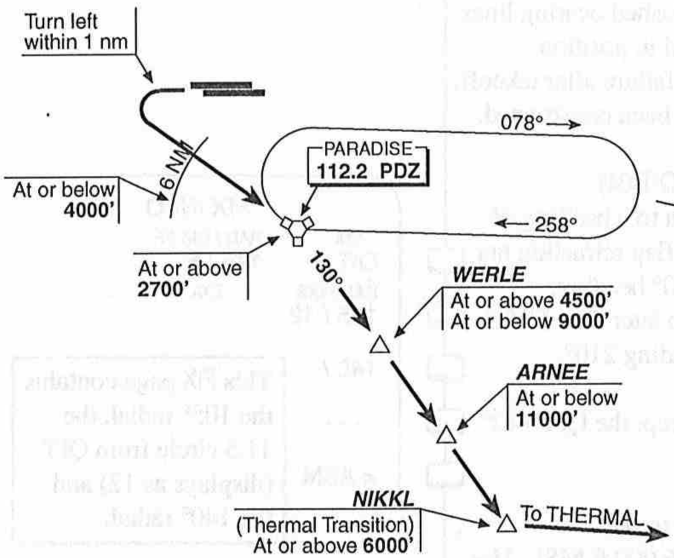
DISTANCE AND BEARING ENTRIES

This example depicts use of a FIX page to create a distance based wpt with a predicted altitude check, and to create a bearing display for a special engine-out procedure.
The departure is the PRADO from rwy 26 at Ontario, California.

- After takeoff turn left to cross 6 nm northwest of PDZ VOR at or below 4000'.
- At 400 ft, select LNAV. Hand fly the airplane to the magenta line and engage the autopilot.
- At 1000 ft AFE select VNAV; all altitude constraints will be met.

LEGS page after selection from database.

```
ACT RTE LEGS              1/3
256° HDG      0.3 NM
(1350)                210/1350A
126°          11 NM
PDZ                   250/2700A
130°          3.0 NM
WERLE            250/4500 9000
131°          3.8 NM
ARNEE                 284/11000B
131°          6.8 NM
NIKKL                 297/6000A
RNP/ACTUAL ------------ EXTENDED
1.00/2.13                 DATA >
```



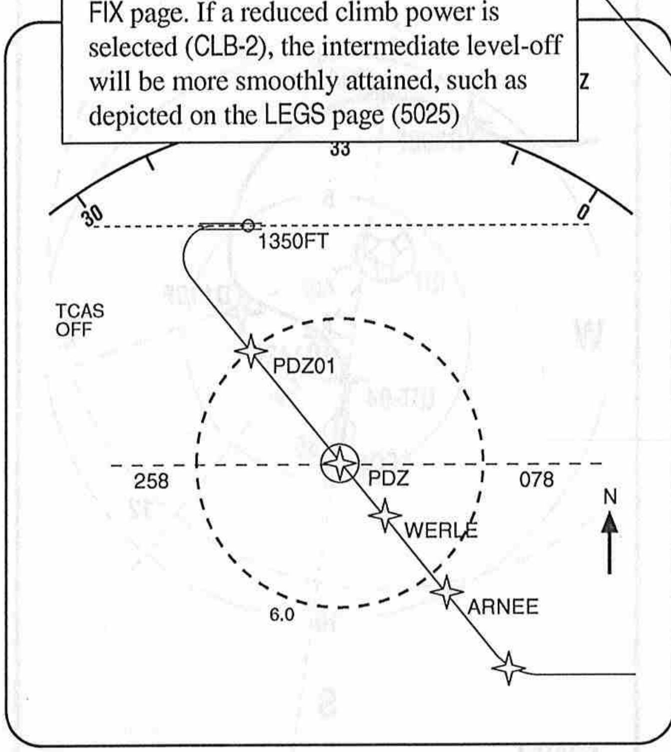
- The special engine out procedure is to hold east of Paradise on the 078° radial, right turns.
- Display the hold radial for situtional awareness by entering the inbound course of 258 on the FIX page.

```
FIX INFO                    1/2
FIX        RAD / DIS FR
PDZ        322 / 9.0
RAD / DIS   ETA       DTG   ALT
305 / 6.0   2328.9 z  5.3   6302
258
```

- Build the 6 nm wpt northwest of Paradise by entering "slash six" in the FIX page. Place this wpt in the proper sequence in the LEGS page (PDZ01) and enter 4000B.
- Notice the predicted altitude of 6302 on the FIX page. If a reduced climb power is selected (CLB-2), the intermediate level-off will be more smoothly attained, such as depicted on the LEGS page (5025)

LEGS page in process of being MODified.

```
MOD RTE LEGS                1/4
256° HDG      0.3 NM
(1350)                210/1350A
126°          5.0 NM
PDZ01                 250/5025
126°          6.0 NM
PDZ           <CTR>   250/2700A
130°          3.0 NM
WERLE            250/4500 9000
131°          3.8 NM
ARNEE                 284/11000B
------------------------ MAP CTR
<ERASE                    STEP >
4000B
```



If cleared to climb "unrestricted", delete 4000B at LSK 1R or the airplane will level-off if in VNAV.

```
ACT RTE LEGS                1/3
126°          2.7 NM
PDZ01                 250/4000B
126°          6.0 NM
PDZ                   250/2700A
130°          3.0 NM
WERLE            250/4500 9000
131°          3.8 NM
ARNEE                 284/11000B
```

ARRIVALS

You get to this page by:

- DEP ARR key.

- Beginning with U7.2 / U8, missed approach procedures will load with the selection of an approach, if contained in the database.
- Under some situations, the Missed Approach Procedure display can cause confusion when it's course crosses or intersects the approach course. It is presently the same color - magenta - as the active route. (Airbus Missed Approach Procedures are a different color!)
- For a visual approach, consider removing the Missed Approach Procedure if it causes situational confusion.

U6 & up

- Upon initiation of a missed approach, DEST information becomes ORIGIN for DEP/ARR SIDs.
- Ref: Missed Approach

DEP / ARR INDEX		1/1
<DEP	KLAX	ARR>
	KIAH	ARR>
DEP	OTHER	ARR
<----		---->
KPHX		

If you must return to airport of ORIGIN, press LSK 1R.

1. Press LSK 2R for ARRival at destination airport. See sample below.

- For OTHER airport arrival information, enter the ICAO airport designator in s/p. Example: Phoenix, Arizona (KPHX)
- … and press LSK 6L for a list of the DEPartures or 6R for a list of the ARRivals.
- It cannot be selected into the flight plan.

- Upon initial page display, an alphabetical listing of all approaches for the airport, followed by a numerical listing of all runways, is displayed.
- Line selection of the desired approach or runway (optional) deletes all other approaches/ runways.

- Upon initial page display, an alphabetical listing of all STARs for the airport is displayed.
- Subsequent line selection of an approach or runway (optional) deletes all STARs not associated with that approach/runway.
- Line selection of the desired STAR deletes all other STARs and non-applicable approaches/ runways, and displays a listing of any arrival transitions applicable to that STAR.

Other pages are approach and runway choices.

KIAH ARRIVALS	1/4
STARS	APPROACHES
COAST2 <ACT>	ILS08
CUGAR6	ILS09
DAS3	ILS14L
GLAND7	VOR14L
ROKIT1	ILS26
< INDEX	ROUTE >

3.
- Select the approach to ILS 14L.
- The missed approach will auto load if contained in the nav db.
- U10.3 & up: option for missed approach in cyan.

2.
- ARRIVALS page display STARS, TRANSitions, APPROACHES, and RUNWAYS for the destination airport.
- In our example, the COAST2 has already been selected by the pilot or programmed as part of the CO ROUTE.

A choice of TRANSitions are offered if applicable.

KIAH ARRIVALS	1/4
STARS	APPROACHES
COAST2 <ACT>	ILS08
TRANS	
JCT	ILS09
CLL <ACT>	ILS14L
BILEE	VOR14L

TECHNIQUE

Quickest way to remove a missed approach is to delete the procedure from the RTE page.

RUNWAY EXTENSION

```
      KIAH ARRIVALS          1/2
   STARS               RUNWAYS
[] BATSN1            <SEL> 14L  []
[] CUGAR4 <ACT>                 []
                      RWY EXT
[] DAS9               - - . - NM []
[] GLAND6                       []
```

- <SEL> turns to <ACT> after EXECution.
- <ACT> indicates the active flight plan arrival.

U5.0 & up

- Any time a RUNWAY is selected, the option RWY EXT appears at 3R.
- An entry from 1 to 25 nm is permissable. This adds a wpt at a selected distance before the runway threshold on the runway centerline.
- This wpt is identified in the form RX-XXX
- Two DISCOs are inserted.
- Entry of a second extension deletes the first.

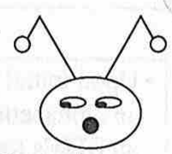
```
   MOD RTE LEGS             1/1
    THEN
[] □□□□□
      - - ROUTE DISCONTINUITY - -
[] RX-14L               ----/------
    THEN
[] □□□□□
      - - ROUTE DISCONTINUITY - -
[] RW14L                   /145
```

- All <SEL> entries propagate to the inactive or MOD RTE and RTE LEGS pages.
- For an existing active route: The EXEC key illuminates upon STAR or approach/runway selection; following SELection, the ERASE prompt is available; Consider executing the selections on the RTE or LEGS pages after examination.
- Arrival matching is performed by comparing the last enroute wpt with the first fix of the arrival procedure. If a match exists, the route is linked to the arrival. If no match exists, a DISCO is inserted.

TECHNIQUE

- If there is no OM charted, create a RWY EXT 5 - 6 mi. from the threshold. This is usually the position of the FAF.
- Assign 1500 - 1800' above the rwy elevation (3:1 = 2.8°)
- If the OM is charted, use that distance.

U7 & 8



Under the following situations, a RUNWAY (s) may not display on certain ARRIVALS pages:

1. The DESTination has no APPROACHES in the nav database, and
2. The DESTination has more than four RUNWAYS .

- When these conditions exist the software erroneously inserts an APPROACHES NONE header in the upper right hand corner of ARRIVALS page 2, 3, etc., thus obscuring a runway selection that would otherwise appear next to LSK 1R.
- This header is appropriate for page one, but not for subsequent pages; this is how a runway can be hidden from view and thus selection.
- You can verify the runway actually exists in the nav database by entering it on the REF NAV DATA page, but entry into the LEGS page is impossible.
- The *missing* runway will be the 5th or the 10th position in the RUNWAY list, at LSK position 1R.
- In this example, the *missing* runways are 14L and 27L at O'Hare.
- One Solution? Add at least one APPROACH to each DESTination.

```
      KORD ARRIVALS          1/3
   STARS            APPROACHES
   BDF3 <ACT>             NONE  []
                       RUNWAYS
   JVL4                     4L  []
   OXI3                     4R  []
   OKK1                     9L  []
   PMM3                     9R  []
   -----------------------------
   <INDEX               ROUTE>  []
```

```
      KORD ARRIVALS          2/3
                    APPROACHES
                          NONE  []
                       RUNWAYS
                           14R  []
                            18  []
                           22L  []
                           22R  []
                      ---------
                        ROUTE>  []
```

```
      KORD ARRIVALS          3/3
                    APPROACHES
                          NONE  []
                       RUNWAYS
                           27R  []
                           32L  []
                           32R  []
                            36  []
                      ---------
                        ROUTE>  []
```

VNAV PATH CONSTRUCTION AND MISSED APPROACH POINT POSITIONS

Thanks to John Kasten and Jim Terpstra of Jeppesen for the text and to Jeppesen for the graphics.

General VNAV Path Rules:

VNAV angles are projected backward from 50 ft above the Landing Threshold Point (LTP) to the altitude at the FAF allowing capture of the VNAV path without penetrating below the intermediate segment altitude. VNAV Path determinations may be influenced by many factors, including the existence of a stepdown fix between the FAF and the LTP. VNAV angles are generally provided for straight-in landings only. The value of 50 ft above the LTP is a default value which may be adjusted to meet operational requirements.

VNAV Path Provisions:

When the civil aviation authority provides a VNAV angle, the specified VNAV angle or angles will be used.

When a civil aviation authority does not provide a VNAV angle, an angle will be calculated by a database supplier using the following criteria:

VNAV to LTP+50: The VNAV angle is to be calculated to the FAF, using a point 50 ft above the LTP elevation, the FAF minimum altitude, and the distance between these two points.

Guidance below MDA: VNAV Path is designed to provide vertical guidance below the MDA to the LTP +50 ft. Descent below the MDA is accomplished in VMC.

Shallow Descent Gradient: If the calculated VNAV angle is less than 2.75°, it will be raised to a minimum of 3°. In some cases, this could mean that the pilot would maintain level altitude after passing the FAF until intercepting the VNAV path.

VASI / PAPI: The VNAV angle should not be less than the angle of the VASI / PAPI. If the VNAV angle is less than the VASI / PAPI angle, the VNAV angle will be raised to a maximum of 3.77°. For 3-bar systems, the angle and the TCH for the upwind bars will apply.

Step Down Fixes: If the calculated VNAV path from the LTP +50 ft to the FAF passes below the minimum altitude of any step down fix the VNAV angle will be increased to pass at or above all step down fix minimum altitudes. In some cases, this could mean that the pilot would maintain a level altitude after passing the FAF until intercepting the VNAV path. Note: Step down fixes are not included in the database.

VNAV Angle Raised Above FAF: When the VNAV angle is raised to the minimum of 3° or when the VNAV angle is raised to ensure clearance at a step down fix, the extended VNAV path will likely pass above the FAF minimum altitude.

Coding Considerations for VNAV path for straight-in:

VDPs: VNAV angles will not be less than the angle fro the VDP to the LTP +50 ft.

NDB vs ILS Approach Angle: When an NDB approach is coded from an LOM, the VNAV angle, the VNAV angle doesn't necessarily match the glide slope angle of the associated ILS. It is usually a slightly higher angle for the NPA.

General Rules for Missed Approach Point (MAP):

The MAP will be the MAP as shown on the non-precision approach procedure by the civil aviation authority. Note: For coding purposes, the MAP will not be relocated to the point where the VNAV path intersects the MDA plane.

Location: If the intent of the procedure designer is to locate the MAP at the LTP and it is within 0.1 nm radius of the LTP, the MAP will be defined at the LTP. Note: If the source document states that the MAP and the LTP are not at the same location even if the distance is 0.1 nm or less, the MAP will not be placed at the LTP.

Identification: The FAA has issued a policy statement which clarifies the identification of fixes at LTPs.

Landing threshold points used as missed approach points will not additionally be given a wpt name.

Wpt names currently assigned to landing threshold points used as missed approach points will be withdrawn.

Missed approach points not at the landing threshold point will be given a wpt name.

Other Coding Considerations: The FAA has issued a policy statement which clarifies the identification of fixes at navaid locations.

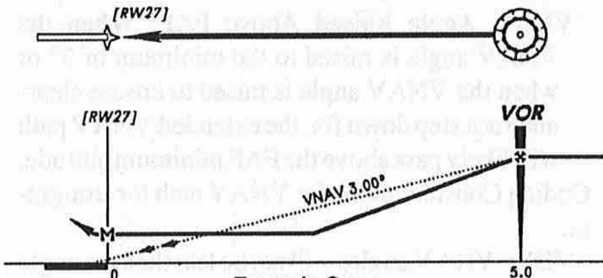
Navaids used as fixes in GPS procedures will not additionally be given a wpt name.

Wpt names currently assigned to navaids used as fixes in GPS procedures will be withdrawn.

GPS procedure fixes not at a navaid location and not at the LTP, will be given a wpt name.

Along Track Distance (ATD) fixes do not have names and will not be named.

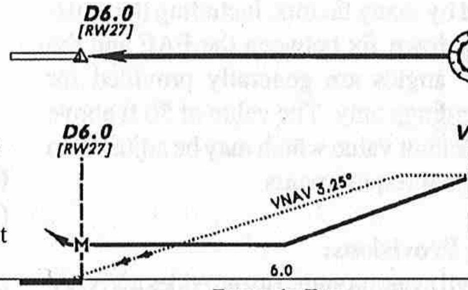
VNAV PATH CONSTRUCTION AND MISSED APPROACH POINT POSITIONS



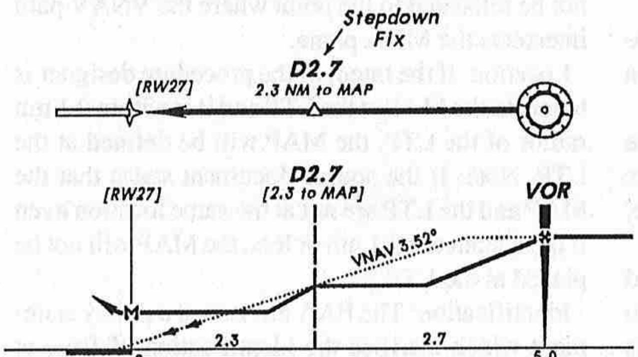
Example One

FAF to MAP at LTP with straight-in landing:
If MAP is at LTP or within 0.1 nm radius of the LTP, MAP is at LTP.
A VNAV angle, calculated from LTP +50 ft to the FAF altitude is provided.

FAF to MAP at LTP with straight-in landing:
If MAP is at LTP or within 0.1 nm of the LTP, MAP is at LTP.
A VNAV angle, calculated from LTP +50 ft to the FAF altitude, raised to an optimum angle of 3.0 or to an angle matching the VASI angle is provided.
Note: In example 2 the VNAV angle could result in a vertical path above the FAF altitude. Airborne equipment would maintain the FAF altitude inbound intercepting the VNAV path inside of the FAF.

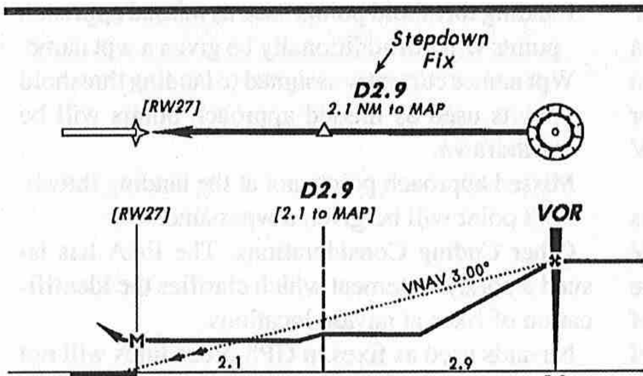


Example Two



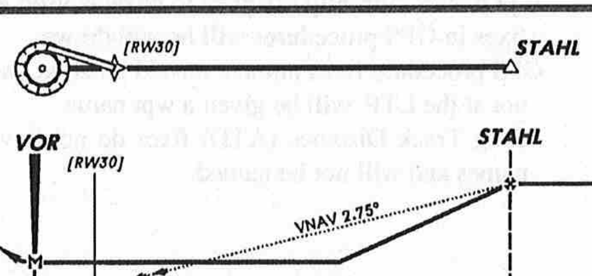
Example Three

FAF to MAP at LTP via a stepdown fix with straight-in landing:
If MAP is at LTP or within 0.1 nm radius of the LTP, MAP is at LTP.
A VNAV angle is calculated from LTP +50 ft to the FAF altitude.
If the VNAV path would pass below the stepdown fix altitude, a VNAV angle is calculated from LTP +50 ft to the stepdown fix altitude and is provided for the complete final approach segment.



Example Four

FAF to MAP at LTP via a stepdown fix with straight-in landing:
If MAP is at LTP or within 0.1 nm radius of the LTP, MAP is at LTP.
A VNAV angle is calculated from LTP +50 ft to the FAF altitude.
If the VNAV path would pass above the stepdown fix altitude, a VNAV angle from LTP +50 ft to the FAF altitude is provided for the complete final aproach segment.

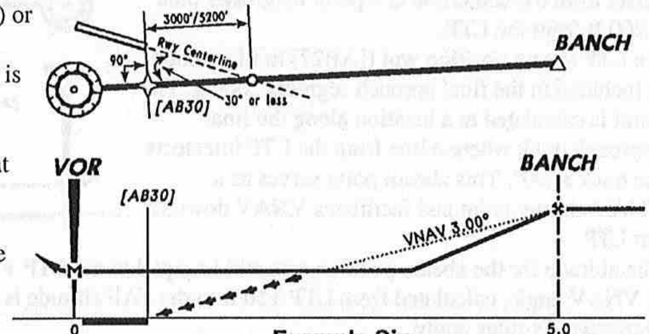


Example Five

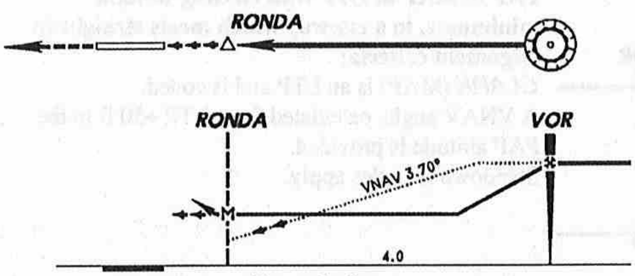
FAF to MAP beyond LTP with straight-in landing:
If final approach segment crosses LTP or within 0.1 nm radius of the LTP, an LTP waypoint ([RW30] in illustration) is included in final approach segment coding prior to the published MAP.
A VNAV angle, calculated from LTP +50 ft to the FAF altitude is provided.
Stepdown fix rules apply.

VNAV PATH CONSTRUCTION AND MISSED APPROACH POINT POSITIONS

FAF to MAP beyond LTP with straight-in landing.
Final Approach segment NOT within 0.1 nm radius of LTP:
Where final approach segment crosses the extended runway centerline within 3,000 ft (off airport facility) or 5,200 ft (on airport facility) of the LTP.
An LTP abeam position wpt ([AB30] in issustration) is included in the final approach segment coding. The point is cacluated at a location on tyhe final aproach track where a line from the LTP intersects the track at 90°. This point serves as a VNAV aiming point and facilitates VNAV down to the LTP +50 ft.
The altitude coded for the abeam position wpt will be equal to the LTP +50 ft.
A VNAV angle, calculated from LTP +50 ft to the FAF altitude is provided with the abeam wpt information.
Stepdown fix rules apply.

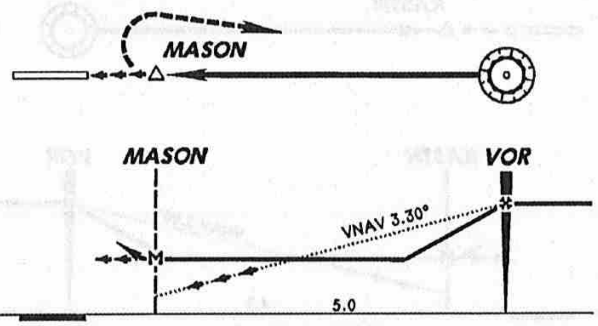


Example Six



Example Seven

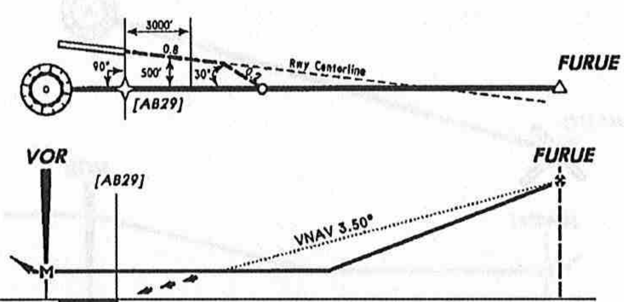
FAF to MAP before LTP with straight-in landing:
The MAP is at the government source location.
A VNAV angle, calculated from LTP +50 ft to the FAF altitude is provided.
Altitude assigned at the MAP wpt is computed using the calculated VNAV angle.
The LTP is not included in the coding as a wpt.
No LNAV or VNAV is provided from the MAP to the LTP.
Stepdown fix rules apply.



Example Eight

FAF to MAP before LTP with straight-in landing:
The MAP is at the government source location.
A VNAV angle, calculated from LTP +50 ft to the FAF altitude is provided.
Altitude assigned at the MAP wpt is computed using the calculated VNAV angle.
The LTP is not included in the coding as a wpt.
No LNAV or VNAV is provided from the MAP to the LTP.
Stepdown fix rules apply.

FAF to MAP beyond LTP with straight-in landing.
Final approach segment NOT within 0.1 nm radius of LTP:
Where the final approach segment crosses the extended runway centerline outside of 5,200 ft of the LTP, but with an offset of 500 ft or less at a point 3,000 ft or less fro the LTP.
An LTP abeam position wpt ([AB29] in illustration) is .ncluded in the final aproach segment coding. The point is calculated at a location on the final approach track where a line from the LTP intersects the track at 90°. This point serves as a VNAV aiming point and facilitates VNAV down to the LTP.
The altitude for the abeam position wpt will be equal to the LTP +50 ft.



Example Nine

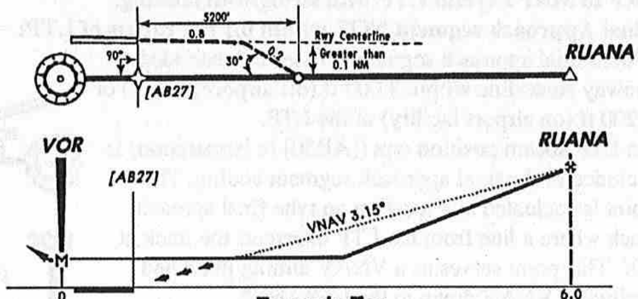
A VNAV angle, calculated from LTP +50 ft to the FAF altitude is provided with the abeam wpt information.
Stepdown fix rules apply.

VNAV PATH CONSTRUCTION AND MISSED APPROACH POINT POSITIONS

FAF to MAP beyond LTP with straight-in landing.
Final approach segment parallel / near parallel to runway alignment:

Where the final approach segment never crosses the extended runway centerline but is more than 0.1 nm offset from the centerline at a point no greater than 5,200 ft from the LTP.

An LTP abeam position wpt ([AB27] in illustration) is included in the final aproach segment coding. The point is calculated at a location along the final approach track where a line from the LTP intersects the track at 90°. This abeam point serves as a VNAV aiming point and facilitates VNAV down to the LTP.

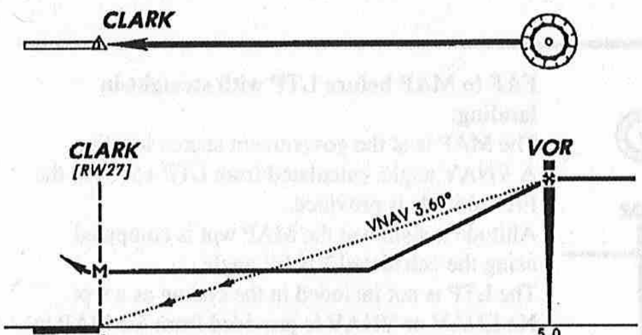


Example Ten

The altitude for the abeam position wpt will be equal to the LTP +50 ft.

A VNAV angle, calculated from LTP +50 ft to the FAF altitude is provided with the abeam wpt information.

Stepdown fix rules apply.



Example Eleven

FAF to MAP at LTP with circling-to-land minimums, to a runway which meets straight-in alignment criteria:

CLARK (MAP) is an LTP and is coded.

A VNAV angle, calculated from LTP +50 ft to the FAF altitude is provided.

Stepdown fix rules apply.

FAF to MAP not at LTP with straight-in landing minimums to a runway which meets straight-in alignment criteria.

The MAP is other than the LTP and is coded.

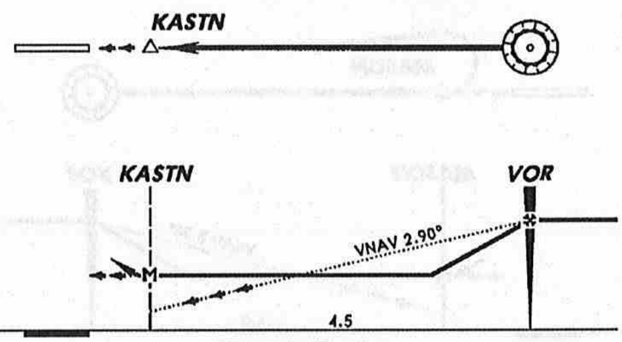
The LTP is not included in the coding as a wpt.

No LNAV or VNAV is provided from the MAP to the LTP. (Note: Some FMS may provide lateral guidance based upon an extended inbound course through the MAP.)

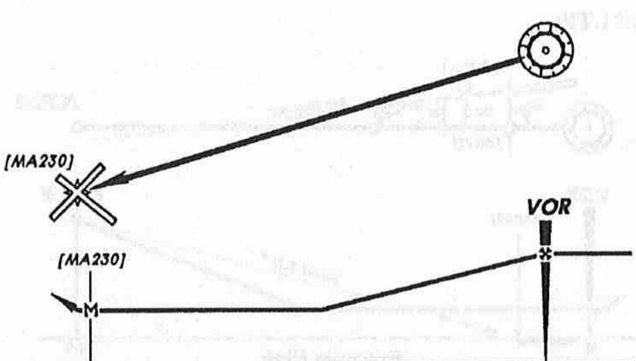
A VNAV angle, calculated from the LTP +50 ft to the FAF altitude is provided.

The altitude assigned to the MAP waypoint is calculated using the calculated VNAV angle.

Stepdown fix rules apply.



Example Twelve



Example Thirteen

FAF to MAP other than LTP with circling-to-land minimums, not aligned with the runway.

The MAP is other than the LTP and is coded.

The VNAV angle is coded from the ARP to the FAF altitude.

INTRODUCTION

If you were to classify descent techniques based on throttle position, there would be two main techniques, *idle throttle descent* and *partial throttle descent*. The *partial throttle* can be further refined to constant angle.

Idle throttle descent:

Tools such as VNAV or LVL CHG will place the throttles at idle in descent. A point in space is calculated where the airplane can begin a long glide to a waypoint down route that contains an altitude restriction. The Smiths FMC can calculate this point very accurately. However, the classic (3-4-5) will fly a high speed VNAV PATH descent better than the Next Generation (600 thru 900). If a high speed descent is needed, VNAV PATH in the next generation airplane may result in VNAV DISCONNECT.

The *idle throttle* descent works best in a situation where the descent path is likely to remain free of ATC interference.

The biggest advantage of using this technique is that the computer calculates the T/D and keeps the airplane on the calculated path; this frees the pilot from making the T/D calculation and requires less monitoring during descent - desirable when you are fatigued or in a high workload environment.

Disadvantages of the *idle throttle* descent technique are steep and sometimes, changing deck angles, faster rate of change in cabin altitude, and no room to meet speed restrictions from ATC without wasting energy (speed brakes). Another undesirable result of using VNAV descent as a habit is that the pilot tends to become complacent in descent calculations.

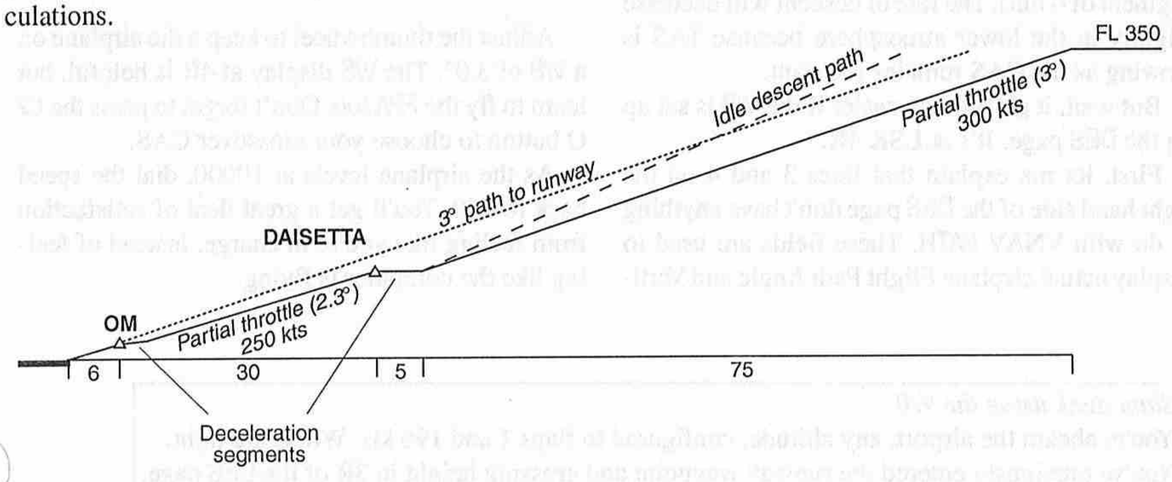
Partial throttle descent:

Using the V/S thumbwheel (MCP), one can select a rate of descent that will maintain a constant angle. The throttles are kept slightly off the idle stops. The top-of-descent will occur earlier than the *idle throttle* technique because some power is used throughout the descent. The airplane is not in a power-off glide configuration. There is no significant fuel savings between *idle throttle* and *partial throttle* descent, especially if the speed brakes are used during an *idle throttle* descent.

The *partial throttle* descent works best in situations where ATC is likely to interfere with speed and/or heading commands, or if a high speed is desired. Other advantages are a more comfortable and constant deck angle, better control of energy or "mass management", resulting in a position to meet speed and route changes without using the speed brakes because your profile does not change. There's also less thermal shock to the engines and it offers a more gradual pressurization change for anyone on board with a head cold. The disadvantage to this technique is that it demands a higher level of monitoring and piloting skill.

Partial throttle-constant angle:

The *partial throttle-constant angle* descent technique uses 3:1 method to calculate distance to descend. This is described on the next page.



Astronauts & engineers: WINDS - GLIDE ANGLE

Minimum glide angle at a given altitude is approximately the same for all weights. If thrust were zero, minimum glide angle would be exactly the same for all weights and would occur by gliding at the maximum lift to drag ratio (Max L/D)

The speed to maintain a minimum glide angle increases with weight. This is necessary since as weight is increased a higher speed is required to keep the same L/D ratio.

Maximum rate of descent is obtained at the highest possible airspeed.

At any constant high speed, the rate of descent is higher for light weights than for heavy weights.

The effect of adding drag by extending the speed brakes or lowering the gear is to increase the rate of descent.

INTRODUCTION

The *Partial throttle-constant angle* descent is set up this way.

Let's assume we're crusing westbound at FL350. There is no significant headwind or tailwind. The restriction down route is 250 kts and 10,000 ft at a waypoint named DAISETTA. It is found on the DAISETTA arrival into Houston Intercontinental from the northeast. If the airplane is cruising at FL350, we have to loose 25,000 ft and then decelerate to 250 kts. Required math:

- Divide the altitude that must be lost by one thousand, then multiply by three.
  25,000 / 1,000 = 25 x 3 = 75 nm.
  Note: If you've got a tail wind greater than 75 kts, multiply by four.
  For the FMC geeks, from this top-of-descent point, the angle, or Vertical Bearing (V/B) to DAISETTA is approximately 3.1°.
- Let's use a descent crossover speed of 300 kts.
- In this example, a deceleration segment is required because the clearance includes a 250 kts speed restriction. The 737 requires slightly less than a mile per ten kts of airspeed to decelerate in no wind, so add 4 nm to slow from 300 to 250. Now the top-of-descent point (T/D) is 79 nm from DAISETTA.
- Just prior to reaching the T/D, we'll roll the thumbwheel over and smoothly start our descent. But what rate to select? Take the groundspeed, divide by two, add a zero and 10%.

Example: Ground speed of 440 divided by two is 220. Add a zero and 10% makes 2400 fpm. This is your initial V/S selection. Continually re-check your position during the descent (3:1 plus the decel segment of 4 mn). The rate of descent will decrease slightly in the lower atmosphere because TAS is slowing as the CAS remains constant.

But wait, it get's much easier if the V/B is set up on the DES page. It's at LSK 4R.

First, let me explain that lines 3 and 4 on the right hand side of the DES page don't have anything to do with VNAV PATH. These fields are used to display actual airplane Flight Path Angle and Vertical Bearing with required Vertical Speed to cross the entry at LSK 3R. Dave Gorrell has named this the "angle calculator".

If the LEGS page has the restriction of 10,000 ft at DAISETTA, the DES page will look something like the one on page 157. See how steep the V/B (think angle) is for an idle descent. (3.9°).

Let's set up for a constant angle descent similar to the 3:1 technique.

We're going to use the V/B indicator to determine when to roll the nose over, but it does not consider a deceleration segment. If you need a decel segment, build a waypoint this side of the restriction using the Along Track Offset method (DAS/-4). It will appear as DAS01. Don't leave it in the LEGS page because it might confuse your teammate.

You've added DAS01 to the temporary database.

Manually enter DAS01/10000 in 3R of the DES page. Now you're looking at the angle (V/B) to that wpt 4 nm this side of DAISETTA.

When the V/B from DAS01 indicates 2.9°, smoothly dial the thumbwheel to that indicated by the V/S at 4R. This places the nose at a FPA of 3.0°, matching the V/B. It will be around 2200 fpm in light winds. (see CDU below)

M.760 PATH DES	1/1
E/D ALT	AT HOAGI
1997	250 / 10000
TGT SPD	TO T/D
.760 / 300	1318z / 10 NM
SPD REST	WPT / ALT
240 / 10000	HOA01I / 10000
	FPA V/B V/S
	0.0 3.0 2228
	SPEED >

Adjust the thumbwheel to keep a the airplane on a V/B of 3.0°. The V/S display at 4R is helpful, but learn to fly the FPA too. Don't forget to press the C/O button to choose your crossover CAS.

As the airplane levels at 10000, dial the speed back to 250. You'll get a great deal of satisfaction from feeling like you're in charge, instead of feeling like the computer is flying.

Slam-dunk using the V/B

You're abeam the airport, any altitude, configured to flaps 1 and 190 kts. Winds are light. You've previously entered the runway waypoint and crossing height in 3R of the DES page. Abeam the runway, you're cleared for the visual. Set the MCP to 1000 AFE, call for gear down, flaps 10, check the speed at 190 kts, spin the thumbwheel, and press LVL CHG. When the V/B indicates 8°, turn to base leg. As you transition through the base leg, slow to 170 and configure to flaps 15; the V/B will be approximately 4.5°. As you turn to final, slow to approach speed and configure for landing. Expect the V/B to be approaching 3.8°. As you continue your descent to the runway you'll catch the desired V/B of 3°.

DES

You get to this page by:

- DES key.
- Automatically displayed at top-of-descent when an active CRZ page displayed, path descent mode is available, and MCP altitude is set below cruise altitude.
- CRZ DES page PLANNED DES prompt (LSK 5R)

NO REQUIRED ENTRIES

- May be used during preflight, climb, cruise, or descent to evaluate or EXECute (for immediate or planned use) one of the standard descent modes.
- DES page defaults to ECON PATH DES.
- Three descent modes are available: ECON (PATH or SPD), Manually selected speeds, or RTA.

- Idle descent speed calculated to meet the first altitude constraint on the LEGS page.
- Target Mach highlighted above crossover alt.
- Target CAS highlighted below crossover alt.
- During descent, CAS will increase and at some point equal and exceed the active Mach. Crossover will then occur. In this example crossover will occur when M.745 is exceeded by CAS of 295 kts.
- ECON descent Mach is set equal to the final ECON cruise mach. The ECON descent CAS values are derived as a function of CI entry.
- VNAV PATH is not suppose to exceed the barber pole; however during the time it takes to pitch up, you may exceed the limit enough to set off the clacker.

U10.2: Reverts to LVL CHG 7 kts prior to VMO/MMO. 10.5: 1 kt. prior to VMO/MMO.

- Max: 12 kts below VMO/MMO.

AT XXXXX

- For a PATH DES: displays the next wpt which has an altitude restriction. Propagated from the LEGS page.
- Blank if no downpath altitude restriction.
- Blank for SPD DES.

TO T/D

- With E/D altitude entered: PATH and SPD DES display ETA and distance to T/D.
- With no E/D altitude entered: PATH DES is blank SPD DES displays ETA and distance to T/D based on SPD DES criteria. TO T/D ADVISORY displayed for U1.x
- Blank if distance greater than 999 nm.
- If an intermediate level-off has occured, displays values for the upcoming intermediate T/D point. TO T/D-XXXX

E/D ALT is the last of the following not preceeded by a discontinuity:

- glideslope intercept point for precision approache or FAF for a non precision approach,
- lowest altitude constraint including the runway threshold altitude,
- threshold crossing height for the runway, or
- missed appraoch point (MA-XX) altitude constraint.

ECON PATH DES	1/1
E/D ALT	AT DAS
10000	250 / 10000
TGT SPD	TO T/D
.745 / 295	1318.5z / 5 NM
SPD REST	WPT / ALT
240 / 10000	DAS / 10000
	FPA V/B V/S
	0.0 3.9 2508
------------	------------
	SPEED >
< FORECAST	DES NOW >

Prior to top of descent

- Input for V/B calculator.
- Wpt and altitude constraint propagates from LEGS page.
- Manual entry permitted
- A manual entry does not drop out after wpt is sequenced - must be manually deleted.
- U10.5 - Allows entry of destination runway. TCH fills in automatically.

Also known as *airport speed restriction.*

- The FMC assumes value of 240 kts below 10,000' (10 kt margin).
- During approach phase, displays XXX/ FLAPS, where XXX is the appropriate flap maneuvering speed.

Intended for early descents (prior to T/D). Execution of DES NOW (formerly called CAPTURE) causes the DES page to become ACTive. An early descent at 1000'/min will commence at the TGT SPD until intercepting the computed path. Three things remove this prompt; FMC already in descent, active leg has a GP angle, or there is no hard alt constraint between you and the next GP angle.

PATH DES

VNAV PATH uses idle thrust and pitch control to maintain a vertical path, similar to a glideslope in 3 dimensions, except there is no ground-based beam. The TGT SPD is used for "planing purposes" only. There is no attempt to maintain the TGT SPD unless the airplane gets too slow.

VNAV PATH descent is slaved to the Path. **It is the pilot's responsibility to control the speed.** If unforecast winds are encountered you may have to intervene. Throttle up if a headwind lasts longer than expected or dive and/or apply speed brakes if a headwind component is less than predicted.

VNAV descent is automatically initiated at T/D if a lower MCP altitude has been selected. The computed profile terminates at the altitude restriction on the LEGS page. A path can be computed **only** if a mandatory "at" altitude restriction is specified.

Example: HOAGI at 10000 ft.

VNAV PATH, SPD, and the RNP

Picture yourself in LNAV and VNAV, descending early (DES NOW) out of cruise altitude per ATC instructions. You're coming downhill at 1000 fpm.

ATC: ***"Barnburner 502, turn right 10 degrees, vectors for descent."***

You press HDG SEL and if you're in a U4 or lower machine, VNAV disconnects. A U5 to U10.3 FMC will revert to VNAV SPD DES at some point!

With U7.1 and up, you will maintain VNAV PATH until the XTK ERROR exceeds the RNP. With 10.3, VNAV PATH will revert to VNAV SPD when XTK ERR exceeds two times the RNP. When the XTK ERR exceeds the RNP, PATH reverts to SPD. If you perform an INTC LEG TO function while in descent, PATH will revert to SPD because the XTK ERR is probably greater than the RNP. The PATH> prompt will reappear when the XTK ERROR is less than the RNP. For smooth operation, engage V/S while monitoring the VERT DEV in this situation.

U7.2 and up: After the intercept function is performed, engage LNAV. A dashed magenta line extends to the intercept route and VNAV PATH can now be re-engaged.

- For ACT SPD and PATH DES, present vertical deviation from the computed vertical path appears after top-of-descent.
- Blank if DES not active.
- Updates to the computed path are performed periodically during stable state conditions, or whenever an entry is made, and every 15 sec. in early (DES NOW) or late (> 750' above path) descent.
- Pressing VNAV or LNAV from OFF to ON may produce an updated display.
- Do not use after an intercept to a wpt on the runway centerline unless LNAV is engaged; VERT DEV is referenced to the lateral path that existed at the time of execution.

ACT ECON PATH DES 1/1

E/D ALT	AT HOAGI
1997	250 / 10000
TGT SPD	TO HOAGI
.740 / 280	1328.5 z / 72 NM
SPD REST	WPT / ALT
240 / 10000	HOAGI / 10000
VERT DEV	FPA V/B V/S
0 FT	2.7 2.6 2720

U1.3 & up

Autothrottle will re-enter the FMC SPD to capture the speed when the a/s falls to more than 15 kts below target.

- Flight Path Angle is the present angle of the aircraft relative to the horizon.
- Displayed on descent.
- The FPA must be equal to or greater than the V/B to meet the req'd restriction in 3R.
- Max descent FPA for predicting interception of the vertical path is 7° when > 1000' above the airport speed restriction altitude (SPD REST at 3L of DES); otherwise 6 °.

Vertical Bearing (angle) from present position direct to wpt in WPT / ALT line 3R.

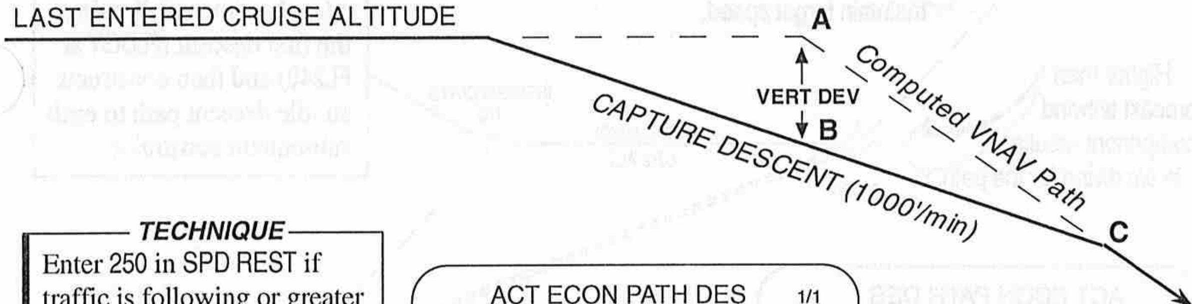
- V/S is the Vertical Speed req'd to fly the vertical bearing based on present groundspeed.
- Does not figure a deceleration segment if one is needed.
- In other words, it's the V/S required to make the restriction in 3R, at the present speed.
- Another good source to monitor during descent if using the MCP, and very useful when pointed straight at the runway.
- Blank if no WPT/ALT entry on line 3R.
- This data is based on a straight line (GC) to the wpt in 3R.

Astronauts & engineers - Modification During Descent

The flight plan modifications entered and executed during the active descent result in the FMC flying the old flight plan until it completes path predictions for the new flight plan. The FMC will fly the old flight plan for no more than 60 seconds while waiting for the new path predictions. If after 60 seconds path predictions for a new flight plan have not been completed, VNAV disengages. This is to protect against possible violation of new constraints in the new plan. Failure to complete path predictions within 60 seconds can be a result of multiple bypasses in descent or insufficient time between crew-entered modifications.

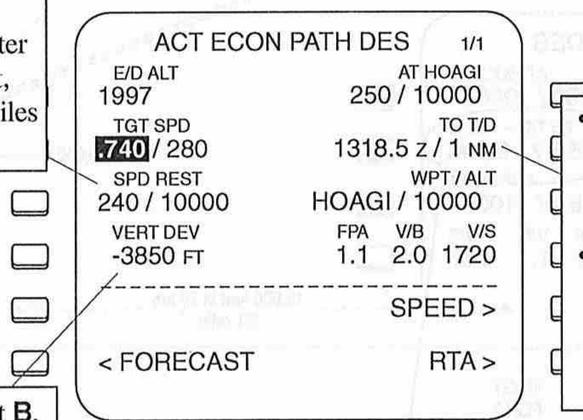
PATH DES (continued)

In this example, ATC wants you to start down early.
Start the descent by using CAPTURE.



TECHNIQUE

Enter 250 in SPD REST if traffic is following or greater than 3:1 ratio to the airport, i.e., when you're still 40 miles from the airport.

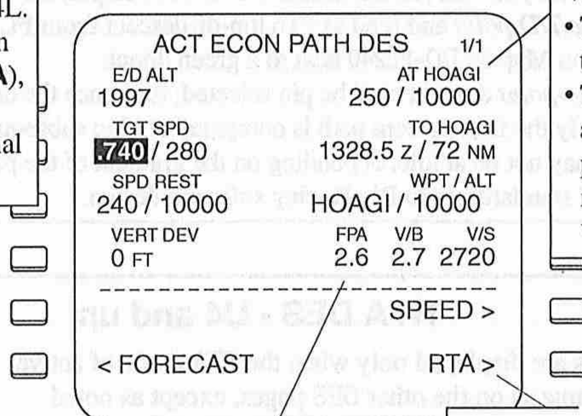


- Don't be fooled. In one mile you'll be at **B**; the throttles are not going to go to idle.
- You are actually 3850' below your path. In fact, the original T/D is about 3850' over your head.

As the a/c approaches point **B**, the VERT DEV from the original computed path is shown on 4L. The deviation will increase in value until passing the T/D (**A**), and will then decrease and become zero when the original path is captured at **C**.

View passing T/D

- The aircraft intercepts the FMC path.
- Throttles go to idle and the aircraft pitches down to maintain the computer VNAV PATH.



CI Crossover speeds

(3-4-5)	(6-7-8)
0 = 250	20 = 270
28 = 280	36 = 280
34 = 291	45 = 290
39 = 300	54 = 300
41 = 311	63 = 310

- Full speed brakes at 320 kts produces a FPA just under 5°.

U 4.0 & up

- Displayed anytime DES NOW (CAPTURE) or ERASE prompt is not displayed.
- Allows line selection of RTA PROGRESS page.
- DES NOW (CAPTURE) prompt will not be available unless a restriction exists on the LEGS.

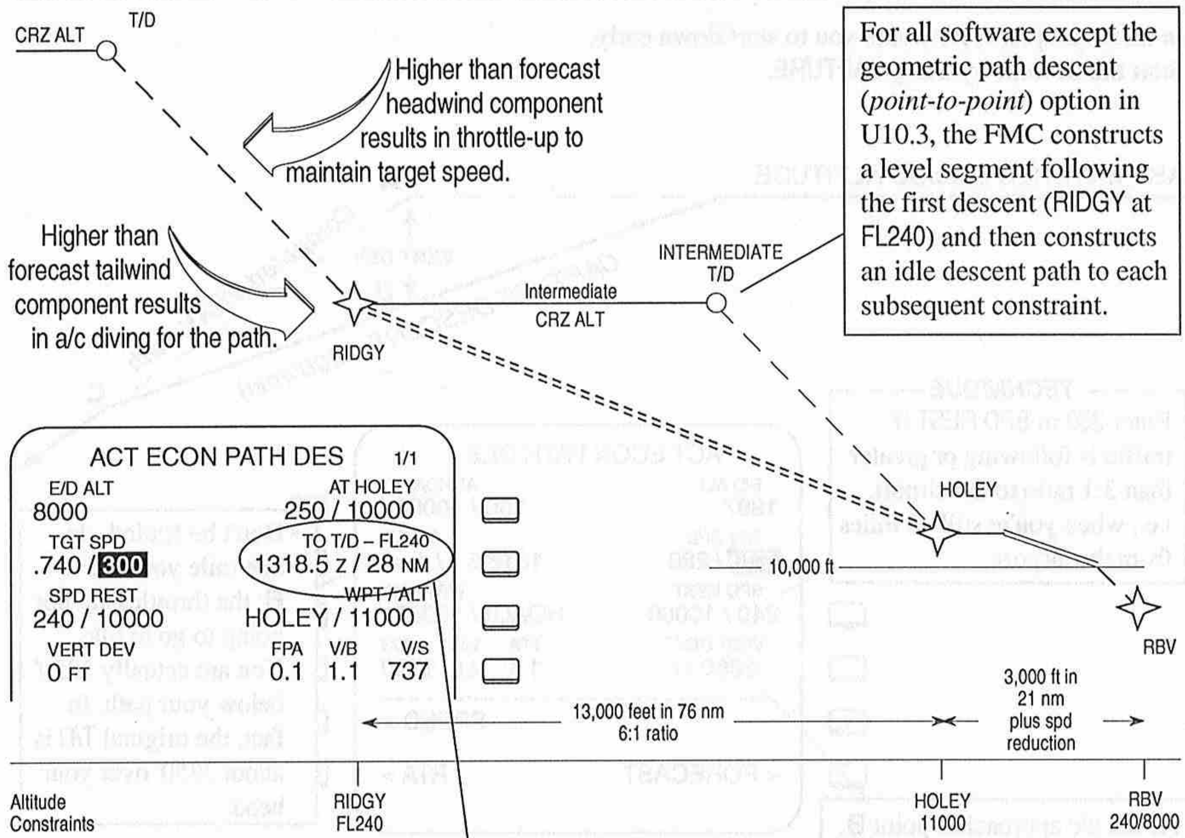
If the aeroplane is inbetween the FMC TGT ALT and the MCP altitude, VNAV cannot be engaged.

Astronauts & engineers - Descent Path Construction

For path descents, a speed profile is first predicted and stored by waypoint. In this context, "waypoint" can include fixed and floating lateral waypoints, as well as phantom waypoints associated with the vertical plan. Each pair of consecutive waypoints forms a segment of the descent speed profile, with a stored speed for each waypoint. When the speed changes in a segment, a gradient is calculated and used to change the target speed linearly as a function of the distance between waypoints. The most significant application of this gradient, in path descents, is in the deceleration segments at 10,000 ft (deceleration to 240 kts to permit a 10 kt margin to the 250 kt restriction) and at approach altitude (deceleration fo flap extension schedule airspeeds).

As the descent profile is actually being flown, the vertical deviation from the reference path is used to adjust the target speed when the aircraft is above the path. This adjustment recognizes that excess energy is inherent in the aircraft position above the path, and compensates the target speed accordingly.

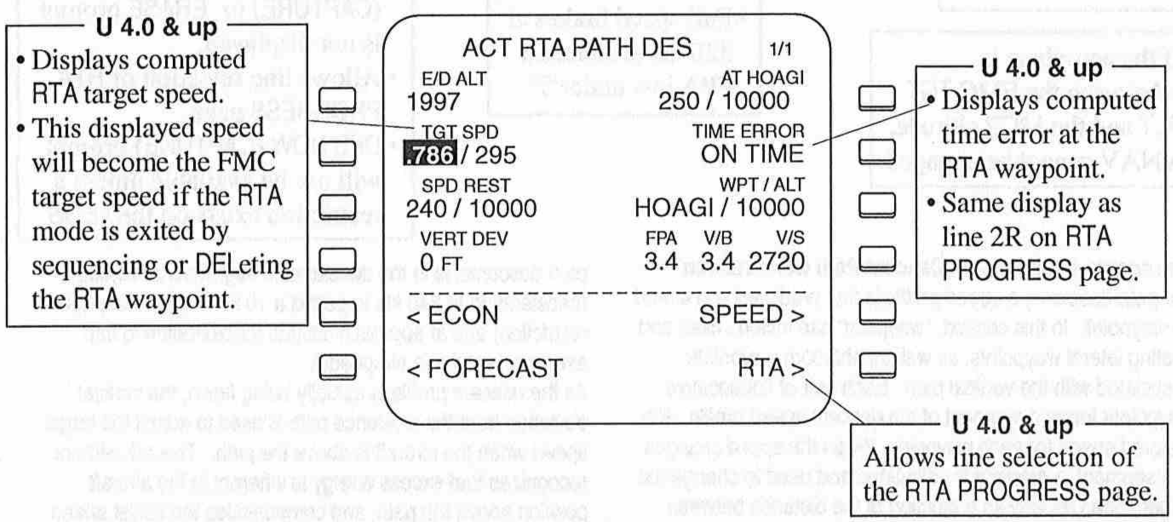
Intermediate Top-of-Descent Points



- At intermediate level offs you will see the header T/D–XXXXX displayed.
- This is an *intermediate T/D point* and read as "To top-of-descent **from** FL 240".
- U7.2/8.1: Displayed on Map as T/D–FL240 next to a green donut.
- U10.3 Option: *Point-to-point* descent may be pin selected; reference the double dashed line above. Only the first descent path is computed at idle; subsequent descent legs may or may not be at idle, depending on the gradient of the path. Smoother descent and standardizes to Big Boeing software design.

RTA DES - U4 and up

– RTA Descent pages are displayed only when the RTA mode of active.
– Displays are the same as on the other DES pages, except as noted.



Maintaining Vertical Path On a Heading Clearance

This lesson discusses the problem of maintaining the desired idle descent vertical path after ATC assigns a heading during descent.

A workaround is available under certain situations.

Assume you're 20 nm from the top-of descent inbound to College Station and planning the COAST ARRIVAL to Houston, Intercontinental.

We'll use three different examples:

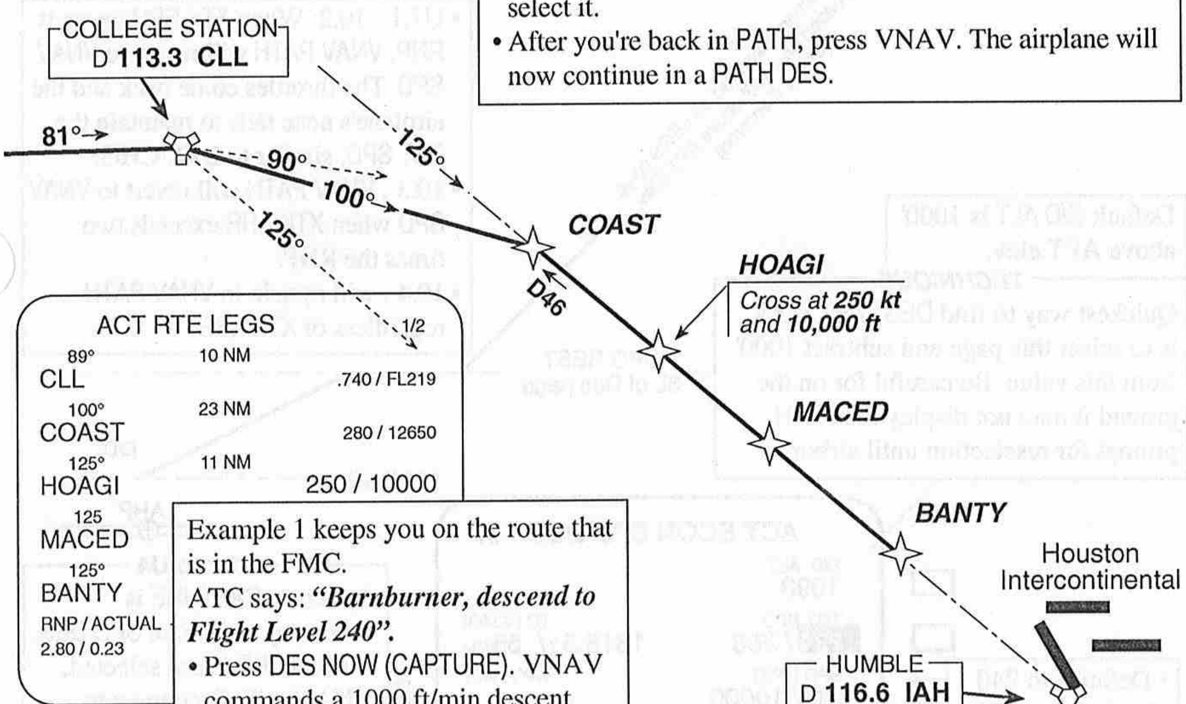
Example one keeps you on the active route; example two puts you on a heading that allows an interept to be built; and example three has you on a heading that does *not* allow an intercept.

Example 2 takes you off the active route but allows an intercept.

ATC: ***"Barnburner, fly heading zero nine zero, vectors for spacing, descend to Flight Level 240".***

The workaround for U7.2 and up is:

- Dial 090 in the MCP and select HDG SEL.
- Set 240 in the ALT SEL and select V/S 1000 fpm.
- Do an intercept to COAST on the 125 inbound course. When the airplane rolls out on the 090 heading, press LNAV. (A problem with this workaround is that you've entered a command into the FMC that may not match the clearance - the intercept.)
- After engaging LNAV, a dash/dot magenta line will extend from the a/c symbol to the solid magenta line. This is called the *capture path.* It requires LNAV to be engaged. VNAV PATH references this capture path.
- Check the DES page to ensure PATH is in title. If the title says SPD DES, check LSK 5R for the PATH> prompt and select it.
- After you're back in PATH, press VNAV. The airplane will now continue in a PATH DES.



ACT RTE LEGS 1/2

89°	10 NM	
CLL		.740 / FL219
100°	23 NM	
COAST		280 / 12650
125°	11 NM	
HOAGI		250 / 10000
125		
MACED		
125°		
BANTY		
RNP / ACTUAL		
2.80 / 0.23		

Example 1 keeps you on the route that is in the FMC.

ATC says: ***"Barnburner, descend to Flight Level 240".***

- Press DES NOW (CAPTURE). VNAV commands a 1000 ft/min descent until capturing the computed path to cross HOAGI at 10,000 ft.

ACT ECON PATH DES 1/1

E/D ALT	AT HOAGI
151	250 / 10000
TGT SPD	
.740 / 280	1328.5 Z / 50 NM
SPD REST	WPT / ALT
250 / 10000	HOAGI / 10000
VERT DEV	FPA V/B V/S
0 FT	2.9 2.8 2700
	SPEED >

Example 3.

ATC says: ***"Barnburner, fly heading one two five, vectors for traffic, descend to Flight Level 240".***

There is no workaround in this situation because it's tough to build a route to keep the airplane in LNAV.

- A good technique is to use V/S, using the FPA, V/B, V/S information on the DES page. This is an excellent skill to develop but takes practice.
- Monitor your 3:1 altitude vs distance ratio to your target (HOAGI).

In a SPD DES, the FMC uses idle thrust and pitch to maintain a target descent speed, similar to a Level Change descent. SPD DES is not path constrained; i.e. if above the path, select speed brakes or increase the TGT SPD.

The FMC protects altitude constraints from missing on the low side only in U5 and up (MCP alt. setting will always stop descent if higher than the FMC restriction) and warns the pilot if constraints will be missed on the high side.

A path prediction is computed and the VERT DEV from this path is displayed.

FMC predictions assume a path from the ARP or the rwy (if entered) at 3° to 1500', then on a path based on the target speed. Speed on final is programmed to be the value in line 3L, so transition to the MCP after the airplane transitions to this SPD REST.

LVL CHG vs SPD DES

- LVL CHG is *heads up* - SPD DES is *heads down.*
- Spd changes are more easily made in LVL CHG.
- In SPD DES, VNAV will stay engaged.
- In SPD DES, the airspeed will automatically reduce to SPD REST in line 3L.
- SPD DES will warn the pilot, via s/p message, if a restriction will not be met.

- **SPD DES** adheres strictly to the speed in line 2L and 3L.
- Will not vary and **may** or **may not** make a crossing restriction.

- **PATH DES** guarantees crossing altitude (HOAGI at 10,000').
- Will vary the pitch angle to make the altitude, sacrificing speed in the process. The pilot is responsible for speed control.

T/D

If no restriction is entered on LEGS page, T/D is based on 1000' above APT Elev. (or rwy if entered)

- U7.1 - 10.2: When XTK ERR exceeds RNP, VNAV PATH will revert to VNAV SPD. The throttles come back and the airplane's nose falls to maintain the TGT SPD, similar to LVL CHG.
- 10.3 : VNAV PATH will revert to VNAV SPD when XTK ERR exceeds two times the RNP.
- 10.4 : will remain in VNAV PATH regardless of XTK ERR.

SPD REST
3L of Des page

E/D

1000' AGL

ARP

Default E/D ALT is 1000' above APT elev.

TECHNIQUE

Quickest way to find DEST APT ELEV is to select this page and subtract 1000' from this value. Be careful for on the ground it may not display the PATH prompt for reselection until airborne.

ACT ECON SPD DES 1/1

E/D ALT	
1098	
TGT SPD	TO HOAGI
734 / 268	1318.5z/ 55NM
SPD REST	WPT / ALT
240 / 10000	-----/-----
VERT DEV	FPA V/B V/S
-110 FT	3.0
<ECON	PATH>
<FORECAST	CAPTURE>

- Defaults to 240 kts below 10000.
- Next wpt altitude for flap-related speed restriction.

U1.x to U4

Selecting CAPTURE is necessary to initiate SPD DES. If CAPTURE is not selected, VNAV will disconnect to CWS PITCH.

U 5.0 & up

Descent is automatically started when T/D is reached if MCP altitude is set below current altitude.

TECHNIQUE

Here's an old Jedi trick. It's the simplest descent technique available. In this example, the destination (Tuscon, Az) has no altitude restrictions or arrival routing. Enter the approach (marker, GS-11 and RW11) and leave the DISCO in the LEGS page.

ATC: ***"DeHavilland Comet, pilot discretion to 8000 ft."***

If approaching the airport toward the landing runway, start down about 8 nm prior to T/D. If circling to land, start down at T/D. After the FMC transitions to SPD REST (10,000 ft), "go tactical" by selecting MCP LVL CHG. You'll turn over the marker and bring the throttles up at 1,000 ft AGL.

DISCUSSION - The following is presented as an educational sample

If a restriction 35 nm from the airport does not exist, it might be useful to create one. Assign 250 kts / 10,000 to it. Forty out at 10,000 and no speed restriction works too. Make sure your wpt is measured from the runway, and not the Airport Reference Point! (El Paso's RW26 is a good example)

Normally, build a route to the FAF and enter the desired speed and altitude. Examine all intermediate predicted altitudes. Enter only necessary crossing restrictions. Try not to enter altitude constraints higher than those predicted, using instead the MCP as the altitude limiter.

You'll see techniques such as building a wpt 5 miles in front of the constraint but generally the 737 FMC does an excellent job at predicting the T/D point. It is only when unforecast winds enter into the equation that the path becomes too steep (exceeding predicted speed) or shallow (throttle up).

EFIS aircraft have provisions on the DES FORECAST page to enter lower-level winds. This creates several shorter linear equations, which results in a more realistic wind model than one created with one long linear equation as discussed on the next page. This allows the FMC wind model to be more accurate when coming out of the jet stream, which is when you should use these entries.

For aircraft without the DES FORECAST feature, the following technique can be helpful when the altitude restriction is combined with a speed restriction.

Before the top-of-descent is reached, check the actual wind at altitude and forecast lower level winds. If you are coming out of the jet stream and winds at lower altitudes are light, choose one of the techniques below.

Descending westbound out of the jet: Problem: as the headwind is lost, the aircraft will be in a position with lots of excess energy - high and fast.

- Enter a wpt 4-5 miles prior to the first restriction and enter the same restrictions. As you loose the high headwind, delete the created waypoint (use V/S during re-computations).

OR

- Enter an altitude approximately 500 ft lower than the clearance. Protect yourself by entering the clearance altitude in the MCP. The MCP will act as your limiter.

OR

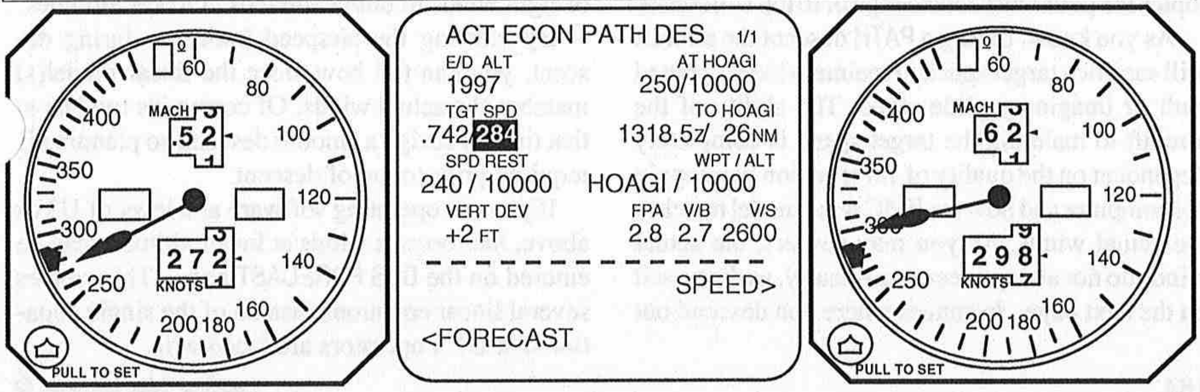
- Start the descent 4-5 miles early using LVL CHG. Keep the VERT DEV (line 4 on the DES page) around 1000' below your computed path. As you come out of the excessive headwind, you will close on your computed path. Transition to VNAV.

OR

Descending eastbound out of the jet: Problem: as tailwind is lost, aircraft is in a position similar to starting down too early and will pitch up to maintain the path. Speed will drop off, and in newer software, throttles will come up, wasting energy. Example.

Start down a few miles beyond the computed descent point! The path will be captured, but with excess energy (exceeds the computed speed). As the high tailwind is lost, this excess energy will trade off.

This is a view of the DES page and airspeed indicators during a situation in which (**left**) the actual tailwind is less than (or headwind is more) and (**right**) actual tailwind is more than (or headwind is less) the FMC wind model. In PATH DES, the path is maintained at the expense of speed.

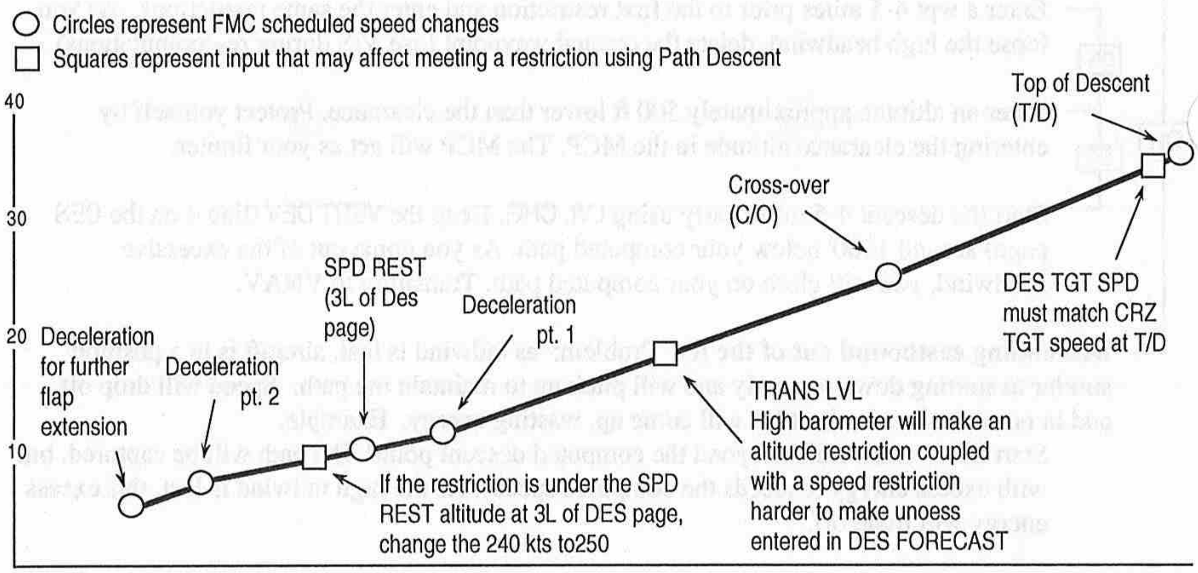


Astronauts & engineers

The path computation processing always proceeds by individual phases, even though a complete profile of takeoff, climb, cruise, and descent phases may be required. Phase by phase, profile predictions compute the required parameters at waypoints, leg by leg, and assemble the lateral and vertical segments into the flight plan navigation legs which are displayed on the CDU.

First step - **Cruise Prediction:** The sequence of waypoints in the computation process is in the normal or forward direction. Initially, the top of descent is unknown. The first cruise predictions are performed for a cruise without a T/D and terminate at an imaginary end of cruise. This is the first waypoint in descent which is allowed to have a speed and altitude restriction and is determined by a rough estimate of distance from the destination. This estimate is designed to ensure that the imaginary end of cruise will always precede the T/D.

Second step - **Descent Prediction:** For initial predictions of all descent modes, the path computation sequence begins with the last waypoint pair in the flight plan and preceeds backwards, to establish the location of T/D. To do this, the approximate location of T/D is estimated, without regard for speed or altitude restrictions, to obtain a speed schedule and path gradient in descent, and a final fuel -remaining estimate. Range in descent is first estimated from the altitude change in descent and an assumed flight path angle constant. Subtracting the range in descent from the total range provides the first estimate of T/D location. This allows for a "cruise with a T/D" calculation of fuel remaining and speed at T/D. Next, the estimated fuel remaining at T/D and wind profile are used to estimate descent range, speed schedule, path gradient, and final fuel remaining. This calculation of range is compared with the initial estimate to determine whether they agree within .5 nm. If not, the second calculation of descent range is used to make another estimate of fuel at T/D, and this new fuel value is used to make a third calculation of range. Then the full leg prediction is commenced using the last set of calculations, leg by leg, backward from the terminal waypoint. This determines a "descent T/D" and a value of predicted fuel remaining. Now the cruise prediction can be completed, forward from the imaginary end of cruise to "cruise T/D", giving another prediction of fuel remaining at T/D. The accuracy of the T/D location is tested by comparing the two values of fuel remaining. If the difference exceeds 1,000 pounds, the descent processing is repeated using fuel remaining and speed at T/D. Then the complete backward descent prediction is repeated using the new final fuel, speed, and path gradient. This process is repeated until predicted values of fuel remaining at "cruise T/D" and the "descent T/D" agree within 1000 pounds. The difference in the two estimates is added to predicted fuel remaining at descent waypoints.



The drawing above represents the FMC computed descent speed schedule and discusses some topics the pilot must consider prior to top of descent.

As you know, during a PATH descent the aircraft will sacrifice target speed to maintain the computed path or imaginary glide slope. The ability of the aircraft to maintain the target speed is completely dependent on the quality of information you supply the computer and how the FMC wind model matches the actual winds. As you may suspect, the actual winds do not always decrease linearly, as discussed on the next page. Instances where you descend out of the jet stream to light winds at lower altitudes do not fit the model. Another example is a descent out of light winds to tail/headwinds at lower altitudes.

By viewing the airspeed indicator during descent, you can tell how close the linear model(s) matches the actual winds. Of course it's too late at that time to design a smooth descent, so planning is required prior to top of descent.

If you are operating software at a level of U3 or above, the forecast winds at lower altitudes can be entered on the DES FORECAST page. This creates several linear equations instead of the single equation that U1.x operators are faced with.

LINEAR WIND DATA

The following data was constructed from linear equations using sample winds at different intervals to zero at the surface.

Comparing the computer generated wind model to forecast descent winds leads to a more precise control over choosing top of descent; helpful when a speed restriction exists at the bottom of descent. The FMC wind model does not fit actual winds when descending out of the jetstream.

LINEAR WIND MODEL ANALYSIS

ax+by+c=0   ax=by-c   x=(-b/a)x

Altitude	36x=175y x=175y/36	36x=150y x=150y/36	36x=125y x=125y/36	36x=100y x=100y/36	36x=82y x=82y/36	36x=75y x=75y/36	36x=62y x=62y/36	36x=50y x=50y/36	36x=36y x=36y/36	36x=25y x=25y/36	36x=12y x=12y/36
41000	199	171	142	114	93	85	71	57	41	29	14
39000	190	163	135	108	89	81	67	54	39	27	13
37000	180	154	129	103	84	77	64	51	37	26	12
35000	170	146	122	97	80	73	60	49	35	24	12
33000	160	138	115	92	75	69	57	46	33	23	11
31000	151	129	108	86	71	65	53	43	31	22	10
29000	141	121	101	81	66	60	50	40	29	20	10
28000	136	117	97	78	64	58	48	39	28	19	9
27000	131	113	94	75	62	56	47	38	27	19	9
26000	126	108	90	72	59	54	45	36	26	18	9
25000	122	104	87	69	57	52	43	35	25	17	8
24000	117	100	83	67	55	50	41	33	24	17	8
23000	112	96	80	64	52	48	40	32	23	16	8
22000	107	92	76	61	50	46	38	31	22	15	7
21000	102	88	73	58	48	44	36	29	21	15	7
20000	97	83	70	56	46	42	34	28	20	14	7
19000	92	80	66	53	43	40	33	26	19	13	6
18000	88	75	63	50	41	38	31	25	18	13	6
17000	83	71	59	47	39	35	29	24	17	12	6
16000	78	67	56	44	37	33	28	22	16	11	5
15000	73	63	52	42	34	31	26	21	15	10	5
14000	68	58	49	39	32	29	24	19	14	10	5
13000	63	54	45	36	30	27	22	18	13	9	4
12000	58	50	42	33	27	25	21	17	12	8	4
11000	54	46	38	31	25	23	19	15	11	8	4
10000	49	42	35	28	23	21	17	14	10	7	3
9000	44	38	31	25	21	19	16	13	9	6	3
8000	39	33	28	22	18	17	14	11	8	6	3
7000	34	29	24	19	16	15	12	10	7	5	2
6000	29	25	21	17	14	13	10	8	6	4	2
5000	24	21	17	14	11	10	9	7	5	4	2
4000	19	17	14	11	8	8	7	6	4	3	1
3000	15	13	10	8	6	6	5	4	3	2	1
2000	10	8	7	6	4	4	3	3	2	1	1
1000	5	4	4	3	2	2	2	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0

HOW TO USE CHART

Situation: Path Descent westbound out of the jetstream. Headwinds at your Flight Level (350) are 97 kts.

Examine your forecast winds at lower levels. Let's assume your flight plan prints these winds at 14,000' at 20 kts on the nose.

From the table above, the FMC headwind component at 14,000' is predicted to be 39 kts.

You can therefore, expect to have excess energy upon your arrival into the lower atmosphere (indicated by the airspeed needle being above the bug).

The excessive speed is required to stay on the path. It is no problem if you have no speed restriction awaiting you at the bottom. But if you must meet a speed restriction, consider a method of selecting an earlier T/D as discussed on page 92, or devise one of your own. (Just let me know if its a good one).

Rule of thumb: To calculate a linear wind at lower altitudes, divide your winds at cruise by 3 and add 10%.

TECHNIQUE

Occasionally you'll find yourself in the position of being on the computed vertical path but fast. One instance where this is very common is on a PATH DES with a dog-leg to the restricted waypoint and suddenly being cleared direct to this waypoint!

On a PATH DEScent, the FMC will prioritize path over airspeed. If it becomes doubtful you'll make the speed restriction, here are two techniques that make use of the rule *parasitic drag increases with the square of the velocity* (increased drag will increase energy dissipation rate.)

- Leave the airplane in VNAV PATH. Since the airplane is slaved to the path to meet the altitude restriction on the LEGS page, all you need to do is regain control of the speed; simply deploy the speed brakes until the actual CAS matches the target speed.
- Select LVL CHG and a high speed. This is called *dialing in drag*. Use the speed brakes if necessary; they will create more drag the faster you are traveling.
- These techniques result in a steeper gradient because the CAS is higher.
- If you really need to descend fast, consider the spiral where high speed drag can be retained while wasting large amounts of pitching energy into the turning. At 45° bank only 70% of the lift energy is holding the plane up in a 1g maneuver.

TECHNIQUE

Lets assume you are descending on an PATH DES with a computed speed of 280 kts.

If ATC wants you to increase your speed in the descent, but you anticipate the next controller will want you to slow **prior to reaching the level off altitude**, try this technique.

ATC: ***"Bellanca Airbus, increase your descent speed to 320 kts for spacing"***

Select V/S. Turn the speed knob up to 320 kts. (Autothrottles are on). Monitor the Path Deviation Indicator and keep the airplane well below the computed path using the V/S wheel. Do not enter 320 in the DES page as this will throw out the shallower path that we want to monitor in anticipation of being slowed early.

Now when ATC wants an early speed reduction, press VNAV. You'll get the DRAG REQUIRED message but the excessive speed will trade off as the nose rises to capture the path.

TECHNIQUE

You're level at ten thousand feet indicating 250 kts. The approach controller says ***"Descend to seven thousand feet, upon reaching seven, slow to 210 kts"***.

Here's a technique to use so you won't forget what the clearance speed is at level-off.

Press the V/S button and dial a descent rate of 1500 ft. Spin the speed knob back to 210. Maintain 250 kts in descent by making small adjustments to the V/S wheel. As you level, the throttles smoothly come in to capture the pre-set speed.

TECHNIQUE TO CALCULATE IDLE POWER TOP OF DESCENT

Calculating your own top-of-descent point forces you to keep your mind active and ahead of the airplane.

Situation: Cruise altitude is 35,000. Restriction exists at 10,000' at 250 kts. 35 - 10 = 25

Partial throttle - V/S (easy)	*Idle throttle* - LVL CHG (much harder)
25 x 3 = 75	280 kt descent, multiply 25 times 2.5
At T/D, set V/S to half the ground speed + 10%	320 kt descent, multiply 25 times 2 + 10%

*Add 1 mile per ten kts for deceleration to 250 kt; for the 737, this is conservative.

*Adjust for tail/head wind of 1 mi. per 10 kts of wind.

*Add 1 mile for each half inch of mercury above standard.

TECHNIQUE

If you are descending with the MCP using V/S, and you want to stop the autothrottles from hunting, de-select SPEED. (The light goes out.) Leave the autothrottle switch ON. Throttles are in ARM. Continue to control descent with the V/S wheel. As aircraft reaches MCP ALT SEL, throttles come in to assume present indicated speed, not the bug speed.

Astronauts & engineers: WINDS - DESCENT

The FMC uses cruise winds (either actual or estimated) at cruise altitude and a linear interpolation of this value down to zero wind at destination. Interestingly, the path is re-computed using current wind values if any modification of the route is performed during the descent. A simple speed change, re-entry of an altitude constraint, or a route modification are examples of a modification that would cause a re-computation of the path. This could result in putting the aircraft above or below the re-computed path but may yield a more accurate descent path for the conditions. More research is needed.

If the wind variation in descent is significantly different than the linear model in the FMC, the result might be a path that is more difficult to stay on, i.e. under/overspeed, deviations over or under the path.

DES FORECASTS

You get to this page by:

- DES page FORECAST prompt (LSK 6L)
- CRZ DES page FORECAST prompt (LSK 6L)

NO REQUIRED ENTRIES

DES FORECASTS page is made ACTive when the vertical flight plan becomes active. It is used to increase the accuracy of the descent path when descending through the jetstream or when forecast winds are significantly different than the computer generated linear model.

When passing through the Transition Layer, your vertical position should be expressed in terms of *Flight Level* (QNE) when climbing and in terms of *Altitude* (QNH) when descending.

TECHNIQUE

- Start descent early. For each 1,000' that 45% N_1 is expected to be used, start down 1 nm earlier than the FMC computed T/D. (May be up to 35 nm earlier than usual) Use of this rule may still require the use of speed brakes, especially when initiation altitude is low.
- Press LVL CHG. Turn autothrottles OFF. Manually position throttles to 45% N_1. Rate of descent is controlled with speed knob.

- The TRANS ALT or TRANS LVL is extracted from the nav database for SIDs, STARs, and approaches (not runways).
- If one of these has not been selected, the value defaults to FL180.
- Carrier can change the default value by purchasing a Perf Defaults Data Base diskette from Smiths.
- Manual entry has priority.

- TAI ON/OFF - Expected altitudes for anti-ice usage. Presently disabled. If Boeing goes back to low idle, it will be enabled.
- U5.0 The altitude band over which anti-icing will be used to help the FMC account for the additional thrust delivered by 28-40% N_1 required for bleed air.

- Predicted cabin rate of descent req'd from CRZ altitude to DEST elevation.
- Helpful if using the stby press.

```
ACT DES FORECASTS          1/1
TRANS LVL            TAI ON/OFF
FL180                 - - - / - - -
CABIN RATE          ISA DEV / QNH
480FPM                - - ° / 30. 20
ALT        - WIND -     DIR / SPD
FL240                 080° / 50KT
14000                 100° / 25KT
- - - - -             - - -° / - - - KT
```

- Destination ISA DEViation and QNH altimeter setting (millibars or inches) to provide compensation for that portion of descent below TRANS LVL. Decimal required.
- Above TRANS LVL, FMC uses baro uncorrected altitude.
- Defaults to 29.92. If you do not enter the true setting, you are telling the FMC to use the default value, which, when desired, does save operating time.

Enter average ISA deviation for desent in °C (±XX) or °F (±XXF), though has negligible effect.

U3 and up

Forecast descent WIND

- FMC will interpolate from the T/D wind to wind(s) entered on this page to predict a complete descent wind profile.
- Enter ALTitude (line 3L) and DIRection / SPeeD (line 3R) for up to 3 forecast true wind values.
- Any altitude sequence entry is allowed.
- FMC initially places each entry at line 3. Subsequent entries displace entry at line 3 to a lower line.

TECHNIQUE

Descending from QNE to a high QNH puts the aircraft above (high) the computed idle path so always make the QNH entry when in a high pressure area.
T/D will be a few miles sooner. Don't bother with an entry when altimeter is lower than standard.

TECHNIQUE

If you think the software consistently puts you above the path in a tailwind…

use the QNH entry to bump the altimeter up an inch. This produces a buffer of about 800' crossing the TRANS LVL. The airplane with pitch up to re-capture the idle path and you'll bleed off about 10 kts of excess speed.

- below the path in a headwind… make a QNH entry an inch lower than reported. The airplane with dive to re-capture the path and you'll gain about 10 kts crossing the TRANS LVL.

TEMPERATURE COMPENSATION TO BARO ALTIMETER

Special thanks to Jim Gregory and George Dewar for help in preparing this lesson.

Pressure altimeters are calibrated to indicate true altitude under ISA conditions. However, a correct setting of the altimeter does not correct for nonstandard temperature.

If the temperature at a given altitude is equal to the standard value at that altitude, and the lapse rate and sea-level conditions are also standard, the altimeter will read the correct altitude. The altimeter can be corrected for sea level conditions, but no way has yet been devised to account for variations in the lapse rate. Any deviation from ISA will therefore result in an erroneous altimeter. And the vertical path, if flown in *baro* VNAV, may not be the same as that printed on the chart.

To ensure appropriate obstacle clearance when an aircraft is operated at any charted minimum IFR altitude, it is necessary to apply a correction to the charted altitude.

RNAV plates specify a minimum temperature at which the procedure can be flown to ensure obstacle clearance in the final approach segment, but conventional approach plates do not - they are designed for +15°C.

If the temperature is other than standard, errors become proportionally greater with altitude above the altimeter site (usually the airport). In the case when the temperature (at the reporting site) is higher than ISA, the true altitude will be higher than the figure indicated by the altimeter. Higher than ISA temperature results in VNAV (Gradient Path) flying a higher approach angle.

Likewise, unless a temperature correction is applied, the true altitude will be lower when the temperature is lower than ISA. Lower than ISA temperature results in VNAV flying a lower approach angle. This will result in less than the required obstacle clearance (ROC) if the aircraft is operated at the charted minimum IFR altitude without a correction. Altimeter errors are significant under conditions of extreme temperatures, therefore it is particularly important to apply a correction to minimum IFR altitudes under these conditions.

Remember the old saying,

"WHEN IT'S COLD, LOOK OUT BELOW".

Example: Assume we're shooting the conventional LOC (BACK CRS) DME Rwy 10 at Calgary. The chart displays the minimum descent altitude at GADIS as 5400 ft MSL *(1853 HAT)*. This minimum IFR altitude provides the required obstacle clearance only under ISA conditions (15°C).

If the temperature at the airport was -30 °C, the true altitude would be about 5100 ft (5400 -300), or just 670 ft above and a mile north of a tower (4430'). Canadian controllers are aware of the effects of cold temperature on aircraft altimeter systems. All ATC minimum vectoring altitudes in Canada account for cold temperature and require no corrective action by the pilot.

It is particularly important to make cold temperature altitude adjustments on initial, intermediate, final approach and missed approach segments if the aircraft is going to be at any minimum IFR altitude during each off these segments, especially in a non radar environment. Doing so will ensure the appropriate obstacle clearance. When cold temperature corrections are made to an initial or missed approach minimum IFR altitude, pilots should advise ATC how much of a correction will be applied.

Any temperature correction made by the pilot to the minimum IFR altitudes on an approach, especially the final segment, will not affect the controller's separation. You will have already obtained your clearance for the approach; therefore altitudes at the point of the receipt of the approach clearance all the way through to the missed approach clearance limit are the pilots.

If an adjustment is necessary for missed approach or minimum enroute altitude simply request a higher altitude from the controller.

It is important to restate that cold temperature corrections are only applied to the minimum IFR altitudes and are not applied while on radar vectors where the ATC assigned altitudes have a temperature correction factor applied.

General Rules:

- *At -30C and at 3000 ft above the field, the intermediate ROC is completely lost.*
- *At -30C and 1500 ft above the field, half the intermediate ROC is lost.*

Required Obstacle Clearance (ROC)
Proc. turn / Arc / Initial App. Segment = 1000 ft
Intermediate App. segment = 500 ft (IAF to FAF)
FAF to MA point = 250 ft
Circling (Cat A, B, C) = 500 ft above the airport
Circling (Cat D) = 600 ft above the airport
(Circling MDA's are based on a 300 ft ROC)

VALUES TO BE ADDED TO PUBLISHED ALTITUDES (ft)
(4 ft per 1,000 ft above the source per ° C off standard)

Source Temp	*Sea Level Aerodrome - Height in ft above the elevation of the altimeter setting source (AGL)*							
°C / °F	200	500	1,000	1,500	2,000	3,000	4,000	5,000
0 / +32	20	30	60	90	120	170	230	200
-10 / +14	20	50	100	150	200	290	390	400
-20 / -04	30	70	140	210	280	430	570	620
-30 / -22	40	100	190	280	380	570	760	860
-40 / -40	50	120	240	360	480	720	970	1,100
-50 / -58	60	150	300	450	600	890	1,190	1,380

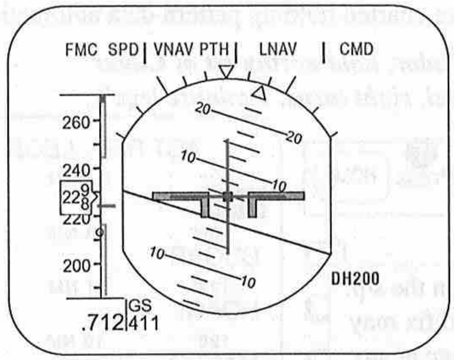
Table calculated for sea level aerodrome - linear variation.
Conservative when aplied at higher aerodrome.

HOLD

U10.2 and up

You get to this page by:

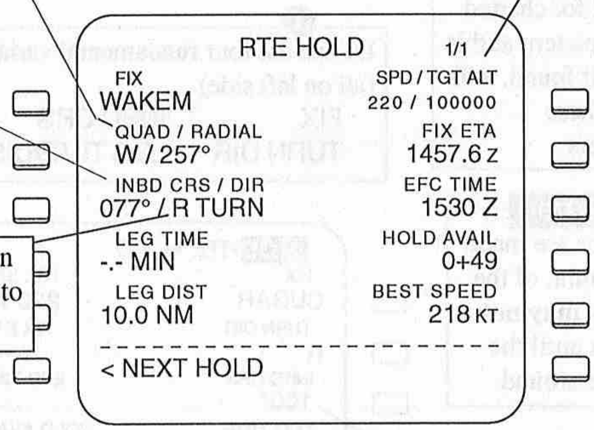
- Select the HOLD key. If a hold does not already exist in the flight plan, this action displays the HOLD AT page which allows the pilot to specify a desired fix for the hold.
- If one or more holds already exist in the flight plan when the HOLD key is pressed, the ACT RTE HOLD page is displayed which shows the characteristics of the nearest hold in the flight plan.
- The NEXT HOLD prompt can be used to access other holds in the flight plan.



- A QUAD entry by itself is not allowed. It's there just to verify the clearance.
- A RADIAL entry does not need a slash – contrary to the *slash rule*.
- A RADIAL entry by itself will cause QUAD and the reciprocal INBD CRS to display.
- Entry in 2L is preferred over 3L because it is in ATC language.
- RADIAL entry is not allowed for a *PB/D hold fix* (ref next page).

- Displays current speed and altitude.
- Speed or altitude may be entered.
- Manual entries are large font, predicted in small font.

INBD CRS defaults to the course of the leg preceding the hold fix.



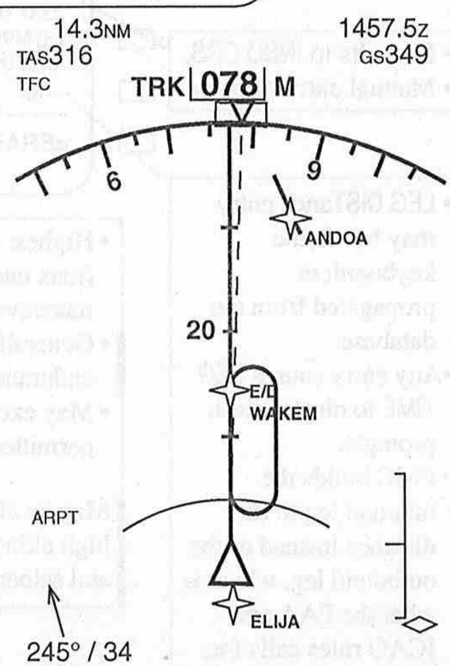
TECHNIQUE

Unless the hold fix is a PBD creation, simply enter the radial into line 2. Entry of the inbound course always wins when defining hold patterns.

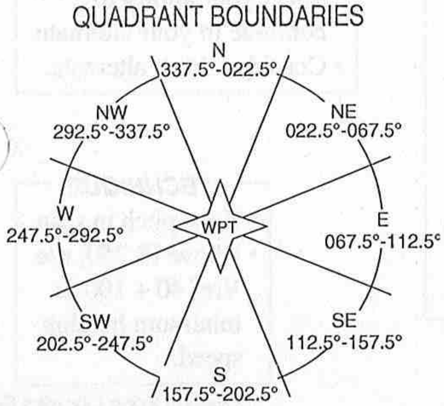
DIRection defaults to R TURN.

U10.4 & up

- If the QUAD/RADIAL, INBD CRS/DIR, or LEG TIME values are default, they are displayed in small font.
- Pilot entries, or hold parameters extracted from the nav database, are displayed in large font.



QUADRANT BOUNDARIES



You get to this page by:

- HOLD key.

The RTE HOLD page provides a means of selecting a holding pattern fix point from either the aircraft present position (PPOS) or a preplanned geographical point. Performance predictions assume level flight. The FMC will complete and perform tear drop, parallel, or direct entry holding patterns according to the hold geometry and the initial course to the hold fix.
Fixes will utilize charted holding pattern data automatically if available from the nav data base.

ATC : ***"Avro Tudor, hold northwest of Cugar on the 280 radial, right turns, 1 minute legs".***

1 Press HOLD

2 Enter CUGAR in the s/p. (Only one hold fix may exist in the route at any one time until U3.0)

3
- Enter CUGAR into 6L.
- The nav database is searched for charted holding pattern at this fix, and if found, will display these parameters.

```
ACT RTE  LEGS                     1/2
  91°          8.4 NM
CLL                        290 / FL213
  100°         23 NM
CUGAR                      290 / 13160
  127°         11 NM
HOAGI                      250 / 10000
  126°         10 NM
MACED                      240 / 10000
  127°         15 NM
BANTY                      240 / 6000
------------ HOLD AT -----------------
□□□□□                          PPOS >
CUGAR
```

- Press PPOS> to hold at *present* position. MOD RTE HOLD page appears and EXEC illuminates.
- *Present* is at the time of EXECution.
- Displayed in flight only.
- The FMC WILL assign a created wpt identifier to the hold point (example, WPT01)

U7.1 and up

- PPOS hold is allowed while on a RTE OFFSET.

4 Define the four fundamental variables: (all on left side)

FIX — INBD CRS
TURN DIR — LEG TIME/DIST

CAUTION

If changes are made inside 3 min. of the wpt, they **may not be flown** until the next time around.

```
MOD RTE HOLD
 FIX                        TGT SPD
CUGAR                        220 KT
 TURN DIR                   FIX ETA
R                             ----Z
 INBD CRS                  EFC TIME
100°                          ----Z
 LEG TIME                HOLD AVAIL
1.0 MIN                        1+48
 LEG DIST                BEST SPEED
-.- NM                       220 KT
-----------------------------------
<ERASE
```

- If no manual entry is made, the predicted BEST SPEED at the fix is displayed.
- VNAV descents made in the Hold are done at idle thrust and TGT SPD; does not consider any path.

- Defaults to INBD CRS.
- Manual entry allowed.

- Holding time if DEST is to be reached with fuel RESERVES remaining. Ref: PERF INIT
- Considers route to DEST, *then* to alternate.
- Holding longer than the HOLD AVAIL time will affect your ability to continue to your alternate.
- Consider closer alternate.

- LEG DISTance entry may be via the keyboard, or propagated from the database.
- Any entry causes LEG TIME to display dash prompts.
- FMC builds the inbound leg to this distance instead of the outbound leg, which is what the FAA and ICAO rules calls for.

- Highest of minimum fuel flow (max endurance), minimum maneuver speed, or initial buffet.
- Generally a little higher than max endurance for turn protection.
- May exceed max holding speed permitted by regulatory body.

CAUTION

May be close to thrust limitations at high altitude. Watch your pitch, and select CLB on autothrottle limit.

TECHNIQUE

- Keep pitch in scan.
- Above FL250, use Vref 40 + 100 as minimum holding speed.

REVIEW OF TITLE SEQUENCES

MOD RTE HOLD	Indicates that holding fix has not been EXECuted.
RTE HOLD	Hold has been EXECuted. This title will remain displayed until established in the HOLD (which is flying over the hold FIX the first time), at which time the title changes to,
ACT RTE HOLD	Hold has been EXECuted with PPOS OR Aircraft has entered the EXECuted holding pattern. (Established in the Hold) EXIT HOLD prompt is displayed at line 6R.

- Manual entry has priority.
- Highlighted by reverse video when RTE HOLD is ACTive.
- Propagated to CLB / CRZ / DES pages as TGT SPD three minutes prior to first reaching the fix.

- If charted pattern is not in the database, the FMC assumes right turns.
- Enter L for left turns.

```
ACT RTE  HOLD            1/1
FIX                  TGT SPD
CUGAR                 220 KT
TURN DIR             FIX ETA
R                    1424.5Z
INBD CRS            EFC TIME
100°                  ----Z
LEG TIME          HOLD AVAIL
1.0 MIN                 0+48
LEG DIST          BEST SPEED
--.-NM                 220KT
----------------------------
<NEXT HOLD        EXIT HOLD>
```

The next time the hold fix will be passed.

- If no entry, FMC assumes standard times for *inbound* leg of 1 minute at or below 14,000' and 1.5 minute above 14,000'.
- Based on predicted altitude of the hold fix wpt until the it becomes the go-to wpt.
- Manual entry has priority.
- ICAO regs require outbound leg to be timed.

U3.0 & up

- Displayed when the route contains less than five holding patterns and there is no route MODification in process.
- Line selection displays:
  - the LEGS HOLD AT page if there is no other holding pattern in the route;
  - the RTE HOLD page for the next nearest hold in the flight plan if there is another holding pattern already entered in the route.

- When an EFC TIME is entered, performance predictions downpath of the holding pattern will assume the aircraft exits the holding pattern at the EFC time.
- If no EFC TIME is entered, performance predictions are based on an immediate exit from the holding pattern.
- Computation of DEST fuel assumes that holding fix will be departed at this time.
- Does not result in automatic exit of the hold pattern.

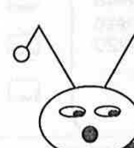
CAUTION

U1 software, because it does not have the capability to generate the message USING RESERVE FUEL; it may dip into preserves without informing you.

TECHNIQUE

After receiving a holding clearance but not yet at the hold fix, consider slowing to reduce time in hold and fuel burn by:

- At lower altitudes, check BEST SPEED by pressing PPOS.
- At higher altitudes, don't fly less than Cost Index of zero. (Max Range)
- Backup the FMC with your own HOLD AVAIL calculation.



CAUTION

- U1 thru U6.2 may experience errors in HOLD AVAIL time when EFC is entered.
- Do not enter EFC time until you have checked HOLD AVAIL. (Consider not entering EFC at all.)
- Display PROGRESS 1/3 to monitor change in FUEL AT destination.
- Blank TO T/D field on PROGRESS page indicates FMC still calculating solution.

"PTA" TECHNIQUE

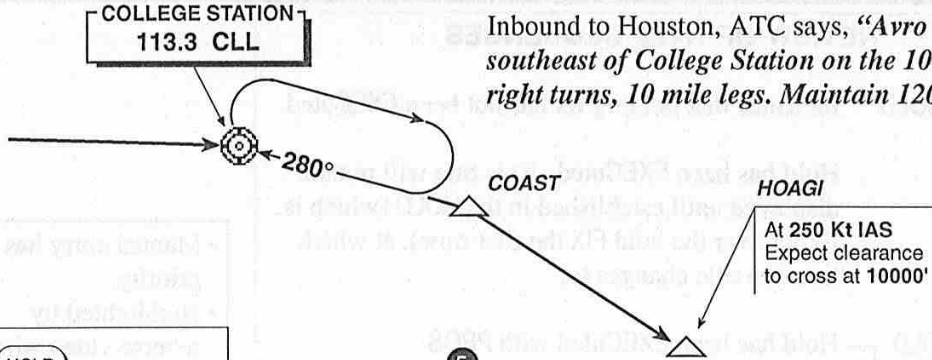
Use the PROGRESS page for reporting established in the hold.

1 Position
2 Time
3 Altitude

```
502 PROGRESS              1/3
(1) FROM   (3) ALT  (2) ATA
CUGAR      12000    1424z    10.6
```

HOLDING AT A DOWN-PATH WPT

Inbound to Houston, ATC says, ***"Avro Tudor, hold southeast of College Station on the 100 radial, right turns, 10 mile legs. Maintain 12000 ft".***



1

Press (HOLD)

------------ HOLD AT ------------
□□□□□ PPOS>

appears at bottom of LEGS page.

2

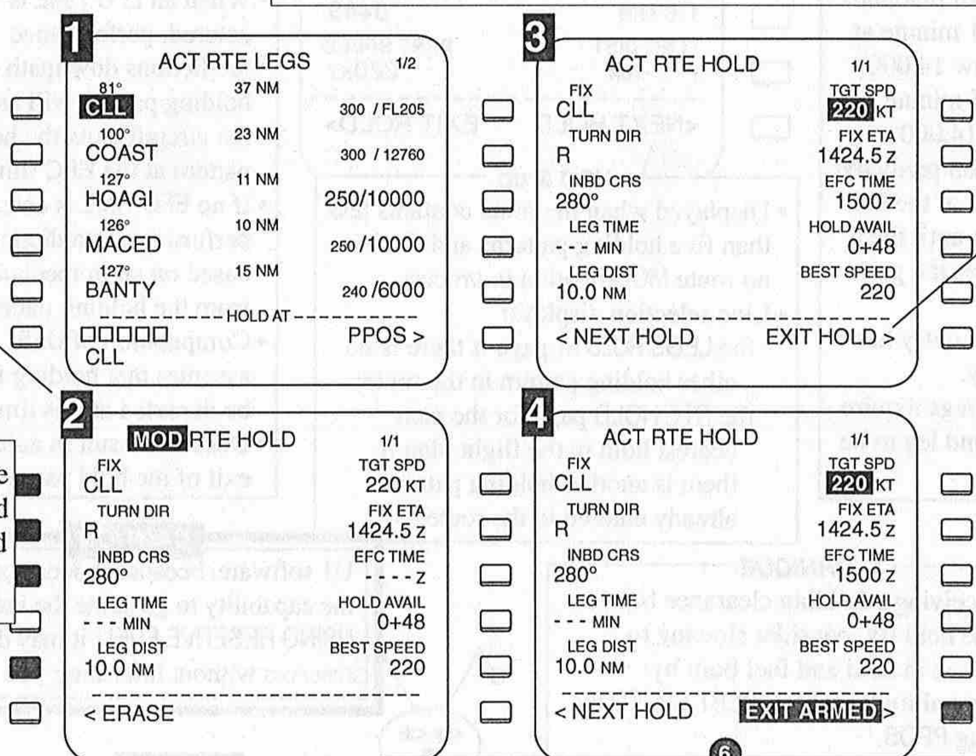
- Enter CLL into the boxes at 6L.
- MOD RTE HOLD page appears.

3

Complete the 4 req'd items and (EXEC)

5

- EXIT HOLD is displayed only on an ACT RTE HOLD page. Hence, EXIT HOLD is availible only **after** you are established in the hold. Selecting EXIT HOLD will cause the EXIT ARMED prompt and an illuminated (EXEC) to appear.
- Prior to U5, selecting direct to CLL (*exit hold point*) before accomplishing an EXIT HOLD will display an INVALID ENTRY.
- The white dashed (modified) line will not reflect the immediate turn to the hold fix; after execution, the magenta line will reflect the change, i.e., turn to cross the hold fix as soon as possible (to cross on the inbound course).
- The GNLU (Collins/Smiths retro FMC) will reflect the shortened route in the modified state.



4

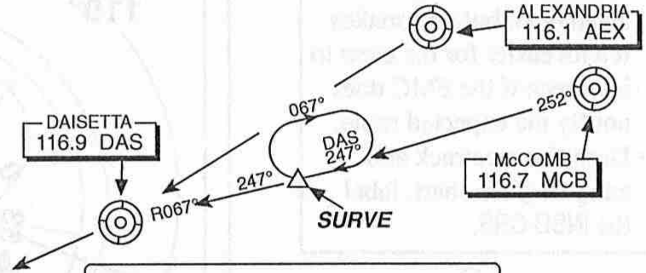
- RTE HOLD is displayed as the page title until established in the hold, at which time ACT RTE HOLD appears.
- If you are cleared direct to a wpt downline **prior** to becoming established in the hold (HOAGI), just proceed direct to that wpt and the hold will be deleted.

6

- EXECute and the aircraft will shorten the hold, return and cross the hold fix (now the *exit hold point*) via the inbound course at TGT SPD and then proceed to the next wpt at CRZ or DES speed, whichever is ACTive. If a speed increase is desired **prior** to crossing the *exit hold point*, use the MCP or enter it in the TGT SPD field.
- EXIT ARMED is high-lighted until passing the *exit hold point.*
- LEGS appears after crossing the *exit hold point.*

HOLDING AT AN OFF-ROUTE WPT

ATC: ***"Boeing 377, cleared direct ALEXANDRIA, SURVE, DAISETTA. Hold at SURVE as published, maintain FL240. Expect further clearance at 2235."***



1

- To set up this clearance, first press the HOLD key.
- Enter SURVE into the boxes that appear at LSK 6L.

```
      ACT RTE  LEGS          1/3
   253°        146NM
  AEX                .805/FL310
   237°        128NM
  DAS                250/10000
   THEN
  □□□□□
  --  ROUTE DISCONTINUITY    --
  MKAYE                ----/ 5000A
   265°          5.1NM
  GRIEG                ----/ 4000A
   RNP/ACTUAL------------------
  2.00/0.05NM          RTE DATA>
  HOLD AT SURVE
```

2

Message HOLD AT SURVE appears because SURVE is not in the active route.

4

- The HOLD page fills with default data.
- Complete and double check the 4 required fields.

```
      RTE  HOLD              1/2
   FIX                SPD/TGT ALT
  SURVE                 205/FL243
   QUAD/RADIAL            FIX ETA
  NE/067°                 2220.0z
   INBD CRS/DIR          EFT TIME
  247°/R TURN               2235z
   LEG TIME            HOLD AVAIL
  -.-MIN                    0+57
   LEG DIST
  20.0NM
  ------
  <NEXT HOL
```

```
  MOD RTE  HOLD              1/2
   FIX                SPD/TGT ALT
  SURVE                  205/------
   QUAD/RADIAL            FIX ETA
  NE/057°                 2220.0z
   INBD CRS/DIR          EFT TIME
  237°/R TURN               ----z
   LEG TIME            HOLD AVAIL
  1.5MIN                    0+55
   LEG DIST            BEST SPEED
  --.-NM                   205KT
  -------------------------------
  <NEXT HOLD
```

3

Here's the trick with this feature. Place SURVE into the proper sequence (LSK 2L), verify, and EXECute.

```
      ACT RTE  LEGS
   253°        146NM
  AEX
   238°         62NM
  SURVE
   HOLD AT
  SURVE              206/FL243
   248°         40NM
  DAS                250/10000
   244°         11NM
  DAYBO              ----/----
   RNP/ACTUAL------------------
  2.00/0.05NM          RTE DATA>
```

5

This is the HOLD page as it becomes active.

```
      ACT RTE  HOLD          1/2
   FIX                SPD/TGT ALT
  SURVE                 205/FL240
   QUAD/RADIAL            FIX ETA
  NE/067°                 2232.4z
   INBD CRS/DIR          EFT TIME
  247°/R TURN               2235z
   LEG TIME            HOLD AVAIL
  3.0MIN                    0+53
   LEG DIST            BEST SPEED
  --.-NM                   205KT
  -------------------------------
  <NEXT HOLD           EXIT HOLD>
```

```
      ACT ECON CRZ           1/1
   CRZ ALT    OPT/MAX
  FL240   FL403/410
   TGT SPD               TO T/D
  205/HOLD       2235.8z/ 13NM
   TURB N1          ACTUAL WIND
  79.1/ 79.1%         250°/ 24
   FUEL AT KIAH
           7.7
  ----------------------------
                      ENG OUT>

  <LRC                    RTA>
```

This is the CRZ page if you hold at cruise altitude.

```
    1859 PROGRESS            1/4
   FROM       ALT    ATA     FUEL
  SURVE      FL240  2222z    9.3
   HOLD AT     DTG    ETA    FUEL
  SURVE        0.9  2235z    8.5
   248°
  DAS           41  2242z    8.2

  KIAH          79  2252z    7.7
   TO T/D               FUEL QTY
  2236z/     4.4NM          9.3
   WIND
  246°/ 25KT         NAV STATUS>
```

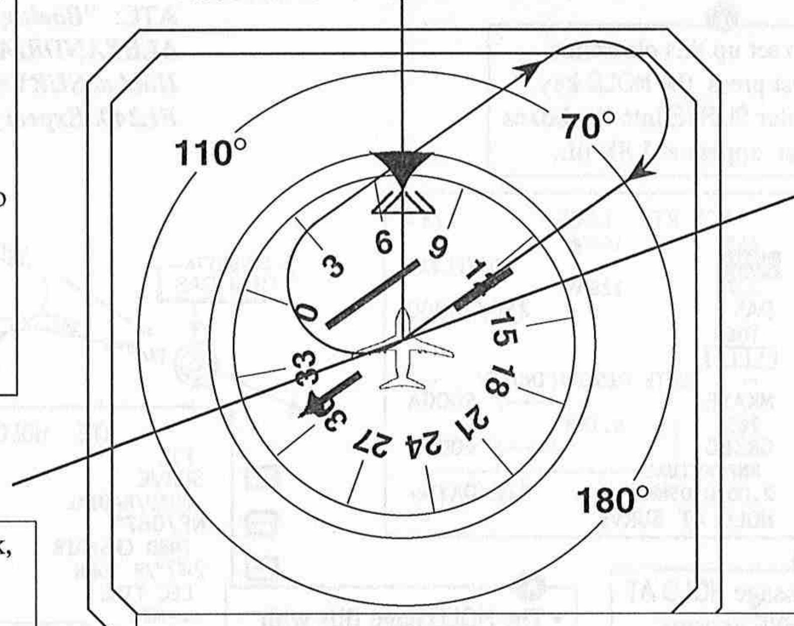
This is the PROGRESS page. Position report would include "entering the hold at Surve at 2222Z at FL240". *PTA*

ENTRY PROCEDURES

TECHNIQUE

- The MP should back up the hold with raw data.
- This not only checks the FMC entry and pattern and the pilot's situational awareness, but also makes it a lot easier for the crew to intervene if the FMC does not fly the expected route.
- Draw the racetrack and entry on your chart; label the INBD CRS.

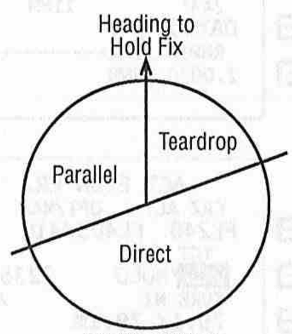
FIGURE MATCHES HOLD ON PREVIOUS PAGE



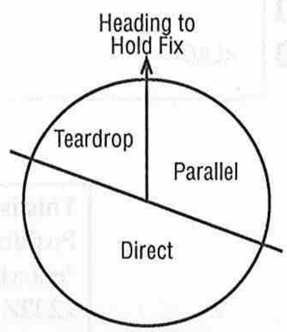
- The FMC plans 25° of bank, but may go to 30°.
- Turn radius is computed at predicted altitude.
- If airspeed is in excess of the FAA hold speeds or ICAO hold speeds, the airplane may leave the protected airspace.
- On an EFIS aircraft, this can be seen on the Map by observing the aircraft symbol or trend vector outside the magenta holding pattern.
- On non-EFIS aircraft, this can be seen on the HSI by observing the course bar moving away from center.

To manually back up the FMC:
- Get established on a heading towards the holding fix,
- Put the tail of the course needle on the holding radial (outbound course)
- If the tail
  - is within the 180° arc - DIRECT entry,
  - is within the 110° arc - PARALLEL entry,
  - is within the 70° arc - TEARDROP entry.

For left turns, draw the 70° arc from left side of heading bug. The "angled upward" side is the teardrop entry side.



RIGHT TURNS



LEFT TURNS

ICAO turbojet max holding speeds:

• Up to and including 14,000 ft	230 kts.
• Above 14,000 (4,250 m) and including 20,000 ft	240 kts
• Above 20,000 and including 34,000 ft	265 kts
• Above 34,000 ft	M.83

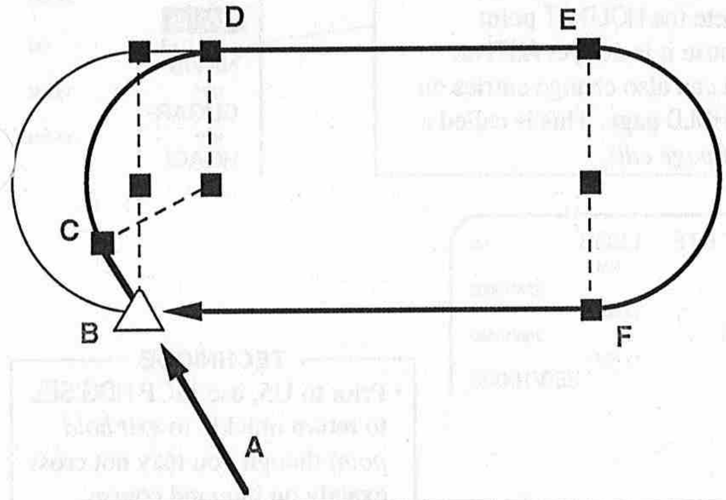
FAA turbojet max holding speeds:

• MHA thru 6000 ft	200 kts.
• Above 6000 and including14,000 ft	230 kts.
• Above 14,000 ft	265 kts.

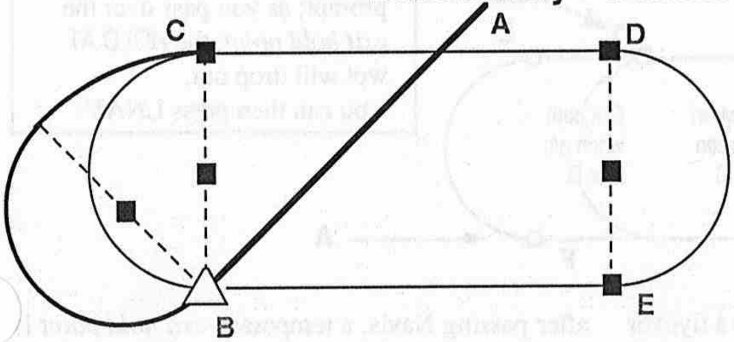
Old FAA turbojet max holding speeds that FMC bases it's protected airspace on:

• MHA thru 6,000 ft	200 kts.
• Above 6,000 and including 14,000 ft	210 kts.
• Above 14,000 ft	230 kts.

Direct Entry - Inside Turn

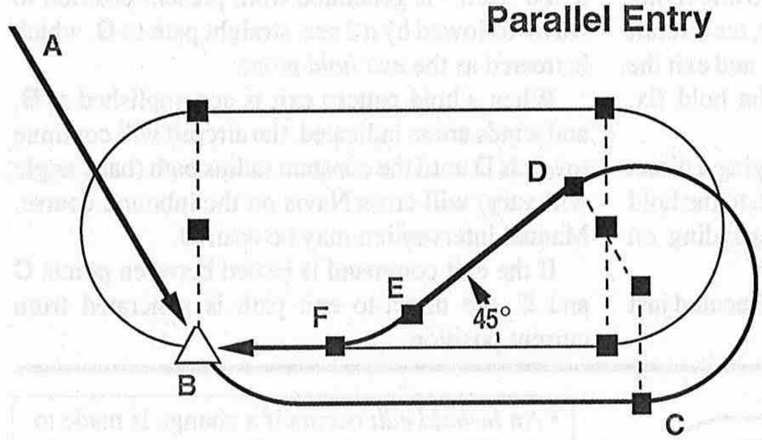


Direct Entry - Outside Turn



One unique aspect of this initial entry is the fact that the turn from **B** to the outbound leg is made up of two separate circular arcs with no straight segment between them. The first arc is a 180 degree turn and the second arc is centered at **B**.

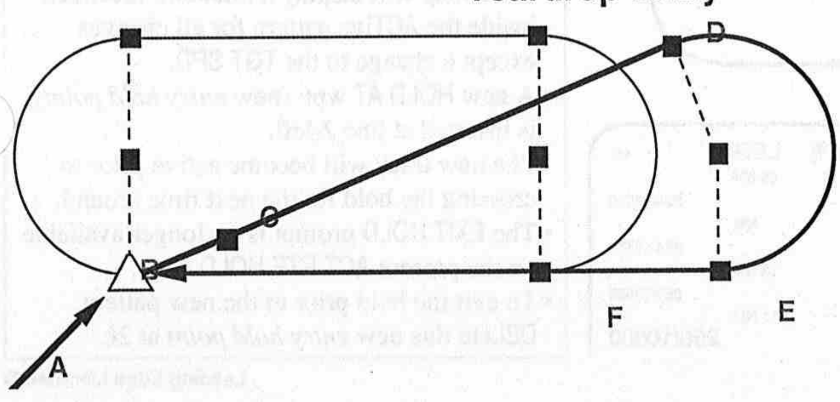
Parallel Entry



If necessary, the entry path may extend out past the holding pattern path in order that an intercept angle of approximately 45 degrees back to the inbound holding course and a leg length from **F** to **B** of 15 seconds results. A short inbound leg will cause this to occur.

Note: Non-EFIS aircraft may fly outbound on the course instead of on a parallel track.

Teardrop Entry

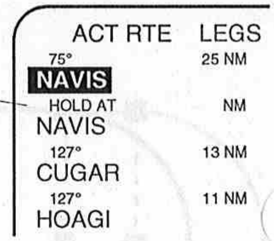


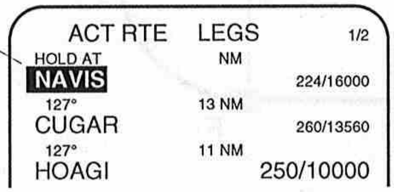
U5 & up 2

- Assume we are now in the hold. The HOLD page is ACTive.
- When ATC clears you direct to the *exit hold point* (Navis in this example), simply perform a DIR TO or an INTC LEG TO NAVIS.
- Don't attempt to DELete an ACTive *exit hold point* for it won't work.
- If in VNAV, the speed will increase to CRZ or DES TGT SPD, whichever is active. There is no guarantee of remaining in the protected holding airspace. Consider using the MCP for speed control until pointed in the right direction.

1

- Assume we are at **A**, approaching the *entry hold point* - NAVIS.
- If ATC cancels the hold, you **can** DELete the HOLD AT point because it is not yet ACTive.
- You can also change entries on the HOLD page. This is called a *hold page edit.*

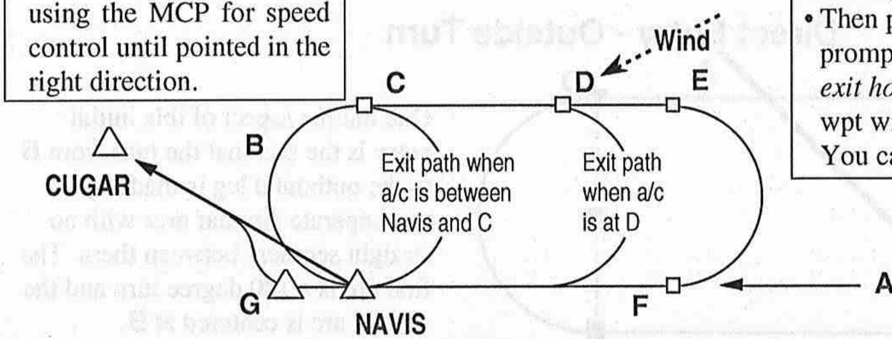




TECHNIQUE

- Prior to U5, use MCP HDG SEL to return quickly to *exit hold point* though you may not cross exactly on inbound course.
- Then press the EXIT HOLD prompt; as you pass over the *exit hold point*, the HOLD AT wpt will drop out.

You can then press LNAV.



All exit paths treat the *exit hold point* as a flyover waypoint, crossing it on the original track.

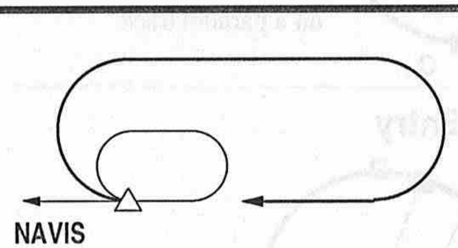
If the EXIT HOLD command is issued while flying either a parallel or a teardrop initial entry, the aircraft will fly the remainder of the initial entry and exit the hold pattern at the next crossing of the hold fix. Manual intervention may be desired.

If the exit command is made while flying a direct initial entry, an immediate direct-to path to the hold fix may or may not be generated, depending on where the aircraft is in the entry path.

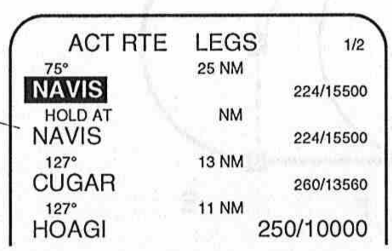
If the hold pattern exit is armed and executed just after passing Navis, a temporary *exit hold point* is built at **G** - 2 sec. past the fix. The exit path - almost a 360° turn - is generated from present position to Navis followed by a 2 sec. straight path to **G**, which is treated as the *exit hold point.*

When a hold pattern exit is accomplished at **B**, and winds are as indicated, the aircraft will continue towards **D** until the constant radius path (bank angle will vary) will cross Navis on the inbound course. Manual intervention may be desired.

If the exit command is issued between points **C** and **E**, the direct-to exit path is generated from current position.



New *entry hold point.*



- An *in-hold edit* occurs if a change is made to the HOLD page after passing the hold fix. The EFIS map will display a minature racetrack inside the ACTive pattern for all changes except a change to the TGT SPD.
- A new HOLD AT wpt (new *entry hold point*), is inserted at line 2-left.
- The new track will become active prior to crossing the hold fix the next time around.
- The EXIT HOLD prompt is no longer available on the present ACT RTE HOLD page.
- To exit the hold prior to the new pattern, DELete this new *entry hold point* at 2L.

PLACE-BEARING / DISTANCE HOLD FIX - U10.2 and up

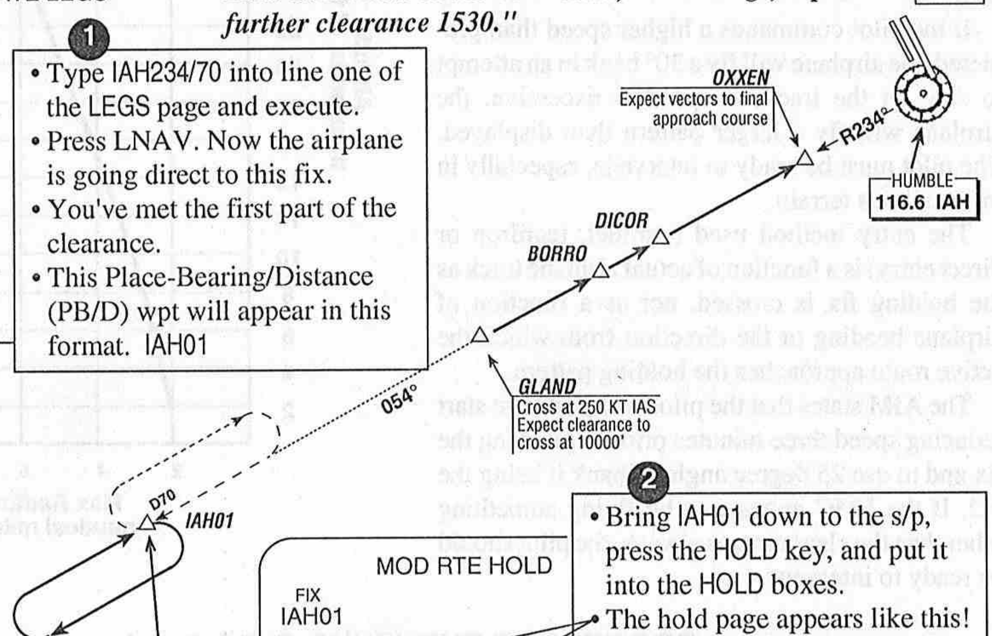
When you are holding at a DME fix, and your inbound course points away from the VOR but into the DME fix, the radial and the inbound course are the same, rather than reciprocals.
There is a special rule in the 737 which is:
If the holding fix is a place-bearing / distance waypoint, where the "place" is a VHF navaid, the radial field on the hold page gets set equal to the "bearing" of place-bearing / distance.

The RADIAL is always displayed relative to the reference navaid for the hold fix.
The INBD CRS now defaults to the course from the reference navaid to the hold fix!
The INBD CRS is "uncoupled" from the RADIAL field and can be changed separately.
This special rule is only invoked when the hold fix is a PBD from a VOR.

Situation:
You're approaching Houston Intercontinental from the south.
Consider the following clearance:
"CLIPPER 42, cleared to the HUMBLE 234 radial, 70 mi fix. Hold Southwest on the 234 radial, 10 mile legs, expect further clearance 1530."

MOD RTE LEGS
335°
IAH01
THEN
□□□□□
-- ROU'
GLAND
54°
BORRO
54°
DICOR
RNP / ACTUAL –
1.70 / 0.25
IAH234/70

1
- Type IAH234/70 into line one of the LEGS page and execute.
- Press LNAV. Now the airplane is going direct to this fix.
- You've met the first part of the clearance.
- This Place-Bearing/Distance (PB/D) wpt will appear in this format. IAH01



2
- Bring IAH01 down to the s/p, press the HOLD key, and put it into the HOLD boxes.
- The hold page appears like this!
- Most of the time the RADIAL is the reciprocal of the INBD CRS, but with a *PB/D hold fix*, the holding pattern is defined purely by the INBD CRS, turn direction, and leg time /distance.
- The quadrant is always the reciprocal of the INBD CRS.

MOD RTE HOLD
FIX
IAH01
QUAD / RADIAL
NE / 234
INBD CRS / DIR
234° / R TURN
LEG TIME
-.- MIN
LEG DIST
-.- NM
< NEXT HOLD

3
- One more step is required.
- Check the INBD CRS vs. the clearance – ***"hold southwest"***. This adds another step.
- Enter an INBD CRS of 054. Notice the QUAD change.

MOD RTE HOLD
FIX
IAH01
QUAD / RADIAL
SW / 234
INBD CRS / DIR
054° / R TURN
LEG TIME
-.- MIN
LEG DIST
10.0 NM
< NEXT HOLD

- With a *PB/D hold fix*, initially, the INBD CRS and the RADIAL are identical -- and the application of a reciprocal calculation for an inbound course may not be appropriate.
- The "default" inbound course may match the clearance. Did the "default" inbound course match the clearance in this example?
- A few rules regarding a *PB/D hold fix*:
Once the *PB/D hold fix* is constructed the RADIAL cannot be changed. The direction of the racetrack can only be changed by entering a different INBD CRS.
An INBD CRS entry will also change the QUAD display, but not the RADIAL - that is tied to the initial construction.

HOLDING CRITERIA

The system's guidance routines for entry are based upon the FAA's 70° sector decision criteria.

Constant radius turns and a Best holding speed is determined by the FMC. A pilot-entered speed may also be used in flying the holding pattern. Sometimes the pilot feels as though the entry is not correct due to the timing of the turn or the bank angle but both of these items have been calculated to maintain the desired holding track.

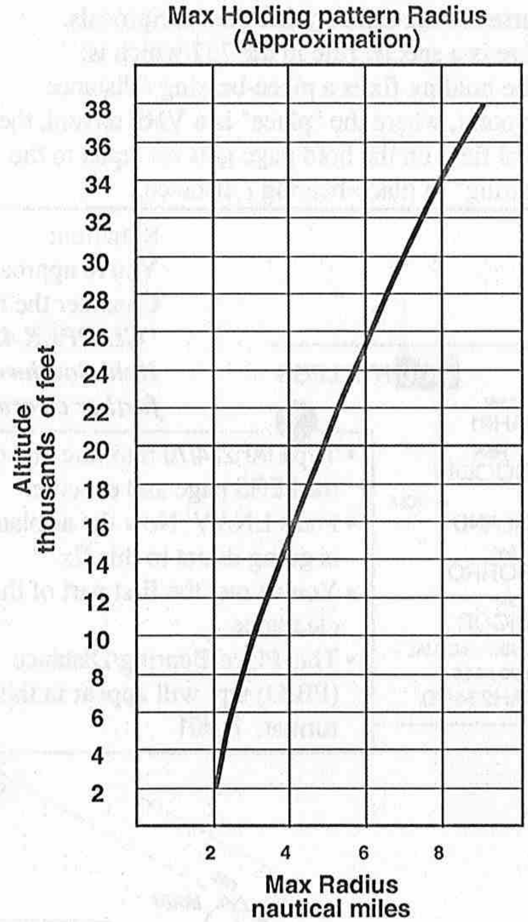
The turn radius of the pattern is determined prior to each successive crossing of the hold fix. It bases its calculation on predicted ground speed at the fix, taking actual wind into account. A max turn radius is programmed as a function of predicted altitude at the fix. Up to 25° bank angle is used to construct the path.

If the pilot commands a higher speed than predicted, the airplane will fly a 30° bank in an attempt to stay on the track; if speed is excessive, the airplane will fly a larger pattern than displayed. The pilot must be ready to intervene, especially in mountainous terrain.

The entry method used (parallel, teardrop or direct entry) is a function of actual airplane track as the holding fix is crossed, not as a function of airplane heading or the direction from which the active route approaches the holding pattern.

The AIM states that the pilot is expected to start reducing speed three minutes prior to reaching the fix and to use 25 degree angle of bank if using the FD. If the FMC appears to be flying something other than the clearance, as always, the pilot should be ready to intervene.

The radii of the turns of the hold patterns are limited as a function of aircraft altitude. This table lists the maximum hold pattern radii as a function of altitude, as programmed in the FMC.



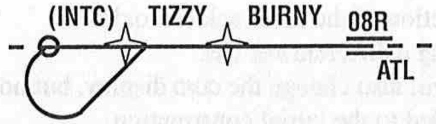
PROCEDURE TURNS (U6, 8, 7.2 & up)

Some databased procedures contain procedure turns. They cannot be manually entered. These maneuvers provide a means of performing a course reversal within defined geographical boundaries.

The nav data base includes procedure turns encoded for the terminal area procedures that require their execution. The FMC will construct predicted paths based on the geometric limitations of the maneuver, predicted winds, and a 170 knot airspeed. In cases where strong winds prohibit accomplishment of the maneuver within the geographic limits, leg length of the maneuver will be shortened in an attempt to fit the maneuver within the prescribed area.

A discontinuity will be inserted if this cannot be accomplished.

```
        ACT RTE LEGS            1/X
 50°           29 NM
ATL                      - - - - / - - - - -
 THEN
□□□□□
         - - ROUTE DISCONTINUITY - -
BURNY                       170 / 4000A
 PROC TURN
(INTC)                      170 / 4000A
 93°           3.0 NM
TIZZY                       - - - - / 4000
 93°           0.1 NM
GS-08R                      160 / 4000
 93°           4.2 NM          GP 3.0°
BURNY                       - - - - / 2620
 93°           4.7 NM          GP 3.0°
RW08R                       - - - - / 1082
 RNP / ACTUAL - - - - - - - - - - - - - - -
1.70 / 0.05                 RTE DATA >
```



APPROACH REF

You get to this page by:

- INIT/REF INDEX page APPROACH prompt (LSK5L).

INIT REF

NO REQUIRED ENTRIES

Prior to U7.0, within 50 nm of the Origin, *Airport Information* relating to a return approach to the Origin is displayed. Beyond 50 nm or before the halfway point (whichever is less) from the Origin, data for the Destination is shown. If the aircraft is not yet airborne, pressing the APPROACH prompt on the INIT/REF INDEX page displays information relating to the Origin airport.

- With U7.0 and on, airport information for the Destination, if selected, is displayed after CRZ is active.

- *Runwy information* associated with approach selected in flight plan. U3 adds dist. in M.
- Blank if no approach has been EXECuted.

- Normally displays present gross wt.
- Manual entry of a planned landing wt for landing speeds is accepted and will display applicable VREF speeds.
- DELeting the manual entry or changing pages will return fields on left and right sides to calculated values.
- Box prompts are displayed if computed gross wt is invalid (e.g. VNAV inop).

```
APPROACH REF                        1/1
GROSS WT          FLAPS            VREF
110.4              15°           141 KT

                   30°           132 KT
KIAH 14L
12000 FT  3658 M   40°           128 KT
ILS 14L / CRS                  FLAP / SPD
111.90 IHSQ / 146°               30 / 132
                               WIND CORR
                                 +05 KT
-----------------------------
< INDEX                     ALTN DEST >
```

- VREF speeds for 3 normal flap settings.
- Based on displayed GROSS WT
- Manual entry is permitted.
- VREF speeds are 1.2 VSO
- Speed tape option. Selection of VREF blanks the next normal flap placard speed pole.
- 10.4: Adds FLAP /SPD display.
- 10.5 & up: 4R will accept manual entry of flap and VREF values for a non-standard flap setting (one not displayed in 1R-3R). A manually entered VREF is then requred because the FMC does not compute a speed for a non-normal settings.

U3.0 & up

- When the VREF speed is selected twice, it becomes the reference for approach. **- R** is displayed on the speed tape equal to the value selected from LSK 1 through 3R. A VREF entry is **not** dynamic.
- U7.1 & up: If in VNAV and if a VREF has not been selected, message APPRCH VREF NOT SELECTED will appear at the final fix (or rwy extension).

Double click on the planned VREF. This will send the target speed to the LEGS page.

Until 10.4

Refererence Go-around N1 limits for current temperature, altitude, and bleed.

- QFE / QNH option for -600/700/800/900.
- The selected landing reference is highlighted.

U1.6 & 7.1 & up

Two digits displayed right of decimal point.

```
APPROACH REF                        1/1
GROSS WT          FLAPS            VREF
110.4              15°           141 KT
GA N1
93.4 / 93.4%       30°           132 KT
LANDING REF
< QFE / QNH        40°           128 KT
KIAH 14L                      WIND CORR
12000 FT  3658 M                  +5 KT
ILS 14L                       FRONT CRS
111.90 IHSQ                        146°
-----------------------------
< INDEX                     ALTN DEST >
```

```
ACT RTE LEGS                        1/1
114°         21.0 NM
GRAFF                       216 / 3000
146°          7.1 NM
GS-14L                      150 / 2000
146°          0.1 NM
MARBE                       137 / 2000
146°          6.0 NM             GP 3.0°
RW14L                       137 / 154
```

U7.1 - 10.3

WIND CORR

- Defaults to 5 kts (small font).
- Manual entry 0 to 20 kts.
- Automatically applied to the landing flaps target speed when the VREF is selected (ex: LSK 2R).
- Landing flaps target speed equals the VREF speed plus the WIND CORR and is displayed on the LEGS page from the final approach fix to and including the runway. It is the FMC command speed (VNAV) when landing flaps are set.

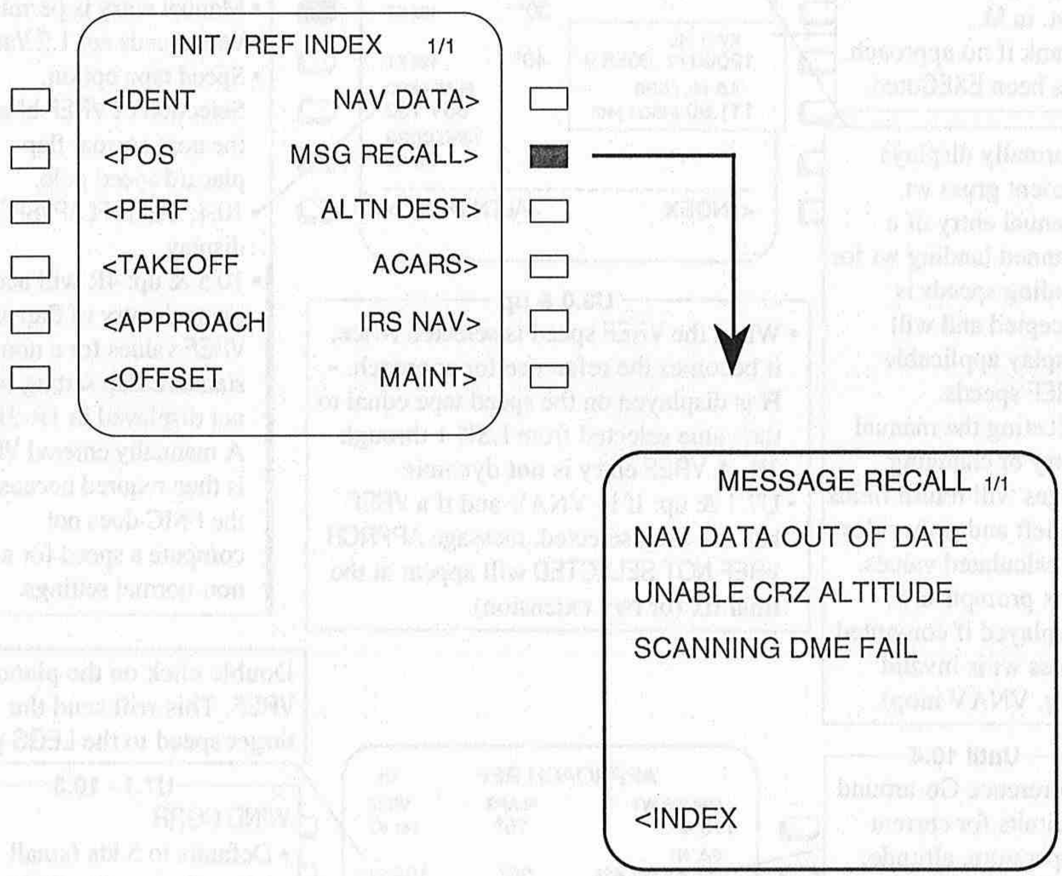
* See TECHNIQUE in center of page.

You get to this page by:

- INIT REF INDEX page MSG RECALL prompt (LSK 2R).

NO ENTRIES ARE ALLOWED

- Lists all alerting and advising messages whose display criteria are still true.
- Messages which have been acknowledged with the CLR key may be checked on this page to see if they are still active.
- Messages which are no longer active because the causing conditions are no longer true, are removed from the list.
- The list has no limit to its size.
- Use NEXT PAGE or PREV PAGE to review additional pages of messages when more than one page exists.



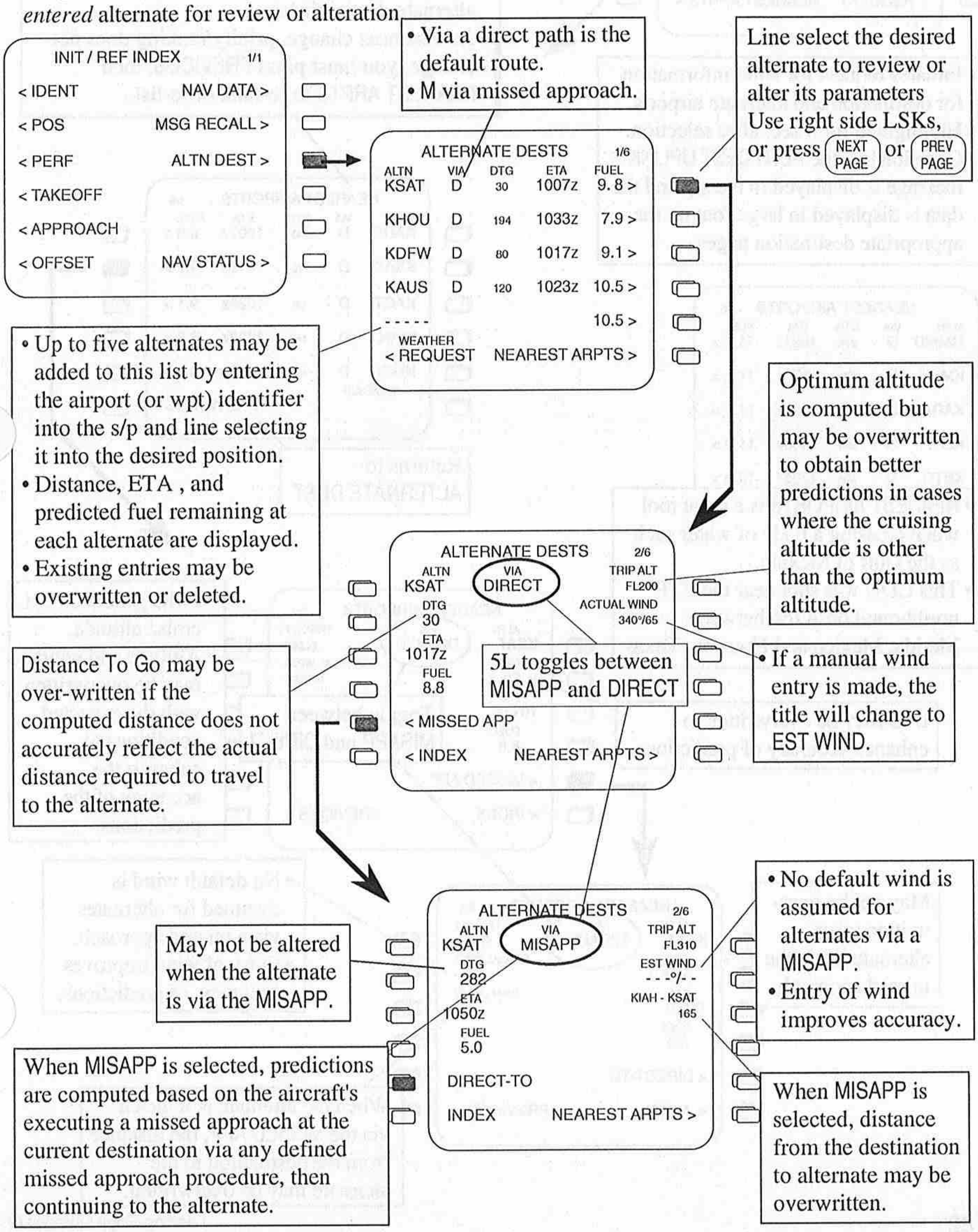
ALTERNATE DESTINATION - U6, U8 & up

You get to this page by:

- INIT/ REF INDEX page ALTN DEST prompt (LSK 3R).
- APPROACH REF page ALTN DEST prompt (LSK 6R).
- RTE page ALTN DEST prompt (LSK 6R) when in air only.
- NEAREST ARPTS page PREVIOUS prompt (LSK 6R)

NO REQUIRED ENTRIES

- This function provides the crew with a simple and quick means of determining the distance, time, and fuel burn to up to five alternate destinations.
- Six pages are available. The first is the summary page; up to five may follow, one page for each *entered* alternate for review or alteration.



You get to this page by:

- ALTERNATE DEST page NEAREST ARPTS prompt (LSK 6R).

```
ALTERNATE DESTS                       1/6
ALTN  VIA  DTG   ETA     FUEL
KSAT  D    30    1007z   9.8 >
KHOU  D    194   1033z   7.9 >
KDFW  D    80    1017z   9.1 >
KAUS  D    120   1023z   10.5 >
- - - - -
WEATHER
< REQUEST      NEAREST APRTS >
```

- Searches database and displays the five airports nearest present position in order of distance with the closest first.
- To review or alter the parameters used to predict fuel and ETA, press the LSK to the right of the airport of interest.
- Parameters for each airport may be reviewed or over-written exactly as is done with the alternate destinations.
- As distances change, priority/ranking does not change; you must press PREVIOUS, then NEAREST ARPTS to re-rank or re-list.

- Initiates request for wind information for destination and alternate airports.
- Highlighted for 3 sec. after selection.
- Once loaded, the ALTN DEST UPLINK message is displayed in the s/p and the data is displayed in large font on the appropriate destination pages.

```
NEAREST AIRPORTS                      1/6
ALTN  VIA  DTG   ETA     FUEL
KAUS  D    30    1007z   9.8 >
KSAT  D    40    1018z   9.7 >
KACT  D    88    1022z   9.1 >
KIAH  D    142   1028z   8.8 >
KHOU  D    154   1033z   8.0 >
WEATHER
                        PREVIOUS >
```

Returns to ALTERNATE DEST

```
NEAREST AIRPORTS                      1/6
ALTN  VIA  DTG   ETA     FUEL
MMMD  D    276   1631z   11.1 >
KMSY  D    278   1631z   11.1 >
KARA  D    288   1632z   11.1 >
KLFT  D    294   1633z   11.0 >
KBTR  D    306   1635z   10.8 >
```

- NEAREST AIRPORTS is a great tool when crossing a body of water such as the Gulf of Mexico.
- This CDU was shot near the ETP northbound on A766 between Merida, Mexico and Houston, Texas

```
NEAREST AIRPORTS                      2/6
ALTN          VIA           TRIP ALT
KSAT          DIRECT           FL200
DTG                      ACTUAL WIND
30                           340°/65
ETA
1017z
FUEL
8.8
< MISSED APP
< INDEX                    PREVIOUS >
```

- FMC generated opt. cruise altitude.
- Altitude and winds may be overwritten with the expected conditions to enhance the accuracy of the predictions.

DTG may be overwritten to enhance accuracy of predictions.

Toggle between MISAPP and DIRECT

```
NEAREST AIRPORTS                      2/6
ALTN          VIA           TRIP ALT
KSAT          MISAPP           FL200
DTG                      ACTUAL WIND
282                          - - -°/- -
ETA                      KIAH - KSAT
1050z                            165
FUEL
8.8
< DIRECT-TO
< INDEX                    PREVIOUS >
```

May not be over-written when alternate is via the missed approach.

- No default wind is assumed for alternates via a missed approach.
- Entry of wind improves accuracy of predictions.

When the alternate is selected via the MISSED APP, the distance from the destination to the alternate may be overwritten.

We'll consider the topic of Diverting (without the Alternates Airports option) using 2 circumstances.

First example: **Diverting Direct To the Alternate.** **FIG. A**
Second example: **Planning a divertion long before it's needed.** **FIG. B**

FIG. A

Example: ILS to RW27R in Miami with a possible missed approach and diversion to Sarasota, Florida

```
ACT RTE     LEGS        3/5
 271°      4.0NM  GP 3.00°
RW27R             /   64
 272°      0.2NM
(800)          ----/  800A
 290°HDG   5.2NM
(INTC)         ----/------
 335°      9.7NM
BRBRA          ----/2000A
 THEN
□□□□□
 RNP/ACT
2.00/0.09
```

- Enter route to alternate after the approach to the destination.
- Separate the two with a DISCO.

```
   ACT RTE     LEGS       4/5
 -- ROUTE DISCONTINUITY --
DHP                ----/------
 322°        50NM
WINCO              ----/------
 322°        33NM
LBV                ----/------
 313°        37NM
ROGAN              ----/------
 313°        1.1NM
MMDUO              ----/------
 RNP/ACTUAL---------------
2.00/0.09NM        RTE DATA>
```

```
   ACT RTE    DATA        4/5
              ETA        WIND
DHP

WINCO

LBV

ROGAN

MMDUO
--------------------WINDS
<LEGS              REQUEST>
```

- Notice that the FMC does not provide predictions beyond the destination airport.
- Once the airplane has been flown to the DEST, the FMC believes it has completed the flight.
- In this example, consult the Alternate Planning table.
- For the -800, 120 miles would take approximately 25 minutes and 2,700 pounds of fuel.

- If a MA is made, you must use either the CLB, CRZ, or PERF INIT page to enter a new cruise altitude. This will reactivate the performance data.
- Then change the destination to that of your alternate.

FIG. B

- Building a route from your destination to your alternate is time consuming but when you are unfamiliar with the area and there are serious terrain considerations, such as diverting from Quito to Guayaquil, it will keep you ahead of the game.
- Separate the approach/missed approach and route to your alternate with a DISCO.

```
 ACT RTE                1/2
VIA                      TO
DIRECT                  MGA

UG439                   QIT

ILS 35                 RW35

MISSED APPRCH           QIT
```

```
 ACT RTE                2/3
VIA                      TO
MISSED APPRCH           QIT
           THEN
--------              □□□□□
 -- ROUTE DISCONTINUITY --
--------              MINDO

W1                    CATRA

-----                 -----
```

Setting up the diversion route early makes the transition from the missed approach much easier.

INTENTIONALLY LEFT BLANK

SELECT DESIRED WPT

You get to this page by:

- Automatically accessed when an entered identifier has more than one location in the nav data base.
- Presently limited to one page, but addition of another is planned.

NO REQUIRED ENTRIES

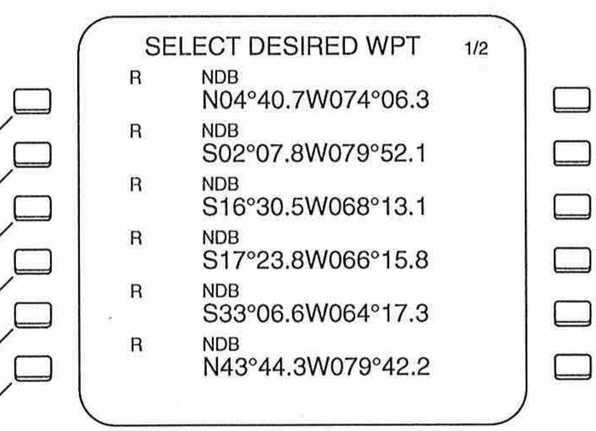
– If an identifier is entered that identifies two or more navaids or waypoints in the FMC database, the SELECT DESIRED WPT page automatically appears.
– It provides a means to further define to the system which of the waypoints having the same identifier is the intended one.
– U1 through U8: The database is searched in the order the data was loaded. It is not searched starting with waypoints closest to the airplane.
– U10: Intelligent sorting is available. The database is searched starting with waypoints closest to the reference position.
  The reference position is defined as follows:
  - If a MOD is being made to a RTE or LEGS page which does not affect the go-to (active wpt), then the reference position is the lat / long of the wpt preceeding the entered wpt.
  - All other operations including a DIR-TO and INTC use the airplane position as the reference position.
- Anytime this page is displayed, ratchet up your concentration a notch. Don't get in the habit of selecting the top choice. This page increases your workload and opens a window for error.

A navaid or waypoint is not always stored in the database under the one-, two-, or three letter coded identifier shown on aeronautical charts and approach plates. Instead, it may be stored under a waypoint name comprising several letters. This inconsistency is particularly common with respect to waypoints in South America.

If the desired waypoint is stored in the FMC under its name rather than its coded identifier, it will not appear on the SELECT DESIRED WPT page at all. A more distant, probably undesired waypoint will appear at the top of the CDU. Before executing the selection at the top of the screen, extreme care should be taken to compare the lat/lon taken from the database against the lat/lon shown by the chart, if available, and to check that the proposed routing shown on the Map display looks reasonable.

- U1 through U8: May list up to 6 wpts on one page.
- U10: Up to 12 wpts with the same identifier may be contained in the database, requiring 2 pages.

- Select desired waypoint from given information using the line select key of your choice (left or right side).
- The display automatically returns to originating page with the selected waypoint entered where the previous entry attempt was made.



NDBs can now be called up from the database by using the ident in the navaid box from the chart, not the full name. This is now the same way we call up a VOR.

ROMEO

```
SELECT DESIRED WPT
R    NDB
     N04°40.7W074°06.3
R    NDB
     S02°07.8W079°52.1
R    NDB
     S16°30.5W068°13.1
R    NDB
     S17°23.8W066°15.8
R    NDB
     S33°06.6W064°17.3
R    NDB
     N43°44.3W079°42.2
```

Dec 1995

ROZO

ROMEO

```
SELECT DESIRED WPT
R    NDB
     N03°35.8W076°22.5
R    NDB
     N04°40.7W074°06.3
R    NDB
     S02°07.8W079°52.1
R    NDB
     S16°30.5W068°13.1
R    NDB
     S17°23.8W066°15.8
R    NDB
     S33°06.6W064°17.3
```

Sept 1996

ROMEO

ROZO is now PALMA (PL)

```
SELECT DESIRED WPT
R    NDB
     N04°40.7W074°06.3
R    NDB
     S02°07.8W079°52.1
R    NDB
     S16°30.5W068°13.1
R    NDB
     S17°23.8W066°15.8
R    NDB
     S33°06.6W064°17.3
R    NDB
     N43°44.3W079°42.2
```

Dec 1996

```
SELECT DESIRED WPT
R    NDB  ROZO
274  N03°35.8W076°22.5
R    NDB  ROMEO
274  N04°40.7W074°06.3
R    NDB  GUAYAQUIL
315  S02°07.8W079°52.1
R    NDB  (unknown)
     S16°30.5W068°13.1
R    NDB  (unknown)
     S17°23.8W066°15.8
R    NDB  (unknown)
     S33°06.6W064°17.3
```

A pilot's idea to improve this page layout.

The ILS's are in the nav database to support LOC updating.

If you enter the ID of an ILS, such as IBFI, it will only display on the LEGS, RTE, or FIX pages if there is a DME associated with that localizer. If there is no DME, like ISEA, you will get the message NOT IN DATA BASE. It is in the database for LOC updating but cannot be used as a wpt.

The coordinates are for the LOC antenna position, which is near the departure end of the runway (Near the landing threshold of the opposite runway).

The DME may be colocated with either the LOC antenna or the GS antenna which is typically abeam the TDZ. If it is colocated with the LOC antenna, there is only one entry in the database. If it is not colocated with the LOC antenna, there will be two entries in the database: one for the LOC and one for the DME.

The location of the ILS DME facility is not on the chart , so there is no way to know in advance when you will get the SELECT DESIRED WPT page.

A DME associated with an ILS is usually at the far end, though not always.

If an ILS approach does not have a DME, the identifier's coordinates will be that of the localizer antenna. (You can tell this by looking at the chart.) Ref: IAH (14L-32R) SJC (12R-30L)

If an ILS approach has a DME, the identifier's coordinates will be that of the DME antenna. (unless the dreaded SELECT DESIRED WPT page comes up, in which case you've got two coordinates)

The following is the only time you'll get the SELECT DESIRED WPT page from an ILS ident entry.

If a runway has an ILS DME approach to EACH end, then ONE of the ILS identifiers will bring up the SELECT DESIRED WPT page, asking you to select the ILS coordinate (localizer antenna) or the DME coordinate.

UNDER DEVELOPMENT

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REF NAV DATA

You get to this page by:

- INIT/REF index NAV DATA prompt (LSK 1R).

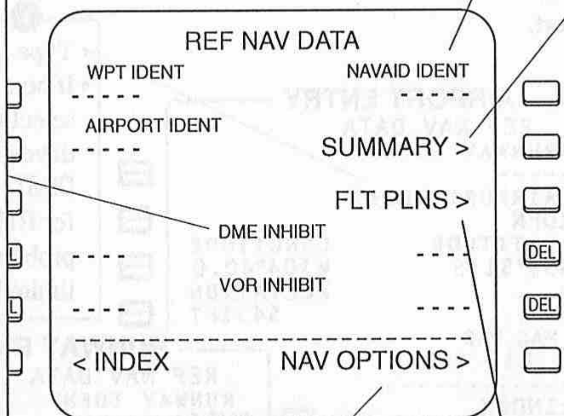
- Provides a means to review Permanent or Temporary data stored in the data base. If the desired data is not stored in the data base, allows the crew to enter new data into the Temporary data base.

U 1.4 to U6

- On U7.0 and up, DME/VOR INHIBIT feature is on the NAV OPTIONS page.
- Up to 2 VORs and 2 DMEs may be entered.
- Entry of a DME identifier inhibits use of DME information for FMC position updating.
- Entry of a VOR identifier inhibits the use of VOR bearing information for FMC position updating. Any co-located DME can still be used for FMC position updating.
- Clear by DELeting.
- Also clears at the end of the flight.
- Check Jepp and Company Nav Data Notams which identify known navaid problems over your route.

Note: LOC updating cannot be INHIBITED if loc frequency is tuned and approach is in the route.

- Dash prompts allow entry of the desired type of identifier.
- Following entry, the display format changes in accordance with the type of identifier entered.



U 6.0 & up

- SUMMARY prompt allows view of all currently defined Temporary and Supplemental nav data base items.
- If the SUMMARY prompt is not displayed, no data exists in either the Temp or Supp data base.

U 7.0 & up

NAV OPTIONS prompt allows access to DME and VOR INHIBIT and selection of update controls.

U 10.3 & up

FLT PLNS (option) allows selection of company route from Jepp Flite Star.

EXISTING DATA BASE ITEMS:

- Dash prompts:
  Enter waypoint, Runway, Airport, or Navaid identifier.
  Data for entered identifier is displayed.

  Note: To display runway data, enter runway identifier in WPT IDENT (RWXX). Box prompts will appear for airport identifier. Enter ICAO airport identifier.
  Ref: Runway Entry next page.

OR

TEMPORARY DATA BASE ITEMS: (Examples on next page)

- Enter identifier in REF NAV DATA (box prompts will appear if entry is not already defined).
- Enter required data in the box prompts and EXECute.

  Note: Runway data cannot be stored in the Temporary database.
  VOR-only navaids must be accessed as wpts.
  REF NAV DATA items may be deleted by using DEL key and EXECute, **but only if the waypoint is removed from the ACTive flight plan and FIX page.**
- All data stored in the temporary data base is cleared at flight completion (squat switch and ground speed less than 20 kts) or loss of power for more than 10 seconds.
- The U1.x FMC can hold up to 20 wpts, 20 navaids, and 3 airports in its Temporary database. U3 and up doubles these numbers; 40 wpts, 40 navaids, and 6 airports.

- 5 characters max. It is impossible to check 6 character database wpt position such as the SEA-05.
- No decimal points allowed.
- If reviewing a created wpt which is already stored in the data base, displays any radial (bearing from) and distance which was used to define the wpt.

WPT ENTRY

```
REF NAV DATA
WPT IDENT
MTWAV
LATITUDE          LONGITUDE
□□□°□□.□          □□□□°□□.□
MAG VAR
----°
REF IDENT         RADIAL/DIST
-----             ---°/---NM
<INDEX
```

Define entry with: LATITUDE and LONGITUDE, or REF IDENT and RADIAL / DIST

Entry of these fields causes Lat/ Lon to display.

Entry to nearest tenth is effective.

Note: You never really have to build the ORIGIN airport. If you enter a DEST first, the FMC creates a phoney ORIGIN named ORGN.

AIRPORT ENTRY

```
REF NAV DATA
RUNWAY IDENT
-----
AIRPORT IDENT
KDEN
LATITUDE          LONGITUDE
N39°51.5          W104°40.0
                  ELEVATION
                     5431FT
MAG VAR
E  11°
------------
<INDEX
```

Airport Reference Point.

1
- Type in 4 ICAO characters.
- If box prompts remain after line selection, the airport is not in the database. If needed for ORIGIN or DEST, you must build this point for RTE req'mts - common problem for ferry aircraft with limited database.

RUNWAY ENTRY

```
REF NAV DATA
RUNWAY IDENT
RW26
AIRPORT IDENT
KDEN
LATITUDE          LONGITUDE
N39°52.6          W104°37.2
                  ELEVATION
                     5291FT
                     LENGTH
                12000FT3650M
```

RW cannot be stored in the FIX page (until U10.5), the Temp or Supp database.

1 Enter desired runway in 1L (Ex. 14L). Leading zero is req'd. U1.x must prefix with RW.

Threshold elevation and length of entered runway. U3 adds distance in meters.

- To rebuild a database, select VOR's along route considering LOP requirements of FMC.
- If rebuiding a database, estimate the class and elevation.

5 characters max.

NAVAID ENTRY

```
REF NAV DATA
                  NAVAID IDENT
                           PUB
                         CLASS
                          VTHW
LATITUDE          LONGITUDE
N38°17.7          W104°25.8
FREQ              ELEVATION
116.70               4760FT
MAG VAR
E 13°
------------
<INDEX
```

A navaid can be entered into the Temporary nav database by entering lat./lon., frequency, magnetic variation, elevation, and classification. This information can be found in the Radio Aids section of the Jeppesen Airway Manual.

NAVAID CLASS
1st letter
V - VOR
2nd letter
D - DME M - Military
T - TCAN I - ILS/DME
3rd letter
H - High Altitude Class
T - Terminal Class
L - Low Altitude Class
U - Unknown Class
4th letter (optional)
A - Auto. broadcast wx.
B - Scheduled broadcast
W - No voice capability
If V is the first character entered, it must be followed by a D or T entry.

SUPPLEMENTAL NAV DATA

U3.0 & up

You get to this page by:

- INIT / REF INDEX page (LSK 1R while on the ground after entering SUPP in the s/p).

- SUPP NAV DATA and REF NAV DATA consist of separate sets of pages which have similar but distinct functions. The counterpart pages of each set have identical displays for Waypoint Data, Navaid Data, Airport Data, and Runway Data. The initial display of each set is unique.

- Either of the SUPP NAV DATA and REF NAV DATA pages can be used to review data (for Waypoints, Navaids, or Airports) which is already stored in any of the nav databases (Permanent, Supplemental, or Temporary). Runway data, which is stored only in the permanent database, can also be reviewed.

- When reviewing stored data, note that the page (SUPP or REF) which is displaying the data has no direct correlation to the specific data base in which the information is stored.
- If the desired data is not already stored in data bases, the crew may use these pages to define new entries.

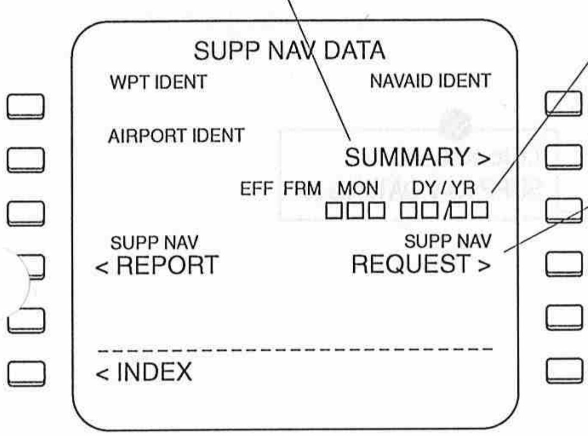
- The SUPP and TEMP databases share storage capacity for 40 navaids and 6 airports; the entries being stored in either database on a first come, first served basis. For the WPT catagory, exclusive storage is reserved in the TEMP data base for 20 entries (including those created on the RTE or LEGS pages). An additional 20 wpts (up to a max of 40) can be stored in either the SUPP or TEMP database on a first come, first served basis. When any storage capacity is full, entries which are no longer required should be deleted to make space for new entries. Created wpts cannot be stored in the database RUNWAY catagory.
- (10.3 & up) SUPP NAV db increased to 40 wpts.
- The SUPP NAV DATA pages are accessible on the ground only by entering SUPP into the s/p prior to selecting the NAV DATA prompt on the INIT/REF INDEX page.
- Nav database updating does not DELete the Supplemental entries.
- Changing the OP PROGRAM will DELete it.

U3.0 & up

EFFECTIVE FROM DATE LINE
- Used for entry and/or display of the effectivity date (MONth, DaY, and YeaR) for data stored in the SUPP database. With a new entry, the EXECute key illuminates.
- The entry must be EXECuted before any entries are permitted on the Identifier lines.
- Entry propagates to the IDENT page.
- If no entry is displayed, lines 1L, 2L, and 1R will not accept entries (no dash prompts).

U6.0 & up

Select SUMMARY to view all currently defined Supp. and Temp. nav database items.



U6, U8, & up

- Fields 4L and 4R provide the capability of reporting or requesting SUPP nav data to or from the airline's ground station, respectively.
- Selecting the REPORT prompt causes the FMC to download the entire contents of the SUPP nav database. This prompt is only displayed when the database contains SUPP data.
- Selecting the REQUEST prompt requests SUPP nav data to be uploaded. Once selected, this field remains highlighted until the SUPP nav data loading is complete.
- After the data is loaded, NAV DATA UPLINK is displayed in the s/p to indicate that the loading is complete.

U3.0 & up

If the entered identifier is already stored in either the Permanent, Supplemental or Temporary data base, then relevant data propagates to the subsequent SUPP NAV DATA display.

If the entered identifier is not stored in any data base, the subsequent SUPP NAV DATA display contains box prompts. Following entry of the required information, the new data may be stored in the Supplemental data base by EXECuting (except runway data).

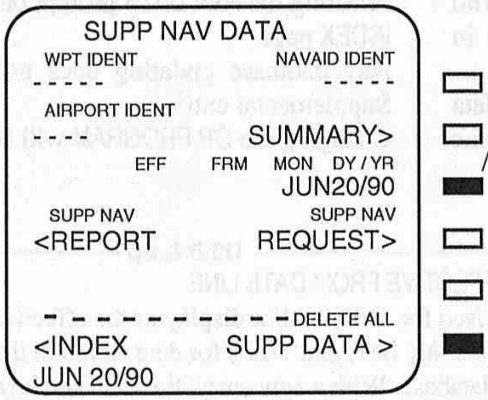
Data is stored indefinitely, but may be subsequently cleared from the Supplemental data base : By DELeting an individual identifier after entry on line 1L, 2L, or 1R; or by using 6R to delete all Supplemental data if an ORIGIN has not yet been entered.

To DELETE, the identifier(s) cannot presently be displayed on any other page, e.g. LEGS, or FIX.

1 Type: J U N 2 0 / 9 0 into scratch pad

U3.0 & up

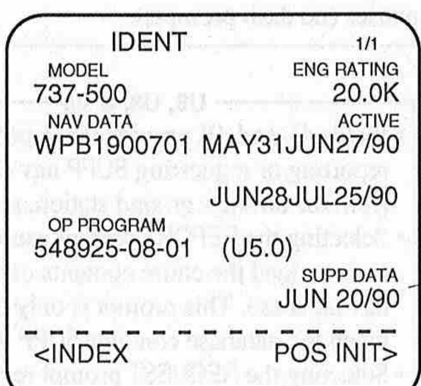
IDENTIFIER LINES
- Dash prompts allow entry of the desired type of identifier. Prompts are displayed only if an EFF FRM date is displayed.
- Following entry (1L, 2L, or 1R), the display format changes in accordance with the type of identifier entered.



2 Line select 3R.

U3.0 & up

DELETE ALL SUPP DATA
- Supplemental nav data items remain stored in the FMC until manually deleted.
- Line selection and subsequent EXECution of 6R deletes all data stored in the Supplemental nav data base.
- Individual entries can be DELeted.
- DELETE ALL function is not available following entry of an ORIGIN airport on the RTE page.



3 Date comes from SUPP NAV DATA page.

U6, U8, & up

You get to this page by:

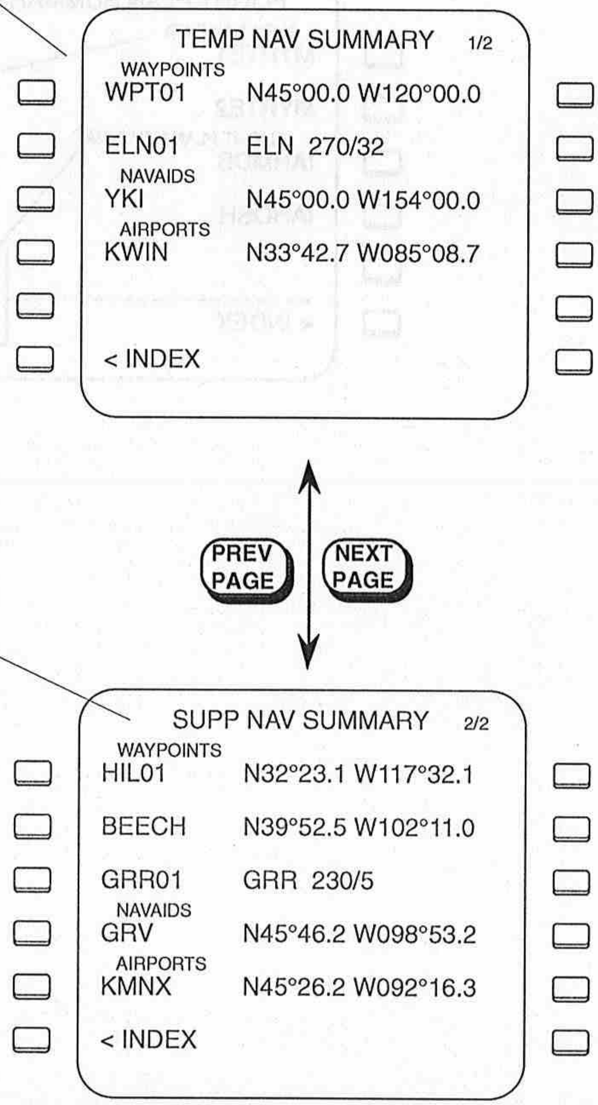
- REF NAV DATA page, SUMMARY prompt (LSK 2R) on.
- SUPP NAV DATA page, SUMMARY prompt (LSK 2R).

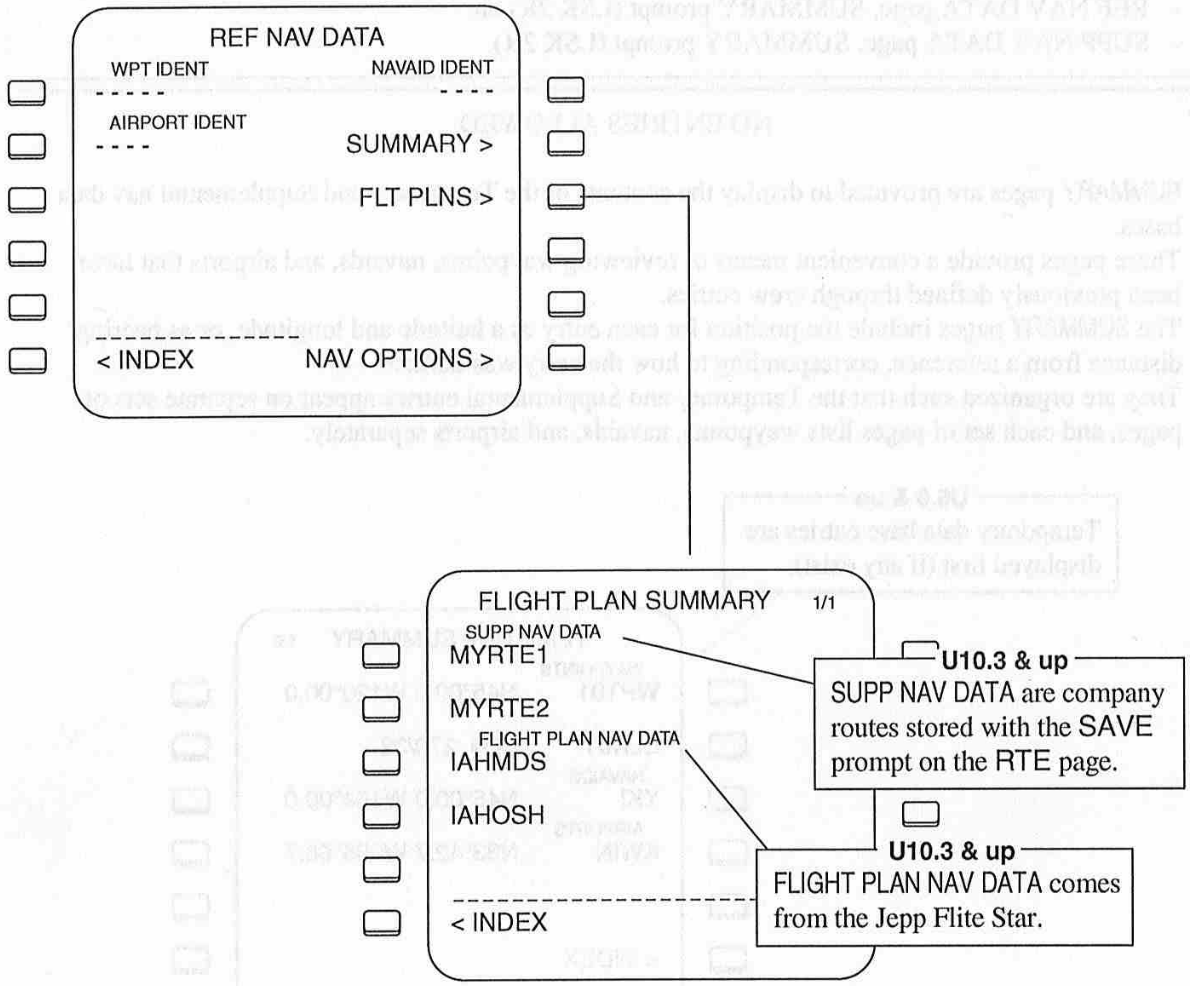
NO ENTRIES ALLOWED

- SUMMARY pages are provided to display the contents of the Temporary and Supplemental nav data bases.
- These pages provide a convenient means of reviewing waypoints, navaids, and airports that have been previously defined through crew entries.
- The SUMMARY pages include the position for each entry as a latitude and longitude, or as bearing/distance from a reference, corresponding to how the entry was defined.
- They are organized such that the Temporary and Supplemental entries appear on separate sets of pages, and each set of pages lists waypoints, navaids, and airports separately.

U6.0 & up
Temporary data base entries are displayed first (if any exist).

U6.0 & up
SUPP NAV DATA entries are provided following the last TEMP NAV SUMMARY page.




REF NAV DATA
WPT IDENT
NAVAID IDENT

AIRPORT IDENT

SUMMARY >
FLT PLNS >
< INDEX
NAV OPTIONS >
FLIGHT PLAN SUMMARY 1/1
SUPP NAV DATA
MYRTE1
MYRTE2
FLIGHT PLAN NAV DATA
IAHMDS
IAHOSH
< INDEX
U10.3 & up
SUPP NAV DATA are company routes stored with the SAVE prompt on the RTE page.
U10.3 & up
FLIGHT PLAN NAV DATA comes from the Jepp Flite Star.

IRS MONITOR

INIT / REF INDEX 1/1

< IDENT	NAV DATA >
< POS	MSG RECALL >
< PERF	ALTN DEST >
< TAKEOFF	
< APPROACH	SEL CONFIG >
< OFFSET	MAINT >

To get to the IRS MONITOR page, take the following route:

INIT / REF INDEX
MAINT >
< FMCS
With single FMC
IRS MONITR >
With dual FMC
< FMC LEFT or < FMC RIGHT
IRS MONITR >

Notes:

Pressing < INDEX brings up the previous page.

Pressing the INIT / REF key returns to the INIT / REF INDEX CDU and stops any tests you may have inadvertently started.

MAINT BITE INDEX 1/1

< FMCS	ENGINE >
< DFCS	APU >
< A/T	FQIS >
< ADIRS	
< CDS	
< INDEX	

FMCS BITE 1/1

< FMC LEFT	
< FMC RIGHT	
< INDEX	

LT FMCS BITE 1/1

< INFLT FAULT	MODEL / ENG >
< CDU TEST	SW OPTIONS >
< SENSORS	PERF FACTR >
< DISCRETES	IRS MONITR >
< FIXED OUTPUTS	
< INDEX	

IRS MONITOR

- Computed 30 sec. after flight completion.
- It is the IRU Position Error Rate(PER) during the last flight for each IRU (nm/hr).
- The PER (drift) for the flight is computed by dividing the distance from the FMC position to the IRS position occuring during the flight by the total flight time.
- If the error rate for any IRU is greater than 2.0 nm/hr for 2 consecutive flights, consider a discussion with maintenance.
- The error rates are retained (unless a long-term power interruption occurs) until the next flight completion at which time the rates will be updated, or if no 2 dimentional updates have occurred in the last hour.
- If blank, monitor data for that leg was invalid.

IRS MONITOR 1/1

IRS L
0.6 NM / HR
IRS C

IRS R
0.8 NM / HR

< INDEX

PERFORMANCE FACTORS

INIT / REF INDEX 1/1

< IDENT	NAV DATA >
< POS	MSG RECALL >
< PERF	ALTN DEST >
< TAKEOFF	
< APPROACH	
< OFFSET	MAINT >

MAINT BITE INDEX 1/1

<FMCS	NAV DATA>
<DFCS	
<A/T	
<IRS	
<EFIS	
<INDEX	

◄ LT FMCS BITE 1/1

< INFLT FAULT	MODEL / ENG >
< CDU TEST	SW OPTIONS >
< SENSORS	PERF FACTR >
< DISCRETES	IRS MONITR >
< FIXED OUTPUTS	LCD CDU >
< INDEX	

- To change a field, type ARM in 6R, line select the field to be changed, and enter the desired value.
- These should not be changed without company's direction.

DRAG FACTOR is the correction applied to the airplane drag level stored in the computer. The purpose is to account for aerodynamic modifications, airplane differences, or drag deterioration. The value is expressed as a percentage. The allowable entry range for drag factor is -9.9% to +9.9%. (1.0 = 101% of predicted drag.)

PERF CODE relates to reduced climb thrust operation. In later software, the PERF CODE has been moved to a discrete.

OPTION CODE determines high idle, rwy remain, rwy offset (F,M) TO speeds, GPS mode, and manual RNP entry.

MIN R/C (minimum rate-of-climb), value is used in the determination of the minimum rate of climb margin, for flight envelop calculations at CLB and CRZ speed. MAX ALT is calculated such that there remains some excess thrust available, equivalent to the minimum rate-of-climb values. Allowable entry range is 0-999 fpm. (-8-9) Consider changing CRZ to 300 fpm to provide more reserve power to hold altitude in the turn maneuver at max altitude. Results in approximately 1,000 ft lower MAX ALT.

F-F FACTOR (fuel flow) is the correction applied to the engine fuel flow model stored in the computer. The purpose is to account for engine modifications, engine differences, or deterioration. The value is expressed as percentage. The allowable entry range for fuel flow factor is -9.9% to +9.9%. (1.0 = 101% of predicted fuel flow.)

PERF FACTORS 1/1

PERF CODE 1000	OPTION CODE 000000000001
DRAG FACTOR + 0.0	MIN R/C
F - F FACTOR +0.0	CLB 300
MNVR MARGIN 1.30	CRZ 100
MIN CRZ TIME 1	ENG OUT 100
<INDEX	- - -

ENG OUT minimum rate-of-climb value is used in the determination of the minimum rate of climb margin, for flight envelop calculation at engine out speed. Maximum altitudes are calculated such that there remains some excess thrust available, equivalent to the minimum rate-of-climb values. Allowable entry range is 0-500 fpm.

All FMC generated data result in performance within the operating envelope defined by maneuver margins, expressed as an acceleration (g's), to initial buffet. The maneuver margin is used for limiting speed targets and advisory altitude displays. The allowable entry range for maneuver margin is 1.15 to 1.60.

MIN CRZ TIME (minimum cruise time) is used in the calculation of TRIP altitude for short range operation. Ref: PERF INIT. The TRIP altitude is determined by calculating a MIN CRZ TIME (in minutes) at the climb, cruise and descent speeds entered, all within the RTE selected distance. The value is used to approximate the minimum fuel profile, and has an allowable entry range of 1 to 20 minutes.

ENABLED SOFTWARE (U10 & up)

FMC-L ANALOG DISC 1/4

	LEFT	RIGHT
ECS PACK	ON	ON
ECS PACK H/L	LO	LO
ISOL VALVE	OP	
COWL A/ICE	OFF	OFF
WING A/ICE	OFF	
OLEO SWITCH	GND	

< INDEX

FMC-L ANALOG DISC 2/4

JAA FLT RULES	DISABLE
KILOGRAM OPTION	DISABLE
MAG / TRUE	MAG
SRCE / DEST IDENT	LEFT
ASPIRATED TAT	DISABLE
°C / °F DEFAULT	°C
PERF CODE	1

< INDEX

FMC-L ANALOG DISC 3/4

FMC SOURCE SEL	NORMAL	
MODEL / ENG	VALID	
ENGINE BLEED	NO.1	NO.2
	ON	ON

< INDEX

FMC-L ANALOG DISC 4/4

VOR INHIBIT	DISABLE
FLIGHT NUMBER	ENABLE
TOGA RW POS UPD	ENABLE
TAKEOFF PROFILE	ENABLE
TAKEOFF SPEEDS	DISABLE
NAVAID SUPRESS	ENABLE
SEL CRS INHIBIT	DISABLE
ACARS INSTALLED	ON

< INDEX

- The ANALOG DISC pages display the software options your carrier has chosen to activate,
- To get to an ANALOG DISC page take the following route:
  INIT / REF INDEX
  MAINT >
  < FMCS
  < FMC LEFT or < FMC RIGHT
  < DISCRETES
  There will be several pages under DISCRETES. This example lists four.

```
FMCS IN FLT FAULTS  1/3
 LRU
ADC        LEFT
ADC        RIGHT
DFCS
DME        LEFT
DME        RIGHT
FUEL SUM
EFIS CP  LEFT
EFIS CP  RGHT
EFIS SC  LEFT
EFIS SG  RIGHT
<INDEX
```

```
FMCS IN FLT FAULTS  2/3
 LRU
VHF NAV  LEFT       34   89
VHF NAV  RIGHT       4 6789
IRS        LEFT           7
IRS        RIGHT          7

DAA        LEFT
DAA        RIGHT
CLOCK

<INDEX
```

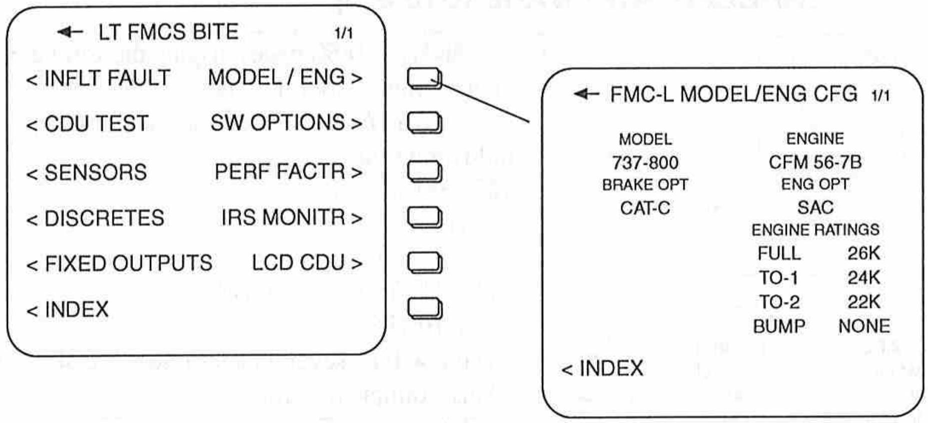
```
FMCS IN FLT FAU
 LRU
CDU        LEFT
CDU        RIGHT
FMC

<INDEX
```

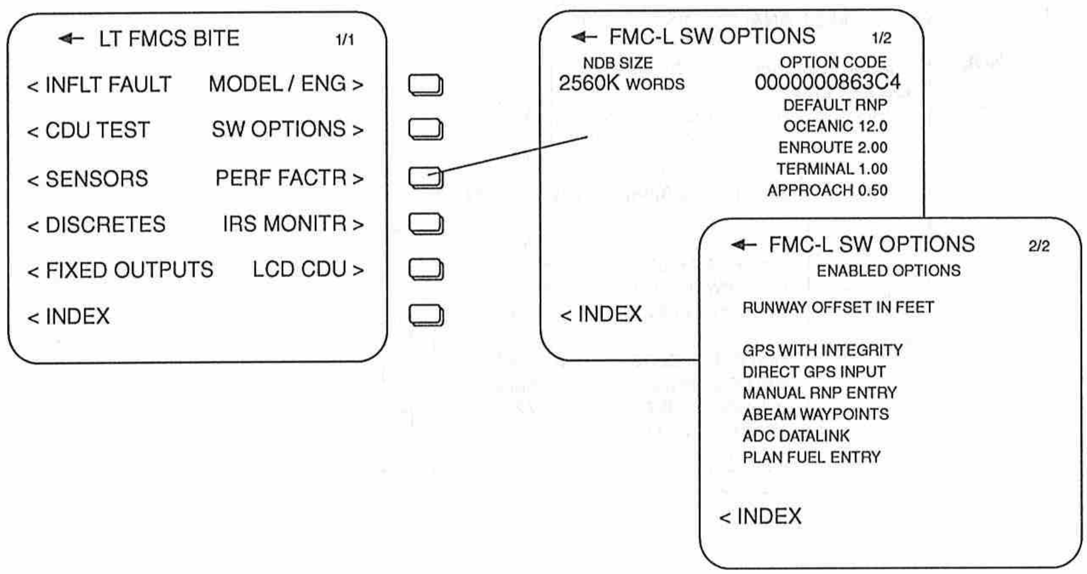
- The FMCS IN FLT FAULTS pages display the hardware that has failed, and the flight leg.
- To get to the FMCS IN FLT FAULTS page take the following route:
  INIT / REF INDEX
  MAINT >
  < FMCS
  < FMC LEFT or < FMC RIGHT
  < INFLT FAULTS
  There will be several pages. This example lists three.

- Pressing < INDEX brings up the previous page.
- Pressing the INIT / REF key returns to the INIT / REF INDEX CDU and stops any tests you may have inadvertently started.

MODEL / ENGINE CONFIGURATION



SOFTWARE OPTIONS



Abeam Waypoints (U10.0 and above)
Alternate Destination (U10.0 and above)
Altitude/Speed Intervention (U10.0 and above)
AOC Datalink (U10.0 and above)
ATC Light & Chime on FIXED OUTPUTS page displayed (U10.4 and above)
ATC Message on Map displayed (U10.4 and above)
CDU Color (U10.2 and above)
Engine-out SIDs (U10.3 and above)
FANS-1 ATS DataLink (U10.4 and above)
FMS RNAV ILS Look Alike Approach (U10.5 and above)
Geometric Descents (U10.3 and above)
GPS Landing System Approach (U10.5 and above)
GPS Operational Mode Bits 1 & 2 (U7.0/8.0 and above)
GPS Select (U7.0/8.0 and above)
Gross Weight Entry inhibit (U10.4 and above)
High Idle Descent (U7.0/8.0 and above)
Manual RNP (U7.0/8.0 and above)
Manual Takeoff Speeds (U7.0/8.0 and above)
Message Recall (U10.0 and above)
Missed Approach on Map displayed in Cyan (U10.4 and above)
Optional Quieting Gradient (U10.3 and above)
Pilot-Defined Company Routes (U10.3 and above)
Plan Fuel (U10.0 and above)
QFE Altitude Reference (U10.0 and above)
Quiet Climb System (U10.3 and above)
Runway Offset/Remaining (in feet)(U7.0/8.0 and above)
Runway Remaining (U7.0/8.0 and above)
Takeoff Derates disabled (U10.4 and above)
Takeoff Speeds certified (U10.0 and above)
Vertical RNP Values loadable by default (U10.5 and above)
VNAV ALT Enable (U8.0 and above)

ALTERNATE NAV

The Alternate Nav System is a GPS based system which provides nav capability independent of the FMS. The Alternate Nav System consists of the Alternate Nav CDU (ANCDU) and on-side GPS. In the event of FMC failure, the ANS provides a backup mode of operation which is immediately available for use.

Each Alternate Nav system operates independently, the left, the right. Each ANCDU performs its own computations based on inputs from its own GPS.

Keep in mind that the ANCDU has special features. AN stands for alternate nav. It has a memory chip and is able to store the FMC route, up to 60 wpts. The FMC automatically sends the current active route to the ANCDU. The ANCDU has no performance or nav database. Thus there is no stored information from which the desired wpts can be extracted by use of their identifiers.

Alternate Nav cannot drive the Maps and cannot provide LNAV to the FCCs.

The ANCDU does not perform VNAV computations, nor provide autothrottle commands. MCP can be used for this function.

The ANCDU cannot tune the VHF nav radios and does not use radio information for position updating.

Both ANCDUs are powered by transfer bus 1.

The ANCDU requires a moment to load the route from the FMC; therefore, it is recommended that the entire route be entered into the FMC either prior to departure or as soon after takeoff as time and duties permit, the ANCDU will probably contain most of the waypoints necessary to navigate to your destination following a dual FMC failure.

Wpts beyond the destination (missed approach procedure) and conditional wpts, are dropped from the flight plan.

The ANCDU flight plan can be in various states of activity. These possible states are inactive, active (ACT), and modified (MOD).

Only certain keys will operate in the Alternate mode; they are the EXEC key, the PREV PAGE and NEXT PAGE keys, the line select keys and the alphanumeric keys, including CLR, "/", ".", and "±".

Four ANCDU pages will be available after failure of an FMC; MENU, ACT IRS/GPS LEGS, ACT IRS/GPS WPT DATA, and IRS/GPS PROGRESS.

Route modifications are made on the ACT IRS/GPS LEGS or ACT IRS/GPS DATA pages. A MOD page will display an ERASE prompt to readily facilitate changing back to the original ACT page.

The database of nav stations and waypoints is contained in the FMC, and since it has failed, you do not have access to it and cannot load waypoints by name not already in the flight plan. Note that the modifications must be made to each ANCDU independently; there is no remote loading or re-syncing of a route. The crew must exercise great care in modifying the route. The pilots must independently cross-check each other's entries.

Complete departure and arrival or approach procedures cannot be manually entered or crossloaded from the FMC. This is because the ANCDU does not accept undefined wpts or legs, that is, no fixed heading or course legs, and no conditional wpts.

For those of you who have experience in Inertial Navigation System (INS) equipped airplanes such as the DC-10 or B-747, the major differences may be summarized as follows:

1) Waypoints cannot be remotely loaded. Each pilot must make identical changes to the route.
2) The GPS position is much more accurate than the INS position.

If in MNPS airspace, notification of navigation system failure to ATC through the appropriate radio is required, but the airplane can still be navigated with sufficient precision in this configuration to remain in the Minimum Navigation Performance Specification (MNPS) airspace. Consult Company regulations for the specific procedures applicable to you.

ALTN NAV course deviation is only displayed on the ISFD (Integrated Standby Display). BBJ only.

ALTERNATE NAV (This page does not cover U10)

INIT / REF INDEX 1/1

< IDENT	NAV DATA >
< POS	MSG RECALL >
< PERF	ALTN DEST >
< TAKEOFF	
< APPROACH	IRS NAV >
< OFFSET	MAINT >

- The Alternate IRS nav pages may be accessed manally at any time, provided that the IRS feeding the ANCDU being used is valid.
- Access to the IRS nav pages while the FMC is valid is made possible through the IRS NAV> prompt that appears on the INIT/REF INDEX page.
- If this prompt is pressed, the ANCDU will enter the Alternate IRS nav mode and display the IRS PROGRESS page or the IRS LEGS page.
- If an active ANCDU flight plan exists, then the IRS PROGRESS page will be displayed; otherwise, the IRS LEGS page will be displayed.
- If the ANCDU determines that the IRS data is invalid, the IRS NAV prompt is not displayed on the INIT/REF INDEX page.

- Only two types of fix entries are displayed following an FMC failure, 5 letter waypoint identifiers and lat/lon wpts.
- Lat/lon wpts can be added to the route by typing the full format (N3949.0W07425.9) and line selecting to the appropriate point in your route.
- A 5 letter waypoint identifier may be moved in the flight plan; once overwritten, cannot be retrieved. It is erased from the ANCDU memory.
- U10.3 can transmit up to 60 wpt to the LCD CDU.

ACT IRS LEGS 1/2

224° M	42 NM	
CYN		00:1
235° T	61 NM	
ENO		00:1
240° T	144 NM	
GVE		00:3
267° T	121 NM	
PSK		-00:28
< CROSSLOAD		
< PROGRESS - -IRS- -WPT DATA >		

- Current course is relative to Magnetic north.
- Computed course for down path legs is relative to True north.

MOD IRS WPT DATA 1/2

CYN	N39°49.0W074°25.9
ENO	N39°13.9W075°31.0
GVE	N38°00.8W078°09.2
PSK	N37°05.3W080°42.8
< CROSSLOAD	
< PROGRESS - -IRS- -WPT DATA >	

- FMC route can be crossloaded to the ANCDU route.
- If the FMC fails, the CROSSLOAD prompt changes to LAST FMC PLAN which provides the last valid route sent by the FMC.

Desired track angle relative to the selected Magnetic or True reference setting.

Current track angle relative to the selected Magnetic or True reference setting.

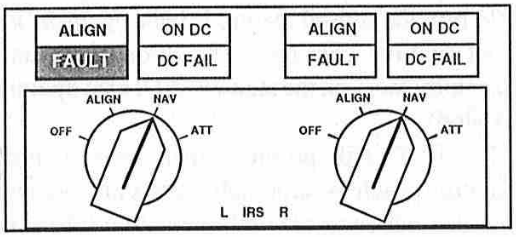
IRS PROGRESS

TO	DTG	ETE
ENO	81 NM	00:13
TK / DSRTK		XTK ERROR
220 M / 250 M		L0.1 NM
GS		WIND
310 KT		270° / 60 KT
IRS R		
N39°50.4 W073°22.7		
< LEGS	- - IRS - -	WPT DATA >

Indicates the computed distance that the a/c is left or right of the active flight path.

- Present position received from the IRS.
- The header indicates which IRS the ANCDU is using (L, C, or R)
- Blank if the current IRS position is not valid.

FAULT LIGHT ON - IN FLIGHT



When the aircraft is moved during alignment, the FAULT light illuminates steadily and the ALIGN light flashes.

To demonstrate while in flight, turn one IRU from NAV to ATT. Saves time by not going to OFF first.

The IRS FAULT light illuminated indicates the respective IRS system has detected a fault. The NAV mode (s) is no longer available, and in most cases the IRU can not be used in ATTitude .

If an IRS looses both AC and DC power, the alignment is lost. Alignment can also be lost if the mode selector is moved out of the NAV position.
If alignment is lost in flight, the navigation mode (including present position and ground speed outputs) is inop for the remainder of the flight.

Mode select unit of failed IRS . . . . SELECT OFF THEN ATT

This clears the fault and extinguishes the FAULT light. There may be a chance that ATT mode will work, depending on what the nature of the fault is. Allows the attitude mode to be used to re-level the system. Requires approximately 20 seconds of straight and level unaccelerated flight to complete the ADI leveling; a little longer for HSI leveling. Some attitude errors may occur during acceleration but will slowly be removed after acceleration. If the FAULT light reappears, the ATTitude mode is inop.

To provide heading information . . . ENTER MAGNETIC HEADING USING ISDU OR CDU

To enter the magnetic heading with ISDU:
1. Place mode selector (s) in ATT.
2. Switch SYS DSPL to affected IRU.
3. Press H 5 (for heading).
4. Enter compass heading using numeric keys.
5. Press ENT

To enter the mag heading with CDU:
1. Place mode selector (s) in ATT.
2. Turn to POS INIT 1/3
3. Enter compass heading in s/p.
4. Enter heading in SET IRS HDG

Crosscheck and verify heading with opposite AHRS or magnetic compass.
Heading flags should retract from view on round-dialed aircraft. Heading indicator is re-displayed for EFIS.
The IRS heading will precess up to 15°per hr. and must be updated periodically.

If the FAULT light reappears, the ATTitude mode is inop. Proceed:

Aircraft is equipped with an IRS TRANSFER switch:

MALFUNCTIONING IRS MODE SELECTOR . . . . .OFF
IRS TRANSFER SWITCH . . . . BOTH ON OPERATING SYSTEM

Switches all associated systems to the functioning IRS. If the switch is moved with an autopilot engaged, it may disconnect.

OR

Aircraft is not equipped with an IRS TRANSFER switch:

MALFUNCTIONING IRS MODE SELECTOR . . . . OFF

COMPASS SWITCH . . . . BOTH ON OPERATING SYS.

ATTITUDE SWITCH . . . . BOTH ON OPERATING SYS.

CROSSCHECK AND VERIFY HEADING AND ATTITUDE.

BOTH IRSs FAIL IN FLIGHT - B 737

Loosing **both** IRSs is a remote possibility, but a quick look at how it affects the pilot is in order.

The IRS's feed data to many important systems in the cockpit such as: ADI, HSI, Autopilot/ Flight Director, FMC, VSI (EFIS aircraft), and the Autothrottle. The most obvious equipment losses are both primary attitude indicators, flight directors, autopilot, and some of the features of the FMC. The sole source of attitude information is now the **standby horizon**. Heading must be obtained from the **magnetic compass**. What this means to the pilot is that his instrument crosscheck just became a real problem. The distance between the magnetic compass and the standby horizon is significant, especially if "IMC". Crew coordination on a higher than normal level is required due to the technique for making instrument turns on the standby compass. Remember all the basic rules for turns on the standby compass? Also, if an approach is required, crew coordination really becomes critical when trying to coordinate the turns and headings with the VOR/ ILS performance readouts on the HSI without heading inputs.

Some performance indicators are lost such as the VSI on EFIS aircraft. However, pressure altitude is available on both the electric and pneumatic indicators. Radio altitude is displayed as normal. The Mach and IAS are operative on the electromechanical indicator (if installed), fast/slow indicator (if installed) and the speed tape (if installed). Airspeed is also available on the pneumatic standby indicator. Groundspeed is inoperative but TAS is displayed on the last PROGRESS page.

The MCP is inop except for the IAS/MACH window, course selector and altitude display. The IAS/MACH window sets the target airspeed bug. The course selector sets ILS and VOR courses which are displayed as normal on the MCP and HSI. The altitude selector triggers the altitude alert system.

Timing or "Dead Reckoning" after the IRS shutdown can assist in determining the airplane's present position since the FMC is no longer receiving position data and the EHSI MAP display is gone. Magnetic bearing to the VOR and DME may or may not be available on the RDMI's depending on avionics installation, but the card is fixed which eliminates the relative bearing function. The ADF bearings are still functional and indicate only the relative bearing from the nose of the airplane. The GSI and CDI on the HSI (in VOR/ILS mode on EFIS aircraft) are operative in both VOR and ILS operation but only provide sensed magnetic bearing information, not relative bearing. The glide slope and localizer indicators on the standby ADI also operate (if installed).

The FMC still provides many perfomance computations such as approach speeds and N1 targets but can not compute any navigation information due to the loss of position data input from the IRS. Therefore, both LNAV and VNAV are disabled. The following is a brief rundown of what the FMC still provides on its pages following the loss of both IRS's.

CLB, CRZ, and DES pages.
No ETAs, fuel predictions or waypoint altitude predictions, but, displays N1 values, airspeed restrictions and target speeds. Pages may sequence to the next phase of flight automatically provided waypoints are manually sequenced by the crew and other conditions are met.

DEP/ARR page operates normally.

HOLD page operates normally except no ETA or HOLD TIME displayed.

IDENT page operates normally.

N1 LIMIT page operates normally.

PERF INIT page 1 operates normally. On U4.0, page 2 of PERF LIMITS operates normally, but the RTA is inop.

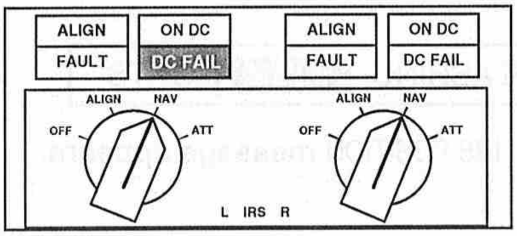
POS INIT page displays the last FMC position prior to IRS failure. Page(s) 2 and 3 (U4.0 only) are blank.

PROGRESS pages retains fuel remaining and time over last waypoint, but no ETAs, DTG or fuel estimates. Also, the FMC will not autotune navaids. On U4.0 only, the RTA page is inop. The last PROGRESS page still displays true airspeed, SAT and ISA deviation.

REF NAV DATA operates normally.

RTE pages retains normal information but does not sequence waypoints automatically.

RTE LEGS page retains flight plan waypoints entered prior to failure and new waypoints may be entered. The courses between waypoints are displayed for all but the active waypoint. It retains altitude and airspeed predictions entered prior to IRS failure and allows new entries. On EFIS aircraft, the PLAN mode operates as normal with the CTR STEP prompt.

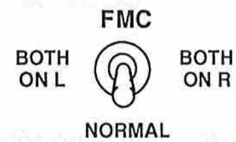


DC FAIL LIGHT ON

DC FAIL light on indicates the respective IRS DC power is not normal.

IRS DC power is inop. If all other IRS lights are extinguished, operate normally.

IRS DRIFT (Dual FMC Installation) (Failed or no GPS)



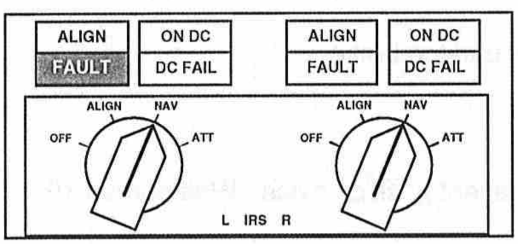
FMC TRANSFER SWITCH . . . . BOTH ON L or R

Move FMC Transfer switch to BOTH ON L if left IRS is the good one; to BOTH ON R if the right IRS is good. This will remove the bad IRS from the position solution.

POS SHIFT page line 3 center will change from IRS (2) to IRS (L) or (R)

Re-engage LNAV and VNAV

FAULT LIGHT ON - ON GROUND



The Built-In-Test (BIT) function of the FMC provides continuous monitoring of the "state of health" of the FMC and CDU. Should any system failures be detected, FMCS functions then decide if downmoding to lower levels of capacity are necessary. The FAULT light will illuminate when a critical failure is sensed.

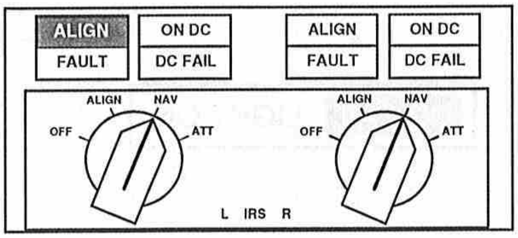
When the aircraft is moved during alignment, the FAULT light illuminates steadily and the ALIGN light flashes.

ON GROUND:

NOTE: Placing the MASTER DIM & TEST switch to TEST for 10 seconds may preclude this fault when associated with the first alignment of the day.

1. Turn MSU mode select switch to OFF. Wait until align light is out (± 30 sec).
2. Verify that aircraft is not moving. Set parking brake.
3. Turn mode select switch to NAV.
4. After align light is on, enter correct present position twice. Wait normal 10 minutes for the IRS to enter NAV.

NOTE: If FAULT light illuminates while on landing rollout, the laser beam may be getting weak. Consider advising maintenance.



FLASHING ALIGN LIGHTS

ENTER IRS POSITION **message appears.**

PROMPT / MAINTENANCE Codes will appear concurrently with a flashing align light. (HDG/STS position)

CODE 03	Excess motion detected. IRS MOTION message. Steps 2 thru 5.
CODE 04	Significant difference between previous and entered positions or an unreasonable present position entry.
CODE 08	Present position not entered. Enter present position..

A flashing align light requires some pilot action. This procedure will always allow recovery from flashing align lights not caused by equipment failure.

1. Select the NAV mode and enter the correct identical present position twice. Ref: Reasonableness Test, System Description.

OR, IF LIGHT DOESN'T STOP FLASHING

2. Turn MSU mode select switch to OFF. Wait until align light is out (about 30 sec).
3. Verify that aircraft is not moving. Set parking brake.
4. Turn mode select switch to NAV.
5. After align light is on, enter correct present position twice. Wait normal 10 minutes for the IRS to enter NAV.

Any time the crew sees a single or dual FMC failure, trouble shooting data is recorded by the FMC. This data can be written to a disk by a maintenance procedure and sent to the vendor to discover the cause of the failure so that it can be corrected in subsequent versions. For this reason it is very important that you inform maintenance as soon as possible of such a failure.

FMC FAILURE ON THE GROUND

E-8 on P-18-3 (CMPTR) . . . . PULL FOR AT LEAST 15 sec. and RESET

NOTE: Maintenance can accomplish the same thing by pressing a RESET switch on the FMC in the avionic bay.

FMC . . . . RE-INITIALIZE

RECORD ANY STATUS CODES

If FMC failure occurs after a complete power down, the failure may be due to a dead internal FMC battery. Maintenance will have to reload the data base. A dead battery in flight will have no affect as ship's power will be the current source.

FMC/CDU FAILURE (Single FMC installation)

The FMC alert light and CDU FAIL light(s) illuminated indicates either an FMC failure (both CDUs display FMC) or a CDU failure (associated CDU display blanks). Check FMCS C/Bs on P18-2 panel (behind Captain): E - 8.

If an FMC Failure (or CDU failure with a single CDU installed):

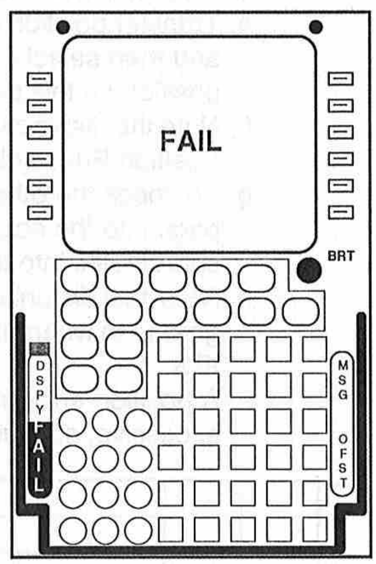
The FMC/CDU is inop; L NAV and V NAV are inop.

Resume conventional navigation.

An attempt may be made to recover the FMC by pulling the CBs for at least 15 seconds. Pulling computer CBs should be regarded as a last resort method only.

On FMA

FMC P/RST



DUAL FMC FAILURE

Indications:

- The VTK flag will appear on both EHSIs.
- The FMC Alert light will illuminate.
- Both CDU FAIL lights illuminate and both CDUs will fail.
- LNAV and VNAV will disengage
- 25-30 seconds later, the MAP flag (yellow) appears. All FMC data disappears from both EHSIs.

Check FMCS CMPTR C/Bs:

No. 1 on P18-3 panel (behind Captain): E-8

No. 2 on P6-1 panel (behind FO): B-9

An attempt may be made to recover an FMC by pulling the CBs for at least 15 seconds. Pulling computer CBs should be regarded as a last resort effort only.

Accomplish the following steps when you suspect an IRS "drift" to be excessive. POS SHIFT page, differences in wind readout of left and right IRSs in flight, large discrepancies in lat/lons on POS page 2/2,and/or high groundspeeds at the gate, all can indicate excessive IRS drift.
Note: Your company may require 2 consecutive flights with the error on each before write up.

RESIDUAL GROUND SPEED TOLERANCE

Groundspeed readout must be taken before the airplane has been stationary for three minutes because the system may zero the display.

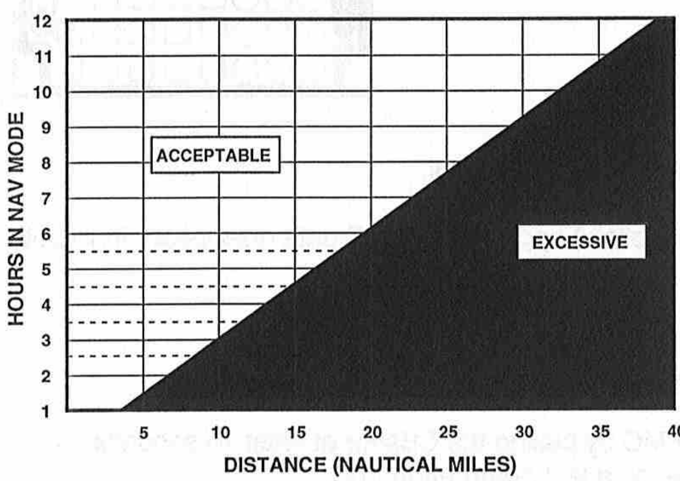
AND

a. Set the suspect IRS's DSPL switch to its own position (L or R).
b. Set DSPL SEL switch to TK/GS.
c. When stationary, the display shows the residual groundspeed error.
d. If the residual g/s error is greater than 20 kts, consult maintenance.

RADIAL POSITION ERROR TOLERANCE

To accomplish the following steps, each IRS Mode Select switch must remain in the NAV position after flight. This is to preserve the IRS position coordinates. These coordinates are displayed on the POS REF 2/2 page.
In the following steps, the airplane's present position and IRS position are entered into the LEGS 1/1 page. When entered, these positions are displayed as waypoints and the distances are compared.

a. Enter any route on the RTE page. Use your present position as the Origin airport. EXECution is not required.
b. Press LEGS key.
c. Enter airplane present position coordinates (use gate position or figure present position from airport diagram) into the first waypoint position. (Decimal points and trailing zeros optional) Displays as WPT01.
d. Press the INIT REF key, then NEXT PAGE. POS REF 2/2 page is displayed.
e. Transfer position of the suspect IRS from POS REF 2/2 page into the scratch pad and then select LEGS page. Place the IRS position coordinates into the second position on this page (LSK 2L).
f. Note the distance and bearing from WPT01 to WPT02. This represents the Radial Position Error (displayed in nautical miles) for the IRS chosen.
g. To check the other IRS, transfer that IRS position coordinate from POS REF 2/2 page into the scratch pad and then select LEGS page. Place these IRS position coordinates into the second waypoint position (behind WPT01).
h. Note the distance and bearing from WPT01 to WPT03 (actual coordinates on ground to where IRS thinks it is). This represents the Radial Position Error for that IRS.
i. A position error exceeding the value of the chart is considered excessive. If it is excessive, consult maintenance.



The equation $\frac{3+3T}{T}$ may also be used. **T** is the hours in the NAV mode (since full alignment).
EXAMPLE: 2 hr. time in NAV.
3 + (3x2) = 9 / 2 = 4.5
If the Radial Position Error exceeded 4.5 nm in this case, that particular IRS has excessive Radial Position Error.

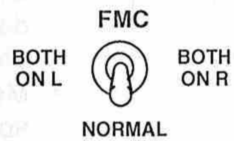
DISAGREEMENT BETWEEN FMCs (Dual FMC installation)

When a disagreement occurs between the left and right FMC, the right FMC "condition fails" and is unavailable. A solution to this software problem is being sought.

Indications:

- FMC Alert light and FMC Message light illuminate.
- ETA and Distance To Go data only blanks on right MAP, CTR MAP, and PLAN.
- 30 seconds later, the MAP flag (yellow) appears. All FMC data disappears from the right MAP, CTR MAP, and PLAN modes.
- Message, SINGLE FMC OPERATION appears in scratchpad.

The V T K flag **does not** appear with a disagreement between the two FMCs. If the flag appears, refer to SINGLE FMC FAILURE (Dual FMC installation) - p.132



FMC switch . . . . BOTH ON L

The right FMC is commanded to re-sync with the left. Allow several minutes for resync. Note: Any switch movement initiates a re-sync.

Message DUAL OPS RESTORED appears in scratchpad.

FMC switch . . . . NORMAL

Re-sync is successful. Do not record in the maintenance manual.

OR

Message DUAL OPS RESTORED does not appear in scratchpad.

FMC switch . . . . BOTH ON L

Re-sync is unsuccessful. Continue with single FMC operation.

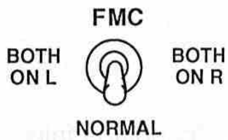
After landing, attempt recovery by complete power down.

After flight completion . . . . RECORD FAILURE

STEPS

1 Go to the INIT/REF INDEX . . . . Press MAINT prompt (6R)
2 MAINT BITE INDEX . . . . Press FMCS prompt (1L)
3 BITE page . . . . Press the FMC L prompt (1L)
4 Displayed BITE . . . . Press INFLT FAULT prompt (1L)
5 INFLT FAULTS . . . . Record abnormalities from any of the 3 pages
6 INFLT FAULTS . . . . Enter 300 in scratchpad, press 6R
7 Displayed FLIGHT SELECT . . . . Press FLIGHT X* and record
8 Displayed FLIGHT . . . . Press INDEX
9 Displayed FLIGHT SELECT . . . . Press the next FLIGHT and record
10 Continue in this fashion until all faults are recorded.
11 Go back to the BITE page by pressing INDEX . . . Press the FMC R prompt (2L)
12 Follow steps 4 thru 10 to record faults for the right FMC.
13 To exit MAINT pages . . . . Press INIT / REF key
14 Take this data to maintenance.

* Space exists in memory for the last 10 flights. If an anomaly has occured it will be labeled FLIGHT X (Example: FLIGHT 4 would mean an irregularity occured on the fourth flight ago.)



SINGLE FMC FAILURE (Dual FMC installation)

OR

The VTK flag appears on **Left** EHSI MAP, CTR MAP, PLAN, and NAV modes and **both CDUs fail.** *

Left FMC Failure with FMC sw. in NORMAL:

- FMC Alert light illuminates.
- ETA and Distance To Go header and data blanks on left MAP, CTR MAP, and PLAN.
- LNAV and VNAV will disengage but can be reengaged if autopilot B is selected.
- 25-30 seconds later, the left MAP flag (yellow) appears. All FMC data disappears from the left MAP, CTR MAP, and PLAN modes.

FMC switch . . . . BOTH ON R
This restores the left EHSI and both CDUs are now controlled by the right FMC.

Check CB: FMCS CMPTR No. 2
P6-1 B-9 and reset one time only.

Continue with single FMC operation.

The VTK flag appears on **Right** EHSI in MAP, CTR MAP, PLAN, and NAV modes and **both CDUs operate normal.** *

Right FMC Failure with FMC sw. in NORMAL

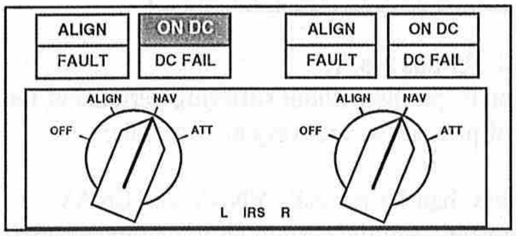
- FMC Alert light and FMC Message light illuminate.
- ETA and Distance To Go header and data blanks on right MAP, CTR MAP, and PLAN.
- Message, SINGLE FMC OPERATION appears in both scratchpads.
- LNAV and VNAV will disengage if autopilot B is in use (can be reengaged if autopilot A is selected).
- 25-30 seconds later, the MAP flag (yellow) appears in right EHSI. All FMC data disappears from the EHSI in MAP, CTR MAP, and PLAN modes.

FMC switch . . . . BOTH ON L
This restores the right EHSI.

Check CB: FMCS CMPTR No. 1
P18-2 E-8 and reset one time only.

Continue with single FMC operation.

* If the VTK flag appears in both EHSIs, and both CDUs fail, you have experienced a dual FMC failure. Without an operating FMC, CDU operation is not possible. LNAV and VNAV are unavailable. Resume conventional navigation.



ON DC LIGHT ON

The IRS is operating from the BATT BUS (limited to 5 minutes for the right IRS).

NO or OUT-OF-DATE DATABASE

Check the MEL.
If you are allowed to dispatch without a database, choose one of the steps below.

OR

Short on time.

1. Align the IRUs. Use the POS INIT page to manually enter the lat / lon position. Have your crew double-check your entry.
2. Navigate using ground-based navaids.
3. Inform your dispatcher and ATC of your status. ("slash alpha")
4. Select EXP VOR or FULL VOR. TCAS and radar can only be viewed on EXP.
5. Do not use Map, center Map, LNAV, or VNAV.
6. FMC probably has the performance database, so if the PERF INIT and TAKE-OFF REF pages are completed, the autothrottle can be used.

Lots of time.

1. Using the REF NAV DATA / AIRPORT, build the ORIGIN AND DESTination airports. Lat / lon is required and can probably be found on your Jepp 10-9. Have your crew double-check your entry of the ORIGIN airport.
2. Align the IRUs. Use the POS INIT page to enter the REF AIRPORT position.
3. The FMC probably has the performance database, so if the PERF INIT and TAKEOFF REF pages are completed, the autothrottle can be used.
4. Define your nav fixes using the REF NAV DATA page. You will use the WPT and NAVAID fields.
5. It may be difficult to find the lat / lon of waypoints (WPT) and VORs. Your flight plan may have this information.
6. The CLASS entry for VOR requires specific entry. Refer to the page that describes REF NAV DATA / VOR entries in this book. VDH should always work. You may have to estimate the elevation.
7. Define VORs alongside your route using the same method. Choose VORs that are within 200 miles of your centerline. The FMC will use these to update its position. If the flight is long and time is short, define just the ones you need at the beginning of the flight and do the others enroute.
8. After all the fixes are defined, you can build the route leg-by-leg on the RTE or LEGS pages, but first enter the ORIGIN and DEST airports.
9. Updating will take place, but will not be as accurate as normal.
10. Use Map for position awareness.
11. Enroute, the applicable ground based navaid must be displayed and is controlling; however, LNAV can be used if you've built the necessary fixes. Using LNAV is much smoother than following a VOR that *scallops*.

POWER LOSS and SENSOR FAILURE RECOVERY

The FMC and both CDUs are powered indirectly by transfer bus No. 1.
The FMC is designed to survive power transients and interruptions without suffering permanent loss of its navigation and guidance capabilities. Three modes of power loss recovery are possible:

1 If electrical power has been interrupted for less than 10 seconds, VNAV and LNAV disengage, all entered data is retained by the FMC, and the system will continue to operate normally as if no interruption had occured.

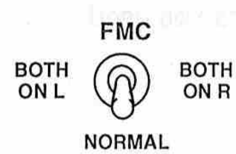
2 If the power has been interrupted for 10 seconds or more while on the ground, the system goes through a complete power-up procedure. All preflight data and flight plan entries must be re-entered when power is restored, including those in the Temporary nav data base.

3 If the power has been interrupted for 10 seconds or more in flight, the system retains all loaded data, LNAV and VNAV disengage, and when power is restored, the CDU reverts to display of a MOD LEGS (page 1/1) with a SELECT ACTIVE WPT / LEG message in the scratch pad. The system will not illuminate the EXEC key until or unless TO waypoint has been defined and a valid radio updated nav mode is available.

NOTE: A software "restart" which results from the FMC entering an impossible computational state, such as division by zero, will appear to the pilots to be a temporary loss of electrical power. The CDU will momentarily blank and then display "FMC".
This is followed quickly by the display of the MOD RTE LEGS page with box prompts in the active waypoint line.
The message SELECT ACTIVE WPT / LEG will be displayed.
In some cases, multiple software restarts inflight will result in FMC failure. The FMC may be re-initialized by removing AC power for more than 10 seconds after landing.

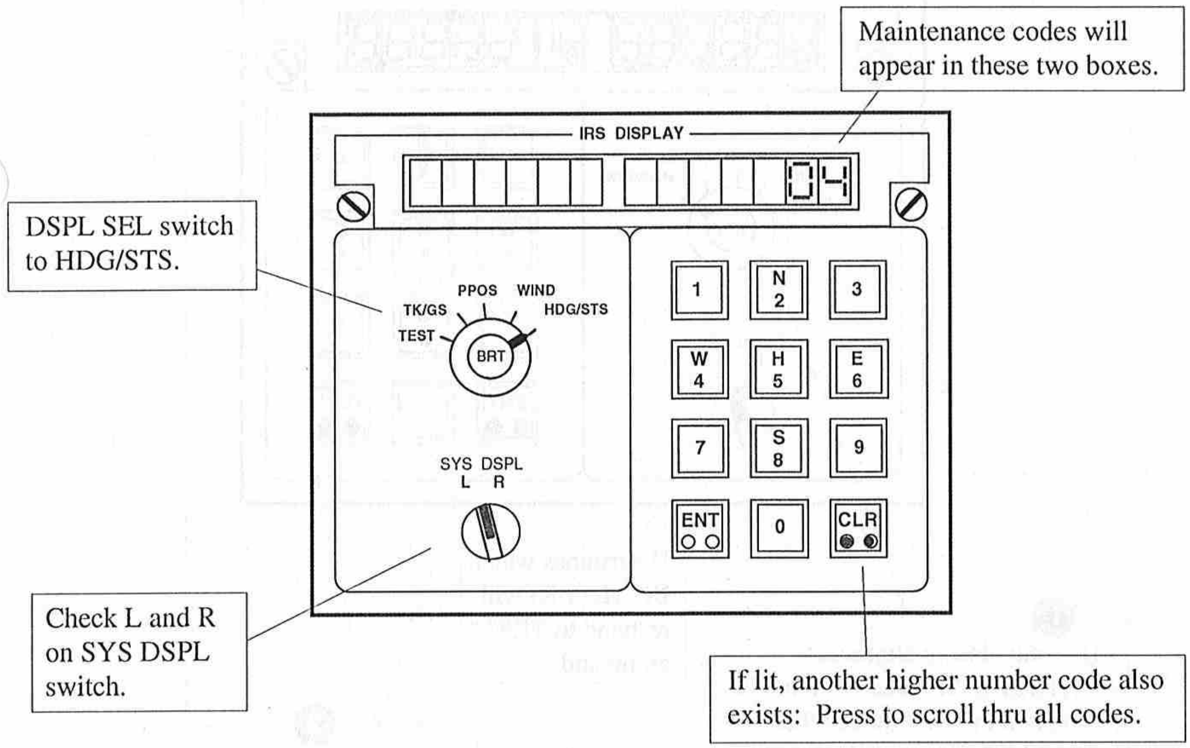
RIGHT FMC FAIL DURING PREFLIGHT
(Dual FMC installation)
(under development)

During *boot-up* of a dual FMC configuration, many comparisons must take place. If any comparisons do not match, the slave, or right FMC, will declare itself invalid. There is much cross-talk going on and usually the FMCs will solve this problem if left alone. It may take 15 minutes. The keyboard will not accept entry while this cross-talk is taking place. The right FMC may come on-line, and drop off-line a few times.



If the right FMC does not stay on line or you run out of time:

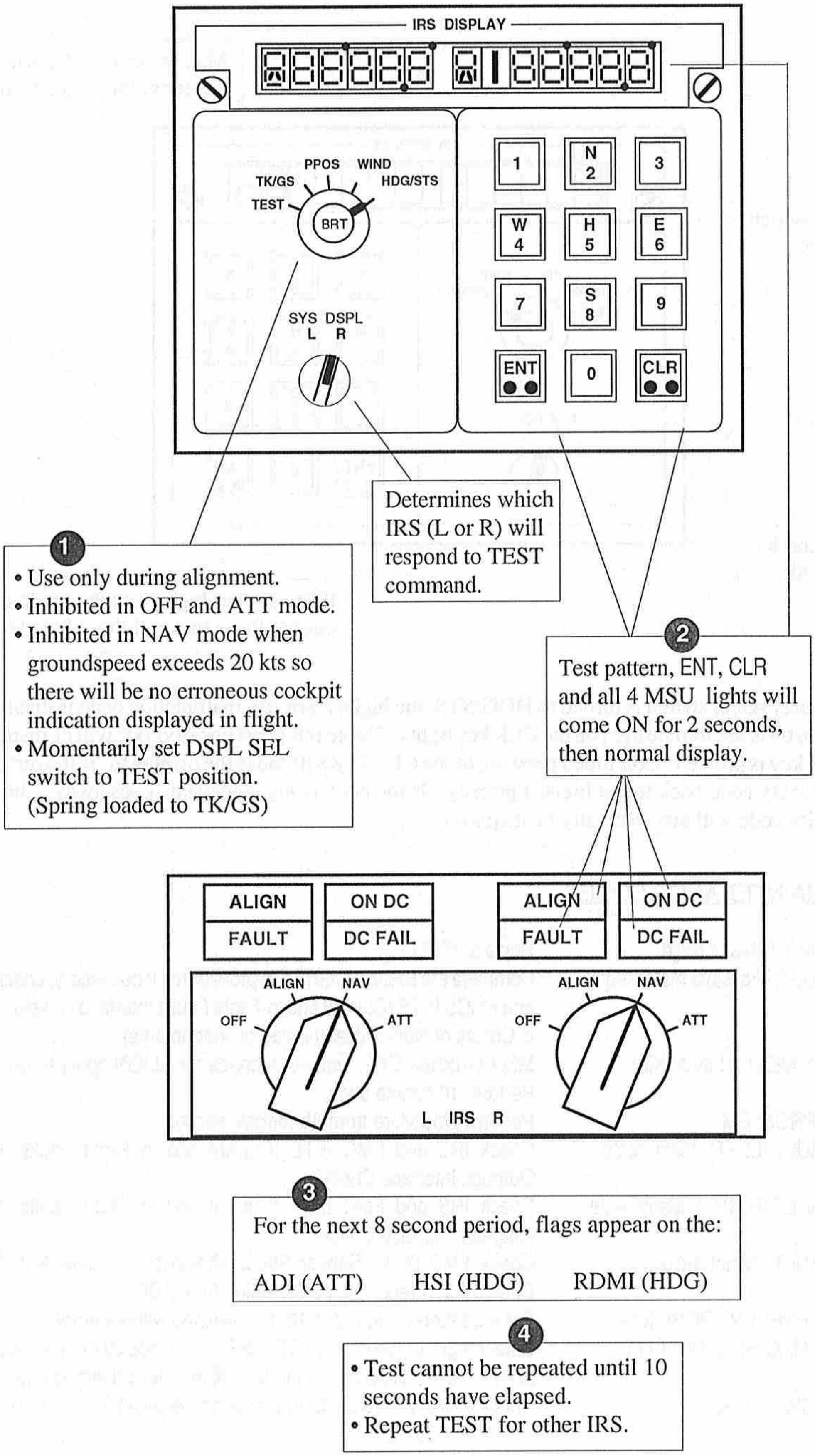
1. Place the FMC swith to BOTH ON L
   This copies the flight plan, perf data, etc, into the problem computer.
   Note: Do Not place the FMC switch to the side with the bad computer.
2. Both Maps will now function and keyboard action will resume.
3. You may get a DUAL OPS RESTORED message later on at which time you can place the FMC switch to NORMAL.
4. Tell maintenance as the FMC stores these faults. Smiths Industries would like to get this stored information to help solve the problem.



When the display select switch is turned to HDG/STS, the highest priority malfunction code is displayed. If another code bit is set, the cue light on the CLR key lights. The next highest priority code will be displayed after the CLR key is pressed. Continued pressing of the CLR key will cause the display to "roll over" from the lowest priority code back to the highest priority. If the code being displayed "goes away", the next highest priority code will automatically be displayed.

PROMPT/MAINTENANCE CODES

01	ISDU FAULT Maint req'd	Replace ISDU
02	IRU FAULT: Possible maint req'd	Complete the FAULT LIGHT ON procedure. If necessary, check IRS and FMCS BITE (Current and In-Flight Faults Interface Check). Fault is Critical or Non-Critcal (no flag on instruments).
03	EXCESS MOTION IN ALIGN	MSU switches OFF, wait 30 seconds for ALIGN lights to go OFF. Perform 10 minute align.
04	ALIGN PROBLEM	Perform procedure from Abnormals section.
05	DAA FAULT (LEFT) Maint req'd	Check IRS and FMC BITE (Current and In Flight Faults, Fixed Outputs, Interface Check).
06	DAA FAULT (RIGHT) Maint req'd	Check IRS and FMC BITE (Current and In Flight Faults, Fixed Outputs, Interface Check).
07	ADC FAULT: Maint req'd	Check FMC BITE (Sensor Status should show same ADC-FAIL) Code 07-IRU receiving Fail Warning from ADC.
08	ENTER PRESENT POSITION	Enter Lat/Long Code 08 if 10 min. elapsed without entry.
09	ENTER MAG HEADING (ATT)	Enter magnetic heading on CDU or ISDU. Code 09 after 30 seconds in ATT mode. HDG flags in view until magnetic heading entered.
10	ISDU POWER LOSS	Check power to IRS's. ISDU power not received from one IRU.


IRS DISPLAY
PPOS
WIND
TK/GS
HDG/STS
TEST
BRT
SYS DSPL
L R
1
N 2
3
W 4
H 5
E 6
7
S 8
9
ENT
0
CLR
Determines which IRS (L or R) will respond to TEST command.
1
• Use only during alignment.
• Inhibited in OFF and ATT mode.
• Inhibited in NAV mode when groundspeed exceeds 20 kts so there will be no erroneous cockpit indication displayed in flight.
• Momentarily set DSPL SEL switch to TEST position. (Spring loaded to TK/GS)
2
Test pattern, ENT, CLR and all 4 MSU lights will come ON for 2 seconds, then normal display.
ALIGN
FAULT
ON DC
DC FAIL
ALIGN
FAULT
ON DC
DC FAIL
ALIGN
NAV
OFF
ATT
ALIGN
NAV
OFF
ATT
L IRS R
3
For the next 8 second period, flags appear on the:
ADI (ATT)
HSI (HDG)
RDMI (HDG)
4
• Test cannot be repeated until 10 seconds have elapsed.
• Repeat TEST for other IRS.

There are two catagories of CDU messages. The generation of any message causes the white CDU MSG light to illuminate.

Alerting *(A)* messages have the highest priority and identify a condition which must be acknowledged and corrected by the crew before further FMCS-guided flight is advisable or possible. These messages appear in the scratch pad as they occur and displace any lower priority messages. Alerting messages also illuminate the amber FMC P/RST alert light on each pilot's FMA.

Entry error advisory *(EE)* messages have lower priority and inform the crew of CDU entry errors or system status regarding readiness for operation or prediction of profile parameters. These messages do not replace data which is already in the scratch pad.

System advisory *(SA)* messages inform the crew that changes made cause unattainable conditons, or ase ued to verify the changes.

ACARS/ATC messages provide status of the ACARS sstem and data transmissions. This option requires at least one of the FMCS displays to be a MCDU type. ACARS messages are not included in this manual.

When multiple messages are generated, they will be stacked for display in priority sequence, or in the order of their occurance if of the same priority. For this reason, it is important to clear your messages.

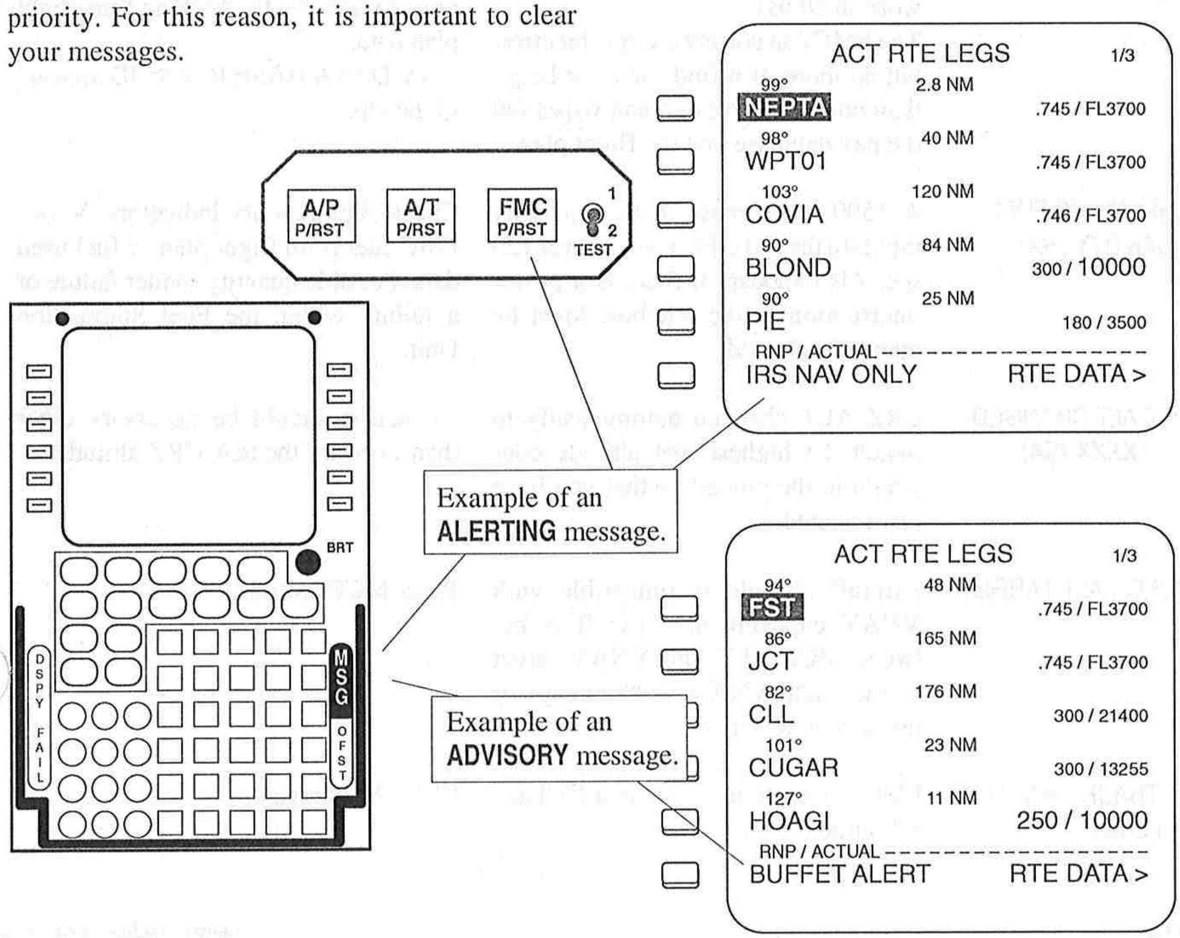
As each message is cleared, the next message in the stack is displayed. Most messages are cleared with the CLR key, or by correcting the condition. Other messages are cleared by changing the displayed page; this will delete the entry which caused the message.

The queue is layered in the following sequence:
ATC Uplink Pending messages
Entry Error Advisory messages
Only displayed on the LCD the error was generated on.
Manually entered data
ACARS Uplink Alerting messages
Alerting messages (active flight plan)
Alerting messages (mod flight plan)
Advisory messages
If these messages pertain to specific data on a specific display page, the message is only displayed when that page is viewed.
ACAS system level messages

The CDU MSG light remains on until all awaiting messages have been displayed.

Non Entry error messages will re-appear after alpha-numeric data entry is complete.

Alternate Nav *(AN)* messages applies to MCDU or FANS MCDU with 10.2 when displaying the alternate nav pages. These messages cause the MSG annunciator to illuinate.



MESSAGE	CAUSING CONDITION	CORRECT ACTION
ABOVE MAX CERT ALT *(SA)*	Aircraft has exceeded its maximum certified altitude.	Descend to an altitude below maximum certified altitude.
ACARS ALERT	Crew action required for ACARS.	Select ACARS MU on an MCDU and perform necessary action. Clear message.
ALT CONSTRAINT AT XXXXX (Altitude value) *(EE)*	Added or modified constraint conflicts with existing downtrack constraints.	Clear message and revise entry.
APPRCH VREF NOT SELECTED *(SA)*	VNAV req'd. FMC is in approach environment and VREF has not been selected.	Select VREF on APPROACH REF page.
ARR N/A FOR RUNWAY *(SA)*	Runway or approach does not match up with the selected arrival procedure.	Modify selection (ARR page) or manually clear message.
BUFFET ALERT *(SA)*	Current conditions result in maneuver margin less than specified. Speed greater than hi speed buffet, lower than low speed buffet, or altitude greater than buffet limited altitude.	Check current airspeed and altitude as compared to buffet limits. Bring aircraft back within operating envelope. U1.3/3.0 has a pad of 5 kts and 300' built into the logic that issues the messages in order to reduce nuisance messages.
CHECK FLIGHT PLAN	The FMC has found, thru its periodic Cyclic Redundency Check, an internal code error (checks parity bits on each word in NDB). The FMC can correct a single bit error, but no more. If it finds an error larger than one bit it gives up and wipes out the nav database and the flight plan.	Check the flight plan and other displayed data on the CDU. If the FMC finds an error larger than one bit, it gives up and wipes out the NDB and any flight plan data. NAV DATA BASE INVALID appears in the s/p.
CHECK FMC FUEL QUANTITY *(SA)*	A 1500 lb decrease in fuel quantity inputs to the FMC for a period over 120 sec. Also appears if there is a power interruption to the left bus. Must be manually cleared.	Check fuel quantity indicators. Verify FMC fuel from flight plan or fuel used data. Possible quantity sender failure or a failure within the Fuel Summation Unit.
CRZ ALT CHANGED TO XXXXX *(SA)*	CRZ ALT changed automatically to match the highest wpt altitude constraint in the procedure that you have just selected.	No action should be necessary other than to verify the new CRZ altitude.
CHECK ALT TARGET	Aircraft altitude incompatible with VNAV engagement. Aircraft is between MCP ALT and VNAV target altitude, and VNAV won't engage or just disconnected.	Reset MCP altitude.
CUTBACK UNAVAILABLE *(A)*	FMC is unable to compute a Cutback N1 value.	Clear the message.

MESSAGE	CAUSING CONDITION	CORRECT ACTION
CYCLE IRS OFF - NAV *(A)*	IRS logic requires manually restarting alignment.	Move IRS control to OFF, then to NAV.
DATA BASE FULL *(EE)*	Entry attempted has exceeded capacity of the Temporary nav data base.	Go to REF NAV DATA or SUPP NAV DATA pages and delete unneeded temporary wpts, navaids, or airports.
DATA BASE INVALID *(A)*	The automatic validity test of the nav database done at power-up has failed. Likely a multiple bit failure the FMC could not correct.	Advise maintenance personnel to reload data base or repair equipment. Consider use of Temporary nav data base.
DES PATH UNACHIEVABLE	After the descent is active, the FMC predictions show the profile constraints at the next wpt cannot be made and the path maintained. Displayed if the required flight path angle to meet the next altitude constraint exceeds 7° for aircraft operation when more than 1,000' above the airport speed restriction altitude; otherwise 6°. VNAV will disengage (CWS)	Modify the active LEGS or DES page plans re-engage LNAV and VNAV.
DISCO INSRTD AFTER XXXXX (WPT identifier) *(A)*	Geometry of the next wpts will not allow the FMC to fly the plane without bypassing more than one wpt.	Amend the active flight plan.
DISCONTINUITY *(A)*	Passing last wpt in the plan prior to a Route Discontinuity (LNAV disengages), or pressing LNAV while in a discontinuity.	Select RTE or LEGS to specify the wpt (s) for a continuous plan.
DRAG REQUIRED *(SA)*	Due to unforecast conditions, the aircraft is 10 kts or more above FMC target speed, or within 5 kts or .01M of V_{MO}/M_{MO}. (PATH DES only).	Use speedbrakes or change drag as required to bring aircraft to within 5 kts of FMC target speed.
DUAL FMC OP RESTORED *(A)*	Movement of the Source Select switch position has caused a resynchronization and dual operation is restored, or the Source Select switch position has not changed, and is in either BOTH-ON-LEFT or BOTH-ON-RIGHT and the FMC has automatically restored DUAL after 5 minutes.	None required.

MESSAGE	CAUSING CONDITION	CORRECT ACTION
DUPLICATE FLIGHT PLAN ID *(EE)*	The entry attempted is a duplicate of an existing supplemental flight plan name.	Clear the message and select a unique flight plan name.
END OF OFFSET *(A)*	2 minutes prior to passing the offset leg termination.	Go to RTE or LEGS and enter the desired waypoints.
END OF ROUTE *(A)*	Passing the last wpt in the route (LNAV disengages).	If desired, go to RTE or LEGS and EXECute a route modification.
ENG OUT SID MOD *(A)*	An ENG OUT SID has been automatically inserted into the flight plan as a modification.	Clear the message.
ENTER IRS POSITION (same as Re-enter Position) *(A)*	IRS is in the alignment mode; it needs PPOS, entry did not go through, or there was a mis-compare of 1° or more with the stored PPOS.	CAUTION: Re-enter IRS position. If present position was previously entered, overwrite displayed data. If necessary, enter present position directly into the IRS CDU.
FMC APP MODE UNAVAILABLE *(A)*	The approved FMS approach cannot be performed. The final approach angle check may have failed.	Verify QFE is not selected on APPROACH REF page. Verify correct FMS approach is selected.
FMC APP/TUNE DISAGREE *(A)*	An FMS approved approach is in the active FP and an approach navaid (ILS/GLS) is being tuned with G/S on.	Turn G/S off. Clear message.
GPS FAIL *(AN)*	GPS data is not being received	Clear message. ALT NAV processing halts.
GPS INTEGRITY LOST *(AN)*	GPS data received is invalid or the GPS HIL value is greater tan two times RNP for the current nav environment.	None.
HOLD AT XXXXX	Holding fix was entered on the RTE LEGS HOLD AT page that is not on the active route.	Place offroute wpt in proper sequence and complete HOLD entries.
INSUFFICIENT FUEL *(A)*	Estimated fuel at destination is less than 2000 lbs (900 kg).	Modify flight plan or cruising altitude, or divert for fuel.
INVALID DELETE *(EE)*	DEL key operation attempted for a data line not allowed.	Clear message and repeat entry with correct data.
INVALID ENTRY *(EE)*	Attempted data entry has incorrect format or range for the selected data line.	Clear the message and select proper field after DEL key is pressed.
INVALID OFFSET *(SA)*	The leg is not offsettable, too short or starts at a wpt followed by a DISCO. This entry may be from an ACARS uplink. An ACARS uplink may also cause the message if a start wpt was uplinked, followed by a disco or end of flight plan dashes.	Close DISCO or enter a valid wpt in end-of-flight-plan dashes.

MESSAGE	CAUSING CONDITION	CORRECT ACTION
INVALID QUAD *(EE)*	The QUAD/RANGE entry is incorrectly formatted or is out of range for a PBD wpt from a VHF navaid.	Ckar message and repeat entry with correct data for desired field.
IRS MOTION *(A)*	IRS has detected motion during alignment resulting in need for re-alignment.	If automatic realignment has not started, then move the IRS mode control knob to OFF, then to NAV.
IRS NAV ONLY Messages inhibited in approach environment when VOR/LOC mode is active from DFCS, both VOR receivers are manually tuned to the Procedure navaid, a valid VOR data is being received, or aVOR/ ILS mode is displayed on at 'east one EHSI.	Discontinued in U10.3 U7.1 and up: Actual Nav Performance (ANP) exceeds Required Nav Performance (RNP). Current default values are: ENVIRONMENT / RNP / TIME TO ALARM OCEANIC / 12.0 nm / 80 sec ENROUTE / 2.0 nm / 80 sec TERMINAL / 1.0 nm / 60 sec APPROACH / 0.5 nm / 10 sec U6 and below: FMC has down-moded to IRS only mode of navigation. Transition from one of the radio updated nav modes to IRS dead reconing occurs 15 seconds after radio measurements lost. Radio updating has not been available for 12 min above or 10 min. below 15000'. U5.0. Updating does not resume within 2 minutes of a reference IRS switch or an FMC nav program reset. After an FMC POS SHIFT to an IRS position, the message will display if updating has not occured for 2 minutes in U5 or 1 minute in U4.0. U5.0. After an inflight power up of the FMC, the message displays if updating has not occured for 2 minutes.	Clear message and check nav radios are set for AUTO tuning. Allow radios to be tuned by the FMC. Check aircraft position. U6 and down: If on an ILS, consider allowing one radio to autotune until on final approach.

MESSAGE	CAUSING CONDITION	CORRECT ACTION
LNAV BANK ANGLE LIMITED *(A)*	LNAV roll command during high altitude maneuvering is limited to the thrust or buffet based bank angle limit.	None
LO POS ACCURACY *(AN)*	The GPS horizontal figure of merit is greater than RNP for the current nav environment.	None.
LOC CAP ACTIVE *(SA)*	Aircraft is approaching its turn onto the localizer course and will maintain an intercept heading.	Clear message manually or wait for AFDS to signal reset to the FMCS.
LOC CAP CANCELLED *(SA)*	Flight plan modifications or the aircraft condition did not facilitate localizer capture.	Clear message manually.
MAX ALT FLXXX *(A)* (Flight Level value)	Altitude entry is above max altitude (current capability-1.3g U.S.A.)	Clear message and amend data entry in scratch pad.
MAX MACH .XXX *(SA)* MAX CAS XXX MIN MACH .XXX MIN CAS XXX	In manually selected cruise speed mode, cruise altitude or target speed entered will result in limit on selected speed.	Clear message; accept limited speed for new altitude, or modify selected altitude or speed.
MCP APP DISARM REQD *(SA)*	A change in the expected FCC approach was uplinked when the mode is already armed or engaged.	Review and accept or reject modification. Change approach type on ARRIVALS page.
MISSED CAPTURE *(A)*	Proper localizer capture maneuver performed, but AFDS did not capture.	Clear message manually.
MODEL / ENG DATA INVALID *(A)*	A valid performance database is not available.	Contact maintenance.
NAV DATA LOADING	Supplemental nav data from ACARS is loading into the FMC.	
NAV DATA OUT OF DATE *(A)*	Nav data base effectivity date does not match Captain's clock date.	Check the clock date and correct if necessary. Otherwise, select effective nav data base or have maintenance reload new nav data base.
NAV INVALID-TUNE XXXXX *(A)* (Navaid ID)	FMC is unable to autotune or receive approach procedure navaid.	Cross-check radios and manually tune specified navaid.
NO ACTIVE ROUTE	LNAV is selected when no route has been activated.	Clear message and activate route or deselect LNAV.
NO DES PATH AFTER XXXXX *(SA)* (Waypoint identifier)	The profile constraints cannot be achieved and the path maintained as planned after the named waypoint.	Modify speed or altitude restrictions on the LEGS page.
NO OFFSET AT LEG XXXXX *(EE)*	Entry of lateral offset start or end wpt for a leg that is non-offsettable.	Review offset plan. Enter a valid start or end wpt.

MESSAGE	CAUSING CONDITION	CORRECT ACTION
NOT IN DATA BASE *(EE)*	FMC does not contain the required data for the entered indentifier.	Clear message and check data entry, or enter required information into Temp or Supp nav data base via REF NAV DATA page.
NOT IN FLIGHT PLAN *(EE)*	RTA wpt or lateral offset start/end wpt entry is not in active FP.	Clear message and amend entry.
NOT ON INTERCEPT HEADING *(SA)*	Present heading (HDG) or course (TRK) does not cross the leg to be captured, or its backward extension, or it is not within 3 nm of the desired leg and LNAV is engaged.	Manually steer aircraft onto a heading which will intercept the active leg of the planned route and engage LNAV.
OFP MISCOMPARE	Primary FMC has detected a discrepancy between its software and that of the secondary FMC.	Contact maintenance.
OFFSET DELETED *(SA)*	The entered start wpt has been deleted from the FP.	Clear the message and amend the route.
OFST ENDS ABEAM XXXXX *(SA)*	An invalid offset leg exists between the end wpt and the start of the offset or no end wpt exists.	Clear the message and amend the route.
OFST ENDS AFTER XXXX *(SA)*	Planned lateral offset path cannot be back by the selected end wpt.	Review offset plan. Enter a valid end wpt.
OFST ENDS BEFORE XXXX	A non-offsettable leg exists prior to the end of the offset plan.	Review and change offset plan to avoid non-offsettable legs.
OP PROGRAM INVALID	A fault is detected in the program memory.	Pull the FMC CMPT circuit breaker for 20 seconds and reset. This will re-boot the computer.
OVERSPEED DISCONNECT *(A)*	Aircraft exceeds airport speed restriction by more than 15 knots or more while below speed restriction altitude.	Slow aircraft to within 10 knots of speed target and re-engage VNAV or clear message manually.
PARTIAL ROUTE LOADED *(A)*	A route is loaded which references data not contained in the database.	Clear the message.*
PATH DES NOT AVAILABLE	Within 5 nm or T/D, a path descent is planned, and a computed path is not available.	Execute a speed descent if desired, or construct an acceptable path, or use MCP for descent.

MESSAGE	CAUSING CONDITION	CORRECT ACTION
PERF DEFAULTS INVALID /DELETED *(A)*	Loaded Perf Defaults table failed CRC check and was deleted.	Maintenance must reload table.
POSITION UNCER-TAINTY U7.0 only	FMC position accuracy is not sufficient for the current phase of flight.	System unusable: advise maintenance personnel. CLR key will not clear message.
PROGRAM PIN ERROR *(SA)*	FMCS connector wiring incorrect.	Contact maintenance personnel.
PROGRAM PIN MISCOMPARE	Primary FMC has detected a discrepancy between its program pin configuration adn that of the secondary FMC.	Clear message. Reload QRH T/O Speeds data.
PROGRAM PIN NOT IN DATABASE *(SA)*	FMC connector wiring does not correspond to valid interconects defined in the MODEL/ENGINE database.	FMC not operational. Call maintenance.
QRH DATA INCOM-PATIBLE	Configuration of loaded QRH T/O Speeds data not compatible with configuration of FMC QRH calculations.	Reload database. Clear message.
QRH T/O SPEEDS INVALID *(A)*	Loaded ORH T/O speeds database is unusable.	Clear message and repeat entry of SET IRS POS on POS INIT page.
RE-ENTER IRS POSTION	At least one IRS did not receive position data correctly from FMC or disagreement between SET IRS POS and IRS feedback position.	Clear message. Verify ACARS MU is powered and operational. Re-initiate the downlink.
RESEND MESSAGE *(A)*	A CDU downlink message is initiated and the FMC is unable to deliver the message to the ACARS MU.	Dial MCP altitude to a lower altitude for descent.
RESET MCP ALT *(A)*	5 nm prior to top of descent point without dialing down MCP altitude.	Clear message and review existing and desired route segments for possible deletion.
ROUTE FULL *(EE)*	Entry of more than 99 wpts attempted or a 6th hold attempted.	Enter an achievable RTA or another performance mode selection.
RTA UNACHIEVABLE *(A)*	RTA does not fall within the computed RTA window.	Clear message and check selections on DEPartures page. Modify as required.
RUNWAY N/A FOR SID *(SA)*	The selected runway is not applicable to the selected departure procedure. 757 - SID is removed.	Tune the proper frequency.
RW/APP CRS ERROR *(A)*	An MCP selected course does not match the FMC flight plan data.	
RW/APP TUNE DISAGREE*(A)*	A tuned frequency does not match the FMC flight plan data.	Select the proper course.

MESSAGES

MESSAGE	CAUSING CONDITION	CORRECT ACTION
SCANNING DME FAIL *(A)*	Both DME inputs are failing (displayed only on aircraft with scanning DME and VOR inhbit options selected).	Clear message and report failure to maintenance.
SELECT ACTIVE WPT / LEG *(SA)*	After first restart or insertion of a different flight plan while airborne.	EXECute a direct-to or leg-intercept to tell FMC which leg of route is active.
SELECT MODE AFTER RTA *(A)*	Exiting RTA into manual speed mode.	Select a normal performance mode such as ECON.
SINGLE FMC OPERATION *(A)*	In a dual FMC installation, one FMC is inoperative.	Refer to company MEL.
SINGLE IRS NAV	Nav environment is OCEANIC and one IRS is invalid.	None.
STEEP DES AFTER XXXXX *(SA)*	FMC altitude constraint at waypoint XXXXX results in a steep descent path - >200' discontinuity - to the next waypoint.	Monitor descent. Remove altitude constraint at XXXXX if allowed. Will probably exceed planned speed to make the path.
SUPP RTE DATABASE FULL *(EE)*	Attempted save of the 11th supplemental flight plan.	Clear the message, delete unneeded supplemental waypoints and re-attempt entry.
SW OPITIONS INVALID	The validity check of the software options database has failed.	Contact maintenance personnel.
TAI ON ABOVE 10° C *(SA)*	Aircraft is operating with anti-icing with TAT above 10° C.	Clear message and check use of anti-icing for engine cowl or wing surfaces.
TAKEOFF SPEEDS DELETED *(A)*	Manually selected takeoff speeds deleted due to change of departure runway.	Reselect desired takeoff speeds. Clear message.
THRUST REQUIRED *(A)*	Airplane is 17 kts below the target speed in cruise.	Increase speed to target speed and clear message.
UNABLE CRZ ALTITUDE *(SA)*	FMC predicts aircraft cannot reach the new CRZ ALT due to performance limitations or no cruise time possible at entered CRZ ALT.	Clear message and review CRZ ALT selection. Enter aircraft altitude or lower. FMC will not recognize descent phase until cruise phase is attained.
UNABLE HOLD AIRSPACE *(A)*	Displayed when lateral's predicted hold path, (during high altitude maneuvering) using the bank angle limit, causes protected airspace to be exceeded.	Reduce speed to return to hold racetrack.

MESSAGE	CAUSING CONDITION	CORRECT ACTION
UNABLE MACH .XXX *(SA)*	In manually selected speed cruise mode, entered Mach not attainable at any altitude.	Clear message and select new speed command.
UNABLE NEXT ALTITUDE *(A)*	Due to an undershoot on climb or an overshoot on descent, the next descent constraint cannot be achieved. U5.0. In VNAV SPD DES, next descent constraint cannot be achieved due to overshoot.	Clear message. If in a climb, review FMC ERROR AT prediction (CLB page) and consider selection of a steeper climb. If in a descent, review vertical information on DES page and consider a steeper descent.
UNABLE REQD NAV PERF-RNP *(A)*	ANP is greater than the RNP. Message also displayed on the EHSI when in the approach environment. Inhibited if VOR LOC is engaged. Inhibited from displaying on the CDU on ground if GPS installed option is not enabled on the FMC. 10.3 anomaly: If ANP exceeds RNP during approach, landing, or rollout and FCC switches are turned off above 20 kts, message will not clear until a/c is in the air and ANP less than RNP. Fixed in 10.4	In flight, check status of updating and check the position differences on POS SHIFT page; if FMC position is clearly corrupted, shift FMC to best sensor position source. If displayed inside FAF and IMC, go around. 10.3 anomaly: On the ground, can clear messaage from MAP by depowering FMC for 15 sec.
UNABLE TO OFFSET *(SA)*	A valid offset cannot be constructed due to geometric limitations.	Clear the message and amend the route.
USING RESERVE FUEL *(SA)* (USING RSV FUEL)	U5.0. A change in route causes fuel burn to exceed total fuel minus reserves.	Clear message and amend the active flight plan.
VERIFY GW AND FUEL *(A)*	Fuel flow data becomes invalid after engine start and fuel value is replaced with dashes. FMC uses last valid fuel quantity for performance predictions until manual entry is made. Message appears 30 minutes afer last manual fuel entry.	Enter fuel weight on PERF INIT page 1/2. Periodic update of fuel weight is required to keep gross weight value current. Use ETA and fuel predictions immediately after a manual entry has been made since this is the only time they are accurate.
VERIFY OFFSET	A change in flight plan is executed that results in a conflict between the new flight plan and a pilot or ACARS entered lateral offset start or end waypoint.	Clear message and amend the active flight plan if required.

MESSAGES

MESSAGE	CAUSING CONDITION	CORRECT ACTION
VERIFY POSITION *(A)* VERIFY POSITION message triggers POS DIFF display on EHSI. POS DIFF display is also triggered if referenced IRS (Single FMC installation) exceeds FMC Sys Pos by 12 nm. FD, AP may not engage. Cause? Excessive IRS drift, an anomoly in the nav signal, or nav data base dumped and FMC unable to update. In the case of the latter, you can place needed navaids in the Temporary data base (estimate elevation and class). Consider LOP.	Position Differences: **On the Ground:** Airport vs: IRS > 4 nm FMS vs: Rwy Upd > 10 nm **In the Air:** L IRS vs: R IRS, for 40 sec. > 10 nm IRS vs: FMC Radio for 150 sec. > 4 nm; FMC Sys vs: IRS for 40 sec. > 10 nm FMC Sys vs. FMC Radio for 150 sec > 2 nm U7.1 FMC Sys vs. FMC Radio for 150 sec > 2.8nm-Enroute for 60 sec > 1.7nm-Terminal for 10 sec > 0,5nm-Approach U7.1 FMC Sys vs: GPS, same as FMC Sys vs. FMC Rad. U7.1 FMC Sys vs: FMC Sys, same as FMC Sys vs. FMC Rad.	On the ground: check entered data for accuracy. In flight: U1.3 or less: Check radio data accuracy using FIX page. Retune to different station if necessary. U1.4 up and EFIS: Check the position differences on POS SHIFT page; if FMC position is clearly corrupted, update FMC to best sensor position source.
VERIFY RNP *(A)*	Default (underlying) RNP becomes less than entered RNP, or a GPS approach has been selected, the FMC is in the approach environment, and the default RNP is active.	Clear message. Check pilot-entered RNP and enter appropriate RNP. GPS Approach requires entry of RNP .3. For an NDB Approach enter RNP .6; VOR approach enter RNP .5.
VERIFY RNP VALUE *(SA)*	Manually entered RNP is larger than default RNP, or manually entered RNP is less than ANP.	Clear message. Check entered value of RNP.
VERIFY TAKEOFF SPEEDS *(A)*	GROSS WT or PLAN or ZFW has changed since the V-speeds were entered. The manually entered V-speeds will default to small font. <REJECT or ACCEPT> prompts appear.	Check selected small font takeoff speeds. Pressing REJECT will drop the V-speeds from the page. Pressing ACCEPT will cause the V-speeds to return to large font.
VERIFY VERT RNP *(A)*	While in descdnt, the manually entered vertical RNP is larger than default vertical RNP.	Clear message and check entered value of RNP.
VERIFY VERT RNP VALUE *(SA)*	Manually entered vertical RNP is larger than the default vertical RNP or the manually entered vertical RNP isless than the vertical ANP.	Delete manually entered RNP or re-enter a different value.
VNAV DISCONNECT *(A)*	The criteria for VNAV engagement are no longer satisfied (FMC disengages VNAV).	Manually control the vertical path.

MESSAGE	CAUSING CONDITION	CORRECT ACTION
V SPEED UNAVAIL-ABLE *(SA)*	Displayed if any of the independent variables used in the calculation of VSPEEDs fall outside of the tabular data set boundaries.	Re-enter correct V SPEEDS
XXXXX * * *(SA)* (MCP altitude value)	Resetting MCP ALTITUDE to a value not equal to the CRZ ALT causes the value to appear in scratch pad (CRZ page only).	Select MCP ALTITUDE value into the appropriate target altitude data line or clear message.
XXXX * * * *(SA)* (Airport identifier)	A REF AIRPORT is entered on POS INIT page and no entry of ORIGIN appears on RTE page 1	Select the airport identifier into the ORIGIN data line.
WAYPOINT NOT DEFINED *(AN)*	An attempt was made to enter a waypoint that does not have a known LAT/LON.	Clear the message. Correct the entry error.
WAYPOINT PREVIOUSLY DEFINED *(AN)*	An attempt to enter an existing identifier using a LAT/LON that is different from the currently stored LAT/LON.	Clear the message. Then correct the possible error in desired LAT/LON data or the delete stored waypoint and re-enter the desired data, or select another name for the desired waypoint.
____ INOP *(SA)*	The key just pressed is not enabled.	Clear the message.

NOTE: XXXXX = Altitude value or waypoint identifier.
XXXX = Airport identifier entered on POS INIT page.
FLXXX = Flight Level value.

* * MCP altitude setting appears in s/p for possible line selectioon into a data field when MCP ALT is changed.

* * * Airport identifier appears on RTE page for possible line selection into the Origin field.

INTENTIONALLY LEFT BLANK

NON-DELETABLE ITEMS

In general, most items that can be entered or selected can also be deleted. Listed below by function are the enterable data items which **cannot** be deleted.
Instead of being deleted, these items **must be changed** by an overwriting entry from the scratch pad.

IDENT
- Nav data base effectivity date

POS INIT
- REF AIRPORT
- GATE
- SET IRS HDG
- SET IRS POS
- GMT

REF NAV DATA
- LAT
- LONG
- CLASS
- FREQ
- MAG VAR
- ELEVATION

SUPP NAV DATA
- EFF DATE

PERF INIT
- GROSS WT
- ZFW
- RESERVES
- COST INDEX
- CRZ ALT
- TRANS ALT

TAKEOFF REF
- OAT
- V-SPEEDS

RTE
- ORIGIN
- DEST
- CO ROUTE
- TO WAYPOINTS
- First ACT VIA

LEGS
- ACT WPT

RTE HOLD
- INBD COURSE
- LEG DIST
- LEG TIME
- TURN DIR
- RTE HOLD when ACTive

CLB
- CRZ ALT
- TGT SPEED

CRZ
- CRZ ALT
- TGT SPEED
- STEP TO

DES
- TGT SPD

DES FORECASTS
- TRANS LEVEL
- CABIN RATE
- QNH

IRS LEGS
- ALL ENTRIES

IRS WPT DATA
- ALL ENTRIES

System default values cannot be deleted. The DEL key is only used to remove crew entries from the system.

The purpose of the Advanced Technique Section is to introduce you to specific features of the FMC as used *on the line* and to discuss procedures not covered in the preceding sections.

Technique

Definitions:

A *technique* is a method of accomplishing a desired aim. No claim is made that these techniques are the best possible. They are simply presented for educational purposes.

A *workaround* is pilot input required due to inadequacies of software/hardware design.

Not every possible combination of displays or key strokes can be shown in a document of this type. Consequently, you must use your own time to build upon the information presented here in learning to apply the flexibility of the FMC to meet your own requirements. Other shortcuts will be recognized through your own experience and ingenuity.

Developing FMC skills takes time and practice. Using the *technique* best suited for a particular approach is challenging.

If any *technique* presented here conflicts with your Standard Operating Procedure, of course your procedure takes precedent.

Fly As Much As You Can

When flying with a pilot that has a high skill-level, feed off of them. You'll learn by watching as well as discussing and your own limits will naturally grow.

Man-Machine Interface Problems

New generation a/c design has created some new problems. The *glass* cockpit has relieved pilot workload in some areas and created workload in others. LNAV is an easy tool to use and well displayed on the Map. VNAV is more complicated, possibly because of fewer pilot interfaces. Mode awareness, where pilots are confused about what the automation is doing, is another concern. Common statements you hear on the flight deck are: "What's it doing now?" "Why did it do that?" "It does that sometimes!" and, "What's it going to do next?" Followed by, 'click' "I've got it."

Credibility of the Glass Cockpit

Automation appears to lose credibility when it unexpectedly fails to do what we expect. There are deficiencies in the design. When you are not satisfied with what the automation is doing, disconnect it.

Backup the Computer

After receiving a clearance, mentally calculate the solution. If the clearance demands an immediate change in the controls, waiting for the FMC calculation may make the restriction more difficult to achieve, though it's tough to beat the latest processor. One technique is to ask your teammate to operate the computer while you arrive at your own solution.

Don't Sacrifice Heads-Up Vigilance

The crew must not sacrifice heads-up vigilance to operate the computer, especially at lower altitudes. Priorities must be set straight. Accomplish the bulk of approach setups where traffic is light, radio communications are minimal, and restrictions are few. To further emphasize this point, 95% of all programming required for descent and approach should be accomplished at cruise altitude. Do not make the blanket statement that programing should not be attempted below 10,000 ft; an experienced user can certainly accomplish FMC tasks below "ten" if circumstances permit and the steps required are minimul.

Glass Cockpit Complicates Some Procedures

In many instances using the MCP or simply hand flying is more desirable. For example, a runway change in visual conditions can become a more difficult maneuver because the pilot is tempted to draw his attention inside the cockpit. Generally, you will see less experienced glass pilot use the FMC more than an experienced pilot, but it takes years!

Be Efficient

Keep your workload as low as possible. Strive for operating efficiency. Allow the computer to use its default information when conditions permit and enter only information you plan to use. This technique helps to keep all skills sharpened.

Monitoring Pilot Responsibilities

As the MP, be careful when making changes in the FMC without direction or consent from the PF. Much can be learned by watching how your teammate tackles a particular maneuver. And backup your teammate with an occasional check of raw data when navigating with LNAV during an intercept or in the holding pattern. I use the term Monitoring Pilot rather than Non Flying Pilot because it is pro-active!

Keep Your Basic Skills Sharp

Finally, don't forget how you used to fly an airplane. You will still have an occasional use for those "rules of thumb" that have gotten you this far in your career, and you need to practice your scan and concentration that hand-flyng demands. Hand fly the a/c without the FD once in a while to keep basic skills sharp. Learn what to change - the *control instruments* (pitch, bank and power) and how much to change - the *performance instruments* (altimeter, compass, VSI, airspeed)

ILS Approach - EFIS

Prior to descent: Select the approach from the ARRIVALS page, tune the radios, select the inbound course, and brief the approach. When building the terminal routing , try to accept as much default information as possible to cut down computer input. EFIS 3-4-5 - prior to the Approch Check, press MANUAL on the nav head to display raw data on the ADI and to monitor altitude : distance ratio to threshold.

U5 and up Technique

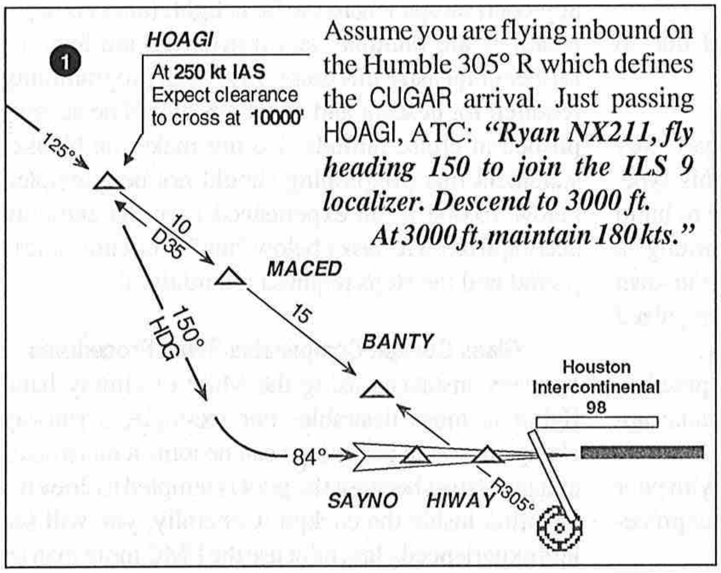
If no localizer DME, create a wpt .1 nm from RW09 using the Along Track feature. Place this wpt in a FIX page and use for position and altitude awareness. U1.x pilot may create a threshold wpt with the LAT/LON entry on the REF NAV DATA page.

ACT RTE LEGS 1/2
125° 2.2 NM
HOAGI 250/10000
126° 10.1 NM
MACED 240/6828
126° 15 NM
BANTY 210/3174
THEN NM
□□□□□
----ROUTE DISCONTINUITY----
SAYNO /3000
RNP / ACTUAL - - - - - EXTENDED
1.70 / 0.15 DATA >

ACT RTE LEGS 2/2
84° 5.3 NM
GS--09 150 / 3000
84° 5.1 NM GP 3.0°
HIWAY 140 / 1830
84° 5.2 NM GP 3.0°
RW09 140 / 148
84° 22 NM
COSBI 220 / 2000

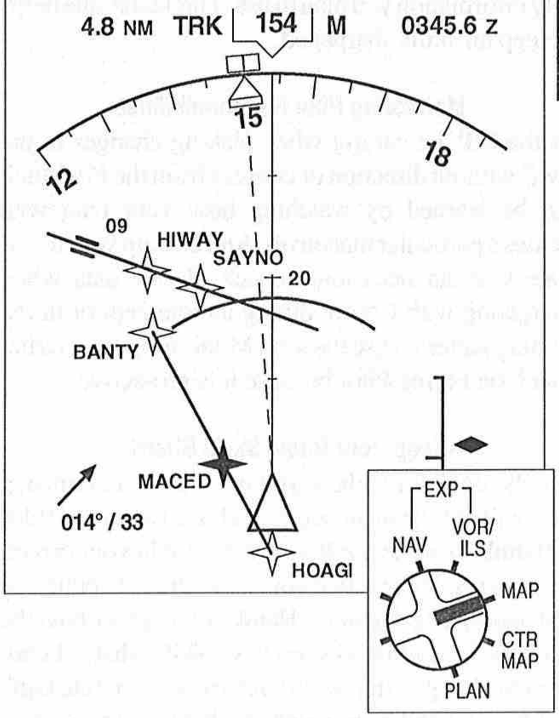
1

Assume you are flying inbound on the Humble 305° R which defines the CUGAR arrival. Just passing HOAGI, ATC: ***"Ryan NX211, fly heading 150 to join the ILS 9 localizer. Descend to 3000 ft. At 3000 ft, maintain 180 kts."***



2

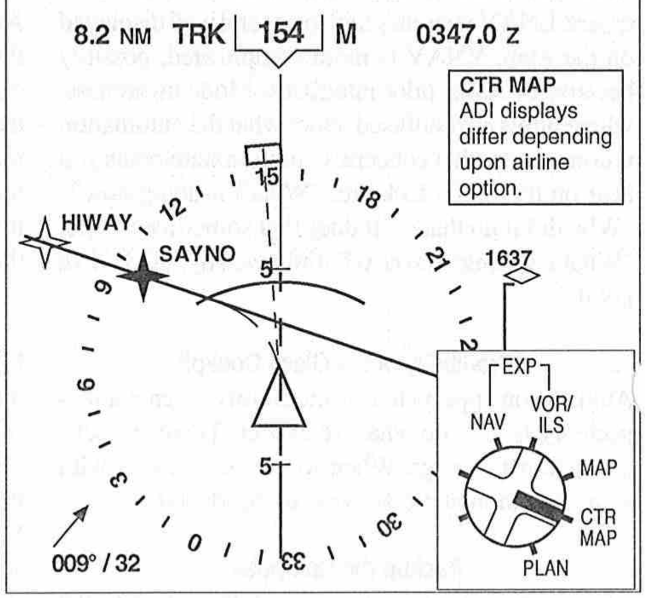
Dial 150° on the MCP and press HDG SEL. Select LVL CHG; after the V/S stabilizes, press V/S and dial the speed bug down to 180. **You have now transitioned to the MCP.**



3

In deciding which course to intercept, try matching your clearance altitude to a wpt on the approach that matches that altitude. In this case, I'd intercept-leg-to SAYNO. (Bring SAYNO to the top of the LEGS page and check the small font at 6R – dashes in this case because of the DISCO preceding SAYNO. Enter 084 at 6R, check the Map and EXECute.)

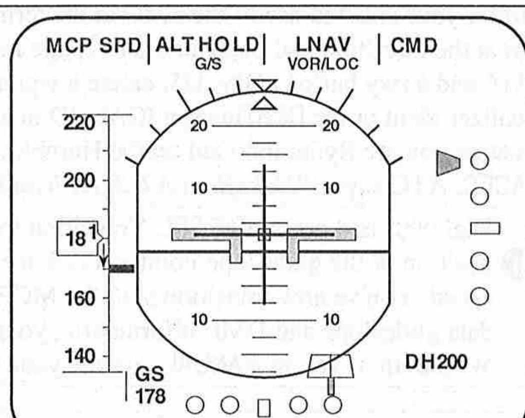
If you want to use the VERT DEV indicator, LNAV must be engaged.



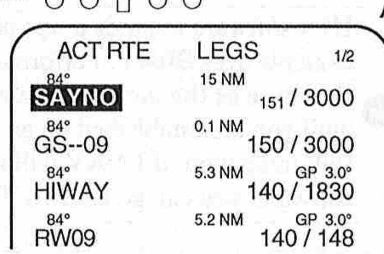
ILS Approach - EFIS (continued)

4

ATC: *"Ryan NX211, maintain 3000 ft, cleared for the ILS 9 approach, contact the tower at HIWAY."*
Press APP (MCP). For those who do not have the option that inhibits GS capture prior to LOC capture, APP is not appropriate until VOR/LOC turns green. If altitude constraints have been met, and cleared for the approach, then press APP.
The U5 and up FMC will position update from a manually tuned localizer. The rwy must be selected from ARRIVALS.
This is your ADI as you await localizer capture (Raw data localizer and glide slope information).
You now leave the Map and transition to the ADI.

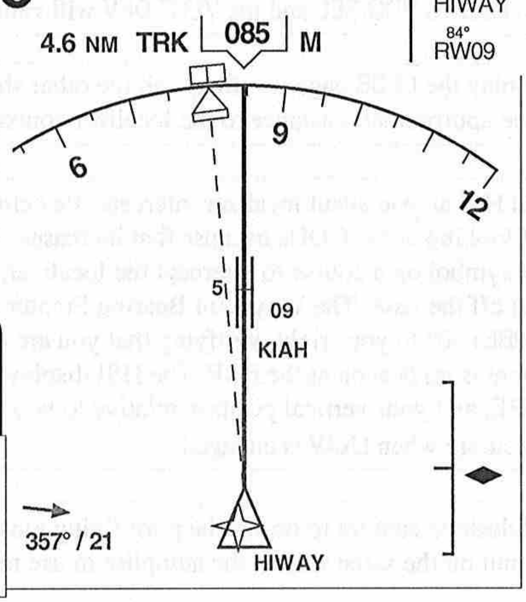


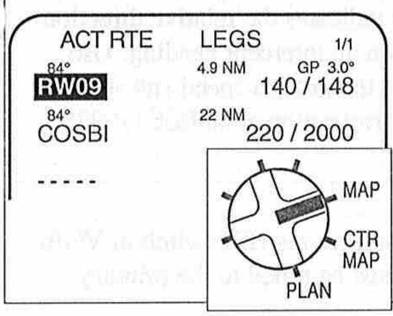
ADI views differ depending upon airline option.



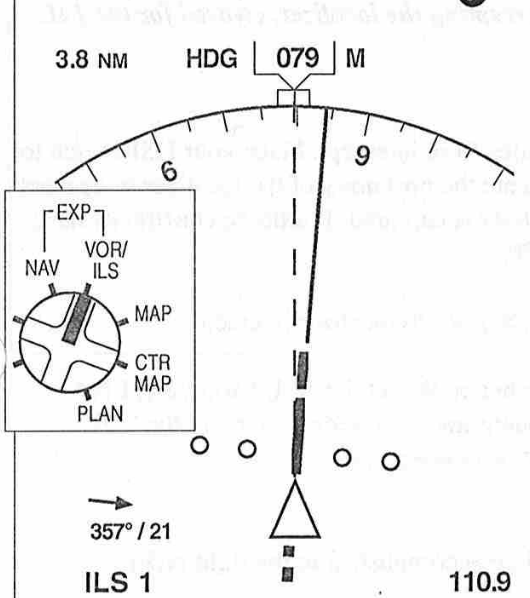
5

Map view crossing the marker: The track-up Map view displays the runway at 12:00. The Heading Pointer (nose of the airplane) is correcting for the crosswind and pointing 080°! Which side of the nose are you going to look for the runway? Left or right?





6



Consider this technique **only** if your carrier **does not** have procedures in place.
Don't be distracted by what display to select for the HSI. Remember, raw data is **always** on the ADI, your primary instrument; it's got everyting you need except the DME counter.
If the weather is below CAT I with strong crosswind, consider selecting raw data on the HSI to avoid disorientation caused by track up displays (Track up may lead you to believe rwy is straight out the windscreen).
Within 5/8 dot of localizer capture, the ADI localizer scale expands to 1 dot each side. If you exceed the one dot display, you will have to go-around unless you have ILS displayed on the HSI. The example shows EXP ILS. Either EXP or FULL ILS mode will display two dots each side of centerline.

ILS Approach - Non EFIS

Prior to descent, brief the approach, tune the radios, and select the inbound course. Explain to your partner your planned use of the FMC in the terminal area. Set up the RDMI to monitor the OM. Create a wpt at the threshold and place in the FIX page for distance - altitude awareness:U1, use the REF NAV DATA and a rwy lat/lon entry; U5, create a wpt at the threshold using the Along Track wpt feature. The localizer ident or the DESTination ICAO ID in a FIX page may also work but may not be at the threshold. Assume you are flying inbound on the Humble 305° radial(CUGAR ARR). A few miles northwest of MACED, ATC says: ***"Nakajima AT-2, fly heading 090°, descend to 3000 ft."***

1. Dial 090° and press HDG SEL. Transition to MCP SPD, with LVL CHG or V/S, depending on the position of the glideslope pointer. Look for a 3:1 ratio ± wind correction and slowing to flap speed. You've now transitioned to the MCP. Press MANUAL (nav head). Now the ADI has raw data glideslope and DME information, your main instrument for the approach.
With both of you in MANUAL - unless your flying a U5 box - updating is no longer taking place.

2. U1.x software requires a wpt behind the marker on the runway centerline for the intercept. The example uses GRAFF. Perform an INTC LEG TO MARBE and EXECute. **Verify the intercept leg is the same as the localizer course** (146° in header of LSK 1L). Continue using MCP HDG SEL until you are established on an intercept heading; then press LNAV. This will update the VERT DEV indication. If LNAV will not engage, you are **not** on an intercept heading (track). With 1.x software, you can go back to HDG SEL and the VERT DEV **will remain useful.**

3. One CDU should display the LEGS page (routing) and the other should be used to display PROGRESS 2/2 for the approximate distance to the localizer course (XTK ERROR) and winds.

4. This is your ADI and HSI as you await localizer intercept. Pay close attention to the FMA and avoid the practice of looking at the CDUs because that increases "heads down" time. The HSI displays the airplane symbol on a course to intercept the localizer, depicted by the course deviation bar still not off the case. The Waypoint Bearing Pointer indicates the relative direction of the next wpt (MARBE) 30° to your right, verifying that you are on an intercept heading. Use this as a lead-in if there is no beacon at the FAF. The HSI displays the ground speed and string-line distance to MARBE, and your vertical position relative to your restriction at MARBE (1997').
VERT DEV is most accurate when LNAV is engaged.

5. For localizer and glideslope capture to occur, the pilot flying must have his HSI switch in VOR/ILS. The VHF nav unit on the same side as the autopilot in use must be tuned to the primary approach facility.

   ATC: ***"Nakajima AT-2, maintain 3000 ft. until intercepting the localizer, cleared for the 14L ILS, contact the tower at MARBE".***

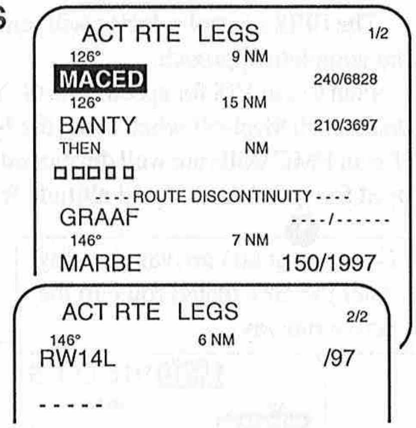
   Consider this procedure:
When the course deviation bar is alive, you're four miles from intercept. Place your HSI switch to VOR/ILS and press LOC. The course bar will now indicate the proximity of the localizer in degrees instead of miles. APP is not appropriate until the localizer is captured. If altitude constraints have been met, and cleared for the approach, then press APP.
Monitor PROGRESS 2/2 for closure with the localizer.
Note: One pilot should place his HSI switch in VOR/ILS prior to localizer intercept.

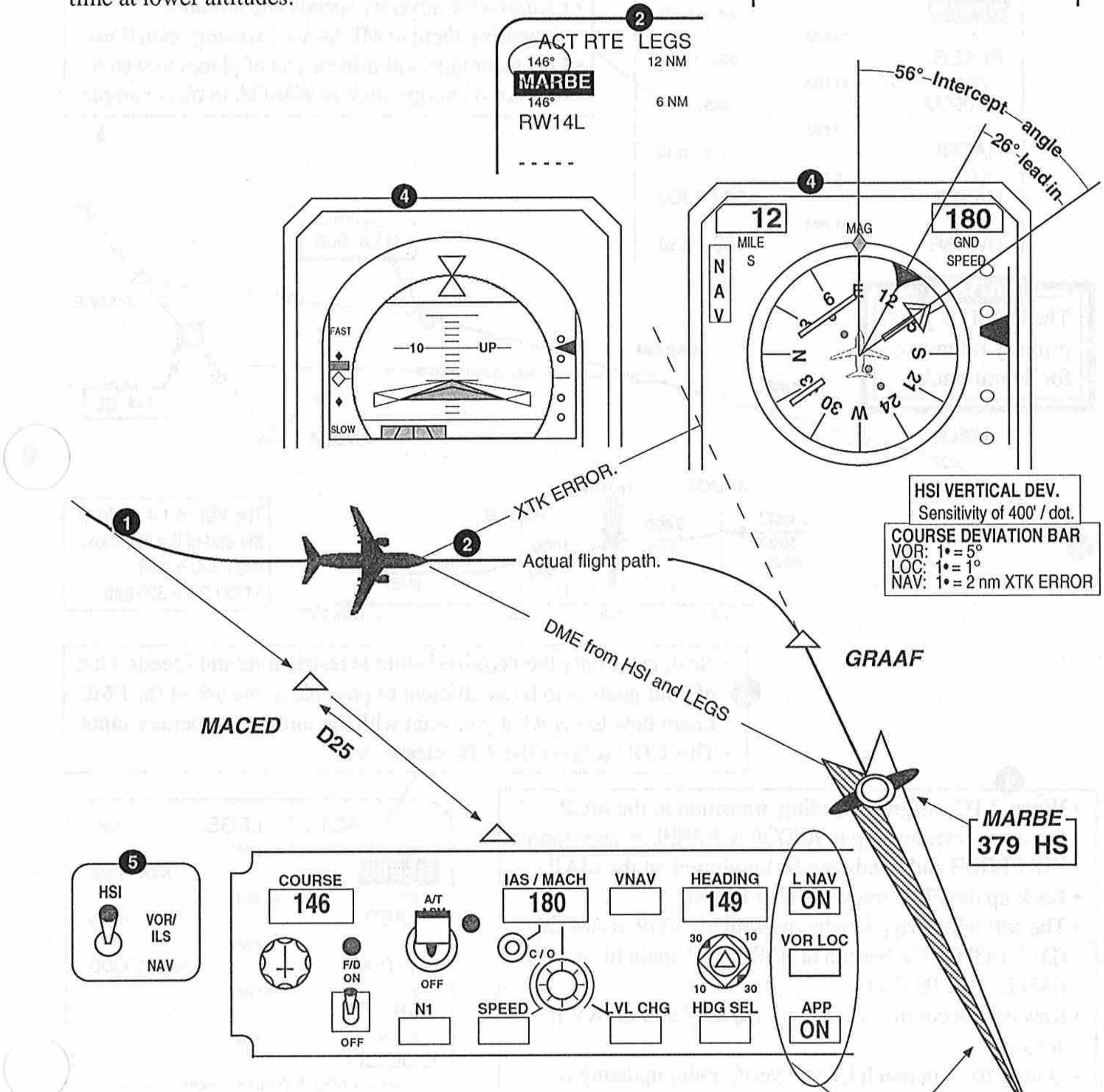
Software below U5 will not update from the localizer beam. With U1.x to U4 software, LNAV intercepts usually do not exacty match the localizer centerline. Therefore, intercept the "LNAV localizer" only during a visual approach to a single runway operation.

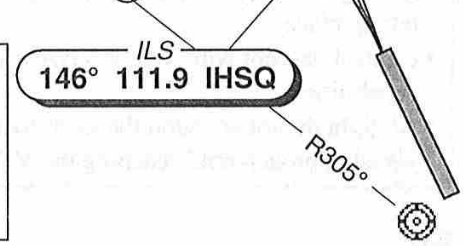
PROS: Very realistic depiction of approach on HSI.
CONS: Complex and takes practice. Some steps must be accomplished in the right order.

ILS Approach - Non EFIS

During cruise, select the APPROACH or RUNWAY. Complete terminal routing at altitude. To keep your workload to a minimum, create waypoints **only** if necessary. If you plan on an INTC LEG TO the OM, ensure a waypoint exists on the final approach course behind the marker. The prefered method is to use a data base wpt such as the GRAAF, in this example; it is usually on centerline. If you must construct a wpt, the quickest method is to use the Place-Bearing/Distance form - MARBE326/5. (Unfortunately, U1.x software requires more pilot input than U5 and up.) Complete all terminal routing prior to descent. This minimizes "heads-down" time at lower altitudes.







TECHNIQUE

LNAV intercept with non-EFIS software is not recommended because the FMC will not update its position with a manually tuned localizer. The LNAV runway centerline may or may not match the VHF localizer course. If IFR, press APP or VOR LOC in addition to LNAV when inbound for the intercept.

NDB Approach - EFIS (GPS overlay)

The EFIS control selector will remain in MAP for the complete approach.

Plan to use V/S for speed control. You should step down each level-off when using the MCP ALT SEL. If your FMC skills are well developed, VNAV can be used for speed control and altitude level-offs.

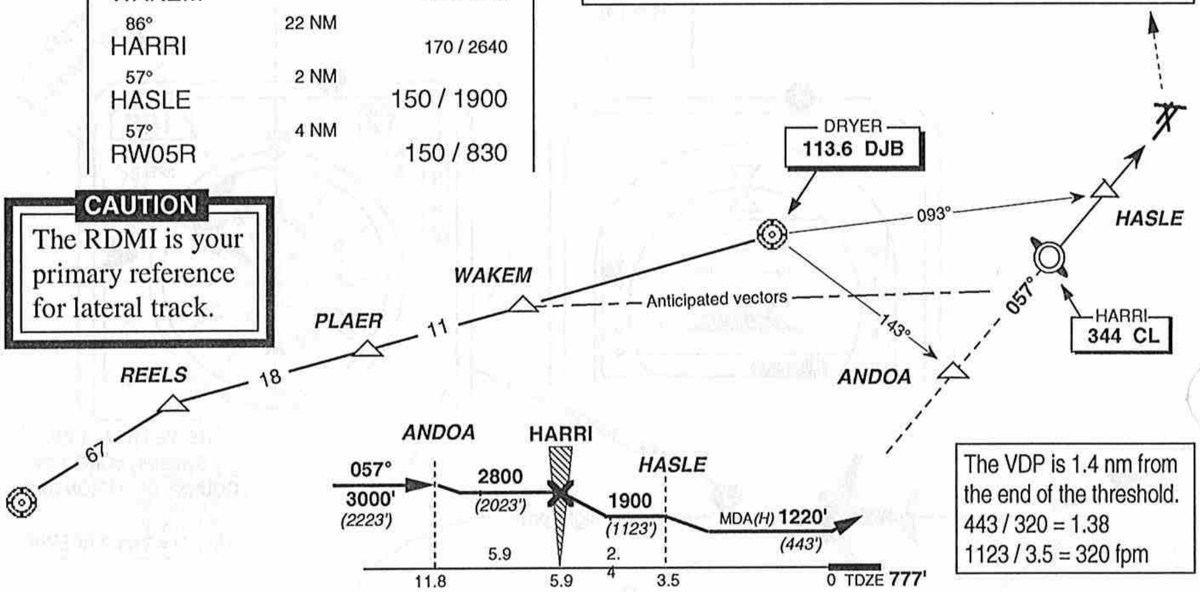
Unless the approach has a VASI or PAPI the non-precision approach may have, all the way to the threshold, obstacles that reach up to the MDA less the Required Obstacle Clearance. ROCs can vary. In the US, an NDB approach with a FAF is 300 ft; an NDB approach without a FAF is 350 ft.

1 For descent and arrival planning, enter the anticipated route to the active runway.

MOD RTE LEGS 1/X
42° 50 NM
REELS 300 / FL206
77° 18 NM
PLAER 300 / 13560
77° 11 NM
WAKEM 240 / 9720
86° 22 NM
HARRI 170 / 2640
57° 2 NM
HASLE 150 / 1900
57° 4 NM
RW05R 150 / 830

2
- Enter the speed and altitude at the FAF. The FMC will compute the predicted altitudes for all other waypoints. The advisory altitudes will only be as accurate as your routing.
- Examine the advisory speeds and altitudes, comparing them to MEAs and crossing restictions.
- This technique will inform you of places to watch for excess energy, such as WAKEM, in this example.

CAUTION
The RDMI is your primary reference for lateral track.



The VDP is 1.4 nm from the end of the threshold.
443 / 320 = 1.38
1123 / 3.5 = 320 fpm

3
- Next, enter only the **required** altitude restrictions and speeds. One of your goals is to be as efficient as possible in the use of the FMC. Learn how to get what you want with the minimum operator input.
- This CDU reflects the ATC clearance.

4
- When ATC assigns a heading, transition to the MCP.
- Set up an intercept leg to ANDOA or HARRI, as appropriate.
- XTK ERROR and winds can be monitored on the MAP.
- Back up the FMC track with the RDMI.
- The MP will verify stepdowns with his VOR at ANDOA (DJB 143°R), the beacon at HARRI, and again his VOR at HASLE (DJB 093°R).
- Raw data is controlling, but fly the MAP and LNAV if accurate.
- During the Approach Check, verify radio updating is taking place.
- Control descent with V/S or VNAV, depending on your capabilities.
- At night do not abandon the instrument procedure for a visual approach until reaching the VDP.

ACT RTE LEGS 1/X
42° 50 NM
REELS 300 / FL206
77° 18 NM
PLAER 300 / 13560
77° 11 NM
WAKEM 240 / 10000
77° 14 NM
DJB ---/------
THEN NM
□□□□□
---- ROUTE DISCONTINUITY ----
ANDOA 170 / 3000
57° 6 NM
HARRI 170 / 2800
57° 2 NM
HASLE 150 / 1900
57° 4 NM
RW05R 150 / 830

NDB Approach to 5R at Cleveland - Non EFIS (GPS overlay)

ATC: ***"Wibault 283, cross Wakem at 10,000 ft."***

The HSI switch will remain in NAV for the complete approach.

Plan to use V/S for speed control. You should step down each level-off when using the MCP ALT SEL. If your FMC skills are well developed, VNAV can be used for speed control and altitude level-offs.

Unless the approach has a VASI or PAPI the non-precision approach may have, all the way to the threshold, obstacles that reach up to the MDA less the Required Obstacle Clearance. ROCs can vary. In the US, an NDB approach with a FAF is 300 ft; an NDB approach without a FAF is 350 ft.

1. For descent and arrival planning, enter the anticipated route to the active runway.

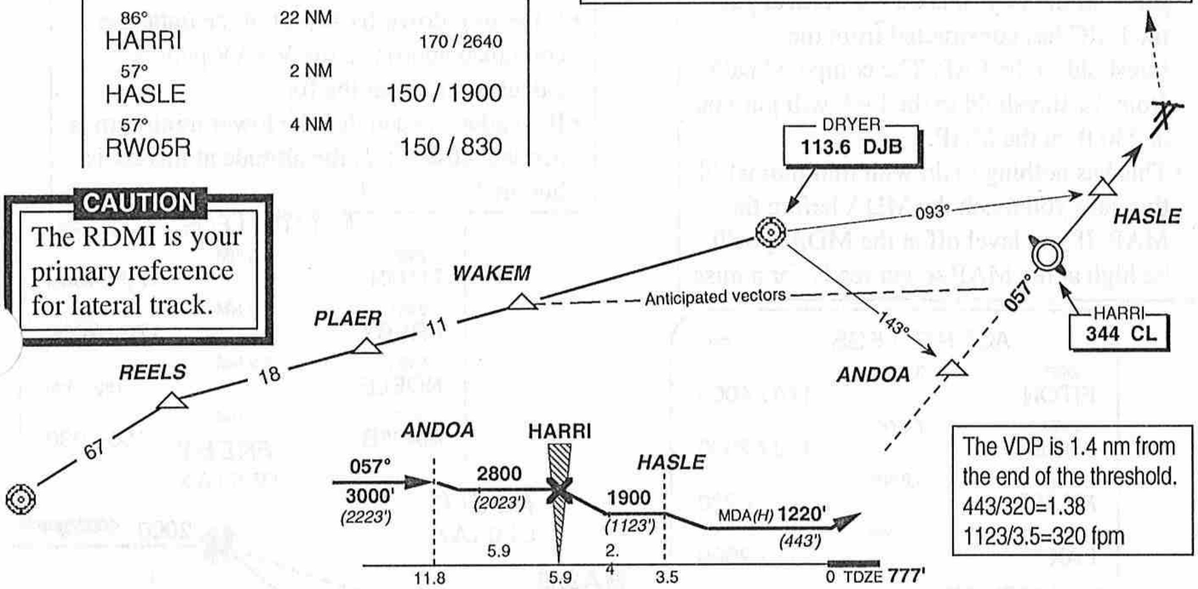
MOD RTE LEGS 1/X

42°	50 NM	
REELS		300 / FL206
77°	18 NM	
PLAER		300 / 13560
77°	11 NM	
WAKEM		240 / 9720
86°	22 NM	
HARRI		170 / 2640
57°	2 NM	
HASLE		150 / 1900
57°	4 NM	
RW05R		150 / 830

2.
- Enter the speed and altitude at the FAF. The FMC will compute the predicted altitudes for all other waypoints. The advisory altitudes will only be as accurate as your routing.
- Examine the advisory speeds and altitudes, comparing them to MEAs and crossing restrictions.
- This technique will inform you of places to watch for excess energy, such as WAKEM, in this example.

CAUTION

The RDMI is your primary reference for lateral track.



The VDP is 1.4 nm from the end of the threshold.
443/320=1.38
1123/3.5=320 fpm

3.
- Next, enter only the **required** altitude restrictions and speeds. One of your goals is to be as efficient as possible in the use of the FMC. Learn how to get what you want with the minimum operator input.
- This CDU reflects the ATC clearance.

4.
- When ATC assigns a heading, transition to the MCP.
- Set up an intercept leg to ANDOA or HARRI, as appropriate, and go to PROGRESS 2/2 for winds and XTK ERROR.
- This is an NDB, not an RNAV approach, so you must back up the FMC track with the RDMI.
- The MP will verify stepdowns with his VOR at ANDOA (DJB 143°R), the beacon at HARRI, and again his VOR at HASLE (DJB 093°R).
- Raw data is controlling, but use LNAV if accurate.
- During the Approach Check, verify radio updating is taking place.
- Control descent with V/S or VNAV, depending on your capabilities.
- At night do not abandon the instrument procedure (IAP) for a visual approach until reaching the VDP.

ACT RTE LEGS 1/X

42°	50 NM	
REELS		300 / FL206
77°	18 NM	
PLAER		300 / 13560
77°	11 NM	
WAKEM		240 / 10000
77°	14 NM	
DJB		---/-----
THEN	NM	
□□□□□		
---- ROUTE DISCONTINUITY ----		
ANDOA		170 / 3000
57°	6 NM	
HARRI		170 / 2800
57°	2 NM	
HASLE		150 / 1900
57°	4 NM	
RW05R		150 / 830

VOR Approach (FMS overlay)

Los Angeles VOR/GPS Runways: 25L / R

We'll use LNAV for lateral path. Since this is not an RNAV approach, the MP will back-up the FMC in a VOR mode. The MP's raw data is used to verify lateral path, step-downs, and the missed approach point. Select a raw data display prior to intercepting the final course.

Vertical restrictions can be met using the V/S thumbwheel or VNAV.

- The Missed Approach Point (MAP) can be prior to, at, or beyond the rwy threshold.
- The RW + 50 ft will be displayed if the MAP is at the threshold. In the example - VOR 25L/R at LAX, the MAP is *prior* to the rwy; the RW may not be displayed.
- This MAP is labeled MA25B (Both) and *prior* to the rwy. It is on the vertical path the FMC has constructed from the threshold to the FAF. The computed path from the threshold to the FAF will put you at 230 ft. at the MAP.
- This has nothing to do with minimums! In this case you reach the MDA before the MAP. If you level off at the MDA, you'll be high at the MAP so get ready for a miss.

Ensure LEGS page crossing restrictions match the charts. Brief the approach thoroughly.

Some non-precision approaches may not be contained in the operator's database. Unless specifically prohibited by your SOP, the approach may be constructed using wpts and the rwy contained in your database.

Unless the approach has a VASI or PAPI, the non-precision approach may have obstacles that reach up to the MDA less the Required Obstacle Clearance. The ROC is generally 250 ft inside the FAF, however ROCs can vary. In the US, a VOR without a FAF is 300 ft.

- If the step-down fix is added by the pilot, the new VNAV path to the threshold may or may not clear this fix. In the example, the predicted altitude at NOELE is 575 ft MSL.
- If the step-down fix is part of the database contained approach, the VNAV path is calculated to clear the fix.
- If weather is such that the lower minimum is needed, ensure that the altitude at this fix is honored.

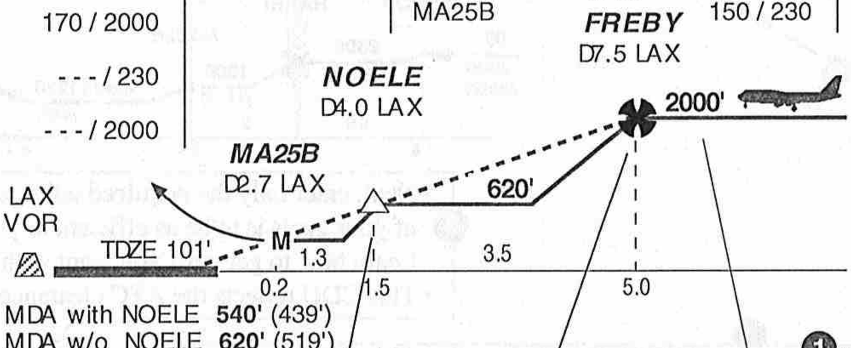
ACT RTE LEGS 2/3

248°	3.0 NM	
FITON		170 / 4000
248°	7.0 NM	
FREBY		170 / 2000
248°	4.8 NM	
MA25B		- - - / 230
248°	3.0 NM	
LAX		- - - / 2000

ACT RTE LEGS 2/3

248°	3.0 NM	
FITON		170 / 4000
248°	7.0 NM	
FREBY		170 / 2000
248	3.5 NM	
NOELE		162 / 575
248°	1.3 NM	
MA25B		150 / 230

RULE OF THUMB
To calculate a 2.8° descent, take one half the ground speed times ten.
3° add 50 ft.
3.2° add 100 ft.



1 Approaching FREBY, (in ALT HOLD) preset the MDA in the MCP. **S**
Two techniques: Set *lower* (500) or *higher* (600). MCP resolution is only 100 ft! Setting the higher provides no protection after leaving 600 ' for the MDA.

2 At FREBY **S**
- If a PDI is available, set the V/S thumbwheel to follow it to the MDA.
- If no PDI, set V/S to 1000 fpm and level-off at MDA, looking for field and VDP.

3 At NOELE
- Thumbwheel down to 540.
- *Lower* technique: At 540 press ALT HOLD and dial the MA in the MCP altitude window.
- *Higher* technique: At 600 dial MA in MCP and V/S down to 540; press ALT HOLD.

4
- Use the VERT DEV as your VDP. If you have ground contact – just prior to the VERT DEV centering, V/S 800 fpm down to set the FD and continue small corrections in V/S to maintain the VASI. If no VASI, use the VERT DEV to supplement the visual reference.
- Observe A/P disconnect limits.

DESCENT PLANNING WITH NO PUBLISHED ALTITUDE CONSTRAINT

- Select the approach - ILS 03R to Panama City in this example. The approach must be selected first otherwise all created wpts will be dropped when the approach is selected later. ❶
- I discarded the glide slope intercept point - optional. (GS-03R)
- Build a wpt one tenth of a mile this side of the threshold by typing RW03R/–.1 and placing on top of the runway. This is needed for entry to the FIX and DEScent pages because the FMC will not recognize RW03R as a waypoint. ❷
- Place this waypoint (RW001) into a FIX page. Build a waypoint 35 nm from this by typing /35. ❸ The FMC will create a waypoint 35 miles from the threshold at a point where it crosses the active flight plan. (reference the dashed circle)
- Downselect this waypoint to the scratchpad and then place it into the LEGS page between MORLI and TBG. Enter 250/10000. ❹

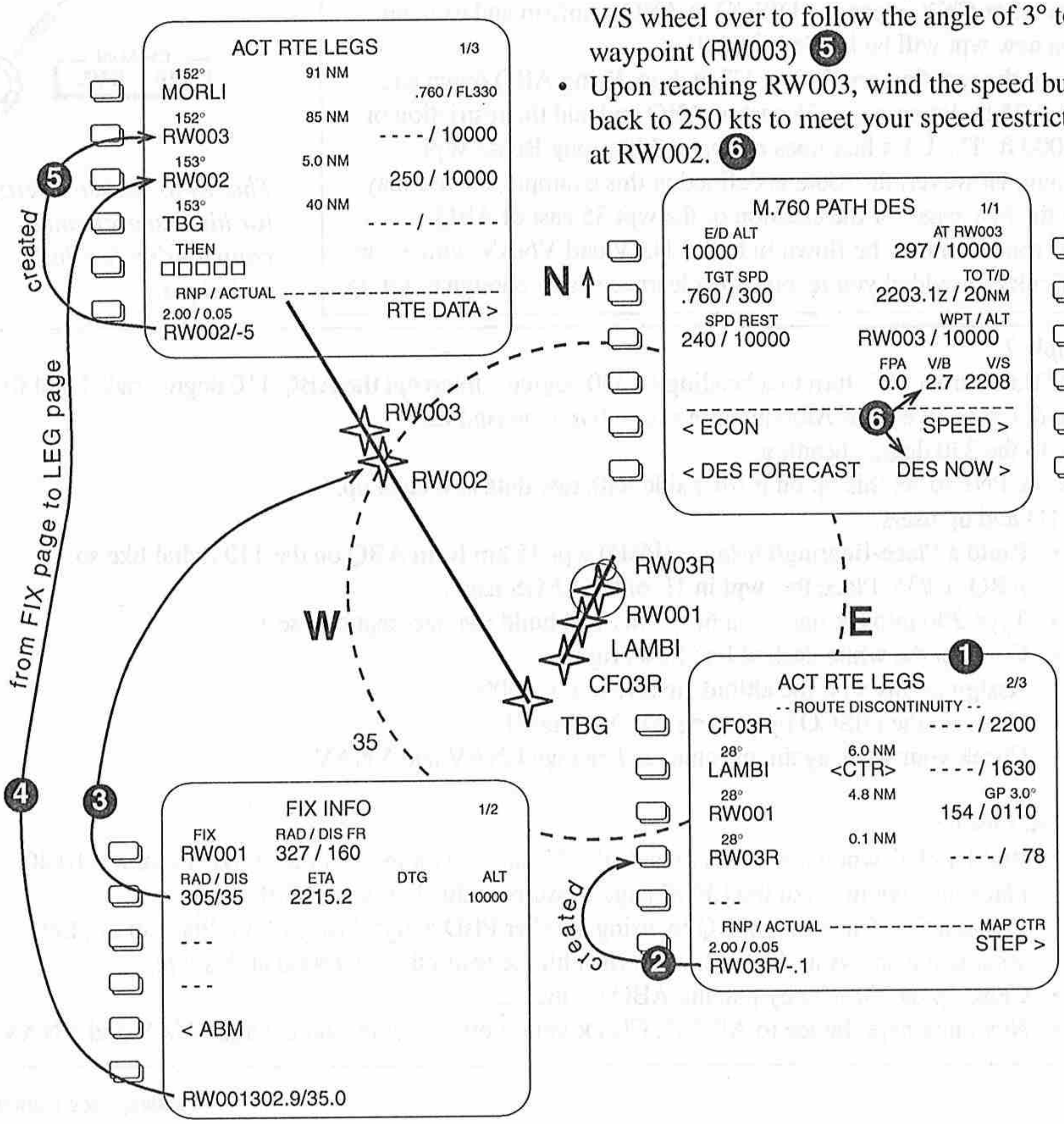
Now decide whether you wish to do a VNAV PATH (idle throttle) descent or a CONSTANT ANGLE (partial throttle) descent.

VNAV PATH DESCENT (idle throttle)

- Enter the destination altimeter setting in the DES FORECAST page if it is above standard.
- A few miles prior to the T/D, select DES NOW for a smooth capture of the descent leg. ❻

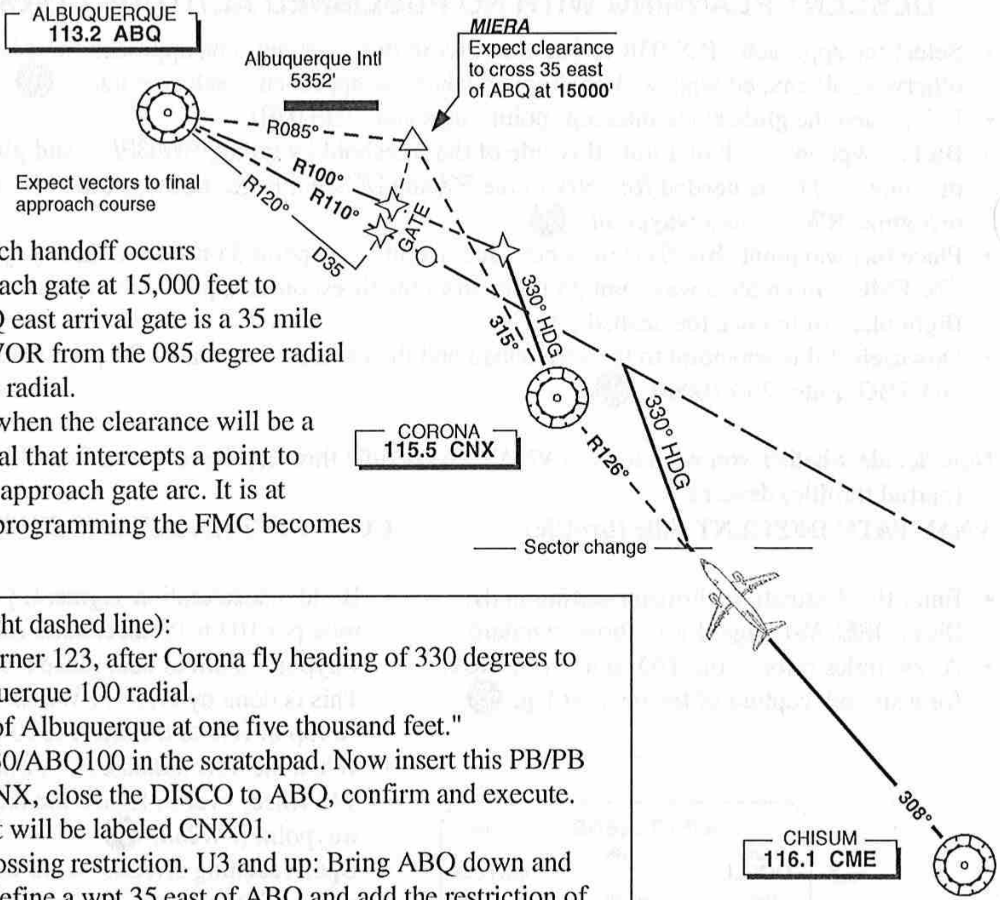
CONSTANT ANGLE DESCENT (part. throttle)

- Build a deceleration segment; you'll need 1 mile per 10 kts to decelerate. Lets build a waypoint 5 nm to decelerate from 300 to 250. This is done by typing RW002/–5 and placing on top of RW002. Enter 10000 ft at this point.
- When the V/B indicates 2.9, thumbwheel the V/S wheel over to follow the angle of 3° to this waypoint (RW003) ❺
- Upon reaching RW003, wind the speed bug back to 250 kts to meet your speed restriction at RW002. ❻



ALONG ROUTE WPT WITH AN INTERCEPT

The STAR is the dashed line. Center-to-center handoff occurs southeast of CNX VOR.
Center-to-approach handoff occurs outside the approach gate at 15,000 feet to 16,000 feet. ABQ east arrival gate is a 35 mile arc of the ABQ VOR from the 085 degree radial to the 120 degree radial.
There are times when the clearance will be a heading to a radial that intercepts a point to the EAST of the approach gate arc. It is at these times that programming the FMC becomes a challenge.



Example 1 (tight dashed line):
ATC: "Barnburner 123, after Corona fly heading of 330 degrees to join the Albuquerque 100 radial.
Cross 35 east of Albuquerque at one five thousand feet."
- Type CNX330/ABQ100 in the scratchpad. Now insert this PB/PB point after CNX, close the DISCO to ABQ, confirm and execute. This new wpt will be labeled CNX01.
- Create the crossing restriction. U3 and up: Bring ABQ down and type /-35 to define a wpt 35 east of ABQ and add the restriction of 15,000 ft. The U1.x box does not have this Along Route Wpt feature. However, the route is defined in this example, so you may use the FIX page for the creation of the wpt 35 east of ABQ.
- This route can now be flown in both LNAV and VNAV without any difficulty, provided you receive the clearnace early enough to set up.

Thanks to Jackson Seltzer, for his research and contribution for this technique.

Example 2:
ATC: "Barnburner 123, turn to a heading of 330 degrees. Intercept the ABQ 110 degree radial and fly inbound. Cross 35 east of Albuquerque at one five thousand feet."
- Turn to the 330 degree heading.
- Ask the PNF to set this up on his/her side with raw data as a back up.

U3 and up users:
- Build a Place-Bearing/Distance (PBD) wpt 35 nm from ABQ on the 110 radial like so: ABQ110/35. Place this wpt in 1L of the LEGS page.
- Type 290 into the dashes at 6R. (This will build the intercept course.)
- Confirm the white dashed line looks right.
- Assign to this wpt, the altitude restriction of 15000.
- Close up the DISCO by placing ABQ in line 2L.
- Check your work again, execute, and engage LNAV and VNAV.

OR

U1.x users:
- Build a PBD wpt a few miles outside the 35 nm gate on the 110 radial like so: ABQ110/40. Place this wpt in 1L of the LEGS page. Assume it displays as ABQ01.
- Create a fix 35 nm from ABQ by using another PBD entry: ABQ110/35. Place in 2L. Let's assume it displays as ABQ02. Enter the altitude restriction of 15000 at this wpt.
- Close up the DISCO by placing ABQ in line 3L.
- Next, intercept the leg to ABQ02. Check your work, execute, and engage LNAV and VNAV.

Changing a Cruise Waypoint to a Descent Waypoint - U6 and below

Situation:
You are northbound on J55-191 at FL370, 24 nm south of Patuxent for the WARRD 3 ARRIVAL to Newark (no longer current). A restriction at KENTON has been entered on the LEGS page.
ATC: ***"Short Solent, cross 20 southwest of Kenton at FL240".***

ACT RTE LEGS 1/3
39° 24 NM
PXT .745/FL370
46° 50 NM
ENO01 280/FL298
45° 7 NM
CANNY 280/FL274
46° 13 NM
ENO 280/FL240
43° 20 NM
SKIPY 280/FL232
EXTENDED DATA>
INVALID ENTRY

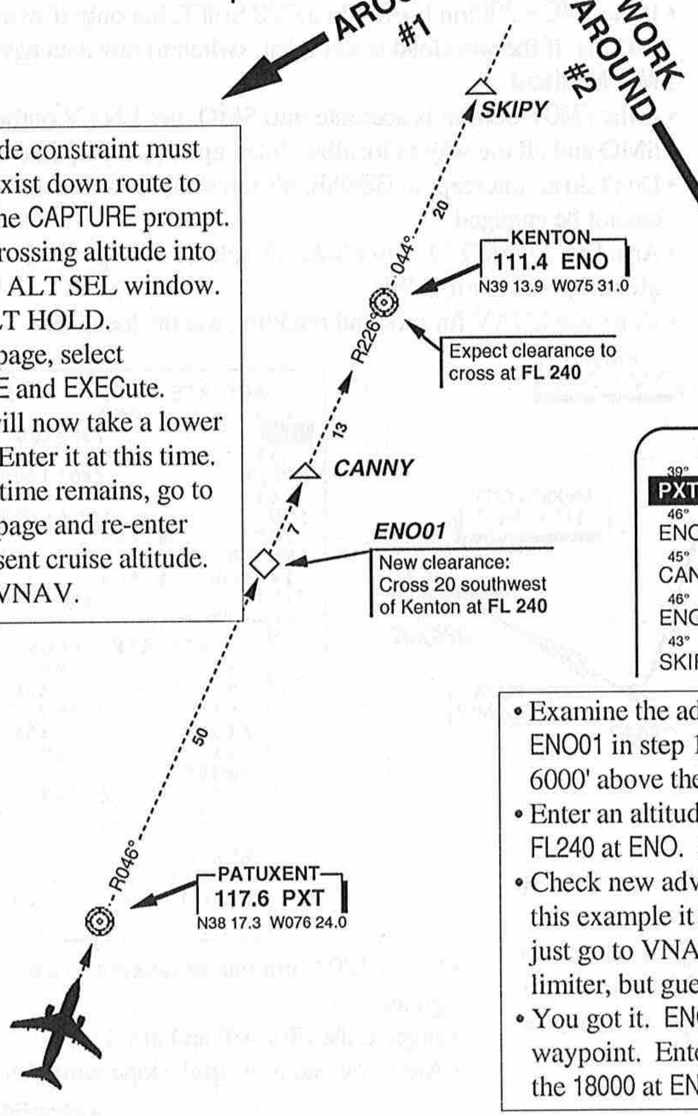
ECON PATH DES 1/1
E/D ALT
TGT SPD
SPD REST WPT / ALT
---/----- ENO01 / 24000
FPA V/B V/S
0.0 1.8 1220

1

- Create a downtrack fix 20 sw of Kenton and plug it in between PXT and CANNY. It will display as ENO01.
- After entering 240 in line 2, the message INVALID ENTRY appears because the FMC has defined ENO01 as a cruise waypoint. Until U7.0, a cruise waypoint cannot have an altitude restriction assigned to it.
- Put ENO01 in the s/p and type /240 behind it.
- Go the the DES page and enter this wpt/altitude at LSK 3R.
- Check V/S. If less than 1000'/min., a Cruise descent may be used to this altitude. If in excess of 2000'/min., you are rapidly nearing the top of descent, depending on winds and planned descent speed.

WORK AROUND #1

- An altitude constraint must already exist down route to display the CAPTURE prompt.
- Put the crossing altitude into the MCP ALT SEL window.
- Press ALT HOLD.
- On DES page, select CAPTURE and EXECute.
- ENO01 will now take a lower altitude. Enter it at this time.
- If cruise time remains, go to the CRZ page and re-enter your present cruise altitude.
- Engage VNAV.



WORK AROUND #2

ACT RTE LEGS 1/3
39° 24 NM
PXT .745/FL370
46° 50 NM
ENO01 280/FL235
45° 7 NM
CANNY 280/FL275
46° 13 NM
ENO 280/18000
43° 20 NM
SKIPY 280/18000

- Examine the advisory crossing altitude at ENO01 in step 1 (FL298). Notice it is about 6000' above the clearance.
- Enter an altitude about 6000' lower than FL240 at ENO. (Example: 18000 in 4R above)
- Check new advisory altitude at ENO01. In this example it is below FL240. We could just go to VNAV and use the MCP as the limiter, but guess what?
- You got it. ENO01 is now a descent waypoint. Enter FL240 at ENO01 and DELete the 18000 at ENO.

MATEO ARRIVAL TO MEXICO CITY

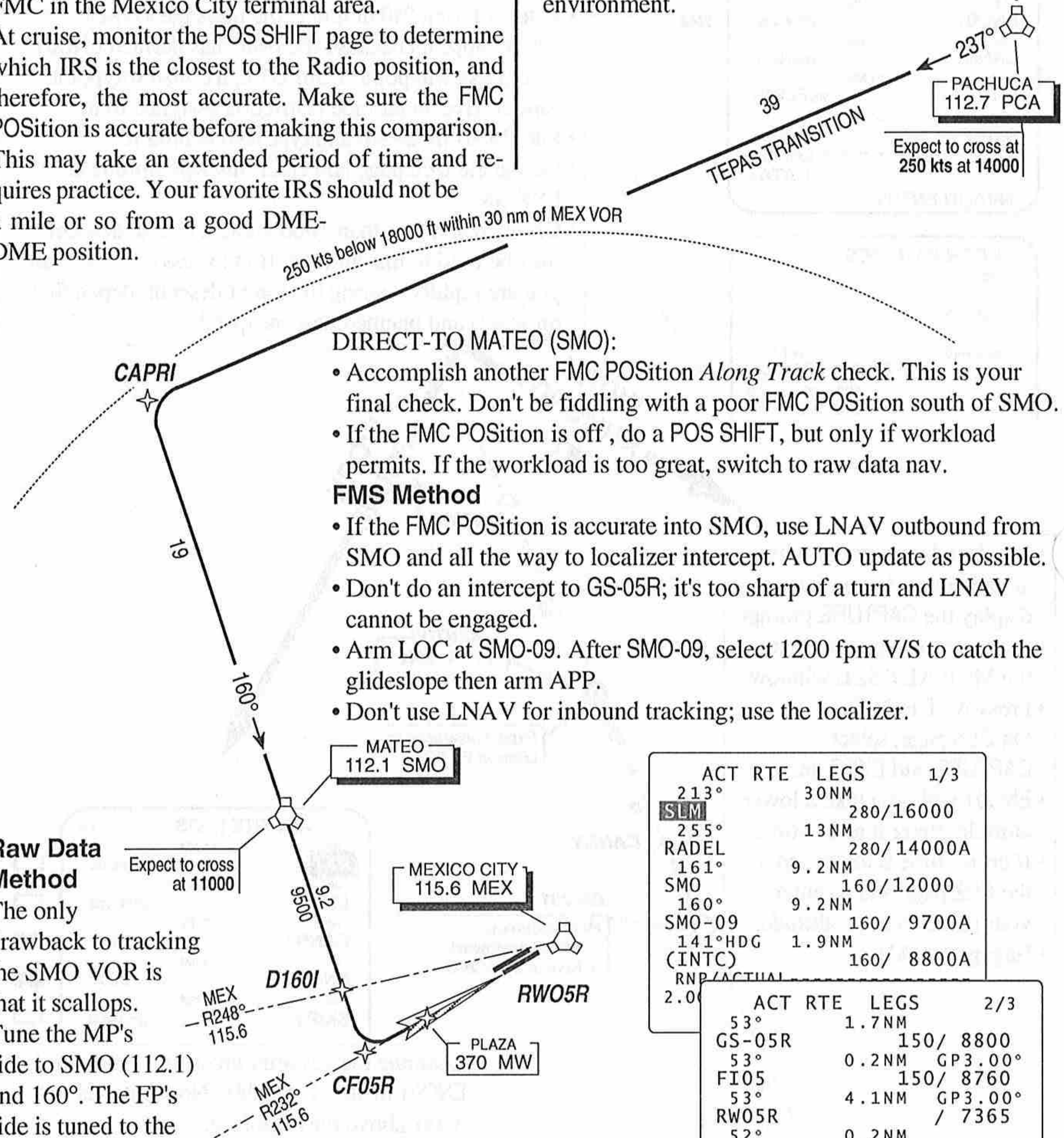
Two things of concern regarding Mexico City ops: (1) FMC position accuracy in the terminal area, (unless you've got GPS) and (2) whether or not to use VNAV. VNAV is not recommended unless you have speed intervention, as the approach controller will probably assign a speed after SMO you cannot hold, such as 160 kts.

During Preflight, align the IRSs to gate coordinates. If you don't have GPS, you may have an inaccurate FMC in the Mexico City terminal area.

At cruise, monitor the POS SHIFT page to determine which IRS is the closest to the Radio position, and therefore, the most accurate. Make sure the FMC POSition is accurate before making this comparison. This may take an extended period of time and requires practice. Your favorite IRS should not be a mile or so from a good DME-DME position.

DESCENT and DIRECT-TO LUCIA (SLM):

- Accomplish an FMC POSition *Along Track* check; manual tune to 116.6 and compare the SLM RDMI DME to the RNAV DME. The raw data DME (slant range) should be about a .2 mile greater than the RNAV DME at 50 miles.
- If the FMC POSition is off, a shift to your favorite IRS should be accomplished. Remain in LNAV during a shift in a high workload environment.



DIRECT-TO MATEO (SMO):

- Accomplish another FMC POSition *Along Track* check. This is your final check. Don't be fiddling with a poor FMC POSition south of SMO.
- If the FMC POSition is off, do a POS SHIFT, but only if workload permits. If the workload is too great, switch to raw data nav.

FMS Method

- If the FMC POSition is accurate into SMO, use LNAV outbound from SMO and all the way to localizer intercept. AUTO update as possible.
- Don't do an intercept to GS-05R; it's too sharp of a turn and LNAV cannot be engaged.
- Arm LOC at SMO-09. After SMO-09, select 1200 fpm V/S to catch the glideslope then arm APP.
- Don't use LNAV for inbound tracking; use the localizer.

```
    ACT RTE  LEGS      1/3
 213°        30NM
SLM              280/16000
 255°        13NM
RADEL            280/14000A
 161°       9.2NM
SMO              160/12000
 160°       9.2NM
SMO-09           160/ 9700A
 141°HDG    1.9NM
(INTC)           160/ 8800A
RNP/ACTUAL----------------
2.0
```

```
    ACT RTE  LEGS      2/3
 53°        1.7NM
GS-05R           150/ 8800
 53°        0.2NM   GP3.00°
FI05             150/ 8760
 53°        4.1NM   GP3.00°
RW05R               / 7365
 52°        0.2NM
(7720)             ----/ 7720A
 53         7.2NM
MEX-06             ----/------
RNP/ACTUAL----------------
2.00/0.25NM        RTE DATA>
```

Raw Data Method

The only drawback to tracking the SMO VOR is that it scallops. Tune the MP's side to SMO (112.1) and 160°. The FP's side is tuned to the ILS (IMMX / 109.1) and 52°.

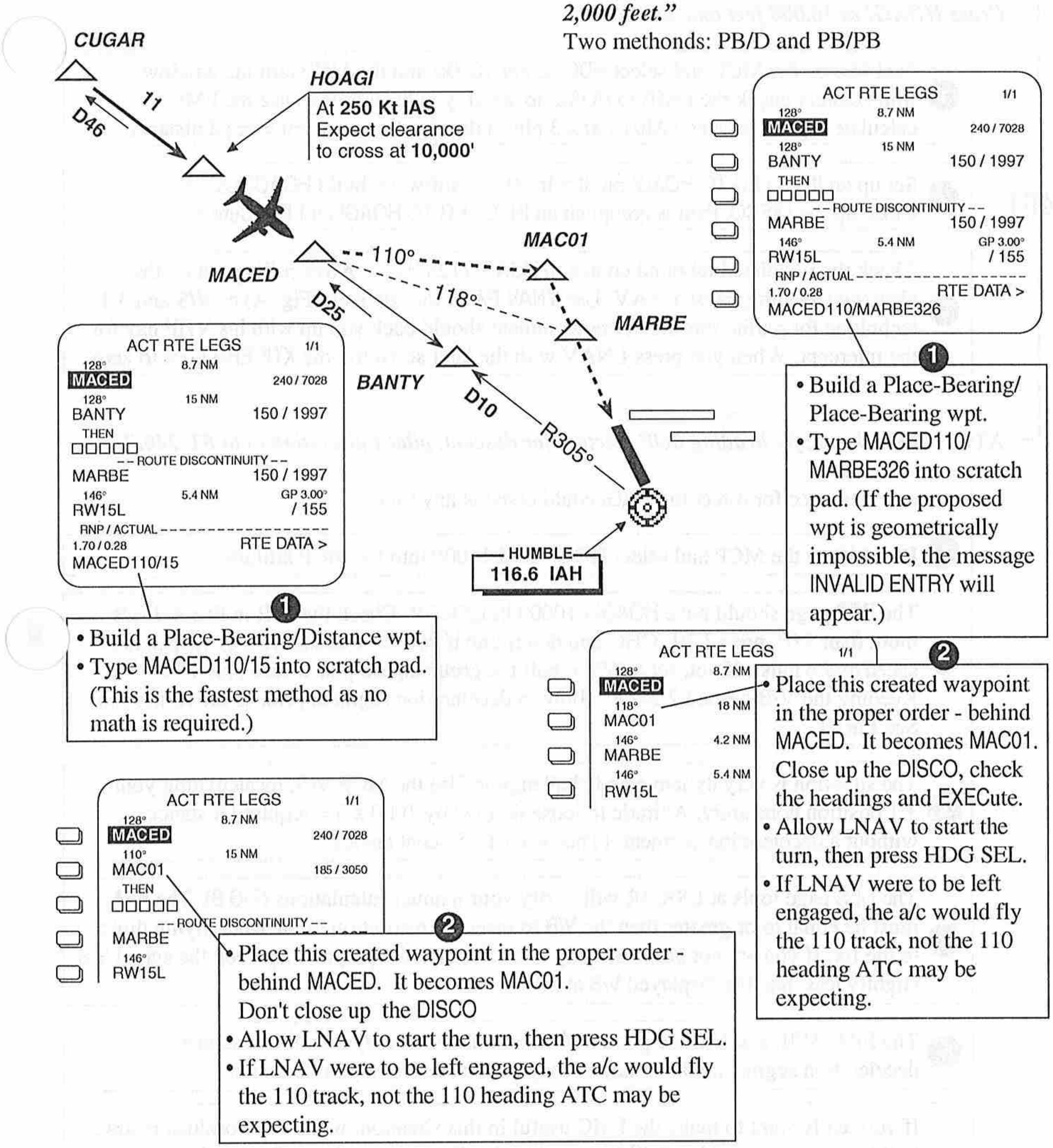
- At SMO, engage the MP's A/P in VOR/LOC. It will track out the 160 radial.
- At 9.2 DME, set the heading bug for a localizer intercept and press HDG SEL (25 or 30° bank). Note the winds and position of the ADF needle PLAZA (MW).
- Select 1200 fpm rate of descent to catch the glideslope.
- Engage the FP's A/P and arm LOC.
- After you catch the glideslope with V/S, arm APP.

Navigate in the Terminal Area with a Created Waypoint

It's helpful to use the FMC to start a turn as a reminder in case workload is such that one forgets the heading clearance. This example uses Houston Intercontinental.

Situation: You're arriving from the northwest for runway 14L. After passing HOAGI and descending from ten thousand for six, ATC says, ***"Tupolev 20, depart MACED heading one one zero, descend to 2,000 feet."***

Two methonds: PB/D and PB/PB



U3.0. 3.1, and U4.0 users only:

There have been FMC position updating problems during runway changes when the updating is from the *manually* tuned localizer. Airplanes flying the ILS have been maneuvered to the opposite runway - via radar vectors - while the airport ILS direction was switched. This resulted in a reversal of the localizer deviation polarity while the FMC thought the airplane as still on the original ILS. The FMC position was driven off at the rate of 8 nm/min while localizer (LOC) updating was continued. This has resulted in large errors in FMC position at a time when the pilots thought everything was normal. If runways are changed after the FMC has started localizer (LOC) updating, the pilots should ensure that the ILS stations are detuned during the initial vectoring. U5.0 corrects this problem.

Intercepting a VOR Radial on Descent

You're on the CUGAR ARRival to Houston Intercontinental. The restriction at HOAGI is 250/10000
Two possibilities: ATC may turn you direct to the restricted wpt (shortening the flight path) or take you all the way to the radial,(lengthening the flight path).

ATC: ***"Latecoere 521, fly heading zero six zero. Intercept the Humble three zero five radial. Cross HOAGI at 10,000 feet and 250 kts."***

1. Dial 060 on the MCP and select HDG. Enter 10000 into the MCP altitude window. Immediately check the DME to HOAGI to see if you have time to use the FMC to calculate top-of-descent. (Alt/1000 x 3 plus a deceleration segment = req'd distance)

2. Set up an INTC LEG TO HOAGI on 305 R. (U1.x software, build HOAGI305/100. Close up the DISCO, then accomplish an INTC LEG TO HOAGI and EXECute.)

3. Check the initialized inbound course to HOAGI (125°±2°). **After** rolling out on the clearance heading, press LNAV. Use VNAV PATH for idle path (Fig. A) or V/S and 3:1 technique for partial throttle. Your teammate should back you up with his VHF nav for the intercept. When you press LNAV with the later software, the XTK ERR goes to zero.

OR

ATC: ***"Sikorsky 42, fly heading 060°, vectors for descent, pilot's discretion to to FL 240."***

Let's assume clearance for direct to HOAGI could come at any time.

1. Dial 060 on the MCP and select HDG. Dial 15000 into the MCP altitude.

2. The DES page should have HOAGI / 10000 in LSK 3R. Check the V/B in line 4. If it's more than 3.0°, press LVL CHG and determine if you have excess energy (depends on speed and winds). If not, set a V/S of half the groundspeed plus a zero plus 10%. Keeping the V/B around 2.2-2.4° allows a deceleration segment prior to the restriction. See Fig. B

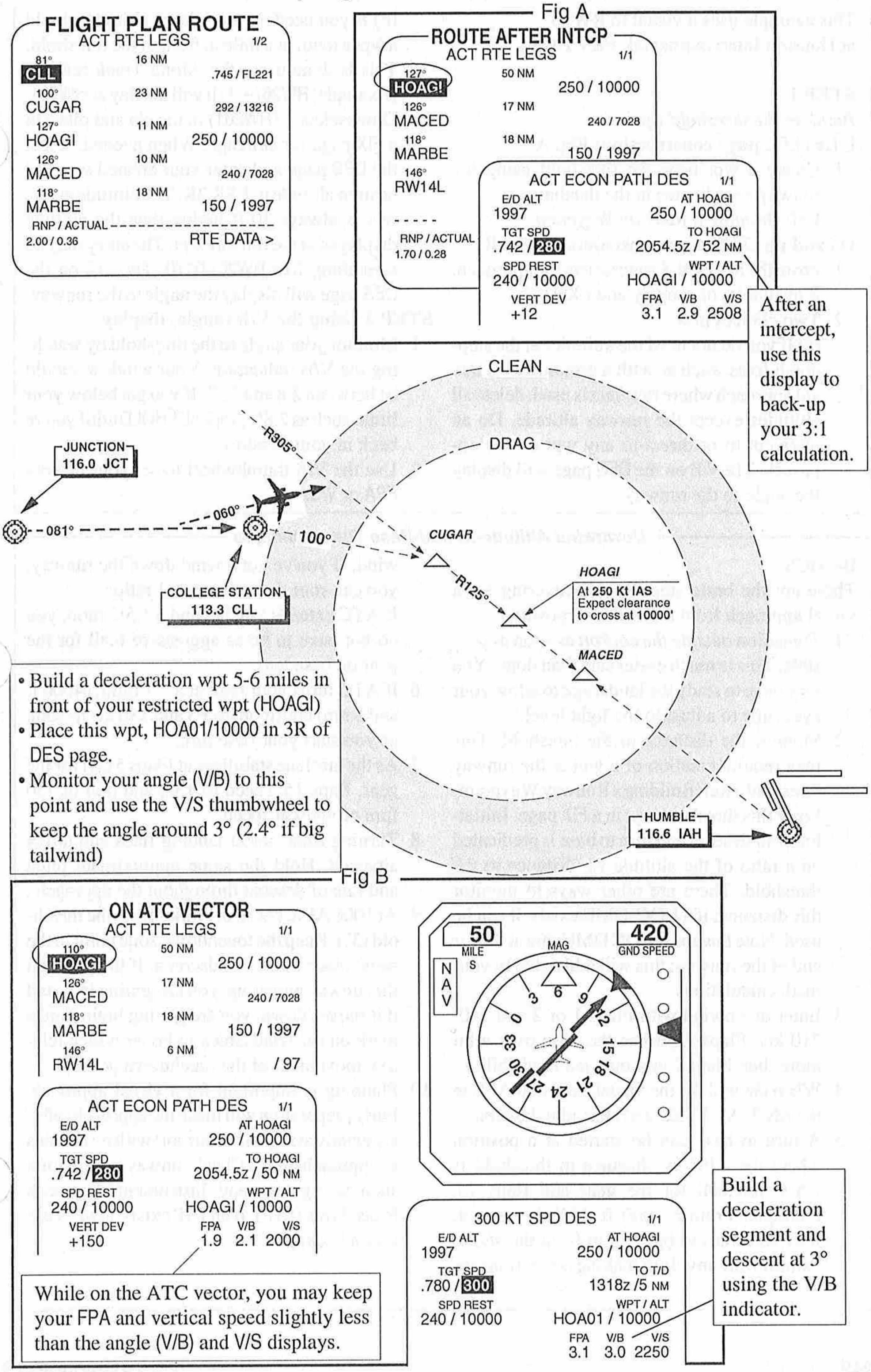
3. The situation is very dynamic and challenging. Use the MCP V/S, recalculating your 3:1 position constantly. Altitude to loose divided by 1000 x 3 = required distance without a deceleration segment. (This is a 3.1° descent angle).

4. The DES page tools at LSK 3R will verify your manual calculations (FIG B). The FPA must be equal to or greater than the V/B to meet the restriction in 3R when flying direct to the fix. If you are not going directly to the restricted wpt, you may keep the actual V/S slightly less than the displayed V/S at 3R.

5. The FPA, V/B, and V/S are good tools, but remember, they do not calculate a deceleration segment, which may or may not be needed in your situation.

6. If you really want to make the FMC useful in this situation, while the workload is low, build a wpt on your side of HOAGI equal to the distance you desire for deceleration. (Example: HOAGI / -5). This will display as HOA01. Next, place this wpt in line 3R of the DES page, along with the altitude restriction. HOA01 / 10000. Don't leave this new wpt (HOA01) in the LEGS page. Now, fly the V/B (angle), selecting a V/S that keeps the V/B at 3-3.2° (light winds). Yes, you can simply use the V/S in line 4! Reaching 11,000 ft, roll the speed knob back to 250 and you've got the restriction met. This take practice but you'll love this tool.

Intercepting a VOR Radial on Descent



VISUAL APPROACH

Angle-to-Runway technique

This example uses a visual to RW26 at Houston Intercontinental. Elev 100 ft.

STEP 1

Building the threshold wpt.

U1.x LEGS **page construction: Fig. A**

1. Create a wpt near the threshold using the runway coordinates in the database. Ref: *Building a Runway Waypoint.*

U3 and up LEGS **page construction: Fig. B**

1. From the ARRIVALS page, select the approach, if available, or runway and EXEC.
2. Two choices now.

   (a) If you do not need the altitudes at the step-down fixes, such as with a ground based nav aid approach where raw data is used, delete all altitudes except the runway altitude. Do an intercept-to or direct-to any wpt on the approach. The V/B on the DES page will display the angle to the runway.

   (b) If you need the step-down altitudes, build a wpt a tenth of a mile in front of the threshold. This is done using the Along Track feature. (Example: RW26/−.1) It will display as RW201. Downselect it (RW201) to the s/p and place in a FIX page for storeage. When needed, select the DES page and enter your created wpt and desired altitude to LSK 3R. The altitude at this wpt is always 30 ft higher than the altitude displayed at the runway wpt. The entry may be something like RW201/0170. The V/B on the DES page will display the angle to the runway.

STEP 2 Using the V/B (angle) display

1. Monitor your angle to the threshold by watching the V/B indication. Your window should be between 2.8 and 3.5°. If you get below your limit, such as 2.8°, press ALT HOLD until you're back in your window.
2. Use the V/S thumbwheel to set your desired FPA or V/S.

Downwind Altitude-to-find-Base Turn technique

BASICS

These are the basic steps in maneuvering for a visual approach from a downwind position.

1 Transition *outside the cockpit* as soon as possible. This is much easier said than done. You may have to study the landscape to allow your eyes time to adjust to the light level.

2 Monitor the distance to the threshold. This may require creation of a wpt at the runway threshold. (Ref: Building a Runway Waypoint) Enter this threshold wpt in a FIX page. Initiating your descent and turn to base is predicated on a ratio of the altitude vs: distance to the threshold. There are other ways to monitor this distance; if a LOC-DME exists, it can be used. Note that most LOC DMEs are at the *far* end of the runway; this will add a step to your math calculations.

3 Enter downwind with Flaps 1 or 2 and 190-210 kts. Flaps 2 pushes the nose over a bit more than Flaps 1 and may aid in visibility.

4 When cleared for the visual, set 1000 AFE in the MCP ALT SEL and start idle descent.

5 A turn to base can be started at a position where the AFE vs. distance to threshold is 1.5:1, but call for the gear and flaps 10. Example: From a 4000 ft AFE downwind, start your turn to base 6 nm from threshold. Pattern work involves making corrections for wind. If you've got a wind down the runway, you can start the turn at a 1:1 ratio.
If ATC extends you beyond a 1.5:1 ratio, you do not have to be as aggressive (call for the gear on base leg).

6 If ATC turns your base at a 2:1 ratio, (4000 ft and 8 nm) configure to F5 and 180 kts as soon as you start your base turn.

7 As the airplane stabilizes at Flaps 5 call for the gear, flaps 15, speed to 150, and dial in 750 fpm of vertical speed.

8 Turning final, select landing flaps and target airspeed. Hold the same approximate pitch and rate of descent throughout the approach .

9 At 1000 AFE, check 3.1 miles from the threshold (3°). Keep the touchdown zone point in the same place in the windscreen. If the point on the runway moves up, you are getting low, and if it moves down, you are getting high. Find a mark on the windscreen to better notice relative movement of the touchdown point.

10 Planning is important for a visual approach. Early preparation will make the approach safer, especially at night to an airport with no navaids or approach lights. Check runway information such as lighting and Instrument Approach Procedures (IAP). If an IAP exists, always use it as a backup.

Visual Approach from a Downwind

Fig. A

MOD RTE LEGS 4/4

-- ROUTE DISCONTINUITY --

FA - - 26		----/------
264°	5 NM	
R201		150 / 1100
264°	3 NM	
R26		150 / 140
264°	0 NM	
RW26		

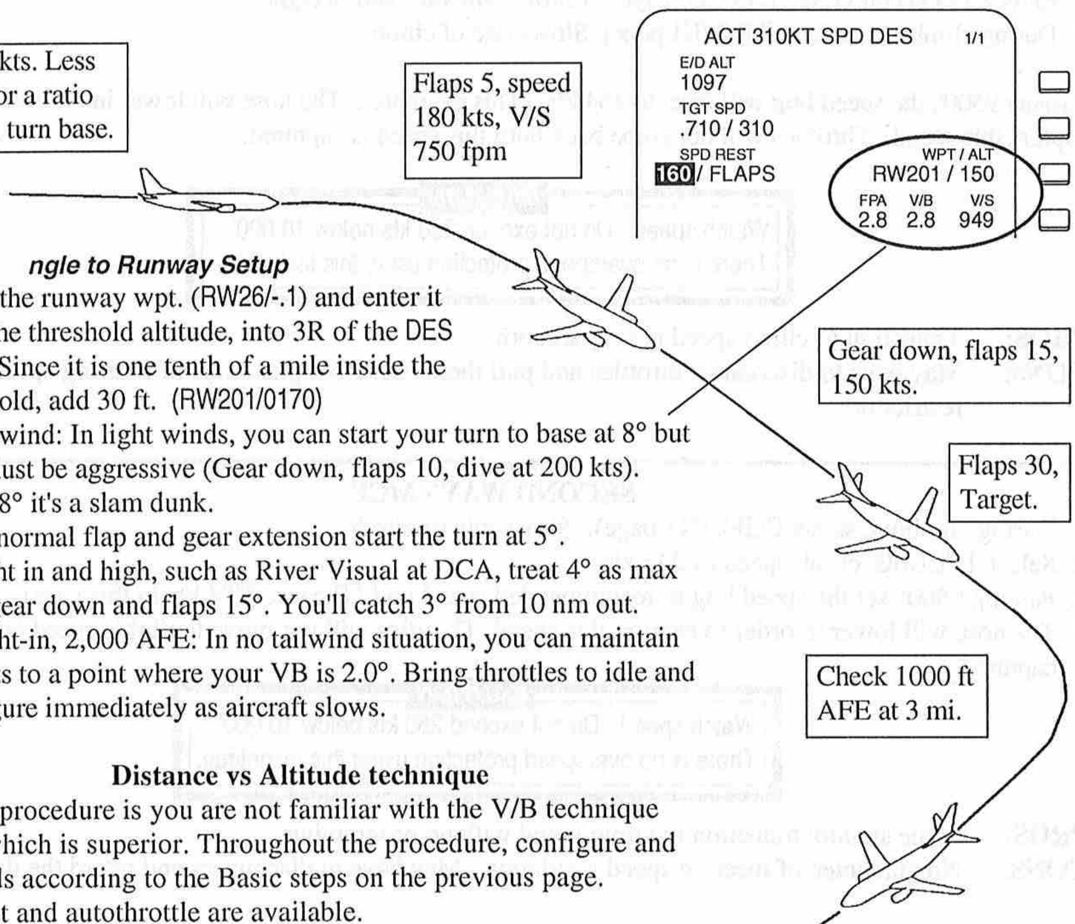
A discontinuity may form between these wpts.

Fig. B

MOD RTE LEGS 4/4

-- ROUTE DISCONTINUITY --

RX - 26		150 / 1100
264°	2.9 NM	
RW201		150 / 140
264°	.1 NM	
RW26		150 / 140



ngle to Runway Setup

1 Build the runway wpt. (RW26/-.1) and enter it with the threshold altitude, into 3R of the DES page. Since it is one tenth of a mile inside the threshold, add 30 ft. (RW201/0170)

2 Downwind: In light winds, you can start your turn to base at 8° but you must be aggressive (Gear down, flaps 10, dive at 200 kts). From 8° it's a slam dunk.

3. For a normal flap and gear extension start the turn at 5°.

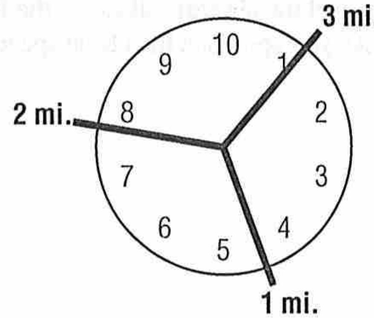
4. Straight in and high, such as River Visual at DCA, treat 4° as max with gear down and flaps 15°. You'll catch 3° from 10 nm out.

5. Straight-in, 2,000 AFE: In no tailwind situation, you can maintain 250 kts to a point where your VB is 2.0°. Bring throttles to idle and configure immediately as aircraft slows.

Distance vs Altitude technique

Use this procedure is you are not familiar with the V/B technique above, which is superior. Throughout the procedure, configure and set speeds according to the Basic steps on the previous page. Autopilot and autothrottle are available.

1. Prior to entering the terminal area, enter the landing threshold in a FIX page for distance information.
2. Turn base leg no sooner than at a position where your distance from the threshold is 1.5 times the altitude above field elevation (AFE).
   Example: From a 6000 ft AFE downwind start your turn to base about 9 nm from the threshold. *"Practice makes perfect"*
3. As you sequence 3 nm to the threshold, check not lower than 900 ft AFE.
4. As you sequence 2 nm, check not lower than 600 ft AFE.
5. As you sequence 1 nm, check not lower than 300 ft AFE.
6. (Distance x 3) + 2 zeros = Altitude at 2.8° angle



VNAV LEVEL OFF at 10,000'

NOTE: Prior to accelerating above 0 Minimum Maneuvering or Best Angle, ensure you are heading towards your destination. Vectors in the wrong direction wastes time and fuel.

Problem: The FMC retards the thrust levers to maintain the 250 kt limit as it approaches 10,000', and then when the altimeter hits 10,000', it changes the target speed to the higher speed for climb and accelerates. FAA certification required that the FMC would not command an acceleration to a speed greater than the speed restriction when the airplane was below the speed restriction altitude.

FIRST WAY - FMC

During preflight:

1. Enter 245/9500 into line 3L of CLB page. (Entries will vary with weight)
2. During climb-out, select CLB-2 (N1 page). Slows rate of climb.

Passing 9500', the speed bug will reset to 284 kts. (This example). The nose will lower in order to capture this speed. Throttles will not come back until this speed is captured.

CAUTION

Watch speed. Do not exceed 250 kts below 10,000'.
There is no overspeed protection using this technique.

PROS: Transition to climb speed is very smooth.
CONS: May have to disconnect throttles and pull them back. No guarantee of meeting speed restriction.

SECOND WAY - MCP

1. During climbout, select CLB-2 (N1 page). Slows rate of climb.
2. Select LVL CHG climb speed of 245 kts.
3. Passing 9500', set the speed bug to recommended speed on CLB page. (284 kts in this case).
4. The nose will lower in order to capture this speed. Throttles will not move until this speed is captured.

CAUTION

Watch speed. Do not exceed 250 kts below 10,000'.
There is no overspeed protection using this technique.

PROS: Same smooth transition to climb speed with no programing.
CONS: No guarantee of meeting speed restriction. May have to disconnect and retard the throttles.

THIRD WAY - HAND FLYING

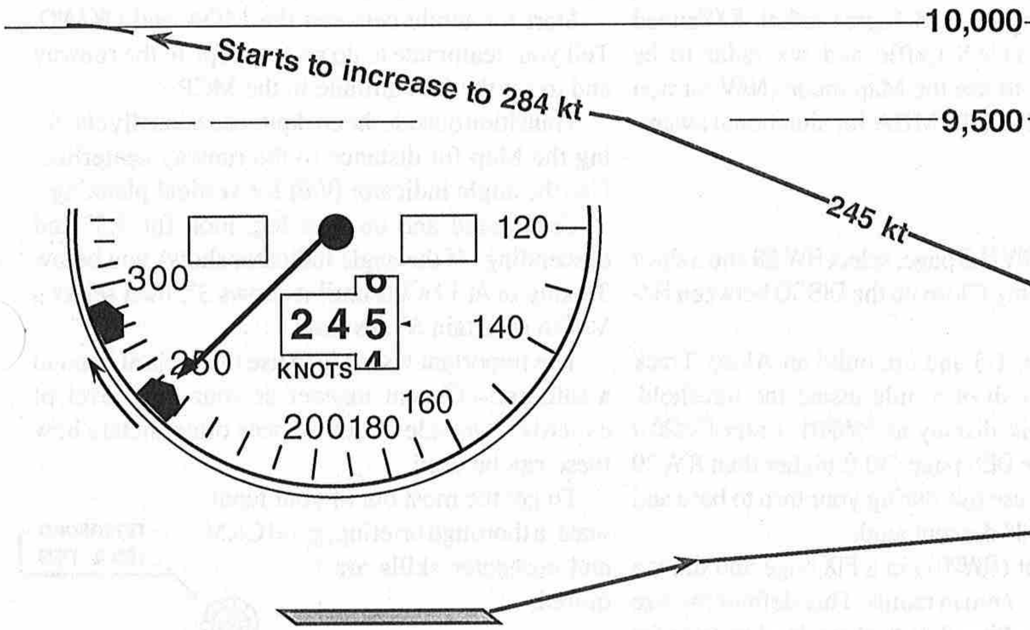
1. Leave aircraft in VNAV
2. As 10,000' is approached, allow the throttles to move rearward a small amount, then simply disconnect them. Turn speed knob to the planned climb speed.
3. Level the aircraft following the FD command bars.
4. As you approach the climb speed, re-engage the throttles and reset the speed bug.

Level-Off at 10,000'

ATC: *"Zeppelin Staaken, climb to and maintain 10,000 ft. Expect further climb clearance in 20 miles".*

System will sense altitude capture sooner at a higher rate of climb (lighter weights). Weight entries will vary with takeoff weight and some experimentation may be necessary.

ACT ECON CLB	1/1
CRZ ALT	
FL330	
TGT SPD	TO FL330
280/.740	1840.3 Z / 82 NM
SPD REST	
245/ 9500	
-----------	CLB-2 N1
	85.5/ 85.5%



CIRCLE TO LAND

This procedure requires some CDU input in the approach environment.

Example: South of New York City, on the Waard Four Arrival for Newark, ATIS is advertising seven thousand scattered, five miles and haze. Temps are 85/65, winds from the east at seven, vectors for a VOR DME Rwy 22L/R, with a circle to runway 29. (This technique will work for any circle-to-land approach).

Now take this ATIS and turn it into real terms.

You're going to be faced with a saturated traffic area, a circle in poor visibility - possibly less than advertised, lining up with a tailwind to a runway 6500 feet long from the threshold! A mistake on anyone's part, such as loosing sight of the runway or poor speed control by a pilot, or poor spacing by the controller could lead to a missed approach.

Don't forget, you cannot continue the approach if you loose sight of the runway or at some point you think it unsafe to continue.

THE APPROACH BRIEFING

Brief runway lighting; RW29 has CL, REIL, and a PAPI on the right side. Shoot the approach in raw data (VOR LOC) or LNAV, but display RW29 on the Map, not RW22. When we're cleared for the approach, switch to the VOR EXPanded mode to confirm you're navigating the 218 degree radial. EXPanded display allows TCAS traffic and wx radar to be monitored. Plan to use the Map mode (NAV for non EFIS) after reaching the MDA for situational awareness.

THE SETUP

From the ARRIVALS page, select RW-29 and a short extension (2-3 nm). Close up the DISCO between RX-29 and RW-29.

With software U3 and up, build an Along Track waypoint one tenth of a mile inside the threshold. (RW-29/-.1) It will display as RW201. Enter RW201/0100 in 3R of the DES page (30 ft higher than RW29 TCH). You will use this during your turn to base and final to set up a 3° descent angle.

Enter this wpt (RW201) in a FIX page and draw a circle around it 1.7 nm in radius. This defines the size of the area that offers 300 ft obstacle clearance for Approach Category C aircraft.

If you want to use LNAV for the approach to RW22-L/R, manually enter the wpts that make up the approach since selection from the ARRIVALS page would throw out the RW29 display.

FLYING THE APPROACH

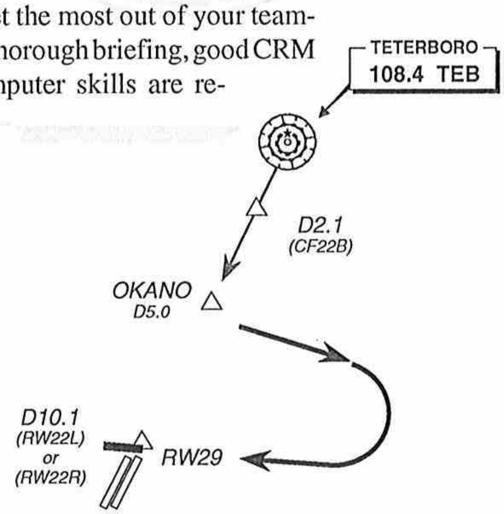
Start the circle between the MDA and OKANO. Tell your teammate to do an intercept to the runway and to set the MA altitude in the MCP.

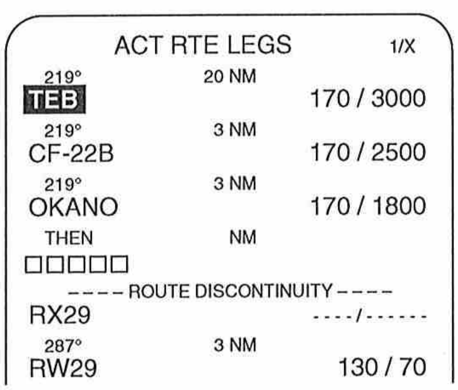
Transition outside the cockpit, occasionally checking the Map for distance to the runway centerline. Use the angle indicator (V/B) for vertical planning.

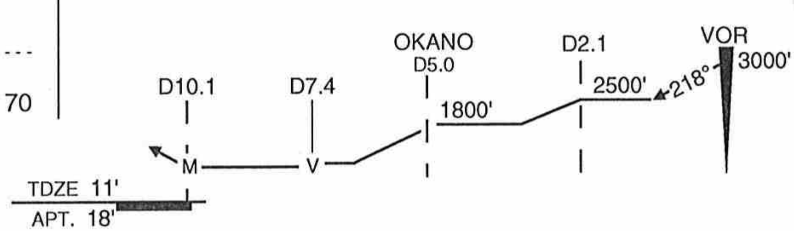
Configured and on base leg, look for 4.5° and descending. If the angle indicator shows you below 3°, stay in ALT HOLD until it shows 3°, then select a V/S to maintain 3° descent.

The important lesson is to use the tools at hand in a safe and efficient manner at your own level of expertise. Outside circumstances often dictate how these can be used.

To get the most out of your teammate, a thorough briefing, good CRM and computer skills are required.







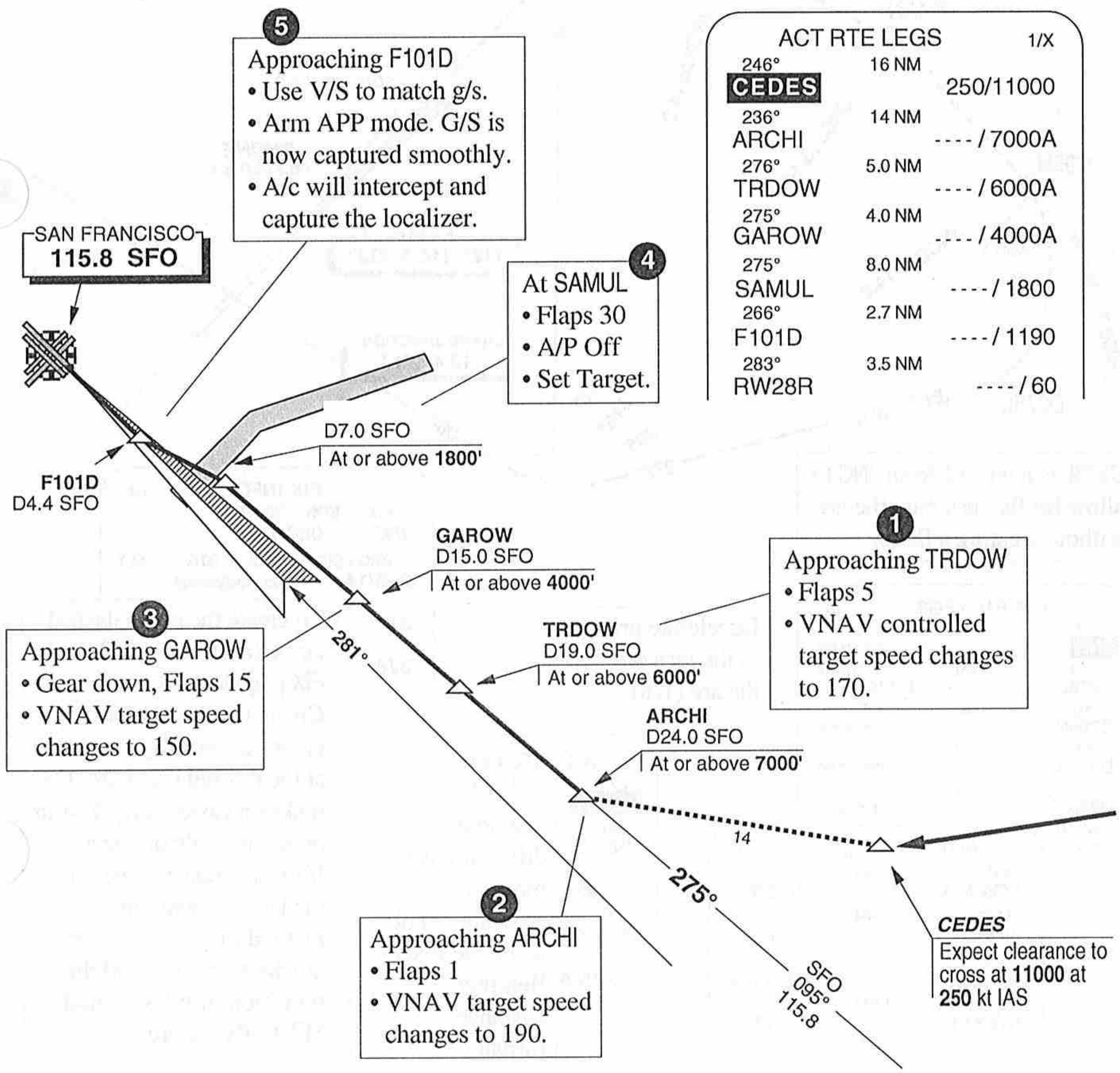
FMS Approach - Bridge Visual

The FMS Bridge Visual to 28R at San Francisco is an officially charted visual procedure in the nav database. Some advantages to having FMS approaches loaded in the database are: reduced pilot workload, greater accuracy, reduced controller workload and potential for lower wx minimums than currently req'd for visual approaches. As for accuracy, manual entries are limited to 0.1 min. lat/lon. Nav database waypoints, provided by the airline to Jeppesen, are accurate to the nearest 0.01 sec. This is a reduction in error tolerance from 600' to 1'. Don't, however, accept clearance for an FMS procedure unless it is defined in your database. Nor should you modify the routing of an FMS procedure unless cleared to do so.

There is no need to display raw data but the FMC must be operating in a radio updating mode. Position radio controls so that updating will take place. The FMC may **P**rocedure tune.

This approach has recently been changed; legs have been lengthened, improving the vertical path.

- This is the display after selecting RNV28R.
- Note that altitude restrictions are included.
- Enter the speeds as displayed below.
- When cleared for the approach, dial the OM elevation (1800') in the MCP ALT SEL.
- If Approach Control needs 180 to the bridge, disconnect the A/T and operate manually.
- Disadvantage: VERT DEV looks at the next wpt rest. **only**. As you approach ARCHI, VERT DEV does not tell you you're actually **above** the desired path to TRDOW, which makes it more difficult to plan speed reductions; and speed is sacrificed for path.

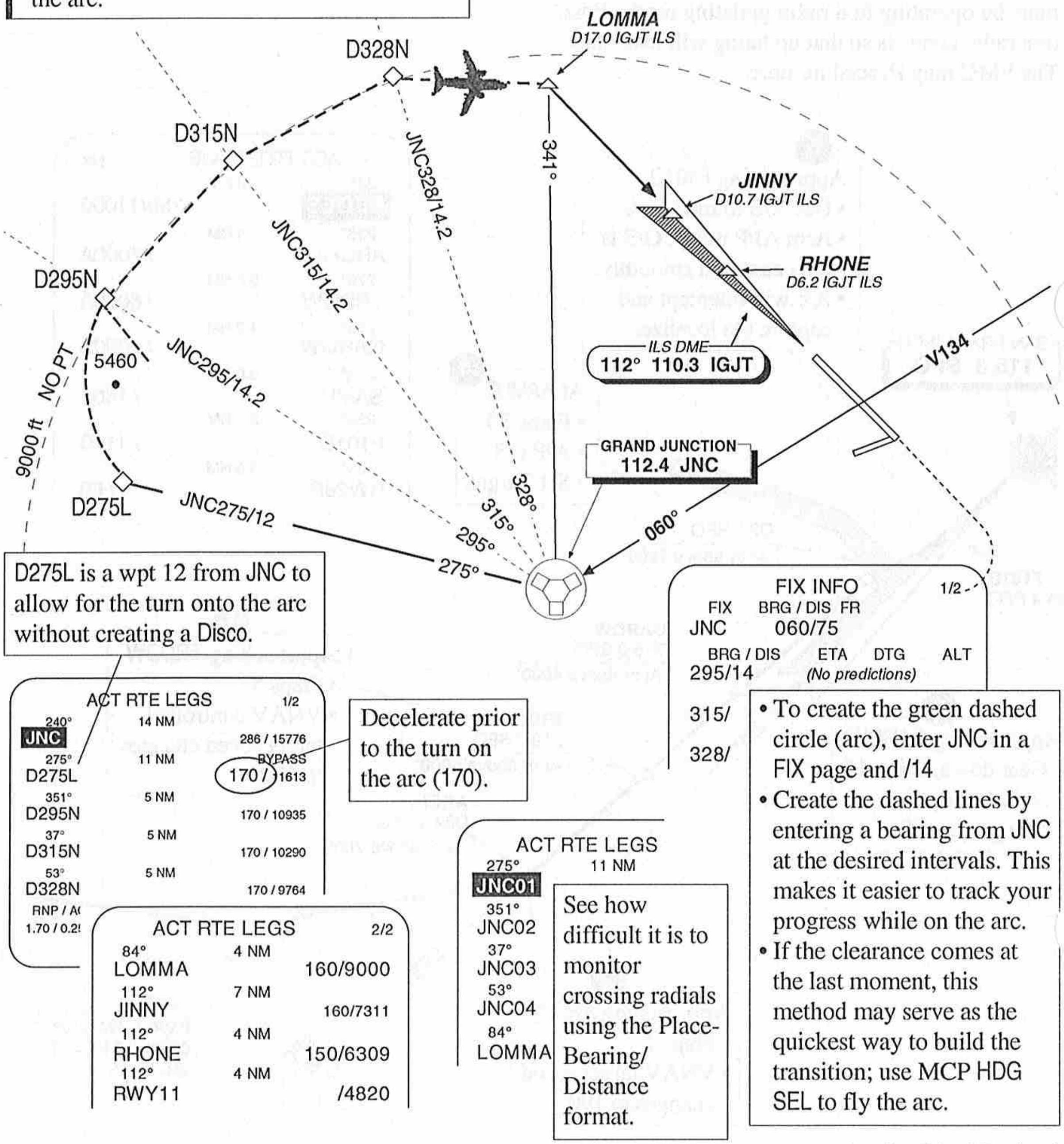


Constructing an Arc Transition

ATC: ***"Savoia Marchetti 75, cleared for the ILS to Runway One One via the 14 DME arc."***

- Tune a nav aid so you can navigate on the arc using the RDMI in case the automation fails. (I've had the LEGS page freeze while on the arc) MP: Using the RDMI, call out crossing each step-down radial and the next altitude.
- Enter the navaid into a FIX page and then enter the crossing radials and arc distance. Now you've got a graphic display (green circle and radial lines) to use as a template as you enter the arc wpts.
- If the arc approach is in the database, the airplane will fly a curved approach. (U10)
- If you do not have the gradient path option, use VNAV SPD or the MCP to descend on the arc.

- Prior to descent, build wpts along the arc matching the chart, and at intervals if needed. It is recommended that standard Bearing-Distance format be used. This format makes it easier to monitor crossing radials.
- If time is a factor, use the LEGS page and the Place-Bearing/Distance format, or simply revert to the RMDI (raw data) and fly the green circle in HDG SEL.
- Select or build the approach.
- First, enter only the restrictions at the marker - (RHONE 150/6309) and examine the advisory altitudes on the arc for descent planning.
- Enter a slower speed to restrict the turn radius onto the arc. (170 kts at D275L)
- Check and enter MEAs, crossing restrictions, and the minimum altitudes on the arc.



D275L is a wpt 12 from JNC to allow for the turn onto the arc without creating a Disco.

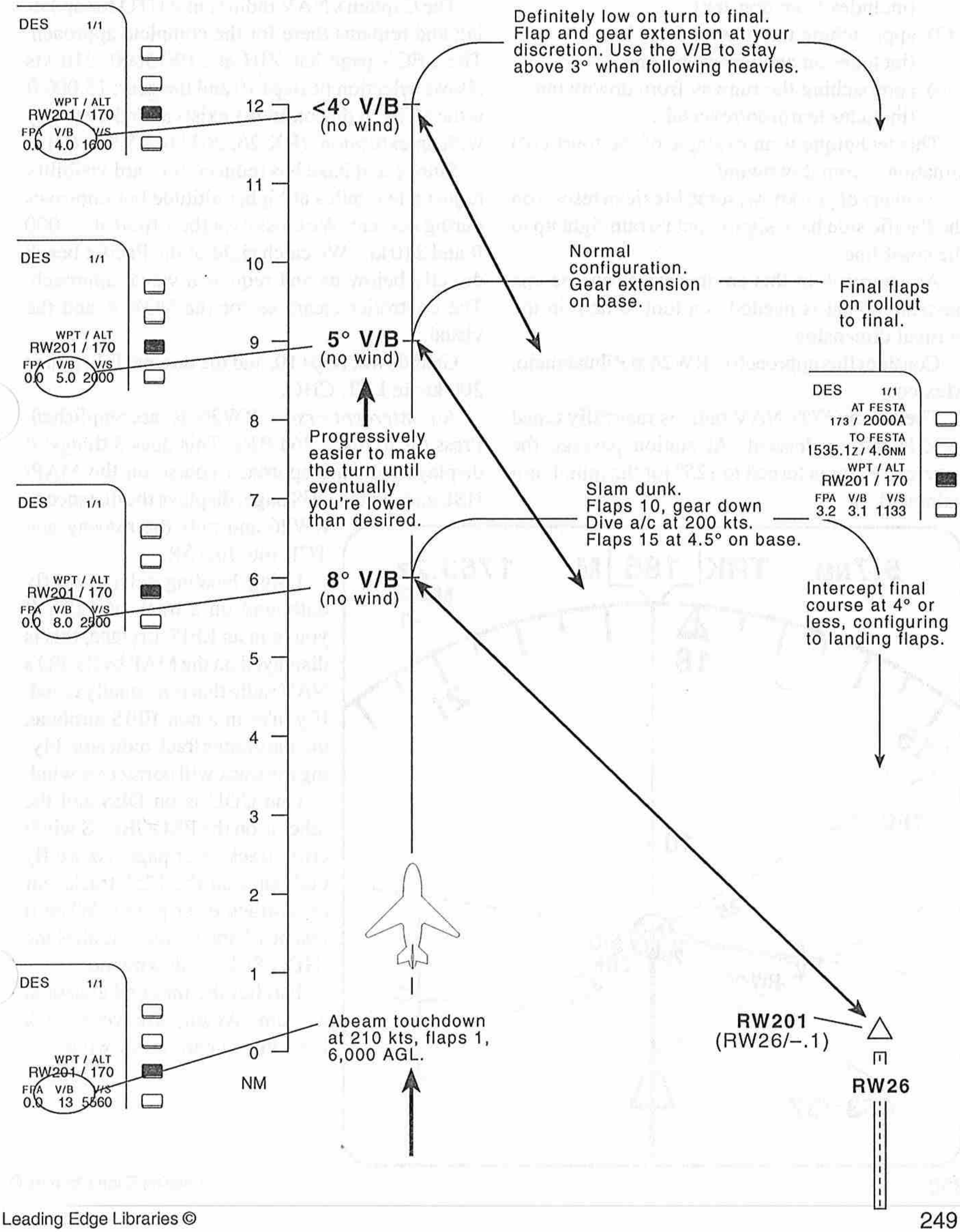
Decelerate prior to the turn on the arc (170).

See how difficult it is to monitor crossing radials using the Place-Bearing/ Distance format.

- To create the green dashed circle (arc), enter JNC in a FIX page and /14
- Create the dashed lines by entering a bearing from JNC at the desired intervals. This makes it easier to track your progress while on the arc.
- If the clearance comes at the last moment, this method may serve as the quickest way to build the transition; use MCP HDG SEL to fly the arc.

V/B to Monitor Energy on Downwind

1. When workload is low, such as prior to descending through 10,000 ft, build a wpt a tenth of a mile from the runway threshold. This is done by down-selecting the runway to the s/p and typing /–.1 behind it. (RW26/–.1) Place it on top of the runway. This creates a new Along Track Wpt in the Temporary database (RW201). Downselect it to the s/p, then press the <ERASE prompt - do not leave this new wpt in the LEGS page as it is not needed and can cause confusion. Place the new wpt in a FIX page for storeage until needed.
   Ref: *Building a Runway Waypoint* in the index.
2. While being vectored for the approach, insert the runway wpt that you built and the crossing altitude (30 ft higher than the altitude at the runway) into the DES page at 3R (RW201/0170). The altitude entry requires 4 characters. You've now got the angle calculator set up to display your angle to the runway from any position in the approach. This tool requires practice, but it can be used in many different ways. This is just one.
   Another excellent application is on the River Visual to 19 at Washington National. I've been inside Cabin at 4.3°, but configured.



V/B On High Overhead Approach

The V/B (Vertical Bearing) indicator on the Descent page is a great tool. But do you know how to use it to its fullest potential?

First, the basics. The V/B indicator is an angle calculator; it shows the elevation angle the airplane is from whatever waypoint is in 3R of the DES page. It can be used in many different situations, but I think you can break it down to 4 basic situations, 3 of which are in the terminal area. The 4 basic situations are:

(1) descent from cruise altitude,
(2) approaching the runway from straight-in (includes from dog-leg),
(3) approaching the runway from base (includes an arc approach), and
(4) approaching the runway from downwind (includes teardrop/reversal).

This technique is an example of the fourth (4) situation - from downwind.

As many of you know, some Mexican resorts on the Pacific side have significant terrain right up to the coast line.

An approach in this environment can become unstable. What is needed is a tool to help in the vertical dimension.

Consider this approach to RW26 at Zihuatanejo, Mexico.

The set-up: FO's NAV radio is manually tuned to ZIH during descent. At station passage the course selector is turned to 125° for the initial turn outbound.

```
      ACT RTE  LEGS       1/2
  195°      147NM
ALIPO            742/FL325
  183°      58NM
ZIH              210/15000
 THEN
□□□□□
-- ROUTE DISCONTINUITY -
RX-26            ----/------
  263°      3.0NM
RW26                 /  69
 RNP/ACTUAL--------------
2.00 / 0.26NM   RTE DATA>
```

The Captain's NAV radio is in AUTO for updating and remains there for the complete approach. The LEGS page has ZIH at 210/15000. 210 kts allows selection of flaps 10 and the gear; 15,000 ft is the MEA. A discontinuity exists after the runway with an extension. (RX-26, 263° to RW26/ 69).

Smoke and haze has reduced forward visibility to just a few miles at higher altitude but improves during descent. We cross over the airport at 15,000 ft and 210 kts. We catch sight of the Pacific beach directly below us and request a visual approach. The controller clears us for the VOR-A and the visual.

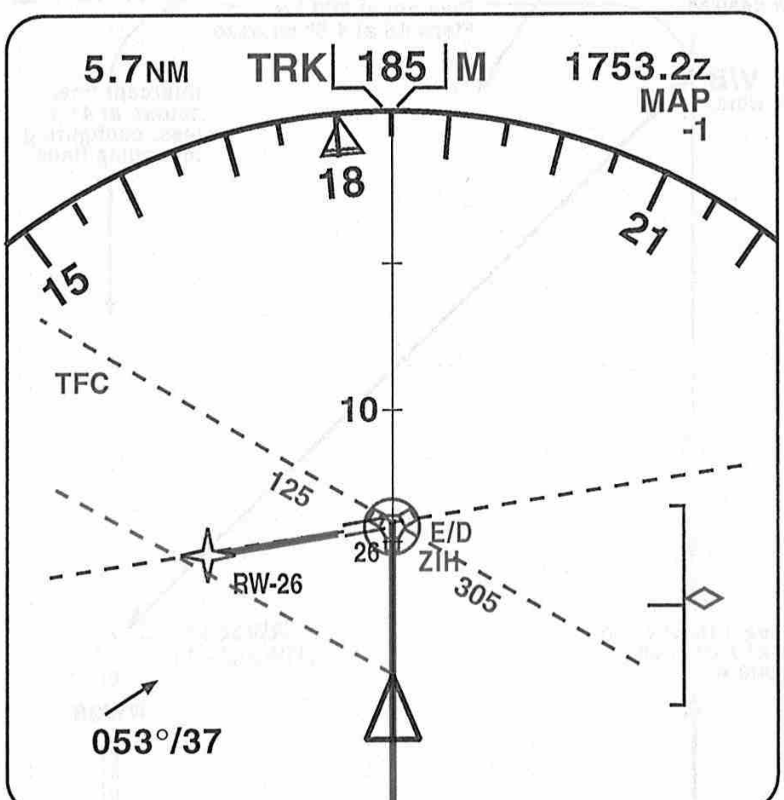
Gear down, flaps 10, and the descent is begun at 200 kts in LVL CHG.

An *intercept-crs-to* RW26 is accomplished. Press 6R to make 263 BIG. This does 3 things: it displays the final approach course on the MAP/ HSI, and, on the DES page, displays the distance to RW26 and puts the runway and TCH into line 3R.

Using heading select, we fly outbound on a track of 125°. If you're in an EFIS airplane, this is displayed on the MAP by the FO's NAV radio that is manually tuned. If you're in a non-EFIS airplane, use the orange track indicator. Flying the track will correct for wind.

One CDU is on DES and the other is on the PROGRESS wind/ cross-track error page. As we fly outbound on the 125° track, our cross-track error grows. When it reaches 4 nm, we turn the airplane (HDG SEL) to downwind.

Parallel the inbound course at 4.5 nm. Again, use your track indicator to correct for wind.



V/B On High Overhead Approach

Of course the elevation angle from the runway to the airplane is initially very steep.

As we continue downwind it decreases until at some point, we can turn base. That angle is 8°. As soon as the V/B shows 8°, we turn directly toward the magenta final approach course (CDI bar in non-EFIS).

```
       280 PATH DES           1/1
 E/D ALT                   AT RW26
69                        134/  69
 TGT SPD                   TO RW26
.740/280           1535.1Z/9.8NM
 SPD REST                  WPT/ALT
240/10000                RW26/  69
                  FPA   V/B   V/S
                  4.8   8.0  2432
---------------------------------
<ECON                       SPEED>

<FORECAST
```

You'll be approximately 10 nm from the runway and under 8,000 ft. Continuing to monitor the angle calculator, I find I can actually round out the turn toward the runway in an effort to keep the vertical bearing around 4.5°, after all, we've got lots of drag and we're descending at a FPA of around 5°.

On the EFIS airplane, the MAP displays the runway. On the non-EFIS airplane, the runway is the yellow waypoint bearing pointer on the HSI. The radar is on to display the Sierra Madre del Sur, right in front of the airplane!

```
       280 PATH DES           1/1
 E/D ALT                   AT RW26
69                        134/  69
 TGT SPD                   TO RW26
.740/280           1535.1Z/7.0NM
 SPD REST                  WPT/ALT
240/10000                RW26/  69
                  FPA   V/B   V/S
                  4.9   4.5  1602
---------------------------------
<ECON                       SPEED>

<FORECAST
```

As we join the final course, flaps go to 15, 25, and 30. Target is set and we join a vertical bearing angle of about 3.5°. It is at this point the V/S display (DES page) becomes useful as we're flying

```
       280 PATH DES           1/1
 E/D ALT                   AT RW26
69                        134/  69
 TGT SPD                   TO RW26
.740/280           1535.1Z/4.1NM
 SPD REST                  WPT/ALT
240/10000                RW26/  69
                  FPA   V/B   V/S
                  3.6   3.5   830
---------------------------------
<ECON                       SPEED>

<FORECAST
```

directly to the WPT in 3R.

The throttles come up before 500 ft AGL and we put the airplane down gently in the landing zone.

We release the parking brake at the gate and note the fuel used from FL350 to parking was 200 lbs. What a fuel savings, and a very safe, efficient approach - all by use of the angle calculator.

You can take a great deal of satisfaction in knowing your exact lateral and vertical position throughout the complete approach.

The V/B indicator can also keep you from getting too low! (below 3°) My wish list includes a runway angle display on the EFIS map.

With practice, you'll find yourself flying curved, near-idle descents for visual approaches. But it does take practice - lots of practice.

With no wind, the soonest a turn from downwind to base can be started is 8° (from 210 kts, flaps 1), but it takes aggressive maneuvering (flaps 10, gear down, 200 kt descent). On your first few attempts, try the technique from 7° as you get a feel for the tool. Treat 8° as a limit. Gear down and flaps 5 might work from 6-7° and be more comfortable. Watch the wind. A tailwind on final will require an angle less than 8°.

A normal turn from downwind to base can be accomplished from 5.5° which is very nice to know when doing a night visual with few approach aids, and feeling a little fatigued. A base turn past 5.5° will place you low on the final approach course.

Practice using the V/B indicator on every approach as a way of monitoring your vertical position and you'll soon become an "angle pilot".

CONSTANT ANGLE NON PRECISION APPROACH

The DEScent page can be used to fly a constant angle to the threshold when the electronic glideslope or VNAV is unavailable.
This is not only useful for a localizer, VOR, or NDB approach, but also for a visual approach at night to a runway with no VASI (the *black hole* approach).

Caution: You must check your area and approach charts for obstructions. Just because the FMC calculates an angle to the threshold does not mean that the path is obstruction free.

NOTES:

1. Use V/S, not LVL CHG. At 1,000 ft AFE max V/S is 1,000 fpm.
2. At each ALT HOLD, set the next altitude and stay ahead of the airplane. This is one of the most difficult tasks of the NPA.
3. At the VDP with approach lights in sight, start down to 100' above TDZE. You may not descend below 100' above the TDZE unless visual reference to the runway is established.
4. Disconnect AP at MDA minus 50'.
5. For LOC/BC and NDB approaches, use LNAV or HDG SEL to maintain final approach course tracking. The localizer is extremely sensitive due to the close proximity of the transmitter.
6. For LOC or VOR approaches, use VOR/LOC, (EXP or FULL). Ground based navaid is preferred and keeps things simple; two differing DME displays such as the slant range DME vs the RNAV DME on the VOR DME approach to 15L to IAH can be confusing, disrupting concentration on step downs. Monitoring Pilot can be in Map mode for situational awareness.
7. RA technique: Set to 300' AGL. This is the altitude the TERPS guarantees terrain clearance on final approach segment.
8. If your LEGS page has RNP / ANP, check the ANP is less than the RNP. A low ANP, such as .3 or less indicates a pretty accurate FMC position.

Calculating a VDP

4 ways to compute Visual Descent Point (VDP), ranked by accuracy and ease of use:

VASI - but won't work if visibility is down.

V/B - DES page, line 4R

Enter the runway threshold and threshold crossing height at LSK 3R of DES page. Assuming you are level at the MDA, the VDP is reached when the V/B indicates 2.8 to 3°.

DME - Rule of Thumb: 300 ft per mile = 2.8° slope. Divide HAT by 300.

Ex: LOC 26 IAH. HAT at MDA is 464 ft. Divide by 300 = 1.5 nm needed to descend from MDA to runway.
VDP is 1.5 nm from runway threshold or D3.2 IJYV. (1.7 + 1.5)

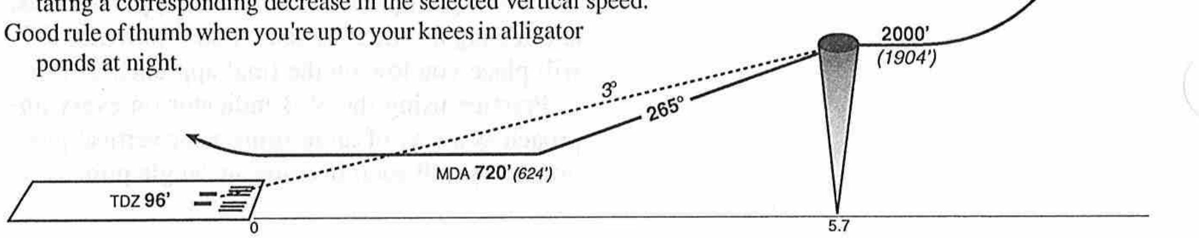
Timing - Rule of Thumb for 130 kt gs: 10 ft per second = 2.8° slope.

[Time from FAF to MAP] minus [10% of HAT]

Ex: NDB 26 IAH. HAT at MDA is 624 ft or 62 seconds.
FAF to MAP is 2:27 at 140 kts. Subtract 62 = 1:25. So, FAF to PDP is 1:25. This is a rough estimate.
For each 10 kts above 130 kt groundspeed, add 10 seconds.

V/S Selection at a 3° point such as the OM or the VDP:

Divide the groundspeed by two. Add a zero. Ex: 140 kts / 2 = 700 fpm
This rate of descent will equal a 2.8° angle. Add 50' for 3°. (750 fpm)
Be very careful in that as you descend, the ground speed usually decreases, necessitating a corresponding decrease in the selected vertical speed.
Good rule of thumb when you're up to your knees in alligator ponds at night.



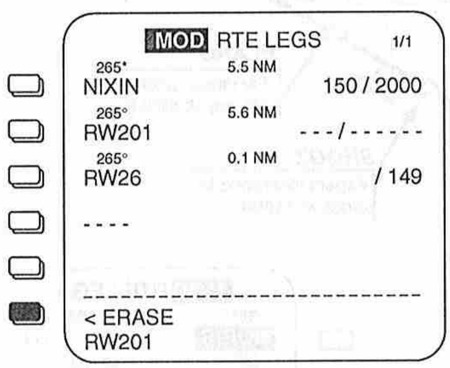
CONSTANT ANGLE FROM A LOCALIZER OR VOR APPROACH

PROCEDURE A
STEP-DOWN APPROACH

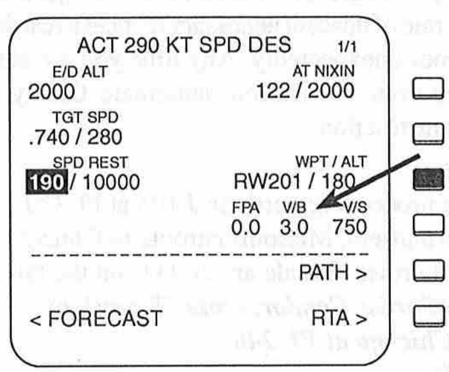
1. Arrive at the FAF fully configured and at target speed.
2. The MDA should be set in the MCP ALT SEL window. V/S is armed.
3. At the FAF, dial 1000 to 1500 fpm descent in the V/S window.
4. At 1000 AGL, reduce V/S to 1000 fpm.
5. At MDA, (ALT HOLD annunciated) set missed approach altitude.
6. If the field is in sight start descent at the VDP, not before or after.
7. If the field does not appear before the VDP fly to the missed approach point and accomplish the missed approach procedure.

PROCEDURE B
WEATHER ABOVE MINIMUMS
CONSTANT ANGLE

1. At cruise and before briefing the approach, build a wpt a tenth of a mile from the runway threshold. This is done by downselecting the runway to the s/p and typing /–.1 behind it. (RW26/–.1) Place it on top of the runway. This creates a new Along Track Wpt in the Temporary database (RW201). Place it in a FIX page for storeage until needed.
   Then hit the <ERASE prompt - do not leave this new wpt in the LEGS page as it is not needed there.
   Ref: *Building a Runway Waypoint.*



2. Plan to shoot the VOR or LOC approach with raw data. Use LNAV for an NDB or LOC/BC approach, but monitor raw data - that is controlling.
3. While being vectored for the approach, insert the runway wpt that you built and the crossing altitude (30 ft higher than the altitude at the runway) into the DES page at 3R (RW201/0150). This is the only computer work required for an angle display.
4. Arrive at the FAF fully configured and at target speed.
5. The MDA should be set in the MCP ALT SEL window. V/S is now armed.
6. At the FAF, note the V/B indication (it will probably be around 3.0°) and thumbwheel the V/S that is indicated at line 4R. (750 in example) If the V/B is less than 3°, remain in level flight until you reach your desired angle, i.e., 3°



7. As you descend, your ground speed will change due to wind and a/c configuration; the V/S will also change - it is very dynamic. The required V/S is usually higher at the FAF than at lower altitudes. Use theV/S wheel in conjunction with the FPA and V/S indicators to keep yourself on the 3° angle (V/B).
   The V/B, right next to the V/S display, shows the angle you are to the threshold. Do not let it get less than your own limit - such as 2.8°. If you get low, thumbwheel V/S to zero until the desired angle is achieved.
8. At the MDA transition to the view outside the windscreen. You'll be impressed with the smoothness of this technique.
9. If the field does not come in sight prior to the MDA, level at the MDA, set the missed approach altitude and continue to the missed approach point. Don't dive for the runway after passing the VDP (steep V/B). And don't rotate through the MDA unless your governing body has approved such a maneuver; the MDA cannot be treated like a DH.

PROCEDURE C
WEATHER AT MINIMUMS
V/B FOR VDP

Steps 1 through 5 are the same as Procedure B.

6. At the FAF, dial 1,000 to 1,500 fpm descent in the V/S window.
7. At 1000 AGL, reduce V/S to 1000 fpm.
8. At MDA, (ALT HOLD annunciated) set missed approach altitude. V/S is armed.
9. When the field comes in sight:
   Start descent when the V/B indicates 2.8°, not before.
   Dial the V/S that is displayed at line 4R.
10. If field does not appear before the V/B indicates 3.0°:
    Fly to the missed approach point and accomplish the missed approach procedure.

LEARNING PROCEDURE

To learn how to shoot these approaches, practice these procedures in visual conditions with a glideslope as backup. You'll learn how to quickly set the FMC up and how the V/B and V/S indications on the DES page operate. This will build confidence in the procedure. Don't wait until you are wading in the alligator pond at night wishing you had these tools.

Bradford Arrival to O'Hare

This procedure demonstrates how to quickly arrive at a rate of descent necessary to meet a restriction that comes unexpectedly. Any time you are cleared direct to your destination, anticipate this type of descent instruction.

In fact, enter the destination VOR in the FIX page to be ahead of the game.

Situation:
You are proceeding north on J 105 at FL370 over Springfield, Missouri enroute to Chicago. Winds at cruise altitude are 100 kts on the tail.
ATC: ***"Curtiss Condor, cross 75 south of Chicago at FL 240".***

- Now where do we put this wpt in the LEGS page?
- Notice the ETA of 2215z.
- When stress is making 4th grade math tough, try this technique.
- Go to the RTE DATA page. Where does 2215z fit in?

RTE DATA 1/2

	ETA	WIND
NORIS	2206z	210°/105
BDF	2212z	200°/95
SHOOZ	2218z	210°/75
PLANO	2220z	220°/75
ORD	2228z	240°/50

1 Using the FIX page, create the DNTKFX 75 south of ORD and put it in the s/p.

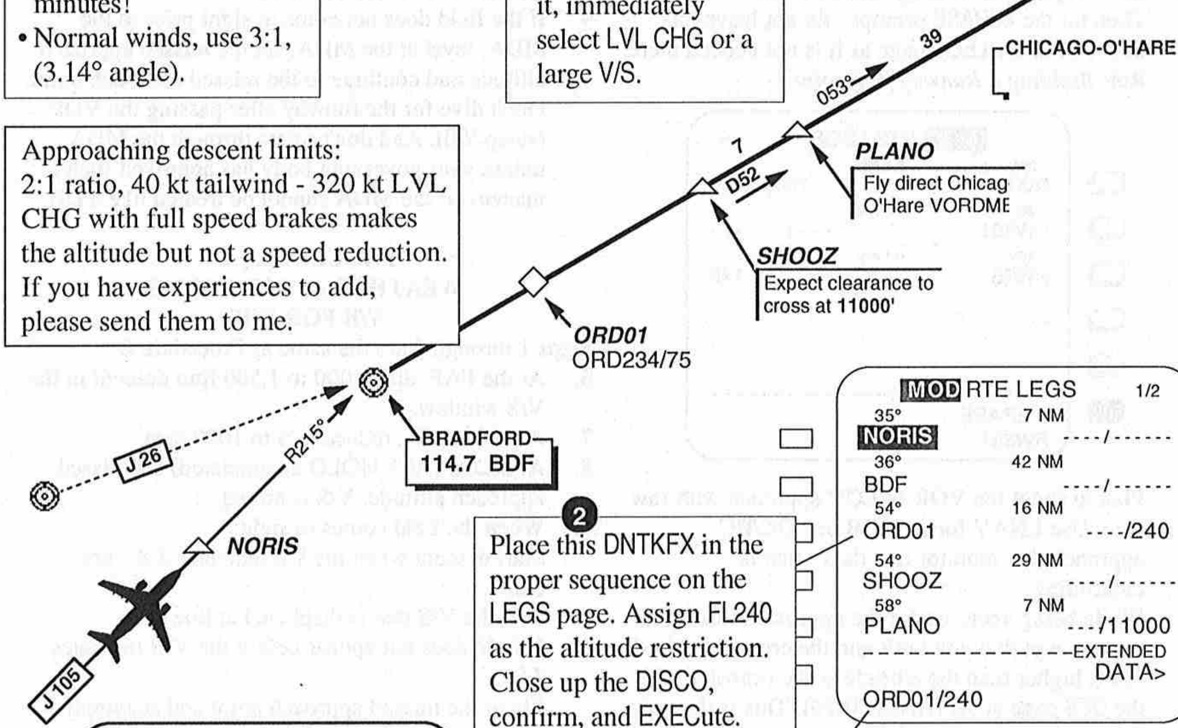
FIX INFO 1/2
FIX ORD BR / DIS 235/140 FR
DNTKFX 234/75 ETA 2215z DTG 65 ALT 18250

<ABEAM
<ERASE
ORD234/75

- Check the DTG.
- With a 100 kt tailwind, we'll need a 4:1 ratio.
  FL370 - FL240 = 13 x 4 = 52 from 65 = 15 nm to T/D.
  That's one and a half minutes!
- Normal winds, use 3:1, (3.14° angle).

- Your next decision is based on the distance to your calculated T/D point.
- If you are at or past it, immediately select LVL CHG or a large V/S.

Approaching descent limits:
2:1 ratio, 40 kt tailwind - 320 kt LVL CHG with full speed brakes makes the altitude but not a speed reduction.
If you have experiences to add, please send them to me.



MOD RTE LEGS 1/2

35°	7 NM	
NORIS		---- / ------
36°	42 NM	
BDF		---- / ------
54°	16 NM	
ORD01		---- /240
54°	29 NM	
SHOOZ		---- / ------
58°	7 NM	
PLANO		---- /11000

------------------EXTENDED DATA>
ORD01/240

2 Place this DNTKFX in the proper sequence on the LEGS page. Assign FL240 as the altitude restriction. Close up the DISCO, confirm, and EXECute.

ECON PATH DES 1/1
E/D ALT
WPT / ALT
ORD01 / 240
FPA 0.0 V/B 1.6 V/S 1500

If you're restricted to 250 kts, anything greater than 1600 fpm will require a drag device.

3
- Now take ORD01 to the s/p, type /240 behind it, and place it in line 3R of the DES page. The V/S req'd to meet this restriction at your present groundspeed appears immediately.
- Select your tool based on the displayed V/S.
- DELete any manual entry to LSK 3R when no longer needed.

Loupe Departure from San Jose, California

This technique demonstrates the planning required to interface the FMC with the MCP in a complex departure. At first examination, this technique will seem too complicated to be practical. But that's not the case. Proper computer set-up reduces the in-flight workload and meets all restrictions.

Your clearance is the LOUPE departure from RW30L at San Jose. A combination of clearances will require you to: maintain 5000' until crossing the 047° radial of the SJC VOR; then, at your discretion, you're cleared direct to the VOR, but you must cross it at 12,000'; then you're cleared to FL230. Do not exceed 250 kts until past the SJC VOR.

ACT RTE LEGS 1/4
303° HDG 3 NM
(SJC-02) ----/ 500A
120° HDG 2 NM
(SJC047) ----/ 5000B
120° HDG NM
(VECTOR) ----/------
° NM
SJC ----/ 12000
339° 8 NM
D339H ----/ 14000A

ECON CLB
CRZ ALT
FL370
TGT SPD
283/.725
SPD REST
215/12000
<MAX RATE
<MAX ANGLE

1

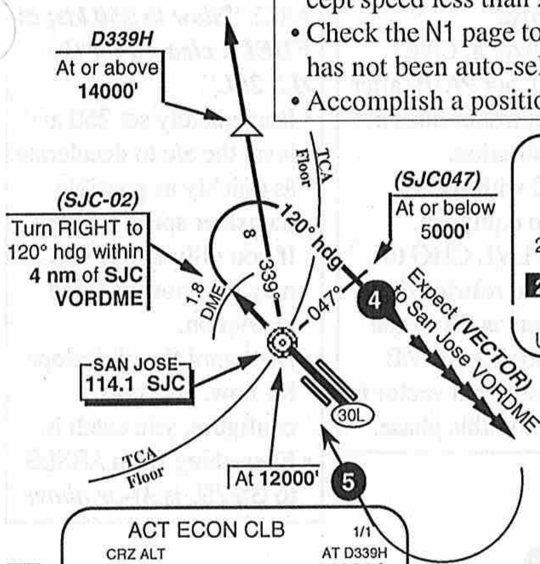
- Initialize IRUs.
- U1.x software: Enter *exact* position. The GATE data base is most accurate; a manually entered gate lat/lon is next best. Prior to push-back, do a *quick align* with GATE entered coordinates because of drift.
- PF Set MCP ALT SEL to 5000
  Set bank angle limiter: 25° for a Flap 1 turn or 30° for a Flap 0 turn.
  Set nav head to AUTO.
- PNF Monitor the SID with raw data.

2

- Select RW30L, LOUPE SID, and proper TRANS.
- Change the TGT SPD to 250 kts. *(Clearance)*
- Check the MAX ANGLE speed for your weight or use top bug plus 20 kts. *(Ex: 215 kts)*
- Enter 215/12000 in 3L. Smiths FMC will accept speed less than 210 kt but will not fly it.
- Check the N1 page to confirm that a RED CLB has not been auto-selected.
- Accomplish a position update at the runway.

3

- Initially use MCP HDG SEL and LVL CHG (200 kt or clean min. maneuvering, whichever is greater).
- After rolling out on the 120° heading, press VNAV. FMC commands a 215 kt climb and levels at 5000'.
- At the 047°R, twist the MCP ALT SEL to 12000. Press VNAV and FMC resumes the max angle climb.



ACT 215KT CLB 1/1
CRZ ALT AT SJC
FL370 12000
TGT SPD TO SJC
250/.725 1840.3z/4NM
SPD REST ERR AT SJC
215/12000 4150 LO
UNABLE NEXT ALT

4

- Accomplish a DIR TO SJC and EXECute.
- Stay in HDG SEL
- The 3R header will display ERR AT SJC and the field will display the predicted error.
- Message UNABLE NEXT ALT appears (Don't bother clearing it; it will do so on its own later).
- Consider the ERR AT advisory only, as the prediction is conservative because it is based on a direct shot to the VOR and does not account for the altitude to be gained in the turn.
- Instead of waiting for an update, do another DIR TO SJC and EXEC. It updates very slowly if left to its own.
- After 3R indicates less than 3000 LO, turn direct to SJC in HDG SEL.

ACT ECON CLB 1/1
CRZ ALT AT D339H
FL370 14000A
TGT SPD TO D339H
283/.725 1842.8z/8NM
SPD REST
---/-----
<ECON

ACT 215KT CLB 1/1
CRZ ALT AT SJC
FL370 12000
TGT SPD TO S.
250/.725 1841.2z/5
SPD REST ERR AT S.
215/12000 1500 L

5

- When *tracking* direct to SCJ, do another DIR TO and press LNAV.
- Reaching 12000', the aircraft transitions to the TGT SPD (250 kts).

6

- At SJC, turn the ALT SEL knob to 23000; VNAV will continue the climb looking at the next restriction, D339H at or above 14000'.
- When it's clear you'll make this restriction - for the nose will lay down to increase to the new TGT SPD, changing predictions - press ECON (283 kt).

Managing A Steep Approach

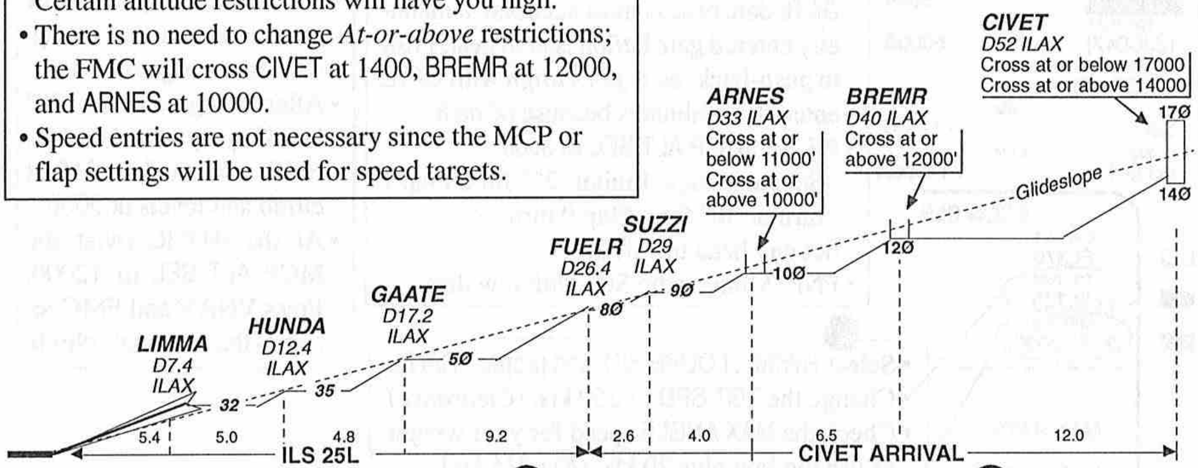
1

- This is a challenging Arrival. Things happen quickly. Use the MCP rather than the FMC for quick changes to the clearance and stay ahead of the airplane.
- SoCal Approach often has lots of traffic. Arrivals late in the *rush hour* will get speed restricted.
- There are many ways to handle this approach. This is my current FMC setup and technique.
- On the DES page, enter a crossover speed of 280 kts.
- For planning, delete all the altitude restrictions above GS-25L. Don't execute. Notice the *desired* altitudes! Certain altitude restrictions will have you high.
- There is no need to change *At-or-above* restrictions; the FMC will cross CIVET at 1400, BREMR at 12000, and ARNES at 10000.
- Speed entries are not necessary since the MCP or flap settings will be used for speed targets.

2

ATC: ***"Pilot discretion to FL240, 320 kts when able".***

- Use V/S, starting at a 3:1 position from CIVET, your first restriction. Add a deceleration segment, such as 6 nm in no-wind situation.
- This technique will keep you under the computed idle-path descent allowing maneuver room if ATC wants a speed change.




```
 ACT RTE  LEGS        2/X
211°      15NM
CIVET    280/14000 17000     280/14761
250°      12NM
BREMR        280/12000A      270/10399
250°      6.5NM
ARNES    246/10000 11000     250/ 9097
250°      4.0NM
SUZZI         250/ 9000A     250/ 7821
250°      2.6NM
FUELR         250/ 8000A     250/ 6992
250°      9.2NM
GAATE         196/ 5000A     195/ 5030
250°      4.8NM
HUNDA         167/ 3500A     166/ 3515
249°      1.0NM
GS-25L        160/ 3200      160/3200
249°      4.0NM  GP 3.00°
LIMMA         141/ 1900
249°      5.4NM  GP 3.00°
RW-25L        141/  151
RNP/ACTUAL-------------
2.00/0.05NM     RTE DATA>
STEEP DES AFTER BREMR
```

3

ATC: ***"Cleared to descend via the CIVET Four Arrival"***

- Engage the localizer at CIVET.
- Use VNAV SPD, not PATH, after ARNES, if the controller does not issue a speed restriction.
- Use VNAV SPD with speed intervention if so equipped.
- Use the MCP in LVL CHG to step down if speed restricted.
- Plug in the runway at 3R of the DES page and monitor the V/B.
- The green altitude trend vector is a very useful tool in this phase.

4

Approaching BREMR, ATC: ***"Slow to 250 kts; at FUELR cleared for the ILS 25L".***

- Immediately set 250 and level the a/c to decelerate as quickly as possible (consider speed brakes). If you dilly-dally, you may get another speed restriction.
- Disregard the glideslope for now. As you configure, you catch it.
- Everything from ARNES to GS-25L is *At-or-above.*

VNAV PATH will honor LEGS page restrictions since it is slaved to the vertical path, but it may exceed the flap speed when high and diving for the path. You may have to use the speed brakes or even the gear to get the airplane down to the desired speed.

VNAV SPD (except for U1.x) will also honor LEGS page restrictions, but only from the low side, i.e. it will level at each wpt restriction. VNAV SPD will not guarantee crossing from the high side since it simply looks at the speed, like LVL CHG.

If you are able to stay in VNAV, you can set the MCP ALT to an altitude such as 3200 ft which lower the workload. VNAV SPD works great on this arrival if you can use it.

5

At ARNES : ***"Maintain 180 kts to LIMMA".***

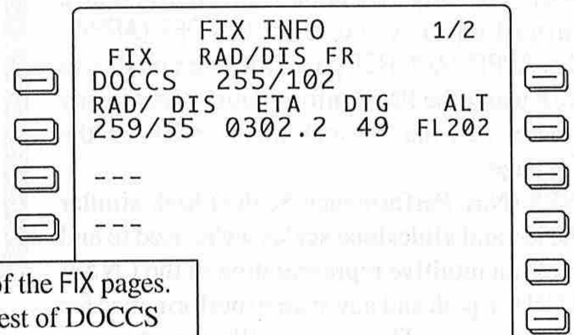
- Immediately pull the nose up to 180 kts, configuring as you do. If you've got a tailwind, the gear is the required energy killer.
- You can afford a V/B to the runway of 3.5 as long as you're got the gear down and F.15.
- Don't arm the APP prior to 3200 ft - beginning of the feather - and don't count on the glideslope to clear all step-downs.
- When it all comes together at LIMMA it's a thing of beauty.

OFF ROUTE DESCENT

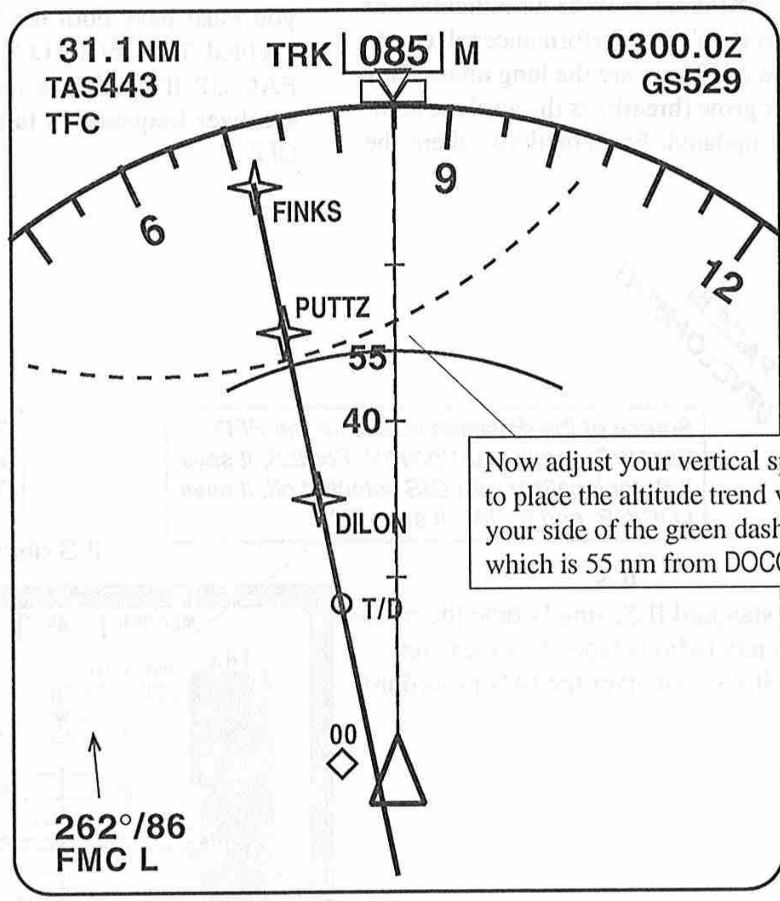
Situation: Inbound to Washington National on the Finks Seven Arrival.
Restrictions include DOCCS at 15,000 ft.
Traffic precludes descent on the present course so ATC takes you off the active route.

ATC: "Columbia 123, turn to a heading of 085 degrees, vectors for descent. Cross 55 west of DOCCS at one five thousand feet."

- Set 15000 in the MCP ALT SEL window.
- Turn to the 085 degree heading.



- Put DOCCS in one of the FIX pages.
- Create a point 55 west of DOCCS by entering ***/55*** on line 2, 3, or 4L.



Now adjust your vertical speed knob to place the altitude trend vector on your side of the green dashed circle, which is 55 nm from DOCCS.

NPS, IAN, and the ILS

IAN

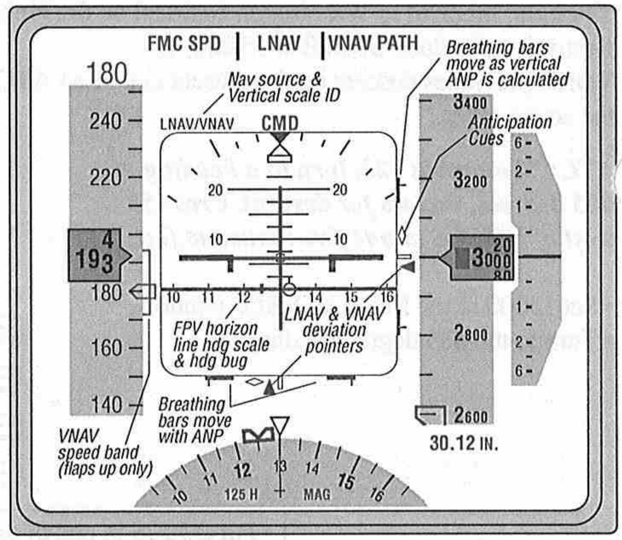
Integrated Approach Nav (IAN) is the Boeing term for using ILS look-alike functions for a non-ILS approach. It will also allow LOC for roll and Gradient Path for pitch.

To use the Integrated Approach Nav, the approach must be selected from the database. The nav radios must not be tuned to a localizer frequency. The only exception is that if you tune a localizer frequency and select G/S OFF (ARRIVALS or APPROACH REF page) the pitch mode can be G/P using the FMC information from the nav database, i.e., the vertical angle or GP on the LEGS page.

NPS (Nav Performance Scales) look similar to the loc and glideslope scales we're used to and provide an intuitive representation of the LNAV and VNAV path and nav system performance for RNP operations. This option will support operations to RNP 0.1 capability and will provide increased capacity for operations such as for closely spaced parallel approaches.

RNP and ANP bars provide an indication of the airplane system's nav performance relative to the RNP. The ANP bars are the long ones. They will shrink or grow (breath) as the airplane position is being updated. For situations where the deviation pointer exceeds the flight technical limit, the pointer will visually overlap the deviation limit bar, the deviation limit bars will turn amber, and the pointer will blink for 10 seconds.

Integraged Appraoch Nav display



To get the anticipation cues (ghost pointers) you must have both the NPS and IAN options enabled. They reflect LOC-G/S if an ILS is tuned, FAC-GP if no ILS is tuned, or LOC-G/P if a localizer frequency is tuned and G/S is selected OFF.

THIS PAGE IS UNDER DEVELOPMENT

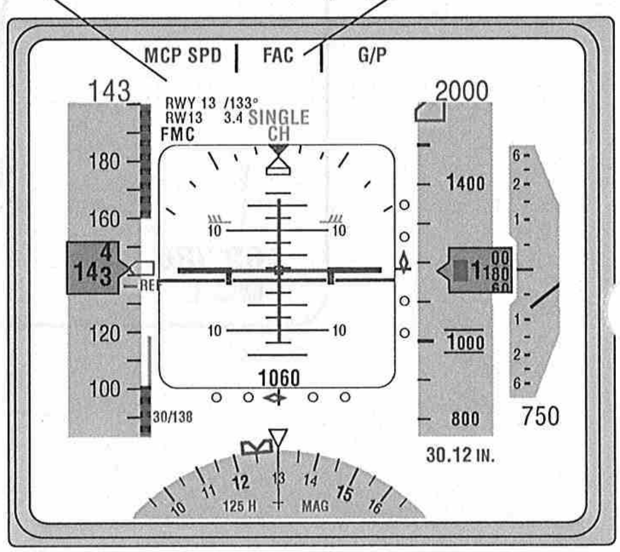
Source of the deviation scales on the PFD. For NPS it says LNAV/VNAV. For ILS, it says ILS; for localizer with G/S selected off, it says LOC/GP, and for IAN it says FMC.

FAC means final approach course. G/P means Glide Path.

ILS

To use the standard ILS, simply tune the radios. Any time a nav radio is tuned to a localizer frequency, it will win over the IAN procedure.

ILS display



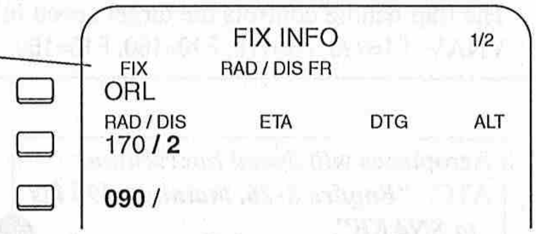
USING FIX PAGE TO MONITOR ALTITUDE RESTRICTIONS AFTER TAKEOFF

Orlando International
Elevation: 96 ft
Runway 36R
Jeff 4 Departure

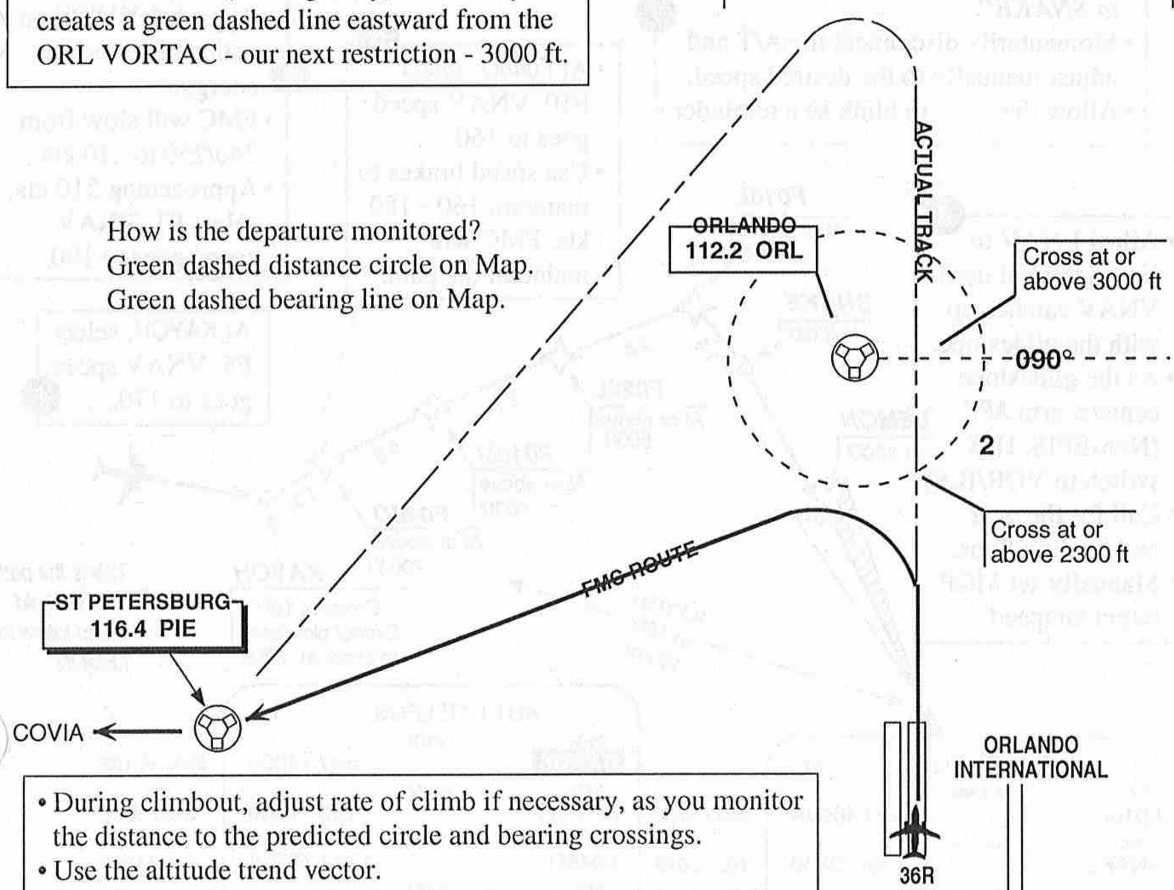
- This is the LEGS page after the route has been entered.
- Altitude predictions displayed on the LEGS and FIX page while on the ground may be a little optimistic.

Select the departure runway - in this example, 36R. This will ensure a runway position update when TOGA is pressed (for those without GPS input).

- Now go to the FIX page and make these entries:
- Enter ORL as the FIX.
- Enter **/2** on LSK 2L. (2 mile distance entry). This creates a green dashed circle around the ORL VORTAC - our restriction is 2300 ft.
- Enter **090** on 3L (bearing entry). This entry creates a green dashed line eastward from the ORL VORTAC - our next restriction - 3000 ft.



How is the departure monitored?
Green dashed distance circle on Map.
Green dashed bearing line on Map.



- During climbout, adjust rate of climb if necessary, as you monitor the distance to the predicted circle and bearing crossings.
- Use the altitude trend vector.
- Each intersection could be placed on the active route by building the route north-ward, past the ORL VOR, but in this example it would be too time consuming.

Critiqued by Captains Craig Johnston and Larry Kruchten

EAST SIDE ARRIVAL TO ORANGE COUNTY

1
- This technique assumes no tailwind and no excess energy upon arrival at KAYOH. If either is present, full speed brakes or the gear may be required to dissipate excess energy.
- Make sure the route and altitude restrictions on the LEGS pages match those on the chart. It's also easier to use the LEGS page or RTE DATA than the chart to keep up with fast changing restrictions.
- Thoroughly brief the arrival. Tell the MP to remain in AUTO until F029L so FMC will *agility tune* as long as possible.
- There's no requirement to program speeds at fixes other than KAYOH.
  With *Speed Intervention*:
    Use *Speed Intervention* for speed control.
  Without *Speed Intervention*:
    The flap handle controls the target speed in VNAV. F1=190, F5=170, F10=160, F15=150.

2
FP, prior to KAYOH, press your nav switch to MANUAL. This will put the LOC and G/S on your ADI and the ISNA DME in your RDMI. It will indicate about a 2:1 ratio at KAYOH, but if the complete approach is flown, you've got 14 miles to loose 4800'.

3
- Maintain last assigned altitude until cleared for lower altitude or cleared to ***"Descend via the Eastside One Arrival"***, then enter 2200' in the MCP. S
  Note: If ATC breaks you off from the approach, make sure you get a new altitude in the MCP.
- VNAV PATH will sacrifice speed to honor LEGS constraints. If you're in VNAV SPD, except U1.x, the FMC will protect from the low side; that is, it will level at each wpt restriction; it will not guarantee crossing from the high side.
- **You must stay in VNAV to ensure aircraft will honor LEGS altitude restrictions since the MCP is set to the OM altitude.** Otherwise, step down with the MCP ALT SEL.
- U1 thru U6: VNAV disconnects at flaps >15.

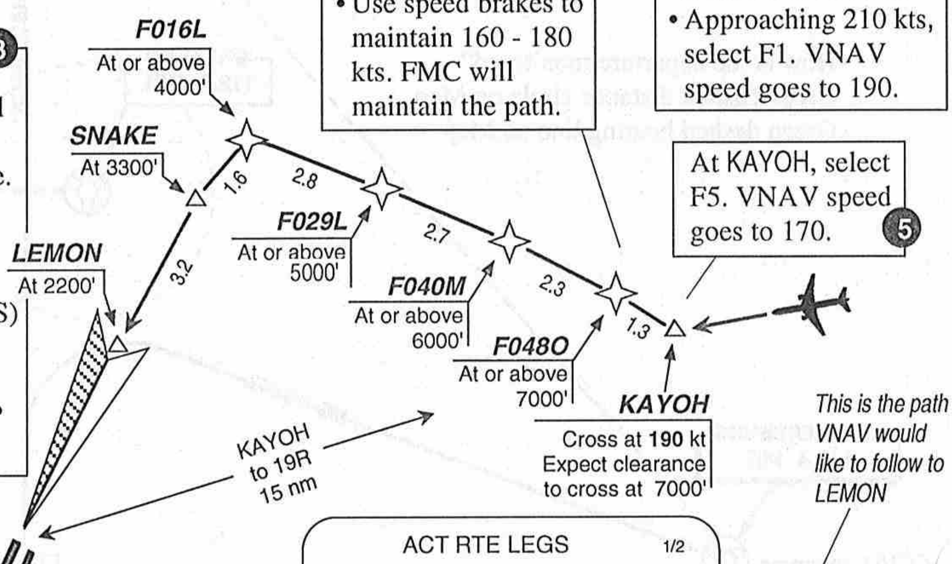
7
Aeroplanes w/o *Speed Intervention*:
ATC: ***"Empire S-26, maintain 190 kts to SNAKE".***
- Momentarily disconnect the A/T and adjust manually to the desired speed.
- Allow the to blink as a reminder.

6
- At F048O, select F10. VNAV speed goes to 160.
- Use speed brakes to maintain 160 - 180 kts. FMC will maintain the path.

4
- Approach KAYOH on path and no excess energy.
- FMC will slow from 240/250 to 210 kts.
- Approaching 210 kts, select F1. VNAV speed goes to 190.

5
At KAYOH, select F5. VNAV speed goes to 170.

8
- Allow LNAV to track inbound until VNAV catches up with the glideslope.
- As the glideslope centers, arm APP. (Non-EFIS, HSI switch to VOR/ILS)
- Call for the gear and landing flaps.
- Manually set MCP target airspeed.



ACT RTE LEGS 2/2

277°	2.8 NM		
F016L		160 / 4000A	203 / 3432
206°	1.6 NM		
SNAKE		160 / 3300	193 / 3049
194°	3.3 NM		
LEMON		150 / 2200	
194°	6.5 NM		
RW-19R		135 / 110	

ACT RTE LEGS 1/2

260°	18 NM		
BANDS		280 / 14000	293 / FL182
247°	38 NM		
KAYOH		190 / 7000	240 / 5626
289°	1.3 NM		
F048O		170 / 7000A	240 / 5186
283°	2.3 NM		
F040M		160 / 6000A	240 / 4437
280°	2.7 NM		
F029L		160 / 5000A	240 / 3910

ANALYSIS OF A CANADIAN ARRIVAL USING A DTW

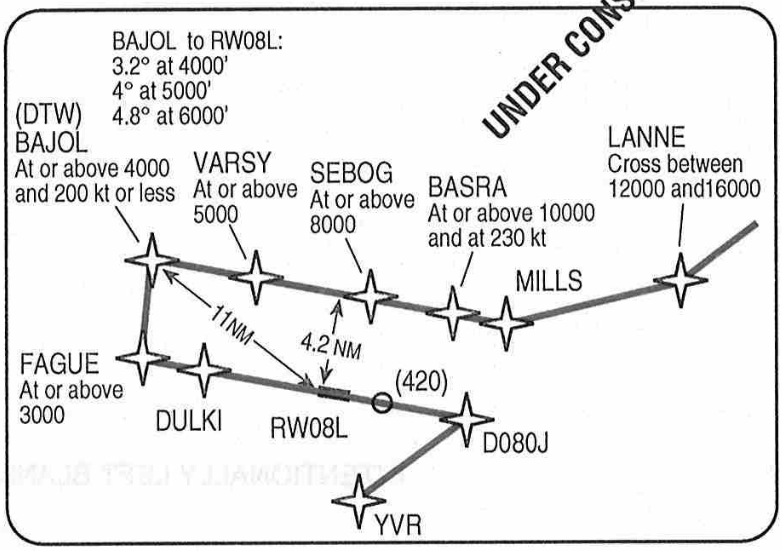
```
 ACT RTE  LEGS        2/5
219°        49NM
BOOTH            ----/------
218°       5.9NM
VITEV            ----/FL210B
210°       8.0NM
STAVE            ----/------
218°        14NM
LANNE     ----/12000 16000
236°        10NM
MILLS            ----/------
```

```
 ACT RTE  LEGS        3/5
260°       4.2NM
BASRA          230/10000A
260°       5.0NM
SEBOG          ----/ 8000A
260°       6.1NM
VARSY          ----/ 5000A
260°       7.3NM
BAJOL          200/ 4000A
260° HDG    NM
(VECTOR)       ----/------
```

```
 ACT RTE  LEGS        4/5
80°          NM
FAGUE          ----/ 3000A
79°        1.9NM
GS-08L         163/ 3000
80°        0.1NM  GP 3.00°
DULKI          ----/ 3000
80°        9.0NM  GP 3.00°
RW08L             /    63
80° HDG    0.2NM
(420)          ----/ 420A
RNP/ACTUAL--------------
2.00/0.05NM     RTE DATA>
```

- This is the CANUCK FIVE Arrival with the BOOTH transition to Vancouver (CYVR), B.C.
- Interesting points: The vertical path is predicted on two hard altitudes, VITEV and GS-08L. All the rest are at-or-aboves.
- There is a speed reduction at BASRA, and a speed at BAJOL that is meant to be at-or-below.
- The Downwind Termination Waypoint (DTW) is BAJOL.

UNDER CONSTRUCTION




```
MOD RTE  LEGS        2/5
219°        49NM
BOOTH            300/FL232
218°       5.9NM
VITEV          300/FL210B
210°       8.0NM
STAVE            300/FL189
218°        14NM
LANNE            300/13296
236°        10NM
MILLS            264/10402
```

```
MOD RTE  LEGS        3/5
260°       4.2NM
BASRA          230/ 9945
260°       5.0NM
SEBOG          230/ 8436
260°       6.1NM
VARSY          230/ 6987
260°       7.3NM
BAJOL          194/ 4772
260° HDG   3.9NM
FAGUE          173/3546
------------------------
<ERASE         RTE DATA>
```

- Delete the altitudes at LANNE, BASRA, SEBOG, VARSY, BAJOL, and FAGUE. Delete the 200 kt speed at BAJOL and connect FAGUE to BAJOL. Don't execute.
- Notice the FMC predicted altitudes. It looks like the airplane will fly the vertical path very nicely, crossing all the waypoints just right, except for BASRA, which will be just a bit high. So with this arrival, I wouldn't change any of the database altitudes.
- Press the ERASE prompt.

```
 ACT RTE  LEGS        3/5
260°       4.2NM
BASRA          230/10000A
260°       5.0NM
SEBOG          230/ 8000A
260°       6.1NM
VARSY          210/ 5000A
260°       7.3NM
BAJOL          194/ 4000A
260° HDG   3.9NM
FAGUE          173/ 3000A
RNP/ACTUAL--------------
2.00/0.05NM     RTE DATA>
```

- There are many ways to shoot this arrival, and this will just give you some ideas.
- Delete the 200 kt speed at BAJOL and connect FAGUE to BAJOL. With the deployment of flaps you're going to be less than 200 kts. If you are not cleared for the approach by BAJOL, use HDG SEL to fly 260°.
- Add a 210 kt speed restriction at VARSY, for this is where you will be abeam the runway. When I'm abeam the runway, I want to be at a speed where I can start adding flaps to help the airplane slow-down and come-down at the same time.
- As you fly past VARSY, control your speed with flaps. BAJOL is 11 nm from the runway, which leaves plenty of room for the turn to base and final, even from 6,000 ft.

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HISTORY OF AN UPDATE

Step 1:
Aircraft manufacturer decides if an update is needed. Computer manufacturer can propose one if problems have developed. Order is then sent to the computer manufacturer.

Step 2:
The software is designed by the computer manufacturer (Smiths Industries or Honeywell).

Step 3:
Software package goes to the aircraft manufacturer where it is added to and subtracted from. Customer (carrier) input takes place here.

Step 4:
Software modification takes place with testing at computer lab.

Step 5:
Aircraft manufacturer certifies the update.

Step 6:
Production box is sent to the aircraft manufacturer. Whole process takes at least 6 months.

The material presented on the next four pages lists selected improvements in FMC software.

UPDATE CERT. DATE	CHARACTERISTICS
CERT	Model originally used for certification.
U1 Nov '84	Engine data, 20 k (CFM56-3B1) - more accurate. Engine data, 22k (CFM56-3B-2) and related software. Hold - enroute holding capability added. Lateral / vertical design improvements. Messages - modified alert and advisory logic to eliminate nuisance displays. Nav data base - expanded capability. Reasonableness tests between Radio position and IRS position. Reasonableness tests for vertical velocity. Software timing improvements. Waypoint bypass logic modifications.
U1.1	Added more nav data base terminal area procedural capability.
U1.2 Oct '86	Displays the derate climb 1 N1 limits above 4000 ft. U1.1 miscomputes the distance at destination when the destination does not have a runway defined or selected. The problem is more noticeable when the destination is south of the origin. The wrong computed distance for the destination causes the FMC to display a jump (100 ft) in vertical deviation when in path or speed descent. The problem only occures in the air. Fixed in U1.2. Not a problem on U 3.0.
U1.3 Mar '88	APPROACH REF page has blank display if the selected destination approach does not contain ILS information (replaces the erroneous BCSC display). Autothrottle will re-enter the FMC SPD mode to capture the speed when actual speed falls to more than 15 kts below target speed. It returns to the ARM position when within 5 kts. Auto re-tune search to the best DME-DME pair each 2 minutes instead of keeping the last pair tuned as long as they remain valid. BUFFET ALERT has a pad of 5 kts and 300' is built into the logic that issues the message in order to reduce the instance of nuisance messages. CYCLE IRS OFF message - displayed whenever IRS logic requires manually restarting of alignment. DES page - If DEST does not have a speed restriction, the SPD REST field will be blank. ENTER IRS POSITION message changes, including (a) a position not equal to the value entered in the SET IRS POS field is returned to the FMC from any IRS, and (b) after entry of a SET IRS POS value, FMC detects an IRS in align mode that requires a position entry and condition has lasted for 45 seconds.

UPDATE	CHARACTERISTICS
U1.3 (Continued)	FIX page displays bearing as a Great Circle path so as to be consistent with course information on LEGS page instead of a flat earth bearing. Flight plan predictions improved whenever there are no waypoints in cruise. FMC will not fail for flight plan leg between the North Pole and the South Pole. IRS MOTION message is displayed whenever the IRS has detected motion and has restarted alignment (if the IRS has that capability), or needs to be manually realigned (if the IRS does not have the automatic realignment capability). Nav Data base is compatible with 3.0 and 3.1 PROGRESS page - No more stray M during step trades. Reduced thrust annunciation displayed only if the actual N1 value is reduced. Restart . . First and second restarts display SELECT ACTIVE WPT / LEG; third displays FMC fail. Counter resets to zero at landing and/or after one minute of most recent restart. SELECT DESIRED WPT page - proper display of multi-defined wpts. SET IRS POSITION has some changes and additions to the message. SIDs that begin with an "FD" leg type can be processed and flown. STEP CLB function checks max altitude when a step altitude is entered. Step-point computed for the step descent and displays it together with the resulting penalty on the CRZ page. Updating is suppressed whenever ground speed is less than 100 kts. VERIFY POSITION has some changes and additions to the message. Waypoint - Ability to define a place/bearing/distance Temporary wpt by referencing a multi-defined waypoint name. Wind - FMC can now tolerate very small values of estimated cruise wind. This fixes the previous problem which caused an occasional fail in the FMC when winds were entered into the PERF INIT page during flight. Wind calculation and display is suppressed whenever TAS is less than 100 kts.
U1.4 Feb '91	Agility tuning ability improved through revision of nav receiver selection . Auto tune increased to range of 200 nm, independent of altitude. Increases number of 10 best list. Fixed Offset (velocity washout) - If the FMC is misled by an erroneous radio update, its position may drift away from the IRS position. In U1.3 this offset error increases with time during IRS NAV ONLY. In U1.4, the offset grows only until the IRS NAV ONLY message is displayed. After this, the offset is held constant until further radio updating occurs. FMC transmits engine rating to the autothrottle instead of engine type on IDENT page. High Idle - Engines assumed to operate in high idle on descent. IDENT page displays engine thrust rating and U1.4. IRS NAV ONLY messsage displayed after 2 min. of operation without radio updating after an IRS position shift has occurred. POS SHIFT display and inflight update capability on third page of POS INIT. RADIO position now displayed on POS REF 2/3. REF NAV DATA page adds capability to inhibit selected VORs and DMEs. TAKEOFF REF page allows for further selection of derated takeoff thrust on page 2. Updating - Single DME updates eliminated. Reduces ability of radio update contamination from misplaced or badly biased DMEs. Updating from a VOR is reduced to a maximum of 25 nm. Velocity divergence test is added to determine if automatic re-initialization of FMC nav is required. Prevents nav reference to a badly drifting IRS. VOR - Reduced gain on VOR input. When updating from VOR/DME, there is less "belief" in the VOR/DME position. Results in less divergence in FMC position. Wind anomaly in using forecast winds during cruise. To be fixed in next update.

SOFTWARE UPDATES - Non EFIS

All U1.x software is found on non-EFIS aircraft.

UPDATE	CHARACTERISTICS
U1.5 May '92	Wind anomaly in U1.4 fixed. Problem: Occasional FMC re-starts have been experienced. The lock-up can occur at the gate or in flight. The problem is more likely to occur when: 1) both nav radios are in the MANUAL tune mode. The computer's search time through its nav data base increases. In a densely populated nav area the search may take too much time, for it searches up to 390 nm. 2) the operator is using the *universal data base format.* A change was made to this nav data base packing program. The changes, made in the January data base for certain operators, have also resulted in additional time required for the navaid search. 3) the operator is using a large nav data base which also extends the search time. Until a permanent solution is implemented, have at least one nav radio in an auto mode (on the ground and airborne) whenever normal operating procedures allow. None EFIS aircraft place the HSI switch to NAV. EFIS aircraft, use the MAP or PLAN position.
U1.6 Mar '95 FMC must be sent back to the factory for re-programming or the carrier can obtain a re-program from Smiths.	APPROACH REF page will display FREQuency to 2 decimal points. Fix: In previous software, when one radio is tuned manually, the FMC would search 5 latitude bands of its memory in its attempt to build the best 10 navaid list to "match angles" with that manually tuned navaid. In an area of high density navaids such as the northeastern United States, this search would "time out" and the FMC would "restart". (The search is also heading sensitive.) The OFP's internal navaid search logic will now search 3 latitude bands to shorten the search time, and change the priority of the search; that is, it does not have to be done in one calculation but can be finished at a later time. REF NAV DATA - NAVAID IDENT page will display FREQuency to 2 decimal points.

UPDATE	CHARACTERISTICS
U2.0	Added EFIS output and backup nav with ANCDU.
U3.0 Jul '80	ALERT and ADVISORY messages have been modified to eliminate nuisance displays. Along Track Offset - capability of creating a waypoint either side of a fix that is in the flight plan by entering the fix, a slash, then a plus or a minus sign and the desired distance into the scratch pad. APPROACH REF page - rwy length in feet or meters. ANCDU compatibility. Aspirated TAT probe (option). Autothrottle will re-enter the FMC SPD mode to capture the speed when the actual speed falls to more than 15 kts. below target speed. Returns to ARM when within 5 kts. Clock input with date. DES FORECAST page - Descent forecast winds and ISA DEV may be entered. Distance-to-go in one-tenth nm. EFIS - Ability to interact with the optional Electronic Flight Instrument System (EFIS), and Alternate Navigation Control / Display Unit (ANCDU). GATE position. HOLD page - capability has been increased to allow for 5 holds in the flight plan. Inhibit VOR capability. Intercept course crew enterable. LEGS page - ACTIVATE prompt added. Localizer updating capability. POS INIT - GATE position may be entered for position initialization. REF NAV DATA - rwy coordinates retrieved by entering RW prefix or airport ident first. RTE page - flight number entry. Propagates to the PROGRESS title. RTE page - optional flight number entry. RTE page - runway entry does not require RW prefix. Runway assigned threshold crossing height instead of threshold elevation. Runway or intersection position update on runway. Scanning DME compatibility. Software restart - Upon occurance of second restart (within 1 min of first software restart), performance data, including ZFW, reserves, flaps, des forecast data, approach speeds, and perf. limit is reset to zero. * SUPP nav database is provided to allow entry of nav information for longer than one flight. TAKEOFF REF page - TAKEOFF SPDS calculation (option) USING RESERVE FUEL message. VERT DEV - HI/LO
U3.1 Dec '87	Auto tuning of best DME-DME pair limited to 2 minutes. Direct to Hold fix allowed. Inhibit DME capability. INTC CRS displays previously entered course to selected wpt. Software restart - same as U3.0
U4.0 Oct '88	Data for CFM56-3C1 (23.5k) engine and aero data for B737-400. POS SHIFT displays sensor position differences and performs inflight position update. RTA PROGRESS - Required Time of Arrival (RTA) fuction and PERF LIMITS page added. Software restart - same as U3.0, but in addition results in 210 kt commanded target spd. STEP CLIMB function checks max altitude when a step altitude is entered. TAKEOFF REF 2/2 - fixed takeoff derates added. VOR - Reduced gain on VOR input, resulting in less divergence in FMC position. WIND - If the cruise wind is entered on the PERF INIT page, the climb wind is erroneously assumed to be the same as the cruise wind, from takeoff through level off.

UPDATE	CHARACTERISTICS
U5.0 May '90	ACARS - Provision for receipt and display of status messages from ACARS. Automatic reset - If an erroneous radio update causes the FMC Position to move away from the IRS position at a rate of more than 8 nm/hr, the FMC position will be automatically reset to the IRS position. The FMC will then follow the IRS position until radio updating is again available. Auto-tune increased to 200 nm (more stations available). Independent of alt. and class. CDU lockup while entering route data during short alignment is fixed. C.G. - Max altitude computation is based on C.G. entry on PERF INIT page. Data (aerodynamic) for -500 airframe and CFM-56-3B1 engine, rerated to 18500 lbs. Disc loader - Ability to load nav database via high speed 3.5" disk loader. DME - Elimination of single DME updates. Reduces the possibility of radio update contamination from misplaced or badly biased DMEs. ENG OUT computation of max alt. based on bleed status by choosing lt or rt engine out. Fixed Offset (velocity washout) - When the IRS NAV ONLY message is displayed, FMC flys a constant offset from the reference IRS. Flap speeds - VNAV target flap extension speeds revised. Previous updates did not account for increased gross weights. Ref p. 68. Global Position System (GPS) provision added including POS SHIFT capability. Heading Reference - If the Heading Ref switch is in the True position, the suffix "T" will be added to the bearing displayed in the bearing/distance field on the REF NAV DATA page. High idle - path predictions based on engines running at high idle during descent. TAI entry on DES FORECAST page still disabled. ILS - ILS approaches with glide path intercept points prior to the FAF wpt can now be accomodated in the data base. Intercept function - upon entry of a new active waypoint at 1L on LEGS page, prompt appears in 6R for intercept course entry. IRS NAV ONLY message logic revised. (If radio updating does not resume within 2 minutes of a reference IRS switch or an FMC nav program reset) IRS NAV ONLY messge resets filter velocity and misalignment errors to zero. Jumps - ETA and flight plan distance jumps during SPD DES problem fixed. LOC DME checked for reasonable activity and rate of change before used for up-dating. MAX altitude - Displayed on line 1 of CRZ page after OPT. When the cruise mode is ECON or LRC, the max altitude is the highest possible altitude within the maneuver margin. This value is independent of the displayed ECON or LRC target speed. However, in U5.0, when the pilot enters a manual cruise speed, the maximum altitude displayed is the highest altitude where that entered speed can be flown within the maneuver margin. MAX / MIN - In manually selected CRZ speed mode, a cruise altitude or speed entry will result in a limit on selected speed. Navaid pair selection to include range to visual horizon in addition to crossing angle. POS SHIFT - reduced roll rate when using the position shift. PROGRESS page displays fuel at last waypoint. Runway Extension replaces FA-XX waypoint. Runway Update has option of runway remaining entry. Scanning DME - if no valid navaids exist for updating, display blanks instead of 108.00 Slash Rule - In previous FMCs, the slash was always entered with the first number. In U5.0, the slash is entered with the number that is closest to the center of the CDU. Change will affect left entries only. (Note FIX page use) Software restart - fixed second restart problem. SPD DES initiated same as PATH DES; i.e. automatically or CAPTURE.

UPDATE	CHARACTERISTICS
U5.0 (Continued)	Step-climb - Wind values are filtered. Primarily based on values found on the PERF INIT page (weight, C.I., and max altitude). Also includes predicted fuel burned in the climb to the step altitude. T/D ADVISORY discontinued. T/D - If LNAV is not engaged while passing T/D with a PATH desent selected, the descent mode changes automatically to VNAV SPD. The aircraft automatically descends if the MCP altitude is set to a lower altitude. Also, if no E/D is entered, a/c starts down if the MCP is set to a lower altitude, reverting to VNAV SPD. TAKEOFF REF page includes optional entry of rny remaining for use in position update. Time and Date provision from GMT clock. UNABLE MACH .XXX - In a manually selected cruise speed mode, UNABLE MACH .XXX is displayed if entered Mach is unattainable at any altitude. UNABLE NEXT ALT message logic revised to include VNAV SPD. Velocity divergence - prevents navigation reference to a badly drifting IRS. VERIFY POS message (causes) changes. Ref Messages. VNAV disengages at sequencing of a GS waypoint. VNAV PATH defaults to VNAV SPD if a roll mode other than LNAV was selected. VNAV SPD - guidance honors intermediate altitude and speed restrictions on LEGS page from the low side. Waypoints - altitude constraints (more) on cruise waypoints are improved. Winds - Problem in U4.0 of erroneous use of winds fixed. Now starts with zero at surface. Problem: Occasional FMC re-starts have been experienced. The lock-up can occur at the gate or in flight. The problem is more likely to occur when: 1) both nav radios are in the MANUAL tune mode. The computer's search time through its nav data base increases. In a densely populated nav area the search may take too much time, for it searches up to 390 nm. 2) the operator is using the *universal data base format.* A change was made to this nav data base packing program. The changes, made in the January data base for certain operators, have also resulted in additional time required for the navaid search. 3) the operator is using a large data base which also extends the search time. Until a permanent solution is implemented, have at least one nav radio in an auto mode (on the ground and airborne) whenever normal operating procedures allow. None EFIS aircraft place the HSI switch to NAV. Nav controller switches to AUTO. EFIS aircraft, must press nav head to AUTO.

SOFTWARE UPDATES

UPDATE	CHARACTERISTICS
U6.0 Dec '90 ACARS interface. Parallel to U5.	ABEAM WPTS - Entered wpt cruise winds may be transferred to the new lateral flight path using the ABEAM prompt. Upon execution of the DIR TO modification, this function creates wpts on the new lateral flight path abeam the wpt on the old flight path. Entered winds assigned to the old wpts will be carried over to the new abeam wpts if the new points are within 100 nm of the old wpt. ACARS - an added ACARS interface allows uplink (flight plan data, performance data, takeoff speeds, wind data, ATC flight plan modifications, user defined uplinks) and downlink (position reports, flight plan data, actual winds, prediction data, user defined downlinks) for FMC functions. ALTERNATE DESTS page computes and displays distance, ETA and fuel for up to 5 selected alternates. Based on PPOS to the alternate or continuing to current destination and then direct to the alternate. Altitude Intervention feature incorporated with MCP. Provides for manual setting of cruise altitude target on MCP with VNAV engaged and for selective deletion of altitude constraints in climb or descent. (option) Computations based on direct route from current position to alternate, or continuing to current destination and then direct to the alternate. Data base extended to 1 million words. Can accomodate world wide coverage for a particular airline. EFIS displays of MSA, MORA grid with altitudes. Flight Number - Provides for entry of 8 digit display and transmission of flight number. IDENT page 2 displays list of loadable default data (via data base loader - i.e. drag, and fuel flow factors, min/max speeds, maneuver margin, etc). In previous updates, the default data was entered by maintenance using BIT. INIT / REF INDEX page adds prompts for MSG RECALL and ALTN DEST. Message Recall - Ability to recall scratch pad messages after being manually cleared whose set logic is still valid. Missed approach - automatic guidance provided by FMC (vertical and lateral) upon activation of missed approach. N1 LIMIT page adds Thrust Reduction Altitude (T/R ALT) feature. NEAREST ARPT prompt on ALTERNATE DEST page causes the FMC to search its data base and display the five airports closest to the aircraft (closest first). PLAN FUEL (PERF INIT) - FMC switches to actual fuel at engine start (pack on & flaps deployed). POS INIT page displays MON/DY. Works in conjunction with date sensitive nav data. Procedure turns - defined from nav data base with automatic guidance from FMC for vertical and lateral steering. QRH TAKEOFF REF - V1, VR, and V2 displays on TAKEOFF REF page accounts for runway length, slope, condition, temperature, takeoff N1, flaps, gross weight, winds, and C.G. (option) Sensor positions (IRSs, GPSs, Radio) displayed on EFIS when POS SHIFT page displayed and EFIS is in PLAN mode. SUMMARYprompt on REF NAV DATA or SUPP NAV DATA pages will display all data in Temporary and Supplemental data base and how they were constructed. Scanning DME installed (opt) blanks the nav radio window. (108.0 is not visible.) Speed Intervention feature incorporated with MCP. Provides for manual setting of speed target on MCP with VNAV engaged. (option) TAKEOFF REF page displays engine rating selected rather than RED TO N1.
U6.1	Minor changes including maneuver margins.
U6.2	Fixed fuel quantity problem.

UPDATE	CHARACTERISTICS
U7.0 Mar '93	4 MCU chasis is smaller and lighter than the old 8 MCU chasis (17lbs vs 25lbs). Also uses less power (25 watts vs 100 watts). Altitude constraints may be entered on any cruise wpt, not just a climb or descent wpt. CHECK FMC FUEL QUANTITY appears if the FMC has detected a decrease in fuel qty. greater than 1500 lbs, and 120 sec. has elapsed since the decrease was detected. EFIS MAP displays the FMC, IRS, GPS (if available) and RADIO sensor positions by selecting the POS SHIFT page while in the PLAN mode. FLIGHT NO. will take up to 8 alpha-numeric digits. FMC - includes option to prohibit manual entry of performance default data via CDU. GPS - monitoring and an advisory option provides a one-shot update to GPS position. IDENT 2/2 displays identification number of the performance defaults data base. IRS NAV ONLY will display when POS ACCURACY is not sufficient for phase of flight. Message is inhibited during the approach phase of flight under certain conditions. IRS NAV ONLY logic revised to include when POS ACCURACY is not sufficient for curent phase of flight. Maneuver margin - lower limit has changed from 1.15 to 1.20. Nav Data Base has option to include a 1-megaword nav data base. Normal is 256 k. NAV OPTIONS prompt is available from the REF NAV DATA or NAV STATUS page. The NAV OPTIONS page allows inhibiting of specific navaids for updating. NAV STATUS prompt on POS SHIFT, INIT/REF (in flight), PROGRESS 1/3, and NAV OPTIONS pages allows selection of NAV STATUS page, which displays status of navaids being tuned by the FMC and reference IRS data. OFFSET prompt is displayed on RTE and INDEX pages. This feature, allowing construction of a lateral OFFSET, is inactive until U7.1. Operational Flight Program (OPF) - on board load of OFP. OP Program 549297-001 (U7.0) displayed on IDENT page. OP PROGRAM INVALID message means a fault is detected i program memory. Action: Pull FMC C/B for 20 sec. and reset. If still invalid reload OPF. Performance Default data - option to prohibit manual entry of default data via the CDU. POS SHIFT page displays additional sensor information and position accuracy. PRE-FLIGHT status prompt deleted with TAKEOFF SPEEDS option. PROGRESS 1/3 includes wind display and NAV STATUS prompt. VHF nav displays moved to NAV STATUS page. RC-XXX - runway centerline intercept wpt added. REF NAV DATA - VOR and DME inhibits removed. SUMMARY prompt allows selection of TEMP NAV SUMMARY page and SUPP NAV SUMMARY page. NAV OPTIONS prompt allows selection of NAV OPTIONS page. Response time is faster from a high speed 32-bit processor. SUMMARY prompt on REF NAV DATA and SUPP NAV DATA pages displays TEMP and SUPP NAV SUMMARY pages. TAKEOFF REF 1/2 - (without VSPDS option) VERIFY TAKEOFF SPEEDS displayed with ACCEPT/REJECT prompts if the gross wieght is changed after takeoff speeds are manually entered. TAKEOFF REF 1/2 - with VSPDS option: Computed takeoff speeds (VSPDS) displayed in center of page and may be selected to right side of page. Select these VSPDS on/off by toggling 6R. Pre-flight status prompts deleted. Message VERIFY TAKEOFF SPEEDS same as above. TAKEOFF REF 2/2 display changed to include thrust rating with the N1 rating. TEMP NAV SUMMARY - displays contents of Temporary nav database. SUPP NAV SUMMARY - displays contents of Supplementary nav database. VERIFY POSITION message is inhibited during approach phase of flight.

UPDATE	CHARACTERISTICS
U7.1 Jan '94 Dual FMC capability Parallels U5	APPROACH REF page - VNAV target speed includes WIND CORRection. APPROACH VREF NOT SELECTED displayed when in VNAV and FMC is in approach environment and VREF has not been selected. FIX page title changes to OFFSET FIX INFO during route offset operation. FMC dual installation: Permits operation with FMC as the primary means of navigation. Basic operation with dual FMC is identical to single FMC operation. An FMC Source Select switch is installed on the aft overhead panel with the standard instrument switches. It permits the selection of Normal (system coordinates FMCs and nav instruments) right or left FMC for all nav purposes. Gradient Path (vertical angles) from the nav data base allows LNAV/VNAV to the runway threshold crossing height. Annunciated on LEGS page. GPS position update option. IRS NAV ONLY will display when ANP is greater than RNP. Message is inhibited during the approach phase of flight under certain conditions. Missed Approach can be manually constructed and flown in LNAV and VNAV. Speed and cruise altitude is assigned to CLB and CRZ pages at time of missed approach. OFP nav data and performance data defaults can be crossloaded onboard. Route offset, accessed from RTE or INIT/REF INDEX page. RNP / ACTUAL position displayed on LEGS and POS SHIFT pages. STEEP DES AFTER XXXXX displayed immediately when an altitude constraint at XXXXX results in a steep path to the next wpt. VNAV maintains PATH DES until XTK ERROR is greater than RNP, at which time it reverts to SPD DES. VNAV path guidance to the TCH or MAP on non-precision approach. VNAV available for any flap setting.
U8.0 Dec '93 Dual FMC capability Parallels U6 ACARS interface.	U8.0 contains all of U7.0, U7.1, and the following capabilities from U6: Abeam waypoints selectable after DIR TO. ACARS interface. Altitude intervention (via MCP). Alternate Destinations / Nearest Airports in data base. Message Recall. Missed approach procedures loaded in database. OFP loadable via the Data Loader Unit. Procedure Hold and Procedure turns in data base. QRH Takeoff Speeds on TAKEOFF REF page. Speed intervention (via MCP).
U7.2 Jan '95	FANS1 MCDU compatibility (VNAV key) GPS is certified as a sensor for FMC position updating. Intermediate T/D point from 2R of DES page sent to SG for display on Map (green circle and text as T/D–XXXXX) Missed Approach procedures, Procedure Holds, and Procedure Turns loaded in database. Nav enhancements - FMC will perform radio updating properly in scenarios that include more than one navaid with the same frequency (no navaids with duplicate frequencies within 400 nm of the a/c will be used for updating). PATH no longer reverts to SPD when XTK ERR exceeds RNP if on an intercept (LNAV). Program enhancement for improved dual FMC operation.
U8.1 Jan '95	Same as U7.2 except that Missed Approach procedures, Procedure Holds, and Procedure Turns were already available. Improved dual operation.

UPDATE	CHARACTERISTICS
U7.3 Winter 95 Dual FMC capable	This upgrade is required for FMC operation with GPS and with manual RNP capabilities. Delection of PROC HOLD/TURN is easier. Also allows deletion of the (INTC) point. Dual restart process will include one additional attempt, after a period of 5 minutes, when the FMCS Source Select switch is in BOTH-L or BOTH-R. GPS clock serves as the internal FMCS clock source when "GPS with Integrity" software is installed. Holding: When in the descent mode, and when an approach speed has been entered on the Approach Ref page, the displayed active speed on the Hold page will be changed to match the target speed for flaps deployed at angles greater than 15°. Holding: Ability to hold on the same wpt twice, once before the approach and again in the missed approach procedure. Message UNABLE REQD NAV PERF-RNP cannot be cleared from EFIS Map. Message VERIFY RNP has revised logic where no manual or nav database RNP has been selected. This will back up the procedure to enter the RNP prior to commencing the approach. Message VERIFY RNP VALUE has revised logic to provide immediate feedback for the case where the manual RNP entry is smaller than the current ANP. NDB Approaches may be included in the database and may be selected from the ARRIVAL page. RNP - new default constraints. TAI ON ABOVE 10° C message logic is revised (minor).
U8.3 Winter 95	Same features as U7.3. Dual FMC capablility. Parallels U7 but offers ACARS interface.
U7.4 U8.4 1996	Data is recorded anytime a single FMC fails in a dual configuration. Fixed dual down-mode to single FMC operation. Holding - Two holds on the same waypoint (one in the missed app, and one in the regular route. Holding pattern can be placed on the same wpt that has a procedure turn from an approach transition. If you try this in 7.2 or earlier, the FMC may fail. Procedure Turn can be deleted by deleting the INTC wpt. NDB approaches in the nav database. RNP default values changed. Support for new higher memory hardware. TAI on above 10°C message revised. Maintenance features allow download bite data.
U7.5 / 8.5 1997	ARRIVALS page display problem fixed regarding runway display. Ref: 15.2. Downmode and software restart problems fixed. El Paso "problem" fixed. Ref: 12.8. ENG OUT page cannot be EXECuted. Though title displays MOD, it is advisory only. FAF defaults to 150 kt speed restriction on database contained non-precision approaches. NAV DATA OUT OF DATE nuisance message fixed. NAV DATA OUT OF DATE year 2000 message eliminated. Maintenance: Additional recording parameters added to download file. RNP: Manual entry of RNP is now the default option. Runway wpt is no longer a "force overfly" wpt. SELECT DESIRED WPT page adds "intelligent sorting", second page if required, second decimal point to NAVAID FREQ, and clears scratchpad when leaving page. VNAV operation with failed fuel input.

UPDATE	CHARACTERISTICS
U10 Certified Oct. 1997	U10 is a derivitive of U6 and 8 with the following added features. 737-600/700/800 thrust rating model. ADIRU automatically adjusts IRU alignment time as a function of latitude (5 to 17 min). Minimizes ground time for alignment. ADIRU is automatically updated (aligned) prior to takeoff. Reduces accumulated drift during extended ground operation (sitting at the gate in NAV). ANP improvements. BITE, maintenance and interface changes for CDS, APU, EEC, FQIS, MMR. CDU is a LCD. Increases reliability and less weight. Climb speed restriction down to 100 kt from 210 kt. VNAV Minimum Limit Speed = Vref + increment. Common Display System interface replaces EFIS display for 737-600/700/800 (9" x 9"). Deceleration Point (DECEL) to the next speed restriction displayed on ND. DES page. DES NOW prompt replaces CAPTURE prompt. Discontinuity auto-sequencing. DME arc. (AF leg) Center required to be a DME. Double by-pass no longer inserts a discontinuity. Possible path overshoot for adverse wind conditions. Downmode and software restart problems fixed. EFIS POS switch displays green VOR and/or cyan ADF bearing vectors. EFIS/ND has additional map ranges of 5 nm and 640 nm. ENG OUT page cannot be EXECuted. Though title displays MOD, it is advisory only. Fixed-radius (constant radius) turns between airway or procedure legs when airway or procedure is so designed. Fixed Radius Enroute Turns. (Eurocontrol routes) Turns less than 135° for non-flyover wpts. Turn radius of 22 nm or 15 nm. FMC (left) and CDU (left) will operate on standby power (option) GPS with integrity ... GPS updating adds a symbol to the tip of the aircraft triangle on the ND Map. High-speed Aero loadable. IDENT page two displays more configuration selections such as QRH T/O SPEEDS and MODEL/ENGINE DATA. Increased approach wpt resolution from 60 ft to 10 ft. INIT / REF INDEX displays SEL CONFIG at LSK 5R while on the ground. ISDU adds a GPS annunciator ... LNAV bank limit increased from 8° to 15° between 200 ft and 400 ft. LNAV will arm on the ground. Roll command is wings level until 50 ft. (-600/-700/-800) Magnetic Variation table coverage extends from 82° N to 82° S except for keyhole areas which coincide with the Magnetic Poles and is common to FMC and ADIRU. MENU page allows selection of system for which the MCDU will be active, such as FMC, ACARS, or DFDAU. MCP flyaway logic - allows pilot to dial MCP altitude to missed approach altitude (above aeroplane) when established in a descent on approach. (-600/-700/-800) Model engine database in the OFP. Multiple approaches of the same type to the same runway. (More than one ILS) Operational Program Configuration (OPC) options via software programming instead of Program Pins. Performance database for -600/700/800 is loadable. PERF LIMITS min and max speeds are stored in the database. Radius to Fix. (RF leg) Any fixed geographic point can define the turn center. RNP values supplied in the nav database for each leg.

UPDATE	CHARACTERISTICS
U10 (continued)	RTA allows entry of "At or Before" or "At or After" as well as "At" times. SELECT DESIRED WPT page increased to two pages with "intelligent sorting" and navaid type displayed in header. Sensor positions sent to ND via POS switch on EFIS Control Panel. Software (FMC) may be loaded via floppy discs. Tabular database is loadable including calculation of takeoff speeds. Replaces pre-defined tables. TAKEOFF REF flap entries are defined in the database. U10 features (OPC) may be selected by the airline. Active options are listed in the MAINT section of the FMC, on the ANALOG DISC pages. VNAV ops may continue with FQIS inop. Message CHECK FMC FUEL QUANTITY will remind pilot to enter fuel quantity. Pilot must keep fuel weight in FMC current. VNAV capability added for engine out in descent phase of flight only. VNAV descent below MCP altitude (requires A/P change) WGS-84 Earth Model.
U10.1 Spring 1998	N1 LIMITS page allows selection of all takeoff ratings. N1 LIMITS page redesigned to accomodate Thrust Bump feature. Revised takeoff thrust limit. Takeoff Flaps box prompts added to TAKEOFF REF page. Thrust bump allows for selection of one engine rating higher than the FULL rating. Thrust Reduction Altitude moved from N1 LIMITS page to TAKEOFF REF page. WET GRV (gravel) runway condition added to TAKEOFF REF page.
U10.2 Aug 1998	Approaches: LDA, SDF, and IGS approaches added. Color when used in conjunction with LCD CDU and appropriate software option code. High altitude maneuver control will provide a bank angle limit, which is calculated as a function of gross weight, altitude, speed, temperature and selected thrust. HOLD page: TURN DIR moved from 2L to 3L, same field as INBD CRS QUAD / RADIAL now displayed at 2L HOLD EXIT altitude restriction. Messages: LNAV BANK ANGLE LIMITED issued when LNAV roll command is limited to the thrust or buffet based bank angle limit. UNABLE HOLD AIRSPACE issued when predicted lateral hold path using the bank angle limit causes protected airspace to be exceeded. VSPEED UNAVAILABLE displayed if any of the independent variables used in the calculation fall outside the tabular data boundaries. Nav database size will increase from 1 meg to 2.5 meg. Runway position TOGA update inhibited when valid GPS data is being received. VNAV disconnects 7 kts before VMO/MMO rather than at VMO/MMO.
U10.2A Dec 1998	Fixed a descent lockup

SOFTWARE UPDATES

UPDATE	CHARACTERISTICS
U10.3 Feb 2000	Alternate Nav capability for LCD CDU adds GPS alternate nav capability. FMC can transmit up to 60 wpts to the LCD CDU. Cannot drive the Maps and cannot provide LNAV to the FCCs. Approaches: Limitation removed to allow LDA and ILS/LOC to same runway. Previously, if there were two localizer based approaches to the same runway, but using different localizer facilities, neither could loc update if both were in the nav database. Block operating speeds for (300-400-500) increased. CLB N1 limits display all the way to T/C. (Prior, only derated CLB N1 was displayed). DIR-TO logic is improved (10 second straight line shortened). Engine Out page is for reference only and no MOD/ACT is possible. Engine Out SIDS can be displayed in MOD format by pushing ENG OUT>. Requires flaps not up and an engine out. Engine Out SID can then be executed or erased. Dual FMC ops improved with better detection of vertical miscompares. Flight plan size has been increased from 100 to 150 waypoints. FMC Block Operating Speeds increased for 3-4-500. (Flap positions 5 and 10) FMC continues operating even if both CDUs fail. LNAV, VNAV and Map operates. Gradient edit rules have changed to maintain GP through various edits, which includes insertion of wpts into a gradient leg and deletion of altitude restriction on gradient leg. Gradient Path now displayed to nearest hundredths.(Ex: GP 3.00 rather than GP 3.0) Geometric path descent (point-to-point) after the first wpt altitude constraint. (option) Allows FMC to fly along a constant gradient from one altitude restriction to the next. Jeppesen FliteStar flight planning tool will load up to 20 company routes and 1,000 waypoints on a disk to be loaded into the FMC. (option) Messages: IRS NAV ONLY discontinued and several added, including CUTBACK UNAVAILABLE, ENG OUT SID MOD, PARTIAL ROUTE LOADED, DUPLICATE FLIGHT PLAN ID, SUPP RTE DATABASE FULL, KEY / FUNCTION INOP. N1 LIMIT page has Takeoff Bump Thrust added. PERF INIT: PLAN FUEL no longer considers pack switches in logic. Polar navigation. FMC will now allow flights over the poles. PROGRESS 3/3 displays GPS track at 4L to support polar navigation to mitigate the loss of all aircraft heading data at the poles in case of dual IRU failure. REVERSE Flight Plan prompt will be available on the RTE page to reverse the existing flight plan. All procedures will be deleted. (included in FliteStar option) RTE page reformated. Airport data on page 1. Airways and enroute data starts on page 2. Runway symbol now retained on the Map during missed approaches. (Prior software it was removed when the runway was sequenced) Runway waypoint can be end-of-descent anytime. PDI defaults to 3° if direct-to. SAVE Flight Plan prompt included in FliteStar option: available on the RTE page to save the current flight plan for recall at another time. Must give it a name. (limit of 10) SUPP Nav database size increased from 20 to 40 waypoints. TAKEOFF REF page automatically changes to CLB page after takeoff. TAKEOFF REF 2/2 "Quiet Climb" (option) CUTBACK prompt along with reduction and restore altitudes. Provides cutback maneuver to support noise abatement such as Orange County (requires -52 autothrottle). UNABLE REQD NAV PERF-RNP message displayed for all cases of ANP exceeding RNP. This is the feature that supports elimination of IRS NAV ONLY message. VNAV no longer disconnects at GS-XX unless FCC G/S armed. This supports ILS overlays VNAV PATH now valid to two-times the RNP, or as long as LNAV is engaged. Weather maps can be displayed on CDU when specific ACARS unit is installed. XTK DEV on PROGRESS 3/3 referenced to lateral steering "path" (previously to "leg") XTK DEV on PROGRESS 3/3 now displayed to nearest hundredth.

UPDATE	CHARACTERISTICS
U10.4 circa Jul 2001	Alternate Nav MCDU (Update 2 LDC) adds 2 functional capabilities beyond the normal MCDU. Provides an alternate nav solution regardless of FMC(s) status. Requires on-side GPS to be operational (option) Provides capability to upload and display weather data maps. Anomoly that caused display of UNABLE REQD NAV PERF-RNP message during approach has been fixed. Prior to 10.4, this message is inhibited as long as VOR/LOC is engaged with FD or A/P on, except that if the FD was turned off above 20 kts, the message was displayed and can only be cleared by a full alignment. APPROACH REF page redesigned to include FLAP/SPD field. GA N1 field removed. CDS (Common Display System), VSD (Vertical Situation Display), and HUD (Head-Up Display), and EGPWS has several new parameters added. Clock source switching improvements. FMC will use GPS clocks exclusively if available, then will use either the Captain's (first choice) or FO's clock (if Captain's has failed). Auto switching from Captain's clock to FO's clock once the source is selected at power-up is prevented. FMC will retain last valid clock value. Compatible with existing 2907A4 FMC and the new model 2907C1 FMC (new single board allowing spare card slots to support growth). Single board FMC hardware will allow spare card slots to support future growth. It also incorporates 3 high speed ethernet channels. 10.4 will run on old hardware as well as on the new hardware. If an old box and a new box are installed on the same airplane, they both run at the same speed as the old box. It will run 50% faster with two new boxes. ENG OUT SID (6-7-8) auto loads MODified EO SID if an engine failure is detected, (climbout and flaps down) and departure runway has an engine out SID in the nav database. (3-4-5) requires selection of ENG OUT prompt on CLB page (option). FMS BITE maintenance page added to allow selection of new H/W CONFIG display. Go Around: If during go-around you select a procedure with a waypoint altitude constraint higher than your current cruise altitude, the crz alt is raised to equal the highest constraint in the procedure and the "CRZ ALT CHANGED TO XXXXX" message is displayed. Cruise altitudes that are "made up by the FMC", such as the crz alt resulting from missed approach, or from selecting a procedure as above are displayed on the crz and perf init pages in small font. Pilot entries are in large font. GPS reasonableness checks added in addition to GPS fault indications. GR WTmanual entry or deletion at 1L of PERF INIT page is inhibited (option). HOLD EXIT prompt improvements: If you are in holding and change the leg time or inbd crs, U10.4 will retain the prompt while you finish the old pattern. Previous software removed the EXIT HOLD prompt until after you finished current pattern. Holding Pattern Resize: If your leg time is 1.5 min because the holding pattern was built above 14000', and you then descend in holding to below 14000', the pattern will resize to 1 min legs. Auto re-size only if leg time or leg length have not been manually entered. If the crew makes a manual entry into either the time or distance field, the hold will not resize. Climbing or descending through 14,200' is the trigger. Holding: Default entries for QUAD/RADIAL, INBD CRS/DIR, or LEG TIME are displayed in small font. Large font for pilot entry or data extracted from nav database. IRS reasonableness checks have been improved in dual FMC installation such that both FMCs are better able to identify and reject a badly drifting IRS. Message VNAV DISCONNECT displayed if FCC goes from VNAV to LVL CHG during approach. Missed Approach path is displayed in cyan prior to being active (option). Model/Engine database size increased to 1.5 mega-words. Previous size was 1.0. Nav database size increased to 3.5 mega-words. Previous size was 2.5 mega-words.

UPDATE	CHARACTERISTICS
U10.4 (continued)	RW/APP TUNE DISAGREE and RW/APP CRS ERROR messages for conditions where a tuned frequency or MCP selected course does not match the FMC flight plan data. TAKEOFF DERATES on N1LIMIT page blanked and disabled for carriers that only use Assumed Temp (option). UNABLE REQD NAV PERF-RNP anomalyhas been resolved. Various fixes including intermittent blanking of the Map. VNAV (max) command reduced from -7° FPA to Mmo/Vmo-5 when above SPD REST. VNAV (max) command reduced from -6° FPA to 250 kts when below SPD REST. VNAV remains in PATH, even if XTK ERR exceeds RNP. Previous software reverted to SPD DES. (idle descent legs and computed gradient legs). VNAV will switch to PATH when speed intervention is exited if not already in PATH.
U10.4A	Corrects 3 problems in 10.4 Adaptable Datalink database part number intermittently / erroneously displayed on CDU FMC failure due to an incorrect ARINC wrap test (limited to 2907C1 hardware) Move boot software problem corrected (limited to 2907C1 hardware)
U10.5 (Jan 2003)	Altitude Constraints: The next active wpt altitude constraint will be displayed on the CDS Map under the wpt identifier even if the RTE DATA switch is off. Approach Ref Speeds: allows entry into 4R of FLAP/VREF values of 0, 1, 2, 5, 10, or 25. If a non-standard flap setting is entered (i.e. one not displayed in 1R-3R) then a VREF speed must be manually entered because the FMC does not compute a speed for these flap settings. ARRIVALS page has G/S ON/OFF prompt. The prompt will work identical to the prompt on the APPROACH REF page. ATC light and chime status, part of FANS-1 option, displayed on Fixed Output page. Calculated Takeoff Speeds changed: thrust rating, temperature, and airport altitude are now included in the calculation of Minimum TOGW (benefits 737-700BBJ) Climb-to-descent transition: VNAV can swtich from climb to descent when it runs into the planned descent path. Previous software required a lower entry of a CRZ altitude. This caused confusion after a missed approach and selection of another approach. Double Derate takeoff and climb thrust mode annunciations can now be displayed on the CDS. The new derated takeoff and climb thrust modes displayed (in place of the R-TO and R CLB) on the CDS will be TO 1, TO 2, D-TO, D-TO 1, D-TO 2, CLB 1, and CLB 2. Engine Performance Model (EPM) modified to table lookups as a function of altitude and corrected N1. FANS-1 via ACARS datalink: (option) ATC datalink (ATC DL) enables ATC/pilot datalink communication via the MCDU; Automatic Dependent Surveillance (ADS) provides for automatic position reporting, and ATS Facility Notification (AFN) provides for logons to ATC facilities to notify ATC of an aircraft's *address*.. Fuel filter time constant decreased to 5 sec on the ground for display on PEF INIT and PROGRESS GPS Landing System Approach (GLS) (option). GLS approach types (LAAS only) if defined in the nav database. Currently, allowed to CAT I minimums. Integrated Approach Nav (IAN): allows FMS RNAV approaches and other approaches to be flown in an ILS look-alike manner, with common crew procedures. Magnetic Variation Model updated to 2005 MagVar model. Table change only. The algorithm, validity region and data point lat/lon spacing remain the same as the 1995 MagVar model. Message ALT CONSTRAINT XXXXX . If the Flight Plan edit results in an altitude conflict with the existing CRZ ALT, (other than manually entering an altitude constraint), the FMC CRZ ALT is automatically changed to the highest constraint in the modified FP.

UPDATE	CHARACTERISTICS
U10.5 (continued)	The resulting modified FP will be executable, with a new alerting level message, CRZ ALT CHANGED TO XXXXX. Previously the FP could not be executed until a new/lower CRZ altitude was entered. Message ATC MESSAGE, part of FANS-1 option, displays on map in amber. Message MCP APP DISARM REQD displayed when a non localizer approach is armed and the nav radio is re-tuned to an ILS (enhancement to CIAP logic). Message VSPEEDS UNAVAILABLE display logic changed: to display if gross weight is less than a value derived from a new Model Engine database table, as a function of thrust rating, ambient temp and pressure altitude. Missed Approach predicted sooner: previous software predicted MA path approximately .8 nm from MA point. MA now predicted full time so that crew can determine turn directions and other data before actually beginning the MA. NAV STATUS page reflects GLS channel tuning; this includes highlighting and prefix nomenclature, i.e., P (procedure), M (manual), or A (autotune) for the tuned channel number. PROGRESS pages 2 and 3 have been reversed to match other Boeing aircraft. RNP: Capability to review and enter lateral and vertical approach RNP values using a new RNP PROGRESS page (3R). Runway of destination can be entered on the FIX page and on the WPT/ALT data field of the DESCENT page. Down-selection of LSK 2L through 4L on FIX page is inhibited. Threshold crossing height fills in automatically with destination runway entry on DES page. (Ex: RW26/) TACAN approaches can be selected from the nav database. TACANs designated as military use ("M" types), channels 1-16 and 60-69 will not be included at this time but the U10.5 s/w may be structured to include them at a later date. The FMC will not tune the procedure navaid associated with the TACAN approach. Thrust Rating Model (TRM): adds new 737-600 configurations with 7B22/B2 bump thrust rating and new 737-700 configurations with 7B26/B2 bump thrust rating. Tropopause breakpoint predictions (add a new phantom vertical wpt at the trop altitude to account for differences in the atmosphere models below and above the trop). Should reduce the tendency to overspeed during path descents that start above FL360. UNABLE CRZ ALTITUDE condition exists, FMC transitions directly from climb to descent predictions when the aircraft cannot reach cruise altitude before it encounters the descent path. The FMC will compute an achievable cruise altitude, referred to as the *internal cruise altitude*. A short cruise segment will be created, but the CRZ page will be suppressed, i.e., if the page is currently displaying the CLB page, the CDU display will automatically switch to the DESCENT page. VNAV limits modified: Max flght path angle is approximately that which will result in a speed of Mmo/Vmo – 5 kt above 10,000 ft and 250 kts below 10,000 ft. VMAV Overspeed: VNAV authority modified. Currently 7° FPA above the airport speed restriction altitude and 6° below the airport speed restriction altitude. Changed to an angle that will result in a speed of Mmo / Vmo – 5 kt above the airport speed restriction altitude and DES page speed restriction + 10 kt below the airport speed restriction altitude. This may result in fewer VNAV disconnects. VNAV Speed Band: this feature depicts upper and lower limit speeds for VNAV PATH. The descent speed will be augmented by the display of a speed band on the speed tape of the PFD. The top of the speed band will indicate the speed at which the descent guidance mode switches from path-on-elevator (VNAV PATH) to speed-on-elevator (LVL CHG). If the A/T is on, the bottom of the speed band will show where the A/T switches from ARM to FMC SPEED. If the A/T is off, the bottom of the speed band will show 15 kts below the speed target, and a THRUST REQD message will be displayed if the speed falls below that value.

SOFTWARE UPDATES

UPDATE	CHARACTERISTICS
U10.5A (Jul 2004)	ANCDU Fixed Outputs problem fixed that prevented access. FMC failure annunciation of the Multi-Mode Receiver (MMR) for GLS installations corrected. FMC logic improvement to reduce the occurrences of nuisance messages: RESET MCP ALT, UNABLE CRZ ALT, THRUST REQUIRED, USING RSV FUEL, CHECK FMC FUEL QUANTITY. MOD Hold Symbol problem corrected (incorrect display). PLAN FUEL display logic revised to ensure the field is correctly displayed on 737NG's with older auto-throttles. Restart problem corrected.
U10.6 (Projected Mar 2005)	Airframe/Engine program pins (2) added to support more 737 model types Altitude Intervention - approach waypoint altitude constraints cannot be deleted to prevent aircraft from flying below minimum altitudes. Earlier software allowed this. ANP is enhanced to account for sensor position and cross-track deviation differences between the 2 FMCs. ANP and position data for the last 10 RNP exceedences or VERIFY POSITION events are recorded by the FMC. ARRIVALS page added field: After selecting one of the destination runways, the FPA header is displayed. The crew can modify the descent gradient angle in the FPA field. Entry propagates to (GP x.xx) on LEGS page. ATS-Datalink: Access to ATS Uplink Delay Timer which allows FANS-1 a/c to operate in European airspace. Crew enters delay value into the LOGON/STATUS page. This change tells the crew if a datalink clearance is older than a voice message that was sent to replace it. Message UPLINK DELAY EXCEEDED displays if time is exceeded. Cruise Speed Propagation (option) - When a manual speed is entered on the CRZ page (CAS or M), it propagates to the DES page. DES - Geometric Path descent is now basic, not optional. Point-to-point instead of stair-step after the first idle descent. Path descent is now always available when at least 1 wpt is included in the descent. SPD DES prompt removed from DES page when active leg is a STAR or when the approach transition leg has a vertical angle. Dual FMC logic changed to reduce the occurrence of reverting to single FMC ops due to dual FMC software logic disagreements. The change allows the dual FMC system to continue operating while disagreements are resolved with no required crew action. Engine Out SID - the FMC will search the E/O SID database to find out if the active wpt is one of the wpts in the E/O SID. If the active wpt exists in the E/O SID, the remaining portion of the E/O SID will be loaded without a lateral discontinuity after the active wpt. Wpts prior to the active wpt are ignored. Estimated Time of Arrival and Fuel Remaining predictions are corrected. Flight Plan Intent Bus Output Option: in support of European 4-D FMS flight trials. FIX page (option) - four added for a total of six. Integrated Approach Nav option: glide path deviation now provides a smoother display under transient conditions and supports classic a/c that has compatible displays and A/P. LNAV nominal bank angle is 1/2 the track angle change with a minimun of 8° to a max of 23°. Not applicable for procedure turns, procedure holds, or holding patterns. Missed Approach LNAV go-around (CDS option) operation is changed to provide automatic re-engagement of LNAV. The missed approach must be in the active flight plan and cannot be followed by a discontinuity. Pressing TOGA while the a/c is below 400 ft AGL places LNAV in an armed state (white on FMA). During climb-out, LNAV is automatically re-engaged at 400 ft AGL. MODEL ENGINE database size is increased from 1.5 to 2.0 mega-words to support more 737 model types.

SOFTWARE UPDATES

UPDATE	CHARACTERISTICS
U10.6 (Projected Mar 2005)	Operational Program Software (OPS) supports APB wingles for -300 and -400 a/c. QRH - new logic ensures that the entered QRH V1 is less than or equal to VR and VR is less than V2 (V1≤VR<V2). If an entry is made that violates V1< Vr < V2, the remaining V speeds are deleted. Quiet Climb modified to keep CUTBACK enabled during re-entry of Vspeeds except when manually disabled or past the cutback altitude. On earlier software, re-entry of Vspeeds during quiet climb disabled quiet climb. SEL DES WPT page improvements: Title changed to SEL DES XXXXX where XXXXX is the ID of the duplicate. 15 characters to display names of airports, VHF navaids, and non-directional beacons. Frequency (VHF or NDB) displayed in left column. New page format can be used with or without extra data in nav database. A maximum of 12 duplicates on two pages may be displayed. SPD DES will switch to PATH DES on point-to-point legs. Vertical Required Navigation Performance (VRNP) will be increased to 400 ft to allow the deviation pointer to come off the upper stop earlier during a normal G/P capture. VNAV Option (common): VNAV SPD is used as the speed on elevator mode for overspeed reversions instead of disconnecting VNAV. This option removes the selectable SPD descent mode and the PATH or SPEED designation from the CDU descent page titles. VNAV DISCONNECT nuisance message will not be displayed when VNAV transitions from a missed approach. VNAV PATH will no longer auto-change to VNAV SPD under any circumstance. Winglet configurations supported for 737-300 and -400.

-300

DISTANCE	COST INDEX				
	0	28	60	100	200
	Time (min) / Fuel Burn (1000 lbs)				
2400	-5 / .2	0 / 0	3 / -.2	7 / -.6	14 / -2.1
2000	-5 / .2	0 / 0	2 / -.1	6 / -.5	11 / -2.1
1500	-5 / .2	0 / 0	2 / -.2	4 / -.5	8 / -1.4
1000	-4 / .1	0 / 0	1 / -.1	3 / -.3	6 / 1.0
500	-4 / .1	0 / 0	1 / 0	2 / -.1	3 / -.4

WIND TRADE TABLE

OFF-OPTIMUM ALTITUDE	WIND DIFFERENCE REQUIRED
+ 2000 ft	7 kts
- 2000 ft	5 kts
- 4000 ft	15 kts
- 6000 ft	30 kts
- 8000 ft	50 kts

737-300 / 20k

OFF-OPTIMUM CONDITION	FUEL MILEAGE PENALTY % LRC	.74M
2000 ft ABOVE	1	1
AT OPT Altitude	0	0
2000 ft BELOW	1	2
4000 ft BELOW	4	4
8000 ft BELOW	10	11
12,000 ft BELOW	15	20

737-700 / -7B24

OFF-OPTIMUM CONDITION	FUEL MILEAGE PENALTY % LRC	.78M	CI30
2000 ft ABOVE	2	2	2
AT OPT Altitude	0	0	0
2000 ft BELOW	1	2	2
4000 ft BELOW	4	5	4
6000 ft BELOW	6	10	7
8000 ft BELOW	9	14	11
10,000 ft BELOW	11	19	14
12,000 ft BELOW	14	24	16

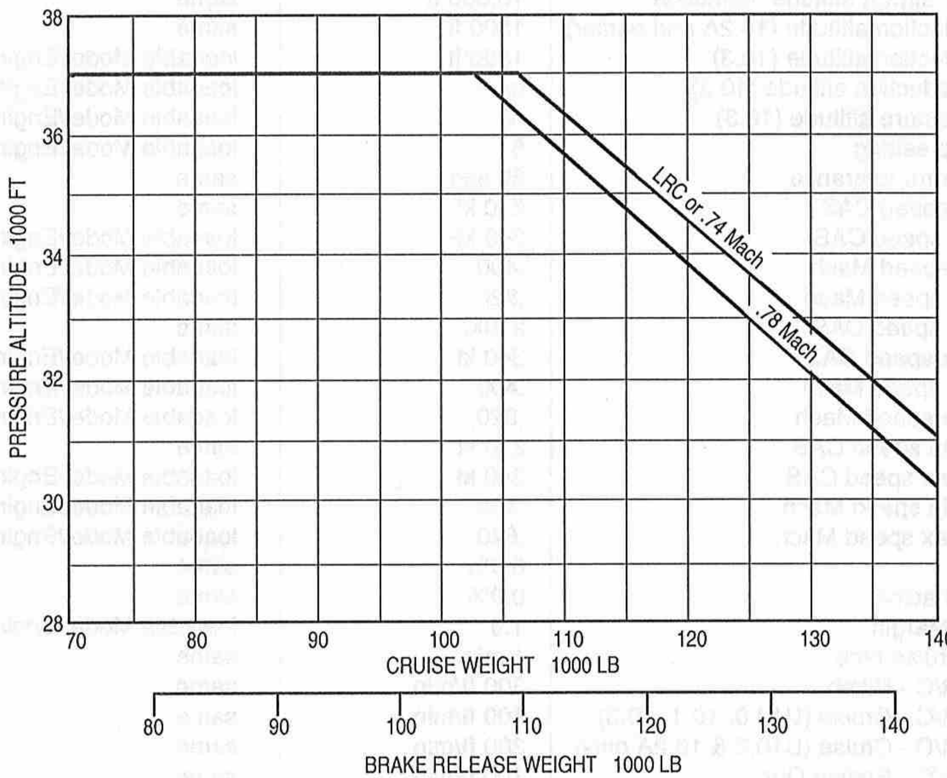
737-800 / 7B26

OFF-OPTIMUM CONDITION	FUEL MILEAGE PENALTY % LRC	.79M	CI30
2000 ft ABOVE	1	1	1
AT OPT Altitude	0	0	0
2000 ft BELOW	1	2	2
4000 ft BELOW	4	6	5
6000 ft BELOW	7	10	8
8000 ft BELOW	9	16	12
10,000 ft BELOW	12	20	15
12,000 ft BELOW	16	23	20

COST INDEX FLIGHT PLANNING TABLES

Use to determine the difference from a Cost Index of 28.
Example: If a -300 flight with a distance to go of 1000 nm were to change from a CI of 28 to 100, it would save approximately 3 minutes to burn 300 extra pounds of fuel.

OPTIMUM ALTITUDE -300 / -500



MACH AIRSPEED DIFFERENCES TABLE

The approximated potential range of CI manipulations is shown in this table, depicting zero wind cruise Mach at CI = 0 and CI = 200 typical for the conditions indicated.

FLIGHT LEVEL	GROSS WEIGHT (1000 lbs) 90.0	100.0	110.0	120.0
	CI = 0 / CI = 200			
370	.714 / .785	.726 / .776	.733 / .772	.736 / .767
350	.696 / .788	.715 / .782	.726 / .775	.733 / .770
330	.675 / .789	.698 / .785	.716 / .780	.725 / .775
310	.654 / .789	.678 / .786	.699 / .783	.715 / .778
290	.632 / .789	.657 / .786	.680 / .784	.698 / .780
250	.590 / .786	.624 / .786	.638 / .784	.658 / .783
200	.540 / .784	.565 / .784	.586 / .784	.609 / .783

FACTORY LOADED DEFAULTS

DEFAULT PARAMETERS	DEFAULT VALUES 737-3-4-5	DEFAULT VALUES 737-6-7-8-9
Hold pattern leg time below 14,000 ft	1.0 min	same
Hold pattern leg time above 14,000 ft	1.5 min	same
Transition Flight Level (descent)	18,000 ft	same
Transition Altitude (climb)	18,000 ft	same
Climb mode	ECON	same
Cruise mode	ECON	same
Descent mode	ECON PATH	same
Departure airport altitude restriction	250 kt	same
Departure airport altitude restriction	10,000 ft	same
Destination airport altitude restriction	240 kt	same
Destination airport altitude restriction	10,000 ft	same
Thrust Reduction altitude (10.2A and earlier)	1500 ft	same
Thrust Reduction altitude (10.3)	1500 ft	loadable Model/Engine db
Cutback Reduction altitude (10.3)	na	loadable Model/Engine db
Cutback Restore altitude (10.3)	na	loadable Model/Engine db
Takeoff flap setting	5	loadable Model/Engine db
RTA time error tolerance	30 sec	same
Climb min speed CAS	210 kt	same
Climb max speed CAS	340 kt	loadable Model/Engine db
Climb min speed Mach	.400	loadable Model/Engine db
Climb max speed Mach	.820	loadable Model/Engine db
Cruise min speed CAS	210kt	same
Cruise max speed CAS	340 kt	loadable Model/Engine db
Cruise min speed Mach	.400	loadable Model/Engine db
Cruise max speed Mach	.820	loadable Model/Engine db
Descent min speed CAS	210 kt	same
Descent max speed CAS	340 kt	loadable Model/Engine db
Descent min speed Mach	.400	loadable Model/Engine db
Descent max speed Mach	.820	loadable Model/Engine db
Drag Factor	0.0%	same
Fuel Flow Factor	0.0%	same
Maneuver Margin	1.3	loadable Model/Engine db
Minimum cruise time	1 min	same
Minimum R/C - Climb	300 ft/min	same
Minimum R/C - Cruise (U10.0, 10.1, 10.3)	100 ft/min	same
Minimum R/C - Cruise (U10.2 & 10.2A only)	300 ft/min	same
Minimum R/C - Engine Out	100 ft/min	same
Cost Index	Box Prompts	same

H

I

K

L

M

N

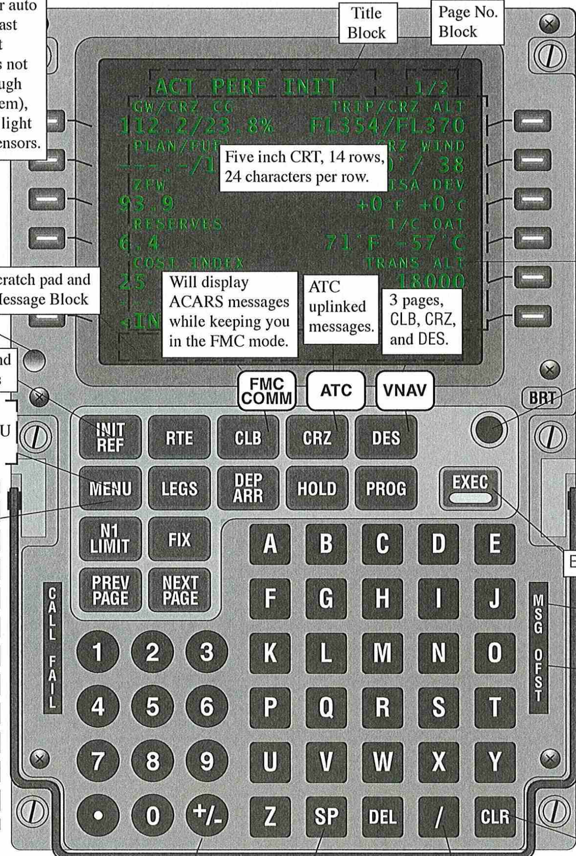
W

X

Z

OFP	P/N	Processor	RAM	NDB size	NDB type
U0	539632	16 bit / 68000	84 kw	96	U1
U1	545271			96	U1
U1.1	547068			96	U1
U1.2	548394			96	U1
U1.3	548720			96, 192	U1, U3
U1.4	549100			96, 192	U1, U3, U5
U1.5	549397			96, 192	U1, U3, U5
U1.6	549791			96, 192	U1, U3, U5
U3	547444		108 kw	96, 192, 288	U3
U3.1	548568			96, 192, 288	U3
U4	548659	16 bit / 68000		96, 192, 288	U3, U5
U5	548925	on ASIC		96, 192, 288	U3, U5
U6	548926		124 kw	96, 192, 288, 512, 1M	U3, U5
U6.1	549260			288, 1M	U3, U5
U6.2	549349			288, 1M	U3, U5
U7	549297-12	32 bit / 68040	512 kw	256, 1M	U3, U5
U7.1	549297-34			256, 1M	U3, U5
U7.2	549297-38			256, 1M	U3, U5
U7.3	549297-41			256, 1M	U3, U5
U7.4	549297-45			256, 1M	U3, U5
U8	549250-15			256, 1M	U3, U5
U8.1	549250-19			256, 1M	U3, U5
U8.3	549250-22			256, 1M	U3, U5
U8.4	549250-26			256, 1M	U3, U5
U10	549849		2M	256, 1M	U3, U5

CONTROL DISPLAY UNIT



- Ambient Light Sensors for auto CRT contrast adjustment
- If screen is not bright enough (day problem), shine map light on these sensors.

Title Block

Page No. Block

Five inch CRT, 14 rows, 24 characters per row.

Data Block

Scratch pad and Message Block

Will display ACARS messages while keeping you in the FMC mode.

ATC uplinked messages.

3 pages, CLB, CRZ, and DES.

Function and Mode Keys

CDU ANCDU only

MCDU only

- CRT Brightness Adjustment
- Visible in 8,000 foot-candle environment.
- When parking the airplane for the night, turn the control to full dim.

EXECute key.

- MSG indicates an alerting / advisory message or pending messages.
- FAIL indicates FMC failure.
- OFST sign is operational on U6 and up. Indicates an offset path is being flown.
- DSPY sign is not presently in use.
- CALL indicates a system not currently under control of the MCDU is requesting service.

Clears Scratch Pad and Advisory Messages.

When entering temperature or an along-track displacement distance, positive values are assumed by the FMC and "+" signs need not be keyed-in. For negative values, key-in the "-" sign.

Space key for MCDU only

- A slash is used to separate scratch pad entries of speed/altitude, wind direction/speed, bearing/range, etc.
- Where both airspeed and Mach can be entered on a line (such as on the CLB and DES pages) simply enter the desired value if only one value is to be entered. A slash is req'd only if entering both airspeed and Mach values.
- U1: If entering only one of the two values, entry of the first value requires use of the slash, such as 250/ for 250 kts or 250°; the slash is optional for entry of only the second value, such as 50 or /50 for range.
- U5 and up: If no slash is used with a single entry, it will be inserted in the field nearest the line select key, i.e., the first entry for a pair on the left side of the CDU and the second entry for a pair on the right side of the CDU.

HOW TO SET UP FOR AN ALTITUDE BUST

You're westbound, cruising at FL280 towards Chicago when Chicago centers says, "***BARNBURNER 100, cross CLAUD at FL 200 and 320 kts***".

You're thinking it's too early to start down, but you do want to increase the speed…

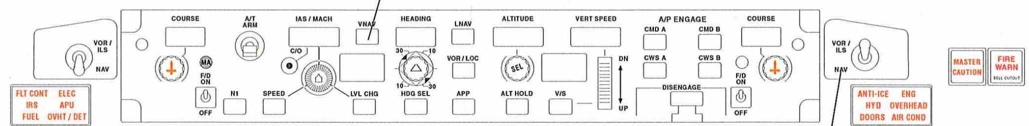
1 Set the new clearance altitude in the MCP (20000)
2 Deselect VNAV to open the speed window (you may not see the FMA change to CWS-P)
3 Wind the speed knob up to 320 kts
4 Take your eyes away from the front panel and you've got a bust as the airplane gently climbs above your cruise altitude.

- Illumination of an MCP light means that a second push will disengage the mode.
- The lack of a light does not mean that a mode is not engaged (ALT HOLD at the MCP altitude and APP for example).
- You must check the FMA to find the engaged mode.

Performance Limit Reversion in V/S mode: -1, -2, and -3 FCCs. When actual airspeed is more than 5 kts below MCP selected airspeed and not increasing, the AFS reverts to LVL CHG.

Example:
On descent and maintaining V/S of 1500 fmp at 300 kts, increasing the speed knob more than 6 kts causes reversion to LVL CHG.

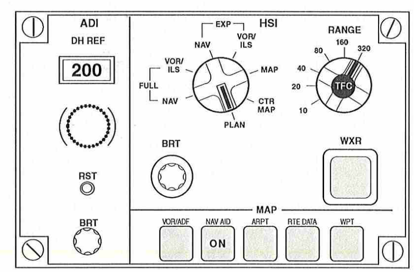
Workarounds:
Deselect A/T mode, thus going to ARM; manually increase speed and adjust MCP speed; re-engage everything when you are at your desired settings, or, de-select V/S, maintain CWS pitch and select new (higher) airspeed; when airspeed is reached, re-select V/S.



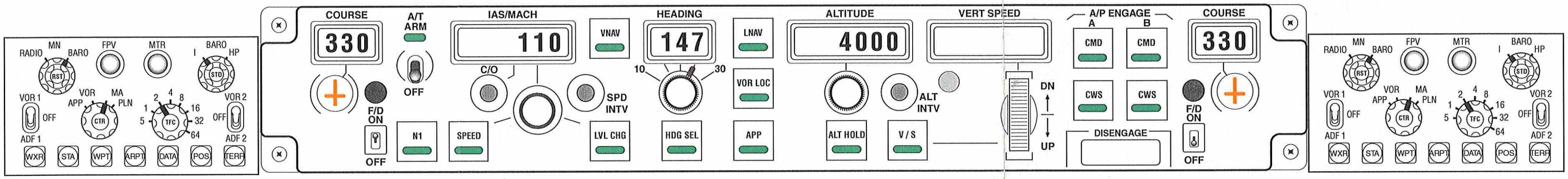
TYPICAL 737 MODE CONTROL PANELS

Non EFIS installation

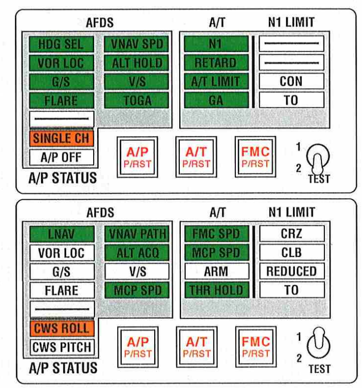
Three types of Control/Display Units (CDUs) are in production:
- CDU - standard CDU (pictured) is a high contrast cathode-ray tube (CRT) that provides interfacing with the FMC.
- Alternate Nav CDU (ANCDU) - It can be used to provide lateral navigation capability in the event of an FMC failure.
- Multi-purpose CDU (MCDU) - It provides interface with other aircraft systems such as ACARS.



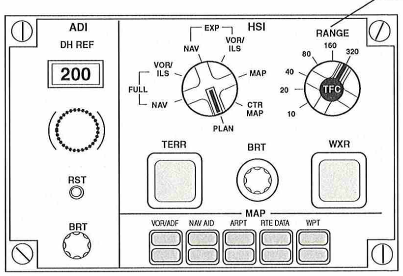
COLLINS MCP



Non EFIS FMA



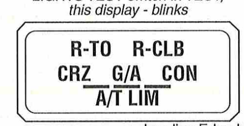
EFIS Control Panel that comes with the 300/500 with GPS.



When EFIS is installed, the FMAs are located in the EADI. The Thrust Mode Annunciator displays N1 thrust modes.

TMA

LIGHTS TEST switch in TEST, this display - blinks



Not endorsed by **any** airline. Attempt to make AC120-29A compliant.
Last change made Jan 29, 2005.

ILS APPROACH
NOTES

PF = Pilot Flying / PM = Pilot Monitoring

B737 PROFILES
PF = Pilot Flying
PM = Pilot Monitoring

CAT I: DA/MDA ≥ 200 Visibility ≥ 1/2 mile or RVR ≥ 1800
1. Requires one transmissometer.
2. If both autopilots are inop, the Monitored Approach Procedure should still be used with the FO flying manually.
3. CAT I or Non-precision approach, PM will call ***"Approach lights in sight"***, and/or ***"Runway in sight"***. Informative, not directive.
4. When conducting non-precision or CAT I ILS approach, you may descend to 100' above TDZE with approach lights in sight.
5. May not descend below 100' above the TDZE unless visual reference to the runway is established.
6. MDA and DA *altitude* value measured by barometric altimeter and is controlling. *Height* value from a radio altitude is advisory.
7. CAT I using MDA are: VOR, LOC, NDB, RNAV without VNAV.
8. CAT I using DA are ILS and RNAV with VNAV.

CAT II: DH ≥ 100 RVR ≥ 1200 RVR ≥ 1000*
1. Will be made with autoland if a/c and crew are autoland capable.
2. Single autopilot is authorized to CAT II minimums.
3. First Officers, think of taking it to the DH then to a missed app.
4. *Height* value (DH), based on RA, is used for CAT II ops except where procedures have "Radio Altitude Not Authorized" (RA NA). Due to irregular underlying terrain, typically use the first indication of arrival at the inner marker as a means to establish DH. A*ltitude* value (DA) measured by barometric altimeter is advisory.
5. CAT II Autoland and CAT IIIA procedures are the same except for the decision height.
6. For CAT II, TDZ, MID, and ROLLOUT RVR should be provided for any runway over 8000 ft.; TDZ and ROLLOUT for runways less than 8000 ft.
7. You are required to have landing minimums prior to GS intercept altitude. If weather goes below landing minimums once established on the glideslope, you may continue to landing on CAT I or CAT II approach if approach lights, red terminating bars, runway end lights, touchdown zone lights, etc are visible at miminums.
8. May not descend below DH unless visual reference to the CAT II lighting system is established.

* If published as the approach minima.

If weather conditions are below 4000 RVR or 3/4 mile visibility a FD must be used or a coupled approach must be made.
LOW VISIBILITY APPROACHES (CAT I, II, III)
If TDZ RVR is at or below 2400 (defines a low visibility approach)
a. monitored Approach should be flown,
b. autopilot should be used,
c. the crew must brief (and fly) the category of approach having the lowest minimum applicable to facility, aircraft, and crew.
If TDZ RVR is at or below 1800 an auto-coupler is required.
If TDZ RVR is below 1600, two transmissometers are required.
If TDZ RVR is below 1200
a. autoland is required,
b. braking action must be fair or better,
c. takeoff or landing ops require Surface Movement Guidance and Control System (Low Visibility Taxi Procedure - ICAO)

CAT III: DH < 100 or no DH RVR < 1200
CAT IIIA: DH < 100 or no DH RVR ≥ 600
~~CAT IIIB: DH < 50 or no DH RVR < 700 but ≥ 150~~
1. Requires 737-NG and autoland.
2. SMGCS defines Low Visibility Taxi Routes and goes into effect when visibility is less than 1200 RVR.
3. Four operational differences between CAT II Autoland and CAT IIIA approach:
   a. Status annunciator must indicate CAT IIIA
   b. RVR minimums for CAT IIIA approach have specific transmissometer requirements (3). (See chart at bottom)
   c. CAT IIIA procedure using a fail-passive autoflight system incorporates a DH set on RA (or an equivalent IM position fix).
   d. Captain makes additonal callouts of "***200***" at 200 ft above TDZE and "***Approaching minimums, I'm going heads up***" at 150 ft above TDZE.
4. You are required to have landing minimums prior to GS intercept altitude. And, you must have the minimum RVR for landing prior to the DH. (May continue to landing if you can use CAT I or II criteria.)

FAIL PASSIVE
A system which, in the event of a failure, causes no significant deviation of aircraft flight path or attitude.

AC 120-29A groups instrument approaches into 3 categories:
(a) xLS
- ILS, MLS, GLS (Global Landing System)

(b) RNAV
- FMS, RNAV using traditional VOR/DME sensors, GNSS

(c) Instrument Approach Procedures other than xLS or RNAV
- traditional approaches such as VOR, NDB, LOC, LOC Back crs, and ASR

Visibility	RVR
1	5000
3/4	4000
1/2	2400
1/4	1600

APPROACH TYPE	BARO SET TO	RA SET TO
CAT I	**Published DA**	Published DH
CAT II	Published DH (TDZE + 200 ft)	**Published RA**
CAT IIIA	TDZE + 50 ft	**50 ft RA**

BOLD indicates controlling altimeter.

GENERAL:
1. Captain briefs Monitored Procedure; FO briefs the approach chart.
2. Flaps 40 slightly more sight over nose
   a. Landing lights optional, cockpit lights low
   b. Max Seat height (consider sighting of FMA)
   c. Autobrakes req'd - recommend 3 and don't kick off till < 80 kts.
   d. Start APU for backup electrics and check stby ADI in ILS APP.
3. ATC is required to have approach/runway lights on step 5.
4. Non-EFIS CAT II ops, both Captain and First Officer must position HSI switch to VOR/ILS prior to commencing the approach.
5. -500: This step not required for NG
   Both pilots must select MANUAL prior to commencing the approach to display ILS data on ADI.
6. Except for dual-channel approach and autoland, autothrottle must be disconnected prior to: non-autoland ILS, no lower than 50 ft AGL non-precision or visual, no lower than 100 ft AGL
7. CAT II and III approaches will not be flown if LLWAS or windshear with reported airspeed gain or loss is greater than 10 kts.

AUTOLAND:
1. Status annunciator will be either CAT IIIA on NG 737 or CAT II AUTOLAND on all other aircraft.
2. Autothrottle and two autopilots are required – criteria for engagement are: valid ILS frequency in both nav radios, same inbound course in both course windows, and APP armed.
3. If you practice an autoland with RVR >2400, ask Approach and Tower for "Beam Protection for autoland". ATC does not hold a/c short of the ILS Hold Short Line until 800 and/or 2 nm. The ILS signal is not protected from airborne interference (i.e. a/c ahead of you) until wx goes below 200 ft ceiling and/or 2000' RVR.
4. When cleared for the approach, arm APP and engage second A/P. If the second A/P is not engaged by 800 ft RA it is locked out.
5. After G/S capture and 1500 ft the second A/P pitch channel is engaged and the ILS Deviation Warning Test is performed. SINGLE CH disappears and FLARE ARMED is annunciated. Dual A/P GA is armed.
6. If FLARE is not armed by 350 ft RA both A/Ps disengage.
7. After touchdown, Captain must disconnect A/P because there is no automatic tracking of centerline.
8. On a missed approach, when LVL CHG is selected at 1000 ft AGL, the last autopilot engaged will disconnect; this will be "A" A/P under normal operations. The Captain, if flying the missed, should be aware that "B" A/P might be the master.
9. Wind limits: headwind 20 kts, crosswind 15 kts, tailwind 10 kts.

	Down to:	Visibility Requirements:	TDZ	MID	ROLLOUT	NOTES	LIGHTS	RVR
CAT I	DA(H)/MDA ≥ 200	Visibility ≥ 1/2 mile or RVR ≥ 1800	Required Controlling	Not req'd Advisory	Not req'd Advisory	MID can sub for TDZ if inop	TDZ and CL	* *
CAT II	DH ≥ 100	RVR ≥ 1200 *	Required Controlling	Not req'd Advisory	Not req'd Advisory	No Substitutions	HIRL, TDZ, CL ALSF I, II, ICAO	* *
CAT III	DH < 100	RVR < 1200	Required Controlling	Required Controlling	Required Advisory	If only two, both control.		* *
CAT IIIA	DH < 100	RVR ≥ 600	Required Controlling	Required Controlling	Required Advisory			* * *
~~CAT IIIB~~	~~DH < 50~~	~~RVR < 600 but ≥ 150~~						* * *

* For CAT II approaches: if TDZ RVR is below 1600, an advisory Mid or Rollout RVR must be reported.
≥ 1000 if published as the approach minima

All US Cat I operating minimums below 1/2 statute mile (RVR2400) and all Cat II and III operating minimums are based on RVR.
** Controlling RVR must be at or above minimums prior to final approach segment.
*** Controlling RVR must be at or above mins prior to final approach segment and prior to descent below DH.

Not endorsed by **any** airline. Attempt to make AC120-29A compliant.
Last change made Jan 29, 2005.

VOR, LOC, LOC (Back Crs), NDB

(Single FMC and DME-DME Updating) (Dual FMC and GPS) / CAT I

B737 PROFILES
PF = Pilot Flying
PM = Pilot Monitoring

APPROACH MATRIX for 300-500 EFIS / non-EFIS

RNAV	modes:	LNAV & VNAV / NA
	displays:	PF - Map (10 mi scale) & AUTO PM - Map (10 mi scale) & AUTO
	RNP:	per chart or .3
GPS		NA
LOC*	modes:	VOR LOC & VNAV
	displays:	PF - Map & MAN / VOR-ILS & MAN PM - Map & AUTO / NAV & AUTO
LOC BC*	modes:	LNAV & VNAV
	displays:	PF - Map & AUTO / NAV & AUTO PM - VOR ILS & MAN
VOR*	modes:	VOR LOC & VNAV
	displays:	PF - VOR ILS & MAN PM - Map & AUTO
NDB*	modes:	LNAV & VNAV
	displays:	PF - Map & AUTO / NAV & AUTO PM - Map & AUTO / NAV & AUTO

* Raw data display required

APPROACH MATRIX for 700/800/900

RNAV	modes:	LNAV & VNAV
GPS	displays:	PF - Map (10 mi scale) PM - Map (10 mi scale)
	RNP:	RNAV = per chart, GPS = .3
LOC*	modes:	VOR LOC & VNAV
	displays:	PF - Map (10 mi scale) PM - Map (10 mi scale)
LOC BC*	modes:	LNAV & VNAV
NDB	displays:	PF - Map (10 mi scale) PM - Map (10 mi scale)
	RNP:	.5 if no raw data display
VOR**	modes:	LNAV & VNAV
	displays:	PF - Map (10 mi scale) PM - Map (10 mi scale)
	RNP:	.5 if no raw data display

* Raw data display required
** Caution: Chart wpts may not match LEGS page

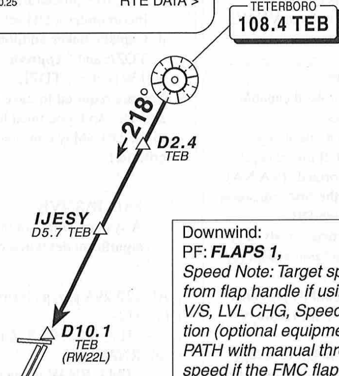
NOTES:

1. At each ALT HOLD, set the next altitude (or zero at FAF), and stay ahead of the airplane.
2. VNAV may be used for descent to the DA or MDA if a GP leg exists from the FAF to the runway. The approach must be selected from the database. Flying a constant angle vertical path using VNAV is an excellent tool. There's no need for a VDP and there is no level-off segment. No runway at minimums? ... start the missed approach climb.
3. If using a DA, set the minimum bugs on the primary altimeters to the DA.
4. CO is authorized to set the MDA if the ball flag is present. If no ball flag, use MDA/DDA Rule.
5. **MDA/DDA Rule:** If using VNAV with an MDA, calculate a Derived Decision Altitude (MDA plus 50') and set the DDA on the baro. altimeter.

ACT RTE LEGS 1/2

218°	5.0 NM	
TEB		190 / 3000
218°	2.4 NM	
CF22L		170 / 2500
220°	3.3 NM	
IJESY		148 / 1500
220°	4.4 NM	GP 3.0°
RW22L		132 / 53
218	0.2NM	
(2000)		---- / 2000A
RNP / ACTUAL ----------------		
0.50 / 0.25		RTE DATA >

- The non-EFIS 737 is not approved for an RNAV approach, but LNAV may be used for an approach that has raw data backup, such as the NDB, VOR, LOC or LOC (Back Crs).
  Raw data must be monitored and is controlling.
- The non-EFIS 737 can use VNAV (ref: NOTES on this page)
- No RNP requirement for approaches using raw data.
- A VOR or NDB approach in aircraft with dual FMS and GPS has RPN requirement of .5 and raw data is not required.



VNAV GOTCHAS:

- Intercepting the wrong wpt.
- Arriving at the FAF with too much energy (too fast)
- Forgetting to dial zero in MCP altitude prior to FAF.
- Forgetting to engage VNAV at FAF.

Downwind:
PF: ***FLAPS 1,***
Speed Note: Target speed comes from flap handle if using VNAV. Use V/S, LVL CHG, Speed Intervention (optional equipment), or VNAV PATH with manual throttles to set speed if the FMC flap-derived speed is undesireable.

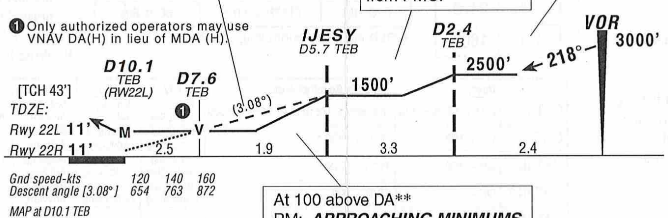
- During the vector phase:
  PF: **APPROACH CHECK**
- On base leg:
  PF: **FLAPS 5**
  See Speed Note.
- Intercept-leg-to a wpt on the final approach course. This can be tricky. To anticipate the wpt the controller is looking at, consider the altitude you're cleared to descend to.

Press TOGA - If A/T is on, press once for reduced thrust, twice for full thrust.
If A/T is off, straight-arm throttles to cursors.
Single A/P
A/P disengages. Manually rotate to 15°.
PF: ***FLAPS 15, CHECK POWER ...***
POSITIVE RATE, GEAR UP
CHECK MISSED APPROACH ALTITUDE
A/T advances to GA/N1 thrust if ON.
GA/N1 is annunciated.
Speed cursor displays maneuvering speed for flap setting.
FD initially commands 15° pitch and a bank to maintain existing ground track.
Pitch stays in TOGA until altitude acquire or other pitch mode is selected.

Approaching the FAF in ALT HOLD:
Set MCP to zero and engage VNAV.
Check FMA for LNAV and VNAV PATH.
PF: **FLAPS 30 / 40**
Target speed comes from FMC.

Approx. 4 miles from FAF:
PF: ***GEAR DOWN***
FLAPS 15,
LANDING CHECK
See *Speed Note.*

* On course for RNAV Approach:
XTK ERR less than RNP entry (.3 nm deviation limit for RNP .3), or on 10 mile scale, the magenta route must not exceed the width of the aircraft symbol without correction. Approximately 1800 ft.
** For non-precision approaches that use a VNAV path, the minimum altitude may be specified as a decision altitude - DA (H). You may rotate through the DA during a missed approach.
If a DA is not published, add 50 ft to the MDA and treat as a DA.



Gnd speed-kts	120	140	160
Descent angle [3.08°]	654	763	872

MAP at D10.1 TEB

STRAIGHT-IN LANDING RWY 22L
MDA(H) **840'** (829')

At 100 above DA**
PM: ***APPROACHING MINIMUMS***
At DA:
PM: MINIMUMS

VPA DEVIATIONS	
A/P TEMP	ACTUAL VPA
+30°C	3.2°
+15°C	3.0°
0°C	2.8°
-15°C	2.67°
-31°C	2.5°

(-300/500)
FLAP MANEUVER SPEEDS

Flaps	≤ 117.0*	> 117.0*
0	210	220
1	190	200
5	180	190
10	170	180
15	150	160
25	140	150

*with Rudder Pressure Reducer

BOLD ITEMS - Req'd call

Not endorsed by **any** airline. Attempt to make AC120-29A compliant.
Last change made Jan 29, 2005.

RNAV (GPS) APPROACH

(Single and Dual FMC, with/without GPS) / CAT I

B737 PROFILES
PF = Pilot Flying
PM = Pilot Monitoring

1. RADAR required.
2. Baro-VNAV not authorized below -15°C (5°F).
3. GPS or RNP-0.3 required.
4. DME/DME RNP-0.3 not authorized.

	STRAIGHT-IN LANDING RWY **26L** LNAV / VNAV DA(H) **580'** *(483')*	ALS out
A B C D	RVR 60 or 1 1/4	1 3/4

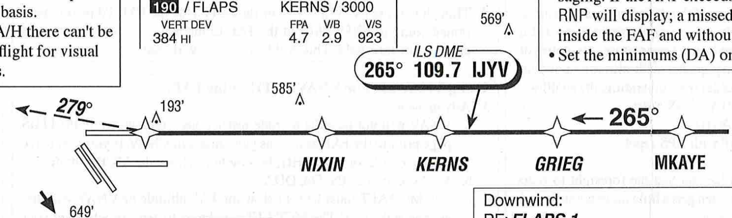
- Check procedure notes and minimums for important information such as equipment, RNP requirements, etc. VOR-DME updating is never allowed for RNAV.
- This approach is not authorized with only DME-DME updating.
- The RNAV approach without GPS requires special approval and may be possible on an airport-to-airport basis.
- With a DA/H there can't be any level flight for visual references.

- In this example, the next stepdown in VNAV PATH will begin in .7 nm. It is displayed on the Map by a green donut with this label.
- Consider doing stepdowns in VNAV SPD or a MCP tool to make things less confusing.

ACT 300 KT SPD DES 1/1
E/D ALT 149 | AT KERNS 173 / 3000
TGT SPD .780 / 300 | TO T/D - 4000 1342.1z / 0.7NM
SPD REST **190** / FLAPS | WPT / ALT KERNS / 3000
VERT DEV 384 HI | FPA 4.7 V/B 2.9 V/S 923

- Aircraft with single FMC and DME-DME updating may be authorized for RNAV approach to specific airports.
- Single FMC installations require special missed approach instructions in case of FMC failure. If the FMC fails, climb on an initial heading consistent with the published missed approach. Report to ATC that you have lost RNAV capability.
- These approaches must be selected from the database.
- After selecting the desired approach, verify the approach on the LEGS page matches the chart.
- RNAV RNP approach requirements per the chart. GPS approach requires RNP .3
- Manual entry of RNP in the LEGS page for "field of view" messaging. If the ANP exceeds the RNP, UNABLE REQD NAV PERF-RNP will display; a missed approach is required if this displays inside the FAF and without visual cues.
- Set the minimums (DA) on the baro altimeter.

- Speed entries on the LEGS page are not required since speed control comes from the flap handle or from the speed window if using Speed Intervention.
- Any approach using LNAV should be flown with the autopilot or FD. AP recommended to reduce lateral error.
- From the APPROACH REF page, select the WIND CORR and VREF speed. This sets the target speed at the runway wpt on the LEGS page.



RNAV / VNAV GOTCHAS:
- Intercepting the wrong wpt.
- Arriving at the FAF with too much energy (too fast)
- Forgetting to dial zero in MCP altitude prior to step-downs and prior to FAF.
- Forgetting to engage VNAV prior to the FAF.

Downwind:
PF: ***FLAPS 1,***
Speed Note: Target speed comes from flap handle if using VNAV. Use V/S, LVL CHG, Speed Intervention (optional equipment), or VNAV PATH with manual throttles to set speed if the FMC flap-derived speed is undesireable.

- During the vector phase:
  PF: ***APPROACH CHECK***
- On base leg:
  PF: ***FLAPS 5***
  See *Speed Note.*
- Intercept-leg-to a wpt on the final approach course. This can be tricky. To anticipate the wpt the controller is looking at, consider the altitude you're cleared to descend to.
- Cleared for approach: Engage LNAV*

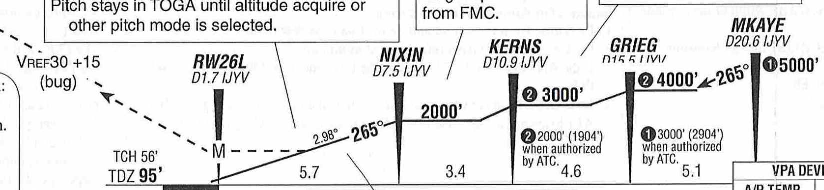
1000' AFE and VREF30 + 15
PF: ***LEVEL CHANGE***
SET TOP BUG
FLAPS 5
At VM5
PF: ***FLAPS 1***
At VM1
PF: ***FLAPS UP***
AFTER T/O CHECK
Climb to 3000 ft AFE at VMO
3000 AFE: VNAV or SET 250

400'
PF: ***HDG SEL*** or ***LNAV***
Tell tower of Missed and intentions.

Press TOGA - If A/T is on, press once for reduced thrust, twice for full thrust.
If A/T is off, straight-arm throttles to cursors.
Single A/P
A/P disengages. Manually rotate to 15°.
PF: *FLAPS 15, CHECK POWER ...*
POSITIVE RATE, GEAR UP
CHECK MISSED APPROACH ALTITUDE
A/T advances to GA/N1 thrust if ON.
GA/N1 is annunciated.
Speed cursor displays maneuvering speed for flap setting.
FD initially commands 15° pitch and a bank to maintain existing ground track.
Pitch stays in TOGA until altitude acquire or other pitch mode is selected.

Approaching the FAF in ALT HOLD:
Set MCP to zero and engage VNAV.
Check FMA for LNAV and VNAV PATH.
PF: ***FLAPS 30 / 40***
Target speed comes from FMC.

Approx. 4 miles from FAF:
PF: ***GEAR DOWN***
FLAPS 15,
LANDING CHECK
See Speed Note.



* Established on inbound track for RNAV Approach: 10 mile scale: the magenta route must not exceed the width of the aircraft symbol without correction. Approximately 1800 ft.

** For RNAV approaches, the minimum altitude may be specified as a decision altitude - DA (H). You may rotate through a DA during a missed approach.
If a DA is not published, add 50 ft to the MDA, call it a DDA, and treat as a DA.

At 100 above DA**:
PM: ***APPROACHING MINIMUMS***
At DA:
PM: MINIMUMS

VPA DEVIATIONS

A/P TEMP	ACTUAL VPA
+30°C	3.2°
+15°C	3.0°
0°C	2.8°
-15°C	2.67°
-31°C	2.5°

(-300/500)
FLAP MANEUVER SPEEDS

Flaps	≤ 117.0*	> 117.0*
0	210	220
1	190	200
5	180	190
10	170	180
15	150	160
25	140	150

*with Rudder Pressure Reducer

BOLD ITEMS - Req'd call

Not endorsed by **any** airline. Attempt to make AC120-29A compliant.
Last change made Jan 29, 2005.

RNAV APPROACH
NOTES

RNAV Considerations:
1. The RNAV Approach (or GPS Approach) is designed to be flown in LNAV and VNAV (BARO VNAV).
2. The RNAV approach in the 737 is not as easy as the ground based ILS but it beats the traditional step-down technique.
3. Practice in VFR conditions, especially if parallel approaches are being conducted. Do not wait until you actually need this tool to use it. With the A/P engaged, take the airplane right down to minimums to see just how well it lines up with the landing threshold. Expect a GPS updated system to perform the best.
4. BARO VNAV presents computed vertical guidance referenced to a specific vertical path angle (VPA). The computer resolved vertical guidance is based on barometric altitude. The correct setting of the altimeter does not correct for non-standard temperature. The only way to meet this requirement is to observe the limiting minimum aerodrome temperature annotated on the chart. Errors become proportionally greater with altitude above the altimeter site, usually an airport. The colder the temperature, the shallower the actual angle flown. Ref: VPA DEVIATIONS chart.
5. (300-500) Place both nav switches in AUTO.
   (700-800) You will notice a lower ANP with GPS input.
6. Speed Control:
   a. If your airline's management team has not had the foresight to order Speed Intervention, the RNAV Approach gets a little more complicated. (You can tell where I stand on this issue)
   b. Speed Intervention allows one to control speed using the open IAS / MACH window while remaining in VNAV.
   Speed Intervention should be standard equipment on the 737, just as it is on all the Big Boeings, but the factory does not see it that way.
   c. It hardly needs to be said that in today's environment, most approaches to a hub airport come with speed clearances from the approach controller. For the crew flying the 737 without Speed Intervention, you have two choices for speed control; use the Mode Control Panel V/S or LVL CHG, which opens the IAS / MACH window, or use VNAV, in which case the target speed follows the flap handle! VNAV offers altitude protection on the LEGS pages, but you may have to disconnect the autothrottle and set the throttles manually. The flap handle derived speed may not match the speed clearance (or your own desired speed). Do not use VNAV SPD with manual throttles.
7. Use the autopilot. This will reduce the chance of cross-track error. On the 10 mile range, the magenta route must not exceed the width of the airplane symbol.
8. When accomplishing the APPROACH CHECKLIST include/consider the following 2 items that are easily forgotten:
   RANGE SELECTOR..............................10 MILES
   RNP.......................... CHECKED / ENTERED (.3)

Using V/S or LVL CHG to the FAF
1. Advantages:
   a. For the crew without Speed Intervention, V/S or LVL CHG is the easiest method of meeting an ATC speed clearance during the stepdown phase; use of the autothrottles may be maintained throughout the approach.
   b. If there is no ATC speed clearance, VNAV SPD or VNAV PATH can be used.
2. Disadvantages:
   a. Each stepdown must be entered in the MCP ALT select.
   b. Tell your teammate to remind you to reset the MCP ALT after each ALT HOLD.
3. Monitor stepdowns using the green altitude trend vector.
4. Though you can use V/S to follow the PDI inside the FAF, I'd recommend transitioning to VNAV PATH at the FAF to maintain the constant vertical angle to the threshold. This will lower your workload.

Using VNAV SPD or VNAV PATH to the FAF:
1. Advantages:
   a. VNAV will not bust the altitude restrictions (stepdowns) on the LEGS page prior to the FAF as long as you remain in VNAV. If you ever leave VNAV or V/S or LVL CHG, be sure to re-check the MCP altitude.
   b. VNAV may bust the DA/DDA.
   c. The MCP ALT must be set below the FAF altitude or VNAV will disengage at the FAF. The MCP ALT may be set to zero (or whatever your SOP calls for).
2. Monitor stepdowns using the green altitude trend vector.
3. I recommend using VNAV SPD for step-downs because it's confusing trying to figure out when PATH will start each idle descent (unless you have the geometric point-to-point option).
   a. In VNAV SPD the airplane will descend at idle throttle at the active speed to the next altitude restriction on the LEGS page. Just like LVL CHG, it is not slaved to the path, but to speed.

Arriving at the DA:
If one of the *required visual references* is not in sight prior to the DA you must level off at the DA. This will result in a mandatory missed approach. Ideally, you want the runway in sight prior to DA/DDA. When the field is in sight, disconnect the autopilot no later than 50ft below the DA/DDA and continue the approach visually.
Initiate a Go-Around for the following:
1. Deviation from the lateral and vertical path, as described.
2. Lack of adequate visual references at minimums.
3. If the ANP exceeds the RNP inside the FAF (message UNABLE REQD NAV PERF).
4. Next Generation a/c with U10.2 software and up allows winding the MCP ALT to the missed approach altitude after passing the FAF by a few hundred feet.

VNAV PATH vs VNAV SPD
VNAV PATH
   a. The vertical flight path is slaved to the PDI.
   b. VNAV PATH will be indicated on the FMA if in VNAV.
   The DES page will be titled ACT PATH DES.
   c. The active speed will be highlighted at 3L on the DES page.
   d. When being vectored for the approach, it will be a speed from the SPD REST field such as 240 or 210 or it may be flap driven such as 190 / FLAPS
   e. Unless you have the geometric point-to-point option (CO does not), the airplane will fly level until intercepting the next step-down path. Active speed is controlled by the flap-handle, or the Speed Intervention window (optional equipment).
   f. For those without speed intervention, disconnecting the autothrottle allows manual control of the airspeed if needed.

VNAV SPD
   a. The vertical flight path is slaved to the active speed on the DES page or the Speed Intervention window; it is very similar to LVL CHG.
   b. VNAV SPD will be indicated on the FMA if in VNAV.
   The DES page will be titled ACT SPD DES.
   The PATH > prompt will be displayed at LSK 5R if the XTK ERR is less than the RNP and can be re-selected. The PATH > prompt will appear after an intercept-leg-to followed by engagement of LNAV or after a direct-to operation.
   c. The active speed will be highlighted at 3L on the DES page.
   d. When being vectored for the approach, it will be a speed from the SPD REST field such as 240 or 210 or it may be flap driven such as 190 / FLAPS

Arriving at the FAF:
1. Don't arrive at the FAF with excess energy. If the controller requests ***"190 to the marker"***, just say ***"Unable"***
2. Desireable configuration:
   4 miles from FAF – Gear down, Flaps 15
   PDI approaching center – Flaps 30
3. Though you can use V/S to follow the PDI, I recommend VNAV; this will lower your workload. If you press the VNAV button (sometimes necessary to hold for a couple of seconds) but it does not engage, then as a backup, use V/S to follow the PDI. Teach yourself how to use the FPA, V/B, and V/S information on the DES page. You did remember to spin the MCP ALT to zero before pressing the VNAV button didn't you?
4. The FMC will automatically change to VNAV PATH when you reach a LEG with a Gradient Path (GP). Gradient Path is a leg with an angle contained in the database, so there's no need to select the PATH prompt (DES page) prior to reaching the marker.
5. The target speed will come from your selection of the VREF on the APPROACH REF page plus the WIND additive. The target speed is active when the gear and landing flaps are selected. If you forget to make your VREF selection, the target speed will not go below the flaps 15 speed, and you'll get a message APPRCH VREF NOT SELECTED.

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Last change made Jan 29, 2005.

CONSTANT ANGLE

Pilot Procedural Technique

(This is not "Vertical Guidance" (VNAV) or an RNAV Approach)

Calculating a VDP

4 ways to compute VDP, ranked by accuracy and ease of use:

VASI - but won't work if in the clouds or greater than 4 nm.

Angle (V/B) indication on DEScent page

Enter runway wpt and threshold altitude at 3R of DES page.

Assuming you are level at the MDA, the VDP is reached when the V/B indicates 2.8 to 3°. Ref: Procedures B and C. This takes study and practice but works great!

DME

300 ft per mile = 2.8° slope. Divide HAT by 300.

Ex: LOC 26 IAH. HAT at MDA is 464 ft. Divide by 300 = 1.5 nm needed to descend from MDA to runway.

VDP is 1.5 nm from runway threshold or D3.2 IJYV. (1.7 + 1.5)

Timing

For 130 kt gs: 10 ft per second = 2.8° slope.

[Time from FAF to MAP] minus [10% of HAT]

Ex: NDB 26 IAH. HAT at MDA is 624 ft or 62 seconds.

FAF to MAP is 2:27 at 140 kts. Subtract 62 = 1:25. So, FAF to VDP is 1:25. This is a rough estimate.

For each 10 kts above 130 kt groundspeed, add 10 seconds.

V/S Selection at a 2.8° point such as the OM or the VDP:

Divide the groundspeed by two. Add a zero. Ex: 140 kts = 700 fpm

This rate of descent will equal a 2.8° angle. Add 50' for 3°. (750 fpm)

CAUTION: As you descend, the ground speed usually decreases, necessitating a corresponding decrease in the selected vertical speed. Good rule of thumb when you're up to your knees in alligator ponds at night.

BUILDING A RUNWAY WAYPOINT

ILS Approach loaded and no need to display step down altitudes.

1. From the ARRIVALS page, select the ILS approach.
2. Delete all altitudes on the LEGS page except the altitude at the runway. Of course you don't want to use this technique when you plan to use these "LEG" altitudes on an RNAV approach.
3. When being vectored in HDG SEL, do an intercept-to or direct-to a wpt on the approach or the runway itself.
4. The V/B on the DES page will display your angle to the runway because it's the only wpt on the LEGS page left with a hard altitude.
5. Note: There can be no DISCOs on the LEGS page prior to the runway.

Altitudes desired to be left on LEGS page.

1. From the ARRIVALS page, select the runway or ILS approach.
2. Not req'd for 10.5 and up. Using the Along Track Wpt feature, place the runway in the s/p, type **/-.1** after it, and place back on top of the runway. A wpt one tenth of a mile inside the threshold will appear. Downselect this new wpt to the s/p and press the ERASE prompt. Now the LEGS page is unchanged. The new wpt in the s/p. This is your new runway threshold wpt. Put this created wpt in a FIX page for storeage for use later. (Ex: RW201)
3. When desired, place your runway wpt from the FIX page to the scratchpad and add the desired altitude to it. Example using RW26, we'd put RW201/0180 into 3R of the DES page. This wpt created .1 nm inside the runway always needs 30 feet more than the threshold crossing height. (needs 4 characters for altitude)
4. The V/B on the DES page will display your angle to the runway.

Non EFIS with U1.x (old) software

1. Must be manually built; two ways.
   Your teammate must back you up in constructing this wpt.
   (a) Retrieve the destination runway's coordinates using the REF NAV DATA page. Write them down then use REF NAV DATA again to build a wpt using these coordinates. Example: Name it R26
   (b) The runway wpt can also be built using a Place-Bearing/Distance method from the OM/FAF.
   Example: NDB approach to RW26 at IAH: NIXIN265/5.7
2. Put this created wpt in a FIX page for storeage and use later.
3. When desired, place your runway wpt from the FIX page to the s/p and add the desired altitude to it. Example using R26, we'd put R26/0150 into 3R of the DES page. The V/B on the DES page will display your angle to the runway.

PROCEDURE A
STEP DOWN PROCEDURE

1. Arrive at the FAF fully configured and at target speed.
2. The MDA should be set in the MCP ALT SEL window. V/S is armed.
3. At the FAF, dial 1000 to 1500 fpm descent in the V/S window.
4. At 1000 AGL, reduce V/S to 1000 fpm.
5. At MDA, (ALT HOLD annunciated) set missed approach altitude. V/S is armed.
6. If field is in sight start descent at the VDP, not before or after.
7. If field does not appear before the VDP fly to the missed approach point and accomplish the missed approach procedure.

PROCEDURE B
CONSTANT ANGLE (VNAV inside FAF not available)

1. At cruise and before briefing the approach, build a wpt at the runway threshold. Ref: *BUILDING A RUNWAY WAYPOINT.*
2. Plan to shoot the VOR or LOC approach with raw data. Use LNAV for an NDB and LOC Back Crs approach, but monitor raw data as it is controlling.
3. While being vectored, take the created wpt from the FIX page and place in 3R of the DES page with the desired altitude. Now you can monitor your angle from the runway by watching the *angle indicator* (V/B). Displays on the DES page at lines 3R and 4R will not interfer with a VNAV PATH/SPD descent. Think ANGLE, not PATH, when looking at the V/B. (Angle calculator)
4. While being vectored for the approach, accomplish an intercept-leg-to the applicable wpt and select the DES page to monitor the angle to the runway.
5. The V/B tool needs an accurate FMC position. The easiest way to check FMC position accuracy is to monitor the ANP. If you don't have ANP, a technique is to compare the LOC or VOR DME (RDMI) to the RNAV DME (FIX page). (Example: Raw data IGHI DME (110.9) vs: RNAV IGHI DME (IGHI entered in the FIX page.)
6. Arrive at the FAF fully configured and at target speed. The MDA should be set in the MCP ALT SEL window. V/S is now armed.
7. At the FAF, check the angle indicator; when it reaches 2.8°, and not until, thumbwheel the V/S that is indicated at line 4R of the DES.
   You're actually setting the FPA to 3°! The angle indicator (V/B), right next to the V/S display, shows the angle you are to the threshold. Do not let it get less than your own limit - mine is 2.8°. (2.75° - 3.77° are considered standard). It's best just to *bracket* 3°. Now keep the FPA at 3° using the V/S thumbwheel.
8. As you descend, the wind usually changes; the V/S required to maintain a 3° V/B will also change - it is very dynamic. If you get below 2.8°, set V/S to zero until the angle is within your desired range. The required V/S is usually higher at the FAF than at lower altitudes. You'll go below your desired V/B if your V/S is greater than that displayed at line 4. You'll find the angle indicator and FPA indicator very handy tools.
9. When the field is in sight, continue flying the V/S that maintains the 3° FPA, then take over visually. You'll be impressed with the smoothness of this technique. Caution: Don't use the FPA or V/B below the MDA or if the FMC position is not accurate.
10. If the field does not come in sight prior to the MDA, level at the MDA, set the missed approach altitude and continue to the missed approach point. Don't dive for the runway after passing the VDP or if the angle indicator is in excess of your own limit. (Don't rotate through the MDA unless your governing body has approved such a maneuver; the MDA cannot be treated like a DH.)

PROCEDURE C
STEP DOWN PROCEDURE
USING V/B FOR VDP

Steps 1 through 6 are the same as Procedure B.

(Steps 7, 8, and 9 are the same as steps 3, 4, and 5 of Procedure A.)

7. At the FAF, dial 1,000 to 1,500 fpm descent in the V/S window.
8. At 1000 AGL, reduce V/S to 1000 fpm.
9. At MDA, (ALT HOLD annunciated) set missed approach altitude. V/S is armed.
10. When the field comes in sight, start descent when the V/B indicates 2.8°, not before. Dial the V/S that is displayed at line 4R.
11. If field does not appear before the V/B indicates 3.0°, fly to the missed approach point and accomplish the missed approach procedure.

LEARNING PROCEDURE

Learn how to shoot Procedure B or C approaches by practicing when an ILS is being conducted in visual conditions. You'll learn how to quickly set the FMC up and how the V/B and V/S indications on the DES page operate. This will lead to confidence in the procedure.

Notes

The Constant Angle technique is only recommended if you do not have the capability of using VNAV. VNAV is superior to this Constant Angle technique because there's less work involved in setup, and the A/P can be coupled to the VNAV path. However, the RNAV approach must be contained in the database with a GP leg and your aircraft must be capable of such an approach; and your carrier must allow and train the procedure.

For non-precision approaches that do not have vertical guidance, the minimum altitude may be specified as a minimum descent altitude - MDA (H). You cannot rotate through the floor of an MDA.

For non-precision approaches that use a VNAV path, such as the RNAV approach in this package, the minimum altitude may be specified as a decision altitude - DA (H). You may rotate through the DA in a missed approach.

This is a collection of "angle notes" from practice over the past several years. The learning curve continues with this tool. Please send me your experiences and questions.

All examples below assume no wind. The angle should be adjusted if configured differently or if you have a headwind or tailwind on final.

With the runway threshold and altitude entered at 3R of DES page...

(1) The limit you can start your turn to base from a downwind is when V/B displays 8° (flaps 10, gr. down and 200 kts).

(2) You can start your turn to base...

from a teardrop when V/B displays 8.5° (flaps 10, gr. down and 200 kts).

You want about 4.5 degrees V/B on 2 nm base, and configured at 170 kts.

You want to be less than 4 degrees turning onto final, configured.

You can fly direct to the runway at 250 kts until the V/B from the threshold is 2.0°, then start decelerating (idle power) and configuring.

If you're flying direct-to or dog-leg-to the runway at V/B from the runway of 3°, 250 kts and calm winds, you've got an energy problem.

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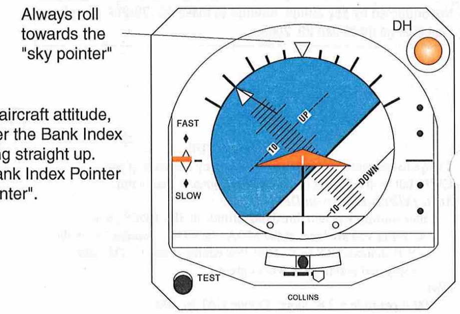
Last change made Jan 29, 2005.

PITCH 'N POWER

CONTROL AND PERFORMANCE METHOD

Helpful hints:
Go into the sim with a positive attitude. It's an opportunity to practice maneuvers, some of which you haven't had the chance to do for a while. It should always be a good learning experience. Practice to improve your instrument scan on the line by flying without the Flight Director on a regular basis. A good scan will help enormously during non-normal ops.

Helpful hints:
Anytime you turn a knob, move a switch, or issue a command, look for results.
"If..., then..."
Both pilots are flying all the time. Just happens one is on the controls.
When you take the active runway for takeoff, that's your que for full concentration.



Regardless of aircraft attitude, always consider the Bank Index Pointer as being straight up. Think of the Bank Index Pointer as the "sky pointer".

PITCH 'N POWER

Parts from *INSTRUMENT FLYING*, Dept of US Air Force, 1960 (I've done some editing)

Learn *what to change* (pitch, bank, or power) and *how much change* is required. This is the *Control and Performance Method.*

The ***control instruments*** are the attitude indicator (ADI) and the power indicators (N1 or Fuel Flow).

The ***performance instruments*** will know when to change the attitude and / or power. They are the altimeter, vertical speed, airspeed, direction, and navigation (HSI or Moving Map) indicators.

Establishing an attitude and power setting (control) will result in the desired performance. Known pitch and approximate fuel flows or N1 will help reduce your workload.

How to know *what to change* (pitch and bank of the nose, or thrust) is simple. Pitch control, by raising or lowering the nose is used primarily to maintain an altitude or to control the vertical speed. Bank control is used to maintain a heading or a desired turn. Bank changes are made in reference to nav requirements, such as a heading vector, tracking the magenta line on the Map, or following the localizer. Fuel Flow/N1 is used for maintaining or changing the airspeed (except during fixed power maneuvers such as climbout).

After or during the change of attitude and / or power, the *performance instruments* are crosschecked to see if their indications changed as desired. Flying by reference to instruments is simply a continuous repetition of this process. You must glance from the ADI to the altimeter - back to the ADI - then a glance at another performance instrument, back to the ADI, and so forth, including the standby ADI. The proper relative amount of attention must be given to each performance instrument. Do not devote too much attention to one performance instrument and fail to cross-check the control instrument.

A good scanning skill can be maintained even when the autopilot is engaged.

Changes in the indications on the *performance instruments* will lag slightly behind changes of attitude and or power. When the attitude and power are properly controlled, indications on the *performance instruments* will stabilize or change smoothly with a minimum of lag.

A level-off leadpoint is the altitude at which you should begin applying control for level flight. This altitude is calculated by using 10% of the climb or descent rate. If you're climbing at 1,500 fpm, begin leveling off no later than 150 ft before reaching the target altitude.

When leveling the 737, pulling the thrust levers back will bring the nose down. Pushing the thrust levers up will raise the nose.

A scan technique should begin and end with the ADI. The instruments scanned depends on the maneuver, but it may include shifting the eyes from the ADI to the altimeter, dart over to the heading indicator, back to the ADI, then to the airspeed. This takes many hours of concentrated practice, especially in a high speed airplane. Left neglected, scanning skills pick up drag rather than speed.

Symptoms of insufficient reference to the control instruments are readily recognizable. If you do not have in mind some definite attitude and power setting that are to be held or established and the indications on the performance instruments fluxuate erratically, then you are not referring sufficiently to the control instruments. You will be "chasing" indications, especially the FD.

Develop these skills and you can save an airplane, crew, and passengers that has lost a system such as the pitot-static or one that has improper Flight Director commands. Learning these skills will make you a better pilot because you can integrate the raw data with the FD cues, and increase your own self confidence.

Banking Rule: For heading changes more than 25°, use 25° bank. Heading change less than 25°, divide the heading change by 2.

Roll-out Rule: Divide the bank angle by 2. For a 20° bank begin roll-out 10° before the desired heading.