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Research and Development Service
Washington, D.C. 20591

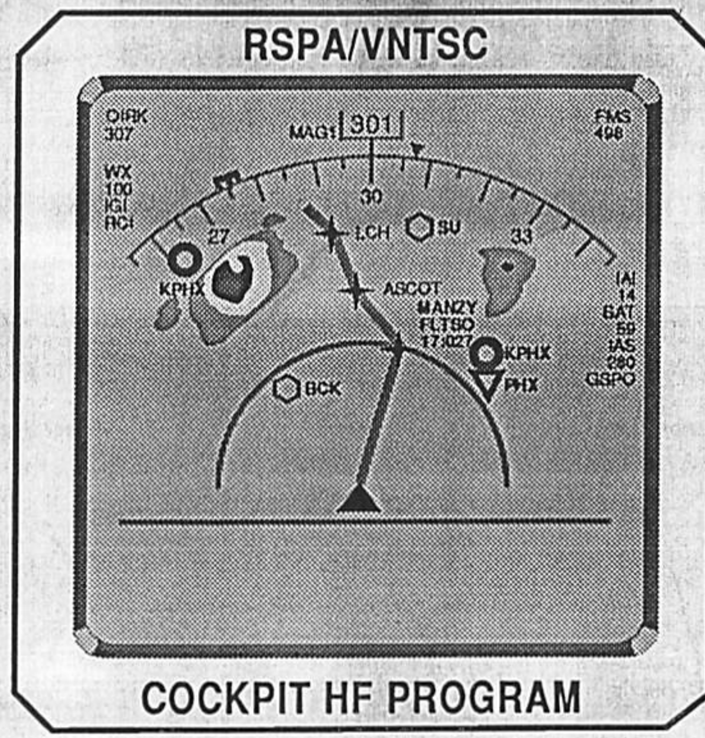
Relation of ASRS reports to system logic?

Conceptual framework for understanding FMSs?

Final report should describe and integrate all efforts:
Lexicon
ASRS Reports

Attempt to integrate error data into the conceptual framework.

Conceptual and Information Structure: A Comparison of the Boeing 757/767, A320, and Universal Flight Management Systems



It looks like the conceptual material is just a verbal rather than graphic description of how to operate the system.

for

M. Stephen Huntley Jr.
Cockpit Human Factors Program
Operator Performance and Systems Analysis Division
Department of Transportation
Volpe National Transportation Systems Center
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by

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March 17, 1993

ROUGH DRAFT

U.S. Department of Transportation
Federal Aviation Administration

DOT/FAA/RD-92/
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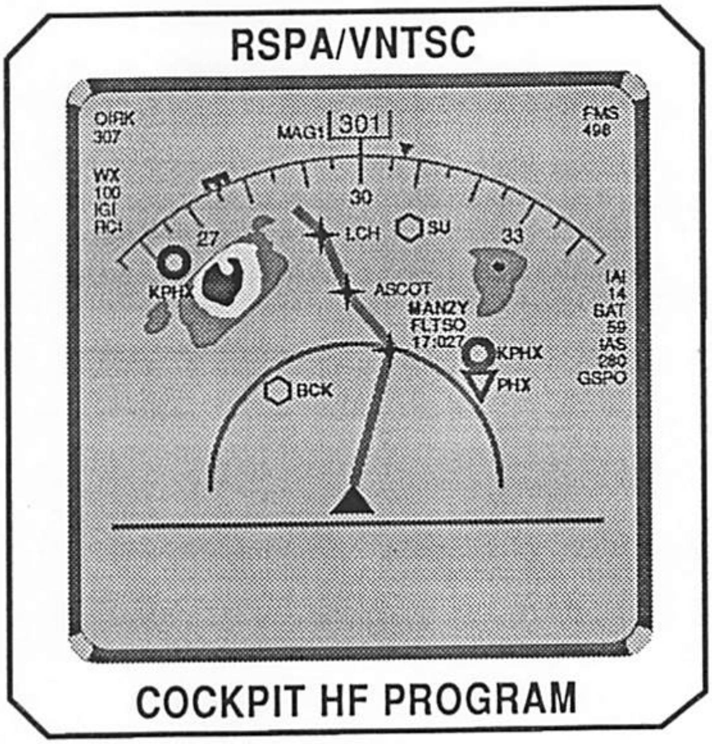
Conceptual and Information Structure: A Comparison of the Boeing 757/767, A320, and Universal Flight Management Systems



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CONCEPTUAL AND INFORMATION STRUCTURE: A COMPARISON OF THE BOEING 757/767, A320, AND UNIVERSAL FLIGHT MANAGEMENT SYSTEMS

FLIGHT MANAGEMENT SYSTEM DESCRIPTION/CHARACTERIZATION PROJECT

for

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March 17, 1993

Rough Draft

Rough Draft

Contents

1. OVERVIEW OF THE PROJECT

PROJECT BACKGROUND

The Flight Management System (FMS) is the principal means by which navigation and in-flight performance optimization take place in most current air carriers and many business jets. The FMS integrates conventional airplane avionics capabilities with software-based digital systems, electronic displays, and other advanced technology features in order to support integrated monitoring and control of the aircraft.

A system capable of providing such a broad range of functionality is an obvious candidate for user complexity. Not surprisingly, flight crews can have difficulty using the system to bring about the desired aircraft performance and may not always be aware of what the aircraft is doing. Although these systems do perform a wide range of functions, the question arises as to whether their complexity is an inherent feature of such systems, or whether modifications in the design can improve their overall usability. The objective of this project is to compare current FMSs so as to identify alternative ways in which similar functions are performed. In this way, it may be possible to identify those design characteristics which might reduce the complexity of FMS use. To this end, three FMSs were selected for analysis: Boeing's 757/767 FMS; the Airbus A320 FMS; and the Universal UNS-1B FMS, which is used in some business jets.

The current report is the third in a series of reports prepared for this project. The first report, *A Review and Discussion of Flight Management System Incidents Reported to the Aviation Safety Reporting System* (Eldredge, Mangold & Dodd, 1992), describes the results of an analysis of reports, submitted to the Aviation Safety Reporting System (ASRS), that describe incidents which were caused, at least in part, by difficulties flight crews had in using FMSs. This review provided a valuable look at the types of problems flight crews have in using these systems, including useful descriptions of how the crews attempted to identify the source of the problems. The outcome was a set of conclusions as to the major types of difficulties flight crews are having with FMSs. This set of FMS difficulties has served as the foundation for later work by helping to guide the focus of the analyses towards those aspects of FMS design most likely to impact flight safety and crew performance.

What were these difficulties?

Once the types of maneuvers which are most likely to be problematic for the crew have been specified, the specific source of the problem (e.g. complicated procedural logic) remains to be identified. To do so, analyses of the FMS itself need to be performed. The complexity of FMSs means that no single type of analysis is likely to possess the breadth to address all critical aspects of the system. A second report, *Overview of an Approach to the FMS Description/Characterization Study* (Mangold & Eldredge, 1991), identifies five sets of analyses that should be performed to adequately characterize FMSs, including analyses of the procedures used to interact with the flight management computer (FMC) and comparisons of procedures for shifting between automation levels. For each type of analysis, a set of analytical tools is recommended.

~~Wto~~ What were these tools?

[Note: For the purposes of this report, "Flight Management System" (FMS) and "Flight Management Computer" (FMC) are not interchangeable terms. "FMS" refers to the overall navigation and performance system used to control the aircraft in other than manual mode. This system includes all levels of automation, such as flight director and autopilot levels. The FMC serves as the highest level of automation within the Flight Management System. Consequently, the term "FMC" refers to a subset of capability within the overall FMS.]

The current report focuses on one of the five sets of analyses described in the 1991 report. Specifically, this report presents the results of comparisons between procedures used by the three FMSs (Boeing, Airbus, Universal) to perform seven tasks by means of the FMC. Analysis of the procedures by which the user can interact with the FMC is critical for the simple reason that the FMC serves as an intermediary between the flight crew and the aircraft. This means, in effect, that there are two separate demands on the crew. First, the crew has to know how to perform the various navigational and control tasks involved in the flight. Second, the crew has to understand how to operate the FMS and FMC so as to perform the required flight tasks by means of these systems.

Interaction with the FMS through the FMC takes place through the control display unit (CDU; see Figure 1-1). When the FMC is used, the CDU, in combination with other flight instruments such as the HSI, serves as the crew's primary "window" to the aircraft. In a sense, the crew's major contact with the aircraft takes place through the FMC. Consequently, the design of the FMC interface becomes a critical determinant of how effective the flight crew can be in controlling the aircraft. Complaints about the high cognitive demands involved in using the FMC, together with the large number of key presses required for critical maneuvers performed under severe time constraints (Eldredge, Mangold & Dodd, 1991) support the importance of addressing FMC procedures. Many of the tasks selected for analysis here were identified by Eldredge, Mangold, and Dodd (1992) as especially problematic for flight crews to perform.

OBJECTIVES OF THE PROCEDURAL ANALYSES

Given this need to look at the procedures used to interact with the CDU, the obvious question becomes what types of issues are of interest and should be addressed. The objective of this phase of the project is to compare FMCs to determine if there are certain procedural logics which are easier to use than others. Given this overall objective, three high-level issues appear to be especially interesting. First is the issue of how easy the procedures are for the crew to understand. The constraints of this study preclude interviewing pilots, conducting experiments, and other empirical methods for answering this question. An alternative approach is to look at the "semantics" of the procedures so as to assess understandability as a function of the number of basic concepts used and the consistency with which they are used.

3

The problem of consistency itself serves as a critical issue. A time-honored precept of user interface design is to ensure that the procedures are consistent (see, for example, Barnard, Hammond, Morton, Long, & Clark, 1981). Consistency means that the user can easily determine which procedures apply to a situation on the basis of rules known to be appropriate in other, similar situations. The advantage of consistency is that it reduces the number of unique procedures that must be learned, remembered, and not confused.

2

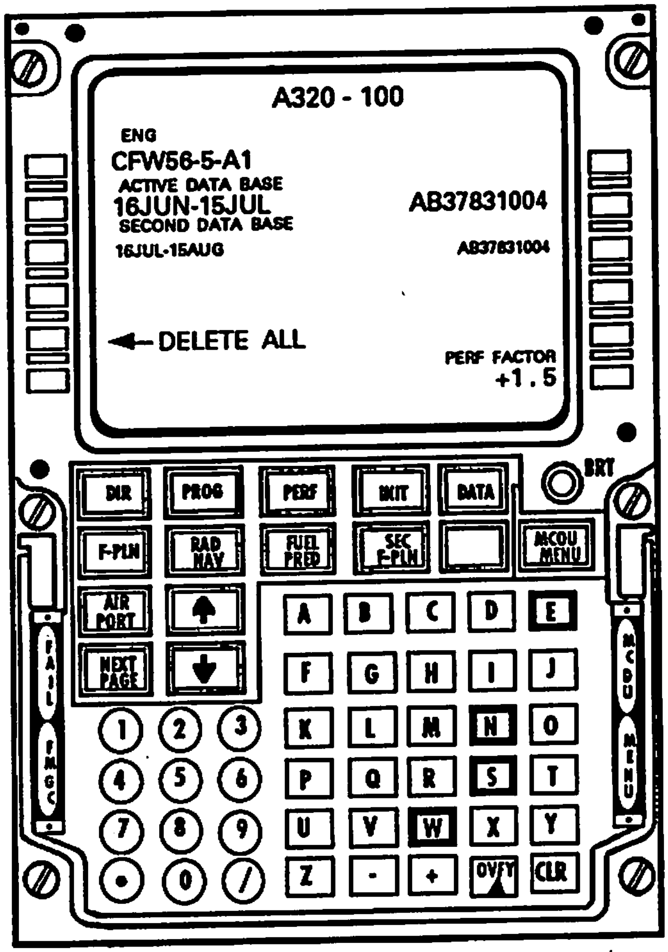


Figure 1-1. The A320 CDU.

3 A third, related concern is the complexity of the procedures. Complexity is a difficult concept to assess. The simplest approach is to assume that complexity is defined by the number of key presses ~~required to perform~~ a given task. Although this approach has the advantage that it offers clearly defined procedures for assessing complexity, it is likely that key press complexity differs as a function of the type of key press. For example, pressing a key to move to another screen probably reflects more complexity than pressing an alphanumeric character to enter an altitude or waypoint name. Moving to a different screen typically entails an element of memory in that the pilot must remember what screen offers the desired information. In addition, moving to a different screen may mean shifting to a different FMC task. Inputting alphanumeric characters, in contrast, may include a memory demand (remembering the to-be-inputted information) but it typically does not entail shifting to a different task. Although this assumption of differing complexity has yet to be empirically tested, it has been used in this study to influence many of the conclusions concerning procedural complexity.

Related to the issues of consistency and complexity is the potential for procedural problems and confusions. For example, the system may be confusing as to how the delete function works. Does the delete key remove only a single character or all of the information in the field? Does the delete character forward delete (remove the character located after the cursor) or back delete (remove the character just before the cursor)? What is the procedure for deleting an entire flight plan? Is it possible to accidentally delete the flight plan when attempting to delete some element of the plan? Procedures that have hidden assumptions or behave in a way that may not be apparent to the user are referred to as "Gotchas."

Concepts such as consistency and complexity can be defined in a variety of ways. For example, complexity is an important concern in the development of software. This report is concerned with consistency and complexity from the user's perspective. This means that if the objective is to develop a methodology for predicting complexity and speed of learning, it must be founded on psychological principles (Green, Schiele, and Payne, 1988). This requirement for a user perspective serves as the fundamental criterion for selection of an analytical tool.

CANDIDATES FOR AN ANALYTICAL TOOL

An adequate analysis of FMC procedures must address each of these issues. Not surprisingly, a variety of approaches can be used (see de Haan, van der Veer & Vliet, 1991, for a useful review). Three common types of approaches are:

- syntactic methods
- performance assessment methods
- user knowledge methods

Syntactic methods attempt to identify the underlying structure of interface procedures. Examples of such methods include Reisner's Action Language (1981, 1983) and Payne and Green's Set Grammar (1983). These methods use a formal notation, such as Backus-Naur form, to describe the legal or grammatically correct rules that can be used with an interface. One advantage of a formal representational structure is its ability to identify commonality in underlying structure, thus supporting assessments of syntactic consistency. Also, syntactic methods are based upon established formal methods whose properties are well understood. Finally, they use well-defined procedures for detecting the underlying structure of user-interface rules and primitives.

A critical disadvantage of syntactic methods is that people tend to be sensitive to semantic as well as syntactic characteristics (Schiele & Green, 1990). In addition, people are not sensitive to all forms of syntactic consistency, one example being the use of command names that have the same number of letters. Since these methods do not differentiate between which types of syntactic consistency people respond to, it is possible to focus on irrelevant characteristics while missing those characteristics of greatest informational value. Consequently, use of a syntactic method alone is likely to miss critical semantic aspects.

Performance assessment methods are a second type of analytical tool. One of the more established assessment tools is the GOMS approach (Kieras, 1988). The GOMS method refers to a family of tools which share the objective of predicting the time required to perform a given task. Predictions are based upon assumptions as to the time required for each of the various elementary physical (pressing a key), perceptual (searching for and finding the cursor), and cognitive (selecting an option) actions involved in the task. A popular GOMS method is Cognitive Complexity Theory (Kieras & Polson, 1985), which translates procedures into a production system notation. Complexity is defined as the number of production rules required to perform a given task. The assumption is that the greater the number of rules involved, the greater the complexity. Unfortunately, this provides a rather narrow view of complexity. One might expect that production rules are like key presses: some rules may be cognitively more complex than others.

The GOMS approach does offer a second source of information about procedural complexity. The performance prediction that is the primary value provided by the method can serve as a global measure of procedural complexity. However, there is no capability to directly address the user's understanding (or misunderstanding) of the task, even in the case of Cognitive Complexity Theory. Although the production rule approach has been suggested as a representational method used by the human cognitive system (e.g., Anderson, 1983), Cognitive Complexity Theory does not specifically attempt to represent the user's conceptual understanding of the system. An additional weakness is the assumption of error-free performance. Finally, there is some ambiguity as to what constitutes a production rule (de Haan, van der Veer & Vliet, 1991). This ambiguity means that users of Cognitive Complexity Theory may not always translate a set of procedures into the same set of production rules.

A third approach involves attempting to model the user's understanding of the interface. For example, the Task-Action Grammar (Payne & Green, 1986; Schiele & Green, 1990) attempts to map the user's understanding of the task structure onto the actions performed to accomplish the task. The task is broken down into "simple tasks," such as "move cursor up." The actions required to perform each simple task are then described. This type of approach is intended to apply a semantic perspective to issues such as consistency. Although this method is not particularly useful as a performance measure, it does look at the interface from a knowledge perspective.

Of the three types of approaches, semantic tools, such as Task-Action Grammar, seem best able to address the specific concerns of this project. The remainder of this chapter looks at the specific semantic approach that has been used in this project.

A SEMANTIC APPROACH

The objective of devising a representation of the user's own conceptual representation of the system may not seem possible for the obvious reason that one system user's representation is likely to differ from another. This particular difficulty can be avoided by assuming that the objective is to identify the representation encouraged by the system itself. This system-induced conceptual representation corresponds with Norman's (1983) "system image," which he defines as the image provided to the user by the system through the information given by the system itself.

A semantic approach has the objective of addressing the meaning of a sequence of key presses. The assumption is that users do not merely memorize sequences of key presses but, instead, learn the structure that underlies the meaning of sequences of presses. If these sequences always have the same meaning, regardless of how they are used in combination with other sequences, users will find the system to be easier to learn and use. Consequently, the approach taken in this report focuses on identifying the concept that is defined by a specific set of key presses. The intent is to identify these concepts, define exactly what they mean, the conditions under which they are used, and the constraints that limit their use. Defining these concepts should satisfy objective of determining if the FMCs investigated here differ as to the concepts conveyed by the procedures.

This focus on concepts is consistent with current cognitive theory which aims at identifying the conceptual structure underlying memory, language, and thought (see, for example, Jackendoff, 1983). The goal is to identify a formalism by which conceptual understanding can be represented so as to be able to apply this common formalism to the identification of concepts which support understanding. These concepts can be integrated together to provide a coherent structure, a mental model, which can be used to understand how a system works and predict the consequences of any interactions with the system. Using this type of approach, the focus becomes the semantics of the task domain and interface.

Identifying the semantic concepts of an interface is one goal. A second is to try to identify the conceptual relations that are used to integrate individual information elements into a coherent, predictable structure. Examples of these coherence relations include expansion relations such as *generalization-specific* (Hobbs, 1983), where general information provides a contextual basis for more specific information, and temporal relations such as *sequence* (Mann & Thompson, 1986), where the occurrence of a second statement necessarily follows the occurrence of the first. Identifying the specific relationships between elements of information should be extremely valuable as a tool for detecting the informational structure used by each of the FMCs.

This approach differs in important ways from most approaches, some of which were described earlier, currently used for user interface design and evaluation. The fundamental difference is that no attempt was made to develop a formal analytical method, such as Reisner's Action Grammar and Payne and Green's Task-Action Grammar. It was felt that the more important objective is to define the concepts used to develop procedures and identify the structure by which information is organized across multiple screens in each FMC.

Existing methodologies do not appear able to achieve these objectives. This is not to suggest that these methods are faulty. Instead, it is important to recognize important differences in the types of interfaces addressed by existing methods. Rasmussen and Goodstein (1988) distinguish between a focus on the user-computer interface and efforts to improve human performance in specific work areas, an area of research called *cognitive engineering*.

This distinction is critical because the opportunities available for each differ radically. Tools for improving the interface were developed to improve the usability of software that is intended to support a variety of users. For example, word processing software is used by people writing letters, lawyers preparing legal briefs, and novelists. Consequently, the interface designer is severely constrained as to the types of user supports that can be provided. The software clearly cannot be designed to support a specific set of tasks since it is difficult to predict how the software ultimately will be used. Instead, the focus is on ensuring that the procedures that must be followed require a minimum number of procedures which possess an inherent consistency. For example, Schiele and Green (1990) analyzed the procedures required to draw various types of shapes in the Macintosh™ program MacDraw™. It is not possible to define *when* a user might want to use a specific form but it is possible to ensure that the same basic set of actions are used if the user wants to draw an ellipse or rectangle.

In contrast, the study of FMCs clearly requires a close look at the specific tasks for which it was designed to be used. This means that the design of the interface is critically constrained by the requirements of the task. Tools intended for use in a specific task domain must be capable of addressing semantic issues. Attempts to formalize such concepts as consistency and complexity are obviously dependent upon the extent to which the formal method represents those aspects of consistency and complexity that actually affect the user. Since no formal methods capable of focusing on semantic structure were available, the decision was made to devise "soft" semantic tools capable of providing the required semantic scope.

ORGANIZATION OF THE REPORT

The distinction between procedures for using the FMC itself and procedures for performing the task influenced the organization of this report. Chapter two focuses on the FMC procedures themselves. Examples of these procedures include entering data into a field and moving from one screen to another. The objective of this chapter is to compare these FMC-oriented procedures in order to identify important similarities and differences.

Characteristic of all three FMCs is the large number of screens they provide. Each FMC organizes all of the screens into a small number of categories, called modes. These modes reflect the FMC designer's view of the major functions to be performed using the FMC. Comparisons between the modal organizations of the three FMCs are described in chapter three.

The remaining chapters compare specific procedures used for performing common flight tasks. Chapter four reviews the procedures for entering the flight plan and the overall structure by which flight plan information is organized. Chapter five looks at some of the procedures used for modifying the vertical path of the aircraft while chapter six reviews some procedures for changing lateral aircraft path.

2. FMC CDU CONCEPTS

OBJECTIVES OF THE FMC CDU CONCEPTS ANALYSIS

In attempting to model the user's understanding of the FMC, it is important to differentiate understanding of the FMC itself from understanding of the flight task. The user must not only understand what the various flight tasks are but also know what procedures to use to get the FMC to perform those tasks.

The objective of this chapter is to look at the procedures for interacting with the FMC alone. These procedures include inputting and modifying data, and moving from one screen to another. Each of these procedures consists of a sequence of actions performed by the FMC user. These procedures can be analyzed to identify a set of primitives which are combined to form procedures.

The analysis involves three steps. First, the simplest tasks involved in using the FMC must be identified. Examples of these simple tasks are enter data into a field, modify the data, move to another screen. Once these tasks have been identified, the sequence of actions or key presses required to perform each task must be identified. The third step is the most complicated. Concepts used to understand the simple tasks must be identified. These concepts are assumed to serve as building blocks by which the FMC user builds an understanding of how to translate flight task goals into FMC procedures. Identifying the concepts works from both a top-down and bottom-up perspective: top-down in that the simple tasks help to define the set of concepts assumed to support understanding of the simple task; and bottom-up in that the sequence of actions required to perform a task often play a decisive role in identifying which concepts are actually involved.

In effect, three levels of analysis are involved. At the highest level are the simple tasks. Given the commonality of flight tasks performed by the three systems, it is unlikely that FMCs will differ substantially in terms of the simple tasks they can perform and, in fact, this was found to be the case. At the lowest level are the action sequences that comprise the procedures. Substantial differences in action sequences would be expected and this proved to be the case. The middle level, that of the concepts, is heavily driven by the action sequences in that the FMC user is attempting to make sense of the procedures used to perform a given simple task. This level is likely to provide the most interesting picture of similarities and differences between FMCs from the user's perspective.

This type of analysis has several potential benefits. First, the analysis should lead to a clearer picture of the user's understanding of the FMC. It should be possible to identify patterns of conceptual structure by which issues such as consistency and complexity might be assessed. People are good pattern recognizers and are able to detect consistent action patterns. After detecting these patterns, people then try to understand their meaning. Consequently, consistency must be assessed not only in terms of action sequences but also with respect to conceptual consistency. The same argument can be made for complexity as well. For this reason, a two-pronged analysis of procedures must be performed, that is, both the action sequences and the conceptual structure must be assessed in terms of issues of consistency and complexity. This mapping of concepts onto action sequences holds great potential for addressing the problem of pilot error in using these systems.

APPROACH TO THE ANALYSES

One of the most important characteristics of the FMC structure is its underlying hierarchical structure (see Figure 2-1). This hierarchy works from the individual procedures through information layout across multiple screens. At the highest level are the FMC modes which reflect the gross-level assignment of information to categories. These categories are accessed by mode select keys (see Figure 2-2), which, when pressed, display an individual screen of information or "page."

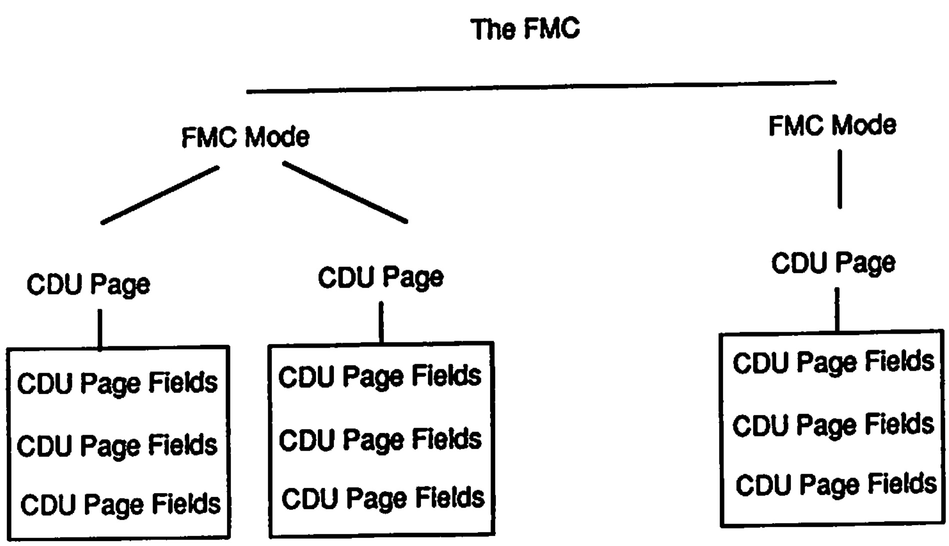


Figure 2-1. The hierarchical structure of the CDU.

Each page is comprised of a set of fields where information is placed for manipulation or display. Information can be moved in or out of fields by using line select keys (see Figure 2-2).

The Boeing and Airbus systems use a scratchpad, located in the lowest line of the CDU display, for manipulating information that can be modified by the user (see Figure 2-2). Alphanumeric information entered through the keypad is first placed in the scratchpad. Line select keys are then used to put the information in the desired field. Pressing a line select key next to a field that contains information places that information in the scratchpad, if the scratchpad is empty. Information located in the scratchpad remains there even if another page is selected, which allows the user to move information from one page to another.

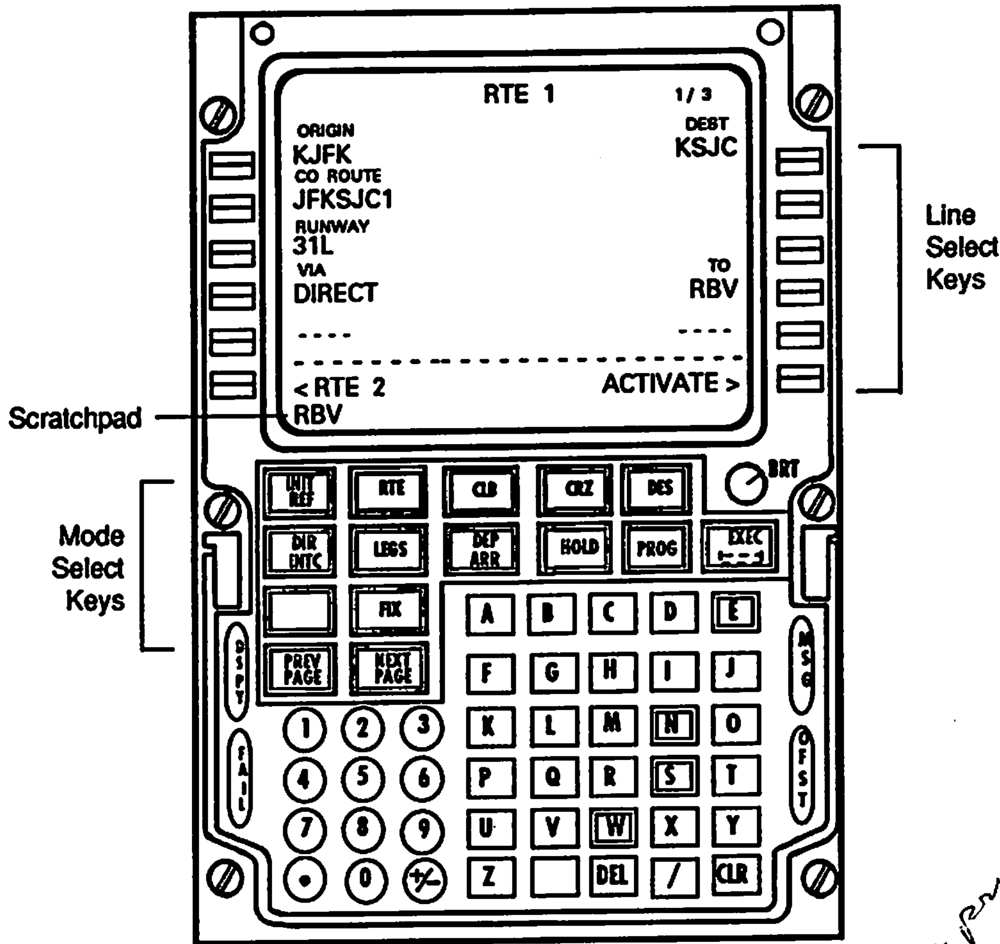


Figure 2-1. The structure of the B-757/767 CDU.

What are primitives

This hierarchical information structure also is found in the procedures themselves. Individual steps in a procedure can be combined to form more complex procedures. One of the goals of this chapter is to define this procedural structure, identifying the primitives and legal rules for combining primitives. In keeping with the project objective of analyzing the FMC from the point of view of the user, an important consideration is to define these primitives and rules in accordance with how users would do so. This is an especially important concern in terms of defining simple tasks. The obvious definition of a simple task is an individual user action, such as a key press. However, this version of a simple task is likely to be meaningless to the user.

A potentially more useful definition of a simple task assumes that they should be defined in terms of basic, meaningful tasks. Decomposition of the task into its smallest meaningful elements becomes the driver of simple-task definitions rather than decomposition of actions. This definition not only makes more sense in terms of a user point of view but also has the advantage that the resulting simple tasks inherently involve meaningful semantic characteristics.

This definition of a simple task suggests that they are "chunks" of individual procedures which are handled as autonomous units. One such primitive is "Enter data into a field." For the Boeing 757/767, this primitive is comprised of the following steps:

- Use the keypad to type in the data. The data will automatically appear in the scratchpad.
- Verify that the data has been correctly entered.
- Press the line select key next to the field where the data are to be placed.
- Verify that the data is in the correct field.

Entering field data is a typical FMC user task. It is assumed that this task is the simplest autonomous unit and should not be decomposed into smaller elements. For example, entering information into the scratchpad is not an action that is ever performed in isolation. Entering data into a field, in contrast, is.

Types of Simple Tasks

Simple tasks involved in using the FMC are:

- Enter New Data into a Field
- Move Existing Data from one Field to Another
- Move From One Page to Another
- Delete Data in a Field
- Delete Data in a Scratchpad (B-757/767 and A320 only)
- Erase Data on a Page (B-757/767 only)
- Execute Modified Data

More complex tasks are then constructed through a combination of simple tasks. For example, moving existing data from one page to another involves two simple tasks: move existing data from one field to another and move from one page to another.

Actions

Actions are the means by which the user performs FMC procedures. There are three basic kinds of actions:

- alphanumeric key presses
- mode select key presses
- line select key presses

Conceptual Structure of The Simple Tasks

The objective of this project is to attempt to analyze FMC procedures from the FMC user's point of view. To understand the user's view of the system means identifying the concepts used. One of the more promising approaches to understanding cognitive functioning suggests that spatial concepts are the scaffolding by which comprehension, reasoning, and other cognitive skills take place (see, for example, Lakoff, 1987; Johnson, 1987). Simply speaking, the human cognitive system is assumed to be organized in terms of concepts, relationships between concepts, and attributes of the concepts. One set of concepts comprises a spatial framework within which the "behavior" of concepts can be predicted. For example, pieces of information can be treated metaphorically as "objects" or things that have states and can participate in events involving their being be moved, manipulated, and modified.

The attempt has been made in this chapter to use spatial concepts to understand the conceptual structure of FMC procedures. Because the Boeing and Airbus FMC procedures are very similar, the conceptual structures of both systems are reviewed together.

The Boeing and Airbus Conceptual Structure

A set of concepts that may be usefully applied to the Boeing and Airbus FMCs are the following.

Objects: Each piece of data information in the FMC is conceptually represented as an object. Objects have the following characteristics:

- New objects can be created.
- Existing objects can be destroyed (i.e. deleted).
- Existing objects can be modified.
- Existing objects can be selected.
- All objects must have a location or place.
- All objects can be moved from one place to another, similar place, if the object shares the logic of that place. In effect, certain places can only handle certain types of objects (a place for holding waypoint will not hold airspeeds).

Is there a place where it is stored?

Places: One of the FMC user's central tasks is to enter or put information elements into the FMC so as to bring about desired aircraft performance. In order to be used appropriately, the information must be put in the proper place. The Boeing and Airbus FMCs provide two types of candidate places, data fields and the scratchpad.

where do you find it?

Select: In order to move or manipulate a piece of information, it must be selected. In the Boeing and Airbus FMCs, either the object or the place can be selected. Both selection methods are used to move a piece of information from one location to another. The to-be-moved information is first selected by pressing the line select key next to that information. This action, in effect, selects the "What." Pressing the line select key next to the object automatically copies the information to the scratchpad. The user then selects the destination place by pressing the line select key next to the destination field. A field is selected by pressing the line select key next to that field. This action defines the "Where" element. By definition, information in the scratchpad is the selected information. Pressing a line select key when the scratchpad contains information will automatically move that information into the field beside the line select key, if the information is legal for that field.

Paths: In a metaphorical sense, the user moves as well as objects. This type of movement involves moving from one page to another.

States: Object states can be changed. Examples of states are creating, modifying, or deleting. States are changed through the application of functions, such as the clear function. An additional state concept involves a user-initiated change in state of a group of objects, such as all of the objects on the same page. In order for changes in navigation or performance data to actually modify the aircraft, its state must be changed. Three states are possible: active, meaning the information is actively being used to guide the system; modified, meaning the information has been changed but is not active; and inactive, the information has not changed but is also not being used to guide the aircraft. The most common changes of state of interest to the user is the change from modified to active or from inactive to active.

The Universal Conceptual Structure

Objects: Each piece of data information in the FMC is represented as an object. Objects have the following characteristics:

- New objects can be created.
- Existing objects can be destroyed (i.e. deleted).
- Existing objects can be modified.
- Existing objects can be selected.
- All objects must have a location or place.

Unlike the Boeing/Airbus FMCs, Universal objects cannot be moved. Once an object has been created, it can only be modified or deleted.

Places: The Universal FMC does not use a scratchpad. Consequently, objects can only be placed in fields.

Select: The Universal FMC does not allow objects to be moved. Consequently, there is no logical "What" component to the system. Only the place where an object is to be created or modified can be selected. In effect, the "What" element is always the same as the "Where" element.

Paths: The user can move from one page to another.

States: Object states can be changed by means of functions that can modify or destroy objects. Although not as clearly defined as the Boeing and Airbus systems, the UNS-1B also appears to have the same three group-level states (active, modified, inactive). The most common changes of state of interest to the user is the change from modified to active or from inactive to active.

Performing Simple Tasks

Table 2-1 displays the set of simple tasks that can be performed by means of an FMC, the concepts the user uses to understand the tasks, and the procedures required for each task. Even-numbered pages display the Boeing and Airbus tasks, concepts, and procedures, while odd-numbered pages display the same information for the Universal system. The S refers to a system action while the U refers to the user concept.

Entering New Data into a Field

With the Boeing and Airbus systems, entering new data into a field is a two-step procedure. First, the information must be created. Upon creation, the information is placed in the scratchpad. *Creating an object automatically places that information in the scratchpad.* Once the information has been created, the place where the information is to be located must be selected. Pressing the line select key next to the destination field defines the "Where" component.

Unlike the other FMCs, the Universal uses no scratchpad. The user only must define the "Where" variable by pressing the line select key next to the destination field. This action positions the cursor in that field. Newly created data is automatically entered into the field where the cursor is located. The Enter key must then be pressed to confirm entry of the object. Pressing the Enter key also serves to move the cursor to the next field. Unlike the Boeing and Airbus FMCs, data is entered one field at a time.

The Universal does possess another method for inputting new data. Entering navigation information, such as waypoints and SIDs, can be done by accessing lists and selecting the information needed off of that list. In effect, this changes the process from creating a new object to copying an existing object.

Move Existing Data from One Field to Another

The Boeing and Airbus FMCs require a two-step process to move data from one field to another. First, the target object must be selected by pressing the line select key next to the information. *Selecting an object automatically places a copy of it in the scratchpad., if the scratchpad is blank* Where the information is to go is then specified by pressing the line select key next to the destination field. *Choosing a field means automatically putting the information in that field.*

Because the Universal FMC has no scratchpad and does not allow objects to be moved, there is no mechanism for moving information from one field to another. Copying information off of a list, if it is navigation information, is an option.

Moving From One Page to Another

Each of the three systems offers the same methods for moving from one page to another. Four methods are available, although which methods can be used at any given time depend upon the type of page being moved to. Figure 2-1 presented the hierarchical structure of the FMC. At the highest level within the FMC are the individual modes, the largest divisions for organizing types of information. Two possible paths for moving from one mode to another are:

- Mode Select Key path: Pressing a mode select key automatically accesses the first page of the selected mode. Which page actually appears is determined by FMC logic since the FMC attempts to provide that page most likely needed at any given time. Typically, the page that is actually accessed is determined by the current phase of flight. This path, called the "mode select key" path, is always available to the user.

- Mode Line Select path: Some pages within a mode provide direct paths to another mode. A prompt, located in one of the fields on the page, names the mode. Pressing the line select key next to the prompt accesses the first page of that mode. Again, the actual page that appears depends upon phase of flight and other factors.

Moving from page to page within a mode can be accomplished by either of two paths:

- Line Select Key path: Related pages within the same mode can be accessed by means of a line select key if there is a prompt on the first page. Pressing the line select key next to the prompt accesses the second page.

- Next/Previous path: Regardless of whether a line select key prompt is available, multiple pages within the same mode can be accessed through the use of the next and previous line select keys.

Both the Boeing and Airbus systems also occasionally use a third type of path for moving from page to page. In response to a data entry by the user a new page may be displayed. This path, called the Automatic Access path, is fundamentally different from all others in that the process used to initiate this movement is hidden.

The assumption is made that each of these paths differ in the extent to which user guidance is provided. The Mode Select Key and Next/Previous paths provide the least guidance to the user in that the user must choose, without prompting, to access the next mode. The Automatic Access path, in contrast, provides the strongest user guidance in that the user is automatically led to the next screen in response to some type of data entry. Intermediate levels of guidance are provided by the Mode Line Select and Line Select Key paths in that prompts are provided to remind the user to move to another page, yet the user has control over whether to follow that path.

Delete Data in a Field

The B-757/767 delete key and the A320 clear key both behave like objects instead of functions. Pressing these keys places the word delete or clear in the scratchpad. This serves as step 1 of the two-step object process which involves defining the "What." The Delete or Clear object is then moved to a field by pressing the line select key next to that field. The Delete or Clear object replaces whatever object was already in that field. This process corresponds to the process used to enter new data in a field.

Deleting information in the scratchpad, in contrast, behaves like a function in that the pressing the clear key causes a change in the object rather than completely replacing the object, as is the case with the Boeing delete key.

Boeing/Airbus Task Procedures	Boeing/Airbus Concepts	Boeing/Airbus Actions
Enter New Data into a Field		
Enter data through the keypad. The data are automatically placed in the scratchpad. Verify that the data have been entered correctly. Data in the scratchpad is placed in a field by pressing the line select key next to that field. Verify that the data have been moved to the correct field.	U:: Create new object S:: Put object in scratchpad U:: Select place S:: Move object from scratchpad and put in field	Alphanumeric Keypad Line Select Key
Move Existing Data from One Field to Another		
Data located in a field are moved to the scratchpad by pressing the line select key for that field. Verify that the correct data have been moved to the scratchpad. Data in the scratchpad is placed in a field by pressing the line select key next to that field. Verify that the data have been moved to the correct field.	U:: Select object S:: Copy old object and put in scratchpad U:: Select place S:: Move old object from scratchpad to field	Line Select Key Line Select Key
Move From One Mode to Another – Mode Select Key		
Pressing one of the mode select keys located on the keyboard accesses the page corresponding to that mode select key. Verify that the correct page has been accessed.	S:: Mode key prompt U:: Select next place S:: Access first mode page	Mode Select Key
Move From On Mode to Another – Line Select Key		
When the appropriate prompt exists on the current page, pressing the line select key next to the prompt brings up the desired page. Verify that the correct screen has been accessed.	S:: Field prompt U:: Select next place S:: Access first mode page	Line Select Key

Table 2-1. Boeing and Airbus procedures for simple tasks (cont. next page).

Universal Task Procedures	Universal Concepts	Universal Actions
Enter New Data into a Field		
Place the cursor in the desired field. Enter data through the keypad. Verify that the data have been entered correctly. Press the Enter key to confirm.	U: Select place S:: Place cursor in selected field U:: Create New Object S:: Put new object in field U:: Press Enter key S:: Move cursor to next logical field	Line Select Key Alphanumeric Keypad Enter Control Key
Move Existing Data from One Field to Another		
None		
Move From One Mode to Another – Mode Select Key		
Pressing one of the mode select keys located on the keyboard accesses the page corresponding to that mode select key. Verify that the correct page has been accessed.	S:: Mode key prompt U:: Select Mode S:: Access First Mode Page	Mode Select Key
Move From On Mode to Another – Line Select Key		
When the appropriate prompt exists on the current page, pressing the line select key next to the prompt brings up the desired page. Verify that the correct screen has been accessed.	S:: Field prompt U:: Select Mode S:: Access First Mode Page	Line Select Key

Table 2-1. Universal procedures for simple tasks (cont. next page).

Boeing/Airbus Task Procedures	Boeing/Airbus Concepts	Boeing/Airbus Actions
Move From One Page to Another Within the Same Mode– Line Select Key		
When the appropriate prompt exists on the current page, pressing the line select key next to the prompt brings up the desired page. Verify that the correct screen has been accessed.	S:: Field prompt U:: Select next place S:: Access next page	Line Select Key
Move From One Page to Another Within the Same Mode– Next and Previous Page Keys		
Pressing the next or previous page key will bring up another page in multi-page modes. Verify that the correct screen has been accessed.	S:: Field or icon prompt U:: Select next place S:: Access next page	Next or Previous Function Key
Delete Data in a Field		
Push the DEL (B767) or CLEAR (A320) key. This action enters the word "Delete" (B767) or CLR (A320) into the scratchpad. Press the line select key next to the field containing the to-be-deleted information.	U:: Select the function S:: Put the word 'Delete' or 'Clear' in the scratchpad U:: Select the place containing the object (move object into selected place) S:: Delete the information in the field	Delete or Clear Key Line Select Key
Delete Data in the Scratchpad (B-757.767)		
Press the Clear key. This clears the alphanumeric characters one at a time, starting with the last character. Holding the key down clears the entire scratchpad.	U:: Select the function	Clear Function Key

Table 2-1. Boeing and Airbus procedures for simple tasks (cont. next page).

Universal Task Procedures	Universal Concepts	Universal Actions
Move From One Page to Another Within the Same Mode– Line Select Key		
When the appropriate prompt exists on the current page, pressing the line select key next to the prompt brings up the desired page. Verify that the correct screen has been accessed.	S:: Field prompt U:: Select next place S:: Access next page	Line Select Key
Move From One Page to Another Within the Same Mode– Next and Previous Page Keys		
Pressing the next or previous page key will bring up another page in multi-page modes. Verify that the correct screen has been accessed.	S:: Field or icon prompt U:: Select next page	Next or Previous Function Key
Delete Data in a Field:		
Place the cursor in the selected field. Use the BACK key as a delete or backspace key.	U:: Select place Press Back key	Line Select Key Back Key
Delete Data in the Scratchpad		
None		

Table 2-1. Universal procedures for simple tasks (cont. next page).

Boeing/Airbus Task Procedures	Boeing/Airbus Concepts	Boeing/Airbus Actions
Erase Data on a Page		
The erase prompt appears on certain pages after a modifying entry or selection has been made to a page.	U:: Return to previous state (modified to inactive)	Erase Line Select Key
Execute Modifications		
Modifications to the route or critical performance data must be executed. When data must be executed, an Activate prompt will appear on the page. Pressing the Activate line select key activates a line on the Execute function key. This key must then be pressed to execute the data.	S:: Provide an activate prompt	
	U: Accept changes	Line Select Key
	S:: Activate execute light	
	U:: Activate changes	Execute Key

Table 2-1. Universal procedures for simple tasks (cont. next page).

The Universal delete, in contrast, behaves like a function. The object to be manipulated (i.e. deleted) is selected by means of a line select key. The Back key is then used to backspace each character at a time.

CONCLUSIONS

The primary difference between the three systems is the scratchpad: the Boeing and Airbus systems use one while the Universal does not. The scratchpad has one major advantage in that it can be used to move data from one field to another, even across different pages. Strategic use of the scratchpad can reduce the number of keystrokes that must be made by the user.

There are several disadvantages to this system. First, the scratchpad requires additional key presses in that, once data has been keyed in, it must still be moved to the appropriate field. In addition, there is some potential for error in using the scratchpad. The logic is very simple:

- If there is no information in the scratchpad, pressing a line select key will copy the information from the selected field to the scratchpad.
- If there is no information in the scratchpad, using the alphanumeric keypad to key in new information will place it in the scratchpad.
- If there is information in the scratchpad, pressing a line select key will move the information from the scratchpad to the field, if the information is logical for that field.

Universal Task Procedures	Universal Concepts	Universal Actions
Erase Data on a Page		
None		
Execute Modifications		
Each entry or modification of a data object is stored in memory by pressing the Enter key or the line select key beside the field.	U:: Activate changes	Enter or Line Select Key

Table 2-1. Universal procedures for simple tasks (cont. from previous page).

The last characteristic suggests that monitoring the status of the scratchpad is an important part of using the Boeing and Airbus FMCs. The potential for mistakenly overwriting information is one of the more critical errors that can occur with this system. This mistake can be fixed, if detected, by pressing the line select key next to the Erase prompt which can be found on many pages. In addition, no modifications to the route or the performance pages will occur unless these changes are executed.

The lack of a scratchpad in the Universal system avoids the problems inherent in a scratchpad. However, instead of monitoring the status of the scratchpad, the user must now monitor the location of the cursor. Otherwise, information could be entered in the wrong field. To help with this, the home position of the cursor is usually off the screen when a page is first accessed. In addition, many pages have a defined path through the page which the cursor will follow each time the Enter button is pressed. Should information be placed in the wrong field, the error can be compensated for by simply not pressing the Enter key.

In addition, the application of functions is more consistent in the Universal system. The delete and clear keys on the Boeing FMC behave in two very different ways, the former behaving like an object, the latter behaving like a function. In the case of the Universal system, functions behave like functions, not objects.

What is the practical or procedural significance of this difference?

3. MODE KEY STRUCTURE

OVERVIEW OF THE MODE KEY ANALYSIS

The FMC, like most complex systems, requires the use of a large number of screens to convey all the information a flight crew might need. Efficient access to these screens requires that this information be assigned to individual screens in a sensible fashion that enables the crew to develop expectations as to where to find desired information. If these expectations are met, the crew can use the logic of information layout to easily access the specific information required. Otherwise, the crew must memorize information locations, which may, of course, mean that locations may be forgotten. The objective of this chapter is to identify the structure used by each FMS to organize information and to determine whether this structure is the same for all three FMSs.

APPROACH TO THE FUNCTION AND MODE KEY ANALYSIS

There is no equation or a priori method for determining how to locate information across multiple screens. Instead, the system designer must devise a logical structure based upon judgments as to what types of information should be located together. The goal of this chapter is to identify the logical structure used for each of the three FMSs under consideration. Once this global structure has been identified it will then be possible to identify how information relates across screens for each of the FMSs.

Certain basic assumptions are made that serve as the framework for identifying the structure underlying information layout. These assumptions are all based on the belief that the interface possesses an inherent structure and has been designed in accordance with basic human factors design principles. Specifically, these assumptions are derived from the more global assumption that information elements located near to each other are somehow related. The implication is that each screen can be treated as a frame which holds related information. Consequently, it should be possible to identify a shared theme for each screen. In addition, there are several types of relationships that can occur between multiple screens. First, two screens may have no relationship at all, that is, they share no obvious informational connection. Second, two screens may both have information pertaining to the same subject, for example, two screens may both provide information about the same phase of flight. Finally, one screen may serve as a continuation to the first screen if there is too much information to provide on a single screen.

Using the above assumptions, identification of the conceptual structure underlying information layout across screens begins at the level of the mode keys (see Figure 3-1), which serve as a high-level "table of contents." Since initial access to all information provided by the FMC takes place

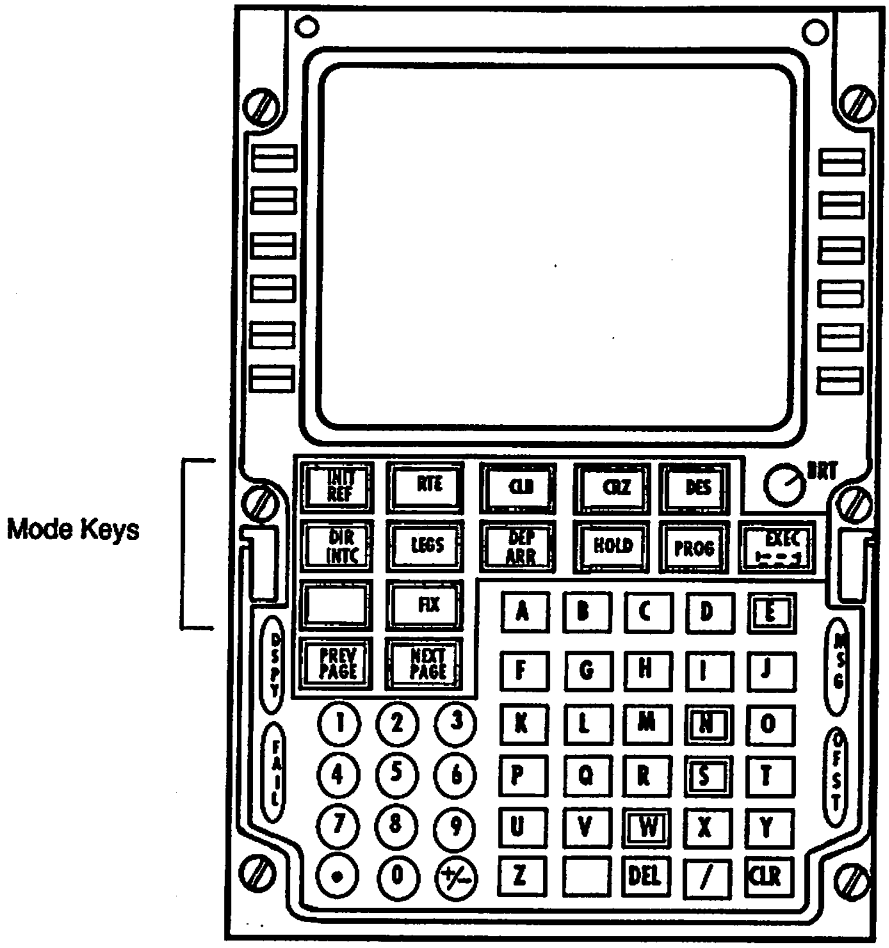


Figure 3-1. Location of the mode keys.

by means of these keys, the highest-level semantic organization is defined by choices FMC designers have made as to how information should be chunked into the corresponding information "chapters."

There are a number of logical ways for organizing information. For example, information could be organized by phase of flight. This would mean that individual mode keys would be provided for preflight, taxi, takeoff, climb, cruise, descent, and approach. Another method might use the pilot's task as a basis for assigning information. For example, the pilot has to define the path (vertical and lateral) the aircraft will follow to reach its destination, monitor the aircraft's progress along that path, monitor aircraft performance (e.g. fuel usage, engine performance), stay aware of where the aircraft currently is, and change the path in response to environmental conditions such as weather and ATC instructions. Finally, information might be organized in accordance with its criticality. For example, those activities which require a rapid response might be assigned their own function key while less critical information could be buried in other parts of the structure. A combination of these logics could also be used, in particular, use of rapid access to critical information in combination with some other structure such as by phase of flight.

This chapter has two objectives: (1) To identify the logic by which information is organized onto multiple screens for each of the three FMSs; (2) To provide a general "road map" of where the various types of information and functions are located within the various FMC screens. The chapter first provides an overview of the structure of each FMC. A comparison of these FMC structures then follows which has the objective of determining whether there is a common structure shared by each of the FMCs or whether alternative configurations exist.

THE BOEING 757/767 MODE KEY STRUCTURE

The Boeing 757/767 has 11 mode keys, which are described in Table 3-1. Each of the screens accessed through this mode is described below.

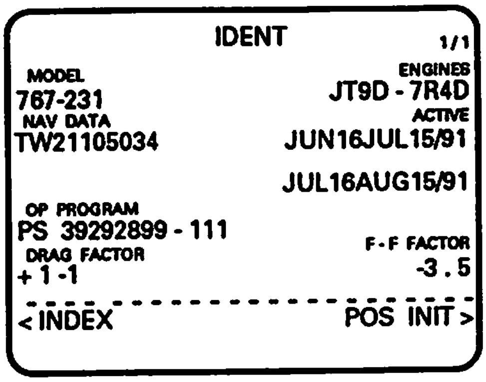
The Boeing Initialization Mode

The Initialization mode key is used to perform those tasks involved in preparing the aircraft for a flight. Six sets of screens comprise this mode, as shown in the Index page below. Each of these screens is shown in Figure 3-2.

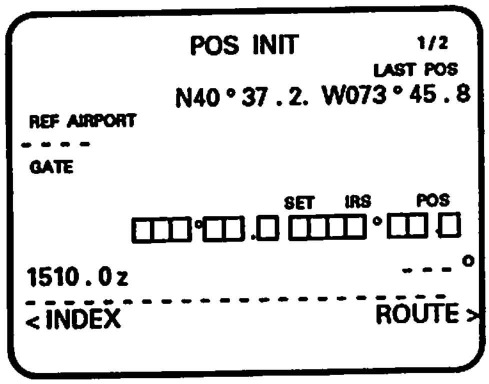
```
        INIT/REF INDEX      1/1

< IDENT               NAV DATA >
< POS
< PERF
< TAKEOFF
< APPROACH
```

Some of the specific functions supported by the initialization/reference mode key on the 757/767 include:

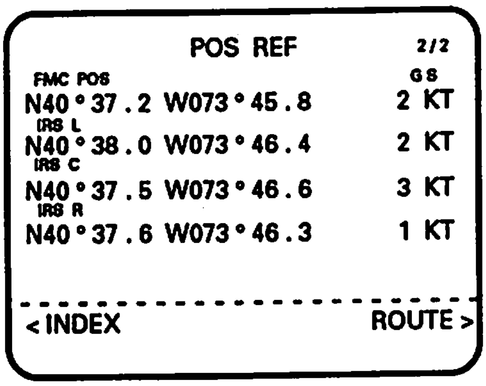
- Confirming database validity to ensure that the data used in the flight are current.
- Initializing the position of the aircraft for FMC and IRS initialization.
- Entering performance data essential for FMC calculations, such as fuel amounts and reserves, cruise altitudes, winds, etc.
- Entering specific data necessary for FMC calculations required for the takeoff and approach phases.



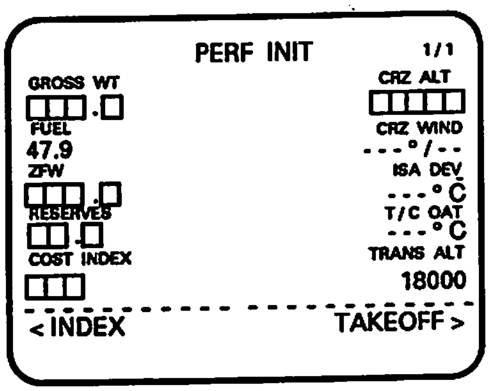
Program Identification Page: Displays FMC database effective dates, as well as drag and fuel flow factors.



Position Initialization: Page one of the Position pages. Used to enter airplane position for FMC and IRS initialization.

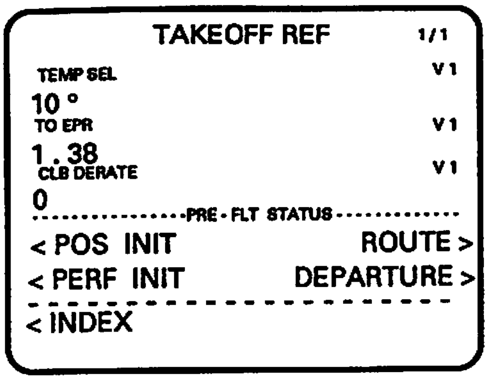


Position Reference: Page two of the Position pages. Used to review airplane position for FMC and IRS initialization.

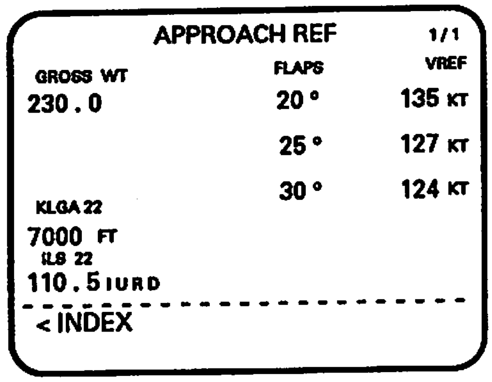


Performance Initialization: Used to enter data for performance calculations, such as fuel amounts and reserves, cruise altitudes and winds, etc.

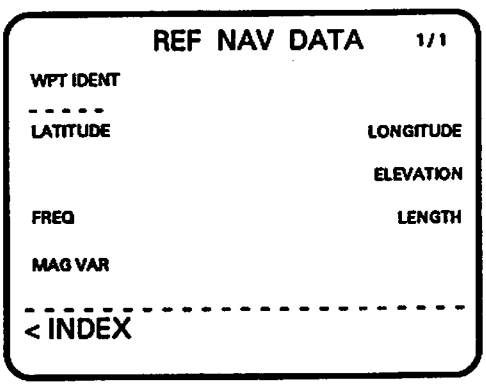
Figure 3-2a. Screens accessible from the Boeing 757/767 Initialization/Reference mode key (cont. from previous page).



Takeoff Reference Page: Displays takeoff speeds, takeoff EPR, and can be used as a checklist for FMC preflight.



Approach Reference Page: Displays FMC-calculated v_{ref} speeds and other approach information



Reference Navigation Data Page: Used to access detailed information on any waypoint, nav aid, airport, or runway in the FMC database.

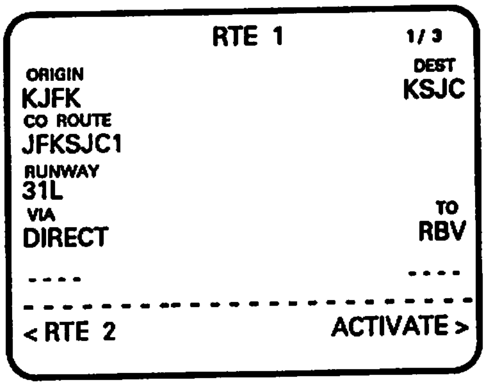
Figure 3-2b. Screens accessible from the Boeing 757/767 Initialization/Reference mode key (cont. from previous page).

- Access reference data on waypoints, nav aids, airports, and runways.

Upon power-up, the Program Identification page (Ident) appears to allow confirmation that the database is current.

The Boeing 757/767 Route Mode

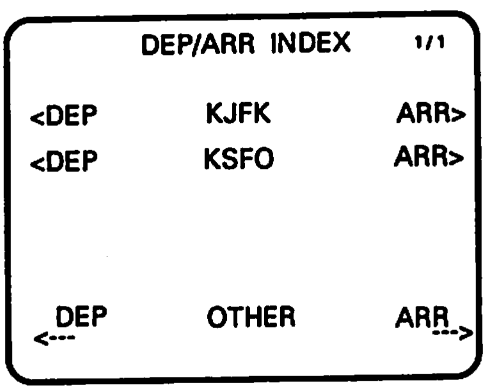
The intended route is programmed into the Boeing FMC by means of two mode keys. Origin, destination, runway, and waypoints are entered through the Route mode. If there is an established company route, the identification number for that route can be used instead and the complete route will appear. SIDs and STARs, on the other hand, are entered through a different mode, "Departure and Arrival."



The B757/767 FMC allows the crew to input two different flight plans. Presumably, this is one method for reducing the amount of in-flight programming. Pressing the Route function key automatically brings up Route 1 unless Route 2 is active.

The Boeing 757/767 Departure/Arrival Mode

SIDs and STARs are selected by means of the Departure/Arrival mode. Pressing the mode key will access one of four pages, depending upon the point in flight when pressed. The FMC attempts to provide that page which is most likely to be desired at that point in the flight. If no active route has been programmed, the Departure/Arrival Index page appears.



If an active route exists but the aircraft has not departed, the SIDs and runways for the departure airport appear.

```
        KJFK DEPARTURES   1/2
SIDS          RTE 1     RUNWAYS
KNDY4                        4L
                            22R
                            31L
                            31R
---------------------------------
< INDEX                  ROUTE>
```

After departure but within 50 NM of the originating airport, the STARs and runways for the originating airport will be shown. Beyond 50 NM, or when the halfway point is reached, whichever is first, the STARs and runway for the destination airport are shown.

```
        KSFO ARRIVALS     1/2
STARS         RTE 1     RUNWAYS
MOSES1                   ILS32R
POTHS                     RNV21
TROY1                     VOR03
                         VOR14L
                          VOR21
---------------------------------
<INDEX                   ROUTE>
```

The Boeing 757/767 Legs Mode

The Legs mode displays detailed information on each leg of the route. The Legs mode is comprised of two pages: Legs and Data. The layout of the legs page resembles a computer flight plan, displaying the waypoints, courses, and distances for each leg, together with the speeds and altitudes at each waypoint. The active waypoint always appears at the top of the page, then disappears from the list as it is passed.

ACT RTE 1 LEGS		5/6
051°		
HVE		.80 / FL350
045°	88 NM	
BCE		.80 / FL310
035°	160 NM	
BLD		.80 / FL290
035°	160 NM	
HEC		.78 / FL210
032°	35 NM	
RESOR		.78 / FL180
		EXTENDED
< RTE 2 LEGS		DATA >

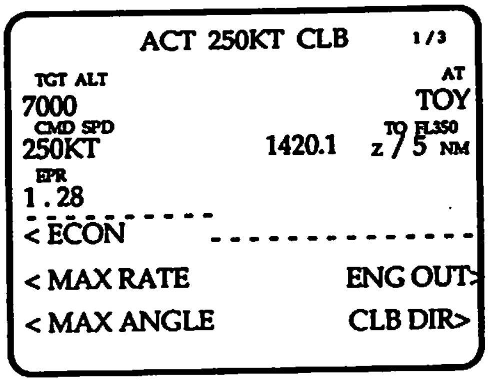
The Route Data page presents ETAs for each waypoint. Forecast winds for each leg can be entered on this page to allow more accurate ETA estimates. Otherwise, estimates are based upon the wind conditions entered on the CRZ Wind line of the Perf Init page. The Data page is also used to enter course offsets.

ACT RTE 1 DATA		5/6
	ETA	WIND
HVE	1912z	255° / 43
BCE	1925z	255° / 43
BLD	1935z	255° / 43
HEC	1948z	255° / 43
RESOR	2005z	255° / 43
OFFSET		
---		LEGS >

The Boeing 757/767 Climb Mode

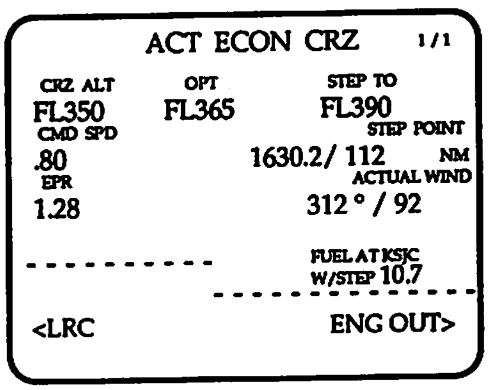
The Climb mode is one of three performance modes, the other two being Cruise and Descent. Beginning with takeoff, the Climb mode continues until the aircraft reaches the selected cruise altitude. The Climb page displays altitude, speed, power settings, and other information relevant to this phase. A Climb page is provided for each climb segment. The active segment page appears when the Climb mode key is pressed. In addition, the crew can select one of five types of climbs, including economy climb, engine out climb, and maximum rate of climb.

If the Climb key is pressed during the cruise phase of the flight, a Cruise Climb page will appear. This page is especially useful in that the crew can enter a candidate altitude, using the FMC to compute a fuel savings or penalty figure based upon selected altitude and winds.



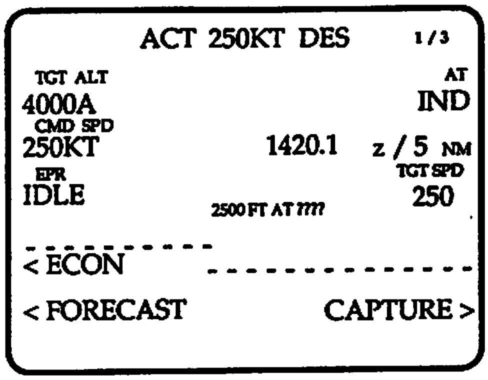
The Boeing 757/767 Cruise Mode

The Cruise phase begins when cruise altitude is reached and continues until reaching the top of descent point. Information on altitude, airspeed, wind, top of descent, and step climb can be accessed by pressing the Cruise mode key. If the Climb page is displayed when cruise altitude is reached, the Climb page will automatically change to the Cruise page. Four types of cruise are available, including economy cruise and long range cruise. The Cruise mode also displays the optimum cruise altitude based upon weight and wind conditions. An altitude also can be entered in the Step To line, enabling the FMC to compute a percent savings or penalty.

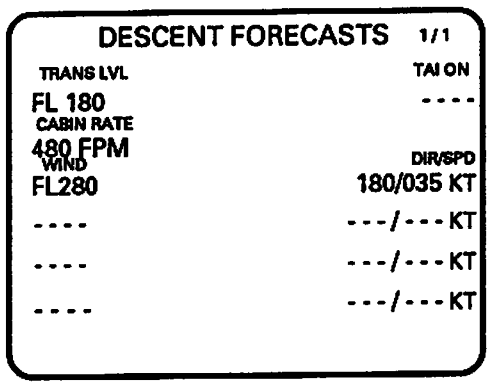


The Boeing 757/767 Descent Mode

Descent phase begins at the top of descent point and continues through the landing phase. The Descent mode behaves in a similar fashion to the Climb mode, showing speed, altitude, ETA and distance to the target altitude, and thrust setting. In addition, a Descent page is computed for each descent segment. Finally, the Descent page appears automatically if the Cruise page is displayed when top of descent is reached. If the Descent key is pressed during the cruise phase, a Cruise Descent page will be displayed.

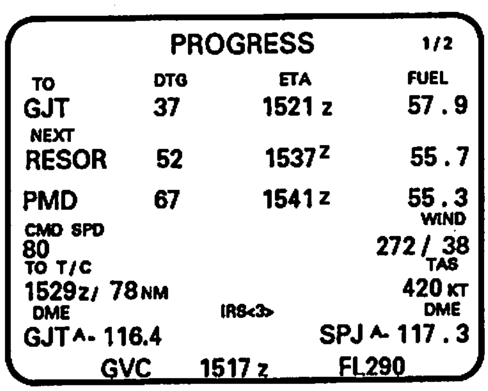


Pressing the forecast line select key accesses a second descent page that allows input of forecast values that will improve the accuracy of the computed descent profile.



The Boeing 757/767 Progress Mode

The Progress mode is comprised of two pages of data useful for monitoring the progress of the flight. The first page presents distance to go, ETA, and predicted fuel for the active waypoint, the following waypoint, and the destination airport. Other waypoints can be entered in the destination airport line by the crew to access distance to go, ETA, and fuel data for that waypoint.



The second Progress page displays headwind or tailwind conditions, crosstrack error relative to the active route, and fuel status.

```
                 PROGRESS              2/2
TAILWIND                         CROSSWIND
13 KT                                 5 KT
XTK ERROR                        VTK ERROR
L0.0 NM
                                       SAT
                                    -23 °C
               FUEL USED
L2.2              TOT          5.3 R 2.0
               FUEL QTY
TOTALIZER                       CALCULATED
49.5                                  49.7
```

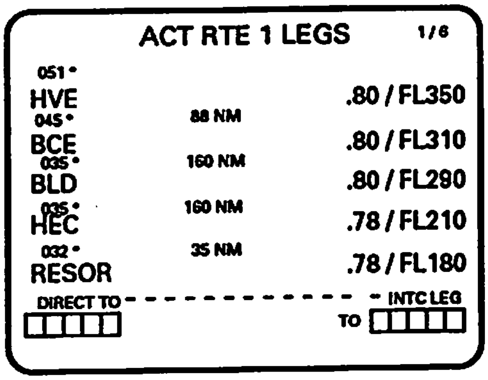
The Boeing 757/767 Fix Mode

ETA, distance to any radials crossing the active route from a selected waypoint, and distance to go can be obtained through the Fix mode. When a waypoint identifier is entered (for any waypoint, radio aid, or airport), displays the magnetic bearing and distance from the current aircraft position to that waypoint. Selecting the Abeam key provides the same data for the point on the active route abeam the selected fix.

```
              FIX INFO              1/1
FIX           BRG / DIS FR
IND           329 / 53
DNTK FX       ETA          DTG      ALT
349 / 22      1439.1       36       FL332
- - -
- - -
 ABEAM

< ERASE
```

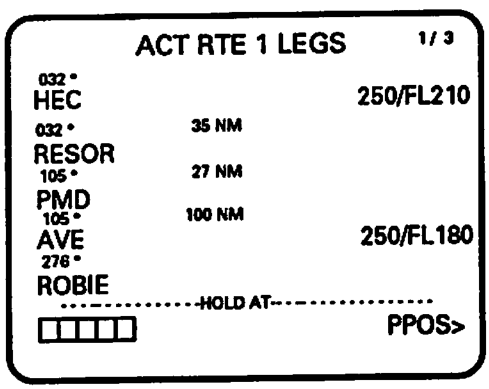
The Boeing 757/767 Direct or Intercept Mode

Rapid modifications to the active route can be made by means of the Direct or Intercept mode. This mode allows the crew to fly directly to a waypoint or intercept a course to a waypoint. Selecting the Direct/Intercept mode accesses a Legs page which has been modified to provide two options, a field to enter a Direct To waypoint and a field for entering an Intercept Leg to waypoint.

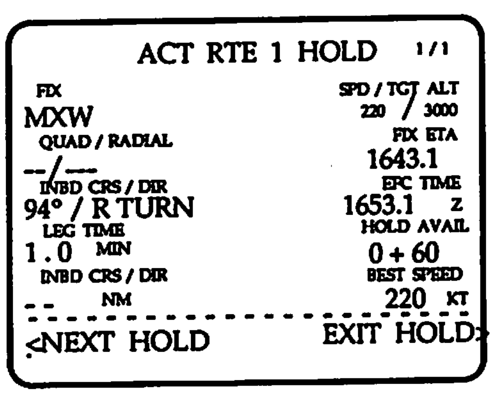


The Boeing 757/767 Hold Mode

Selection of a holding pattern takes place through the Hold mode. Pressing the Hold mode key accesses a Legs page which has been modified to provide Hold options. The Hold feature can be used in one of two ways. During a flight, a hold can be initiated by entering a hold location or using the present aircraft position option. Or a hold can be introduced into the flight plan by entering the waypoint identifier and adding the holding pattern to the active route.



Once a waypoint identifier has been entered in the box prompt, a Hold page for that waypoint is displayed. This page provides the information necessary for performing that hold, including inbound course and turn direction, speed and altitude, and expected further clearance time.



The Boeing 757/767 Structure

A variety of methods are available for organizing the information provided by the FMC. The most likely methods are:

- Phase of flight
- Pilot's task as a basis for assigning information (e.g. define the vertical and lateral aircraft path; monitor aircraft progress; monitor aircraft performance.
- Criticality of the activity.

As Table 3-2 shows, the Boeing structure clearly uses a combination of these logics.

Phase of Flight	Pilot Task	Task Criticality
Climb	Route	Direct To or Intercept
Cruise	Progress	Hold
Descent	*Initialization	
*Initialization	Legs	
Departure/Arrival		

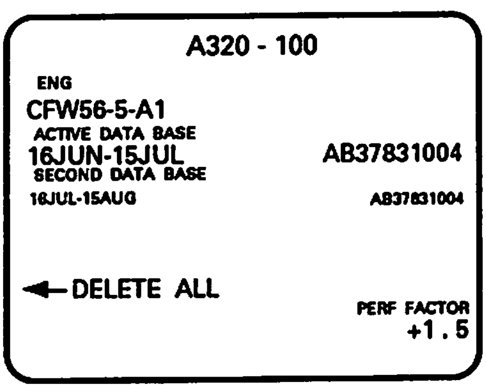
Table 3-2. The mixed structure of the Boeing FMC information layout.

THE AIRBUS A320 MODE KEY STRUCTURE

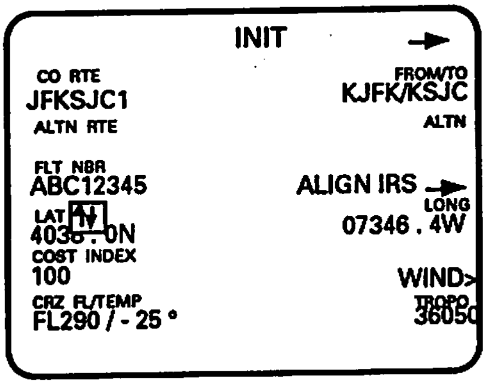
The Airbus 320 has nine mode keys, which are described in Table 3-1.

The Airbus Initialization Mode

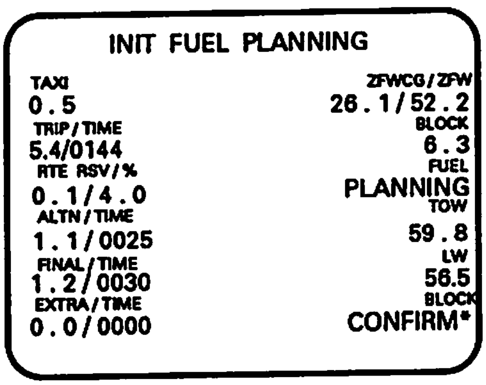
Like the Boeing system, the Airbus 320 has an initialization mode. The Airbus mode is comprised of two pages. A third page, the Status page is used to assess the currency of the database.



The first initialization page is used to define the origin and destination airports, and company route for both the primary and secondary flight plans. Additional computational information, including position initialization and winds, are defined on this page as well.



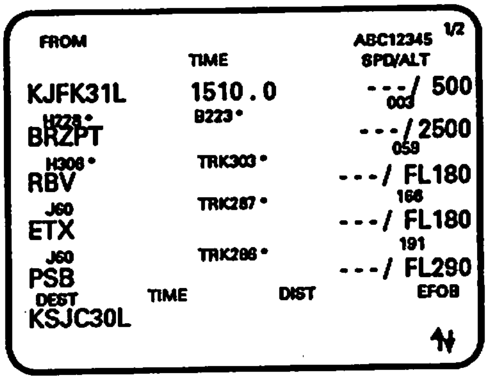
The second initialization page is used for fuel planning. This page is only available prior to engine start.



In comparison with the Boeing system, the A320 provides a greatly condensed initialization mode. In particular, the reference navigation data provided in the Boeing initialization mode has been shifted to its own mode, the data mode, in the A320 FMC.

The Airbus Flight Plan Mode

The flight plan mode acts as a combination of the Boeing route and legs modes. Like the route mode, the flight plan mode is used to input the flight plan but the flight plan mode includes substantially more information than the route mode, including the capability to display and allow modifications of times, speeds, and altitudes for each leg. This information is provided by the legs mode on the Boeing FMC.



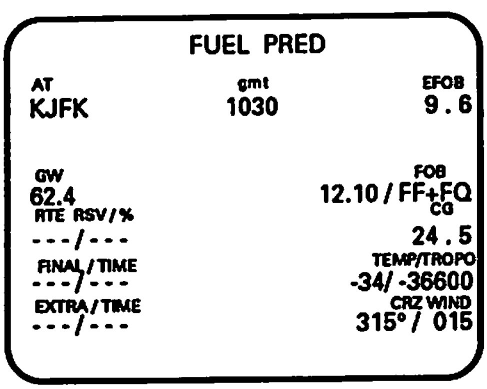
Modifications to the flight plan page involve an additional set of screens that are directly accessed from this page by means of the line select keys. Pages allowing modifications to the lateral path are accessed using the left line select keys. These modifications are referred to as lateral modifications. Changes to airspeed and altitude, known as vertical modifications, are made by using the right line select keys. These pages are described in Chapter 4.

The Airbus Secondary Flight Plan Mode

Both the Boeing and Airbus FMCs allow the crew to enter a second, alternative flight plan. In the Boeing system, this second flight plan is treated as a second route. Accessing the second, inactive plan occurs by pressing a line select key on the route mode page. The Airbus system, in contrast, treats the backup flight plan as a separate mode. The pages provided by this mode are the same as those found in the flight plan mode, and behave in the same fashion.

The Airbus Fuel Prediction Mode

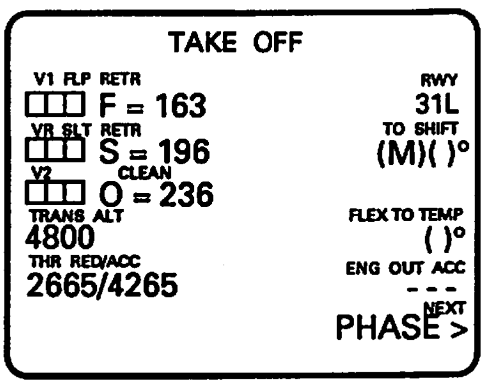
The second page of the Airbus initialization mode provided information necessary for fuel planning. This page is only available prior to engine start. After engine start, the fuel prediction mode is used.

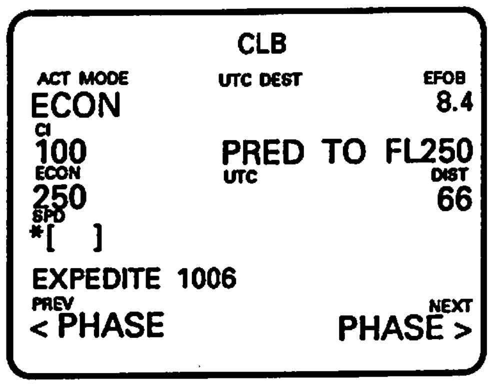


The Airbus Performance Mode

Three Boeing modes are used to provide performance data, climb, cruise, and descent. The Airbus FMC gathers all of these pages and combines them into the performance mode. Each phase of flight defines the page that appears when the performance mode select key is pressed. Pages for later phases can be accessed by pressing the next phase line select key.

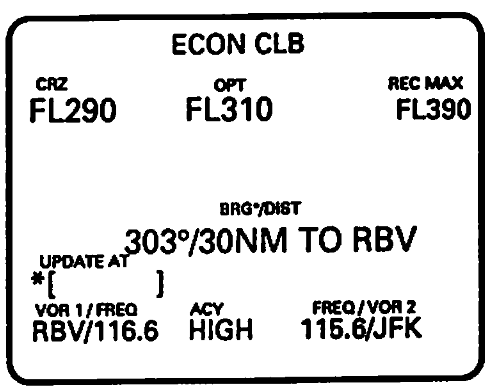
Performance mode pages are intended to be used prior to takeoff for specifying important performance characteristics the FMC needs to perform its calculations. During the flight, these pages provide important performance data concerning speeds and fuel. As examples of these pages, the takeoff and climb performance pages are shown.





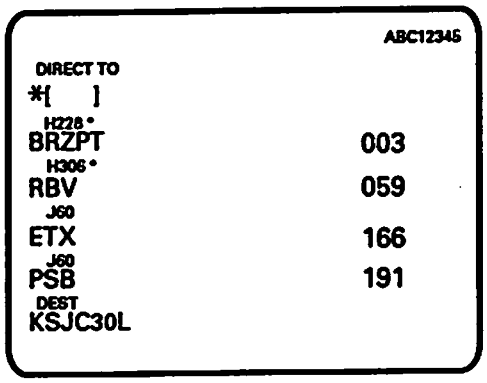
The Airbus Progress Mode

Like the performance modes of the Airbus and unlike the progress page of the Boeing system, the Airbus progress mode provides a page for each phase of the flight. Important vertical and lateral navigation information is provided. For example, during the climb phase, information about the target altitude, the optimum performance altitude, and the maximum altitude are provided. In addition, the page provides relevant communication frequencies that can be used to obtain a current fix. .



The Airbus Direct Mode

Like the Boeing system, the direct mode provides an efficient method for updating the flight plan. Selecting the direct mode accesses a modified version of the flight plan.



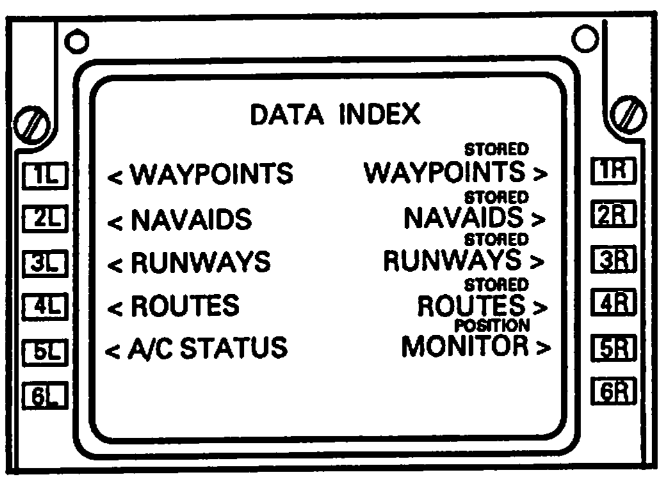
This page is used by typing in the waypoint which will serve as the direct to waypoint. If the waypoint already is apart of the flight plan, the waypoint name can be line selected to the scratchpad then moved to the direct to line.

The Airbus Radio Navigation Mode

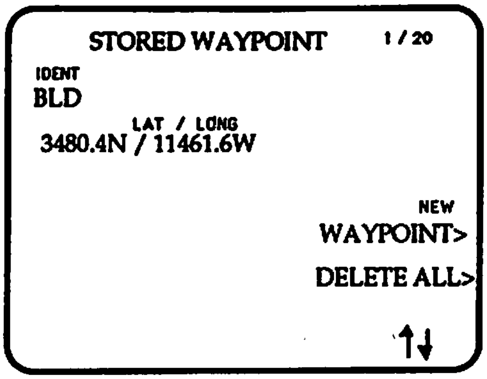
This mode is used to tune the various navaids, including VORs, DMEs, and ILSs.

The Airbus Data Mode

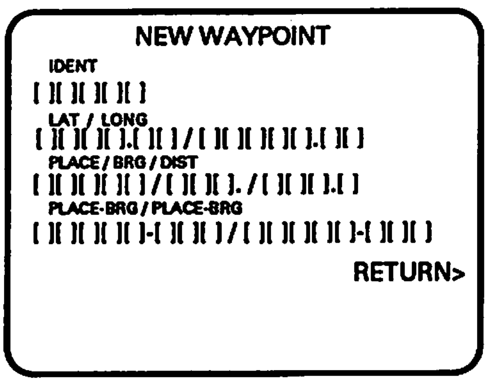
The data mode supports two uses. First, data pertaining to existing waypoints, navaids, runways, and routes can be accessed through this mode. In addition, new waypoints, navaids, runways, and routes can be entered into the database. Accessing the data mode brings up an index screen.



If a waypoint is already defined, the following page will appear.



Creating a new waypoint uses the following page.



The Airbus A320 Structure

The A320 uses a somewhat different than the Boeing 757/767. The three categories of organization used to explain the Boeing system (phase of flight, pilot task, criticality) presented in Table 3-2 do not perform well with the A320. An alternative is to suggest that the Airbus uses two primary mode categories:

- Data input, which supports inputting and modification of data required for navigation and aircraft performance;
- Flight performance, which includes those modes required for monitoring and controlling the flight.

Some modes, such as the flight plan, belong to both categories.

Data Input	Flight Performance
Initialization	Performance
*Flight Plan	*Flight Plan
*Secondary Flight Plan	*Secondary Flight Plan
Data	Progress
Radio Navigation	Direct
Fuel Prediction	

Table 3-3. The structure of the Airbus A320 FMC information layout.

THE UNIVERSAL UNS-1B

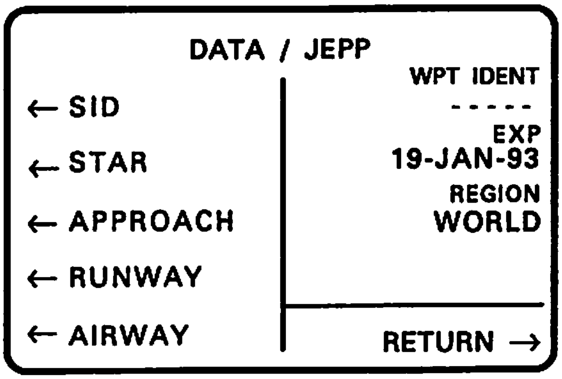
The Universal FMC reflects a slightly different philosophy in keeping with its primary use in business jets. It uses a strongly hierarchical structure that helps to lead the user through the various procedures involved, especially with respect to entering the flight plan and storing or accessing data. In terms of the mode level, the UNS-1B most closely resembles the A320. Eight modes are used, which are described below.

The Universal UNS-1B Data Mode

The Data mode provides two major types of information: (1) Database information, which includes two types of navigation information, Jeppesen-defined and pilot-defined. (2) Information about the configuration of the FMS and the aircraft. Pressing the mode select key accesses a data index.

```
          DATA    1/4
← JEPPESEN              CONFIG →

← PILOT

← DISK

← AFIS

← HOLD POS
```

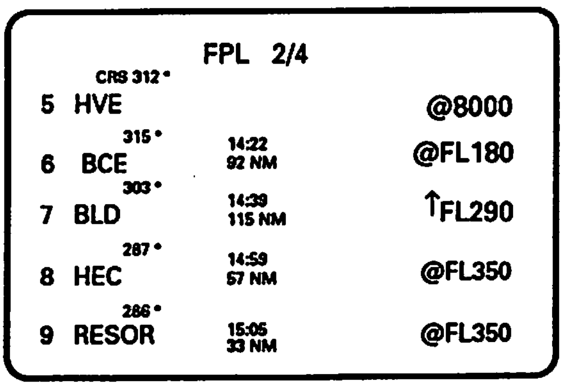
Accessing specific Jeppesen, pilot-defined data, or configuration data takes place through a series of menus. For example, pressing the Jeppesen line select key brings up second menu. From this menu, the crew can access specific data on any navigation element stored in the database.



The pilot database allows the flight crew to permanently store pilot-defined SIDs, STARs, approaches, runways, and airways. Menu-based guidance leads the user through the various steps involved in adding a navigation element to the database.

The Universal UNS-1B Flight Plan Mode

This hierarchical structure is also apparent in the flight plan mode. This mode is used to construct a new flight plan or to modify the current plan.



Flight plan construction, which is discussed in more detail in Chapter 4, involves filling in the blank flight plan page that is first accessed when the flight plan mode key is selected and no flight plan exists. Routes, departure SIDs and transitions, and arrival STARs and transitions are copied into the flight plan from the data mode where they are stored.

The completed flight plan view shows the waypoints, ETAs, altitudes (if defined through the VNAV mode), distances between waypoints, and bearings. Procedural legs of SIDs, STARs and approaches are also shown.

FPL MENU	
← NORMAL	WPT TO DEST →
← COMPRESSED	WPT DEFN →
← PPOS TO WPT	APPR PLAN →
← DEPART	ARRIVE →
← STORE FPL	RETURN →

The Universal FMC offers a range of flight plan views by means of the flight plan menu which is accessed by depressing the menu function key while in the flight plan mode.

The crew can choose a range of views from a compressed overview of the entire plan, listing the waypoints that comprise the flight plan, to close-up views of departure and arrival procedures. Distance and ETA information from the present position to any other waypoint can also be easily accessed. The Universal system has again utilized the hierarchy to provide easy access to a range of navigational information.

The Universal UNS-1B Navigation Mode

The navigation mode provides a variety of navigation data as well as methods for modifying the current navigation leg. Information provided includes: current FROM, TO, and next waypoints; distance, course, and bearing to the TO waypoint; wind direction and speed; and current groundtrack and groundspeed.

NAV 1/2	
FMS 1 POS N 47 12.5	FMS 1 Q = 05
W 110 17.2	OSS / IRS
← HOLD POS	SENSORS →

The second navigation page presents FMS system position and the quality factor for that computed position.

The Universal UNS-1B VNAV Mode

The vertical path of the aircraft is defined using this mode. A vertical flight profile can be defined for those waypoints included in the flight plan. Deviation from this flight plan is also provided in this mode.

Four pages can be accessed through the VNAV mode. The vertical navigation cruise page, available when in the cruise mode or VNAV is inactive, allows the vertical flight profile to be defined or intercepted.

To Be Completed

CONCLUSIONS

Comparisons between the three FMCs. Table 3-1 summarizes the modes for each FMC. Conclusions will be drawn as to the logic of each system and the implications each logic has for information layout across pages.

To Be Completed

I want implications for operator's utility ! !

Boeing 757/767	Airbus A320	Universal UNS-1B
Initialization/Reference Mode: Selects page for initializing the navigation systems and various categories of reference data.	*Initialization Mode*: Selects page for initializing the navigation systems and various categories of reference data.	*Data Mode*: Selects page for reviewing existing Jeppesen navigation data, pilot-defined navigation data, and aircraft configuration.
Route Mode: Selects page for entering or changing origin, destination, or route.	*Flight Plan Mode:* Selects page for inputting or reviewing the flight plan.	*Flight Plan Mode*: Selects flight plan page for entering, modifying, or reviewing the flight plan.
Climb Mode: Selects page for evaluating and changing climb schedule.	*Secondary Flight Plan Mode:* Selects page for inputting or reviewing a second flight plan.	*Navigation Mode*: Selects page that displays navigation data for the current leg, including present position, for review or modification.
Cruise Mode: Selects page for evaluating and changing cruise schedule.	*Performance Mode:* Selects the climb, cruise, and descent performance pages. Each of these pages is used for evaluating and modifying that phase of flight.	*VNAV Mode*: Selects page that allows crew to define desired vertical flight path.
Descent Mode: Selects page for evaluating and changing descent schedule.	*Direct:* Selects page for entering route from present position direct to waypoint.	*Direct To*: Selects page for performing "direct to" clearances.
Direct/Intercept Mode: Selects page with box prompts required for entering route from present position direct to waypoint, or to intercept designated course to waypoint.	*Fuel Prediction:* Selects page for review of current and anticipated fuel usage.	*Fuel Mode*: Selects page fo rperforming all fuel management functions.
Legs Mode: Selects page showing lateral and vertical details of each leg of route. Selects page for modifying lateral or vertical waypoints; selects page for controlling HSI Plan mode map.	*Progress Mode*: Selects page for review of flight and navigation data, including ETAs for next two waypoints and destination.	*Tune Mode*: Selects a page that supports tuning of radios and storage of frequences.
Fix Mode: Selects page for creation of intersections between active route and bearing from an offroute fix.	*Data:* Selects page for review of stored navigation data.	
	Radio Navigation: Selects page for tuning navigation equipment.	

Table 3-1. Comparison of the Mode Keys for the B-757/767, A-320, and Universal (cont. next page).

Boeing 757/767
Departure/Arrival Mode: Selects page for entering or changing departure and arrival procedures for route one or route two.
Hold Mode: Selects page for entering or exiting holding pattern in active route.
Progress Mode: Selects current dynamic flight and navigation data, including ETAs for next two waypoints and destination.

Table 3-1. Comparison of the Mode Keys for the B-757/767, A-320, and Universal (cont. from previous page).

4. INPUTTING THE FLIGHT PLAN

FLIGHT PLAN GUIDING PHILOSOPHIES

Inputting the flight plan is one of the first tasks the flight crew must accomplish during pre-flight. The Boeing and Airbus FMCs are designed to allow the crew to simply enter a company route number and the FMC will automatically enter the appropriate data, from runway to waypoints. If necessary, an entirely new route can be entered manually but the new route cannot be saved as part of the permanent database. The guiding assumption appears to be that the flight crew will always fly a known company route and should not have to be involved with programming new routes.

The Universal, in keeping with its use in business jets, adopts a different philosophy. Flight plans can be constructed from existing routes, as is the case with the Boeing and Airbus FMCs, but the crew can also prepare new routes that can then be permanently stored in the database.

Both the Boeing/Airbus systems and the Universal treat the flight plan as comprised of two elements, route information and airport information. The rationale for this is the same in both cases: because different transitions can be used for the same runway, SIDs and STARs should not be included in the routes.

The remainder of this chapter examines these philosophies in more detail.

ENTERING THE BOEING FLIGHT PLAN

Before looking at the structure of the Boeing flight plan, the procedures for entering the flight plan are reviewed.

Boeing Flight Plan Procedures

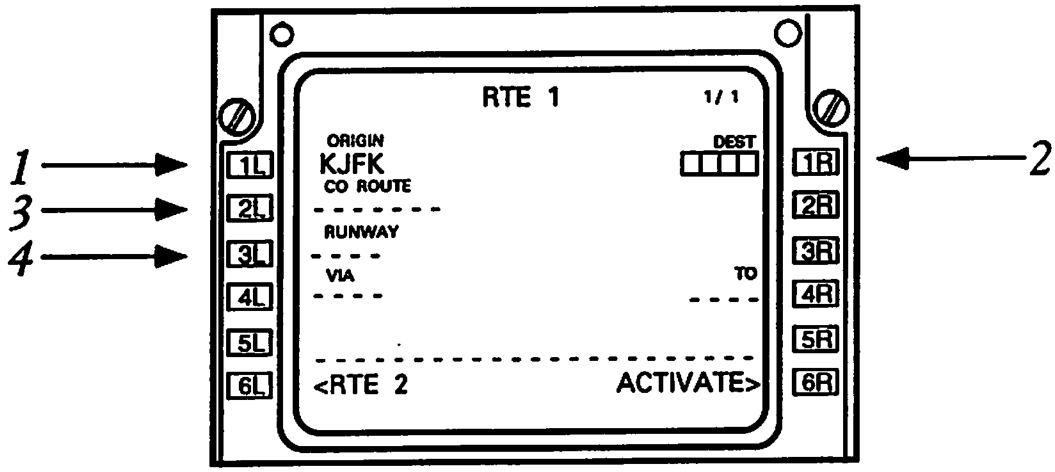
The Boeing system uses two modes to input the flight plan, the Route mode and the Departure/Arrival mode. The format of the route page is similar to an ATC clearance. Two methods can be used for inputting the flight plan into the Route mode. The first approach involves entering the company route number.

1. Make sure the airport of origin is entered in line 1L. If it is not, enter the correct ICAO station designation into the scratchpad, then line select to the appropriate field.

2. Enter the destination airport into line 1R.

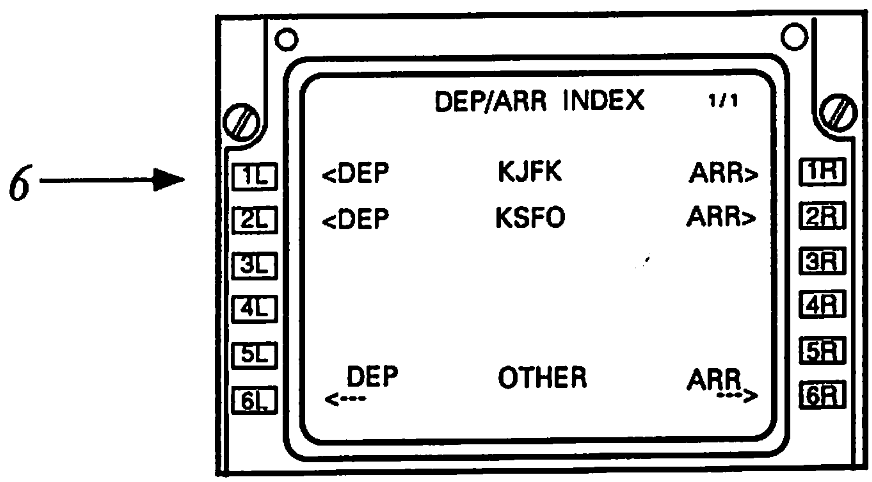
3. Enter the company route number.

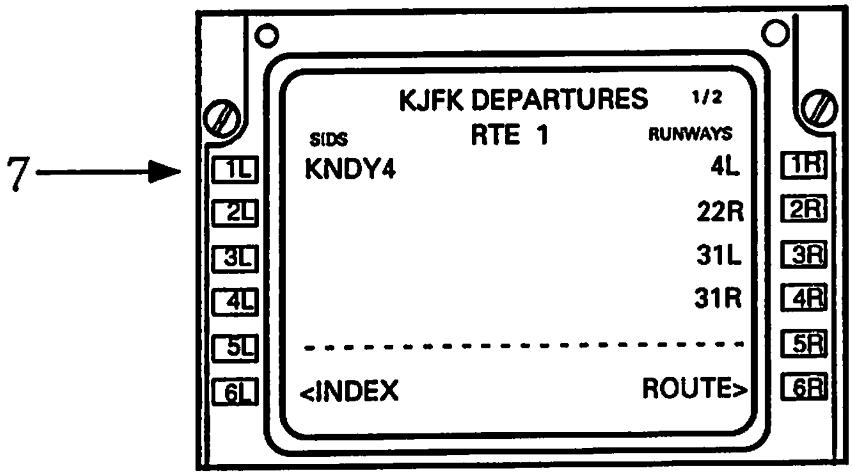
4. Enter runway, if known. If not known, runway will have to be entered before takeoff.



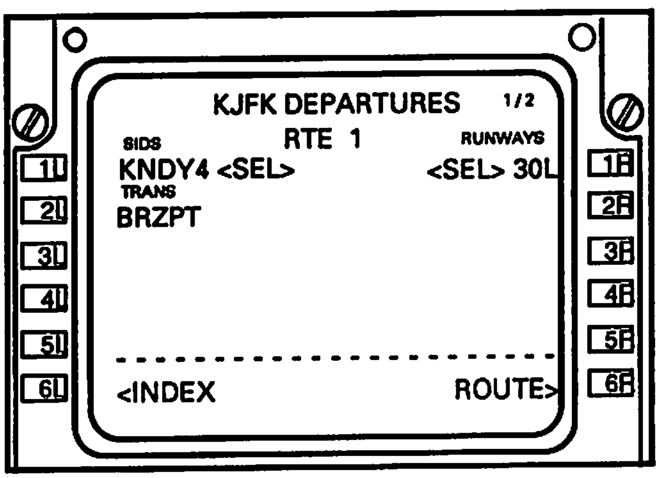
5. Move to the DEP/ARR mode by pressing the DEP/ARR mode key. Since there is no active route that has been entered, the DEP/ARR index page will appear.

6. Select the line select key corresponding to the departure airport.

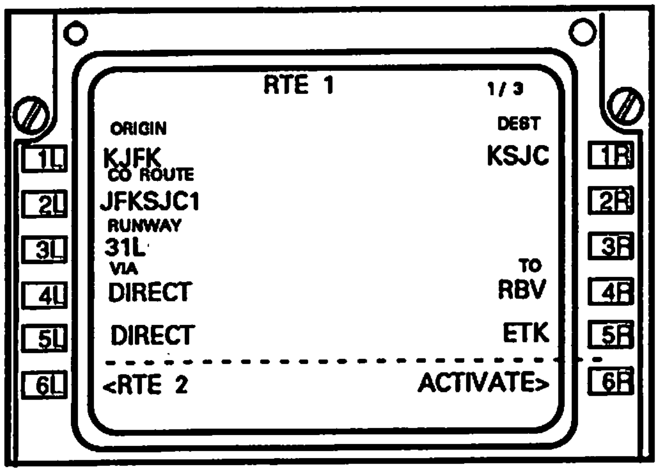




7. A list of SIDs and runways will appear. Push the line select key for the appropriate departure procedure. <SEL> appears next to the selected departure procedure.

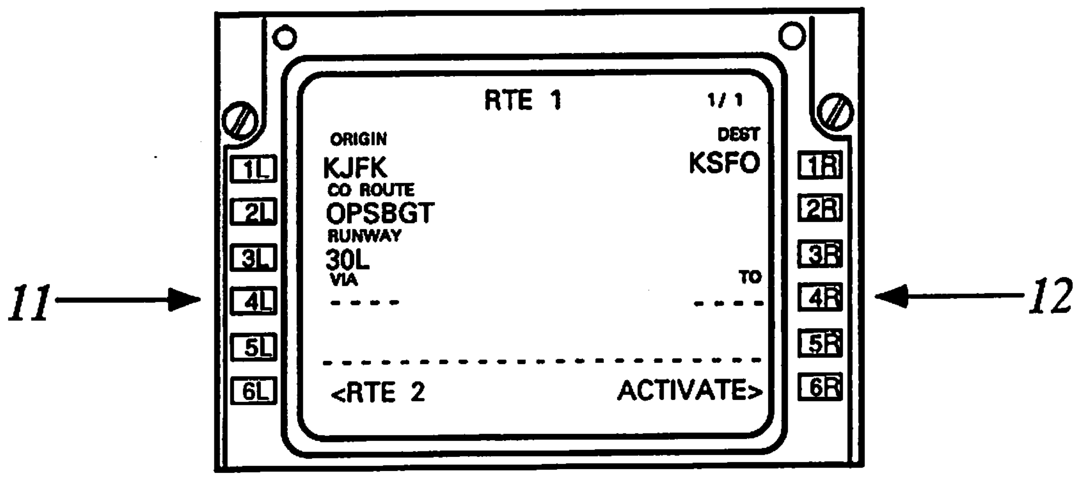


8. Selecting the desired SID will display all the transitions and runways associated with that SID. Select the desired transition. <SEL> appears next to the selected transition.



9. Press the ROUTE line select key.

10. Departure procedures selected through the Departure page now appear on the Route page. The flight plan is now complete but must be executed. To do so, the activate line select key is pressed. This lights the Execute function key on the CDU. Pressing the Execute key activates the flight plan.



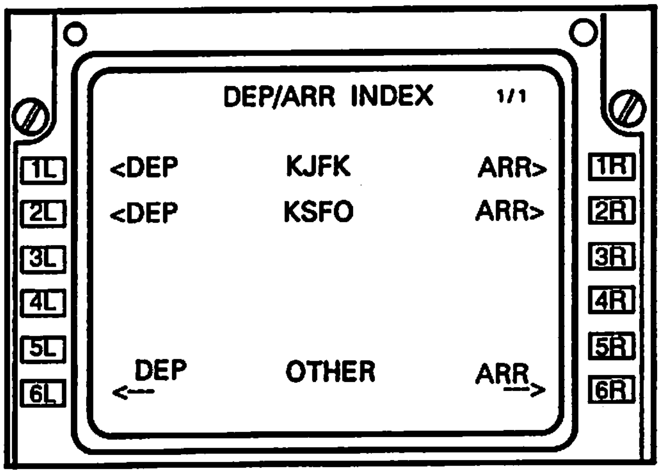
If a company route number is not used, the beginning and ending points of each airway are entered, as follows.

11. Enter the next route segment into the scratchpad. For example, Direct, then use the fourth line select key to place it in the field beneath "Via."

12. Then enter the name of the termination location in the scratchpad and use the fourth line select key on the right to place it in the field beneath "To." Repeat this process until all of the waypoints have been entered.

13. When all of the route segments have been entered, arrival procedures must be entered. Press the DEP/ARR mode key.

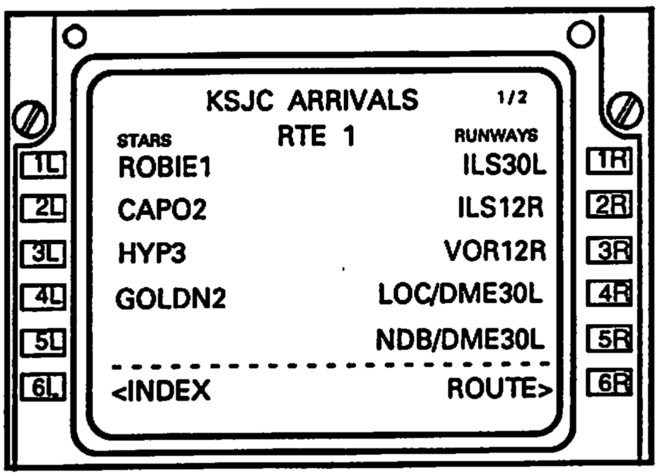
13



14

14. Select the destination airport by pressing the arrival line key select that corresponds to that airport, in this example, KSJC.

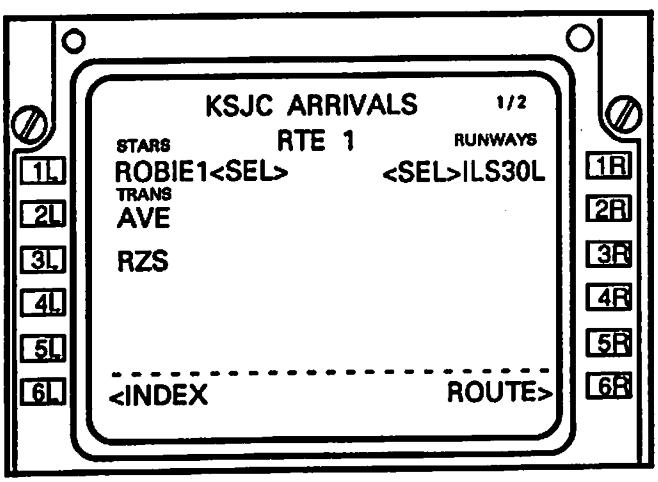
15a



15b

15. Select the appropriate STARS (15a) and runway (15b).

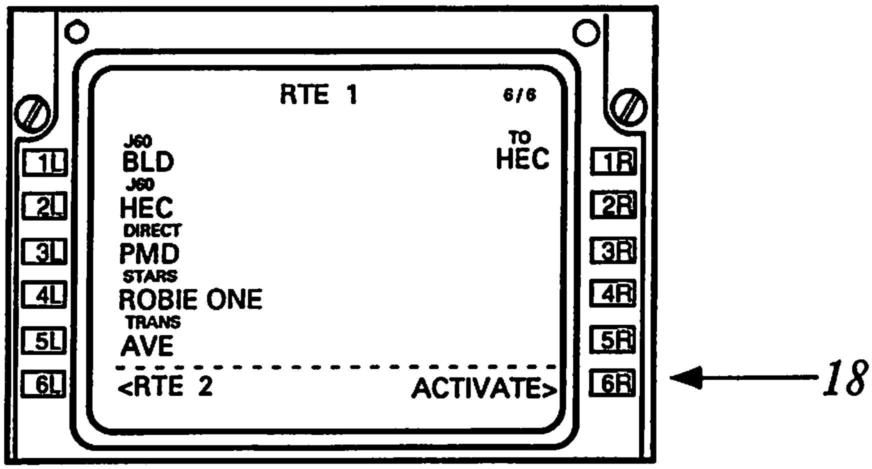
16



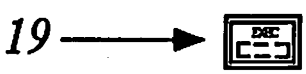
17

16. When the desired arrival procedure has been selected, transitions can be selected.

17. Press the line select key next to route. Arrival procedures that have just been input will appear.



18. The flight plan is now complete but must be executed. To do so, the activate line select key is pressed. This lights the Execute function key on the CDU.



19. By pressing the execute key the flight plan becomes active.

The Boeing Flight Plan Structure

The flight plan structure has two central components, the route mode and the departure/arrival mode. Selection of SIDs, STARs, and transitions takes place through the departure/arrival mode, while the various paths and waypoints are entered through the route mode.

Although both modes are integral to entering the flight plan, they behave, for the most part, as separate entities. The previous chapter suggested that the Boeing system can integrate modes through the use of prompts that, through selection of a line select key, will lead directly to another mode. Given this definition, the design of the two modes suggests that they be considered separate entities, with one exception. In the Departure/Arrival mode, a prompt to access the route mode is provided. Otherwise, no line select paths are provided.

Although no guidance is provided in moving between the route and departure/arrival modes, integrated clusters of procedures are used within each mode. In the case of the route structure, the route is constructed through a simple sequence paths and waypoints. Prompts in the form of field labels provide guidance for completing the route plan.

The departure/arrival mode also has an integrated cluster of procedures. Once in this mode, the FMC guides the user by providing a set of options from which the user chooses the one that is desired. This recognition-based guidance is provided for selecting the departure or arrival airport, the SIDs and STARs, runways, and transitions.

THE AIRBUS FLIGHT PLAN

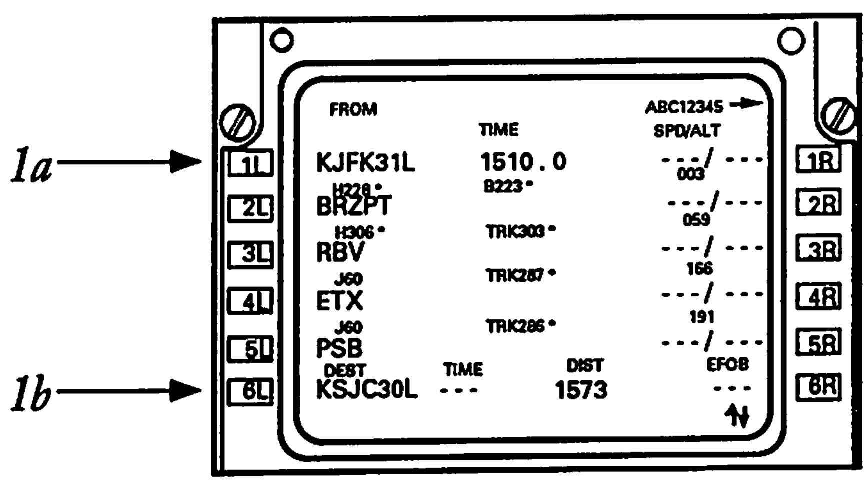
The Airbus FMC offers a more coherent set of procedures for entering a flight plan. Again the assumption is that a company route will be used.

Flight Plan Procedures

Like the Boeing system, the A320 FMC was designed to support input of the flight path based upon an established company route. Using this method, inputting the flight plan begins by entering the company route, origin airport, and destination airport on the initialization page. An alternative route can also be entered on that page. The user then accesses the first page of the flight plan mode using the FPLN mode select key.

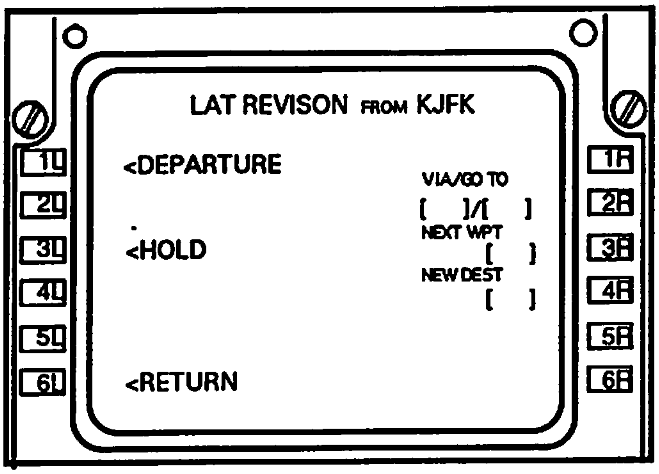
1. After accessing the first page of the flight plan mode, make sure the airport of origin and departure runway are entered in line 1L (1a) and the destination airport and landing runway in 6L (1b). In the example shown below, the runway information is shown. If the runway is not shown or is incorrect, the runways, SIDs, STARs, and transitions must be entered by using a lateral revision.

2. In this example, we will assume that a departure procedure was selected but must be changed. To perform a lateral revision, press the left line select key next to the airport with the missing runway. Lateral revisions are always initiated with a left line select key. A lateral revision page will appear.

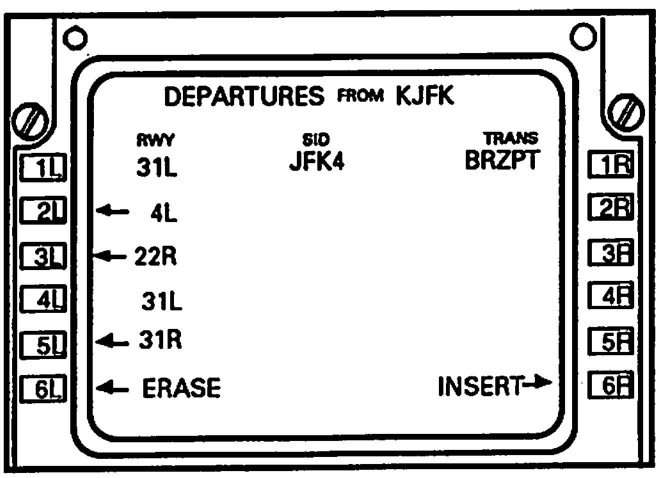


3. Press the first left line select key to access the Departure page.

4. The original procedures are shown across the top. Change the departure runway by pressing the appropriate line select keys.



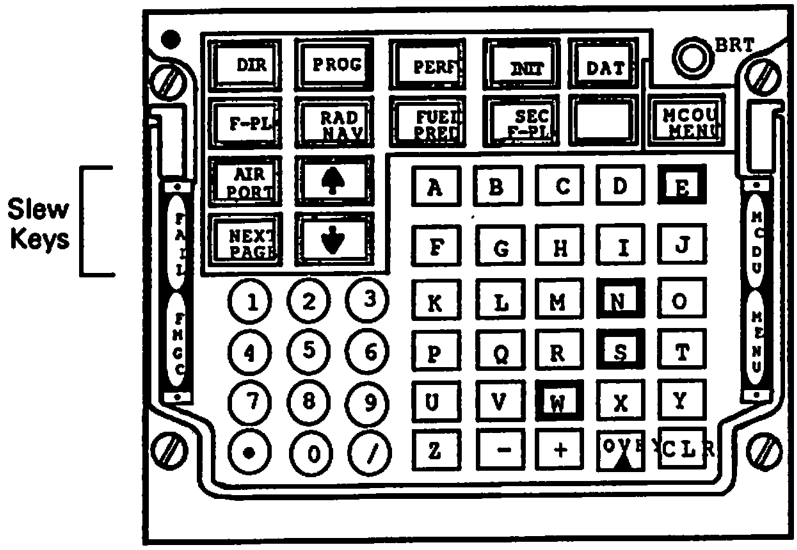
5. Selecting a runway automatically accesses SIDs and transitions pages. These are selected in a similar fashion. Once the runway, SIDs, and transitions are selected, they are automatically presented on the flight plan page.



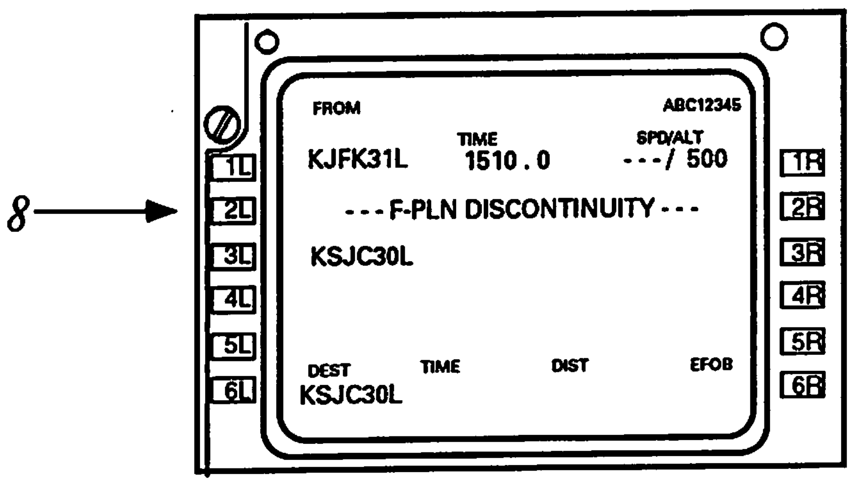
6. Entry of the flight plan is now complete. The entire flight plan can be reviewed by using the slew keys, identified by the arrow icons on the keys.

If a company route is not available, the route must be inputted as a series of waypoints.

7. Enter the origin and destination airports and procedures, as above.



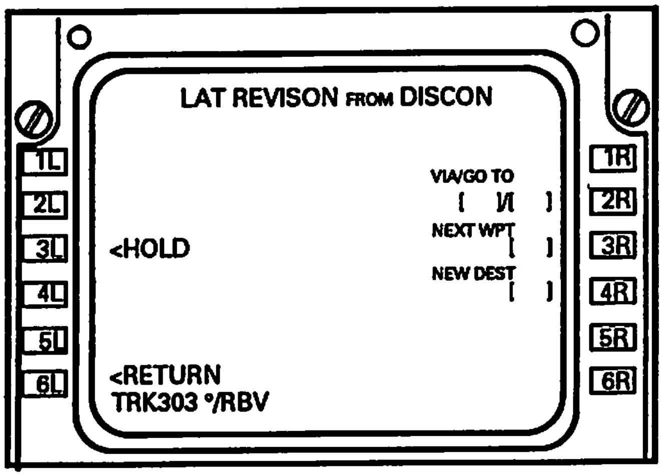
8. Because the flight plan contains no waypoints between the origin and destination airports, a flight plan discontinuity message appears. Press the line select next to the message. A lateral discontinuity page will appear.



9. Enter new waypoint in the scratchpad - MCDU KBD

16. Line Select at VIA/GO TO (LSK 2R) - MCDU

9 →



17. Verify new MCDU display (TEMPORARY F-PLN) - MCDU
18. Line Select INSERT at LSK 6R - MCDU
19. Verify new Situation Display on ND - NB
20. Verify new MCDU display - F-PLN DISCONTINUITY (LSK 3L) - MCDU
21. Line Select at F-PLN DISCONTINUITY - MCDU
22. Verify new MCDU display LAT REV FROM RBV - MCDU
22. Enter Airway/New Waypoint (J60/ETX) in Scratchpad -MCDU KBD
23. Line Select at VIA/GO TO (LSK 2R) - MCDU
24. Verify new MCDU display (TEMPORARY F-PLN) - MCDU
25. Line Select INSERT at LSK 6R - MCDU
    • REPEAT FOR ALL REMAINING AIRWAY/NEW WAYPOINTS
26. Verify new MCDU display (F-PLN Page A) - MCDU
27. Verify/Monitor new Situation Display on ND - NB

To Be Completed

The Airbus Flight Plan Structure

There are some important differences between the Boeing and Airbus flight plan structures.

Lateral revision format

Another important difference is the treatment of the vertical path in the Airbus system. The Boeing route page did not include fields for altitudes and airspeeds. Only information concerning the lateral path is provided. This additional information must be accessed through the Legs mode. The Airbus, in contrast, integrates this information on the flight plan pages. If the crew has this information and wishes to input it on the flight plan, they can.

To Be Completed

THE UNIVERSAL FLIGHT PLAN STRUCTURE

Universal UNS-1B Flight Plan Structure

The UNS-1B structure derives from ARINC 424 which defines 19 ways of defining a path over the earth. To accomplish this, information is organized in a hierarchical fashion A procedural leg consists of two parts, a leg path and a leg terminator. Accordingly, selection of leg path occurs first. The UNS-1B distinguishes between Routes, Legs, and Flight Plans. The Flight Plan defines the navigation leg sequence the aircraft will follow. It normally consists of SIDs, legs, and STARs. The flight plan is temporary: it must be programmed in at the beginning of a flight and is erased when the UNS-1B is turned off. Flight plans typically change during the course of the actual flight. These changes are temporary, that is, appropriate only for that flight. For this reason, Flight Plans are only temporarily stored. Routes, in contrast, are stored permanently in memory and can be copied into the Flight Plan. Any changes made to the Flight Plan do not alter the original Route used to build the Flight Plan. Of course, the Flight Plan can be permanently saved as a Route. However, the procedures (SIDs, STARs and Approaches) and their transitions are not stored as part of the Route. They must be re-entered into the Flight Plan each time.

To Be Completed

Universal UNS-1B Flight Plan Procedures

Can access an alphabetical listing of all the routes stored in the data base: DATA/PILOT/ROUTES

To Be Completed

5. MODIFYING AIRCRAFT VERTICAL PATH

VERTICAL PATH MODIFICATION SCENARIOS

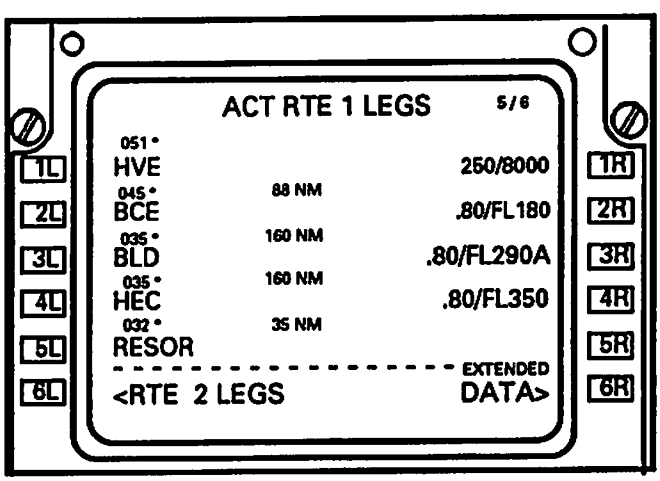
Controlling the vertical path of the aircraft is one of the most critical tasks to be performed by the crew. In a review of incidents reported to ASRS that involved FMSs, failing to meet an altitude restrictions was the most cited cause for having to file a report. Clearly, some flight crews are having trouble controlling their altitudes using the FMS technology. This chapter reviews the procedures for modifying vertical path required by each of the three FMCs. In each case, the scenario will involve a climb situation, even though controlling the descent on final is also a serious problem. Since the procedures used are the same, only examples involving climbs will be used. A second constraint is that procedures for modifying vertical path that do not involve the FMC are not included nor are the interactions required between the FMC and the mode control panel.

Two common situations requiring modifications to the vertical path are described. The first involves inputting altitude restrictions into the flight plan. Expediting the climb in order to reach the top-of-climb altitude more quickly will serve as the second example. The procedures demonstrated represent common methods for performing these modifications. However, there are a number of other methods that can also be used. In many cases, either company policy or personal preference determine the choice of procedures.

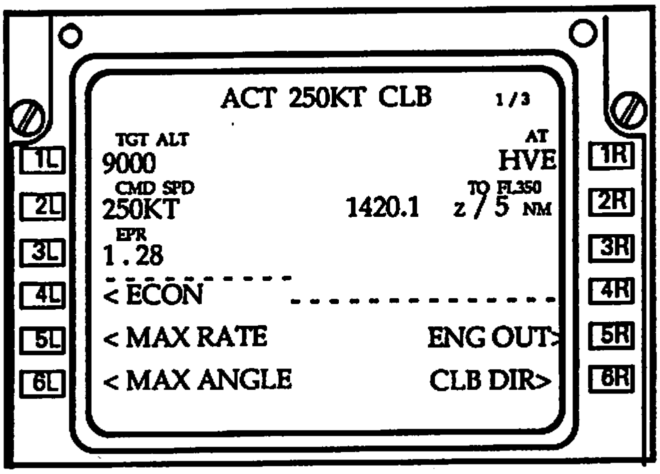
MODIFYING THE FLIGHT PLAN VERTICAL PATH

BOEING 757/767 VERTICAL PATH MODIFICATION

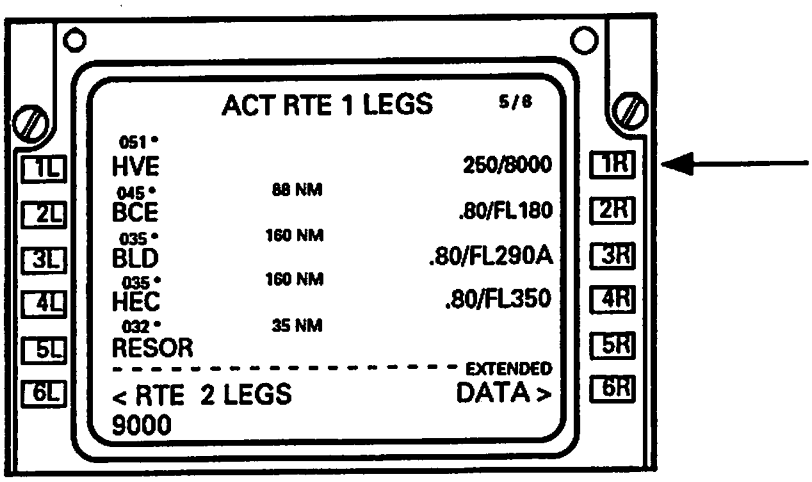
Two modes are likely to be used to modify the vertical path during flight. The legs mode provides summary information about the planned lateral and vertical path of the aircraft.



The climb mode page also typically is used to provide current data on aircraft performance.

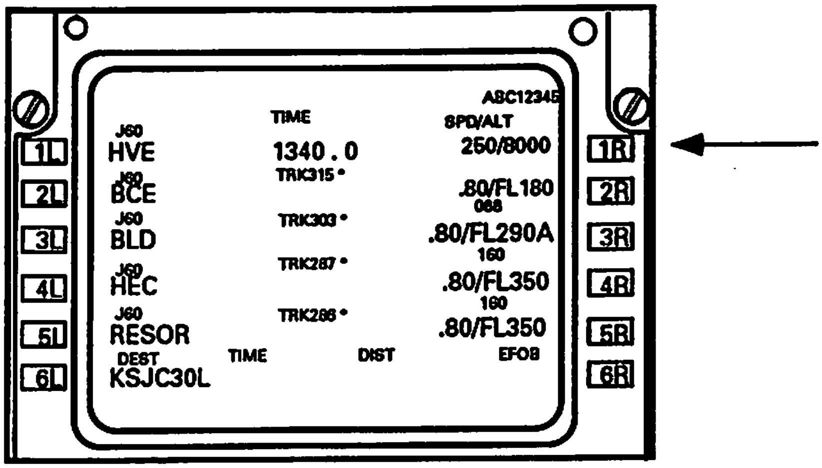


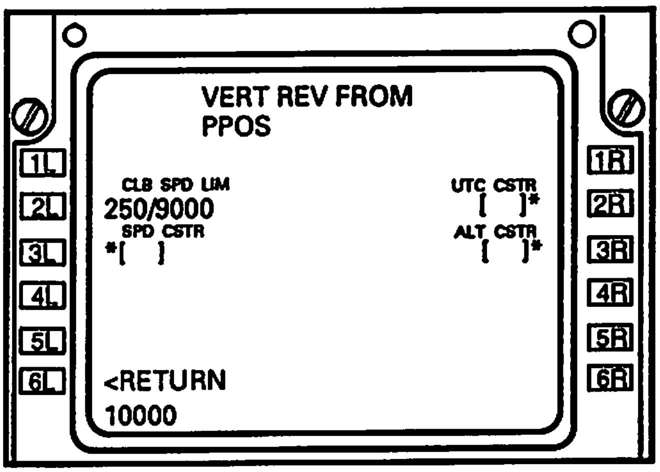
The legs page showed that the FMC forecasts that HVE will be crossed at an altitude of 9,000 feet. FMC forecasts are differentiated from crossing restrictions by presenting forecasts in a smaller font size. Changes to a leg altitude can be made through the legs page. The desired altitude is simply typed into the scratchpad and moved, using the right line select key to the appropriate field. Pilot-selected altitudes are treated as crossing restrictions and are presented in the larger font size.



Airbus A320 Vertical Path Modification

The flight plan page provides information about both the lateral and vertical path of the aircraft. Consequently, changes to altitude can be made through this page. Such changes, which are referred to as vertical revisions, require the use of a vertical revision page which is accessed with the right line select key located next to the to-be-modified field.





Modifying the altitude during climb is usually accompanied by careful monitoring two other modes, the performance and progress modes.

Universal UNS-1B Vertical Path Modification

To Be Completed

Vertical Path Modification Conclusions

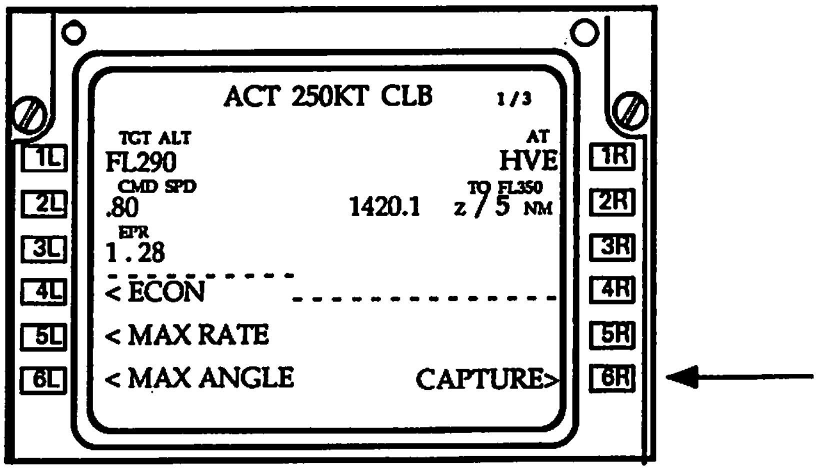
To Be Completed

Expediting the Climb

The climb phase is usually broken up into segments. For example, the Boeing 757/767 assumes two climb segments, takeoff to 10,000 feet and 10,000 feet to cruise altitude. Additional crossing restrictions can result in additional segments. Although these segments may be programed into the FMC, an ATC instruction may occasionally request that the crew climb more quickly, bypassing lower restrictions.

Boeing 757/767 Expedited Climb

The performance mode of the Boeing 757/767 offers one or more pages for each phase of flight. In addition, the climb performance mode provides a page for each climb segment. On all but the active leg page, the lowest right-hand line select key has a prompt called "capture."



Pressing the capture line select key one the page showing the segment with the target altitude bypasses all previous segments.

Airbus A320 Expedited Climb

An expedited climb on the A320 is performed by means of the mode control panel, rather than the FMC.

Universal UNS-1B Expedited Climb

To Be Completed

Expedited Climb Conclusions

To Be Completed

VERTICAL PATH CONTROL CONCLUSIONS

To Be Completed

6. LATERAL REVISIONS TO THE FLIGHT PLAN

LATERAL REVISIONS SCENARIOS

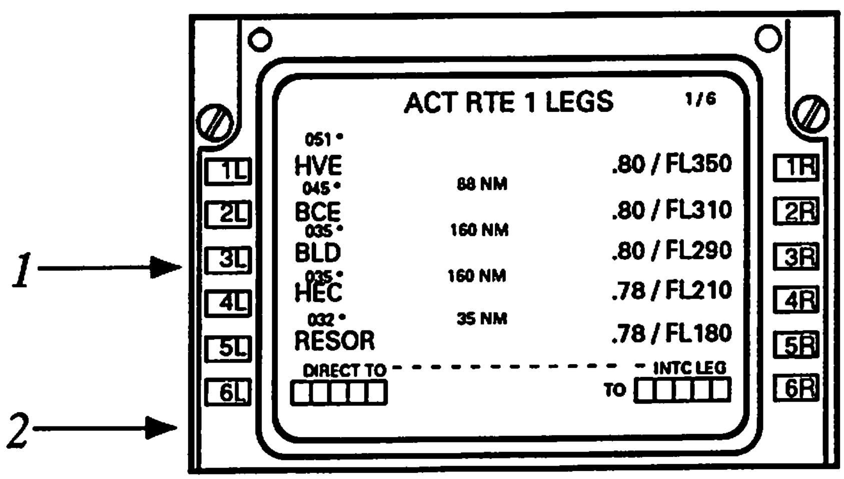
Lateral modifications to the flight plan can occur for a number of reasons, including weather and traffic. Procedures for implementing four common types of modifications are described in this chapter. These particular maneuvers were selected either because they are common maneuvers or because they have been cited as especially problematic when performed by means of the FMC (Eldredge, Mangold, & Dodd, 1992).

DIRECT TO A WAYPOINT

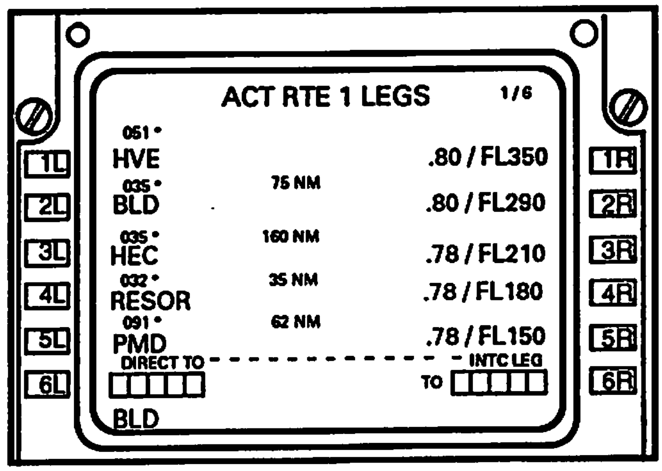
Resuming the path defined by the flight plan following temporary modifications to the flight plan often requires re-programming the FMC to perform a "direct to" a waypoint which is already part of the flight plan.

Boeing 757/767 Direct to a Waypoint

The Boeing system has a direct/intercept mode. Pressing this mode select key accesses a modified version of the legs page.



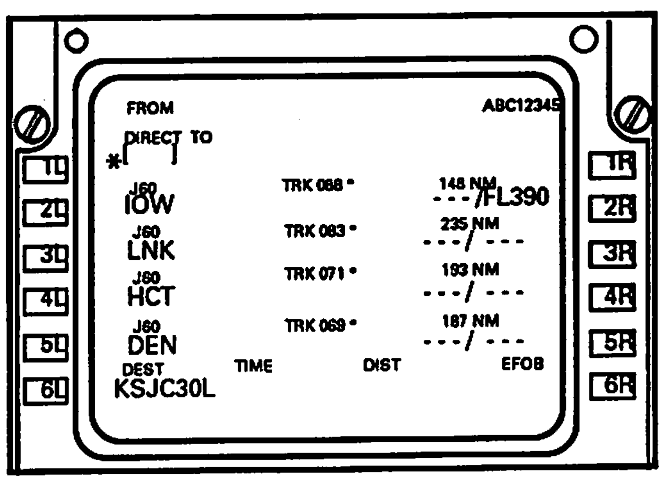
Copy the desired waypoint to the scratchpad (#1), using the appropriate line select key, then line select it to the DIRECT TO line (#2).

3


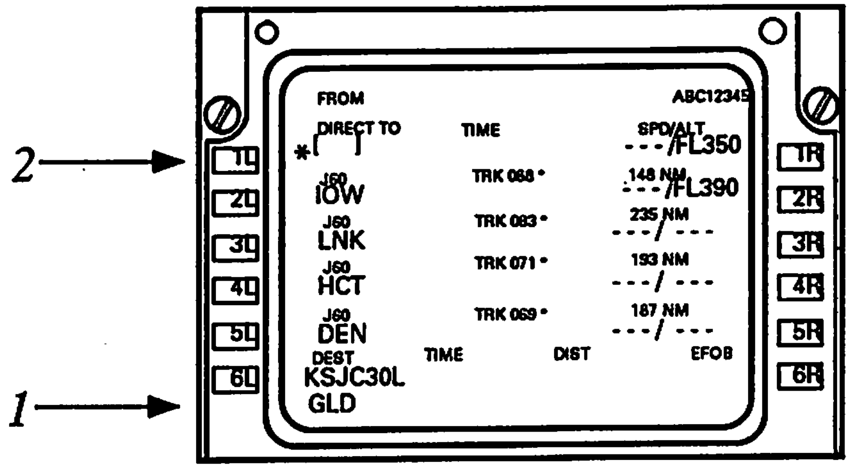
Line select the waypoint into the desired location within the sequence (#3).

Airbus A320 Direct to a Waypoint

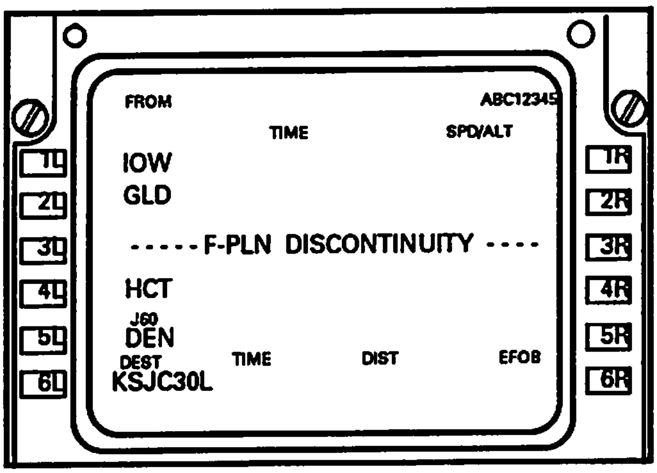
While in the flight plan page, press the direct to mode select key to display the DIRECT TO prompt and field on the flight plan page.



Enter the desired waypoint in the scratchpad (#1). Use the first line select key to move the waypoint to the Direct To field (#2).



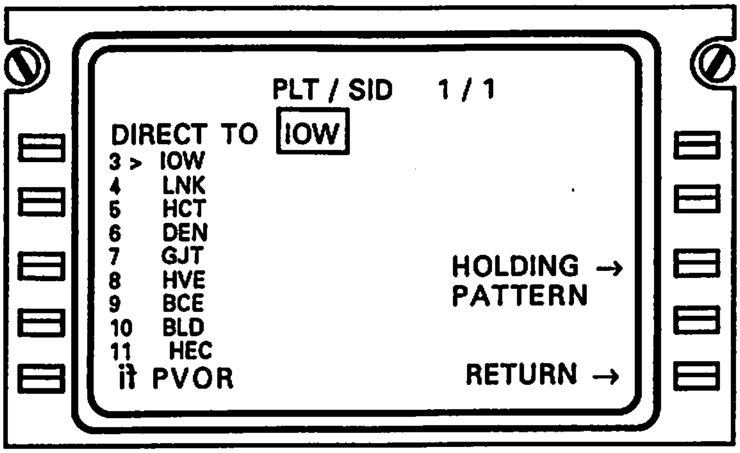
A flight plan discontinuity prompt should appear.



Press the clear function key. Clear will appear in the scratchpad. Select the line select key next to the flight plan discontinuity prompt to clear the prompt.

Universal UNS-1B Direct to a Waypoint

A direct to begins by selecting the direct to mode select key. The cursor will automatically appear in the Direct To field. Also, a list of flight plan waypoints will be shown.



If the waypoint is listed, associated reference number can be entered. If not, type in the identifier. Pressing the enter key concludes the procedure. If the waypoint is part of the flight plan, the navigation page will appear, with the present position in the from waypoint position and the direct to waypoint identifier in the to position. If the waypoint is not part of the existing flight plan, present position will be in the from position, the direct to waypoint will be in the to position, and the cursor will be in an entry field that will allow the new to waypoint to be integrated into the flight plan. Entering the reference number of the waypoint that comes after the new to waypoint will complete the procedure.

Conclusions

To Be Completed

ENTERING A CROSSING RADIAL FROM A FIX AS A ROUTE WAYPOINT

Occasionally, the crew may be asked to to enter enter a fix which will serve as a waypoint. A radial from this waypoint then defines the leg (bearing) from that waypoint. This example assumes a downtrack rather than abeam course.

Boeing 757/767 Crossing Radial from a Fix

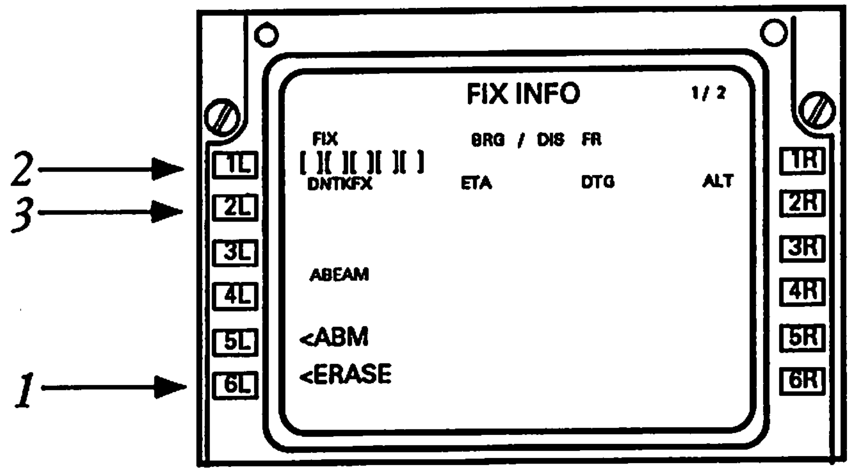
The first step involves defining the fix which is to serve as the waypoint. This is accomplished by pressing the fix mode select key.

Boeing 757/767	Airbus A320	Universal UNS-1B
From the LEGS page, select the DIR/INTC mode select key to display the LEGS page with DIRECT TO and INTC LEG TO prompts and fields. Verify that the prompts and fields appear.	From the F-PLN page, select the DIR mode select key to display the DIRECT TO prompt and field on the F-PLN page. Verify that the prompt and field appear.	Access the Direct To mode by pressing the Direct To mode select key. The cursor will be positioned over the Direct To waypoint field and a list of waypoints included in the flight plan will appear.
Enter the desired waypoint in the scratchpad. Verify that the waypoint has been entered correctly.	Enter the desired waypoint in the scratchpad. Verify that the waypoint has been entered correctly.	Enter the identifier of the desired Direct To waypoint by entering the associated reference number or typing in the three-character designator. If the waypoint is not part of the flight plan, enter the three-character designator.
Use line select key 6L to move the waypoint to the DIRECT TO field. Verify that the waypoint has been moved into the correct field.	Use line select key 1L to move the waypoint to the DIRECT TO field. Verify that the waypoint has been moved into the correct field.	The navigation page will appear. If the Direct To waypoint is included in the flight plan, the present position will be in the From position and the Direct To waypoint will be in the To position. If the Direct To is a new waypoint, the cursor will appear in the next identifier entry field to allow the next waypoint in the sequence to be entered.
Press the EXEC mode select key to designate that waypoint as the active waypoint.	A flight plan discontinuity prompt should appear.	
	Select the clear function key. CLR will appear in the scratchpad.	
	Select the line select key next to the flight plan discontinuity prompt. This will clear the prompt.	

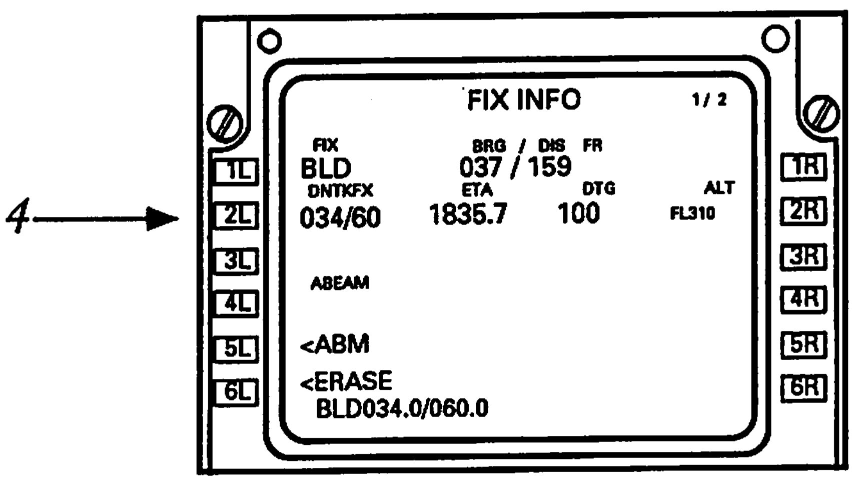
Table 6-1. Comparison of Direct To procedures for the B-757/767, A-320, and Universal (cont. next page).

Boeing 757/767	Airbus A320	Universal UNS-1B
Select Direct To Mode (Mode Select Key path)	Select Direct To Mode (Mode Select Key path)	Select Direct To Mode (Mode Select Key path)
Move Existing Data From Field to Field (Select Object; Select Field)	Move Existing Data From Field to Field (Select Object; Select Field)	Key in Designator (Create Object) or Select from List (Copy Object)
Press Activate Line Select Key (Accept Changes)	Press Clear Function Key (Select Object)	Press Enter Key (Accept and Activate Changes)
Press Execute Function Key (Activate Changes)	Line Select to Field with Discontinuity Prompt (Select Field)	

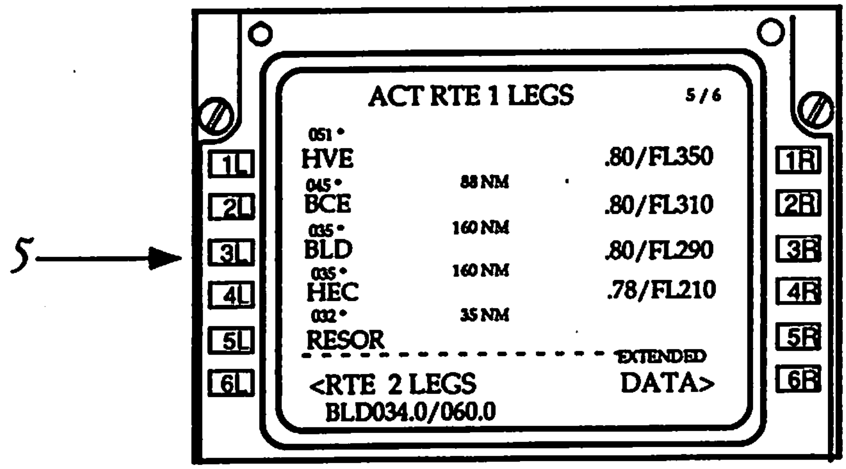
Table 6-1. Comparison of Direct To procedures for the B-757/767, A-320, and Universal (cont. from previous page).



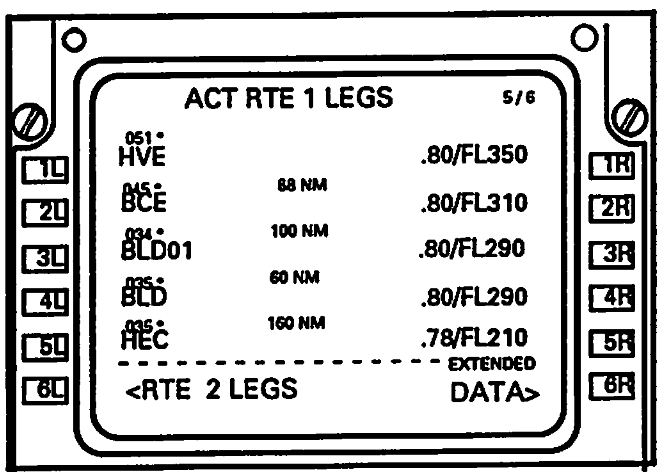
Next, a three-letter identifier is entered in the scratchpad (#1) and line selected to the first left field (#2). Bearing and distance information will appear next to the fix name. The desired radial from the fix is then entered into the downtrack field (#3). Radial/distance from the fix to that point where the radial crosses the active route is automatically displayed. Pressing the first line select key copies the fix/radial/distance to the scratchpad (#4).



The legs page must then be accessed.



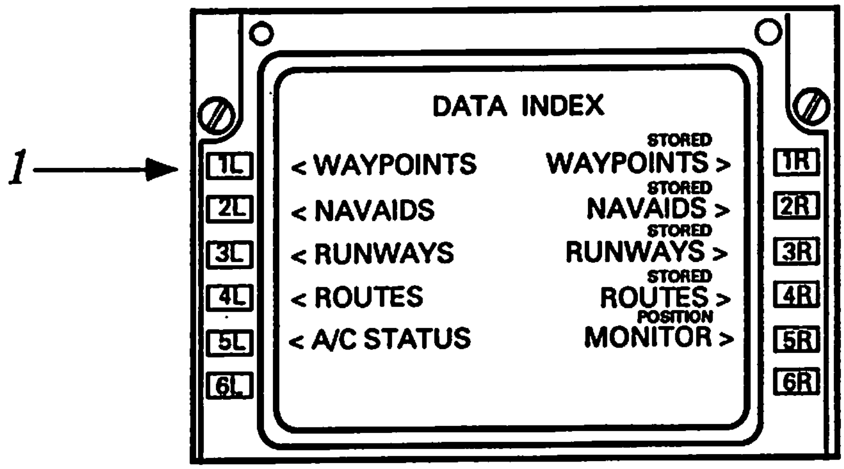
The fix, radial, and bearing information appears on the scratchpad. This data must then be line selected to the appropriate location within the waypoint sequence (#5).



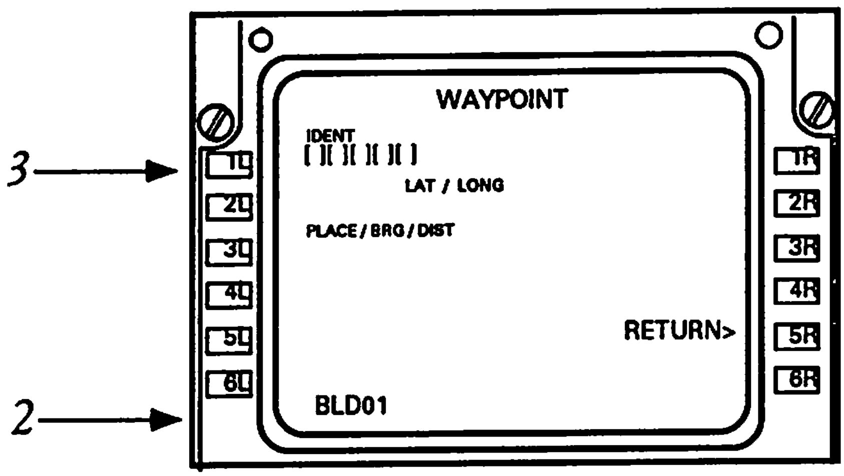
Airbus A320 Crossing Radial from a Fix

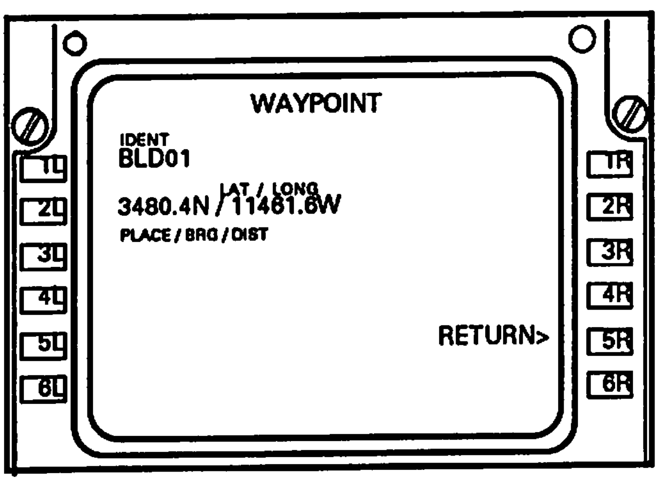
Entering a crossing restriction begins by accessing the data mode.

Press the first line select key on the left (#1).



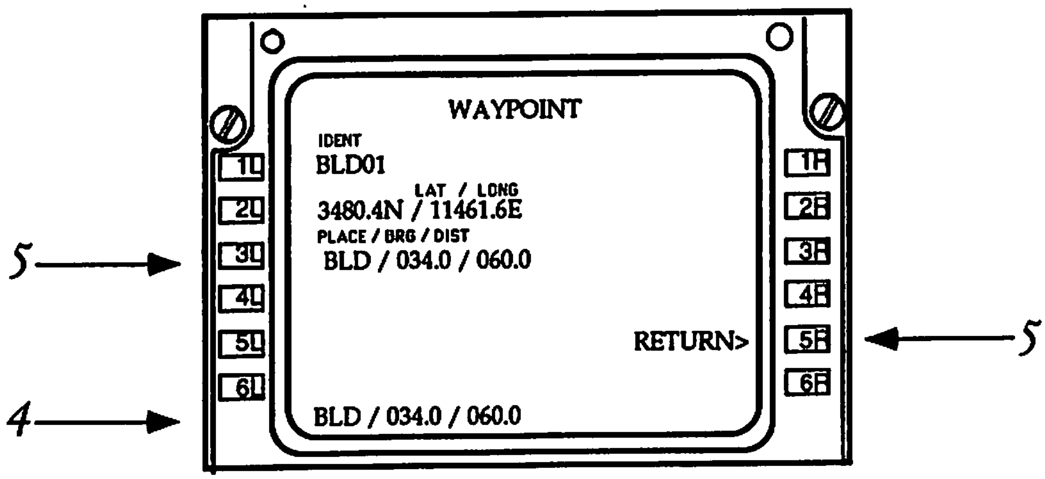
Enter the waypoint into the scratchpad (#2), then line select to the first field (#3). Latitude and longitude information now appears.



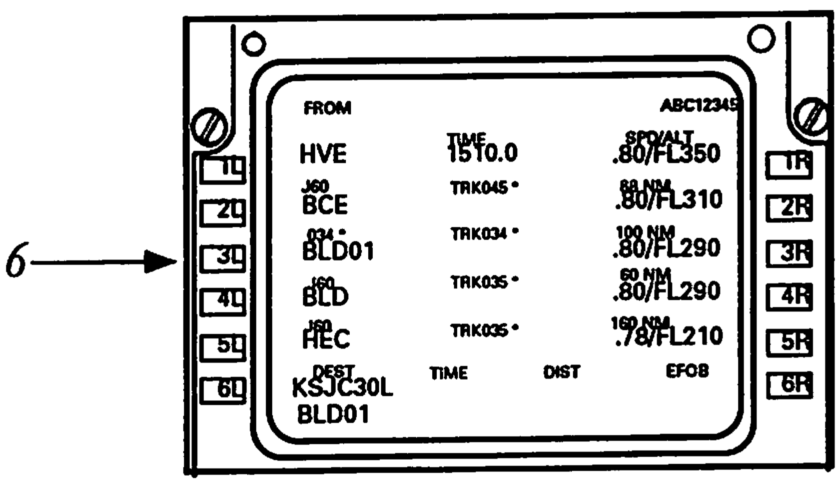


Place, bearing, and distance information must now be entered into the scratchpad (#4) and line selected to the third field (#5).

Press the return line select key (#5).



The new waypoint must now be entered into the flight plan. Enter new waypoint into the scratchpad, then press the line select key next to the appropriate place in the waypoint sequence (#6).



Universal UNS-1B Crossing Radial from a Fix

To Be Completed

Crossing Radial from a Fix Conclusions

To Be Completed

EXECUTING A HOLD

Holds may be executed in response to ATC instructions or following a missed approach. In many cases, executing a hold takes place under high workload conditions, contributing to the need for hold procedures that are easy to understand and accomplish.

The holding parameters are: Inbound Course; Left or Right Turn;and Time/Distance

A holding may be inserted in the F-PLN

- Automatically as part of the procedure
- Manually at a fixed waypoint
- Manually at Present Position (PPOS)

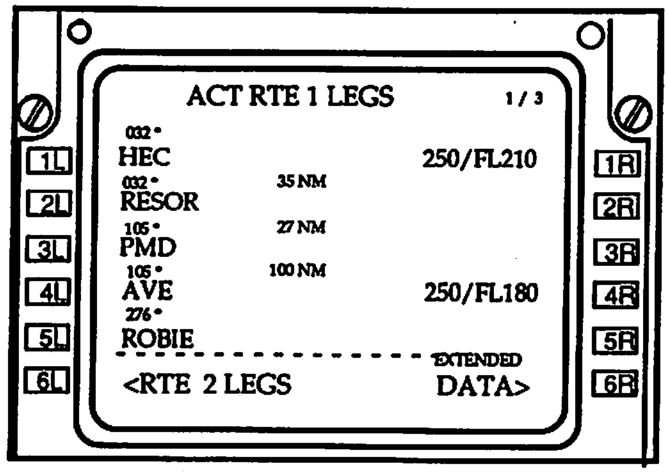
A holding manually inserted is

- either automatically COMPUTED by the FMS
- or retrieved from the DATABASE if a database-defined holding exists at the revise point.

A holding defined by DATABASE or COMPUTED by the FMS or inserted as a PROCEDURE may be modified manually by the pilot. In this case a prompt in line 2R allows reversion to the previous definition. The following displays show the various possible combinations.

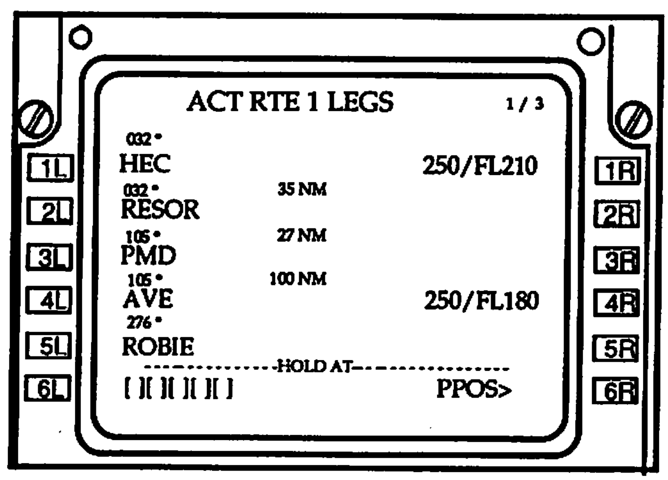
The Boeing 757/767 Hold

1. Verify current CDU display (ACT RTE 1 LEGS) - CDU



2. Select HOLD Mode Key - CDU KBD

3. Verify new CDU display (ACT RTE 1 LEGS- modified) with HOLD AT selections at LSK 6L/6R - CDU

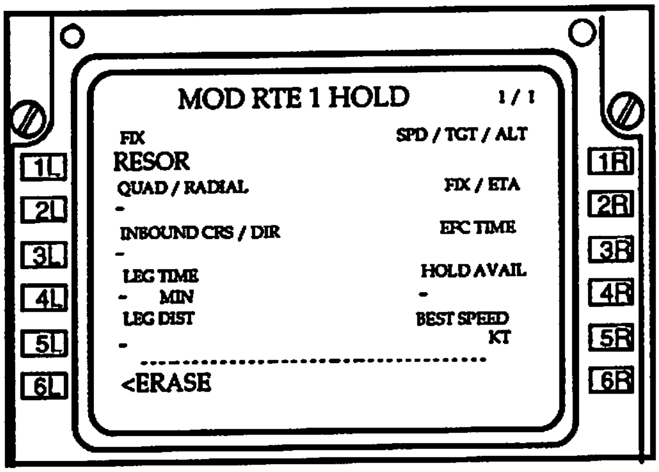


4. Enter HOLD Fix in scratchpad - CDU KBD

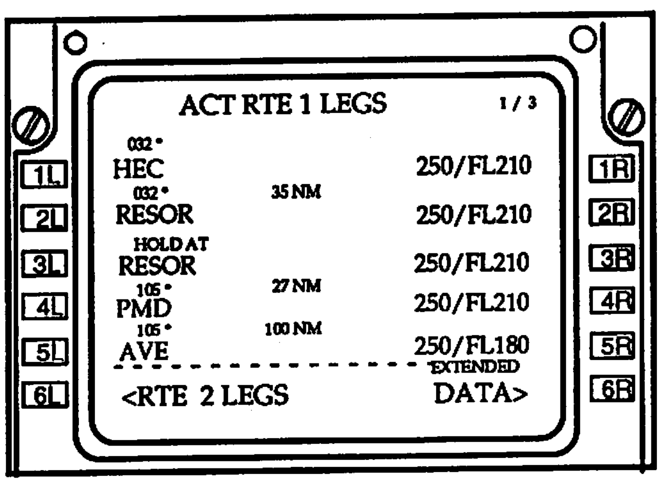
5. Line Select to LSK 6L - CDU

6. Verify new CDU display (MOD RTE 1 HOLD) - CDU

   (NOTE: If HOLD exists in DATABASE, new CDU display will be ACT RTE 1 HOLD.)



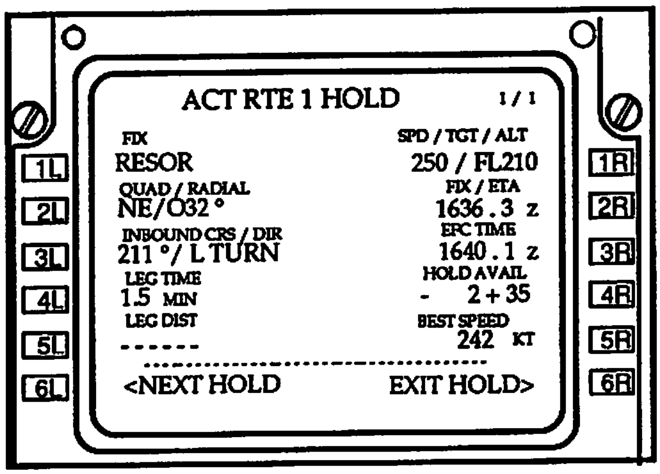
7. Enter HOLD Pattern variables/data into scratchpad - CDU KBD
8. Line Select to appropriate line (LSK xL/xR) - CDU
9. Verify current CDU display (MOD RTE 1 HOLD - with data) - CDU



10. Select EXEC Mode Key to add HOLD Pattern to the active route - CDU KBD
11. Select LEGS Mode Key to display the ACT RTE 1 LEGS page with HOLD AT displayed above the intended wpt - CDU KBD
12. Verify current CDU display (ACT RTE 1 LEGS page with HOLD AT displayed) - CDU

ENTER HOLD

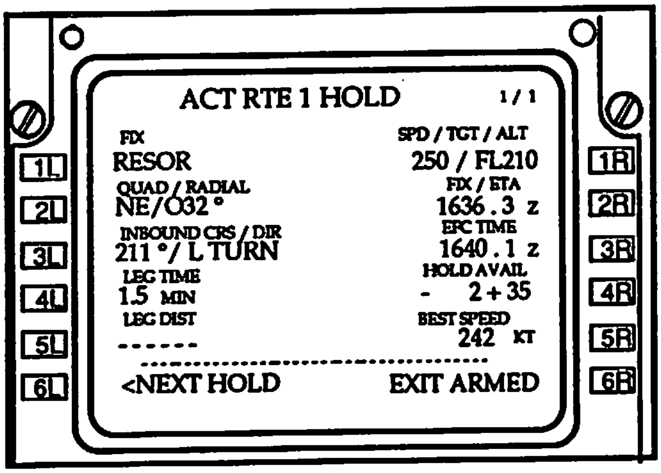
13. Verify current position using CDU (ACT RTE 1 LEGS page with HOLD AT displayed) and Navigation Display - CDU & ND
14. Select HOLD Mode Key - CDU
15. Verify current CDU page (ACT RTE 1 HOLD) - CDU



16. Execute Turn To HOLD
17. Monitor HOLD Execution - CDU & ND

EXIT HOLD

18. Verify current CDU page (ACT RTE 1 HOLD) - CDU
19. Line Select EXIT HOLD (LSK 6R) - CDU
20. Verify current CDU page (ACT RTE 1 HOLD with EXIT ARMED at LSK 6R) - CDU

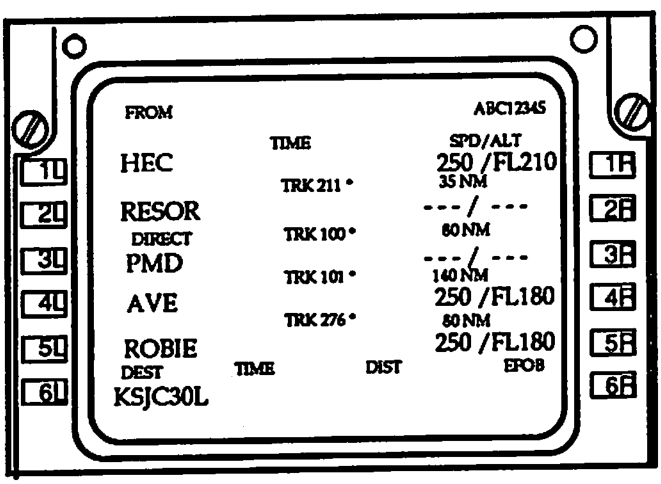


21. Select EXEC Mode Key - CDU KBD

22. Verify current CDU page (ACT RTE 1 LEGS) and monitor return to current course CDU & ND

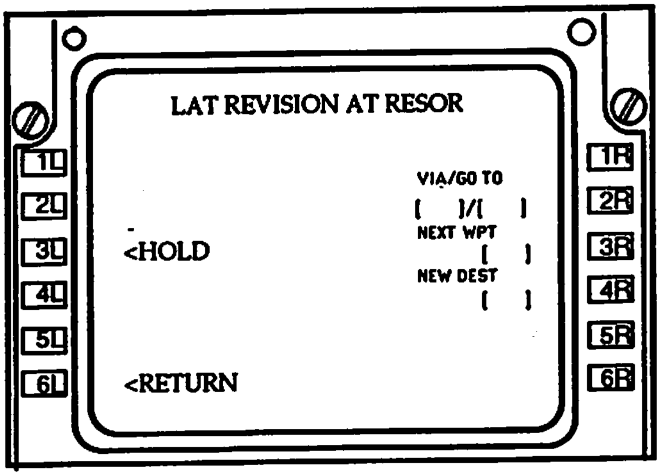
Airbus A320 Hold

1. Verify current MCDU display (F-PLN page A) - MCDU



2. Line Select RESOR (FROM WPT) (LSK 1L) - MCDU

3. Verify new MCDU display (LAT REVISION AT RESOR) - MCDU



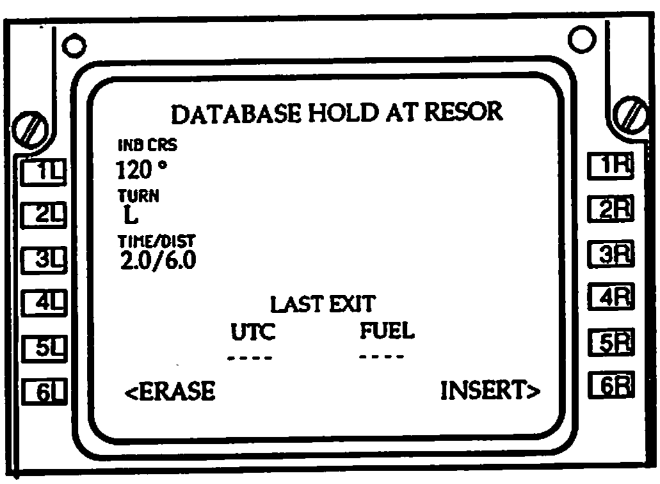
4. Line Select **HOLD** (LSK 3L) - MCDU

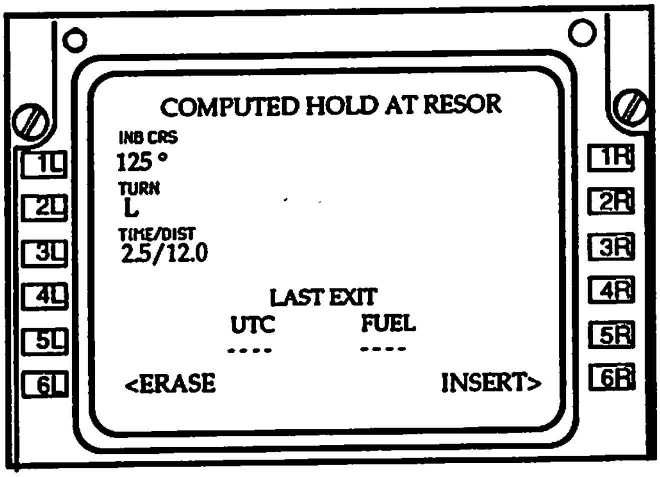
NOTE:

A. If HOLD exists in the Database, the new MCDU display will be titled: DATABASE HOLD AT RESOR; and the holding procedure will be inserted from the database;

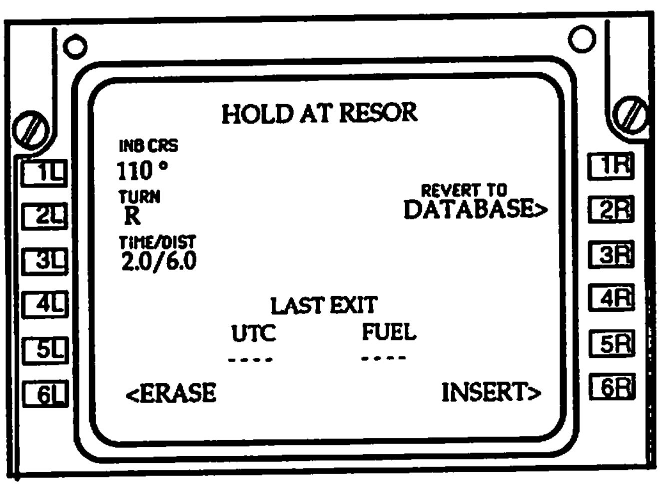
B. If DATABASE HOLD does not exist, the FMGC will propose a default computed HOLD, and the MCDU display will be titled: COMPUTED HOLD AT RESOR;

C. If the pilot elects to modify the HOLD pattern the MCDU display will be titled: HOLD AT RESOR.

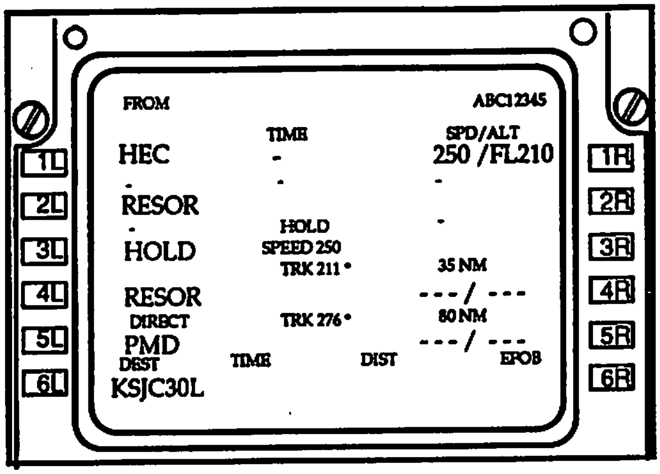




5. Enter desired parameter changes in scratchpad (changes) - MCDU KBD
6. Line Select to appropriate position (LSK xL) - MCDU
7. Verify new MCDU display (HOLD AT RESOR) - MCDU



8. Line Select INSERT at LSK 6R - MCDU
9. Verify new MCDU display (F-PLN Page A) - MCDU
10. Verify new Situation Display on ND - ND



Universal UNS-1B Hold

To Be Completed

Executing Holds Conclusions

To Be Completed

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