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LOCAL FLOW MANAGEMENT/PROFILE DESCENT ALGORITHM

FUEL-EFFICIENT, TIME CONTROLLED PROFILES FOR THE NASA TSRV AIRPLANE

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1.0 SUMMARY

This document describes a Local Flow Management/Profile Descent (LFM/PD) algorithm designed for NASA's Transport System Research Vehicle (TSRV) program. The algorithm provides fuel-efficient altitude and airspeed profiles consistent with ATC restrictions in a time-based metering environment over a fixed ground track. The model design constraints include accommodation of both published profile descent procedures and unpublished profile descents, incorporation of fuel efficiency as a flight profile criterion, operation within the performance capabilities of the Boeing 737-100 airplane with JT8D-7 engines, and conformity to standard air traffic navigation and control procedures. Holding and path stretching capabilities are included for long delay situations.

2.0 INTRODUCTION

On November 15, 1976, the FAA issued the Local Flow Traffic Management National Order, 7110.71. The purpose was to establish "a local-flow traffic management program designed to enhance safety, conserve aviation fuel and reduce the impact of aircraft noise on the local communities." The order directed Air Traffic Divisions, Air Route Traffic Control Centers, and Air Traffic Terminal Facilities to review and revise procedures to:

"1) Reduce flying time at altitudes below 10,000 feet above airport elevation (AAE) by:

   (a) Minimizing the use of speed of less than 210 knots.
   (b) Eliminating holding and excessive vectoring.
   (c) Designing the shortest practical route from the metering fix to the runway.

"2) Provide for maximum use of profile descents from cruising altitude/level to the approach gate. As a minimum, provide for profile descents during all periods of operation from at least 10,000 feet AAE and preclude routine level flight below this altitude except as required for:

   (a) Simultaneous 'turn-ons' to parallel runways.
   (b) Stabilization for glide slope or final approach course interception.
   (c) Speed adjustments.

"3) Avoid requiring abnormal high descent rates close in to the airport. Aircraft shall be given a distance for descent which is sufficient to permit a stabilized final approach with interception below the glide slope as defined in Chapter 4, Section 9, of Handbook 7110.65.

"4) Enable departures to climb unrestricted to the extent possible and ensure maximum compatibility with new or revised arrival procedures. Routine altitude restrictions below 5,000 feet above ground level should be avoided."

The order, in addition, established a metering program to develop procedures "to monitor the arrival flow to determine when the number of aircraft approaches system capacity. Traffic shall then be metered so as not to exceed this capacity. When delays are imposed, the priority of landing shall be based on the calculated time of arrival (CTA) for each aircraft. CTAs shall be calculated based on the estimated time of arrival at the metering fix plus the estimated flying time to the runway. These times shall then be adjusted to resolve simultaneous demands at the airport and to establish the time that an arrival aircraft will be required to cross the metering fix.

   "a) Each facility shall, as required, establish operating positions which will be responsible for monitoring and metering the flow of traffic to and from affected airports. Establishment of these positions shall be subject to regional review and approval.

   "b) Procedures shall insure that the metering position be supplied with information on all conditions which affect the terminal acceptance rate. This information is not limited to changes in runway, airport conditions or weather but also includes demands placed on the IFR runways by VFR, tower en route and internally generated IFR traffic landing at the impacted or a satellite airport. Metering techniques, therefore, shall insure that all aircraft operating within the system receive equitable distribution of delays.

"c) Delay absorbing techniques (holding, speed control, and vectoring) shall be used to provide time intervals between succeeding arrival aircraft which will allow for only the most expeditious routes to be flown from the metering fix to the runway at optimum system speeds. Holding should be accomplished at or above FL 200, and whenever possible, prior to the metering fix."

Profile descent procedures were published at Denver, Atlanta, St. Louis, Los Angeles, Miami and San Francisco. Time-based metering programs were developed at Denver and Ft. Worth Centers as an extension of the NAS En Route Stage A program. The metering function has been integrated into the NAS Stage A software and delivered to all centers. Beyond the current metering program the FAA has several advanced flow management concepts under study or development. These include metering and spacing, en route metering, automated en route ATC and strategic control.

Present ATC developments indicate an evolution of the system into a strategic control concept of air traffic management wherein a central control authority determines, and assigns to each participating airplane, a conflict-free, four-dimensional route-time profile. The route-time profile assignments are long-term as compared with the short-term, immediate nature of tactical control instructions. The route-time profiles are determined in a manner that provides for predictable and efficient use of both airspace and available runway operation times. This concept results in terminal area capacity increases, delay reductions, safety improvement, controller workload reductions and reduced fuel use. Maximum benefits are expected to occur at the busy terminal areas where demand is high and airspace is at a premium.

The Local Flow Management (LFM) avionics research objective is to define airborne navigation/guidance capabilities for efficient operation in the ATC integrated flow management system under development. The NASA TCV program Local Flow Management avionics research plan is shown in figure 1. This plan was developed under NAS1-14880, Task Requirement AB-11. Subtasks 1 and 2 under NAS1-14880 (Task Requirement A-100) have been completed and a contractor report was published, which delineated the major areas to be addressed in the LFM research plan. Subtasks 3 and 9 identified in Figure 1 are being pursued as part of the long-range research effort.

As part of TR A-103, two tasks were completed. A generalized path definition algorithm for operating in the flow management environment was developed satisfying

1) determination of minimum-fuel profile descent from cruise altitude to near the airport without an assigned metering fix time; and

2) determination of minimum-fuel descent profile to the metering fix with an assigned metering fix time and profile descent from the metering fix to near the airport.

In addition, an interim path definition algorithm was also developed and used in early flight tests at Denver in 1979. The design of the generalized algorithm to provide path definition computations was completed in July 1979[1]. The development of additional capabilities

1. *Development and Test Results of a Flight Management Algorithm for Fuel-Conservative Descents in a Time-Based Metered Traffic Environment,* Charles E. Knox and Dennis G. Cannon, NASA technical paper 1717, October 1980.

(including holding and path stretching to absorb excess ATC delay) and refinement of the algorithm based on analysis, simulation and flight test results were completed in July 1980. This report is submitted as the contractor report.

Subtasks performed as part of the algorithm development activity were:

1) Functional logic development;

2) Trade studies and analysis;

3) Algorithm design;

4) Software implementation, test and validation;

5) Interim algorithm development, flight test and evaluation;

6) Algorithm refinements and extensions; and

7) Documentation.

This report documents the algorithm design and software implementation, test, and validation subtasks.

Based on trade study results and analysis, a set of design ground rules was formulated.

1) Let-downs employ clean configuration and idle-thrust trajectories wherever possible.

2) Let-downs employ conventional Mach/CAS indicated airspeed schedules.

3) Point-mass, steady-state equations of motion are used by the trajectory generation algorithm.

4) Basic airplane performance data used by the algorithm include thrust, drag, fuel flow and operational speed limits.

5) Geometry and ATC constraints accommodate all FAA-published profiles with or without metering.

The algorithm that has been developed provides fuel-efficient altitude and airspeed profiles consistent with ATC restrictions over a fixed ground track. These profiles provide a reference trajectory allowing efficient operations in an LFM/PD environment. Specific design constraints that have been assumed in the algorithm design activity include: (1) accommodation of both published runway profile descent procedures and unpublished profile descents, (2) fuel efficiency as a flight profile criterion, (3) flight performance capabilities of the Boeing 737-100 with JT8D-7 engines, (4) standard air traffic navigation and control procedures, (5) 4-D holding and path stretching capability in the LFM environment, and (6) accommodation of anti-icing power requirements.

The Local Flow Management/Profile Descent algorithm as now operational includes an optimized vertical path for any of the published profile descent procedures (at Denver or other applicable airport) by input of the desired approach procedures file. The following operational features have been incorporated:

1) Descent to provide minimum fuel,

2) Descent to meet an assigned metering fix time with minimum fuel,

3) Descent to meet an assigned metering fix time with holding at optimum altitude using minimum fuel,

4) Descent to meet an assigned metering fix time when holding at an ATC-assigned altitude using minimum fuel,

5) Descent to meet an assigned metering fix time with stack holding using minimum fuel,

6) Descent to meet an assigned metering fix time with path stretching using minimum fuel, and

7) Descent with anti-ice power in preselected altitude band to meet a metering fix time using minimum fuel.

Figure 2 provides a summary of model input, processing and output elements. Model inputs include an approach geometry file, current and forecast wind and temperature data, an aircraft performance data base, the aircraft initial conditions (time, position, weight) and ATC clearance data (metering fix times, holding instructions). The model computes an optimum path by determining lateral path parameters required (path segment distance and course information), constructing wind and temperature models for the descent, computing a trial speed schedule (Mach and calibrated airspeeds), integrating the vertical path to provide clean, idle descents where consistent with approach constraints to minimize fuel use, evaluating the descent profile (times and fuel used), iterating as required to meet 4-D constraints, and displaying outputs. Outputs include an input report, the output path array, data detailing segments requiring thrust or drag, detailed holding information and summary outputs.

The algorithm is currently operational on a CYBER 175 computer, written in FORTRAN IV. The development of an airborne version of the generalized path definition algorithm for installation, testing and demonstration is the next step in the algorithm development plan.

Following sections of this report describe the LFM/PD Algorithm Functional Logic (Section 4), Computer Model Structure (Section 5) and Computer Model Test/Validation Approach (Section 6).

3.0 SYMBOLS AND ABBREVIATIONS

γ	flight path angle, in radians
τ_a	holding fix crossing time interval, in minutes
Δh	altitude interval, in feet
D	drag force, in pounds
L	lift force, in pounds
T	engine thrust, in pounds
ΔVTAS	difference in true airspeed, in knots
W	airplane gross weight, in pounds
AAE	above airport elevation
ATC	air traffic control
BOD	bottom of descent
CAS	calibrated airspeed
CDU	control and display unit
CTA	calculated time-of-arrival
FAA	Federal Aviation Administration
HPD	high profile descent
IFR	instrument flight rules
ISA	International Standard Atmosphere
KCAS	knots calibrated airspeed
kn	knots
LAX	Los Angeles International Airport
LFM/PD	Local Flow Management/Profile Descent
MF	metering fix
NAS	national airspace system

nmi	nautical miles
N1	airplane turbine rpm at station 1
POD	point of descent
RPD	runway profile descent
TOD	top of descent
TSRV	Transport System Research Vehicle
VFR	visual flight rules

4.0 LFM/PD ALGORITHM FUNCTIONAL LOGIC

This section of the Local Flow Management/Profile Descent Guidance Algorithm Development report provides an overview of the algorithm designed to provide fuel-efficient descents. Section 5, Computer Model Structure, provides an overview of the computer implementation of the algorithm. Figure 3 indicates the top level functions involved in the generation of a profile descent. Seven functions are indicated. First, the in-plane geometry data and ATC speed and altitude constraints are input. Second, the wind and temperature forecast data are input and wind and temperature versus altitude models constructed. The next five functions are repeated, once for each profile computed. The descent initialization function consists of inputing the current path, altitude, speed and weight data, either for a nominal or revised path. The descent profile is now constructed for the last portion of the descent (from the metering fix to an aimpoint near the runway). Next, the aeroperformance envelope is determined (fast- and slow-speed boundaries and Mach-to-indicated airspeed transition altitudes). The High Profile portion of the descent provides a speed schedule and altitude profile from cruise altitude to the metering fix. The High Profile provides a letdown with or without a metering fix time assignment. Holding or path stretching to make good a metering fix time is also accommodated. Finally, the algorithm displays the resultant profile. If another letdown is desired, the algorithm returns to the descent initialization step. The following paragraphs describe each of the seven functional areas in greater detail.

4.1 IN-PLANE GEOMETRY AND ATC CONSTRAINTS

This section of the functional logic description details the geometry and ATC constraints for which the profile descent is generated. An approach path is defined for each metering fix to runway combination. Each approach path is broken into path segments. A path segment is comprised of a beginning and an ending waypoint, together with a segment distance and track. A waypoint can be defined for any speed or altitude constraint or for a heading change. As an example of the in-plane geometry and ATC constraints definition process, a published profile descent for Los Angeles International Airport Runways 24 and 25 will be considered. Figure 4 shows the form of the published profile from Peach Springs and Figure5 indicates the published ILS approach for runway 25L. The sequence of waypoints and chart information contained in these two figures, which are used in the LFM/PD algorithm, is summarized in table 1. The table contains the altitude and speed constraints, and segment distances and headings for each waypoint.

Within the algorithm computation process, four of these waypoints have special designations. The first waypoint in the sequence (PGS in this example) is called the entry fix. The last waypoint (LIMMA) is the aimpoint. One intermediate waypoint (CIVET) is designated the metering fix. A second intermediate waypoint (BAIRS) is designated as the holding fix. Profiles are computed from the entry fix to the aimpoint. Time assignments (to allow ATC to meter aircraft to the runway) may be required at the metering fix. Holding to absorb excess ATC delay occurs at the holding fix. Various initial conditions for the aircraft can be assumed at the entry fix. A profile is constructed to the specified speed and altitude at the aimpoint.

In addition to the published waypoints (in the LAX example, those noted in table 1), additional waypoints are supplied in the algorithm computation process to indicate to the pilot when to initiate an acceleration or deceleration or a descent form a level cruise condition. The algorithm computation process completes the speed and altitude profile for the descent within the constraints imposed at the waypoints.

Figure 6 summarizes the functional logic of the approach geometry and ATC constraints process employed in the model. The number of approach paths to be defined is read initially. For each approach path the following data are obtained:

1) The number of path segments,

2) The fixed waypoint distances (referenced to the outer marker),

3) Those waypoint speeds that are ATC-constrained,

4) Those waypoint altitudes that are ATC-constrained (either floors, ceilings or "hard" altitudes), and

5) Course data for each path segment (referenced clockwise from local magnetic North).

4.2 WIND AND TEMPERATURE MODELING

The wind and temperature data employed in the descent profile generation process consist of preflight forecasts and real-time updates of wind and temperature at the altitude of descent initialization. Forecast data provided during preflight include forecast altitude, wind direction, wind magnitude and temperature. The wind modeling process converts wind forecast data into zonal and meridional components. At descent initialization the forecast profiles are updated with current wind and temperature data at altitude. An error function is constructed by assuming measured data at altitude and by linearly approaching the forecast profile as aimpoint elevation is approached. The corrected forecasts are then connected by piecewise linear functions into profiles. The resultant corrected profiles are shown in Figure 7. Based on this modeling, wind components and temperature data are available in the profile construction process from any altitude between en route cruise and airport elevation.

Figure 8 summarizes the functional logic employed in the preflight wind/temperature forecast entry process. The development of linear wind and temperature models and the correction based on real-time inflight data are summarized in Figure 9.

4.3 DESCENT INITIALIZATION

The descent initialization process involves the entry into the on-board flight management system of those real-time data elements and operational decisions required in the descent calculation process. Specific data and decisions required to begin the profile construction process include:

1) Wind at altitude

2) Temperature at altitude

3) Initial gross weight

4) Descent path selected (metering fix and runway)

5) Metering fix time assigned (if metering is in effect)

6) Cruise Mach number

7) Cruise altitude

8) Estimated time of arrival at the entry fix

9) Engine anti-ice region, if required

10) Holding information, if needed

The sequence of operations performed in the descent initialization is summarized in Figure 10. Revisions to the path geometry beyond the metering fix, forced by runway changes, weather diversions, ATC vectors or area navigation routing, are accommodated in the algorithm.

4.4 RUNWAY PROFILE DESCENT (RPD) CALCULATION

The Runway Profile Descent (RPD) calculation process involves the complete definition of the descent profile from the metering fix to the aimpoint. The calculation process begins at the aimpoint and works backward to the metering fix (in the RPD calculation process), and then proceeds from the metering fix to the entry fix in the High Profile Descent (HPD) calculation (described in subsection 3.6). Figure 11 shows the relationship between the data input elements of the program and the RPD and HPD functions. In both RPD and HPD calculations a speed schedule is first determined. For the RPD profile the airspeeds are based on ATC constraints. In the HPD profile, computation speed schedules are determined subject to basic aircraft performance data. In the HPD calculations, speed schedules may be iterated to generate multiple descent profiles until a desired time criterion is achieved at the metering fix or a minimum fuel letdown may be selected. A holding or stretched path to absorb time in excess of a slow-speed descent to the metering fix is also calculated in the HPD profile.

In either case (RPD or HPD), after the speed schedule is specified a series of path segment calculations take place. These calculations proceed from the aimpoint out toward the entry fix. An estimate of aircraft gross weight at the aimpoint is made based on entry fix weight and distance from entry fix to aimpoint. The segment calculation process takes into account changing gross weight with fuel burn, and an iterative convergence to aimpoint gross weight is used as required. Each path segment is analyzed to determine whether an acceleration or deceleration is required and whether altitude constraints require descent. Figure 12 summarizes the functional logic used in the path segment calculations. This logic is illustrated in Figure 13 for one pair of waypoints (designated the initial and final waypoints). The path determination process is assumed to have been completed to the initial waypoint (that is, a speed and altitude have been determined). The speed at the initial waypoint is then compared to the assigned speed at the final waypoint. If a speed change is required, a change of speed waypoint is determined following the initial altitude. Either a level decelerating or a level accelerating segment calculation module is employed. A clean, idle (or anti-icing thrust) descent trajectory is next constructed from the bottom-of-descent (BOD) point (here the change of speed waypoint) to the final waypoint. An idle (or anti-ice) descent over a fixed distance path segment calculation module is employed. If the resultant altitude at the final waypoint lies within the minimum and maximum altitude constraints, the clean idle (or anti-ice) trajectory is used and the associated altitude at the final waypoint is assigned. If the clean, idle (or anti-ice) trajectory altitude is too low (below the minimum altitude constraint) a steeper trajectory is required. The spoiler descent over a fixed altitude and distance calculation module is then used to determine the amount of drag required and the resultant time and fuel used. Similarly, if the clean idle (or anti-ice) altitude at the final waypoint is too high (as indicated in the figure) additional thrust is required to descend. In this situation, the minimum fuel strategy is to compute a top-of-descent point employing the module that calculates idle (or anti-ice) descent between two altitudes (the initial altitude and the maximum constraint altitude). A level, constant speed segment calculation module is used to compute the remaining time and fuel from the point of descent to the final waypoint. Alternatively, a thrusted descent over a fixed distance calculation module can be employed, which determines the added thrust required to descend the fixed altitude interval and distance required.

All of the path calculations described in the preceding paragraph employ seven basic path segment calculation types. These are summarized in Figure 14 together with corresponding inputs required and outputs determined. The seven path segment types developed are:

1) A level, constant speed segment over a fixed distance

2) A level, decelerating segment between two fixed airspeeds

3) A level, accelerating segment between two fixed airspeeds

4) An idle (or anti-ice power) descent over a fixed distance

5) An idle (or anti-ice power) descent between two fixed altitudes

6) A spoiler descent between two fixed altitudes and distances

7) A thrusted descent between two fixed altitudes and distances

The solution of each path segment provides those inputs required to process the next path segment in the calculation sequence. At each step (for each path segment) the calculation process results in the complete altitude, time, distance and fuel specification of the descent profile.

The solution of each segment itself involves an iterative computation of the basic point-mass, steady-state equations of motion of the aircraft. Where a descent computation is involved, an altitude iteration is employed until a distance or altitude step is achieved. Figure 15 summarizes the basic forces solved in each altitude step. Specific computation steps over an interval, Δh (500 ft), involve

1) Computation of the true altitude interval employing the modeled temperature profile,

2) Determination of the change in true airspeed from beginning to end of the altitude interval given the speed schedule,

3) Computation of average ground speed over the interval employing the wind profile and segment heading,

4) Computation of thrust, drag and fuel flow parameters given current altitude and airspeed (including anti-ice power),

5) Computation of an acceleration factor,

6) Computation of rate of descent,

7) Determination of flight path angle, and

8) Computation of time, fuel and distance over the interval.

The computation is repeated for the next altitude interval until the required altitude or distance step is traversed. In the iteration process, the final state of the previous interval is used as the initial state of the next interval.

The functional logic of the RPD calculation process is summarized in Figure 16. The RPD calculations end at the metering fix with the descent profile specified to that point.

4.5 AEROPERFORMANCE ENVELOPE DETERMINATION

The aeroperformance envelope determination consists of the development of high- and low-speed boundaries as a function of altitude for descent and the definition of the altitude at which a Mach to calibrated airspeed schedule transition occurs. Figure 17 shows the B737's operating envelope in terms of altitude and true airspeed. High-speed limits are based on (1) maximum operating Mach, (2) high-speed initial buffet, (3) thrust limits, and (4) maximum operating velocity. Low-speed limits are based on (1) low-speed buffet and (2) procedural flap extension speeds. The high-speed limit is determined for a particular weight and altitude by taking the minimum of the four high-speed factors. The low-speed limit is determined by taking the maximum of the two low-speed factors.

The determination of the transition altitude for moving from a constant Mach to constant calibrated airspeed (CAS) schedule is based on a sensitivity study of various Mach/CAS transitions. An important model design consideration was to make maximum use of the available time envelope, consistent with Mach/CAS procedures and gross weights, by the model's defining a constant CAS descent at minimum speed and the fastest Mach/CAS descent at maximum speed. An empirical linear relationship (altitude vs true airspeed) assumed between the two limits, as depicted in Figure 17, closely approximated the Mach/CAS families of descent speed schedules suggested in the B737 flight operations manual.

The functional sequence of calculations to define the aeroperformance envelope is shown in Figure 18. The envelope construction is determined before the High Profile Descent routine, to provide a family of speed schedules for use in the HPD generation process.

4.6 HIGH PROFILE DESCENT (HPD) CALCULATION

The High Profile Descent (HPD) calculation process completes the definition of the descent profile, which specifies speed schedules and altitude/range relationships between the metering fix and the entry fix. The speed schedule derived is based on making good an assigned time at the metering fix, or alternatively, provides a minimum-fuel speed schedule. When additional delay is needed beyond the maximum delay attainable with a slow-speed descent to the metering fix, a path stretching maneuver or holding path is constructed. As in the RPD calculation process, once the speed schedule is assigned, the segment calculation routines are employed. Beginning at the metering fix a sequence of segment calculations is made. The functional logic for the path segment calculations and the types of calculation modules are exactly the same as in the RPD computation process described in subsection 4.4.

Figure 19 summarizes the functional logic employed in the HPD calculation process. Note that the solution of a metering fix time assignment involves an iteration process that selects various speed schedules within the aeroperformance envelope.

4.7 DELAY CALCULATION

When additional delay is required to make good a metering fix time, the algorithm determines the extra delay needed. Excess delay absorption techniques in the algorithm include holding and path stretching and become operational in the HPD portion of the descent. Figure 20 illustrates the delay logic employed by the algorithm.

Holding is required if other airplanes ahead are holding or if the additional delay is at least a single, minimum-time circuit around the designated holding fix, calculated at the nearest approved holding altitude intersecting the fuel-efficient, minimum-speed descent path.

To establish a holding exit time, a fuel-efficient path is constructed from the metering fix back to the holding fix from which the airplane would leave at a predetermined exit altitude.

Then, the holding fix entry (crossing) time is determined based on the calculation of a fuel-efficient path from the top-of-descent to the holding fix at the assigned entry altitude. The difference between the entry and exit times specifies the additional delay required to make good the metering fix time. With the delay and wind conditions known, the algorithm specifies the number of patterns to be flown, the turn and straight leg parameters, and bank angle requirements. To effect the timing mechanization, the time interval τ_a is defined as the holding fix crossing interval; i.e., the amount of time taken between two successive holding fix crossings. Its value is determined by circular revolution time given a prescribed bank angle and the no-wind leg times applicable at the assumed exit altitude and within ATC constraints. Another aspect of the holding mechanization is that the airplane makes its fixed bank angle turns relative to the air mass instead of a defined racetrack ground pattern with semicircular ends and takes into account drift in the turns and straight legs. With wind, this implementation requires no modulated bank angle coupling to the autopilot during the turns and solves for the unequal inbound and outbound leg times while satisfying ATC inbound leg time constraints at all applicable holding altitudes. The following cases are incorporated in the algorithm:

1) Single airplane holding:
   a) Holding at the aircraft-determined optimum altitude (i.e., the altitude intersecting the normal, no-holding slow-speed descent path). This procedure presumes no other aircraft holding ahead and an ATC clearance.
   b) Holding at a single ATC-assigned altitude

2) Multiple airplane holding: holding in a stack

When the required additional delay is less than the minimum circuit time as described in the previous section, then the logic calls for path stretching to be carried out at cruise altitude, prior to the top of descent. The algorithm constructs a parallel path offset from the inbound course, computing the offset distance and the times of the outbound and inbound legs. The legs are assumed to be perpendicular to the inbound course and constrained to a maximum offset of 10 nmi. The current mechanization does not model the times to turn away from and return toward the inbound path during the banks and, therefore, assigns all the excess delay to the legs.

4.8 DISPLAY OF RESULTS

The final LFM/PD guidance algorithm function is the display of the completed profile. Tables 2 and 3 show the results of the profile generation process. Table 2 shows a typical example of a completed profile. Table 3 shows the summary data extracted from profile for presentation to the flight crew. The profile shown is for the Los Angeles International Airport Profile Descent (CIVET 25) described in subsection 4.1, In-Plane Geometry and ATC Constraints, and illustrated in Figures 4 and 5. The resultant altitude profile is shown plotted in Figure 21 as a function of path distance together with the altitude constraints for the descent.

Figure 22 shows the logic flow of the algorithm functions to display the profile generation results.

5.0 COMPUTER MODEL STRUCTURE

This section of the LFM/PD report describes the computer model implementation of the algorithm. The first two subsections describe the considerations used in the algorithm's design, while the remaining subsections describe considerations used in the implementation of the design.

5.1 DESIGN APPROACH

The Profile Descent Algorithm was created with a top-down functional approach. In this context, a function refers to those elements which contribute to the execution of a single task. The top-down approach used to design this algorithm was accomplished in two steps.

First, the profile descent was expressed in terms of the functions that the algorithm must perform. Each function was then considered individually and expressed in terms of subfunctions necessary to accomplish the parent function. This process was continued level by level until the solution to the problem was completed and the problem was represented by a hierarchy of functions.

The second part of the design process was step-wise refinement. This process analyzed the interrelationships between the components on a given level of the functional hierarchy and then took into consideration the actual sequence and timing of each function on that level.

This top-down approach produces an algorithm that is modular in nature and has the advantage that both the design and the code are more easily tested during development. Furthermore, the finished product is more reliable and easier to maintain.

The functional design produced a hierarchy that had nine functions at the first level and continued until reaching eleven levels. The program was coded to conform to the functional decomposition as much as possible. The modules were transformed into SUBROUTINES and, at the lowest level, FORTRAN FUNCTIONS. The current version of the program contains 164 subroutines and functions.

5.2 PROGRAM MODULES SUMMARY DESCRIPTION

The program PROFIL modules here are grouped into seventeen functional areas:

1) Profile construction modules

2) Segment analysis modules

3) Segment computation modules

4) Descent computation modules

5) Geometry, ATC constraints, and descent initialization input modules

6) Wind and temperature forecast modules

7) Wind model modules

8) Temperature model modules

9) Aeroperformance computation modules

10) Aeroenvelope construction modules

11) Atmosphere parameter modules

12) Delay modules

13) Altimeter and altitude modules

14) Speed conversion modules

15) Anti-icing modules

16) Output modules

17) Program utility modules

A description of inputs, processing and outputs for each program element follows in figure 23. They are grouped by the seventeen function areas.

5.3 INPUT/OUTPUT SPECIFICATIONS

5.3.1 INPUT DESCRIPTION

The information required to generate the profile can be divided into five areas:

- Profile geometry
- FAA winds aloft forecast
- Specific approach information
- Current cruise information
- Method selected to satisfy altitude constraints

The algorithm has been designed to be capable of accessing required data either interactively or from local files. The current algorithm configuration accesses the profile geometry from the local file TAPE1 and the FAA winds aloft forecast from the local file TAPE2. The remaining information is supplied interactively.

Two calculation options are provided at the start of the program for segments unable to meet an altitude floor. Segments can be considered on an individual basis; in this case, the current computational situation is displayed before requesting the selection of a level cruise to intercept a minimum-thrust descent or a thrusted descent over the interval. The results of the selection are displayed and will be discussed further in the output section. The other option provides automatic selection of level cruise in each case.

Each routine containing I/O operations reads from the file INFILE and writes to the file OUTFILE. The local files INFILE and OUTFILE are defined in data statements in the declarative section of the routines. Therefore, all that is required to change the I/O configuration is to redefine the file numbers for INFILE or OUTFILE in the data statement.

5.3.2 SAMPLE INPUT

It has previously been explained that data for the program can be accessed either from local files or interactively. Sample interactive input that describes the profile geometry for the CIVET 25 Profile Descent into Los Angeles International Airport is shown in Table 4. Each input record follows the input designator, I>.

Table 5 shows the same profile geometry when the information is accessed from a local file. The formats for the individual records can be identified by locating the corresponding input record in the interactive input.

A sample interactive input for FAA winds aloft section for Denver is for the test situation of nonzero winds and nonstandard temperatures and is shown in Table 6. Table 7 shows the same information when accessed from a local file. Table 8 is the section of input which contains the specific approach information and the current cruise information. These data are most commonly supplied interactively with the algorithm allowing iterations for different cruise conditions and different profile geometries.

Additional input is required when time-based metering is in progress. Table 9 shows the information required to initiate the calculation. It should be noted that an acceptable time interval for the metering fix time assignment is displayed.

Table 10 shows the choices of either a thrusted descent or a level cruise when segments are considered on an individual basis. Since the profile is calculated from the aimpoint to the entry fix, segments requiring thrust show altitude constraints violated in the direction of the profile calculation. The altitude constraint of 10,000 feet at ARNES refers to the inability to compute the segment from ARNES to CSFIX1 with the current thrust setting. In this instance, a thrust-assisted descent is performed. For the segment from DIKES to EMMEY, the option to cruise level until reaching the point of descent (the point which intercepts the idle clean descent to EMMEY) is calculated. This point is inserted into the waypoint stream and in this case is also the top-of-descent (TOD). If altitude restrictions must be violated to complete the profile, a prompt is given requesting ATC approval to complete the profile.

5.3.3 OUTPUT DESCRIPTION

The output description is divided into three sections: a section describing the deviations from minimum-thrust clean descents, a detailed description of the profile descent, and a summary section.

The first section describes deviations from a minimum-thrust, clean-configuration required to conform to altitude restrictions. Drag to be added is reported as a percentage of maximum spoiler drag available. When thrust is required, the selection of a level cruise to intercept a minimum-thrust, clean descent or a continuous thrust-assisted descent is made. For the level cruise option, the point of interception with the idle clean path is calculated and inserted into the waypoint stream as a point of descent (POD). For a thrust-assisted descent, the thrust to be added is reported as a percentage of maximum cruise thrust.

5.3.4 SAMPLE OUTPUT

The outputs that describe the nonmetered profile are in Tables 11 and 12. If drag is required it is reported under the heading "DESCENT REQUIREMENTS." Table 11 shows the full profile.

The summary section is shown in Table 12. This section provides descent summary items, such as profile distance, information pertaining to entry points, change of speeds, and metering.

The completed profile for a metered case is illustrated in Tables 13 and 14.

6.0 COMPUTER MODEL TEST/VALIDATION APPROACH

Testing of the profile descent algorithm was performed to establish the algorithm's conformity to design specifications.

The overall approach of the testing was to determine whether correct inputs produced predictably accurate and appropriate results. Test cases were selected to examine representative data, data for limit/boundary conditions, and data to test all functional paths through the algorithm.

To accomplish these goals, the algorithm was tested on both a subsystem and system level.

6.1 SUBSYSTEM TESTS

This group of tests used individual subroutines and functions that are combined to form self-contained modules. Inputs were chosen so as to operate the modules over a wide range of input values and to identify cases where incorrect operation occurs. Tests supported the following conclusions.

6.1.1 WIND MODULE

Wind speeds ranging from 1 to 200 knots are routinely handled, as are windshear conditions. The wind module accepts as many as 9 or as few as 3 forecast points. Cruise altitudes for the known wind ranging from meter fix altitude to the highest forecast altitude are accepted, as are aimpoint altitudes from the ground up to the MF altitude. The modeling of winds outside the range of forecast altitudes produced reasonable values.

6.1.2 TEMPERATURE MODULE

Testing of the temperature module indicated that large, small, positive, zero, and negative temperatures are correctly processed. As many as 9 or as few as 3 forecast points are accepted. Cruise altitudes ranging from meter fix altitude to the highest forecast altitude are acceptable, as are aimpoint altitudes from ground level up to the meter fix altitude. Temperature inversions are also correctly processed. The modeling of temperatures above the highest forecast altitude may not produce valid results when the highest forecast altitude is 39,000 feet or greater. The modeling of temperatures below the lowest forecast altitude produces reasonable values.

6.1.3 CRITICAL ALTITUDE MODULE

This module consists of aeroperformance, temperature, and airspeed conversion subroutines. Temperature and gross weight variations produce reasonable changes in the critical altitude function. Slow- and high-speed buffet boundaries, maximum operating speeds, flap extension speeds, and thrust-limited speeds are correctly compared. Airspeed conversions are properly made, and the critical altitude correctly defined.

6.1.4 SEGMENT CALCULATION MODULE

This module uses thrust, drag, fuel flow, true altitude, airspeed conversion, and speed profile subroutines to calculate the 4-D paths for the various types of segments. Various gross weights and altitudes produced reasonable fuel flows, speeds, distances, and times.

6.1.5 TRUE ALTITUDE MODULE

Testing of the true altitude module indicates correct trends and reasonable values for various temperature profiles resulting in lapse rates from -1.5X standard to +1.5X standard.

6.1.6 ATMOSPHERE MODULE

Testing of this module indicates correct trends and reasonable values of atmospheric pressure and density for various temperature profiles.

6.1.7 EXCESS DELAY MODULE

The excess delay module was verified for path stretching, optimum altitude holding, ATC-assigned-altitude holding, and holding in a stack. Results were verified against published holding restrictions. Also, computations for each type of additional delay were made using performance manual values for various altitudes, speeds, and thrust settings. All tests produced reasonable values of fuel flow, leg lengths, and circuit times.

6.1.8 ANTI-ICING MODULE

The anti-icing was tested using an aeroperformance program to drive the routines. Results were checked against engineering performance data. The anti-icing module accepts upper and lower altitude boundaries for the icing region. The minimum thrust required for thermal anti-icing is input as percent N1 rpm.

6.2 BASELINE VALIDATION

The program was validated by checking the results of a typical profile descent into Denver, the KEANN 26 Profile Descent. The results of the calculated profile were checked by manual calculation, using B737 performance handbook data. The profile results were then considered to be a baseline against which other system tests could be compared.

The baseline cruise parameters were:

- Cruise altitude—35,000 feet
- Entry fix speed—.765 Mach
- Gross weight—85,000 pounds
- ISA temperatures
- Zero wind
- No metering

The baseline validation results are found in Tables 15 and 16.

The level flight speed, time, and fuel are in agreement with handbook figures, and Mach/airspeed conversions agree with standard charts. Level deceleration times and distances are not available in performance handbooks but were validated using another Boeing aeroperformance computer program. Idle descent speeds and times also are not available as handbook data, so they were validated using another computer program. Idle fuel flow is in agreement with published data.

6.3 SYSTEM LEVEL TESTS

This group of tests uses the program in its complete form, as did the baseline validation. Nine categories of tests were identified, with each category examined in turn while baseline conditions were retained for all other inputs.

6.3.1 NONSTANDARD TEMPERATURES

Nonstandard temperature conditions were tested to study their effect on airspeed conversions, critical altitude, fast/slow Mach, and true altitude calculations. Two methods of varying the temperature were used: ISA plus a constant increment, and lapse rate deviations of 1/2 standard and 1 1/2 standard lapse rates.

The major effect of ISA plus an increment is to vary the elapsed time for a distance-constrained segment, due to the airspeed dependence on temperature. The major effect of nonstandard lapse rates is to vary waypoint altitudes, due to true altitude dependence on lapse rate. All expected effects were noted and confirm proper operation of the program.

6.3.2 WIND VARIATIONS

Wind variations on a system level were tested by comparing the segment elapsed time to a calculated time using the segment distance, headwind, and true airspeed. All effects noted due to wind were the same as those calculated manually.

6.3.3 GROSS WEIGHT VARIATIONS

Gross weight variations were tested for their effect on critical altitude by noting the resulting Mach/CAS descent schedules. Weight burnoff compared with performance manual values.

6.3.4 CRUISE ALTITUDE VARIATIONS

Fuel flow and speed trends were as expected and confirm proper operation of the program.

6.3.5 ENTRY FIX SPEED VARIATIONS

Trends in deceleration time and distances, and fuel flows were as expected.

6.3.6 METER FIX TIME VARIATIONS

Meter fix time variations reflect the proper selection of critical altitude as shown by the resultant Mach/CAS descent schedules. Cases where delay is required, or the descent is impossible are correctly identified, along with testing the complete range of meter fix time assignments. An example of processing a metering fix time assignment is shown in Table 17.

6.3.7 SYSTEM DELAY

The results of the excess delay capability indicate the proper choice of path stretching or holding. Table 18 is an example of path stretching using parallel offset, since required delay beyond that available by slowing is less than one complete minimum holding pattern.

Tables 19 through 21 give examples of optimum altitude holding, ATC-assigned-altitude holding and holding in a stack, respectively. In addition, an example of holding in a stack in the presence of wind is given in Table 22. (Wind values are given in Table 6.)

Each case provided reasonable values of holding parameters and conformed to ATC constraints, such as maximum bank angle, minimum four-minute turns, minimum holding airspeed, maximum leg lengths, and holding altitudes.

6.3.8 ANTI-ICING

System level tests indicate the proper use of anti-icing. The anti-icing boundaries are correctly inserted into the descents. Multiple checks of anti-icing performance indicate expected performance. An example of anti-icing is given in Table 23.

6.3.9 PROFILE RE-INITIALIZATION

The use of revised geometry provides a means of using a selected portion of the profile from the first usable waypoint and inserting new waypoints at the desired distances and headings. The capability for introducing course changes and re-initialized paths was checked and validated. A sample case is given in Table 24.

6.4 SAMPLE INPUT/OUTPUT DATA SETS

The following are typical of the input and output data sets used for test and validation of the computer program.

The algorithm has been tested by calculating typical profile descents selected from each of the published profile geometries and were updated using Jeppesen charts. Two exceptions have been made. Although a published procedure exists at Atlanta, it is defined by only one point and was not calculated. Conversely, although no procedure has been published for Dallas-Fort Worth, time-based metering is used there in conjunction with the STARS. Therefore, a calculation has been made assuming that metering occurs at the cornerposts. The results of these profile calculations are shown in Tables 25-30. The profile calculation for CIVET 25 is given in Tables 2 and 3.

The BIG SUR profile descent, Table 28, illustrates a situation in which the geometry would not allow a normal profile descent to occur. Even with the spoilers deployed to flight limit, the descent required between waypoints CSFIX1 and D20/BSR was beyond the descent capabilities of a B737. When this occurs the caution shown in Table 28 is displayed.

7.0 FIGURES AND TABLES

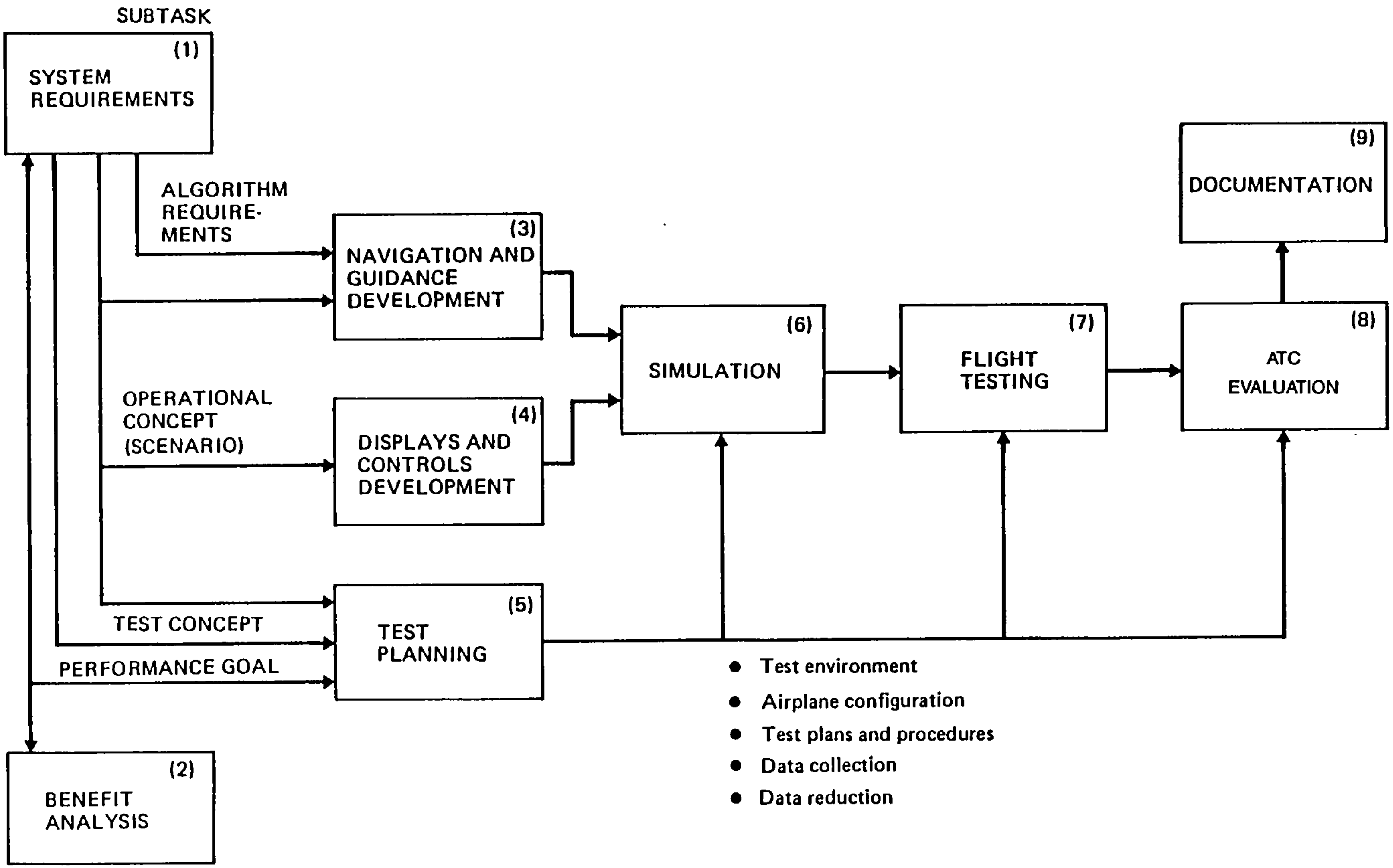


Figure 1. Local Flow Management Avionic Research Approach

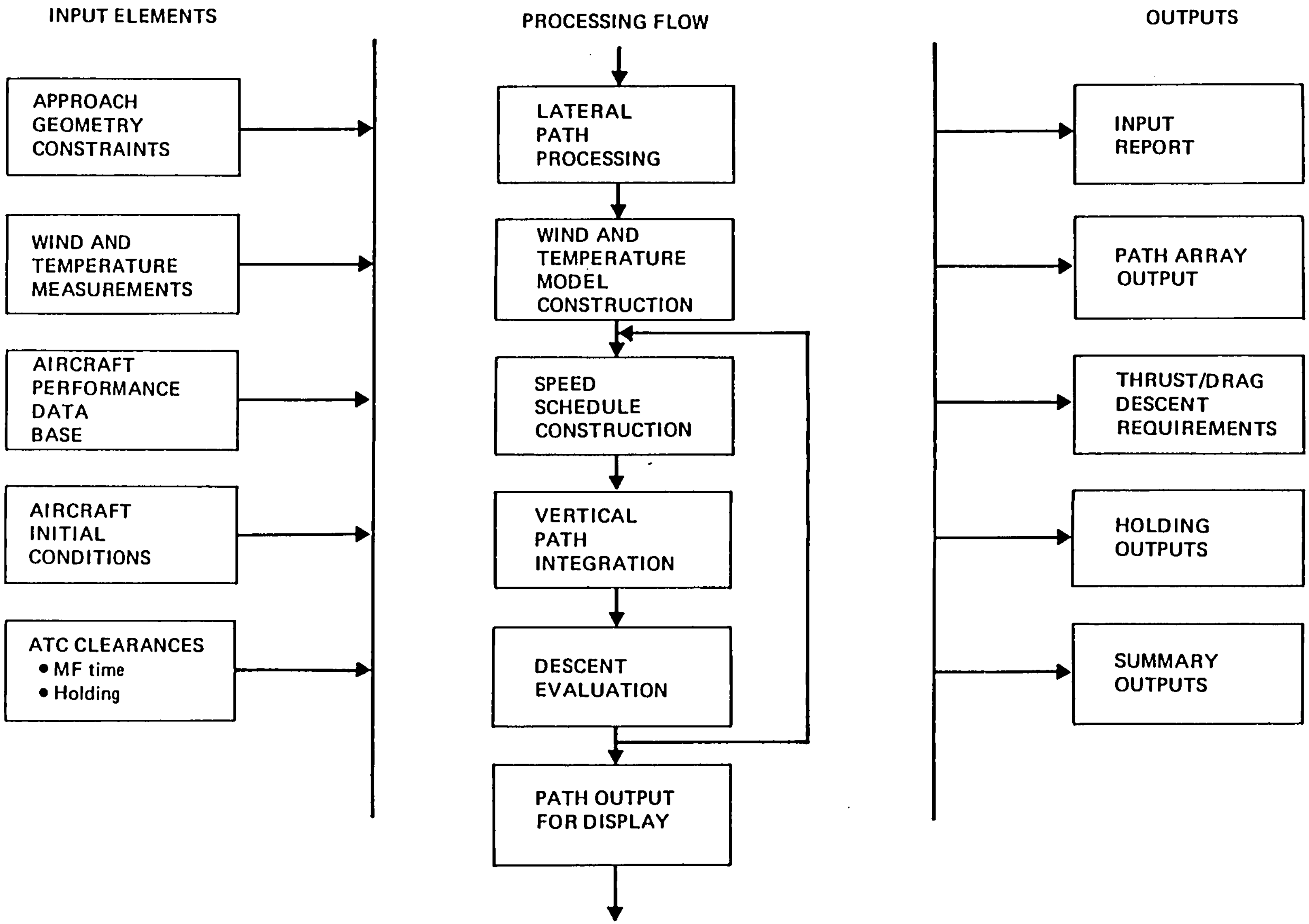


Figure 2. Summary of Model Input, Processing, and Output Elements

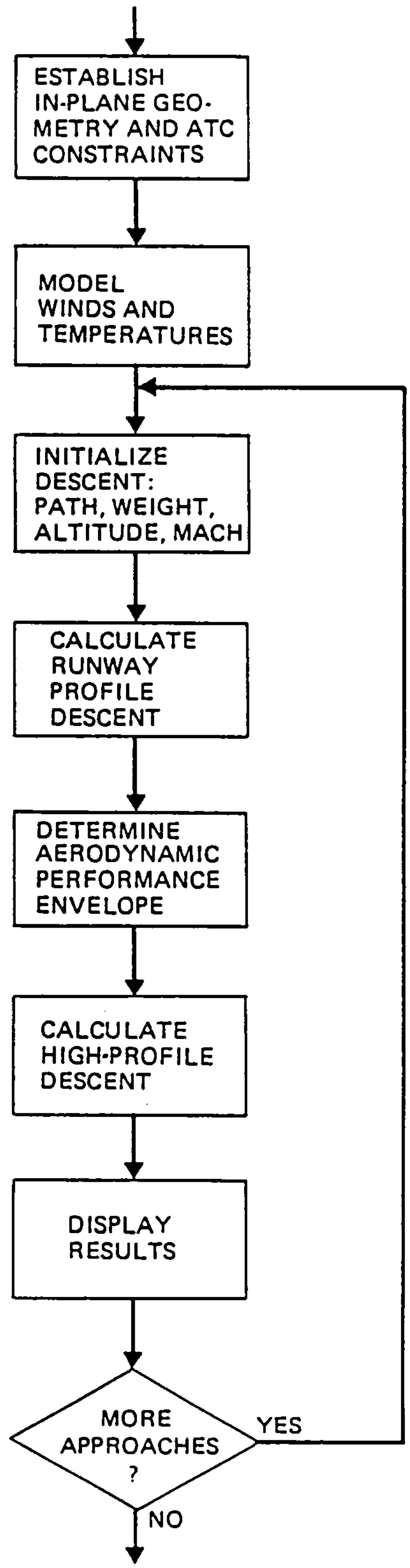


Figure 3. LFM/PD Algorithm Functional Flow

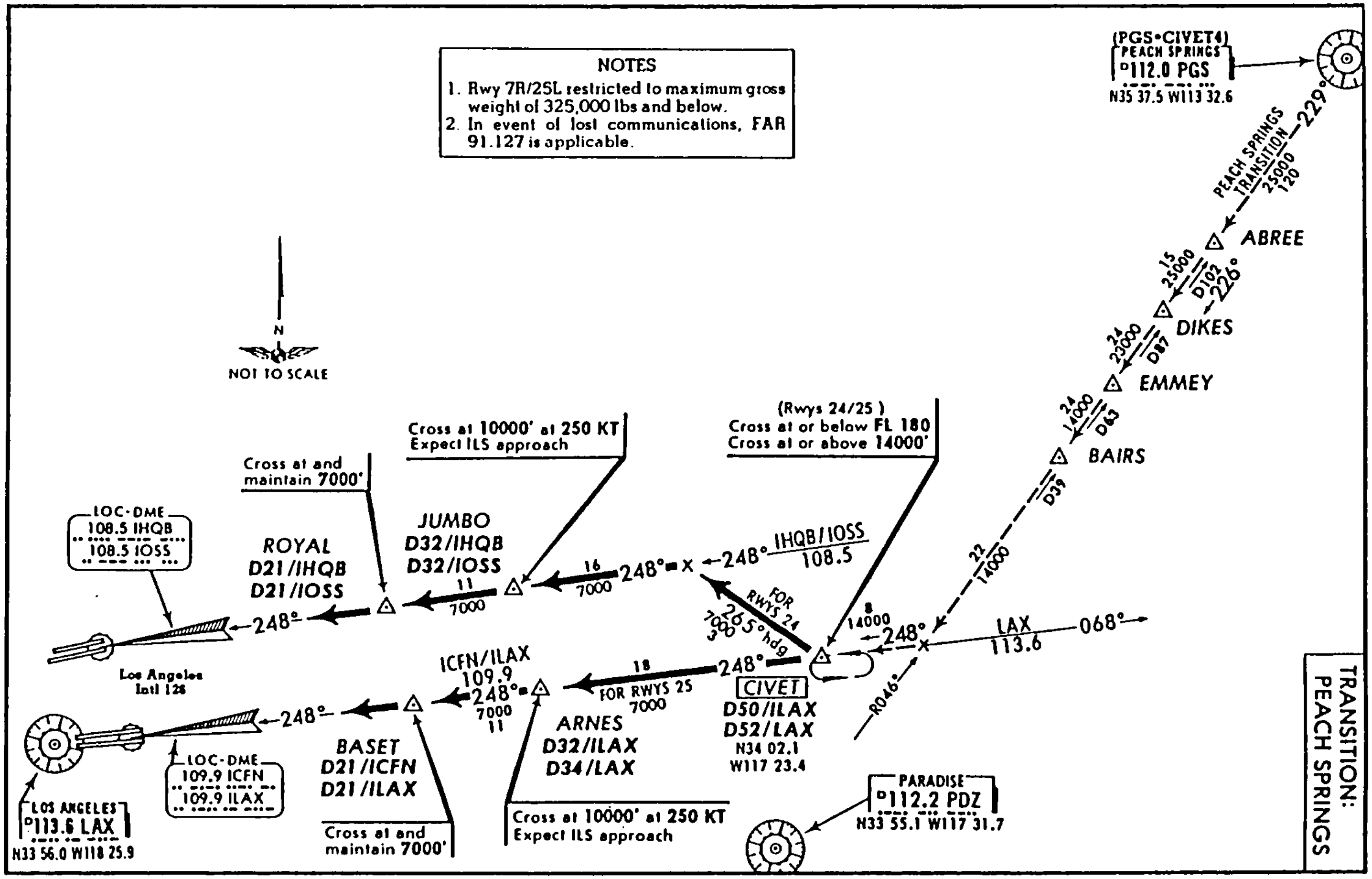


Figure 4. Profile Descent for Los Angeles International Runways 24 and 25 Via Peach Springs

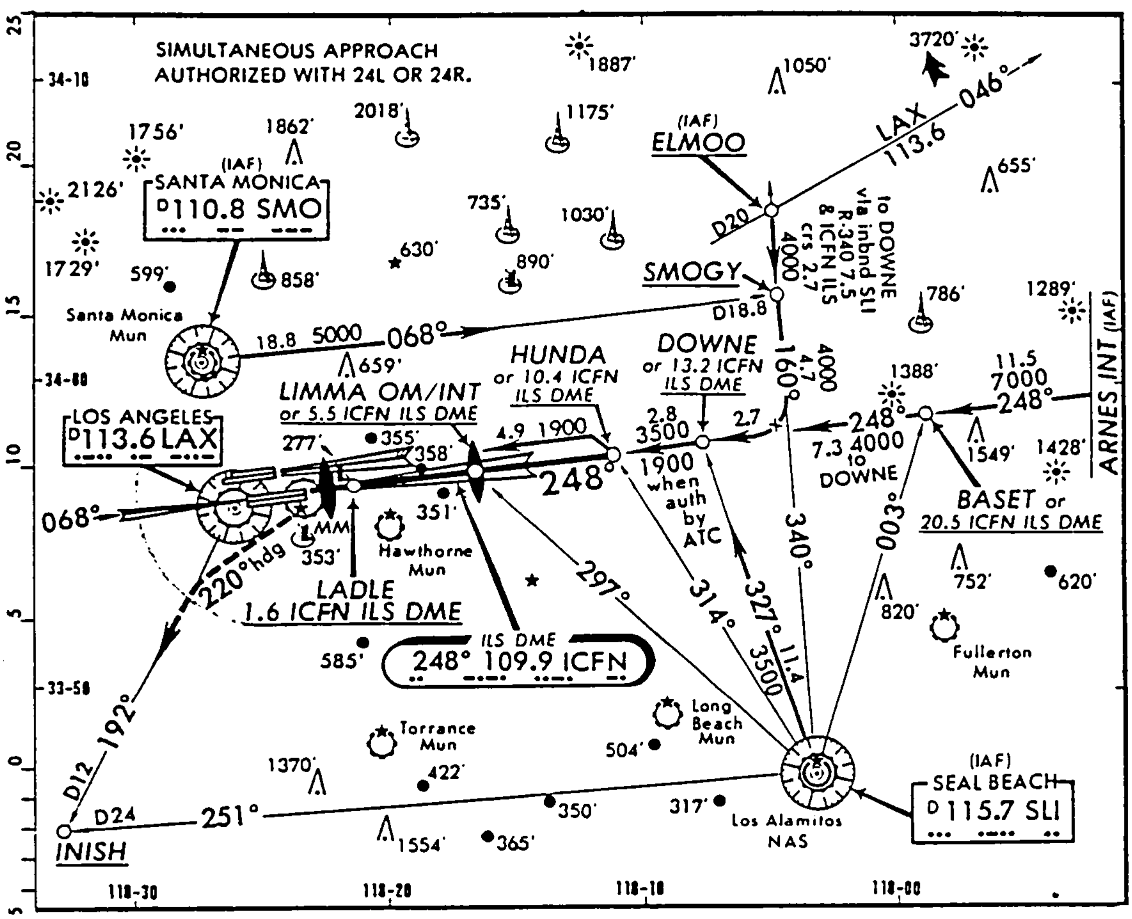


Figure 5. ILS Approach for Los Angeles International Runway 25L

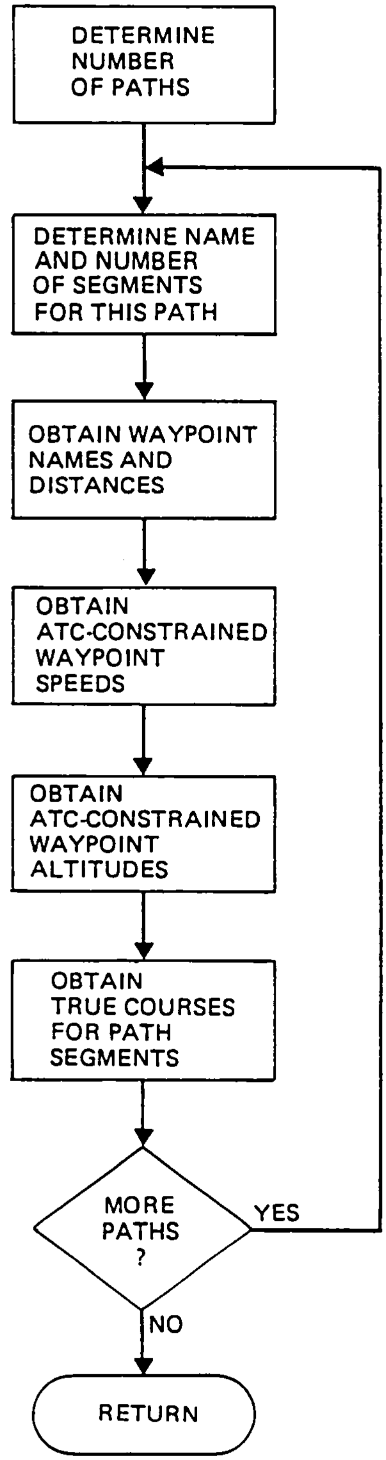


Figure 6. Flow for Obtaining Approach Geometry and ATC Constraint Data

Process:

1. Preflight temperature, winds aloft forecast
2. Conversion of altitudes to pressure altitudes
3. Conversion of winds to zonal, meridional components
4. Entry of temperature, wind at altitude
5. Revision of forecast with error function

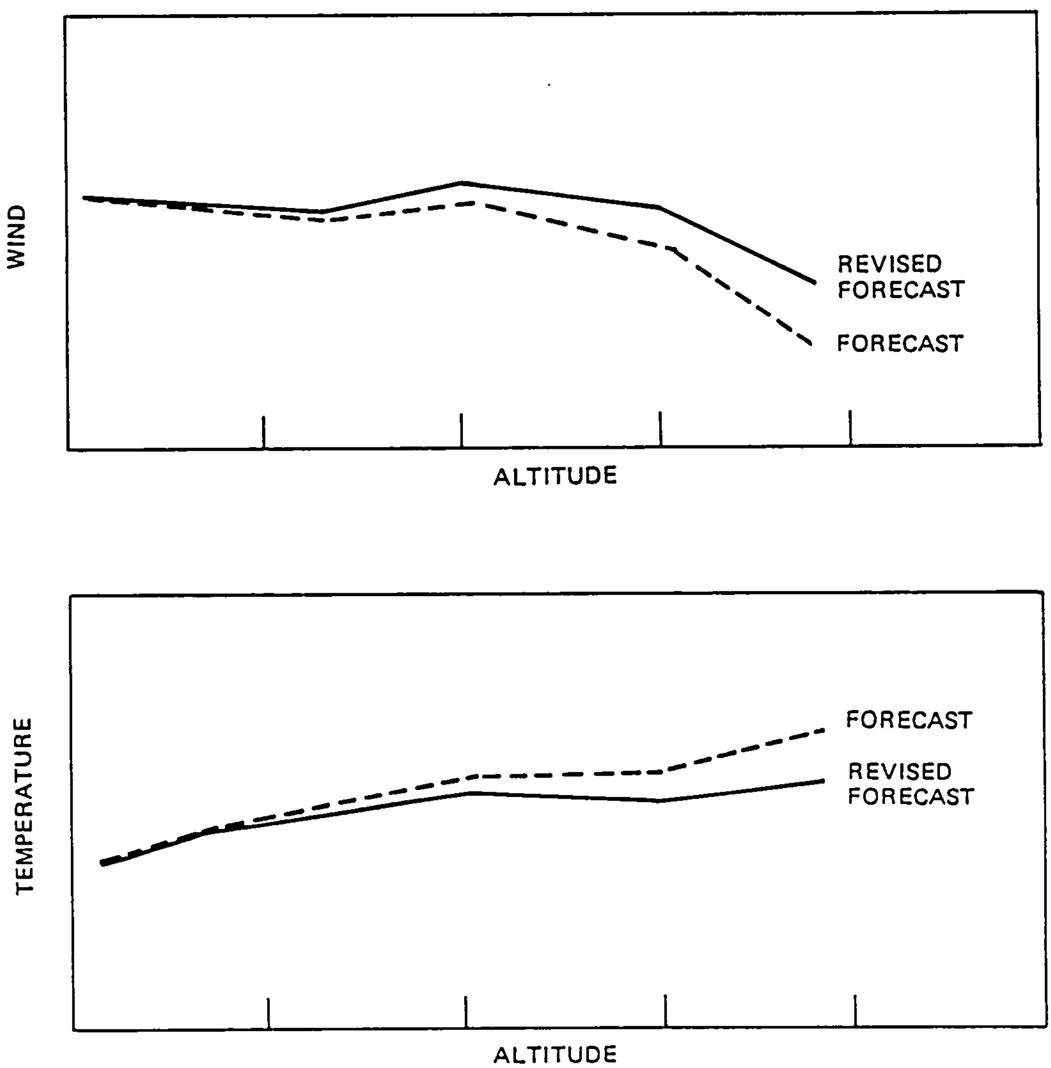


Figure 7. Wind and Temperature Modeling

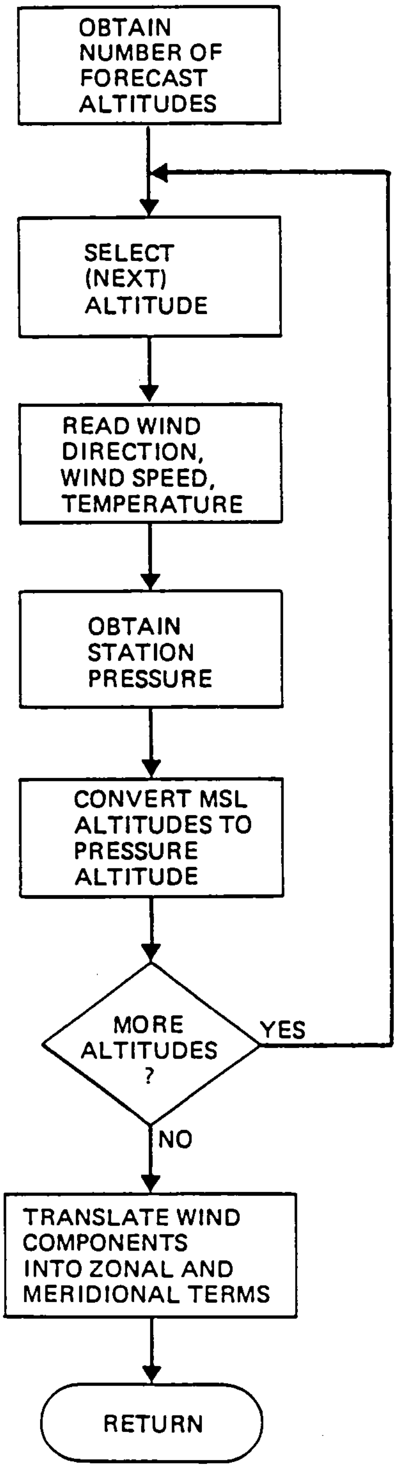


Figure 8. Flow for Obtaining Wind and Temperature Forecast Data

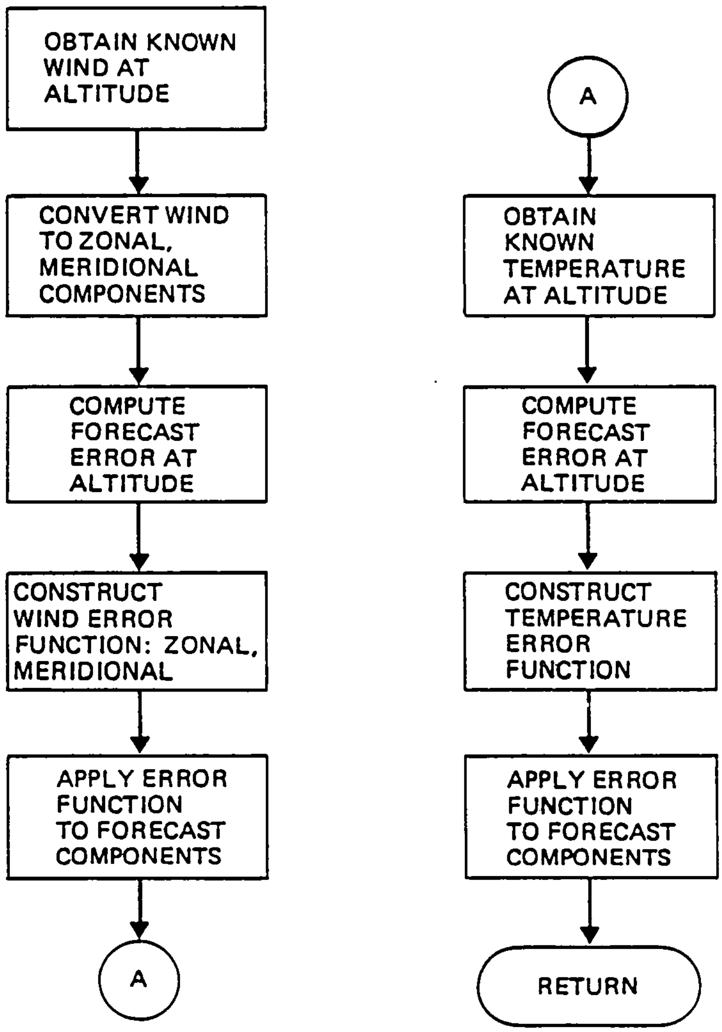


Figure 9. Wind and Temperature Model Computations

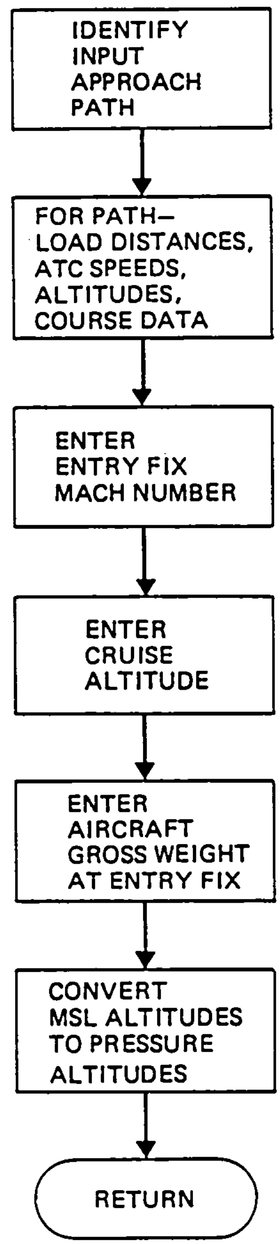


Figure 10. Flow to Initialize Descent Calculation

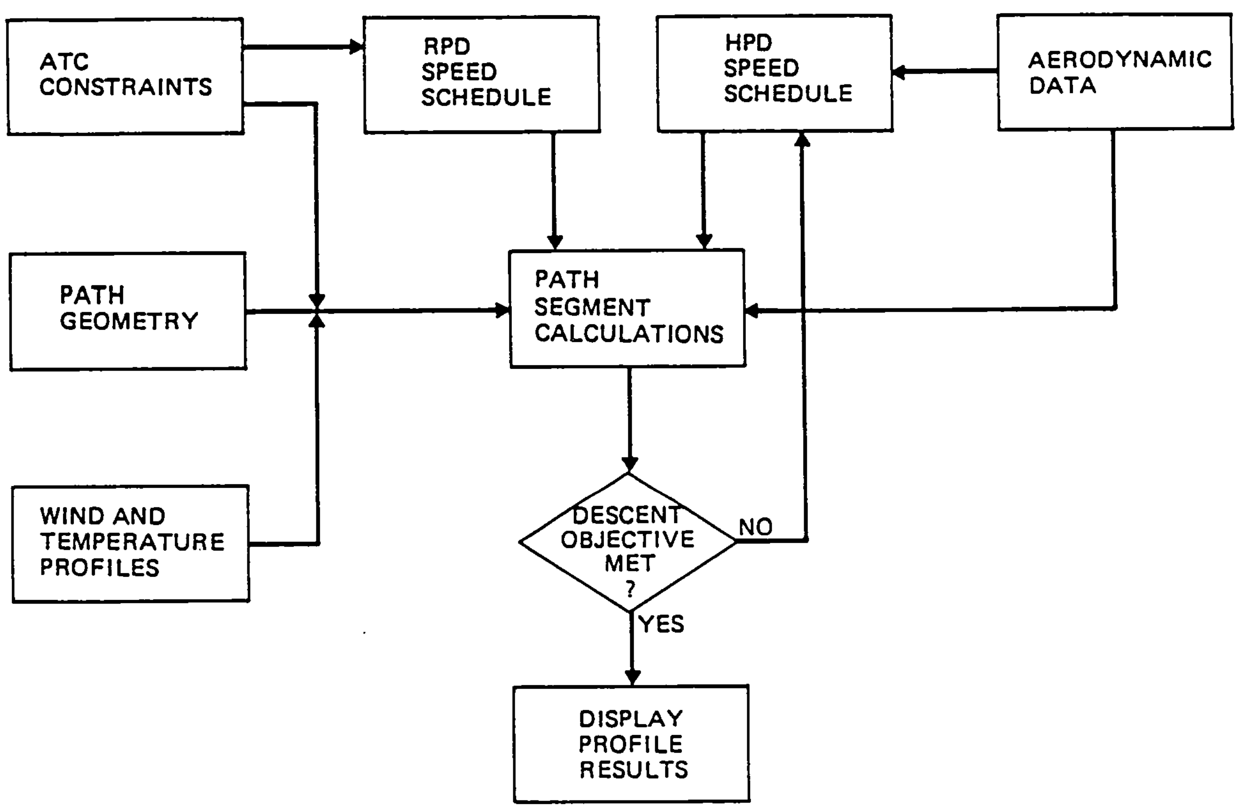


Figure 11. RPD and HPD Segment Calculations

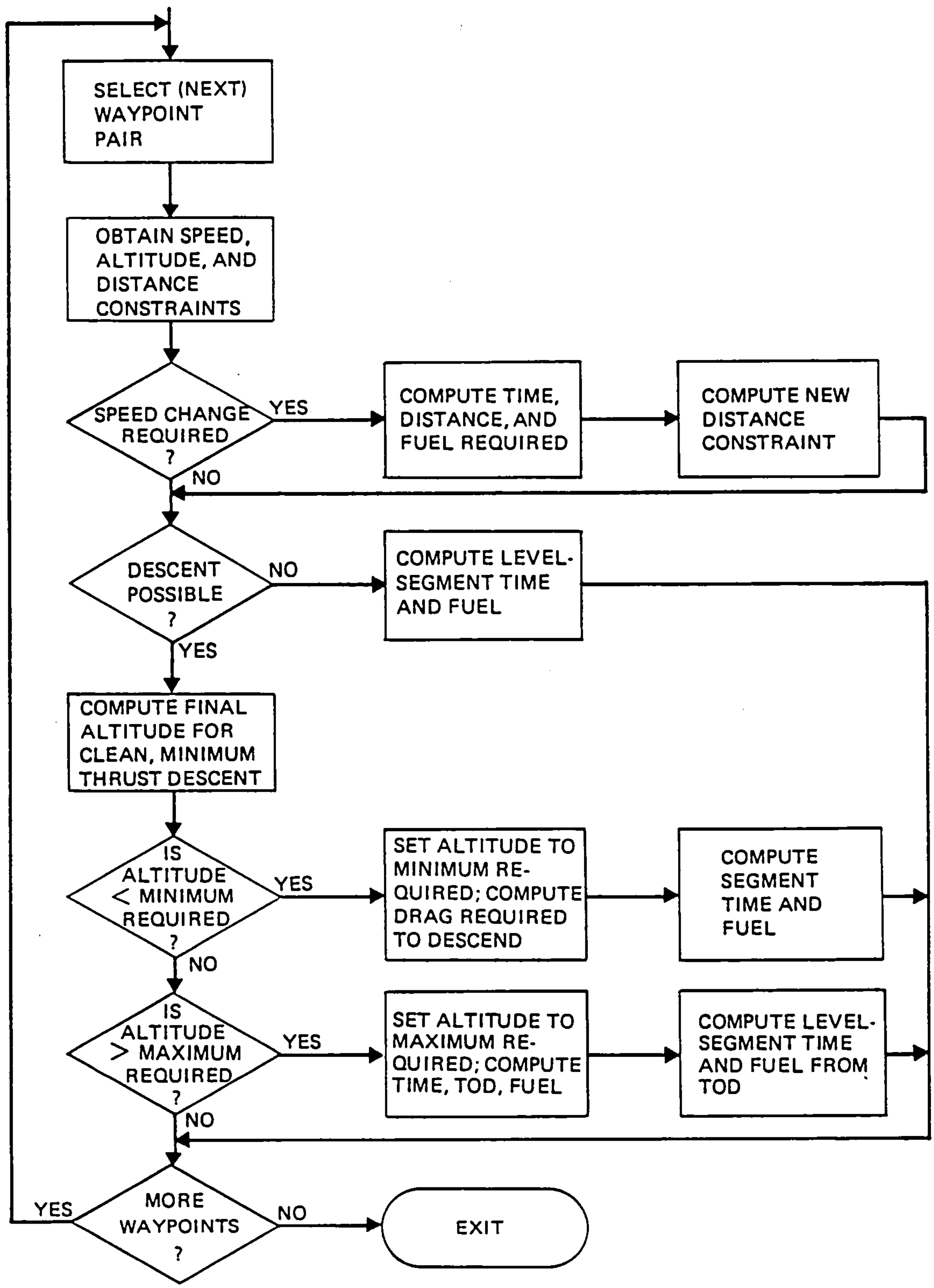


Figure 12. Functional Logic for Path Segment Calculations

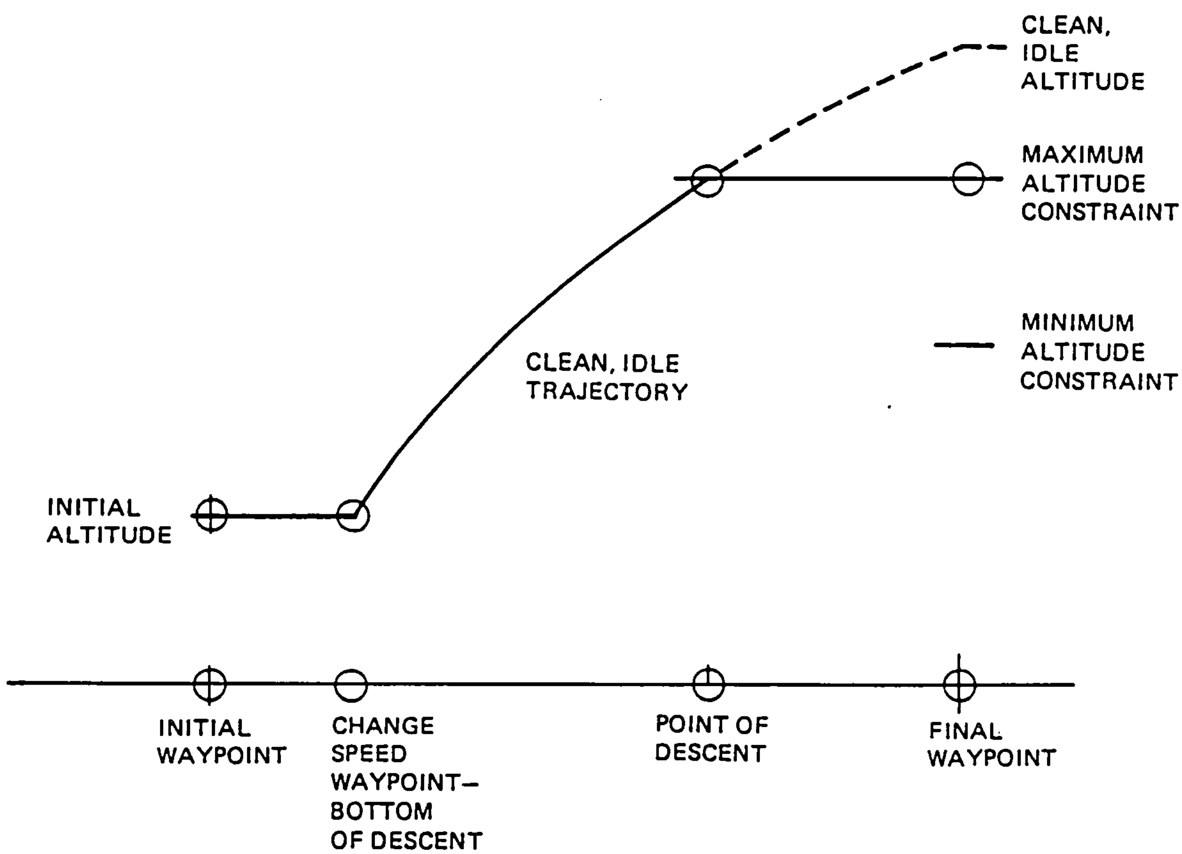


Figure 13. Path Segment Geometry

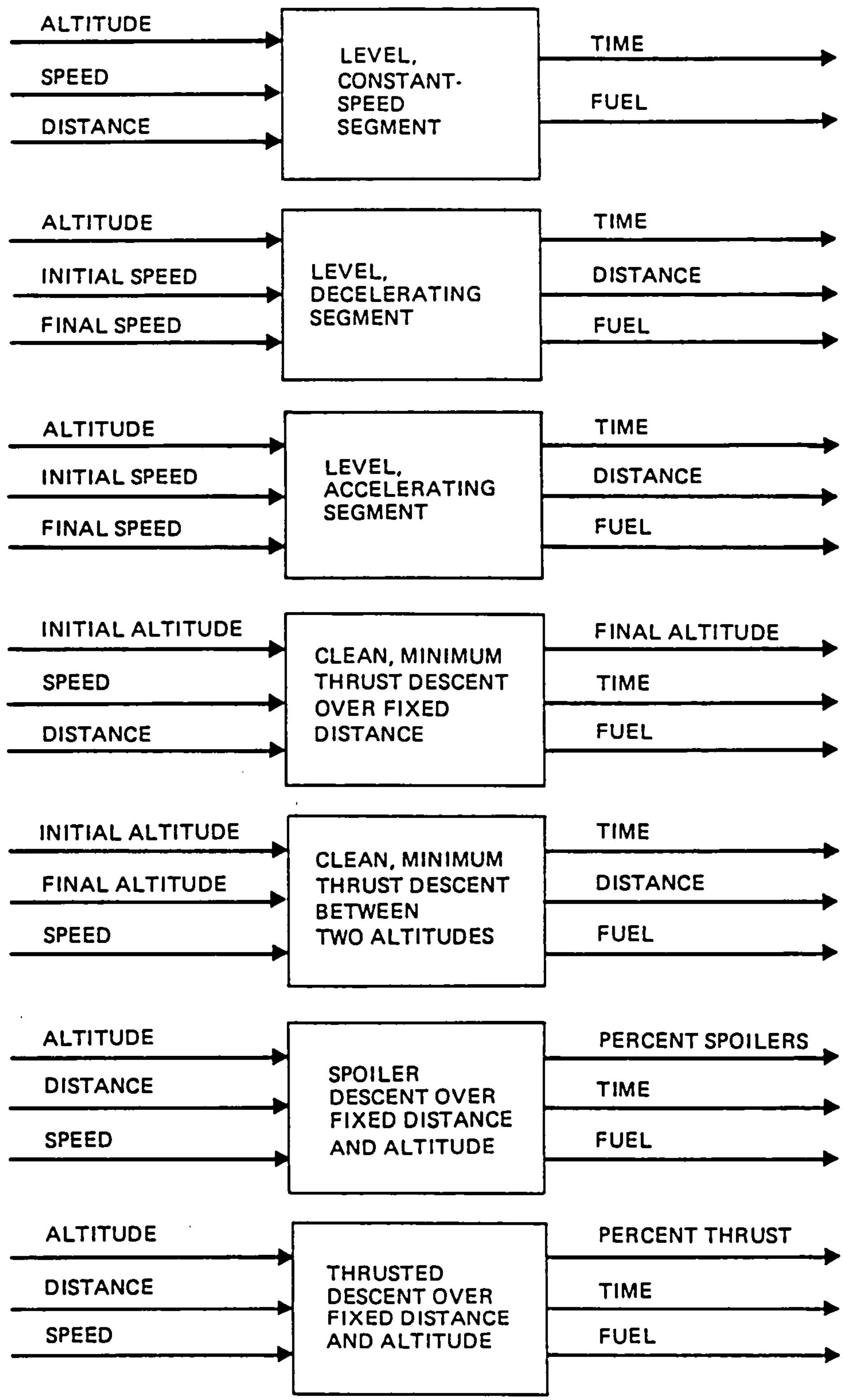


Figure 14. Path Segment Calculation Modules

Computation steps over Δh:

1. Compute true altitude interval
2. Compute Δ VTAS
3. Compute average ground speed
4. Compute thrust, drag, fuel flow
5. Compute acceleration factor
6. Compute rate of descent
7. Compute flight path angle, γ
8. Compute Δ time
9. Compute Δ fuel (Δ gross weight)
10. Compute Δ distance

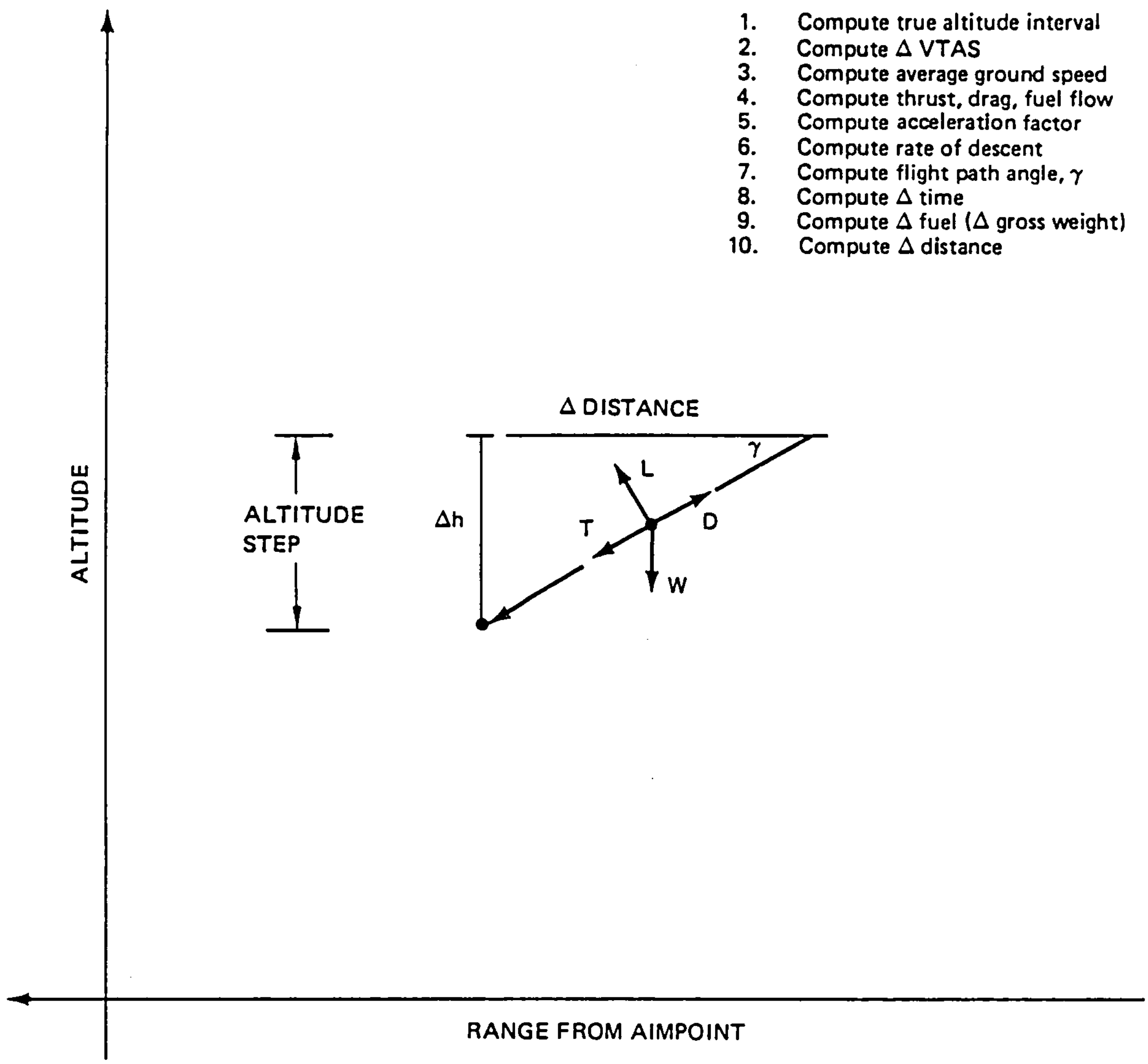


Figure 15. Computation of Equations of Motion Over Altitude Interval

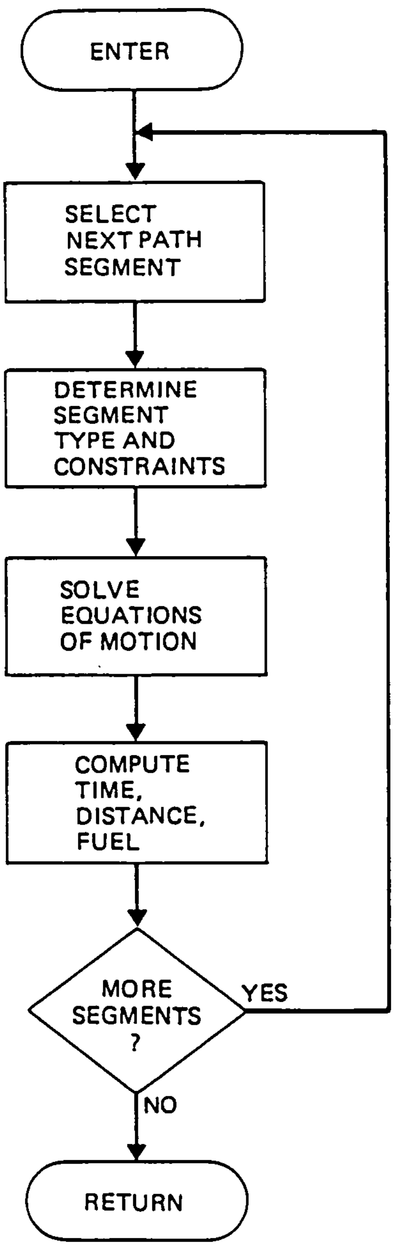


Figure 16. Runway Profile Descent Calculation

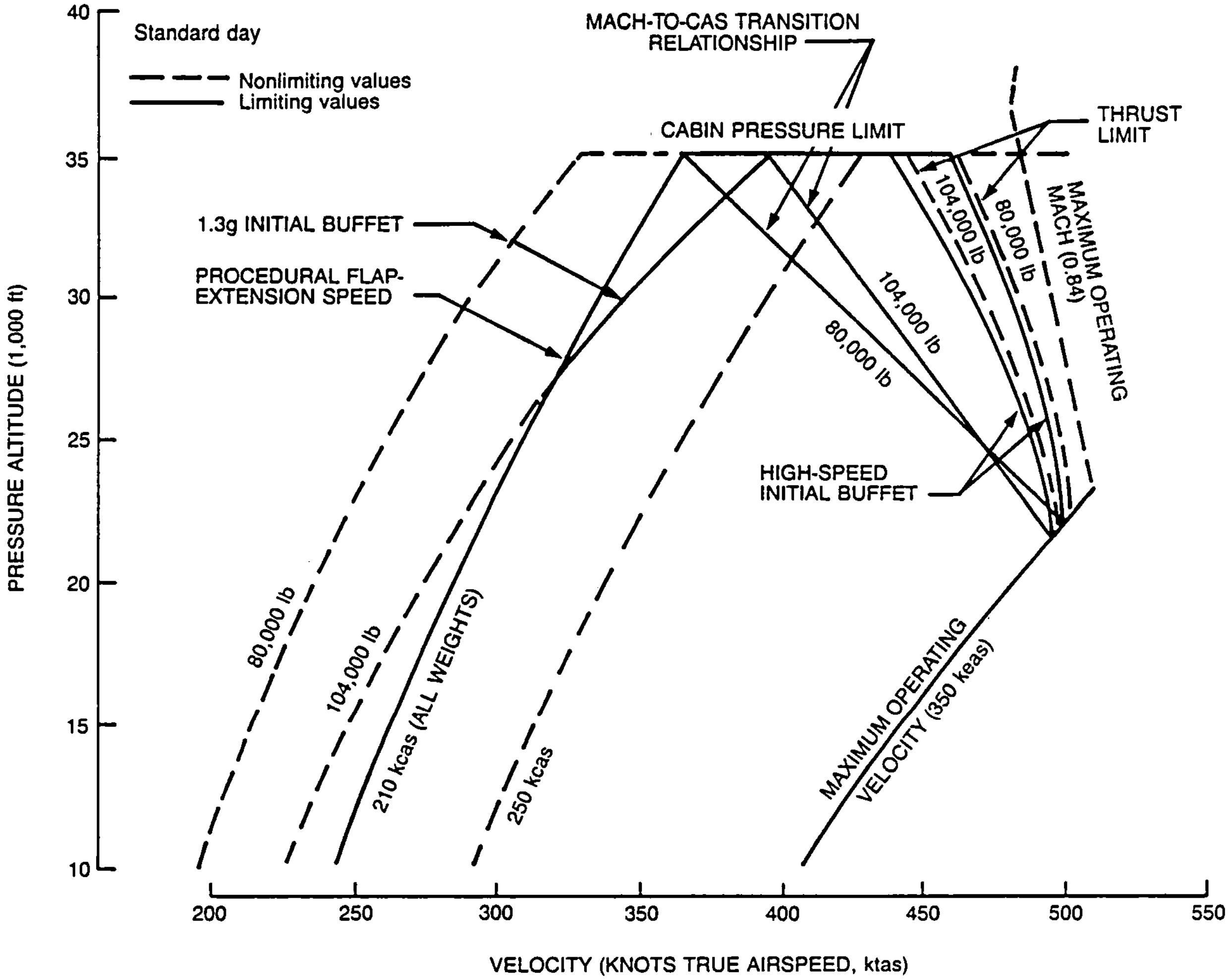


Figure 17. Aerodynamic Performance Envelope

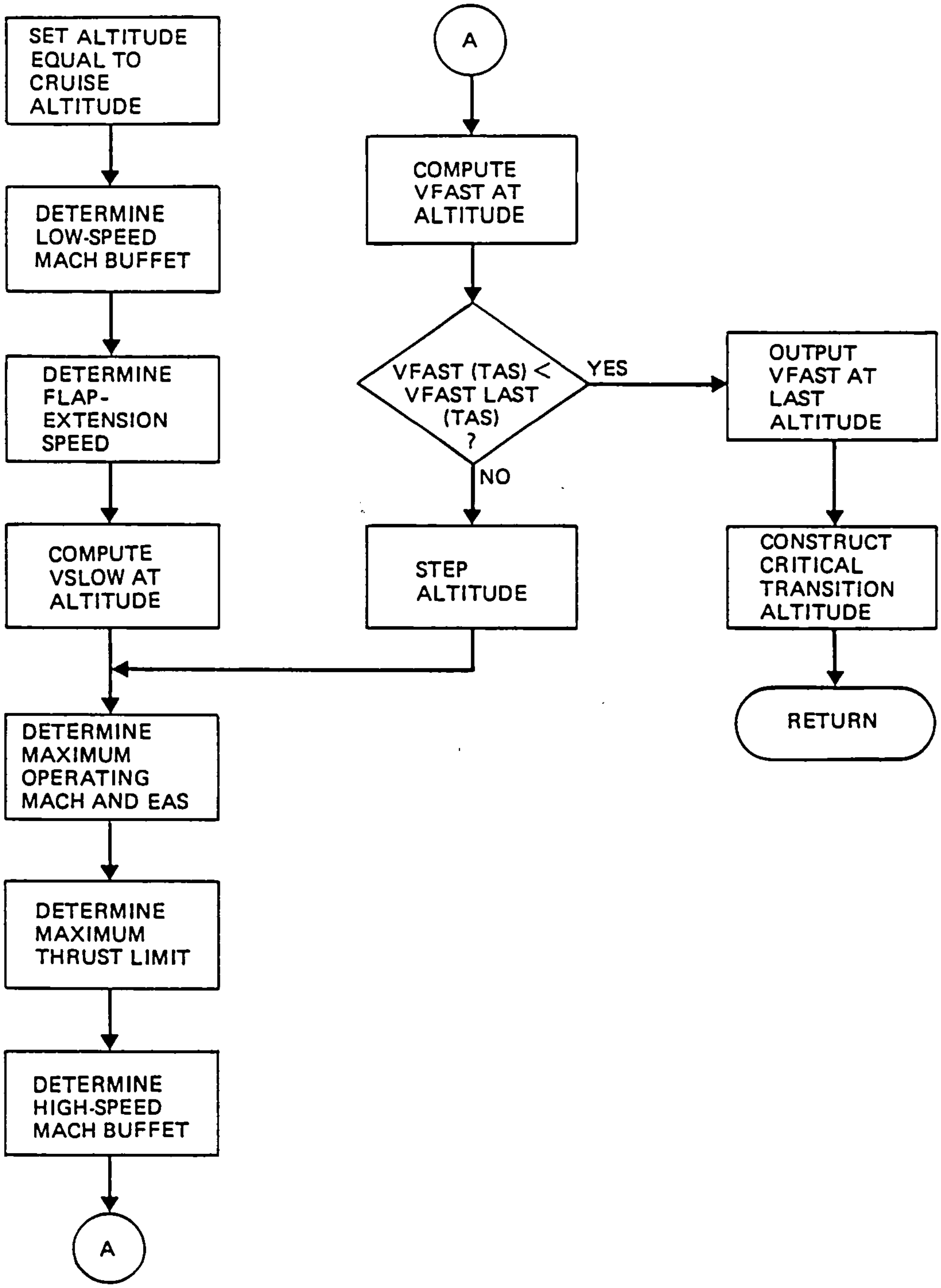


Figure 18. Determination of Aerodynamic Performance Envelope

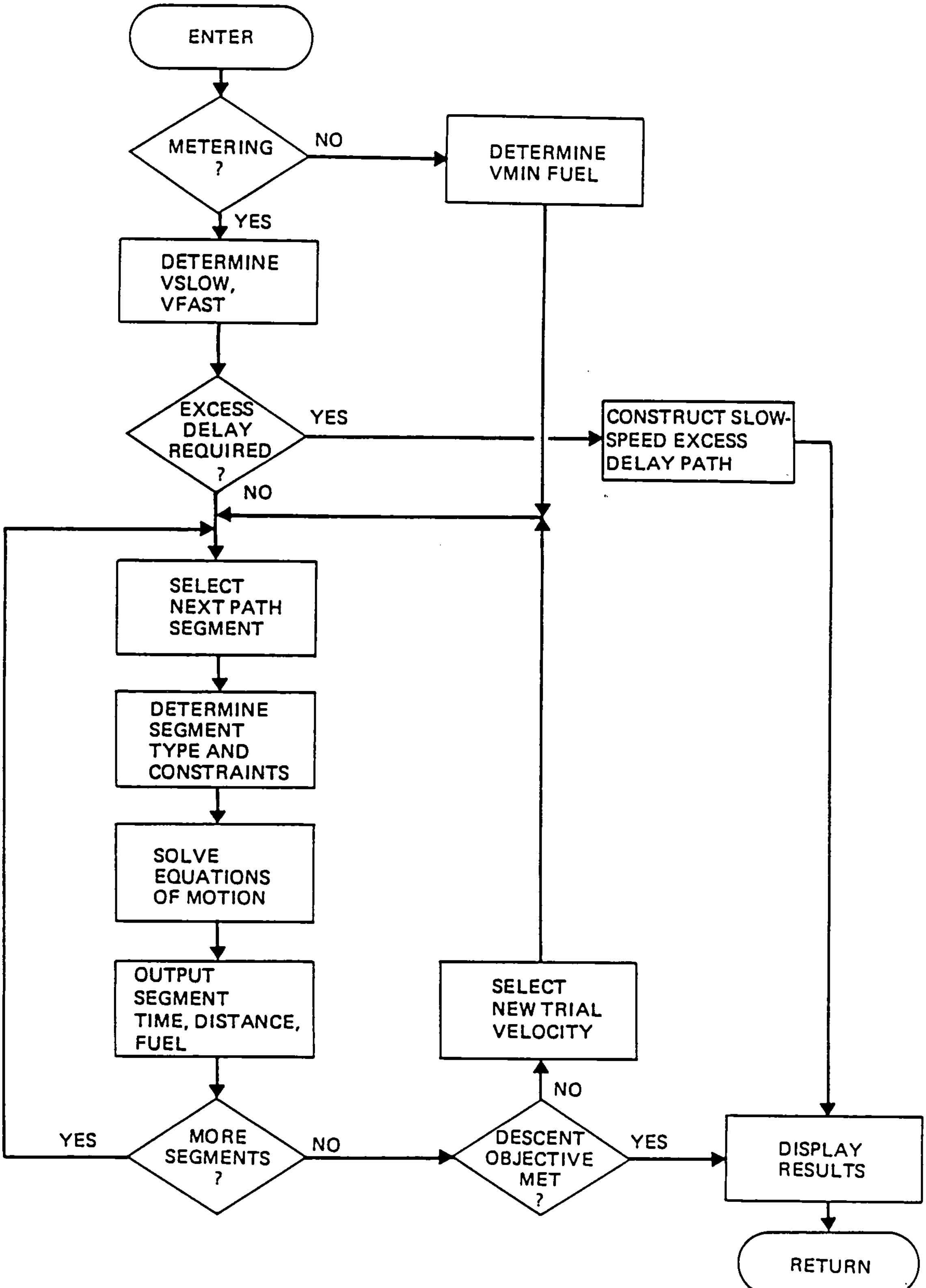


Figure 19. High-Profile Descent Calculation

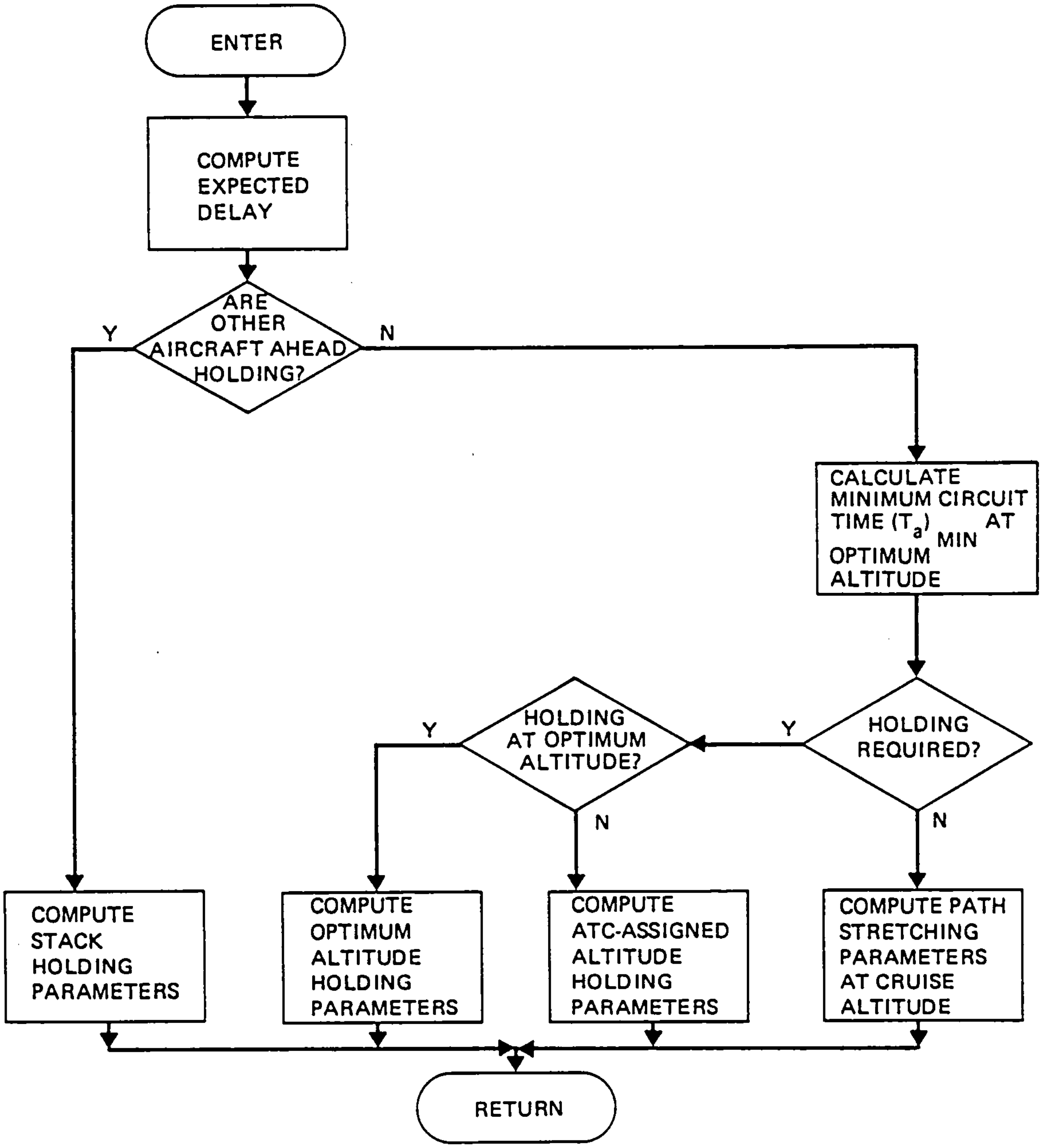


Figure 20. Delay Parameters Calculation

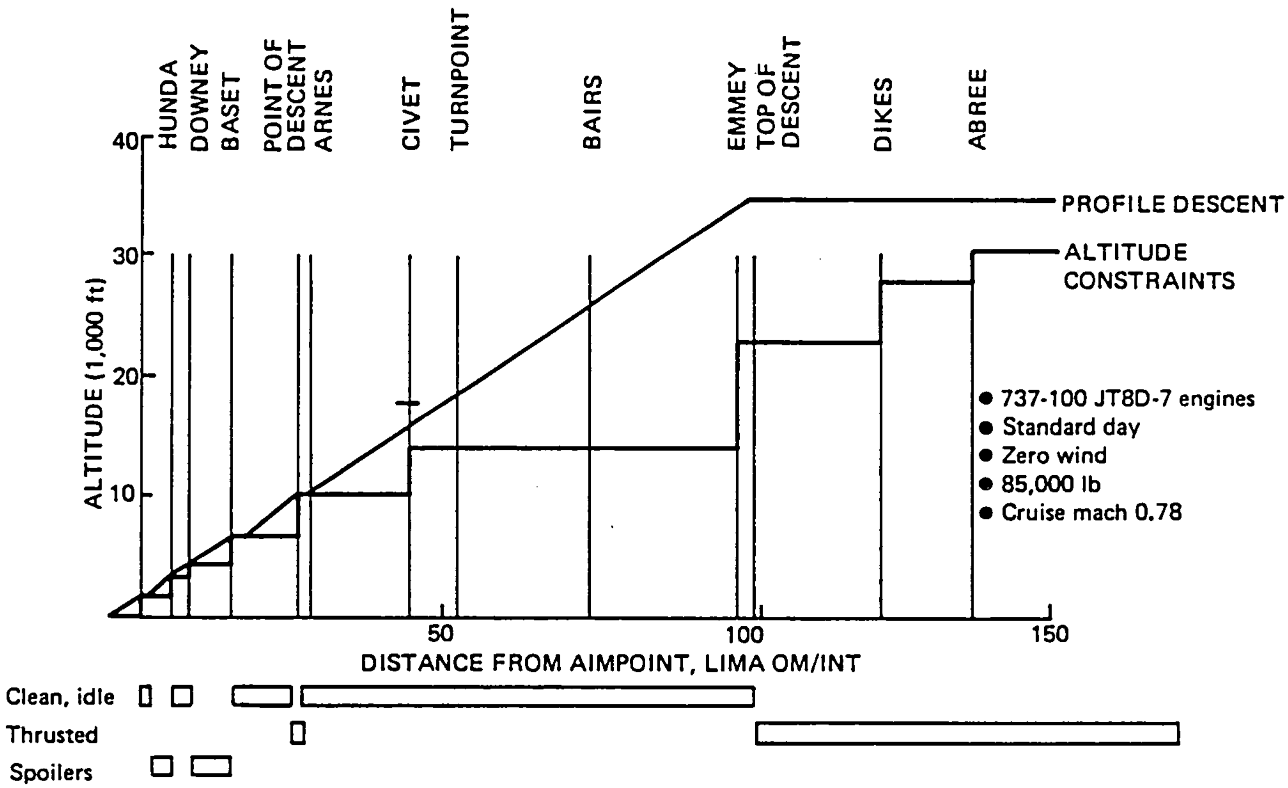


Figure 21. CIVET 25 Profile Descent

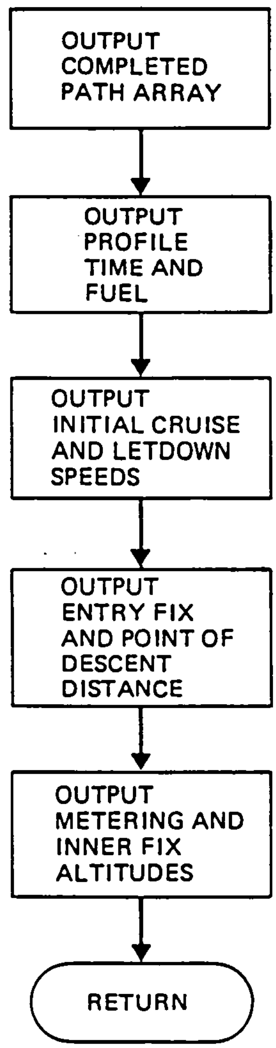


Figure 22. Display of Results

PROFILE CONSTRUCTION MODULES

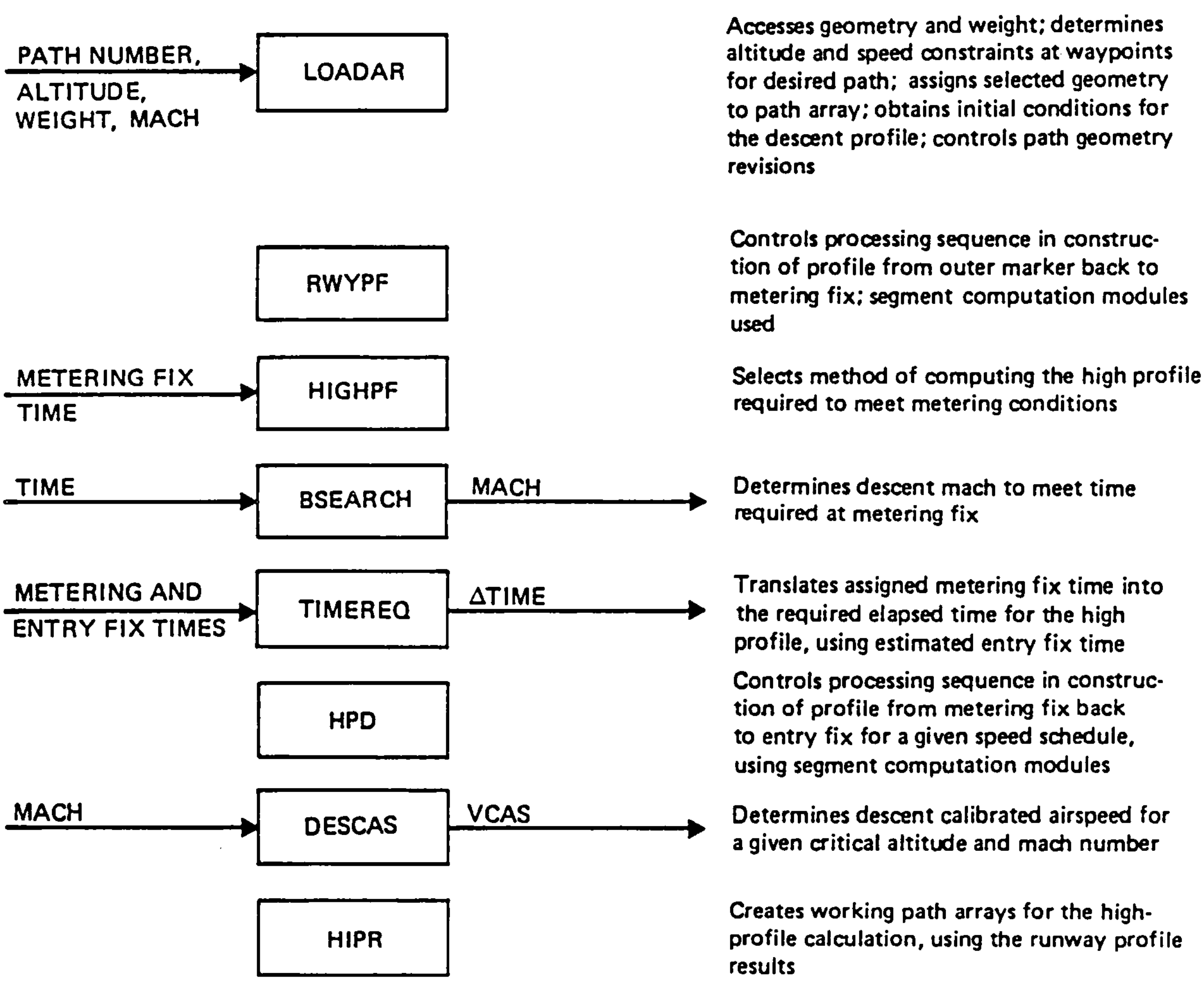


Figure 23. PROFIL Modules

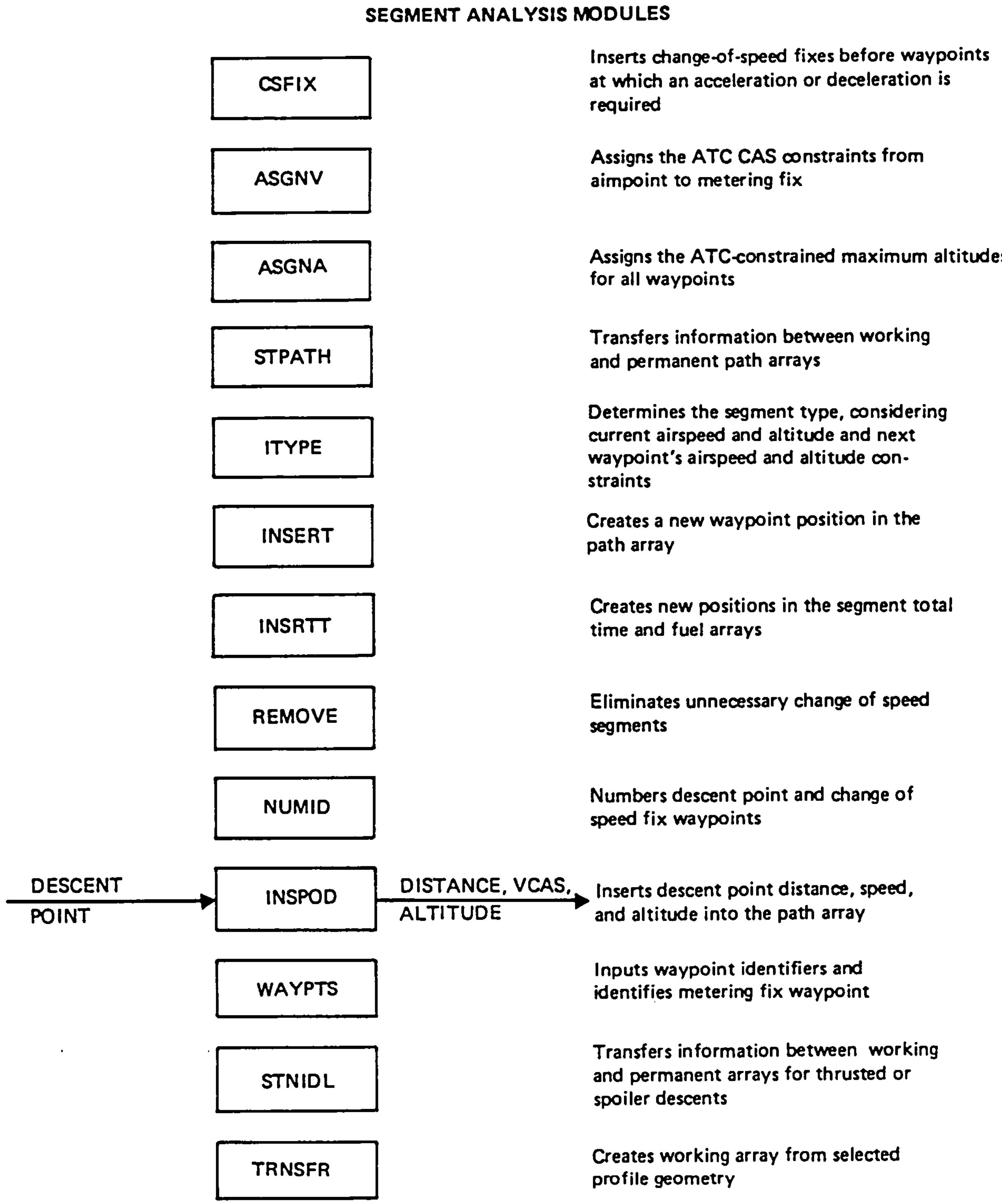
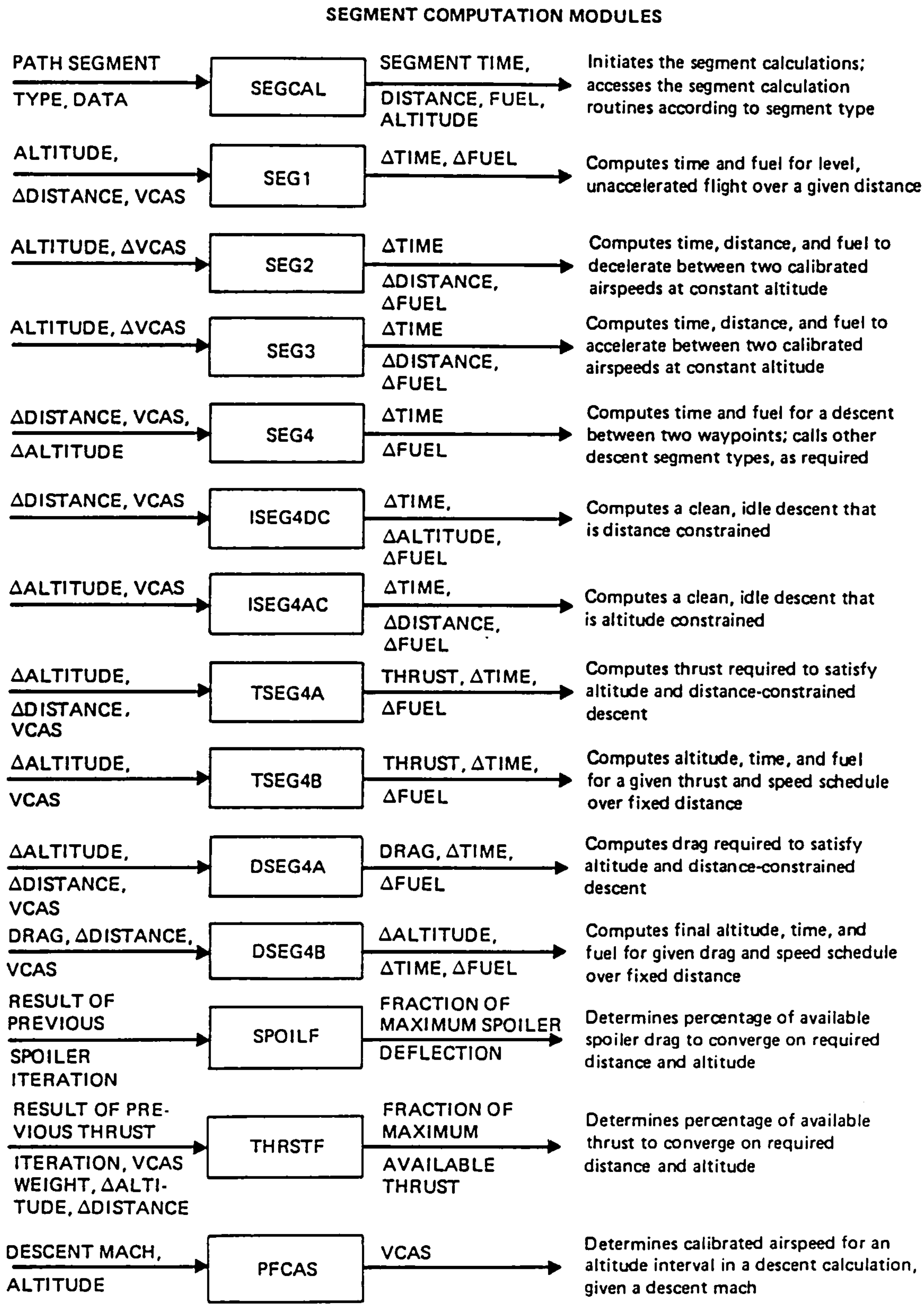


Figure 23. PROFIL Modules (Continued)



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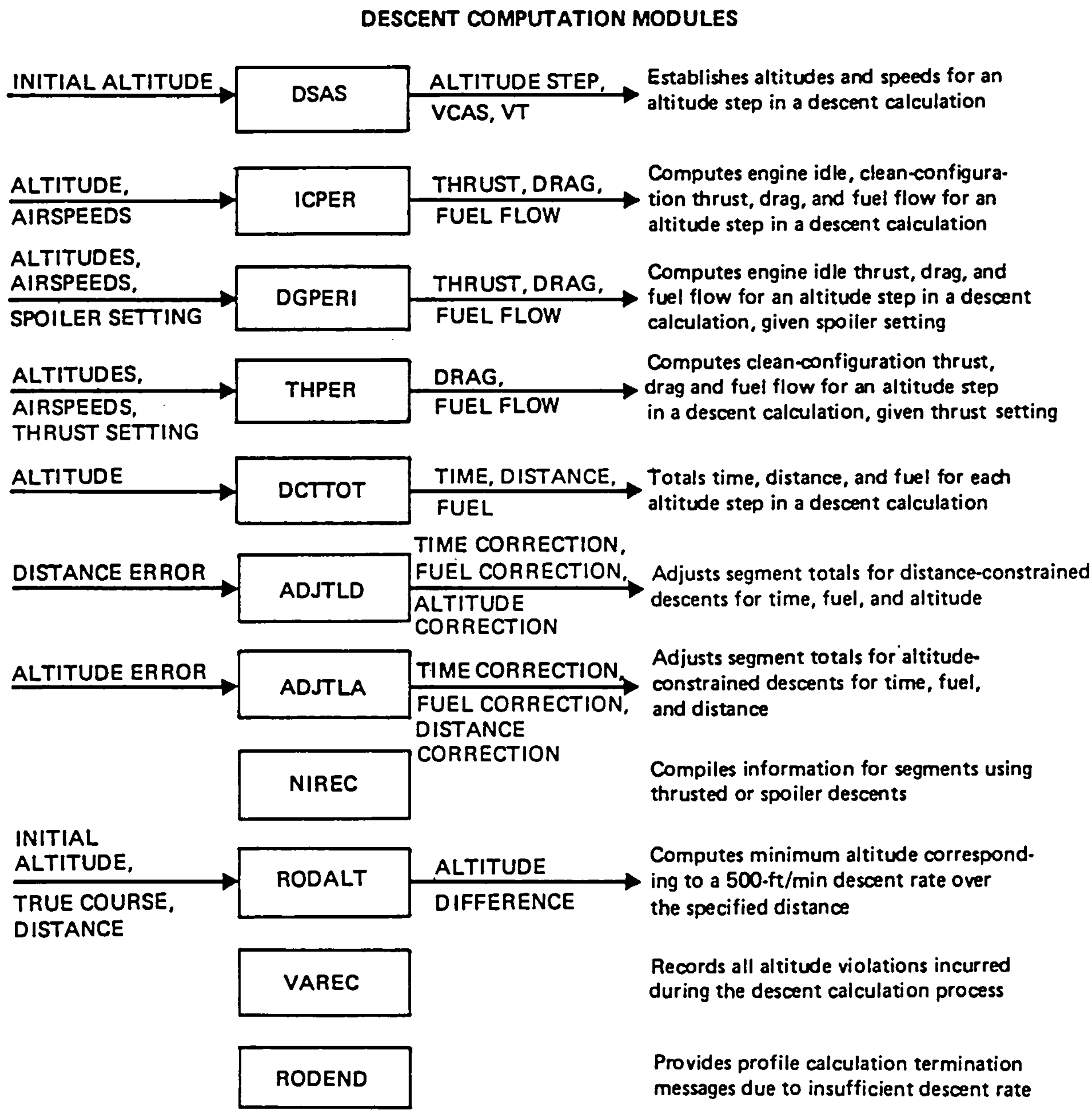

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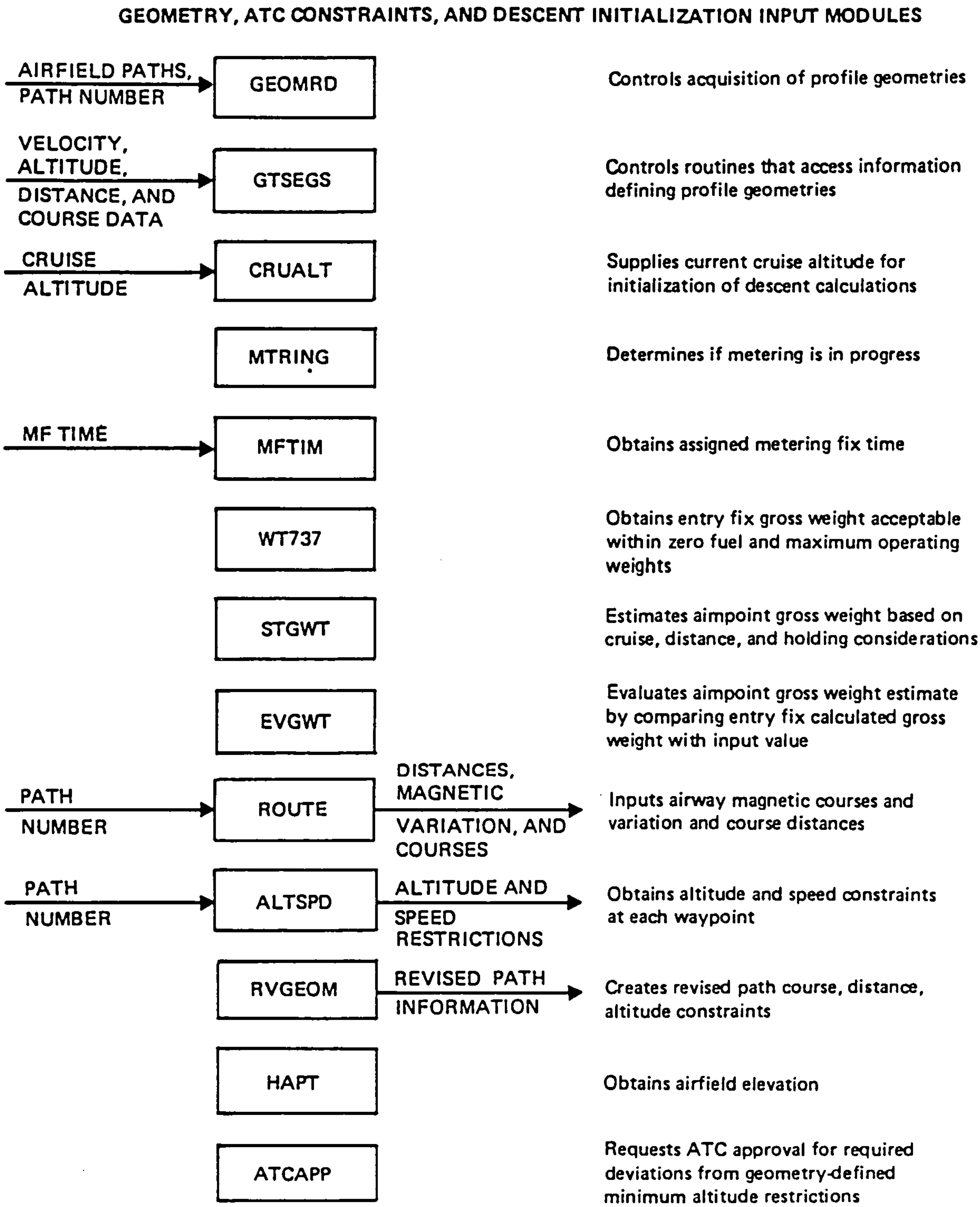

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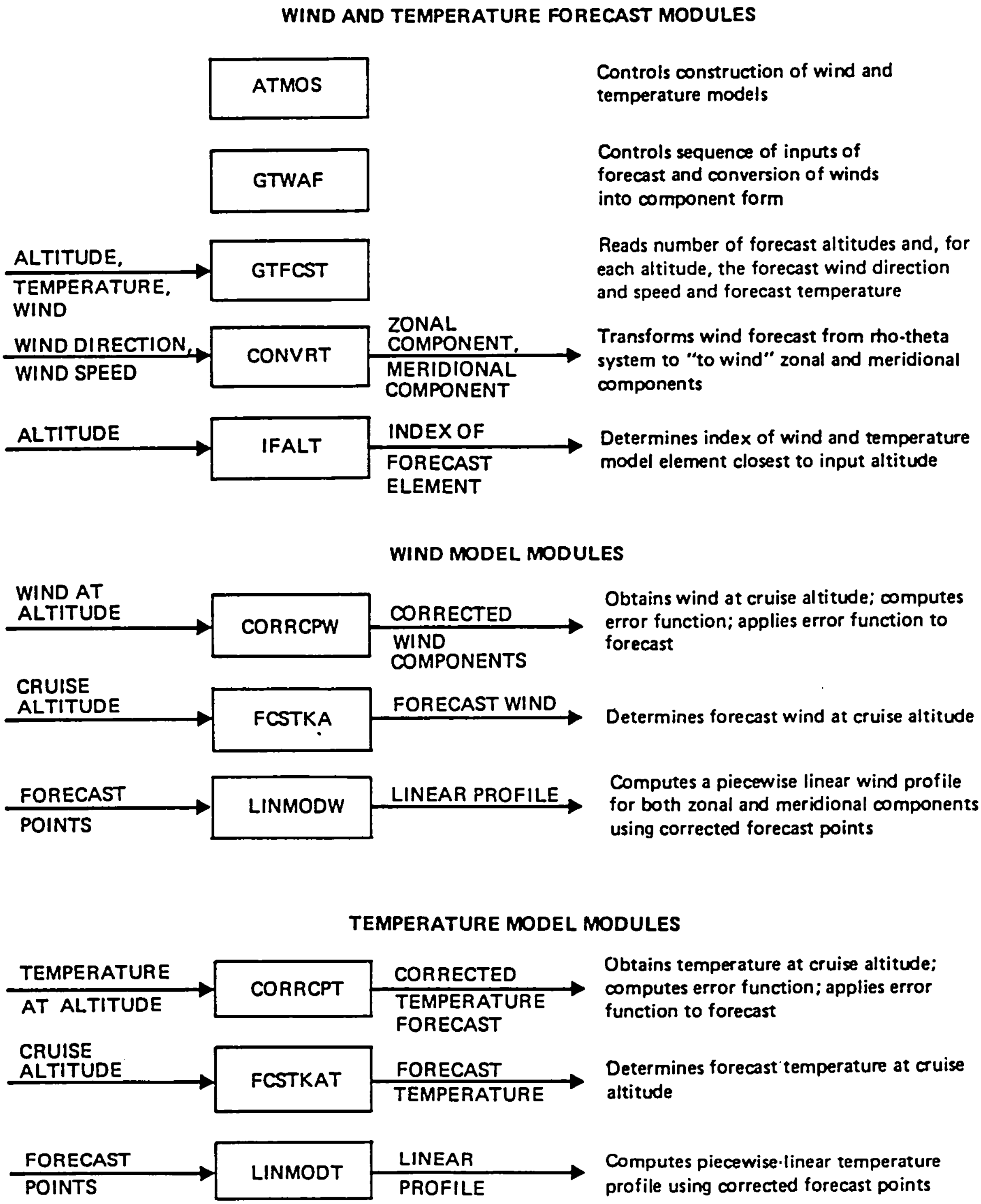

Figure 23. PROFIL Modules (Continued)

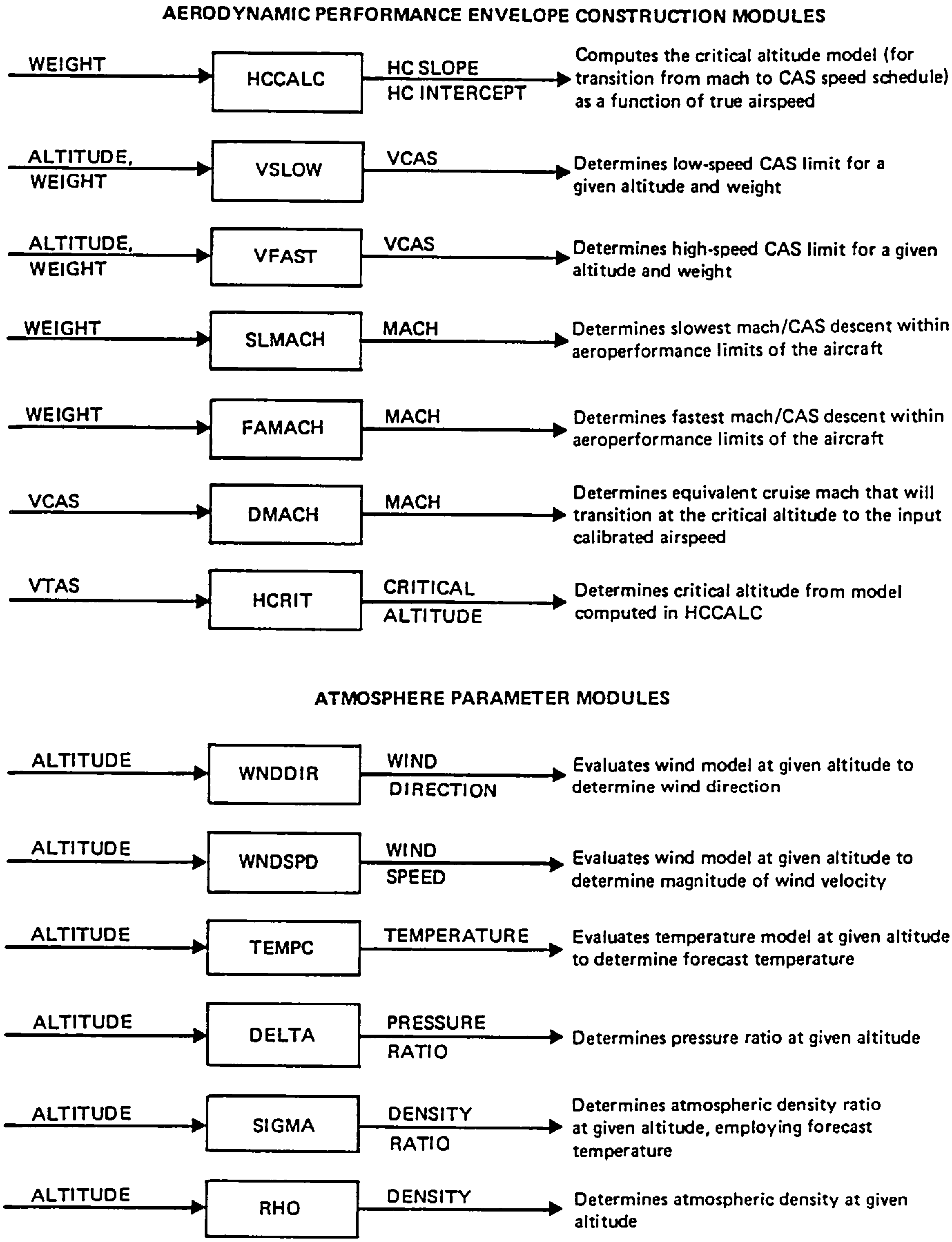

Figure 23. PROFIL Modules (Continued)

DELAY MODULES

DELAY	Controls construction of delay profile
HLDPRF	Controls computation of the holding path
HPRHLD	Coordinates construction of high-profile path with holding
COMPCI	Completes altitude and airpseed information in the path array when the calculation reaches cruise altitude
HLDINF	Obtains inputs to initiate holding path calculations
HLDSTA	Obtains assigned top and bottom stack altitudes
HLDSA	Obtains valid single altitude assignment
HLDOA	Determines the closest holding altitude intersecting the calculated fuel-efficient profile at the holding fix
HLDSPD	Obtains valid holding airspeed
IDHWPT	Obtains valid holding fix identifier
TAS → BNKANG → BANK ANGLE	Computes holding bank angle

Figure 23. PROFIL Modules (Continued)

DELAY MODULES (Continued)

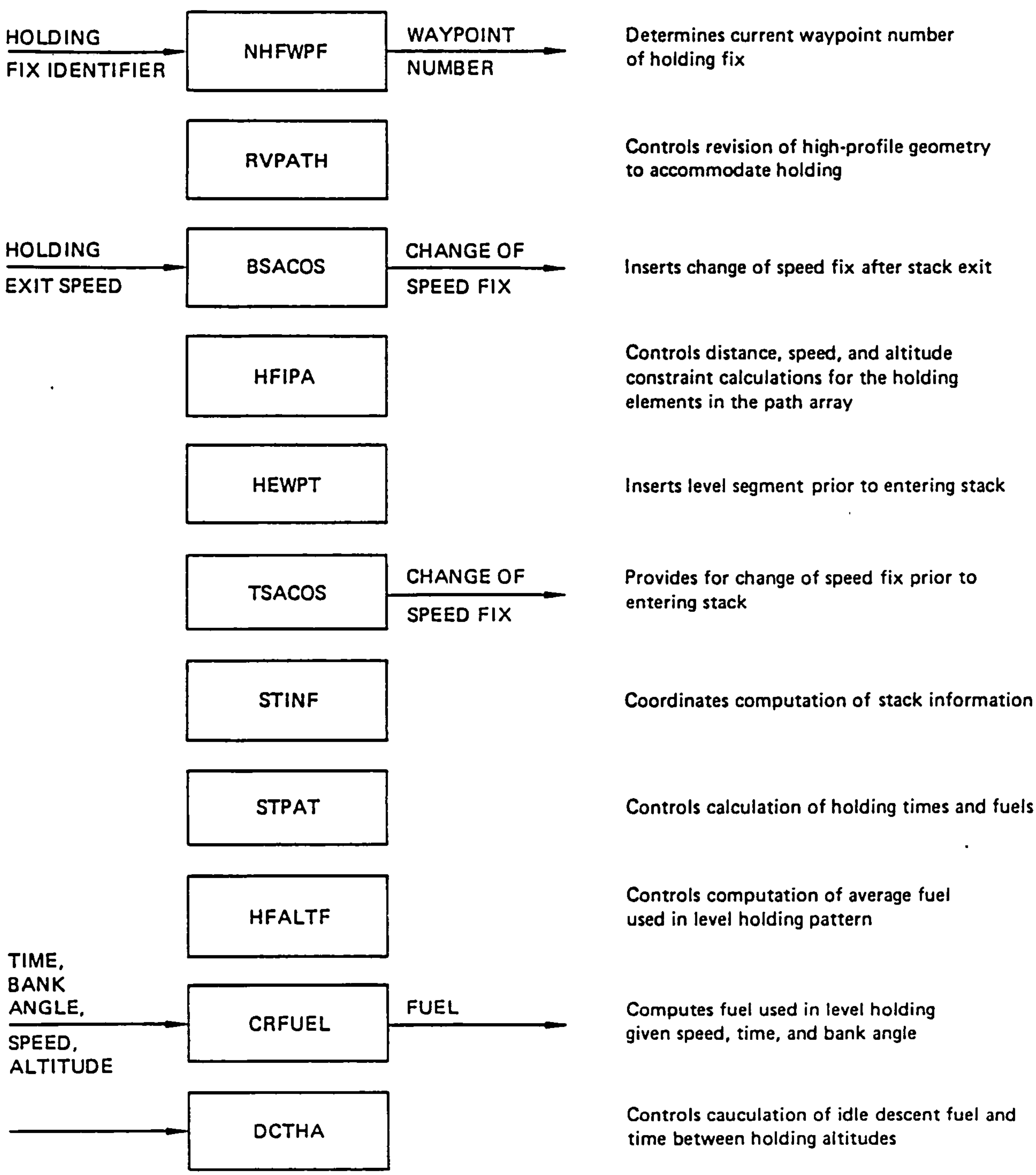

Figure 23. PROFIL Modules (Continued)

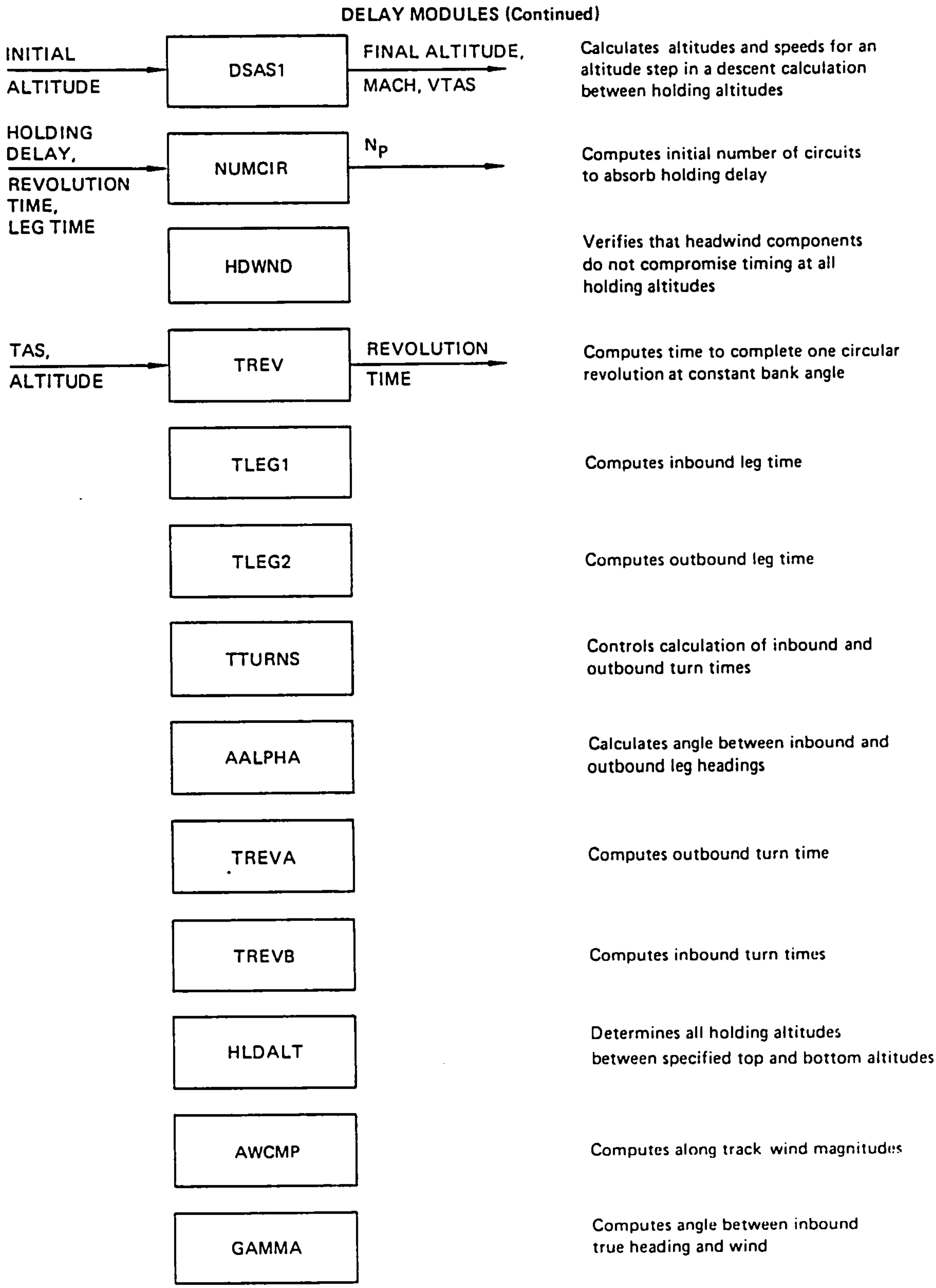

Figure 23. PROFIL Modules (Continued)

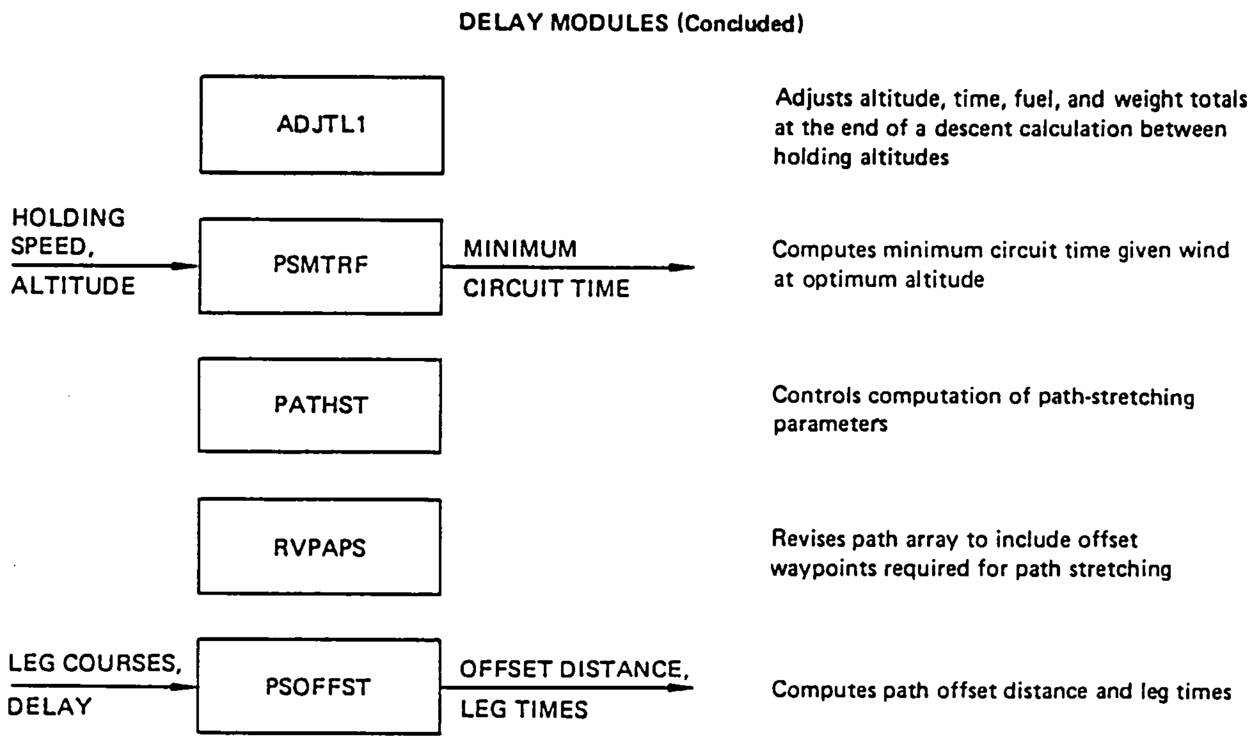

Figure 23. PROFIL Modules (Continued)

ALTIMETER AND ALTITUDE MODULES

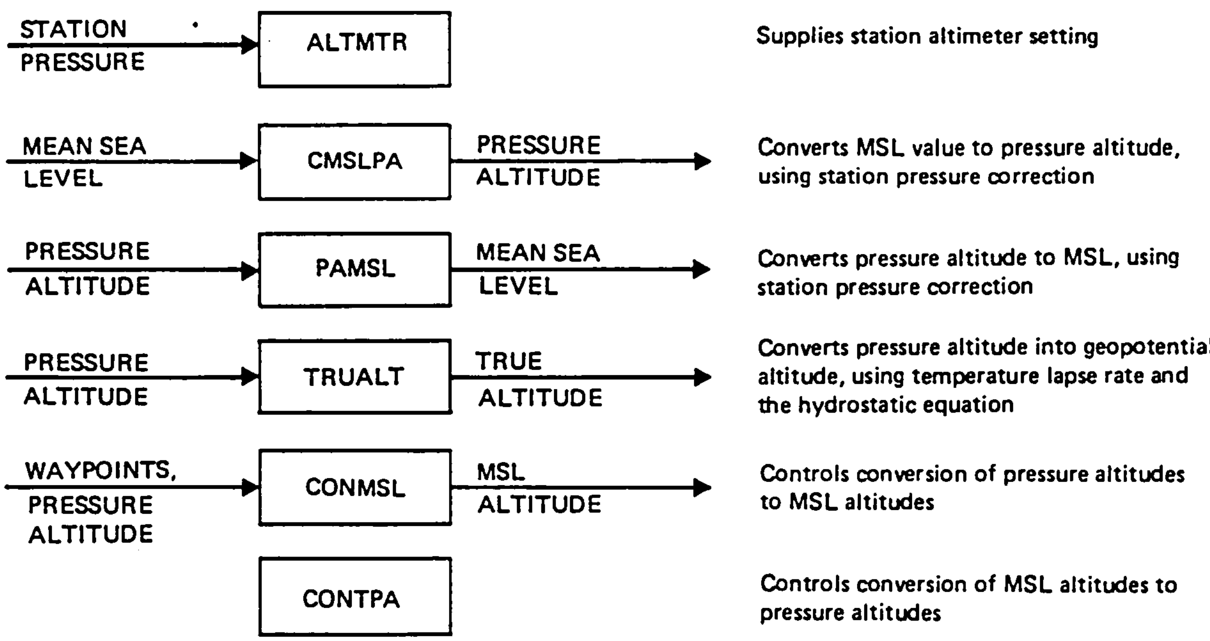

Figure 23. PROFIL Modules (Continued)

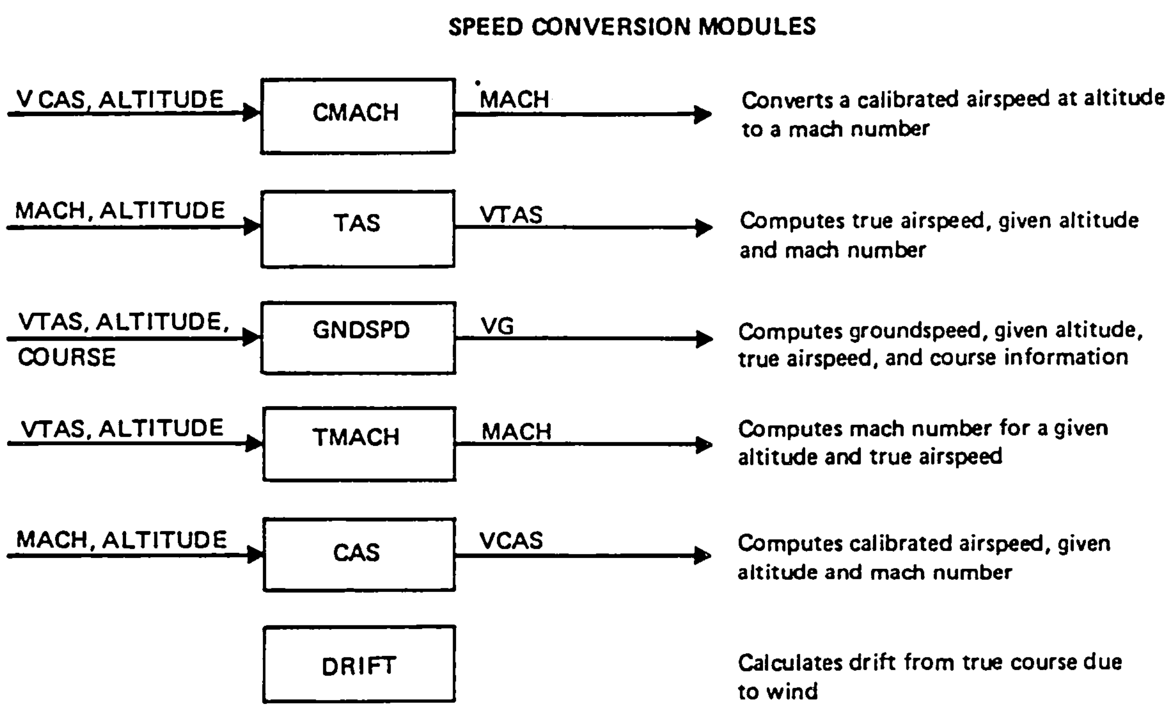

Figure 23. PROFIL Modules (Continued)

ANTI-ICING MODULES

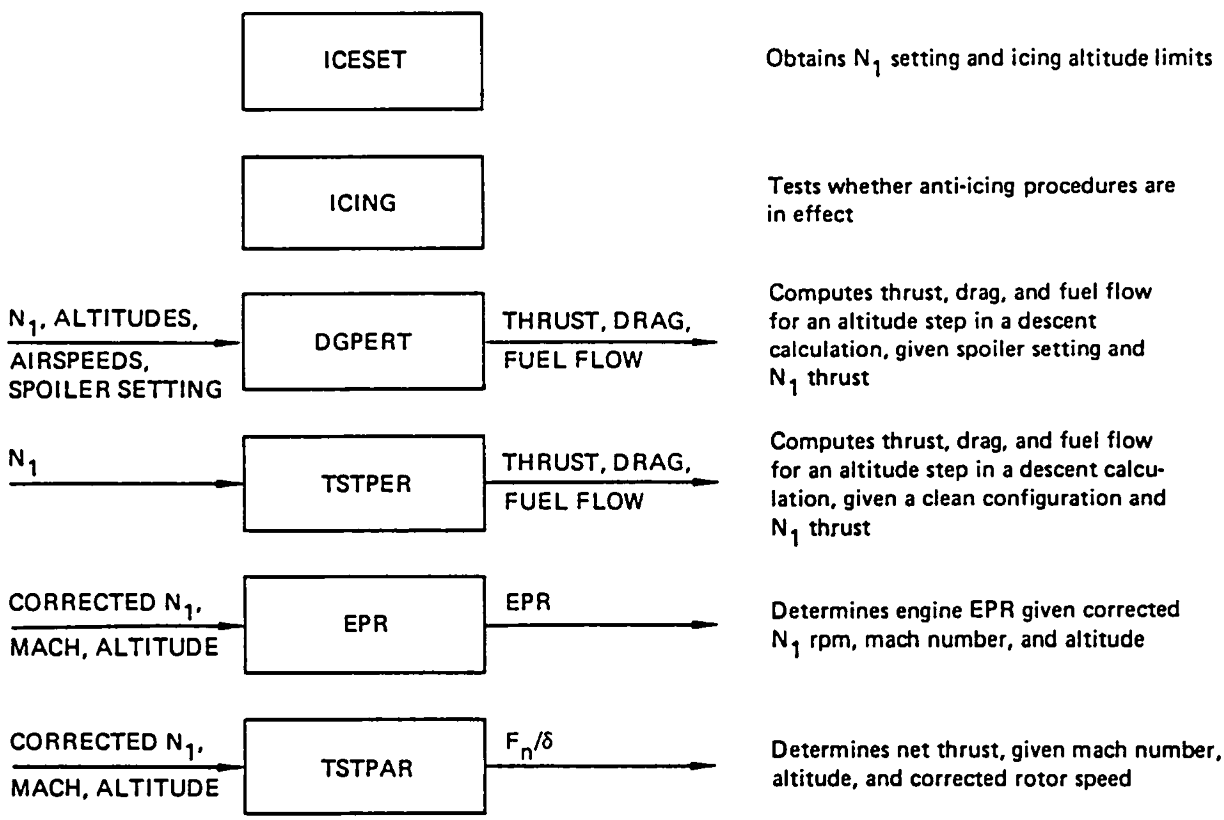

Figure 23. PROFIL Modules (Continued)

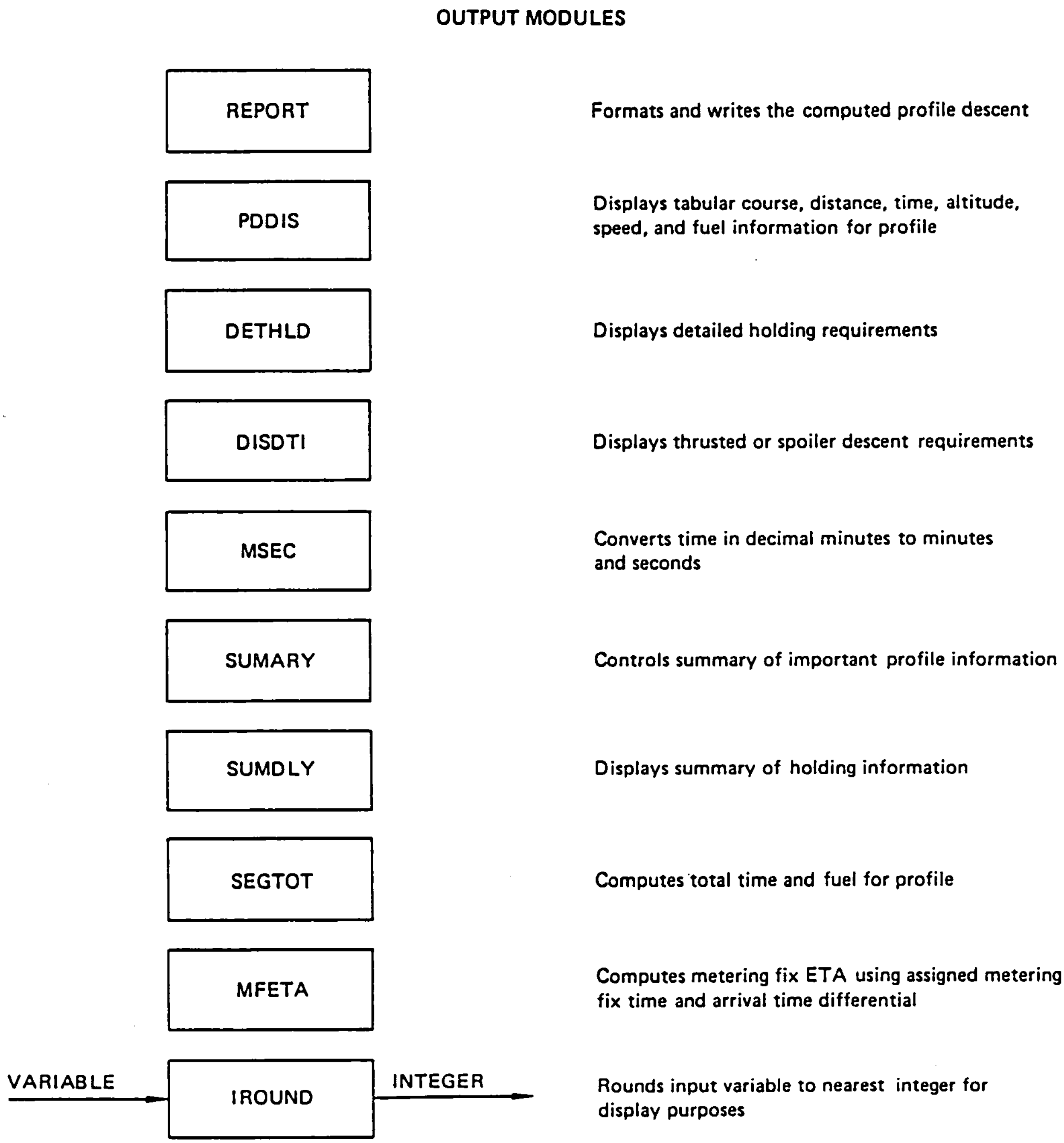

Figure 23. PROFIL Modules (Continued)

GENERAL UTILITY MODULES

VALDTE	Validates input records after they have been displayed
TBLU2	Two-dimensional table look-up routine providing polynomial interpolation of array of two variables
TBLU3	Three-dimensional table look-up routine
LINREG	Linear regression computation

Figure 23. PROFIL Modules (Concluded)

Table 1. Los Angeles International Profile Descent Geometry and ATC Constraint Inputs

WAYPOINT	ALTITUDE MINIMUM (ft)	ALTITUDE MAXIMUM (ft)	SPEED CONSTRAINT (kcas)	SEGMENT DISTANCE (nmi)	SEGMENT HEADING (deg mag)
PGS	25,000				
ABREE	25,000			120.0	226
DIKES	23,000			15.0	226
EMMEY	23,000			24.0	226
BAIRS	14,000			24.0	226
TURN POINT	14,000			22.0	226
CIVET	14,000	18,000		8.0	248
ARNES	10,000	10,000	250	18.0	248
BASET	7,000		250	11.5	248
DOWNEY	4,000		250	7.3	248
HUNDA	3,500		250	2.8	248
LIMMA	1,892	1,892	250	4.9	248

Table 2. CIVET 25 Profile Descent Path Segment Array

THE FOLLOWING ALTITUDES ARE REQUIRED TO COMPLETE THE PROFILE
THE DESIRED ALTITUDE AT HUNDA IS AT OR BELOW 3436. FT
WILL ATC APPROVE THESE REVISIONS - (Y OR N)
I>Y
DISPLAY FULL PROFILE - (Y OR N)
I>Y

CIVET 25 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
PGS	ECSFIX	227	5.5	47.1	35000	35000	259	228	14.1
ECSFIX	ABREE	227	114.5	1051.1	35000	35000	228	228	1203.9
ABREE	DIKES	226	15.0	137.6	35000	35000	228	228	156.7
DIKES	TOD	226	23.2	212.5	35000	35000	228	228	241.4
TOD	EMMEY	226	.8	7.7	35000	34754	228	229	2.3
EMMEY	BAIRS	226	24.0	221.8	34754	26952	229	250	66.5
BAIRS	TP	226	22.0	224.7	26952	19681	250	250	67.4
TP	CIVET	248	8.0	88.4	19681	16771	250	250	26.5
CIVET	ARNES	248	18.0	214.2	16771	10000	250	250	73.4
ARNES	POD2	248	1.0	12.1	10000	10000	250	250	16.3
POD2	CSFIX1	248	7.9	100.7	10000	7000	250	250	41.8
CSFIX1	BASET	248	2.6	37.4	7000	7000	250	210	15.9
BASET	DOWNE	248	7.3	115.3	7000	4361	210	210	51.1
DOWNE	HUNDA	248	2.8	45.3	4361	3436	210	210	21.5
HUNDA	CSFIX2	248	3.2	52.9	3436	1892	210	210	26.3
CSFIX2	LIMMA	248	1.7	30.4	1892	1892	210	180	15.5

DESCENT REQUIREMENTS

STARTING AT BASET 21.9 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO DOWNE TO MAINTAIN THE PROFILE

STARTING AT HUNDA 100.0 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 3. CIVET 25 Summary

```
CIVET 25   SUMMARY
------------------

ENTRY FIX      PGS
METERING FIX   CIVET
AIMPOINT       LIMMA

PROFILE DISTANCE  257.5 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT PGS

DESCENT INFORMATION

TOP OF DESCENT  99.3 NMI FROM LIMMA
DESCENT SCHEDULE .682 MACH / 250 KCAS

METERING FIX INFORMATION

ALTITUDE AT CIVET    16771
AIRSPEED AT CIVET    250

AIMPOINT INFORMATION

ALTITUDE AT LIMMA     1892
AIRSPEED AT LIMMA      180
GROSS WT AT LIMMA    82959 LB

SEGMENT TOTALS

TOTAL TIME  43 MINUTES 19.1 SECONDS
TOTAL FUEL 2040.7 LB
```

Table 4. Interactive Geometry Input

```
                              GEOMETRY INPUT SECTION

ENTER NUMBER OF PATHS (MAXIMUM OF 16)
I>1
     NUMBER OF PATHS    1
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER PATH IDENTIFIER - 10 CHARACTERS LEFT-ADJUSTED
I>CIVET 25
     PATH IDENTIFIER  CIVET 25
 IS INPUT CORRECT - (Y OR N)
I>Y
 THE FOLLOWING SECTION OBTAINS THE INFORMATION WHICH DEFINES
                         CIVET 25
 ENTER THE NUMBER OF WAYPOINTS (MAXIMUM OF 15)
I>12
     CIVET 25   HAS 12 WAYPOINTS
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER WAYPOINT IDENTIFIERS BEGINNING AT AIMPOINT
 7 CHARACTERS LEFT-ADJUSTED
  WAYPOINT  1
I>LIMMA
  WAYPOINT  2
I>HUNDA
  WAYPOINT  3
I>DOWNE
  WAYPOINT  4
I>BASET
  WAYPOINT  5
I>ARNES
  WAYPOINT  6
I>CIVET
  WAYPOINT  7
I>TP
  WAYPOINT  8
I>BAIRS
  WAYPOINT  9
I>EMMEY
  WAYPOINT 10
I>DIKES
  WAYPOINT 11
I>ABREE
  WAYPOINT 12
I>PGS
```

Table 4. Interactive Geometry Input (Continued)

```
WAYPOINT IDENTIFIERS
      WAYPOINT  1   LIMMA
      WAYPOINT  2   HUNDA
      WAYPOINT  3   DOWNE
      WAYPOINT  4   BASET
      WAYPOINT  5   ARNES
      WAYPOINT  6   CIVET
      WAYPOINT  7   TP
      WAYPOINT  8   BAIRS
      WAYPOINT  9   EMMEY
      WAYPOINT 10   DIKES
      WAYPOINT 11   ABREE
      WAYPOINT 12   PGS
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER THE WAYPOINT NUMBER OF THE METERING FIX
I>6
     WAYPOINT  6 CIVET   IS THE METERING FIX
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER VARIATION
NEGATIVE FOR EAST VARIATION  POSITIVE FOR WEST VARIATION
I>-15
     VARIATION IS  -15.0
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER COURSE THEN DISTANCE FOR EACH PATH SEGMENT
   PGS     TO ABREE
I>227 120
  ABREE   TO DIKES
I>226 15
  DIKES   TO EMMEY
I>226 24
  EMMEY   TO BAIRS
I>226 24
  BAIRS   TO TP
I>226 22
  TP      TO CIVET
I>248 8
  CIVET   TO ARNES
I>248 18
  ARNES   TO BASET
I>248 11.5
  BASET   TO DOWNE
I>248 7.3
  DOWNE   TO HUNDA
I>248 2.8
  HUNDA   TO LIMMA
I>248 7.9
```

Table 4. Interactive Geometry Input (Continued)

```
PATH SEGMENT          COURSE   DISTANCE
  PGS      TO ABREE      227.      120.0 NM
  ABREE    TO DIKES      226.       15.0 NM
  DIKES    TO EMMEY      226.       24.0 NM
  EMMEY    TO BAIRS      226.       24.0 NM
  BAIRS    TO TP         226.       22.0 NM
  TP       TO CIVET      248.        8.0 NM
  CIVET    TO ARNES      248.       18.0 NM
  ARNES    TO BASET      248.       11.5 NM
  BASET    TO DOWNE      248.        7.3 NM
  DOWNE    TO HUNDA      248.        2.8 NM
  HUNDA    TO LIMMA      248.        7.9 NM
 IS INPUT CORRECT - (Y OR N)
I>Y
         ENTER WAYPOINT CONSTRAINTS
 MAXIMUM ALTIDUDE  MINIMUM ALTITUDE  AIRSPEED
  WAYPOINT LIMMA
I>1892 1892 0
  WAYPOINT HUNDA
I>0 3500 0
  WAYPOINT DOWNE
I>0 4000 0
  WAYPOINT BASET
I>0 7000 210
  WAYPOINT ARNES
I>10000 10000 0
  WAYPOINT CIVET
I>18000 14000 250
  WAYPOINT TP
I>0 14000 0
  WAYPOINT BAIRS
I>0 20000 0
  WAYPOINT EMMEY
I>0 23000 0
  WAYPOINT DIKES
I>0 25000 0
  WAYPOINT ABREE
I>0 25000 0
  WAYPOINT PGS
I>0 0 0
```

Table 4. Interactive Geometry Input (Concluded)

```
    WAYPOINT CONSTRAINTS
 WAYPOINT   MAX     MIN  SPEED
            ALT     ALT
 PGS
 ABREE             25000.
 DIKES             25000.
 EMMEY             23000.
 BAIRS             20000.
 TP                14000.
 CIVET     18000.  14000.  250.
 ARNES     10000.  10000.
 BASET              7000.  210.
 DOWNE              4000.
 HUNDA              3500.
 LIMMA      1892.   1892.
IS INPUT CORRECT - (Y OR N)
I>Y
```

Table 5. Local File Input–Geometry

```
 1
Y
CIVET 25
Y
12
Y
LIMMA
HUNDA
DOWNE
BASET
ARNES
CIVET
TP
BAIRS
EMMEY
DIKES
ABREE
PGS
Y
 6
Y
-15.
Y
227. 120.
226. 15.
226. 24.
226. 24.
226. 22.
248. 8.
248. 18.
248. 11.5
248. 7.3
248. 2.8
248. 4.9
Y
 1892.   1892. 0.
0.       3500. 0.
0.       4000. 0.
0.       7000. 210.
10000. 10000. 0.
18000. 14000. 250.
0.      14000. 0.
0.      20000. 0.
0.      23000. 0.
0.      25000. 0.
0.      25000. 0.
0.      0.     0.
Y
```

Table 6. Interactive Input–FAA Winds Aloft Forecast

```
FAA WINDS ALOFT FORECAST INPUT SECTION

ENTER NUMBER OF FORECAST ALTITUDES
I>7
 NUMBER OF FORECAST ALTITUDES  7
 IS INPUT CORRECT - (Y OR N)
I>Y
  FOR EACH FORECAST ALTITUDE INPUT -
  ALTITUDE  WIND DIRECTION  WIND SPEED  TEMPERATURE
  BEGIN AT LOWEST PUBLISHED FORECAST ALTITUDE
 ENTER VALUES FOR ALTITUDE  1
I>9000 280 38 0
     ALTITUDE  9000.  DIRECTION  280.  SPEED  38.  TEMPERATURE     0.0
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER ALTIMETER SETTING
I>29.92
     ALTIMETER SETTING   29.92
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER VALUES FOR ALTITUDE  2
I>12000 280 42 -6
     ALTITUDE 12000.  DIRECTION  280.  SPEED  42.  TEMPERATURE    -6.0
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER VALUES FOR ALTITUDE  3
I>18000 270 50 -19
     ALTITUDE 18000.  DIRECTION  270.  SPEED  50.  TEMPERATURE   -19.0
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER VALUES FOR ALTITUDE  4
I>24000 260 60 -31
     ALTITUDE 24000.  DIRECTION  260.  SPEED  60.  TEMPERATURE   -31.0
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER VALUES FOR ALTITUDE  5
I>30000 240 71 -43
     ALTITUDE 30000.  DIRECTION  240.  SPEED  71.  TEMPERATURE   -43.0
 IS INPUT CORRECT - (Y OR N)
I>Y
ENTER VALUES FOR ALTITUDE  6
I>34000 240 64 -47
     ALTITUDE 34000.  DIRECTION  240.  SPEED  64.  TEMPERATURE   -47.0
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER VALUES FOR ALTITUDE  7
I>39000 250 51 -47
     ALTITUDE 39000.  DIRECTION  250.  SPEED  51.  TEMPERATURE   -47.0
 IS INPUT CORRECT - (Y OR N)
I>Y
```

Table 6. Interactive Input–FAA Winds Aloft Forecast (Concluded)

```
                 WINDS ALOFT FORECAST
      ALTITUDE      DIRECTION/SPEED   TEMPERATURE
        9000.          280.      38.         0.0
       12000.          280.      42.        -6.0
       18000.          270.      50.       -19.0
       24000.          260.      60.       -31.0
       30000.          240.      71.       -43.0
       34000.          240.      64.       -47.0
       39000.          250.      51.       -47.0


 THE CURRENT CRUISE ALTITUDE IS      0.
 IS ANOTHER ALTITUDE DESIRED - (Y OR N)
I>Y
 ENTER CRUISE ALTITUDE
I>35000
     CRUISE ALTITUDE  35000.
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER WIND DIRECTION AND SPEED AT CRUISE ALTITUDE
I>245 70
     WIND DIRECTION 245.  WIND SPEED  70.
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER OAT AT CRUISE ALTITUDE
I>-47
     OAT IS -47.0
 IS INPUT CORRECT - (Y OR N)
I>Y
```

Table 7. Local File Input–FAA Winds Aloft Forecast

```
7
Y
9000. 280.  38.  0.0
Y
29.92
Y
12000. 280.  42. -6.
Y
18000. 270.  50. -19.
Y
24000. 260.  60. -31.
Y
30000. 240.  71. -43.
Y
34000. 240.  64. -47.
Y
39000. 250.  51. -47.
Y
Y
35000.
Y
240.  60.
Y
-47.
Y
```

Table 8. Specific Approach Input

```
SELECT CALCULATION OPTION FOR PATH SEGMENTS REQUIRING THRUST:
   1 USE LEVEL CRUISE UNTIL INTERCEPTING A CLEAN-IDLE DESCENT
   2 CONSIDER SEGMENTS ON AN INDIVIDUAL BASIS
I>1

                             PATH ARRAY INPUT SECTION



 ENTER GROSS WEIGHT AT ENTRY FIX
I>85000
     GROSS WEIGHT IS 85000.
 IS INPUT CORRECT - (Y OR N)
I>Y
                  AVAILABLE PROFILE DESCENT GEOMETRIES
   1  CIVET 25
 ENTER NUMBER OF DESIRED PATH
I>1
     DESIRED PATH CIVET 25
 IS INPUT CORRECT - (Y OR N)
I>Y
 THE CURRENT AIRFIELD ELEVATION IS   0.
 IS ANOTHER VALUE DESIRED - (Y OR N)
I>Y
 ENTER AIRFIELD ELEVATION
I>126
     AIRFIELD ELEVATION IS   126.
 IS INPUT CORRECT - (Y OR N)
I>Y
 REVISE SELECTED GEOMETRY - (Y OR N)
I>N
 ENTER CAS AT AIMPOINT
I>180
     CAS AT AIMPOINT 180.
 IS INPUT CORRECT - (Y OR N)
I>Y
 THE CURRENT CRUISE ALTITUDE IS 35000.
 IS ANOTHER ALTITUDE DESIRED - (Y OR N)
I>N
 ENTER CRUISE MACH AT ENTRY FIX
I>.765
     CRUISE SPEED AT ENTRY FIX   .765 MACH  259. CAS
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS ICING ANTICIPATED - (Y OR N)
I>N
 IS HOLDING ANTICIPATED - (Y OR N)
I>N
```

Table 9. Time-Based Metering Input

```
 IS METERING IN PROGRESS - (Y OR N)
I>Y
 ENTER ENTRY FIX ETA - HH MM SS.S
I>12 00 00
     ENTRY FIX TIME   12 HR  0 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y

   FOR LOW SPEED PROFILE - METERING FIX ETA SHOULD BE 36 MINUTES 52.5 SECONDS
   AFTER ENTRY FIX ETA

   FOR HIGH SPEED PROFILE - METERING FIX ETA SHOULD BE 28 MINUTES 32.4 SECONDS
   AFTER ENTRY FIX ETA


 THE CURRENT METERING FIX TIME ASSIGNMENT IS   0 HR  0 MIN  0.0 SEC
 IS ANOTHER TIME DESIRED (Y OR N)
I>Y
 ENTER METERING FIX TIME - HH MM SS.S
I>12 32 00
     METERING FIX TIME   12 HR 32 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y

          THE FOLLOWING ALTITUDES ARE REQUIRED TO COMPLETE THE PROFILE

            THE DESIRED ALTITUDE AT HUNDA   IS AT OR BELOW  3436. FT

 WILL ATC APPROVE THESE REVISIONS - (Y OR N)
I>Y
 DISPLAY FULL PROFILE - (Y OR N)
I>Y
```

Table 10. Deviations From Minimum Thrust Descent

```
     THE ALTITUDE CONSTRAINT OF 10000. HAS BEEN EXCEEDED
     WITH    .7 NMI REMAINING TO ARNES
     EITHER A THRUSTED DESCENT OR A LEVEL CRUISE WILL BE  PERFORMED
     IS A THRUSTED DESCENT DESIRED - (Y OR N)
I>Y
 IS METERING IN PROGRESS - (Y OR N)
I>N

     THE ALTITUDE CONSTRAINT OF 35000. HAS BEEN EXCEEDED
     WITH  23.0 NMI REMAINING TO DIKES
     EITHER A THRUSTED DESCENT OR A LEVEL CRUISE WILL BE  PERFORMED
     IS A THRUSTED DESCENT DESIRED - (Y OR N)
I>N

          THE FOLLOWING ALTITUDES ARE REQUIRED TO COMPLETE THE PROFILE

            THE DESIRED ALTITUDE AT HUNDA   IS AT OR BELOW  3436. FT

 WILL ATC APPROVE THESE REVISIONS - (Y OR N)
I>Y
 DISPLAY FULL PROFILE - (Y OR N)
I>Y
```

Table 11. Nonmetered Profile Generated From Example Input

CIVET 25 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
PGS	ECSFIX	227	5.4	47.0	35000	35000	259	228	14.1
ECSFIX	ABREE	227	114.6	1050.8	35000	35000	228	228	1203.9
ABREE	DIKES	226	15.0	137.6	35000	35000	228	228	156.7
DIKES	TOD	226	23.1	211.9	35000	35000	228	228	240.9
TOD	EMMEY	226	.9	8.2	35000	34737	228	229	2.5
EMMEY	BAIRS	226	24.0	221.8	34737	26935	229	250	66.5
BAIRS	TP	226	22.0	224.7	26935	19661	250	250	67.4
TP	CIVET	248	8.0	88.5	19661	16750	250	250	26.5
CIVET	ARNES	248	18.0	214.2	16750	9978	250	250	73.5
ARNES	CSFIX1	248	8.9	113.1	9978	7000	250	250	46.9
CSFIX1	BASET	248	2.6	37.4	7000	7000	250	210	15.9
BASET	DOWNE	248	7.3	115.3	7000	4361	210	210	51.1
DOWNE	HUNDA	248	2.8	45.3	4361	3436	210	210	21.5
HUNDA	CSFIX2	248	3.2	52.9	3436	1892	210	210	26.3
CSFIX2	LIMMA	248	1.7	30.4	1892	1892	210	180	15.5

DESCENT REQUIREMENTS

STARTING AT ARNES 5.1 PERCENT OF MAXIMUM CRUISE THRUST
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

STARTING AT BASET 21.9 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO DOWNE TO MAINTAIN THE PROFILE

STARTING AT HUNDA 100.0 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 12. Nonmetered Profile Summary

```
CIVET 25   SUMMARY
------------------

ENTRY FIX      PGS
METERING FIX   CIVET
AIMPOINT       LIMMA

PROFILE DISTANCE  257.5 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT PGS

DESCENT INFORMATION

TOP OF DESCENT  99.4 NMI FROM LIMMA
DESCENT SCHEDULE .682 MACH / 250 KCAS

METERING FIX INFORMATION

ALTITUDE AT CIVET    16750
AIRSPEED AT CIVET    250

AIMPOINT INFORMATION

ALTITUDE AT LIMMA     1892
AIRSPEED AT LIMMA      180
GROSS WT AT LIMMA    82971 LB

SEGMENT TOTALS

TOTAL TIME  43 MINUTES 19.0 SECONDS
TOTAL FUEL 2029.3 LB
```

Table 13. Metered Profile Generated From Example Input

CIVET 25 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
PGS	ECSFIX	227	4.1	34.3	35000	35000	259	237	10.3
ECSFIX	ABREE	227	115.9	1026.3	35000	35000	237	237	1211.2
ABREE	DIKES	226	15.0	132.8	35000	35000	237	237	156.1
DIKES	EMMEY	226	24.0	212.4	35000	35000	237	237	249.6
EMMEY	TOD	226	2.8	25.1	35000	35000	237	237	29.5
TOD	BAIRS	226	21.2	185.5	35000	27062	237	272	55.6
BAIRS	TP	226	22.0	207.9	27062	19120	272	272	62.4
TP	CSFIX1	248	5.9	60.7	19120	16771	272	272	18.2
CSFIX1	CIVET	248	2.1	22.2	16771	16771	272	250	6.7
CIVET	ARNES	248	18.0	214.2	16771	10000	250	250	73.4
ARNES	POD2	248	1.0	12.1	10000	10000	250	250	16.3
POD2	CSFIX2	248	7.9	100.7	10000	7000	250	250	41.8
CSFIX2	BASET	248	2.6	37.4	7000	7000	250	210	15.9
BASET	DOWNE	248	7.3	115.3	7000	4361	210	210	51.1
DOWNE	HUNDA	248	2.8	45.3	4361	3436	210	210	21.5
HUNDA	CSFIX3	248	3.2	52.9	3436	1892	210	210	26.3
CSFIX3	LIMMA	248	1.7	30.4	1892	1892	210	180	15.5

DESCENT REQUIREMENTS

STARTING AT BASET 21.9 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO DOWNE TO MAINTAIN THE PROFILE

STARTING AT HUNDA 100.0 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 14. Metered Profile Summary

```
CIVET 25   SUMMARY
-------------------

ENTRY FIX      PGS
METERING FIX   CIVET
AIMPOINT       LIMMA

PROFILE DISTANCE  257.5 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 237 KCAS AT PGS

DESCENT INFORMATION

TOP OF DESCENT  95.7 NMI FROM LIMMA
DESCENT SCHEDULE .707 MACH / 272 KCAS

METERING FIX INFORMATION

ALTITUDE AT CIVET    16771
AIRSPEED AT CIVET    250
ETA TO CIVET    12 HR 31 MIN 47.2 SEC

AIMPOINT INFORMATION

ALTITUDE AT LIMMA     1892
AIRSPEED AT LIMMA      180
GROSS WT AT LIMMA    82939 LB

SEGMENT TOTALS

TOTAL TIME  41 MINUTES 55.4 SECONDS
TOTAL FUEL 2061.5 LB
```

Table 15. Baseline Validation

KEANN 26 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
EFIX	ECSFIX	226	5.4	46.8	35000	35000	259	228	14.0
ECSFIX	TOD	226	96.1	881.8	35000	35000	228	228	1009.0
TOD	WIGGI	226	38.5	366.1	35000	22571	228	250	109.8
WIGGI	KEANN	226	10.0	106.4	22571	19077	250	250	31.9
KEANN	CSFIX1	226	13.7	156.1	19077	14000	250	250	48.0
CSFIX1	FLOTS	226	3.3	41.8	14000	14000	250	210	13.5
FLOTS	POD2	152	.2	2.8	14000	14000	210	210	3.2
POD2	WATKI	152	11.9	172.9	14000	10000	210	210	59.5
WATKI	CSFIX2	258	8.2	123.6	10000	7200	210	210	48.7
CSFIX2	ALTUR	258	1.9	32.2	7200	7200	210	180	13.3

DESCENT REQUIREMENTS

STARTING AT WATKI 9.4 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 16. Baseline Profile Summary

```
KEANN 26   SUMMARY
------------------

ENTRY FIX      EFIX
METERING FIX   KEANN
AIMPOINT       ALTUR

PROFILE DISTANCE  189.2 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT EFIX

DESCENT INFORMATION

TOP OF DESCENT  87.7 NMI FROM ALTUR
DESCENT SCHEDULE .682 MACH / 250 KCAS

METERING FIX INFORMATION

ALTITUDE AT KEANN    19077
AIRSPEED AT KEANN    250

AIMPOINT INFORMATION

ALTITUDE AT ALTUR     7200
AIRSPEED AT ALTUR      180
GROSS WT AT ALTUR    83649 LB

SEGMENT TOTALS

TOTAL TIME  32 MINUTES 10.5 SECONDS
TOTAL FUEL 1351.0 LB
```

Table 17. Results of Time Assignment Requiring Descent Faster Than High Speed Boundary

```
 IS METERING IN PROGRESS - (Y OR N)
I>Y
 ENTER ENTRY FIX ETA - HH MM SS.S
I>12 00 00
     ENTRY FIX TIME    12 HR  0 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y

   FOR LOW SPEED PROFILE - METERING FIX ETA SHOULD BE 26 MINUTES  4.5 SECONDS
   AFTER ENTRY FIX ETA

   FOR HIGH SPEED PROFILE - METERING FIX ETA SHOULD BE 20 MINUTES  5.0 SECONDS
   AFTER ENTRY FIX ETA


 THE CURRENT METERING FIX TIME ASSIGNMENT IS   0 HR  0 MIN  0.0 SEC
 IS ANOTHER TIME DESIRED (Y OR N)
I>Y
 ENTER METERING FIX TIME - HH MM SS.S
I>12 18 00
     METERING FIX TIME   12 HR 18 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 CURRENT METERING FIX TIME REQUIRES A DESCENT    2.1 MINUTES FASTER
 THAN THE HIGH SPEED LIMIT
 * REQUEST A NEW METERING FIX TIME *
```

Table 18. Path Stretching

```
IS METERING IN PROGRESS - (Y OR N)
I>Y
 ENTER ENTRY FIX ETA - HH MM SS.S
I>12 00 00
     ENTRY FIX TIME   12 HR  0 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
   FOR LOW SPEED PROFILE - METERING FIX ETA SHOULD BE 26 MINUTES  4.5 SECONDS
   AFTER ENTRY FIX ETA

   FOR HIGH SPEED PROFILE - METERING FIX ETA SHOULD BE 20 MINUTES  5.0 SECONDS
   AFTER ENTRY FIX ETA

 THE CURRENT METERING FIX TIME ASSIGNMENT IS   0 HR  0 MIN  0.0 SEC
 IS ANOTHER TIME DESIRED (Y OR N)
I>Y
 ENTER METERING FIX TIME - HH MM SS.S
I>12 29 00
     METERING FIX TIME   12 HR 29 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 CURRENT METERING FIX TIME REQUIRES A DESCENT    2.9 MINUTES SLOWER
 THAN THE LOW SPEED LIMIT

                * DELAY ABSORPTION PROCEDURES WILL BE REQUIRED *

 ENTER HOLDING FIX WAYPOINT IDENTIFIER
 HOLDING FIX MUST BE BETWEEN (BUT MAY NOT INCLUDE)
 METERING FIX AND ENTRY FIX
I>WIGGI
     WAYPOINT WIGGI   IS ASSIGNED AS THE HOLDING FIX
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS STACKING IN PROGRESS - (Y OR N)
I>N
 WILL A HOLDING ALTITUDE BE ASSIGNED - (Y OR N)
I>N
 ENTER HOLDING AIRPSEED (KCAS)
     MINIMUM SPEED 200. KCAS
     RECOMMENDED AIRSPEED 210. KCAS
     MAXIMUM AIRSPEED 230. KCAS
I>210
     HOLDING AIRSPEED IS 210. KCAS
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER INBOUND HOLDING MAG COURSE
I>226
     INBOUND COURSE IS 226.
 IS INPUT CORRECT - (Y OR N)
I>Y
 TO ABSORB 175.5 SECONDS DELAY ,AN OFFSET OF  8.8 NMI MUST BE FLOWN
 WILL ATC APPROVE THIS REVISION - (Y OR N)
I>Y
 ENTER DIRECTION OF OFFSET - (L OR R)
I>R
```

Table 18. Path Stretching (Continued)

KEANN 26 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	END	SPEEDS(CAS) BEGIN	END	FUEL (LB)
EFIX	ECSFIX	226	8.6	77.4	35000	35000	259	210	23.2
ECSFIX	PSOFST1	316	8.8	87.7	35000	35000	210	210	94.2
PSOFST1	PSOFST2	226	81.2	805.3	35000	35000	210	210	859.9
PSOFST2	TOD	136	8.8	87.7	35000	35000	210	210	93.3
TOD	WIGGI	226	50.1	557.4	35000	21350	210	210	167.2
WIGGI	CSFIX1	226	7.1	90.5	21350	19077	210	210	27.1
CSFIX1	KEANN	226	2.9	33.9	19077	19077	210	250	85.6
KEANN	CSFIX2	226	13.7	156.1	19077	14000	250	250	48.0
CSFIX2	FLOTS	226	3.3	41.8	14000	14000	250	210	13.5
FLOTS	POD2	152	.2	2.8	14000	14000	210	210	3.2
POD2	WATKI	152	11.9	172.9	14000	10000	210	210	59.5
WATKI	CSFIX3	258	8.2	123.6	10000	7200	210	210	48.7
CSFIX3	ALTUR	258	1.9	32.2	7200	7200	210	180	13.3

DESCENT REQUIREMENTS

STARTING AT WATKI 9.4 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 18. Path Stretching (Concluded)

```
KEANN 26   SUMMARY
------------------

ENTRY FIX      EFIX
METERING FIX   KEANN
AIMPOINT       ALTUR

PROFILE DISTANCE  206.9 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 210 KCAS AT EFIX

DESCENT INFORMATION

TOP OF DESCENT  99.3 NMI FROM ALTUR
DESCENT SCHEDULE .631 MACH / 210 KCAS

DELAY TOTALS
  DELAY TIME    2 MIN 55.5 SEC
  DELAY FUEL     93. LB

METERING FIX INFORMATION

ALTITUDE AT KEANN     19077
AIRSPEED AT KEANN     250
ETA TO KEANN     12 HR 29 MIN  0.0 SEC

AIMPOINT INFORMATION

ALTITUDE AT ALTUR      7200
AIRSPEED AT ALTUR       180
GROSS WT AT ALTUR     83463 LB

SEGMENT TOTALS

TOTAL TIME  37 MINUTES 49.4 SECONDS
TOTAL FUEL 1536.8 LB
```

Table 19. Optimum Altitude Holding

```
 IS HOLDING ANTICIPATED - (Y OR N)
I>Y
 ENTER EXPECTED DELAY IN MINUTES AND SECONDS  MMM SS.S
I>15 00
     EXPECTED DELAY IS  15 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER HOLDING FIX WAYPOINT IDENTIFIER
 HOLDING FIX MUST BE BETWEEN (BUT MAY NOT INCLUDE)
 METERING FIX AND ENTRY FIX
I>WIGGI
     WAYPOINT WIGGI   IS ASSIGNED AS THE HOLDING FIX
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS STACKING IN PROGRESS - (Y OR N)
I>N
 WILL A HOLDING ALTITUDE BE ASSIGNED - (Y OR N)
I>N
 ENTER HOLDING AIRSPEED (KCAS)
     MINIMUM SPEED 200. KCAS
     RECOMMENDED AIRSPEED 210. KCAS
     MAXIMUM AIRSPEED 230. KCAS
I>210
     HOLDING AIRSPEED IS 210. KCAS
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER INBOUND HOLDING MAG COURSE
I>226
     INBOUND COURSE IS 226.
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS METERING IN PROGRESS - (Y OR N)
I>Y
 ENTER ENTRY FIX ETA - HH MM SS.S
I>12 00 00
     ENTRY FIX TIME   12 HR  0 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y

   FOR LOW SPEED PROFILE - METERING FIX ETA SHOULD BE 26 MINUTES  3.5 SECONDS
   AFTER ENTRY FIX ETA

   FOR HIGH SPEED PROFILE - METERING FIX ETA SHOULD BE 20 MINUTES  5.1 SECONDS
   AFTER ENTRY FIX ETA
```

Table 19. Optimum Altitude Holding (Continued)

KEANN 26 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
EFIX	ECSFIX	226	2.7	42.0	35000	35000	259	210	23.3
ECSFIX	TOD	226	75.9	751.9	35000	35000	210	210	804.4
TOD	ESHFIX	226	51.3	571.6	35000	21000	210	210	171.5
ESHFIX	WIGGI	226	10.0	125.0	21000	21000	210	210	135.9
WIGGI	WIGGI	226	0.0	785.5	21000	21000	210	210	874.2
WIGGI	POD2	226	1.2	14.4	21000	21000	210	210	15.6
POD2	CSFIX1	226	6.0	76.1	21000	19086	210	210	22.8
CSFIX1	KEANN	226	2.9	33.5	19086	19086	210	250	84.4
KEANN	CSFIX2	226	13.7	155.5	19086	14000	250	250	47.8
CSFIX2	FLOTS	226	3.3	41.7	14000	14000	250	210	13.5
FLOTS	POD3	152	.1	1.8	14000	14000	210	210	2.0
POD3	WATKI	152	12.0	172.4	14000	10000	210	210	59.4
WATKI	CSFIX3	258	8.2	123.6	10000	7200	210	210	48.8
CSFIX3	ALTUR	258	1.9	32.2	7200	7200	210	180	13.3

DISPLAY DETAILED HOLDING INFORMATION - (Y OR N)

I>Y

DETAILED HOLDING INFORMATION

ALTITUDES	TIMES (MINUTES SECONDS - MM SS.S) TURN OUTBND	LEG OUTBND	TURN INBND	LEG INBND	AT HLD ALTITUDE	DSCT FM ALTITUDE	FUELS (LB) AT HLD ALTITUDE	DSCT FM ALTITUDE
21000	2 0.0	1 16.4	2 0.0	1 16.4	13 5.5	0 0.0	874.2	0.0

DESCENT REQUIREMENTS

STARTING AT WATKI 6.3 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 19. Optimum Altitude Holding (Continued)

```
 THE CURRENT METERING FIX TIME ASSIGNMENT IS    0 HR  0 MIN  0.0 SEC
 IS ANOTHER TIME DESIRED (Y OR N)
I>Y
 ENTER METERING FIX TIME - HH MM SS.S
I>12 40 00
     METERING FIX TIME   12 HR 40 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 CURRENT METERING FIX TIME REQUIRES A DESCENT   13.9 MINUTES SLOWER
 THAN THE LOW SPEED LIMIT

               * DELAY ABSORPTION PROCEDURES WILL BE REQUIRED *

STANDARD HOLDING PATTERN - (Y OR N)
I>Y
 DISPLAY FULL PROFILE - (Y OR N)
I>Y
```

Table 19. Optimum Altitude Holding (Concluded)

```
               KEANN 26   SUMMARY

               -----------------

ENTRY FIX      EFIX
HOLDING FIX    WIGGI
METERING FIX   KEANN
AIMPOINT       ALTUR

PROFILE DISTANCE  189.2 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 210 KCAS AT EFIX

DESCENT INFORMATION

TOP OF DESCENT 110.5 NMI FROM ALTUR
DESCENT SCHEDULE 210 KCAS

HOLDING INFORMATION

HOLDING ALTITUDE IS 21000. FT

PATTERN INFORMATION
  STANDARD TURNS
  HOLDING AIRSPEED 210. KCAS
  INBOUND COURSE 226.

DELAY TOTALS
  DELAY TIME  13 MIN  5.5 SEC
  DELAY FUEL   874. LB

METERING FIX INFORMATION

ALTITUDE AT KEANN    19086
AIRSPEED AT KEANN    250
ETA TO KEANN    12 HR 40 MIN  0.0 SEC

AIMPOINT INFORMATION

ALTITUDE AT ALTUR     7200
AIRSPEED AT ALTUR      180
GROSS WT AT ALTUR    83576 LB

SEGMENT TOTALS

TOTAL TIME  48 MINUTES 47.2 SECONDS
TOTAL FUEL 2316.8 LB
```

Table 20. ATC-Assigned-Altitude Holding

```
 IS HOLDING ANTICIPATED - (Y OR N)
I>Y
 ENTER EXPECTED DELAY IN MINUTES AND SECONDS  MMM SS.S
I>15 00
     EXPECTED DELAY IS  15 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER HOLDING FIX WAYPOINT IDENTIFIER
 HOLDING FIX MUST BE BETWEEN (BUT MAY NOT INCLUDE)
 METERING FIX AND ENTRY FIX
I>WIGGI
     WAYPOINT WIGGI   IS ASSIGNED AS THE HOLDING FIX
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS STACKING IN PROGRESS - (Y OR N)
I>N
 WILL A HOLDING ALTITUDE BE ASSIGNED - (Y OR N)
I>Y
 ENTER ASSIGNED ALTITUDE
I>20000

     THE ASSIGNED HOLDING ALTITUDE IS 20000. FT
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER HOLDING AIRSPEED (KCAS)
     MINIMUM SPEED 200. KCAS
     RECOMMENDED AIRSPEED 210. KCAS
     MAXIMUM AIRSPEED 230. KCAS
I>210
     HOLDING AIRSPEED IS 210. KCAS
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER INBOUND HOLDING MAG COURSE
I>226
     INBOUND COURSE IS 226.
 IS INPUT CORRECT - (Y OR N)
I>Y
IS METERING IN PROGRESS - (Y OR N)
I>Y
 ENTER ENTRY FIX ETA - HH MM SS.S
I>12 00 00
     ENTRY FIX TIME   12 HR  0 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y

   FOR LOW SPEED PROFILE - METERING FIX ETA SHOULD BE 26 MINUTES  4.8 SECONDS
   AFTER ENTRY FIX ETA

   FOR HIGH SPEED PROFILE - METERING FIX ETA SHOULD BE 20 MINUTES  6.1 SECONDS
   AFTER ENTRY FIX ETA
```

Table 20. ATC-Assigned-Altitude Holding (Continued)

```
 THE CURRENT METERING FIX TIME ASSIGNMENT IS   0 HR  0 MIN  0.0 SEC
 IS ANOTHER TIME DESIRED (Y OR N)
I>Y
 ENTER METERING FIX TIME - HH MM SS.S
I>12 40 00
     METERING FIX TIME   12 HR 40 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 CURRENT METERING FIX TIME REQUIRES A DESCENT   13.9 MINUTES SLOWER
 THAN THE LOW SPEED LIMIT

                * DELAY ABSORPTION PROCEDURES WILL BE REQUIRED *


 STANDARD HOLDING PATTERN - (Y OR N)
I>Y
 DISPLAY FULL PROFILE - (Y OR N)
I>Y
```

Table 20. ATC-Assigned-Altitude Holding (Continued)

KEANN 26 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
EFIX	ECSFIX	226	2.8	42.0	35000	35000	259	210	23.3
ECSFIX	TOD	226	72.8	720.9	35000	35000	210	210	771.8
TOD	ESHFIX	226	54.4	611.4	35000	20000	210	210	183.4
ESHFIX	WIGGI	226	10.0	127.5	20000	20000	210	210	139.8
WIGGI	WIGGI	226	0.0	773.3	20000	20000	210	210	866.5
WIGGI	POD2	226	4.4	55.9	20000	20000	210	210	60.8
POD2	CSFIX1	226	2.8	35.5	20000	19110	210	210	10.7
CSFIX1	KEANN	226	2.9	33.5	19110	19110	210	250	84.5
KEANN	CSFIX2	226	13.7	156.2	19110	14000	250	250	48.0
CSFIX2	FLOTS	226	3.3	41.7	14000	14000	250	210	13.5
FLOTS	POD3	152	.2	3.2	14000	14000	210	210	3.7
POD3	WATKI	152	11.9	172.4	14000	10000	210	210	59.4
WATKI	CSFIX3	258	8.2	123.6	10000	7200	210	210	48.8
CSFIX3	ALTUR	258	1.9	32.2	7200	7200	210	180	13.3

DISPLAY DETAILED HOLDING INFORMATION - (Y OR N)

I>Y

DETAILED HOLDING INFORMATION

ALTITUDES	TIMES (MINUTES SECONDS - MM SS.S) TURN OUTBND	LEG OUTBND	TURN INBND	LEG INBND	AT HLD ALTITUDE	DSCT FM ALTITUDE	FUELS (LB) AT HLD ALTITUDE	DSCT FM ALTITUDE
20000	2 1.1	1 12.7	1 58.9	1 14.0	12 53.3	0 0.0	866.5	0.0

DESCENT REQUIREMENTS

STARTING AT WATKI 6.3 PERCENT OF MAXIMUM SPOILER DRAG

MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 20. ATC-Assigned-Altitude Holding (Concluded)

```
              KEANN 26   SUMMARY

              ------------------

ENTRY FIX      EFIX
HOLDING FIX    WIGGI
METERING FIX   KEANN
AIMPOINT       ALTUR

PROFILE DISTANCE  189.2 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 210 KCAS AT EFIX

DESCENT INFORMATION

TOP OF DESCENT 113.6 NMI FROM ALTUR
DESCENT SCHEDULE 210 KCAS

HOLDING INFORMATION

HOLDING ALTITUDE IS 20000. FT

PATTERN INFORMATION
  STANDARD TURNS
  HOLDING AIRSPEED 210. KCAS
  INBOUND COURSE 226.

DELAY TOTALS
  DELAY TIME  12 MIN 53.3 SEC
  DELAY FUEL   866. LB

METERING FIX INFORMATION

ALTITUDE AT KEANN     19110
AIRSPEED AT KEANN     250
ETA TO KEANN     12 HR 40 MIN  0.0 SEC

AIMPOINT INFORMATION

ALTITUDE AT ALTUR      7200
AIRSPEED AT ALTUR       180
GROSS WT AT ALTUR     83494 LB

SEGMENT TOTALS

TOTAL TIME  48 MINUTES 49.4 SECONDS
TOTAL FUEL 2327.2 LB
```

Table 21. Holding in a Stack

```
 IS HOLDING ANTICIPATED - (Y OR N)
I>Y
 ENTER EXPECTED DELAY IN MINUTES AND SECONDS  MMM SS.S
I>45 00 00
     EXPECTED DELAY IS  45 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER HOLDING FIX WAYPOINT IDENTIFIER
 HOLDING FIX MUST BE BETWEEN (BUT MAY NOT INCLUDE)
 METERING FIX AND ENTRY FIX
I>WIGGI
     WAYPOINT WIGGI   IS ASSIGNED AS THE HOLDING FIX
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS STACKING IN PROGRESS - (Y OR N)
I>Y
 ENTER TOP STACK ALTITUDE THEN BOTTOM STACK ALTITUDE
I>25000 21000

     TOP STACK ALTITUDE IS 25000.
     BOTTOM STACK ALTITUDE IS 21000.
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER HOLDING AIRSPEED (KCAS)
     MINIMUM SPEED 200. KCAS
     RECOMMENDED AIRSPEED 210. KCAS
     MAXIMUM AIRSPEED 230. KCAS
I>210
     HOLDING AIRSPEED IS 210. KCAS
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER INBOUND HOLDING MAG COURSE
I>226
     INBOUND COURSE IS 226.
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS METERING IN PROGRESS - (Y OR N)
I>Y
 ENTER ENTRY FIX ETA - HH MM SS.S
I>12 00 00
     ENTRY FIX TIME   12 HR  0 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y

   FOR LOW SPEED PROFILE - METERING FIX ETA SHOULD BE 30 MINUTES 38.6 SECONDS
   AFTER ENTRY FIX ETA

   FOR HIGH SPEED PROFILE - METERING FIX ETA SHOULD BE 23 MINUTES 32.1 SECONDS
   AFTER ENTRY FIX ETA
```

Table 21. Holding in a Stack (Continued)

```
 THE CURRENT METERING FIX TIME ASSIGNMENT IS  12 HR 40 MIN  0.0 SEC
 IS ANOTHER TIME DESIRED (Y OR N)
I>Y
 ENTER METERING FIX TIME - HH MM SS.S
I>13 15 00
     METERING FIX TIME   13 HR 15 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 CURRENT METERING FIX TIME REQUIRES A DESCENT   48.9 MINUTES SLOWER
 THAN THE LOW SPEED LIMIT

                  * DELAY ABSORPTION PROCEDURES WILL BE REQUIRED *


 STANDARD HOLDING PATTERN - (Y OR N)
I>Y
 DISPLAY FULL PROFILE - (Y OR N)
I>Y
```

Table 21. Holding in a Stack (Continued)

KEANN 26 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
EFIX	ECSFIX	226	2.8	43.1	35000	35000	259	210	23.9
ECSFIX	TOD	226	88.8	879.8	35000	35000	210	210	1011.7
TOD	ESHFIX	226	38.4	414.0	35000	25000	210	210	124.2
ESHFIX	WIGGI	226	10.0	117.2	25000	25000	210	210	132.4
WIGGI	WIGGI	226	0.0	2921.5	25000	21000	210	210	3270.1
WIGGI	POD2	226	.4	5.2	21000	21000	210	210	5.8
POD2	CSFIX1	226	6.6	83.6	21000	18924	210	210	25.1
CSFIX1	KEANN	226	3.0	35.6	18924	18924	210	250	90.0
KEANN	CSFIX2	226	13.7	155.2	18924	13990	250	250	47.7
CSFIX2	FLOTS	226	3.3	42.3	13990	13990	250	210	13.7
FLOTS	WATKI	152	12.1	174.3	13990	10000	210	210	60.0
WATKI	CSFIX3	258	8.1	123.4	10000	7200	210	210	48.6
CSFIX3	ALTUR	258	2.0	32.5	7200	7200	210	180	13.4

DISPLAY DETAILED HOLDING INFORMATION - (Y OR N)

I>Y

DETAILED HOLDING INFORMATION

ALTITUDES	TIMES (MINUTES SECONDS - MM SS.S) TURN OUTBND	LEG OUTBND	TURN INBND	LEG INBND	AT HLD ALTITUDE	DSCT FM ALTITUDE	FUELS (LB) AT HLD ALTITUDE	DSCT FM ALTITUDE
25000	2 0.0	1 28.7	2 0.0	1 28.7	9 2.8	0 41.5	644.2	12.5
24000	2 0.0	1 28.7	2 0.0	1 28.7	9 4.5	0 39.8	640.3	11.9
23000	2 0.0	1 28.7	2 0.0	1 28.7	9 4.4	0 39.9	633.8	12.0
22000	2 0.0	1 28.7	2 0.0	1 28.7	9 4.3	0 40.0	629.5	12.0
21000	2 0.0	1 28.7	2 0.0	1 28.7	9 44.3	0 0.0	673.9	0.0

DESCENT REQUIREMENTS

STARTING AT WATKI 12.5 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 21. Holding in a Stack (Concluded)

```
            KEANN 26   SUMMARY

            ------------------

ENTRY FIX      EFIX
HOLDING FIX    WIGGI
METERING FIX   KEANN
AIMPOINT       ALTUR

PROFILE DISTANCE  189.2 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 210 KCAS AT EFIX

DESCENT INFORMATION

TOP OF DESCENT  97.6 NMI FROM ALTUR
DESCENT SCHEDULE 210 KCAS

HOLDING INFORMATION

STACK INFORMATION
  TOP ALTITUDE    25000.
  BOTTOM ALTITUDE 21000.

PATTERN INFORMATION
  STANDARD TURNS
  HOLDING AIRSPEED 210. KCAS
  INBOUND COURSE 226.

DELAY TOTALS
  DELAY TIME  48 MIN 41.5 SEC
  DELAY FUEL  3270. LB

METERING FIX INFORMATION

ALTITUDE AT KEANN    18924
AIRSPEED AT KEANN    250
ETA TO KEANN     13 HR 15 MIN  0.0 SEC

AIMPOINT INFORMATION

ALTITUDE AT ALTUR     7200
AIRSPEED AT ALTUR      180
GROSS WT AT ALTUR    87306 LB

SEGMENT TOTALS

TOTAL TIME  83 MINUTES 47.5 SECONDS
TOTAL FUEL 4866.6 LB
```

Table 22. Holding in a Stack With Wind

```
 IS HOLDING ANTICIPATED - (Y OR N)
I>Y
 ENTER EXPECTED DELAY IN MINUTES AND SECONDS  MMM SS.S
I>45 00 00
     EXPECTED DELAY IS  45 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER HOLDING FIX WAYPOINT IDENTIFIER
 HOLDING FIX MUST BE BETWEEN (BUT MAY NOT INCLUDE)
 METERING FIX AND ENTRY FIX
I>WIGGI
     WAYPOINT WIGGI   IS ASSIGNED AS THE HOLDING FIX
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS STACKING IN PROGRESS - (Y OR N)
I>Y
 ENTER TOP STACK ALTITUDE THEN BOTTOM STACK ALTITUDE
I>25000 21000

     TOP STACK ALTITUDE IS 25000.
     BOTTOM STACK ALTITUDE IS 21000.
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER HOLDING AIRSPEED (KCAS)
     MINIMUM SPEED 200. KCAS
     RECOMMENDED AIRSPEED 210. KCAS
     MAXIMUM AIRSPEED 230. KCAS
I>210
     HOLDING AIRSPEED IS 210. KCAS
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER INBOUND HOLDING MAG COURSE
I>226
     INBOUND COURSE IS 226.
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS METERING IN PROGRESS - (Y OR N)
I>Y
 ENTER ENTRY FIX ETA - HH MM SS.S
I>12 00 00
     ENTRY FIX TIME   12 HR  0 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y

   FOR LOW SPEED PROFILE - METERING FIX ETA SHOULD BE 30 MINUTES 38.6 SECONDS
   AFTER ENTRY FIX ETA

   FOR HIGH SPEED PROFILE - METERING FIX ETA SHOULD BE 23 MINUTES 32.1 SECONDS
   AFTER ENTRY FIX ETA
```

Table 22. Holding in a Stack With Wind (Continued)

```
 THE CURRENT METERING FIX TIME ASSIGNMENT IS   0 HR  0 MIN  0.0 SEC
 IS ANOTHER TIME DESIRED (Y OR N)
I>Y
 ENTER METERING FIX TIME - HH MM SS.S
I>13 15 00
     METERING FIX TIME   13 HR 15 MIN  0.0 SEC
 IS INPUT CORRECT - (Y OR N)
I>Y
 CURRENT METERING FIX TIME REQUIRES A DESCENT   44.4 MINUTES SLOWER
 THAN THE LOW SPEED LIMIT

                  * DELAY ABSORPTION PROCEDURES WILL BE REQUIRED *


 STANDARD HOLDING PATTERN - (Y OR N)
I>Y
 DISPLAY FULL PROFILE - (Y OR N)
I>Y
```

Table 22. Holding in a Stack With Wind (Continued)

KEANN 26 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
EFIX	ECSFIX	226	2.6	43.3	35000	35000	259	210	24.0
ECSFIX	TOD	226	95.6	1111.1	35000	35000	210	210	1298.3
TOD	ESHFIX	226	31.8	421.7	35000	25000	210	210	126.5
ESHFIX	WIGGI	226	10.0	143.7	25000	25000	210	210	162.8
WIGGI	WIGGI	226	0.0	2633.3	25000	21000	210	210	2960.0
WIGGI	POD2	226	3.9	59.3	21000	21000	210	210	66.6
POD2	CSFIX1	226	3.3	50.5	21000	19748	210	210	15.1
CSFIX1	KEANN	226	2.7	37.1	19748	19748	210	250	92.5
KEANN	CSFIX2	226	14.1	181.0	19748	14000	250	250	55.5
CSFIX2	FLOTS	226	2.9	42.5	14000	14000	250	210	13.7
FLOTS	POD3	152	.6	8.2	14000	14000	210	210	9.7
POD3	WATKI	152	11.5	154.8	14000	10460	210	210	52.8
WATKI	CSFIX3	258	8.4	150.2	10460	7200	210	210	58.7
CSFIX3	ALTUR	258	1.7	32.6	7200	7200	210	180	13.5

DISPLAY DETAILED HOLDING INFORMATION - (Y OR N)

I>Y

DETAILED HOLDING INFORMATION

ALTITUDES	TIMES (MINUTES SECONDS - MM SS.S) TURN OUTBND	LEG OUTBND	TURN INBND	LEG INBND	AT HLD ALTITUDE	DSCT FM ALTITUDE	FUELS (LB) AT HLD ALTITUDE	DSCT FM ALTITUDE
25000	1 19.7	0 18.0	2 40.3	1 11.2	8 4.9	0 41.7	580.0	12.5
24000	1 14.6	0 20.5	2 45.4	1 8.7	8 6.7	0 40.0	577.2	12.0
23000	1 14.2	0 21.5	2 45.8	1 7.6	8 6.6	0 40.0	571.6	12.0
22000	1 13.8	0 22.6	2 46.2	1 6.5	8 6.5	0 40.1	567.5	12.0
21000	1 13.4	0 23.8	2 46.6	1 5.4	8 46.7	0 0.0	615.0	0.0

Table 22. Holding in a Stack With Wind (Concluded)

```
                KEANN 26   SUMMARY
                -----------------

ENTRY FIX      EFIX
HOLDING FIX    WIGGI
METERING FIX   KEANN
AIMPOINT       ALTUR

PROFILE DISTANCE  189.2 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 210 KCAS AT EFIX

DESCENT INFORMATION

TOP OF DESCENT  91.0 NMI FROM ALTUR
DESCENT SCHEDULE 210 KCAS

HOLDING INFORMATION

STACK INFORMATION
  TOP ALTITUDE     25000.
  BOTTOM ALTITUDE 21000.

PATTERN INFORMATION
  STANDARD TURNS
  HOLDING AIRSPEED 210. KCAS
  INBOUND COURSE 226.

DELAY TOTALS
  DELAY TIME  43 MIN 53.3 SEC
  DELAY FUEL  2960. LB

METERING FIX INFORMATION

ALTITUDE AT KEANN     19748
AIRSPEED AT KEANN     250
ETA TO KEANN     13 HR 15 MIN  0.0 SEC

AIMPOINT INFORMATION

ALTITUDE AT ALTUR      7200
AIRSPEED AT ALTUR       180
GROSS WT AT ALTUR     87447 LB

SEGMENT TOTALS

TOTAL TIME  84 MINUTES 29.3 SECONDS
TOTAL FUEL 4949.7 LB
```

Table 23. Anti-Icing

```
 IS ICING ANTICIPATED - (Y OR N)
I>Y
 IS 55 PER CENT N1 DESIRED - (Y OR N)
I>Y
 ANTIICING FROM 20000 FT TO GROUND - (Y OR N)
I>Y
 IS HOLDING ANTICIPATED - (Y OR N)
I>N
 IS METERING IN PROGRESS - (Y OR N)
I>N

          THE FOLLOWING ALTITUDES ARE REQUIRED TO COMPLETE THE PROFILE

            THE DESIRED ALTITUDE AT WATKI   IS AT OR BELOW  9066. FT

 WILL ATC APPROVE THESE REVISIONS - (Y OR N)
I>Y
 DISPLAY FULL PROFILE - (Y OR N)
I>Y
```

Table 23. Anti-Icing (Continued)

KEANN 26 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
EFIX	ECSFIX	226	5.4	46.8	35000	35000	259	228	14.0
ECSFIX	TOD	226	87.2	800.4	35000	35000	228	228	917.5
TOD	WIGGI	226	47.3	459.5	35000	19648	228	250	139.4
WIGGI	KEANN	226	10.0	110.6	19648	17000	250	250	46.1
KEANN	CSFIX1	226	12.1	142.3	17000	12000	250	250	68.0
CSFIX1	FLOTS	226	4.9	64.7	12000	12000	250	210	36.6
FLOTS	WATKI	152	12.1	179.0	12000	9066	210	210	112.5
WATKI	CSFIX2	258	5.8	88.9	9066	7200	210	210	61.1
CSFIX2	ALTUR	258	4.3	71.2	7200	7200	210	180	53.1

DESCENT REQUIREMENTS

STARTING AT KEANN 84.4 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

STARTING AT FLOTS 40.6 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO WATKI TO MAINTAIN THE PROFILE

STARTING AT WATKI 100.0 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 23. Anti-Icing (Concluded)

```
            KEANN 26   SUMMARY

            ------------------

ENTRY FIX      EFIX
METERING FIX   KEANN
AIMPOINT       ALTUR

PROFILE DISTANCE  189.2 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT EFIX

DESCENT INFORMATION

TOP OF DESCENT  96.5 NMI FROM ALTUR
DESCENT SCHEDULE .682 MACH / 250 KCAS

ANTIICE INFORMATION
  AN N1 SETTING OF 55 SHOULD BE USED
  BETWEEN 20000 AND     0 FT

METERING FIX INFORMATION

ALTITUDE AT KEANN    17000
AIRSPEED AT KEANN    250

AIMPOINT INFORMATION

ALTITUDE AT ALTUR     7200
AIRSPEED AT ALTUR      180
GROSS WT AT ALTUR    83552 LB

SEGMENT TOTALS

TOTAL TIME  32 MINUTES 43.4 SECONDS
TOTAL FUEL 1448.4 LB
```

Table 24. Profile Re-Initialization

```
 REVISE SELECTED GEOMETRY - (Y OR N)
I>Y
       PUBLISHED PATH GEOMETRY - KEANN 26
    PATH   WAYPOINT  WAYPOINT
   SEGMENT   BEGIN      END      COURSE  DIST
      1      EFIX     WIGGI       226.   140.0
      2      WIGGI    KEANN       226.    10.0
      3      KEANN    FLOTS       226.    17.0
      4      FLOTS    WATKI       152.    12.1
      5      WATKI    ALTUR       258.    10.1
 ENTER THE NUMBER OF THE FIRST USABLE PATH SEGMENT
I>2
     FIRST USABLE PATH SEGMENT IS WIGGI   TO KEANN
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER IDENTIFIER FOR WAYPOINT PRIOR TO WIGGI
 7 CHARACTERS LEFT-ADJUSTED
I>REVGFIX
 ENTER COURSE AND DISTANCE FOR REVGFIX TO WIGGI
I>205 130
     REVGFIX TO WIGGI       COURSE 205.     DISTANCE 130.0
 IS INPUT CORRECT - (Y OR N)
I>Y
 ADD ANOTHER PATH SEGMENT - (Y OR N)
I>N
 ENTER MAXIMUM AND MINIMUM ALTITUDES FOR NEW WAYPOINTS
 ENTER ALTITUDE CONSTRAINTS AT REVGFIX
I>35000 30000
    NEW WAYPOINT CONSTRAINTS
             MAXIMUM   MINIMUM
   WAYPOINT  ALTITUDE  ALTITUDE
    REVGFIX   35000.    30000.
 IS INPUT CORRECT - (Y OR N)
I>Y
 ENTER CAS AT AIMPOINT
I>180
     CAS AT AIMPOINT 180.
 IS INPUT CORRECT - (Y OR N)
I>Y
 THE CURRENT CRUISE ALTITUDE IS 35000.
 IS ANOTHER ALTITUDE DESIRED - (Y OR N)
I>N
 ENTER CRUISE MACH AT ENTRY FIX
I>.765
     CRUISE SPEED AT ENTRY FIX   .765 MACH  259. CAS
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS ICING ANTICIPATED - (Y OR N)
I>N
 IS HOLDING ANTICIPATED - (Y OR N)
I>N
 IS METERING IN PROGRESS - (Y OR N)
I>N
 DISPLAY FULL PROFILE - (Y OR N)
I>Y
```

Table 24. Profile Re-Initialization (Continued)

KEANN 26 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	END	SPEEDS(CAS) BEGIN	END	FUEL (LB)
REVGFIX	ECSFIX	205	5.4	46.8	35000	35000	259	228	14.0
ECSFIX	TOD	205	85.9	788.0	35000	35000	228	228	902.6
TOD	WIGGI	205	38.7	367.2	35000	22536	228	250	110.2
WIGGI	KEANN	226	10.0	106.1	22536	19050	250	250	31.8
KEANN	CSFIX1	226	13.7	155.4	19050	14000	250	250	47.7
CSFIX1	FLOTS	226	3.3	41.8	14000	14000	250	210	13.5
FLOTS	POD2	152	.1	1.2	14000	14000	210	210	1.4
POD2	WATKI	152	12.0	173.0	14000	10000	210	210	59.5
WATKI	CSFIX2	258	8.2	123.6	10000	7200	210	210	48.7
CSFIX2	ALTUR	258	1.9	32.2	7200	7200	210	180	13.3

DESCENT REQUIREMENTS

STARTING AT WATKI 9.4 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 24. Profile Re-Initialization (Concluded)

```
              KEANN 26   SUMMARY

              -----------------

ENTRY FIX      REVGFIX
METERING FIX   KEANN
AIMPOINT       ALTUR

PROFILE DISTANCE  179.2 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT REVGFIX

DESCENT INFORMATION

TOP OF DESCENT  87.9 NMI FROM ALTUR
DESCENT SCHEDULE .682 MACH / 250 KCAS

METERING FIX INFORMATION

ALTITUDE AT KEANN    19050
AIRSPEED AT KEANN    250

AIMPOINT INFORMATION

ALTITUDE AT ALTUR     7200
AIRSPEED AT ALTUR      180
GROSS WT AT ALTUR    83757 LB

SEGMENT TOTALS

TOTAL TIME  30 MINUTES 35.4 SECONDS
TOTAL FUEL 1242.9 LB
```

Table 25. Drako 26 Profile Descent, Denver, Colorado

```
        THE FOLLOWING ALTITUDES ARE REQUIRED TO COMPLETE THE PROFILE
           THE DESIRED ALTITUDE AT TFINL   IS AT OR BELOW  8244. FT

 WILL ATC APPROVE THESE REVISIONS - (Y OR N)
I>Y
 DISPLAY FULL PROFILE - (Y OR N)
I>Y
                              DRAKO 26    PROFILE  DESCENT
                              ----------------------------
```

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
EFIX	ECSFIX	133	5.4	46.8	35000	35000	259	228	14.0
ECSFIX	TOD	133	105.7	970.1	35000	35000	228	228	1110.6
TOD	DRAKO	133	38.8	369.7	35000	22450	228	250	110.9
DRAKO	JASIN	133	18.0	196.6	22450	16000	250	250	59.1
JASIN	POD2	133	3.5	40.5	16000	16000	250	250	51.6
POD2	TDWND	133	6.7	78.2	16000	13487	250	250	25.0
TDWND	CSFIX1	80	9.3	112.7	13487	10000	250	250	41.4
CSFIX1	TBASE	80	2.8	38.7	10000	10000	250	210	14.7
TBASE	TFINL	170	5.0	75.2	10000	8244	210	210	29.0
TFINL	CSFIX2	260	2.2	33.2	8244	7200	210	210	13.5
CSFIX2	ALTUR	260	1.9	32.2	7200	7200	210	180	13.3

```
                                  DESCENT REQUIREMENTS
                                  --------------------

     STARTING AT TBASE     12.5 PERCENT OF MAXIMUM SPOILER DRAG
    MUST BE ADDED FOR THE SEGMENT TO TFINL   TO MAINTAIN THE PROFILE

    STARTING AT TFINL   100.0 PERCENT OF MAXIMUM SPOILER DRAG
    MUST BE ADDED FOR THE SEGMENT TO CSFIX   TO MAINTAIN THE PROFILE
```

Table 25. Drako 26 Profile Descent, Denver, Colorado (Concluded)

```
                    DRAKO 26   SUMMARY
                    ------------------

ENTRY FIX      EFIX
METERING FIX   DRAKO
AIMPOINT       ALTUR

PROFILE DISTANCE  199.4 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT EFIX

DESCENT INFORMATION

TOP OF DESCENT  88.2 NMI FROM ALTUR
DESCENT SCHEDULE 228 KCAS

METERING FIX INFORMATION

ALTITUDE AT DRAKO     22450
AIRSPEED AT DRAKO     250

AIMPOINT INFORMATION

ALTITUDE AT ALTUR      7200
AIRSPEED AT ALTUR       180
GROSS WT AT ALTUR     83517 LB

SEGMENT TOTALS

TOTAL TIME  33 MINUTES 13.9 SECONDS
TOTAL FUEL 1483.3 LB
```

Table 26. Blue Ridge 17L STAR, Dallas, Texas

BLUE RIDGE PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
TUL	ECSFIX	172	5.5	47.2	35000	35000	259	228	14.2
ECSFIX	MLC	172	75.5	693.4	35000	35000	228	228	794.5
MLC	TOD	189	38.2	351.0	35000	35000	228	228	400.0
TOD	YARBB	189	16.8	153.1	35000	29372	228	250	45.9
YARBB	RADEX	189	14.0	134.6	29372	25081	250	250	40.4
RADEX	BUJ	189	29.0	312.9	25081	14886	250	250	94.4
BUJ	BATON	230	14.0	169.9	14886	9592	250	250	61.0
BATON	ALKID	230	8.0	102.7	9592	6556	250	250	43.2
ALKID	CSFIX1	230	7.5	100.4	6556	3697	250	250	46.7
CSFIX1	HAMAK	230	2.5	36.2	3697	3697	250	210	17.5
HAMAK	CSFIX2	256	4.3	70.3	3697	2287	210	210	34.6
CSFIX2	JIFFY	256	1.7	30.5	2287	2287	210	180	15.3

Table 26. Blue Ridge 17L STAR, Dallas, Texas (Concluded)

```
              BLUE RIDGE SUMMARY
              ------------------

ENTRY FIX     TUL
METERING FIX  BUJ
AIMPOINT      JIFFY

PROFILE DISTANCE  217.0 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT TUL

DESCENT INFORMATION

TOP OF DESCENT  97.8 NMI FROM JIFFY
DESCENT SCHEDULE .682 MACH / 250 KCAS

METERING FIX INFORMATION

ALTITUDE AT BUJ      14886
AIRSPEED AT BUJ      250

AIMPOINT INFORMATION

ALTITUDE AT JIFFY     2287
AIRSPEED AT JIFFY      180
GROSS WT AT JIFFY    83392 LB

SEGMENT TOTALS

TOTAL TIME  36 MINUTES 42.2 SECONDS
TOTAL FUEL 1607.6 LB
```

Table 27. Leila 27 Profile Descent, Miami, Florida

LEILA 27 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
SRQ	ECSFIX	137	5.4	46.8	35000	35000	259	228	14.0
ECSFIX	TOD	137	65.2	598.8	35000	35000	228	228	685.9
TOD	LEILA	137	7.4	67.3	35000	32479	228	241	20.2
LEILA	PEATE	121	43.0	425.2	32479	18460	241	250	127.6
PEATE	MFIX	121	4.0	44.7	18460	17000	250	250	13.4
MFIX	POD2	121	9.4	105.6	17000	17000	250	250	134.3
POD2	CSFIX1	121	23.9	289.0	17000	8000	250	250	103.1
CSFIX1	TWND	121	2.7	37.9	8000	8000	250	210	15.5
TWND	TBASE	90	8.2	129.2	8000	4103	210	210	56.4
TBASE	SARCO	360	4.7	78.8	4103	2515	210	210	38.3
SARCO	CSFIX2	267	3.2	53.7	2515	1459	210	210	27.4
CSFIX2	KEYES	267	1.7	30.2	1459	1459	210	180	15.7

DESCENT REQUIREMENTS

STARTING AT TWND 96.9 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO TBASE TO MAINTAIN THE PROFILE

Table 27. Leila 27 Profile Descent, Miami, Florida (Concluded)

LEILA 27 SUMMARY

```
ENTRY FIX      SRQ
METERING FIX   MFIX
AIMPOINT       KEYES

PROFILE DISTANCE  178.8 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT SRQ

DESCENT INFORMATION

TOP OF DESCENT 108.2 NMI FROM KEYES
DESCENT SCHEDULE .682 MACH / 250 KCAS

METERING FIX INFORMATION

ALTITUDE AT MFIX     17000
AIRSPEED AT MFIX     250

AIMPOINT INFORMATION

ALTITUDE AT KEYES     1459
AIRSPEED AT KEYES      180
GROSS WT AT KEYES    83748 LB

SEGMENT TOTALS

TOTAL TIME  31 MINUTES 47.0 SECONDS
TOTAL FUEL 1251.8 LB
```

Table 28. Big SUR 28 Profile Descent, San Francisco, California

```
 SELECT CALCULATION OPTION FOR PATH SEGMENTS REQUIRING THRUST:
   1 USE LEVEL CRUISE UNTIL INTERCEPTING A CLEAN-IDLE DESCENT
   2 CONSIDER SEGMENTS ON AN INDIVIDUAL BASIS
I>1


                    PATH ARRAY INPUT SECTION


 ENTER GROSS WEIGHT AT ENTRY FIX
I>85000
     GROSS WEIGHT IS 85000.
 IS INPUT CORRECT - (Y OR N)
I>Y
                   AVAILABLE PROFILE DESCENT GEOMETRIES
   1  BIG SUR 28
 ENTER NUMBER OF DESIRED PATH
I>1
     DESIRED PATH BIG SUR 28
 IS INPUT CORRECT - (Y OR N)
I>Y
 THE CURRENT AIRFIELD ELEVATION IS     0.
 IS ANOTHER VALUE DESIRED - (Y OR N)
I>Y
 ENTER AIRFIELD ELEVATION
I>11
     AIRFIELD ELEVATION IS    11.
 IS INPUT CORRECT - (Y OR N)
I>Y
 REVISE SELECTED GEOMETRY - (Y OR N)
I>N
 ENTER CAS AT AIMPOINT
I>180
     CAS AT AIMPOINT 180.
 IS INPUT CORRECT - (Y OR N)
I>Y
 THE CURRENT CRUISE ALTITUDE IS 35000.
 IS ANOTHER ALTITUDE DESIRED - (Y OR N)
I>N
 ENTER CRUISE MACH AT ENTRY FIX
I>.765
     CRUISE SPEED AT ENTRY FIX   .765 MACH  259. CAS
 IS INPUT CORRECT - (Y OR N)
I>Y
 IS ICING ANTICIPATED - (Y OR N)
I>N
 IS HOLDING ANTICIPATED - (Y OR N)
I>N
 IS METERING IN PROGRESS - (Y OR N)
I>N
```

Table 28. Big SUR 28 Profile Descent, San Francisco, California (Concluded)

```
THE DESCENT REQUIRED FROM ECSFIX  TO D20     CANNOT BE ACCOMPLISHED
USING ONLY FLIGHT LIMIT SPOILERS FOR DRAG.  AIRCRAFT PERFORMANCE REQUIRES
A FLIGHT PATH ENDING AT 30918. FT WHICH IS BELOW THE CRUISE ALTITUDE
OF 35000. FT.

          ***************************************************
          ***  CURRENT PROFILE CALCULATION IS TERMINATED  ***
          *** REVISE THE GEOMETRY OR SELECT A NEW PROFILE ***
          ***************************************************

 IS ANOTHER PROFILE DESIRED (Y OR N)
I>N
```

Table 29. ATLIS 24 Profile Descent, St. Louis, Missouri

ATLIS 24 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
COLIE	ECSFIX	116	5.4	46.8	35000	35000	259	228	14.0
ECSFIX	TOD	116	33.7	308.8	35000	35000	228	228	354.3
TOD	UIN	116	9.9	90.3	35000	31517	228	247	27.1
UIN	ATLIS	143	30.0	290.3	31517	22122	247	250	87.1
ATLIS	VOGEL	143	17.0	186.2	22122	16031	250	250	56.0
VOGEL	HARDI	143	7.0	82.1	16031	13402	250	250	26.3
HARDI	WIRED	143	9.0	110.4	13402	10000	250	250	40.6
WIRED	CSFIX1	105	15.3	200.1	10000	3807	250	250	87.8
CSFIX1	TBASE	105	2.5	36.3	3807	3807	250	210	17.5
TBASE	MENNA	149	2.5	40.0	3807	3000	210	210	19.4
MENNA	CSFIX2	239	3.1	50.3	3000	2000	210	210	25.2
CSFIX2	ZUMAY	239	1.7	30.4	2000	2000	210	180	15.4

DESCENT REQUIREMENTS

STARTING AT WIRED 14.1 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

STARTING AT MENNA 6.3 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 29. ATLIS 24 Profile Descent, St. Louis, Missouri (Concluded)

```
ATLIS 24   SUMMARY
------------------

ENTRY FIX     COLIE
METERING FIX  WIRED
AIMPOINT      ZUMAY

PROFILE DISTANCE  137.1 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT COLIE

DESCENT INFORMATION

TOP OF DESCENT  98.0 NMI FROM ZUMAY
DESCENT SCHEDULE .682 MACH / 250 KCAS

METERING FIX INFORMATION

ALTITUDE AT WIRED    10000
AIRSPEED AT WIRED    250

AIMPOINT INFORMATION

ALTITUDE AT ZUMAY     2000
AIRSPEED AT ZUMAY      180
GROSS WT AT ZUMAY    84229 LB

SEGMENT TOTALS

TOTAL TIME  24 MINUTES 32.1 SECONDS
TOTAL FUEL  770.7 LB
```

Table 30. MODUC 06 Profile Descent, St. Louis, Missouri

MODUC 06 PROFILE DESCENT

SEGMENT DESCRIPTION		MAG COURSE	DISTANCE (NMI)	TIME (SEC)	ALTITUDES BEGIN	ALTITUDES END	SPEEDS(CAS) BEGIN	SPEEDS(CAS) END	FUEL (LB)
DENNI	ECSFIX	295	5.4	46.8	35000	35000	259	228	14.0
ECSFIX	TOD	295	10.4	95.6	35000	35000	228	228	109.7
TOD	MWA	295	1.2	10.6	35000	34647	228	230	3.2
MWA	MODUC	291	45.0	434.8	34647	20034	230	250	130.4
MODUC	BURCK	323	14.0	155.5	20034	14970	250	250	47.1
BURCK	FLORA	323	8.0	94.3	14970	12000	250	250	31.8
FLORA	POD2	323	5.4	64.3	12000	12000	250	250	85.4
POD2	ARCHO	323	10.6	132.7	12000	8000	250	250	52.2
ARCHO	CSFIX1	270	10.5	139.9	8000	3946	250	250	63.3
CSFIX1	TBASE	270	2.5	36.4	3946	3946	250	210	17.4
TBASE	GOFIN	330	2.5	41.6	3946	3105	210	210	20.1
GOFIN	CSFIX2	59	2.7	45.5	3105	2200	210	210	22.7
CSFIX2	TONNI	59	1.7	30.5	2200	2200	210	180	15.4

DESCENT REQUIREMENTS

STARTING AT ARCHO 3.1 PERCENT OF MAXIMUM SPOILER DRAG
MUST BE ADDED FOR THE SEGMENT TO CSFIX TO MAINTAIN THE PROFILE

Table 30. MODUC 06 Profile Descent, St. Louis, Missouri (Concluded)

```
                  MODUC 06   SUMMARY
                  ------------------

ENTRY FIX      DENNI
METERING FIX   FLORA
AIMPOINT       TONNI

PROFILE DISTANCE  119.9 NMI

ENTRY INFORMATION

CRUISE SPEED .765 MACH (259 KCAS)
CHANGE SPEED TO 228 KCAS AT DENNI

DESCENT INFORMATION

TOP OF DESCENT 104.1 NMI FROM TONNI
DESCENT SCHEDULE .682 MACH / 250 KCAS

METERING FIX INFORMATION

ALTITUDE AT FLORA     12000
AIRSPEED AT FLORA     250

AIMPOINT INFORMATION

ALTITUDE AT TONNI      2200
AIRSPEED AT TONNI       180
GROSS WT AT TONNI     84387 LB

SEGMENT TOTALS

TOTAL TIME  22 MINUTES  8.5 SECONDS
TOTAL FUEL  612.7 LB
```

8.0 CONCLUSIONS

The LFM/PD algorithm can compute fuel-efficient descent profiles in an ATC flow management environment with or without time-based metering over a fixed ground track. These profiles conform to all ATC restrictions and procedures and to performance capabilities of the Boeing 737-100 airplane with JT8D-7 engines. All pertinent constraints are stored in the navigation, engine and airframe data bases and serve as boundary conditions of the point-mass, steady-state aerodynamic equations of motion to derive airplane airspeed and altitude data at all published and performance-generated waypoints. Waypoint crossing times and fuel burn throughout the descent are also computed. When no ATC system delay is required, the algorithm constructs a fuel-efficient descent profile from the entry fix to the aimpoint. When metering is in effect and an ATC metering fix time is assigned to the TCV airplane, a fuel-efficient profile requiring an airspeed schedule consistent with making good the fix crossing time is computed, including holding or path stretching to absorb excess ATC delay. Ground speeds at all waypoints are derived from the metered profile and serve as the guidance reference for time-based navigation. Profiles requiring anti-ice power are also accommodated. Finally, the algorithm displays a profile table and summary data.

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16. Abstract

The Local Flow Management/Profile Descent (LFM/PD) algorithm designed for the NASA Transport System Research Vehicle program is described. The algorithm provides fuel-efficient altitude and airspeed profiles consistent with ATC restrictions in a time-based metering environment over a fixed ground track. The model design constraints include accommodation of both published profile descent procedures and unpublished profile descents, incorporation of fuel efficiency as a flight profile criterion, operation within the performance capabilities of the Boeing 737-100 airplane with JT8D-7 engines, and conformity to standard air traffic navigation and control procedures. Holding and path stretching capabilities are included for long delay situations.

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