727 APPROACH ENERGY MANAGEMENT
SYSTEM AVIONICS SPECIFICATION

(Preliminary)

D.O. Jackson, A. A. Lambregts

August 1976

Boeing Commercial Airplane Company
P.O. Box 3707
Seattle, Washington 98124

for
Ames Research Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Page intentionally left blank

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR 137906		
4. Title and Subtitle		5. Report Date
727 Approach Energy Management System Avionics Specification (Preliminary)		August 1976
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
D. O. Jackson A. A. Lambregts		D6-44119
		10. Work Unit No.
9. Performing Organization Name and Address		
Boeing Commercial Airplane Company P.O. Box 3707 Seattle, Washington 98124		11. Contract or Grant No.
		NAS 2-8953
		13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address		Equipment Specification
Ames Research Center National Aeronautics and Space Administration Moffett Field, California 94035		14. Sponsoring Agency Code
15. Supplementary Notes		

NASA Technical Monitor: Dr. John S. Bull
Guidance and Navigation Division
Ames Research Center

16. Abstract

This document presents hardware and software requirements for an Approach Energy Management System (AEMS) consisting of an airborne digital computer and cockpit displays. The displays provide the pilot with a visual indication of when to manually operate the gear, flaps, and throttles during a delayed flap approach so as to reduce approach time, fuel consumption, and community noise. The AEMS is an independent system that does not interact with other navigation or control systems, and is compatible with manually flown or autopilot coupled approaches. Operational use of the AEMS requires a DME ground station colocated with the flight path reference (ILS or VASI).

This specification was written as part of a NASA-Ames Research Center (ARC) research study to investigate applicability to the B727 of an energy management concept developed and flight tested on the CV-990 by the ARC. The purpose of the specification is to define the configuration resulting from the Boeing study and to provide a basis for obtaining budgetary hardware implementation costs. The specification should not be used for hardware procurement until another design cycle has been conducted to refine the configuration.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Airborne Computer Noise Abatement Fuel Conservation Energy Management Delayed Flap Approach	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	126	

Page intentionally left blank

LIST OF FIGURES

PRECEDING PAGE BLANK NOT FILMED

REV SYM

TABLE OF CONTENTS

REV SYM

REV SYM

REV SYM

REV SYM

REV SYM

REV SYM

1.0 SCOPE

This specification defines the design, fabrication, maintenance and test requirements for the avionics portion of the 727 Approach Energy Management System (AEMS). The system shall meet FAA TSO Standards. This specification is intended for obtaining hardware cost estimates and for initiating development of flight test hardware suitable for application to a 727-200 airplane using JT8D-9 engines. The computer algorithm is applicable to standard day conditions.

1.1 GENERAL OPERATION

The AEMS avionics consist of an airborne computer and cockpit displays which provide the pilot with a visual indication of when to manually operate the landing gear, flaps, and throttle. This allows the pilot to fly a delayed flap approach procedure which will reduce approach time, fuel consumption, and noise. The system can be used during either manual or autopilot coupled approaches, under VFR or IFR conditions and does not involve any modifications to the existing flight control system. A DME ground station at the approach end of the runway is required for system operation.

1.2 DESIGN OBJECTIVES

The primary design objectives for the delayed flap avionic system components are:

a. Low cost and simple construction
b. High reliability
c. Good fault isolation and self test
d. Ease of maintenance

The system is not a flight critical item because it is advisory in nature. The system will be used during the landing approach and will require good self test and failure monitoring to provide confidence that it is operating correctly. A fail safe design will not be required.

REV SYM

1.3 PRODUCT RESPONSIBILITY

The supplier is responsible for designing and manufacturing the AEMS avionics to meet the requirements of this specification, all applicable technical standard orders (TSOs), FAA regulations, and Advisory Circulars. The supplier shall demonstrate that the equipment performs within specification limits, is free of manufacturing defects and will operate in the specified environment. Boeing shall approve all changes that affect form, fit, function, safety, maintainability, and reliability.

Boeing shall have overall system responsibility.

1.4 DEVIATIONS

Requests for deviations to this specification shall be made by specific reference to the affected paragraph(s), together with the specific reasons for, and detailed explanation of, each requested deviation. Deviations which are granted shall be described by formal revisions to this specification.

1.5 CROSS INDEX

Each prospective supplier shall supply a cross index of his proposal and this specification if the proposal paragraphs are not numbered to correspond with the paragraphs and titles of this specification. Deviations from any requirement of this specification shall be clearly listed and reasons discussed in supplier proposals.

2.0 APPLICABLE DOCUMENTS

Applicable portions of the following documents and drawings of the issue in effect on the date of invitation for bids or the exact issue shown, form a part of this specification to the extent specified herein. When conflicting requirements exist, the requirements of this specification shall govern. One copy of the documents marked with an asterisk will be furnished on request to vendors that are sent a copy of this specification.

2.1   BOEING DOCUMENTS

        *D6-1274   Electrical Power Characteristics and Utilization
                                Equipment Requirements

        *D6-5244   Electrical Interference Control Requirements -
                                Electrical and Electronic Equipment

        *D6-5431   Vibration Test Requirements for Items of Equipment
                                Installed in Model 727 Airplanes

        *BAC-5714   Electrodeposited Cadmium Plating Aluminum Alloy

        *D6-5762-1   Reliability Guide for Suppliers

        *D6-5800   General Requirements Supplement to Source Control
                                Drawings for Commercial Model Airplanes

        *10-61209   Cabin Pressure Control System

        *10-6079   Flap Position Indicator

        *10-61229   Central Air Data Computer

        *10-61317   Flap Position and Stall Warning Transmitter

        *10-61439   Central Air Data Computer

2.2   NONGOVERNMENT SPECIFICATIONS

        ASA-Y32.16   Electrical and Electronics Reference Designations

        IPC-ML-910   Rigid, Multilayered Printing Wiring Boards
        June 68

        IPC-ML-950A   Performance Specification Multilayer
        Sept 70   Printed Circuit Boards

        RTCA-DO-160   RTCA Environmental Conditions and Test Procedures for
                                Airborne Electronic Electrical Equipment and
                                Instruments

        ARINC Spec   Air Transport Equipment, Cases and Racking
        404A

        ARINC 406A   Standardized Pin Connections and Index Pin Codes
        31 July 72   for Airborne Electronic Equipments

        ARINC Spec   Airborne Distance Measuring Equipment
        568-4

2.3   FEDERAL SPECIFICATIONS

TSO-C9b   Civil Aeronautics Administration Technical
TSO-C9c   Standard Order

2.4   MILITARY SPECIFICATIONS

MIL-STD-210A   Military Standard Climatic Extremes for
Military Equipment

MIL=STD-454D   Standard General Requirements for Electronic
Equipment

MIL-STD-806C   Graphic Symbols for Logic Diagrams

MIL-STD-801C   Environmental Test Methods

MIL-STD-883   Test Methods and Procedures for Micro Electronics

MIL-Q-9858A   Quality Program Requirements

MIL-M-38510A   General Specification for Microcircuits

REV SYM

3.0   REQUIREMENTS

3.1   AEMS DESCRIPTION

3.1.1   Avionics Components

The system is shown in figure 1. The avionic components are as follows:

a. Digital computer including interface equipment
b. Pilot input control panel
c. Annunciator panel

The input control panel and annunciator panel shall be installed in the cockpit panel locations shown in figure 2. The desired computer location is an integrated unit with the control panel to minimize wiring and simplify the system. If this integration will increase the system cost the computer can be separately located in the electronic equipment bay. The proposed computer location shall be coordinated with Boeing.

3.1.2   Functional Description

To reduce approach time, fuel, and noise, the delayed flap approach procedure is initiated from a low drag configuration (e.g., clean) at a relatively high initial approach speed (e.g., 220 knots). Gear and flaps are extended while decelerating at a reduced power setting to the final approach speed. The final approach is stabilized in the landing configuration at a speed and altitude (above 500 feet) selected by the pilot. The remainder of the approach is conventional.

The deceleration phase of the approach is flown with throttles fixed, essentially at idle. Drag management, rather than throttle modulation is used to control energy so as to arrive at the selected stabilization altitude at the proper speed. The AEMS computer determines when the pilot should select the various flap, gear, and throttle settings. This is done with the computer algorithm defined in Appendix A, which performs three basic functions:

REV SYM

SHIPS POWER

ANNUNCIATOR PANEL
PILOTS CENTER PANEL

CONTROL PANEL
PILOTS FWD RADIO & RADAR
PANEL

CAPT.
AND F.O.
ADI

EPR

GEAR
FLAPS
INOP

DISPLAY DRIVERS

SERIAL DIGITAL RECEIVER AND DECODING

INTERFACE AND SERIAL DIGITAL XMITTER

1	2	3
4	5	6
7	8	9
COPY	0	CLEAR

VFINAL
VREF 30 — FIELD EL
WEIGHT — H MIN
TEST — G/S
ANGLE
OFF

FAST/SLOW INDIC IN ADI

THROTTLE ANGLE XDUCER

PROVISIONS FOR SWITCHING OF
FAST/SLOW TO EXISTING INPUTS

POWER SUPPLY

ROM READ ONLY MEMORY

RAM RANDOM ACCESS (SCRATCH PAD) MEMORY

CPU

SERIAL OUTPUT XMITTER AND LATCH

INPUT RECEIVER AND DECODE AND LATCH

ALTITUDE DUAL SYNCHRO TO DIGITAL DECODE

AIRSPEED SYNCHRO TO DIGITAL DECODE

FAST/SLOW INDICATOR SWITCH AND DIGITAL TO ANALOG CONVERTER

DME/RANGE PULSE SPACING TO DIGITAL CONVERTER

DME/RANGE RATE PULSE FREQUENCY TO DIGITAL CONVERTER

FLAP POSITION SYNCHRO TO DIGITAL CONVERTER

DISCRETE DATA INTERFACE

THROTTLE ANGLE ANALOG TO DIGITAL CONVERTER

FIELD ELEVATION ANALOG TO DIGITAL CONVERTER

COMPUTER

NEW PARTS COVERED IN SPECIFICATION

CONNECTION TO EXISTING SENSORS

FLIGHT DIRECTOR
MODE CONTROL PANEL
28VDC GO-AROUND LOGIC

| FINE | COARSE |
| BARO. CORRECTED ALTITUDE |
| ALTIMETER | |

| AIRSPEED |
| CADC |

| RANGE | RANGE RATE |
| DME RECEIVER | |

OUTBOARD FLAP POSITION SYNCHRO TRANSMITTER (3 WIRE SYNCHRO OUTPUTS)

ENGINE ANTI-ICE SWITCH

LANDING GEAR SELECTOR LEVER SWITCH

LANDING ALTITUDE POTENTIOMETER CABIN PRESSURE CONTROL COMPUTER

DELAYED FLAP AVIONICS SYSTEM

FIGURE 1

D.O. JACKSON : d.k.schaer

FAS/SLO INDICATOR ON ADI

ANNUNCIATOR PANEL

PILOTS' LIGHTSHIELD

CONTROL PANEL

CAPTAIN'S

FIRST OFFICER'S

PILOTS' FWD RADIO & RADAR
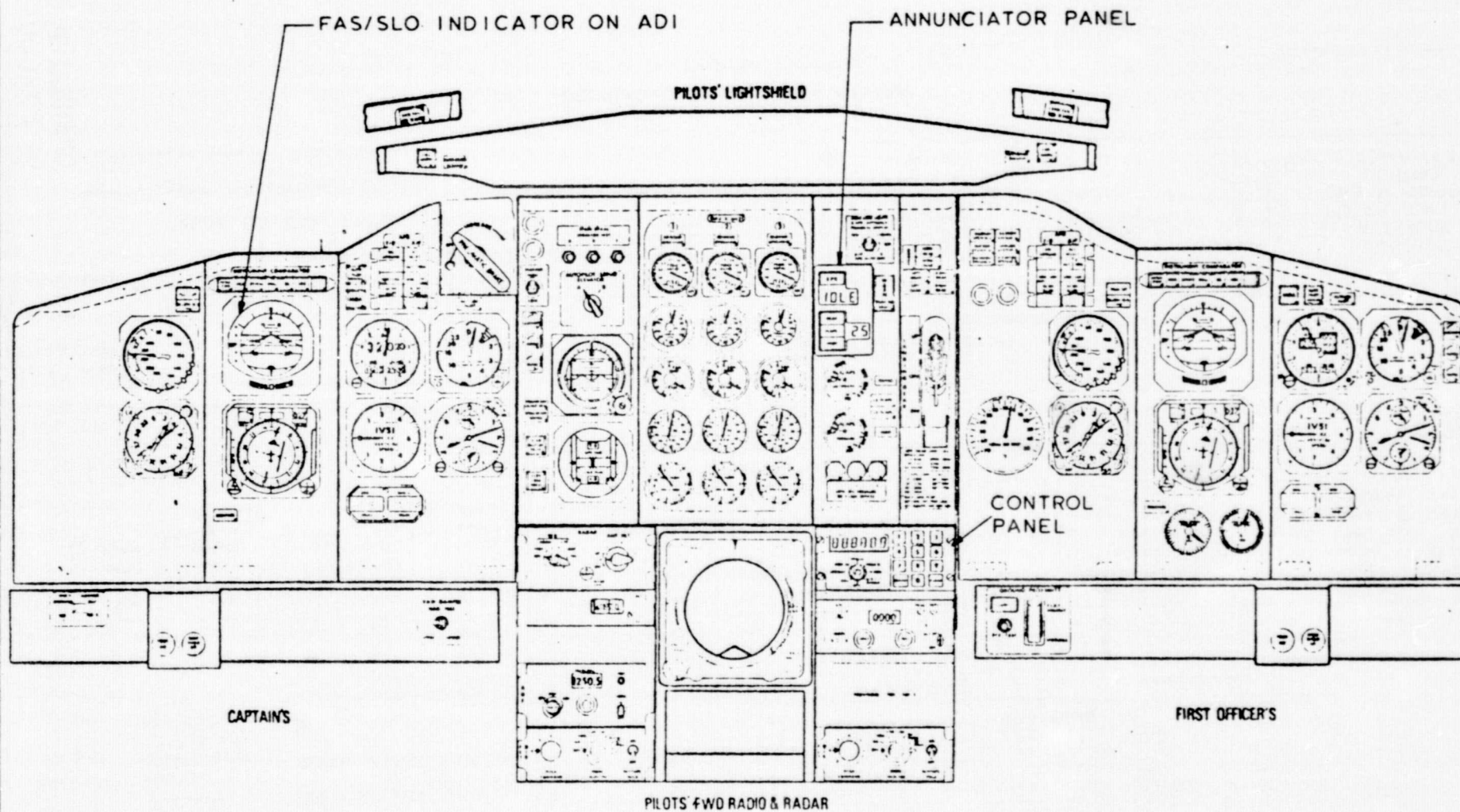
FIGURE 2 - COCKPIT PANEL LOCATIONS

a. Profile Prediction - A speed vs distance profile is computed starting at the existing flight condition and following a predetermined speed schedule for flap/gear/throttle setting. The prediction is updated at least once a second.

b. Operational Logic - Logic is provided to determine when the next flap/gear/throttle command should be displayed to the pilot, based on the results of the profile prediction.

c. Energy Indication - The predicted profile provides an energy reference for driving the "fast/slow" doughnut on the ADI.

The pilot input control panel is used to enter the desired final approach speed, stabilization altitude, and other operational variables (weight, glide slope angle, and field elevation).

The proper time to make the successive flap/gear/power settings is determined by the computer and displayed on the annunciator panel by illuminating the appropriate annunciator light. At the same time, the corresponding digital display indicates the desired flap or EPR setting. When the pilot responds to the command, as determined by the flap/gear/throttle position sensors, the annunciator light is turned off. A typical sequence is EPR IDLE, Flaps 2, Flaps 5, Flaps 15, Gear, Flaps 25, EPR 1.1, Flaps 30, EPR APP.

The AEMS operational modes are defined in section 3.1.3. System setup would normally be accomplished by the pilot as part of the descent-landing checklist. When first turned on, the system cycles through the "power-up" mode into the "standby" mode. Default values for all pilot input parameters except "WEIGHT" are automatically entered into the computer during the power-up sequence. The pilot enters the airplane landing weight using the selector switch and keyboard on the control panel, and monitors the input data on the lighted digital display. When weight has been set, the approach reference speed (VREF) and a default value for final approach speed (VFINAL) based on VREF will be computed and stored. The pilot can monitor these speeds on

REV SYM

the numerical display and can change the VFINAL input, if desired, by entering a new value through the keyboard. In a similar manner he can monitor and change the other input parameters. If power goes off, the WEIGHT input is zeroed, and the above sequence must be repeated. Otherwise, the inputs remain at the last settings.

With the computer setup complete, the pilot will leave the AEMS in the standby mode until the approach DME is tuned in and the airplane is on a final approach course intercept heading. Then the "compute" mode will be engaged to activate the annunciator panel and the fast/slow indicator. The compute mode incorporates an engage/run test sequence which checks for proper inputs and computer operation, as defined in section 3.5.1. The compute mode will be disengaged if an overshoot situation is predicted or if an engage/run test is failed. Compute mode disengagement and associated cockpit indications are discussed in sections 3.1.3.5 and 3.5.2.

REV SYM

3.1.3 Operational Modes

The system modes of operation shall be entered only as described in the following sections.

3.1.3.1 OFF Mode

When the selector switch is in the "OFF" position no electrical power shall be supplied to the system.

3.1.3.2 Power Up Mode

The power up mode shall be entered when the selector switch is moved from the "OFF" position, when airplane power is applied with the selector switch in any position except "OFF," and for power interruptions long enough to affect system operation.

The power up mode shall initiate the proper startup sequence to get the computer into the standby mode and to initialize the pilot set inputs and other data to ready the computer for a new problem.

3.1.3.3 Test Position

When the selector switch is moved to the "TEST" position a signal shall be applied to light all the displays and test the drivers and indicators.
The computer shall be in the standby mode.

3.1.3.4 Standby Mode

The computer shall enter the standby mode when the power up mode sequence is complete. In this mode pilot input data can be entered, changed, and displayed on the control panel. The annunciator panel shall remain off. The computer shall not compute the delayed flaps profile in this mode, but it shall compute an airspeed corresponding to the "WEIGHT" input to be displayed when the selector switch is in the "VREF 30" position.

The computer shall also enter the standby mode from the compute mode or inoperative mode when the "CLEAR" button or "INOP" press to reset indicator is pressed.

The fast/slow doughnut shall be out of view.

REV SYM

3.1.3.5   Compute Mode

The compute mode shall be engaged from the standby mode by pressing the "COMPUTE" button. The computer shall return to the standby mode if the "CLEAR" button is pressed.

When the compute mode is engaged, an engage/run test sequence shall be performed at the beginning of each computation frame as described in section 3.5.1. If these tests are passed the computation shall proceed through one complete flight profile prediction and command update cycle for the algorithm defined in Appendix A. The computer shall then return to the engage/run test sequence and repeat the process at the iteration rate defined in section 3.2.3.2. If the engage/run tests are not passed or if the overshoot warning output discrete is set, the AEMS shall immediately revert to the standby or the inoperative mode, depending on the situation, as defined in section 3.5.2.

Engagement of the compute mode shall be indicated by immediately lighting the digital flap position indicator on the annunciator panel and by moving the doughnut into view on the "fast/slow" indicator as soon as the proper indication has been computed. During a routine delayed flap approach, the fast/slow indicator shall continuously display energy reference information, and the FLAP/GEAR/EPR commands shall be annunciated at the proper times, as determined by the computer algorithm. Visual cockpit indications of command annunciation shall be as follows:

a.   Alert Light (Prior to Command) - none

b.   Command - The appropriate annunciator light(s) and the
     corresponding digital display (FLAP and/or EPR setting)
     shall illuminate steadily at the proper time for the
     pilot to select the new FLAP/GEAR/EPR setting as
     determined by the algorithm: FLAPS 5
                                         ↑ └ digital display
                                         └ annunciator light

22

c. Command Satisfied - When the pilot has responded to a command, as determined by the FLAP/GEAR/THROTTLE position sensors, the associated lights and digital displays shall blank out. An exception is the digital flap position display which shall remain illuminated as an indication that the compute mode is operating.

d. Failure to Set Approach Power - If throttles have not been advanced within three seconds after the "EPR APP" command is given, the "EPR" light shall begin flashing.

When in the compute mode it shall be possible to display, but not to change, selected data by rotating the selector switch. The inoperative mode shall take precedence on the display to show the cause of entering that mode.

3.1.3.6 Inoperative Mode

The inoperative mode shall be entered for several conditions:

a. The initial engage/run test sequence described in section 3.5.1 is not passed.

b. After the system is running in the compute mode one of the periodic engage/run tests as described in section 3.5.1 is not passed.

c. The algorithm computes that an overshoot will occur using the delayed flaps schedule, and sets the warning flag (IWARN).

When the inoperative mode is entered, the "INOP" indicator on the annunciator panel shall light and all other indicators on the annunciator panel shall go off. Pressing the "INOP" indicator

or the "CLEAR" button on the control panel, shall put the
computer into the standby mode and turn off the "INOP" indicator.
The other control buttons and switches shall not affect the
system except that turning the selector switch to the "OFF"
position shall turn the system and "INOP" indicator off.

When the inoperative mode is entered, the display on the
control panel shall not indicate pilot data inputs as in
the other modes; but it shall indicate a code word to
indicate the reason for entering the inoperative mode. If
incorrect pilot input data are detected, the display shall
indicate "DATA," so that the pilot can correct the input data
and go to compute again. If an input data sensor invalid flag
(e.g., DME flag) is detected the display shall indicate "FLAG."
If the computer has failed, the display shall indicate "FAIL"
so that the computer can be turned off and later checked.
If an overshoot is calculated, this display shall indicate
"FAST" so that the pilot knows that the computer is okay and
that he will have to change his approach or make a go-around.
If the initial approach interlock is engaged, an appropriate
indication such as illumination of all the light segments
shall be provided so the pilot will know the difficulty is asso-
ciated with the DME ground speed input, and that he can possibly
correct the problem and try again to enter the compute mode.

3.1.3.7 Maintenance Test Mode

The computer shall be turned on and be in a standby mode, and then the maintenance test mode shall be entered by operating a switch on the computer front panel. Any faults shall be shown on an indicator. The test mode shall only be momentary, long enough to perform the test as specified in section 3.5.9.

3.2 AEMS HARDWARE

3.2.1 Annunciator Panel

The annunciator panel shall consist of individually mounted parts conforming to the arrangement shown in figure 3. The panel shall be installed in the pilots' center instrument panel which will be visible to all the flight crew.

3.2.1.1 Modularity Requirements

The subassemblies in the annunciator panel such as the indicators, drivers, electronics, etc, shall be designed in a modular form so that the panel arrangement and size can be easily reconfigured for other airplane installations.

3.2.1.2 Display Requirements

The annunciator panel shall include the following displays:

EPR display section 3.3.7.7
GEAR display section 3.3.7.8
FLAPS display section 3.3.7.9
INOP display section 3.3.7.10

3.2.1.3 Panel Electronics

An objective shall be to locate all the driver and data receiver electronics on the annunciator panel to minimize the wiring required to the computer.

REV SYM

SHOWN
FULL
SCALE

2
1
3
4

EPR

8.888

3

GEAR

FLAPS

88

3

INOP
PUSH TO RESET

(SEE NEXT
PAGE FOR
FLAG NOTES)

5

FIG. 3   **ANNUNCIATOR PANEL**

3   **6**

00000.00

1	2	3
4	5	6
7	8	9
COMP	0	CLEAR

VFINAL
VREF 30   FIELD EL
WEIGHT   H MIN
DIM
TEST   G/S
ANGLE
OFF
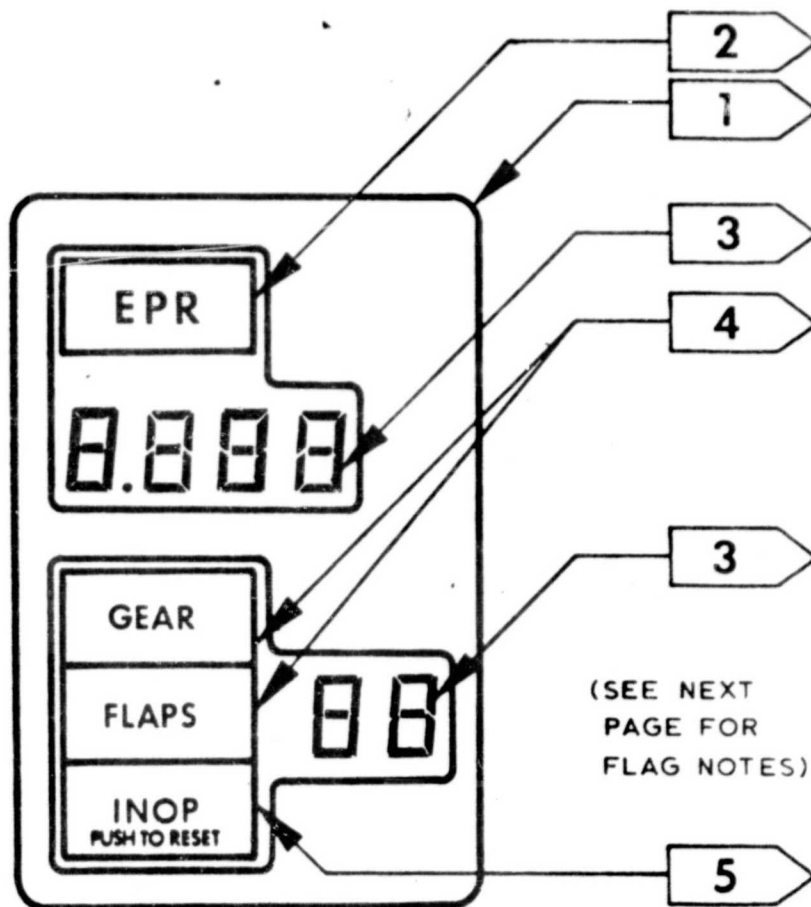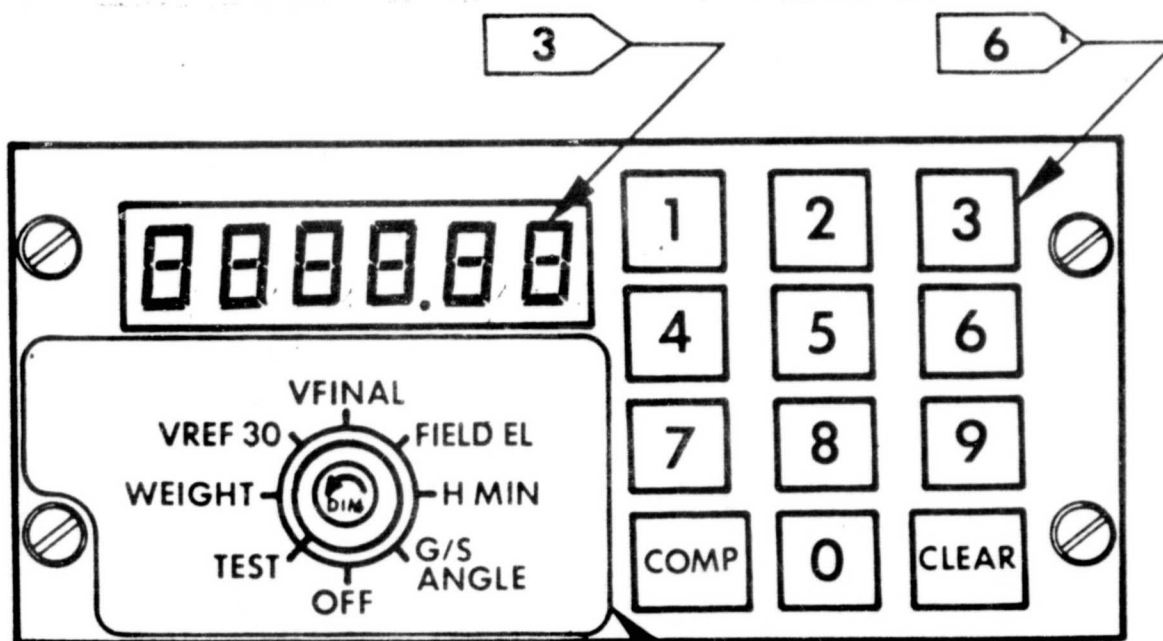
FIG. 4 **CONTROL PANEL**

1

1> Lightplate to conform to Boeing documents 10-61437 (707), 10-61467 (727) and 10-61800 (737) as required.

2> Annunciator light to conform to Boeing document 10-61803. Character height to be .156 in. Letters to be translucent, visible at all times, on an opaque black background. When energized will show illuminated white letters.

3> Seven segment, incandescent lighted matrix display, character height approximately as shown. Light intensity to be 300 ± 150 foot lamberts at 5 volts DC when full bright and 0.6 ± .2 foot lamberts when in the full dim position. Characters to be illuminated white.

4> Annunciator light to conform to Boeing document 10-61803. Character height to be .125 in. Letters to be translucent, visible at all times, on an opaque black background. When energized will show illuminated white letters.

5> Switch light to conform to Korry 318-630 series specification. Character height to be .125 in. Letters to be translucent, visible at all times, on an opaque black background. When energized will show illuminated amber letters.

6> Keyboard push-button switches to be illuminated white background with opaque black engraved characters. Maximum light intensity to be 3 ± 1 foot lamberts at 5 volts DC. Provisions to be made for hookup to the general control panel background dimming circuit.

1-6: Flag notes for Figures 3 and 4

REV SYM

3.2.2 Control Panel

The control panel shall be a standard "DZUS" mounted panel conforming to the dimensions shown in figures 4 and 5. The panel shall be installed in the pilots aisle stand panel.

3.2.2.1 Control Inputs Required

The control panel shall include the following provisions for pilot input data:

Weight input - Section 3.4.1.6
Final approach speed input- Section 3.4.1.7
Field elevation input - Section 3.4.1.8
Minimum altitude input - Section 3.4.1.9
Glide slope angle input - Section 3.4.1.10

There shall be a numerical pushbutton keyboard containing the numbers 0 through 9 and a "CLEAR" and "COMPUTE" button to enter the pilot input data. There shall be a rotary selector switch to select the above inputs for display or entry from the keyboard. The selector switch shall have the following positions in order:

1. "OFF"
2. "TEST"
3. "WEIGHT"
4. "VREF30"
5. "VFINAL"
6. "FIELD EL"
7. "H MIN"
8. "G/S ANGLE"

There shall be a mechanical stop to prevent the switch from going past the "G/S ANGLE" position in a clockwise direction to the "OFF" position.

D1 4100 7740 ORIG. 3/71

5.75 ± .000 / .020

5.365 ± .005

.192 ± .000 / .010

2.625 + .000 − .030

1.500 ± .005

VFINAL
VREF 30 — FIELD EL
WEIGHT — H MIN
TEST — G/S ANGLE
OFF

1 2 3
4 5 6
7 8 9
COMP 0 CLEAR

.562 ± .000 / .015

ELECTRICAL CONNECTOR

5.75 MAX

5.00 MAX
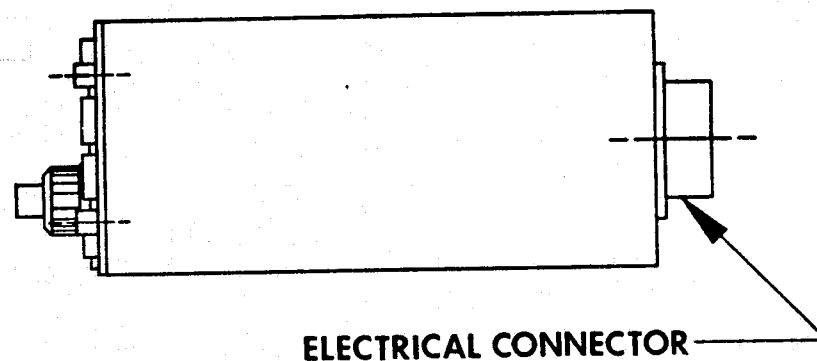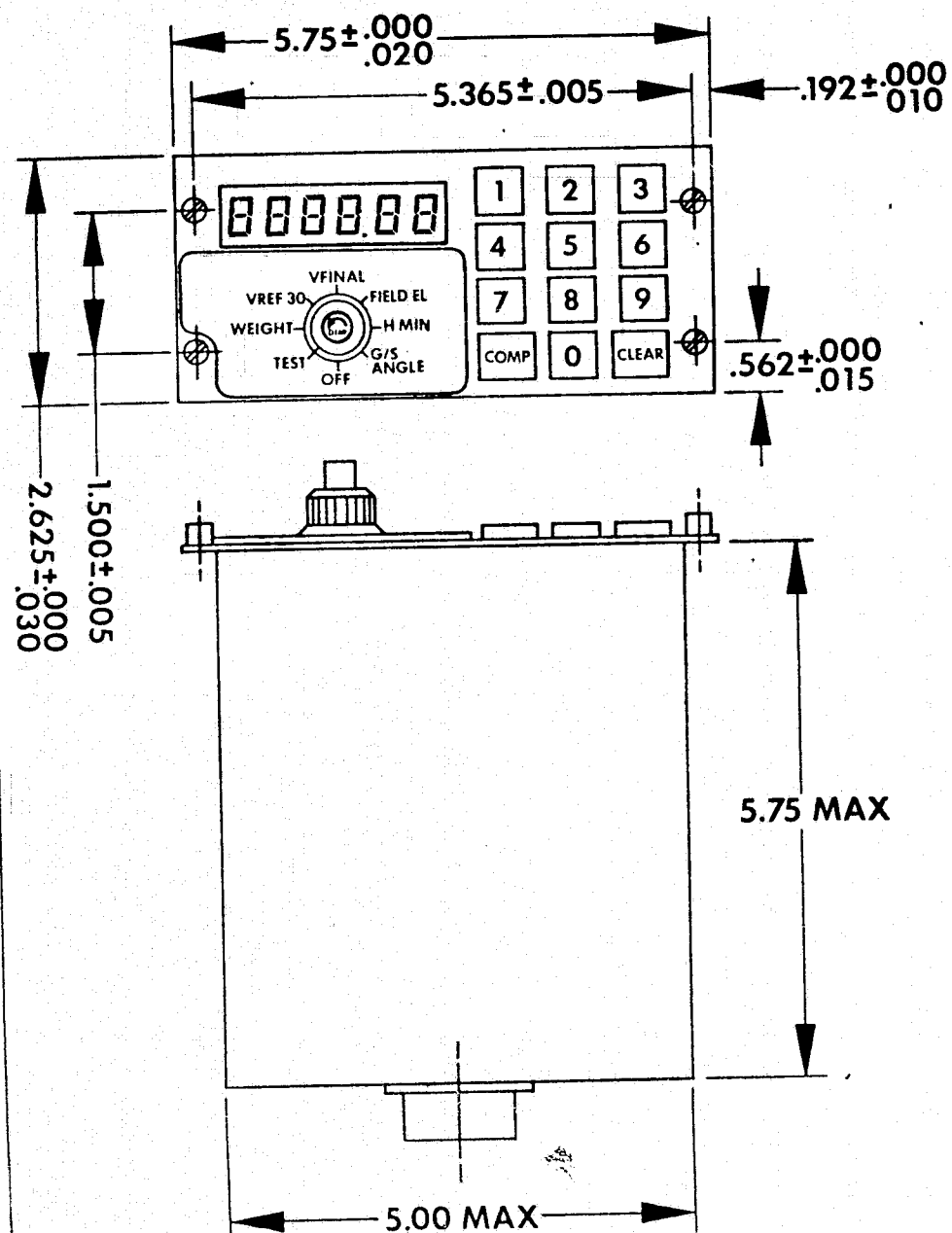
CONTROL PANEL DIMENSIONS

FIGURE 5

29

3.2.2.2   Input Operation

The operation of the control panel for inputs shall be as follows:

a.   The numerical value of each variable in the computer shall be
     displayed on the numeric display on the control panel as the
     selector switch is rotated to the appropriate position, such
     as "WEIGHT."

b.   A new value can be set into the computer by pressing the "CLEAR"
     button and then typing in the proper numerical value on the key-
     board. The numeric display shall become blank as the "CLEAR"
     button is pressed and display the numbers as the keys are depressed
     automatically positioning the numbers and zeros to correspond to
     the data being input. The "VREF30" value is a function of weight
     input, is a display value only, and shall not be affected by the
     "CLEAR" or other keys.

c.   The keyboard input shall be transmitted to the computer and then
     the computer shall then transmit back the information to be
     shown on the display to serve as a check that the computer received
     the data correctly. The display shall not be controlled directly
     by the keyboard.

3.2.2.3   Compute Operation

The use of the "COMPUTE" pushbutton switch to engage the system is
described in section 3.1.3.5. The system may go into the inoperative
mode as described in section 3.1.3.6 if certain tests are not passed.
When in the inoperative mode the "INOP" indicator on the annunciator
panel shall come on and the display on the control panel shall display
a code word to indicate the fault rather than the data indicated by
the selector switch position.

3.2.2.4   Numeric Display

A numeric display shall be provided with the capability of displaying
up to six numbers. The display shall also have the capability of

displaying certain code words by making use of the standard 7 segment bars to form a restricted set of alphabetical characters. A decimal point will be required in one position to display a two-place fraction for glide slope angle (example 2.75 degrees). The numbers and characters shall be under computer program control.

3.2.2.5 Panel Electronics

An objective shall be to locate the data transmitter electronics on the control panel to minimize the wiring required to the computer.

3.2.3 Computer

The computer shall be a general purpose, internally stored program machine of minimum reasonable size and weight.

3.2.3.1 Configuration

The desired computer configuration is an integrated unit with the control panel, generally within the size constraints of figure 5. This configuration shall be used if practical and cost effective, otherwise the alternate configuration shall be used.

The alternate configuration shall locate the computer in the electronic equipment bay. The computer shall be designed as a standard ATR size case in accordance with the requirements of ARINC characteristic 404A, "Air Transport Equipment, Case and Racking." The rear electrical connectors shall be a standard type to be agreed upon with Boeing. Pin assignments are to be coordinated with Boeing.

The computer shall be furnished with Camlock Fastener Corp equipment handles, Model 4012-2 or Deutch Part No. D4100-1A.

3.2.3.2 Speed

The computer shall have a computational cycle frame time of one second or less. The entire delayed flap schedule algorithm and the periodic confidence test shall be capable of iteration in a maximum of two-thirds of this frame time. Portions of the program will be multirated

REV SYM

and will be performed many times during each frame time, such as the fast/slow drive which requires an update each .1 second.

3.2.3.3   Memory

During the software development phase the program memory shall be programmable by the supplier and nonvolatile. This memory can be either removable semiconductor memory which is reprogrammed in a separate machine or core type memory which can be reprogrammed within the computer. The final production program storage shall be a read-only type (ROM) memory. Differences in the development and production memories shall not affect the system performance.

3.2.3.4   Overflow

"Software failures" resulting from arithmetic overflow shall be prevented. The methods of prevention employed may include but shall not necessarily be limited to:

a. Proper scaling to prevent overflow
b. Software limiting at key computational points
c. Automatic detection of and failure indication for conditions not prevented by a. and b.

3.2.4   Data Adaptor

The computer shall contain a data adaptor that will provide the necessary interfacing between the digital computation and the input and output devices. This adaptor shall contain the necessary analog to digital converters, buffer amplifiers, digital transmitters and receivers, discrete data converters, and any necessary multiplexers.

The following sections contain necessary requirements or specifications for design:

a. Computer output   - Section 3.3.7
b. Pilot set inputs   - Section 3.4.1
c. Fast/slow display   - Section 3.4.2
d. Existing aircraft sensors - Section 3.4.4
e. Additional transducers   - Section 3.4.5
f. System test and interlocks - Section 3.5

3.3 AEMS SOFTWARE

3.3.1 Computer Algorithm

The supplier shall implement the AEMS Algorithm defined in this specification by using the flow charts shown in section 3.3.1.1 and the Fortran listing in section 3.3.1.2. The supplier shall develop the necessary software to implement the input and output functions, test functions, and other requirements described in this specification. It is important that the software and hardware be implemented in such a way that the unit can be readily checked and tested as described in section 3.3 for verification and validation of the program.

3.3.1.1 Flow Chart

The AEMS Algorithm is described in the flow chart shown in Appendix A and the Fortran listing in section 3.3.1.2. The Fortran variables and program step numbers are carried over to the flow chart for easy reference.

3.3.1.2 Program Listing

The AEMS Algorithm shown here has been developed as a Fortran program that is presently run on a NOVA computer. The supplier shall develop the program for the system by translating this Fortran program into the appropriate language and format for the computer that is to be supplied. The program listing is shown in Appendix A.

3.3.1.3 Symbol Definition

Symbol definition is shown in Appendix A.

3.3.1.4 Memory Organization

The computer read only memory (ROM) storage for certain portions of the AEMS algorithm shall be specially organized and physically located in a minimum number of memory units that can easily be changed. The portions of the program that compute the drag and engine performance characteristics shall be organized in this manner and shall be configured so that the constants in the program can be

easily changed by replacing the memory units with other ones. This shall allow easy alteration of the system for development and other airplane configurations.

3.3.2 Supplier Software Document

The supplier shall furnish early in the program, and update as required, a software document that illustrates how the software requirements of this specification are being met and the software and related hardware features of the system.

This document shall also contain the following:

a. Details of computer architecture, speed, limitations, etc.

b. Details of computer software instruction sets, coding microinstructions, limitations, etc.

c. Structural arrangement of the AEMS System software as implemented in the computer.

d. Detailed descriptions of higher level language systems if used.

3.3.3 Flight Resident Program

The supplier shall furnish a complete assembly and machine code listing and tape of the program implemented in the computer when the first system is delivered to Boeing. The format and method shall allow convenient checking of the system as detailed in section 3.3.5.

3.3.4 Software Support Programs

The supplier shall furnish the required software support programs, documentation, and references required to allow Boeing to follow and duplicate if required, the software development to the machine code level. Boeing will not have the capability to load the program into the computer.

REV SYM

3.3.5 Simulation Program

The supplier shall furnish early in the program a software program that will enable Boeing to implement a simulation of the operation and instruction sets of the airborne computer. This simulation shall be implemented on a convenient Boeing computer that will be agreed upon in cooperation with the supplier. The simulation shall be capable of the following tasks:

a. Verify and test the operation of the critical software elements prior to receipt of the first computer.

b. Determination of the effects of errors and failures in the software and hardware.

c. Developing changes of the system for different airplane configurations or conditions

3.3.6 Verification and Validation

The computer shall be designed for ease of software access, control, and connection with external test equipment and output peripherals, to allow the following:

a. Verification that a correct, error free program is resident in the computer

b. Validation that the software modules and overall system work as planned

The system shall be designed for convenient software and hardware troubleshooting. A debug method shall be available using external test equipment and printer that shall perform at least the following functions:

a. Single step program execution
b. Stop at address
c. Print contents of memory locations, registers, data inputs, etc
d. Print output of computational subroutines while stopped or running

e. Print out contents of data tables and constants

f. Display address and contents of memory locations while running or stopped

g. Print out of memory block dumps

h. Check sums of memory

3.3.7 Computer Output

The system shall provide output displays and associated decoding and drivers to indicate to the pilot the computer output. These devices shall be arranged on the annunciator panel as described in section 3.2.1 and drive a fast-slow indicator on the attitude director indicator (ADI).

3.3.7.1 Display Design Objectives

A design objective shall be to provide the following:

a. High reliability
b. Good visibility and readability
c. Compact and rugged design at reasonable cost
d. Means for testing and/or failure monitoring

3.3.7.2 Display Data Requirements

The suppliers shall furnish data on the selected displays and driving electronics to indicate the following information:

a. Expected service life
b. Reliability
c. Visibility and readability under various ambient light conditions

d. Environmental effects, temperature, vibration, etc

3.3.7.3 Serial Data Transmission

The display system shall incorporate a serial digital transmission system to minimize the number of wires between the displays and

the computer. This shall not be a requirement if there is an unfavorable tradeoff of cost versus number of wires saved.

3.3.7.4 Signal Interfacing

The computer drive signals to the displays shall be buffered, filtered, and error corrected if necessary to insure that external noise or interference cannot produce incorrect pilot displays.

3.3.7.5 Display Power

The electrical power for the displays, drivers, and other interface units shall be supplied by the computer.

3.3.7.6 Fail-Safe

The display electronics and displays shall be designed for a fail-safe configuration such that a failure cannot display an incorrect command.

3.3.7.7 EPR Display

The engine pressure ratio (EPR) display shall be an illuminated "EPR" indicator followed by a numeric display capable of showing the legends "APP", "IDLE", "1.1", and "1.2." The display shall be under computer control and capable of flashing as well as steady illumination.

3.3.7.8 Gear Display

The flaps display shall be an illuminated "GEAR" indicator. The display shall be under computer control and capable of flashing as well as steady illumination.

3.3.7.9 Flaps Display

The flaps display shall be an illuminated "FLAPS" indicator followed by a numeric display capable of showing the numbers 0, 2, 5, 15, 25, and 30. The display shall be under computer control and capable of flashing as well as steady illumination.

REV SYM

3.3.7.10 Inoperative Display

The inoperative display shall be illuminated "INOP" indicator. The display shall be under computer control and capable of flashing as well as steady illumination.

3.3.7.11 Fast/Slow Output

The computer shall provide drive current to a fast/slow indicator and provide mode switching as described in section 3.4.3.1 and section 3.4.3.2.

3.4 SYSTEMS INTERFACE

The delayed flap avionics will interface with various systems by several means as described in this section. These interfaces include existing airplane sensors, new transducers, pilot set inputs, and a fast/slow display.

3.4.1 Pilot Set Inputs

The system shall provide a switch system for the pilot to communicate initial conditions to the computer. These switches shall be arranged on the control panel and operate in the manner described in section 3.2.2.

3.4.1.1 Pilot Set Input Design Objectives

A design objective shall be to provide the following:

a. High reliability
b. Digital output
c. Means for testing or failure monitoring

3.4.1.2 Transducer Data Requirements

The supplier shall furnish data on the selected transducers to indicate the following information:

a. Expected service life
b. Reliability

c. Environmental effects such as dirt, moisture, temperature, vibration, etc

d. Actual service performance characteristics

3.4.1.3 Serial Data Transmission

The pilot set input system shall incorporate a serial digital transmission system to minimize the number of wires between the transducers and the computer.

3.4.1.4 Signal Interfacing

Incoming digital signals shall be received by dedicated line receivers. The signals shall be buffered, filtered, and error corrected if necessary to insure that external noise or interference cannot produce incorrect inputs to the computer.

3.4.1.5 Control Panel Power

The power to the control panel and remote signal converters or transmitters shall be supplied by the computer.

3.4.1.6 Weight Input

The weight input shall allow manual setting and visual readout of the setting, of airplane weight in 1000 pound increments from 110,000 to 155,000 pounds. The weight input shall be automatically cleared to zero when the computer goes into the standby mode such as at the conclusion of the approach.

3.4.1.7 Final Speed Input

The final speed input shall allow manual setting and visual readout of the setting of the final stabilization speed in 1 knot increments from 110 to 160 knots. The computer shall compute VREF30 from the weight information and display for the "VREF30" switch position. The computer shall add 5 knots margin to this speed and use it for the initial input and display for the final speed input "VFINAL". The

pilot can then change the value if he desires a different speed. These speeds shall be automatically cleared to zero with the weight input when the computer goes into the standby mode such as the conclusion of the approach.

3.4.1.8   Field Elevation

The field elevation input shall allow manual setting and visual readout of the setting, of airport field elevation, in 1 foot increments from 0 to 10,000 feet. When power is applied the computer shall initialize the input and display at the value of landing altitude as derived from the cabin pressurization system. The pilot can then change the value if he desires. The last entered value shall remain until the power is turned off.

3.4.1.9   Minimum Altitude

The minimum altitude input shall allow manual setting and visual readout of the setting, of minimum altitude in 100 foot increments from 500 to 1000 feet. When power is applied the computer shall initialize the input and display at a value of 500. The pilot can then change the value if he desires. The last entered value shall remain until the power is turned off.

3.4.1.10   Glide Slope Angle

The glide slope angle shall allow manual setting and visual readout of the setting, of glide slope angle as a three digit, two place decimal between 2.50 and 3.50 degrees. When power is applied the computer shall initialize the input and display at a value of 3.0 degrees.   The pilot can then change the value if he desires. The last entered value shall remain until the power is turned off.

3.4.2   Fast/Slow Display

The computer shall provide an analog output current to drive a fast/slow indicator in the pilot and copilot's attitude director indicators (ADIs), and an indicator switching circuit.

REV SYM

3.4.2.1 Fast/Slow Indicator Drive

The normal drive current required is $\pm$ 2.2 MA $\pm$ 10 percent for full scale deflection in either direction around neutral. The meter drive load is 1000 $\pm$ 100 ohms.

The driver shall have the capability of driving ADI fast/slow indicators with other drive current requirements either by change of software scaling or by a plug-in adaptor. The range of currents required for full-scale deflection is from $\pm$ 2.2 MA to 135μA.

3.4.2.2 Fast/Slow Indicator Switching

The computer shall include a well isolated switching circuit to switch the fast/slow indicator drive from its normal operation with other equipment to operation from the delayed flaps system. The switching shall occur only when the computer is in "COMPUTE" mode and shall revert to normal operation when not engaged, when the power is off, or for failure conditions.

3.4.3 Aircraft System Interfacing

3.4.3.1 Interface Isolation

Incoming signals shall be individually conditioned in dedicated signal circuits designed to provide buffering and isolation. These circuits shall be fail-safe such that failures will not propagate or degrade the incoming signal for normal airplane use.

3.4.3.2 Signal Interfacing

Incoming digital signals shall be received by dedicated line receivers. The signals shall be buffered, filtered, and error corrected if necessary to insure that external noise or interference cannot produce incorrect inputs to the computer.

3.4.3.3 Signal Conversion

Incoming analog signals shall be prefiltered prior to analog to digital conversion to eliminate aliasing, foldover, and other sampled

data phenomena. Prefiltering of individual signals shall be determined by the iteration rate of the computation in which the variable is used.

The incoming signals may be either individually converted to digital signals or scaled and demodulated and then multiplexed through a single analog to digital converter.

3.4.3.4 Failure Warning Signals

The interface shall also be capable of receiving any failure warning signals from the sensor, such as the Distance Measuring Equipment (DME) flag, so that the computer can indicate a failure. A method of testing for valid data from those sensors not having failure warning signals should be devised if possible.

3.4.4 Existing Aircraft Sensors

The input for some parameters shall be provided from sensors that form part of the existing airplane signaling system as described in this section.

3.4.4.1 Navigation Sensors

The range (distance) and the range rate (velocity) input shall be supplied by the Distance Measuring Equipment (DME) as described in ARINC specification 568-4.

The range is transmitted as a pulse pair with a spacing proportional to range, according to the following formula:

$$\text{PULSE SPACING(MICROSECONDS)} = 50 + 12.39 \times \text{DISTANCE (NAUTICAL MILES)}$$

An alternate range output is also provided as a serial binary coded decimal output and this may be used instead of the pulse pair if desired.

The range rate is transmitted as an output pulse with every .01 nautical mile change in distance. The accuracy of conversion shall be within ± .1 nautical mile for range, and ± 1 knot for range rate.

3.4.4.2 Airspeed

The airspeed inputs shall be obtained from the Central Air Data Computer (CADC) as described in Boeing Specification 10-61229 or 10-61439.

The airspeed input is supplied as a synchro signal with a scale factor of 1.5 knots per degree. The decoding range required is from 120 to 200 knots and a required decoding accuracy of $\pm$ .5 knot. The input to the computer for this signal shall be high impedance balanced load higher or equal to an ARINC 500 ohm control transformer.

3.4.4.3 Altitude

Barometrically corrected altitude is available from the altimeter output which also serves the "Altitude Alert" system. The altitude input will be supplied as a dual synchro signal as described by Boeing Specification 10-61826, section 3.3.8.2 with the following characteristics:

Fine synchro -   Scale factor of 360 degrees per 5000 feet

Coarse synchro -   Scale factor of 360 degrees per 135,000 feet

Deconding Range Required $\}$- 0 ft to 15,000 ft and decoding accuracy of $\pm$ 20 ft

Electrical Characteristics $\}$- Size 8 synchro (ARINC 545) indexed at 0 ft

3.4.4.4 Flap Position

The flap position input will be supplied from the outboard flap position transmitter as described in Boeing Specifications 10-61317 and 10-60791.

The flap position input is supplied as a synchro signal that is a function of flap travel not flap angle. The minimum decoding range is -7 to 280 electrical degrees and a required decoding accuracy of $\pm$ 1 degree.

The input to the computer for this signal shall be high impedance balanced load higher or equal to an ARINC 500 ohm control transformer.

3.4.4.5 Landing Altitude Input

The system shall provide field elevation for initializing the computer by using landing altitude information from the Cabin Pressure Control System as described in Boeing Specification 10-61209.

The landing altitude signal consists of a d.c. voltage produced by a manually set potentiometer control. The signal is a nonlinear function of altitude but sufficient accuracy will be obtained by assuming that the signal is linear with a scale factor of -.6442 volts per 1000 feet starting at 7.954 volts for 0 feet of altitude. The decoding range required is 8.1 volts to 1.5 volts with a conversion accuracy of $\pm$ .025 volts.

The input to the computer shall be a very high impedence load in excess of 10 megohms to minimize any loading influence on the signal.

The tapped off signal shall be suitably isolated to preclude any affect on the Cabin Pressure Control System due to any single failure or feedback disturbance within the Delayed Flap System.

3.4.4.6 Engine Anti-ice

The system shall provide indication of engine anti-ice operation by sensing the position of the engine anti-ice switch located on the pilots' overhead panel. The switch, when closed (anti-ice activated), will provide a ground for the sense circuit. Each of the sense circuits shall be isolated from the anti-ice circuitry by a series resistor and diode to preclude any possible feedback disturbance or single failure condition from affecting operation of the anti-ice system. The sense circuit, which is part of the AEMS system, shall show when anti-ice is being used on one or more engines. Filtering of the input signal shall be provided to preclude short term transients and noise from affecting the anti-ice on signal.

3.4.4.7 Landing Gear

The system shall provide indication of landing gear extension by sensing the position of the landing gear select lever. This lever, when down, will close a switch which will provide a ground for the sense circuit. The sense circuit shall be isolated from the landing gear logic circuit by a series resistor and diode to preclude any possible feedback disturbance or single failure condition from

affecting operation of the landing gear system. Filtering of the input signal shall be provided to preclude short term transients and noise from affecting the landing gear down signal.

3.4.4.8   Flight Director Mode Switch

The system shall obtain an indication that the flight director "go around" mode has been selected by tapping off 28 vdc from the flight director mode control panel connector: Collins 614E-7E pin J1-7, or Collins 614E-10 series, pin 19.

3.4.5   Additional Transducer

An additional transducer shall be added to the airplane to sense required information where the airplane does not have an existing data source. Boeing will supply the mounting bracket. The supplier shall provide the transducer and coordinate its selection with Boeing.

3.4.5.1   Throttle Angle Transducer

A new transducer shall be provided as part of the system to sense throttle angle position. This transducer will be mounted as shown in figure 6 on a pulley and bracket to be supplied by Boeing. This will allow the transducer to sense throttle cable motion for the left engine.

The transducer shall allow 360° rotational mechanical travel with no stops. The electrical sensing range shall be a minimum of 160° from idle to the forward stop. A mechanical indication or assembly method shall be provided for zero alignment with the pulley.

An objective shall be to provide a transducer with a digital readout if economically feasible.

REV SYM

FWD
LEVER
STOP

STA.
362.25

IDLE RIG POS.

REVERSE
LEVER
STOP

1.500

WL 203.61

THROTTLE
CABLE
PULLEY

THROTTLE ANGLE
TRANSDUCER
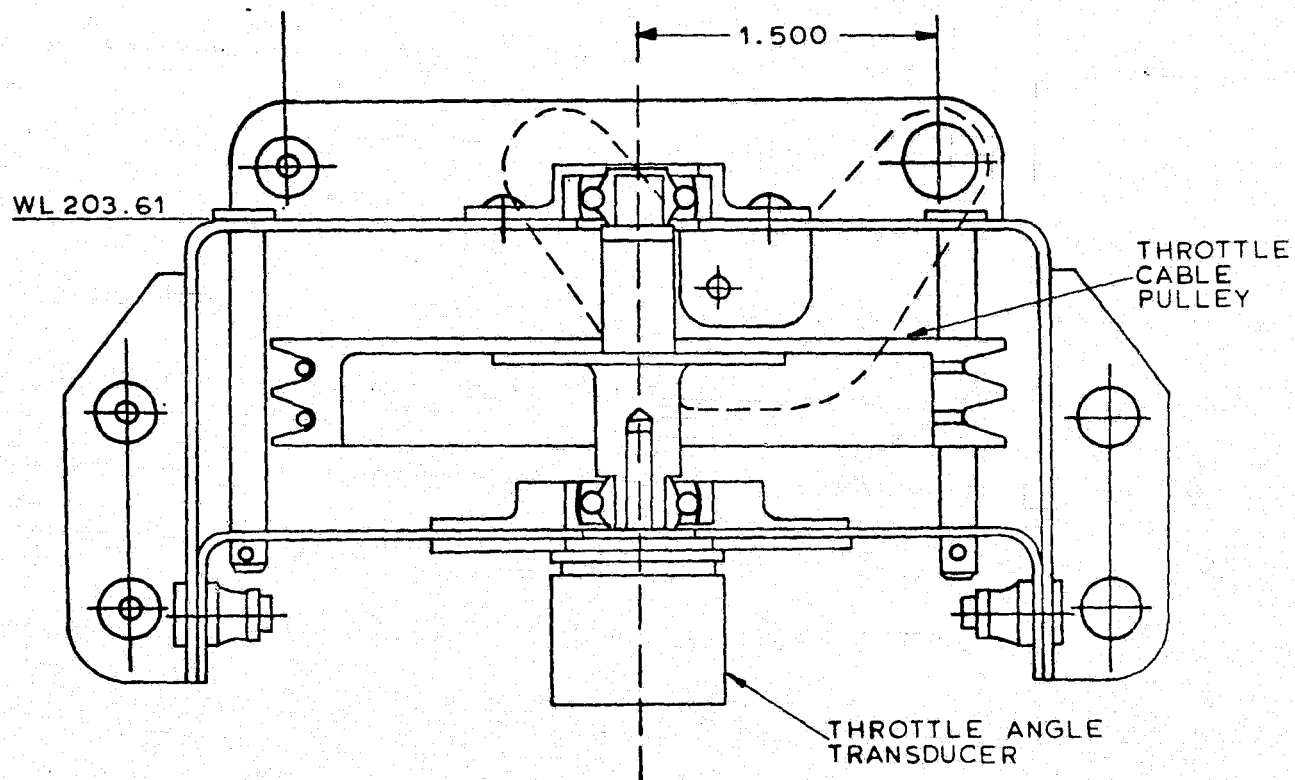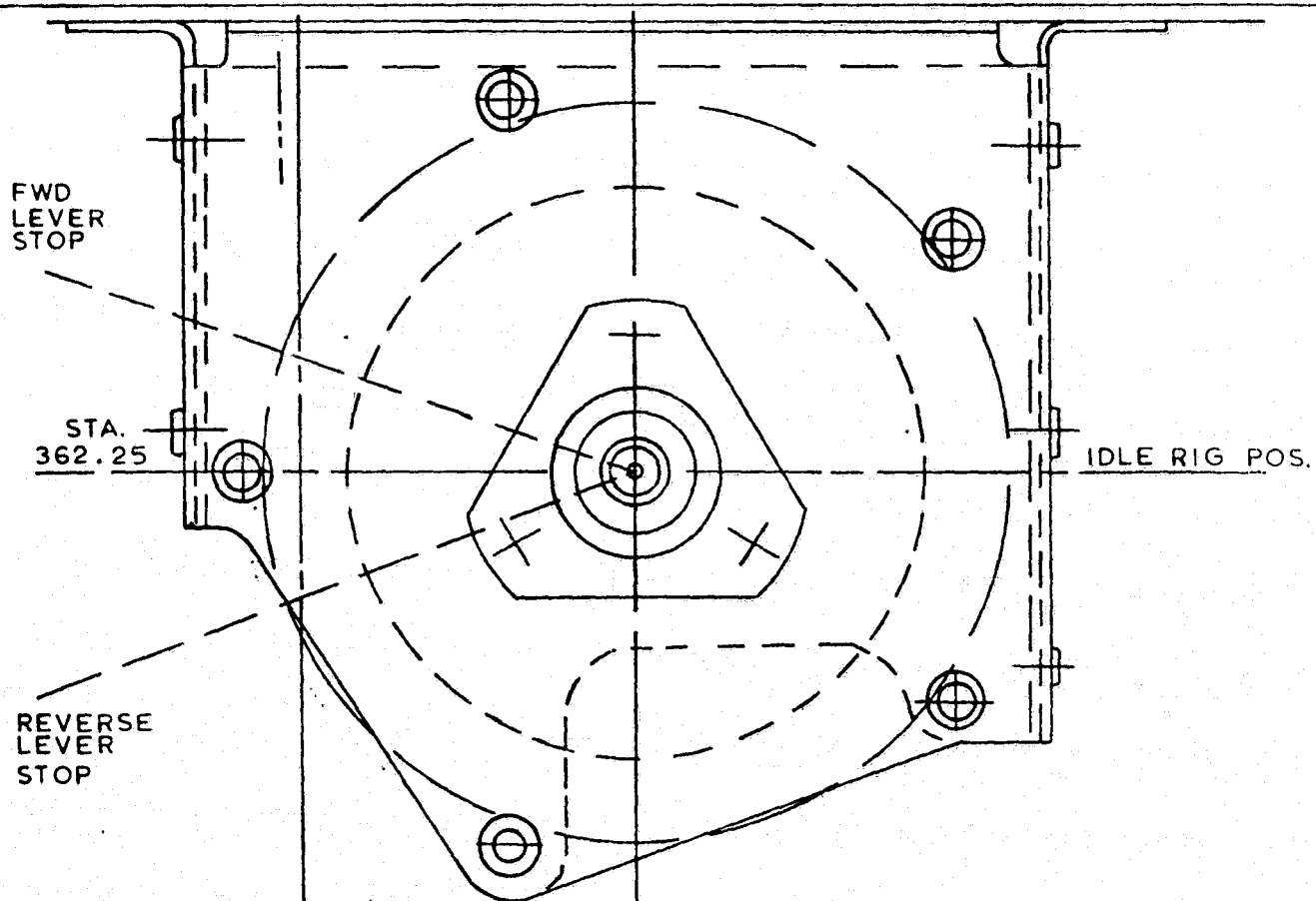
FIG. 6 THROTTLE ANGLE TRANSDUCER INSTALLATION

REV SYM

3.5   SYSTEM TEST AND INTERLOCK

3.5.1   Engage/Run Tests

The computer shall initiate an engage test sequence when the
compute mode is engaged. This sequence shall include the
following tests:

a.   Operational Interlocks   - Section 3.5.3
b.   Valid Input Tests   - Section 3.5.4
c.   System Failure Tests:

     o   Interface Test   - Section 3.5.5
     o   Computer Self Tests - Section 3.5.6
     o   Loss of Electrical   - Section 3.5.7
          Power
     o   Computer Lockup   - Section 3.5.8

The computer shall repeat these tests or a modified version of them
at least once a second while running in the compute mode. If any
test is failed the system shall disengage from the compute mode.

3.5.2   Disengage Features

Upon disengagement from the compute mode, the AEMS shall revert to
standby or inoperative mode. When disengaged, the doughnut on the
fast/slow indicator shall be moved out of view and the FLAP/GEAR/EPR
annunciator lights and digital displays shall blank out. The mode
to be entered; the "INOP" light status, and the message to be
displayed on the control panel shall be as defined below:

Cause of Disengage	Mode to Enter	"INOP" Light	Code Word*
o "Clear" button actuated	Standby	Off	Selected Data Readout
o Operational Interlock			
(1) Runway Threshold	Standby	Off	Selected Data Readout
(2) Go Around	Standby	Off	Selected Data Readout
(3) Initial Approach	Inoperative	On	All Segments Lighted

*See Section 3.2.2.4

REV SYM

Cause of Disengage	Mode to Enter	"INOP" Light	Code Word*
o Valid Input Test			
(1) Pilot Input	Inoperative	On	"DATA"
(2) Sensor Input	Inoperative	On	"FLAG"
o System Failure Test	Inoperative	On	"FAIL"
o Loss of Electrical Power	Sequentially: (1) Inoperative (2) Power up (3) Standby	On	Blank
o Overshoot Prediction	Inoperative	On	"FAST"

When in the inoperative mode, pressing the "INOP" button or the "CLEAR" button shall return the computer to the standby mode and turn off the "INOP" light.

3.5.3 Operational Interlocks

Since compatibility with visual approaches (VASI) is a design objective for the AEMS, interlocks with the ILS localizer and/or glide slope are not specified. The pilot is primarily responsible for engaging the compute mode at the proper time. However, operational interlocks with the DME and flight director systems are specified to preclude compute mode operation under certain conditions as follows:

a. Approach Complete - The system shall revert to the standby mode when the delayed flap approach is complete as indicated by breaking of one of the following interlocks:

   (1) Runway Threshold - The runway threshold interlock shall be broken when DME range becomes less than 1000 ft (absolute value)

   (2) Go-Around - The go-around interlock shall be broken when the flight director is switched into the go-around mode.

b. Initial Approach - The system shall revert to the inoperative mode unless range as sensed by the DME is decreasing at a rate greater than 50 knots. The DME failure flag is tested as part of the valid input tests described in section 3.5.4.

The intent of the decreasing DME range requirement is to preclude engaging the compute mode until proceeding inbound. The 50 knot minimum DME ground speed requirement provides a gross check on several other conditions under which the system should not be engaged:

o Erroneous ground speed input

o Large approach course intercept angle (e.g., DME range rate would be near zero for a 90 degree intercept)

o Extreme headwinds

3.5.4 Valid Input Tests

3.5.4.1 Pilot Set Inputs

All pilot set inputs must be within normal operating limits.

3.5.4.2 Sensor Inputs

The computer shall test the input sensors for the following:

a. Sensor failure flags, if available

b. Valid transducer tests, if available

All sensor inputs shall be tested for reasonableness. In case of a single-sensor invalid flag or unreasonable sensor input, a sensor data substitute routine shall be entered to replace the bad data for up to 5 computation cycles. If the bad data or sensor invalid persists for more than 5 cycles, the computer shall enter the "INOP" mode.

3.5.5. Interface Tests

The computer shall test the input and output units such as the following:

a. Synchro, pulse, and discrete signal converters

b. Digital to analog converters

c. Digital data transmitters and receivers

3.5.6 Computer Self Tests

The computer shall perform a test of itself to verify that it is functioning properly. The minimum tests shall include:

a. Central Processor Unit (CPU)

o Instruction set

REV SYM

o   Addressing modes

o   Register operations

NOTE: Proposals of alternate implementations of the computer
        confidence test will be considered.

b. Control Unit (CU)

o   Microprocessor cperations (if any)

o   Program timing (real time check, execution order,
    Iteration reset)   /

c. Memory Unit

o   Scratch pad operability

o   Memory contents (program and fixed data)

3.5.7   Loss of Electrical Power

The computer shall function as described in section 3.6.2.3 for power
interruptions.

3.5.8   Computer Lockup

The computer shall automatically go to the inoperative mode for
conditions of computer lockup in which the normal software tests
cannot act.

3.5.9   Maintenance Test

The maintenance test is a ground operated test that shall expand on
the confidence test (3.5.1) so as to determine which line replaceable
unit (LRU) is faulty, if any. Test accomplishment may consist of
several separate steps provided the procedure is quick, simple, and
straightforward. It shall be easy for one man to conduct the test
from one location. No specialized test equipment shall be required.
The preferred method is to set up the tests from the pilot input control
panel and to use the displays on the annunciator and control panels to
indicate the faulty LRU. Sensor inputs may be simulated as required
to complete the test.

3.5.10   Output Driver Test

The selector switch "TEST" position shall test operation of the
output drivers and displays.

3.6   GENERAL STANDARDS

3.6.1   Basic Design Standards

This drawing and the information contained in D6-5800 establish the
requirements for the general design, data, interchangeability, mate-
rials and processes and other pertinent requirements and capabilities
of equipments specified herein. Where conflicts exist between this
specification and the referenced documents, this specification shall
govern.

3.6.1.1   Deviations

The supplier's proposal shall include a statement that all
requirements of the specification will be met. If any deviations
are required, a special request shall be made by specific ref-
erence to the affected paragraph, together with specific reasons
for, and detail explanation of, each requested deviation.

3.6.1.2   Materials and Processes

All materials and processes which affect or are used in the end
product must be controlled by specification. A copy of critical
specifications used for the production of the specification con-
trol article shall be submitted to Boeing for review prior to
initiation of production for the specification control item. After
the specifications have been reviewed by Boeing, no changes may be
made by the supplier without first notifying Boeing and, when
requested, submitting these changes to Boeing for review prior to
their incorporation.

3.6.1.3   Fasteners

Parts such as screws, bolts, nuts, cotter pins, etc, shall be of
types which will fulfill their intended functions during conditions
of vibration, corrosion and other environmental requirements of this
specification. Captive screws or similar devices shall be used within
modules to prevent the possibility of screws falling into the circuitry.

3.6.1.4 Metals

Metals shall be of the corrosion resistant type unless suitably protected to resist corrosion during normal service life as specified herein.

The use of dissimilar metals, in contact with each other shall be avoided where practicable.

No cadmium plating shall be permitted on parts contained in sealed or tightly enclosed units that operate at temperatures exceeding 200°F.

3.6.1.5 Magnetic Materials

Nonmagnetic materials shall be used. The use of magnetic material in fasteners (screws, bolts, nuts, roll pins, etc) is permitted. The additional use of magnetic materials shall be subject to approval by Boeing.

3.6.1.6 Flammable Materials

The use of flammable materials shall be held to a minimum. Required flammable materials shall not liberate noxious fumes or gasses when burned. No material shall liberate gasses which will combine with the atmosphere to form acids or any corrosive alkali. Insulation materials shall not support combustion or form current conducting tracks when subjected to electrical arcs or explosions or gaseous vapors. The supplier shall provide a list of flammable materials and include gaseous data demonstrating that the above requirements are met by the material.

3.6.1.7 Fungus-Proof Materials

Materials which are not nutrients for fungi shall be used to the greatest extent practicable. In cases where materials that are nutrients for fungi are used, such materials shall be treated with a suitable fungicidal agent. The materials shall be capable of passing the fungus test of method 50B.1, MIL-STD-810.

3.6.1.8 Finishes

The requirements of MIL-E-5400 paragraph 3.1.10 shall be met. Nonconductive oxides or other nonconductive finishes shall be removed from the actual contact area of all surfaces required to act as a path for electric current and from local areas to provide continuity of electrical shielding and bonding. All mating surfaces of cases, enclosures, brackets, etc, shall be clean and carefully fitted as required to minimize radio frequency impedence at joints, seams, and mating surfaces. The resultant exposed areas after assembly at such joints or spots shall be kept to a minimum.

3.6.1.8.1 Aluminum Alloy Anodizing

Aluminum parts shall be anodized in accordance with MIL-A-8625C, Anodic Coatings, for aluminum and aluminum alloys, or shall receive an approved chemical film in accordance with MIL-C-5541B, Chemical Films for Aluminum Alloys, except as required to permit electrical grounding or bonding. A two to five minute immersion in a solution containing 5 to 10 percent chromic acid in water and maintained at 49 degrees centigrade to 50 degrees centigrade may be used in lieu of anodizing; or a chemical film in accordance with MIL-C-5541B may be used on parts fabricated from aluminum 2S, aluminum alloys, 3S, 52S, 61S, 63S, 72S or equally corrosion resistant alloys. For aluminum parts which require electrical grounding or bonding, aluminum 2S, or aluminum alloys 3S, 52S, 61S, 63S, 72S or equally corrosion resistant alloys shall be used and shall not be anodized. A caustic dip, with or without lacquer finish is acceptable. Cadmium plating aluminum alloy per BAC 5714 is acceptable.

3.6.1.8.2 Ferrous Alloy Finishes

Ordinary iron and steel shall be plated or finished in accordance with paragraph 3.6.1.8.3. Iron and steel laminations used in magnetic circuits need not be plated or given a protective finish if they are otherwise protected against corrosion.

REV SYM

3.6.1.8.3 Plating

Plating shall be in accordance with the applicable specification for each particular type as follows:

a. Cadmium QQ-P-416C, Plating, Cadmium (Electrodeposited)
b. Chromium QQ-C-329B, Chromium Plating (Electrodeposited)
c. Nickel   QQ-N-290A, Nickel Plating (Electrodeposited)
d. Zinc   QQ-4-325B, Zinc Coating, Electrodeposited, Requirements for

3.6.1.8.4 Zinc and Zinc-Plated Parts

Zinc parts and zinc-plated parts shall be given a dichromate treatment in accordance with QQ-Z-3258.

3.6.1.9 Snap Ring Retainers

Snap ring retainers are prohibited except where failure of the retainer cannot affect the safety of the components or system.

3,5,1,19 Safety Wire and Stakes

Accidental loosening of screws and screw parts, and other connections shall be prevented by safety wiring (.032 inch minimum OD) or other approved methods. The use of NC-20 Monel Safety Wire, .020 inch diameter, for No. 10 screws or smaller is authorized. Staking is not an approved method.

3.6.1.11 Standard Parts

All utility parts, such as nuts, bolts, cotter pins, washers, etc. shall conform to AN or MS Standards where possible.

3.6.2 Electrical Power Characteristics

The equipment shall operate within specifications when supplied by electrical power as specified in D6-1274.

3.6.2.1 Transient Voltage Effects

The equipment shall not suffer or produce adverse effects due to voltage transients caused by power source variations which fall within the limits of D6-1274.

3.6.2.2   Modulation

The equipment shall not produce control signals, suffer or produce adverse effects due to voltage and frequency modulation conditions which fall within the limits specified in D6-1274.

3.6.2.3   Power Interruptions

The equipment shall operate within design limits for power interruptions at least up to 20 milliseconds in duration. For power interruptions that are long enough to affect proper system operation, the system shall shut down in an orderly fashion, and when power is restored the system shall go into the power up mode and then into the standby mode as described in section 3.1.3.2.

3.6.2.4   Warm-Up-Time

The system shall be operating within specifications within 60 seconds after application of power. This requirement applies anywhere within the operational environmental conditions.

3.6.3   Environment

The design of the equipment specified herein shall be adequate to demonstrate operation within the performance requirements during and/or after exposure to the following minimum environmental conditions.

3.6.3.1   Temperature and Altitude

The equipment shall meet the performance specification in constant or varying up to 1 degree/second ambient temperatures of -30°C to +55°C, at altitudes between -1000 feet and 15,000 feet.

The equipment shall not be damaged if the pressure drops to 50,000 feet for 10 minutes while operating or is subjected to startup temperatures of -55°C to +70°C.

The equipment shall not be damaged by exposure to storage temperatures of -65°C to +83°C and altitudes of -1000 to 50,000 feet.

3.6.3.2 Humidity

0 to 100 percent relative humidity including conditions of condensation of moisture on the equipment in the form of water or frost.

3.6.3.3 Sand and Dust

Airborne sand and dust that would be encountered in desert areas and defined in paragraphs 2.8.2 and 2.8.3 of MIL-STD-210.

3.6.3.4 Fungus

Fungus spores which would be encountered in tropical regions and defined in Method 508, MIL-STD-810.

3.6.3.5 Salt Atmosphere

Atmosphere containing 1.5 parts per million of salt by weight.

3.6.3.6 Vibration

The equipment shall be designed to operate without malfunction or failure while being vibrated at the levels specified in D6-5431.

3.6.3.7 Acceleration

The equipment shall be capable of operating without malfunction while experiencing the following inertia loads acting independently:

Flight and Ground Load Forces:

1.3 g forward combined with 1.5 g down
0.75 g aft combined with 1.5 g down
Lateral loads .75 g combined with 1.5 g down
Vertical loads 5 g down and 1.9 g up.

The equipment attachments shall be capable of holding the equipment in place while the equipment is applying the following crash load forces on its attachment:

Crash Load Forces:

Forward	9.0 g
Down	4.5 g
Up	2.0 g
Side	1.5 g
Aft	1.5 g

3.6.3.8   Shock

The equipment shall be capable of withstanding shocks encountered during bench handling and shipping.

3.6.4   Electronic Packaging

Packaging design shall be conducted to achieve optimum electrical component selection, proper circuit functional grouping, efficient thermal management, optimum card/module size, effective interconnection techniques, proper EMI shielding and RFI suppression. The design objective is to develop highly reliable, unified equipment that is easily maintained and shall consider provisions to facilitate repair of those items with high replacement costs.

3.6.4.1   Packaging Density

The LRUs shall be designed for minimum size and weight. This should not be construed as requiring redesign of existing and proven packaging techniques and design.

3.6.4.2   Spare Space

There shall be a minimum of twenty percent spare space at all levels of the equipment design (connector pins, subassembly, and assembly).

3.6.4.3   Packaging Design

If a chassis/enclosure type design is used, the chassis shall have sufficient structural integrity to withstand normal service and handling requirements when the outer enclosure is removed.

3.6.4.4 Functional Design

The equipment shall be packaged to facilitate logical isolation of malfunctioning components to both the line replaceable unit and the individual card or replaceable subunit assembly level.

3.6.4.5 Arrangement

Electronic components and circuits shall be assembled to facilitate shop repair. Stacking of individually replaceable components shall be avoided. Spacing components on cards shall be such as to facilitate shop repair; construction shall permit card and module removal without part interference.

3.6.4.6 Sealing

It shall be possible to gain access to all repairable or overhaulable components without opening a permanent type of fusion seal. Minor subassemblies designed for replacement rather than repair may be fusion sealed. These throw-away subassemblies shall be individually identified and an expected mean-time-between-failure provided.

3.6.4.7 Fasteners

A design objective shall be the use of techniques which will enable rapid removal and replacement of components and subassemblies.

3.6.4.8 Interconnects

Packaging shall keep requirements for interconnecting wiring between components to a practical minimum.

3.6.4.9 Electromagnetic Interference

The equipment shall be designed to meet the test requirements of D6-5244 for EMI generation and susceptibility control.

3.6.4.10 Dielectric Requirements

The equipment shall be designed to meet the dielectric requirements of D6-1274.

3.6.4.11   Grounding

Chassis ground shall be brought out of the case through
individual pins on the case connectors.

3.6.5   Microelectronics

Application of large-scale integration and microminiaturization
techniques in all equipment is encouraged, particularly where
analysis can show improvements in reliability, maintainability,
and cost factors.

3.6.5.1   Derating Requirements

Microelectronics devices shall be derated as called out in
section 3.6.6.3.

3.6.5.2   Specification Requirements

Microelectronic parts shall be covered by Military Specifications
or Boeing Standards list if possible.

If parts are required for which no Military Specifications exist
or for which no manufacturers are qualified, the best available
commercial grade part based on manufacturer's performance data and
specification control shall be used. These parts and specifications
will require Boeing approval.

High reliability and cost effectiveness shall be an important
consideration in the selection of parts. The formalities of data
submission and approvals normally associated with high reliability
parts procurement shall be kept to a minimum in the interest of
reducing cost. If parts not in The Boeing Company Standards list
are required for which no Military Specification or qualified source
exists, the best available commercial grade part based on performance
data and specification control shall be used. Steps shall be taken
to ensure that selected parts are built by device manufacturers
utilizing materials and process controls which demonstrate a history
of producing parts with failure rates among the lowest consistent
with state-of-the-art figures.

REV SYM

3.6.5.3 Analysis Requirements

Microelectronics and microminiaturization techniques require an analysis to show reliability, maintainability, and cost factors.

The application of microelectronics detailed process specifications used shall be subject to the approval of Boeing.

3.6.5.4 Custom Hybrid Circuits

The use of custom hybrid circuits and the suppliers specification shall be approved by Boeing.

3.6.5.5 Testing Requirements

Microcircuits, which include monolithic, hybrid, MSI and LSI shall receive 100 percent acceptance testing. Burn-in screening procedures, as defined in the individual specifications, shall be for a minimum of 168 hours at a junction temperature of 150°C.

Custom hybrid circuits must be 100 percent screened and tested per MIL-STD-883. These tests shall include preseal visual inspection, stabilization bake, leak tests, thermal cycling, centrifuge, and 168 hour burn-in.

It shall be the responsibility of the supplier to ensure that these tests are accomplished either in-house or by the device manufacturer.

3.6.5.6 Workmanship Standards

The establishment and maintenance of workmanship standards shall be a consideration of microelectronic packaging design. Workmanship has a particularly high correlation with the realizable goals of maintainability and reliability in assemblies of microelectronics.

3.6.6 Electrical Parts Selection and Application

The supplier shall submit a complete parts list showing all parts specifications, tests, and qualifications, which shall be updated with any substitutions or redesigns. An effort shall be made to select parts from standard Boeing, military, or industry lists that will guarantee future availability for replacement purposes.

The use of supplier-generated parts specifications is acceptable
provided the equivalent minimum quality levels specified in this
section are achieved. Boeing approval will be required for all
supplier specifications used to procure parts for this application.
Parts of a higher quality level will be used whenever their appli-
cation is justified by cost and availability or required to meet
system reliability goals.

A design objective is 100 percent solid state electrical and
electronics elements.

3.6.6.1   Parts Derating

The following derating criteria shall be applied.

3.6.6.1.1   Semiconductor Devices and Integrated Circuits

All semiconductor devices and integrated circuits (monolithic and
hybrid) shall be derated for maximum rated junction (or substrate)
temperatures as shown in the following table. This derating applies
to equipment subjected to normal operating environment.

SEMICONDUCTOR TEMPERATURE DERATING

Device Junction or Substrate Maximum Rated Temperature	Device Junction or Substrate Maximum Derated Temperature
200°C	112°C
175°C	100°C
150°C	87°C
125°C	75°C

Devices designed for high temperature applications, Tj rating
higher than 200°C, will require approval by Boeing prior to their
usage.

Normal airplane voltage transient conditions as specified in D6-1274
shall not cause voltages on discrete semiconductor devices of more
than 80 percent of maximum device ratings or on monolithic or hybrid
integrated circuits of more than recommended operating voltages.

REV SYM

Abnormal voltage transient conditions shall not cause voltages to exceed maximum device ratings for either discrete semiconductor devices or integrated circuits.

3.6.6.1.2   Silicon Control Rectifiers (SCR)

SCRs shall be derated per the manufacturer's specifications with reference to "on" phase conductance.

3.6.6.1.3   Metal Oxide Semiconductors (MOS) - Field Effect Transistors (FET)

MOS-FET shall not be used unless the devices are internally protected for static charges and voltage transients.

3.6.6.1.4   Digital Circuits

Microelectronic digital circuits shall operate at the manufacturer's recommended voltage and are subject to approval by Boeing. Fan-in and fan-out of these parts shall be derated to account for worst case drift throughout their design life.

3.6.6.1.5   Linear Circuits

Microelectronic linear circuits, such as operational amplifier integrated circuits, shall be derated from the maximum voltage of the device to operate at the manufacturer's recommended voltage and are subject to approval by Boeing.

3.6.6.1.6   Hybrid Circuits

Hybrid circuits shall be derated consistent with that specified for digital or linear circuits as applicable.

3.6.6.1.7   Capacitors

Capacitors shall be derated as shown below:

Capacitor Type	Voltage Derating (percent of rated)*	Temp Derating (Deg C below rated)**
Aluminum electrolytic	80	10
Ceramic	90	10
Glass	90	10
Metalized paper/plastic	80	10
Mica, dipped	90	10
Paper, plastic	90	10

REV SYM

3.6.6.1.7   Capacitors (cont'd)

Capacitor Type	Voltage Derating (percent of rated)*	Temp Derating (Deg C below rated)**
Tantalum, wet slug**** (glass sealed)	80	10
Tantalum, solid Electrolytic***	80	20
Tantalum, foil	80	20
Tantalum, foil (rectangular case)	30	20

    * D.C. plus peak a.c. voltage should not exceed listed values.

    ** Ambient temperature plus ΔT due to a.c. ripple should not exceed listed values.

    *** Solid dielectric tantalum capacitors shall have a series resistance of 3 ohms per volt minimum.

    **** Wet slug tantalum capacitors shall be protected from reverse voltage.

NOTE: Oil-bath and oil filled capacitors shall not be used.

3.6.6.1.8   Resistors

Resistors shall be derated to operate at 50 percent of rated power except that wire would power resistors which are not mounted on heat sinks shall be derated to operate at 20 percent of rated power. Wire would power resistors shall not be mounted close to heat-sensitive parts.

3.6.6.1.9   Switching Devices

Switching devices which are not solid state or relays, shall conform to MIL-E-5400, paragraph 3.1.2.2 and shall be derated to operate at no greater than 50 percent of the rated contact current.

3.6.6.1.10   Transformers

Transformers shall comply with the requirements of MIL-STD-454, requirement 14, and shall be derated to operate at no greater than 75 percent of the rated working power.

3.6.6.1.11 Relays

The use of relays in place of solid state switching circuits shall be subject to Boeing approval. All relays used shall conform to MIL-E-5400, paragraph 3.1.18 and shall be derated to operate at no greater than 50 percent of the rated contact current.

3.6.6.2 Magnetics

Parts containing power transformers or chokes shall use magnet wire conforming to the requirements of MIL-W-583. Wire shall be class 200 type K2 or better, and insulation systems shall be compatible to obtain full temperature capability. The magnetic component when installed and operating shall not exceed a temperature rise of 100°C with the external ambient temperature of 25°C, nor shall the average maximum temperature ever exceed 150°C under worst case power, temperature and load conditions. (Temperature measured by resistance change is average).

Class 180 type H2 wire or better may be used if the temperature rise does not exceed 70°C under the same conditions.

3.6.6.3 Printed Wiring Boards

Printed wiring boards shall conform to the requirements of MIL-P-55110, "Printed Wiring Boards" and MIL-STD-275, "Printed Wiring for Electronic Equipment," except as specified herein. If a supplier has his own standards for printed wiring boards, they shall be made available to Boeing for approval prior to usage.

3.6.6.3.1 Board Material

The board material shall be epoxy glass (type GF or better, in accordance with MIL-P-13949, "Plastic Sheet, Laminated, Copper Clad (for Printed Wiring)." Paper base phenolic or melamine shall not be used.

3.6.6.3.2 Multilayer Boards

The use of multilayer printed circuit boards requires Boeing approval. If approved for use they shall meet the following requirements:

a. Design Standards

Multilayer boards shall be designed in accordance with IPC-ML-910 except as specified herein.

b. Interconnection

Interconnections shall be of the plated-through-hole (PTH) type. All PTHs not containing soldered-in part leads or wires shall be solder filled by dip or flow soldering methods.

c. Process Control Specimens

The boards shall contain removable process control specimens containing PTHs representative of the smallest hole size of the board. The control specimens shall be available for Boeing evaluation prior to final acceptance of deliverable equipment.

d. Multilayer Board Performance

The boards shall meet the requirements of IPC-ML-950, Class A, except that 50 temperature cycles are required.

e. Process Qualification

The supplier shall submit representative process qualification test plans and test reports for Boeing review and approval prior to production of multilayer circuit boards for the specification control item.

3.6.6.3.3 Part Mounting

a. Hardware

Hardware, such as eyelets, standoff terminals, part holders, etc, shall not be directly attached to any part of the conductive wiring pattern. Where standoff terminals are to be used, a terminal area shall be provided. The hardware shall be soldered to this area (isolated from the conductive pattern) and the electrical connection to the terminal shall be made by means of a jumper wire from a conductive terminal area to the standoff.

REV SYM

Part mounting hardware (such as connector screws, etc) shall be securely tightened prior to soldering and shall not be adjusted after soldering in order to avoid stressing soldered connections of part leads.

b. Part Lead Bending

The inside bend radius of part leads shall not be less than the lead diameter for round leads or the lead thickness of ribbon leads. The beginning of bend shall be a minimum of 0.05 inch from the body of the part. Junction welds, glass seals or encapsulant menisci are considered to be within the part envelope. Reduction of the 0.05 inch dimension will be permitted only when it can be demonstrated that, during bending, the leads are firmly gripped between the part body and the bend, preventing any stress application to the part.

c. Part Insulation

Parts mounted over exposed printed wiring shall be insulated. Where a malfunction could be caused by lead deflection, protective insulation shall be applied to the other conductor, or, preferably, to the lead itself.

d. Part Lead Stress Relief

All component (e.g., resistors, modules, hybrid, etc) mounting leads shall be formed so as to provide stress relief bends between the part body and its lead solder joint. Differential expansion of materials under thermal cycling shall not cause solder joint cracking or failures.

3.6.6.3.4 Conformal Coating

Board assemblies shall be protected from moisture and contamination by a uniform coating of repairable encapsulant per MIL-I-46058. The material specification and the application process specification shall be approved by Boeing.

3.6.6.3.5 Plating and Coating

Plating and/or coating shall be specified by the supplier and shall conform to the requirements of MIL-STD-275. These specifications shall be approved by Boeing.

3.6.6.3.6 Board Guides for Plug-In Boards

Board guides shall be provided so that boards will mate with their receptacles without incurring damage. In addition to connector pin protection, the guides shall assure that each assembly is sufficiently aligned during insertion and removal so that no parts mounted on an adjacent board can be displaced. There shall be sufficient space between adjacent surfaces so that no physical contact is possible due to deflection under shock or vibration.

3.6.6.3.7 Board Support

Sufficient mechanical support shall be provided to meet vibration and shock requirements when the boards are mounted in the equipment box. The boards must be positively held in place.

3.6.6.3.8 Keying or Polarizing

A different keying or polarization feature shall be provided for each board assembly that is not identical to another (i.e., same part number) to prevent insertion of board into the wrong connector.

3.6.6.4 Standardization

Modular units, cards, and other subassemblies shall be standardized with respect to form, fit, and function. To the greatest extent possible, circuits should be packaged to simplify system wiring, to aid fault isolation to individual cards, to reduce spares and to reduce troubleshooting time.

3.6.6.5 Interchangeability

Modular units, cards and other subassemblies shall be interchangeable with other subunits bearing the same part number. Those items

REV SYM

requiring matched sets shall have Boeing approval. Plug-in items or assemblies having the same part number shall not require calibration or adjustment to meet system performance requirements.

3.6.6.6   Identification

All modules, circuit boards and subassemblies shall be identified by an assembly number marked in a conspicuous location. Reference designations per ASA-Y 32.16 shall be used to identify detail part locations on circuit boards and chassis. These identical reference designations shall be used in part catalogues, wiring diagrams, assembly drawings and schematics. Symbols on diagrams and schematics shall conform with MIL-STD-806.

3.6.6.7   Connectors

The connectors (type and mounting) shall conform to the general requirements in Chapter 3 of ARINC 404A for ATR packages. It shall be the responsibility of the supplier to obtain the index code registration in accordance with ARINC specification 404 and ARINC Report 406.

Unmated connectors shall be protected from contamination. Dust caps shall be provided where necessary. If dust caps are to be retained with the equipment they shall be attached to the equipment to prevent loss or damage.

3.6.6.8   Wiring and Cabling

All wiring shall be coded for ease of identification and shall be in accordance with MIL-W-16878, Type E or EE teflon TFC or polyimide insulation. Printed flexible wiring and cabling may be used if it can be justified in terms of reliability, maintainability, safety, and weight savings. Terminations of such printed cables will be subject to approval by Boeing.

Wiring shall be isolated from hot components so that heat damage to insulation cannot occur. The smallest permissible internal wire size for stranded conductors shall be No. 26 AWG. Larger wire sizes shall be used when required for current carrying or voltage drop consideration.

68

Cable assemblies shall be designed for minimum conductor lengths, and they shall be routed to avoid part access restrictions. Cables shall be secured at appropriate intervals to prevent chafing or other damage. Cable bundles must not be tied to adjacent electrical components or subassemblies. All wires and bundles shall be supported sufficiently so that strain or load at the terminal shall not cause joint failures. Cable bundle lays shall be neat, accessible, and appropriately labeled for efficient fault detection and failure analysis. Stress relief of all cable bundles shall be required.

Crimping of wires, stripping of insulation, and all wire terminations shall be accomplished per MIL-STD-454, requirements 5 and 19.

The wiring designer shall avoid assigning circuits having a high voltage differential to adjacent connector pins. As a guide, the normal working voltage on adjacent pins should not exceed one-tenth of the rated dielectric withstanding voltage of the connector. Specifically, 115 vac and 28 vdc circuits shall not be assigned to adjacent pins.

In addition, connector pin assignment shall be made so that the exposure of sensitive circuit connector pins to EMI producing connector pins is minimized.

Wire wrap, if used, shall comply with MIL-STD-1130, Class "A" "Connections, Electrical, Solderless Wrapped." The current specification (12 November 1965) does not cover wire wrapping of No. 28 and No. 30 AWG. If these smaller gages are used and the specification has not been updated to include these, the Department of the Navy, Special Projects Office, Washington, D.C., specification, NAVORD WS 6119, "Process Specification for Connections, Electrical Solderless Wrapped" shall be used pending the updating of MIL-STD-1130.

3.6.6.9   Isolation and Separation Requirements

Power cables, ground wires and signal lines (input and output) shall be physically separated from each other. Electromagnetic interference and cross talk between conductors shall be minimized through the use of ground planes, twisted pairs, or shielded conductors.

REV SYM

3.6.6.10 Enclosure/Chassis Design

All rack mounted components shall be housed in ATR cases conforming to the requirements of ARINC 404A. Type B hold-downs shall be used. Camlock 40L2 type (or Boeing approved equivalent) handles shall be used for insertion, extraction, and retention of the cases in the equipment bay shelf.

3.6.6.11 Thermal Design

The equipment design shall include a thermal design concept which is incorporated into the equipment design. Specific modes and paths for heat transfer from all heat generating elements or components in the equipment shall be planned as an integral part of the design. Temperatures of all components shall be controlled, (i.e., component temperatures will not exceed predetermined limits based upon component derating curves for worst case environmental conditions specified for the equipment). These temperature limits shall be maintained for all combinations of steady state and transient conditions.

3.6.6.11.1 Cooling Air

The equipment shall operate normally without any requirement for forced cooling air.

No blowers or equipment fans will be allowed within the equipment.

3.6.6.11.2 Thermal Interface

The thermal interface of the computer and the airplane shall be as defined in ARINC 404A. The side case average temperature of adjacent units will not exceed 150°F (65.6°C). Side case average temperature of the computer shall be measured per attachment 17 of ARINC 404A and shall not exceed 150°F (65.6°C).

3.6.6.11.3 Thermal Analysis

As part of the thermal design for the equipment, a thermal analysis shall be required. This must demonstrate analytically the adequacy of the cooling provisions in the equipment.

REV SYM

3.6.7 Reliability

The supplier shall indicate the reliability goal that he proposes to meet, anticipated initial value at delivery, the estimated growth and the expected period for attaining the objectives.

3.6.7.1 Minimum Requirements

The system shall be designed for a minimum MTBF of 7000 operating hours for confirmed failures, increasing to 10,000 hours in three years.

The MTBF of any monitoring or built-in test equipment shall be at least ten times greater than the function being monitored.

3.6.7.2 Failure Definition

The failure of the system to successfully pass the maintenance test procedure in the airplane shall be deemed a failure.

A line replaceable unit (LRU) removed from an aircraft for suspected failure shall be deemed a confirmed failure when upon being subjected to test in the condition removed from aircraft, it is unable to pass the test for that LRU specified by the Seller's Overhaul Manual, or other mutually agreeable test procedure. The specified test must be comparable in scope to the Seller's acceptance test for production equipment. The test may be performed in the customer's facilities or those of his FAA approved designee by personnel previously certified by the supplier.

Where a LRU has been charged with a confirmed failure, the removal and replacement of an additional item(s) within the same LRU still operating but predicted to fail or operate outside established tolerances shall not be considered a second failure and therefore, be excluded from the MTBF calculations.

Irrelevant failures shall not be counted in the MTBF determination. Irrelevant failures are defined as follows:

D1 4100 7740 ORIG.3/71

REV SYM

a. Failures covered by maintenance or overhaul procedures, parts, or processes not in accordance with those specified in the approved maintenance and overhaul manuals.

b. Improper operation of the systems in which the unit is installed.

c. Exposure of unit to an environment beyond the limits described in this specification.

d. Unit not updated to the latest configuration within four months after modification kits or parts are available to the customer.

e. Unit damaged by consequential or secondary action.

f. Removal of a unit from an aircraft for suspected failure, but no failure is found during test.

3.6.7.3 Reliability Report

A reliability analysis shall be submitted. This report shall include a Technical and Administrative Section as outlined in D6-5762-1, "Reliability Guide for Suppliers."

3.6.7.4 Production Reliability Technical Reports

In-service failure data shall be gathered and maintained by the supplier and made available to Boeing upon request. Paragraph 3.3.1 of D6-5762-1, "Reliability Guide for Suppliers," shall be used as a guide in the preparation of the production reliability technical report.

3.6.7.5 Corrective Action

If the reliability objective described in paragraph 3.6.7.1 is not met, the supplier shall promptly supply Boeing with all data showing the causes of failure and the corrective action. Concurrently, the supplier shall repair, modify, consign spares, and re-engineer the system as necessary at no charge to the customer.

3.6.7.6 Design Changes

In the event of design changes, the supplier shall submit a revision of his reliability analysis reflecting the effect of these changes.

3.6.8 Maintainability

The supplier shall indicate the initial maintainability goals that he proposes to meet, estimated improvement to be expected and time to reach the final objective.

3.6.8.1 Minimum Requirements

The installed mean unscheduled maintenance task time per LRU shall not exceed 20 minutes. This value excludes access to the equipment in the airplane but includes troubleshooting, identification of each line replaceable unit, (LRU) components or modules, and replacement to obtain a functioning system.

The shop manhours required to test and repair each LRU shall not exceed two hours. It may be assumed that the overhaul work is being accomplished by personnel experienced in working with the product and that the work is being accomplished per instructions which would be contained in an overhaul manual.

3.6.8.2 Scheduled Maintenance

There shall be no required scheduled inspections, checks, lubrications or adjustments.

There shall be no scheduled replacement of parts. All parts replacement shall be done on an "ON CONDITION" basis; that is, when it fails to meet the minimum operational requirements.

To facilitate "repair as necessary" and promote minimum maintenance costs, modular construction, replaceable wear surfaces and bushings, rework margins, easily replaceable seals, quick partial disassembly and construction features shall be used. All wear surfaces that will not last the life of the airplane shall be replaceable or repairable.

3.6.8.3   Maintenance Test

A manually actuated maintenance test mode shall be provided to enable checkout of the system independent of ground support equipment. A test switch shall be located on the front panel of the computer along with a status indication.

Annunciation of fault location shall be displayed in coded format, using display lights on computer front panel. The annunciators shall reset with press-to-test. No specialized test equipment shall be required.

The self test circuitry shall be designed such that the operational reliability of the computer is not degraded especially when the test switches are not returned to normal.

3.6.8.4   Bench Test

The system shall be designed to make maximum use of self test fault isolation and require a minimum of test equipment. The bench test shall allow isolation of a fault to the module level.

The supplier shall provide a description of the test equipment required to maintain and test the delayed flap system.

The unit shall be designed to be compatible with automatic test equipment.

3.6.8.5   Schematics

Functional schematics of the delayed flap system shall be provided to facilitate fault isolation. These schematics shall be available for operational and maintenance analysis prior to delivery of the first system components.

3.6.8.6   Interchangeability

Interchangeability of any line replaceable unit (LRU) with any other LRU bearing the same part number shall not necessitate readjustment of any component in order to meet the performance requirements.

functionally nonidentical components or modules shall not be mechanically interchangeable. Interchangeability of functionally nonidentical calibrators between different models may be controlled by electrical interlocks.

3.6.8.7 Identification

a. Circuit Boards and Chassis

Each circuit board and major circuit chassis shall be identified permanently and conspicuously with its assembly number. Circuit components shall be legibly and permanently identified by code designation adjacent to their location or circuit boards or chassis structure; identical code designations shall be utilized in illustrated parts breakdowns, wiring diagrams, and functional schematics to facilitate fault isolation and component replacement.

b. Relays and Switches

Relay and switch terminals shall be conspicuously identified. A schematic identifying normal contact continuity shall be installed on or adjacent to all switches and relays.

c. Connectors

Electrical connectors shall be permanently identified, with the marking legible when the mating connector and wiring are installed.

3.6.8.8 Unit Name Plate Identification

The following information shall appear on the unit name plate:

(1) Nomenclature
(2) Supplier's name
(3) Supplier's part number
(4) Supplier's serial number
(5) Coding for the year and month of manufacture
(6) Modification status information
(7) Boeing part number
(8) DO-160 qualification identification (test categories)

3.6.9   Software Design

The software design shall follow the principles of structured programming and shall be suitable for application to read-only memory.

A general structure shall be developed first and then expanded into a tree-like or hierarchial structure. The requirement is a program with strong modular construction, simple connections between modules, topdown readability and, which can be later modified without compromise of system integrity and safety.

The programming techniques and resultant code shall be simple and easy to comprehend, providing good visibility to "program checkers" and managers. Design (flow charting) and coding shall be limited to three basic patterns of control structures: linear sequence, selection and loop.

3.6.9.1   Program Symbology

The supplier shall consult with Boeing and provide a standardized list of names for software terms used. A list using Fortran like names is desirable.

3.6.9.2   Program Listing

The supplier shall provide an annotated program listing. Comment lines and comment fields shall be used to annotate the source program. Annotation shall be clear, concise, and explain exactly what is happening. It shall be provided to the level of detail needed to permit identification, association, and determination of compliance with the detail design. Redundant and overly prosaic annotation shall be avoided. The structure and flow of control shall be made visible by use of statement or comment alignment, indentation, and page control. Each module shall be annotated so as to show its purpose, the type of meaning of each argument, the calling sequence, and any modifications made to arguments. The following are examples of items where visibility is to be enhanced by careful annotation:

o Changing of scale factors

o Indexing/indirect addressing schemes

o Usage of temporary storage

o I/O operations, data base

o Units of measurements

o Precision

o Failure monitoring techniques

4.0   QUALITY ASSURANCE PROVISIONS

The supplier is responsible for the performance of all inspection, analysis, and test requirements, and the implementation of an effective and economical quality control program in accordance with MIL-Q-9858A. Boeing reserves the right to witness the performance of any inspections or tests to insure compliance to the requirements. The supplier shall define and schedule all inspections and tests such that Boeing can determine which activity will be witnessed and to allow for scheduling and travel time by Boeing personnel.

4.1   CONFIGURATION CONTROL

4.1.1   Hardware Configuration Control

Each LRU tabulated in the parts list, as fabricated and assembled, shall be inspected to verify compliance with the criteria specified in the supplier's drawings and configuration control documents. The "as manufactured" configuration of components of each LRU which cannot- be inspected at the fully assembled condition to the level of detail necessary to fully establish configuration conformance shall be verified by extracts from production records or inspection records.

4.1.2   Software Configuration Control

The software configuration control will proceed in two phases as the program progresses:

a.   Development software in a stage of checkout and development prior to Beoing acceptance

b.   Flight software in an advanced stage which satisfies flight worthy requirements and is accepted by Boeing.

4.1.2.1   Development Software Configuration Control

Software control during the development phase will be keyed mainly to the software document. After formal release of the software document any changes to that document shall require the approval of

Boeing. Any program changes that affect a software requirement in the software document shall require the approval of Boeing prior to change. Program source decks shall be retained by, and under the control of, the supplier. The supplier's own software control procedures shall be subject to approval by Boeing.

4.1.2.2 Flight Software Configuration Control

Software that has been accepted by Boeing and satisfies flight worthy requirements shall be subject to formal configuration control by a Boeing Software Control Board. The Control Board shall control the master source decks and all other software and have the final authority to approve changes and various configurations as required. The supplier shall serve as advisor when required.

4.2 QUALIFICATION TESTS

The supplier shall perform tests to verify that the equipment is in compliance with the requirements of section 3.0.

4.2.1 Qualification Test Procedures

Detailed test procedures shall be prepared by the supplier. These procedures shall clearly list and define test conditions, test equipment, testing environment set-up and procedure, performance tests and allowable tolerances. Preparation of the test procedures will be based on the requirements of the applicable technical standard order and this specification. The detailed test procedures shall be subject to Boeing approval and shall be submitted to Boeing 30 days prior to the start of qualification testing.

4.2.2 Notification of Qualification Test Start

Notification of test start shall be made at least five days before start of testing to enable Boeing witness of qualification testing if desired.

4.2.3   Examination of the Article

The equipment shall, at the discretion of Boeing, be inspected to
verify conformance to specified materials, design, workmanhsip,
finish, physical dimensions, weight, and item identification
requirements.

4.2.4   Number of Test Articles

At least one complete delayed flap system shall be tested and
complete interchangeability of subunits for which there is such
a requirement shall be demonstrated.

4.2.5   Test Specimens

Qualification test samples shall be essentially identical with
the corresponding production parts.

4.2.6   Similarity of Test Articles

Partial fulfillment of qualification testing requirements on the
basis of similarity of the article to previously qualified articles
is permissible, provided the similarity is clearly defined and
provided the components which could affect the test results or integ-
rity of the article have not been modified, deleted, or replaced with
parts of a different configuration. All nonidentical parts shall
be compared with the corresponding parts in the similar article
and all differences shall be clearly described in detail. Pic-
torial as well as written evidence shall be provided. All similarity
data shall be submitted in a single report and only directly appli-
cable data shall be included. The test report for the similar article
shall be submitted.

4.2.7   Test Equipment and Conditions

4.2.7.1   Test Equipment

It shall be the responsibility of the supplier to establish the
accuracy requirements for measurement of the various parameters
during any test, unless otherwise specified herein. The accuracies

of the test equipment shall be included in the test procedures, shall comply with MIL-C-45662 and are subject to approval. Approval of the supplier's test procedures and test setups shall be obtained prior to acceptance or qualification testing.

4.2.7.2   Calibration

Calibration data shall be available for the instrumentation as part of the data package available to the first article inspection.

4.2.7.3   Special Test Equipment

The design and construction of all special test equipment shall be approved by Boeing prior to their use. This approval shall be obtained in sufficient time to allow required changes without affecting system delivery schedule.

4.2.7.4   Test Conditions

Whenever the pressure and temperature conditions at the time of the tests are not specified definitely in the particular test procedure, it is understood that the test shall be accomplished at nominal atmospheric pressures, room temperatures and voltages.

4.2.8   Environmental Tests

Each environmental test shall be conducted on each article described in this specification control drawing, except as noted, to indicate compliance with specified design requirements. During environmental tests, the external connections shall be connected to simulate all physical conditions of actual installations. Each article shall be operated before, during, and after all environmental tests unless otherwise specified. A record shall be made of all data necessary to determine compliance with the specified performance requirements. When subjected to the environmental test conditions which follow, no significant degradations in performance from that obtained at normal room temperature and pressure conditions shall be permitted. Adjustments of any article during the complete schedule of tests shall not be permitted.

4.2.8.1 High Temperature

The test article shall be placed in a test chamber and the pretest performance checked per Method 501.1, Procedure II of MIL-STD-810. The ambient temperature shall be maintained at 70°C for 24 hours. The ambient temperature shall then be lowered in accordance with the requirements of section 3.6.3.1, and the test article operated. The test article shall comply with the performance requirements throughout the temperature range of -30°C to +55°C.

4.2.8.2 Low Temperature

The test article shall be installed in a test chamber and the pretest performance checked per Method 502, Procedure I of MIL-STD-810. The ambient temperatures shall be maintained at -55°C for 24 hours. The ambient temperature shall then be raised in accordance with the requirements of section 3.6.3.1 and the test article operated.

4.2.8.3 Temperature Shock

The test article shall be subjected to the temperature shock test as specified in Method 503.1, Procedure I of MIL-STD-810.

4.2.8.4 Temperature-Humidity-Altitude

The test article shall be subjected to the temperature-humidity-altitude test as specified in Method 518, Procedure I of MIL-STD-810.

4.2.8.5 Shock

The test article shall be subjected to a shock test as specified in Method 516.1, Procedure I of MIL-STD-810. The shock pulse shall be as shown on figure 516.1-1, Procedure I. The test article as packaged for shipment shall be tested for rough handling as specified in Method 516.1, Paragraph 3.95 of MIL-STD-810.

4.2.8.6 Vibration Test

Vibration tests shall be conducted on each article in accordance with D6-5431

4.2.8.7   Sand and Dust

A dust test in accordance with Method 510 of MIL-STD-810 is not required. The requirements of section 3.6.3.3 shall be considered for design but are not required to be verified.

4.2.8.8   Fungus and Salt Atmosphere

Verification of compliance with the fungus resistance and salt atmosphere requirements of section 3.6.3.4 and 3.6.3.5 shall be established by production records or the issuance of a suppler certification.

4.2.9   Power Supply Variations

The equipment specified herein shall operate without performance variations and with no affect on outputs when subjected to the following power supply settings:

   a.c. 130 volts at 365 and 430 cps
        104 volts at 365 and 430 cps

A.C. sinusoidal amplitude modulation $\pm$ 1 volt through the range of 1 to 18 cps.

A.C. step voltage changes of 3 volts through a range of 104 to 130 volts.

Operation shall be satisfactory and have no affect on the outputs when subjected to power interruptions as specified in para 3.6.2.3.

4.2.10   Electrical Interference

Tests shall be performed to prove compliance with D6-5244.

4.2.10.1   Electrical Interference Control Data

A report on interference test procedures and test results shall be submitted prior to final approval. The test report shall include the following information if not previously submitted to Boeing:

REV SYM

Any interconnecting or external wire circuits susceptible to electromagnetic field or conducted interference, or wiring circuits requiring twisting, shielding, or special treatment shall be identified and the following data noted:

a. Circuit function

b. Nominal signal level and frequency

c. Minimum signal to noise ratio that will preclude interference

d. Nominal impedance (R+JX) at all terminations

e. Recommended circuit configuration as to grounding, twisting, shielding, shield termination, etc.

Any wire circuit with interference level above the limits of D6-5244 shall be identified and the interference levels noted.

4.2.11   Over-Voltage Test

The equipment shall be subjected to the rms voltages shown below applied to the input leads for a 0.5 second period, during which time the equipment shall be connected for operating. Ten 0.5 second pulses shall be applied to the article with 5 second interval between pulses after completion of the test. Operation of the equipment shall be satisfactory.

Normal Input Voltage	Test Voltage
115v - a.c.	172 volts
28v - d.c.	42 volts
26v - a.c.	39 volts
5v - a.c.	7.5 volts

4.2.12   Dielectric Test

High potential test voltage of two times rates rms operating voltage plus 1000 volts rms but not less than 1500 volts rms at 60 or 400 cps shall be applied between mutually-insulated parts. The test voltages shall be applied and removed at a uniform rate of 250 to 500 volts per second and shall be maintained at the specified test voltage for

a period of one minute. When the equipment consists of more than
one circuit which must be tested, each application of the specified
test voltage shall be for a period of one minute.

4.2.12.1   Leakage Current

Any leakage current flow which exceeds 0.5 milliamper at the specified
test voltage shall constitute failure. Where the high potential test
is called for following preproduction tests which simulate service
use the test voltage shall be reduced to 75 percent of the value
specified.

4.2.12.2   Insulation Resistance Test

The resistance of the insulation between all mutually-insulated parts
of the equipment shall be measured after the high potential test to
make certain that no unobserved insulation damage or insulation break-
down occurred. The resistance after the high potential test shall
not be less than 20 megohms. A megohm bridge or "megger" type instru-
ment with an output voltage of 500 volts d.c. or twice rated voltage
of the equipment under test, whichever is greater shall be used. The
instrument shall also have scale divisions which will permit an
accuracy of $\pm$ 10 percent at the minimum specified value of insulation
resistance. Components and parts which are subject to possible damage
from test voltage; i.e., capacitors, diodes and transistors, shall be
electrically isolated before performing insulation resistance tests.

4.2.12.3   Humidity Effects

The insulation resistance test specified in the preceding section
shall be performed before and after the humidity test of paragraph
3.6.3.2.

4.2.13   Software Tests

A set of tests shall be developed to demonstrate that the software
required in this specification has been implemented in the computer,
that the system functions correctly, and that the test routines
adequately check the software and hardware.

4.2.13.1 Software Modules

The software module testing shall provide documented verification that software modules are correctly defined and coded. All branches in the code shall be checked to assure proper functioning.

The signal inputs and discretes shall be simulated for polarities and amplitudes both within and outside of limit values, and the resulting output values measured. There shall be no false or misleading outputs generated.

4.2.13.2 System Function

The tested software modules shall be added to form a complete system. System testing shall verify that the software modules function properly with each other and with all hardware systems. All executive and higher modes and levels shall be tested for correct function. A confidence test of the combined modules shall be obtained by selecting a number of sample points based on worst case data and checking for proper function.

Testing shall include all data and conditions whether actual or simulated.

4.2.13.3 Test Routines

The test routines shall be checked and tested to assure that all components of the system as required by this specification to be tested, are being tested. A program of simulated faults and errors shall be used to verify the correct functioning of the routines and determine the accuracy of the maintenance tests in defining the fault or error.

A list of all faults, errors, failures, etc, that cannot be detected by the confidence test shall be produced which shall include the resulting output indications on the annunciator panel.

4.2.13.4   Test Documentation

Documentation shall consist of:

o   Test philosophy and procedures
o   Resulting test outputs (graphs, charts, printouts, etc)
o   Analysis of above results showing valid operating range
     and worst case conditions within this range

4.3   FIRST ARTICLE ACCEPTANCE TEST

Five (5) copies each of the supplier's internal and system wiring diagrams, and test specifications, including a list of test equipment and its tolerances, shall be delivered to and must be approved by Boeing three months prior to the delivery of the first article.

The supplier shall conduct a complete inspection and acceptance test on the first ship set of equipment intended for shipment to Boeing. Boeing representatives may elect to participate in or witness the inspection and testing at the supplier's facility. The first article of each type must be approved by Boeing prior to delivery.

4.4   PRODUCTION TESTS AND INSPECTIONS

The supplier shall be responsible for development of the functional test procedure for production units. These procedures must be approved by Boeing and will subsequently be added to and become a part of this specification. The test procedure shall be delivered to Boeing three months prior to scheduled first article delivery.

4.4.1   Examination

The equipment shall be inspected to verify conformance to specified materials, design, workmanship, finish, physical dimensions, weight, item identification, etc. These inspections must be made during production and a statement of compliance must be submitted on the test data sheets required with each component.

REV SYM

4.4.2   Operational Checks

The equipment shall be subjected to the functional test procedures at ambient room conditions.

4.4.3   Test Stamp

Each unit passing the tests shall be rubber stamped, near the nameplate, with the letters "FT" and the date on which satisfactory inspection and tests were completed.

4.4.4   Documentation

Three (3) copies of the supplier's final test results, including calibration at each test point of the applicable table of tolerances, shall be furnished with the delivery of each computer.

4.4.5   Test Equipment

Supplier's production, calibration, and test equipment maintenance and certification standards and procedures shall be furnished.

4.4.6   Acceptance Test

Boeing reserves the right to perform any or all of the functional test procedures as a condition of acceptance of the unit.

4.4.6.1   Rejections

The unit shall be rejected if it fails to meet any of the acceptance test requirements. Units rejected after rework and retest shall not be resubmitted without the specific approval of Boeing.

5.0 PREPARATION FOR DELIVERY

Packaging and marking of the article covered by this specification control drawing shall be in accordance with the provisions of D6-5800.

5.1 COMPONENT IDENTIFICATION

A nameplate containing the following information, legibly and permanently marked, shall be securely attached to each component:

 (1) Nomenclature

 (2) Supplier's name

 (3) Supplier's part number

 (4) Supplier's serial number

 (5) Coding for the year and month of manufacture

 (6) Modification status information

 (7) Boeing part number

 (8) DO-160 qualification identification (test categories)

6.0 CONTRACT DATA REQUIREMENTS

6.1 RELIABILITY REPORTS

An updated reliability report shall be submitted two weeks prior to each design review, and summarized in a final reliability report. This report shall show compliance and deviations from the requirements of section 3.6.7. It shall contain failure criteria, parts lists, failure data used, adjustments applied to data, and block diagrams or functional schematics. The data shall be supplemented by reliability data obtained from the qualification tests.

6.2 FAILURE EFFECTS ANALYSIS AND VERIFICATION REPORT

A failure effects analysis and a subsequent verification report will be required. The analysis shall be a detailed analysis of the failure aspects of all circuits, input and output devices, test routines, and software. The results of this analysis shall be used during

REV SYM

qualification testing and a verification report prepared indicating the results which verify the initial analysis and those which indicate new or contrary results.

6.3 MAINTAINABILITY ANALYSIS

An updated maintainability analysis shall be submitted two weeks prior to each design review, and shall be summarized in a final maintainability analysis. This analysis shall show the compliance and any deviations from the requirements of section 3.6.8. It shall indicate the unscheduled maintenance task time and the test and repair time and costs for the units together with the analysis methods used. The analysis shall indicate those features of the units, any required test equipment, special tools and tests that will allow good maintainability. The analysis shall be supplemented by analysis of actual failures and repairs experienced.

6.4 SOFTWARE REPORT

The supplier shall furnish and update the software documents and programs as listed in this specification at least two weeks prior to each design review, and shall provide a final report and program.

The minimum documents and programs required are as follows:

a. Supplier Software Document - Section 3.3.2
b. Flight Resident Program   - Section 3.3.3
c. Software Support Programs - Section 3.3.4
d. Simulation Program   - Section 3.3.5

These documents shall include the requirements of section 3.6.9 including standardized program symbology and annotated program listing.

REV SYM

APPENDIX A

ALGORITHM DEFINITION SUPPLEMENT
TO
AEMS SPECIFICATION

Prepared: July 1976   A.A. Lambregts

A-1.0 ALGORITHM DEFINITION

The computer algorithm is defined by the "airborne computer portion" of the FORTRAN program listing presented in Section A-3.0. The other materials in Appendix A are explanatory in nature and are provided for reference only.

The algorithm specifies the 727-200/JT8D-9 standard day deceleration profile prediction routine, logic for determining when to display each command, and the fast/slow reference signal. The AEMS avionics vendor shall develop the additional programming required for hardware interfacing, such as numeric display programming.

The algorithm is defined by a FORTRAN listing solely for the purpose of facilitating communication with the computer manufacturer. This program will run on a NOVA mini computer and generate the desired outputs. Other computer languages and alternate programming techniques are acceptable provided the input/output relationships remain unchanged.

REV SYM

A-2   FLOW DIAGRAMS AND DESCRIPTION

A macro flow diagram of the algorithm is prescribed in figure A-1. A more detailed diagram is prescribed in figure A-2.

After the power up the computer automatically enters the "standby" routine in which pilot inputs (Weights, V Final, H Field, H Min Gammag) are accepted and all constants and flags are calculated or set to their proper values as required to do the initialization for the V-X profile calculations. The minimum speeds and the speed schedule are also computed.

The algorithm keeps cycling through this "standby" routine until the "compute" mode is selected. It then enters the "compute" routine starting at address 45. The "compute" routine starts with the setting of the nominal deceleration schedule. In the "Nav Parameter Update" section the sensor information calibrated airspeed, altitude, distance, and ground speed are updated and true airspeed and glide path deviations are computed. After the glide slope has been captured and the first flap command has been given the initial altitude for profile computation is normalized to glide slope altitude and an airspeed correction applied consistent with constant total energy. Here also the "computer interlocks" are tested. If any of the interlock tests fail the warning flag (IWARN) is set. If IWARN = 1 the computer is inoperable and resets all displays. The warning flag can be set by computer failures, sensor failures, incompatible data or by an overspeed condition which would prevent stabilizing at the target altitude.

The "path geometry" routine, starting at address 60, uses airplane position, the glide slope angle set into the control panel, and the last computed IP distance to determine the path geometry. The IP point is a precomputed distance from touchdown where the first flap command is predicted to occur. The geometry is updated prior to each profile prediction. Next the IP status check is performed and the proper flags are set if IP must be updated.

The "wind reference" section, starting at address 75, first computes the wind at flight altitude (V_W) from actual airspeed and DME ground speed inputs. A reference wind at tower height (V_{REF}) is then computed for an assumed shear

POWER UP

PILOTS CONTROL PANEL → PILOTS INPUTS

PRELIMINARY CALCULATIONS

STANDBY

COMPUTE

NAV. PARAM. UPD. ← SENSORS

COMPUTE INTERLOCK TEST

IWARN=1

PATH GEOMETRY

WIND REF UPDATE

LIGHTS RESET DISPLAY INOP

INITIALIZATION X,V,FL,ETC.

STOP

X-V PROFILE COMPUTATION

EPR,FLAP,GEAR COMMAND UPDATE

AIRSPEED ERROR COMPUTE FAST/SLOW DRIVE → FAST/SLOW INDICATOR

LIGHT LOGICS UPDATE → ANNUNCIATOR PANEL

BOEING 727 AEMS MACRO FLOW CHART
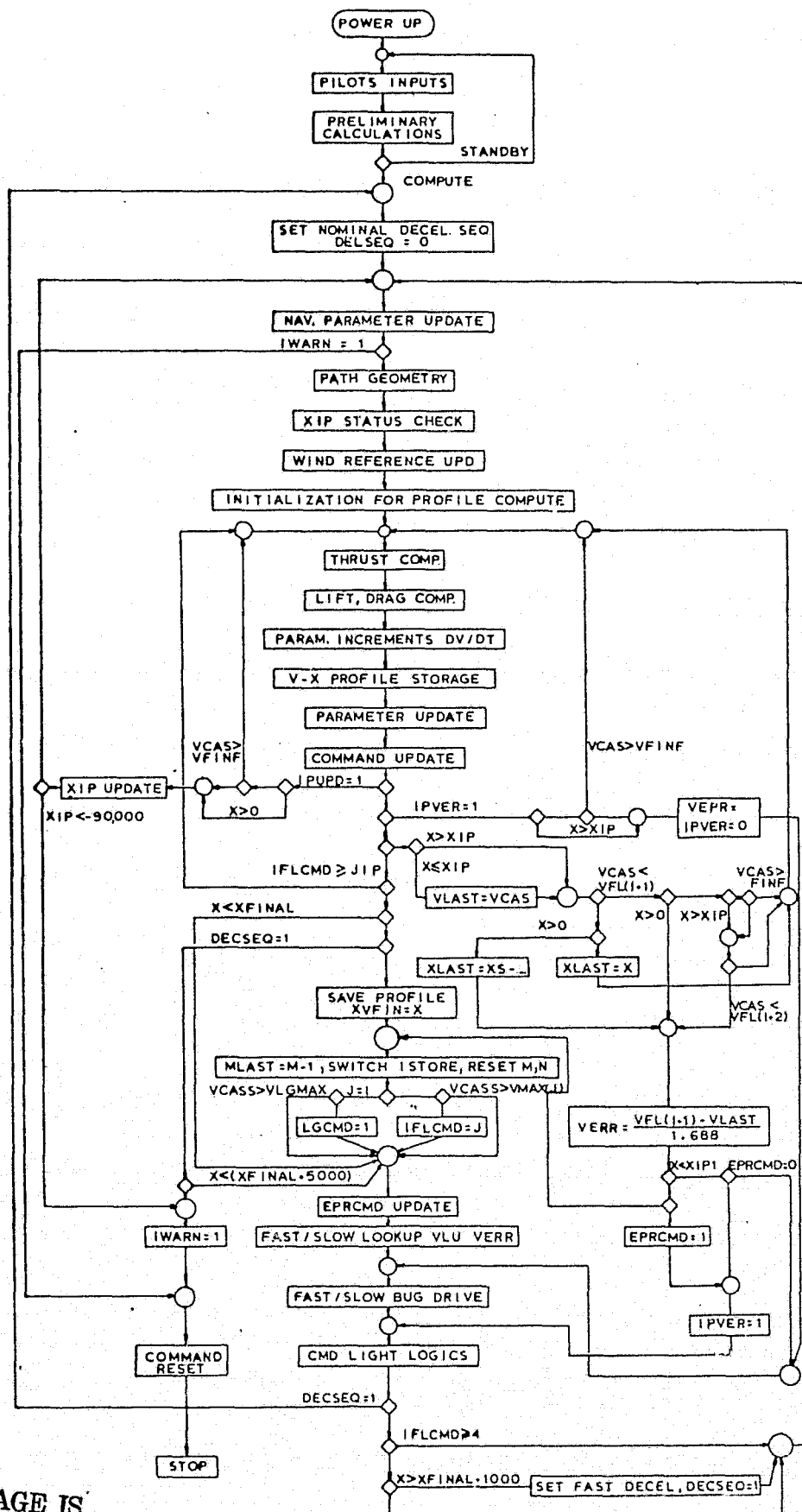
REV SYM

FIGURE A-2

BOEING 727 AEMS DETAILED FLOW CHART

profile. This reference wind (filtered) and the same shear profile are later used in the "V-X Profile Computation" routine to define the assumed wind variation as computed altitude varies along the predicted profile.

In the "Initialization" section, beginning at address 100, the starting conditions for the profile computation are updated prior to each profile prediction. Normally the starting conditions correspond to the actual airplane position, speed, configuration, thrust and wind. However, when computing the IP location, the prediction is initialized at the last computed IP position at the IP flight conditions. The initialization routine also contains logic which determines the starting conditions when an IP update is required. The stopping point for the profile calculations is set at the same time. Normally the profile calculation is stopped when the predicted speed reaches the final approach speed. However, it may also be stopped as a function of distance (e.g., to determine predicted speed error at the IP for display).

The "profile computation" loop starts at address 200 and predicts a flight profile between the beginning and end points set by the initialization routine. The profile prediction concept is depicted in figure A-3. First thrust and drag are computed using approximate equations representing steady state performance data for standard atmospheric conditions. Engine dynamics are represented as a first order lag.

Next, the deceleration relative to the earth dV_G/dt is computed from a single degree of freedom deceleration equation which assumes the airplane is in one g flight, using the computed thrust, lift, drag, as well as glide slope angle and wind information. The deceleration dV_G/dt, and the ground speed V_G are integrated numerically for step t, using simple rectangular integration to obtain the next point of the V-X profile. Also altitude is updated and the new wind at this altitude is computed. Ground speed and wind determine airspeed. True airspeed and altitude define calibrated airspeed. Flap position and landing gear position are updated as required by the configuration/speed schedule. The routine then tests if speed or distance for terminating the profile computation has been reached. If not so, the computation then cycles back to address 200 to compute thrust lift drag, etc., for the next point on the V-X

PROFILE PREDICTION CONCEPT USING ON-BOARD COMPUTER

BASIC DECELERATION EQUATION

STORED THRUST TABLES

STORED DRAG POLARS

WIND DERIVED FROM GROUND SPEED (DME) AND AIRSPEED

$$\frac{\partial V}{\partial t} \simeq g \left[\frac{T}{W} - \frac{C_D}{C_L} - \gamma_{GS} \left(1 + \frac{V_W}{V_{TAS}} \right) \right]$$

DECEL RELATIVE TO GROUND

PILOT INPUT

COMPUTED ALONG PROFILE

PILOT INPUT

COMPUTED ALONG PROFILE

NOTE: PROFILE PREDICTION ASSUMES EPR/FLAPS/GEAR SEQUENCED PER DESIRED SPEED SCHEDULE

SPEED/DISTANCE CALCULATION

VARIABLE TIME INCREMENT CORRESPONDING TO .5 KNOT SPEED CHANGE; i.e.

$$V_G = V_{G_{IC}} + \int \frac{\partial V_G}{\partial T} \Delta T \qquad \Delta T = \frac{.5}{\partial V / \partial T}$$

FROM DME

$$X = X_{IC} + \int V_G \, \Delta T$$

$$V_{TAS} \simeq V_G - V_{WIND}$$

ARB SHEAR PROFILE ASSUMED FOR PATH PREDICTIONS

FIGURE-A3
PROFILE PREDICTION CONCEPT

profile. When the test speed or distance for terminating the profile computation is reached, the algorithm branches to the "EPR, FLAP, GEAR COMMAND UPDATE" section. The computed V-X profile is stored in a table. If the profile does not result in a new command and/or the profile is not used to lookup the command speed for a given airplane distance, then the just-computed profile is discarded. The next computed profile is written over the previous profile. If the profile does generate a command and is to be used for command speed lookup, the profile is saved and the next profile is stored in a second table.

Starting at address 800, the commands are updated. The principle of the command timing is based on the prediction of the speed-distance (V-X) profile assuming the next schedule command is executed at the instantaneous airplane condition and the remaining commands are executed at their scheduled speeds. Repeating this profile calculation with continually updated starting conditions, a new command is generated whenever the speed at the target point is greater than desired or the distance where VFINAL is reached is closer to the touchdown point than desired, see figure A-5. However, if the airplane speed is higher than the placard speed, the command is not displayed. Also, if the airplane speed is below 1.3 V_S the next flap command is given, regardless of timing.

After the commands are updated the algorithm continues with "AIRSPEED ERROR COMPUTATION" and "FAST/SLOW DRIVE." Next the "LIGHT LOGICS" for command display are updated and the algorithm is then ready to cycle back to the NAV update routine to begin computation of a new V-X profile. Before doing so, the predicted profile is checked for overshoot condition. If any overshoot is predicted the program sets a "fast deceleration" schedule and computes a profile along the flap placards. If this profile still overshoots the target the warning flag is set (IWARN = 1) and the computer reverts to the "INOP" mode. If not, the command computations will continue.

The algorithm continues to cycle through these routines until the last command has been generated, then continues to generate a FAST/SLOW indication until the

airplane reaches the runway threshold. At this point the computer commands and displays are cleared in the "LIGHTS RESET" routine.

Deceleration Equation - The deceleration equation is programmed in the algorithm in the form

$$\frac{dV_G}{dt} = g \cos^2\left[\frac{T-D}{L} - \left(\frac{VW_H * \cos \gamma}{V_T} + 1\right) * TAN \gamma\right]$$

Configuration Sequencing - The thrust and drag terms of the equation are updated as the computation progresses to reflect the preprogrammed configuration/thrust command sequence. The starting configuration normally is the same as the actual airplane configuration (the IP calculation is an exception). The profile prediction then begins assuming the next command to be displayed to the pilot is executed (e.g., if at flaps 2, the prediction would begin with the flaps just starting to move from 2 to 5).

The sequencing logic is implemented by a set of counters within the digital program which are first set to the desired initial condition (e.g., synchronized to denote configuration changes as the profile computation progresses. The counters are reset prior to each profile prediction, so any configuration change made by the pilot would be automatically reflected in the initial conditions for the next prediction.

Thrust - The thrust calculation assumes three equal engines are operating at equal power setting. Steady state curves converting power setting into engine pressure ratio (EPR) and normalized thrust (FN/δ) are used. The atmospheric pressure ratio (δ) and Mach number (MACH) are computed for the instantaneous condition to obtain total net thrust (F_N).

It was found necessary to include the initial power setting and the effects of engine dynamics to obtain sufficiently accurate modeling of the airplane deceleration profiles. The thrust calculation provides for standard day conditions only.

Lift Coefficient - The lift coefficient calculation was simplified considerably by using calibrated airspeed instead of equivalent airspeed. This was done

REV SYM

because the complicated conversion formulas would slow down the profile computation, thereby losing accuracy in the timing of the commands, while gaining little in the computation of the correct speed.

Drag Coefficient - The drag coefficient (C_D) calculation includes polars for every flap detent that were curve-fit with the data points used in the airplane simulation in the region between 1.3 V_S and $V_{placard}$.

The drag for two flap detents is used to interpolate to the actual flap position. Landing gear drag is calculated separately and gear transition effects are included. Speed brake drag is not included.

Path Geometry (γ) - The path geometry routine determines the initial (γ_2) and final (γ_{GS}) path angles and the intersection point for switching the value of in the deceleration equation from γ_2 to γ_{GS}. The logic is depicted in figure A-4.

Wind Profile - The profile prediction uses the ARB wind shear profile (reference 5) to account for wind variations along the computed profile. The ARB profile is defined by the equation,

$$V_W/V_{W_{REF}} = .43 \, LOG_{10} \, h + .35$$

where V_W is the wind at the altitude (h), which varies along the computed profile. The logarithmic function was approximated by

$$V_W/V_{W_{REF}} = (2.226 \, H + 2893)/(H + 2152)$$

in the algorithm, to simplify the computation. This approximation is accurate between 450 and 10,000 feet.

The reference wind velocity ($V_{W_{REF}}$) at tower height (33 ft) is held constant during each profile prediction. The reference wind is computed onboard (i.e., not set by the pilot) and is updated prior to each profile prediction.

Air Data - The basic air data sources used are calibrated airspeed (VCASS) from the CADC and baro corrected altitude (HP) above sea level from the altimeter system as used for the ALTITUDE ALERT system.

PATH GEOMETRY ASSUMED FOR PROFILE CALCULATIONS
(NOT USED FOR PATH GUIDANCE).

INITIALLY ~ 2 SEGMENT PATH

CASE 1
ABOVE GLIDE SLOPE
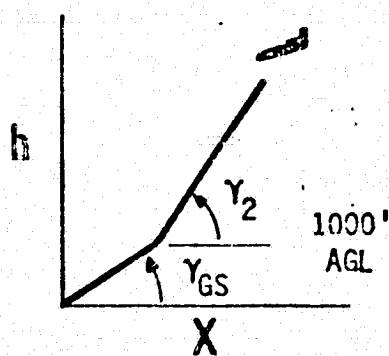
CASE 2
BELOW GLIDE SLOPE
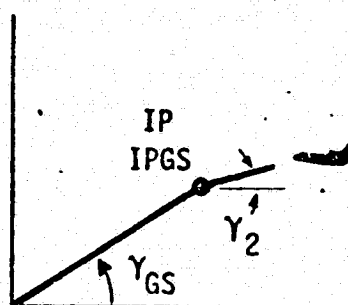
A) ABOVE IPGS   B) BELOW IPGS
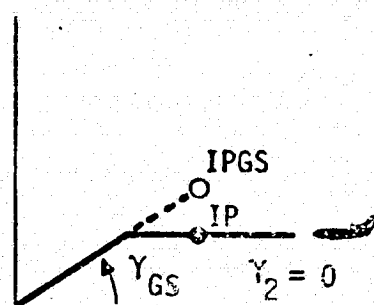
AFTER GS CAP AND FL2 CMD ~ 1 SEGMENT PATH + ENERGY COMP

START PROFILE CALCULATION ON GS

$$h_p = h + \Delta h$$

$$V_p = V - \frac{g}{V} \Delta h$$

ACTUAL V, h
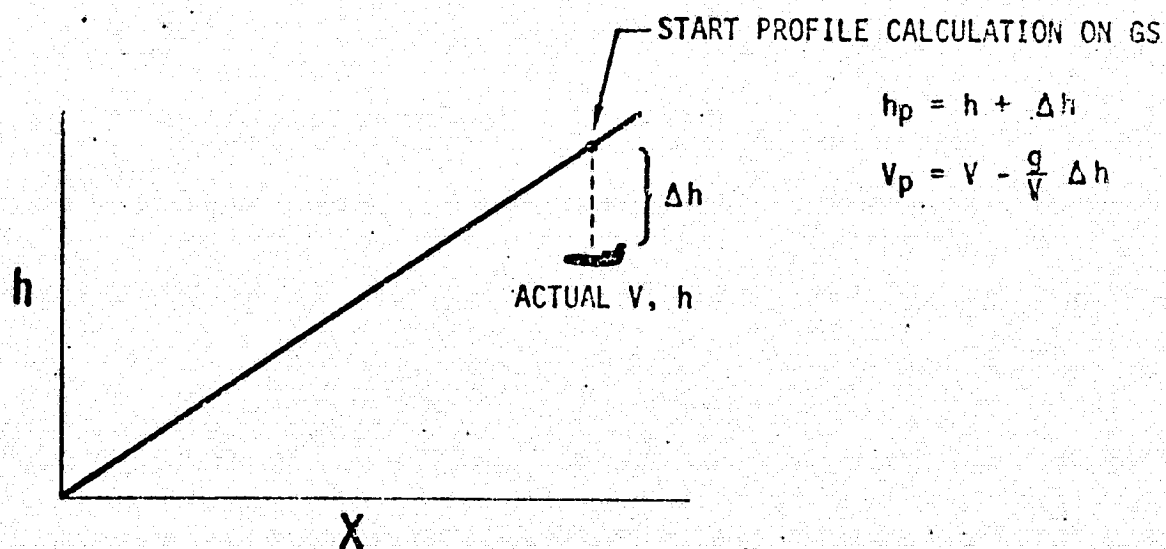
FIGURE-A4
PATH GEOMETRY CONCEPT

101

The calibrated airspeed VCASS is converted to true airspeed (VTS) using the following approximate relationship:

$$VTS = VCASS * (1 + .0000147 * HP)$$

As address 75 VTS is subsequently used in conjunction with ground speed (VGS) to compute the instantaneous wind at altitude which in turn is used to update the reference wind (VWR) at tower altitude using a simple digital update filter.

Subsequently for profile computation true airspeed and calibrated airspeed are computed using ground speed (VG) and wind (VWH) derived from the wind reference (VWR) by the inverse formula.

Mach number is calculated from calibrated airspeed (VCAS) and pressure altitude (HP), using the following approximation formula:

$$Mach = (.000896 - .16876 * HP)*VCAS \text{ whereby VCAS in ft/s, HP in ft.}$$

Delta (δ) is calculated from HP using a second order approximation formula:

$$DELTA = 1. - .3604E-4*HP+.048E-8*HP*HP$$

Configuration Command and FAST/SLOW display generation.

Phase 1

The initial commands (Power Cut and First Flap Command) called Phase 1 of the approach, are generated in two steps, see figura A-5. The computer first locates an initial point (IP) defined as the point at which the first flap command occurs on the desired deceleration profile. This is done by assuming the initial IP distance is far out, then computing the end point of the profile. Subsequently the IP profile calculation is repeated with the starting point IP adjusted by the distance between the target point and the end point of the previous IP profile. The iteration continues until the end point falls within 1000 feet of the target point. Thereafter the IP is updated at regular intervals until the first flap command has been generated. This computed profile follows a predetermined speed schedule for

GENERATION OF FLAP/GEAR/THRUST COMMANDS AND FAST/SLOW DISPLAY USING ON-BOARD COMPUTER ALGORITHM

PHASE I   PRIOR TO FLAP COMMAND

STEP 1   LOCATE IP

FAS/SLO DISPLAY

ΔV

ΔV

IP

V_{FINAL}

STABILIZATION POINT

V

X_{FINAL}

X

STEP 2   PREDICT V AT IP ASSUMING POWER CUT
o DISPLAY ΔV
o FLASH "IDLE" FOR $\Delta V \geq 0$

PHASE II   FLAP/GEAR COMMANDS*

WHEN $\Delta X = 0$
o FLASH CMD
o STORE PROFILE FOR FAS/SLO REF

REPEAT UNTIL $\Delta X = 0$

PREDICT X AT V_{FINAL} ASSUMING NEXT CONFIG HAS JUST BEEN SELECTED

$\vdash \Delta X \dashv$

TARGET

V_{FINAL}

V

* NOTE: EPR 1.1 AND APPR EPR CMDS BASED ON SPEED ONLY

X_{FINAL} X_{VFINAL} X

FIGURE-A5
COMMAND GENERATION CONCEPT

EPR/FLAP/GEAR sequencing and terminates at the altitude selected by the pilot for stabilizing in the landing configuration. After locating the IP. the computer predicts a profile starting with the actual airplane position, speed, and configuration and termination at the IP distance. This portion of the prediction assumes that the throttles have just been retarded to idle and that the current flap configuration (e.g., clean) and idle power are maintained all the way to the IP with speed brakes retracted. The difference between the predicted speed and the desired speed at the IP is displayed on the fast/slow indicator. This assists the pilot in hitting the IP at the desired energy level. The "EPR IDLE" command is given on the annunciator panel when the predicted speed at the IP equals or exceeds the desired speed. The first flap command (normally flaps 2) is also generated using the Phase 1 logic. For this prediction the flaps are assumed to have just been moved from the initial position to the next flap detent position.

Phase 2

After the first flap command has been generated, the computer switches to the Phase 2 logic. In Phase 2, the complete profile is predicted starting with the actual airplane position, speed, and configuration and terminating at the final speed selected by the pilot. The prediction assumes that the next (EPR/FLAP/GEAR setting has just been selected. When the predicted profile terminates at or lower than the target altitude selected by the pilot, the assumed command is illuminated on the annunciator panel. At this instant, the predicted speed vs distance profile is stored in the computer memory for reference; and the computer begins predicting a new profile assuming the next EPR/FLAP/GEAR setting has just been selected; etc. The fast/slow deviation is determined by entering the stored speed vs distance profile with the actual airplane distance (DME) to obtain the "desired" speed at that instant. After applying an energy correction to account for path deviations, the computer compares the actual speed to the (corrected) desired speed and displays the difference as an energy error on the fast/slow indicator. After the approach has been stabilized, the fast/slow display indicates energy deviations relative to the final approach speed and flight path selected by the pilot.

REV SYM

Fast/Slow Scaling - Although the fast/slow should be interpreted as meaning high or low on energy, the algorithm output to the instrument is in speed units. The fast/slow displays two types of information depending on the approach phase (figure A-5) with scaling as follows:

Phase	Data Displayed	Half-scale Indication (To first index mark)
1	Speed error predicted at the IP	20 knots
2	Speed deviation from desired profile*	10 knots

*NOTE: "Desired" profile is stored when each command is given.
Below the stabilization point the "desired" speed is
constant at the VFINAL selected by the pilot.

The 20 knot scaling for Phase 1 gives the pilot an indication of whether or not to use speed brakes prior to the IP. If the fast indication is below the first index mark (20 knots), the airplane will arrive at the IP at less than the flap placard speed. The Phase 2 scaling is expanded for better sensitivity on final approach.

REV SYM

A-3.0 LIST OF SYMBOLS

COSGG	=	COS (ASSUMED FLIGHT PATH ANGLE)
COSGG2	=	COS^2 (ASSUMED FLIGHT PATH ANGLE).
COSGA	=	COS (GAMMAG)
COSGA2	=	COS^2 (GAMMAG)
CD	=	DRAG COEFFICIENT
CDFL0	=	DRAG COEFFICIENT, FLAPS 0, GEAR UP
CDFL2	=	" " " 2, " "
CDFL5	=	" " " 5, " "
CDFL15	=	" " " 15, " "
CDFL25	=	" " " 25, " "
CDFL30	=	" " " 30, " "
CDGU	=	" " GEAR UP
CDI	=	" " GEAR UP, FIRST FLAP SETTING
CD2	=	" " GEAR UP, SECOND FLAP SETTING
CL	=	LIFT "
DCDG0	=	DELTA GEAR DRAG, FLAPS 0
DCDG2	=	" " " " 2
DCDG5	=	" " " " 5
DCDG15	=	" " " " 15
DCDG25	=	" " " " 25
DCDG30	=	" " " " 30
DCDLG1	=	" " " FIRST FLAP SETTING
DCDLG2	=	" " " SECOND FLAP SETTING
DCDGD	=	" " " GEAR DOWN
DCDLG	=	" " " AS FUNCTION OF TIME
DECSEQ	=	DECELERATION SEQUENCE FLAG
DELTA	=	RATIO OF AIR PRESSURES
DELXIP	=	CHANGE IN XIP AFTER XIP ITERATION
DFLM	=	FLAP POSITION TOLERANCE ON FLAP LIGHT
DH	=	ALTITUDE INCREMENT
DTLG	=	TIME INCREMENT IN LANDING GEAR LOWERING SEQUENCE
DVG	=	GROUND SPEED INCREMENT FT/S
DVGDT	=	INSTANTANEOUS DECELERATION FT/S^2

DVPLAC	=	FLAP PLACARD SPEED DECREMENT TO YIELD VMAX (I)
DVREF	=	INCREMENT ON 1.3*VSI TO YIELD VBUG
DVS(I)	=	INCREMENT ON KVMIN* VS(I) TO YIELD VMIN(I)
DX	=	DISTANCE INCREMENT
EPR	=	ENGINE PRESSURE RATIO
EPRCMD	=	EPR COMMAND
EPRIC	=	INITIAL ENGINE EPR
EPRICE	=	EPR SETTING FOR ANTI-ICING
EPRIDL	=	STEADY STATE IDLE EPR
EPRSET	=	ENGINE EPR SETTING
EPRSS	=	STEADY STATE ENGINE EPR
EPRS1	=	FIRST ENGINE EPR SETTING DURING DECELERATION
EPRS2	=	SECOND ENGINE EPR SETTING DURING DECELERATION
FL	=	FLAP POSITION DURING PREDICTION CALCULATION
FLS	=	ACTUAL AIRPLANE FLAP POSITION
FLCMD(I)	=	FLAP COMMAND INDEX DURING DECELERATION PREDICTION
FLCMDC	=	FIRST FLAP COMMAND ASSUMED DURING DECELERATION PREDICTION
FLR	=	FLAP RATE
FLØ	=	FLAP POSITION BEFORE START DECELERATION
FL1	=	FIRST FLAP DETENT USED FOR DRAG INTERPOLATION
FL2	=	SECOND FLAP DETENT, USED FOR DRAG INTERPOLATION
FN	=	NET THRUST, ONE ENGINE
FNOD	=	NORMALIZED NET THRUST, ONE ENGINE
FNOD1	=	NORMALIZED NET THRUST, ONE ENGINE, 1ST MACH NO
FNOD2	=	" " " " " 2ND "
GAMMAG	=	GLIDE SLOPE ANGLE SELECTED BY PILOT
H	=	ALTITUDE DURING DECELERATION PREDICTION
HERR	=	AIRPLANE'S ALTITUDE ERROR RELATIVE TO GS
HFIELD	=	FIELD ELEVATION
HIPGS	=	GLIDE SLOPE ALTITUDE AT XIP
HMNCAP	=	ASSUMED MINIMUM ALTITUDE FOR CAPTURING GLIDE SLOPE FROM ABOVE

REV SYM

HNAV	=	FILTERED AIRPLANE ALTITUDE SIGNAL
HP	=	PRESSURE ALTITUDE
HS	=	SENSED AIRPLANE ALTITUDE ABOVE FIELD
HXIP	=	ALTITUDE AT WHICH LAST XIP WAS CALCULATED
I	=	FLAP DETENT INDEX CORRESPONDING TO AIRPLANE
ICE	=	ANTI-ICING MODE LOGIC SIGNAL
IDVDT	=	COUNTER OF NUMBER OF ITERATIONS WITH DVGDT $>$ 0
IEIFA	=	FIRST EPR COMMAND LIGHT LOGIC SIGNAL
IE2FA	=	SECOND " " " " "
IE3FA	=	THIRD EPR COMMAND LIGHT LOGIC SIGNAL
IFL1FA	=	FLAP 2 " " " "
IFL2FA	=	FLAP 5 " " " "
IFL3FA	=	FLAP 15 " " " "
IFL4FA		FLAP 25 " " " "
IFL5FA		FLAP 30 " " " "
IFLCMD	=	FLAP COMMAND INDEX
IGS	=	GLIDE SLOPE CAPTURE LOGIC SIGNAL
ILGFA	=	LANDING GEAR COMMAND LIGHT LOGIC SIGNAL
IPUPD	=	MODE LOGIC SIGNAL FOR XIP CALCULATION
IPVER	=	" " " FOR VERR CALCULATION AFTER FIRST EPR CMD, RELATIVE TO XIP
ISTORE	=	V-X - TABLE STORE INDEX
ITI	=	LOGIC SIGNAL SETTING MACHS AT FIRST EPR COMMAND
IT2	=	LOGIC SIGNAL SETTING MACHS AT SECOND EPR COMMAND
IWARN	=	LOGIC SIGNAL, INDICATING INOPERABLE COMPUTER CONDITION
IWR	=	LOGIC SIGNAL SETTING INITIAL VWR
J	=	FLAP INDEX FOR FIRST ASSUMED FLAP COMMAND DURING DECELERATION PREDICTION
JIP	=	FIRST FLAP COMMAND INDICATOR
K	=	RUNNING FLAP COMMAND INDEX DURING DECELERATION PREDICTION
KVMIN	=	MINIMUM SPEED FACTOR RELATIVE TO STALL SPEED
KWIND	=	FILTER CONSTANT VWR CALCULATION

REV SYM

L	=	LIFT
LGCMD	=	LANDING GEAR COMMAND
LGCMDC	=	ASSUMED LANDING GEAR COMMAND FOR DECELERATION PREDICTION
LGS	=	ACTUAL LANDING GEAR POSITION
M	=	V-X PROFILE POINTS COUNTER
MACH	=	MACH NUMBER DURING DECELERATION PREDICTION
MACHS	=	MACH NUMBER AT LAST EPR SETTING
MACHI	=	FIRST MACH NO FOR FNODI LOOKUP
MACH2	=	SECOND MACH NO FOR FNOD2 LOOKUP
MLAST	=	LAST POINT IN V-X TABLE
MMAX	=	MAX NUMBER OF POINTS IN V-X TABLE
N	=	TABLE LOOKUP COUNTER
T	=	TOTAL NET THRUST DURING DECELERATION PREDICTION
TANGA	=	TAN(GAMMAG)
TANGG	=	TAN (γ)
TANG1	=	TAN (ASSUMED GS INTERCEPT ANGLE)
TANVER	=	TAN (ASSEMED GS INTERCEPT ANGLE, AT TIME OF FLCMD (JIP)
TANXIP	=	TAN (ASSUMED GS INTERCEPT ANGLE AT TIME OF LAST XIP CALCULATION)
THRPOS	=	AIRPLANE THROTTLE POSITION
TLG	=	TIME DURING LANDING GEAR LOWERING SEQUENCE
TLGT	=	TOTAL TIME REQUIRED TO LOWER GEAR
TRTHRP	=	TRIM THROTTLE POSITION ON GLIDE SLOPE FLAPS 30, GEAR DOWN
VAPPR	=	CALCULATED APPROACH SPEED
VBUG	=	AIRSPEED BUG DRIVE SIGNAL
VCAS	=	CALIBRATED AIRSPEED DURING DECELERATION PREDICTION PT/S
VCASS	=	AIRPLANE'S CALIBRATED AIRSPEED (KTS)
VEPRS2	=	SPEED AT WHICH SECOND EPR CMD IS PROGRAMMED TO OCCUR (KTS)
VEPRS3	=	SPEED AT WHICH APPROACH EPR CMD IS PROGRAMMED TO OCCUR (KTS)

REV SYM

VEPR2F	=	SPEED AT WHICH SECOND EPR COMMAND IS PROGRAMMED TO OCCUR (ft/S)
VFINAL	=	FINAL APPROACH SPEED SELECTED BY PILOT (KTS)
VFINF	=	FINAL APPROACH SPEED SELECTED BY PILOT (ft/S)
VFLT2	=	PROGRAMMED SPEED FOR FLAP COMMAND 2 (KTS)
VFLT5	=	" " " " " 5 "
VFLT15	=	" " " " " 15 "
VFLT25	=	" " " " " 25 "
VFLT3∅	=	" " " " " 30 "
VFL(I)	=	PROGRAMMED SPEED FOR FLAP COMMAND I (ft/S)
VG	=	GROUND SPEED DURING DECELERATION PREDICTION (ft/s)
VGNAV	=	FILTERED AIRPLANE GROUND SPEED ft/s
VGS	=	SENSED AIRPLANE GROUND SPEED (KTS)
VLAST	=	LAST COMPUTES VALUE OF VCAS @ $X < XIP$
VLGD	=	PROGRAMMED SPEED FOR LOWERING LANDING GEAR (KTS)
VLGDF	=	PROGRAMMED SPEED FOR LOWERING LANDING GEAR (FT/S)
VLG MAX	=	MAXIMUM SELECTED SPEED FOR LOWERING LANDING GEAR (KTS)
VLGMF	=	MAXIMUM SELECTED SPEED FOR LOWERING LANDING GEAR (ft/S)
VLGPL	=	LANDING GEAR PLACARD SPEED (KTS)
VLGPLF	=	LANDING GEAR PLACARD SPEED (ft/S)
VHAX(I)	=	MAXIMUM SELECTED SPEED FOR LOWERING FLAP TO Ith DETENT (KTS)
VMAXF(I)	=	MAXIMUM SELECTED SPEED FOR LOWERING FLAP TO Ith DETENT (ft/S)
VMIN(I)	=	MINIMUM SPEED AT Ith DETENT AT WHICH FLAPS ARE COMMANDED TO NEXT DETENT (KTS)
VMINF(I)	=	MINIMUM SPEED AT Ith FLAP DETENT AT WHICH FLAPS ARE COMMANDED TO NEXT DETENT (ft/S)
VOLTM	=	VOLTAGE REQUIRED TO DRIVE F/S FULL SCALE
VOUTP	=	FAST/SLOW OUTPUT VOLTAGE
VPLAC(I)	=	FLAP PLACARD AT Ith DETENT (KTS)
VSI	=	STALL SPEED AT INTERMEDIATE FLAP POSITION (KTS)
VS(I)	=	STALL SPEED AT Ith FLAP DETENT POSITION (KTS)
VT	=	TRUE AIRSPEED (FT/S) DURING DECELERATION PREDICTION
VTNAV	=	FILTERED TRUE AIRSPEED (FT/S) OF AIRPLANE
VTS	=	SENSED TRUE AIRSPEED OF AIRPLANE (KTS)
VWOVWR	=	RATIO OF WIND AT ALTITUDE AND WIND AT REFERENCE ALTITUDE

REV SYM

VWH	=	COMPUTED WIND AT ALTITUDE
VWM	=	MEASURED WIND AT ALTITUDE
VWR	=	WIND AT REFERENCE ALTITUDE
VWRC	=	COMPUTED WIND AT REFERENCE ALTITUDE
VWRXIP	=	WIND AT REFERENCE ALTITUDE COMPUTED AT TIME OF LAST XIP UPDATE
V1(M)	=	PREDICTED SPEED STORED IN TABLE 1 FOR X = X1(M)
V2(M)	=	PREDICTED SPEED STORED IN TABLE 2 FOR X = X2(M)
WEIGHT	=	AIRPLANE WEIGHT, SELECTED BY PILOT
X	=	DISTANCE FROM G.S. INTERCEPT (FT)
XCAPT	=	DISTANCE AT WHICH GS CAPTURE IS PROJECTED TO OCCUR
XEND	=	END DISTANCE CALCULATED FOR XIP PROFILE
XFINAL	=	END DISTANCE OF DECELERATION PROFILE, SELECTED BY PILOT THROUGH H FINAL
XIP	=	PREDICTED DISTANCE FOR COMMANDING THE FIRST FLAP COMMAND
XLAST	=	DISTANCE FOR WHICH THE SCHEDULED SPEED FOR FIRST FLAP CHANGE IS REACHED
XLU	=	LOOK UP DISTANCE FOR DEVELOPING THE COMMAND SPEED FOR AIRSPEED ERROR DISPLAY
XNAV	=	FILTERED DISTANCE SIGNAL OF AIRPLANE
XS	=	SENSED AIRPLANE DISTANCE
XVFIN	=	DISTANCE AT WHICH VFINAL IS PROJECTED TO OCCUR
XXIP	=	AIRPLANE DISTANCE AT WHICH XIP WAS LAST UPDATED
X1(M)	=	DISTANCE FOR PREDICTED SPEED V1(M), STORED IN TABLE I
X2(M)	=	DISTANCE FOR PREDICTED SPEED V2(M), STORED IN TABLE 2
XIP1	=	PREDICTED DISTANCE FOR COMMANDING THE SECOND FLAP COMMAND

A - 4.0 FORTRAN LISTING

A FORTRAN listing of the NOVA computer program used to develop the AEMS algorithm is provided on the following pages. The program has been organized and annotated so as to distinguish between the airborne computer algorithm (pages 116 thru 126) and the auxiliary routines (pages 113   thru 115) which were used to exercise the algorithm on a ground based (NOVA) computer. The "NOVA-only" routines provide inputs to the airborne computer algorithm simulating an approach with the "airplane" moving in discrete steps along a defined flight profile.

```
C     PROGRAM: DFAA
C     THIS "DELAYED FLAP APPROACH ALGORITHM" WAS DEVELOPED FOR THE
C     BOEING 727-200 UNDER NASA CONTRACT NAS2-8953 TO PROVIDE
C     FUEL AND NOISE BENIFITS BY DECELERATION UNDER COMPUTER CONTROLLED
C     THROTTLE AND FLAP COMMANDS TO THE PILOT
C     THE PROGRAM IS DEVELOPED FOR STANDARD DAY ONLY
      DIMENSION IDATE(3),ITIME(3)
      REAL MACH,MACHS,L,KVMIN,KWIND
      INTEGER EPRCMD
      COMMON VMIN(0:5),VS(0:5),DVS(0:5),VMAX(0:5),
     CVMAXF(0:5),VMINF(0:5),VFL(0:5),X1(250),X2(250),V1(250),V2(250),
     CFLCMD(0:5),VPLAC(0:5),KWIND,TLGT,VOLTM,KVMIN,MMAX,
     CDFLM,EPRMIN,VLGPL,DTLG,TLG,ISTORE,IT1,IT2,IFLCMD,LGCMD,
     CEPRCMD,VWR,VOUTP,IWARN,EPRSET,
     CIE1FA,IE2FA,IE3FA,ILGFA,IFL1FA,IFL2FA,IFL3FA,IFL4FA,IFL5FA,
     CVFINF,VLGMF,VLGPLF,VEPR2F,DECSEQ,XS,HS,HP,FLS,VCASS,VTS,
     CVGS,LGS,EPR,HNAV,XNAV,VGNAV,VTNAV,H,DVCOR,VT,VCAS,
     CMACH,DELTA,VWOVWR,VWM,VWRC,J,K,MACH1,MACH2,FNOD1,FNOD2,
     CMACHS,FNOD,FN,T,L,CL,CDFLO,CDFL2,CDFL5,CDFL15,CDFL25,
     CCDFL30,DCDG0,DCDG2,DCDG5,DCDG15,DCDG25,DCDG30,CD1,CD2,
     CDCDLG1,DCDLG2,FL1,FL2,CDGU,DCDGD,DCDLG,CD,DVG,DVGDT,DX,
     CFLR,X,M,N
      WRITE(12) "PROGRAM: DFAA (BOEING 727-200 DELAYED FLAP APPROACH ALGORITHM)"
      WRITE(12 ) "DATE LAST MODIFIED 3/17/76"
      WRITE(12) "SEE TONY LAMBREGTS FOR DETAILS ON THIS PROGRAM"
      CALL DATE(IDATE,IER)
      CALL TIME(ITIME,IER)
      WRITE(12) "DATE:",IDATE(1),"/",IDATE(2),"/",IDATE(3)
      WRITE(12) "TIME:",ITIME(1),":",ITIME(2),":",ITIME(3)
      CALL FOPEN(11,"DFAAD")
      READ(11)WEIGHT,HFIELD,GAMMAG,ICE          ◄─────── PILOT INPUTS
      READ(11)HFINAL,VFINAL
      READ(11)VLGMAX,IVW,IPRINT
      READ(11)HS,XS,VWR,VCASS,FLS,LGS,HDS        ◄─────── SENSOR INPUTS
      IF(IVW.EQ.0) VWH = CONSTANT,  IF(IVW.EQ.1) VWH = VWR0*(.43*ALOG10(H)+.35)
C     (.43*ALOG10(H)+.35) IS APPROXIMATED BY (2.226*H+2893.)/(H+2152.)
C     THIS APPROXIMATION IS VALID BETWEEN 450 AND 10000 FT
C     IF IPRINT=0, PROFILE CALCULATION IS NOT PRINTED STEP BY STEP
C
C     THE NEXT STATEMENTS FOR NOVA ONLY
      VTS = VCASS*(1+.0000147*(HS+HFIELD))
      VWOVWR = (2.226*HS+2893)/(HS+2152.)
      VWH = VWOVWR*VWR
      VGS =SQRT(VTS*VTS-HDS*HDS/1.688/1.688) + VWH
      TANHDS = HDS/(VGS*1.688)
      COSHDS = SQRT(1/(1+TANHDS*TANHDS))
C     FOR CONVENIENCE VWR IS INPUT ON NOVA, VGS IS COMPUTED
C     TANHDS ESTABLISHES THE ACTUAL AIRPLANE DESCEND ANGLE
C     COMPUTATION OF TRIM THROTTLE POSITION
      ITRIM = 0
      IC = 0
      L = WEIGHT*COSHDS
      CL = .539*L/(VCASS*VCASS*1.688*1.688)
      TLG = 0
      IF(LGS.EQ.1)TLG = 5
      FL = FLS
      GO TO 300
    1 HP = HS + HFIELD
      VT = VCASS*1.688*(1+.0000147*HP)
      MACH = (.000896+.16876E-7*HP)*VCASS*1.688
      DELTA = 1-.3604E-4*HP+.048E-8*HP*HP
      VWH = VWR*(2.226*HS+2893.)/(HS+2152.)
      T = L*(CD/CL+(VWH*COSHDS/VT+1)*TANHDS)
      FNOD = T/(DELTA*3)
```

```
      EPR = (13150+FNOD)/13500
      CRSA = (EPR+.04+.6215*MACH)/(.02453+.0083*MACH)
      THRPOS = (CRSA-38)*1.125
      WRITE(12,2)
  2   FORMAT("1",3X,"XS",9X,"HS",7X,"TANHDS",4X,"VCASS",5X,"FLS",3X,"THRPOS",
     C3X,"LGS",3X,"VFINAL",4X,"HFINAL",5X,"GAMMAG",5X,"WEIGHT",4X,"HFIELD",
     C6X,"VWR",3X,"ICE")
      WRITE(12,3) XS,HS,TANHDS,VCASS,FLS,THRPOS,,LGS,VFINAL,HFINAL,GAMMAG,
     CWEIGHT,HFIELD,VWR,ICE
  3   FORMAT("0",F8.0,4X,F6.0,4X,F7.4,4X,F5.1,4X,F4.1,4X,F5.1,4X,I1,4X,F5.1,4X,
     CF7.0,4X,F7.4,4X,F7.0,4X,F6.0,4X,F5.1,4X,I1)
      GO TO 40
C
  5   IF(IPUPD.EQ.1)GO TO 23
      IF(EPRCMD.EQ.0)GO TO 6
      IF(IFLCMD.GE.JIP) GO TO 6
      IF(IPVER.EQ.1) GO TO 6
      WRITE(12,4) VERR
  4   FORMAT("0",5X,"PREDICTED VERR AT XIP, ASSUMING NO FLAP CHANGE:
     CVERR =",F6.1,//)
      GO TO 29
  6   WRITE (12,7)
  7   FORMAT ("0",6X,"XS",6X,"VCASS",5X,"FLS",7X,"LGS",7X,"HS",7X,"VERR",
     C7X,"DVCOR",7X,"VLU")
      WRITE (12,8) XS,VCASS,FLS,LGS,HS,VERR,DVCOR,VLU
  8   FORMAT (4X,F7.0,3X,F6.1,3X,F5.0,4X,F5.0,6X,F6.0,4X,F5.1,7X,F5.1,5X,F6.1,/)
      WRITE (12,9)
  9   FORMAT (7X,"X",7X,"XFINAL",5X,"TANG1",5X,"XIP",7X,"HLU",6X,"TANVER",
     C5X,"DVLU",8X,"VCASLU")
      WRITE (12,10) X,XFINAL,TANG1,XIP,HLU,TANVER,DVLU,VCASLU
  10  FORMAT (4X,F7.0,3X,F7.0,4X,F7.4,3X,F7.0,2X,F6.0,4X,F7.4,4X,F5.1,8X,F6.1,/)
      WRITE (12,11)
  11  FORMAT (5X,"EPRCMD",4X,"IE1FA",5X,"IE2FA",5X,"IE3FA")
      WRITE (12,12) EPRCMD,IE1FA,IE2FA,IE3FA
  12  FORMAT (4X,I4,5X,I5,5X,I5,5X,I5,/)
      WRITE (12,13)
  13  FORMAT (5X,"LGCMD",5X,"ILGFA")
      WRITE (12,14) LGCMD,ILGFA
  14  FORMAT (3X,I5,5X,I5,/)
      WRITE (12,15)
  15  FORMAT (5X,"IFLCMD",4X,"IFL1FA",4X,"IFL2FA",4X,"IFL3FA",
     C4X,"IFL4FA",4X,"IFL5FA")
      WRITE (12,16) IFLCMD,IFL1FA,IFL2FA,IFL3FA,IFL4FA,IFL5FA
  16  FORMAT (4X,I4,5X,I5,5X,I5,5X,I5,5X,I5,5X,I5,/)
      WRITE(12,17)
  17  FORMAT(5X,"IWARN",5X,"DECSEQ")
      WRITE(12,18) IWARN,DECSEQ
  18  FORMAT(5X,I3,8X,F3.0,//)
      IF(IDVDT.NE.20) GO TO 20
      WRITE(12,19)
  19  FORMAT("0",10X,"XIP CANNOT BE CALCULATED: GS INTERCEPT TOO STEEP")
  20  IF(XS.GT.-1000) GO TO 3500
      IF(IPVER.EQ.1) GO TO 50
      IF(IWARN.EQ.0) GO TO 29
      WRITE(12,22)
  22  FORMAT("0",10X,"WARNING ALGORITHM ABORT, OVERSHOOT CONDITION")
      GO TO 3500
  23  WRITE(12,24) XIP,TANXIP
  24  FORMAT("0",2X,"XIP=",F8.0,5X,"TANXIP=",F8.4,//)
      GO TO 50
  25  IC = 1
      IF(IPRINT.EQ.0) GO TO 200
      WRITE(12,26)
  26  FORMAT("0",3X,"X",8X,"H",7X,"TANGG",5X,"VCAS",5X,"VT",6X,"VG",6X,"VWH",
```

```
        C5X,"FL",3X,"TLG",4X,"EPR",7X,"T",7X,"CL",6X,"CD",6X,"DVGDT",/)
27      WRITE(12,28) X,H,TANGG,VCAS,VT,VG,VWH,FL,TLG,EPR,T,CL,CD,DVGDT
28      FORMAT(F8.0,3X,F6.0,3X,F7.4,3X,F5.1,3X,F5.1,3X,F5.1,3X,F5.1,3X,F4.1,
        C3X,F3.1,3X,F5.3,3X,F6.0,3X,F5.3,3X,F6.4,3X,F6.2)
        IF(M.EQ.1) GO TO 200
        GO TO 800
C
C       RE-INITIALIZATION FOR PROFILE  COMPUTATION
29      IF(IWARN.EQ.1) GO TO 3500
        IGS = 0
        IF(ABS(HS-XS*TANGA).LT.15) GO TO 30
        HS = HS + 1000.*TANHDS
        GO TO 31
30      IGS = 1
        COSGG = COSGA
        COSGG2 = COSGA2
        TANGG = TANGA
31      XS = XS + 1000.
        IF(IGS.EQ.0) XINTC = XCAPT
        IF(IGS.EQ.1) HS = XS*TANGA
        VWH = VWR
        IF(IVW.EQ.1) VWH = VWR*(2.226*HS+2893.)/(HS+2152.)
        COSGG = COSHDS
        IF(IGS.EQ.1) COSGG = COSGA
        IF(EPRCMD.EQ.0) GO TO 39
        DT = 1000/(VGS*1.688)
        FLR = .313
        IF(FLS.GE.5) FLR = 3.0
        FLS = FLS + FLR*DT
        IF(FLS.GT.FLCMD(IFLCMD)) FLS = FLCMD(IFLCMD)
        N = 2
        IF(IFLCMD.GE.JIP) GO TO 33
        TANVER = TANG1
        GO TO 34
33      IF(ISTORE.EQ.1) GO TO 36
34      IF(XS.LT.X1(N)) GO TO 35
        IF(N.EQ.MLAST) GO TO 35
        N = N+1
        GO TO 34
35      VCASLU=V1(N-1)+(XS-X1(N-1))*(V1(N)-V1(N-1))/(X1(N)-X1(N-1))
        GO TO 38
36      IF(XS.LT.X2(N)) GO TO 37
        IF(N.EQ.MLAST) GO TO 37
        N = N+1
        GO TO 36
37      VCASLU=V2(N-1)+(XS-X2(N-1))*(V2(N)-V2(N-1))/(X2(N)-X2(N-1))
38      IF(XS.GT.XFINAL) VCASLU = VFINF
        HLU = XINTC*TANGA + (XS-XINTC)*TANVER
        DALT = HS-HLU
        VTSF = VCASLU*(1+.0000147*(HS+HFIELD))
        DVLU = 32.2*DALT/VTSF
        VTS = (VTSF-DVLU)/1.688
        VGS = VTS*COSGG + VWH/1.688
        VCASS = VTS/(1+.0000147*(HS+HFIELD))
        IF(LGS.EQ.1) TLGIC = 5
        IF(LGCMD.EQ.1) TLGIC = TLGIC + DT
        IF(TLGIC.GT.5) TLGIC = 5
        IF(TLGIC.EQ.5) LGS = 1
        IF(EPRCMD.EQ.1) THRPOS = 0
        IF(EPRCMD.EQ.2) THRPOS = 14
        IF(EPRCMD.EQ.3) THRPOS = TRTHRP + 1
        GO TO 50
C       THESE THROTTLE POSITIONS GOOD FOR STANDARD DAY ONLY
39      VTS = VCASS*(1+.0000147*(HS+HFIELD))
```

```
          VGS = VTS*COSGG+VWH/1.688
          GO TO 50
C
C
C         SETTING OF CONSTANTS          ◄──────── START OF AIRBORNE COMPUTER ALGORITHM
   40     EPRS1 = 1.0
          EPRS2 = 1.1
          IF(ICE.EQ.1) EPRS1 = 1.2
          IF(ICE.EQ.1) EPRS2 = 1.2
          KWIND = .1
          TLGT = 5.
          TLGIC = 0
          VOLTM = 10.0
          VOUTP = 1.5*VOLTM
          KVMIN = 1.3
          VWR = 0
          MMAX = 250
C         ON NOVA MMAX=250 WAS SELECTED TO ALLOW PRINT OUT OF COMPLETE PROFILE
          DFLM = 1.0
          DVPLAC = 0
          DVREF = 0
          XVFIN = 0
          XEND = 0
          DVCOR = 0
          DVGDT = -.5
          FL0 = FLS
          HMNCAP = 1000.
          XIP = -90000.
          IPVER = 0
          IEPRAP = 0
          EPRCMD = 0
          LGCMDC = 0
          IFLCMD = 0
          ISTORE = 1
          IWARN  = 0
          IWR    = 0
          JIP    = 1
C         ALL SENSOR INPUT FLAGS SHOULD BE TESTED ***************************
C         ANY INVALID FLAG SETS IWARN =1          ***************************
C         VGS LESS THAN +75 KTS ALSO SETS IWARN = 1 ***************************
C
          IE1FA = 0
          IE2FA = 0
          IE3FA = 0
          ILGFA = 0
          IFL1FA =0
          IFL2FA =0
          IFL3FA =0
          IFL4FA =0
          IFL5FA =0
C
          FLCMD(0) = 0.
          FLCMD(1) = 2.
          FLCMD(2) = 5.
          FLCMD(3) = 15.
          FLCMD(4) = 25.
          FLCMD(5) = 30.
C
          VLGPL = 270.
C
          VPLAC(0) = 300
          VPLAC(1) = 230
          VPLAC(2) = 215.
          VPLAC(3) = 205.
```

```
           VPLAC(4) = 185.
           VPLAC(5) = 185.
C
           COSGA = COS(GAMMAG)
           COSGA2 = COSGA*COSGA
           TANGA = TAN(GAMMAG)
           XFINAL = HFINAL/TANGA
C
           DO 41 I=0,5
    41     VMAX(I) = VPLAC(I) + DVPLAC
C
           IF(WEIGHT.LT.110000.) IWARN = 1
           IF(WEIGHT.GT.155400.) IWARN = 1
           VS(0) = 119.5+62.E-5*(WEIGHT-1.E5)
           VS(1) = 112.0+59.E-5*(WEIGHT-1.E5)
           VS(2) = 95.5+47.E-5*(WEIGHT-1.E5)
           VS(3) = 89.5+43.5E-5*(WEIGHT-1.E5)
           VS(4) = 83.75+40.0E-5*(WEIGHT-1.E5)
           VS(5) = 82.0+40.E-5*(WEIGHT-1.E5)
C
           DVS(0) = 0.
           DVS(1) = 0.
           DVS(2) = 0.
           DVS(3) = 0.
           DVS(4) = 0.
           DVS(5) = 0.
C
           DO 42 I=0,5
    42     VMIN(I) = KVMIN * VS(I) + DVS(I)
           IF(VFINAL.LT.(1.3*VS(5))) IWARN = 1
           VAPPR = 1.3*VS(5)+5.
           VFLT2 = 200+.00060*(WEIGHT-130000.)
           VFLT5 = 185+.00075*(WEIGHT-130000.)
           VFLT15 = 174+.00070*(WEIGHT-130000.)
           VFLT25 = 152+.00065*(WEIGHT-130000.)+3.*(VFINAL-VAPPR)/15.
           VFLT30 = 134+.00060*(WEIGHT-130000.)+14.*(VFINAL-VAPPR)/15.
           VLGD= 165+.00070*(WEIGHT-130000.)+5.*(VFINAL-VAPPR)/15.
           VEPRS2 = 143+.00065*(WEIGHT-130000.)+26.*(VFINAL-VAPPR)/15.
           VEPRS3 = 131+.00055*(WEIGHT-130000.)+16.*(VFINAL-VAPPR)/15.
C
           VFINF = VFINAL*1.688
           VLGMF = VFLT15*1.688-1
           DO 43 I=0,5
    43     VMAXF(I) = VMAX(I) * 1.688
           DO 44 I=0,5
    44     VMINF(I) = VMIN(I) * 1.688
           VLGPLF = VLGPL * 1.688
           VEPR2F = VEPRS2 * 1.688
    45     CONTINUE
C          SETTING OF NOMINAL DECEL. SCHEDULE
           DECSEQ = 0
C          VFL(0) IS A DUMMY VARIABLE
           VFL(0) = 250*1.688
           VFL(1) = VFLT2*1.688
           VFL(2) = VFLT5*1.688
           VFL(3) = VFLT15*1.688
           VFL(4) = VFLT25*1.688
           VFL(5) = VFLT30*1.688
           VLGDF = VLGD*1.688
C          THE NEXT STATEMENT FOR NOVA ONLY*******************************
C          IF(IWR.EQ.1) GO TO 5
C
    50     CONTINUE
C          NAV UPDATE
```

```
         IF(ICE.EQ.0) GO TO 52
         IF(FLS.LT.15.) IWARN = 1
         IF(LGS.NE.1) IWARN = 1
    52   IF(IWARN.EQ.1) GO TO 890
         HNAV = HS
         XNAV = XS
         IF(XNAV.GT.-1000.) GO TO 885
         VTS = VCASS*(1+.0000147*(HNAV+HFIELD))
         VGNAV = VGS*1.688
         VTNAV = VTS*1.688
         H = +HNAV
         X = XNAV
         VT = VTNAV
         IF(ABS(HNAV-XNAV*TANGA).GT.30) GO TO 55
         IF(IFLCMD.LT.JIP) GO TO 55
         H = XNAV*TANGA
         HERR = HNAV - H
         DVCOR = 32.2* HERR/VTNAV
         VT = VTNAV + DVCOR
    55   VCAS = VT/(1 + .0000147*(H+HFIELD))
         MACH = (.000896+.16876E-7*(H+HFIELD))*VCAS
C
C        DETERMINATION OF GLIDE SLOPE INTERCEPT GEOMETRY
C        THE NEXT STATEMENT FOR NOVA ONLY *******************************
         IC = 0
         IF(ABS(HNAV-XNAV*TANGA).GT.15) GO TO 62
         IGS = 1
C        AIRPLANE ON GS
         XCAPT = XNAV
         COSGG = COSGA
         COSGG2 = COSGA2
         TANGG = TANGA
         GO TO 65
    62   IGS = 0
         IF((HNAV-XNAV*TANGA).LT.0.) GO TO 63
C        GS CAPTURE FROM ABOVE
         XCAPT = HMNCAP/TANGA
         TANGG = (HNAV-HMNCAP)/(XNAV-XCAPT)
         COSGG2 = 1/(1+TANGG*TANGG)
         COSGG = SQRT(COSGG2)
         GO TO 65
C        GS CAPTURE FROM BELOW
    63   HIPGS = XIP*TANGA
         IF(HNAV.GT.HIPGS) GO TO 64
C        LEVEL GS CAPTURE
         XCAPT = HNAV/TANGA
         TANGG =0.
         COSGG = 1.
         COSGG2 = 1.
         GO TO 65
C        DESCENDING GS CAPTURE
    64   XCAPT = XIP
         TANGG = (HNAV-HIPGS)/(XNAV-XIP)
         COSGG2 = 1/(1+TANGG*TANGG)
         COSGG = SQRT(COSGG2)
    65   TANG1 = TANGG
C        TANGG IS RESET AT GS CAPTURE
C        IP UPDATE CRITERIA
         IF(IFLCMD.GE.JIP) GO TO 75
         IF(ABS(FLO-FLS).GT..1) GO TO 67
         IF(ABS(XFINAL-XEND).GT.1000.) GO TO 67
         IF((XXIP-XNAV).GT.5000.) GO TO 67
         IF((HXIP-HNAV).GT.250.) GO TO 67
         IF((VWRXIP-VWR).GT.5.) GO TO 67
```

```
        IF((TANXIP-TANGG).GT..01) GO TO 67
C       COMPUTATION OF COMMANDS AND VERR BEFORE IFLCMD = JIP
        IPUPD = 0
        GO TO 75
C       IP UPDATE
   67   XXIP = XNAV
        HXIP = HNAV
        VWRXIP = VWR
        TANXIP = TANGG
        IPUPD = 1
        X = XIP
        H = XCAPT*TANGA + (XIP-XCAPT)*TANGG
C
C       WIND REFERENCE CALCULATION
   75   VWOVWR = (2.226*HNAV+2893.)/(HNAV+2152.)
        VWM = VGNAV-VTNAV*COSGG
        VWRC = VWM/VWOVWR
        VWR = VWR+KWIND*(VWRC-VWR)
        IF(IWR.EQ.0) VWR = VWRC
        IWR = 1
C
        CONTINUE
C100    INITIALIZATION FOR V-X PROFILE CALCULATION
        I = 0
        J = 0
        K = 0
        IDVDT = 0
        FL = FLS
        LGCMD = LGS
C       FOR AIRBORNE COMPUTER CHANGE NEXT STATEMENT TO "TLG = 0" ***************
        TLG = TLGIC
C       AS SOON AS LG HANDLE GOES DOWN LGS = 1
        IF(LGS.EQ.1) TLG = TLGT
        DTLG = 0
  110   IF(FL.LE.(FLCMD(I)+.1)) GO TO 120
        I = I + 1
        GO TO 110
  120   IF(VCASS.GT.VMIN(I)) GO TO 130
        I = I + 1
        GO TO 120
  130   IFLCMD = I
        IF (I .EQ. 5) GO TO 900
        IF(IPVER.EQ.1) GO TO 155
        IF(EPRCMD.EQ.0) GO TO 155
        IF (LGS .EQ. 1)GO TO 160
        IF (VLGDF .LT.VFL(I)) GO TO 135
        GO TO 160
  135   IF (VLGDF .GT. VFL(I+1))GO TO 150
        GO TO 160
  150   LGCMDC=1
  155   J=I
        GO TO 170
  160   J=I+1
  170   IF(IPUPD.EQ.0) GO TO 180
        J = I+1
        JIP = J
  180   K = J
        FLCMDC = FLCMD(J)
        M = 1
        N = 2
        IT1 = 0
        IT2 = 0
        EPRSET = EPRS1
        IF(EPRCMD.EQ.0)EPRIC=-.04-.6215*MACH+(.02453+.0083*MACH)*(38.+
```

```
        CTHRPOS/1.125)
        IF(IPVER.EQ.1) GO TO 183
        IF(ICE.EQ.0) GO TO 182
        EPRICE = 1.2
        IF(EPRCMD.EQ.1) EPRIC=EPRIC+.5*(EPRICE-EPRIC)
        GO TO 183
  182   EPRIDL = 1.0439-.0912*MACH-.4134*MACH*MACH
        IF(EPRCMD.EQ.1)EPRIC = EPRIC+.5*(EPRIDL-EPRIC)
        IF(EPRCMD.EQ.2)EPRIC = EPRIC+.5*(1.1-EPRIC)
C       FILTER CONSTANT SHOULD BE ADJUSTED SO THAT ALGORITHM LOOPING TIME
C       EQUALS ENGINE TIME CONSTANT* FILTER CONSTANT
  183   EPR = EPRIC
        VWOVWR = (2.226*H+2893.)/(H+2152.)
        VWH = VWOVWR*VWR
        VLAST = VFL(I+1) + 1
        IF(IPUPD.EQ.0) GO TO 185
        VCAS = VFL(J)
        VT = VCAS*(1 + .0000147*(H+HFIELD))
  185   VG = VWH + VT*COSGG
        HP = H+HFIELD
        MACH = (.000896 + .16876E-7*HP)*VCAS
        DELTA = 1-.3604E-4*HP +.048E-8*HP*HP
        IF(IPUPD.EQ.0) GO TO 222
        IF(ICE.EQ.1) GO TO 190
        EPR = 1.0439-.0912*MACH-.4134*MACH*MACH
        GO TO 200
  190   EPR = 1.2
C
  200   CONTINUE
C       THRUST COMPUTATION --JT8D-9 ENGINE
        IF (VCAS .LT. VEPR2F)GO TO 210
        IF (EPRSET .GT. 1.0)GO TO 205
        EPRSS = 1.0439-.0912*MACH-.4134*MACH*MACH
C       THIS REPRESENTS THE EPR WITH THROTTLE AT IDLE
        GO TO 220
  205   IF (IT1 .EQ. 0)MACHS = MACH
        IT1 = 1
C       THIS MEMORIZES THE MACH NUMBER AT START OF FIRST DECEL PHASE
        GO TO 215
  210   EPRSET = EPRS2
        IF (IT2 .EQ. 0)MACHS = MACH
        IT2 = 1
C       THIS MEMORIZES THE MACH NO AT START OF 2ND DECEL PHASE
  215   EPRSS = EPRSET+.22*(MACHS-MACH)
  220   EPR = EPR + .2*(EPRSS - EPR)
  222   MACH1 = .3
        FNOD1 = -20857.+27769.*EPR-6637.*EPR*EPR
        IF (MACH .GT. .3)GO TO 225
        MACH2 = .2
        FNOD2 = -24689.+33686.*EPR-8849.*EPR*EPR
        GO TO 230
  225   MACH2 = .4
        FNOD2 = -22393.+31692.*EPR-8849.*EPR*EPR
C       LINEAR INTERPOLATION OF FNOD FOR MACH BETWEEN MACH1 AND MACH2
  230   FNOD = FNOD1+(MACH-.3)*(FNOD2-FNOD1)/(MACH2-.3)
        FN = FNOD*DELTA
        T = 3 * FN
C
C250    LIFT COEFFICIENT CALCULATION
        L = WEIGHT * COSGG
        CL = .539*L/(VCAS*VCAS)
C       VCAS IS USED FOR SIMPLIFICATION
C
C       DRAG COEFF. CALCULATION
```

```
300   IF (FL .LE. 2)GO TO 310
      IF (FL .LE. 5)GO TO 320
      IF (FL .LE. 15)GO TO 330
      IF (FL .LE. 25)GO TO 340
      IF (FL .LE. 30)GO TO 350
310   CDFL0 = .020-.01136*CL+.0656*CL*CL
      DCDG0 = .03175-.00175*CL
      CDFL2 = .0442-.0248*CL+.0599*CL*CL
      DCDG2 = .03175-.00175*CL
      CD1 = CDFL0
      CD2 = CDFL2
      DCDLG1 = DCDG0
      DCDLG2 =DCDG2
      FL1 = 0
      FL2 = 2
      GO TO 360
320   CDFL2 = .0442-.0248*CL+.0599*CL*CL
      DCDG2 = .03175-.00175*CL
      CDFL5 = .0746-.0577*CL+.0716*CL*CL
      DCDG5 = .03-.00175*CL
      CD1 = CDFL2
      CD2 = CDFL5
      DCDLG1 = DCDG2
      DCDLG2 = DCDG5
      FL1 = 2
      FL2 = 5
      GO TO 360
330   CDFL5 = .0746-.0577*CL+.0716*CL*CL
      DCDG5 = .03-.00175*CL
      CDFL15 = .0924-.0678*CL+.0710*CL*CL
      DCDG15 = .0275-.00175*CL
      CD1 =CDFL5
      CD2 = CDFL15
      DCDLG1 =DCDG5
      DCDLG2 = DCDG15
      FL1 = 5
      FL2 = 15
      GO TO 360
340   CDFL15 = .0924-.0678*CL+.0710*CL*CL
      DCDG15 = .0275-.00175*CL
      CDFL25 = .1283-.0846*CL+.0758*CL*CL
      DCDG25 = .0275-.00175*CL
      CD1 = CDFL15
      CD2 = CDFL25
      DCDLG1 = DCDG15
      DCDLG2 = DCDG25
      FL1 = 15
      FL2 = 25
      GO TO 360
350   CDFL25 = .1283-.0846*CL+.0758*CL*CL
      DCDF25 = .0275-.00175*CL
      CDFL30 = .1309-.0386*CL+.0547*CL*CL
      DCDG30 = .0235-.00175*CL
      CD1 = CDFL25
      CD2 = CDFL30
      DCDLG1 = DCDG25
      DCDLG2 = DCDG30
      FL1 = 25
      FL2 = 30
C
C     GEAR UP DRAG
C
360   CDGU = CD1+(FL-FL1)*(CD2-CD1)/(FL2-FL1)
C
C     LANDING GEAR DRAG
```

```
C
      DCDGD = DCDLG1+(FL-FL1)*(DCDLG2-DCDLG1)/(FL2-FL1)
      DCDLG = DCDGD*TLG*.2
C
C     TOTAL DRAG COEFFICIENT
      CD = CDGU+DCDLG
C     THE NEXT 3 STATEMENT FOR NOVA ONLY ***************************
      IF(ITRIM.NE.0)GO TO 500
      ITRIM = 1
      GO TO 1
C
C     INTEGRATION ROUTINE
C     COMPUTE INCREMENTS FIRST
  500 DVG = -.844
      IF(ABS(H-X*TANGA).GT.15.) GO TO 510
      IGS = 1
      COSGG = COSGA
      COSGG2 = COSGA2
      TANGG = TANGA
  510 DVGDT = 32.2*COSGG2*(T/L-CD/CL-(VWH*COSGG/VT+1)*TANGG)
      IF(DVGDT.GT.-.1) IDVDT = IDVDT + 1
      IF(IDVDT.LT.20) GO TO 520
      IF(IPUPD.EQ.1) GO TO 885
  520 DT = ABS(DVG/DVGDT)
      IF(DT.GT.1.0) DT = 1.0
      DVG = DVGDT*DT
      DX = VG*DT
      DH = DX*TANGG
      FLR = .313
      IF (FL .GT.5)FLR = 3.0
      IF (VCAS .LE. VLGDF) DTLG = DT
      IF (LGCMDC .EQ. 1) DTLG = DT
      IF (VCAS .GT. VLGMF) DTLG = 0
      IF (VCAS .GT. VMAXF(K)) FLR = 0
      IF (FL .GE. FLCMDC) FLR = 0
C     THE NEXT STATEMENT FOR NOVA ONLY ****************************
      IF(IC.EQ.0) GO TO 25
C
C600  PARAMETER UPDATE
      VG = VG+DVG
      X = X+DX
      H =H + DH
      IF(IGS.EQ.1) H = X*TANGG
      VWH = VWR*(2.226*H+2893.)/(H+2152.)
      VT = (VG-VWH)/COSGG
      HP = H+HFIELD
      DELTA = 1-.3604E-4*HP+.048E-8*HP*HP
      VCAS = VT/(1+.0000147*HP)
      MACH = (.000896+.16876E-7*HP)*VCAS
      FL = FL +FLR*DT
      IF(K.EQ.5) GO TO 610
      IF (VCAS .LT. VFL(K+1))K = K+1
  610 FLCMDC = FLCMD(K)
      IF (FL .GT. FLCMDC)FL = FLCMDC
      TLG = TLG+DTLG
      IF (TLG .GT. TLGT) TLG = TLGT
C
C700  VCAS-X PROFILE MEMORIZATION
      IF(M.EQ.MMAX) GO TO 800
      IF(ISTORE.EQ.2) GO TO 760
      V1(M) = VCAS
      X1(M) = X
      GO TO 770
  760 V2(M) = VCAS
```

```
          X2(M) = X
  770     M = M+1
C         THE NEXT STATEMENT FOR NOVA ONLY ********************************
          IF(IPRINT.EQ.1) GO TO 27
C
  800     CONTINUE
C         COMMANDS UPDATE
          IF(M.LE.2) GO TO 200
          IF(IPUPD.EQ.1) GO TO 840
          IF(IPVER.EQ.0) GO TO 810
          IF(X.GT.XIP) GO TO 805
          IF(VCAS.GT.VFINF) GO TO 200
  805     VERR = (VFL(I+1)-VCAS)/1.688
          IPVER = 0
          GO TO 1110
  810     IF(IFLCMD.GE.JIP)GO TO 850
          IF(X.LT.XIP) VLAST = VCAS
          IF(VCAS.LT.VFL(I+1)) GO TO 820
          IF(X.GT.0)GO TO 815
          XLAST = X
          GO TO 200
  815     XLAST = XS-(VCASS-VFL(I+1)/1.688)*XS/(VCASS-VCAS/1.688)
          GO TO 825
  820     IF(X.GT.0)GO TO 825
          IF(X.GT.XIP) GO TO 822
          IF(VCAS.GT.VFINF) GO TO 200
  822     IF(VCAS.GT.VFL(I+2)) GO TO 200
  825     VERR = (VFL(I+1)-VLAST)/1.688
          IF(X.LT.XIP1) GO TO 830
          IF(EPRCMD.EQ.1) GO TO 860
          EPRCMD = 1
          GO TO 832
  830     IF(EPRCMD.EQ.0) GO TO 1110
  832     IPVER = 1
          GO TO 1200
  840     IF(X.GT.0) GO TO 845
          IF(VCAS.GT.VFL(I+2)) XIP1 = X
          IF(VCAS.GT.VFINF) GO TO 200
  845     DELXIP = XFINAL-X
          IF(XIP*TANGA.GT.HXIP) DELXIP = .4*DELXIP
          XIP = XIP+DELXIP
          XIP1 = XIP1 + DELXIP
          IF(XIP.LT.-90000.) GO TO 885
          XEND = X
C         CHANGE NEXT STATEMENT TO "GO TO 50" FOR AIRBORNE COMPUTER **********
          GO TO 5
  850     IF(VCAS.GT.VFINF) GO TO 200
          IF(X.LT.XFINAL) GO TO 900
          IF(DECSEQ.EQ.1) GO TO 880
C         SAVE PROFILE
          XVFIN = X
  860     MLAST = M-1
          TANVER = TANG1
          M = 1
          N = 2
          IF (ISTORE .EQ. 1)GO TO 865
          ISTORE = 1
          GO TO 870
  865     ISTORE = 2
  870     IF (J .EQ. 1)GO TO 875
          IF (VCASS .LE. VMAX(J)) GO TO 872
          IF(IFLCMD.LT.JIP) IPVER = 1
          GO TO 900
  872     IFLCMD = J
```

```
      GO TO 900
  875 IF(VCASS.LT.VLGMAX) LGCMD = 1
      GO TO 900
C     FAST DECEL SEQUENCE TEST
  880 IF(X.LT.(XFINAL+5000.)) GO TO 900
  885 IWARN = 1
C     DECEL COMPUTATION ABORTS,TOO FAR BEHIND SCHEDULE
C     WARNING LIGHT OR MESSAGE ON
C     FAST/SLOW DOUGHNUT OUT OF VIEW
  890 VOUTP = 1.5*VOLTM
      IE1FA = 0
      IE2FA = 0
      IE3FA = 0
      ILGFA = 0
      IFL1FA = 0
      IFL2FA = 0
      IFL3FA = 0
      IFL4FA = 0
      IFL5FA = 0
C     CHANGE NEXT STATEMENT TO "GO TO 3500" FOR AIRBORNE COMPUTER ********.
      GO TO 5
C     EPRCMD STATUS UPDATE
  900 IF(ICE.EQ.1) GO TO 910
      IF(VCASS.LT.VEPRS2) EPRCMD = 2
  910 IF(VCASS.LT.VEPRS3) EPRCMD =3
C
C1000 FAST/SLOW TABLE LOOK UP VLU
      XLU = XNAV + (XVFIN - XFINAL)
      IF(IFLCMD.EQ.JIP) XLU = XNAV+(XLAST-XIP)
      IF(XNAV.GT.XFINAL) GO TO 1020
      IF(ISTORE.EQ.1) GO TO 1010
 1002 IF(XLU.LT.X1(N)) GO TO 1005
      IF(N.EQ.MLAST) GO TO 1005
      N = N + 1
      GO TO 1002
 1005 VLU=V1(N-1)+(XLU-X1(N-1))*(V1(N)-V1(N-1))/(X1(N)-X1(N-1))
      GO TO 1100
 1010 IF(XLU.LT.X2(N)) GO TO 1015
      IF(N.EQ.MLAST) GO TO 1015
      N = N + 1
      GO TO 1010
 1015 VLU=V2(N-1)+(XLU-X2(N-1))*(V2(N)-V2(N-1))/(X2(N)-X2(N-1))
      GO TO 1100
 1020 VLU = VFINF
C
 1100 CONTINUE
      VCMD = (VLU-DVCOR)/1.688
      VERR = VCMD - VCASS
C
 1110 VOUTP = VERR*VOLTM/20
      IF(EPRCMD.EQ.0) VOUTP = VERR*VOLTM/40
      IF(VOUTP.GT.VOLTM)VOUTP = VOLTM
      IF(VOUTP.LT.-VOLTM)VOUTP = -VOLTM
      VSI = VS(5)
      IF(I.EQ.5) GO TO 1122
      VSI=VS(I+1)+(FLCMD(I+1)-FLS)*(VS(I)-VS(I+1))/(FLCMD(I+1)-FLCMD(I))
 1122 VBUG = 1.3*VSI + DVREF
C
C     LIGHT LOGICS DEVELOPMENT
 1200 IF(EPRCMD.EQ.0) GO TO 2600
      GO TO(1210,1230,1250), EPRCMD
 1210 IE1FA = 1
      IF(THRPOS.GT.2.) GO TO 1300
      IE1FA = 0
```

```
         GO TO 1300
 1230 IE1FA = 0
      IE2FA = 1
      IF(THRPOS.LT.12.)GO TO 1300
      IE2FA = 0
      GO TO 1300
 1250 IE2FA = 0
      IE3FA = 1
      IF(IEPRAP.EQ.1) GO TO 1280
      L = WEIGHT*COSGA
      CL = .539*L/(VFINF*VFINF)
      CD = .1544-.04035*CL+.0547*CL*CL
      HP = HS + HFIELD
      VT = VFINF*(1+.0000147*HP)
      DELTA = 1-.3604E-4*HP+.048E-8*HP*HP
      VWH = VWR*(2.226*HS+2893.)/(HS+2152.)
      T = L*(CD/CL+((VWH*COSGA/VT+1)*TANGA)
      FNOD = T/(DELTA*3)
      EPR = (13150+FNOD)/13500
      CRSA = (EPR+.04+.6215*.2)/(.02453+.0083*.2)
      TRTHRP = (CRSA-38)*1.125
      IEPRAP = 1
 1280 IF(THRPOS.LT.TRTHRP) GO TO 1300
      IE3FA = 0
C
 1300 CONTINUE
      IF(LGS.EQ.1) GO TO 1310
      IF(LGCMD.EQ.1) ILGFA = 1
      GO TO 1400
 1310 ILGFA = 0
C
 1400 IF(IFLCMD.EQ.0) GO TO 2600
      GO TO(1410,1430,1450,1470,1490),IFLCMD
 1410 IFL1FA = 1
      IF(FLS.LT.(2-DFLM)) GO TO 2600
      IFL1FA = 0
      GO TO 2600
 1430 IFL1FA = 0
      IFL2FA = 1
      IF(FLS.LT.(5-DFLM)) GO TO 2600
      IFL2FA = 0
      GO TO 2600
 1450 IFL2FA = 0
      IFL3FA = 1
      IF(FLS.LT.(15-DFLM)) GO TO 2600
      IFL3FA = 0
      GO TO 2600
 1470 IFL3FA = 0
      IFL4FA = 1
      IF(FLS.LT.(25-DFLM)) GO TO 2600
      IFL4FA = 0
      GO TO 2600
 1490 IFL4FA = 0
      IFL5FA = 1
      IF(FLS.LT.(30-DFLM)) GO TO 2600
      IFL5FA = 0
C
 2600 IF(DECSEQ.EQ.1) GO TO 45
      IF(IFLCMD.GE.4) GO TO 3100
      IF(IFLCMD.LT.JIP) GO TO 3100
      IF(X.LT.(XFINAL+1000.)) GO TO 3100
      DECSEQ = 1
      DO 3000 ID = 0,5
 3000 VFL(ID) = VMAXF(ID)
```

```
      VLGDF = VLGMF
 3100 GO TO 5
C     FOR AIRBORNE COMPUTER RETURN TO 50 ***************************************
 3500 STOP
      END
```