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FINAL REPORT OF A FEASIBILITY STUDY FOR AN ADVANCED AVIONICS FLIGHT TEST AIRCRAFT

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HOUSTON, TEXAS

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CORNELL AERONAUTICAL LABORATORY, INC.
Flight Research Department

FINAL REPORT OF A FEASIBILITY STUDY FOR AN ADVANCED AVIONICS FLIGHT TEST AIR-CRAFT

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SUMMARY

An engineering study has been performed from which recommendations were generated for modification of an existing aircraft to a configuration that will be suitable for flight demonstration of the integrated electronics system that is intended to be used for the guidance and control of the reusable space shuttle vehicle. From a wide variety of aircraft initially examined, fifteen were selected and examined in further depth for compliance with the program requirements. After seven weeks investigation, the candidate aircraft were reduced to three, the Convair 580, Lockheed P3D, and the Lockheed C-130. Cost estimates were prepared for the conversion of these three candidate aircraft to the configuration of the Space Shuttle Vehicle Electronics Test Aircraft. After review of the conversion costs, the sponsor selected the C-130E aircraft as the one most suitable to the mission requirements. A detailed specification has been written which sets forth the requirements for conversion of the selected aircraft to the desired electronic test bed configuration. A copy of this specification is included in this report in Appendix A.

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INTRODUCTION

NASA had undertaken the development of a reusable space shuttle vehicle for general purpose orbital operations. It is intended that the guidance and control functions of these advanced vehicles be part of an Advanced Integrated Electronics System. The Advanced Integrated Electronics System will use a digital computer to provide inputs to the multi-purpose cathode ray type displays and to provide a fly-by-wire control system having a capability of automatic checkout, failure detection and fault isolation. In addition, the Advanced Integrated Electronics System will incorporate a multiplex data bus system. While no single element of this system appears to be beyond the present state of the art, the combined features of this system have never before been combined in a single flight vehicle. It would therefore appear appropriate to develop a flight test vehicle that would permit the evaluation of the new flight control concepts under controlled conditions, to permit the examination during actual flight of new display concepts, to provide crew training, familiarization and for the demonstration of the system to interested observers. The task was undertaken by Cornell Aeronautical Laboratory under NASA contract NAS9-10987 administered by NASA Manned Spacecraft Center to examine a wide variety of aircraft and from those candidate aircraft determine that one aircraft that is most suitable for the conversion to an Electronic Test Aircraft configuration and prepare a set of test vehicle requirements specifications in sufficient detail so as to permit an aircraft modification contractor to convert an existing aircraft to a Space Shuttle Vehicle Electronics Test Aircraft. This report summarizes the results of that investigation and a copy of the test vehicle requirements specification is appended to this report.

TEST VEHICLE REQUIREMENTS

The desired characteristics of the flying test bed are set forth in detail in Exhibit A of NASA Contract 9-10987 entitled "Statement of Work for Feasibility Study for an Advanced Avionics Flight Test Aircraft." Figures 1 and 2 of that statement of work, included herein for convenience, specify the altitude, the airspeed envelope, and the desired flight path angle - evaluation cockpit deck angle operating schedule. The test vehicle is intended to provide a safe platform for the evaluation and demonstration of the Advanced Integrated Electronics System. Safe operation is assumed by having safety pilots who use a flight control system completely independent of the test system; in event of failure of the Advanced Integrated Electronics System, control of the aircraft reverts to the safety pilots in their independent flight control system. A two-man evaluation crew, seated in a flight deck whose configuration closely resembles that of the space shuttle vehicle, flies the Advanced Avionics Flight Test Aircraft through the Integrated Electronics System. Provisions will be made for a two-man test engineering crew station with equipment that will permit operating the aircraft in a data gathering mission. Provisions are also to be made to permit conversion of the test engineer station to a passenger-observer configuration, allowing either crew familiarization, training or demonstration of unique features of the system to interested observers. It is desired that both evaluation pilots and test engineer stations should permit operation in a shirt-sleeve environment.

In the development of the specification, it has been assumed that the Space Shuttle Vehicle Integrated Electronics System hardware will be furnished to the aircraft modification contractor by NASA. The Advanced Integrated Electronics System will include sensors, digital computers, digital to analog, analog to digital converters for inputting or outputting data, heat transmission equipment for cooling, flight control devices, controls and panels to permit operating mode select, and pilot - test engineer displays. This equipment must properly interface with, and be compatible with, the flight control system of the base vehicle, the ground support equipment, the onboard data recording equipment, the flight telemetry equipment, as well as the ground based navigation aids such as VOR/DME, TACAN and ILS. In addition, failure detection and switching functions will be incorporated in this equipment. While no special requirements were imposed upon the test vehicle response to control deflections, it will be the responsibility of the modification contractor to define those response characteristics to NASA.

At the initiation of the contract effort, the volume and weight of the GFE avionics equipment were established at 18 cu. ft. and 1580 lbs. respectively. Correspondence with Manned Spacecraft Center personnel during the program, however, has indicated that the weight has subsequently increased to 4000 lbs. and the volume increased to 45.5 cu. ft.. These changes have a significant impact on the final selection of the vehicle.

PROGRAM SYNOPSIS

In the process of conducting the study, a wide variety of aircraft was examined that extended from the Gulfstream I, having a takeoff gross weight of 36,000 lbs., to the Convair 990 which had a takeoff gross weight of 170,000 lbs. After seven weeks investigation, the results were verbally presented to NASA Manned Spacecraft Center (Ref. 1). At this point the candidate aircraft were reduced to three: namely the Convair 580, Lockheed P3D, and the Lockheed C-130. Estimates were then prepared for costs to convert these three candidate aircraft to the configuration of the Space Shuttle Vehicle Electronics Test Aircraft (Ref. 2). After review of the conversion costs, the sponsor then selected one aircraft to be the flying test bed and the specification for conversion of a C-130E to the desired configuration was prepared and is included in this report as Appendix A.

ANALYSIS

A wide group of aircraft was initially examined for compliance with the program requirements. This initial screening narrowed down the candidates to fifteen. Aircraft rejected were done so for one or more of the following reasons:

1. Unable to carry the desired payload.
2. Fuselage volume limited.
3. Inability to satisfy the speed envelope requirements, i.e. stalling speed in excess of 100 knots or unable to meet the 300 knot or .65 Mach number upper limit.
4. Aircraft not manufactured in the United States, therefore making spare parts a critical item.
5. Fuselage configuration not adaptable to Electronic Test Aircraft requirements.

Fifteen of the aircraft initially screened were examined in detail for compliance with the program requirements. The aircraft examined are listed below.

Gulfstream I
Lockheed JetStar
Grumman Gulfstream II
Fokker F-28
USAF/TIFS (Convair 580

AT/TIFS (Convair 580)
BAC-111
Douglas DC-9
Boeing 737-100
Lockheed Electra
Lockheed P3D
Convair 880
Convair 990
Lockheed C-130E
Boeing 367-80

Each aircraft was examined to determine the feasibility of incorporating three possible cockpit configurations: a) a split cockpit, b) single safety cockpit on top of fuselage, and c) side-by-side seating with the evaluation crew on top of the fuselage. In addition, each aircraft was examined to determine the ability to accept a test engineer - observer facility in the aft fuselage. Examples of this investigation are shown in Figures 3 through 20. The results of this portion of the study are summarized in Figures 21 and 23. Figure 21 indicates which configurations are feasible in the different aircraft as well as the limitations which became apparent during the evaluation. Figure 22 provides an indication of the relative ease with which each of these aircraft may be modified to the Electronic Test Aircraft configuration and, to a similar degree, the relative ease with which each of these aircraft can be maintained. The thrust response characteristics are of considerable importance from a safety standpoint, since the aircraft is descending at relatively high sink rates to altitudes of less than 1,000 ft. above the ground. It should be noted that none of the aircraft examined is capable of maintaining level flight with the drag devices extended so as to achieve the desired lift/drag ratio even at full rated power. Hence, to permit the rapid reduction in the aircraft sink rate with a minimum speed loss, the engine response time must be as short as possible. Aircraft with constant speed turboprops or aircraft that use thrust reversers to achieve the desired flight path angle provide the desired characteristics. Operating costs presented are those obtained for the aircraft when used in airline service. Although the figures then do not reflect actual day-to-day operating and maintenance costs for these aircraft in research programs, they do provide a means of indicating the maintenance cost of the vehicles relative to each other (Figure 22).

From the data indicated above, the field of candidate aircraft was reduced to three, namely the Convair 580, the Lockheed P3D and Lockheed C-130E. It should be noted that with the original requirements of 1580 lbs of GFE equipment on board the aircraft, aircraft smaller than the Convair 580 would likely be both volume and weight limited when converted to the test bed configuration. During the course of the analysis, the sponsor indicated that the equipment weights and volumes would increase to 4,000 lbs and 45.5 cu. ft. With careful management, the Convair 580 aircraft should be able to handle these increased installed equipment weights. However, no room would be available for further equipment growth.

Costs were estimated for conversion of these three aircraft to the Electronic Test Aircraft configuration. In addition, the cost to convert and lease the AT/TIFS aircraft from TIFS, Inc. was included as an addendum to the Cost Analysis. Costs to convert the P3D and C-130E to a one safety pilot, one evaluation pilot configuration; one safety, two evaluation pilots configuration; and two safety pilots plus two evaluation pilots configurations were determined. Costs for conversion of a Convair 580 to the test aircraft configuration were based on the assumption that the engineering data used during the conversion to AT/TIFS would be available for use. Options were provided a) to install hydraulically operated direct lift flaps to control the flight path during the descent portion of the maneuver, and b) to install electrohydraulic servos to replace the presently installed autopilot. Table I is a summary of these costs.

The conclusion reached from this Cost Analysis indicated that the bare Convair 580 airplane could be converted to an Electronic Test Aircraft for approximately 3.8 million dollars and will require a minimum of eighteen months elapsed time after award of contract. This price is based upon the fact that much of the engineering work to convert the original Convair 580 to the TIFS configuration was done under government contract and would therefore be available to NASA at no cost. This configuration as shown in Figure 8 would utilize a 707 cockpit as the simulation cockpit.

The most expensive conversion was that of the Lockheed C-130 (Figure 17) configuration in which a single safety pilot with the standard primary flight controls is seated on top of the C-130 fuselage and the normal nose of the C-130 is used as the evaluation station. That aircraft would include utilization of electrohydraulic servos to operate the primary flight control system when the ship is operating in the test mode. Direct lift flaps would be installed, but no provision was to be made for a speed brake device. In addition, no costs were included for installation of a flight director system in the safety pilots' flight deck. Converting the C-130E to this configuration would cost approximately 7.4 million dollars and would require a minimum of three years elapsed time after award of contract.

After careful examination of the costing data, and making allowances for future growth of equipment to be installed in the airplane, and considering additional uses of the vehicle, the sponsor selected the C-130 aircraft in the configuration shown in Figure 8. It should be noted that while the figures produced in Reference 2 reflect comparative costs between the various configurations examined, the costs shown in this analysis may be inadequate. For instance, engineering costs were assessed at $15/hr and fabrication costs were assessed at $11/hr. Both of these figures include overhead. While these figures were correct two years ago, it is not likely at the present time that a contractor will be able to accomplish the work at these quoted costs. In addition, as a result of the experience gained by both the sponsor and CAL during the course of the investigation, it became evident that additional requirements beyond those originally contemplated would be required if the desired mission performance were to be achieved. The costs generated in Reference 2 do not include these additional costs. The proposed detail specification, in its entirety, for converting an airplane to the final Electronic Test Aircraft configuration is presented in Appendix A. Every attempt has been made to make the specification general in nature. However, the C-130 aircraft was used as a basis for generating the document.

REFERENCES

1. Notes and slides used in verbal presentation on Feasibility Study of an Advanced Avionics Flight Test Aircraft made at NASA Manned Spacecraft Center on 11 August 1970, FRM No. 445.

2. Estimated Costs for Conversion of Three Candidate Aircraft to a Space Shuttle Vehicle Avionics Flight Test Aircraft, FRM No. 442, September 1970.

TABLE I

COST SUMMARY

	*Modification Cost	** DLF Cost	** Hyd. Servos Cost	Speed Brakes
P3D, One Safety SPilot, One Evaluation Pilot (Figure 13)	$ 1, 499, 120	$2, 374, 760	$ 156, 150	$ ----
P3D, One Safety Pilot (on top), Two Evaluation Pilots (Fig. 14)	3, 364, 010	2, 374, 760	156, 150	----
P3D, Two Safety Pilots, Two Evaluation Pilots **(on top)** (Fig. 15)	2, 089, 600	2, 374, 760	156, 150	----
C-130, One Safety Pilot, One Evaluation Pilot	1, 497, 200	3, 293, 700	162, 750	----
C-130, One Safety Pilot, (on top) Two Evaluation Pilots	3, 899, 430	3, 293, 700	162, 750	----
C-130, Two Safety Pilots Two Evaluation Pilots (on top)	2, 328, 850	3, 293, 700	162, 750	----
CV-580, Two Safety Pilots, Two Evaluation Pilots (in front)	2, 055, 060	1, 211, 800	100, 050	364, 790

*Autopilot Actuators utilized
** Incremental Cost

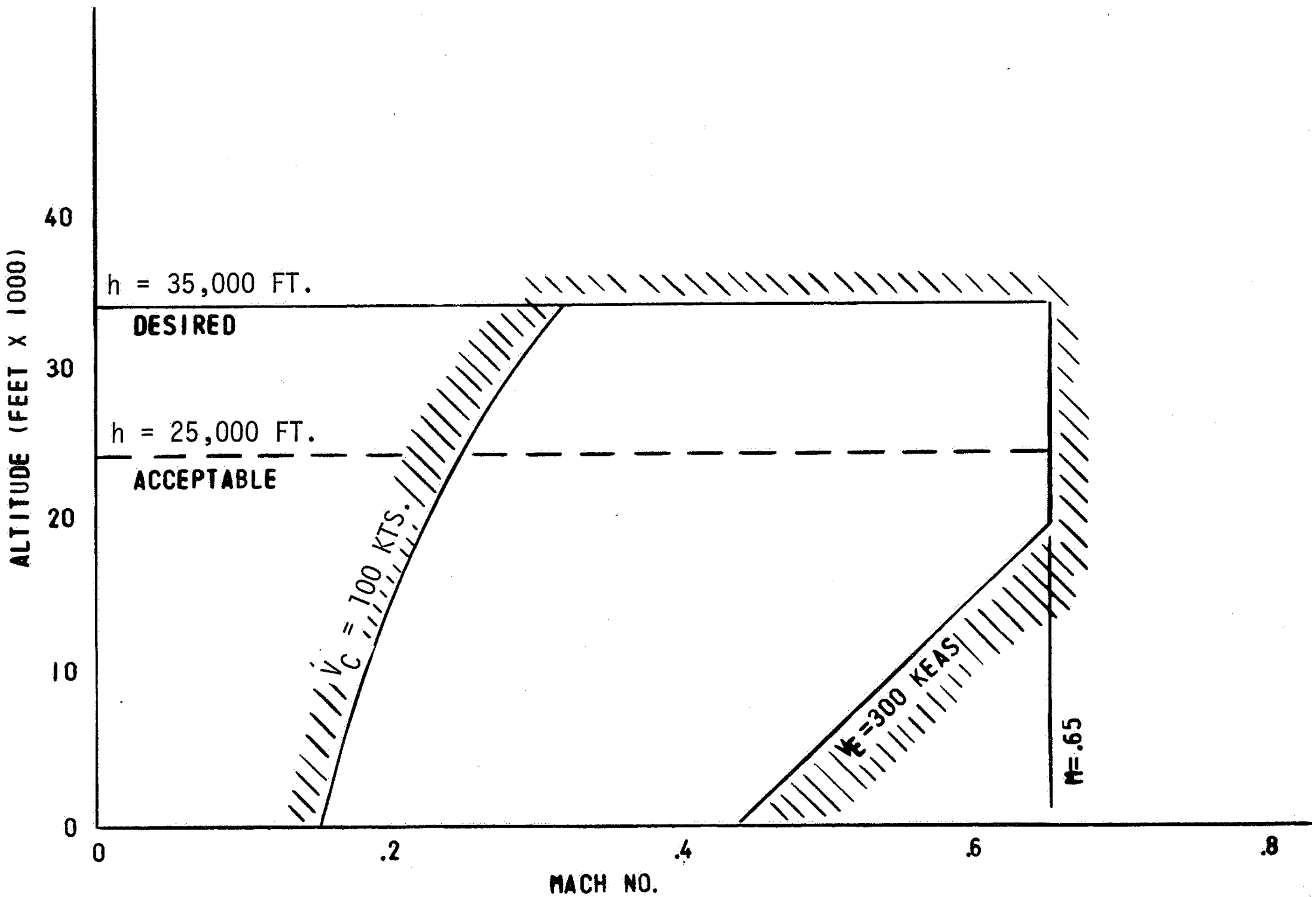

FIGURE 1 MINIMUM OPERATING ENVELOPE FOR PROPOSED ELECTRONICS TEST AIRCRAFT

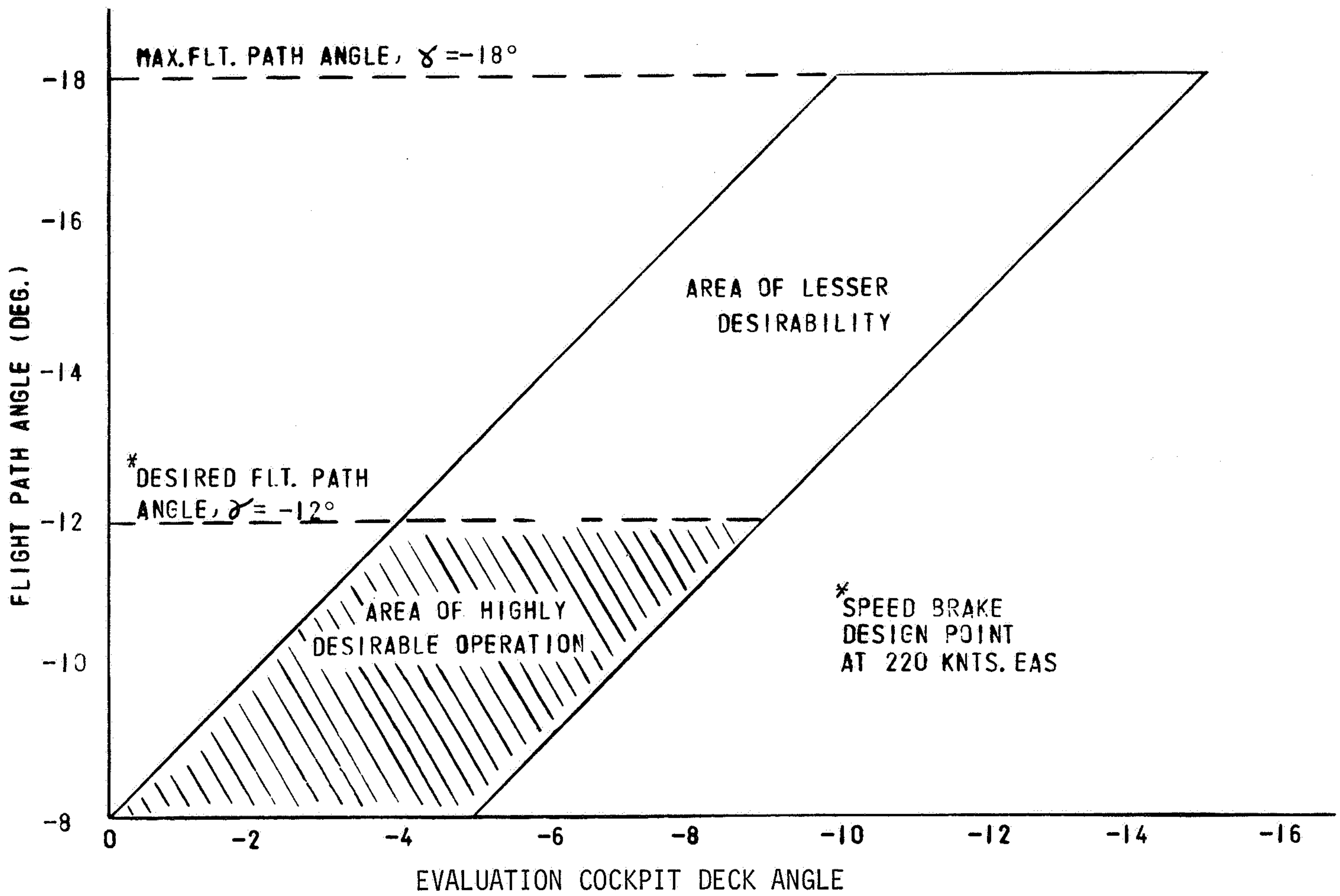

FIGURE 2 DESIRED ENVELOPE FOR STEEP FLIGHT PATH TRAJECTORY SIMULATION AT 200 $\pm$20 KNOTS EAS

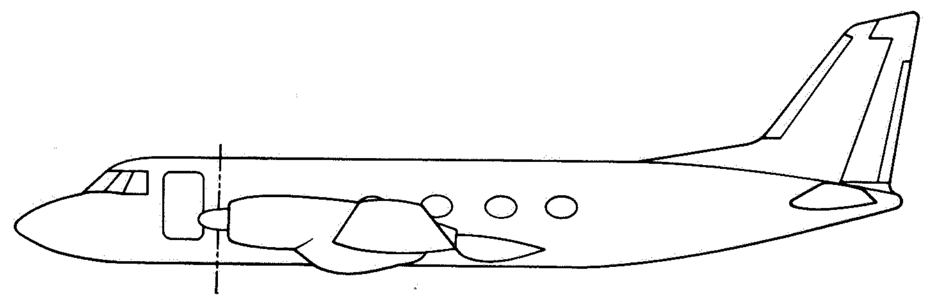

Figure 3 GRUMMAN GULFSTREAM I CONVERSION

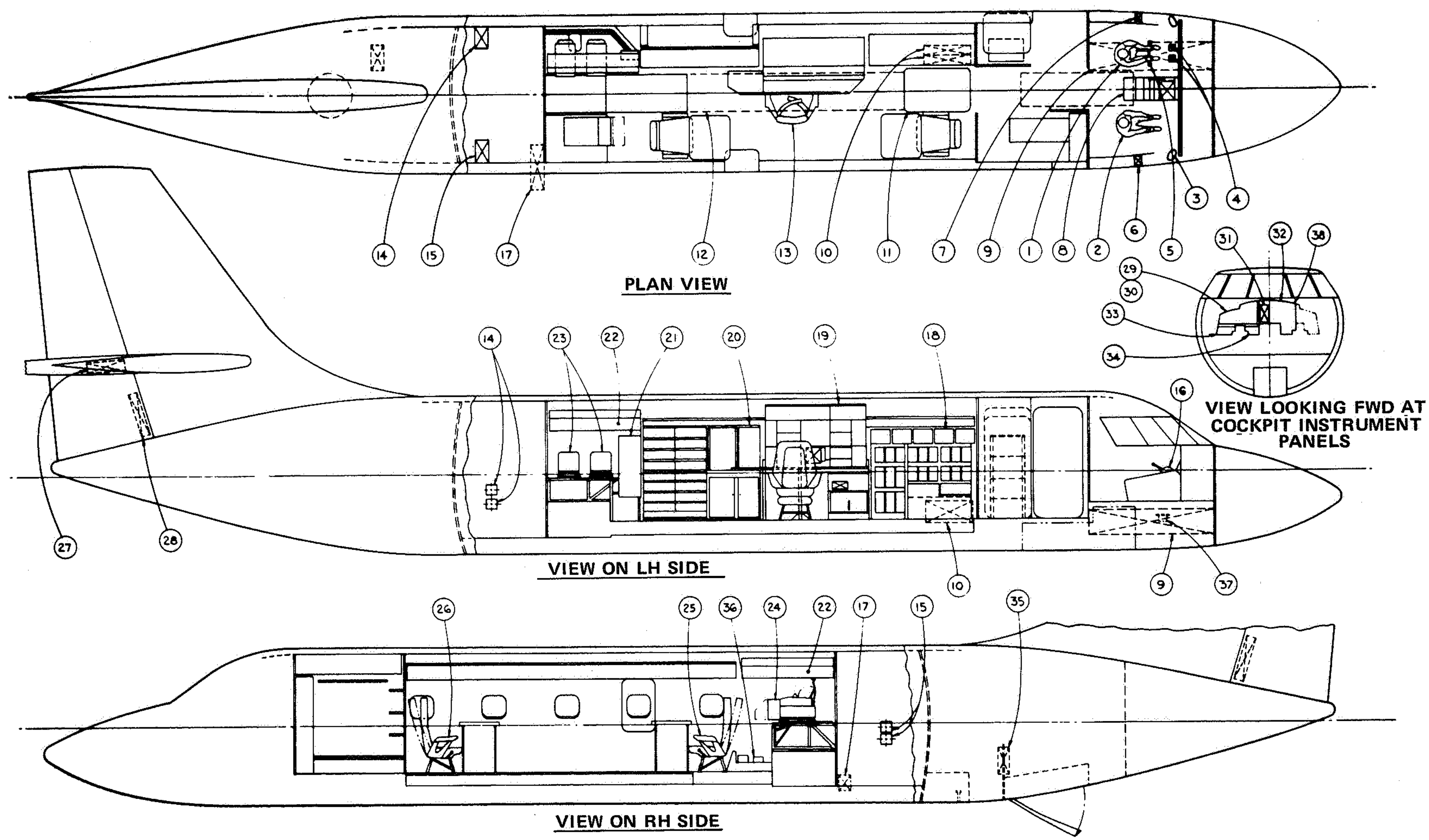

Figure 4 LOCKHEED GPAS JET STAR CONVERSION

1 TEST PILOT
2 SAFETY PILOT
3 NOSE WHEEL STEERING
4 PEDAL DYNAMOMETER
5 CONTROL WHEEL
6 ENG. WARN LT. RH SIDE CONSOLE
7 FEEL ENGAGE PANEL LH SIDE CONSOLE
8 CENTER STAND CONTROL PANEL
9 FEEL SERVO MECHANISM AND ELEV. FEEL SERVO
10 AILERON AND RUDDER FEEL SERVOS
11 ACCESS PANEL, ESCAPE HATCH
12 CABIN FLOOR, CENTER WELL
13 ENGINEER'S SEAT ARRANGEMENT
14 LH ENGINE CONTROL SERVOS
15 RH ENGINE CONTROL SERVOS
16 SIMULATED THROTTLE CONTROL
17 AILERON POSITION SERVO
18 MCS, RFS, FGS RACK
19 ENGINEER'S CONSOLE
20 AIRBORNE COMPUTER
21 PATCH PANEL DAS
22 SIGNAL CONDITIONING BOX
23 OSCILLOGRAPHS-LH SIDE
24 OSCILLOGRAPH-RH SIDE
25 AFT OBSERVER SEAT
26 FWD OBSERVER SEAT
27 RUDDER POSITION SERVO
28 ELEVATOR POSITION SERVO
29 NO. 1 TEST PILOT'S PANEL (GPAS)
30 NO. 2 TEST PILOT'S PANEL (FERRY)
31 SIMULATION SYSTEM CONTROL PANEL
32 CENTER PANEL
33 LH OUTBOARD PANEL
34 RH OUTBOARD PANEL
35 PANEL - NO. 4 HYDRAULIC SYSTEM
36 SENSOR PLATFORM
37 PILOT ACCELEROMETER
38 INSTRUMENT PANEL INSTALLATION

Figure 4a KEY TO LOCKHEED GPAS JET STAR CONVERSION

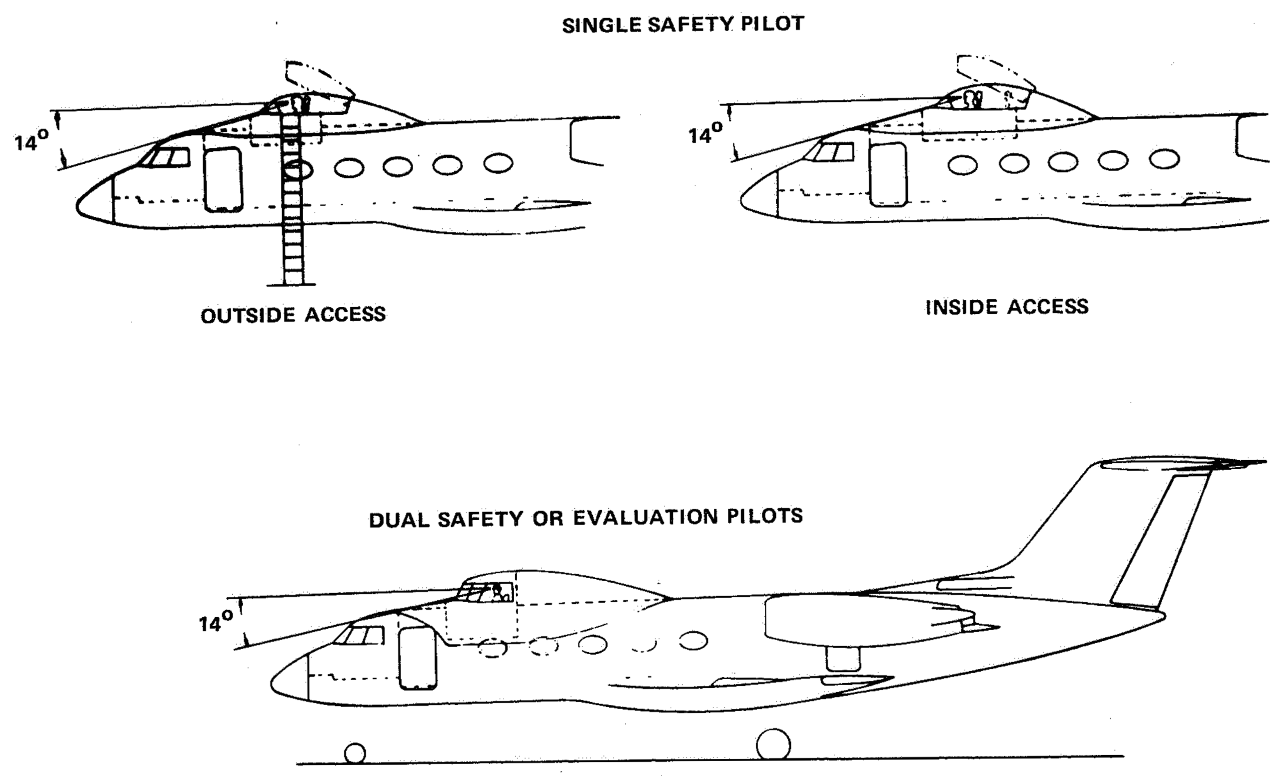

Figure 5 GRUMMAN GULFSTREAM II CONVERSION

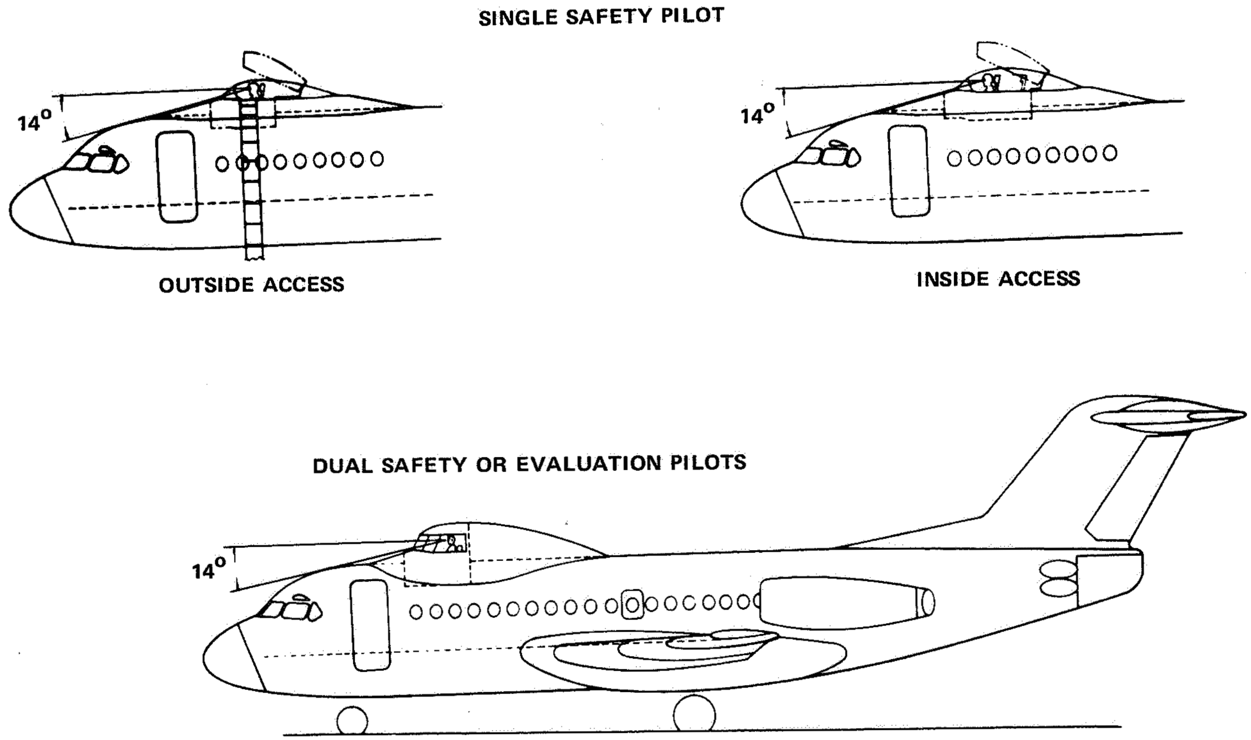

Figure 6 FOKKER F.28 CONVERSION

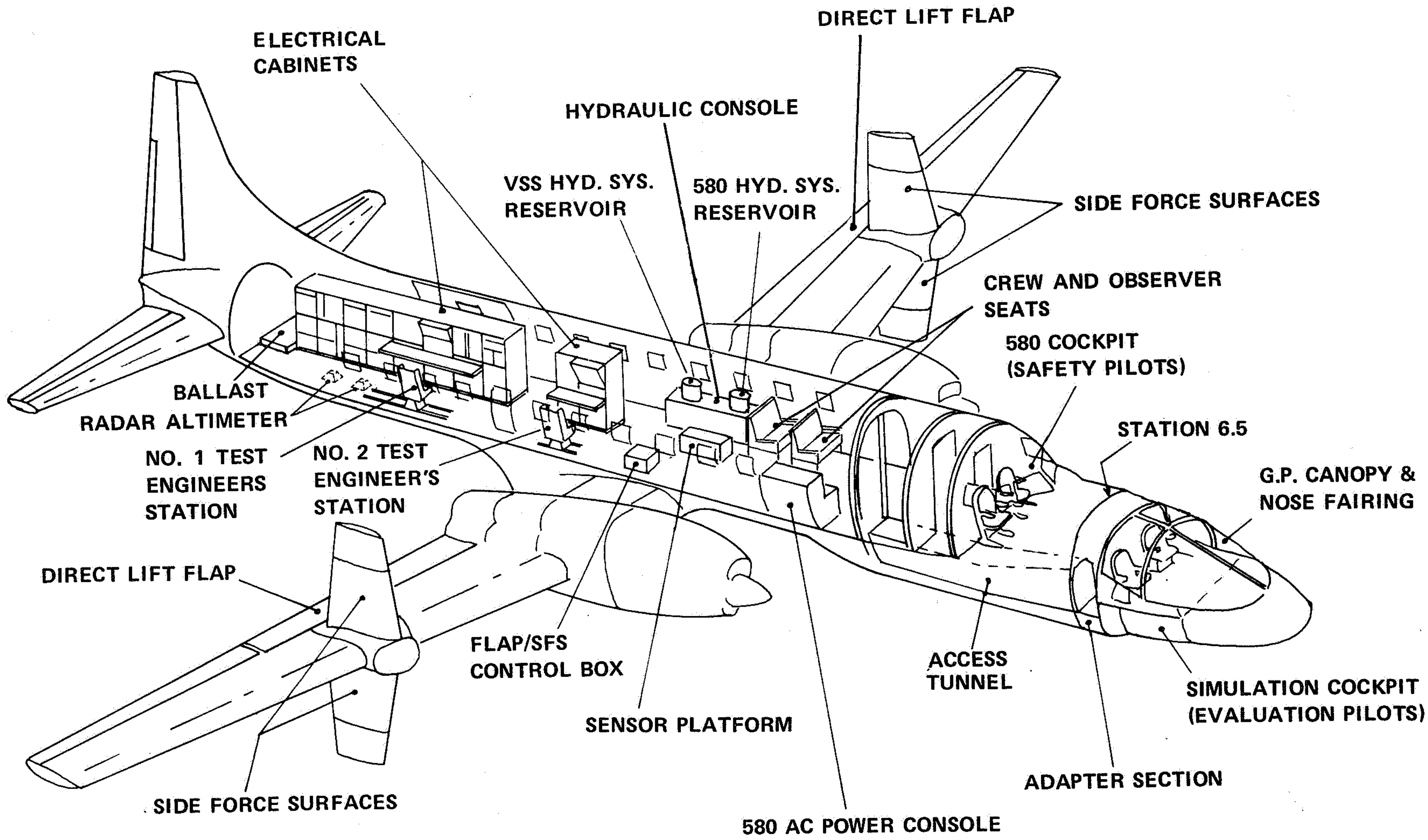

Figure 7 CONVAIR USAF TIFS SYSTEM ARRANGEMENT

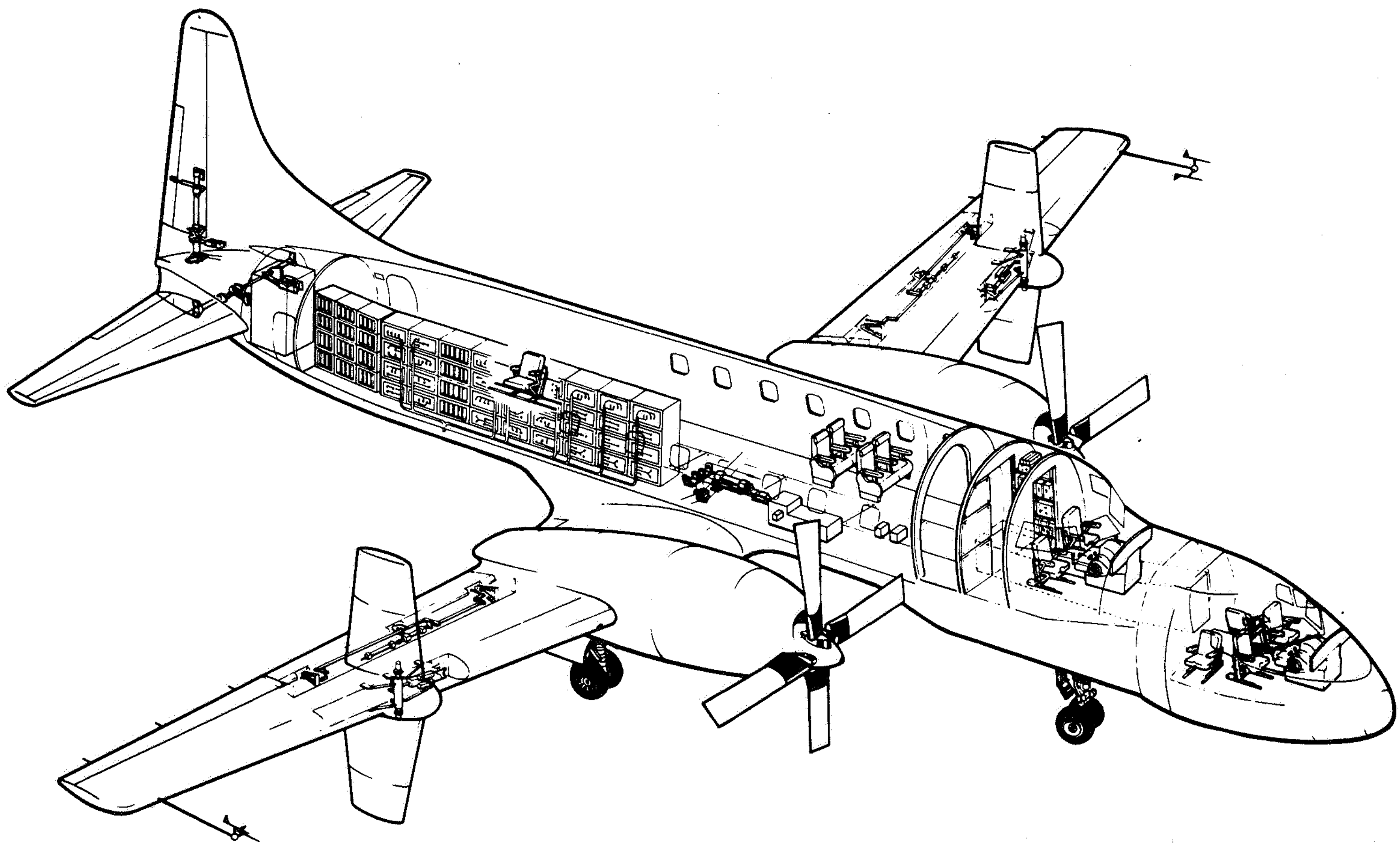

Figure 8 CONVAIR AT/TIFS SYSTEM ARRANGEMENT

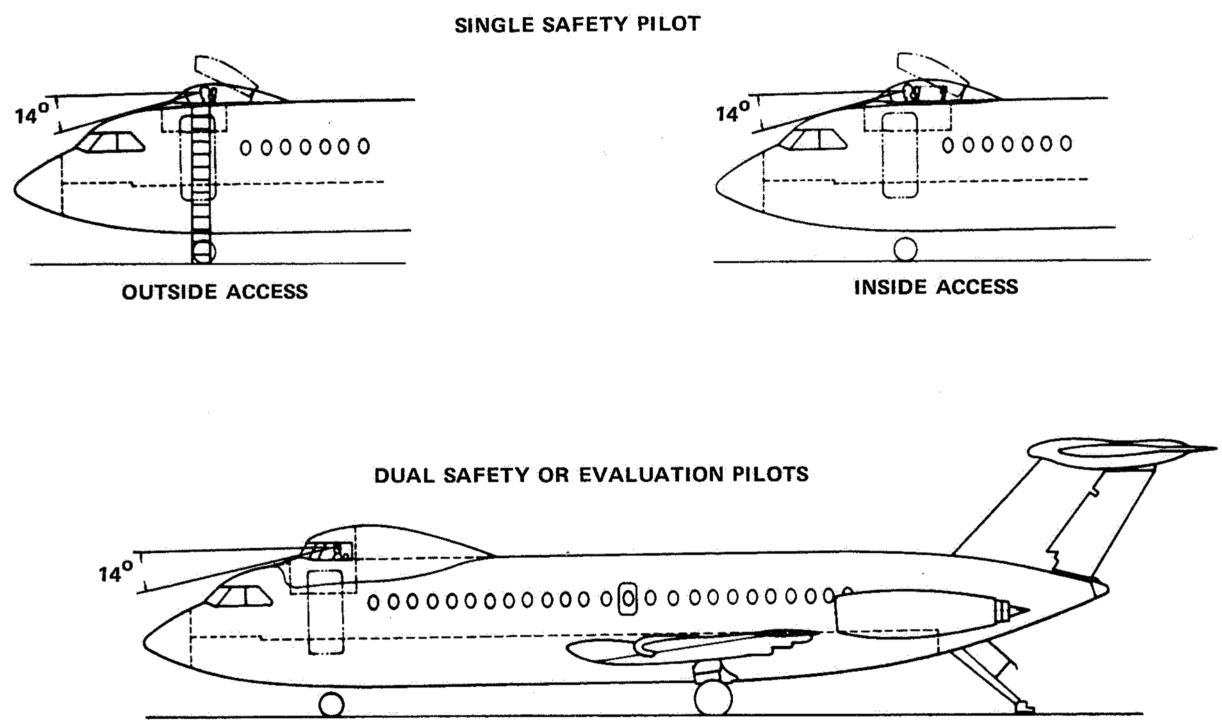

Figure 9 BAC III CONVERSION

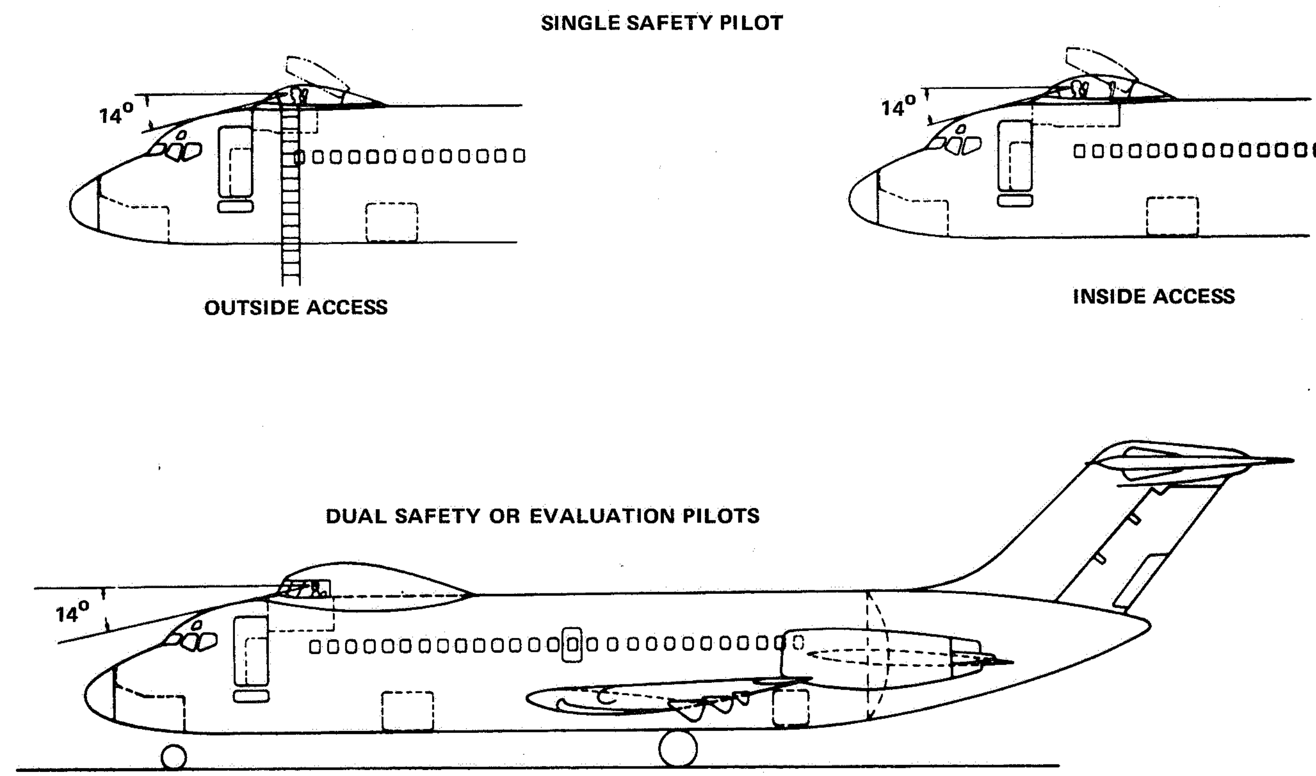

Figure 10 DOUGLAS DC 9-10 CONVERSION

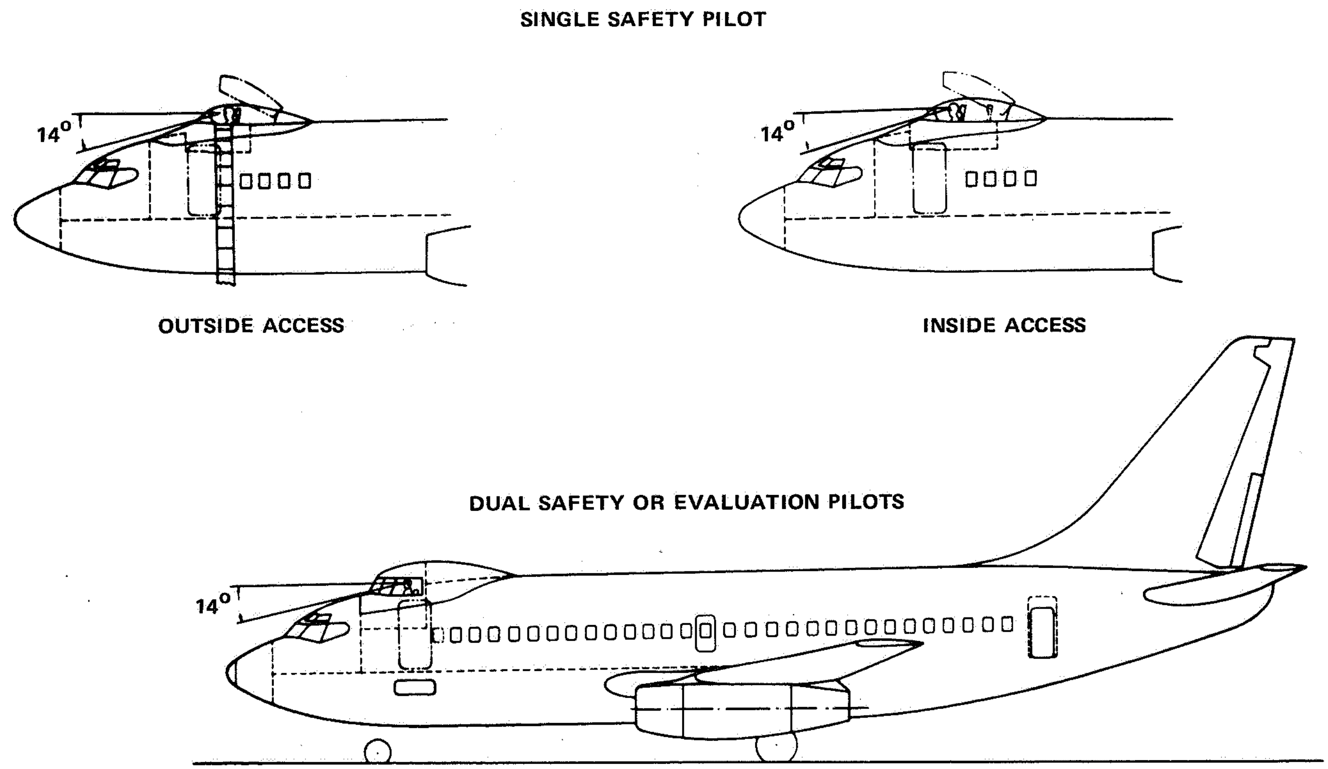

Figure 11 BOEING 737-100 CONVERSION

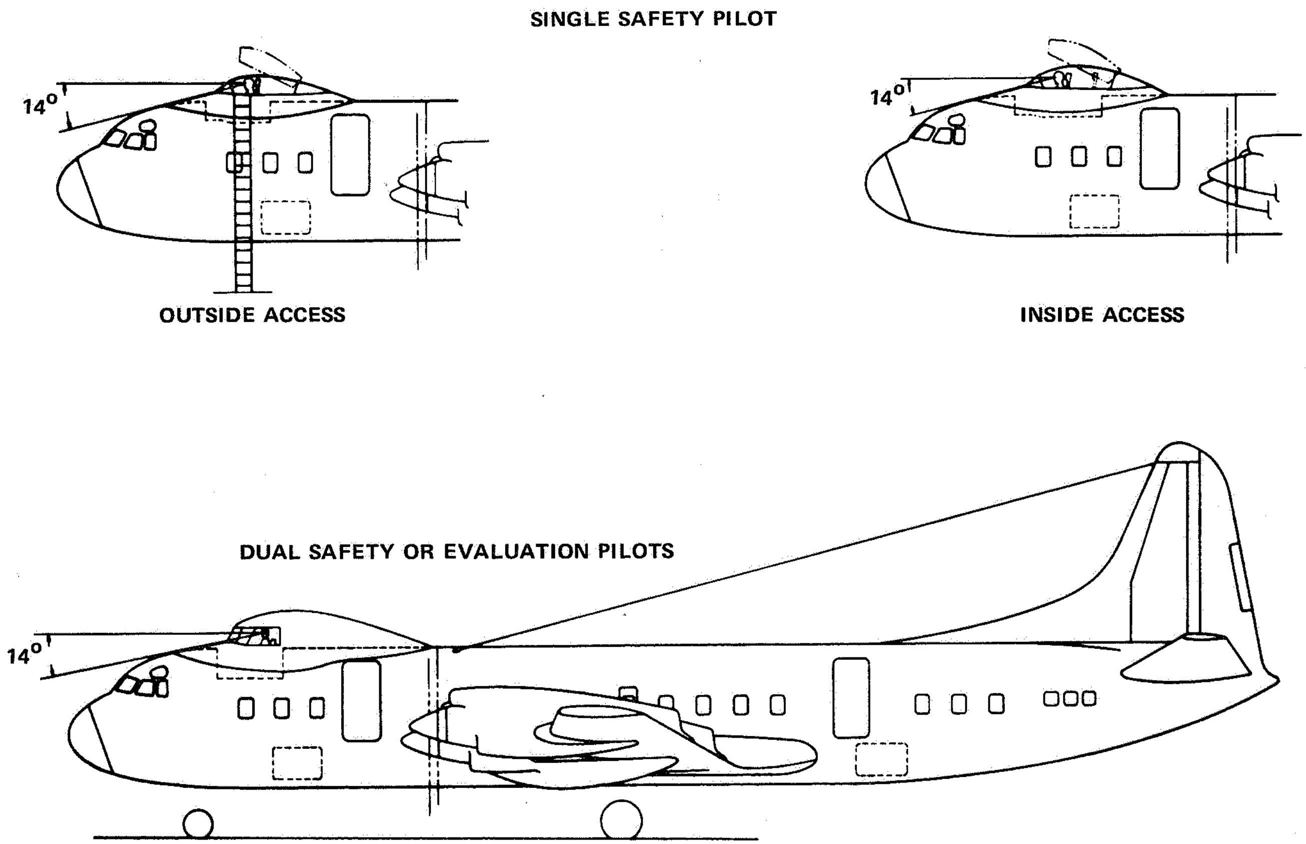

Figure 12 LOCKHEED ELECTRA CONVERSION

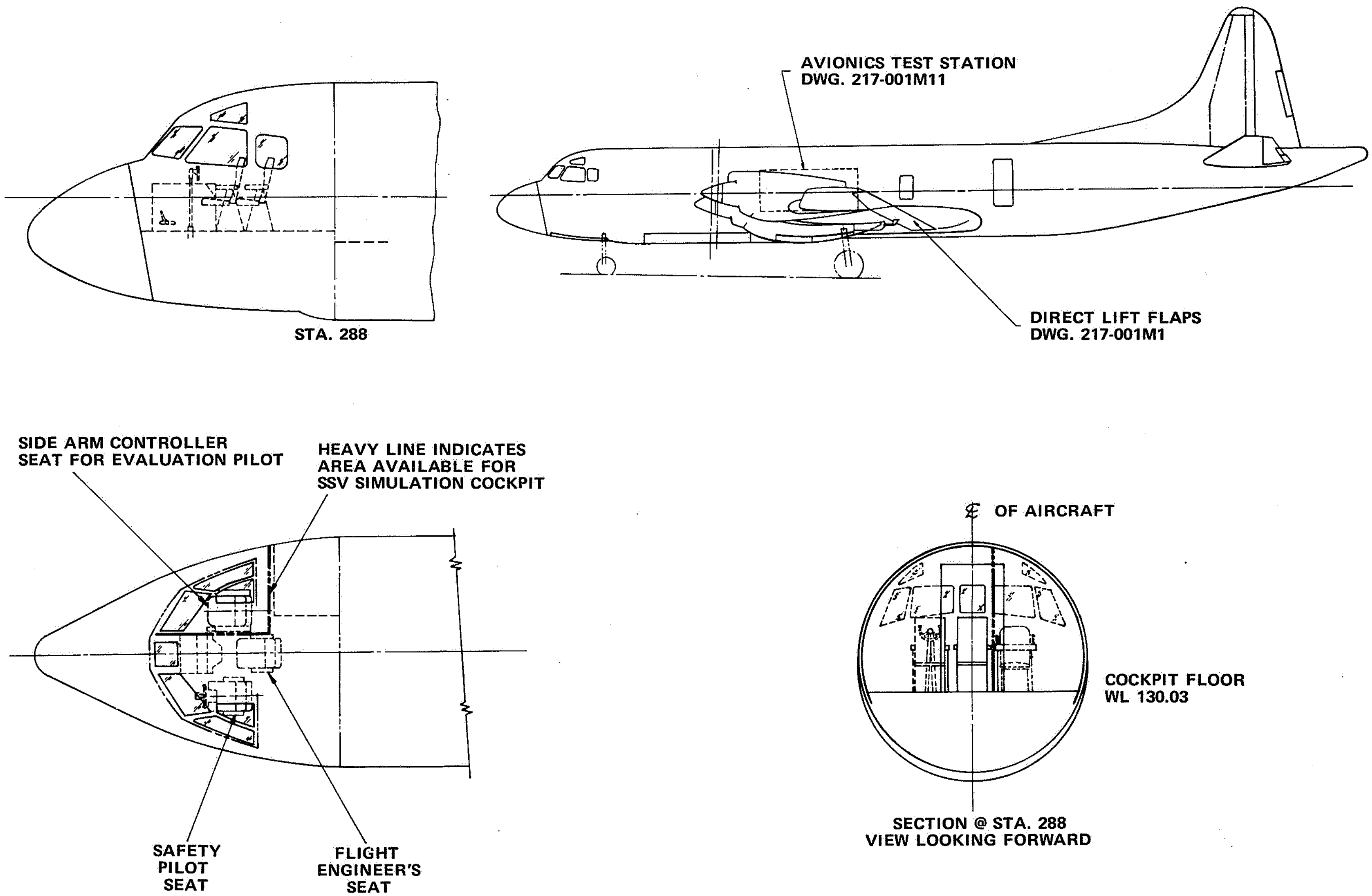

Figure 13 LOCKHEED P3D CONVERSION

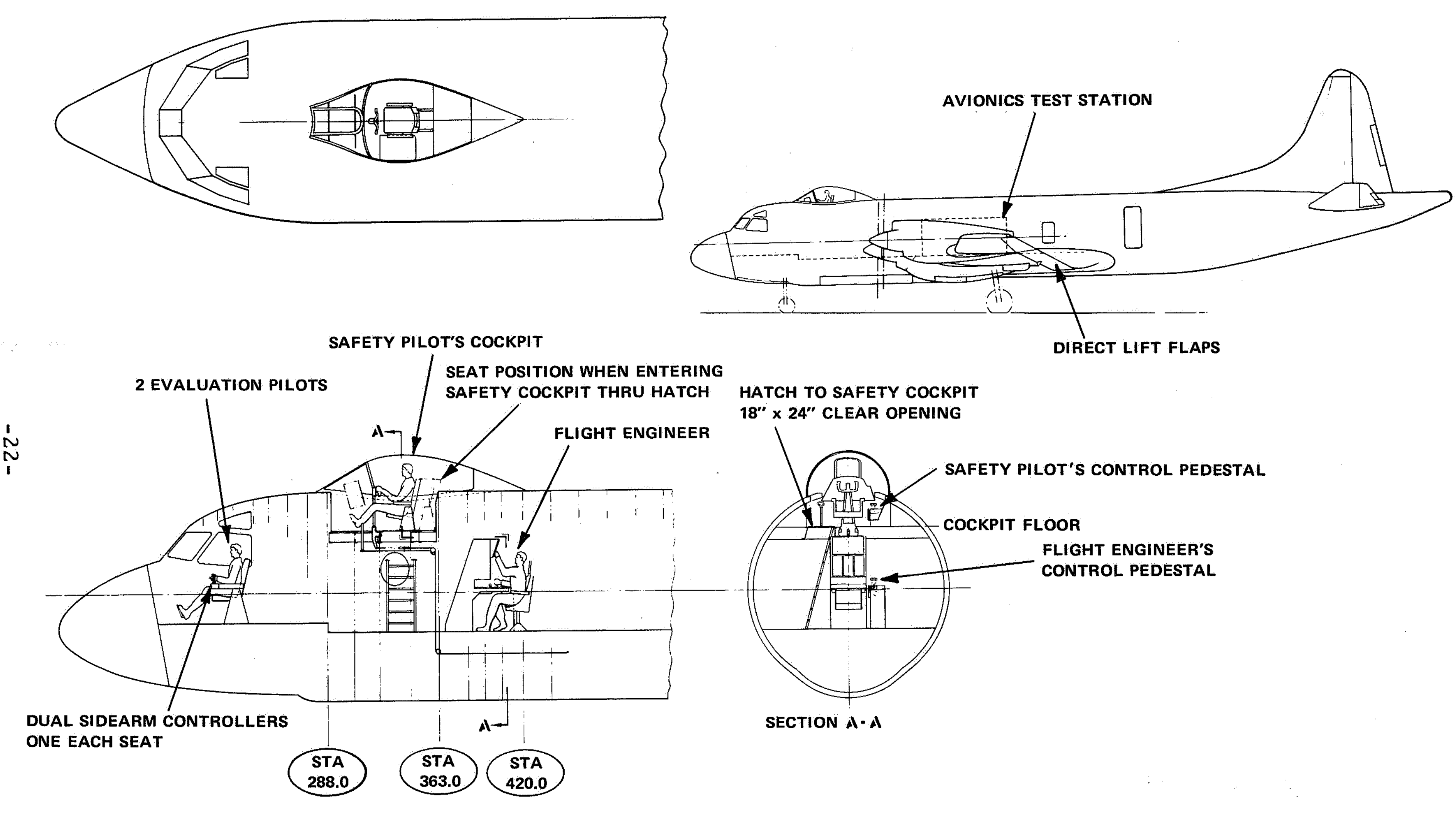

Figure 14 LOCKHEED P3D CONVERSION - SINGLE SAFETY PILOT, INSIDE ACCESS

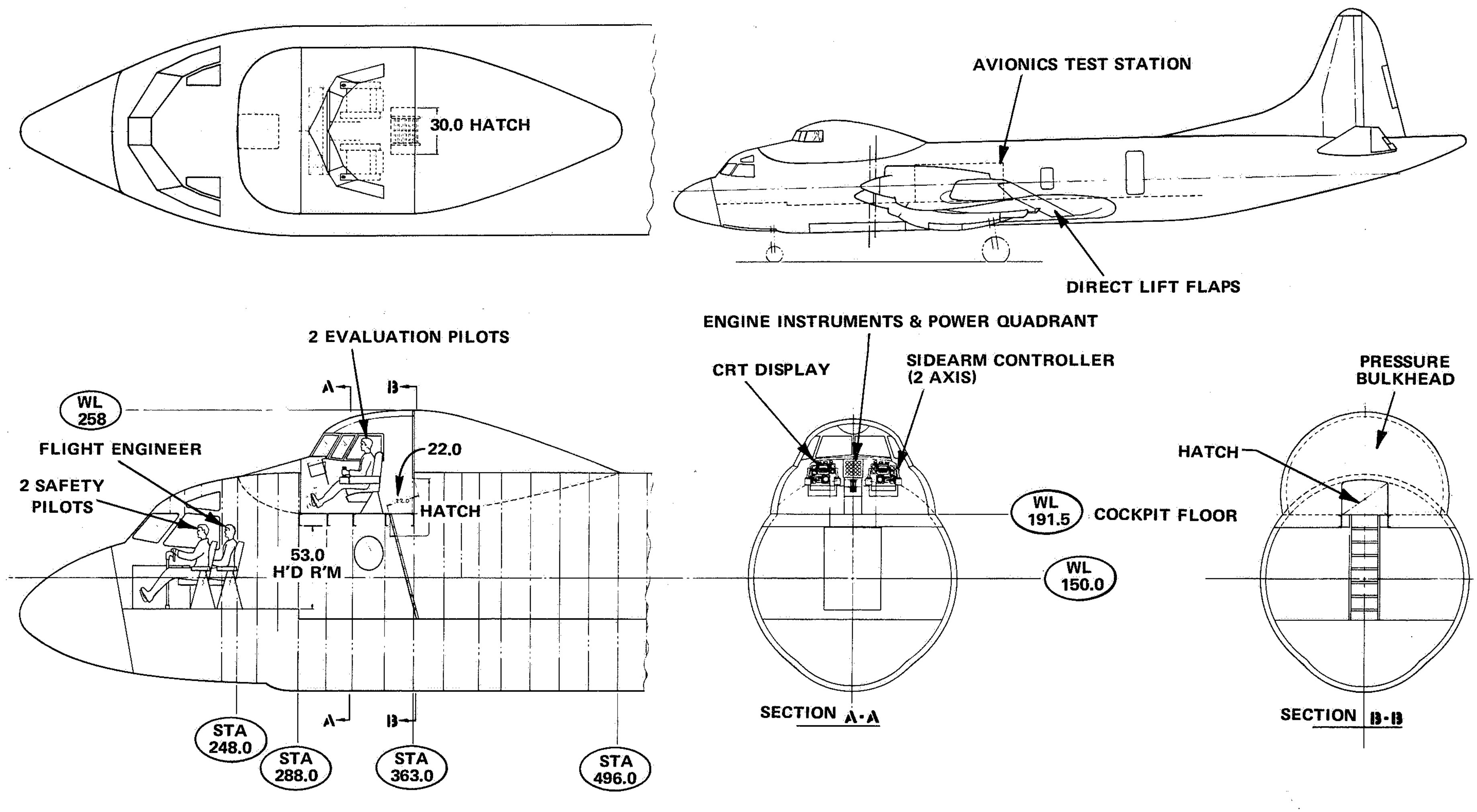

Figure 15 LOCKHEED P3D CONVERSION - DUAL EVALUATION PILOTS

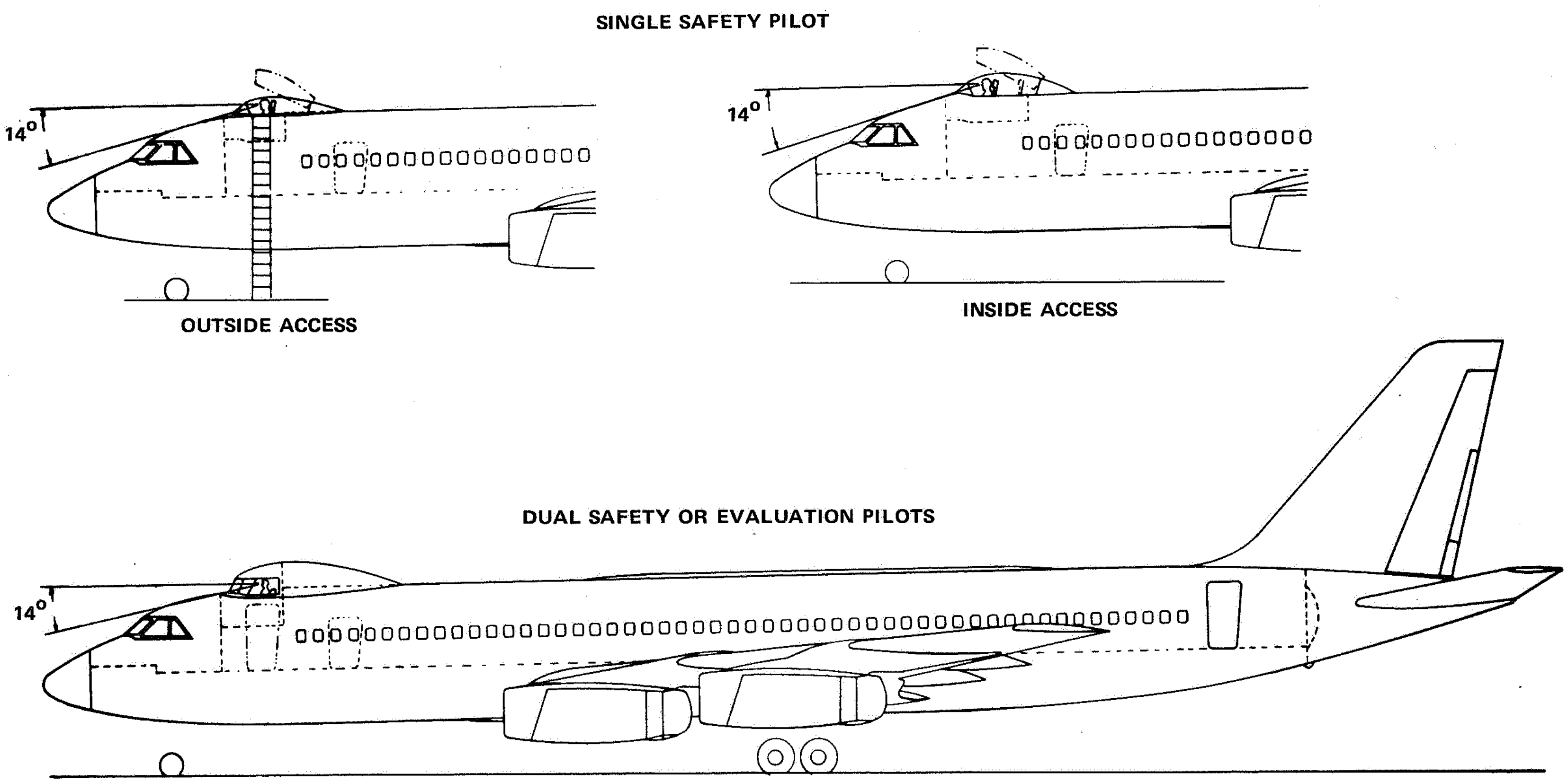

Figure 16 CONVAIR 990 CONVERSION

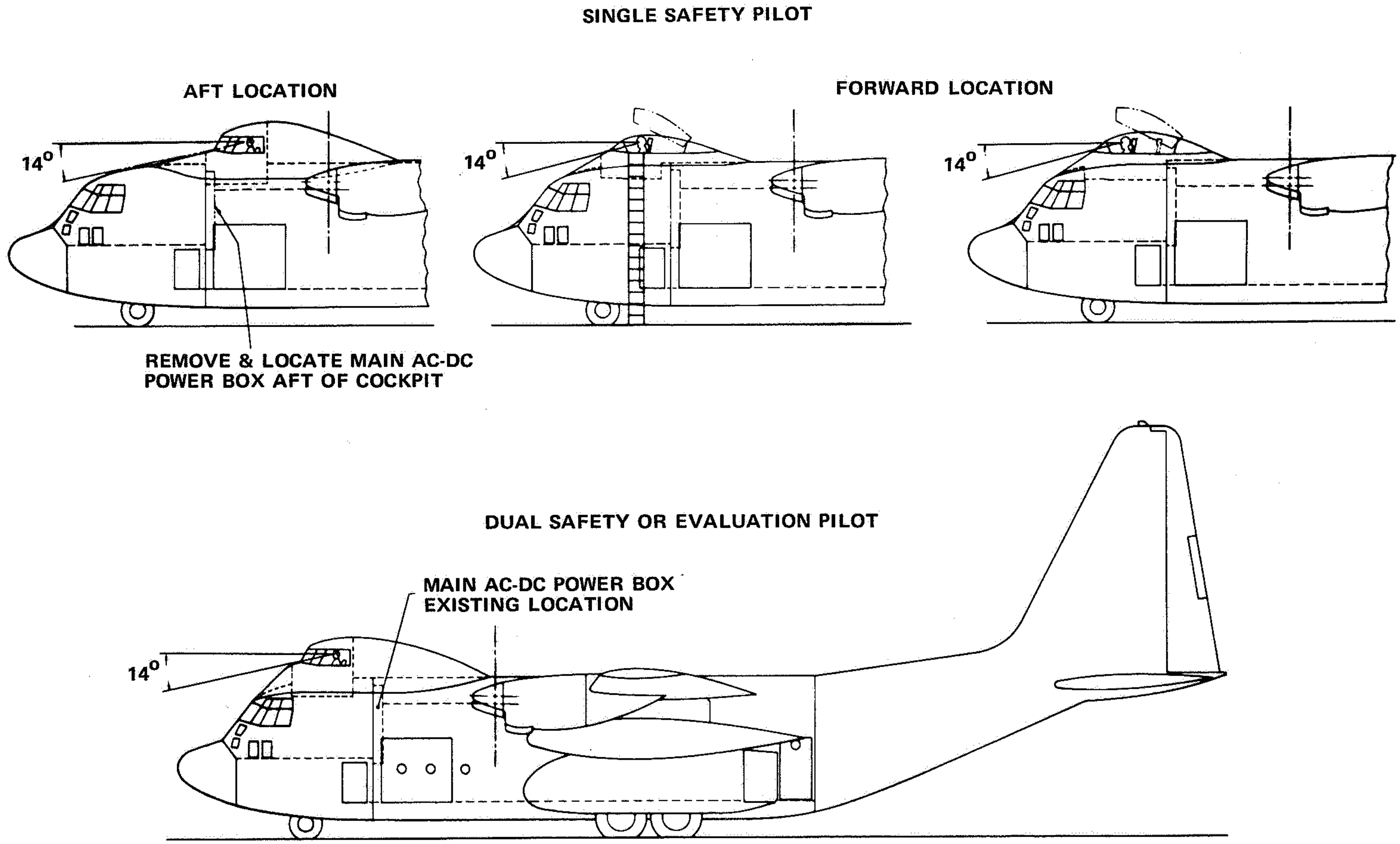

Figure 17 LOCKHEED C-130E CONVERSION

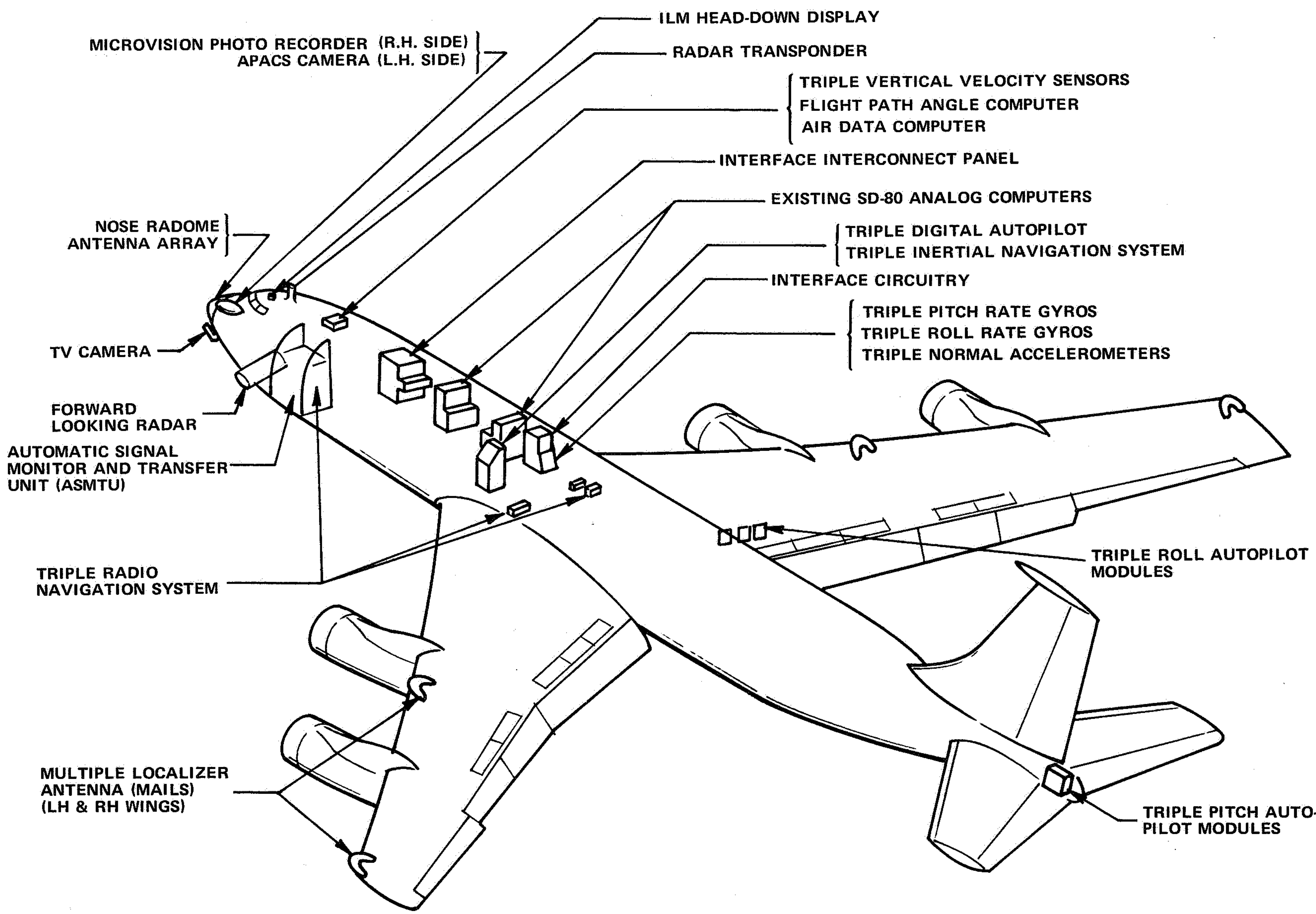

Figure 18 BOEING 367-80 CONVERSION

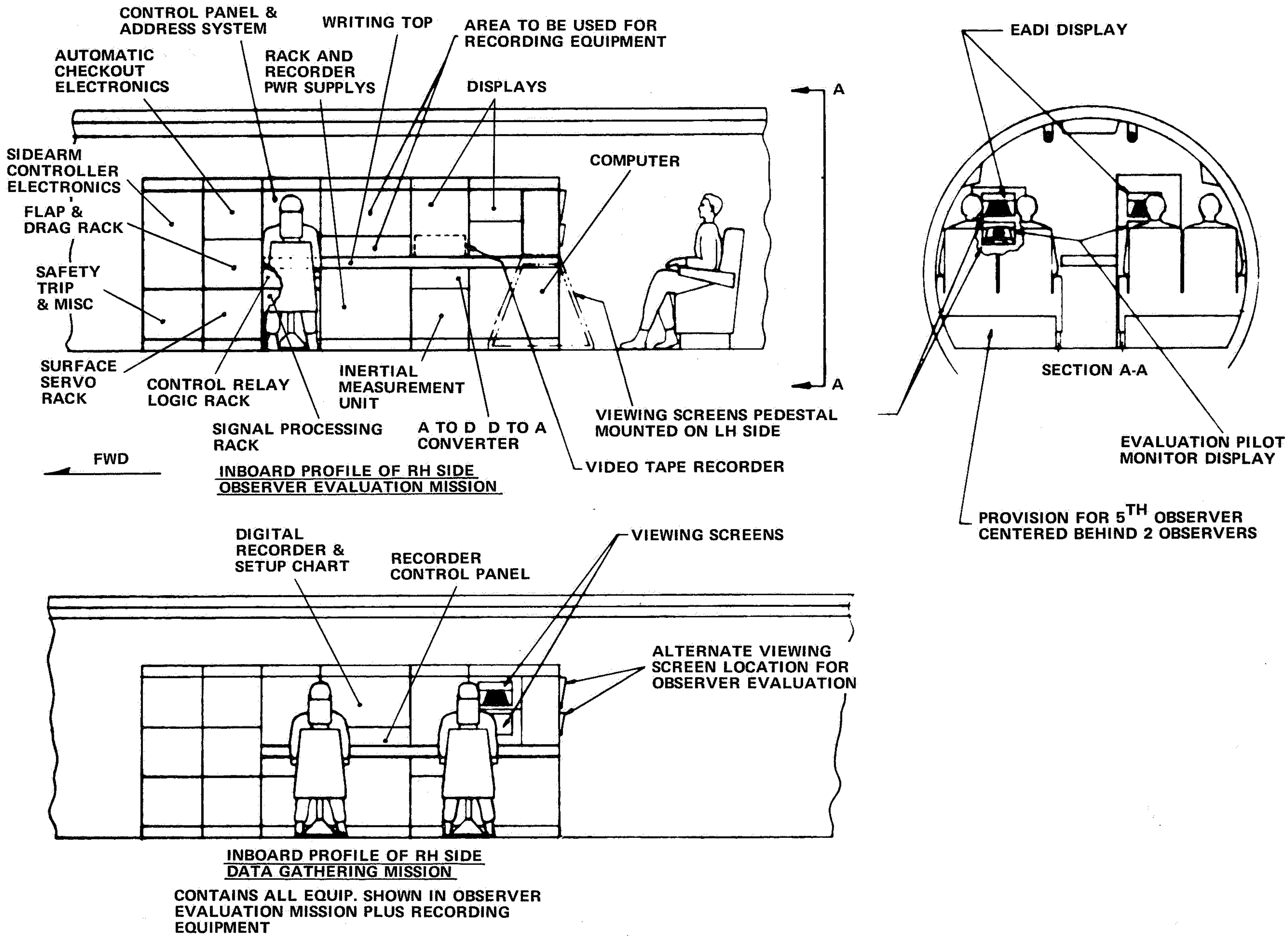

Figure 19 TYPICAL TEST ENGINEER – OBSERVER CONFIGURATION

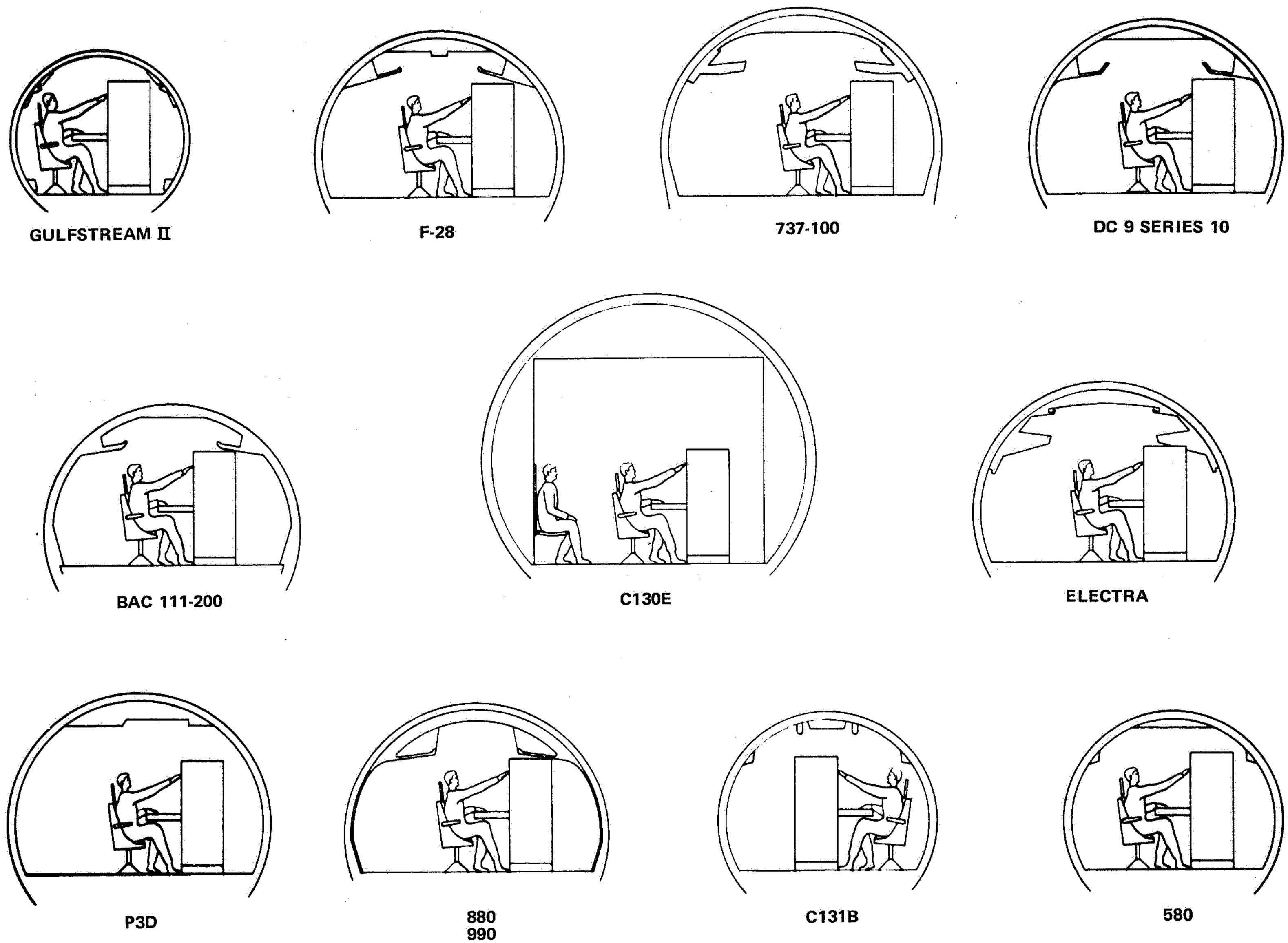

Figure 20 TYPICAL TEST ENGINEER SEATING CONFIGURATION

AIRCRAFT TYPE	CONFIGURATION	LIMITATIONS *
GULFSTREAM I	I, II?	-- NONE
JETSTAR	I,	V_s = 106 kts, γ
GULFSTREAM II	I, II, IIa?	V_s = 114 kts, γ
580, C-131 H	I, II, IIa, III, IIIa	M = .506, γ
BAC 111-200		γ = -11°
DC 9-10		V_s = 115 kts, γ
737-100		NONE
ELECTRA		γ
P3D		V_s = 109 kts, γ = 16°
CONVAIR 880/990		NONE / V_s = 110 kts, γ
C-130 E (MOD)		-- NONE
BOEING - 80		MACH NO

NOTE:

CONFIGURATION I - 1 SAFETY & 1 EVALUATION PILOT

II - 1 SAFETY & 2 EVALUATION PILOTS

III - 2 SAFETY & 2 EVALUATION PILOTS

a - HYDRAULIC SPEED BRAKES SUBSTITUTED FOR DRAG CHUTE

γ = FLIGHT DATA ANGLE 12° DOWN FROM HORIZONTAL

V_s = STALLING SPEED-APPROACH CONFIGURATION

* Reference Exhibit A of Statement of Work
(Contract NAS9-10987)

Figure 21 SSV AVIONICS FLIGHT TEST BED MODIFICATION FEASIBILITY

SUMMARY

AIRCRAFT TYPE	*MODIFICATION DIFFICULTY	*MAINTENANCE DIFFICULTY	THRUST RESPONSE CHARACTERISTICS	**COSTS FUEL/MAINTENANCE
GULFSTREAM I	5	2	RAPID	$ 80.37/97.68
JETSTAR	5	4	POOR	150/83
GULFSTREAM II	5	4	POOR	202/141.00
580, C-131 H	2	2	RAPID	51/50.
BAC 111-200	2	3	POOR	98/110
DC 9-10	2	3	POOR	116/83
737-100	2	3	RAPID	109/79
ELECTRA	2	4	RAPID	80/152
P3D	2	4	RAPID	SEE ELECTRA
CONVAIR 880/990	2	4	POOR	203/228 // 243/252
C-130 E	2	4	RAPID	SEE ELECTRA
BOEING - 80	ALREADY MODIFIED	4	POOR	LEASE
AF/TIFS	(1) DESIGN AVAILABLE	2	RAPID	LEASE
AT/TIFS	(1) DESIGN AVAILABLE	2	RAPID	LEASE

- NOTES -

*INCREASING DIFFICULTY 1→5

**COSTS/FLIGHT HOURS REF. AIR TRANSPORT WORLD, AVIATION WEEK
NO ALLOWANCE FOR DEPRECIATION, INSURANCE, CREW COSTS

Figure 22 SSV AVIONICS FLIGHT TEST BED MODIFICATION FEASIBILITY

APPENDIX A

ELECTRONIC TEST AIRCRAFT SPECIFICATION

Flight Research Memorandum No. 444

CORNELL AERONAUTICAL LABORATORY, INC.

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FRM No. 444

ELECTRONIC TEST AIRCRAFT SPECIFICATION

FLIGHT RESEARCH MEMORANDUM NO. 444

Contract NAS9-10987

October 19, 1970

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ELECTRONIC TEST AIRCRAFT SPECIFICATION

1. SCOPE

This specification is to cover the transformation of an existing aircraft to a configuration suitable for the flight evaluation and demonstration of the guidance and control functions of the integrated electronics system destined to be installed in the Space Shuttle Vehicle. It is the intention of this document to define the use and desired operating characteristics of the Electronic Test Aircraft in sufficient detail to permit an airframe modification contractor to design, construct, install, functionally check, and calibrate the ETA in addition to providing such training and technical manuals as are required to permit NASA to operate and maintain the vehicle after delivery.

Possible problem areas likely to be encountered in implementing the requirements specified here are also identified.

2. SPECIFICATIONS

2.1 General Specifications

All materials, supplies, parts and components shall be of standard, approved aerospace quality, and previously qualified to military, FAA or NASA standards. Where such articles are not available because of their nature or characteristics, or where newly developed articles are utilized in specific applications, the use of non-qualified articles shall be reviewed and approved by NASA. The Contractor shall submit a written request for approval of such items. The written request shall include a description and specification of the item, and results of any tests specified herein or of any previous tests, or experience with the item.

2.2 Applicable Documents

The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification.

Specifications

MIL-P-27733	Procedures for Installation of Equipment in Aerospace Vehicles for Test Purposes (Class II Modification) General Requirements for.
MIL-W-5088	Wiring, Aircraft, Installation of
MIL-E-5400	Electronic Equipment, Aircraft, General Specification for.
MIL-H-5440	Hydraulic System, Aircraft, Types I and II, Design, Installation, and Data Requirements for.
MIL-E-5272	Environmental Testing, Aeronautical and Associated Equipment, General Specification for.
MIL-L-6503	Lighting Equipment, Aircraft, General Specification for Installation of.

MIL-A-8064 Actuators and Actuating System, Aircraft, Electromechanical, General Requirements for.

MIL-F-9490 Flight Control Systems -- Design, Installation and Test of, Piloted Aircraft, General Specification for.

MIL-E-25499B (USAF)
Electrical Systems, Aircraft, Design and Installation of, General Specification for.

Publications

AFSC Design Handbooks Series 2-0 Aeronautical Systems
AFSC DH2-1 Airframe
AFSC DH2-2 Crew Station and Passenger Accommodations

Federal Aviation Regulation Pt. 25. Airworthiness Standards, Transport Category Airplanes.

MIL-HDBK-5A Metallic Materials and Elements for Aerospace Vehicle Structures.

3. SYSTEM DESCRIPTION

3.1 General

A large aircraft will be modified to a configuration that will permit the in-flight evaluation and demonstration of the guidance and control functions of an Advanced Integrated Electronic Control System. The AIECS will use a multi-purpose cathode ray tube display, fly-by-wire flight control system with digital control computer, multiplexed data bus system, automatic checkout, failure detection and fault isolation features.

The intended purpose of the test vehicle is to provide a safe environment for the evaluation and demonstration of the AIECS by providing a backup control mode in the event of a failure or malfunction of the equipment being evaluated or demonstrated. It is intended that the test aircraft will be used for the following purposes:

1. Development of avionics, guidance, navigation and control hardware and software.

2. Demonstration of advanced avionics and operational systems concepts.

3. Crew station configuration development.

4. Crew familiarization and training.

It is also intended that the aircraft be capable of operating the completed system in the ground or flight modes.

The anticipated configuration of the test aircraft is shown in drawing 217-001MSP1. There are several major modification areas, the most obvious being provision for a two-man evaluation crew seated side by side in a new cockpit the design of which is to be based broadly on the SSV layout and which will contain appropriate flight controls, cathode ray tube, conventional instruments, and system status displays for control of the test aircraft through SSV guidance and control hardware.

The safety crew will occupy the original flight crew station and may assume command of the test aircraft at will by either 1) disengaging the evaluation system and resuming control of the aircraft using the control system utilized during normal flight, or 2) manually overpowering the evaluation system inputs through the normal flight control system. Instrument panels in the safety crew cockpit will be modified as required to permit continuous monitoring of the AIECS and basic aircraft system status at all times.

Aft in the fuselage area, there shall be a station accommodating two test engineers. In addition, the arrangement of equipment in the fuselage will be capable of being changed to accommodate up to five passenger-observers during certain flights. The latter will have easy access to the flight crew station and maximum visibility of the test engineers' station. A general outline which satisfies these requirements is shown in drawing 217-001MSP3.

Other modifications to the test aircraft will be the addition of speed brakes, the conversion of the flight control boost actuators to electro-hydraulic servos, and the addition of throttle servos.

The aircraft operating envelope will be in accordance with Figures 1 and 2. The flight condition of 220 knots equivalent airspeed and flight path angle 12° downward from the horizontal shall be used as the design condition for sizing the drag device. The aircraft is to be at its design gross weight with landing gear extended, engines at flight idle and lift flaps in the retracted position.

The evaluation crew and passenger cabins shall have the capability of maintaining 7.5 psi pressure above ambient at 35,000 ft. pressure altitude.

3.2 Airframe Modification

3.2.1 Procedure

In order to convert an existing aircraft to the Electronics Test Aircraft configuration, extensive design, construction and installation must be accomplished prior to completion of the test article. All preliminary and conceptual designs involved in these efforts are subject to NASA review and approval in accordance with procedures described in the following paragraphs.

3.2.1.1 Preliminary Design Effort

On completion of preliminary design layouts and cardboard or wood mockups which will facilitate visualization of the changes to be made to the basic aircraft, a Preliminary Design Review shall be held at the Contractor's facility. Unless approved otherwise by NASA, the Contractor shall present at that time the overall conceptual design of the test aircraft which shall include but not be limited to the following:

(a) schematics and layouts of all structural changes to the base aircraft such as the evaluation cockpit structure, the engineer/observer's station installation, the speed brakes, the modifications to the flight controls.

(b) schematics and load requirements for the hydraulic and electrical power supply system.

(c) overall layout of equipment in the base airplane.

(d) list of equipment to be removed or relocated in the base airplane.

(e) preliminary weight and balance computations.

(f) results of any stress analysis or other studies performed to that date.

(g) layout of the test engineers' station with schematics and preliminary wiring diagrams associated with equipment therein.

3.2.1.2 Preliminary Design Review

The preliminary design review will be held at the Contractor's facility not later than ___ weeks after award of contract.

3.2.1.3 Airframe Load Analysis

An airframe load analysis will be performed. This may require the use of wind tunnel models to determine the impact of the airframe modification on the aerodynamics of the airframe. The operating envelope will be examined in detail to determine the impact of the aerodynamic changes on the maneuver and gust airframe design envelope.

3.2.1.4 Detail Design and Stress Analysis

Following the Preliminary Design Review, detail design will be performed. Stress analysis will be performed simultaneously. Stress reports will be prepared.

3.2.1.5 Critical Design Reviews

Prior to release of any drawings to a manufacturing facility, critical design reviews at a subsystem level will be accomplished with NASA representatives participating in the reviews. At this point, configuration control will be exercised and subsequent changes in configuration will require NASA approval.

3.2.1.6 Fabrication and Manufacture

After completion of each critical design review, approved drawings will be released to the shop for fabrication and installation purposes.

3.2.2 Evaluation Crew Station

3.2.2.1 General

The aircraft is to be modified to provide a cabin environment which generally reflects the configuration of a reusable space shuttle craft. The anticipated configuration is that shown on drawing 217-001MSP2. The flight crew seating is to be side by side with dual flight controls and integrated cathode ray tube displays (CRT) for the purpose of displaying the information needed for controlling the aircraft and determining status of the integrated electronics system.

3.2.2.2 Evaluation Crew Displays

Provisions shall be made for accommodating various types of visual displays utilized by the pilot to control the flight path of the vehicle and monitor the performance of the aircraft and its subsystems. It shall be reasonably convenient to change the display configuration so as to permit evaluation by the flight crews. The displays are to be supplied as GFE, reference paragraph 3.3.10.

3.2.2.3 Flight Controls

Provisions shall be made for accommodating various types of three-axis flight controllers. These may be side-arm controllers with appropriate foot rests, side-arm controllers and rudder pedals, or a conventional form of control wheel and rudder pedals. It shall be reasonably convenient to change control configurations to permit evaluation of different pilot input devices. The pilot input devices will be identified in NASA Spec ________.

3.2.2.4 Evaluation Crew Station Access

Access to the evaluation flight deck will be from the safety pilot's flight deck by means of ladder and hatchway.

3.2.2.5 Evaluation Crew Station Lighting

The aircraft interior lighting will be in accordance with the requirements of AFSC DH2-2, Chapter 2.

3.2.2.6 Evaluation Crew Station Windshield

To provide adequate bird strike resistance, it is intended that suitable windshield framing and window panels from a currently in-production jet aircraft will be purchased and installed.

3.2.2.7 Evaluation Crew Station Environment

A shirt-sleeve environment will be provided in the evaluation crew station.

3.2.3 Test Engineer and Observer's Stations

3.2.3.1 Configuration

This crew station is designed for two purposes. 1) During the equipment development and evaluation stage of the program, it is to be used as a test monitoring and data gathering facility. 2) During the crew training and crew familiarization periods, the station is to be used to permit up to five observers to watch the operation of the system. A representative configuration of this crew station is shown in drawing 217-001MSP3.

3.2.3.2 Installation

The cabinets as shown in the drawing 217-001MSP3 shall be shock mounted. Provisions shall be made for installing avionics equipment, the size and weight of which shall be designated by NASA. It is expected that portions of this equipment will be supplied either directly by NASA or by the airframe modification contractor, or by other equipment subcontractors. This will require careful configuration control and liaison between all parties concerned.

3.2.3.3 Lighting

White lighting in accordance with MIL-L-6503 will be provided.

3.2.3.4 Cooling

Portions of the GFE-furnished avionics hardware uses ethylene glycol as a cooling agent. Provisions must be made for heat exchangers to dissipate the heat during ground and flight operations.

3.2.4 Drag Device

3.2.4.1 Design Point

With the test airplane in the following configuration: 1) lift flaps up, 2) engines at flight idle, 3) gear down, and with additional drag from a variable drag device, it is expected that the aircraft will be able to operate within the descent envelope shown in Figures 1 and 2. The design point for the system shall be 220 knots equivalent airspeed, flight path angle 12° downward from horizontal, at the aircraft design gross weight. Drawing 217-001MSP4 shows a suggested position and size for the speed brake.

3.2.4.2 Operation

It is desired that the operation of the speed brakes will have a minimal effect upon the aircraft's C_m and C_L.

3.2.4.3 Fail Safe Operation

The drag device shall be designed to a fail safe concept, that is, failure of electrical signal or hydraulic power will result in automatic closing of the speed brake and arrangement made to alert the pilot by both visual and and aural alarms.

3.2.4.4 Location

The drag device shall be located so as to minimize structural buffeting when the brakes are open.

3.2.4.5 Operating Rates

The operating mechanism shall be designed to provide operating rates of 20° per second that can be modulated smoothly from fully closed to fully open.

3.2.4.6 Speed Limitations

The blowdown speed for the drag device shall be 250 knots equivalent airspeed.

3.2.5 Flight Control System

3.2.5.1 General

The flight control system for the primary surfaces on the airframe -- elevator, aileron and rudder -- shall be modified such that the positions of these surfaces can be controlled by electrical signals generated in the SSV avionics package. The throttles on the aircraft are to be modified such that they can be controlled by electrical signals generated in the SSV avionics package. The throttle servo may be either electro-hydraulic or electro-mechanical depending upon which technique can best satisfy the requirements. The modified flight control system shall be capable of meeting the following requirements in order to maximize crew safety and provide the desired aircraft performance.

3.2.5.2 Effect of Modifications on Normal Flight Controls

There shall be negligible effect upon the safety pilot's ability to fly the normal airplane due to the additional components required to obtain the desired performance in the fly-by-wire mode.

3.2.5.2.1 Forces

The forces sensed by the safety pilot shall not be appreciably affected by added inertia, friction, or compliance.

3.2.5.2.2 Performance

The dynamic performance of the normal airplane control system shall not be degraded.

NOTE: (For what follows in sections 3.2.5.2.2.1 through 3.2.5.2.2.4 it is assumed that the unmodified airplane has a fully powered flight control system.)

3.2.5.2.2.1 Stability

The servos which are used during normal airplane operation shall satisfy the same stability requirements as the original equipment.

3.2.5.2.2.2 Accuracy

The positional accuracy of the modified flight control system during normal flying shall be as good as or better than the original equipment.

3.2.5.2.2.3 Rates

The maximum rate of surface motions which can be produced during normal flying shall be within ±10% of the value for the original equipment.

3.2.5.2.2.4 Phase Lag

The phase lag between motion of the normal airplane pilots' controls and surface motion shall be equal to or smaller than the values in the original equipment.

3.2.5.2.3 Failure Mode

The airplane shall be capable of being flown manually by the safety pilot in the event of loss of all hydraulic power. The performance shall not be degraded beyond that of the unmodified aircraft operating in the same mode.

3.2.5.3 Control Transfer

Transferring control of the primary surfaces from the normal airplane control system to the fly-by-wire mode shall be accomplished in a safe and reliable manner.

3.2.5.3.1 Transfer Position Error

There shall be negligible changes in surface positions when the fly-by-wire mode is engaged.

3.2.5.3.2 Transfer Time

The time required to transfer from the fly-by-wire to the normal mode shall be less than 50 milliseconds.

3.2.5.4 Mechanical Control System

A mechanical linkage from the normal aircraft pilot's controls to each flight control surface shall exist. This may be the control linkage used during normal flying. It shall meet the following requirements after the modification is accomplished.

3.2.5.4.1 Control Response

The normal pilot's controls shall move in response to changes in surface positions when the fly-by-wire system is engaged.

3.2.5.4.2 System Override

The normal airplane pilots shall be capable of overriding surface motions commanded by the fly-by-wire system at any time without exceeding specified pilot applied loads. (Reference paragraph 25.143 Federal Air Regulations for temporary applications.)

3.2.5.5 Electro-hydraulic Servo Requirements

The electro-hydraulic servos which are operational when in the fly-by-wire mode shall meet the following requirements.

3.2.5.5.1 Forces

The maximum force which the servo actuator produces shall result in a hinge moment about the axis of rotation for the surface which is equal to or less than the value developed by the normal aircraft control system.

3.2.5.5.2 Rates

The maximum rate of surface motion which can be produced by the actuator shall be greater than 40°/sec and less than 60°/sec.

3.2.5.5.3 Gains

The servos shall allow variations in loop gains of 25% without becoming unstable.

3.2.5.5.4 Phase Lag

The phase lag between the position commanded by the SSV avionics and position of the surface shall be minimized. The maximum value which the phase lag can be is given by Figure 3.

3.2.5.5.5 Bandwidth

The amplitude ratio between the position commanded by the SSV avionics and the position of the surface shall be within the outlines shown in Figure 4.

3.2.5.5.6 Resolution

The resolution of the servos shall be better than .2% of the maximum change in position which can be produced.

3.2.5.5.7 Linearity

The linearity between the position commanded by the SSV avionics and the surface position shall be better than ±10% when defined as the result of the difference between the surface position and the commanded position being divided by the commanded position.

3.2.5.6 Electro-mechanical Servo Requirements

The electro-mechancial servos which control forces generated on the airframe in the fly-by-wire mode shall meet the following requirements.

3.2.5.6.1 Forces

The maximum force which the actuator can exert shall result in a force on the affected safety pilot's control that is low enough to be easily overcome by the safety pilot.

3.2.5.6.2 Rates

The maximum rate of motion which can be produced by the actuator shall result in moving the controlled element stop to stop in less than ____ seconds and more than ______ .

3.2.5.6.3 Gains

The servos shall allow variations in loop gains of 25% without becoming unstable.

3.2.5.6.4 Phase Lag

The phase lag between the position commanded by the SSV avionics and the position of the actuator shall be minimized.

3.2.5.6.5 Bandwidth

The amplitude ratio between the position commanded by the SSV avionics and the position of the actuator shall not reach a maximum of more than +3 db. The frequency at which the -3 db point occurs will be maximized consistent with the limitation on peaking of the amplitude response.

3.2.5.6.6 Resolution

The resolution shall be better than .2% of the maximum change in position which can be produced.

3.2.5.6.7 Linearity

The linearity between the position commanded by the SSV avionics and the actuator position shall be better than ±5% when defined as the difference between the actuator position and the commanded position divided by the commanded position.

3.2.6 Test Bed Airframe Dynamics

The response feedback mode of variable stability simulation is to be used. By its very nature, this mode is likely to be sensitive to variations in the parameters defining the base vehicle from the nominal design values. This is true since response feedback does not directly incorporate any means for reducing the system's sensitivity to these parameter variations. Normally, estimates of the base vehicle's parameters are obtained from manufacturer's data which is in turn obtained from theoretical analysis and wind tunnel testing. However, this data is often inaccurate, particularly for those parameters defining the dynamic responses of the vehicle. Because of this, inaccuracies in obtaining a valid simulation can normally be expected with the response feedback mode of variable stability simulation.

For the particular problem under consideration, the definition of the base vehicle is further complicated by several factors. For one, the base vehicle is to be modified with an added cockpit and speed brakes which provide a destabilizing effect. In addition, the large difference in the handling qualities of the model and base vehicle places stringent requirements on the accuracy with which the base vehicle must be known, for example, the model modes. While a small error in the definition of the relatively high damping of the base vehicle would be undetectable to a pilot, this same error could be translated into a large noticeable error when the simulation having low damping is attempted. Furthermore, the large flight envelope over which the simulation is to be conducted, Figures 1 and 2, adds another dimension to the problem of defining the base vehicle since the parameters defining it could be expected to undergo variations with fuel loading, c.g. changes, altitude, airspeed or dynamic pressure. In order to faithfully simulate the SSV over this flight regime, a gain scheduled system would have to be used. This, however, requires an accurate definition of the base vehicle over the expected range of flight conditions.

In view of these factors, the contractor shall:

A. As accurately as possible estimate the coefficients of the base vehicle throughout the flight range by means of the airframe manufacturer's and wind tunnel data.

B. Validate this data by flight test.

C. As needed, use the latter to update the original data defining the base vehicle and transmit to NASA.

3.2.7 Hydraulic and Electrical System

3.2.7.1 Hydraulic System Requirements

The hydraulic system in the aircraft shall be modified in order to meet the following requirements.

3.2.7.1.1 Flow Requirements

The maximum flow from any hydraulic pump which provides power to the fly-by-wire system shall be greater than .636 Q_{max}, where Q_{max} equals the amount of flow required to produce simultaneously the maximum rates specified for the hydraulic actuators which receive power from that pump when operating in the fly-by-wire mode.

3.2.7.1.2 Pressure Requirements

The change in hydraulic system pressures due to the occurrence of high flow demands in the fly-by-wire mode shall be less than 15% of the system pressure when no flow is demanded.

3.2.7.1.3 Hydraulic Specification

Additions to or changes in the original hydraulic system shall comply with MIL-H-5440, as applicable.

3.2.7.2 Electrical Requirements

The electrical power supply on the aircraft shall be modified to meet the following requirements.

3.2.7.2.1 Electrical Voltages

Three phase 115 volt AC, 400 cps, and 28 volt DC shall be provided to the electrical equipment which is being added to the aircraft.

3.2.7.2.2 Load Analysis

A load analysis per MIL-E-7016 will be performed to determine if the aircraft has sufficient surplus power to meet the demands of the added equipment.

3.2.7.2.2.1 Speed Brake

All electrical power required by the speed brake system shall be available from the aircraft emergency buses. Modifications to the emergency power systems will be made if necessary to meet this requirement.

3.2.7.2.2.2 Fly-by-Wire System

Electrical power for the equipment used only in the fly-by-wire mode may be obtained from surplus power available when the aircraft is flown normally in the same flight regimes as intended for fly-by-wire operation.

3.2.7.2.3 Failure Conditions

In case of failure, it will be possible to revert to a condition which satisfies the requirements of MIL-7016 by turning OFF all added equipment other than the speed brake system.

3.2.8 Landing Gear Restrictions

The C-130 in its present configuration has a landing gear limit speed of 165 knots. The desired operating conditions as specified in Figures 1 and 2 of this specification indicate a desired operating airspeed of 220 knots. To remove the present airspeed limitation, it will be necessary to examine the structural analysis of the landing gear, landing gear doors, and operating mechanism to determine which items are speed limited. Operation of the aircraft with landing gear doors removed is considered an acceptable approach to solution of the problem. It is anticipated that removal of the landing gear doors will precipitate buffeting problems. It can therefore be expected that spoilers of some configuration will be required to reduce the buffet intensity to acceptable limits. The use of the wind tunnel model for study of this problem may be required.

3.3 Avionics

3.3.1 General

The SSV Test Bed System is a fly-by-wire digital computer controlled flight control system. The test system will be connected in parallel to the aircraft flight control system and allow the evaluation pilots to fly the aircraft. When operating in the SSV simulation mode, the basic airframe will be protected through a safety trip system which will automatically transfer control of the aircraft from the evaluation pilots to the safety pilots when undetected malfunctions or failures occur. A block diagram of the anticipated system is shown in Figure 5.

3.3.2 System Engagement

3.3.2.1 System Engagement Control

The safety pilot will have control of the system engagement sequence.

3.3.2.2 System Engagement Sequence

Power ON -- electrical power supplied to the system.
READY -- _____ sec. delay to allow system electronics to stabilize.
Balance check -- automatic check to determine that command inputs to surfaces are zero.
* Pressurize -- hydraulic power supplied to the system.
Engage -- aircraft control transferred to system.

*Not applicable to aircraft with fully powered boost system.

3.3.2.3 System Engagement Monitors

All stations will be provided with repeater lights to indicate system engagement status.

3.3.2.4 System Engagement Nullmeters

The safety pilot shall be provided with a positive indication of commands required to trim the aircraft prior to system engagement. Upon engaging system, the nullmeters will display control surface hinge moment.

3.3.2.5 System Engagement Transients

No dangerous transients shall occur during system engagement.

3.3.3 Automatic Pitch Trim

3.3.3.1 Automatic Pitch Trim Function

The automatic pitch trim system will maintain the aircraft in trim at all times so that at the time of system disengagement, the safety pilot will not be required to exert excessive pilot effort to maintain control of the aircraft.

3.3.3.2 Automatic Pitch Trim Operation

The stabilizer trim actuator shall automatically operate when the average elevator deflection deviates from the null (zero hinge moment) position by a predetermined and preset value when the longitudinal (elevator) system servo is engaged to provide automatic following and minimize disengage transients. All other stabilizer trim commands, except emergency stabilizer trim, shall be inoperative when the elevator system servo is engaged.

3.3.3.3 Automatic Pitch Trim Monitor

A monitor system will be incorporated to provide the safety pilot with a warning and indication of elevator hinge moment developed if the auto pitch trim system fails and the hinge moment exceeds *___ lbs. -ft for 6 sec. duration (*equivalent to 10 lbs. pilot effort).

3.3.4 System Disengagement

3.3.4.1 System Disengagement Function

System disengagement will transfer control of the aircraft to the safety pilot.

3.3.4.1.1 System Disengagement Manual

All flight stations will be provided with a readily accessible disengage switch.

3.3.4.1.2 System Disengagement Automatic

A safety trip system will sense critical aircraft rates and accelerations and automatically disengage the system if a signal exceeds a predetermined safe limit. The safety trip system will be a fail safe device.

3.3.4.2 System Disengagement Signals

The system will be disengaged if any of the following conditions occur:

1) Electrical power failure.
2) Hydraulic power failure.
3) Electrical error signals in the servo loops that would result in surface rates in excess of 80% of maximum shall be monitored and cause automatic disengagement.
4) Engagement of the system shall be disallowed if an excessive error signal exists prior to engagement.
5) Excessive aircraft accelerations, n_z, n_y
6) A study shall be made to determine additional safety trips necessary to limit any other critical loads that could occur on the airframe. These sensors shall be incorporated as part of the safety trip system.

3.3.4.3 System Disengagement Transients

No dangerous transients shall occur during system disengagement.

3.3.4.4 System Disengagement Indication

All flight stations will be provided with a flashing red light to indicate that the system has disengaged. An easily identifiable beeping tone will be provided to the intercom system to indicate the system has disengaged.

3.3.5 NAV/COMM

3.3.5.1 Intercom System

The intercom system will provide onboard communications between all flight stations.

3.3.5.1.1 Intercom System Control

The safety pilot will have control of the intercom system and have the capability to isolate stations to allow private communications between the other stations.

3.3.5.1.2 Intercom System Call Override

The intercom system will have a call override capability for emergency communications from any station to all other stations regardless of the intercom configuration selected by the safety pilot.

3.3.5.1.3 Intercom System Voice Recording

All stations will have the capability of local voice recording without transmitting to the other stations.

3.3.5.2 Navigation System

The navigation system will have the capability of receiving VOR/DME, TACAN and ILS information.

3.3.5.2.1 VOR/DME Channel Selector Control

The safety pilot will have control of the VOR/DME channel selector.

3.3.5.2.2 TACAN Channel Selector Control

The safety pilot will have control of the TACAN channel selector.

3.3.5.2.3 Navigation System Interface

The navigation system data will be supplied to the flight director display of the safety pilot and to the data adapter.

3.3.5.3 Communication System

The communication system will consist of two VHF transmitter receivers.

3.3.5.3.1 Communication System Control

The safety pilot will have control of all communications emitting from the aircraft.

3.3.5.3.2 Evaluation Pilot Communications

The safety pilot will have the capability of permitting the evaluation pilot to transmit on transmitter No. 1.

3.3.5.3.3 Test Engineer Communications

The safety pilot will have the capability of permitting the test engineers to transmit on transmitter No. 2.

3.3.5.4 Navigation - Communication Audio

Each station will be able to independently select the audio from the various navigation and communication receivers. Each station will be able to listen to this audio on either earphones or speakers.

3.3.6 Air Data System

An air data system will provide pressure altitude (h_p), pressure altitude rate ($\dot{h}_p$) and dynamic pressure ($\bar{q}_c$) analog signals to the data adapter. System accuracy and resolution will conform to NASA Spec ___________.

3.3.6.1 Air Data System Sensors

Static and dynamic pressure sensors.

3.3.6.2 Air Data System Interface

A ±10V DC signal range will be supplied to the data adapter from the air data system.

3.3.7 Electrical Power Distribution

Meters will be provided to the test engineers to monitor electrical power being supplied to the system.

3.3.7.1 Electrical Power Distribution Protection

Individual units of the system will be provided with circuit breakers.

3.3.7.2 Circuit Breaker Location

All system circuit breakers will be located in one area to allow quick visual inspection.

3.3.8 Data Acquisition

3.3.8.1 Data Acquisition System

The data acquisition system will consist of:

1) 60 channel digital tape recorder.
2) 6 channel strip chart recorder.
3) 60 channel telemetry system.
4) 2 video tape recorders.

3.3.8.1.1 System Option No. 1

Data from the data adapter will be transferred in digital form (compatible with ground processing equipment) directly to the digital tape recorder and the telemetry system.

3.3.8.1.2 System Option No. 2

Data from the data adapter in analog (± 10 V DC) form will be transferred to a recording patch panel. Data will be patched through filters and processed for the digital tape recorder and telemetry system.

3.3.8.2 Airborne Digital Tape Recording System

A 60 channel compact airborne data recording system will consist of a digital tape control unit and tape recorder. (Note: A minimum of 2 channels will be required for bookkeeping, i.e., record number and frame number.)

3.3.8.2.1 Digital Tape Control Unit

A remote control unit will contain a digital package, the remote control head and the control junction box.

3.3.8.2.2 Digital Tape Recorder

The recorder will be a two capstan recorder to minimize the tape speed changes resulting from rotation of the tape machine during turns and maneuvers.

3.3.8.2.3 Digital Tape System Magnetic Tapes

The magnetic tapes recorded by this system will be compatible with the NASA Houston data processing system.

3.3.8.3 Strip Chart Recorder

An airborne 6 channel strip chart recorder will be supplied by the contractor.

3.3.8.3.1 Strip Chart Recorder Flexibility

Six rotary switches with 10 positions each will be provided to allow sixty data channels to be monitored.

3.3.8.3.2 Strip Chart Recorder Interface

Analog signals (±10V DC) will be supplied from the data adapter.

3.3.8.4 Telemetry System

A 60 channel telemetry system will be supplied by NASA. (Ref. NASA Spec. ______)

3.3.8.4.1 Telemetry System Mobile Ground Station

A mobile ground station will be supplied by NASA. (Ref. NASA Spec. ______).

3.3.8.5 Video Tape Recorders

Two airborne video tape recorders will be supplied by NASA. (Ref. NASA Spec. ______).

3.3.9 Guidance and Control Computer

3.3.9.1 Data Adapter

The data adapter will provide analog to digital (A to D) and digital to analog (D to A) conversion, moding and failure detection. The data adapter will be supplied by NASA. (Ref. NASA Spec. ______).

3.3.9.2 Inertial Measurement Unit

The inertial measurement unit contains inertial reference integrating gyros and pulse integrating pendulous accelerometers. The inertial measurement unit will be supplied by NASA. (Ref. NASA Spec. ______).

3.3.9.3 Digital Computer

The digital computer contains a timer, sequence generator, central processor, priority control, an input, output section and a memory. The digital computer will be suppli ed by NASA. (Ref. NASA Spec. ______).

3.3.9.4 Digital Computer Keyboard

The evaluation pilot will be supplied with a digital computer keyboard to allow loading of information and initiating any program stored in the digital computer memory. The digital computer keyboard will be supplied by NASA. (Ref. NASA Spec. ______).

3.3.10 Displays

3.3.10.1 Evaluation Pilot and Co-Pilot Displays

Cathode ray tube (CRT) displays which display system status and flight control information will be supplied by NASA. (Ref. NASA Spec. ______).

3.3.10.2 CRT Repeater Displays

The safety pilot and the test engineer will be provided with repeater displays of the evaluation pilots' display. The repeater displays will be supplied by NASA. (Ref. NASA Spec. ______).

3.3.10.3 Observer Displays

Provision shall be made for an additional display to be installed at the test engineers' station for use by observers.

3.3.10.4 Closed Circuit Television Cameras

Closed circuit TV cameras will be installed to 1) provide a forward looking view during the landing approach for integration in the evaluation pilots', safety pilot and test engineers' displays, 2) provide a view of the evaluation pilots' flight controls and displays. (Display and video recording functional block diagram, Figure 6.)

3.3.10.5 Safety Pilot Flight Director Display

A flight director display will be provided.

3.3.11 Ground Simulation

3.3.11.1 Ground Simulation System

A means will be provided to substitute analog computer signals for the aircraft sensor signals. These signals will be supplied to the digital computer.

3.3.11.2 Ground Simulation Equipment

3.3.11.2.1 Analog Computer

The analog computer will be programmed to accept inputs from the evaluation pilot and to output simulated aircraft sensor response. The analog computer will be supplied by NASA. (Ref. NASA Spec. ______)

3.3.11.2.2 A to D, D to A Converters

Analog to Digital and Digital to Analog converters will process the signals between analog computer and the digital computer. The A to D and D to A converters will be supplied by NASA. (Ref. NASA Spec. ______).

3.4 Ground Support Equipment

Provisions are to be made for use of the electronic test aircraft in the ground operate mode. Operation of the test equipment in this mode will permit:1) conduct of initial system checkout prior to first flight,

2) routine preflight checkout of total system prior to each flight, 3) use of the electronic test aircraft for demonstration and training purposes.

3.4.1 Support Equipment Required

3.4.1.1 Hydraulic Test Stand

A portable hydraulic test stand capable of providing flow rates in section 3.2.7 with variable pressure up to 3000 psi will be provided. The results of the study accomplished under Section 3.2.7 shall be used to determine the required hydraulic flow rates.

3.4.1.2 Electrical Power Supplies

Electrical power of both 28 volts DC and 400 cycle three-phase 115 volts will be required to operate the system. The results of the study accomplished under section 3.2.7 will be used to size the equipment.

3.4.1.3 Analog Computer

An analog computer with interface digital to analog, analog to digital converters will be provided. This computer is to be used to represent the aerodynamics of the base airplane and also to replace the onboard sensors which are part of the NASA supplied digital computer.

3.4.1.4 Cooling

Adequate means shall be provided for cooling all electronic equipment during the ground operate mode. Note: It is anticipated that all equipment required to comply with this requirement will be supplied by NASA as Government Furnished Equipment.

4. TRAINING

4.1 Training Program

It is intended that NASA personnel will operate and maintain the test aircraft after delivery. It will be necessary therefore to provide a training program and appropriate documentation preparatory to transferring the operation of the aircraft from the modification contractor to the NASA Manned Space Center. It is therefore required that during the modification of the aircraft, preliminary versions of a maintenance manual will be prepared so that at completion of the modification, documentation will be available for use in training programs for both flight and maintenance personnel training programs.

4.1.1 Maintenance Manual

The maintenance manual must be in sufficient depth and detail to permit maintenance personnel at the technician level to perform routine maintenance on the equipment.

4.1.2 Liaison Services

Because a substantial portion of the avionics control system is expected to be provided by a contractor other than the aircraft modification contractor, provisions for engineering liaison service and technical representatives must be allowed for in the bids.

4.1.3 Training

It is anticipated that the training of the personnel would be accomplished by:1) lecture sessions, 2) equipment demonstrations with the system operating in the ground mode,and 3) flight demonstrations including both flight crew and maintenance personnel.

5. QUALITY ASSURANCE

5.1 General

Quality provisions to be observed by the Contractor during the period of this contract will be in accordance with the requirements defined in this section.

5.2 Reliability, Materials, Workmanship

Reliability shall be an area of prime consideration. In accordance with the provisions of Section 2 of this specification, essentially all materials, supplies, parts, and components shall be of serviceable, approved aerospace type and quality, and any required exceptions shall be processed in accordance with the provisions of Section 2.1. Workmanship, methods, and processes shall conform to the best established aerospace practices.

5.3 Quality Program Plan

Subsequent to the award of contract, but no later than 30 days after award of contract, the Contractor shall submit a "Quality Program Plan" for review by the NASA Manned Spacecraft Center. As a basic requirement the Quality Program Plan shall define the proposed quality and inspection organization, the relationship of such organization to other Contractor units and groups, and the techniques and procedures planned for implementing and maintaining a quality program as related to articles and services described in the contract. In complying with the requirement for establishing a Quality Program Plan, the Contractor may reference, and submit for approval, quality manuals, organizational charts, quality procedures, and similar documents, systems, and controls in existence at the Contractor's facility, and which may be applicable to, or modified to suit, the contract.

Submittal by the Contractor, for approval, of any written manual, instruction, process, or similar material as a part of the Quality Program Plan, shall signify firm intent of the Contractor to utilize such material during the period of this contract. Approval by the NASA Manned Spacecraft Center of any such material shall make that material a part of the contract specifications.

5.4 Quality Program Records

The Contractor shall maintain historical records of all processing, inspection, and tests performed, including results, malfunctions, nonconformance, and corrective action. Such records shall be available at the Contractor's facility for review by NASA personnel.

6. PREPARATION FOR DELIVERY

6.1 Ground Checkout

6.1.1 Planning

Prepare a detailed program for performing ground checkout of each subsystem after installation and checkout of the entire system.

6.1.2 Conduct Ground Checkout

Ground checkout will be conducted in accordance with paragraph 6.1.1 utilizing ground based analog computers where appropriate to permit system operation in both the ground and flight operate mode.

6.2 Flight Checkout Program

6.2.1 Planning

Prepare comprehensive flight test program which will permit 1) determination of base aircraft stability derivatives, 2) verification of system performance, 3) demonstration of operation of entire system to NASA personnel prior to acceptance by NASA.

6.2.2 Conduct Flight Test and Demonstration Flight Program in accordance with paragraph 6.2.1.

6.2.3 Deliver Aircraft to NASA.

6.2.4 Prepare Summary Flight Test Report

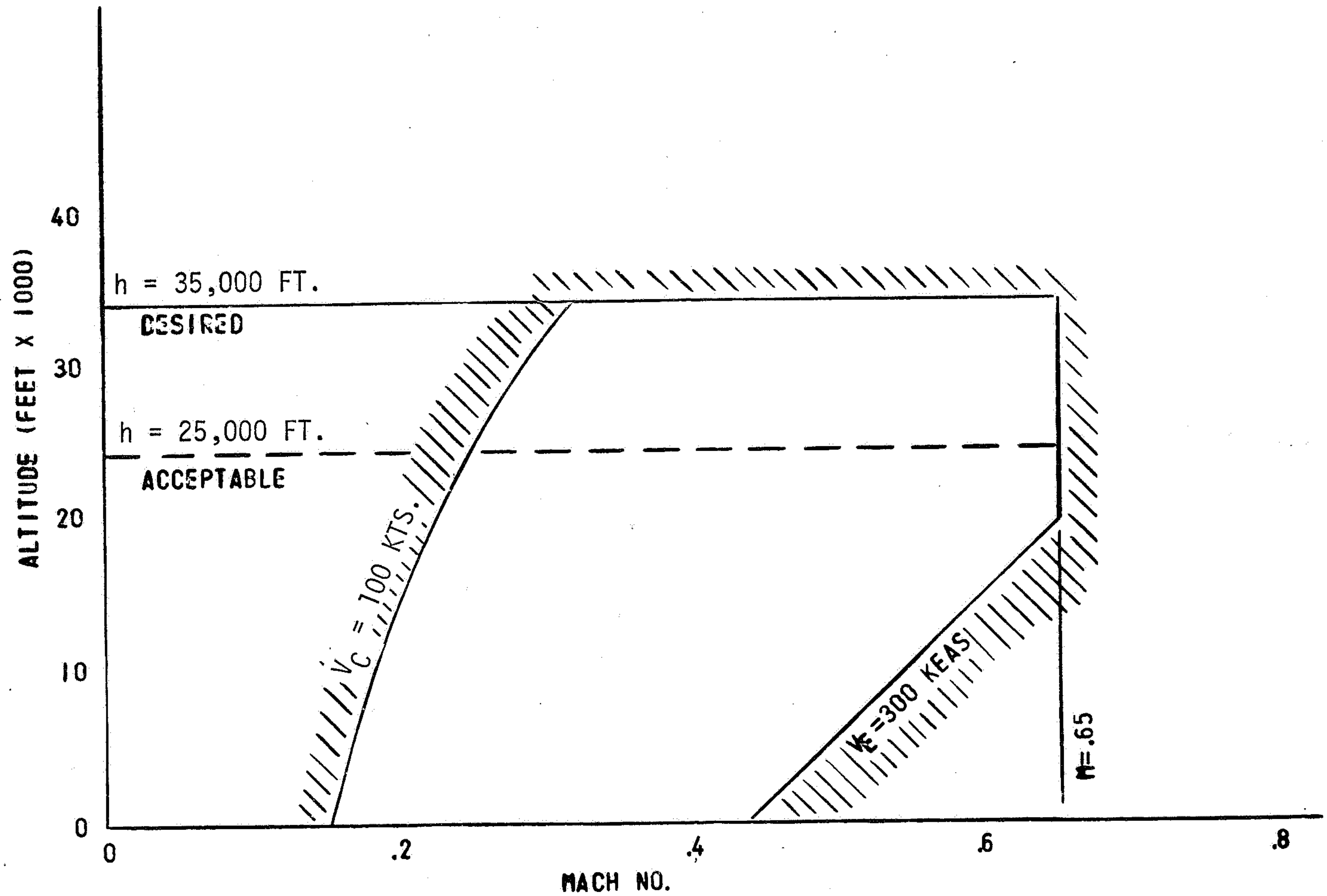

FIGURE 1 MINIMUM OPERATING ENVELOPE FOR PROPOSED ELECTRONICS TEST AIRCRAFT

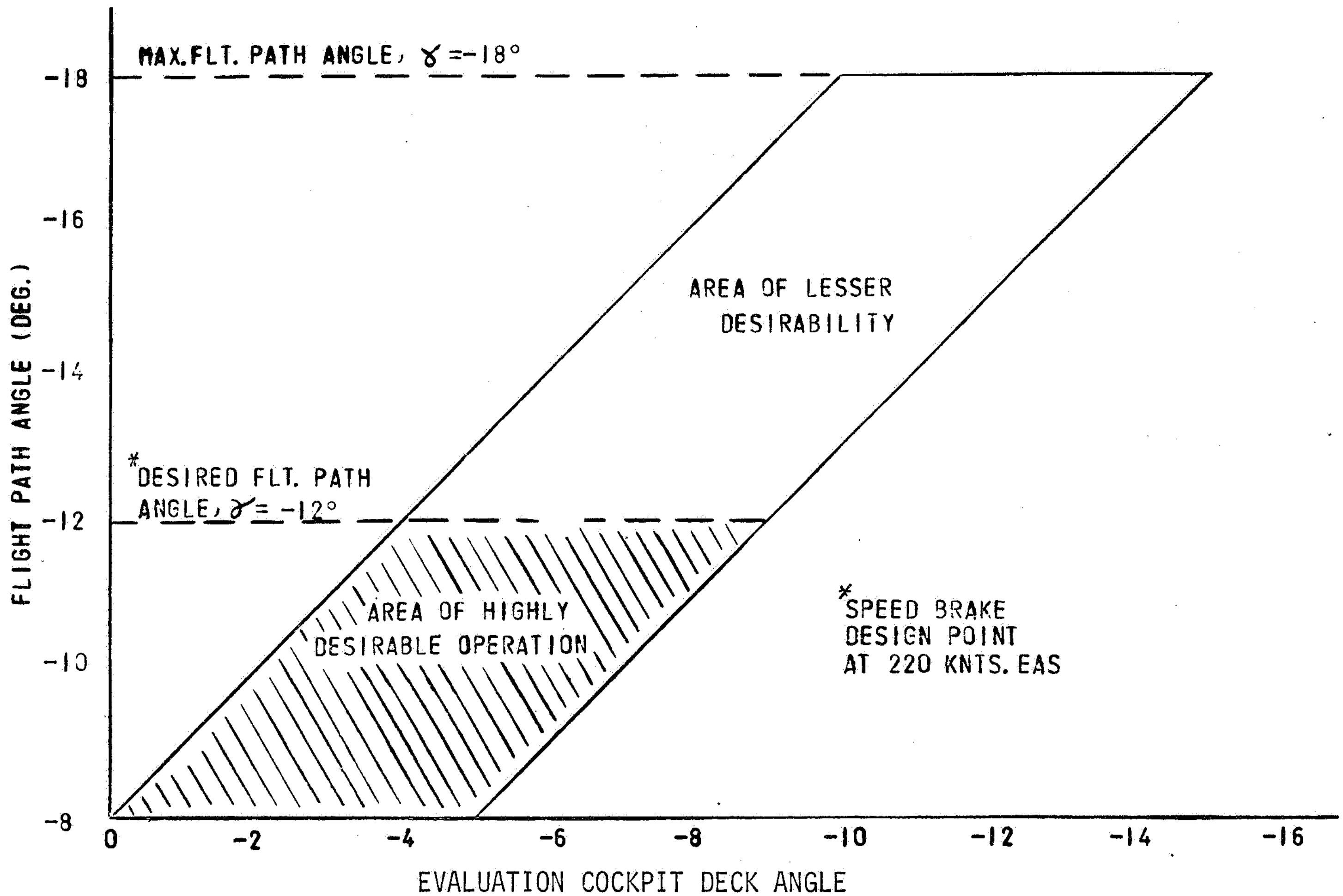

FIGURE 2 DESIRED ENVELOPE FOR STEEP FLIGHT PATH TRAJECTORY SIMULATION AT 200 ±20 KNOTS EAS

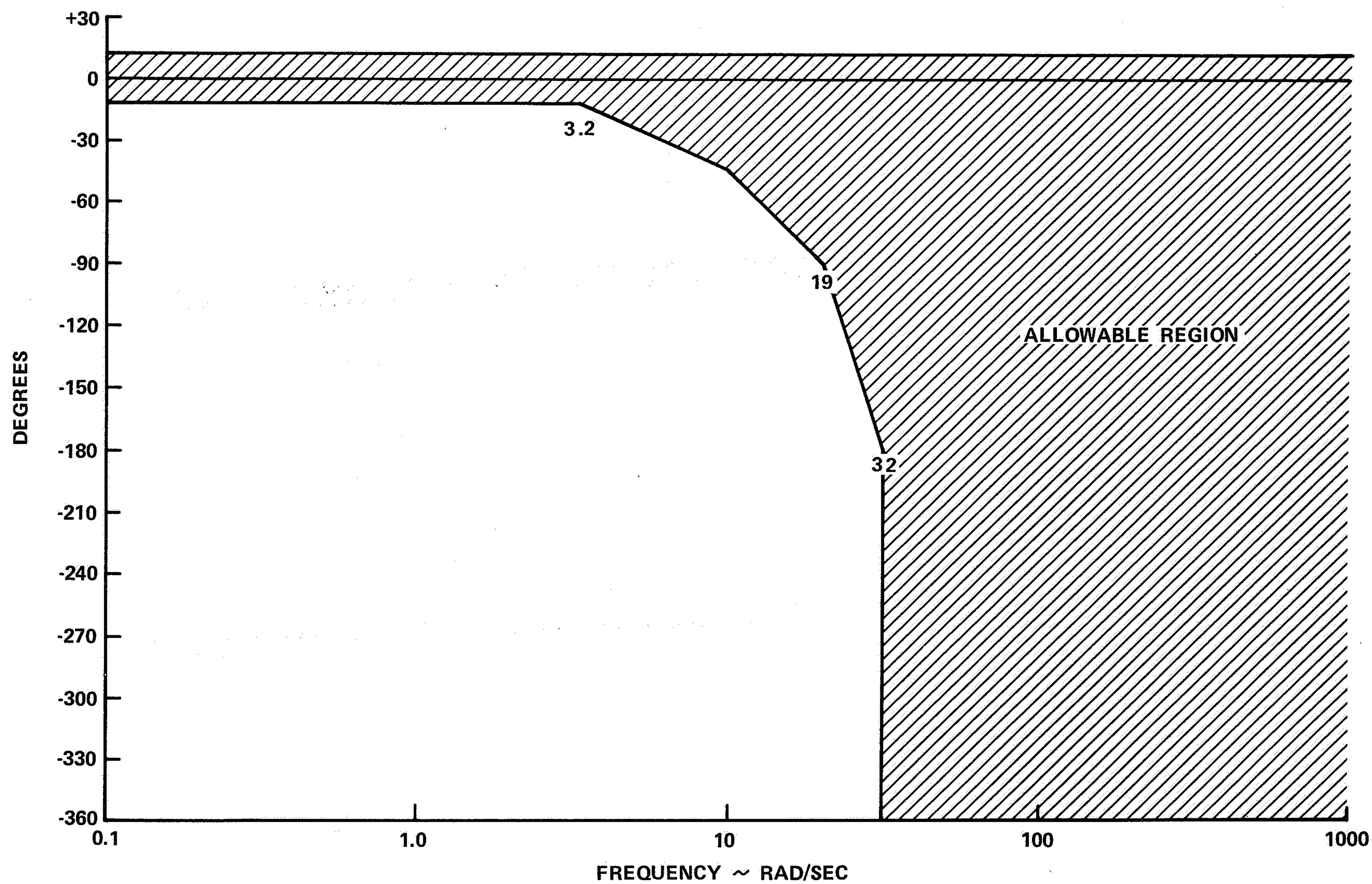

FIGURE 3 PHASE LAG BETWEEN SURFACE POSITION AND COMMANDED POSITION

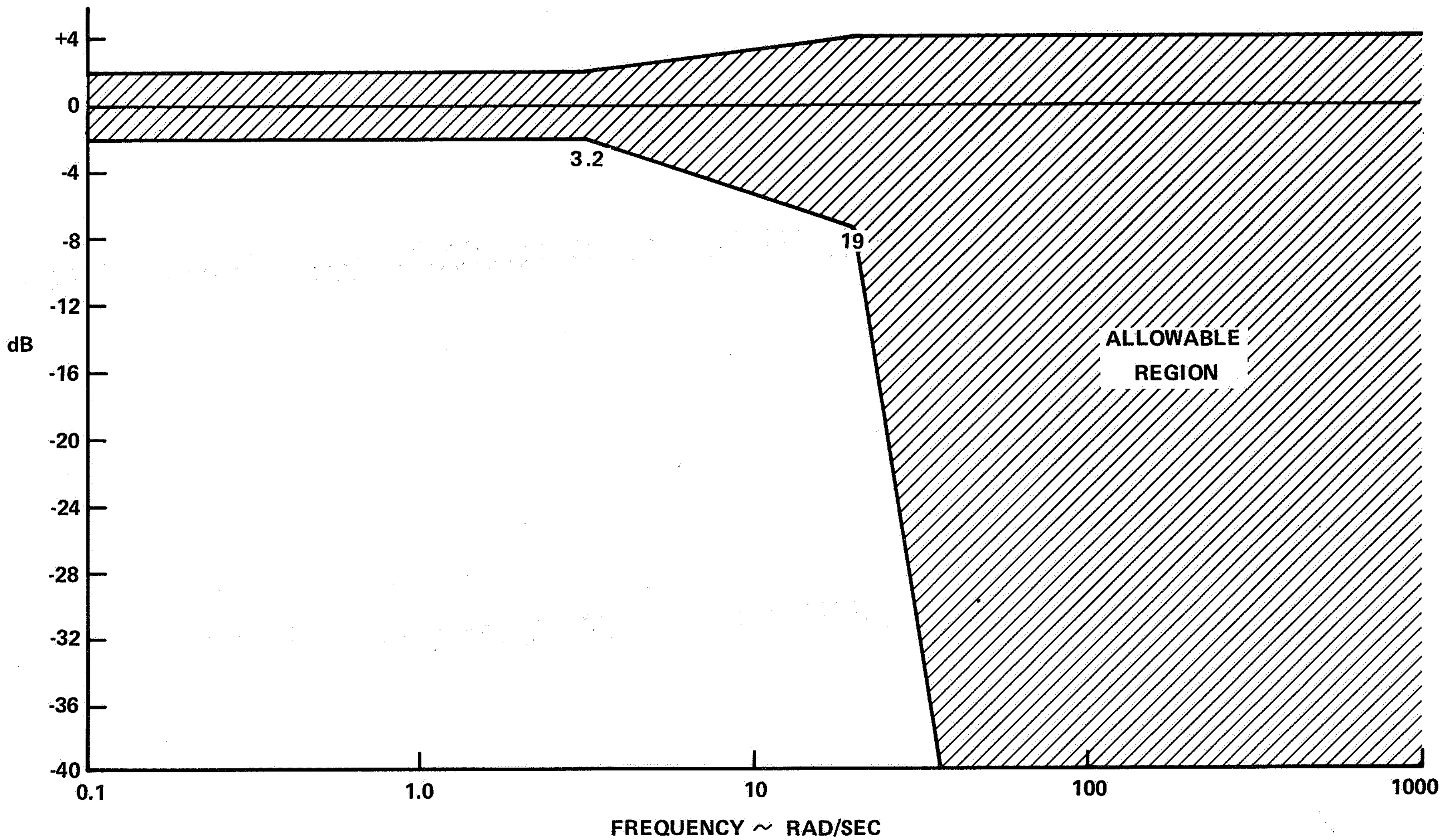

FIGURE 4 AMPLITUDE RATIO BETWEEN SURFACE POSITION AND COMMANDED POSITION

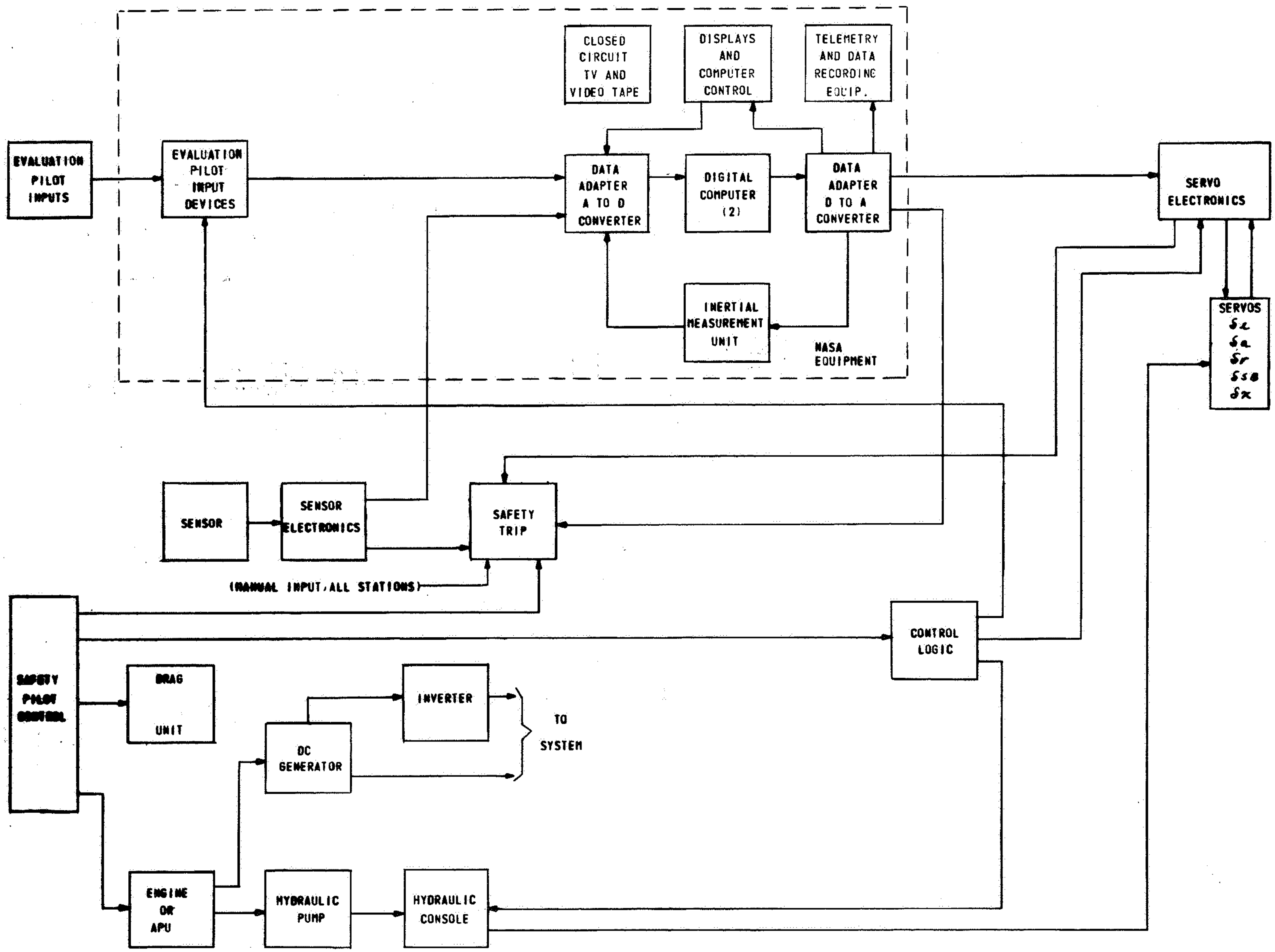

FIGURE 5 ELECTRONIC TEST AIRCRAFT SYSTEM BLOCK DIAGRAM

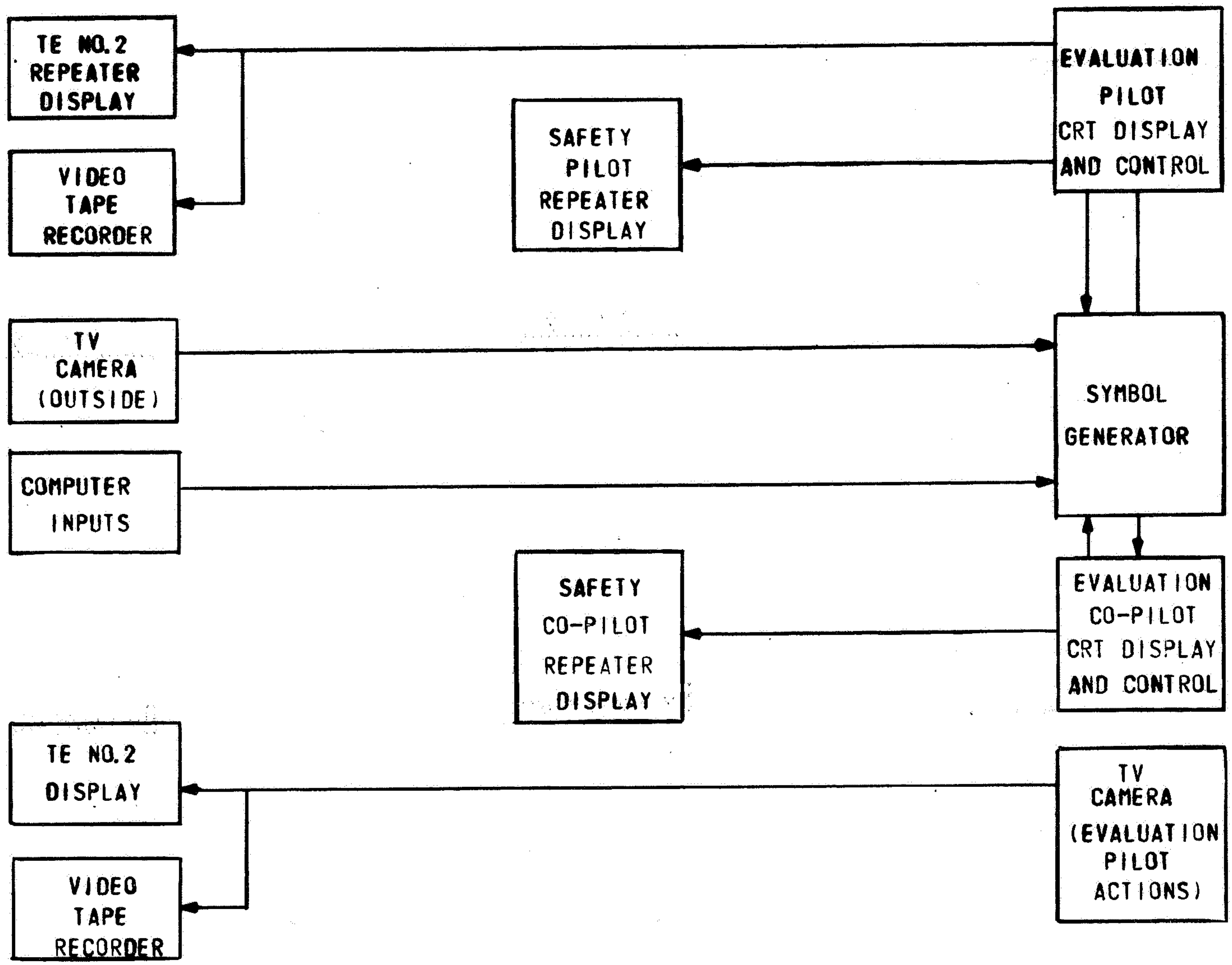

FIGURE 6. ETA DISPLAYS

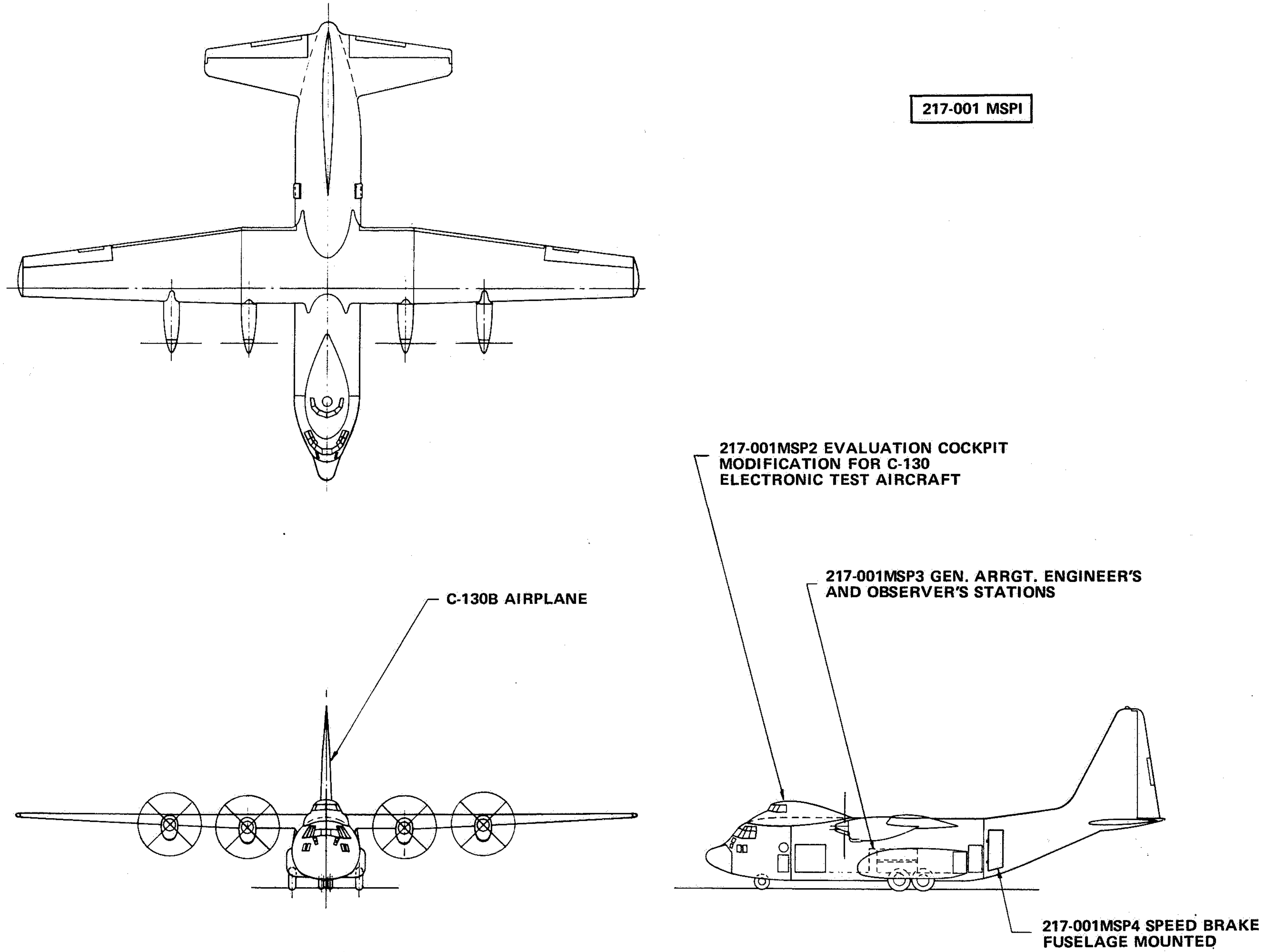

Figure 7 C-130B CONVERSION (FROM CAL DRAWING 217-001 MSP 1)

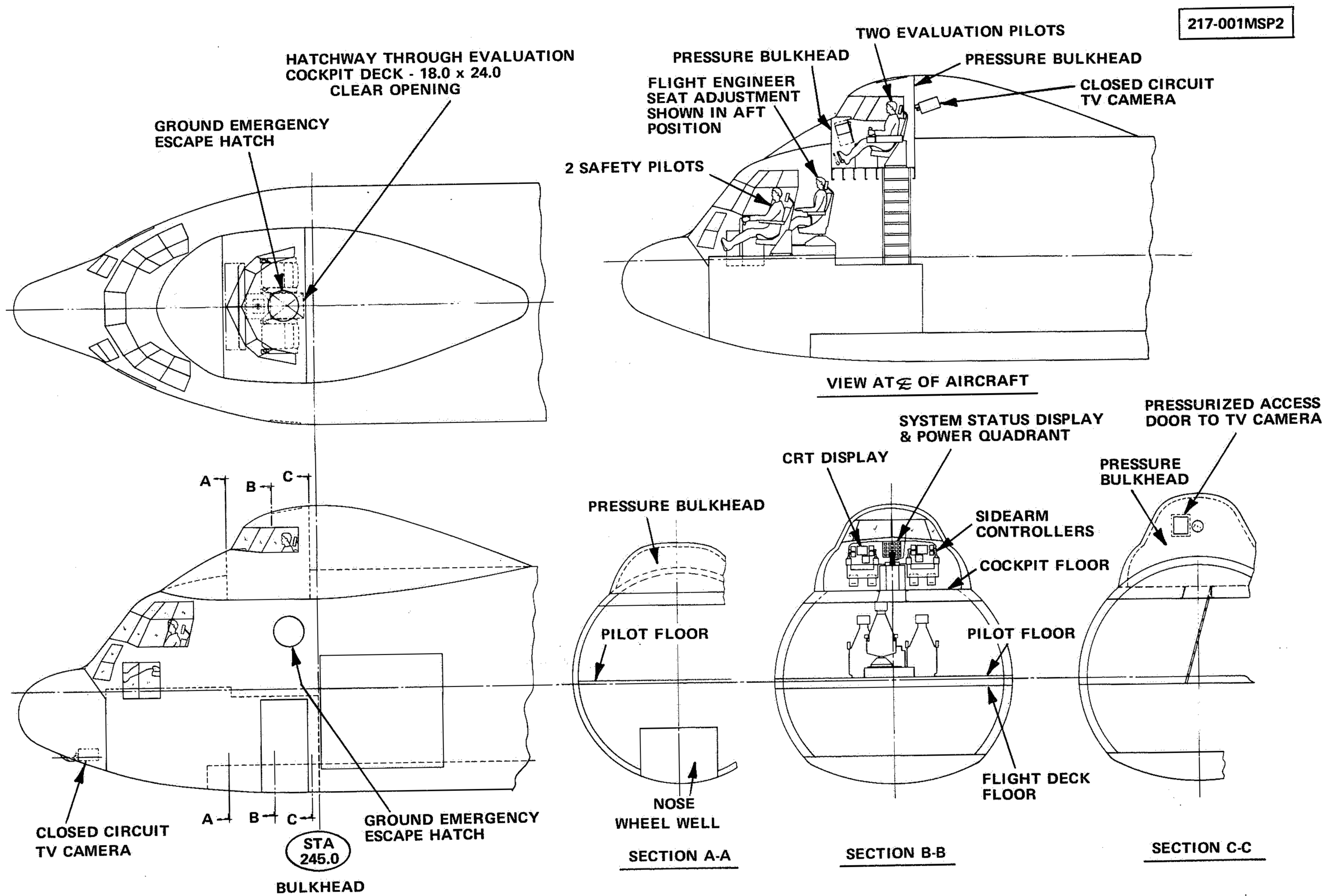

Figure 8 EVALUATION COCKPIT MODIFICATION
(FROM CAL DRAWING 217-001MSP2)

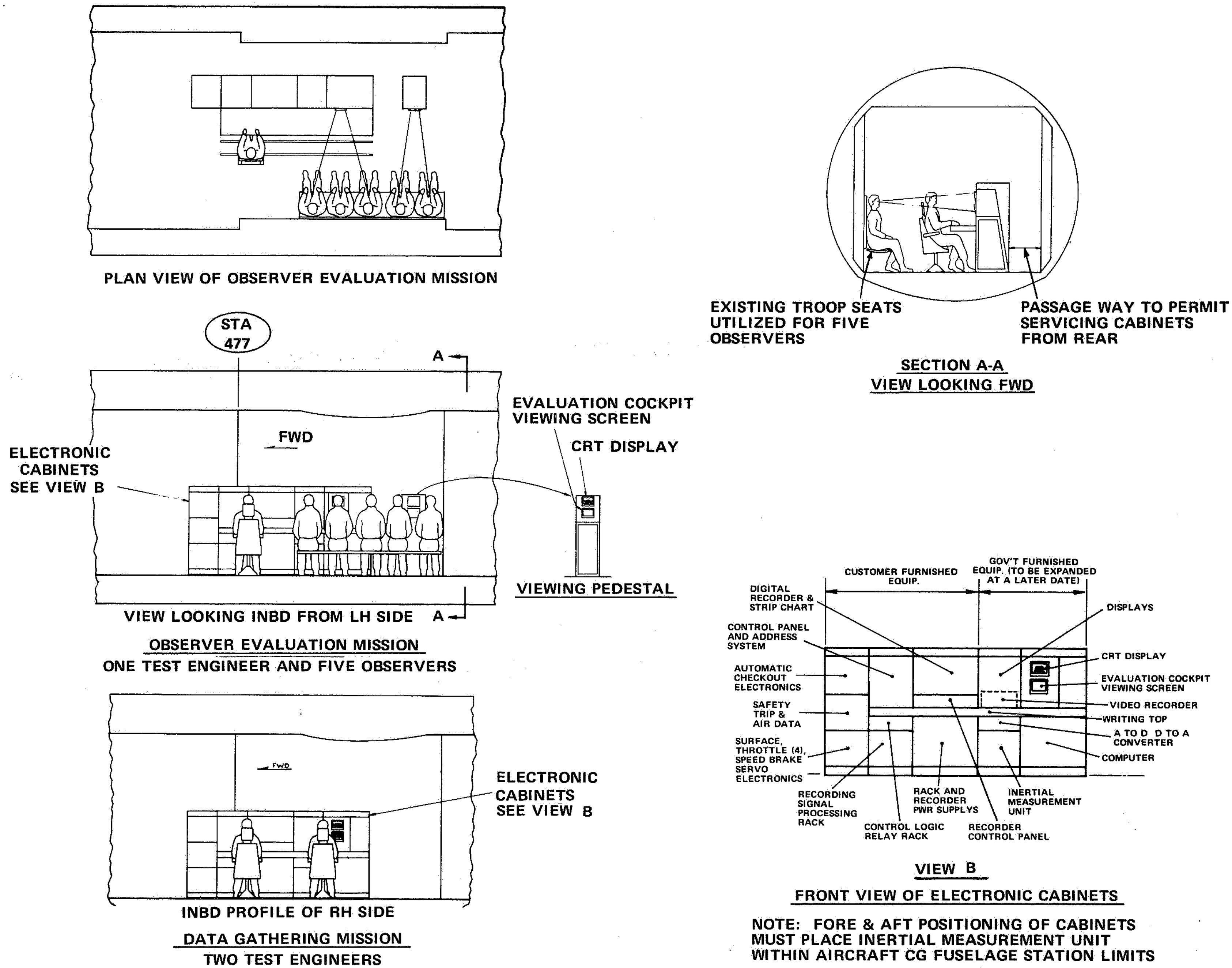

Figure 9 GENERAL ARRANGEMENT OF ENGINEER'S AND OBSERVER'S STATIONS (FROM CAL DRAWING 217-001MSP3)

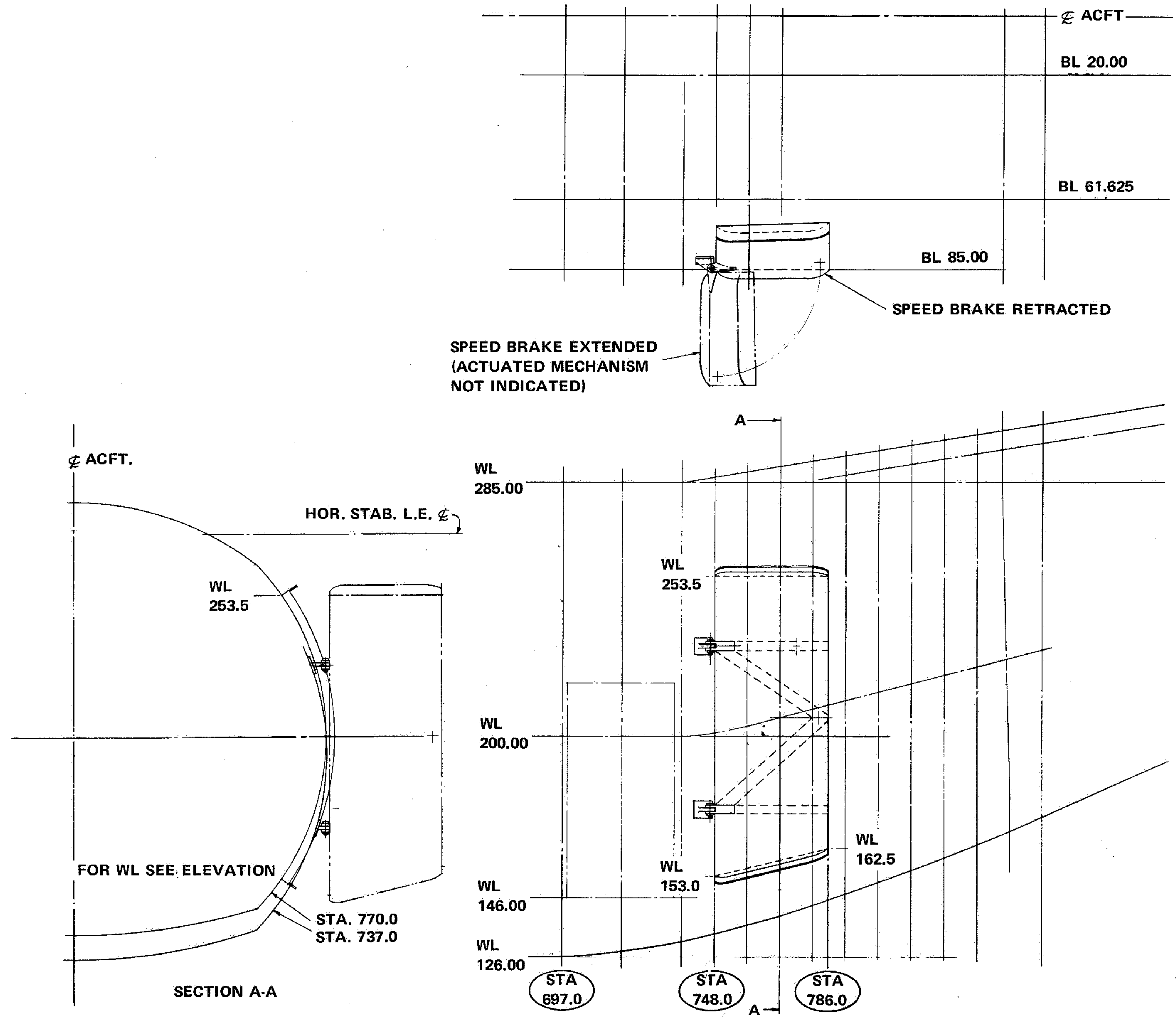

Figure 10 FUSELAGE MOUNTED SPEED BRAKE INSTALLATION
(FROM CAL DRAWING 217-001MSP4)