AFFDL-TR-75-58
VOLUME II

CONTROL-DISPLAY INTEGRATION PROGRAM

HIGH ACCELERATION COCKPIT CONTROLLER LOCATIONS

Volume II - Test Plan

McDonnell Aircraft Company
St. Louis, Missouri 63166

May 1975

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Final Report for period June 1974 - December 1974

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AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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A high acceleration cockpit/controller design and integration program was conducted, using a full scale design aid. Alternate cockpit/controller configurations were developed for comparison using this full scale design aid in a formally structured evaluation including mission related task elements. Crew station and controller characteristics were thus related to operator needs in a mission context for advanced fighter concepts.

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FOREWORD

This technical report summarizes research performed at McDonnell Aircraft Company (MCAIR), P. O. Box 516, St. Louis, Missouri, 63166, a division of McDonnell Douglas Corporation, under Air Force Contract F33615-74-C-3093, Project 6190, from 1 June 1974 to December 1974. This report consists of three volumes:

Volume I	Program Summary
Volume II	Test Plan
Volume III	Onsite Pilot Evaluations

The contract was initiated under AF Project 6190, "Control-Display for Air Force Aircraft and Aerospace Vehicles," which is managed by Mr. J. H. Kearns, III, as project engineer and principal scientist for the Flight Deck Development Branch (AFFDL/FGR), Flight Control Division, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. The work was performed as a part of Task Number 6190 0326 under the guidance of Mr. J. A. Uphaus, Jr. (AFFDL/FGR) as task engineer.

High Acceleration Cockpit Program activities are conducted within the McDonnell Aircraft Company (MCAIR) Advanced Aircraft Systems Project, under the cognizance of Mr. H. H. Ostroff, Director - Advanced USAF Fighter/Attack Systems. This project is an element of MCAIR Advanced Engineering, directed by Mr. H. D. Altis, Director - Advanced Engineering Division. The High Acceleration Cockpit Project is managed by Mr. J. M. Sinnett, Project Advanced Design Engineer.

The principal contributors to this volume in addition to the authors and for the program elements reported here, are: D. C. Gendreau, Senior Design Engineer; R. E. Mattes, Senior Design Engineer; L. L. Pingel, Senior Design Engineer; and J. W. Roberts, Jr., Technical Specialist, Avionics.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

Symbol	Definition
A	Auditory
A/A	Air-to-Air
A/B	Afterburner
A/C	Aircraft
A/G	Air-to-Ground
AAA	Anti-Aircraft Artillery
AAI	Airborne Air Intercept
ADI	Attitude Direction Indicator
AFCS	Automatic Flight Control System
ANOVA	Analysis of Variance
AP	Avionics Panel
BIT	Built In Test
C	Communication
DFC	Direct Force Control
ECM	Electronic Countermeasure
EEG	Electro-Encephalogram
EO	Electro-Optical
F	Feet
FBW	Fly-by-Wire
G	Acceleration of Gravity
HAC	High Acceleration Cockpit
HPL	Human Performance Laboratory
HSD	Horizontal Situation Display
HUD	Head Up Display
IFF	Identification - Friend or Foe

LIST OF ABBREVIATIONS AND SYMBOLS (Cont'd)

Symbol	Definition
ILS	Instrument Landing System
INS	Inertial Navigation System
IP	Information Processing
L	Left
LGB	Laser Guided Bomb
MDC	McDonnell Douglas Corporation
MSD	Multisensor Display
MVR	Maneuver Limit Control
NAV	Navigation
O	Objective
R	Right
S	Subjective
SAM	Surface-to-Air Missile
sec	Seconds
TDS	Target Designator System
TEWS	Tactical Electronic Warfare System
THR	Throttle
VC	Visual Cockpit
VO	Visual Outside
VT	Visual Target

SECTION I

INTRODUCTION AND SUMMARY

This test plan describes the demonstration and evaluation goals for the High Acceleration Cockpit (HAC) Controller Location Study. The overall objective of this effort was to investigate controller location and mechanization concepts and provide an evaluation by operational pilots in a fighter task environment. This program is an outgrowth of the effort begun under Contract No. F33615-73-C-3067 performed for the Air Force Flight Dynamics Laboratory, References (1) through (4). During the previous effort, the need for additional controller/mechanization refinement was identified. This refinement centers on maintaining adequate pilot/controller access and utility while minimizing the impact of controller mechanization on articulating seat design. The relationship of the test and evaluation phase of the overall program is shown in Volume I of this report.

The current effort draws upon the previous contract in that: (1) an existing design aid is modified to accept the new controller concepts; (2) the mission evaluation profile and required flight functions remain constant; and (3) an existing, proven test plan is modified only to increase the emphasis on controller location and integration specific to this study. The test evaluation and demonstration covers both combat and noncombat modes. Evaluation criteria are applied to assess pilot workload/task items as they relate to control/display configuration, cockpit geometry, external vision envelope, and functions complexity/congestion. The evaluation criteria consider subjective and objective measures such as anthropometric dimensions, task performance time, magnitude of head and eye movements, magnitude of reach movements, and paired comparisons ranking. The design aid developed under the previous contract is used as the baseline for this evaluation. This design aid (see Figure 1) has the capability of being reconfigured efficiently to accommodate the four controller/mechanization concepts selected for this evaluation. The testing is designed to accomplish the following objectives:

- Evaluate physical and performance aspects of the high acceleration cockpit designs and associated controller options

- Provide a measure of pilot acceptance based on fulfillment of mission functional task objectives using the four controller options

- Provide an assessment of high acceleration cockpit influence on anthropometric design (design influence for accommodation of 5th through 95th percentile pilots)

- Determine indices of pilot workload for the configuration alternatives using an objective pilot simulation model.

This test plan encompasses subjective and objective goals, criteria, test design approach, data analyses, subject requirements, test schedule and duration, and facility for each mission phase. Results of this testing are presented in Volume I of this report.

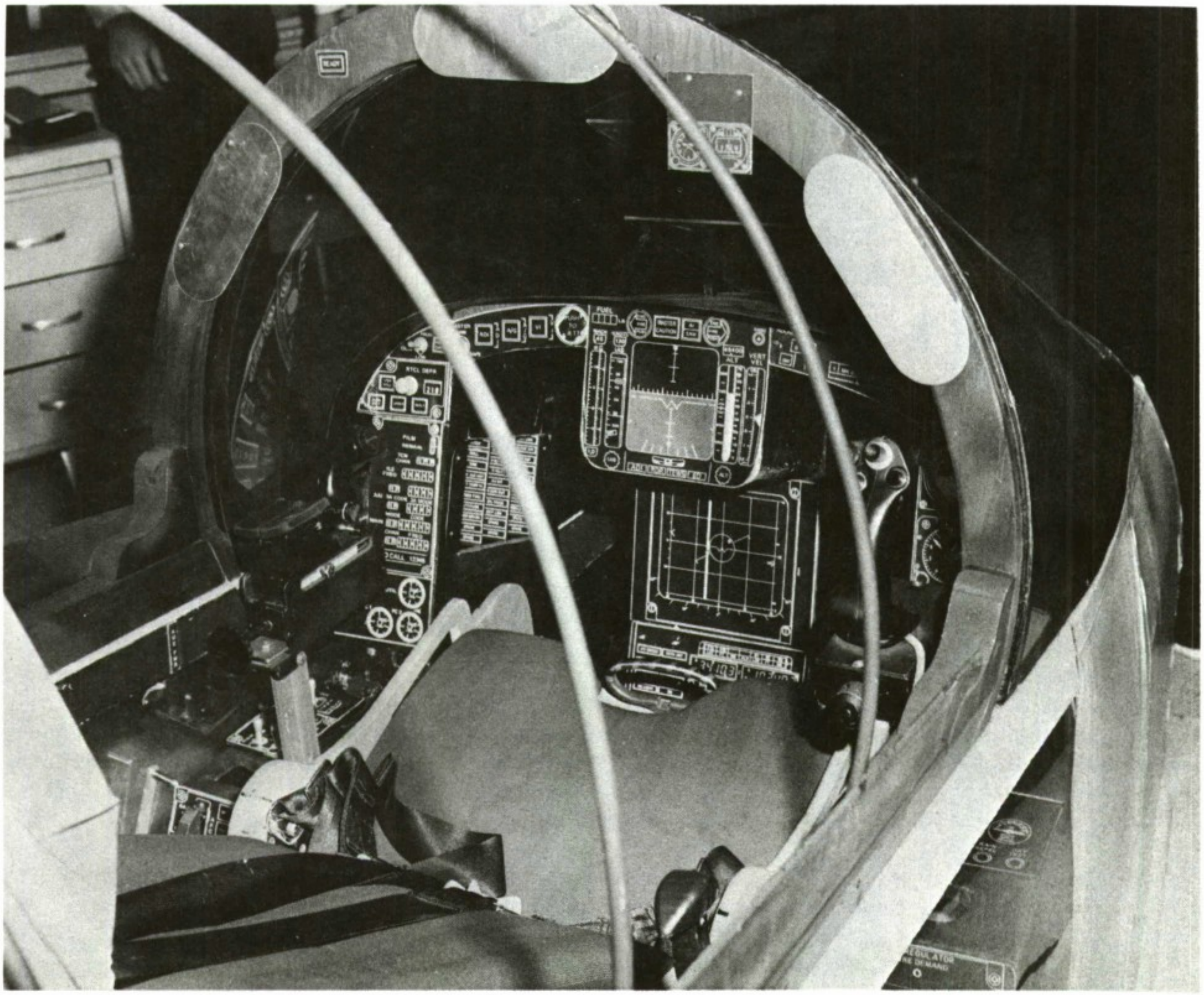

FIGURE 1
HIGH ACCELERATION COCKPIT DESIGN AID

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SECTION II

IDENTIFICATION AND SELECTION OF TASKS FOR ANALYSIS

Combat and normal flight task analysis data are used as an aid in establishing the order of priority for the test and evaluation of pilot tasks. These workload requirements relate to the mission scenario established in Reference (1). This mission profile is displayed in a total sense in Figure 2, including a takeoff, target area descent and an in-flight refueling prior to the return leg and landing. Figure 3 illustrates the combat phases. Throughout the mission two aircraft are used in complementary roles to provide a rationale for a single operator performance and reasonable aircraft size to accomplish the various combat elements. The mission tasks normally associated with communication between airplanes are replaced by the test conductor's narrative. While it is recognized that the principal advantage for use of elevated load factor in combat is in the air-to-air phase, air-to-ground elements have been included to verify cockpit adequacy for multi-role use without preempting modest air-to-ground capability. Mission combat elements include AAA penetration and SAM evasion, air-to-ground weapons delivery (bomb, strafing) and an air combat engagement. The combat phase is completed by a flight join-up and aerial refueling prior to base return. Conventional penetration evasion and weapons delivery tactics were used for a combat evaluation, with minor modifications to utilize effectively the fighter direct lift, direct side force and advanced maneuverability capabilities. Direct force capabilities are used for wings level altitude or heading changes in jinking, for offset and slant range tracking corrections and for variable fuselage elevation. Higher normal accelerations are considered as an increase in G level to improve SAM evasion, provide a steeper dive angle to minimize time over target, and provide a shorter turn option for earlier missile and gun solution in air combat.

PILOT WORKLOAD DATA DECK

The pilot tasks are broken down by mission segment. Sequential pilot task listings, required equipment, and pilot sensory mode required for task execution are included for each segment. Test evaluation elements are also defined and subjective/objective tasks identified.

Task listings for the combat phases and their associated logic sequence profiles can be used in the Pilot Simulation Model for digital pilot workload analysis. This model provides the air combat time line. Through model iterations, different cockpit configurations can be evaluated in terms of pilot workload. It is anticipated that the model results will enable a direct correlation to the demonstration/evaluation results, and enable a quantified performance ranking of concepts tested.

In order to provide for more flexibility in analysis of the task listings, each task has been punched on a computer card along with its associated data. The coding key is as follows:

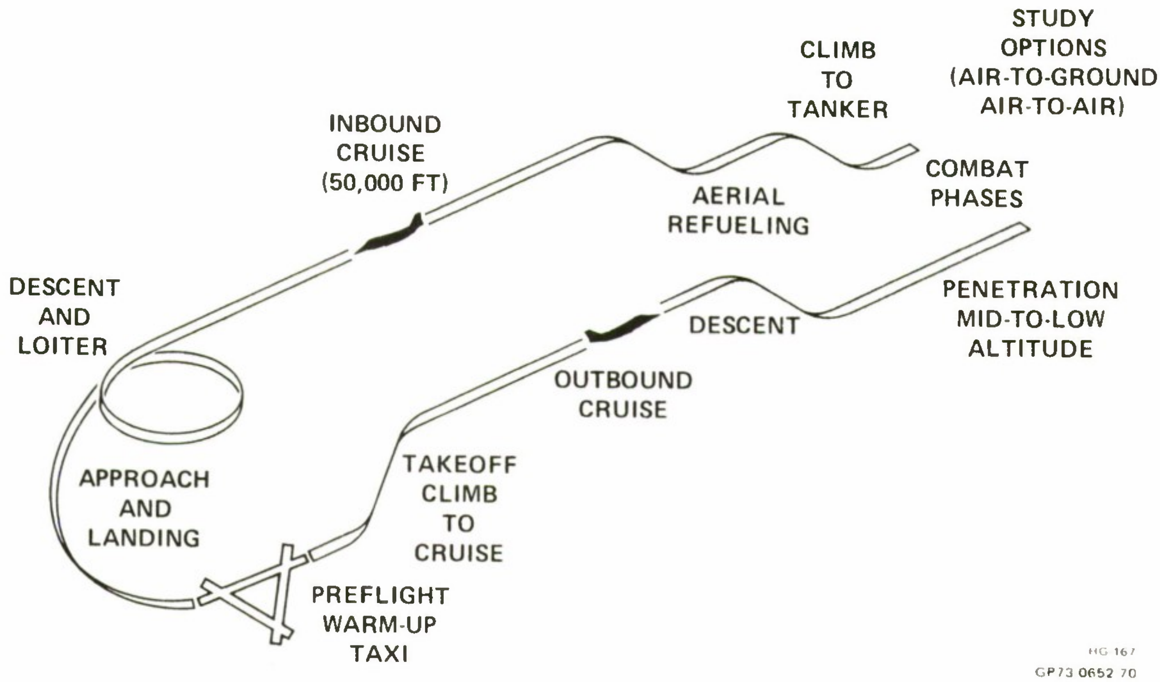

FIGURE 2
FIGHTER MISSION EVALUATION PROFILE

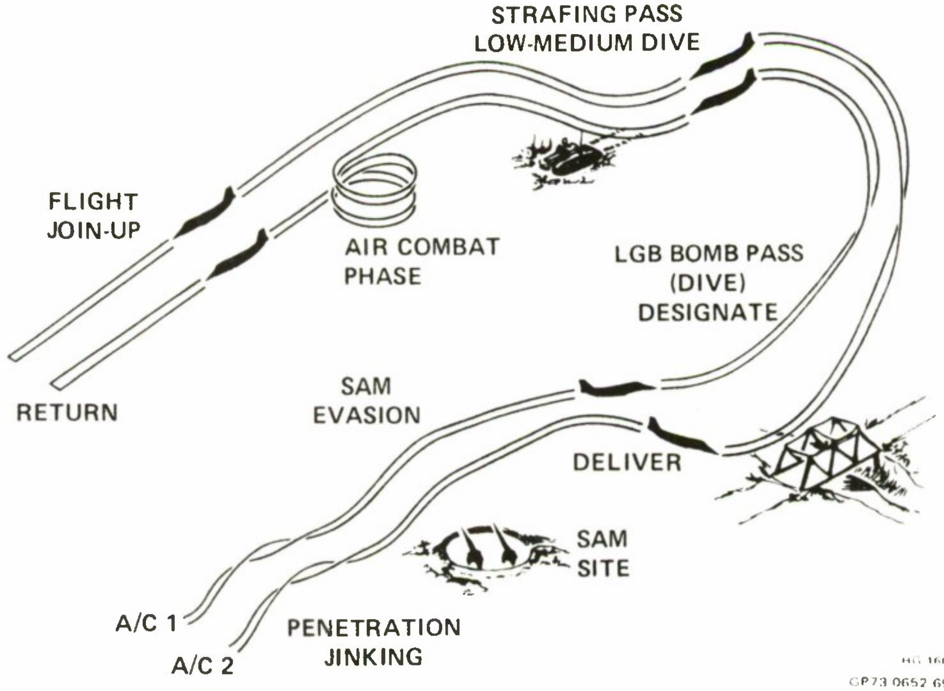

FIGURE 3
COMBAT EVALUATION PROFILE

Columns	Function	Input
1-3	Pilot Task Number	1-999
5-46	Pilot Task Title	
48-50	Sensorimotor/Information Processing Task Element Requirement	A-Auditory C-Communications F-Feet IP-Information Processing L-Left Hand R-Right Hand VC-Visual Cockpit VO-Visual Outside VT-Visual Target
52-54	Equipment Identification	1-999
57	Subjective/Objective Test	S, Ø
59-66	Independent Variables	
69-76	Dependent Variables	
79-80	Test Equipment	

Each pilot task is uniquely identified by a numerical call (not necessarily) sequential) and title. The pilot task element loads, defined as those task loads which contribute to total pilot workload (notably visual, information processing or mental functioning, right hand, left hand, feet, and communication task elements) are established. The visual workload includes internal cockpit scan, outside scan, and target tracking requirements. Eye movement and head positioning are determined by equipment location and relative position of the target in the air-to-air engagements used. Actual cockpit equipment data are also tabulated and equipment identification numbers assigned. Equipment numbers are not necessarily at the same system level of description (e.g., 17 represents the throttle controls and 25 represents speed brake switch which may be located on a throttle control).

The remainder of the data deck (columns 57-80) defines the static design aid test evaluation parameters. Each task is identified as a subjective or objective test evaluation task. The independent/dependent variables and test equipment associated with each pilot task are also listed. These test variables are provided in Section III of this test plan. A sample of a pilot workload printout is illustrated in Figure 4.

COLUMN

0 10 20 30 40 50 60

1	CRUISE (CHECKOUT AND INS UPDATED)	IP	0	S
2	ENGAGE AFCS PILOT RELIEF MODES	VCL	33	O
3	CHECK FBW CAUTION	VC	33	S
4	MONITOR ROLL (+-60 DEG)	VC	49	S
5	MONITOR PITCH (+-45 DEG)	VC	49	S
6	ACTIVATE FBW ATT HOLD	VCL	33	O
7	POSITION FLIGHT CONTROLLER (1 LB FORCE)	R	83	S
8	SENSE ATTITUDE HOLD DISENGAGE	IP	0	S
9	RELEASE MANUAL PRESSURE ON CONTROLLER	R	83	S
10	ACTIVATE FBW VEL VEC HOLD	VCL	33	O
11	POSITION CONTROLLER (3.5 LBS LONGITUDINAL)	R	83	S
12	MONITOR ALTITUDE	VC	52	S
13	RELEASE MANUAL PRESSURE ON CONTROLLER	R	83	S
14	MONITOR FBW STATUS	VC	33	S
15	MONITOR KIAS (AS REQUIRED)	VC	51	S
16	MONITOR MASTER CAUTION (AS REQUIRED)	VC	43	S
17	MONITOR ALTITUDE (AS REQUIRED)	VC	52	S
18	MONITOR HEADING AND RANGE (AS REQUIRED)	VC	53	S
19	MONITOR ATTITUDE (AS REQUIRED)	VC	49	S
20	MONITOR FLY-TO-POINT (AS REQUIRED)	VC	53	S
21	MONITOR THREAT DISPLAY (AS REQUIRED)	VC	53	S
22	MONITOR VERTICAL VELOCITY INDICATION (ASR)	VC	48	S
23	DISENGAGE AUTOPILOT (AS REQUIRED)	R	83	O
24	DISENGAGE FBW VEL VEC HOLD	VCL	33	O
25	CONTROL NEW ALTITUDE (AS REQUIRED)	VCR	83	S
26	ENGAGE FBW VEL VEC (AS REQUIRED)	VCL	33	O
27	DISENGAGE FBW ATTITUDE (AS REQUIRED)	VCL	33	O
28	CONTROL NEW ATTITUDE (AS REQUIRED)	VCR	83	S
29	ENGAGE FBW ATTITUDE (AS REQUIRED)	VCL	33	O
30	OPERATE INS	IP	57	S
31	DEPRESS (STEER) FIRST PLANNED CHECKPOINT	VCR	57	O
32	SELECT STEERING MODE (NAV)	VCR	57	O
33	ACTIVATE MASTER MODE (ADI)	VCR	49	O
34	OBSERVE ADI FORMAT WITH BANK STEERING BAR	VC	49	S
35	OBSERVE POINTER AT DESTINATION BEARING	VC	53	S
36	OBSERVE MILES DISTANCE	VC	53	S
37	OBSERVE HEADING MARKER ON DESTINATION	VC	53	S

FIGURE 4
SAMPLE PILOT WORKLOAD DATA DECK PRINTOUT

PILOT WORKLOAD SUMMARY

The pilot task analysis data deck includes task element requirements for each mission scenario segment. Table 1 depicts the summary of present pilot workload requirements and the test evaluation subjective/objective balance, including two classes of emergency (ejection and seat stuck in the reclined position) in addition to the mission phases. The equipment used for all the mission segments, both normal flight and combat, is provided in the data deck and corresponds directly to that required for full mission accomplishment (see Section III).

TABLE 1
PILOT WORKLOAD SUMMARY

MISSION ELEMENTS	NUMBER REQUIRED		TEST EVALUATION BALANCE			
			SUBJECTIVE		OBJECTIVE	
	PILOT TASKS	EQUIP	NO.	%	NO.	%
1. Preflight	469	65	200	42.6	269	57.4
2. Instrument Takeoff	94	34	65	69.1	29	30.9
3. Cruise	185	34	87	47.0	98	53.0
4. SAM Evasion	35	15	13	37.1	22	62.9
5. LGB Strike	97	29	53	54.6	44	45.4
6. Strafing Attack	55	28	17	30.9	38	69.1
7. Air-to-Air Combat	67	34	31	46.3	36	53.7
8. Inflight Refueling	76	20	20	26.3	56	73.7
9. Approach/Landing	158	27	80	50.6	78	49.4
10. Post Flight	38	21	11	28.9	27	71.1
11. Emergency						
A. Ejection	26	7	8	30.8	18	69.2
B. Seat in Recl Pos	8	3	3	37.5	5	62.5
TOTALS	1308	94*	588	45.0	720	55.0

*Several equipments are used in more than one mission phase

The equipment list considers the following major avionics subsystems:

- Communications and Identification
- Air Data System
- Flight Control System
- Sensor Units (Radar and EO/Laser Search and Track Set)
- Mission Computer
- Navigation
- Tactical Electronic Warfare System
- Flight and Engine Instruments
- Warning and Caution, Lighting, and Built-In Test
- Weapons Delivery.

SECTION III

TEST VARIABLES

Physical testing includes use of a high acceleration cockpit concept design aid, illustrated in Figure 5. This design aid is constructed primarily of plywood and is segmented into four lightweight sections. Each segment is mounted on a platform base to facilitate independent console work. The canopy lines are simulated with aluminum tubing for definition of the physical envelope constraints.

The basic HAC test concepts emphasize cockpit/seat/flight and throttle controller integration with preservation of ejection clearances. Primary emphasis was placed on internal (display) and external visual capability, control location and utility, anthropometry and ejection capability. The primary controls and display philosophy was to provide optimum head-up operation during close-in combat. This head-up capability was enhanced by the following significant features:

- o Attack mode and weapon are selected by a control on throttle
- o Attack displays for the selected weapon are automatically provided on the Head-Up Display (HUD)
- o While tracking the target on HUD, the pilot can command radar and missile seeker acquisition by depressing switches on the flight control stick.

The number and frequency of pilot tasks during the attack phases lead to this design approach as an excellent solution to provide full pilot capability while avoiding task overlap.

In the noncombat mode, the cockpit design approach was to reduce the number of pilot tasks for normal flying operations. Pilot workload was eased by the following features considered included in the airframe subsystems:

- o Automatic fuel transfer and tank sequencing to eliminate switching and selective feed if required to maintain a balanced state
- o Multiple fuel quantity indications, fuel level low, and Bingo fuel warning
- o Rapid engine ignition for ground and air starting
- o Environmental control system with automatic temperature control and continuous windshield anti-fogging
- o Balanced cockpit lighting with control flexibility
- o Master Caution Light and TEWS warning lights located at the center of the primary field-of-view
- o Built-in-test monitoring.

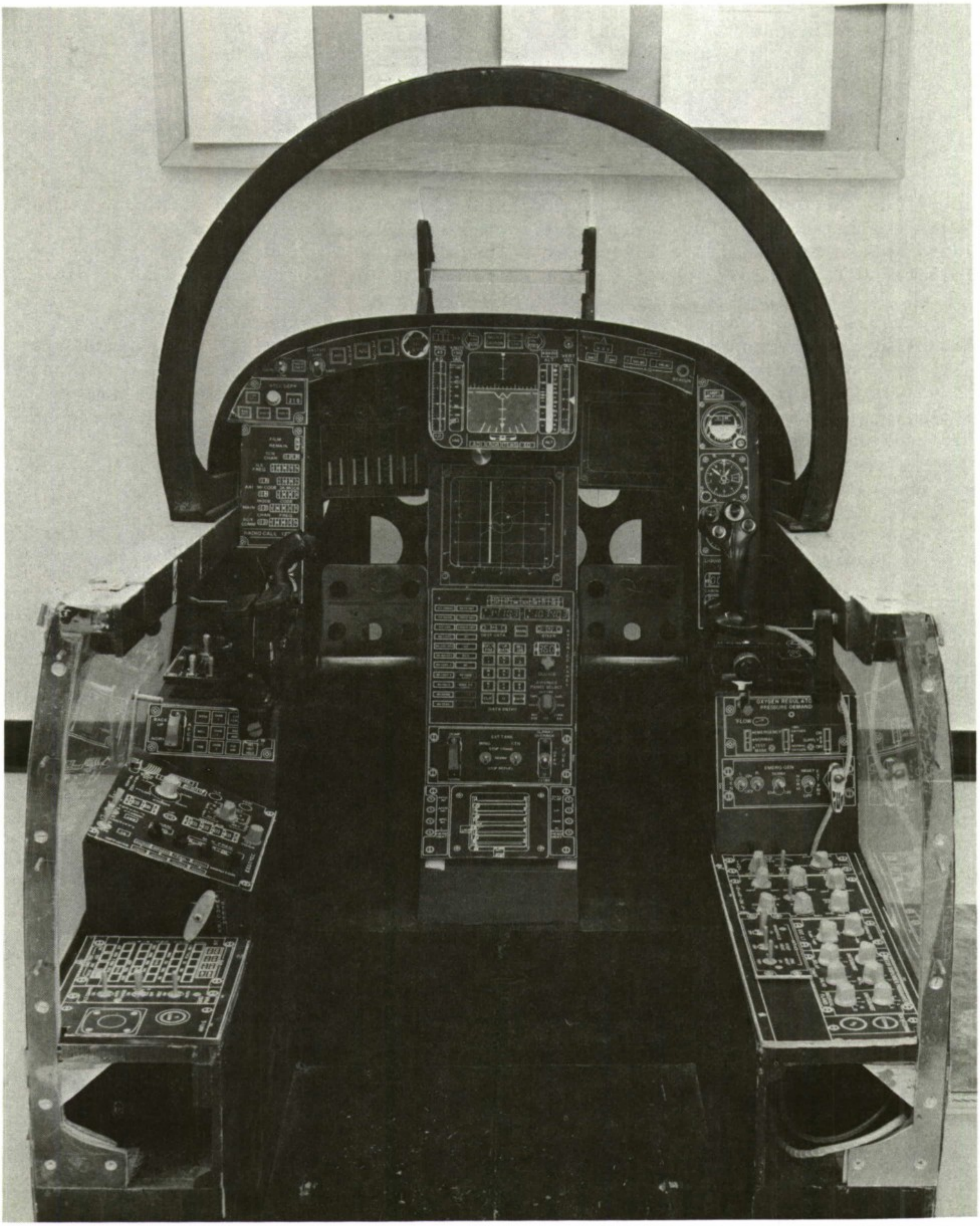

FIGURE 5
DESIGN AID ASSEMBLY

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The major determining factor for high acceleration cockpit designs is the vision from the reclined position. To maximize direct viewing, the pilot's eye must be kept high. In no case is it deemed a requirement to improve the pilot's physical visual field-of-view in the reclined position beyond that which is available when seated upright. Physiological visual field-of-view improvement at elevated load factors is a matter of record.

INDEPENDENT TEST VARIABLES

This test phase covers the evaluation of the controller mechanization concepts for potential use in an advanced maneuverability fighter design. The seat mechanization provides for a reclining angle of 65° under a high acceleration condition, while maintaining 15° over the nose vision. The "upright position" back angle is 20°. Rudder pedal accessibility is retained in the G-protected position. Ejection is from the "upright" position.

The shoulder pivot seat concept developed during the previous effort, Reference (1), is used for this evaluation. By installing the seat pivot at the shoulder, the location of the design eye and shoulder may be retained throughout the complete range of back angles. Since the headrest does not traverse aft during articulation, the seat structure is reclined independent of the seat ejection provisions (rails, rocket, and parachutes). This permits simplified seat mounting while reducing the total weight which must be articulated. The headrest remains fixed, thereby allowing cockpit visual design setup from either normal flight or combat modes. Relaxed normal flight head position is slightly forward of the design eye, while the head is kept to the headrest when reclined. For this seat concept, the headrest angle of 20° provides comfortable head support position (135° included angle relative to the seat back) when reclined.

Evaluation of four controller-throttle locations is the object of this test plan. The previous HAC study has revealed a need to perform additional research in the area of developing a controller-throttle configuration that is compatible with the reclining seat concept while minimizing the impact on seat design. In the previous effort, a fixed, console mounted concept was evaluated which provided minimum impact on seat design. This concept, however, proved to have drawbacks in the areas of pilot utility and pilot/controller orientation in the reclined position. An over-the-lap configuration was also evaluated which provided excellent pilot access and orientation. Since this configuration was attached to the seat, it was considered desirable to assess console or instrument panel mounted concepts which provided minimum impact on seat design while maintaining acceptable pilot access and orientation. One of the goals of this test plan, therefore, is to perform comparative testing of the previous concepts and the two new controller-throttle configuration concepts developed in this effort.

A total of seven controller/mechanization concepts were evaluated in arriving at the two selected configurations, reference Volume I of this report. The design criteria applied to the selection of test candidates were based on a pooled ordering of the following parameters: (1) visual blockage, (2) reach constraint, (3) panel area loss, (4) mechanization complexity, (5) pilot/controller orientation, (6) ejection interface, (7) durability/maintainability, (8) general applicability, and (9) tendency toward blood pooling in the arms and hands. This ordering approach provided a means for assigning a weighting value for each parameter in accordance with its assessed importance.

The selected test configurations (A, B, D, and E) are depicted in Table 2. The alternative locations of the flight and throttle controllers relative to the ejection seat and the side consoles are shown in Figures 6 and 7. Two types of flight and throttle controllers will be evaluated as noted in Table 2. The baseline designs correspond to those previously evaluated. The integrated flight controller and canted throttle are designed to reduce grip width facilitating the mounting location of configuration D. Configurations C, F, and G were dropped from the demonstration and evaluation phase.

Controller Locations

The four controller/throttle locations evaluated under this test plan are:

Configuration A - Fixed Console Mounted - This configuration was evaluated in the previous contract, Reference (3). The grips are located below the sills with fore-and-aft adjustment capability. The grip location is shown in Figure 8 in both the full forward position and full aft position corresponding to the reach capabilities of 95th and 5th percentile pilots, respectively.

TABLE 2
SEAT/CONTROLLER TEST CONFIGURATIONS

Test Configuration	Controller Locations	Flight Controller Type	Throttle Type	Control/Display Configurations
A	Fixed on Console	Baseline or Integrated	Baseline or Canted	I
B	Overlap on Seat	Baseline or Integrated	Baseline or Canted	II
D	Instrument Panel Mounted	Integrated	Canted	III
E	Longitudinal Console Mounted	Baseline or Integrated	Baseline or Canted	III

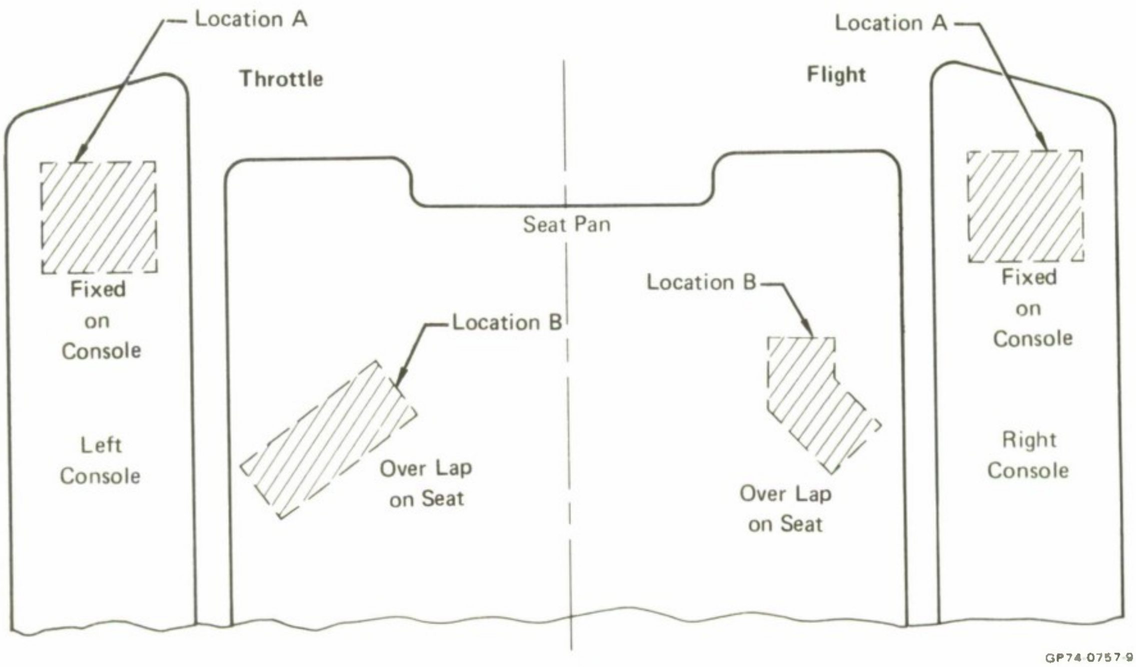

FIGURE 6
CONTROLLER LOCATIONS A AND B

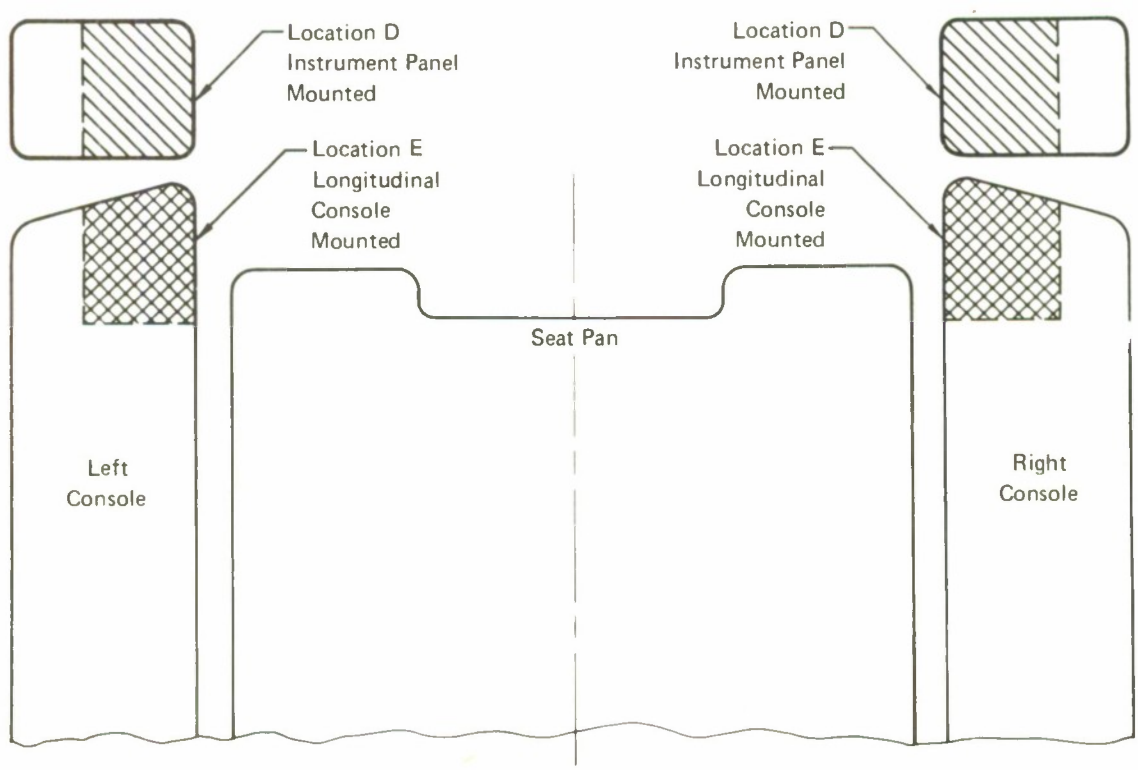

FIGURE 7
CONTROLLER LOCATIONS D AND E

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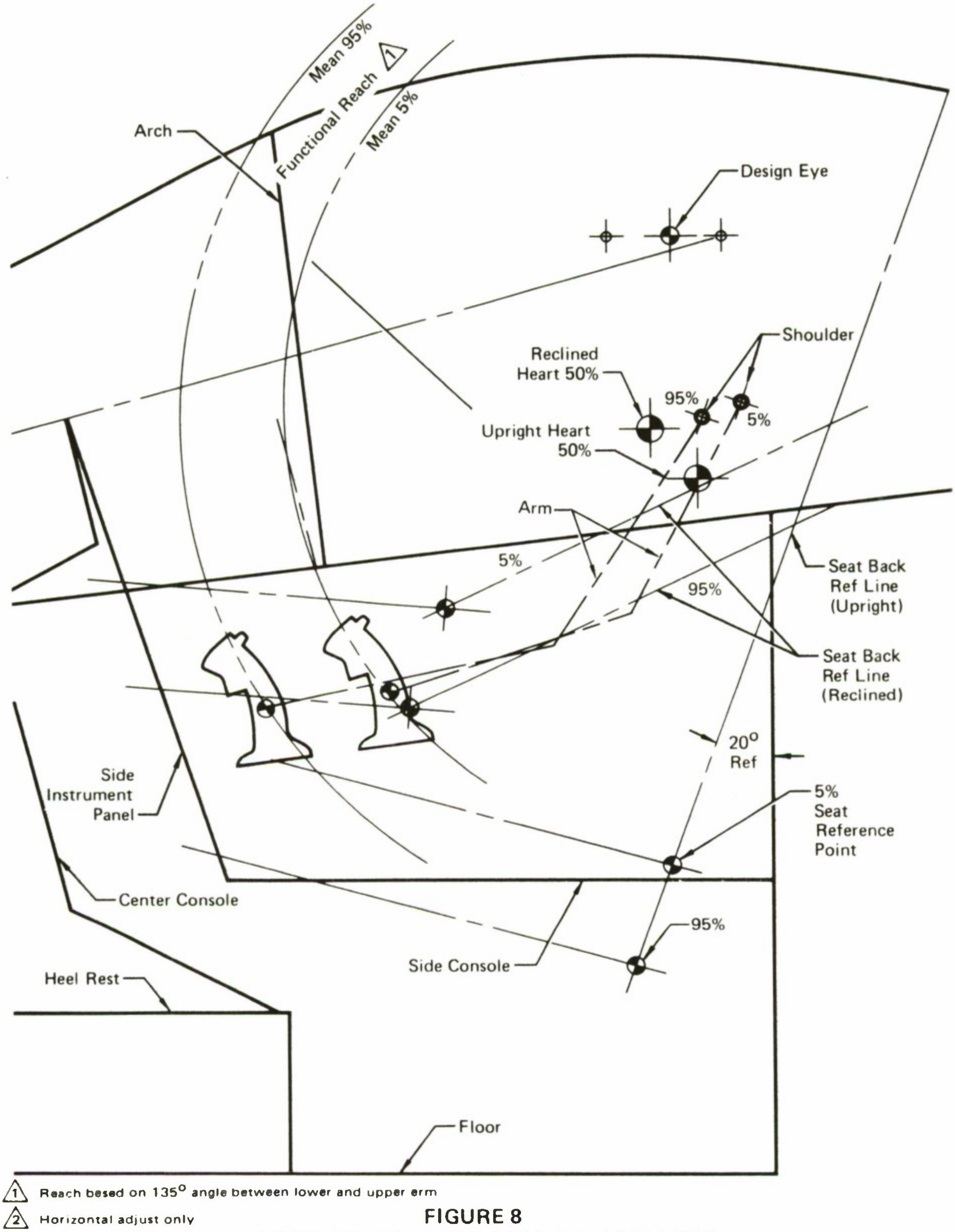


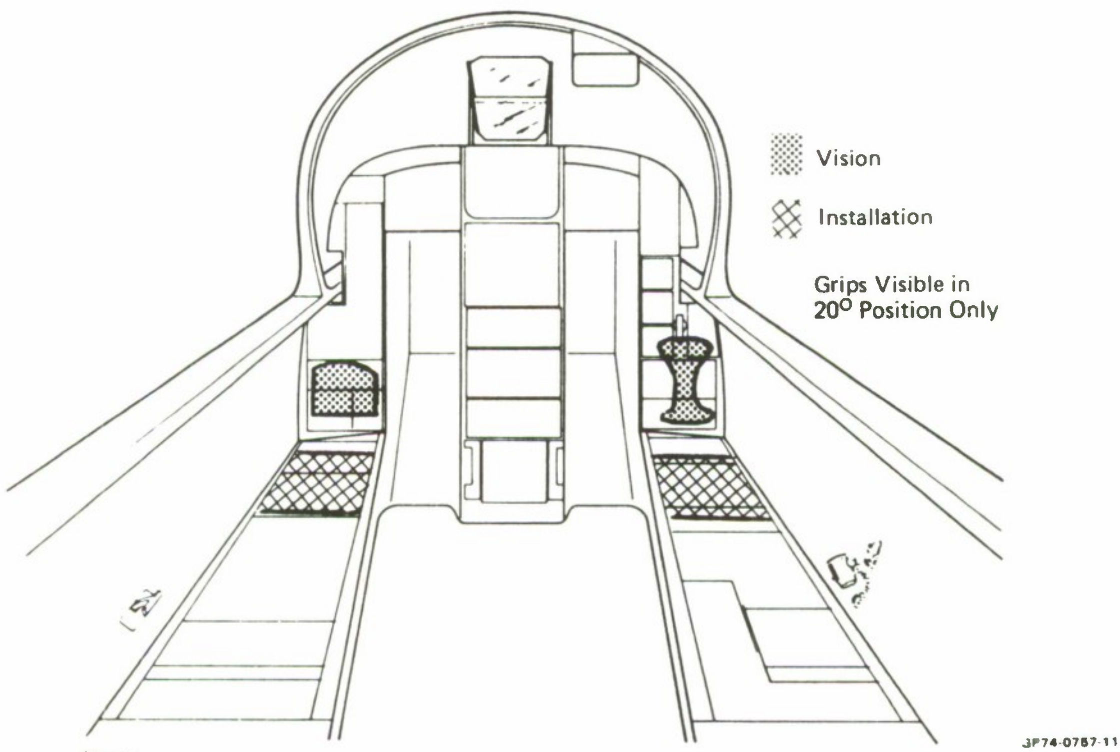
FIGURE 8
FIXED CONSOLE MOUNTED CONTROLLERS
Configuration A

This profile drawing is used to illustrate the grip positions for the configuration to be evaluated. Reach envelopes for 5th and 95th percentile pilots are shown, based on maintaining an angle of 120° to 150° between the forearm and biceps. Per MIL-STD-1472B (Proposed), these angles represent near maximum arm force extertion capability and may, therefore, correspond to minimum pilot effort and fatigue. The limits of adjustment for Configuration A correspond to an included arm angle of 135° for the extremes of pilot arm length. The position of the heart (in both seat positions) is also identified in this profile view to assess any tendency toward blood pooling in the arms.

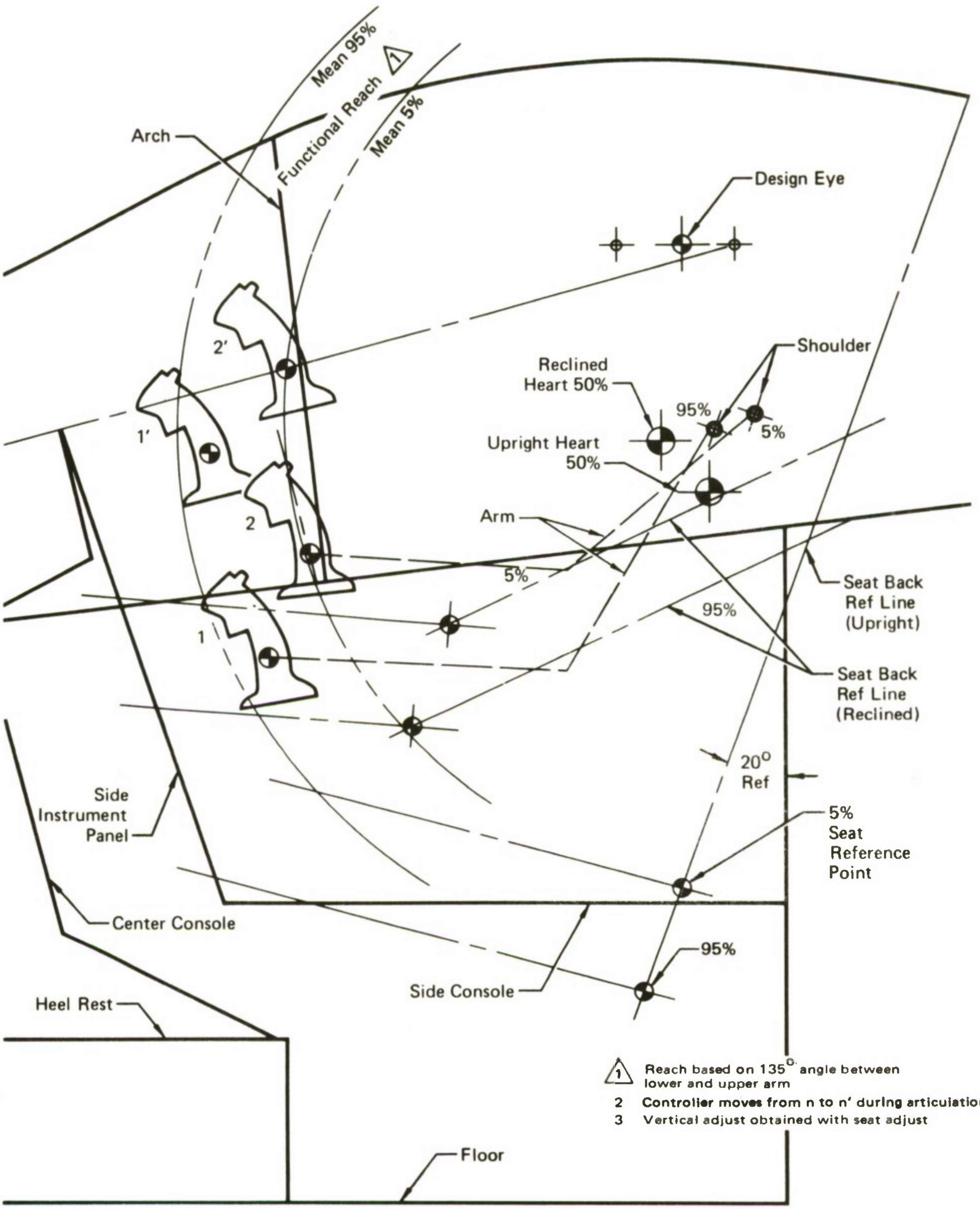
This under-the-sill grip location is illustrated in Figure 9. The figure represents a pilot's view of the controller grips neglecting visual restrictions for the seat/man combination. This factor is essentially constant for all configurations and, therefore, need not enter into a comparison of concepts. The approximate console space required for controller installation is also shown in Figure 9.

Configuration B - Over The Lap - Seat Mounted - This configuration was also previously evaluated, Reference (3). The grips are mounted on an arm rest with the controller pivoted over the lap of the pilot. The pivot point is attached to a four-bar linkage which maintains a near constant clearance between the arm rest and seat pan during articulation as shown in Figure 10. The arms are supported

FIGURE 9
FIXED CONSOLE MOUNTED CONTROLLER
VISION/INSTALLATION
Configuration A



Notes:
1. Horizontal Adjust
2. Fixed During Articulation



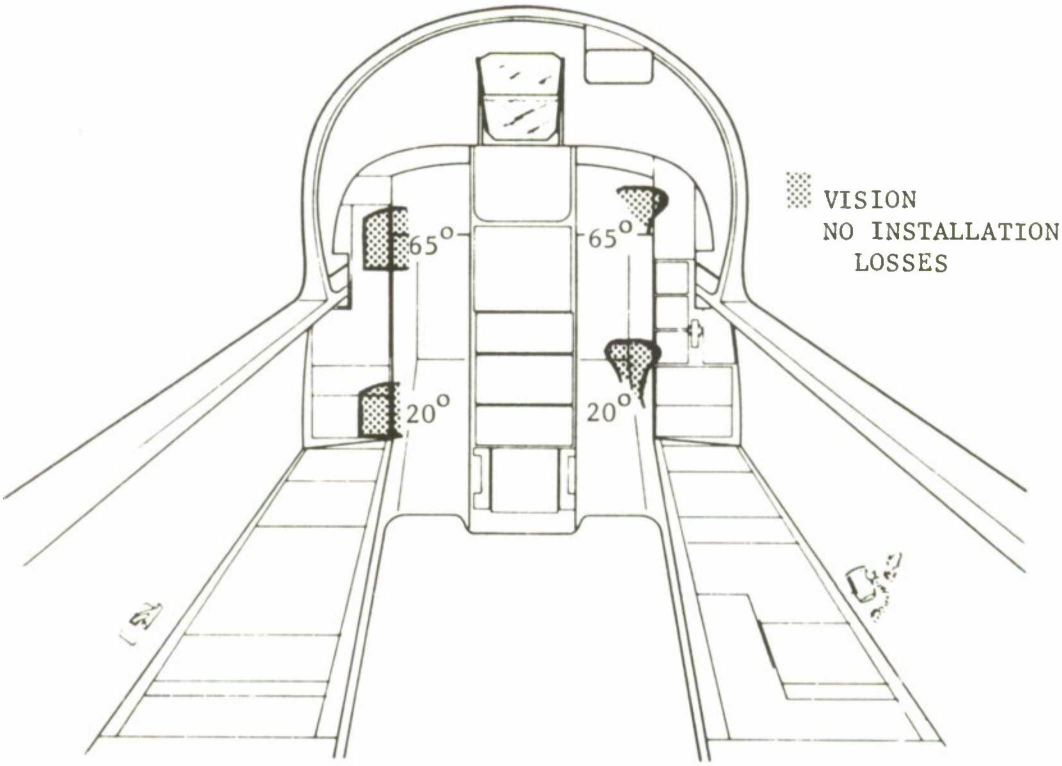
1 Reach based on 135° angle between lower and upper arm
2 Controller moves from n to n' during articulation
3 Vertical adjust obtained with seat adjust

FIGURE 10
SEAT MOUNTED CONTROLLERS
Configuration B

GP74-0757 15

in a near natural position. The mechanism is driven by the seat and does not require additional actuation to synchronize the controllers with respect to the seat. The controllers are mounted over the lap of the pilot and must be pivoted to the sides prior to seat/man separation. This rotation would occur in the initial stages of the ejection sequence.

Grip location for both upright and reclined positions from the pilot's viewpoint is shown in Figure 11. Since the controller mounting mechanization is attached to the seat, no console or panel space is required for installation.



Notes: 1. Vertical Adjust With Seat

FIGURE 11
OVER THE LAP SEAT MOUNTED CONTROLLER
VISION/INSTALLATION
Configuration B

Configuration D - Instrument Panel Mounted with Vertical Adjust - By locating the controllers near the sill line and providing both longitudinal and vertical adjustment, the pilot/aircraft orientation can be improved relative to Configuration A. The location/adjustment envelope, shown in Figure 12, can encompass the extremes of a 95th or 5th percentile pilot (sitting height) with 5th or 95th percentile arms, respectively, while maintaining recommended forearm/biceps angles. Since this configuration does not move during articulation, the pilot's view of the grips shown in Figure 13 is the same for both upright and reclined seat positions. This configuration also simulates mounting the grips on a fixed seat bucket with an articulating liner.

Configuration E - Console Mounted - Vertical Travel - Longitudinal - This configuration provides essentially the same pilot/controller orientation in a vertical sense as Configuration B (over the lap - seat mounted). The primary difference is in the mounting and drive mechanization and the location of the grips external to the seat envelope. For Configuration E the grips are mounted on vertical actuators which must be synchronized with the seat during articulation. The adjustment range is sufficient to encompass the 5th to 95th percentile pilot range. Grip location with respect to seat position is shown in Figure 14.

The pilot's view of the controllers and installation space is shown in Figure 15. No controller motion is required during ejection since the grips are external to the ejection envelope.

Controllers

Two different (baseline and integrated) flight and throttle controllers are evaluated in conjunction with evaluating the controller locations. The flight and throttle controllers developed during the Reference (1) study are employed as a baseline for comparisons with the new configurations. The grips are fitted with active switches (force and displacement) to enable evaluation of switch placement in terms of access and ease of operation.

Flight Controllers - The flight controller developed during the previous study is shown in Figure 16. This controller incorporates provisions for the basic flight control functions (pitch and roll) through force applied to the grip or small angular displacements. Additionally, the following functions are incorporated to provide accessibility and to reduce work load during critical mission phases. Direct lift and side force controls are incorporated in a cupped, isometric thumb control button directly in line with the grip centerline. In-flight trim and manual fuselage aiming are located in an arc scribed by the thumb along the top of the grip. Fuselage aiming enables pointing the fuselage at a selected target independent of the flight path of the aircraft. Weapons release and automatic fuselage aim functions are located immediately below this arc. The gun trigger is positioned in the normal forefinger location. This trigger has two detents. The first activates the HUD camera and the second initiates gun firing. The HUD camera is also activated upon depression of the weapons release button. A nose gear steering/automatic acquisition mode dual function push button is located on the lower portion of the grip and is activated by the little finger. When weight is on the wheels, this button provides a nose gear steering mode of $\pm 45°$. After gear retraction this push button operates as an automatic radar acquisition selector and as an air refuel disengage control. A two-position switch is provided on the right side for seat control. This control is located on the grip to allow pilot

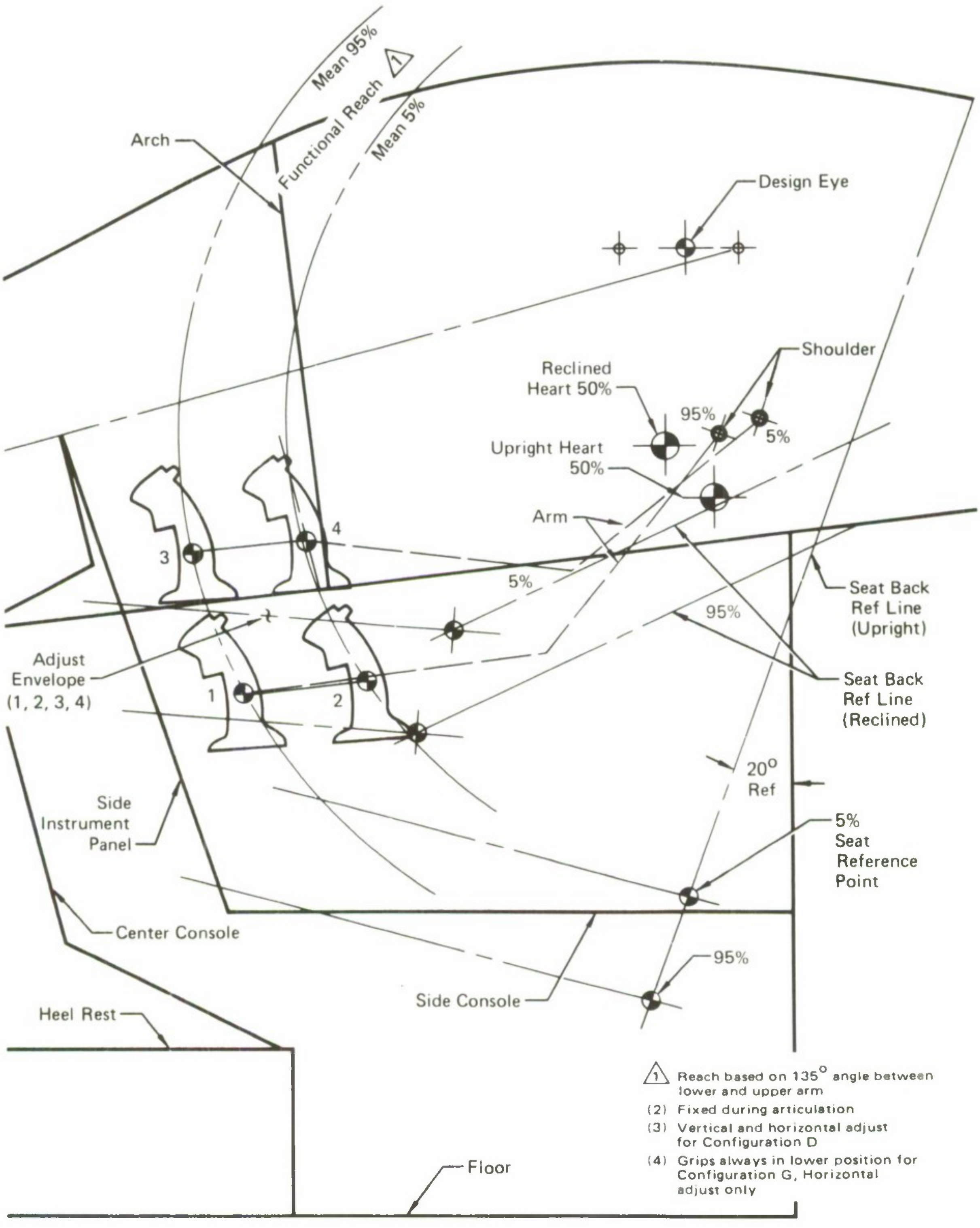
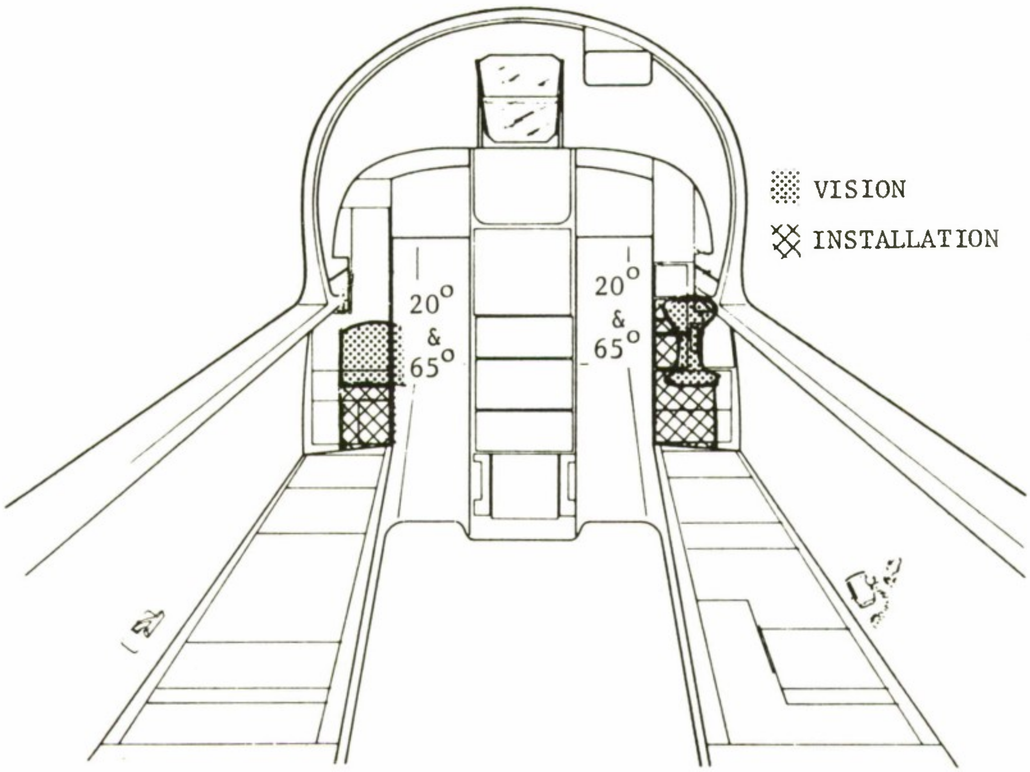


FIGURE 12
INSTRUMENT PANEL MOUNTED CONTROLLERS
Configuration D

GP74 0757 16



Notes: 1. Fixed During Articulation

FIGURE 13
INSTRUMENT PANEL MOUNTED CONTROLLER-VERTICAL AND HORIZONTAL ADJUST VISION/INSTALLATION
Configuration D

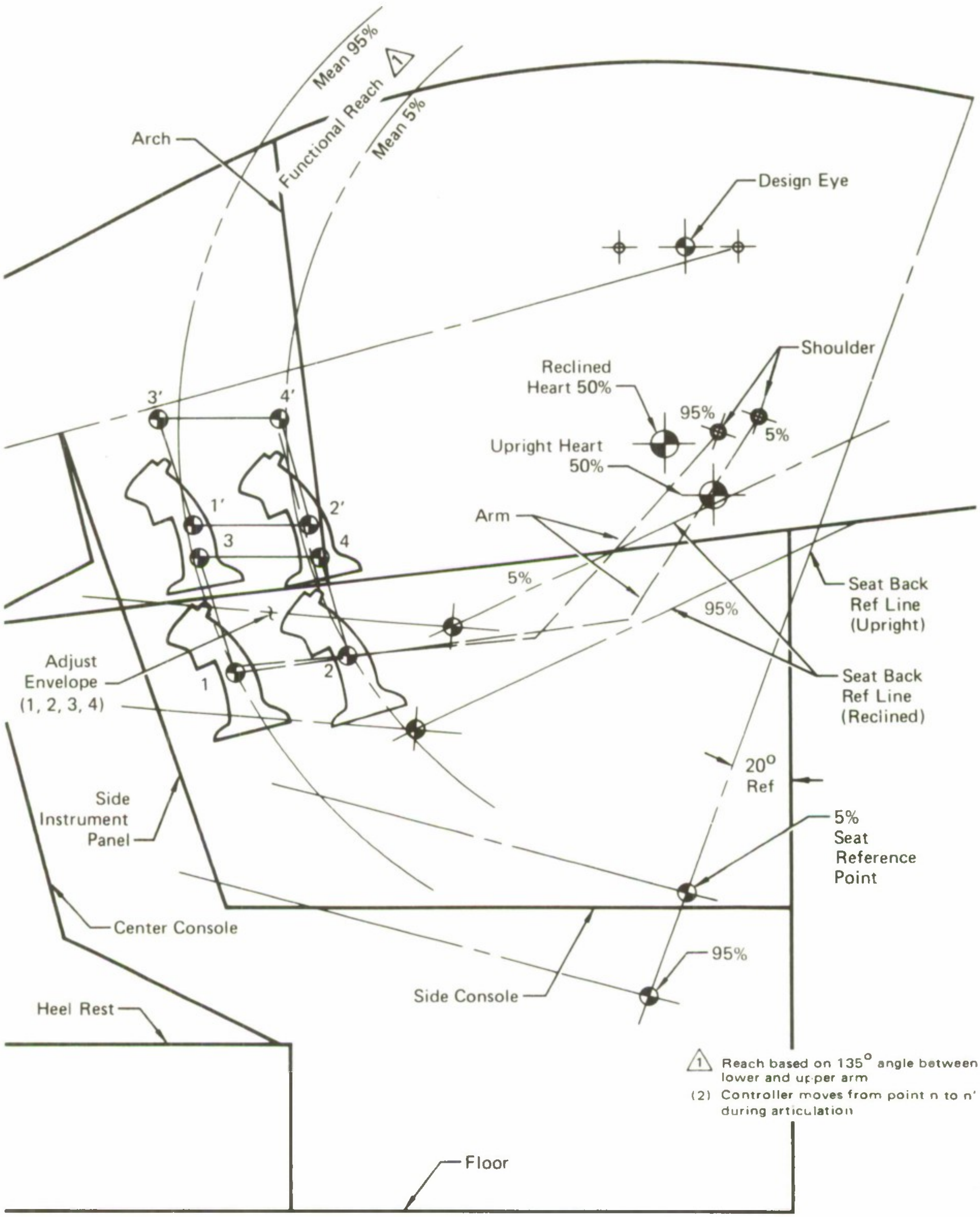
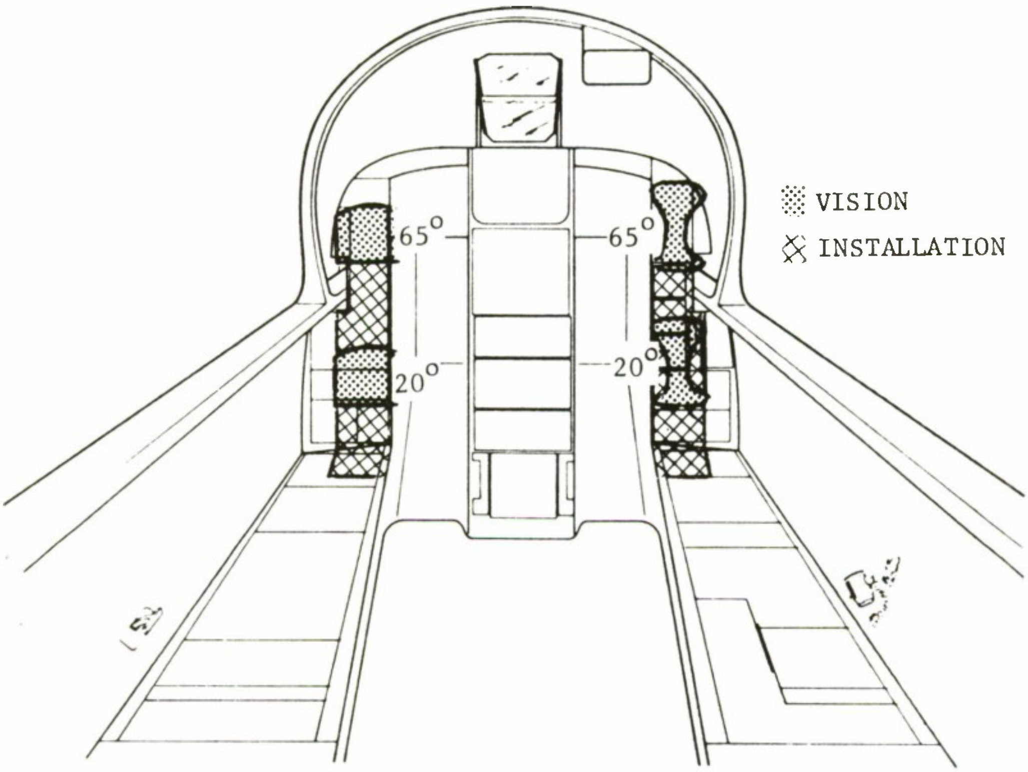


FIGURE 14
CONSOLE MOUNTED CONTROLLERS
Configuration E

GP74 0757 1?

FIGURE 15
CONSOLE MOUNTED CONTROLLER-LONGITUDINAL VISION/INSTALLATION
Configuration E



Notes: 1. Vertical and Horizontal Adjust
2. Vertical Travel During Articulation

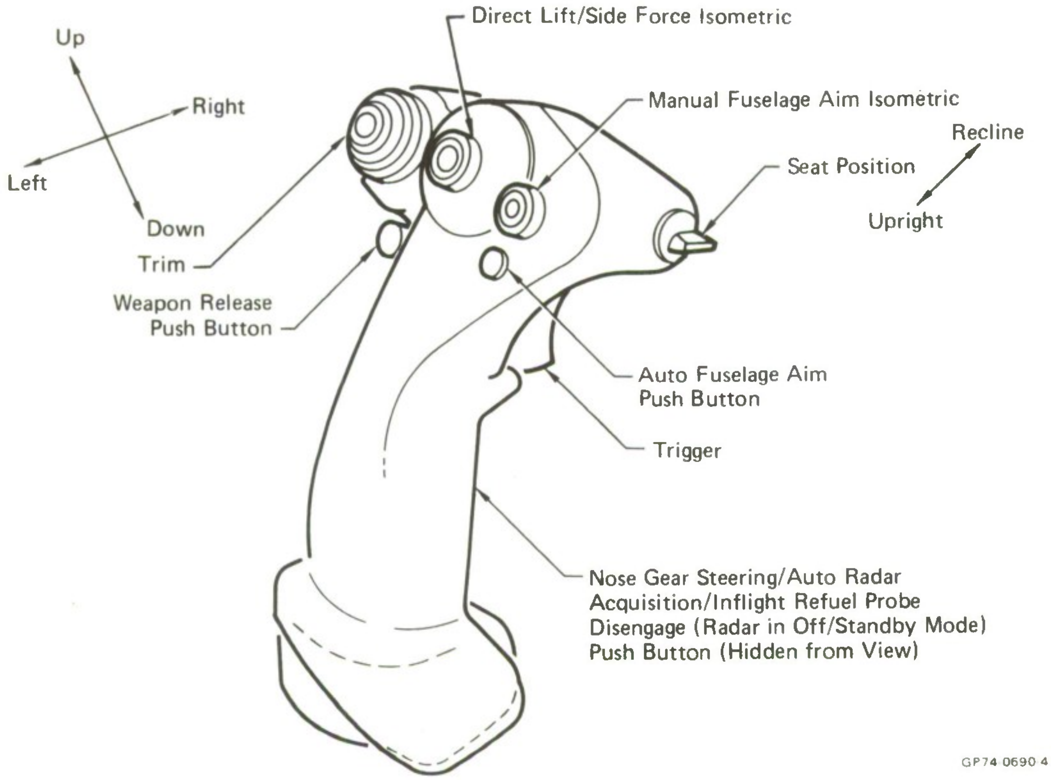


FIGURE 16
FLIGHT CONTROLLER FUNCTIONS
Baseline Design

access synchronous with G command and also provide immediate access while the seat is reclined in the event of an emergency situation. This grip design is compatible with controller Locations A, B, and E.

For Configuration D, where the grip is located between the seat sides and aircraft sill, the flight controller was redesigned as shown in Figure 17, permitting retention of a 26" sill width. The redesign primarily centered on reducing the maximum width,thereby providing sufficient knuckle/seat/sill clearance. Removal of the discrete trim control and integration of this function and the fuselage aiming mode function with the isometric thumb controller are the primary design changes. These changes reduced the overall grip width by approximately 3/4 of an inch. Because of the multi-mode isometric,a visual cue on the HUD would be provided to indicate the current operating mode. The pilots are exposed to both designs and comments obtained relative to pilot preference and operational aspects.

Throttle Controllers - The throttle grip developed during the previous study is shown in Figure 18. By maintaining the throttle motion in a waterline plane, the throttles can be moved by pilot force inputs under both high and low G loading.

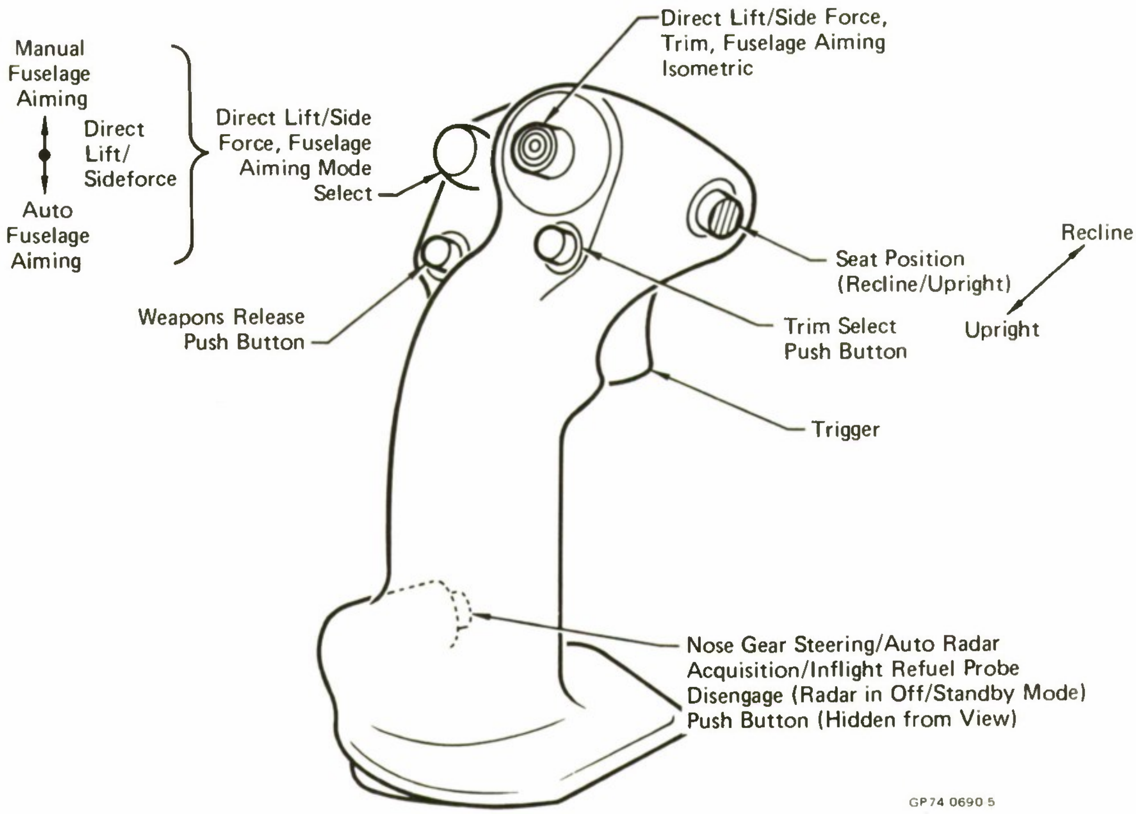


FIGURE 17
FLIGHT CONTROLLER FUNCTIONS
Integrated Design

A radar designator control is mounted on the front of the throttle. As with the flight controller, other control functions are incorporated into the throttle. A three-position weapon/mode select switch and missile/weapon uncage push button are mounted on the side surface of the right throttle. The weapon mode select switch is used to select gun, AIM-9L missiles, or missile reject. When the missile mode is selected and master arm activated, the uncage push button uncages either missiles or bombs depending on programmed flight phase (air-to-air and air-to-ground). For other weapon mode selections, this button provides rudder trim. Finger lift controls are provided for engine cutoff. Five additional controls are located on the throttle to perform the following functions:

(1) Speed brake/modulated drag
(2) Communications - transmit/receive
(3) IFF interrogate
(4) ECM - Chaff/off/special ECM Dispenser or Flares
(5) Radar Elevation.

As with the baseline flight controller, the grips shown in Figure 18 are compatible with controller Locations A, B, and E. For Configuration D it was again necessary to redesign the grip. The overall width of the grip/hand combination for the baseline design is approximately 4.5 inches. By canting the grip at a 35° angle, as shown in Figure 19, the overall width is reduced to approximately 3.5 inches allowing placement between the seat and sill. Functionally, the throttles are identical with those shown in Figure 18. The pilots again are exposed to both baseline and canted designs and comments obtained.

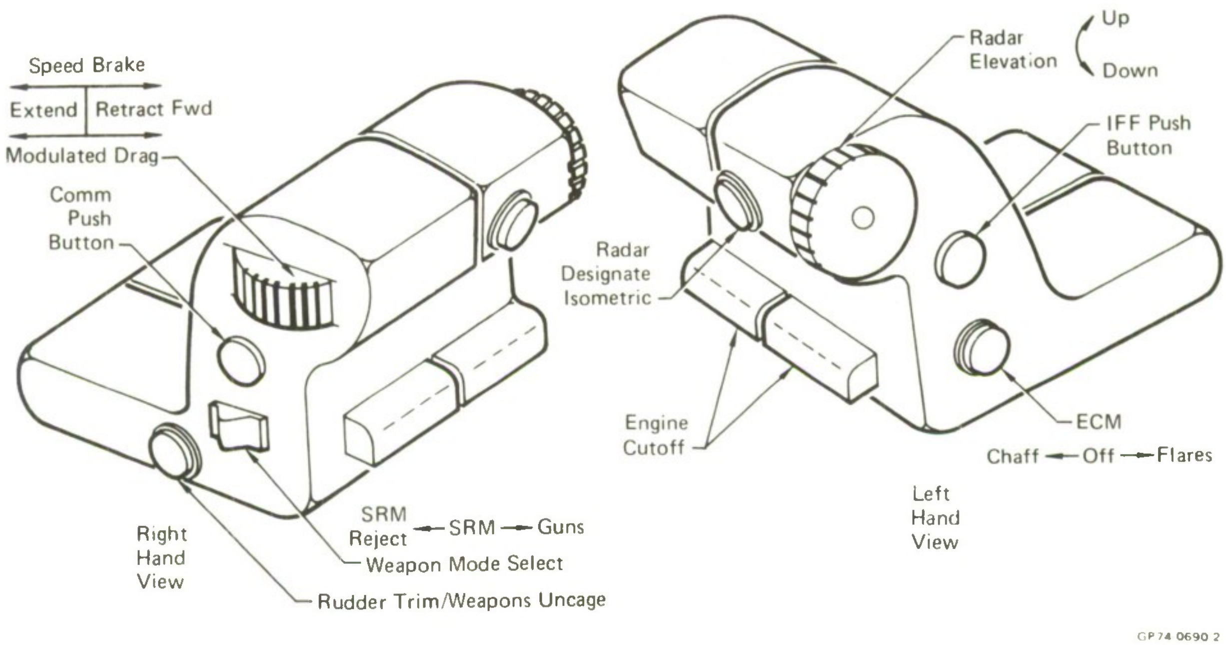


FIGURE 18
THROTTLE CONTROL FUNCTION
Baseline Design

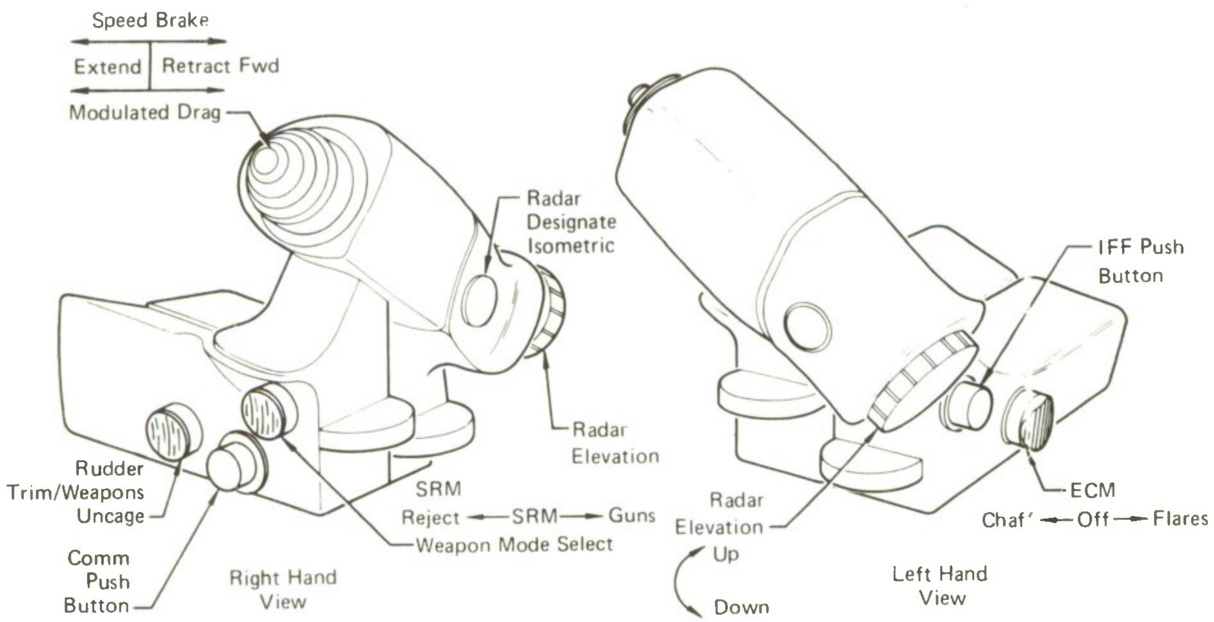


FIGURE 19
THROTTLE CONTROL FUNCTIONS
Canted Grip

Control/Display Configurations

Three arrangements of the controls and displays were developed for the design aid, based on providing visibility of and access to those functions required during both reclined and upright flight conditions. The layout has considered the vision and reach envelopes compatible with the four controller/mechanization configurations. These configurations are differentiated by the location of the flight controller and throttle. The three configurations are: (1) Fixed Console Mounted Controllers; (2) Over-The-Lap-Seat Mounted Controllers; and (3) Console/Instrument Panel Mounted Controllers illustrated by Figures 20, 21, and 22, respectively.

A summary of the controller location/control/display combinations is presented in Table 2.

The display configurations, developed for four (4) throttle-controller locations, provide a large A/A and A/G mission capability in a small-sized cockpit. The configuration, location and extent of integration are primarily a function of cockpit size, controller location and pilot task requirements for two different seat positions (high G and normal). In the normal seat position all controls and displays are available for utilization. For the four cockpit configurations, different avionics capabilities are possible for the normal seat position because flight controller and throttle locations influence the accessability of different cockpit areas. In the reclined seat position, there is a considerable reduction in reachable and viewable areas of the cockpit. This requires the cockpit design to provide whatever controls and displays to the pilot he may require when he is seated in that position.

Hence, the control/display configuration differences associated with the four controller location independent test variables are:

<u>Left Hand Console</u>

- o Location of master engine and ESC control panel (left hand and left center console)
- o Location of navigation display panel (left hand and main center console)
- o Location of fuel control panel (left hand and main center console)
- o Location of armament/comm control panel
- o Location of BIT control panel
- o Location of ground power panel
- o Location of anti-G panel
- o Location of auxiliary power control
- o Location of emergency speed brakes control
- o Location of FBW control panel (left hand and main center console).

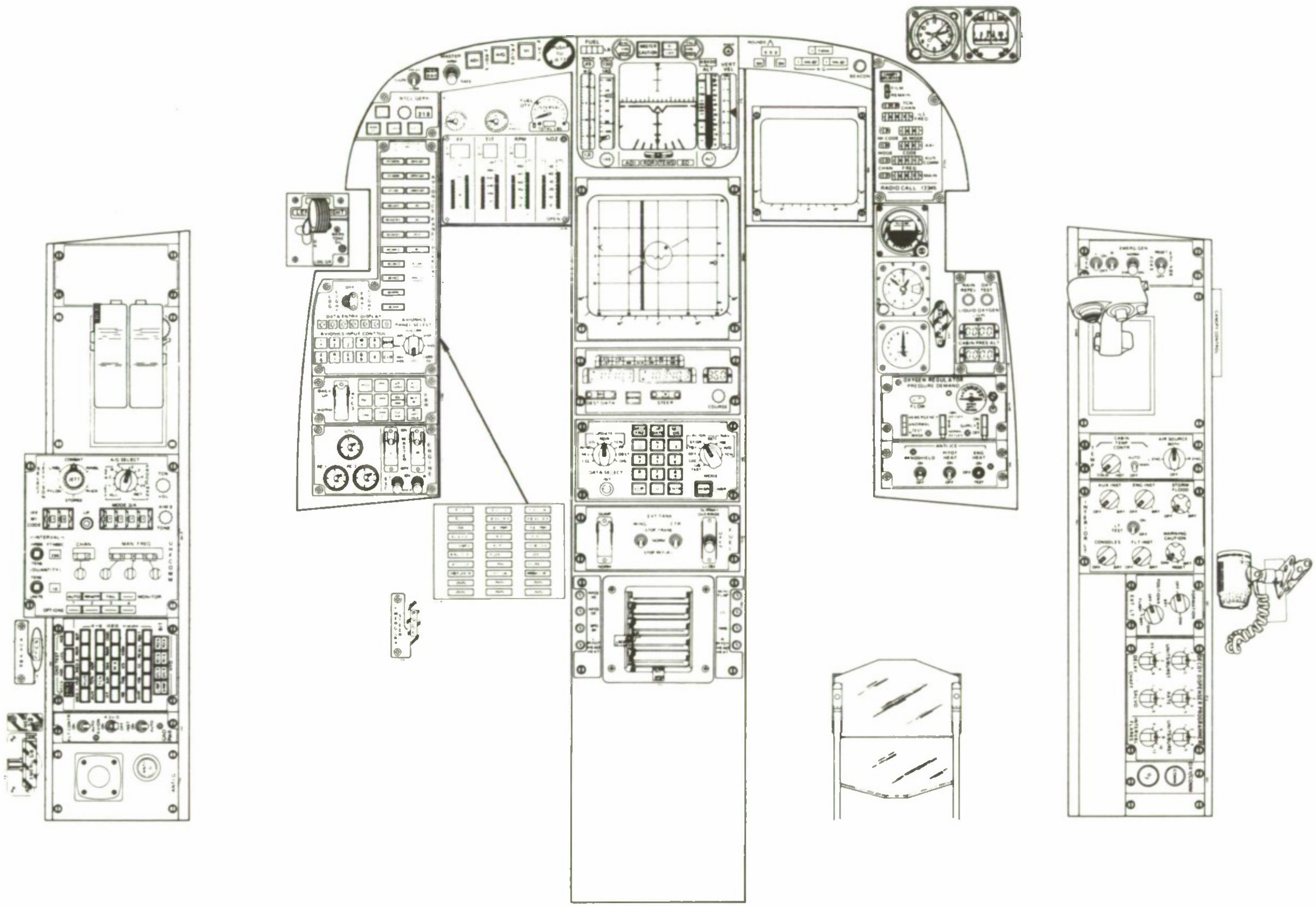


FIGURE 20
FIXED CONSOLE MOUNTED CONTROLLER CONFIGURATION
Used With Controller Configuration A
Configuration I

GP74-0757-1

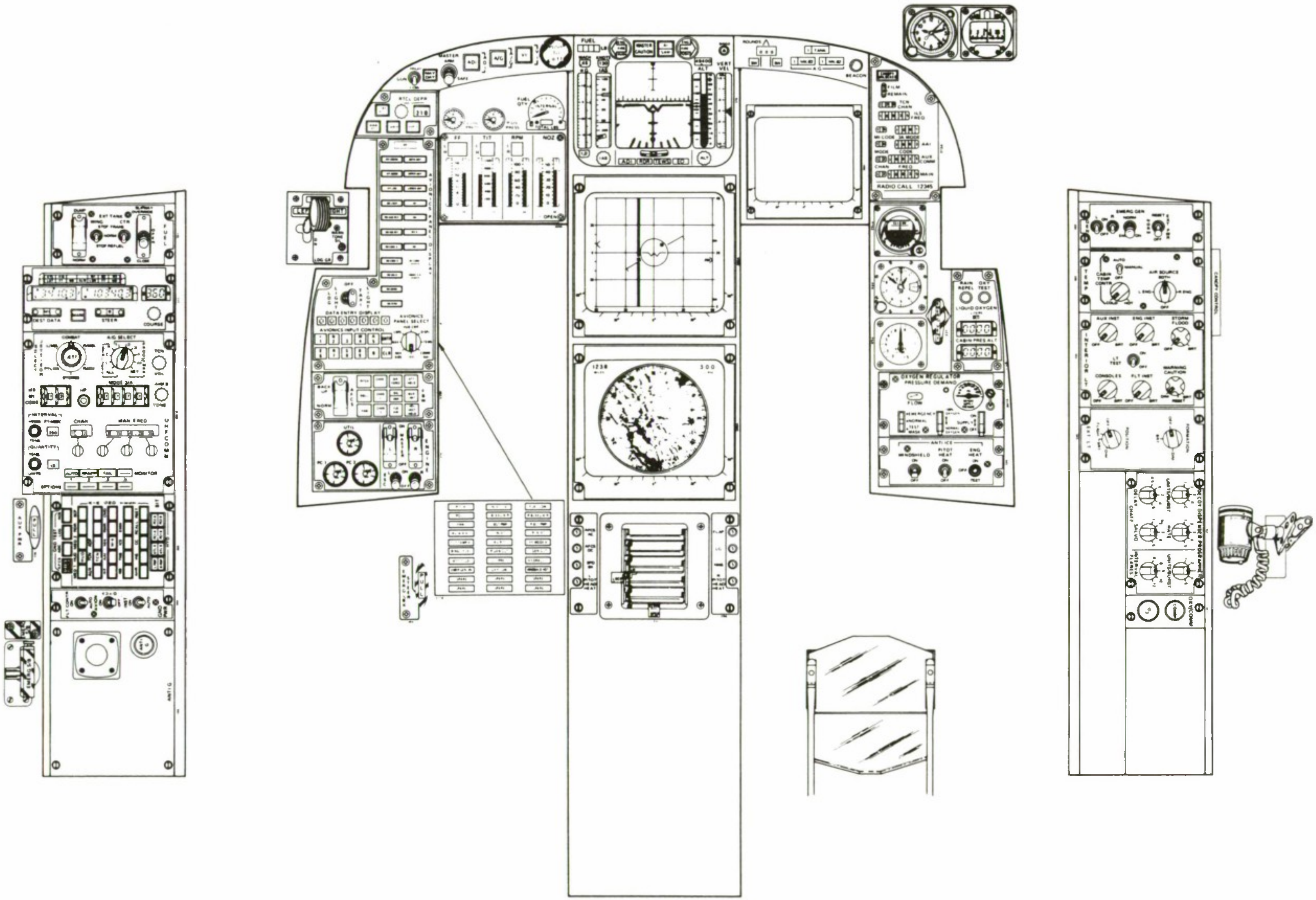


FIGURE 21
SEAT MOUNTED CONTROLLER CONFIGURATION
Used With Controller Configuration B
Configuration II

GP74-0757-2

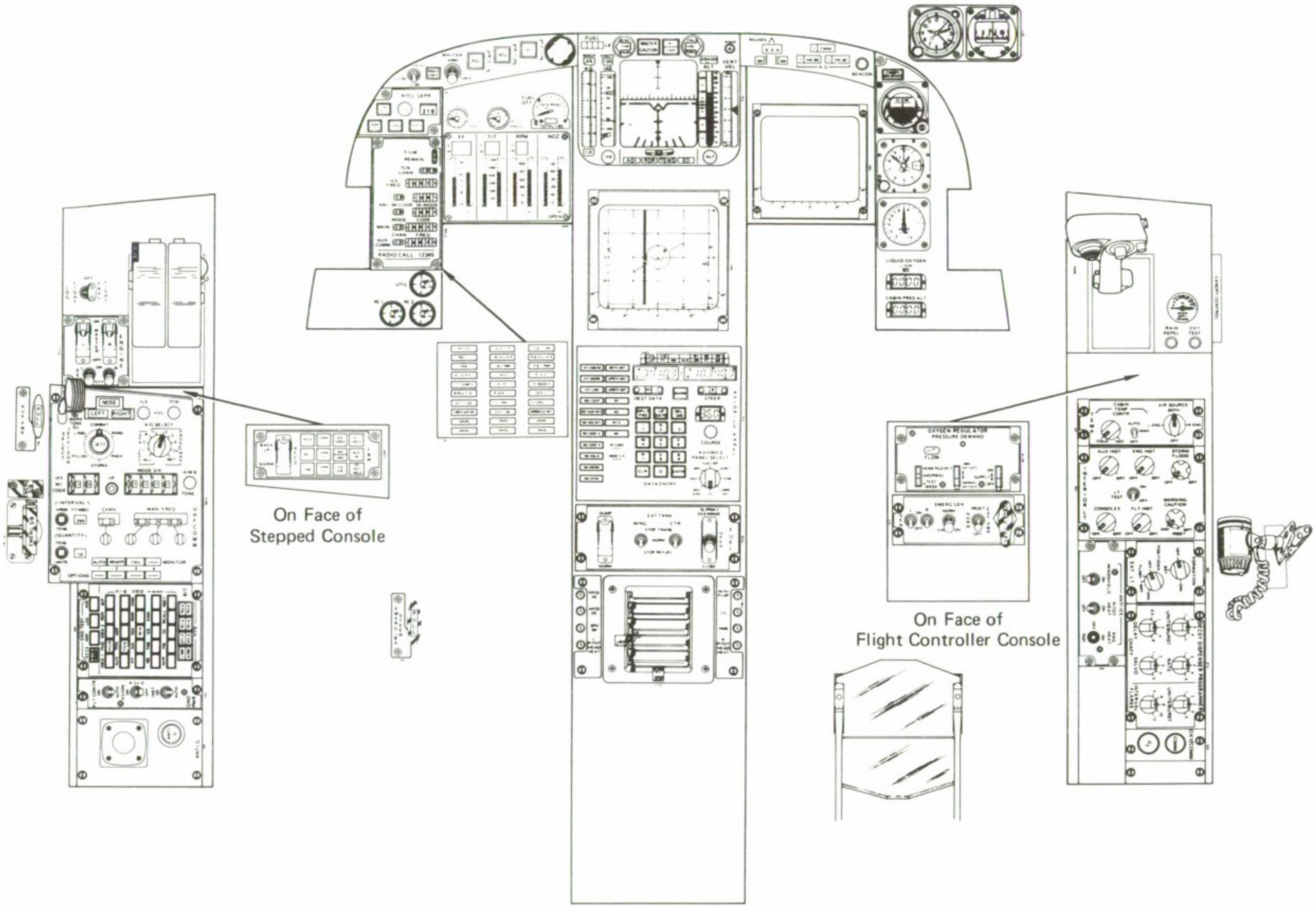


FIGURE 22
CONSOLE/INSTRUMENT PANEL MOUNTED CONTROLLER CONFIGURATION
Used with Controller Configuration D and E
Configuration III

GP74-0757-3

Left Center Console

- o Addition of INS into avionics control panel
- o Location of master engine and ESC control panel (left hand and left center)
- o Location of fuel control panel (left hand and left center console)
- o Location of avionics control panel (left center and main center console)
- o Location of hydraulic pressure indicators
- o Location of communications status panel (left center and right center console)
- o Location of FBW control panel (left hand and left center console)
- o Location of landing/taxi lights switch.

Main Center Console

- o Location of navigation display panel
- o Addition of INS control panel (left hand and main center console)
- o Location of fuel control panel (left hand and main center console)
- o Quantity (3 or 4) of multipurpose displays
- o Location of horizontal situation display
- o Location of air vent
- o Location of circuit breaker panels
- o Location of avionics control panel (left center and main center console).

Right Center Console

- o Location of cabin pressure altimeter indicator (right center and right hand console)
- o Location of liquid oxygen indicator (right center and right hand console)
- o Location of communications status panel (right center and left center console)
- o Location of standby instruments
- o Location of emergency vent control
- o Location of rain repel and oxygen test push buttons (right center and right hand console)
- o Location of oxygen regulator control panel (right center and right hand console)
- o Location of anti-ice control panel (right center and right hand console).
- o Location of oxygen supply indicator (right center and right hand console).

Right Hand Console

- o Location of emergency generator control panel
- o Location of temperature control panel
- o Location of interior light panel
- o Location of right hand controller (four positions)
- o Location of external lights panel
- o Location of decoy dispenser programmer
- o Shape and location of storage area
- o Communication/oxygen connectors
- o Location of oxygen regulator control panel (right hand and right center console)
- o Location of oxygen supply indicator (right center and right hand console)
- o Location of rain repel and oxygen test push buttons (right center and right hand console)
- o Location of anti-ice control panel (right center and right hand console)
- o Location of emergency vent control (right center and right hand control).

Seat

- o Location of throttles (four positions)
- o Shape and location of ejection handle(s) (side, D-ring, and face curtain)
- o Location of right hand controller (four positions).

The displays and controls identifications for the cockpit arrangements are depicted in Figures 23, 24, and 25. Table 3 provides a listing of equipment numbers. These identifications correlate with the pilot test listings described in Section II of this test plan.

FIXED TEST CONDITIONS

The following variables are held constant during the evaluation:

- o General setting for the experiment
- o Measuring instruments used
- o Crew station shell geometry
- o Number of test trials allowed
- o Quantity of task requirements
- o Pilot personal equipment required (helmet, oxygen mask, flight/suit, gloves, and anti-G suit).

ATTRIBUTES OF PILOT TEST SUBJECTS

The following organismic variables are measured:

- o Pilot anthropometric measures (inches)
- o Pilot high G experience (flight and centrifuge, hours)
- o Pilot flight and combat experience (hours)
- o Pilot fighter type aircraft (F-4, F-105, F-111, etc.)
- o Pilot visual envelopes (degrees).

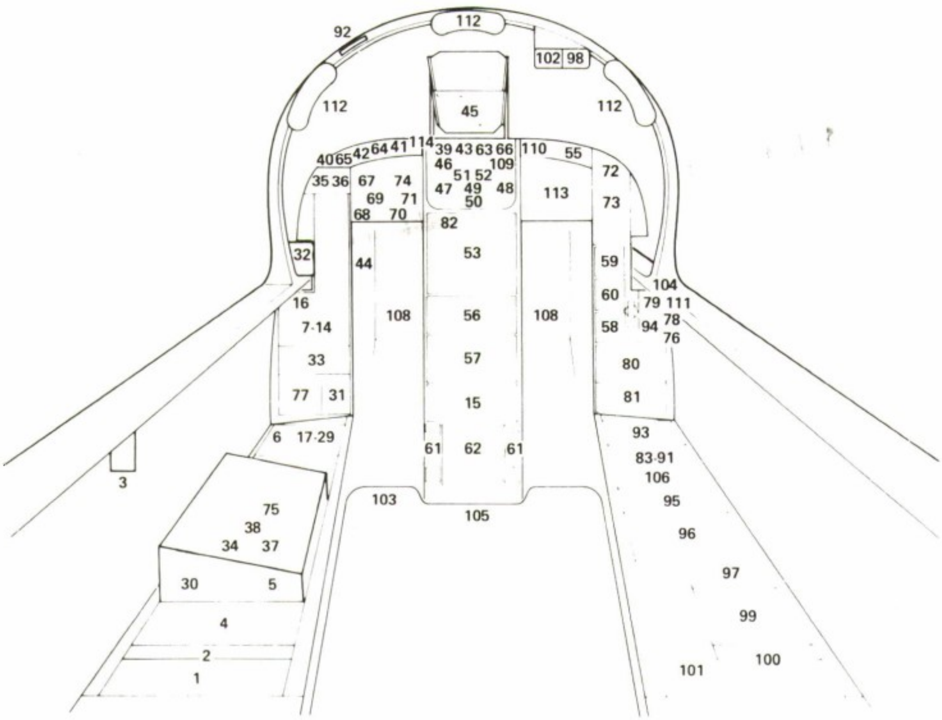


FIGURE 23

CONTROL/DISPLAY CONFIGURATION I EQUIPMENT IDENTIFICATION

Applicable for Test Configuration A

GP74-0757-4

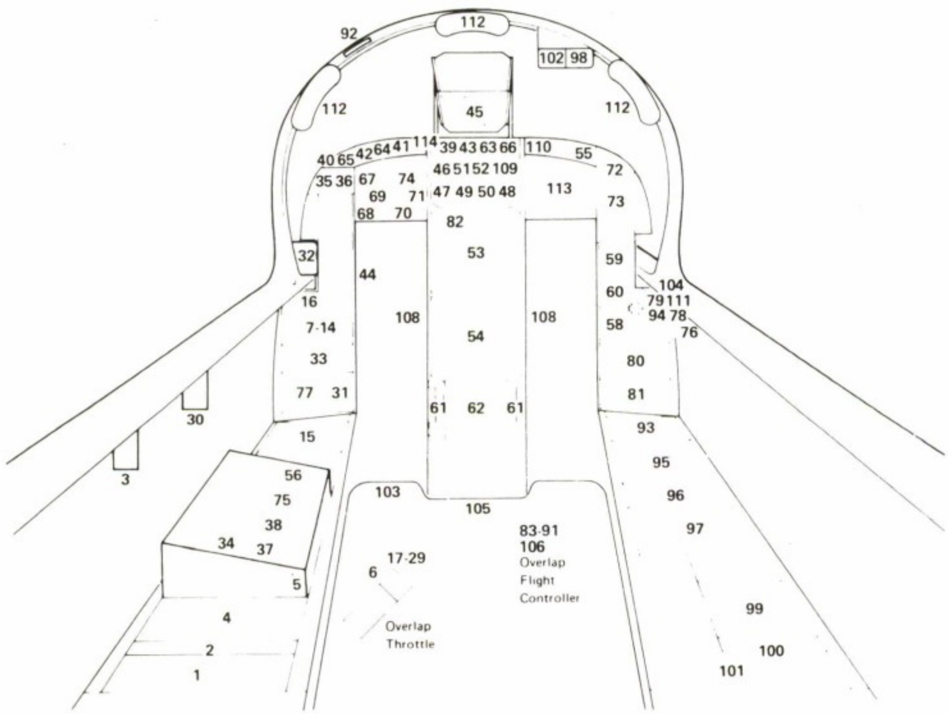


FIGURE 24

CONTROL/DISPLAY CONFIGURATION II EQUIPMENT IDENTIFICATION

Applicable for Test Configuration B

GP74-0757-5

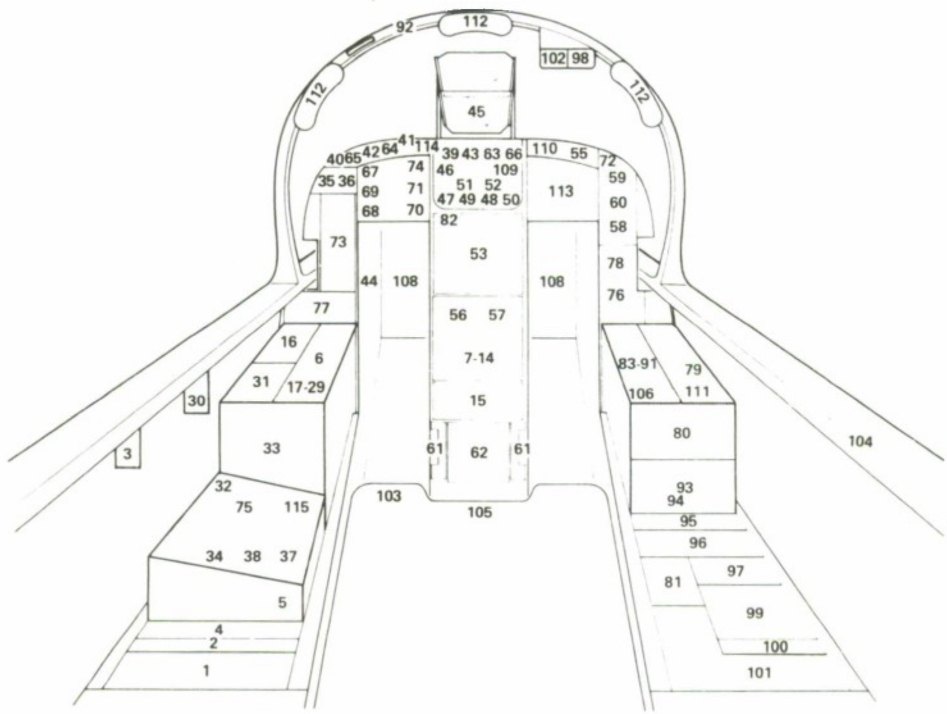


FIGURE 25
CONTROL/DISPLAY CONFIGURATION III EQUIPMENT IDENTIFICATION
Applicable for Test Configurations D and E

GP74-0757-6

TABLE 3
EQUIPMENT LIST

1. Anti-G Suit Connector Panel
2. Ground Power Control Panel
3. Emergency Speed Brake Control Handle
4. Built In Test (BIT) Control/Display Panel
5. Emergency Brake/Steering Handle
6. Engine Air Start Control (On THR)
7. Comm/AAI Controls (Avionics Panel - AP)
8. Identification Friend or Foe (IFF) Controls (AP)
9. Sensor Controls (AP)
10. Head Up Display/Camera (HUD/CMR) Controls (AP)
11. Displays Control (AP)
12. Navigation Controls (AP) (Seat Controller Only)
13. Navigation Aids Controls (AP)
14. Tactical Electronic Warfare System (TEWS) Controls
15. Fuel Control Panel
16. Landing/Taxi Light Control
17. Throttle - Left (Outbd) and Right (Inbd)
18. Radar Elev Position Control (THR)
19. Radar Designate/Servo Drive Mode Select (THR)
20. Missile Uncage Control (THR)
21. Left Engine Cutoff Finger Lift (THR)
22. Radar Target Designator/Servo Drive Control (THR)
23. Weapon/Mode Select Control (THR)
24. Speed Brake/Mod Drag Mode Select (THR)
25. Speed Brake/Mod Drag Control (THR)
26. Comm Control (THR)
27. IFF Interrogate Control (THR)
28. ECM Dispenser Control (THR)
29. Right Engine Cutoff Finger Lift (THR)
30. Auxiliary Power Control
31. Engine Control Panel
32. Landing Gear Control
33. Automatic Flight Control System Control Panel
34. Stores Options Indicator
35. TEWS Easy Access Mode Controls
36. Reticle Depression Control
37. Blind Communication Controls
38. Blind IFF and TCN Controls
39. Left Engine Fire Warning Light/Control
40. Gunfire Rate Control High/Low
41. Emergency Jettison Control
42. Master Arm Control
43. Master Caution Indicator
44. Caution Light Panel
45. Head Up Display (HUD)
46. Angle of Attack Indicator
47. Accelerometer
48. Vertical Velocity Indicator
49. Multisensor Display 1 (MSD 1)
50. MSD 1 Mode Select Controls
51. Airspeed Indicator
52. Altimeter
53. Multisensor Display 2 (MSD 2)
54. Multisensor Display 3 (MSD 3)
55. Marker Beacon Indicator Light
56. Navigation Display Panel
57. Inertial Navigation System Controls (Fixed Control Only)
58. Standby Airspeed Indicator
59. Standby Attitude Direction Indicator
60. Standby Altimeter
61. Circuit Breaker Panels
62. Air Vent
63. AI6SAM TEWS Warning Light
64. Master Mode Select Controls
65. May Day Call Pushbutton
66. Right Engine Fire Warning Light/Control
67. Oil Pressure Indicators (L/R Engines)
68. Fuel Flow Indicator
69. Turbine Inlet Temperature Indicator
70. RPM Indicator
71. Nozzle Position Indicator
72. Canopy Unlocked Warning Light
73. Channel/Frequency/Mode Display
74. Fuel Ouantity Indicator
75. Air-to-Ground Arm Control
76. Cabin Pressure Indicator
77. Hydraulic Pressure Indicators (PC1, PC2, UTL)
78. Liquid Oxygen Ouantity Indicator
79. Rain Repel Control
80. Oxygen Control Panel
81. Anit-Ice Control Panel
82. Rudder Pedal Adjust Control
83. Flight Controller (Flt Cont)
84. Automatic Fuselage Aim (Flt Cont)
85. Manual Fuselage Aim Control (Flt Cont)
86. Direct Lift/Direct Side Force Control (Flt Cont)
87. Trim Control (Flt Cont)
88. Seat Adjust Control (Flt Cont) Fwd/Rec
89. Trigger (Flt Cont)
90. Weapon Release
91. Automatic Acquisition/Nose Gear Steer/Air Refuel Disengage
92. Air Refuel Advisory Lights
93. Generator Control Panel
94. Emergency Vent Control
95. Temperature Control Panel
96. Interior Lightning Control Panel
97. Exterior Lightning Control Panel
98. Compass
99. Decoy Dispenser Programmer
100. Communication/Oxygen Connectors
101. Storage Area
102. Clock/Magnetic Compass
103. Shoulder Harness Release
104. Canopy Control
105. Ejection Control
106. Manual Seat Positioning Control
107. Communications Headset
108. Rudder Pedals (L/R)
109. Bingo Fuel Warning Light
110. Stores Monitor
111. Oxygen Test Pushbutton
112. Mirror
113. Multisensor Display 4 (MSD 4)
114. Digital Fuel Quantity
115. Blind ILS Vol Control

GP74 0757 7

DEPENDENT TEST VARIABLES

The recorded dependent or response variables are:

Objective

- o Pilot task performance times (seconds)
- o Pilot eye and head movement measures (degrees)
- o Pilot reach area plot (inches).

Subjective

- o Pilot task performance (yes, no, maybe)
- o Pilot ranking of controller/mechanization options (numerical ranking, scores; paired comparison)
- o Pilot opinion (essay).

TEST SESSIONS

Based upon the foregoing variables, the design evaluation is divided into the following twenty test sessions:

Objective

(1) Session 1 - Pilot Background Questionnaire
(2) Sessions 2 through 6 - Pilot Measures
- Visual Envelope
- Anthropometric
- Physical (Reach and Interference) Envelope
- Task Performance
- Eye and Head Movement

Subjective

(1) Sessions 7 through 17 - Functional Task Evaluations based upon Mission Scenario Elements:
- Pre-Flight
- Instrument Takeoff and Climb
- Cruise
- SAM Evasion
- Bomb Delivery
- Strafing Pass
- Air Combat Maneuvers
- In-Flight Refueling
- Approach/Landing
- Post-Flight
- Emergency

(2) Sessions 18 and 19 - Questionnaire
- Paired Comparison Questionnaire
- Pilot Interview Questionnaire

(3) Session 20 - Pilot Debriefing/Concept Critique.

The equipment features to be evaluated in each mission phase are listed in Tables 4 and 5 and were selected based on mission phase impact.

The questionnaire sessions are delineated as separate sessions to facilitate test structuring and reporting. Administration of the test questionnaires is interspersed at convenient break points throughout the test period. This allows timely paired comparison testing of design issues and avoids a massive battery of questions at any one time.

In addition to the experiment evaluation, a prebriefing session, pilot interviews, and post-briefing sessions are performed. Planned testing is divided into two one-week periods, with two pilots participating each week (4 pilots total).

TABLE 4
MISSION PHASE CONTROL/DISPLAY UTILIZATION
Test Sessions 7 Through 12

EQUIPMENT NO.	EQUIPMENT TYPE	TEST MISSION PHASES: PREFLIGHT	TAKEOFF AND CLIMB	CRUISE	SAM EVASION	LGB DELIVERY	STRAFING PASS
	LEFT HAND CONSOLE						
1.	Throttles	X	X	X	X	X	X
2.	Navigation Display Panel	X		X	X		
3.	Fuel Control Panel	X					
4.	Aux. Power	X					
5.	Master Engine and ECS Control Panel	X					
6.	Arm/Comm Control Panel	X	X	X		X	
7.	BIT Control Panel	X					
8.	Ground Power Panel	X					
9.	Anti G Panel	X					
10.	Emergency S/B						
11.	FBW Control Panel	X		X		X	X
	LEFT CENTER CONSOLE						
(3.)	Fuel Control Panel	(X)					
(5.)	Master Engine and ECS Control Panel	(X)					
(11.)	FBW Control Panel	(X)		(X)		(X)	(X)
12.	INS Into AP	X		X	X		
13.	MSD3 Controls Into AP	X		X	X		
14.	Avionics Control Panel	X	X	X		X	
15.	Hydraulic Press. Ind.	X					
16.	Comm Status Panel	X	X	X			
17.	Landing/Taxi Lights	X	X				
	MAIN CENTER CONSOLE						
(2.)	Navigation Display Panel	(X)		(X)	(X)		
(3.)	Fuel Control Panel	(X)					
(14.)	Avionics Control Panel	(X)	(X)	(X)		(X)	
18.	INS Control Panel	X		X	X		
19.	Displays (3 or 4)	X	X	X	X	X	X
20.	HSD	X	X	X	X		
21.	Air Vent	X					
22.	Circuit Breaker Panel	X					

( ) Indicates that this equipment was previously listed in another console location.

TABLE 4 (CONTINUED)
MISSION PHASE CONTROL/DISPLAY UTILIZATION
Test Sessions 7 Through 12

EQUIPMENT		TEST MISSION PHASE				
NO.	TYPE	AIR-TO-AIR COMBAT	INFLIGHT REFUELING	APPROACH/ LANDING	POST-FLIGHT	EMERGENCY
	RIGHT CENTER CONSOLE					
(16.)	Comm Status Panel		(X)	(X)	(X)	(X)
(21.)	Air Vent					(X)
23.	Cabin Press. Alt.					X
24.	Liq. Oxy. Ind.					X
25.	Rain Repel. & Oxy. Test				X	X
26.	Oxy. Reg. Cont. Panel				X	X
27.	Anti-ice Control Panel				X	X
28.	Oxygen Supply Ind.				X	X
	RIGHT HAND CONSOLE					
(21.)	Air Vent					(X)
(23.)	Cabin Press. Alt.					(X)
(24.)	Liq. Oxy. Ind.					(X)
(25.)	Rain Repel. & Oxy. Test					(X)
(26.)	Oxy. Reg. Cont. Panel				(X)	(X)
(27.)	Anti-ice Cont. Panel				(X)	(X)
(28.)	Oxygen Supply Ind.				(X)	(X)
29.	Emerg. Gen. Cont. Panel				X	X
30.	Temp. Panel				X	X
31.	Interior Lights		X	X	X	X
32.	Flight Controller	X	X	X	X	X
33.	External Lights		X	X	X	X
34.	Decoy Dispenser				X	X
35.	Storage Area				X	
36.	Comm/Oxy. Connectors				X	
	SEAT					
(1.)	Throttles	(X)	(X)	(X)	(X)	(X)
(32.)	Flight Controller	(X)	(X)	(X)	(X)	(X)
37.	Ejection Handles					X

( ) Indicates that this equipment was previously listed in another console location.

TABLE 5
MISSION PHASE CONTROL/DISPLAY UTILIZATION
Test Sessions 7 Through 12

EQUIPMENT		TEST MISSION PHASE				
NO.	TYPE	AIR-TO-AIR COMBAT	INFLIGHT REFUELING	APPROACH/ LANDING	POST-FLIGHT	EMERGENCY
LEFT HAND CONSOLE						
1.	Throttle	X	X	X	X	X
2.	Navigation Display Panel		X	X		
3.	Fuel Control Panel		X		X	
4.	Aux. Power					X
5.	Master Engine and ESC Control Panel				X	X
6.	Arm/Comm Control Panel		X	X	X	
7.	BIT Control Panel				X	X
8.	Ground Power Panel				X	
9.	Anti G Panel				X	
10.	Emergency S/B				X	X
11.	FBW Control Panel	X	X	X	X	X
LEFT CENTER CONSOLE						
(3.)	Fuel Control Panel		(X)		(X)	
(5.)	Master Engine and ESC Control Panel				(X)	(X)
(11.)	FBW Control Panel	(X)	(X)	(X)	(X)	(X)
12.	INS Into AP		X	X	X	
13.	MSD3 Controls Into AP		X	X	X	
14.	Avionics Control Panel	X	X	X	X	X
15.	Hydraulic Press. Ind.					X
16.	Comm Status Panel		X	X	X	X
17.	Landing/Taxi Lights			X	X	
MAIN CENTER CONSOLE						
(2.)	Navigation Display Panel		(X)	(X)		
(3.)	Fuel Control Panel		(X)			
(14.)	Avionics Control Panel	(X)	(X)	(X)	(X)	(X)
18.	INS Control Panel		X	X		
19.	Displays (3 or 4)	X	X	X	X	
20.	HSD		X	X		
21.	Air Vent					X
22.	Circuit Breaker Panel					X

( ) Indicates that this equipment was previously listed in another console location.

TABLE 5 (CONTINUED)
MISSION PHASE CONTROL/DISPLAY UTILIZATION
Test Sessions 7 Through 12

EQUIPMENT		TEST MISSION PHASES					
NO.	TYPE	PREFLIGHT	TAKEOFF AND CLIMB	CRUISE	SAM EVASION	LGB DELIVERY	STRAFING PASS
	RIGHT CENTER CONSOLE						
(16.)	Comm Status Panel	(X)	(X)	(X)			
(21.)	Air Vent	(X)					
23.	Cabin Press. Alt.	X	X	X			
24.	Liq. Oxy. Ind.	X	X	X			
25.	Rain Repel. & Oxy. Test	X					
26.	Oxy. Reg. Cont. Panel	X					
27.	Anti-ice Control Panel	X					
28.	Oxygen Supply Ind.	X		X			
	RIGHT HAND CONSOLE						
(21.)	Emerg. Vent	(X)					
(23.)	Cabin Press. Alt.	(X)	(X)	(X)			
(24.)	Liq. Oxy. Ind.	(X)	(X)	(X)			
(25.)	Rain Repel & Oxy. Test	(X)					
(26.)	Oxy. Reg. Cont. Panel	(X)					
(27.)	Anti-ice Control Panel	(X)					
(28.)	Oxygen Supply Ind.	(X)		(X)			
29.	Emerg. Gen. Cont. Panel	X					
30.	Temp. Panel	X					
31.	Interior Lights	X					
32.	Flight Controller	X	X	X	X	X	X
33.	External Lights	X					
34.	Decoy Dispenser	X					
35.	Storage Area	X	X	X			
36.	Comm/Oxy. Connectors	X					
	SEAT						
(1.)	Throttles	(X)	(X)	(X)	(X)	(X)	(X)
(32.)	Flight Controller	(X)	(X)	(X)	(X)	(X)	(X)
37.	Ejection Handles	X					

( ) Indicates that this equipment was previously listed in another console location.

SECTION IV

TEST APPROACH AND DATA ANALYSIS

A description of the test objectives, approach, and data analysis technique are provided for twenty test sessions.

PREBRIEFING

Objective: The prebriefing introduces the pilots to the general test objectives. An overall view of the program context, baseline aircraft operational features, crew stations, design characteristics and test objectives are presented.

Approach: The pilots are given a presentation detailing the following elements:

- o High Acceleration Cockpit approach, background utility and payoff
- o Characteristics and tactics pertinent to direct lift and direct side force features
- o Organization of mission segments
- o Structure of test plan and schedule
- o Interactive manned air combat simulation.

SESSION 1 - PILOT BACKGROUND QUESTIONNAIRE

Objective: The Background Questionnaire is used to determine pilot experience in aircraft, combat, high G levels, etc.

Approach: The Pilot Background Questionnaire is a written form, composed of questions to ascertain pilot experience in a variety of areas. These areas include the following:

- o Type of aircraft flown
- o Aircraft currency
- o Aircraft experience (log hours)
- o Air combat experience
- o Air-to-ground weapons delivery experience
- o High G maneuvering experience.

The questions are the fill-in type. The following are examples:

- o What military aircraft have you flown?
- o In your flight experience, have you ever been subjected to high G loads; if so, estimate the G load and duration?

Data Analysis: The range of pilot experiences is tabulated. These data lend credence to the generalizing of the subsequent test data to the pilot population.

SESSION 2 - VISUAL ENVELOPE

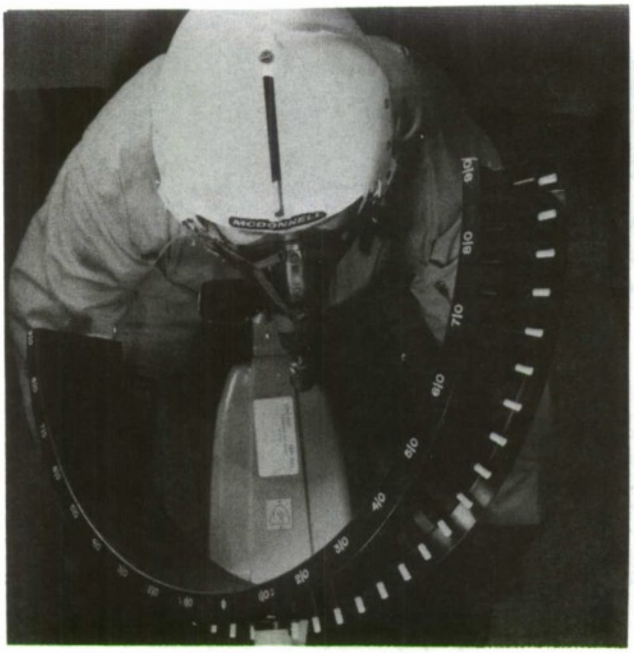
Objective: The peripheral vision envelopes of the pilots are measured in order to determine individual differences in vision envelopes. This measurement eliminates problems potentially present in later sessions in terms of vision limits in the crew station.

Approach: The pilot is seated at a table in front of a screening perimeter (Figure 26). He wears his flight helmet and oxygen mask. The perimeter's protractor scale has 5° graduations, and intermediate positions can be interpolated with reasonable accuracy. Illumination on the black arch is kept uniform. The non-test eye is occluded with an eye shield. The pilot is seated so that his head remains erect, and his eye is level with respect to the fixation point, a white target "O" with a cross mark which is centered on the perimeter's black arch. The pilot is instructed to look at the fixation target at all times throughout the examination. To expose a target, the examiner pushes the applicable arc button. The pilot's response as to whether he sees the target is then recorded. The targets are exposed using the sequential method of limits approach with counterbalanced starting positions.

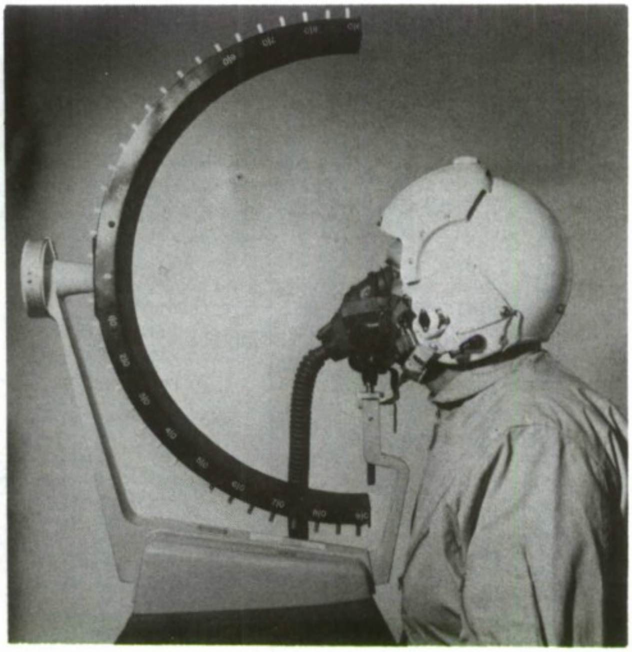
Data Analysis: The data are plotted, on a polar projection (Figure 27), to show the visual envelope of the pilot. These results are used to construct mean vision loss envelopes for the crew station design. A G-level algorithm then can be superimposed to illustrate effects of peripheral loss due to load factor application.

SESSION 3 - ANTHROPOMETRIC MEASUREMENTS

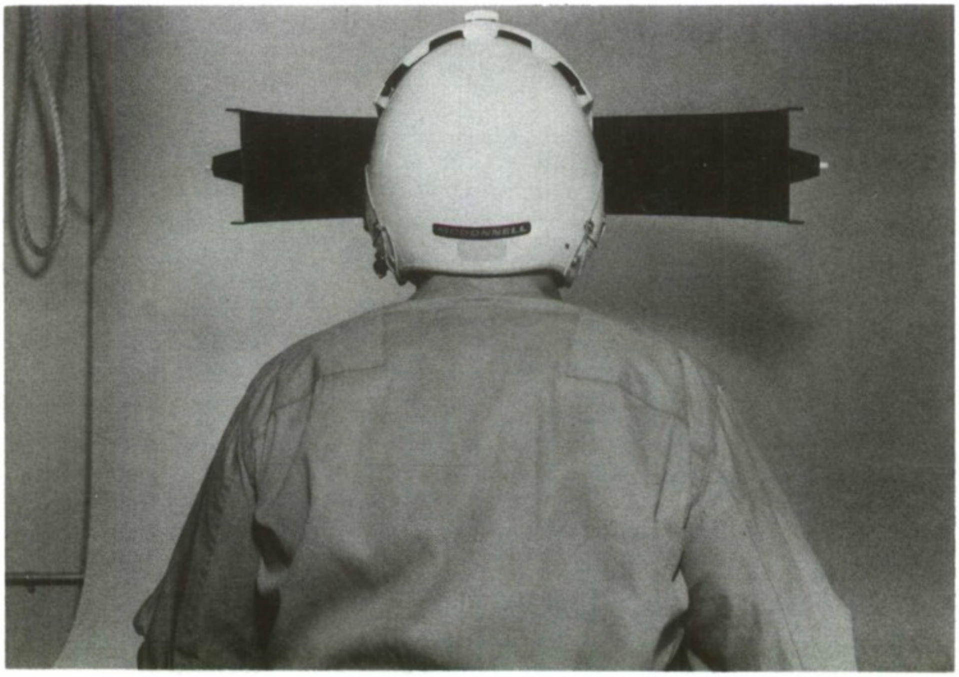
Objective: Anthropometric measurements are taken for each pilot. By knowing relative pilot size, such as sitting height and reach distance, his responses and capabilities in later test sessions become even more meaningful. These can be incorporated into the digital model to illustrate relative performance comparisons.



Intermediate Position



Vertical Position



Horizontal Position

FIGURE 26
VISUAL MASKING MEASUREMENTS

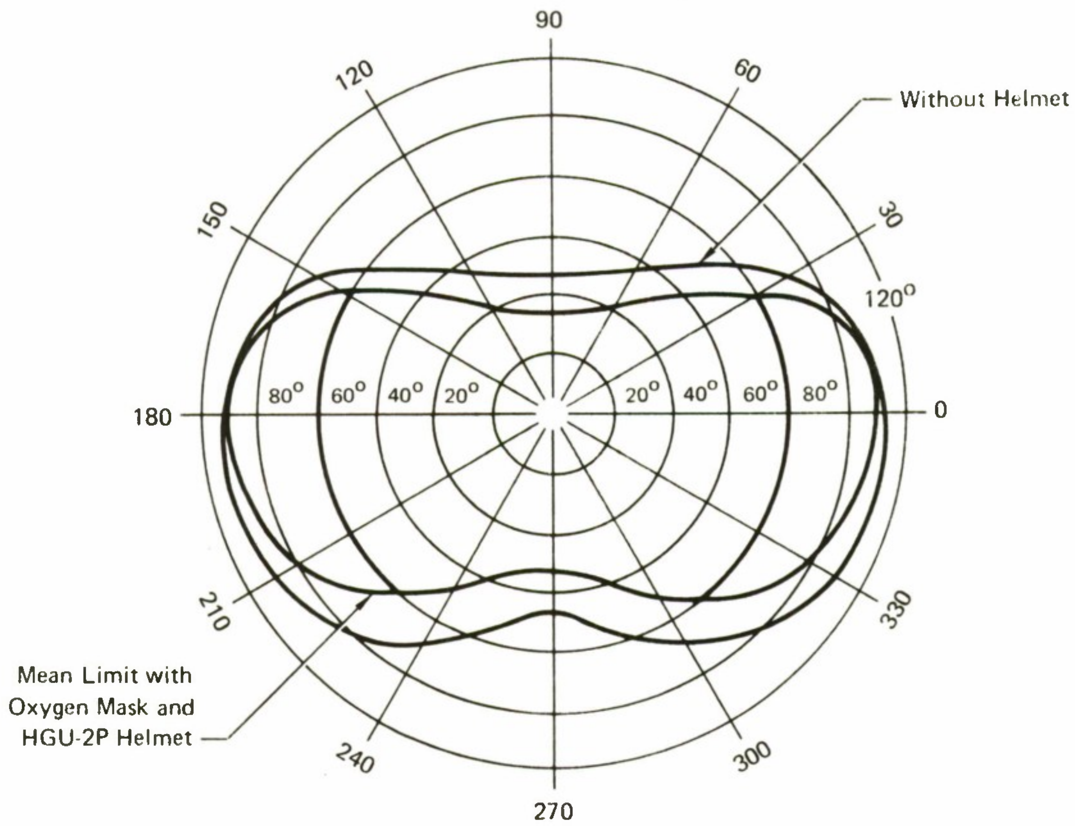


FIGURE 27
VISUAL MASKING

Approach: Measurements are made with each pilot wearing his flight suit and flight helmet. In all cases the pilot either stands or sits in an erect manner. An anthropometer is used to take the measurements.

- o Body height (standing)
- o Body height (sitting)
- o Maximum body width
- o Eye height (sitting)
- o Shoulder height (sitting)
- o Shoulder to elbow length
- o Arm reach
- o Shoulder breadth
- o Elbow height (sitting)

- o Forearm - hand length
- o Elbow to elbow breadth
- o Hip breadth (sitting)
- o Thigh height (sitting)
- o Buttock - knee length
- o Knee height (sitting)
- o Buttock - leg length
- o Hand thickness
- o Hand length
- o Hand breadth at thumb
- o Hand breadth at metacarpal.

Data Analysis: The measurements are used to determine pilot percentile in each of the areas. In this manner evaluation of the design aid is in terms of the capabilities gained or lost by pilots of differing percentiles in the area affected.

SESSION 4 - PHYSICAL REACH AND INTERFERENCE ENVELOPES

Objective: Measurements of each pilot's physical reach and interference envelopes are taken with the pilot in the crew station design aid for each of the four test configurations. The pilot is restrained in the seat by the lap belt and an unlocked shoulder harness. The pilot's helmet is restrained within the canopy envelope when necessary for maximum reach tasks. In this manner the crew station design aid in general, and configurations in particular, are evaluated in terms of a pilot's ability to reach the necessary controls with a minimum of interference from control or seat placement.

Approach: The pilot is seated in the crew station design aid, wearing:

- o Flight suit
- o Flight helmet
- o Oxygen mask
- o Anti-G suit
- o Gloves.

He is asked to reach different controls in different sequences from both the upright and reclined seat positions. Each of the test configurations is presented and the pilot asked to reach and operate controls which include the following as a minimum:

- Master caution
- Engine fire warning pushbuttons
- Multisensor display mode pushbuttons
- Landing gear handle
- Avionics panel
- Emergency speed brake
- Rudder pedal adjust
- Engine air start
- Emergency generator controls
- Emergency jettison control
- Fly-by-wire control panel
- Master arm
- Master mode pushbuttons
- Emergency vent
- Throttles and throttle mounted controls
- Flight controller and flight controller mounted controls
- Emergency brake/steering control
- Ejection handles.

Data Analysis: Data are recorded in terms of pilot ability or inability to reach the controls. Reasons for failure to reach or operate a control also are noted. Examples of such reasons are:

- Too far away
- Interference from flight controller
- Clearance/control interference.

Data, tabulated in terms of configuration and pilot, measure the effect of each configuration on pilot operating capability and the interaction of different percentile pilots with the configurations.

SESSION 5 - TASK PERFORMANCE

Objective: Pilot performance of flight tasks is measured and recorded. Results are used in evaluation of the controller/display configurations and in overall analysis of the crew station.

Approach: The pilot is seated in the crew station design aid, wearing the standard equipment, specified in Session 4. He is restrained in the seat by the shoulder harness. The experimenter instructs the pilot to perform a certain task. With his hands at a neutral starting point (on throttle or flight controller) the pilot performs the task as quickly as possible, returning his hand to the neutral position. His response time (from neutral position to neutral position) is clocked by stopwatch.

Data Analysis: Task performance times are recorded and tabulated for each pilot. Measurements for each task are averaged for the participating pilots. These times are used in a digital pilot simulation model to analyze pilot workloads. From these analyses indices of pilot workload for the configuration alternatives are available.

SESSION 6 - EYE AND HEAD MOVEMENT

Objective: In order to determine pilot visual patterns, the eye and head movements of each pilot are measured. These patterns are useful in the digital pilot simulation model workload analyses and in the evaluation of visibility of the pilot for the design aid configurations.

Approach: The pilot is seated in the crew station and restrained by the lap belt and an unlocked shoulder harness. He wears the standard equipment, specified in Session 4. An optical or biopotential measuring technique is used.

Optical techniques are based upon the fact that the spherical center of the cornea is not at the center of rotation of the eyeball. Hence, a beam of light shown on the cornea is reflected in different directions depending on the angular displacement of the eye. The reflected light is often monitored with a television camera. A variety of special contact lenses has also been used to provide the reflection. The disadvantages of these methods are that eye blinking obscures the reflection, and the equipment required is cumbersome and distracting.

The biopotential technique employs instrumentation to measure the potential difference between the cornea and retina, which varies as the eye rotates. The eyeball is electrically polarized due to the greater metabolic activity of the retina compared to the cornea. This polarization creates an electric field around the eye which varies with eye movement. The variations can be detected through skin electrodes.

Head movement for this test is determined by mechanical means. A two piece assembly hinged at the center is connected to potentiometers at the top of the head rest and at the top of the helmet (Figure 28). The potentiometer readings are recorded as the pilot moves his head and converted to corresponding angles, producing a single head angle. The pilot is instructed to fix his eyes on certain instruments of cockpit areas. Angular readings are then recorded.

Data Analysis: The individual head motion and eye motion patterns are used to calculate the pilot's visual center of attention. The analysis of the electrical signals and computation of the associated angle is accomplished with a computer. Having calculated these angles, a correlation to similar data from the digital pilot simulation model workload analyses can be produced to illustrate visual zone occupation during pilot tasks.

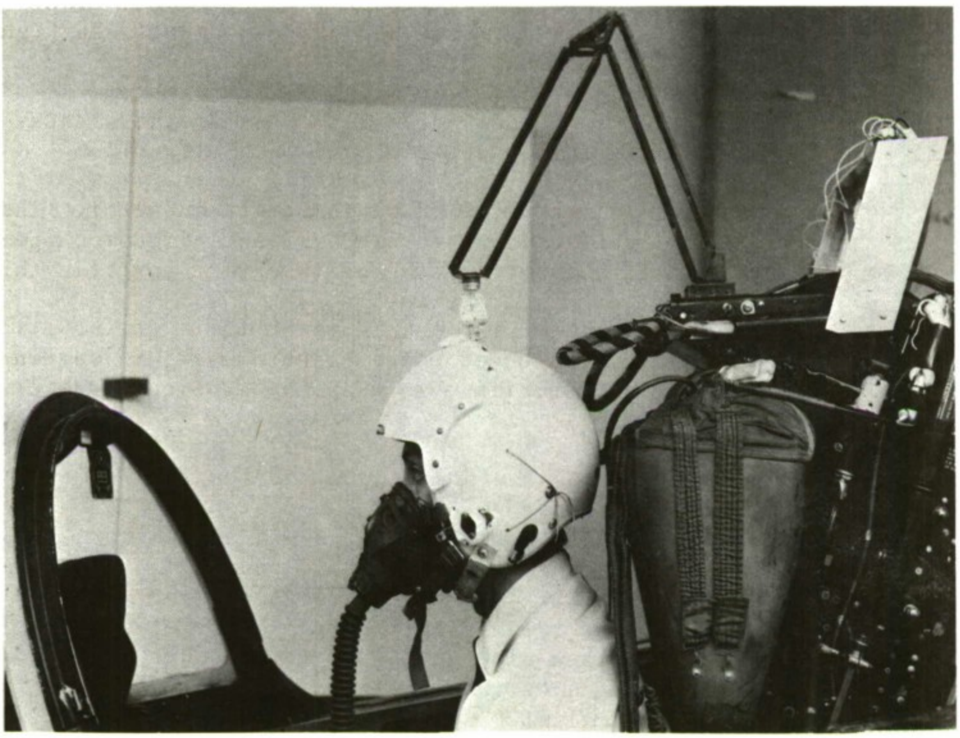


FIGURE 28
HEAD MOVEMENT TECHNIQUE

SESSIONS 7 THROUGH 16 - MISSION

Objective: Functional task evaluation is based upon discrete mission scenario elements. Subjective measurements of pilot tasks performed within the context of a mission phase are recorded. These measurements are of the following type:

- o For pilot task performance; yes, no, maybe
- o Pilot opinions.

Measurements of this type provide:

- o Evaluation of the high acceleration cockpit designs in terms of physical and performance aspects as related to the mission scenario
- o Determination of indices of pilot workload for configuration alternatives for mission phases
- o Pilot acceptance based on fulfillment of mission functional task objectives using high acceleration cockpit configurations
- o Tangible basis for establishment of research and development goals leading to development of an operational high acceleration cockpit.

Approach: The pilot is seated in the design aid wearing the standard equipment specified in Session 4.

The task sequences are narrated by the test conductor. The pilot is provided an opportunity to express his opinion or suggestions concerning the task or associated equipment at any time throughout the test. Pilot comments are recorded.

The pilot performs tasks for all mission phases, in sequence, before the configuration is changed. The mission phase sequence is as follows:

- o Preflight
- o Takeoff and climb
- o Cruise
- o SAM evasion
- o LGB delivery
- o Strafing pass
- o Air-to-air combat
- o Inflight refueling
- o Approach and landing
- o Post flight.

The four configurations are tested with the test schedule reflecting a counterbalanced start sequence. Therefore, each pilot performs the total mission scenario four times. However, the control/display configuration differences do not apply to all test sessions per Tables 4 and 5. Therefore, for data analysis purposes and a general description, each mission phase has a separate test session. The critical pilot tasks per mission phase are analyzed with an existing analysis of variance (ANOVA) computer program. Each of these tasks is specified in the following paragraphs.

SESSION 7 - PREFLIGHT

Objective: The purpose of performing preflight tasks is to evaluate the different controller configurations in terms of their impact on pilot task performance in this mission phase. As shown in Table 4, Section III, the preflight mission phase is impacted by use of more control/display functions than any other mission phase. It is important, therefore, to gain a measure of pilot acceptance based on ability to perform required tasks in each configuration.

Approach: Preflight tasks are those performed prior to takeoff. They include exterior aircraft inspection, basic cockpit inspection, engine start procedures, after start checks, taxi, arming procedures, canopy closure, and final flight preflight checks.

The pilot, seated in the design aid and wearing his flight gear, is talked through individual tasks for the test configurations. An example is "check throttles off". The task is a visual cockpit (VC) requirement, involving equipment number 17 (Table 3, throttle controls), and would require subjective (S) test evaluation. The pilot's subjective response to questions concerning his ability to do tasks is recorded.

Data Analysis: The subjective pilot responses are tabulated and analyzed to provide some means of comparing the relative pilot acceptance of each configuration for the preflight mission phase. Subjective results are provided for all defined subjective and objective pilot tasks established in an analytical phase. As a minimum, the following official task responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
12	Select COMM/AAI on AP
13	Select Comm ON
14	Select Man Freq (108.35)
15	Depr Keys for Freq and Verify
16	Select Enter
17	Select Chan Sel (12)

18	Depr Keys for Chan (12) and Verify
19	Select Enter
20	Sel Com Chan
21	Adj Vol Cont
98	Sel Nav Mode
99	Sel Stor
100	Sel Entr PP
101	OBS Pres Position LAT/LONG
102	Depr N Key to Desig North
103	Depr Keys to Desig LAT and Verify
104	Sel Enter
105	Depr E or W Key
106	Depr Keys to Desig Long and Verify
107	Sel Enter
174	Sel Displays Mode
175	Sel MSD 1 ON
176	Sel ADI on MSD 1
177	Adj BRT as Reqd
178	Sel AUTO Cont
183	Sel MSD 3 ON
184	Sel HSD
185	Adj BRT as Reqd
186	Sel AUTO Cont
260	Check Eng Oil Press Ind
261	Check Turb Inlet Temp
262	Check Fuel Flow
263	Check Hydraulic Press Ind
264	Check RPM
324	OBS Canopy Unlocked Warn Lt OFF
328	Set Pitot Heat Switch to ON.

SESSION 8 - TAKEOFF AND CLIMB

Objective: Takeoff and climb tasks are performed to evaluate the controller configurations as they impact pilot performance during this phase. Beginning with this phase, the impact of the independent test variables upon pilot workload becomes evident.

Approach: Tasks presented for this phase are those involved in the aircraft takeoff and climb to cruise altitude. Included are standard takeoff procedures, ground roll/runway track, lead formation instrument takeoff, departure procedures for an IFR climb and set up for desired cruise conditions. An instrument takeoff is tasked, thus providing a worst case workload.

Data Analysis: Subjective pilot data are tabulated and analyzed to provide a relative ranking of configurations in terms of pilot acceptance. In this manner a tangible basis should be provided for the establishment of research and development goals needed to further develop the high acceleration cockpit. As a minimum, the following critical takeoff and climb task responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
27	Advance Throttles to Afterburner
28	Activate Nosegear Steering
33	Check all engine instruments
34	Monitor Warning and Caution Lights
35	Monitor Airspeed
38	Lift Aircraft
42	Check Altimeter
44	Trim Aircraft
48	Retract Landing Gear
64	Select Outbound Radial
70	Monitor Vertical Velocity
72	Monitor Attitude
75	Verify Fuel Transfer
80	Monitor Heading
90	Check Cabin Altimeter
91	Check Fuel Quantity
92	Check Oxygen Quantity Pressure/Blinker.

SESSION 9 - CRUISE

Objective: For the Cruise phase, the independent test variables are manipulated to determine their effect on pilot performance. This determined effect is used to further evaluate the cockpit in terms of physical and performance aspects.

Approach: During the outbound cruise leg, the pilot is required to establish the desired cruise condition. Tasks are required such as: "Monitor vertical velocity indication (As Required, ASR)", which requires cockpit vision (VC), equipment number 48 (vertical velocity indicator), and requires subjective evaluation (S); "Select steering mode (NAV)" which requires cockpit vision and left hand (VCL), equipment number 57, (the inertial navigation system control panel) and also requires an objective evaluation (O) in Session 5, Task Performance.

Also required during this segment are checks on the flight controls, radar system, armament control navigation, weapon system, and displays.

Data Analysis: Subjective pilot responses are tabulated and analyzed, and data used to show the effect of the independent test variables on pilot task performance. In this manner an evaluation is made for relative acceptability of the configurations in the Cruise mission phase. As a minimum, the following critical cruise task responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
3	Check FBW Caution
6	Activate FBW ATT HOLD
10	Activate FBW Vel Vec HOLD
14A	Activate FBW DFC, MVR, FUS AIM
15	Monitor KIAS
16	Monitor Master Caution
17	Monitor Altitude
18	Monitor Heading and Range
19	Monitor Attitude
20	Monitor Fly-to-Point
33	Activate Master Mode (ADI)
34	Observe ADI Format
35	Observe Course Destination
45A	Select UHF Channel
46	Monitor Channel
81	Activate TEWS
82	Select RWR AAA
164	Perform Visual INS Update
165	Select Visual INS (Data select)
166	Observe Overfly/Freeze
167	Update Activate (AD NAV)
168	Select NAV Mode (Destination Steer Number)
169	Observe Range North and East Errors
170	Maneuver Aircraft to Fly Directly Over Update Point
171	Depress OFLY FRZ
172	Depress Update.

SESSION 10 - SAM EVASION

Objective: The SAM Evasion task sequence is performed to determine pilot ability to perform this mission phase under different control/display configurations. The independent test variables are evaluated to show their effect on this phase. Because this is a crucial mission phase, it is important that the detrimental aspects of each configuration be determined.

Approach: Penetration is accomplished at mid-to-low altitudes. A jinking flight path is established, radar and ECM tasks are performed, visual outside and visual target tasks are performed throughout this segment. Evasive maneuvers are used as required against SAM and AAA threats. Conventional AAA penetration/SAM evasion tactics are being used, modified slightly to utilize more fully the direct lift, direct side force, and advanced maneuverability capabilities of the candidate aircraft.

Data Analysis: Results are used to provide a measure of pilot acceptance of the configurations. The independent test variables which have the largest effects on pilot performance are determined. As a minimum, the following critical SAM evasion task responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
10	Monitor Threat Display
16	Detect Enemy RDR Locked On
19	Activate ECM
20	Select Decoy
22	Detect SAM
27	Activate Seat G Mode
29	Advance Throttles to Max A/B
30	Perform Evasive Maneuvers.

SESSION 11 - BOMB DELIVERY

Objective: In this combat phase, the independent test variables are manipulated to determine their effect on mission phase success. The objective is to evaluate the impact of alternate control/display configurations on performance of this phase.

Approach: Navigation (INS) and radar tasks are initially required to set a target course. Armament control tasks are performed for weapon system selection and arming (e.g., "Select LGB on Line" VCL, visual cockpit, left hand, armament control set, also an objective Session 5 task). Target detection and recognition are accomplished using EO system (e.g., "Acquire EO potential target," VC, Multisensor Display, S). The target is then engaged and weapon delivery accomplished by the aircraft.

A visual representation of an aircraft pass on a bridge target (Figure 29) is presented on a screen before the pilot, in the form of slides of a bombing run. In this manner the realism of the test can be heightened.

Data Analysis: Data are tabulated and analyzed to show the relative acceptance of each configuration, by the pilots, in terms of ability to perform this mission phase. The effects on pilot workload are also shown for each configuration. As a minimum, the following critical bomb delivery task responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
25	Select Sensors
26	Select MAP
27	Verify Optimum RDR Range Scan
28	Verify Optimum RDR Elev Scan
28A	Select TDS ON
29	Select EO
29A	Select Reqd Depr Angle Alt
30	Select LGB Bombs on Line
31	Verify Desired Stations

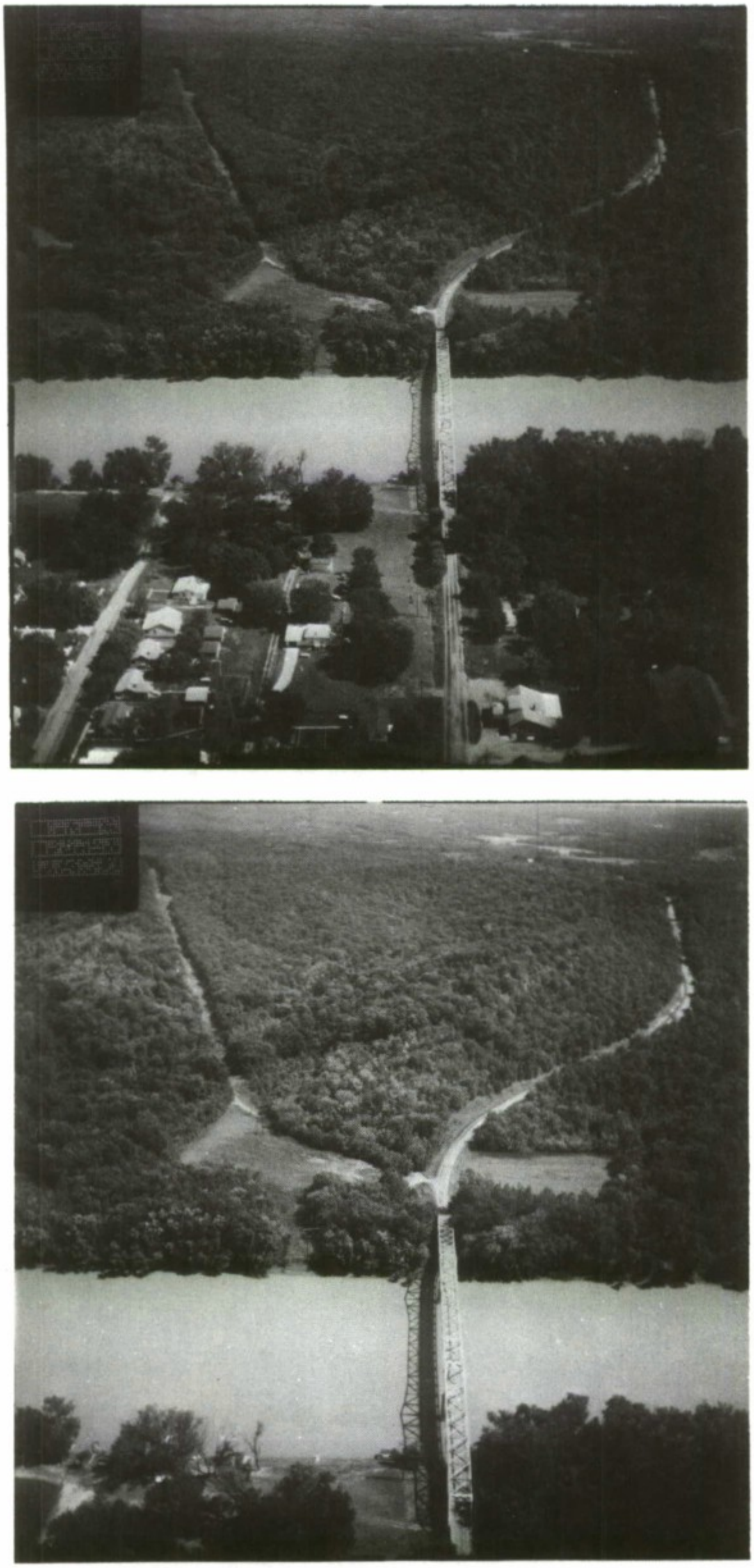


FIGURE 29
VISUAL CUES
Weapon Delivery

Task No.	Title
46	Activate A/G Master Mode
53	Depress Master Mode ON
57	Move Cursors Over Target
58	Verify Cursors on Target
63	Select EO for MSD 1
72	Depress Target Designate
79	Position for Dive
85	LGB Release
87	Pull-Up Maneuver.

SESSION 12 - STRAFING PASS

Objective: Strafing Pass tasks are performed for each of the four configurations to determine suitability of each configuration with respect to the task performance. Few control/display differences are involved in testing this mission phase (Table 4, Section III).

Approach: Targets of opportunity are sought in this segment. Visual search tasks are performed using the EO system. A target is recognized and the pilot initiates radar tracking functions. Direct force capabilities are utilized for offset and slant range tracking corrections and for fuselage aiming. The target is attacked, using a gun attack; and the independent fuselage aiming capability is used to increase gun solution time on the target. High acceleration capability provides more gun time by allowing a steeper pull up out of the attack.

As in Session 11, a visual presentation of the strafing pass is presented on a screen before the pilot.

Data Analysis: Results are tabulated and analyzed to evaluate the effect of the independent test variables on the mission phase pilot workload. Evaluation of the data provides a basis for research and development goals for development of an operational high acceleration cockpit. As a minimum, the following critical strafing task responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
13	Retard Throttle
14	Push Flt Cont Fwd
15	Monitor Altitude
16	Level Off at FL50
35	Maneuver to Position Target for Attack
36	Select Gun Mode
37	Select Gun Fire Rate High
38	Monitor Rounds Remaining
39	Set Master Arm to Arm
39A	Position Seat for Maneuvering

Task No.	Title
41A	Select Manual Fuselage Aim Mode
43	Align Aim Symbol Over Target
44	Verify in Range Symbol
45	Depress Trigger.

SESSION 13 - AIR-TO-AIR COMBAT

Objective: Purpose of simulating Air-to-Air Combat phase is to manipulate the independent test variables to determine their effect on pilot performance. Evaluation of the configurations in air-to-air combat for effectiveness is crucial, since there is no room for pilot inefficiency due to controller-design or control/display layout.

Approach: The air combat segment assumes a disadvantaged start. The pilot receives a threat warning on the TEWS system. Appropriate maneuvers are performed to accomplish target identification. Weapon selection is made and visual combat maneuvers are performed using high acceleration and direct force capabilities to gain the tactical advantage. The target is radar acquired and tracked visually with the aid of the HUD for steering and display of gun or missile solution.

Relative aircraft kinematics during combat have been determined from manned air combat simulation runs using direct lift, direct side force and high acceleration capabilities of the friendly aircraft against an advanced opponent using a conventional configuration.

A task sequence and an illustrated combat demonstration are performed for each configuration. The first is task performance only. Figure 30 illustrates the typical tasks performed and the time sequencing for those tasks.

The demonstration presents a visual target to provide the pilot with a HUD view of the target. A video monitor placed in the HUD field-of-view, and a video tape of simulated air combat maneuvers enable the pilot to track the target while performing the required tasks.

Data Analysis: Results are used to evaluate the effect of the independent test variables on pilot task performance in this phase. Pilot workload is analyzed to show effects of the configuration on this mission phase. As a minimum, the following critical air-to-air combat task responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
4	Select TEWS on MSD 1
11	Conduct outside search

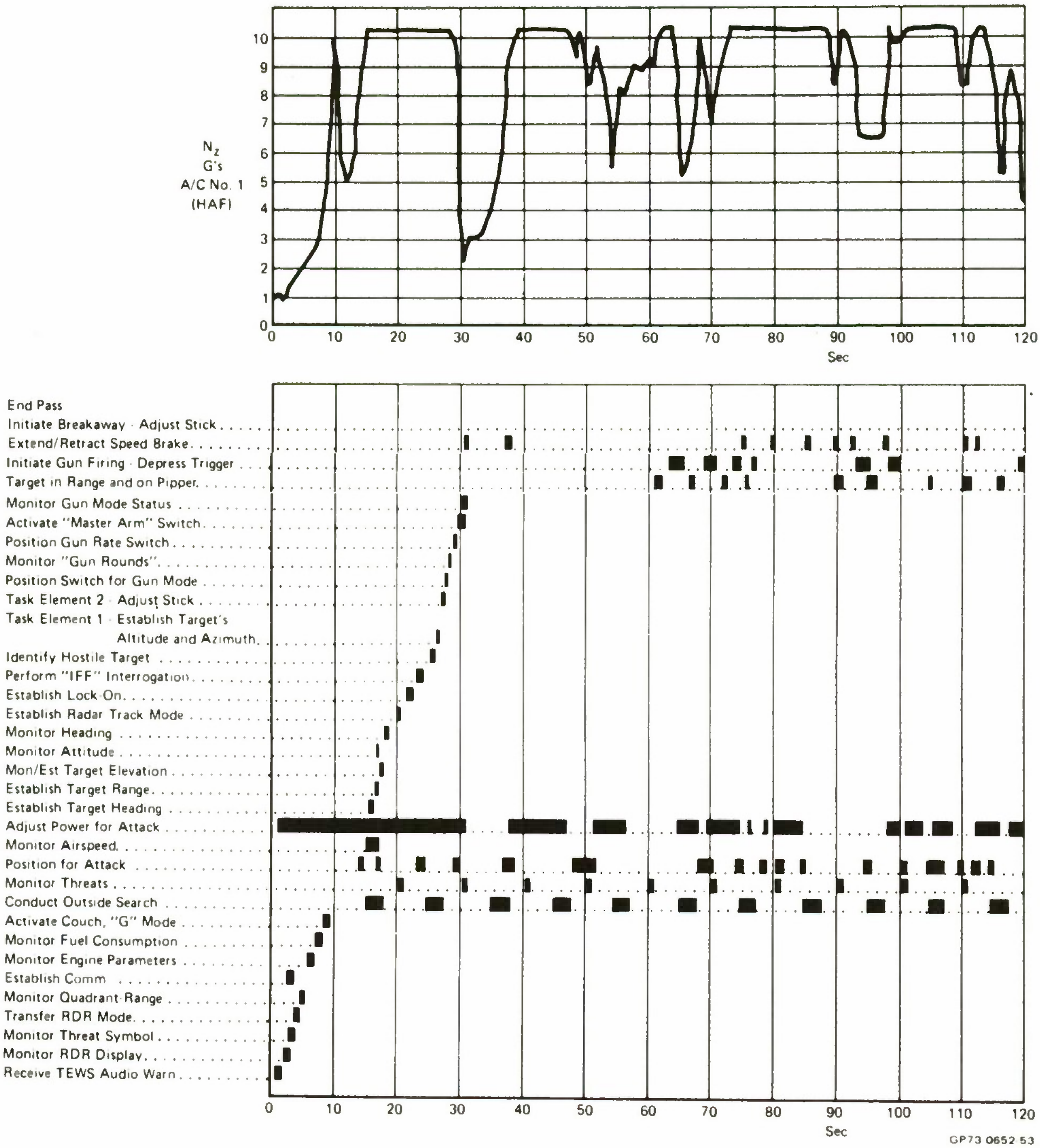


FIGURE 30
PILOT WORKLOAD DURING MANEUVERING

Task No.	Title
16	Position for attack
17	Activate Direct Lift Cont
19	Adjust Power for Attack
20	Extend and retract speed brake
35	Select SRM Weapon Mode
36	Verify Missile Status
37	Activate Master Arm
38	Verify STBY Indic; Change to RDY
39	Verify "Cool" Option on Stores Indicator
40	Verify "Scan" Option on Stores Indicator
43	Position Seat for Maneuvering
50	Select GUN WEAPONS MODE
51	Monitor Rounds Remaining Readout
52	Select GUN FIRE RATE HIGH
57	Track Target
58	Maneuver for GUN Solution
60	Depress Trigger to Initiate Gun Firing
65	Monitor Bingo Fuel Light.

SESSION 14 - INFLIGHT REFUELING

Objective: Inflight Refueling tasks are performed in order to evaluate configuration compatibility with this mission phase.

Approach: Following the air combat segment, the aircraft join up and proceed to a rendezvous with a tanker aircraft. Navigation tasks are required to locate the tanker, pre-refueling procedures are performed, and refueling configuration tasks are performed by the pilot. Positioning the aircraft for hook-up is facilitated by the direct force capabilities which can be used for precision control of the aircraft attitude. Communications between the boom operator and refueling pilot comprise almost a third of the tasks in the segment. Boom hook-up is performed, fuel transfer accomplished, and the boom disconnected successfully. Post refueling checks are done and the aircraft turns for home base.

A visual presentation enhances simulation of this task. Several 35 mm slides of actual fighter aircraft refueling, as seen from the pilot's view, are presented on a screen in front of the design aid.

Data Analysis: Results are analyzed to evaluate the effect of the independent test variables on this mission phase. Pilot workload is analyzed for signs of configuration effects. As a minimum, the following critical inflight refueling task responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
6	Verify RDR Mode A/A
7	Check Master Arm on Safe
22	Activate VI Mode
39	Set Slipway Switch to Open
40	Observe Slipway Rdy Lt Illum
43	Maneuver to Pos Behind/Aligned with Tanker
49	Set Radar Mode to Standby
53	Maintain Precise Refueling Position with DSF and DLF
55	Observe Ready Lt "Off" when Nozzle Latched
57	Monitor Fuel Qty Ind for Complete Trans
63	Maintain Precise Refuel Position Till Cleared.

SESSION 15 - APPROACH/LANDING

Objective: Approach and landing tasks are performed in order to evaluate pilot task performance with each control/display configuration.

Approach: Following an inbound cruise leg similar to the outbound segment but with fewer equipment checks, an enroute descent with IFR is made, a TACAN hold initiated, and penetration begun following ground control approval. A typical ILS approach and landing is also tasked for the pilot.

Data Analysis: Subjective pilot responses are tabulated and analyzed to provide a relative ranking of configurations in terms of pilot acceptance. As a minimum, the following critical approach and landing pilot responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
11	Select NAV AIDS
12	Select ILS/TCN STEER MODE
13	Select Chan Sel
13A	Depr Keys to Desig Chan and Verify
13B	Depr Enter
16	Select HSI COURSE (193)
31	Maintain Inbound TCN COURSE
34	Monitor DME Counter
38	Adj Pitch to Maintain Altitude FL200
115	Select ILS/NAV STEER MODE
142	Extend Landing Gear
143	Monitor Gear Lights
145	Set Landing Lights Switch to ON
150	Maintain Glide Slope and Heading
155	Retard Throttle
156	Position Flight Controller for Landing
162	Directional Control using Rudder Pedals
165	Brake as necessary.

SESSION 16 - POST FLIGHT

Objective: Post Flight task simulation, like Preflight task simulation, serves to evaluate the different configurations in terms of their impact on the performance aspects of this mission phase.

Approach: Post-landing procedures include taxiing from the active runway, basic ground operations, de-armament, engine shutdown, and execution of functional check lists.

Data Analysis: Results are analyzed to provide a measure of the effect of the different configurations on mission phase task performance and mission phase success. As a minimum, the following critical post flight pilot responses are analyzed with an analysis of variance (ANOVA):

Task No.	Title
3	Retract Speed Brake
6	Set Landing/Taxi Lights Switch as Reqd
7	Set Radar Power Control to OFF
15	Verify Fuel Dump Switch Normal
19	Check Master Arm in Safe
22	Apply Brakes to Stop in Arming Pit
33	Check Fuel Slipway Override Closed
36	Position all Switches/Controls to OFF
37	Disconnect All Personnel Equipment Leads.

SESSION 17 - EMERGENCY

Objective: Purpose is to provide a functional task evaluation based upon a discrete emergency ejection scenario. The following subjective measurements of pilot tasks are recorded:

- o Pilot task performance (yes, no, maybe)
- o Pilot opinions.

The results provide:

- o Evaluation of high acceleration cockpit concepts
- o Determination of indices of pilot workload for configuration alternatives
- o Pilot acceptance based on fulfillment of functional task objectives
- o Tangible basis for establishment of ejection research and development goals.

Approach: Emergency procedures are reviewed to determine the extent to which they are impacted by incorporation of high acceleration cockpit concepts. Those reviewed appear to be impacted in the same manner by the inclusion of the HAC seat as in a conventional aircraft.

Any emergency which occurs at a time when the seat is in the full upright position can be handled using standard emergency procedures. If the emergency should occur at a time when the seat is in the full reclined (65^o) position, it is anticipated that the emergency can be handled from that position or the seat returned to the full upright position, and the emergency handled using standard procedures.

At any time an emergency situation is indicated, the pilot attempts to take appropriate action to cancel that emergency. The pilot may elect to eject from the aircraft at any time he feels that any action is no longer feasible or the situation is too grave to spend any more time at a solution. These tasks are performed by the pilots during this test session.

Data Analysis: The subjective pilot responses are tabulated and analyzed to provide a means of comparing the relative pilot acceptance of each ejection configuration (side, D-ring, and face curtain).

SESSION 18 - PAIRED COMPARISON QUESTIONNAIRE

Objective: A subjective evaluation of the design aid (controller concepts and crew station) is conducted to determine controller requirements for normal flight and the high acceleration combat mode with the articulating seat concept. Pilot acceptance is determined by use of a subjective poll and subsequent statistical evaluation techniques to rank their desires and compare these with test results.

Approach: Evaluation of largely qualitative factors such as controls and displays has always proven to be a challenge. The large number of relevant factors to be considered in the design aid evaluation by the four test subjects requires application of a disciplined approach to data analysis. An approach which has been used successfully involves the "Method of Paired Comparisons" to process basic qualitative judgement data. The "Method of Paired Comparisons" allows the test subject to identify his preference for one item over another. Repetition of this process results in a preference ranking for all of the design aid items. Therefore, an organized procedure is provided to rank items by an individual subject. This method is often regarded as the most adequate way of securing value judgements. This decision theory technique can be readily applied to the analysis of data obtained from the design aid evaluation to obtain a quantitative ranking of the candidate concepts.

The subject's task at any one moment is simplified to the utmost because he has only two design aid items being considered. He compares these in a certain respect, passes to another pair, and so on until all the items have been judged. In preparing his shuffled list of all the pairs to be given, an evaluator can guard against time and space errors by placing each design aid item first in some pairs and second in others. If every specimen is paired with every other one, the number of pairs is n(n-1)/2, which makes 190 pairs of 20 design aid items. The job can be legitimately shortened (e.g., break up a long series of design aid items into two or more overlapping series).

Data Analysis: Prior to conducting the experiment a tabular form is prepared similar to the completed example shown in Table 6. Each design aid item is assigned a row and column. If, for example, a subject prefers A to B, the letter A is written at the intersection of the A column and the B row. When all the choices have been made, the choice scores (C scores) are established. To obtain the percent score or P score, each C score is divided by (n-1). There are checks: the sum of the C scores must be n(n-1)/2; and the average P score must be .50.

TABLE 6
SUBJECTIVE RANKING VIA PAIRED COMPARISONS

Identify Evaluation Categories
(e.g.: Controls, Display, Seat Related, Geometry)

Construct Comparison Matrices within Categories
(e.g.: Digital, Scale, Dial, Combination Displays)

Compare Matrix Items, by Pairs

Design Aid Items	A	B	C
A	o	A	A
B		o	B
C			o

Comparison Score and Ranking
A = 2
B = 1
C = 0

Rank Selected Variables
- Comparison Score, Simple Ranking
- Percent Score, Relative Ranking

Each C score tells how often a particular design aid item dominated the selection and the corresponding P tells in what percent of cases it dominated. Dominance is determined over over the entire series of design aid items. It is reasonable, accordingly, to handle Paired Comparison data on the following basis:

the experiment is equivalent to one with constant stimuli, the given field of items takes the place of a single standard; and the P values can legitimately be converted into a normal standard deviate (or z-value). The use of z-scores is certainly desirable; and several techniques are available for conversion of percent scores to normalized deviates.

These scales should not be misunderstood. They do not state, for example, that a design aid item was judged twice as good as another. They only state that one item stood midway between two others. The numbers mark off distances along a continuum, some longer than others, and Paired Comparison data provide a measurement of these relative distances to provide a ranking of the subjective judgements.

This paired comparison approach provides a significant improvement over previously reported control/display analyses. When combined with the objective measures, a meaningful evaluation of the high acceleration cockpit concept results.

SESSION 19 - PILOT INTERVIEW QUESTIONNAIRE

Objective: This session's objective is to provide another measure of pilot acceptance based on fulfillment of mission functional task objectives using the high acceleration cockpit configuration options.

Approach: The pilots are presented with a questionnaire or questionnaires during their free simulation time. The questions are short answer type with yes/no multiple choice answers qualified by a confidence/intensity rating and further qualified by pilot remarks. Collection of these three responses (i.e., rating, confidence/intensity, and remarks) to each question aids in the determination of the influence of each item questioned on the other subjective and objective results.

This session's primary purpose is to collect comments related to control/display design, grouping and locations. In addition, the design aid questionnaire will consider vision (external and internal), seat adjustment, back angle, body support, restraint and escape systems. As a result, the alternate display and fire control configurations are evaluated as an integral part of the controller designs.

As a minimum, pilot opinions on the following design concepts are requested for each configuration developed in the normal flight and combat positions:

o Over-the-nose and over-the-side visibility

o Leg position

- Aft visibility and head rest
- Windshield design
- Overall cockpit layout for each configuration
- Control/display locations and grouping
- Integrated multipurpose displays
- Radar, lighting, fuel management, armament, FBW, inertial navigation, propulsion, oxygen, environmental control and electrical control panels
- Flight mode select, flight instruments, engine starter, ECM, and communication and identification panels
- Throttle and flight controllers
- Vertical situation display, horizontal situation display, and head-up display
- Test and checkout panel, computer interface (keyboard), and electrical control panel
- Canopy concepts, landing gear actuator handle, ejection handles, and warning/emergency provisions.

SESSION 20 - POST DEBRIEFING/CONCEPT CRITIQUE

Objective: The objective is to provide a final measure of pilot acceptance and to establish potential R&D goals.

Approach: The pilots are interviewed as a group. In general, this session is an open exchange of ideas and comments related to design aid demonstration/evaluation.

Data Analysis: Comments are related to the questionnaire results.

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SECTION V

SUBJECTS, SCHEDULING, AND TEST DURATION

Four test subjects are provided by the Air Force with the following background prerequisites:

- Jet pilots
- Current flight status in fighter type aircraft (F-4, F-105, F-111, etc.)
- Air combat experience
- Air-to-ground weapons delivery experience
- ACM experience.

Each subject brings with him to the test his personal flight equipment. This equipment includes:

- Flight helmet
- Oxygen mask
- Gloves
- Anti-G suit.

By requiring subjects to provide their own equipment, the time required to procure and fit equipment is saved. The possibility of ill-fitting equipment interfering with the testing also is eliminated.

The scheduling of the twenty sessions listed in Section IV requires that two pilot subjects be tested each week for two successive weeks. Scheduling pilots in this manner allows both pilots to be kept active for the week of the test.

The anticipated duration of the test sessions is shown in Table 7. The total time for the entire test period is approximately twenty-six hours. Four days are allowed for testing each of the two pilot pairs. Figure 31 shows the relationship between the time required for each of the mission test sessions (7 through 16).

Using the session durations above and the four day testing time frame for two pilots, the schedule shown in Table 8 was formulated. This schedule allows the testing to begin on Monday and finish on Thursday. In addition to the experimental evaluation, a prebriefing session, pilot interviews, and a postbriefing session are included.

TABLE 7
TEST SESSION DURATION

Session	Hours
Pre-Briefing	4.00
1 - Pilot Background Questionnaire	1.00
Pilot Measures:	
2 - Visual Envelope	0.50
3 - Anthropometric	0.75
4 - Physical Reach and Interference Envelopes	0.75
5 - Task Performance	0.50
6 - Eye and Head Movement	1.00
Functional Task Evaluations:	
7 - Pre-Flight	2.00
8 - Instrument Takeoff and Climb	0.40
9 - Cruise	1.00
10 - SAM Evasion	0.40
11 - Bomb Delivery	0.40
12 - Strafing Pass	0.50
13 - Air Combat Maneuvers	0.60
14 - In-Flight Refueling	0.40
15 - Approach/Landing	1.00
16 - Post Flight	0.40
17 - Emergency	0.40
Questionnaire:	
18 - Paired Comparison Questionnaire	6.00
19 - Pilot Interview Questionnaire	2.00
20 - Pilot Debriefing/Concept Critique	2.00
Total:	26.00

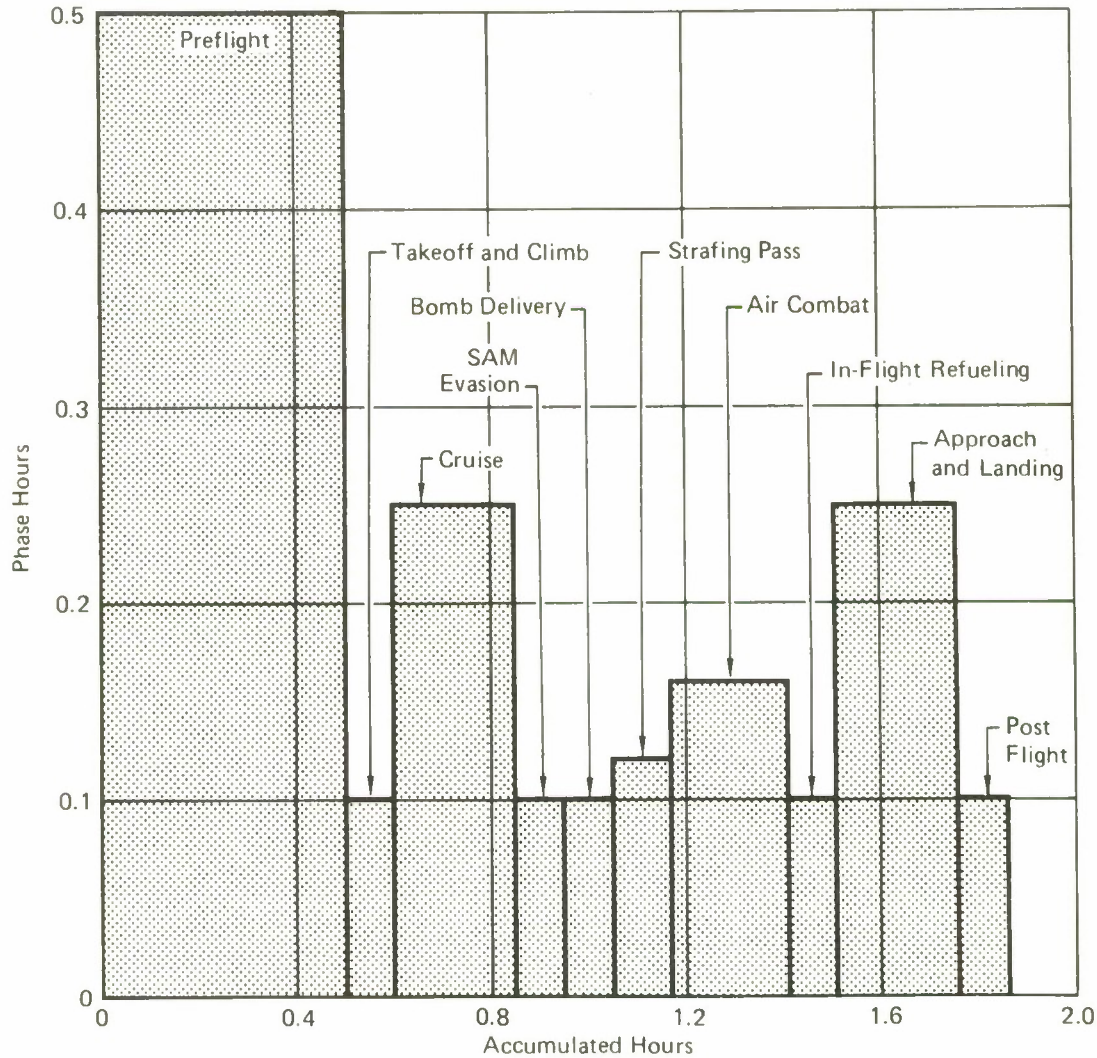

FIGURE 31
MISSION TEST DURATION

TABLE 8
TEST SCHEDULE
4 Test Configurations

DAY	TIME	FUNCTION: PILOT 1	FUNCTION: PILOT 2
1	AM	Pre-Briefing	Pre-Briefing
	PM	1 - Pilot Background Questionnaire 2 - Visual Envelope 3 - Anthropometric 18 - Paired Comparisons	4 - Physical Envelopes 5 - Task Performance 6 - Eye Movement 18 - Paired Comparisons
2	AM	4 - Physical Envelopes 5 - Task Performance 6 - Eye Movement 18 - Paired Comparisons	1 - Pilot Background Questionnaire 2 - Visual Envelope 3 - Anthropometric Sessions 7-17 (Mission) Configuration B
	PM	Sessions 7-17 (Mission) Configuration A	Tour
		Tour	Session 7-17 (Mission) Configuration D
3	AM	Sessions 7-17 (Mission) Configuration B	18 - Paired Comparisons
		18 - Paired Comparisons	Sessions 7-17 (Mission) Configuration E
	PM	Sessions 7-17 (Mission) Configuration D	18 - Paired Comparisons
		Tour	Sessions 7-17 (Mission) Configuration A
4	AM	Sessions 7-17 (Mission) Configuration E	18 - Paired Comparisons
		18 - Paired Comparisons	19 - Pilot Interview Questionnaire
	PM	19 - Pilot Interview Questionnaire	Tour
		20 - Pilot Debriefing/ Concept Critique	20 - Pilot Debriefing/ Concept Critique

SECTION VI

TEST EQUIPMENT

Evaluation of the design aid is conducted in the Human Performance Laboratory (HPL). The HPL consists of five basic areas: vision laboratory, auditory laboratory, engineering anthropology/human engineering area, computer area and video crew task evaluation facility (Figure 32). The high acceleration cockpit design aid is evaluated in the video crew task evaluation facility.

All the equipment required to achieve the primary objectives of the evaluation is available in the HPL. Access to the test area can be controlled and external distraction held to a minimum. The following equipment is required for the test:

- Bell and Howell, color, one inch, video tape recorder, Model 2932
- Sony, color, half inch video tape recorder, Model AVC 8600
- Sony video camera, Model AV 3400
- Conrac, 25 inch video monitor, black and white
- Panasonic audio cassette tape recorder
- Allied seven inch reel to reel audio tape recorder
- American Optical Screening Perimeter
- Eye/head movement measuring technique.

The video crew task evaluation facility contains a variety of video recording and playback equipment. A number of different type video recorders, cameras and monitors are available. Both black/white and color recording/playback are possible. Other equipment available includes special effects generator, character generator/titler, overhead quartz studio lights, background curtain, microphones and head phones. By using the special effects generator, it is possible to record from two cameras simultaneously with either a split screen (horizontal, vertical or cornered) or overlay (one picture faded over the other) format.

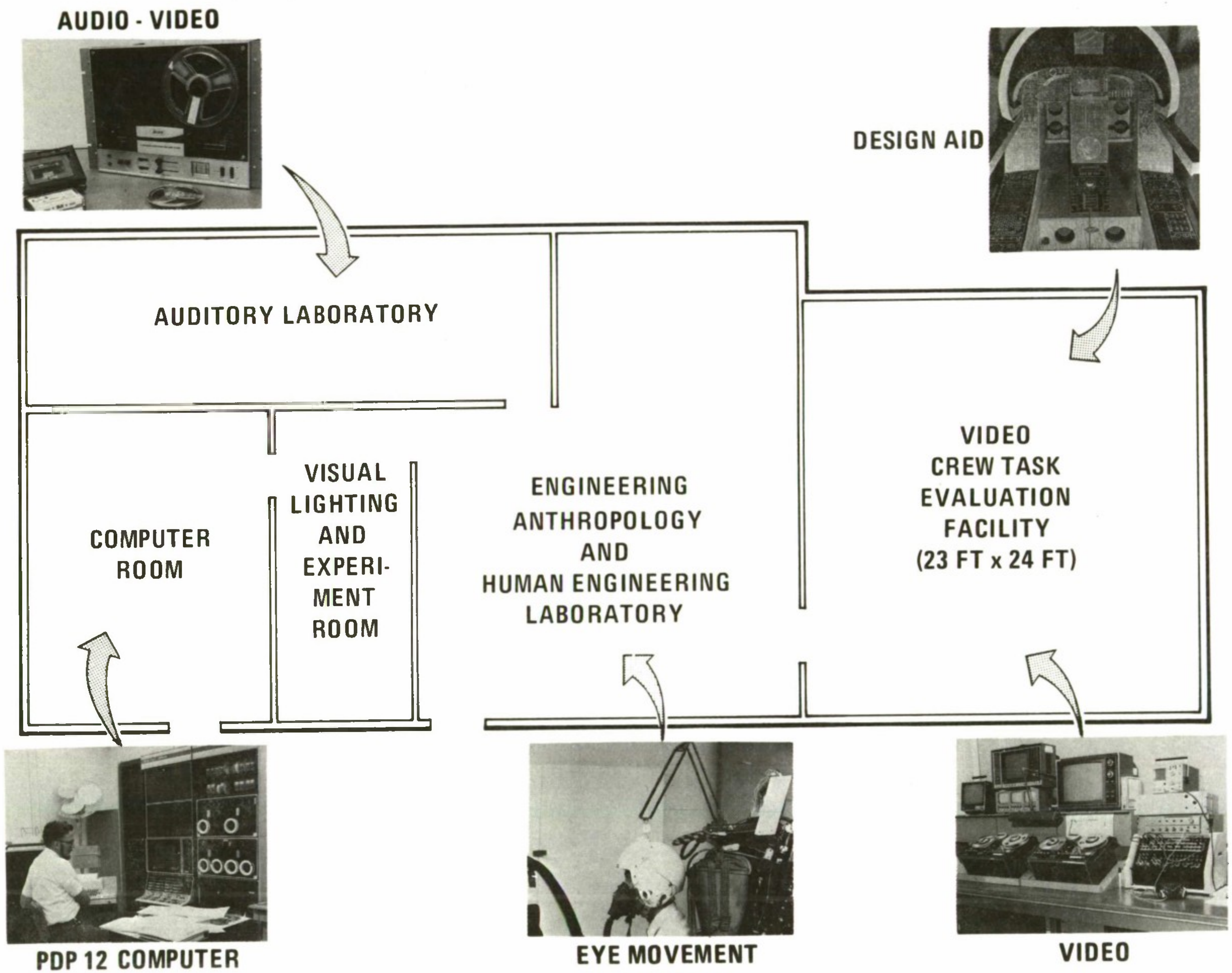

FIGURE 32
HUMAN PERFORMANCE LABORATORY

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