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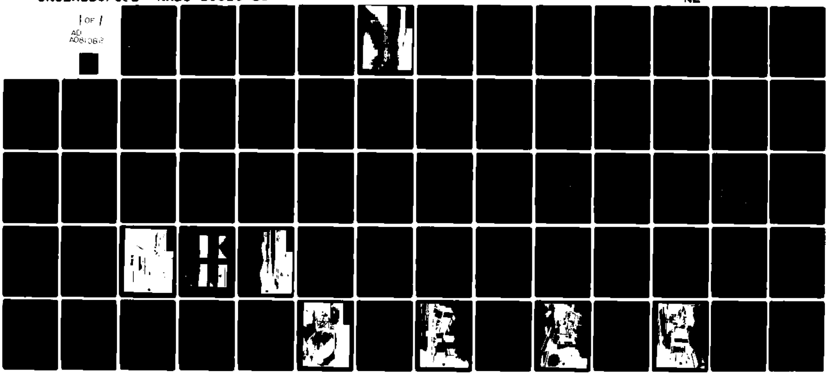

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LEVEL II

NAVAIRDEVCEN DYNAMIC FLIGHT SIMULATOR DESIGN AND MULTIPURPOSE CREWSTATION CONCEPT DESIGN AND DEVELOPMENT PLAN

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the mission task analysis and design of the NAVAIRDEVCEN Dynamic Flight Simulator, consisting of a multipurpose cockpit crewstation, a high sustained "g" motion system, a real world visual display system, a scene/target generation system, a cockpit/computer interface system, a problem control station and a number of digital and analog computers.

Summary

Introduction

The general objective of this IR/IED study task is to design a Dynamic Flight Simulator which can be utilized to address a wide spectrum of rapidly applied and sustained "G" profiles and multistress flight mission problems. These flight mission problems would include the F-14 Spin Simulation Program, the High acceleration Cockpit Seat Program, and the V/STOL Transition Flight (From vertical to longitudinal) Program.

The specific objectives can be separated into 3 tasks. Task I presents the simulation mission tasks in which the NAVAIRDEVCEN should accomodate. It also analyzes the simulator parameters required to handle the simulation mission tasks. Task II presents the NAVAIRDEVCEN Dynamic Flight Simulator mission tasks and the hardware and software requirements. Task III details a design and development plan for the construction of a multipurpose dynamic crewstation and cockpit/computer interface system for the NAVAIRDEVCEN Dynamic Flight Simulator. A costs and schedule estimate for the development of the multipurpose dynamic crewstation is included.

The approach that is utilized in this IR/IED study, in presenting a multipurpose crewstation concept design, is to first address the entire NAVAIRDEVCEN Dynamic Flight Simulator design problem and then to present a development plan for just the crewstation and crewstation/computer interface portion of the Dynamic Flight Simulator.

The Dynamic Flight Simulator utilizes a human centrifuge, illustrated in Figure 1, to provide the high sustained "g" loading environment (up to 40gs) for dynamic flight simulation. The centrifuge gondola is capable of accommodating the crew station, with the crew, and as a result of its gimballing action is capable of producing almost any force vector through human tolerance, varying from short duration to long term sustaining accelerations.

The Dynamic Flight Simulator offers a number of distinct advantages, as opposed to using an aircraft, in performing rapidly applied and sustained g profile mission tasks. These include,

- Safety-Pilot/Aircraft
- Cost
- Statistical Significance
- Repeatability
- Parameter Variability

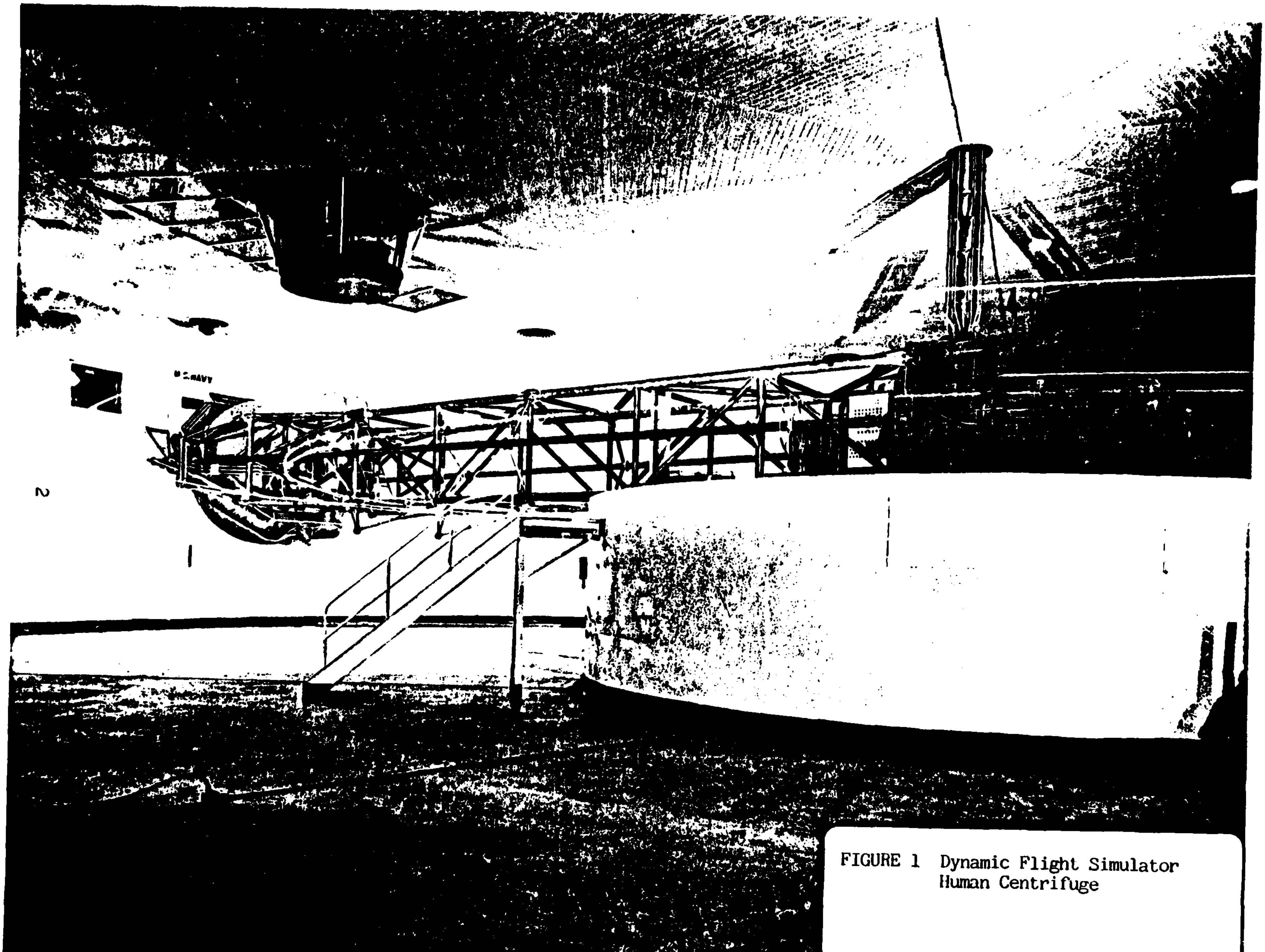


FIGURE 1 Dynamic Flight Simulator Human Centrifuge

- Broader Data Base
- Data Handling and Analysis Techniques
- System Reliability
- Theoretical Reliability
- Theoretical understanding
- Availability
- Fuel Costs
- Weather Conditions

The NAVAIRDEVCEN is addressing the problem of more efficiently using existing laboratory resources to study aircraft Systems problems which have common application across a variety of navy platforms. These resources are comprised primarily of existing NAVAIRDEVCEN simulation facilities, which will be utilized for the investigation of common system problems. Commonality in actual aircraft hardware will aid in the reduction of aircraft system procurement expenses as well a reducing logistics problems. A subsystem laboratories intepretability and planning board has been established which will determine current and future simulation mission tasks, and identify which NAVAIRDEVCEN facility is capable of handling specific elements of these mission tasks. Also, coordination of each mission task element with the total NAVAIRDEVCEN system effort is being analyzed. The Dynamic Flight Simulator is one of several simulation facilities, at the NAVAIRDEVCEN, that is being considered capable of handling specific elements of these mission tasks. The NAVAIRDEVCEN Dynamic FLight Simulator described in detail, later in this study report, consists of a multipurpose cockpit crewstation, a motion system, a real world visual display system, a scene/target generation system, a cockpit/computer interface system, a problem control station and a number of digital and analog computers.

The NAVAIRDEVCEN Dynamic Flight Simulator multipurpose cockpit design will have the flexibility of being configured into a variety of aircrafts and can utilize the basic instrumentation of that specific aircraft. The multipurpose crewstation concept, illustrated in Figure 2, consists of a general cockpit structure and platform, housing a specific cockpit panel, and "J-BOX" wiring interface enclosure. This cockpit panel assembly will be an exact replica of the particular aircraft involved in the mission task, including panel width, down vision, and pilot eye to panel dimension. The cockpit panel assembly, including the front panel, instrumentation, and cockpit/computer interface, will be constructed as a drawer, with the capability of being removed and a new cockpit panel assembly, with completely different aircraft features, being installed. A different cockpit panel assembly will be utilized for each aircraft type. The Dynamic Flight Simulator concept also includes a multipurpose cockpit/computer interface system which is compatable with the

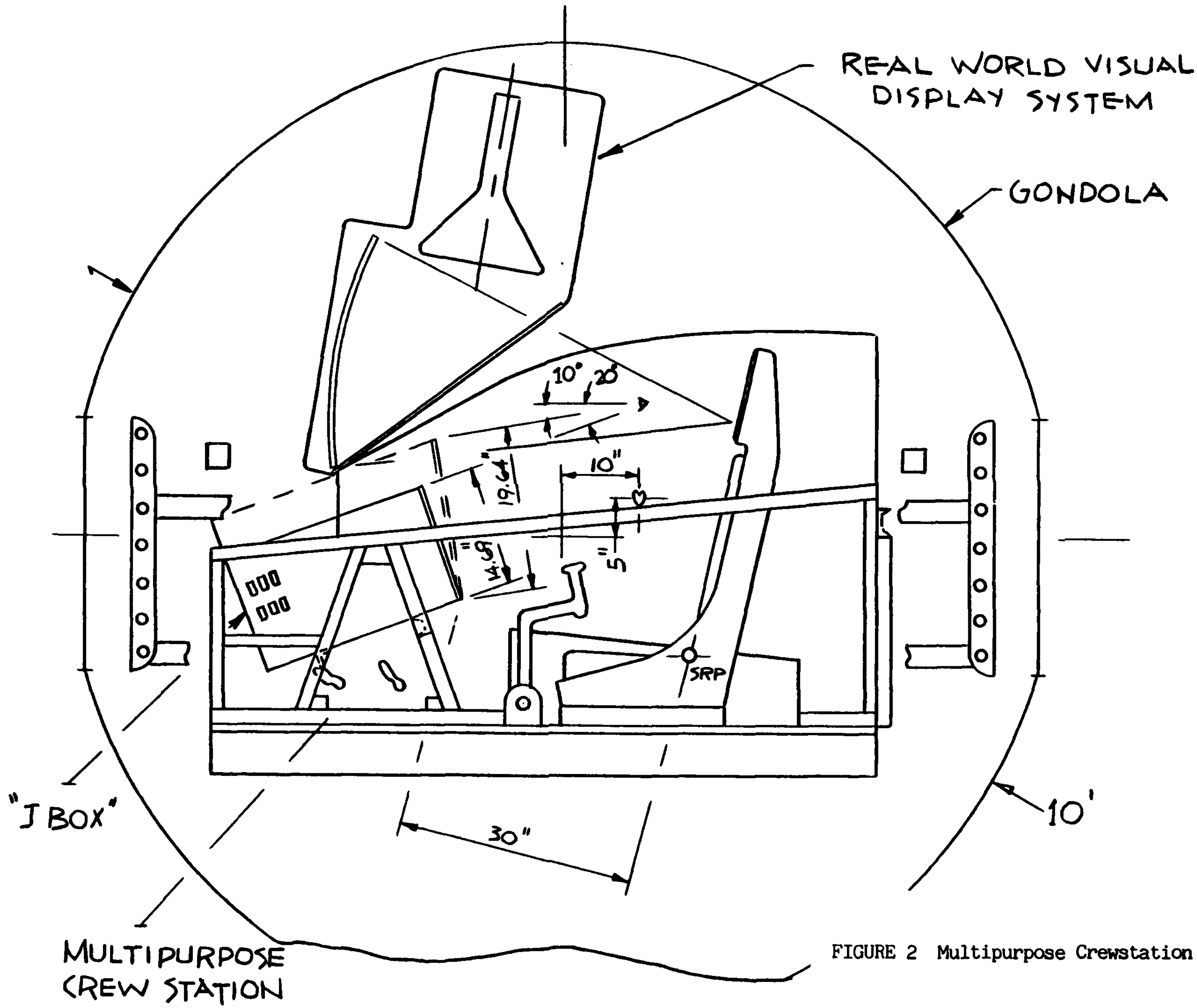


FIGURE 2 Multipurpose Crewstation

gondola slip ring wiring complement. The cockpit structure will be constructed with enough flexibility to obtain certain features of the simulated aircraft, such as cockpit width. The pilot consoles will be constructed so that the forward and side angles may be varied to conform to the simulated aircraft. Two cockpit structure stations could be utilized for a side by side cockpit configuration.

The multipurpose crewstation concept minimizes the cost of producing a specific simulator for a specific mission task, and reduces the time for developing a simulator for future mission tasks. Also, a new aircraft cockpit panel assembly can be fabricated and wired off line, while experimental design work is being conducted on the existing centrifuge cockpit.

Background

The NAVAIRDEVCEN Human Centrifuge Facility was constructed in 1952 as a dynamic simulation facility to be utilized for,

- o Medical Research
- o Psycho-Psychological Studies
- o Space Program Human Engineering

Studies

- o Astronaut Training

In recent years the NAVAIRDEVCEN Human Centrifuge has been utilized primarily for,

- o Psycho-Physiological Studies on the Effects of combined Stress on Naval aircrews.
- o NAVAIRSYSCOM Sponsored Simulation Studies.

Specific recent centrifuge programs involving the dynamic simulation of military and commercial aircraft in emergency conditions include,

1. Simulation and effects of severe turbulence on jet airline pilots
2. Evaluation of a career takeoff director system in simulated night catapult launching of the A-7 Aircraft
3. Dynamic Spin Simulation of F4 aircraft
4. Acceleration effects on the ability to activate emergency devices in the F-4 cockpit
5. Integrated simulation of atmospheric pressures and dynamic forces during accidental decompression and subsequent emergency descent of high altitude transport aircraft.

The performance and results of these specific mission tasks indicated certain centrifuge limitations. These limitations identified the requirements for,

1. Digital Computer computational capability
2. Cockpit display generator and online data acquisition/reduction
3. Improved real world visual cues
4. Aero data at high angle of attack

5. Variable force pilot stick control loader system

6. Improved centrifuge control drive algorithms

7. Improved control console

8. Solid state analog computer

9. Gimbal hydraulic drive (1st and 2nd axis)

10. Gondola third axis drive

Improvements in the Dynamic Flight Simulators capabilities are constantly being incorporated. The following list of improvement tasks in addition to those detailed in this report, are currently being pursued or require funding to accomplish.

1. Implement digital computer capability (active)

2. Purchase cockpit display generator and online data acquisition/reduction system (active)

3. Purchase real world visual display and scene generation system (preliminary funding acquired))

4. Improve centrifuge drive algorithms (active)

5. Upgrade centrifuge control console (funding required)

6. Purchase solid state analog computer (funding required)

7. Purchase centrifuge gimbal hydraulic drive for the 1st and 2nd axis (funding required)

8. Purchase centrifuge gondola 3rd axis (funding required)

The current basic NAVAIRDEVCEN Human Centrifuge Facility designated Dynamic Flight Simulator (DFS) is described in Appendix A of this report.

This IR/IED study basically deals with the cockpit crewstation, and required cockpit/computer interfaces, portion of the NAVAIRDEVCEN Dynamic FLight Simulator. The design of a multipurpose cockpit crewstation and cockpit/computer interface system would enable a more efficient utilization of the NAVAIRDEVCEN Dynamic Flight Simulator and therefore provide the capability of handling a larger volume and variety of dynamic simulation mission tasks.

Conclusions

The NAVAIRDEVCEN Dynamic Flight Simulator will provide the Department of Defense with the only dynamic flight simulator in which solutions to a wide spectrum of man/machine interface problems can be safely evaluated in a rapidly applied, sustained g, multi-stress flight environment, throughout the entire flight regime of a modern high performance aircraft. A summary of the primary mission tasks (requiring high sustained "g" force/motion environment), and the secondary mission tasks (not necessarily requiring high sustain "g" environment), which the Dynamic Flight Simulator should accomodate, are listed below. Included under the mission tasks are specific planned/proposed Dynamic Flight Simulator programs.

Primary Mission Tasks

- o Specific Planned/Proposal Programs

1. Survivability and Vulnerability
   - o F-14 Spin Simulation Program
2. Flight Performance-Transition
   - o V/STOL Flight Transition Program
3. Equipment Test and Evaluation
   - o High Acceleration Cockpit Program
   - o Personnel Restraint System Program
   - o Integrated Protective System
4. Human Factors Physiological and Environmental
   - o Combined Stress Program
5. Training-Familiarization
   - o F-14 Spin Simulation Program

Secondary Mission Tasks

1. Takeoff and Landing
2. Air Combat meneuvering
3. Weapon Delivery
4. Human Factors - Task Loading
5. Human Factors - Automatic Decision Aids

It is difficult to provide an exact cost figure for a simulated aircraft system without specifically detailing the aircraft type and the active instrumentation, so the cost estimates in this report will be based on a typical flight simulator with selected instrumentation, as illustrated in Figure 3. The most immediate program which would utilize the Dynamic Flight Simulator is the F-14 Spin Simulation program. The cockpit panel configuration will be an exact replica of the F-14 aircraft and the selected instrumentation will include equipment normally utilized on a typical fixed winded aircraft, as well as the F-14 aircraft. No equipment will be supplied that is specifically designed for the F-14 aircraft This equipment will be funded by the F-14 Project Office.

Existing NAVAIRDEVCEN equipment will be utilized whenever applicable. In addition, equipment not specifically related to proving the multipurpose crewstation concept, such as the real world visual display system, will be funded separately.

The hardware and software development cost for the design, fabrication and checkout of the Dynamic Flight Simulators multipurpose crewstation and cockpit/computer Interface system is about 360K. A development cost breakdown includes,

W1 Software (W1.1-W1.5)	
Inhouse Labor	
Engineering (4 man months) (5K/mo) =	20.0K
Shop/Tech. (0 man months) (4.2K/mo) =	0.0K
Materials/Computer	10.0K
Contracts	0.0K
Sub Total	30.0K
W2 Hardware (W2.1-W2.5)	
Inhouse Labor	
Engineering (18.5 man months) (5K/mo) =	102.5K
Shop/Tech (29.5 man months) (4.2K/mo) =	124K
Materials/Computer	45K
Contracts	60K
Sub Total	331.5
Multipurpose crewstation Development Cost Total	361.5K

The multipurpose crewstation development software will be limited to a minimal amount of computer costs and software labor required to integrate, checkout and demonstrate the basic concept. The software required to drive the human centrifuge, cockpit instrumentation, displays, flight controls etc, will have to be provided by a specific program.

In summary, the multipurpose cockpit crewstation portion of the Dynamic Flight Simulator, which includes the cockpit, structure, instrumentation, displays, flight controls, panels, and cockpit/computer interface system requires about 361.5K in funding, so that the feasibility of the design concept can be validated.

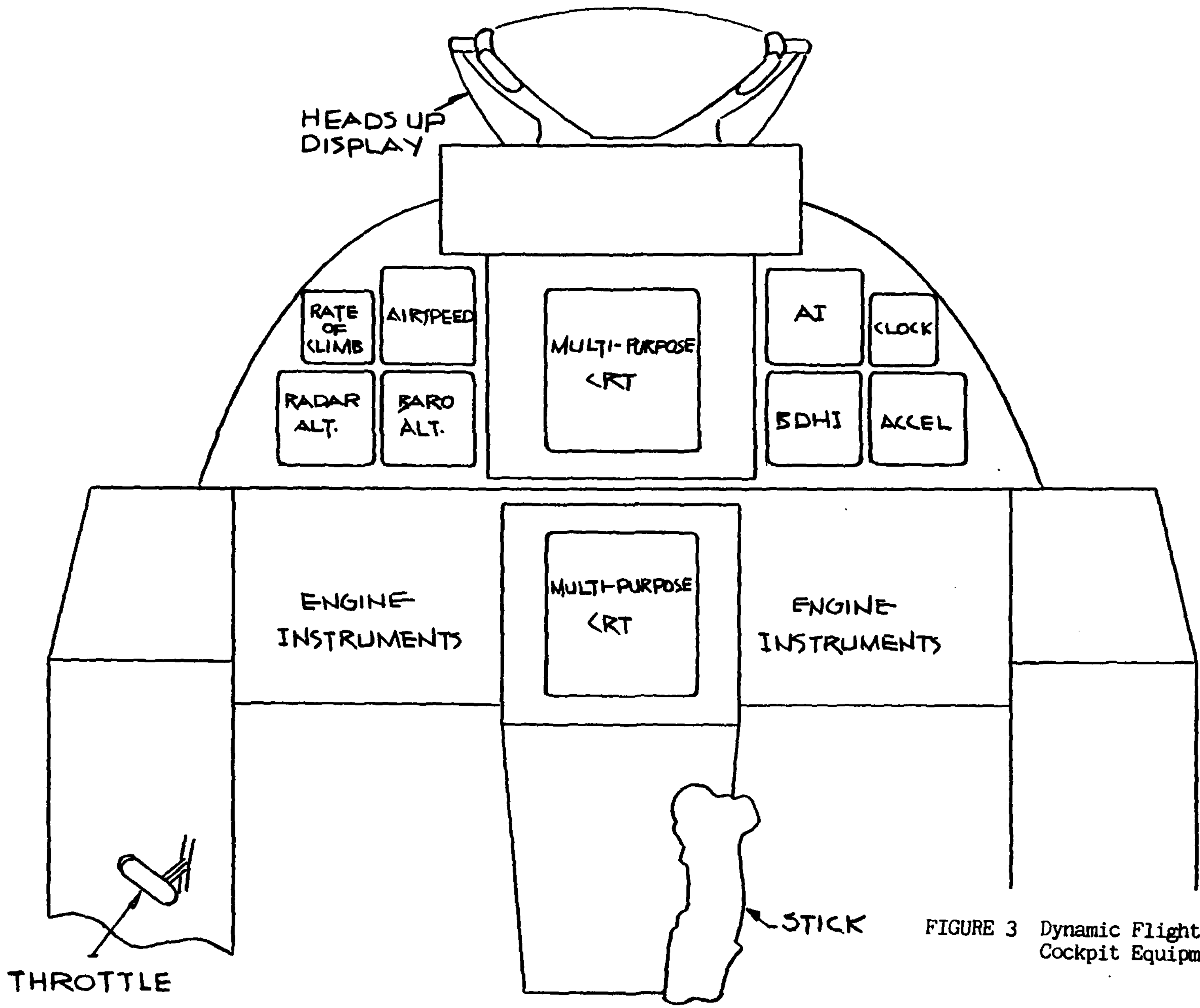


FIGURE 3 Dynamic Flight Simulator Cockpit Equipment

Recommendations

The NAVAIRDEVCEN Dynamic Flight Simulator Development Plan report should be utilized to obtain funding to fabricate an experimental multipurpose crewstation prototype, so that the feasibility of the design concept can be validated.

A real world visual display system should be purchased and utilized with the multipurpose crewstation as an integral part of the NAVAIRDEVCEN Dynamic Flight Simulator.

TABLE OF CONTENTS

List of Figures

List of Tables

I Dynamic Flight Simulator Mission Tasks and System Parameters

A particular programs mission tasks and systems parameters must be analyzed to determine if the Dynamic Flight Simulator is the type of simulator to be utilized for the program. Also, the Dynamic Flight Simulators capabilities must be analyzed to determine if this program could be adequately performed on this specific simulator. Obviously, a criteria must be formulated to provide the guidance necessary to determine if a program is ideally suited for the Dynamic Flight Simulator, and to determine the simulator requirements. The following sections will detail a list of potential mission tasks in which the NAVAIRDEVCEN Systems resources should accomodate. Also, a list of simulation system parameters will be presented. A criteria will be formulated to determine what mission tasks should utilize the Dynamic Flight Simulator. These mission tasks will be analyzed to determine the Dynamic Flight Simulators hardware requirements.

1. Simulation Mission Tasks

A representative list of simulation mission tasks in which the NAVAIRDEVCEN should accomodate should include those presented in Table 1.

Table 1

NAVAIRDEVCEN Simulation Mission Types/Tasks

(1) Flight Performance (Pilot Function)
- o Airways Navigation
- o Operational Navigation
- o Takeoff and Landing
- o Air Combat Maneuvering
- o Flight Transition (V/STOL)

(2) Tactics (Crewmen Function)
- o Target Tracking
- o Contact and Tracking Correlation
- o Tactical Execution
- o Tactical Aids

(3) Sensors (Crewmen Function)
- o Detection
- o Detection
- o Classification
- o Sensor Improvement

(4) Weapons (Pilot and Crewmen function)
- o Weapon Launch Decisions
- o Target Identification
- o Air to Air Weapon Delivery
- o Air to Ground Weapon Delivery

(5) Hardware Systems (Equipment Function)
- o Vehicle Interface
- o Equipment Test Evaluation (Displays, Instruments, Flight Controls, etc.)

(6) Software Systems (Equipment Function)
- o Computer Processing Architecture
- o Computer Hardware
- o Software Routines

(7) Human Factors (Man-Machine Systems Function)
- o System Control and Management
- o Survivability and Vulnerability
- o Automatic Decision Aids
- o Task Loading
- o Functional Requirements Multi-sensor Correlation
- o Multi-Sensor Correlation
- o Information Distribution
- o Environment Considerations

(8) Training (Training Function)

o Familiarization

The mission tasks are somewhat general and; therefore would have to be broken down further into sub tasks, to specifically determine the optimum simulator to utilize with these tasks. This study, however, will deal with these general mission tasks and attempt to provide hardware requirement guidelines to determine a criteria for the selection of the general mission tasks that should be accomodated on the Dynamic Flight Simulator.

2. Simulator System Parameters

Simulation is a never ending series of compromises because the parameters involved in producing a man-machine flight simulator are usually not well defined at the initiation of a program. Some engineers insist that the cockpit configuration of a flight simulator must be an exact replica of the aircraft being simulated. This is not always practical because in order that the simulator construction is delayed until final cockpit information is available, valuable fabrication time is lost and there is a possibility that the flight simulator will not be completed in time to have an impact on the program. Other engineers feel that if the cockpit configuration of a flight simulator were built to a generic configuration the simulation would not only be completed early in the program, but this flight simulator could be used for other programs. One problem with this approach is that some simulation flight missions, such as training, require the simulator to approach an exact replica configuration. Another problem is that the cockpit configuration of a fixed wing aircraft is considerably different than that of a helicopter configuration, which adds to the problems of using one flight simulator for both aircraft types. Most flight simulators, including those at the NAVAIRDEVCEN, have compromised the problem by utilizing a combination of both generic and exact replica cockpit configuration disciplines. Another type of simulator configuration, designated, Integration laboratory, utilizes actual aircraft system, usually in a generic configuration. This simulator is not utilized for man-machine experimental design functions but rather to check out the interface of actual aircraft equipment and the software programming involved in the aircraft system.

The following is a list of the primary simulator cockpit configuration utilized at the NAVAIRDEVCEN.

1. Generic (Functional Requirement Function)

2. Generic and exact replica combination (experimental design function)

3. Exact replica (training function)

4. Aircraft equipment integration (interface and software function)

The NAVAIRDEVCEN includes simulator cockpit configurations of each of these categories. In order to address the multiplicity of systems problems a variety of simulator configurations, utilizing a variety of simulated and actual aircraft equipment, will be necessary. It is important to determine the capability of each of these simulators so that a particular common mission task can be properly located on a specific simulator, and that this simulator has the necessary hardware and software capability to handle the mission task.

In order that a man - machine flight simulator is properly developed for a mission task several general hardware and software requirement must be specified. A representative list of simulator Parameter information data should include,

(1) Simulator Cockpit Configuration
- o Generic
- o Generic and Exact Replica Combination
- o Exact Replica
- o Integration Lab

(2) Aircraft Type
- o Fixed Wing
- o Helicopter
- o V/STOL

(3) Cockpit Seating configuration
- o Single Seat
- o Side by Side
- o Tandem
- o Three Crewmen
- o Four Crewmen

(4) Cockpit Flight Controls
- o Control Stick
- o Side arm controller
- o Collective
- o Throttle
- o Rudders

(5) Cockpit Instrumentation
- o Airspeed indicator
- o Barometric altimeter
- o Radar altimeter
- o Attitude Indicator
- o Horizontal Situation Indicator
- o Rate-Of-Climb Indicator
- o Accelerometer
- o Angle of attack
- o Clock

(6) Cockpit Displays
- o Multipurpose
- o Vertical Situation Display
- o Horizontal Situation Display
- o Heads Up

(7) Aircraft Inflight Cues
- o Real World Visual
- o Motion
- o "G" Suit
- o "G" Seat

(8) Sensors
- LOFAR
- DIFAR
- CASS
- MAD
- Radar
- ESM

(9) Computers
- Digital (Central)
- Digital (Mini)
- Digital (Microprocessor)
- Analog

(10) Cockpit/Computer Interface
- A/D Converters
- D/A Converters
- Synchro Converters
- Cockpit "J Box"

After a determination has been made, regarding the general simulator hardware and software requirements necessary to perform a particular mission task, specific hardware and software requirement information should be detailed for the following simulator subsystems

- Cockpit (including instrumentation, displays, switches, indicators, communications and flight controls)
- Motion
- Visual Display
- Scene/Target Generator
- Cockpit/Computer Interface
- Problem Control Station
- Computer

This detailed simulator subsystem information should include,

<u>(1.) Cockpit</u>

PANEL CONFIGURATION

- Down Vision Angle (degrees)
- Panel Width (inches)
- Pilot Eye to Panel Distance (inches)

COCKPIT DISPLAY

- Input output signals
- Display screen size (in, cm)
- Resolution (arc min)
- Brightness (fL)
- Contrast (ratio)
- Display image sizes (in., cm)
- Display functions

- o Writing speed an refresh ratio (in/usec. cm/usec)
- o Phospher color
- o Linearity (percent)
- o Allowable distortion (percent)
- o Bandwidth (MH)
- o Additional features including phospher protection, high-voltage protection, gamma correction

(2) <u>Motion System</u>

- o Degrees of Freedom
- o Total payload (lb, gram)
- o Motion displacement (longitudinal, lateral, and vertical) ($\pm$ in, $\pm$ cm)
- o Motion velocity (longitudinal, lateral, and vertical) (in sec, cm/sec)
- o Motion acceleration (longitudinal, lateral, and vertical) (in/sec, cm/sec)
- o Motion rotation (roll, pitch, and yaw) (degrees/sec)
- o Motion rotational acceleration (roll, pitch, and yaw) (degrees/sec)

(3) <u>Visual Display</u>

- o Field of view (degrees horizontal, degrees vertical, degrees downward)
- o Brightness (fL)
- o Depth of field
- o Contrast (ratio)
- o Exit pupil diameter (in.cm)
- o Picture color (black and white or chromatic)
- o Geometric distortion (percent)
- o Collimination error (arc min of convergence, divergence, and dipvergence)

(4) <u>Scene/Target Generator System</u>

Computer Generated Scene

- o Color (black and white or chromatic)
- o Input/Output signals
- o Special features (curved surface shading, edge smooting, variable fog, aerial perspective, broken clouds, texturing, etc.) yes or no
- o Number of display edges
- o Number of stored edges
- o Video raster (number of TV lines)
- o Scan rate (number of frames per second)
- o Number of point lights
- o Number of channels
- o Special-purpose computer (bit word site, number of words of core memory, memory expandable to words, number of hardware instructions)

Computer Generated Image Target

- o Simulated aircraft altitude (0-y, 0-y m)
- o Simulated aircraft attitude (degrees)
- o Simulated aircraft angular rates (degrees/sec)
- o Simulated aircraft translational rates (ft/sec, m/sec)
- o Accuracy of simulated altitude (± ft, ± m)
- o Accuracy of simulated altitude (± degrees)
- o Accuracy of translational position (± in, ± cm)

Terrain Model Scene Generator Systems

- o Interface definition and associated equipment
- o Input/output signals
- o Special features
- o Color (black and white or chromatic)
- o Terrain and white or chromatic)
- o Terrain model scale (ratio)
- o Gantry displacement (longitudinal, lateral, and vertical) (±ft. ± meters)
- o Gantry velocity (longitudinal, lateral and vertical) (in/sec, cm/sec)
- o Gantry acceleration (longitudinal, lateral and vertical) (in/sec, cm/sec)
- o Gantry accuracy (in, cm)
- o Gantry minimum smooth track velocity (in/sec, cm/sec)
- o Optical probe field of view (degrees)
- o Optical probe field of view (degrees)
- o Optical probe movement (roll, pitch, yaw) (degrees)
- o Optical probe velocity (roll, pitch, yaw) (degrees/sec)
- o Optical probe acceleration (roll, pitch, yaw) (degrees/sec)
- o Optical probe accuracy (degrees)
- o Optical probe minimum smooth track velocity (degrees/sec)

High-Fidelity Target Generator Systems

- o Input/output signals
- o Static position accuracy (yaw, pitch, roll) (degrees)
- o Position limits (yaw, pitch, roll) (degrees)
- o Maximum slew rate (yaw, pitch, roll) (degrees/sec)
- o Minimum slew rate (yaw, pitch, roll) (degrees/sec)
- o Bandwidth (rad/sec)

(5) Computer/Cockpit Interface System

The specification headings for the computer/cockpit interface system are not included in this report.

(6) Instructor Control Station

- o Display type/number
- o Keyset type/number of keys
- o Types of instruments
- o Readouts and indicators
- o Playback capability

(7) Computers

- o Description of processing system
- o Description of display generation system
- o Description of all peripherals
- o Description of real-time system
- o Description of interface to simulation device
- o Upper level block diagram of hardware configuration
- o Word length
- o Cycle time(s)
- o Memory capacity and characteristics
- o Software language capabilities
- o Editing, debug, and diagnostic aids
- o Operating system including real-time interrupts (with priorities) for general-purpose and symbol generation
- o Software/system documentation

The following general information should be requested for each of the simulator subsystem proposed for implementation in a simulator concept:

- o Manufacturer's name and model number
- o Brief functional description
- o Illustration showing the location of major components
- o Overall size (ft, m)
- o Weight (lb, kg)
- o Power requirements (kW)
- o Cost

3. DFS Mission Tasks and System Parameter Criteria

This report will not attempt to list all of the specific subsystem requirements detailed in the previous section of this report, but will present a selected number of these requirements so that a multipurpose dynamic flight simulator can be designed. Also, some subsystem specifications such as motion are inherent in the existing human centrifuge and cannot be easily altered. The NAVAIRDEVCEN Dynamic Flight Simulator requirements; therefore will be a combination of existing features and selected subsystem requirements necessary to handle the proposed mission tasks.

The most important Dynamic Flight Simulator system parameter is rapidly applied and high sustained "g" motion, so that all mission tasks would first have to be judged to determine if high sustained "g" is a major requirement. The specific human centrifigue motion specifications are detailed in reference 1, and selected specifications are presented in section III of this report.

The human centrifuge can also provide a multi stress environment including variations in temperatures, pressures, noise, and buffeting. Each mission task should be analyzed to determine if a multi-stress environment is an important factor in the mission task performance.

Many mission tasks such as takeoff and landing, could be run on the human centrifuge, eventhough high sustained "g" forces are not required and; therefore these missions must be considered secondary utilization tasks. Secondary tasks would have to be judged on other parameter tradeoffs such as cost, schedule, etc. Other secondary tasks might include air combat maneuvering or task loading mission tasks, required as part of a primary mission task such as a spin simulation program.

Finally the overall NAVAIRDEVCEN Centrifuge Facility capability, described in Appendix A, should be utilized as a trade off judging factor in the selection of the mission tasks that could utilize the Dynamic Flight Simulator.

The multipurpose crewstation cockpit configuration should utilize a generic and exact replica combination cockpit configuration, designated in the last section of this report as an Experimental Design Simulator. Research has generally shown that functional similarity between aircraft and simulator produces greater pilot acceptance and therefore aids in his motivation.

The cockpit panel should maintain as minimum, the correct Mil Standard down vision, panel width, pilot eye to panel and ejection envelope dimensions. The cockpit panel instrument and display layout should also closely resemble the specific simulated aircraft.

High sustained "g" requirements indicates the simulation of a fixed wing aircraft; however the Dynamic Flight Simulator could be utilized for certain mission tasks with a helicopter or V/STOL cockpit configuration. The type of aircraft utilized in the Dynamic Flight Simulator will dictate the requirements for instrumentation, flight controls, displays, etc. The cockpit seating configuration will be limited to single seat and side by side because of space limitations in the centrifuge gondola. The aircraft inflight visual and motion cues will be dictated by the mission tasks. Sensor simulation mission tasks, with the possible exception of tactical radar, should probably not be done on the Dynamic Flight Simulator.

4. DFS Mission Tasks and System Parameter Requirements.

Representative simulation tasks of the type that should be addressed at the NAVAIRDEVCEN are presented in table 2, along with those primary and secondary mission tasks which could utilize the Dynamic Flight Simulator.

Table 2 Dynamic Flight Simulator Mission Tasks

Simulation Mission Tasks	Dynamic Flight Simulator	
	Primary Tasks	Secondary Tasks
(1) FLIGHT PERFORMANCE		
o AIRWAYS NAVIGATION	-	-
o OPERATIONAL NAVIGATION	-	-
o TAKEOFF AND LANDING	-	✓
o AIRCOMBAT MANEUVERING	-	✓
o TRANSITION (VERTICAL TO FORWARD)	✓	-
(2) TACTICS		
o TARGET TRACKING	-	-
o CONTACT & TRACKING CORRELATION	-	-
o TACTICAL EXECUTION	-	-
o TACTICAL AIDS	-	-
(3) SENSORS		
o DETECTION	-	-
o CLASSIFICATION	-	-
o SENSOR IMPROVEMENT	-	-
(4) WEAPONS		
o WEAPON LAUNCH DECISIONS	-	-
o TARGET IDENTIFICATION	-	✓
o AIR TO AIR WEAPON DELIVERY	-	✓
o AIR TO GROUND WEAPON DELIVERY	-	✓
(5) HARDWARE SYSTEMS		
o VEHICLE INTERFACE	-	-
o EQUIPMENT TEST & EVALUATION	✓	✓
(6) SOFTWARE SYSTEMS		
o COMPUTER PROCESSING ARCHITECTURE	-	-
o COMPUTER HARDWARE	-	-
o SOFTWARE ROUTINES	-	-
(7) HUMAN FACTORS		
o SYSTEM CONTROL AND MANAGEMENT	-	-
o SURVIVABILITY AND VULNERABILITY	✓	-
o AUTOMATIC DECISION AIDS	-	✓
o TASK LOADING	-	✓
o FUNCTIONAL REQUIREMENTS	-	-
o MULTI-SENSOR CORRELATION	-	-
o INFORMATION DISTRIBUTION	-	-
o ENVIRONMENTAL CONSIDERATIONS	✓	✓
o PSYCHO-PHYSIOLOGICAL STUDIES	✓	-
(8) TRAINING		
o FAMILIARIZATION	✓	✓

It would be useful at this point to discuss planned/proposed specific programs that might utilize the Dynamic Flight Simulator, so that the primary and secondary mission tasks, selected in Table 2, might be reinforced.

(1) The F-14 Spin Simulation Program requires the high sustained "g" environment of the centrifuge, since many spins occur in this environment. This program also requires some limited air combat maneuvering capability, since inadvertent spins occur during high task loading situations, during air combat maneuvering missions. Also, certain aircraft equipment involved in the overall spin problems; such as cockpit, displays, warning indicators, engine instruments etc., can be tested and evaluated in a simulated spin environment. Spin familiarization training is another useful mission task that can be accomplished on the centrifuge.

(2) The V/STOL Flight Transition Program (Vertical to Forward) will require the continued motion conditions that are available on the human centrifuge.

(3) The High Acceleration cockpit Seat Program requires the high sustained "g" environment of the centrifuge, for the test and evaluation of the crewmans rotating seat, during a high acceleration flight maneuver.

(4) The Personnel Restraint System Program requires the high sustained "g" environment, of the centrifuge, for the test and evaluation of various crew restraint systems.

(5) The Combined Stress Program requires a multi-stress environment including high sustained "g" to determine the Psycho-Physiological effect on aircrew performance during various mission tasks.

The general Simulator parameters necessary to determine the Dynamic Flight Simulator requirements are presented in table 3 and the parameters required for the following primary and secondary mission tasks are indicated.

Primary Mission Tasks

- Flight Performance Transition
- Survivability and Vulnerability
- Equipment Test and Evaluation
- Human Factors - Psycho - Physiological and Environmental Considerations
- Training - Familiarization Tasks

Secondary Mission

- Takeoff and Landing
- Air combat Maneuvering
- Weapon Delivery
- Human Factors Task Loading
- Human Factors Automatic Decision Aids

Table 3

Dynamic Flight Simulator Parameter Requirements

Simulator Parameters	PRIMARY MISSION TASKS					SECONDARY MISSION TASKS				
	Flight Perf. Trans.	Surv. & Vul.	Equip. T&E	HF Psys. & Envir. Consid.	Train. Fam.	Take-off and Landing	Air Combat Man.	Weapon Delv.	HF Task Loading	HF Auto Aids
1. Simulator Cockpit Configuration										
. Generic	-	-	-	-	-	-	-	-	-	-
. Generic and Exact Replica Combination	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Exact Replica	-	-	-	-	-	-	-	-	-	-
. Integration Lab	-	-	-	-	-	-	-	-	-	-
2. Aircraft Type										
. Fixed Wing	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Helicopter	-	-	-	-	-	-	-	-	-	-
. V/STOL	✓	-	✓	✓	✓	✓	-	-	✓	✓
3. Cockpit Seating Configuration										
. Single Seat	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Side by Side	✓	-	✓	✓	✓	✓	✓	✓	✓	✓
. Tandem	-	-	-	-	-	-	-	-	-	-
. Three Crewmen	-	-	-	-	-	-	-	-	-	-
. Four Crewmen	-	-	-	-	-	-	-	-	-	-

	PRIMARY MISSION TASKS					SECONDARY MISSION TASKS				
Simulator Parameters	Flight Perf. Trans.	Surv. & Vul.	Equip. T&E	HF Psys. & Envir. Consid.	Train. Fam.	Take-off and Landing	Air Combat Man.	Weapon Delv.	HF Task Loading	HF Auto Aids
4. Cockpit Flight Controls										
. Stick	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Side-Arm Controller	-	-	-	-	-	-	-	-	-	-
. Collective	-	-	-	-	-	-	-	-	-	-
. Throttle	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Rudders	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5. Cockpit Instrumentation										
. Airspeed Ind.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Barometric Alt.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Radar Alt.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Attitude Ind.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Horiz. Sit. Ind.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Rate of Climb Ind.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Accelerometer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Angle of Attack	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Clock	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6. Cockpit Displays										
. Multipurpose	✓	-	✓	✓	✓	✓	✓	✓	✓	✓
. Horiz. Sit. Display	-	✓	-	-	✓	-	-	-	✓	-
. Vert. Sit. Display	-	✓	-	-	✓	-	-	-	✓	-
. Heads Up	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

	PRIMARY MISSION TASKS					SECONDARY MISSION TASKS				
Simulator Parameters	Flight Perf. Trans.	Surv. & Vul.	Equip. T&E	HF Psys. & Envir. Consid.	Train. Fam.	Take-off and Landing	Air Combat Man.	Weapon Delv.	HF Task Loading	HF Auto Aids
7. Aircraft Inflight Cues										
. Real World Visual	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Motion	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. High Sustained G	-	✓	✓	✓	✓	-	✓	-	✓	✓
. G Suit	-	-	-	-	-	-	-	-	-	-
. G Seat	-	-	-	-	-	-	-	-	-	-
8. Sensor Equip.										
. LO Far	-	-	-	-	-	-	-	-	-	-
. DI Far	-	-	-	-	-	-	-	-	-	-
. CASS	-	-	-	-	-	-	-	-	-	-
. MAD	-	-	-	-	-	-	-	-	-	-
. Radar	-	-	-	-	-	-	-	-	-	-
. ESM	-	-	-	-	-	-	-	-	-	-
9. Computers										
. Digital (6600)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Digital (Mini)	-	-	-	-	-	-	-	-	-	-
. Digital (Micro-processor)	-	-	-	-	-	-	-	-	-	-
. Analog	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Display	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Simulator Parameters	PRIMARY MISSION TASKS					SECONDARY MISSION TASKS				
	Flight Perf. Trans.	Surv. & Vul.	Equip. T&E	HF Psys. & Envir. Consid.	Train. Fam.	Take-off and Landing	Air Combat Man.	Weapon Delv.	HF Task Loading	HF Auto Aids
10. Cockpit/Computer Interface										
. A/D Converters	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. D/A Converters	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
. Synchro Converters	-	-	-	-	-	-	-	-	-	-
. Cockpit "J Box"	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

II Dynamic Flight Simulator System

Requirements

1. Hardware

The Dynamic Flight Simulator System must have sufficient hardware equipment to handle the mission tasks presented in table 2. This hardware equipment will include,

- o Multipurpose cockpit (including instrumentation, displays, switches, indicators, communications
- o Motion Base System
- o Visual Display System
- o Scene/Target Generation System
- o Computer System
- o Cockpit/Computer Interface
- o Problem Control Station

The hardware requirements for each of these subsystems will be described in the following paragraphs.

1.1 Multipurpose cockpit. The simulator cockpit geometry should be close to a replica of the aircraft that is being simulated. Research has generally shown that functional similarity between aircraft and simulator produces greater pilot acceptance, and therefore aids in his motivation. Normally the Dynamic Flight Simulator will be configured as a fixed wing aircraft, but the capability of incorporating a V/STOL or helicopter aircraft configuration should be included. Enough active instrumentation, displays, switches, indicators and flight controls are required to perform the mission tasks outlined in Table 2. The instrumentation should include flight instruments, such as airspeed, rate-of-climb, radar altimeter, barometric altimeter, altitude, bearing/distance/heading, accelerometer, angle of attack and turn and slip indicators and engine instruments, such as rotor speed, turbine inlet temperature, and basic fuel flow.

The number of cockpit display systems, such as a Vertical Display Indicator or a Horizontal Situation Display Indicator, will depend on the simulated aircraft; however the multipurpose cockpit should be flexible enough to facilitate the required displays. The capability of incorporating a Heads UP Display system into the cockpit should be included.

Selected switches, indicators, and panels, dictated by the type of simulated aircraft and the mission tasks, should be made active.

Active flight controls should include a close facsimile of the simulated aircrafts stick, and rudder system and either a fixed wing aircrafts throttle or a helicopter collective system.

Communications between the multipurpose cockpit, the instrumentation station, computer rooms and the gondola loading platform, should be provided.

A motion buffet system designed to produce the required aerodynamic buffeting cues, during certain aircraft aerodynamic maneuvering situations, should be provided.

1.2 Motion System

The Dynamic Flight Simulator motion requirements in theory depend on the mission task motion requirements; however the centrifuges motion capabilities are well defined, as detailed in reference a. A mission task therefore will have to be designed according to the centrifuges current motion specifications.

1.3 Real World Visual Display System

The Dynamic Flight Simulators mission tasks require a real world visual display system, which will present the proper scene/target required for each task. This scene will include, as a minimum, a horizon, some ground terrain and sky features, to allow the pilot to perform certain aerodynamic maneuvering tasks, depending on the mission. Also, a target aircraft will be superimposed on the real world display during certain experimental design tasks.

The real world viewing area should be as large as possible; however this field-of-view will be limited to the space constraints of the centrifuge gondola. A high fidelity real world image should be presented directly in front of the pilot. A low fidelity real world image can be presented in the area of the pilots peripheral vision. The visual display system should have a resolution of at least 6 arc minutes and a brightness of at least 4 ft lamberts. A chromatic real world system is desired but not required.

The visual display system must be capable of withstanding the centrifuges 10-15g dynamic loading requirements. The physical size of the real world visual display unit must conform to the gondolas space limitations, detailed in reference b.

1.4 Scene/Target Generation

The scene/target generation system must be capable of generating the real world image, described in the previous section of this report. This system must also have the capability of updating the scene/target image, a minimum of every 1/30 sec, in proper perspective, to conform to the pilots aerodynamic maneuvers. Reasonable coordination of the aircraft simulators visual and motion cues is required.

1.5 Computer Systems

The Dynamic Flight Simulator system requires the utilization of a complete computer facility, including analog, digital and display generation computers. This capability should include access to the Computer Facilities 6600 Digital Computer, EAI Analog Computer and the IDI Display Generator Computer System.

1.6 Cockpit/Computer Interface

A cockpit/computer "J BOX" interface must be provided, in the gondola. This interface must conform to the centrifuge slip ring complement of input and output wires and be capable of providing an adequate number of potentiometer signals (utilized for instrumentation and flight controls), switch closures indiscretes, lamp driver outdiscretes, display signals, power inputs and physiological outputs. Additional cockpit/computer interface equipment, depending on the mission task, might include analog/digital converters, digital to analog converters, synchro converters, display interface and a discrete interface.

1.7 Problem Control Station

The basic equipment required for the Dynamic Flight Simulator systems Problem Control Station, exists at the NAVAIRDEVCEN. Selected instrumentation, displays, switches, or indicators should be provided, as dictated by the particular mission task.

2. Software

The software requirements to handle a flight simulator such as the Dynamic Flight Simulator are complex, expensive and generally beyond the scope of this study. This function would normally be directed toward a specific program such as the F-14 Spin Simulation program. The software requirements and description for the F-14 Spin Simulation Program are detailed in the NAVAIRDEVCEN F-14 Spin Simulation Program Proposal Report (reference c). The Dynamic Flight Simulator; however does require a limited software program for the integration, checkout and demonstration of the Dynamic Flight Simulator multipurpose crewstation concept. This software requirement should be included in the Dynamic Flight Simulator cost estimate.

III Dynamic Flight Simulator System Description

Description

I. Hardware

The Dynamic Flight Simulator hardware block diagram, illustrated in Figure 4, includes the centrifuge gondola hardware equipment and the computer complex and peripheral equipment, necessary to perform the designated mission tasks. The computer complex and peripheral equipment, described in appendix A, are part of the NAVAIRDEVCEN simulation facility and are not included in any DFS multipurpose crewstation Dynamic Flight Simulator cost estimates. Also, existing NAVAIRDEVCEN cockpit equipment will be utilized if it is applicable to the Dynamic Flight Simulator. The centrifuge gondola hardware and related system equipment consist of the following systems:

- o DFS Cockpit (including instrumentation, displays, switches, indicators, communications and flight controls)
- o Motion Base
- o Visual Display
- o Scene/Target Generator
- o Computers
- o Cockpit/Computer Interface
- o Problem Control Station

Each one of these systems will be described in detail in the following paragraphs

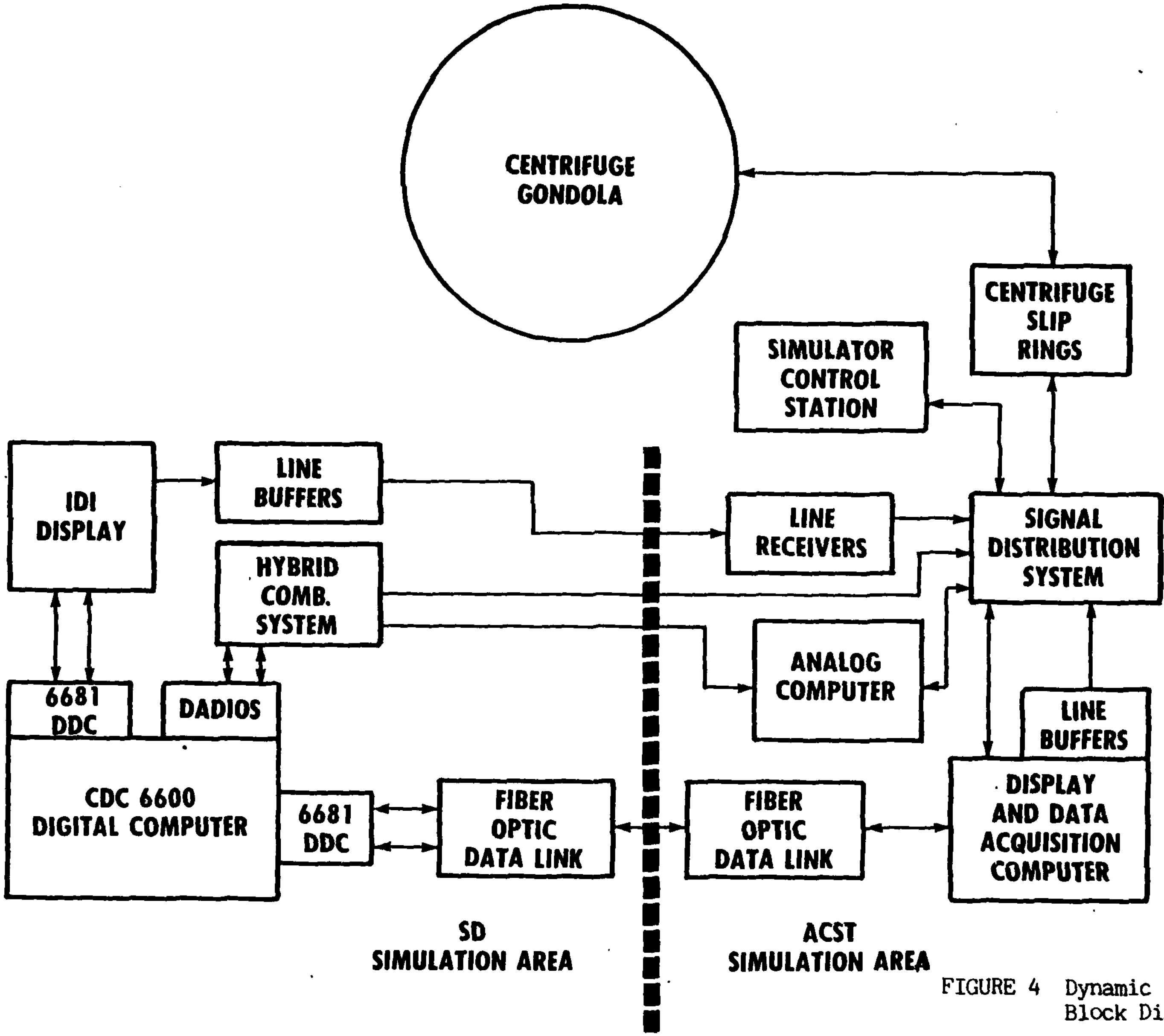


FIGURE 4 Dynamic Flight Simulator Block Diagram

1.1 Dynamic Flight Simulator Cockpit

The multipurpose crewstation, as described in the summary of this memorandum and, illustrated in Figure 2, consists of a general cockpit structure and platform housing a specific cockpit panel and "J-Box" wiring interface enclosure. This cockpit panel assembly will be a replica of the particular aircraft involved in the mission task, including panel width, down vision, and pilot eye to panel dimension. A different cockpit panel assembly will be utilized for each aircraft type. The cockpit structure will be constructed with enough flexibility to obtain certain features of the simulated aircraft, such as cockpit width. The pilot consoles will be constructed so that the forward and side angles may be varied to conform to the simulated aircraft. Two cockpit structure stations could be utilized for a side by side cockpit configuration.

The dynamic flight simulator instrumentation depends on the aircraft required for the mission task. The instrumentation normally required includes the following indicators:

Airspeed (I)
Rate of climb (R/CI)
Radar altimeter (R I)
Barometric altimeter (BAI)
Altitude (I)
Bearing, Distance, Heading (BDHI)

Depending on the type of aircraft to be simulated, additional instrumentation required could include the following indicators:

Accelerometer (gI)
Angle of attack (AOAI)
Turn and Slip (T/SI)
Engine (EI)

These cockpit instruments can be commercially purchased from the Malwin Electronics Corporation, as a simulated exact replica of the aircraft instruments with a simple variable d.c. voltage input, simulating the actual aircraft sensor input. The Dynamic Flight Simulator cost estimate will include the angle of attack. altitude and bearing, distance, heading indicators, and will utilize existing airspeed, rate of climb, radar altimeter, barometric altimeter and accelerometer indicators.

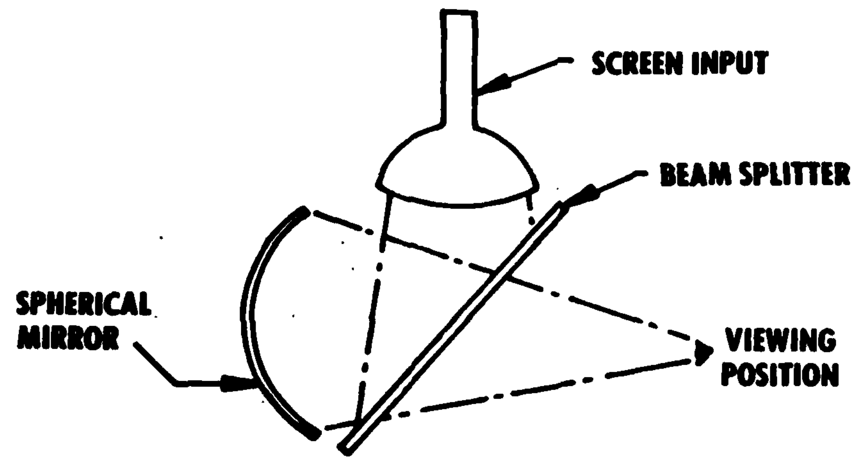
The required cockpit display system again includes the displays which are located in the simulated aircraft. These displays might include a vertical display, horizontal display and heads-up display. The cockpit display system will utilize a stroke or random vector display system, which simultaneously moves the CRT beam in an arbitrary X and Y direction directly to the point at which the graphic element is to be displayed. The CRT beam is turned on and the graphic element is traced from point to point. This display system offers high resolution and is directly compatible with the Information Display Inc (IDI) Display Generation system, described in appendix A. The cockpit displays must be puchased on special order, because of the 10 - 15 g loading requirements, dictated by the centrifuge dynamics. A magnetic deflection display unit is capable of handling higher "g" loading requirements than an electro-static display unit. The Orwin Associates Co. can produce a quality calligraphic CRT display designed to adhere to the cockpit display requirements. The Dynamic Flight Simulator cost estimate will include two multipurpose cockpit displays and will utilize an existing Heads Up display unit.

The Dynamic Flight Simulator's flight controls will include a control stick and rudder force loading system and, depending on the aircraft to be simulated, a simulated throttle or collective system. A simulated universal control loading system is commercially produced by the McFadden Electronic Co. This pilots stick and rudder system includes integral rotary actuators, valves, transducers, servo controls, and function generating electronics designed to provide the pilot with realistic "feel" cues. The McFadden Electronic Co control loader system cost is about 125K. An existing NAVAIRDEVCEN stick and rudder control loader system will be utilized in the initial checkout of the Dynamic Flight Simulator. The cost estimate will include a fixed wing aircraft throttle system.

An intercommunication system is available at NAVAIRDEVCEN which facilitates the programming of signals between various stations such as the gondola, the instrumentation station, the computer rooms, and the gondola loading platform. Selected switches and indicators on the stick, throttles/collective, displays, caution and warning panels will be provided, depending on the mission tasks. Also, active or partly active console panels will be provided.

The Dynamic Flight Simulator will be provided with a vertical motion buffet system. This hardware will consist of a hydraulic actuator system, attached to the simulated cockpit structure, designed to produce the required buffeting cues, during certain aircraft aerodynamics maneuvers.

REAL WORLD VISUAL DISPLAY



GENERAL FEATURES

- PRODUCES INFINITY VIRTUAL IMAGE
- COMPACT SIZE
- LIGHT WEIGHT
- INEXPENSIVE
- 10 G LOADING CAPABILITY

SPECIFICATIONS

• FIELD-OF-VIEW	48° HORIZ. 32° VERTZ.
• RESOLUTION	5 ARC MIN.
• BRIGHTNESS	5 FT. LAM.
• CONTRAST	30 TO 1
• COLOR	CHROMATIC

FIGURE 5 Real World Visual Display System General Features

1.2 Motion

The Dynamic Flight Simulator motion is provided by the Human Centrifuge. The centrifuge, illustrated in Figure 1, is essentially a tubular steel arm, 50 feet long, which is rotated in a horizontal plane about the axes of a vertically mounted 4000 hp direct current motor. The centrifuge arm has a maximum angular acceleration rate of 1.78 radians/sec and a maximum velocity of 173 miles/hour. The test subject is enclosed in a spherical gondola, 10 feet in diameter, located at the end of the arm. The gondola is attached to the end of the arm by means of a two gimbal system which permits complete rotational freedom, designated pitch and roll. A third rotational degree of freedom may be incorporated by installing a six foot diameter yaw cylinder within the main sphere. The gondola structure can support a weight of 40,000 pounds, or its acceleration equivalent, 1000 pounds at 40 g's. The following are the maximum angular motion rates about the gondola's geometric center:

Roll acceleration	6.7 radians/sec squared
Pitch acceleration	6.7 radians/sec squared
Yaw acceleration	10.0 radians/sec squared
Roll velocity	30 RPM
Pitch velocity	30 RPM
Yaw velocity	30 RPM

The motions listed above may all occur simultaneously. During these motions, the optimum position of both the pilot's heart and the center of mass of the gondola is the geometric center of the gondola. A detailed description of the NAVAIRDEVCEN centrifuge is presented in reference a.

1.3 Real World Visual Display. A centrifuge visual display system study, conducted last year, reference b, determined that the non pupil Forming Reflective Visual Display system is the most practical real world visual system that can be incorporated into the centrifuge gondola. This visual display system, illustrated in figure 5, consists of an input (CRT, a beamsplitter and a spherical mirror to produce a virtual image, appearing at infinity. The compact construction and light weight makes this system compatible with the gondola's limited space. The overall light transmission is good, but the beamsplitter reduces the image brightness to about twenty percent of the input source. The most limiting characteristic is in the restricted field-of-view (48 degrees horizontal by 32 degrees vertical) and, in particular, the vertical field-of-view. The real world visual horizontal field-of-view will be supplemented by locating two TV monitor systems at the pilot's peripheral vision.

The real world visual display system can be purchased commercially on special order, from several manufactuers, including the General Electric Co., the Redifon Simulation Co., and the McDonnell Douglas Corporation. The cost of a non Pupil Forming Reflective Visual Display system, capable of withstanding 10 - 15 g dynamic loading requirements, is about 125K.

1.4 Scene/Target Generator. Several scene generation inputs can be utilized with the Non-Pupil Forming Visual Display system including video tape, terrain model boards and computer generated image systems. The computer generated image method of producing a scene is the newest and fastest growing scene generator type system, and is the most practical system for the Dynamic Flight Simulator. Surface terrain and objects to be simulated are modeled in numeric form and stored in the memory of an image generator. The image generator converts the three dimensional numeric representation of the ground area in the data base into a two dimensional scene projected on the viewing surface of a cockpit window. The following is a list of the advantages in utilizing computer generated images.

- o Exact perspective
- o Moving objects can be presented
- o Quick visual environment change
- o Unlimited altitude position and rates
- o Large area of flight coverage
- o Multiple channel generation
- o All objects are in focus

Commercially available scene generator systems include:

- o McDonnell Douglas Corp. VITAL IV System
- o Redifon Simulation Inc. SP1 System
- o Redifon Simulation Inc. SP2 System
- o Singer Co. Visulink System
- o General Electric Co. Compu Scene System

The specifications for each of the five visual display systems is presented in figure 6. The scene generation capability of three of these systems is illustrated in figures 7 to 9. Each display system has characteristics that make that display system the best one for a particular visual simulation specification. The Dynamic Flight Simulators scene/target requirements of presenting a horizon, some ground terrain and sky features, and also a target aircraft, can be accomplished with any of the five candidate systems. Also, each system has the capability of updating the scene/target image a minimum of every 1/30 second, in proper perspective, to conform to the pilot's aerodynamic maneuvers. All five display system candidates provide for a resolution of at least 6 arc minutes, but the VITAL IV, SP1 and Visulink sytems cannot produce the required 4 ft lamberts of brightness. These three visual display systems are also similar in that they utilize a beam penetration tube and present a two color (shades of red and green) image. Also, these three systems are relatively inexpensive (400 - 500K).

REAL WORLD VISUAL DISPLAY SYSTEM DATA COMPARISON

MANUFACTURER ADDRESS REF/TEL. NO.	VISUAL DISPLAY SYSTEM	DISPLAY CRT DATA				DISPLAY PRESENTATION						SCENE GENERATION			EXPANSIBILITY FEATURES	DELIVERY	COST
		CALLIGRAPH (C) RASTER (R)	BEAM PENETRATION (BP) SHADOW MASK (SM)	COLOR RED/GREEN & BLUE	CRT TUBE SIZE	NO. POLYGONS /LINES	NO. LIGHT POINTS	RESOLUTION (ARC MINS)	BRIGHTNESS (FT LAM.)	NO MOVING TARGETS	ILLUS. OF	COMPUTER /K MEMORY	STORAGE MEDIUM	NO. SCENES AVAILABLE			
MDONNELL DOUGLAS CORP ST. CHARLES, MISSOURI MR RIVERS N. BURRELL (314) 925-4457	VITAL IV	C	BP	10 SHADES OF RED & GREEN	21"	300 POLYGONS	8000	3	1	3	FIGURE	SPERRY V-76	FLEXIBLE DISCS	50 ON-LINE 3 SEC ACCESS	CAN BE CONVERTED TO 3 COLOR SYSTEM (BLUE ADDED) (COST ABOUT 750K) CANNOT BE CONVERTED TO RASTER DISPLAY	9 MONTHS	395 K (DISPLAY 155K SCENE GENERATOR 225K DIGITIZER [illegible])
REDIFON SIMULATION INC ARLINGTON, TEXAS MR ROY MOLYNEAX (817) 460-8411 X 526	SP-1	C	BP	64 SHADES OF RED & GREEN	25"	400 POLYGONS	6000	3	.5	3	FIGURE	TI 980B	FLEXIBLE DISCS	11 ON-LINE 5 SEC ACCESS	CAN BE CONVERTED TO SP-2 INCLUDING RASTER DISPLAY (COST ABOUT 500K)	8 MONTHS	550K
REDIFON SIMULATION INC. ARLINGTON, TEXAS MR ROY MOLYNEAX (817) 460-8411 X 526	SP-2	C OR R	SM	128 SHADES OF RED GREEN & BLUE	25"	250 POLYGONS	6000 NIGHT 1000 DAY	3	4	3	FIGURE	TI 980B	FLEXIBLE DISCS	11 ON-LINE 5 SEC ACCESS	CAN BE EXPANDED TO 1000 POLYGONS OF DISPLAY (COST ABOUT 200 K)	12 MONTHS	850K
SINGER CO. SILVER SPRINGS MD./WASH. D.C. MR KARL REEVES (202) 457-1520	VISULINK	C	BP	7 SHADES OF RED & GREEN	25"	250 POLYGONS	10,000	NO DATA	NO DATA	NO DATA	NONE AVAIL.	PDP 11 /32K WORDS	FLEXIBLE DISCS	NO DATA	CANNOT BE CONVERTED TO 3 COLOR OR RASTER SCAN DISPLAY SYSTEM	15 MONTHS	550K
GENERAL ELECTRIC CO DAYTONA BEACH, FLORIDA MR RAY CARPENDER (904) 258-2631	COMPU SCENE	C OR R	SM	RED GREEN & BLUE	25"	1000 LINES (BASIC SYSTEM)	1000	5	6		FIGURE	PDP 11 /32K WORDS			CAN BE EXPANDED TO 20,000 EDGES OF DISPLAY		2,500 K

FIGURE 6

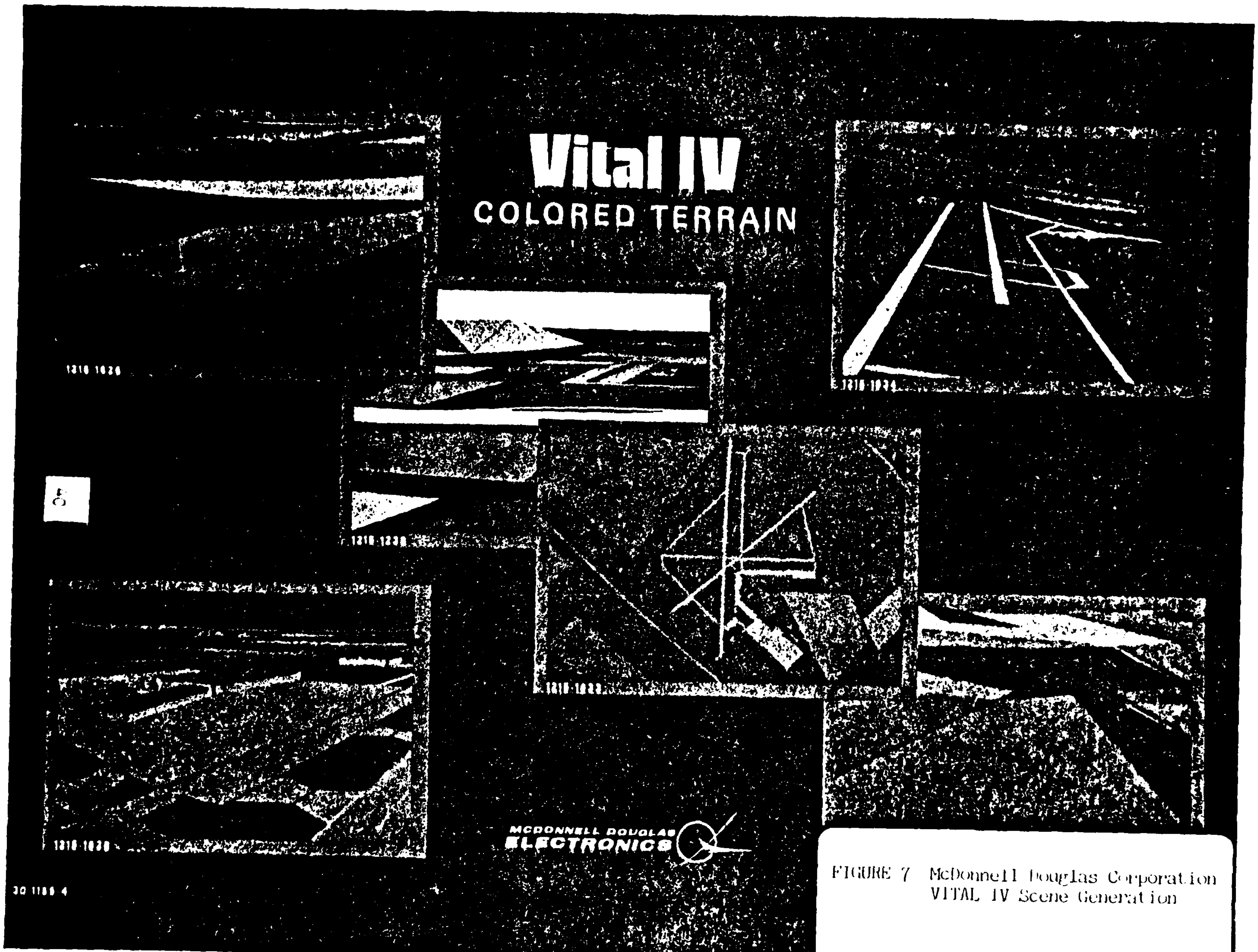


FIGURE 7 McDonnell Douglas Corporation VITAL IV Scene Generation

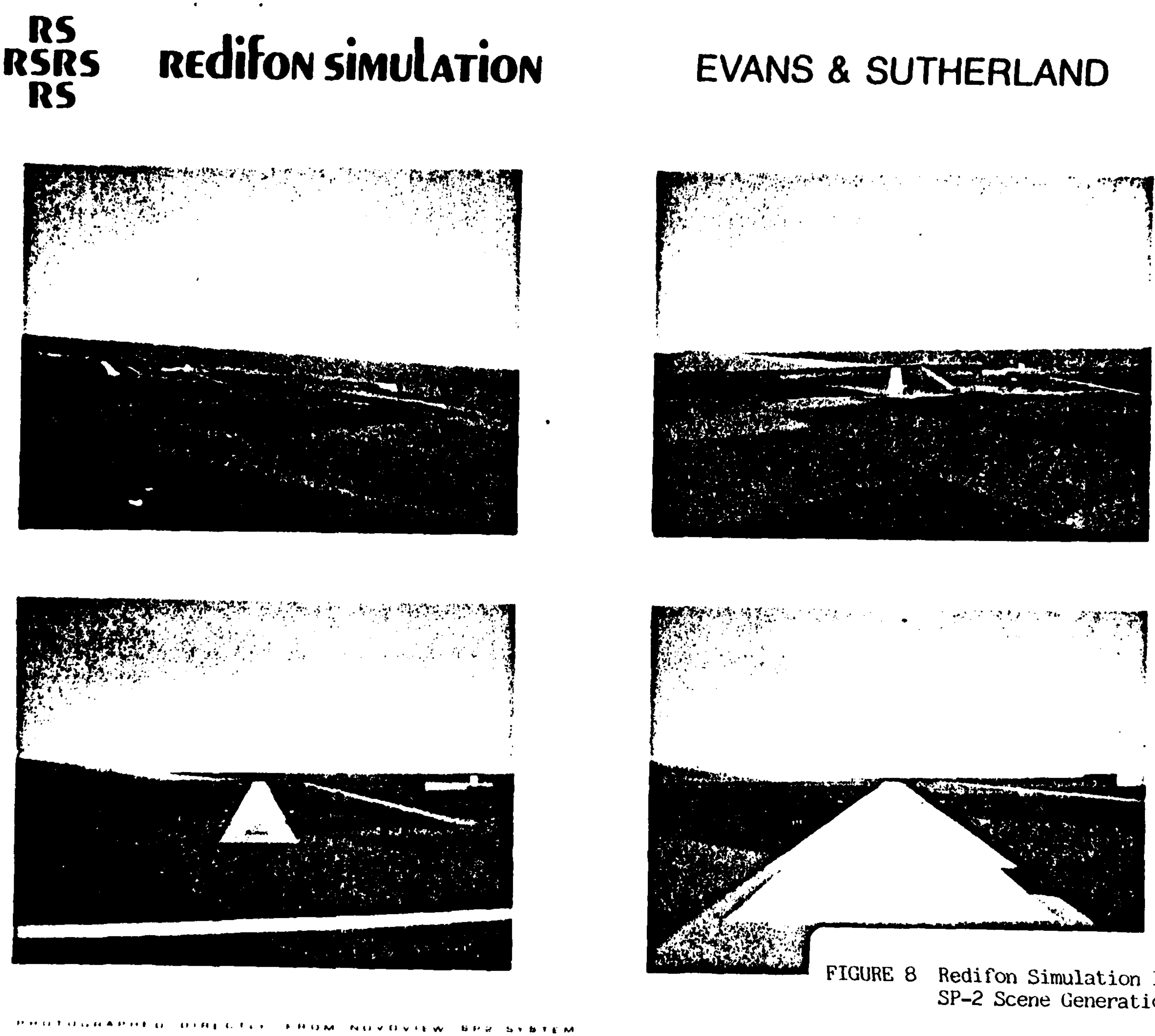


FIGURE 8 Redifon Simulation Inc.
SP-2 Scene Generation

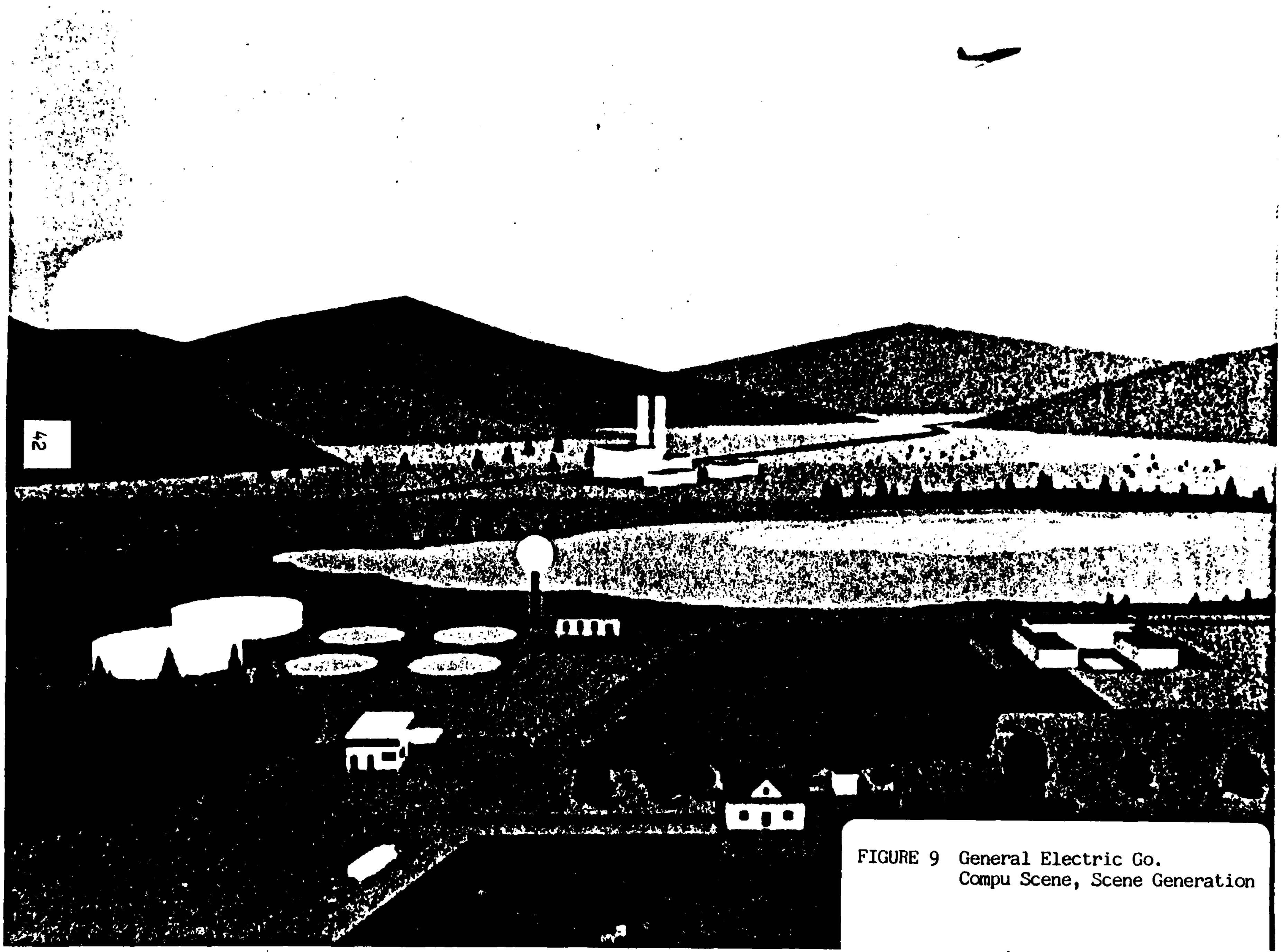


FIGURE 9 General Electric Go.
Compu Scene, Scene Generation

The SP2 and Compu Scene systems meet all requirements including resolution and brightness. In addition, they utilize a shadow mask tube and present a three color (shades of red, green, and blue) image. A basic SP2 system costs about 850K while a basic Compu Scene system costs about 2500K. These systems can be expanded to provide a more detailed real world image. The obvious tradeoff between the five system candidates is cost, display brightness, terrain detail and 2 vs 3 color presentation.

The real world visual display system and scene generation equipment will be purchased with funding not detailed as part of the multipurpose dynamic crewstation portion of the Dynamic Flight Simulator.

1.5 Computer Systems

The Dynamic Flight Simulator system will provide for the utilization of the 6600 Digital computer, EAI Analog Computer and the IDI Display Generator computer systems, as described in Appendix A. No additional costs are required to provide the computer capability to handle the Dynamic Flight Simulator mission tasks; however depending upon the specific mission tasks, cockpit/computer interface equipment will have to be provided. These costs will be discussed in the next section of this memorandum.

1.6 Cockpit/Computer Interface

The cockpit/computer interface network, required for the Dynamic Flight Simulator, includes existing NAVAIRDEVCEN interface units, basically described in Appendix A and specific Dynamic Flight Simulator interface units which will depend to some degree on the simulated aircraft and the mission task. The Signal Distribution System, illustrated in Figure 4, must be wired to conform with the Dynamic Flight Simulators requirements. A "J BOX" interface unit is required to interface the equipment within the centrifuge gondola with the various computers, and their peripheral equipment. The gondola allows for the following wiring complement through the systems slip rings.

NAVAIRDEVCEN Centrifuge
Table 4 Gondola Slip Ring Wiring Complement

Section	Quantity	Current Rating	Volts AC	Shielding
Physiological	15	1 amp.	250	Individual
Instrument and Control	48	5 amp.	250	Pairs
Instrument and Control	26	1 amp.	250	Pairs
Power	16	15 amp. (Gondola) 35 amp. (Hub)	250	----
Coaxial	19	75 ohm. 30 mc	250	Individual
Total	124			

Obviously the gondola wiring lines are limited; so therefore an interface wiring scheme is required that takes these limitations into account. The proposed Dynamic Flight Simulator "J BOX" is integrated into the rear of the cockpit panel structure, as illustrated in Figure 10.

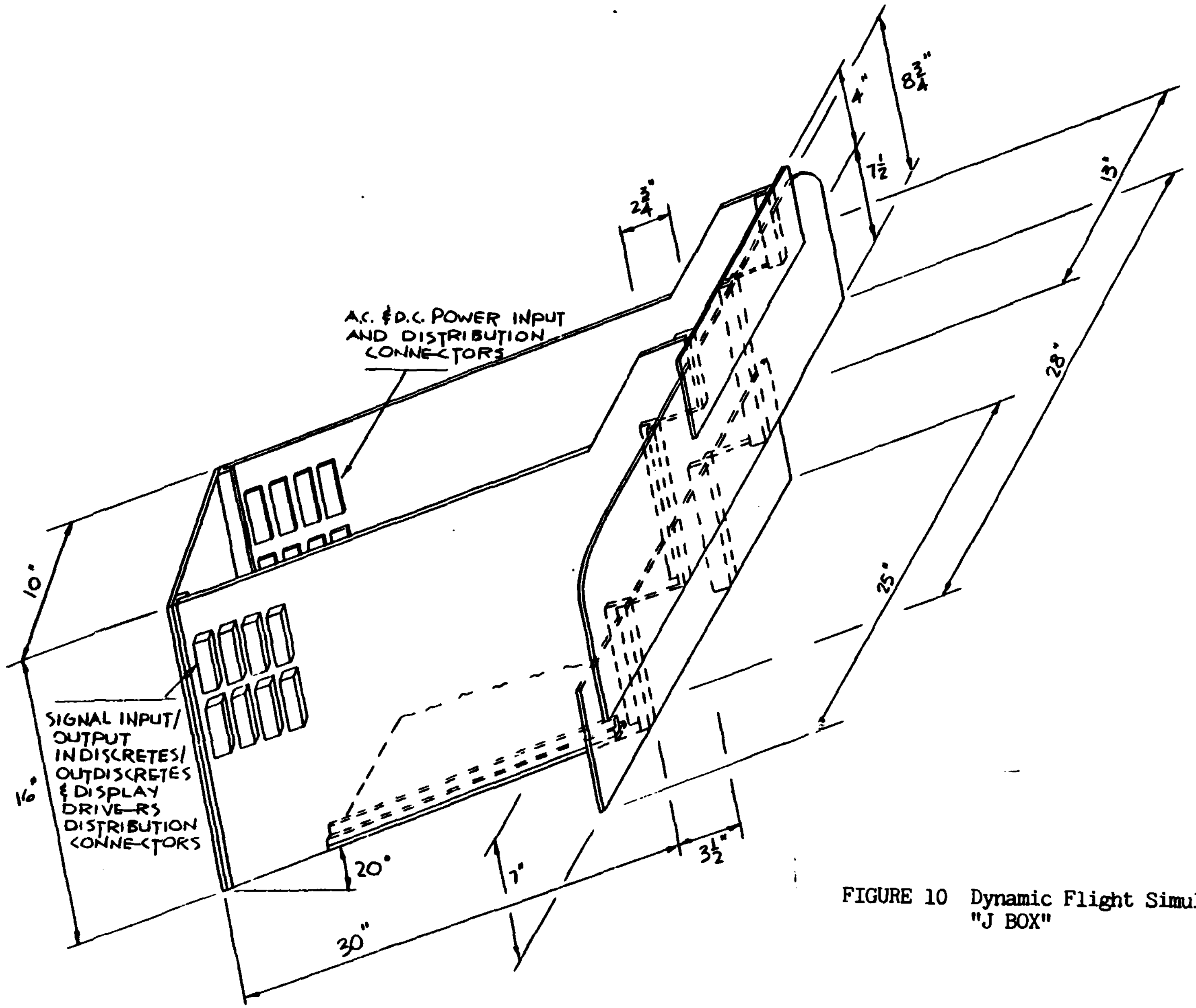


FIGURE 10 Dynamic Flight Simulator "J BOX"

The cockpit panel structure is an exact replica of a F-14 aircraft, but the interface wiring scheme is designed to accomodate any future flight simulator program.

The "J BOX" wiring distribution, illustrated in Figure 11, consists of four 20 pin coax amp connectors and twelve 56 pin Elco connectors.

o Twelve coax lines are utilized to drive cockpit displays

o Twelve shielded pairs (5 amp wire) are utilized for the outdiscrete requirements (24 maximum outdiscretes)

o Seven shielded pairs (1 amp wire) are utilized to provide a maximum of 63 indiscretes, coded as a binary word, with a differential circuit on each wired pair. (One shieled pair is used as a control line). This indiscrete wiring scheme requires the fabrication of an indiscrete interface encoder unit costing about 15K

o Six shielded pairs (5 amp wire) are utilized to provide 20 input potentiometer signals and 10 output potentiometer signals. These signals will be transferred serially across four of the shielded pairs, and two shielded pairs are used as control lines. This potentiometer signal wiring scheme requires the fabrication of a potentiometer signal serial interface unit, costing about 15K.

o Seven coax lines, six shielded pairs (1 amp wire) and six shielded pairs (5 amp wire) remain to be used to drive the additional Dynamic Flight Simulator functions, such as the buffet assembly etc.

o Sixteen power lines are utilized to provide the necessary cockpit equipment power inputs. Eight 56 pin Elco connectors are used for the cockpit power distribution interface. Twenty-eight Elco pins are jumpered together, on each connector, to provide the necessary number of input lines.

1.7 Problem Control Station. The basic equipment required for the Dynamic Flight Simulator Program Problem Control Station, illustrated in reference 1, exists at NAVAIRDEVCEN as an integral part of the complete centrifuge facility. Selected instrumentation, displays, switches, or indicators, will be provided, as dictated by the specific Dynamic Flight Simulator mission task.

2.0 Software. The Dynamic Flight Simulator Software will be limited to a minimal amount of computer costs and software labor required to integrate, checkout, and demonstrate the basic multipurpose crewstation. The majority of the software required to drive the human centrifuge, cockpit instrumentation, displays, flight controls, etc., will have to be provided by a specific program.

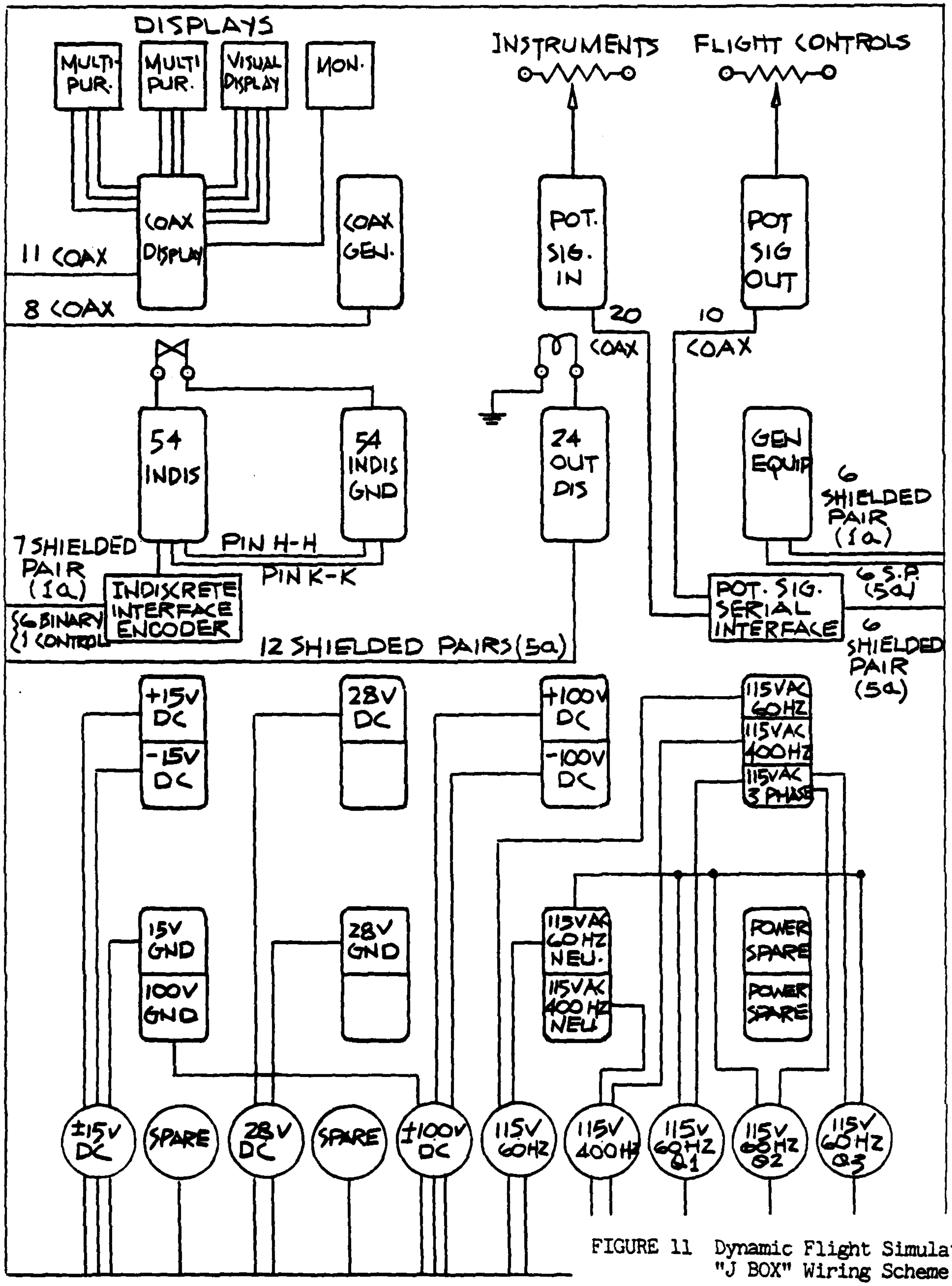


FIGURE 11 Dynamic Flight Simulator "J BOX" Wiring Scheme

IV Crewstation Simulation Development Effort

1. Work Breakdown Structure

The Work Breakdown Structure for the design and development of the Dynamic Flight Simulator is presented in figure 12. The multipurpose crewstation labor breakdown (man-months) portion of the Work Breakdown Structure is presented in table 5.

2. Schedule

The design and development schedule, as illustrated in figure 13, requires a two year period for completion. This schedule is dictated by the available funding.

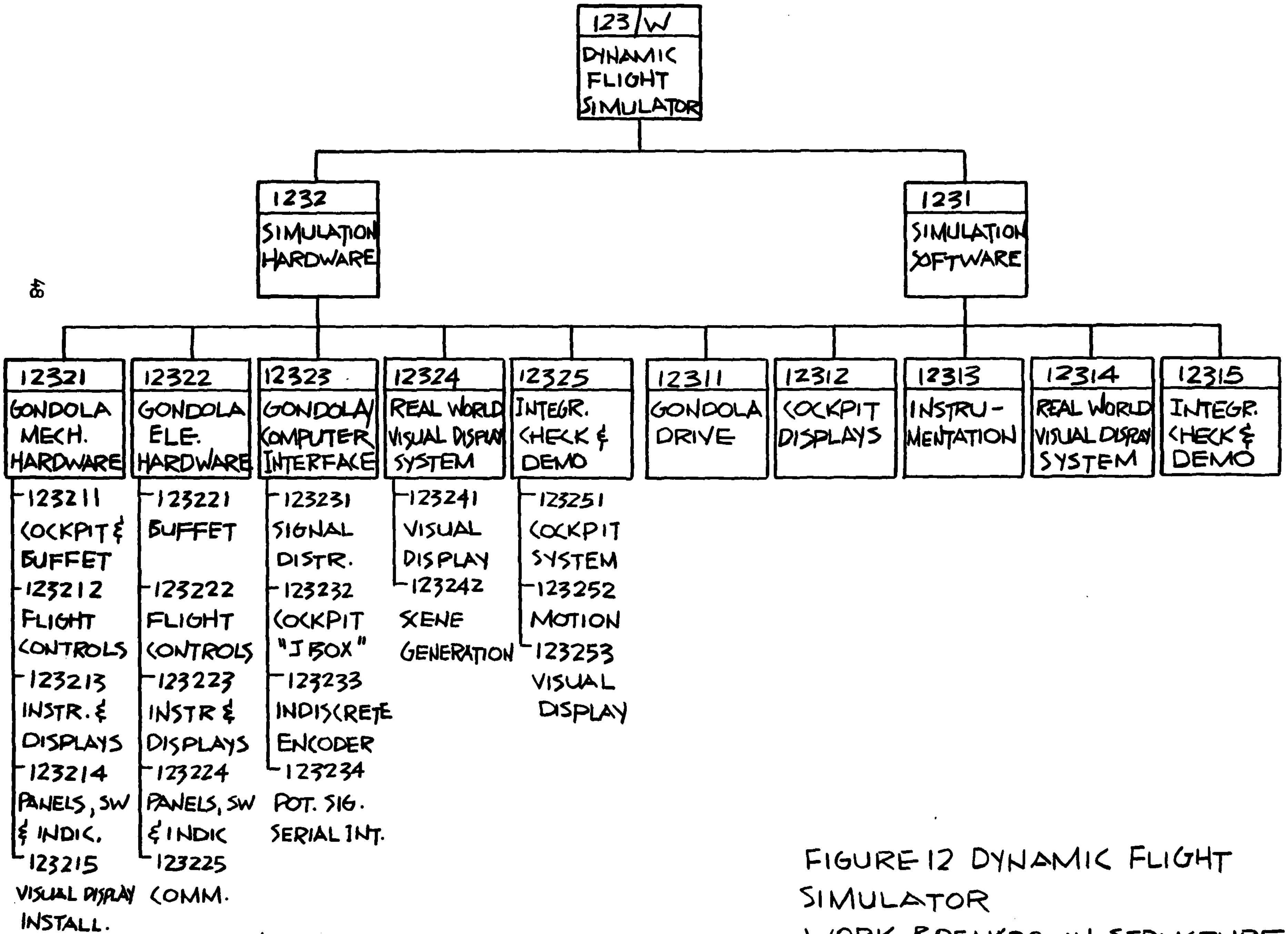


FIGURE 12 DYNAMIC FLIGHT SIMULATOR WORK BREAKDOWN STRUCTURE

Table 5 Multipurpose Crewstation Labor Work Breakdown W/123

	Labor Breakdown (man months)			
W1.0 Software Development				4.0
W1.1 Gondola Drive			0.0	
W1.2 Cockpit Displays			0.0	
W1.3 Instrumentation			0.0	
W1.4 Real World Visual Display System			0.0	
W1.5 System Integration and Checkout			4.0	
W2.0 Hardware Development				48.0
W2.1 Gondola (Mechanical Hardware)			30.5	
W2.1.1 F-14 Cockpit and Buffet System		18.0		
W2.1.1.1 Design (E)	5.75			
W2.1.1.2 Material Acquisition (E)	.25			
W2.1.1.3 Fabrication (T)	10.0			
W2.1.1.4 Contract Negotiation (E)	0			
W2.1.1.5 Contract Fab Liaison (E)	0			
W2.1.1.6 Installation (T)	2.0			
W2.1.2 Flight Controls		3.0		
W2.1.2.1 Design (E)	.75			
W2.1.2.2 Material Acquisition (E)	.25			
W2.1.2.3 Fabrication (T)	1.5			
W2.1.2.4 Contract Negotiation (E)	0			
W2.1.2.5 Contract Fab Liaison (E)	0			
W2.1.2.6 Installation (T)	.5			
W2.1.3 Instrumentation and Displays		2.0		
W2.1.3.1 Design (E)	.5			
W2.1.3.2 Material Acquisition (E)	0			
W2.1.3.3 Fabrication (T)	1.0			
W2.1.3.4 Contract Negotiation (E)	.25			
W2.1.3.5 Contract Fab Liaison (E)	.25			
W2.1.3.6 Installation (T)	0			
W2.1.4 Panels, Switches and Indicators		4.5		
W2.1.4.1 Design (E)	1.25			
W2.1.4.2 Material Acquisition (E)	.25			
W2.1.4.3 Fabrication (T)	3.0			
W2.1.4.4 Contract Negotiation (E)	0			
W2.1.4.5 Contract Fab Liaison (E)	0			
W2.1.4.6 Installation (T)	0			
W2.1.5 Real Work Display System Installation	3.0			
W2.1.5.1 Design (E)	1.0			
W2.1.5.2 Material Acquisition (E)	0			
W2.1.5.3 Fabrication (T)	1.5			
W2.1.5.4 Contract Negotiation (E)	0			
W2.1.5.5 Contract Fab Liaison (E)	0			
W2.1.5.6 Installation (T)	.5			

		Labor Breakdown (man months)		
W2.2	Gondola (Electrical Hardware)			4.5
W2.2.1	Flight Controls Instrumentation, Displays, Panels, Switches, Indicators, Buffet System Communications, Etc. (Wiring & Cabling)		4.5	
W2.2.1.1	Design (E)	1.25		
W2.2.1.2	Material Acquisition (E)	.25		
W2.2.1.3	Fabrication (T)	2.5		
W2.2.1.4	Contract Negotiation (E)	0		
W2.2.1.5	Contract Fab Liaison (E)	0		
W2.2.1.6	Installation (T)	.5		
W2.3	Gondola/Computer Interface - (Mechanical and Electrical Hardware)			10.0
W2.3.1	Signal Distribution System, Cockpit "J" Box, Indiscrete Encoder, Pot. Signal Serial Interface		10.0	
W2.3.1.1	Design (E)	4.5		
W2.3.1.2	Material Acquisition (E)	.5		
W2.3.1.3	Fabrication (T)	5.0		
W2.3.1.4	Contract Negotiation (E)	0		
W2.3.1.5	Contract Fab Liaison (E)	0		
W2.3.1.6	Installation (T)	0		
W2.4	Real World Visual Display System			0
W2.4.1	Visual Display		0	
W2.4.1.1	Design (E)	0		
W2.4.1.2	Material Acquisition (E)	0		
W2.4.1.3	Fabrication (T)	0		
W2.4.1.4	Contract Negotiation (E)	0		
W2.4.1.5	Contract Fab Liaison (E)	0		
W2.4.1.6	Installation (T)	0		
W2.4.2	Scene Generation System			
W2.4.2.1	Design (E)	0		
W2.4.2.2	Material Acquisition (E)	0		
W2.4.2.3	Fabrication (T)	0		
W2.4.2.4	Contract Negotiation (E)	0		
W2.4.2.5	Contract Fab Liaison (E)	0		
W2.4.2.6	Installation (T)	0		
W2.5	System Integration and Checkout		3.0	3.0
W2.5.1	Cockpit System (E&T)	3.0		
W2.5.2	Real World Display Systems (E&T)	0		

DFS MULTIPURPOSE CREWSTATION DEVELOPMENT SCHEDULE

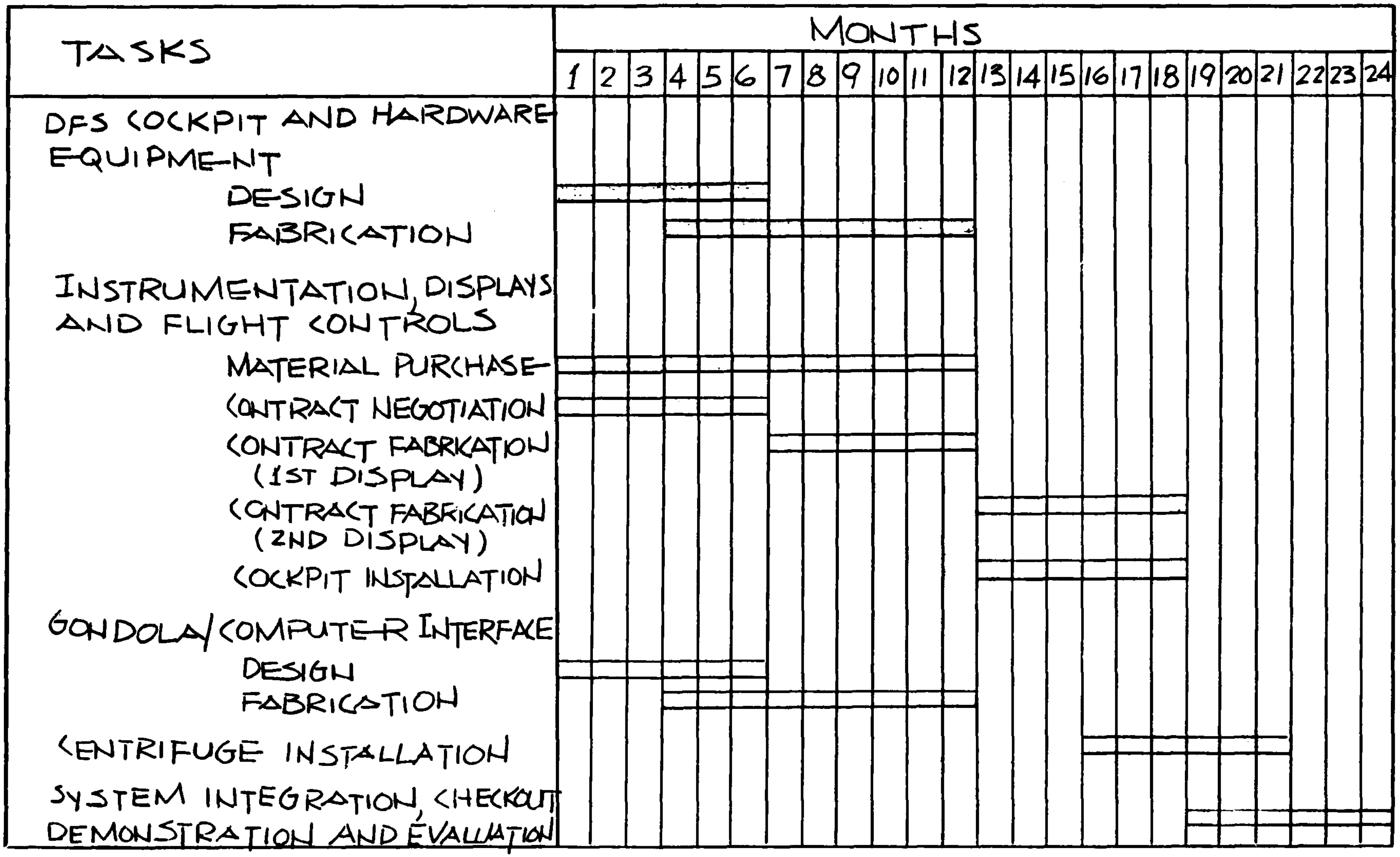


FIGURE 13

V. Resources

1. NAVAIRDEVCEN Manpower Requirements

Development

W1	Software (W1.1 - W1.5)		
	Inhouse Labor		
	Engineering		4.0 Man Mo.
	Shop/Tech		0.0 Man Mo.
		Sub Total	4.0 Man Mo.
W2	Hardware (W2.1 - W2.5)		
	Inhouse Labor		
	Engineering		18.5 Man Mo.
	Shop/Tech		29.5 Man Mo.
		Sub Total	48.0 Man Mo.
		Development Total	52.0 Man Mo.

The total estimates of the Dynamic Flight Simulator Program manpower requirements over the next two years are about

FY80 (Development	2.7 Man Yrs.
FY81 (Development and Demonstration)	1.5 Man Yrs.

2. Facilities

Development

W1 Software

The software facilities include periodic use of the NAVAIRDEVCEN 6600 computer "A" system for debug and "B" System for integration/validation.

W2 Hardware

The centrifuge gondola is required periodically over a 6 month period for installation, integration and checkout of the Dynamic Flight Simulator equipment.

3. Contracts

Development

W1 Software

None

W2 Hardware

Cockpit Display System (2 required)	60K

VI Costs

W1 Software (W1.1 - W1.5)

Inhouse Labor

Engineering (4 man months) (5K/mo) =	20.0K
Shop/Tech (0 man months) (4.2K/mo) =	0
Materials/Computer	10
Contracts	0
Sub Total	30.0K

W2 Hardware (W2.1 - W2.5)

Inhouse Labor

Engineering (18.5 man months) (5K/mo) =	102.5K
Shop/Tech (29.5 man months) (4.2K/mo) =	124
Materials/Computer	45
Contracts	60
Sub Total	331.5K
Dynamic Flight Simulator Development Cost Total	361.5K

VII References

(a) General Description and Performance characteristics of the Human Centrifuge by W.D. Daymon, Crew System Department, NAVAIRDEVCEN, January 1975

(b) High Acceleration Cockpit Program Visual Display System Study by G. Terry Thomas and John S. Mudryk, Technical Memorandum 78-HAC-001

(c) NAVAIRDEVCEN F-14 Spin Simulation Program Proposal Report Software and Computer Directorate, Aircraft and Crew Systems Technology Directorate Sept 1979

APPENDIX A

A DYNAMIC FLIGHT SIMULATOR CENTRIFUGE

I. DYNAMIC FLIGHT SIMULATOR

The NAVAIRDEVCEN Human Centrifuge, illustrated in Figure 14, is one of the world's larget and most versatile centrifuges. In a climate of large amplitude six degrees- of-freedom dynamic flight simulators, it is the only device capable of simulating, under pilot control, the rapidly applied and sustained G profiles (including buffet) associated with air combat maneuvers; or the multi- directional complex G profiles associated with out-of-control flights such as spin.

Additionally, the centrifuge can simulate the near vacuum condition of 125,000 ft altitude, dual-axis vibration from zero to 25 hg., ambient temperature changes form 40 degrees F, sound levels to 130 decibles, and flight levels from complete darkness to extreme brightness. These capabilities are providing the scientists and engineers of the Aircraft and Crew Systems Technology Directorate a very unique tool for investigating the effects of each of the individual stresses of acceleration, vibration, altitude, temperature, sound, light, and disorientation on pilot performance combined in an environment such as the real world combines stresses.

Actual and simulated cockpits of the F-4, F-14, and A-7 aircraft have been inserted in the 10 ft spherical gondola with all controls and displays activated through a local analog computer. Studies have been performed to determine man's psychological response to the realistic stress environment of a fighter pilot.

Those studies include an evaluation of the type and location of various emergency activation devices, the dynamic verification of a number of controls and displays, and the dynamic testing of various personnel protection and life support equipment.

Planned improvements to the simulator include an expansion of its current analog computer system to include both digital and hybrid computer capabilities in order to provide more complex cockpit displays and controls for the simulator pilot and to provide the capability of simulating more complex aircraft, such as the F14, F15, F16, F18 and future high performance aircraft.

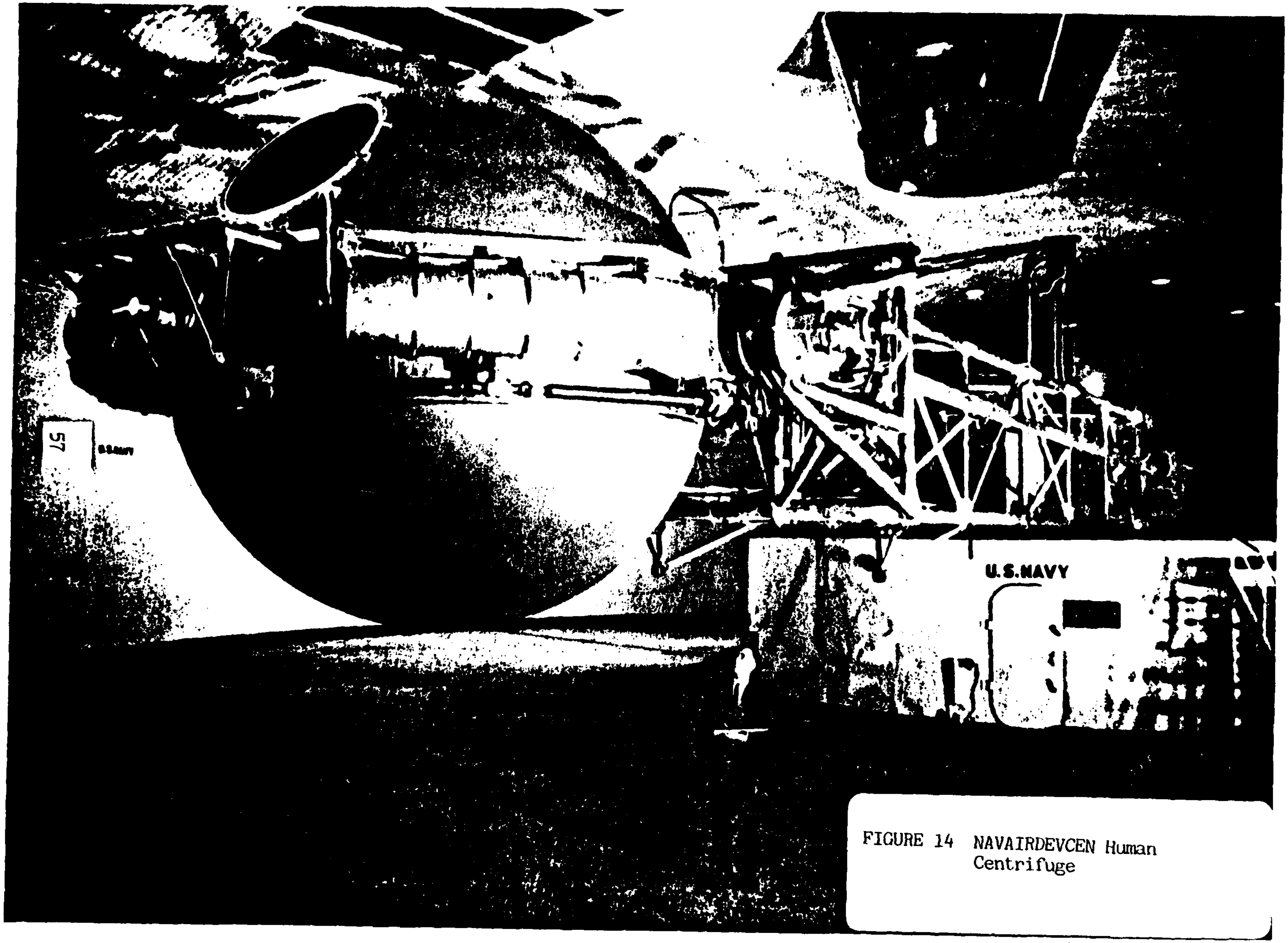


FIGURE 14 NAVAIRDEVCEN Human Centrifuge

2 DYNAMIC FLIGHT SIMULATOR COMPUTER FACILITY

2.1 NAVAIRDEVCEN'S CDC 6600 COMPUTER

The 6600 computer system pictured in Figure 15 is a CDC 6600 series hybrid computer system which was developed for the Naval Air Development Center and is specifically tailored to NAVAIRDEVCEN's requirements. The system provides the capability of simultaneously processing various real-time simulation programs concurrently with the processing of batch jobs, multiple user communication with the computer system in a conversation mode via terminals, graphics, and automatic test-data acquisition and processing.

The system consists of two CDC 6600 central processing units (CPUs), ten peripheral and control processors and a complement of peripheral equipment, most of which can be shared between the computers. This results in an interesting and unique configuration in that the central processor is an extremely high-speed arithmetic processor which communicates only with central memory while the smaller, slower peripheral and control processors communicate with both central memory and the peripheral devices. This permits the central processor to continue high-speed computations while the peripheral and control processors do the slowe I/O and supervisory operations.

The real-time requirements are satisfied by two hardware real-time monitors (one per CPU), which initiate real-time operation in response to an interrupt using the least-time-to-go algorithm, four direct analog/discrete input/output systems (DADIOS) which send and receive data from NAVAIRDEVCEN's real time equipment and a read-write bus adaptor to interface between the DADIOS and HRTM and central memory.

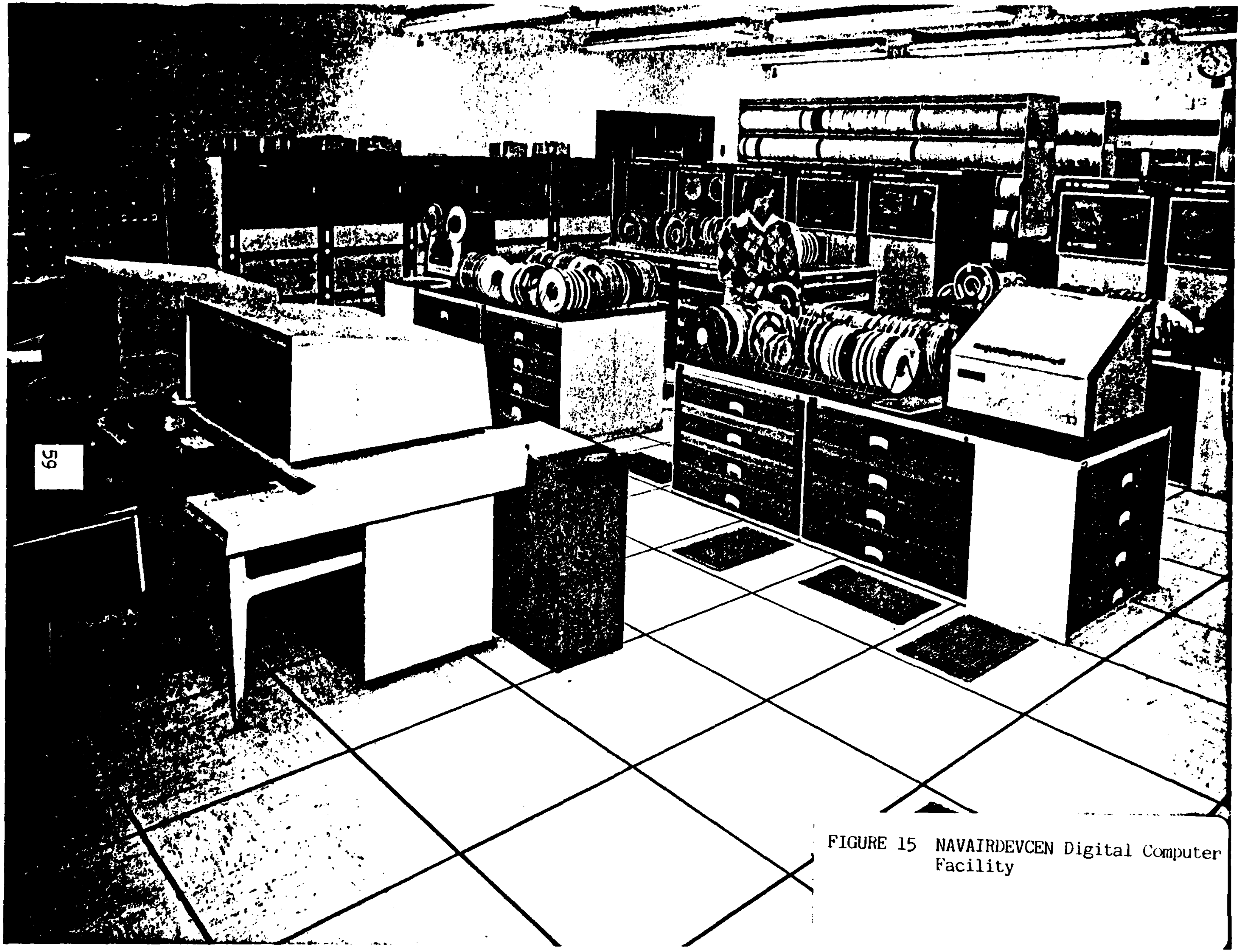


FIGURE 15 NAVAIRDEVCEN Digital Computer Facility

2.2 PROGRAMMABLE DISPLAY GENERATORS

The major portion of the display work is performed by three PDP-8 mini-computers and two IDIOM II computers, pictured in Figure 16. The PDP-8 is a high speed, general purpose digital computer which operates on 12-bit binary numbers and has a cycle time of 1.5 microseconds. It is a single address parallel machine that uses two's complement arithmetic. The PDP-8 is supported by a comprehensive set of operating system software which allows the user to efficiently program his applications. Also contained in this computer is the 338 Programmed Buffered Display which is a display subsystem that controls a CRT. Up to eight CRTs may be remotely slaved to the 338 Display, and they may receive identical or different information depending on certain display file instructions.

The PDP-8 is usally driven by the 6600 computer using an interrupt procedure. An I/O routine is called to direct or control the reading of data into storage in the PDP-8. The data consists of positional coordinates, alphanumerics, verctor lengths, and symbol flag words that specify the items that are to be displayed. This data may be used to present flight information to a pilot in a cockpit, acoustical information to a sensor operator, or tabular information.

The two IDIOM II computers are the most recent additions to the simulation computer facility. The IDIOM is a 16 bit machine with approximately ten times the display capabilities of the PDP-8s.

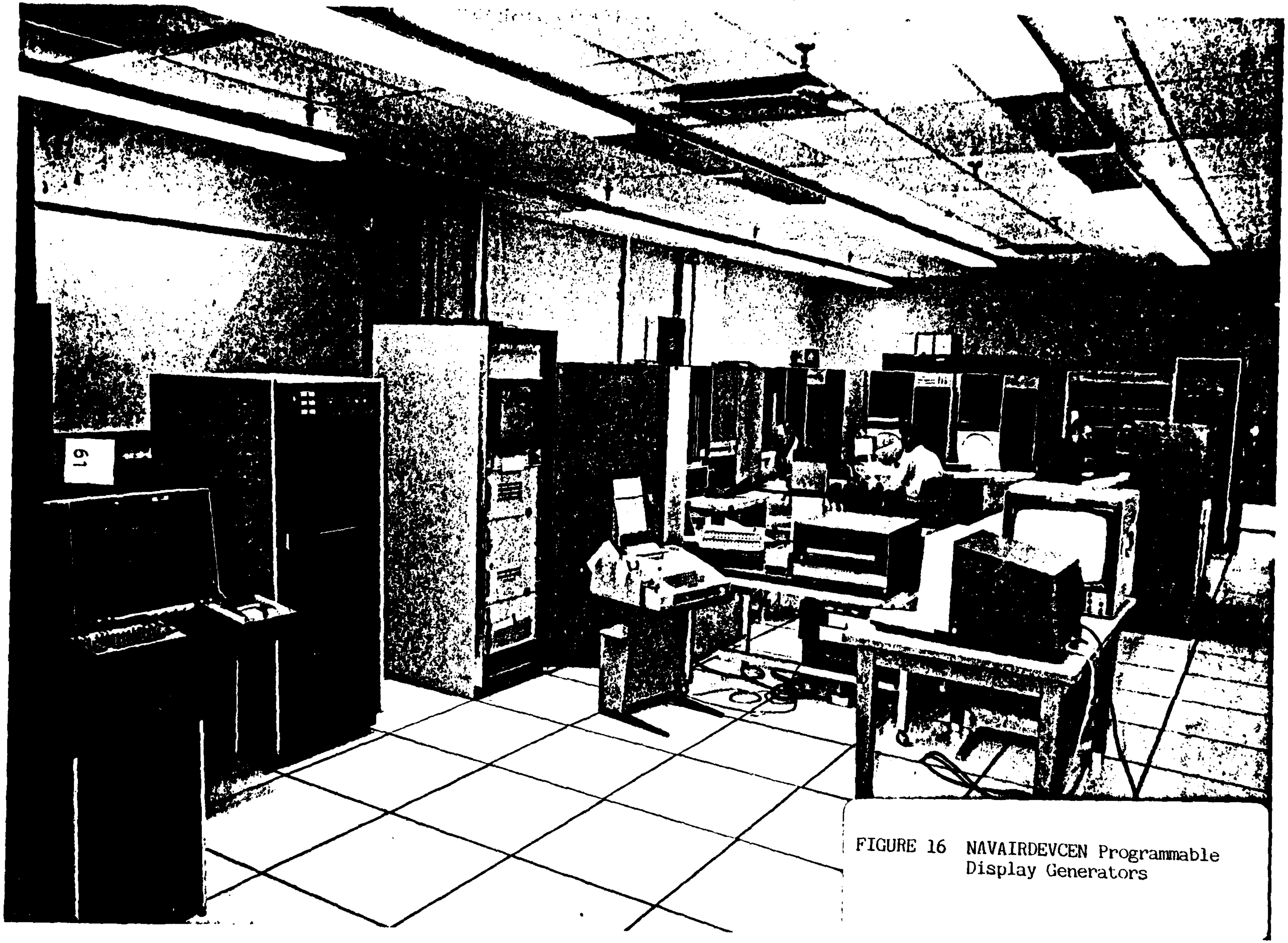


FIGURE 16 NAVAIRDEVCEN Programmable Display Generators

2.3 ELECTRONIC ASSOCIATES, INC. ANALOG COMPUTER

The Electronic System Simulator (ESS), pictured in Figure 17, is a solid state, 100 volt reference analog machine with parallel digital logic. The analog and digital components are programmable through analog and digital patchboards. Each hybrid/analog machine is connected to the real-time digital system via trunking to the A/D units and D/A units. Other trunks are terminated at the various simulation mock-ups.

In general, the hybrid/analog machine is used in the modeling of aircraft control systems to take advantage of its continuous solutions of complex transfer functions. Five of the devices are located in the computer simulation Facility of the Systems Analysis and Engineering Department.

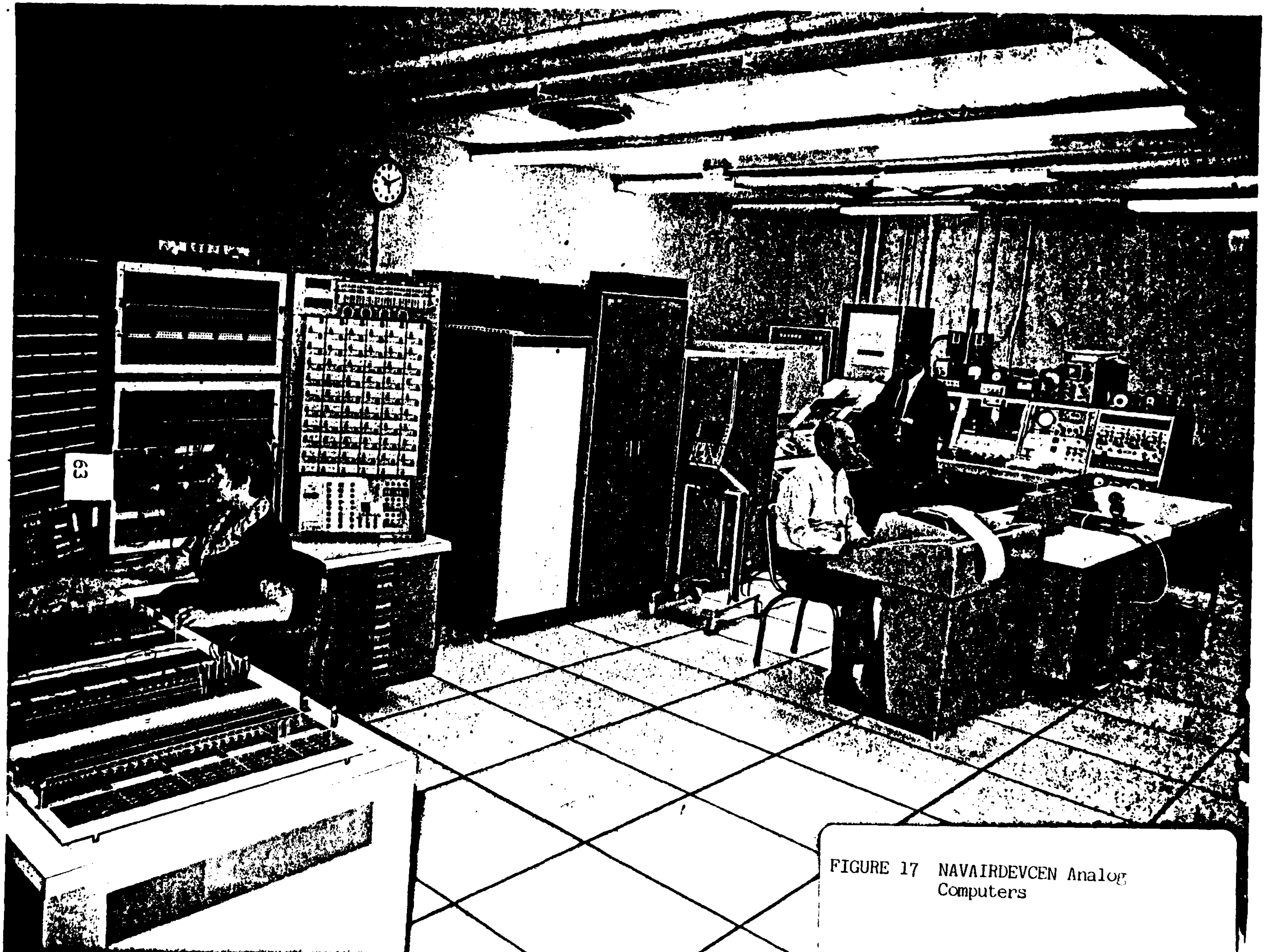


FIGURE 17 NAVAIRDEVCEN Analog Computers

3. DYNAMIC FLIGHT SIMULATOR CENTRIFUGE/COMPUTER INTERFACE

NAVAIRDEVCEN is currently engaged in linking the central computer system to the Dynamic Flight Simulator (centrifuge). This effort will be completed 1 October 1979. The program consists of three major elements.

The first is the acquisition of a display and data collection computer. The second is the development of fiber optic digital-to-digital link and third, the laying of high-quality video and analog transmission lines. Figure 18 shows the three computers and devices in the link.

A detailed description of the major elements follows.

DISPLAY/DATA ACQUISITION COMPUTER

- o PROCESSOR
  - Varian (Sperry) V77 Mini-Computer
    64K - Words of 660 Nano-Sec Dual Port MEMORY
    Hardware Floating Point Processor
    Vortex-Real Time Operating System
    1. Handles Display Program Generation and Updates
    2. Performs Real Time Data Acquisition and Handling Tasks

FIBER OPTIC DATA LINK

FUNCTION

High Speed Data Transfer Between CDC 6600 Simulation Computer and Display/Data Acquisition Computer

DATA TRANSFER CHARACTERISTICS

- o Data Transferred @ 5 Million bits per second (faster than CDC 6681 channel)
- o Data Transferred in 256 x 16 bit blocks
- o Total Data Transmission Time for 1 block = 2.1 milliseconds

CABLE TIE IN

- Fiber Optic Cable (Galite 5000D-73) - 2 cables
  - o For High Speed Digital
- 24 Coax Cable with External Guard Shield
  - o For Single Ended Signals
- 54 Twisted Pairs Each with Foil Shield
  - o For Differential Analog Signals.
- High Quality Double Shielded Twisted Pair Cable - 8 cables
  - o Primarily for Differential Video Signals

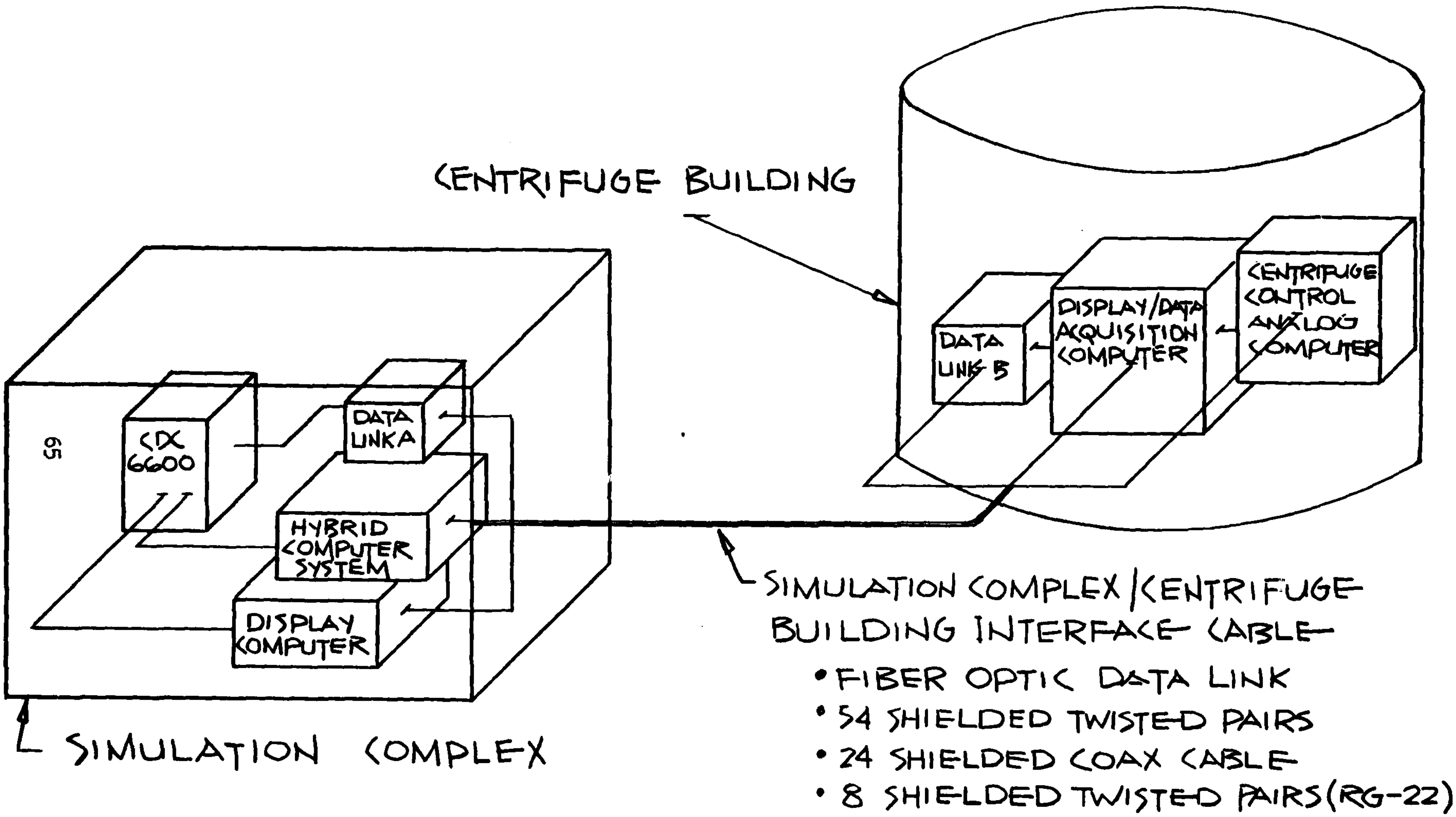


FIGURE 18 Dynamic Flight Simulator Centrifuge/Computer Interface Link