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TECHNICAL REPORT TD-77-1

MIRADCOM/AFATL HYBRID SIMULATION
FACILITY COMPATIBILITY STUDY

VOLUME II - SIMULATION CAPABILITIES
IN THE ADVANCED SIMULATION CENTER

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Aeroballistics Directorate
Technology Laboratory ✓

8 February 1977

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Air Force Armament Laboratory
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AFATL-TR-76-153 ✓

US Army Missile Research and Development Command
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**MIRADCOM/AFATL HYBRID SIMULATION
FACILITY COMPATIBILITY STUDY
VOLUME II - SIMULATION CAPABILITIES
IN THE ADVANCED SIMULATION CENTER**

D. H. Dublin, K. L. Hall, and W. M. Holmes

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FOREWORD

The study documented herein was requested and funded by the Air Force Armament Laboratory, Armament Development and Test Center, System Analysis and Simulation Branch, Eglin Air Force Base, Florida under MIPR 7621-76-90056.

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I. INFRARED SIMULATION SYSTEM

A. System Concept

The infrared simulation system (IRSS) is a simulation tool for the design, development, and evaluation of IR sensor systems applicable to surface-to-air, air-to-air, and air-to-surface missiles. Sensors in the 0.2- to 0.4- μ and 1.0- to 5.0- μ bands are hybrid computer-controlled in six degrees-of-freedom during the target engagement sequence. A gimballed flight table provides pitch, yaw, and roll movements to the sensor airframe. A target generator simulates a variety of target/background combinations which includes tailpipes, plumes, flares, and fuselages in single or multiple displayed against a clear, clouded, overcast, or sunlit sky. These are then displayed in azimuth, elevation, range, and aspect by the target projection subsystem through a folded optical network, a display arm, and a display mirror. Simulation capability ranges from open-loop component evaluation to closed-loop total system simulation.

B. System Description

Functionally, the IRSS is divided into four major entities.

a) Target generation and display subsystem where energy images are generated by up to eight projectors and the energy beam is transferred from point to point until it is displayed on the oval mirror of the display arm.

b) Guidance unit mount with its pitch, yaw, and roll capability controlling the three rotational degrees of freedom required by the sensor.

c) Operator controls and servocontrol electronics subsystem from which the simulation is conducted.

d) Command and data management subsystem (CDMS) through which the "physical effects simulator" is controlled and operated. Figures 1 and 2 illustrate the general relationship of these elements. Tables 1, 2, and 3 describe the simulation capabilities of the system.

1. Target Generation and Display Subsystem

a. General

The target generation and display subsystem consists of an assembly of equipment and components which provide for generation and display of simulated targets, backgrounds, and countermeasures. The purpose of this assembly is to present to the guidance unit (sensor) under evaluation suitable radiation sources to simulate the physical and dynamic characteristics of targets, backgrounds, and countermeasures. These characteristics are designed to be manually or

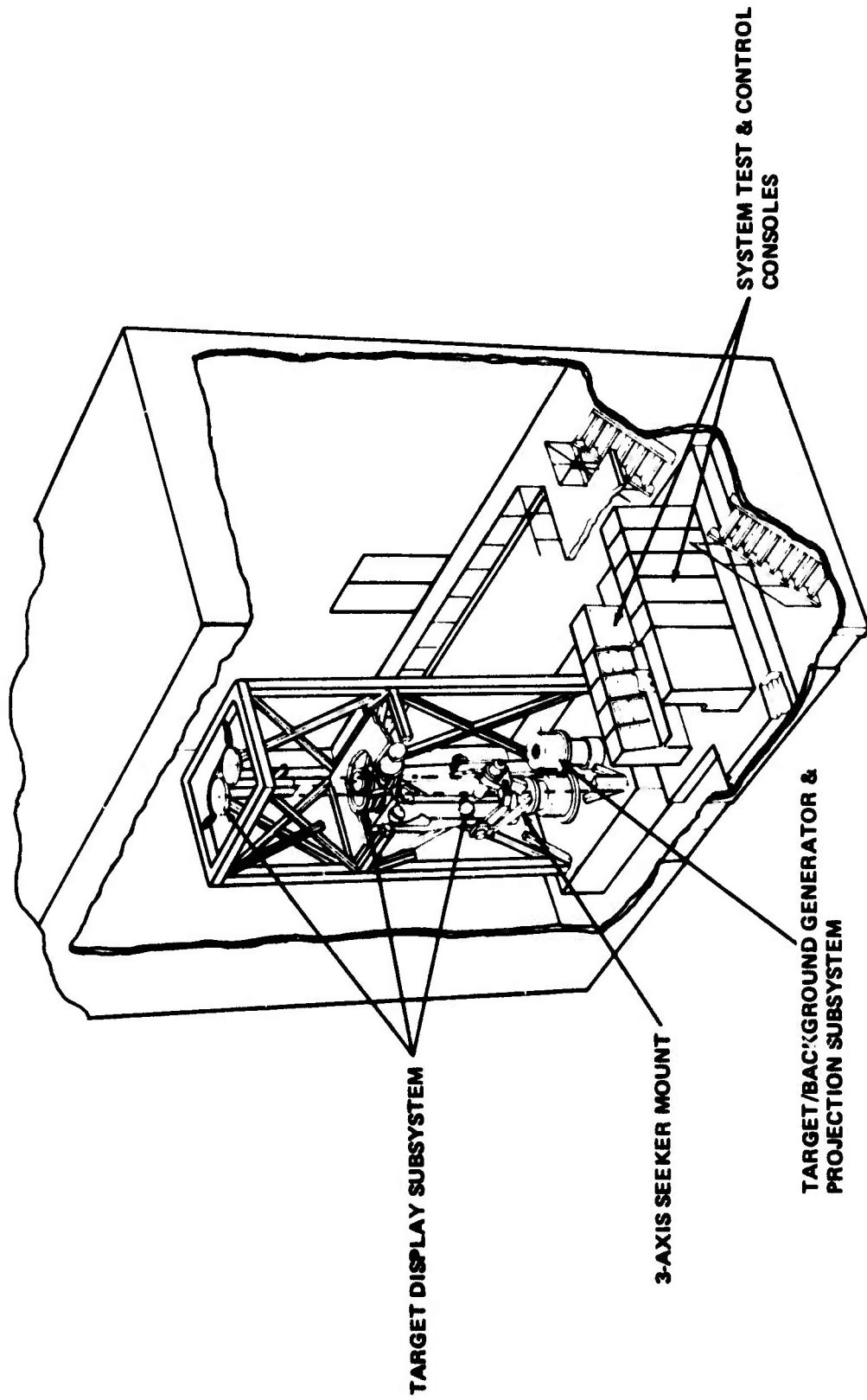


Figure 1. Infrared simulation system.

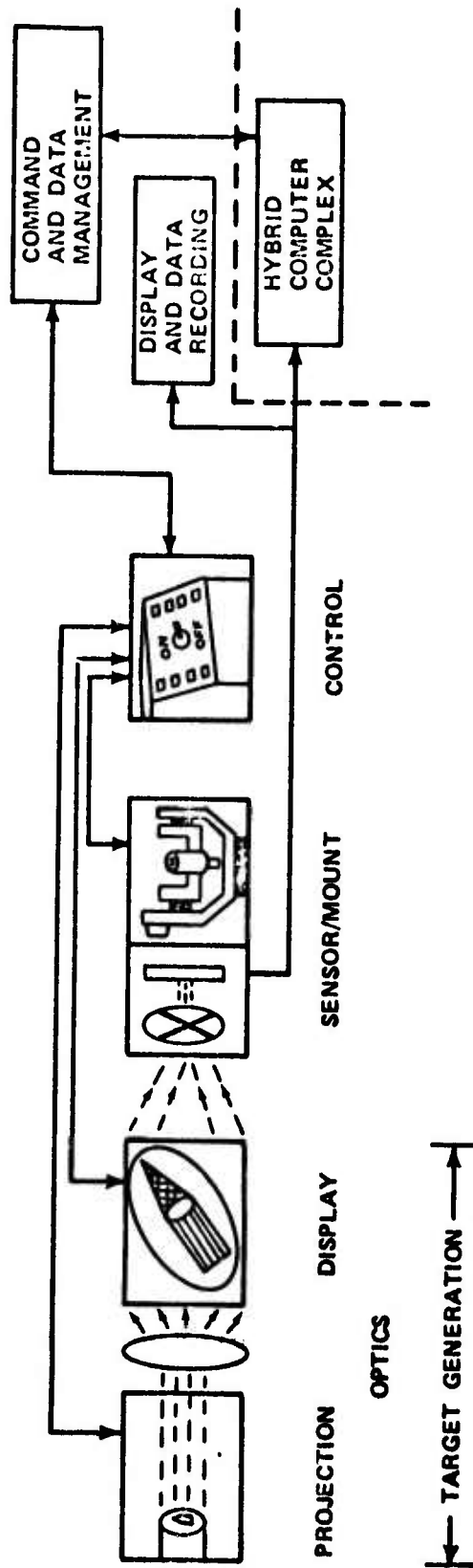


Figure 2. Functional schematic.

automatically controlled. Local instrumentation provides manual control, while automatic programmed control is provided through either open-loop (stand alone) capability or closed-loop (through the hybrid computer complex). Full system capability is available in open-loop and closed-loop modes of operations. More information on the control of operational modes and data transfers is contained in Section 1.F.

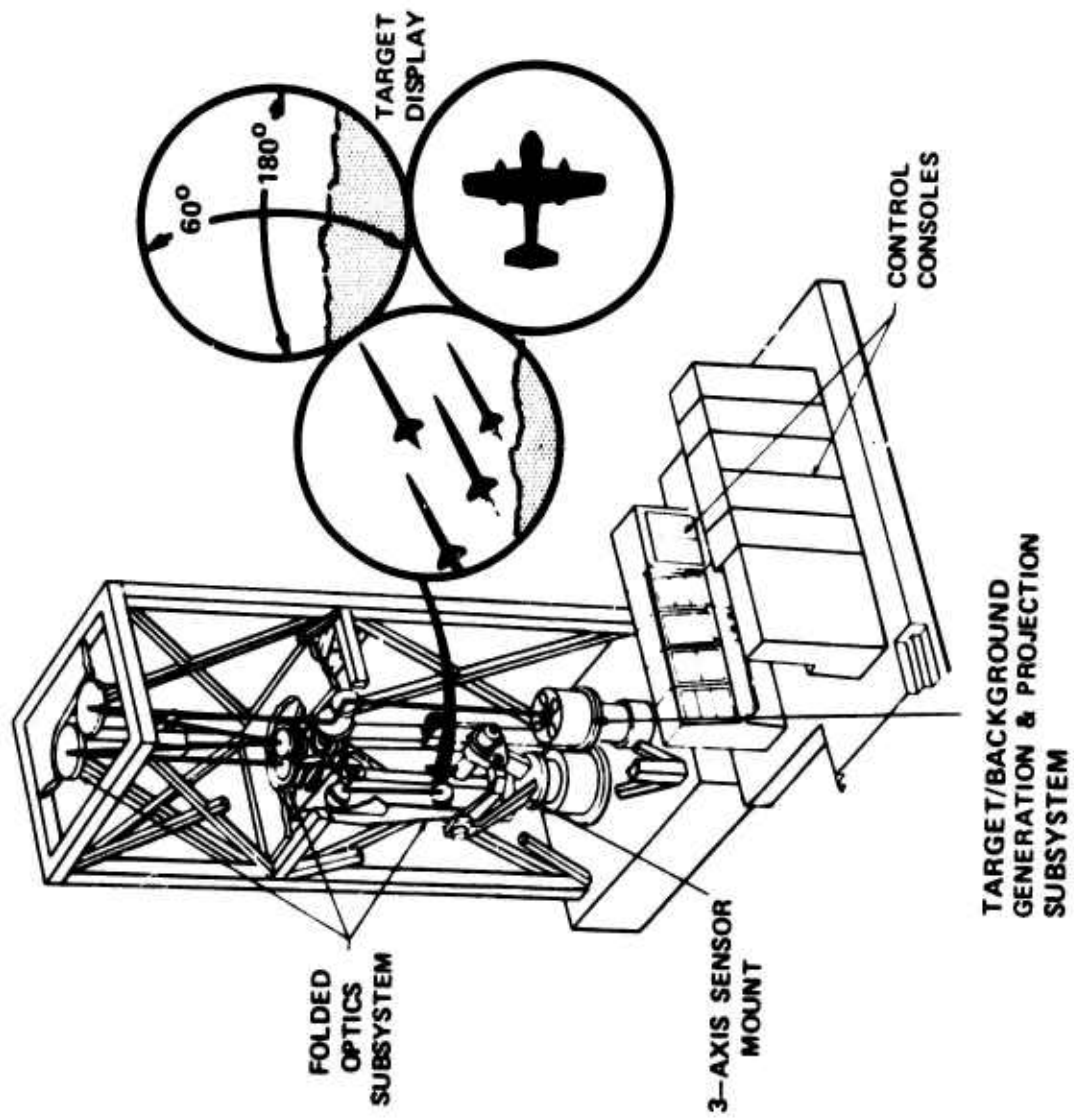
b. Functions

The functions of the target generation and display subsystem are as follows:

- a) To generate a spatially and spectrally complex target system whose geometry and radiation characteristics appear to the sensor substantially as they would in the real world, to full scale, and in real time.
- b) To display to the sensor the generated target system in its true inertial position in real time.
- c) To provide the sensor with a window into target space at all times when the sensor is tracking.
- d) To cause the radiation from each target or target element to fill the sensor aperture fully and uniformly as long as the sensor is tracking.

c. Operation

An assembly of up to eight independent projectors (one being a dual-purpose one) focused at infinity projects as many as seven scene elements plus two spectral backgrounds into a series of spherical mirrors which form a composite in-register image of the complex scene on a special dimpled spherical mirror. The dimpling expands the solid angle of radiation from each projector to insure filling the sensor aperture with each scene element. The second spherical mirror then forms a virtual image of this composite scene at infinity. The sensor in the guidance unit mount observes this scene through the window held before it by the display arm and mirror. The target projection subsystem is mounted on a single-axis table which removes the display scene rotation caused by azimuth motion of the display arm. Fine positioning of the targets within the display window is done by small two-axis gimballed mirrors (i.e., directional mirrors) in the projection subsystem. Each projector provides control of spectral radiance, size, shape, and aspect for a single target by using servodriven transparencies, irises, and spectral and neutral density filters. The target generation and display subsystem is diagrammed in Figure 3 and Figure 4 shows the installed hardware.



**TARGET/BACKGROUND
GENERATION & PROJECTION
SUBSYSTEM**

Figure 3. Target generation and subsystem.

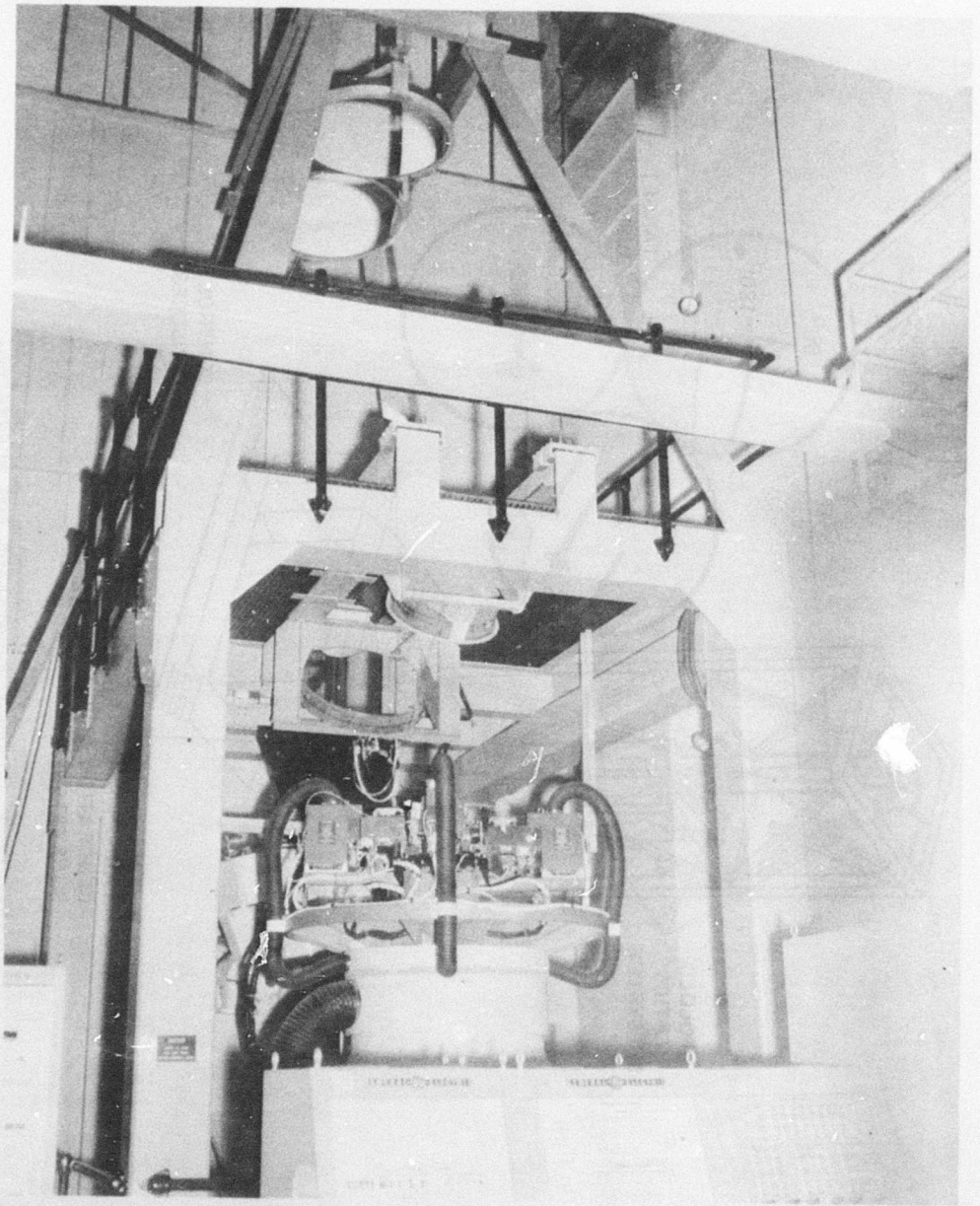


Figure 4. Target generation and subsystem.

The IRSS (Figure 3) presently includes four projectors. Two of these projectors display circular targets of variable size and intensity in the 1.0- to 5.0- μ region to simulate tailpipe targets and decoying countermeasures. A third projector presents a triangularly shaped target of variable size and intensity in the 3.0- to 5.0- μ region to simulate a jet aircraft plume. The fourth projector is an ultraviolet (UV)-visible projector which presents a rectangular target upon a sky background. The background simulates blue sky, clouds, and hazy sky and is variable in brightness. The rectangular target used to simulate an aircraft fuselage can be adjusted in intensity to be darker or brighter than the background, i.e., negative and positive contrast targets. These targets are illustrated in Figure 5.

Development effort is currently in progress to enhance the target projection complement of the IRSS. Projectors operating in the 8.0- to 14.0- μ region, a laser projector, and a modulated circular target projector are being developed.

2. Guidance Unit Mount

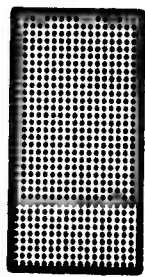
The guidance unit mount shown in Figure 6 is a three-axis, hydraulically powered, servocontrolled table on which the sensor is mounted. It will produce, on command, all of the rotational motions that a missile would experience during an actual flight. Slip rings are provided for transmitting guidance unit signals through the roll gimbal. For cooling the IR detector, high-pressure rotary joints are provided for transmitting high-pressure cryogenic cooling gas to the guidance units.

3. Operator Control and Servocontrol Electronics Subsystem

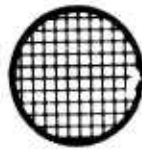
The operator control and servocontrol electronics subsystem, as the name implies, contains all of the system operator controls and displays, power distribution, servocontrol, projector lamp control, analog computation, and mode control electronics.

4. Command and Data Management Subsystem

The CDMS provides system control, timing, and command and performance data distribution and management during all testing. It functions as a digital interface between the Advanced Simulation Center (ASC) hybrid computer complex and the IRSS during closed-loop operation. In this mode, system commands are calculated in real time by the hybrid computers and sent to the digital computer within the IRSS for issuance to the system. System positions and rates and guidance unit signals are continuously transmitted to the hybrid computers for simulation updating and recalculation of IRSS commands.



FUSELAGE

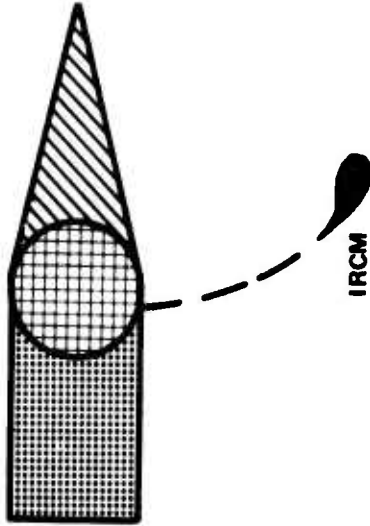


TAILPIPE



PLUME

COMPOSITE IMAGE



IRCM

Figure 5. Target simulation models.

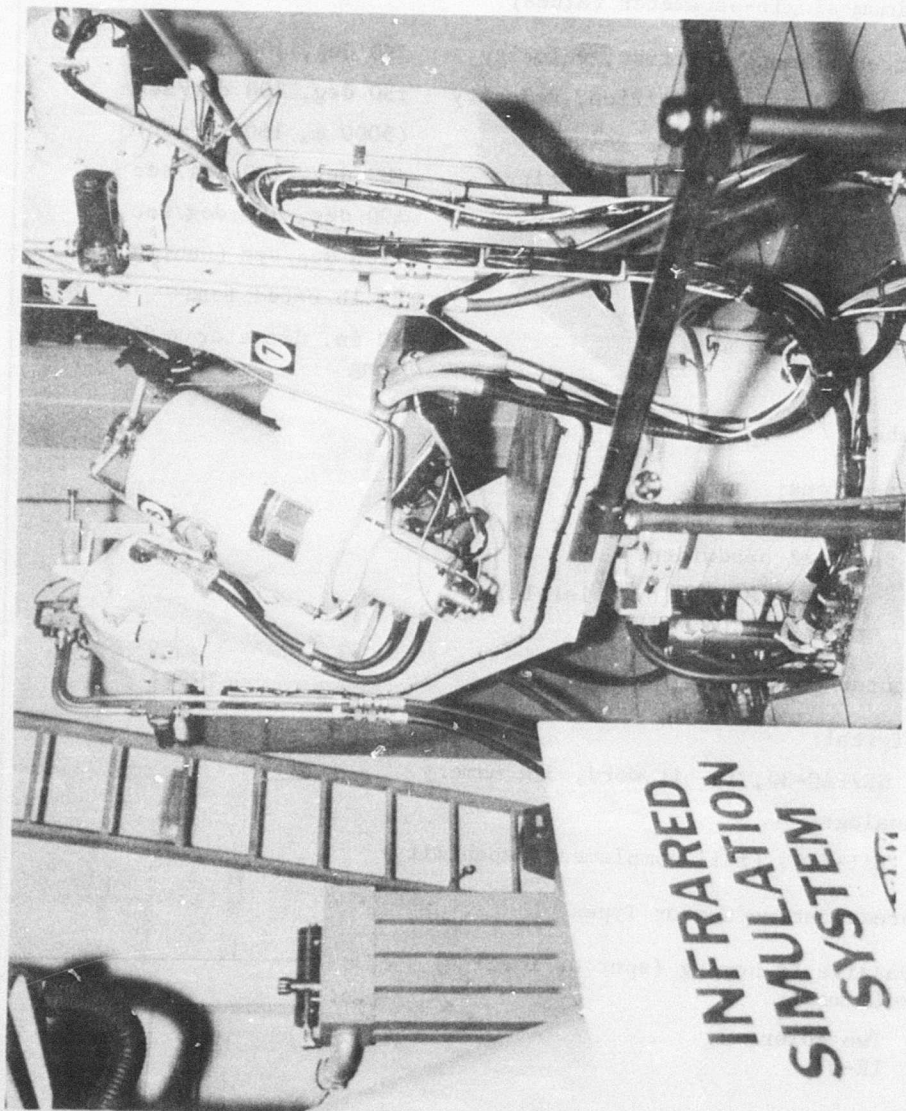


Figure 6. Guidance unit mount.

TABLE 1. SIMULATION CAPABILITIES

Simulation Flight Parameters (maximum single-parameter values)	
Target azimuth position, velocity	±90 deg, 100 deg/sec
Target elevation position, velocity	±30 deg, 100 deg/sec
Target range, closing velocity	(5000 m, 1500 m/sec)
Sensor pitch position, velocity	±80 deg, 100 deg/sec
Sensor yaw position, velocity	±90 deg, 100 deg/sec
Sensor roll position, velocity	7200 deg/sec (Continuous)
Sensor system weight	25 lb rated load
Sensor system size	10 in. diameter × 25 in. long
Chamber	
Dimensions:	
45 ft long × 20 ft wide × 42 ft high	
Spectral bandwidth:	
-0.2 to 0.4 μ (UV, visible)	
-1.0 to 5.0 μ (IR)	
Computer Capability	
Digital:	
GE/PAC-30, 16-bit word, 32K memory	
Analog:	
EAI-7800 (full complement capability)	
Representative Sensor Types	
Passive IR homing (spot or imaging)	
Multimode:	
Two color	
IR-UV	
Growth Potential	
Extension of bandwidth capability to long wave infrared	
Addition of surface-to-surface and air-to-surface applications	

TABLE 2. TARGETS AND BACKGROUND SIMULATION CAPABILITIES

Target Background Elements					
	Quantity	Shape	Size (m)	Spectral Bandwidth (μ)	Apparent Target Radiance ($\text{W}/\text{cm}^2\text{-sr}$)
Tailpipe /flare	2	Circular	0.15 to 1 dia	1.0 to 5.0	1.3×10^{-4} to 0.13
Plume	1	Triangular	1 x 1 to 1 x 5	3.0 to 5.0	4×10^{-5} to 0.02
Fuselage	1	Rectangular	1 x 1 to 3 20	0.2 to 0.4	10^{-6} to 10^{-3}
Background	1	---	---	---	10^{-3} (max)
Target Motion					
	Azimuth	Elevation	Range (50 to 5000 m)		
Displacement	± 90 deg	± 30 deg	160 to 16,000 ft		
Velocity	0 to 100 deg/sec	0 to 100 deg/sec	0 to 4900 ft/sec (0 to 1500 m/sec)		
Acceleration	0 to 400 deg/sec ²	0 to 400 deg/sec ²	---		
Accuracy	± 1 mrad	± 1 mrad	$\pm 5\%$		
Repeatability	± 0.5 mrad	± 5 mrad	$\pm 1\%$		

TABLE 3. SENSOR MOUNT CAPABILITIES

Maximum Load			
Sensor system size - 10 in. diameter × 25 in. long			
Sensor system weight - 25 lb			
Dynamic Capabilities* (at stated load - maximum single parameter performance)			
	Pitch	Yaw	Roll
Displacement	±80 deg	±90 deg	Continuous
Velocity	100 deg/sec	100 deg/sec	7200 deg/sec
Acceleration	7800 deg/sec ²	4400 deg/sec ²	12,300 deg/sec ²
Positioning accuracy:			
Analog	±0.5 mrad	±0.5 mrad	±1.0 mrad
Digital	±0.2 mrad	±0.25 mrad	±0.25 mrad
Repeatability	±0.1 mrad	±0.1 mrad	±0.1 mrad
Velocity mode dynamic range	10,000:1	10,000:1	10,000:1
Frequency response	20 Hz	15 Hz	25 Hz

*Position or rate mode operation

Rotary joints on all three axis for gas or liquid transfer at pressure up to 6000 psig

Low-noise slip-rings (88 each) on roll axis for power and signal transmission when rolling

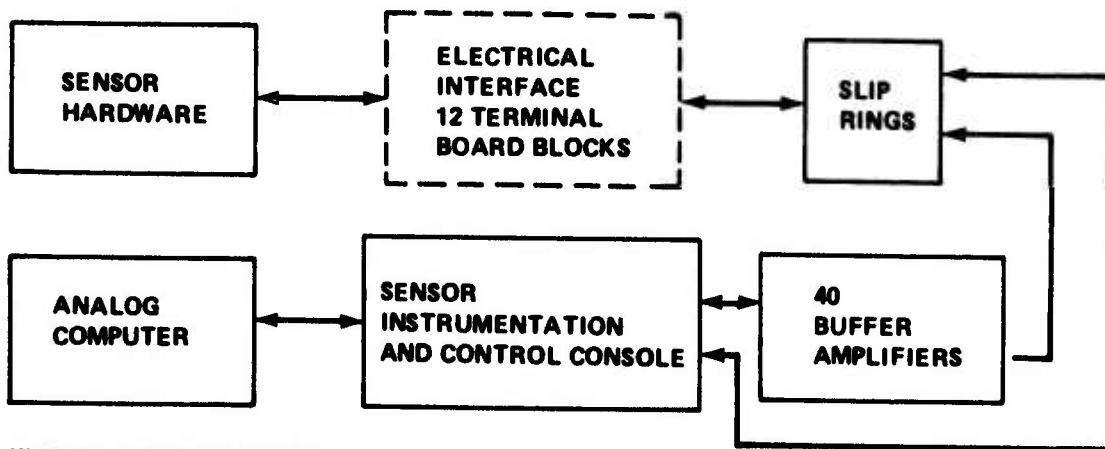
In the open-loop mode of operation, the CDMS acts as a multichannel, high-speed function generator using either the digital or analog computer within the cell while the guidance units' outputs are monitored and/or recorded to aid in decision making for the next test or for analysis at some future data.

C. Sensor Hardware - IRSS Interface

The sensor hardware interface with the IRSS in the guidance unit mount can be divided into the following three groups or sections.

- 1) The electrical interface.
- 2) The mechanical interface.
- 3) The cryogenic interface.

The following diagram shows the sensor hardware electrical interface with the IRSS via twelve terminal board blocks located on the roll axis of the guidance unit mount.



WIRING CONFIGURATION:

- 36 EACH - NO. 20 AWG TWISTED SHIELDED PAIR
- 4 EACH - NO. 20 AWG SINGLE SHIELDED COMMON
- 6 EACH - NO. 16 AWG TWISTED SHIELDED PAIR

Forty ± 15 -V buffer amplifiers for sensor signal unloading are provided adjacent to the guidance unit mount. The amplifiers are configured for a gain of (+1).

The mechanical interface between the sensor hardware and the roll axis of the guidance unit mount is defined by two mounting surfaces: one on the front of the roll axis and one in the back of the roll chamber.

The cryogenic interface consists of a stainless steel 1/4 in. male flare fitting.

D. Future Capabilities

A design study is currently taking place to determine the optimal approach for the design of a long wave infrared (LWIR) target/background projector for the IRSS. This design study will be used as a guideline for the design and fabrication of an 8 through 14 μ projector in the near future.

Another future capability will be a high-pressure nitrogen facility which will be capable of supplying a continuous flow of 6000 psig GN_2 over an extended period time. This facility should be available for use within 12 months.

E. Typical Weapon System Data that May be Obtained During Testing

Typical weapon data that may be obtained during testing are as follows:

- 1) Sensor gimbal limits.
- 2) Signal-to-noise measurements.
- 3) Line-of-sight rate capability.
- 4) Target acquisition range and acquisition capabilities.
- 5) Tracking accuracy.
- 6) Target-flare sensitivity information.
- 7) Multiple target acquisition capabilities.
- 8) Maximum slew rate while sensor caged.
- 9) Launch to intercept dynamic, real time tracking capabilities.
- 10) Servo cross-coupling of guidance information.
- 11) Sensitivity to UV-IR targets.
- 12) Sensitivity to different target aspect angles.
- 13) Cage accuracy.

II. ELECTROOPTICAL SIMULATION SYSTEM

A. System Concept

The EOSS (Figures 7 and 8) provides realistic and precisely controlled environments for the nondestructive simulation of a wide variety of UV, visible, and near IR sensor systems. Actual sensors are hybrid computer controlled in six degrees of freedom while viewing targets under controlled illumination level (10^{-4} to 10^3 foot-candles) in an indoor simulation chamber and under ambient conditions on an outdoor simulation range. Three-dimensional (3-D) target simulation is provided on a 32- x 32-ft terrain/target model/transporter which features a variety of topographical and man-made complexes at 600:1 and 300:1 scales, removable model sections, and fixed and moving targets at any desirable scale. A moving projection subsystem provides two-dimensional (2-D) representation.

A gimballed flight table (capable of simulating pitch, yaw, and roll movements to the sensor airframe) is attached to a transport which moves vertically and laterally. The terrain/target model or the 2-D projection subsystem is moved toward the flight table to provide the sixth degree of freedom. An adjacent high resolution TV/joystick console and proposed helicopter crew station provide a means of evaluating man-in-the-loop guidance and target acquisition concepts.

B. Growth Potential

Growth potential areas for the EOSS are as follows:

- 1) Crew station simulation.
- 2) IR terrain model.
- 3) Laser target simulation.
- 4) Sun-moon simulation.
- 5) ± 15 -deg lens sweep proving a 15:1 zoom capability sweep.

C. Representative Sensor Types

The following items are representative sensor types:

- 1) Optical contrast/correlation passive homing.
- 2) Semiactive homing.
- 3) Command-to-a-line-of-sight (CLOS).
- 4) Beam riders.
- 5) Radiation homing.
- 6) Various multimode.

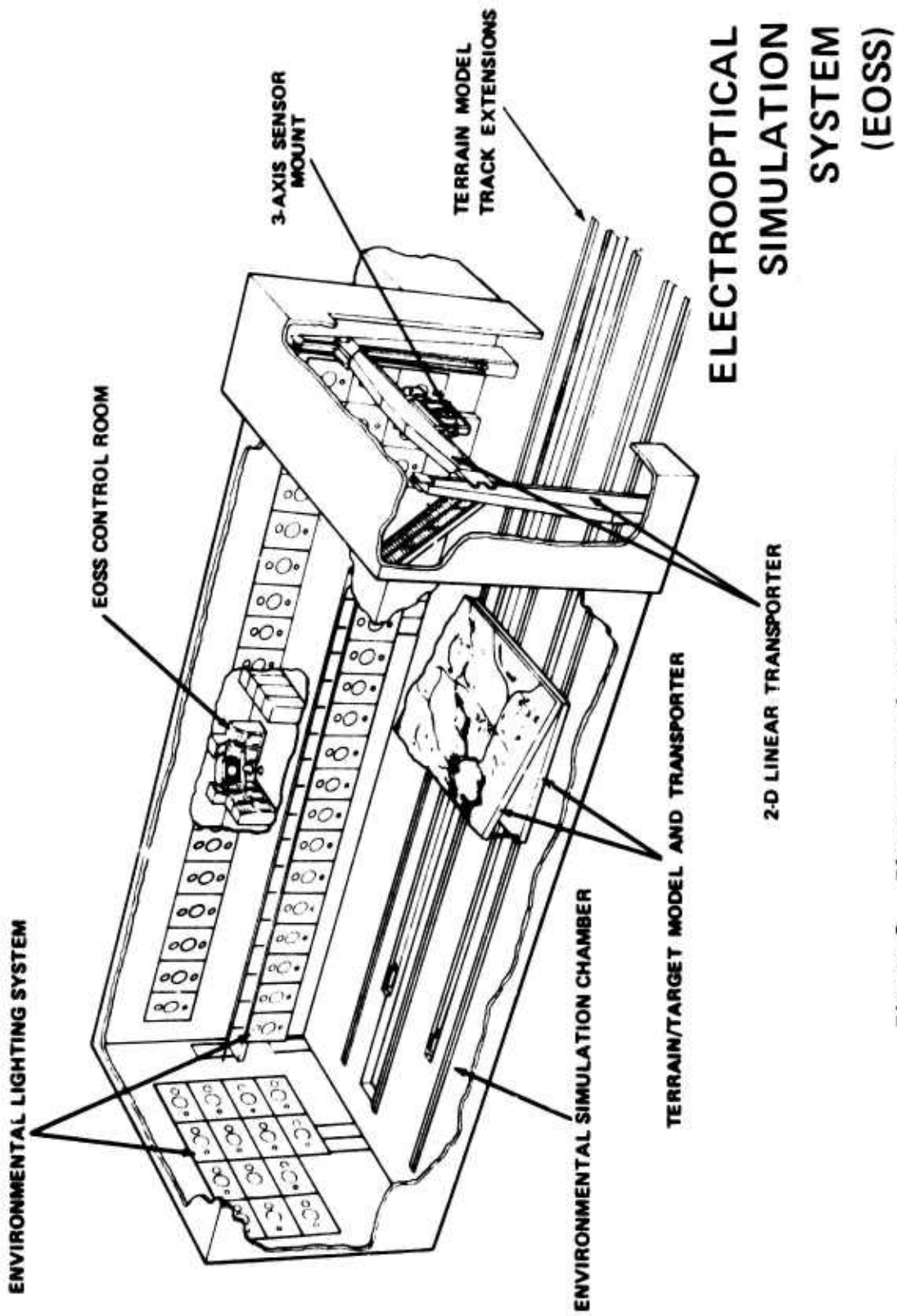


Figure 7. Electrooptical simulation system.

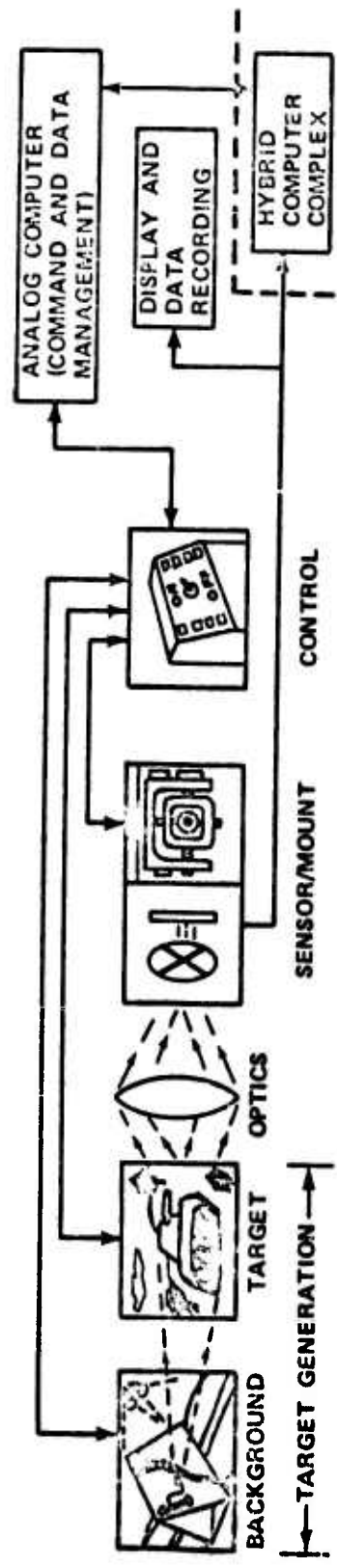


Figure 8. Functional schematic of EOSS.

D. Electrooptical Simulator Tasks

Electrooptical simulator tasks that are completed are as follows:

- 1) Dual mode seeker (TV)
- 2) Remote piloted vehicle (RPV)
- 3) Target acquisition studies - Naval Surface Weapons Center (NSWC), Dahlgren
- 4) Advanced TV seeker (ATVS)
- 5) Beam rider zoom optics
- 6) Cannon launched beam rider projectile - Armament Command (ARDCOM) Northrop
- 7) Solid state imaging device - Honeywell
- 8) Scene matching area correlator - Navy Avionics Facility Indianapolis (NAFI)
- 9) RPV with ATVS
- 10) Operator target acquisition study - Rockwell International

E. Typical Weapon System Data that May be Obtained

Typical weapon system data that may be obtained are as follows:

- 1) Scale factors for weapon system outputs.
- 2) Rate gyro outputs to autopilot.
- 3) Missile body motion-rate gyro cross-coupling.
- 4) Line-of-sight rate measurements.
- 5) Initial aiming and lock-on accuracy.
- 6) Aspect angle sensitivity.
- 7) Tracking slew rate.
- 8) Cage accuracy.
- 9) Gimbal error map.
- 10) Gimbal cage time.
- 11) Seeker bandwidth.
- 12) Light level sensitivity.
- 13) Launch transient effects.
- 14) Signal-to-noise Measurements.
- 15) Target reacquisition capability.

F. Nonroll System

The nonroll system is composed of the following:

- 1) 19 each - No. 22 AWG twisted shielded pair (all buffered).
- 2) 7 each - No. 22 AWG single shielded conductors (all buffered).
- 3) 1 each - RG-58 A/U coax cable.
- 4) 1 each - RG-187 coax cable.
- 5) 1 each - RG-195 coax cable.
- 6) 1 each - Quad group shielded for three phase 400-Hz power.
- 7) 2 each - Twisted shielded pair for dc power.

G. Continuous Roll System

The continuous roll system is compared of the following:

- 1) 2 each - No. 22 AWG twisted shielded pair.
- 2) 7 each - No. 22 AWG single shielded conductor.
- 3) 1 each - RG-58 A/U coax cable.
- 4) 1 each - RG-187 coax cable.
- 5) 1 each - RG-195 coax cable.
- 6) 1 each - Quad group shielded for three phase 400-Hz power.
- 7) 1 each - Twisted shielded pair for dc power.

Twenty 10-V buffer amplifiers for sensor signal unloading are provided on the flight table adjacent to the sensor. The amplifiers may be configured for gains of 0.5, 1, 5, 10 and 20.

H. Simulation Flight Parameters

Table 4 presents the simulation flight parameters of the EOSS.

TABLE 4. EOSS FLIGHT PARAMETERS

Sensor system size - 14 in. diameter × 36 in. long		
Sensor system weight - 150 lb		
Scale	600:1	300:1
Slant range:		
Indoor	23 km	10 km
Outdoor	40 km	20 km or horizon
Altitude	21,000 ft	10,500 ft
Lateral		
Range	To 19,000 ft	To 9750 ft
Velocity	To 2400 ft/sec	To 1200 ft/sec
Acceleration	185 g	93 g
Longitudinal		
Velocity	To 900 ft/sec	To 4500 ft/sec
Acceleration	185 g	92 g
Vertical		
Velocity	To 3600 ft/sec	To 1800 ft/sec
Acceleration	110 g	56 g
Outer gimbal (pitch)		
Position	±120 deg	±120 deg
Velocity	To 200 deg/sec	To 200 deg/sec
Middle gimbal (yaw)		
Position	±45 deg	±45 deg
Velocity	To 200 deg/sec	To 200 deg/sec
Inner gimbal (roll)		
Position	Continuous	Continuous
Velocity	To 2000 deg/sec	To 2000 deg/sec

I. Chamber

The chamber indoor outdoor measurements are as follows:

Indoor: 120 ft long × 40 ft wide × 38 ft high
Outdoor: 240 ft tract length

J. Open-Loop Computer Capability

The open-loop computer capability is as follows:

Digital: PDP 11/20, 16-bit word, 16K memory and 20 megaword disk
Analog: AD-4 (special resolver configuration)

K. System Description

The capabilities of the EOSS provide for six degrees of freedom; three degrees of rotational motion and three degrees of translational motion. The three degrees of rotation are provided by a three-axis, gimballed flight table (Figure 9) where the sensor is mounted in the inner (roll) gimballed housing. Figure 10 shows various types of equipments mounted in the flight table. This flight table provides for all missile body angular displacements, body rates, and accelerations required for open-loop or closed-loop simulation. The three degrees of translational motion are provided by three transport subsystems. The lateral transport moves the flight table, which is suspended beneath a horizontal beam. The horizontal beam assembly operates through an end box/rack and rail inside the vertical column housing structure. This translation provides all vertical or altitude displacements, rates, and accelerations. These five degrees of freedom are hardware interfaced such that they can be considered to comprise a five degree-of-freedom assembly. The longitudinal transport system moves the terrain/target model through a carriage-interfaced rack and rail assembly toward the flight table. This longitudinal travel provides range closure displacements, rates, and accelerations. The longitudinal subsystem transports the 3-D terrain/target model which provides 3-D static and dynamic signatures to the sensor. Figure 11 shows an overall view of the EOSS. Flight table and translational drive characteristics are presented in Tables 5 and 6, respectively.

L. Technical Discussion

1. Scale Factors

Scale factors used in the EOSS are primarily regulated by the scale of the target model. To establish the most versatile scaling, three types of weapon systems were considered:

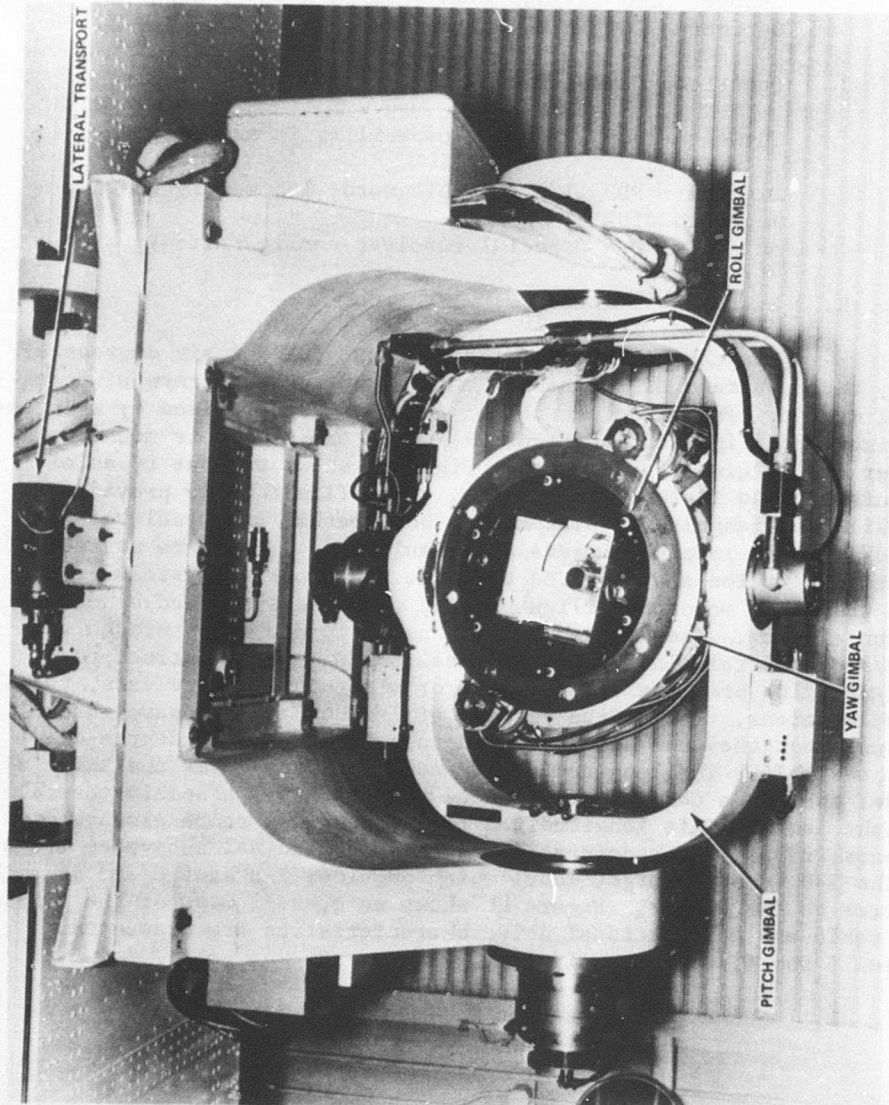


Figure 9. Three-axis flight table.

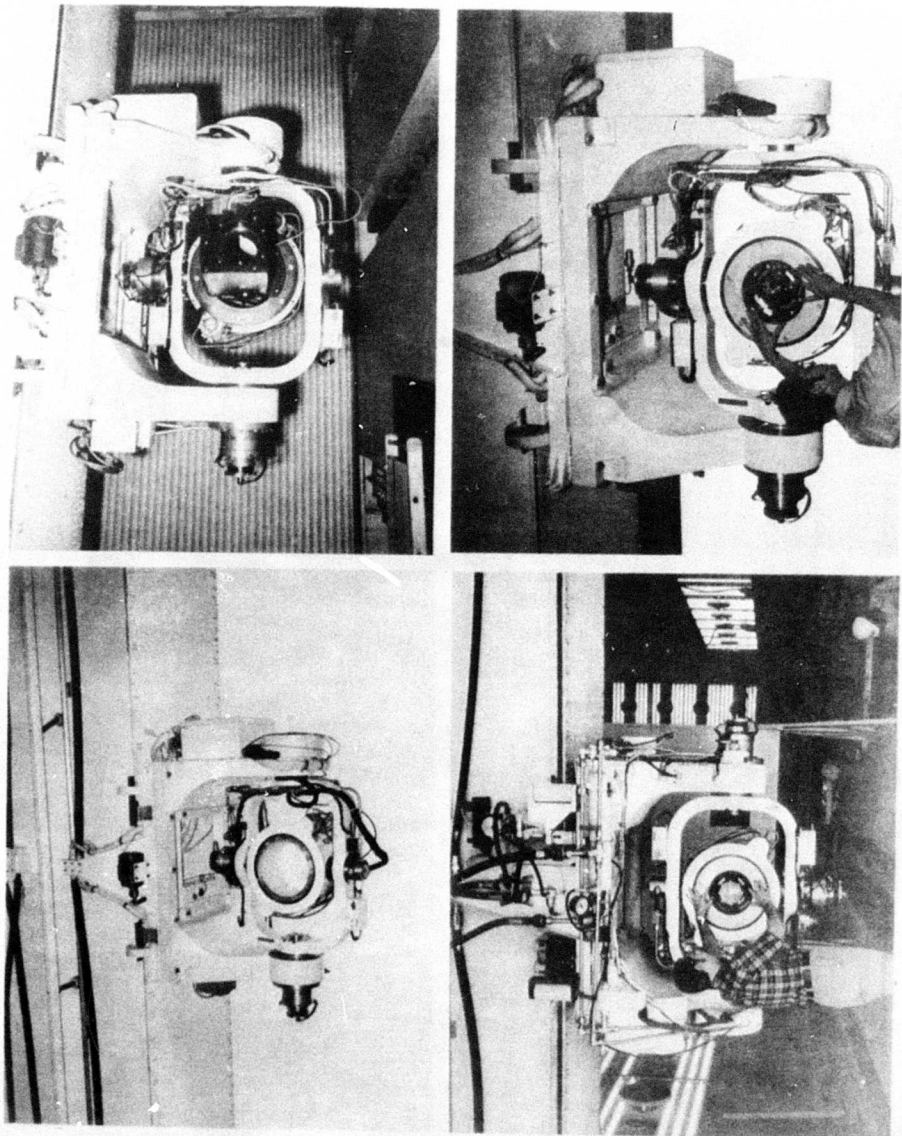


Figure 10. Three-axis flight table in various configurations.

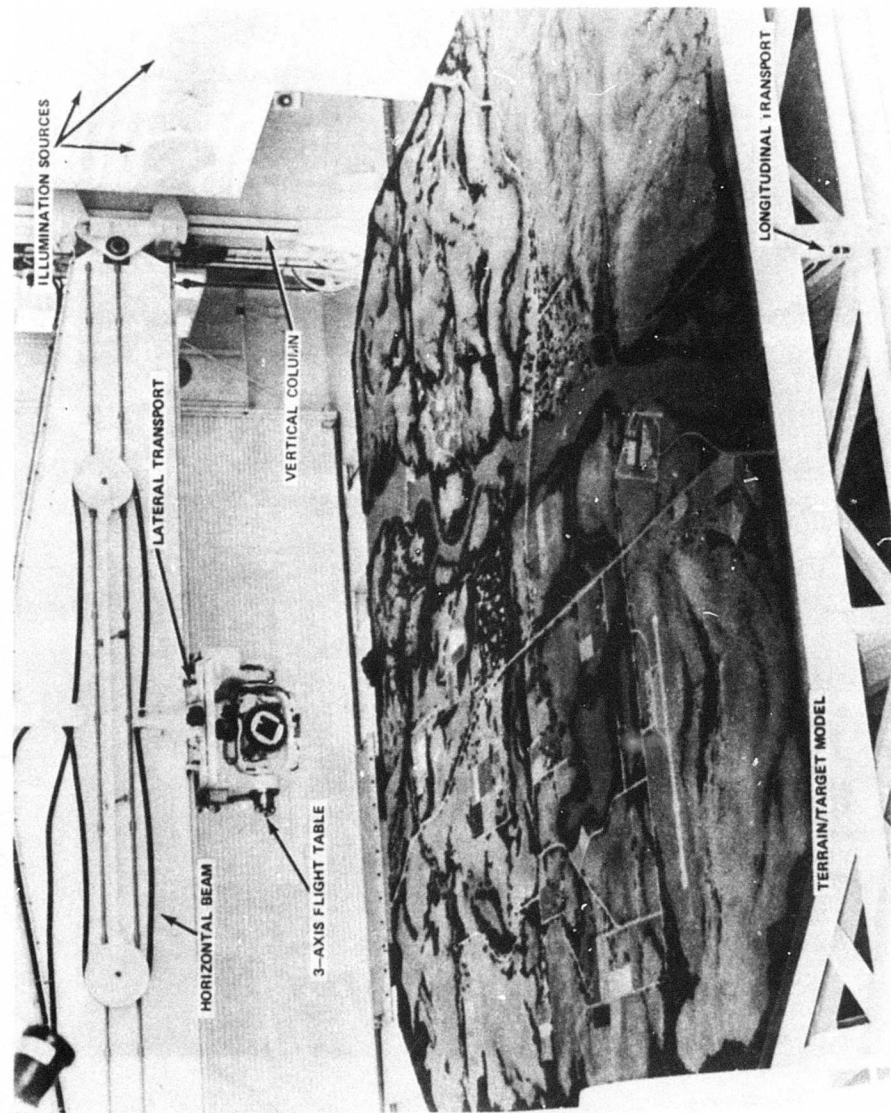


Figure 11. Equipment view.

TABLE 5. FLIGHT TABLE LOAD AND PERFORMANCE CHARACTERISTICS

Specification	Pitch	Yaw	Roll
Displacement	±120 deg	±45 deg	Continuous
Velocity, maximum exceeds (150 lb load)	±200 deg/sec	±200 deg/sec	±2000 deg/sec
Ratio, maximum to minimum controlled velocity	10^4	10^4	10^4
Rate mode	5×10^5	5×10^5	5×10^5
Position mode	8000 deg/sec^2	$10,000 \text{ deg/sec}$	$10,000 \text{ deg/sec}$
Acceleration maximum exceeds (50 lb load)	0.25 mrad	0.25 mrad	0.25 mrad
Position accuracy	±0.1 mrad	±0.1 mrad	±0.1 mrad
Repeatability			
Response			
Bandwidth (50 lb load)	6 Hz	7 Hz	7 Hz
Position mode:	10 Hz	20 Hz	23 Hz
(45-deg phase, 10-deg p-p)			
(90-deg phase, 1-deg p-p)			

Note:

- Flight table weight (typical) - 1000 lb
- Load inertia (maximum) - 18 lb in./sec² about roll axis
- 51 lb in./sec² about pitch and yaw axis
- Load size (typical) - Cylinder: 10 in. diameter, 18 in. long
- Load size (maximum) - Cylinder: 14 in. diameter, 36 in. long
- Load weight (typical) - Up to 50 lb
- Load weight (maximum) - 150 lb
- Orthogonality of axis - ±0.1 mrad
- Intersection of axis - ±0.002 in.

TABLE 6. TRANSLATIONAL DRIVES CHARACTERISTICS

Specification	Longitudinal Axis	Vertical Axis	Lateral Axis
Displacement			
Indoors	~ 120 ft	35 ft	~ 34 ft
Outdoors	~ 240 ft		
Total	~ 360 ft		
Velocity, maximum exceeds	15 ft/sec	6 ft/sec	4 ft/sec
Ratio maximum to minimum, controlled velocity	1000:1	1000:1	1000:1
Acceleration, maximum exceeds	10 ft/sec ²	6 ft/sec ²	10 ft/sec ²
Braking deceleration	32 ft/sec ²	32 ft/sec ²	32 ft/sec ²
Position accuracy	±0.5 in.	±0.125 in.	±0.125 in.
Repeatability	±0.031 in./2 ft	±0.031 in./2 ft	±0.031 in./2 ft
Readout capability	±0.003 in.	±0.001 in.	±0.001 in.
Frequency response, velocity mode	60-deg phase at 3.0 Hz	60-deg phase at 3.0 Hz	60-deg phase at 3.0 Hz

Note: Orthogonality of axis: 0.25 mrad.

- a) A short range surface-to-surface missile.
- b) A helicopter-launched guided weapon.
- c) A short range direct fire weapon.

Consideration was given to the sensor's field of view, slant range, altitude, line-of-sight depression angles, and trajectories. The ellipses formed in the ground plane or on the terrain-target model were determined for fitting on the terrain target model.

For these studies, the results showed a scaling of 600:1 as having no restrictions for the ellipses fitting on the terrain/target model. When the error analysis was considered for evaluating a 1-ft scaled miss distance, a terrain/target model scaling of 300:1 approached error budget limitations. The resulting compromise has three-fourths of the terrain/target model scaled at 600:1, but features are such that a ready conversion for 300:1 or even 1200:1 can be made. The remaining one-fourth of the terrain/target model is scaled at 300:1, but scales of 150:1 or 600:1 can readily be used.

2. Terrain/Target Model

The terrain/target model (Figure 12) is transported on the longitudinal subsystem and provides a series of straight-line contrast areas, bland topography with a variety of contrasting targets, and servocontrolled moving target models. The straight-line contrast areas with a target located close to the contrast line exercises the closure shift-drift problem experienced in most correlators. The bland area with various contrasting targets exercises the acquisition and hold-lock capability under different lighting and contrast ratios. The moving targets provide dynamic tracking capability against changing background scenes. The target model can be tilted to an infinite number of positions from 0 to 30 deg from the horizontal so that various geometries and altitudes can be accommodated. When the target model is horizontal, it can be rotated in azimuth and secured at each 90-deg point presenting different aspect angles to the sensor. Figure 13 shows a movable target (tank). Figures 14 and 15 show actual features versus the scaled representations on the terrain/target model.

3. Moving Target

The moving target simulation provides a dynamic and rocking capability to the sensor under tests. Two moving targets are available. One moving target runs a predetermined lateral course and a straight line longitudinal course. The other moving target provides a more difficult tracking task by following a predetermined zigzag course. This provides a means of evaluating sensor cross-coupling between axes.

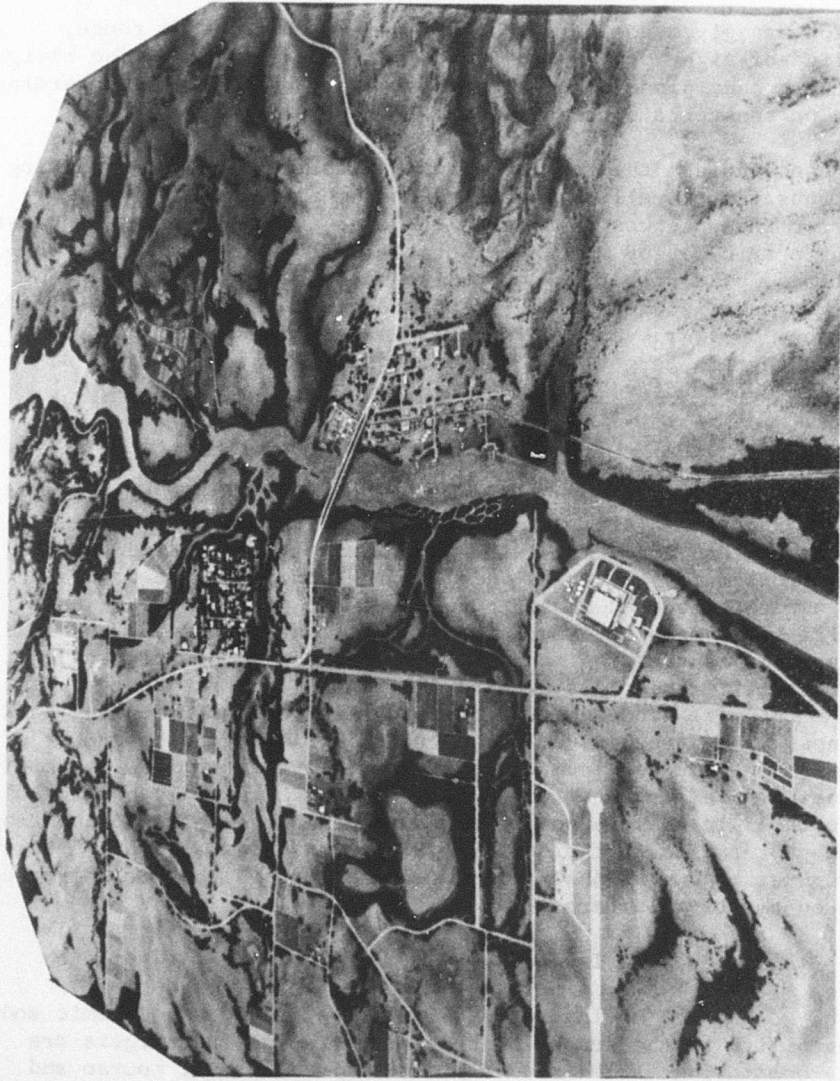


Figure 12. Terrain/target model.

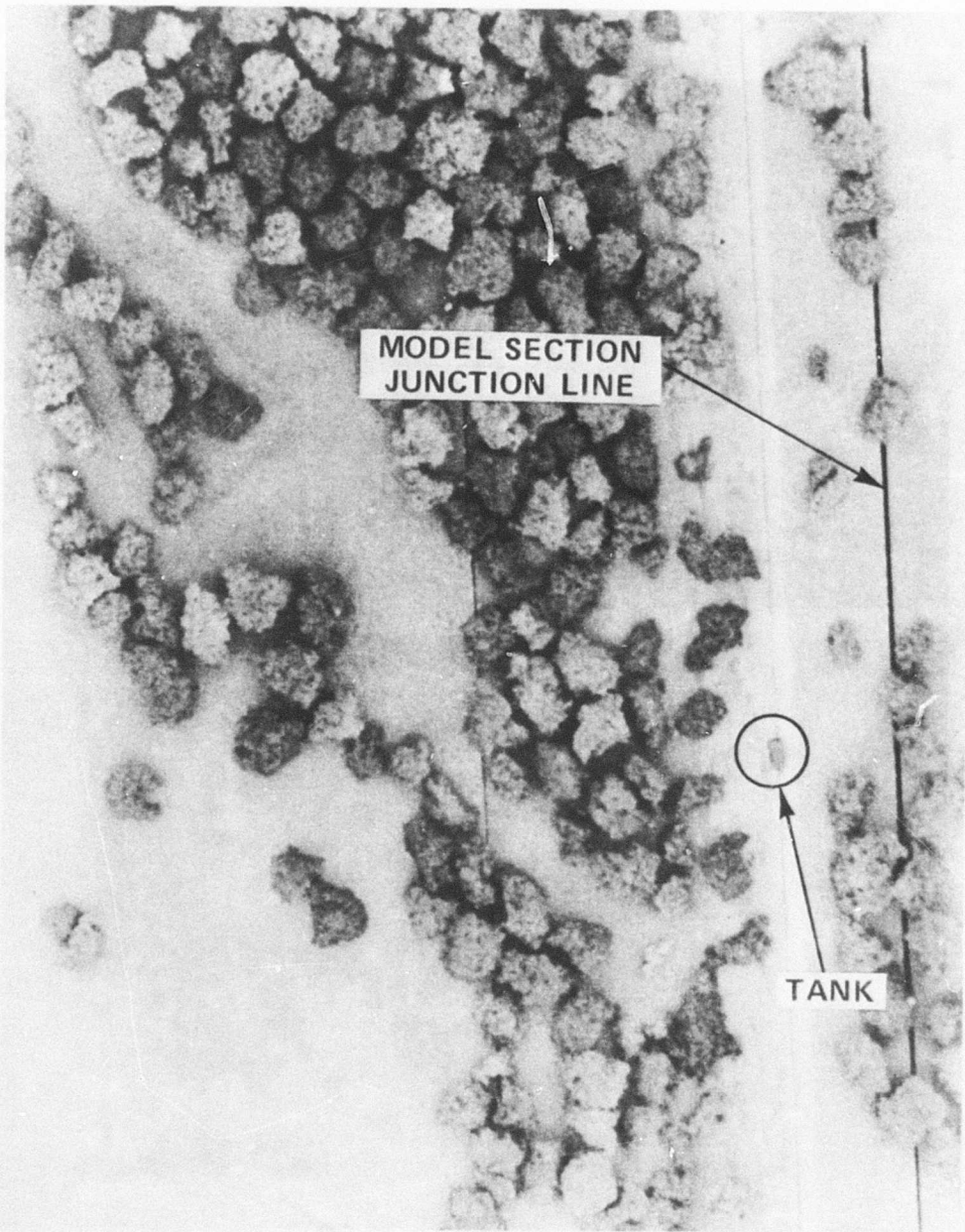


Figure 13. Target model (moveable tank 300:1 scale).

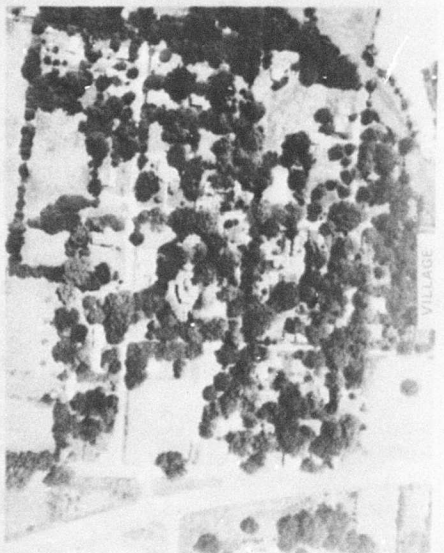
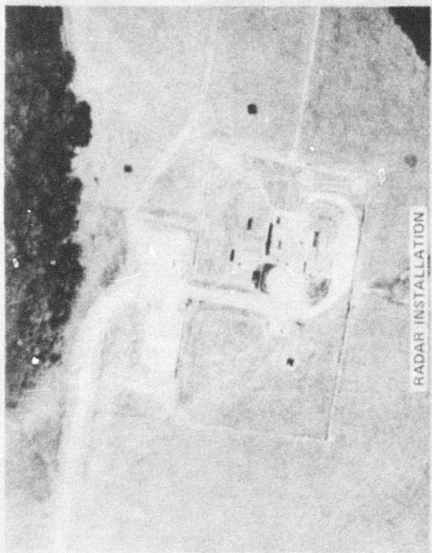
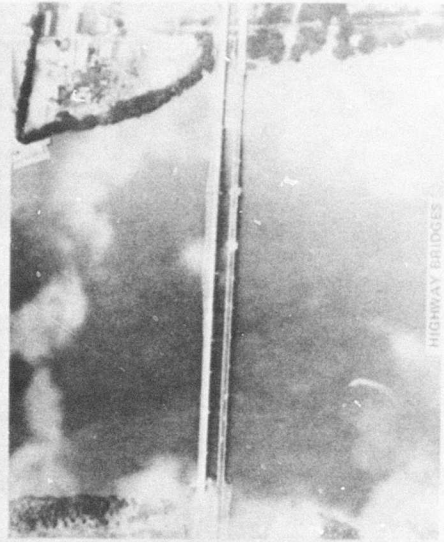
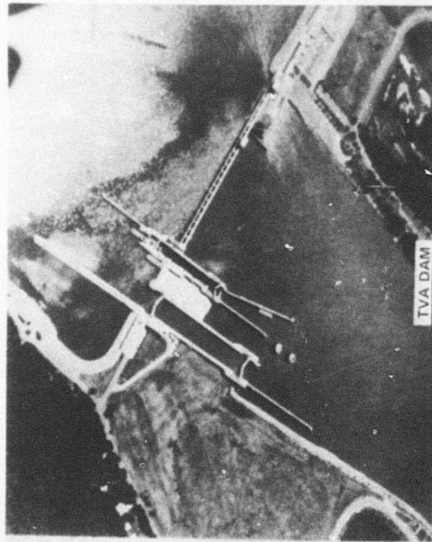


Figure 14. Aerial view of real world scenes.



Figure 15. View of terrain/target model scenes.

4. Optics

The optical systems consist of an autofocusing lens (AFL) subsystem, a zoom lens subsystem, filters, lenses, bar charts and gray scales, light level measurement subsystem, high resolution TV subsystem, and a closed-circuit TV subsystem. The AFL subsystem is a servo-controlled, motor-driven subsystem that provided infinity focusing of targets from 5 to 160 ft. To accommodate the long focal length lenses (250 mm) used in optical guidance sensors to the EOSS scaled-down real world distances, an AFL subsystem (Figure 16) must be used for collimating the light in the near field. As the terrain/target model closes range toward the sensor, the sensor-target slant range is computed and processed by the AFL servo units. The AFL servo changes the unit's focal length and maintains an appropriately focused image in the sensor's image plane.

The zoom lens subsystem (Figure 17) is used primarily with the high resolution TV subsystem for breadboard investigations of TV guidance units and to perform human factors studies on experimental and prototype TV systems.

The light level measuring subsystem, consisting of six barium sulphate plaques and a telephotometer, provides calibrated light level readings. The high-resolution closed circuit TV subsystem provides a means of performing human factors studies of electrooptical systems and a monitoring capability to evaluate performance of new types of TV sensor systems.

5. Illumination

The terrain/target model/transport subsystem is operable on the indoor range under controlled artificial lighting conditions from 10^{-4} to 1000 feet-candles and may be moved to the outdoor range for sunshine and natural lighting conditions. The EOSS lighting subsystem covers the spectral response from the red colour temperature of 500K to 1000K up to that approaching 6000K and greater of sunlight and starlight. For light blockage caused by moving structures in the EOSS during range closure, supplementary lights may be attached to the flight table.

High, medium, and low intensity incandescent lamps and a fluorescent lighting system provide indirect, hemispherical lighting from darkness to full daylight on the terrain-target model. The fluorescent lamps are powered from a three-phase, 400-Hz supply to provide a 2400-Hz flicker rate, which is out of the TV bandpass. This high-intensity incandescent lamps are powered from a variable dc voltage, SCR supply, while the medium and low intensity lamps operate from a 28-Vdc supply.

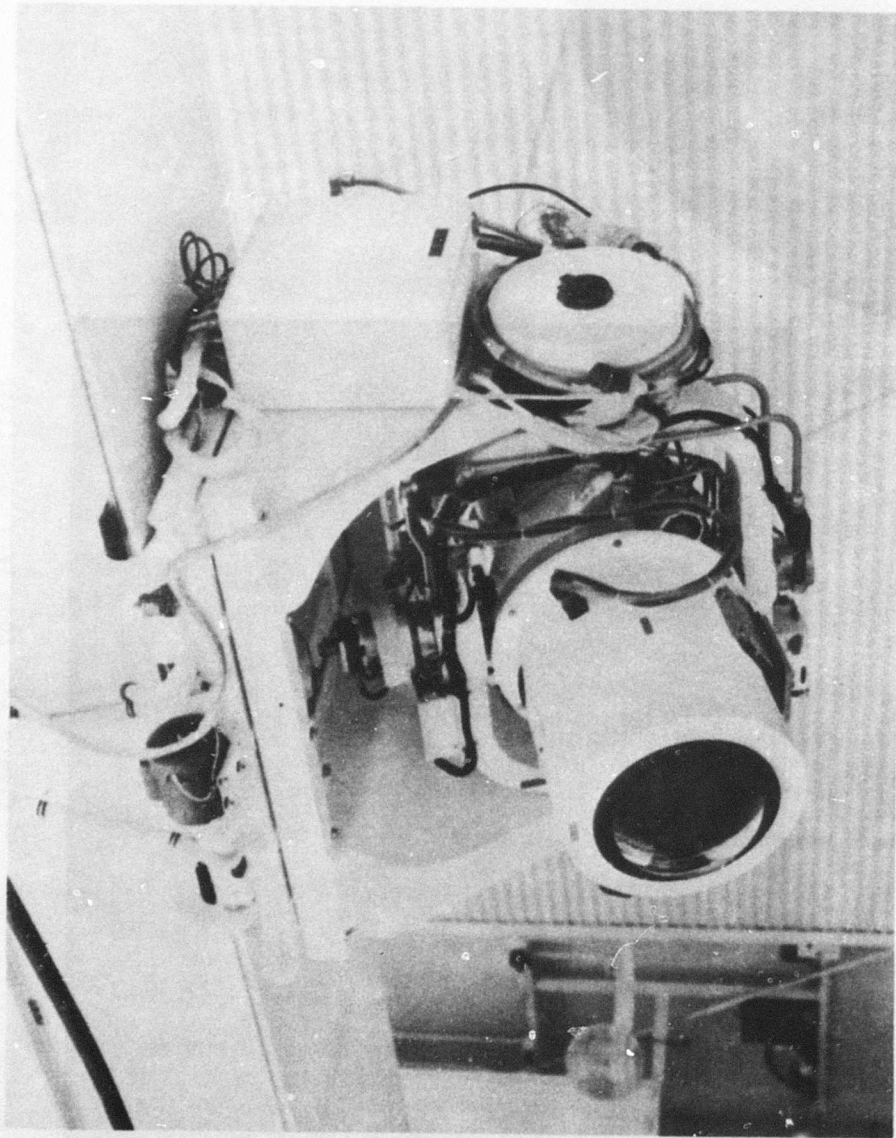


Figure 16. Three-axis flight table with AFL.

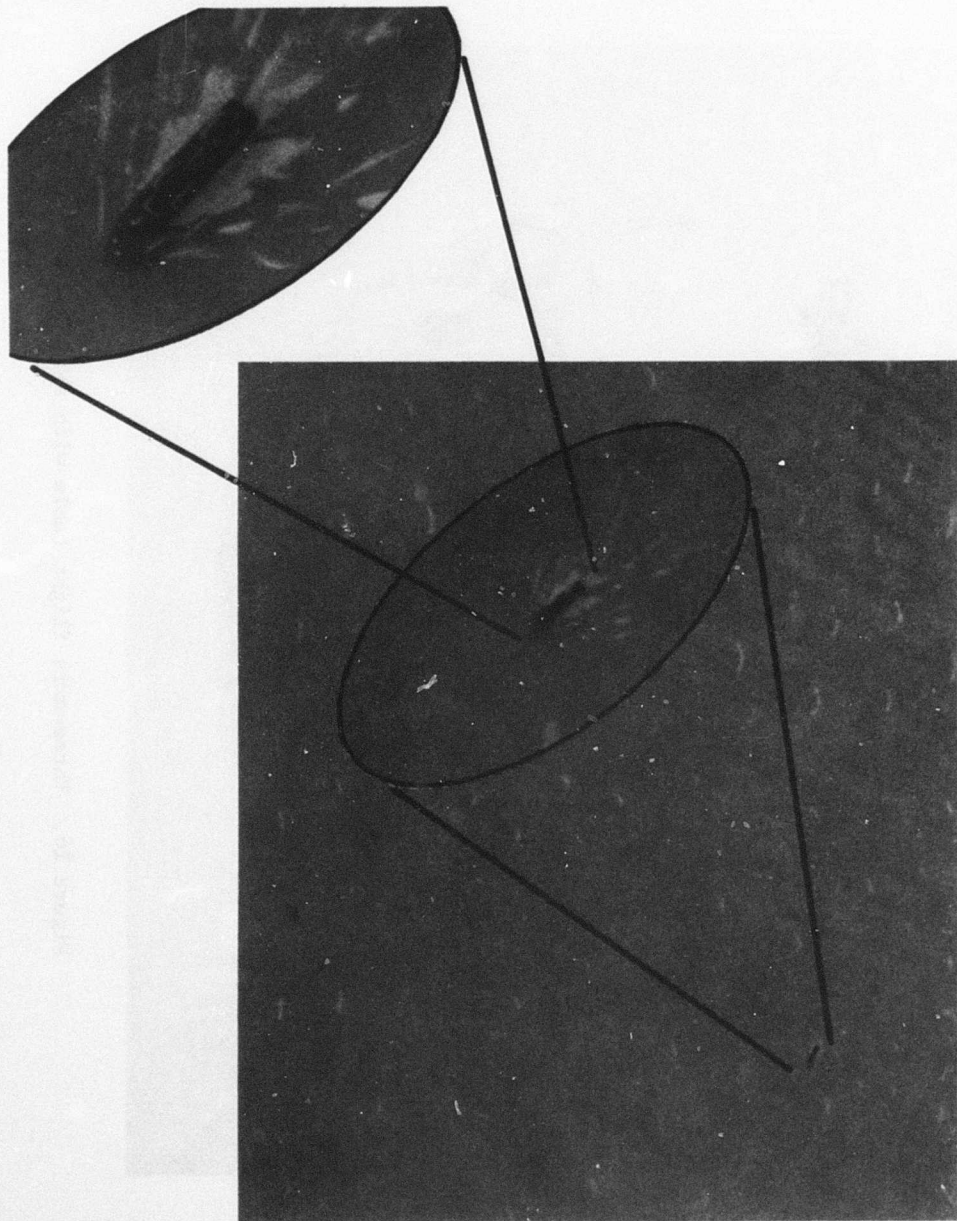


Figure 17. Zoom lens capability.

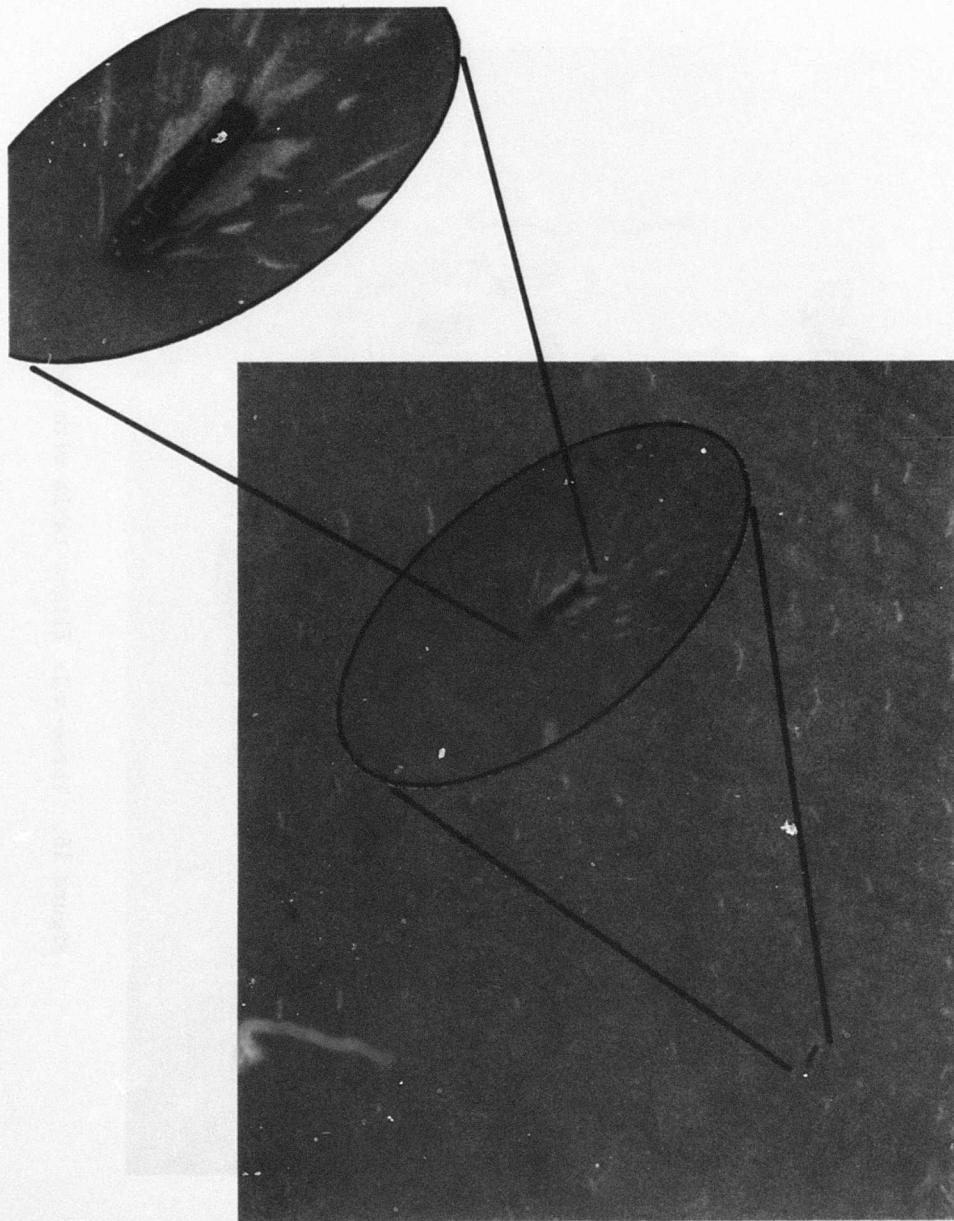


Figure 17. Zoom lens capability.

6. 2-D Subsystem

Added target scenes for flexibility are provided by means of a 2-D projection subsystem (Figure 18). Both 35-mm slide projectors and a 16-mm movie projector backlight a high resolution screen. The 2-D subsystem is primarily used for low light level systems and CLOS systems. The subsystem is part of the indoor range and may be either placed statically at a position along the longitudinal track and rail transport subsystem or it may be powered for range closure. The 2-D projection subsystem adds another medium of target area with a wide variety of scaling and target scenarios.

7. Control Room

The control room is the nerve center of the EOSS because all equipment are operated from this point, all data collected, and EOSS conditions are monitored here. The control room houses the control consoles (Figure 19) from which all rotational and translational drives are operated. The closed circuit TV, lens drives, and 2-D projection subsystem are also controlled from consoles in this room. The instrumentation lines from the sensors are brought into an instrumentation console for subsequent rerouting to consoles and data handling/recording equipment.

8. Video Scan Converter

The video scan-converter provides a means for collecting (i.e., snatching) quantized video information (e.g., CCD camera generated data) and storing this information on the PDP-11/20 computer or via the PDP-11/20 in the extended core storage area of the CDC 6600 computer for off-line processing, data reduction, and analysis. These same video histories can be processed in a real time environment. For example, this information can provide tracker updates and be evaluated by algorithms for correlation schemes when required by the experiment. The scan converter is general purpose in nature, and the video data that are collected can be custom tailored (i.e., formatted) for the experiment, thereby being readily adaptable to the hardware interface requirements of the data generating equipment. The current configuration of the converter requires six twisted pair buffered transmission lines (i.e., four for video data and two for control). The scan converter accepts a four-bit video, word which is shifted by a video word timing strobe into the converters registers until a frame strobe is received at the end of 25 video words. This process generates a five by five matrix of video information (i.e., five lines of five words each line). This frame of video information is then stored via software into the PDP-11 or CDC 6600 computer. This configuration has been run with interlaced and noninterlaced CCD cameras. The x-y coordinate system of this video matrix is read into the sense register (i.e., 16 bit register, 8 bits x, 8 bits y) on the AD/4 analog computer at the end of each frame. The PDP-11 software obtains the x-6 information

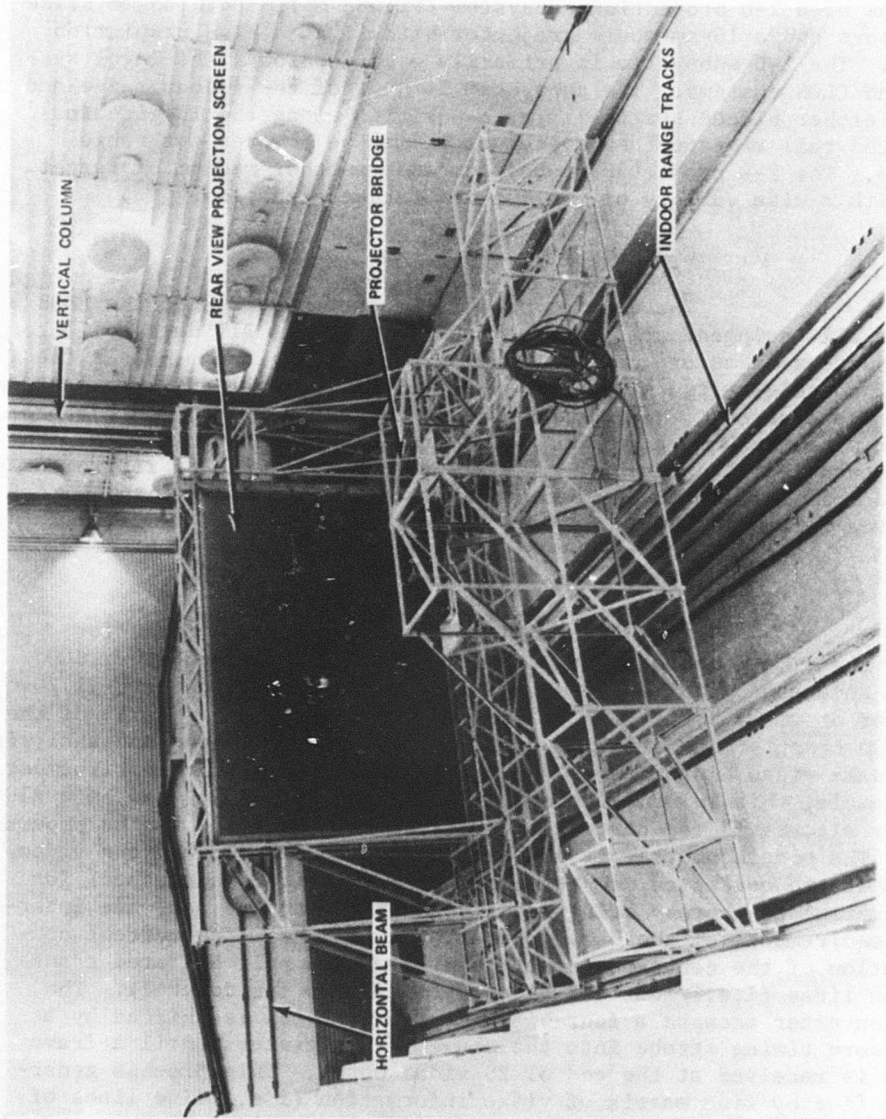


Figure 18. 2-D projection subsystem.



Figure 19. EOSS control console.

from the AD/4 and passes it along with each video data frame. A permanent history of the experiment scenario can be generated at the end of each run and this information saved on magnetic tape.

M. EOSS Stand-Alone Simulation Capability

1. Stand-Along Hybrid Computer System

A medium size stand-alone hybrid computer system (Figure 20) is contained within the EOSS. The system consists of an Applied Dynamics' AD/4 analog computer with hybrid interface and a Digital Equipment Corp. PDP-11/20 digital computer. This system has the capability of performing most six-degree of freedom simulations. It can support open-loop and closed-loop simulations within its own complement of equipment. For larger closed-loop programs and additional resources it can interface with computer components in the ASC hybrid computing complex.

a. AD/4 Analog Computer

The AD/4 contains six solid-state resolvers. These six resolvers are sufficient to do a complete forward and backward resolution of any six-degree of freedom simulation. In addition to the normal complement of analog trunks, the AD/4 contains 104 extra trunks to provide complete interface with the EOSS. Table 7 contains a complete equipment breakdown for the AD/4.

b. PDP-11/20

The PDP-11/20 is interfaced to the AD/4 through the remote interface (RIF). The PDP-11/20 can be used for setup, check-out, and automatic control of the simulation on the AD/4. The PDP-11/20 can also update parameters in the simulation through eight DAC on the AD/4. Table 8 presents a list of software available to support the PDP-11/20 and the EOSS. Basically, the PDP-11/20 consists of a 16K core memory unit, a unibus, a paper tape reader/punch, two deck tape units, a 4010-1 Tektronic CRT, a 4610 Tektronic hard copy unit, and a 64K disk unit. An additional disk unit containing 20 million words of storage capability will be installed in the near future. The PDP-11/20 is interfaced to the EOSS to record all laboratory positions and several discrete signals. The PDP-11/20 also has a direct interface to the CDC 6600 digital computer.

2. Large Complex Simulations

The AD/4 is interfaced to the ASC hybrid computing complex through analog and logic trunks. Through these trunks it has access to resources such as the CDC 6600 digital computer, a large signal conversion system, a function generation system which can give functions of up to three variables and three AD/4 analog computers, and

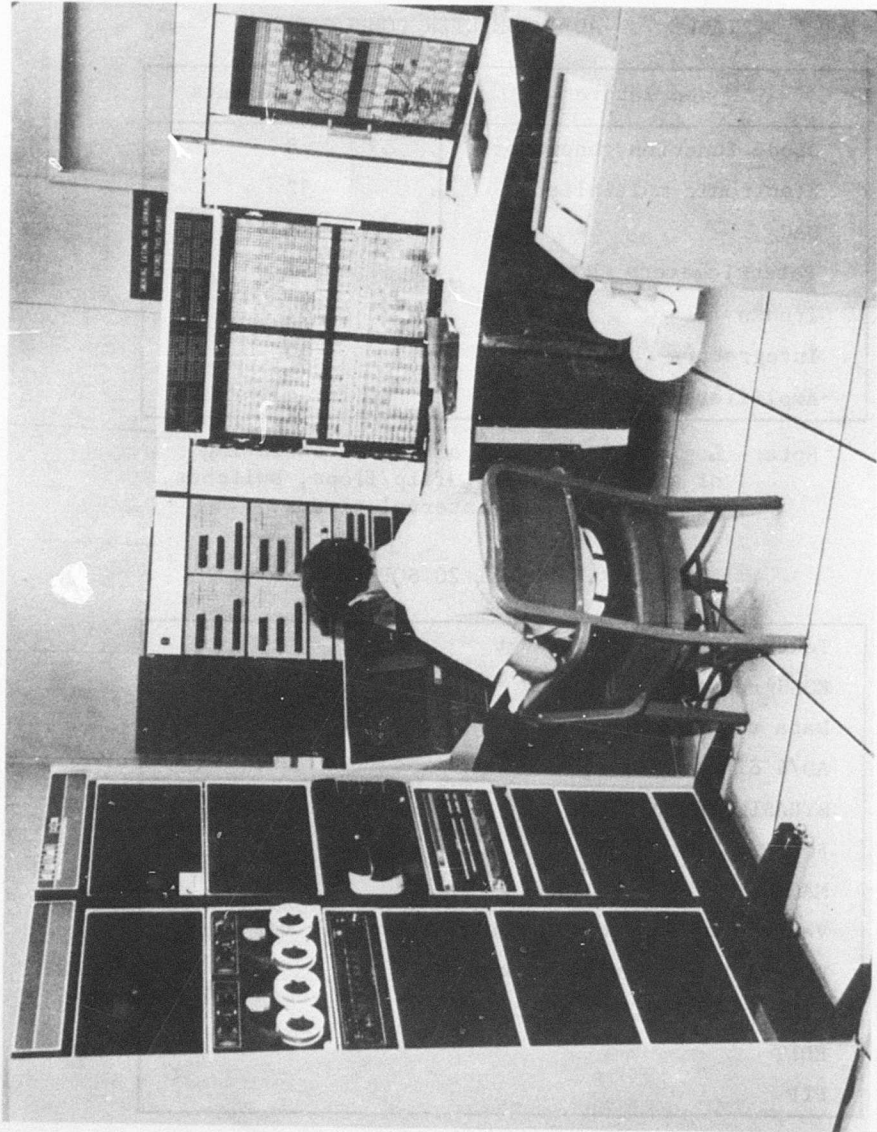


Figure 20. EOSS hybrid computer.

an Electronic Associates 781 parallel processor. Through the ASC trunking station, the AD/4 can be linked to the equipment in the IRSS and the radio frequency simulation system.

TABLE 7. AD/4 COMPUTER COMPLEMENT

Nomenclature	No. of Components
Diode function generators	8
Electronic multipliers	32
DAC	8
Potentiometers (POTS)	192
Trunks	232
Integrators (bipolar)	30
Amplifiers (bipolar)	54

Note: Logic - Complement of logic consisting of gates, counters, flip/flops, switches, comparators, and interval timers.

TABLE 8. PDP-11/20 SOFTWARE

Tektronix graphic package
EOSS readiness software
Data acquisition software
AD/4 diagnostic routines
HYBASIC and BASIC
FORTRAN IV
MACRO
Variety of diagnostic routines for the PDP 11/20
DOS-8A (DOS 10 will be added)
LINK
EDIT
PIP

III. RADIO FREQUENCY SIMULATION SYSTEM CAPABILITIES AND LIMITATIONS SUMMARY

A. Introduction

The Radio Frequency Simulation System (RFSS) is designed to enhance missile system research, development and engineering capabilities. The primary application is the evaluation of active, passive, and semiactive radar terminal-guidance systems for surface-to-air, air-to-air, and air-to-surface missiles in the 4.0- to 18.0-GHz band. Four independent targets can be generated in the 4- to 12-GHz range and two targets in the 12- to 18-GHz range. Two additional targets will be available in the 12- to 18-GHz range by June 1977. With additional radio frequency (RF) signal amplifier equipment, RFSS capabilities may be extended to cover the 2.0- to 4.0-GHz band. An artists' concept of the RFSS laboratory and a tactical air-defense scenario that may be simulated in the laboratory is shown in Figure 21. The location of RFSS within the McMorrow Laboratories is shown in Figure 22.

The RFSS is designed to facilitate the following research, development, and engineering related objectives and activities.

- 1) Breadboard and brassboard performance evaluation.
- 2) Evaluation of design modifications to existing software and hardware.
- 3) Establishment of optimum values for component parameters.
- 4) Determination of missile subsystem tolerances to relate manufacturing and testing tolerances to weapon system life.
- 5) Preflight and post-flight analyses.
- 6) Determination of miss-distance statistics.
- 7) Studies including electronic countermeasure (ECM) and electronics counter-countermeasure (ECCM) analyses and vulnerability studies.
- 8) Clutter, multipath, polarization, glint and scintillation effects.

1. Applications

The primary applications of the RFSS are open-loop tests of missile flight hardware and dynamic closed-loop missile guidance simulation. These applications are depicted in Figure 23.

In open-loop tests of flight hardware, "open-loop" refers to the guidance loop. Tests of flight hardware may involve closed-loop response tests without a closed guidance loop. Flight hardware may be tested as individual units or in some combination such as elevon system plus autopilot or autopilot plus guidance sensor.

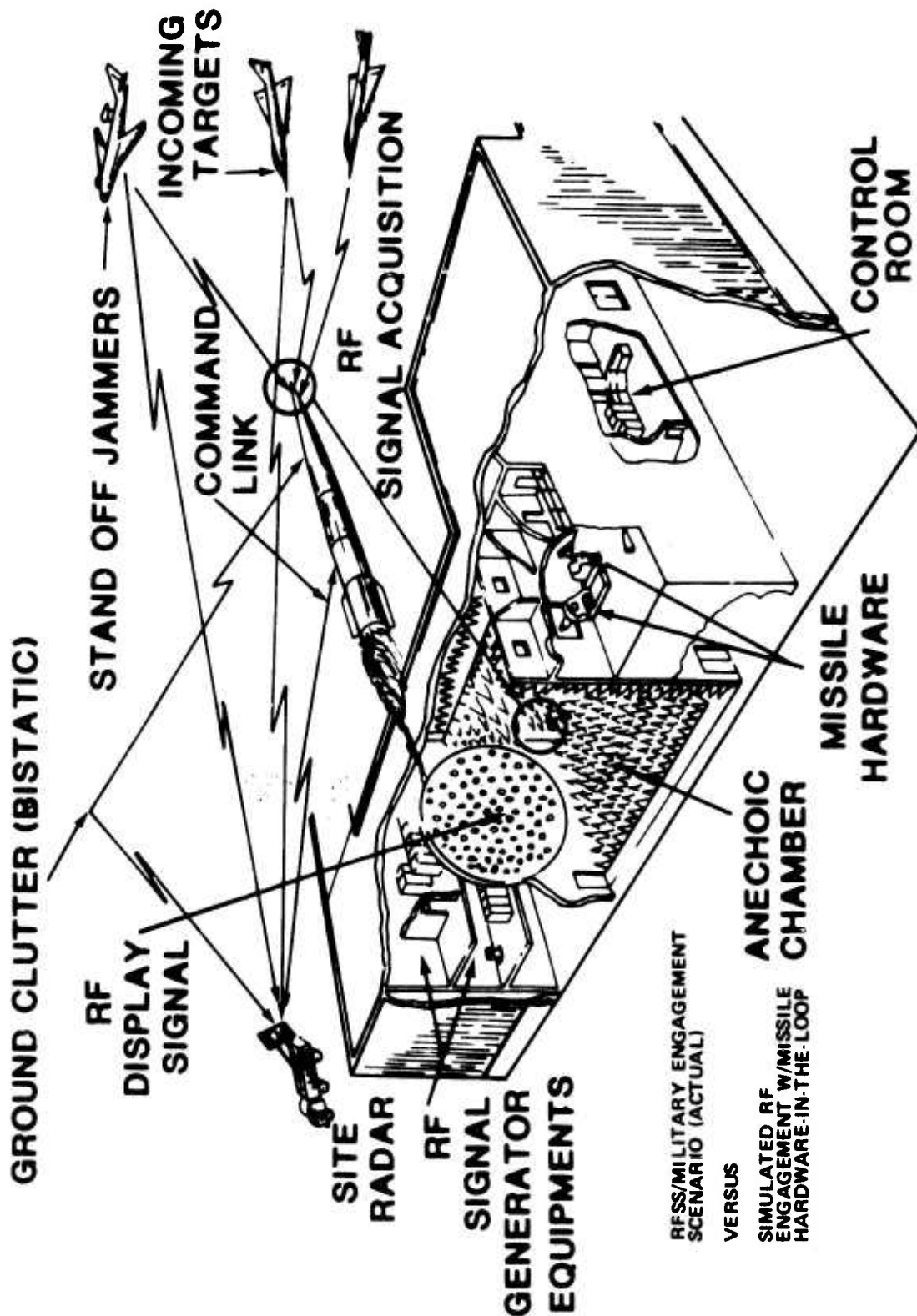


Figure 21. Radio frequency simulation system.

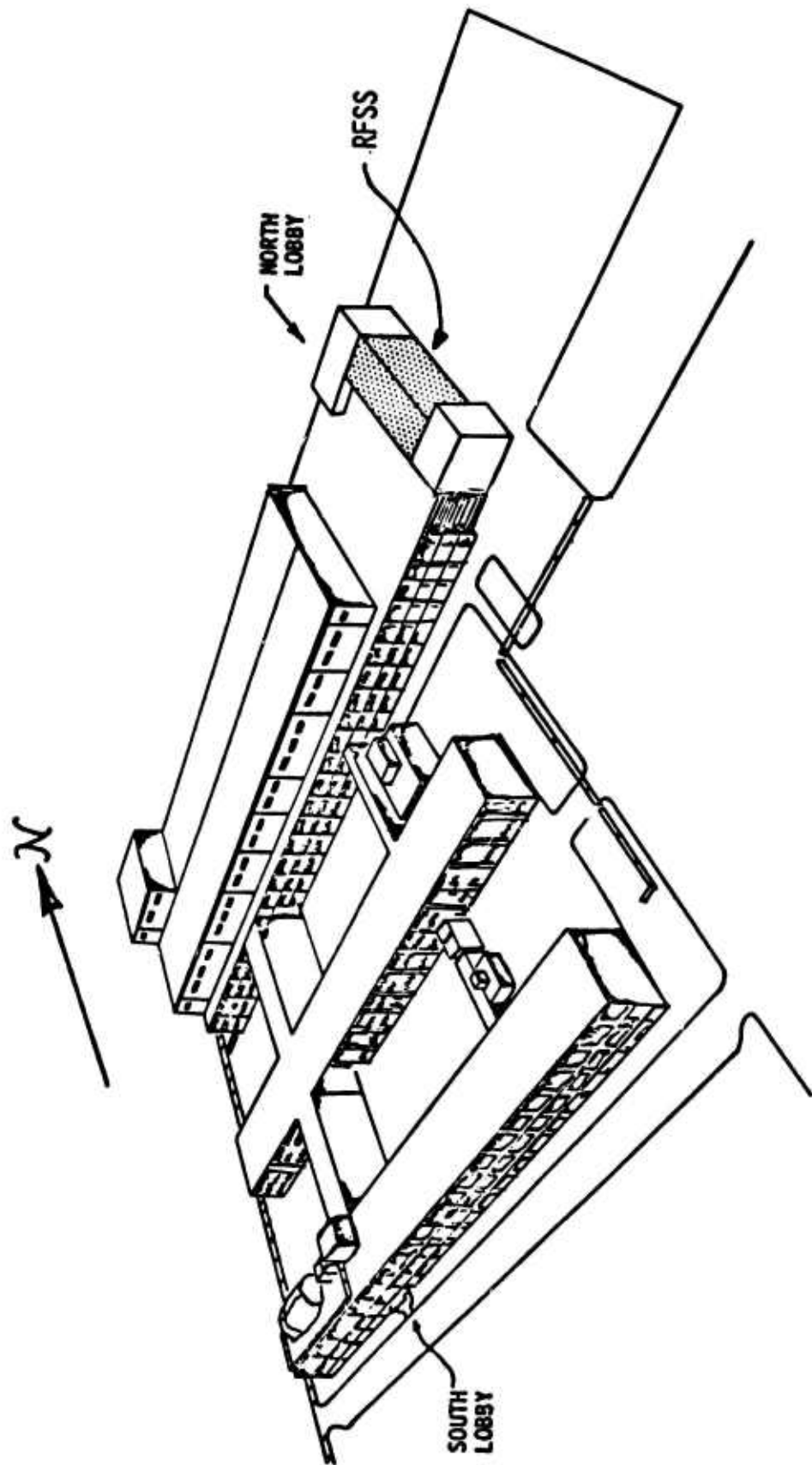


Figure 22. Francis J. McMorrow missile laboratories.

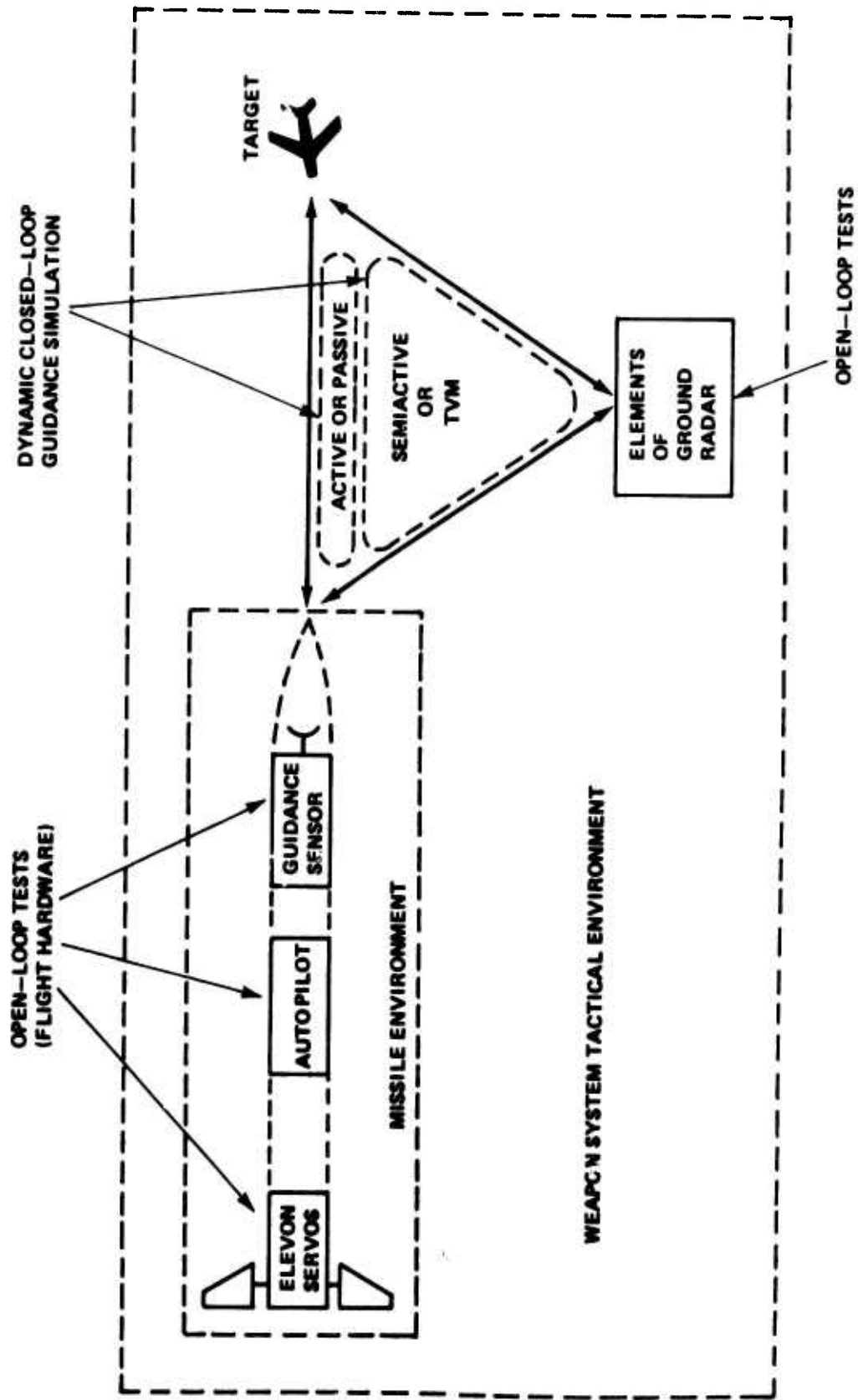


Figure 23. RFSS primary applications.

Hardware open-loop tests provide performance data for evaluation purposes or information for the development of software models. The overall simulation capability and efficiency is enhanced by the availability of hardware and software models.

The dynamic closed-loop guidance simulation may be an all-software simulation or may incorporate one or more of the flight hardware items shown in Figure 23. Hardware elements of a ground radar may also be involved.

As depicted in Figure 23, closed-loop guidance simulations can be conducted for several types of radar guidance systems: track via missile (TVM), active, passive, and semiactive. Active and passive systems involve signal propagation between missile and target. Three signal paths are involved in semiactive and TVM systems.

For either open-loop tests of flight hardware or closed-loop guidance simulation with hardware in the loop (HWIL), the RF environment for the flight hardware is physically simulated in the RFSS. The three categories of the simulated environment are identified in Figure 24 by the boxes with the widened lower edge: aerodynamic moments, angular motions, and the electro-magnetic environment. The electromagnetic environment may be categorized according to the boxes shown in Figure 24. For example, propagation path effects include range delay, space loss, line-of-sight rotation, etc. Target radar signatures include glint, scintillation, doppler effects, etc.

Figure 25 identifies the RFSS equipment which simulates the environment for the flight hardware and the type of software required to represent other elements of a missile/target engagement. As shown in the hardware-area of the figure, a control system aerodynamic loader (CSAL) simulates aerodynamic moments on elevon shafts, and two three-axis rotational flight simulators (TARFS-1, -2) simulate missile rotational motions for the guidance sensor and autopilot gyros, each mounted separately on the individual tables. The electromagnetic environment for guidance sensor is simulated within a shielded anechoic chamber by means of two-dimensional target and ECM arrays, and a RF signal generation system.

The chamber simulates a free-space environment for the radiation of signals from target and ECM arrays to the guidance sensor. Up to four simultaneous, independent target signals with continuously controllable polarization parameters may be radiated from the target array in the 4- to 12-GHz spectrum and up to two independent target signals in the 12- to 18-GHz frequency range. One or two simultaneous denial ECM signals may be radiated from the ECM array. Denial ECM signals may be either vertically, horizontally, or circularly polarized. Two-dimensional motions of the phase-center of radiation of the target array simulate missile-target line-of-sight rotations include target angle noise (glint).

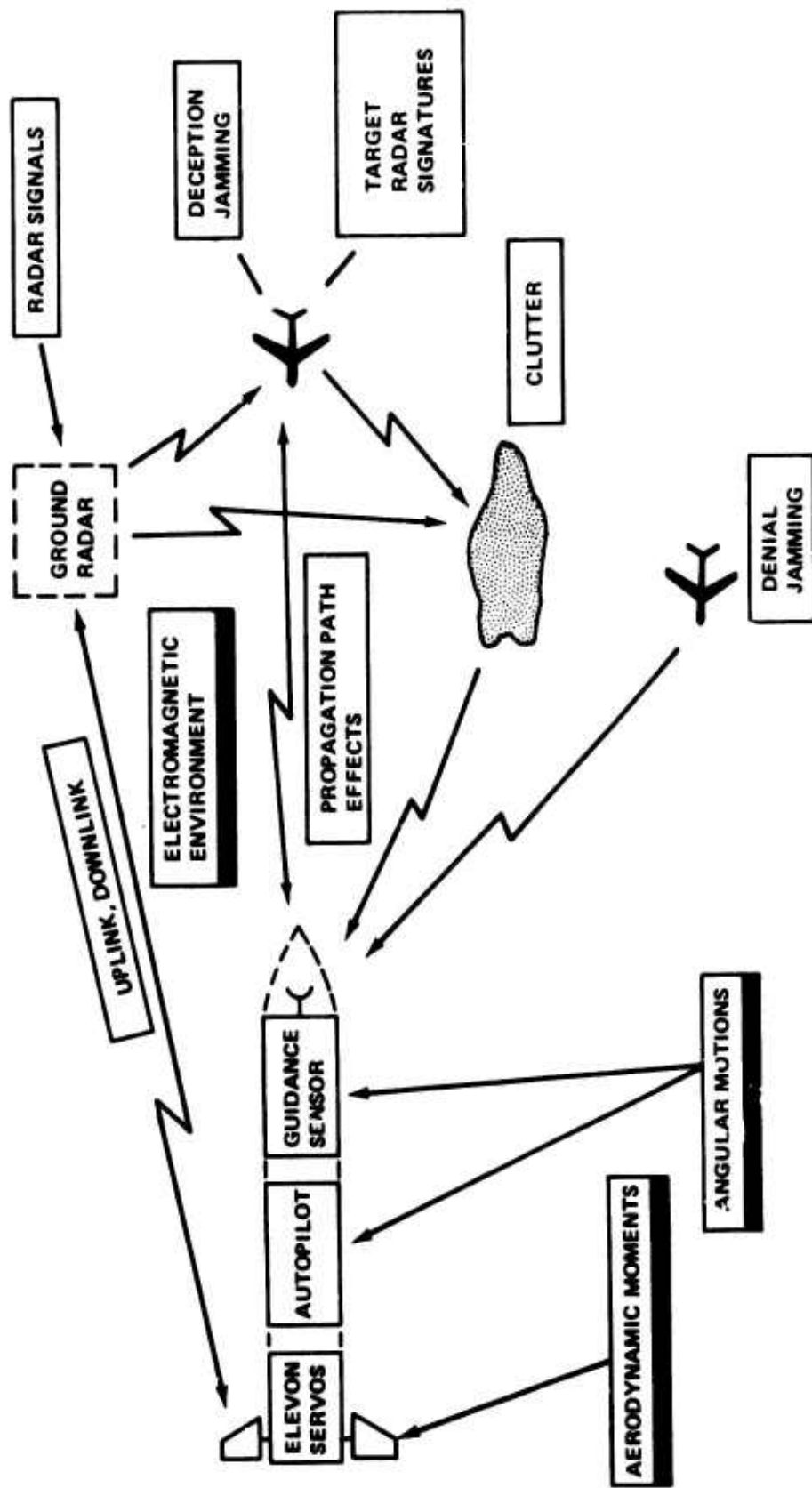


Figure 24. Flight hardware environment.

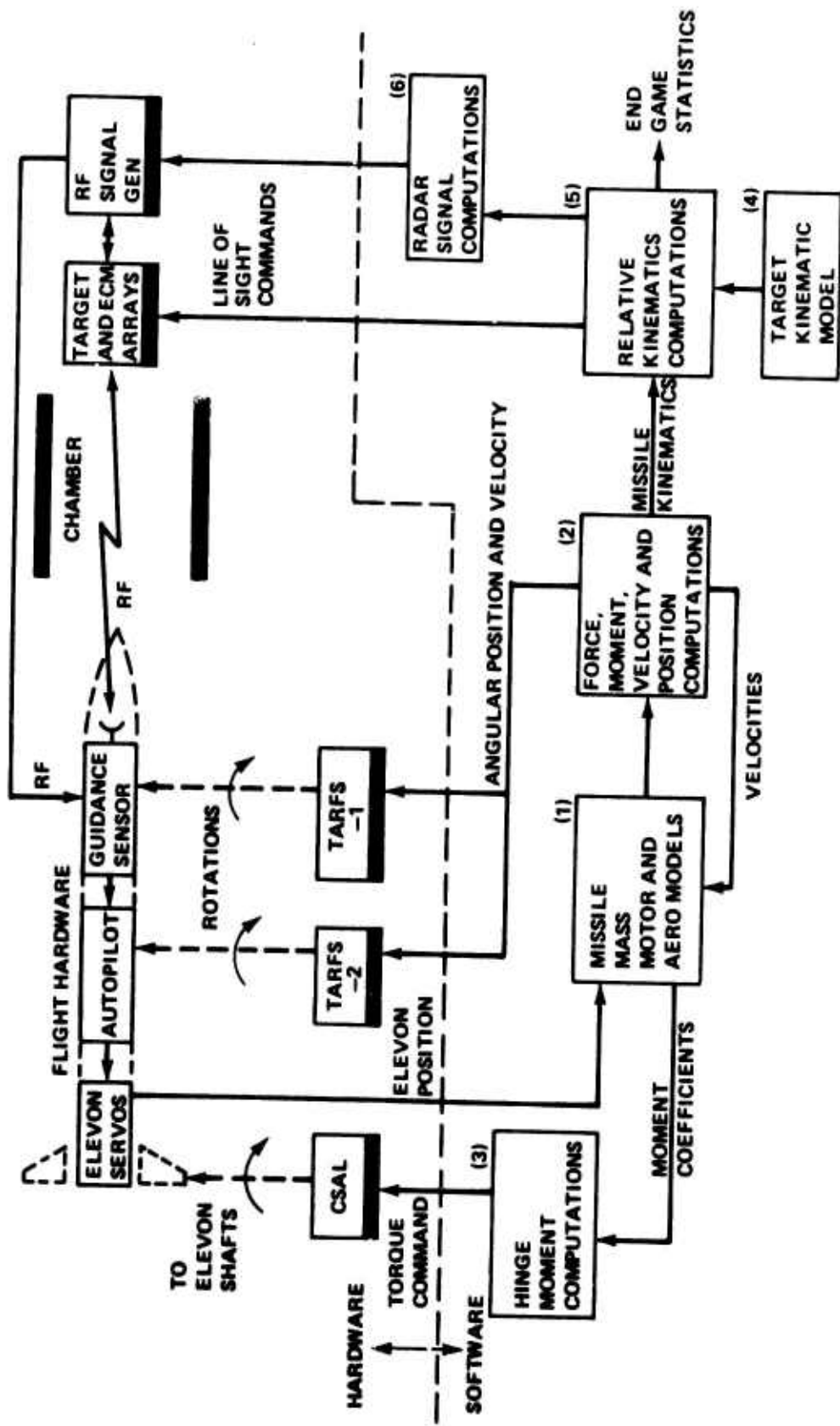


Figure 25. Missile environment and closed-loop guidance simulation.

The RF signal generation system generate signals with the time, frequency, phase and amplitude characteristics required to simulate radar reflections from airborne targets, and denial and deception jamming. By means of coaxial-cable and waveguide paths between the RF signal generation system and the guidance sensor, simulated reference or uplink signals, clutter signals, and fuzing signals may be inserted at appropriate points in the guidance sensor. The hardwired paths also provide a route for down-link signals.

The software area of Figure 25 generally indicates the software that represents other elements of a missile/target engagement. Block 1 contains the missile mass, motor and aerodynamic models. The outputs of block 1 are missile aerodynamic force and moment coefficients, mass, center-of-mass location, moments of inertia, motor thrusts, etc.

In block 2 of Figure 25, missile linear and angular accelerations are computerd. These quantities are integrated to determine missile linear and angular velocities and positions. These computations are performed in the missile coordinate system and, therefore, a missile-to-laboratory coordinate transformation is required to determine position and velocity commands for the TARFS.

From block 2, missile velocities are fed back to block 1 where elevon aerodynamic-moment coefficients are computed. Hinge moments are computed in block 3 to derive torque commands for the CSAL. The positions of the elevons are fed back from the elevon servos to block 1.

Missile kinematics from block 2 and target kinematics from block 4 are used to determine missile/target relative kinematics in block 5. From repetitive runs of the guidance simulation, end-game statistics are determined. End-game statistics include miss distance, miss angle, missile angles-of-attack, closing speeds, relative orientation of missile and target, etc. End-game statistics are used in fuzing, war-head, and kill effectiveness studies.

2. Physical Characteristics

The rooms and equipment in the RFSS laboratory are identified in the cutaway and plan views (Figures 26 through 29). In the following paragraphs, the rooms and equipment within each room are briefly described.

a. ECM Room

The ECM room is reserved for US Army Missile Research and Development Command (MIRADCOM) special-purpose ECM equipment. The ECM equipment may be used in conjunction with open-loop or closed-loop guidance simulations or guidance-sensor tests. Signals from the ECM room may be routed by coaxial cable to (1) the target (main)

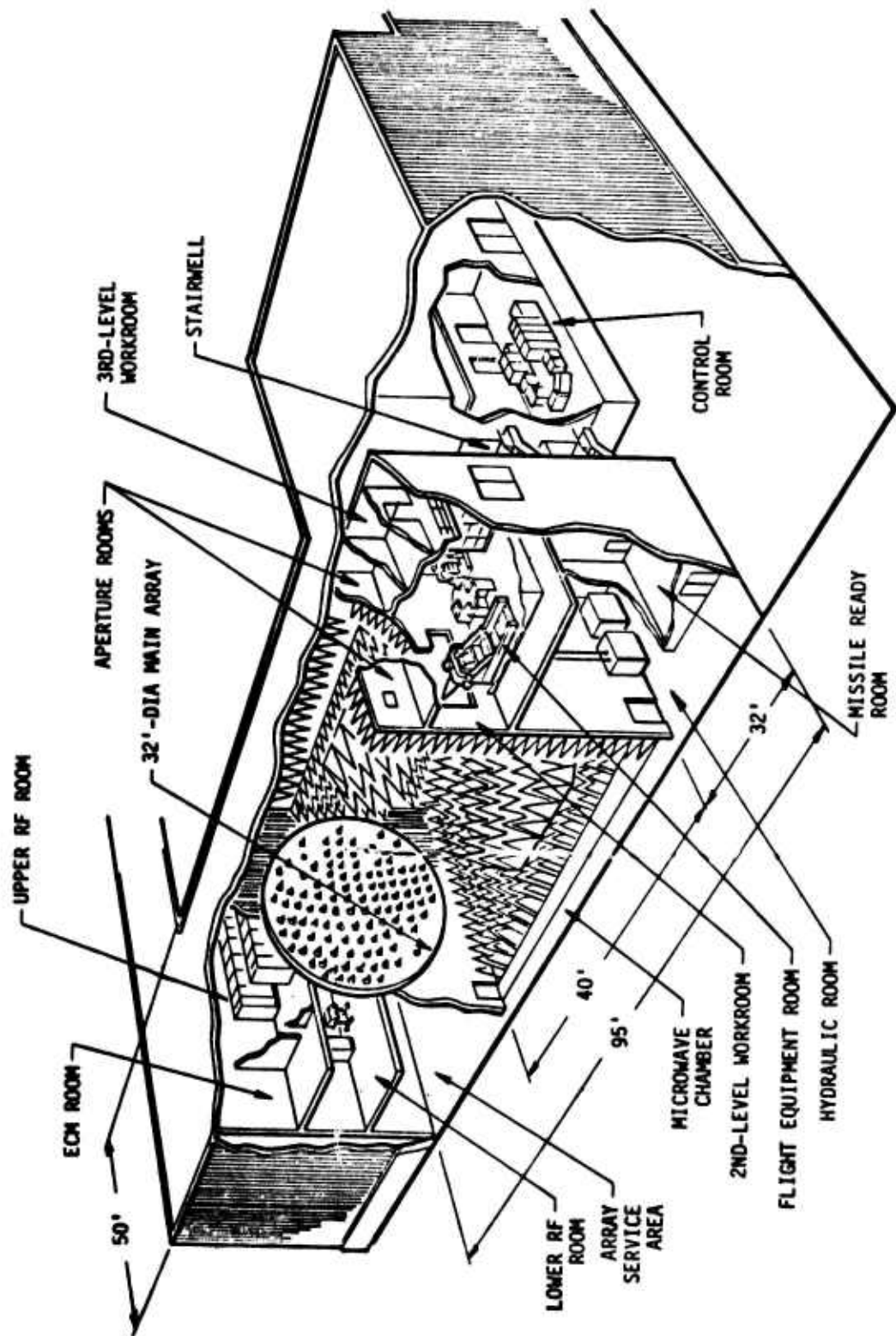


Figure 26. RFSS facility.

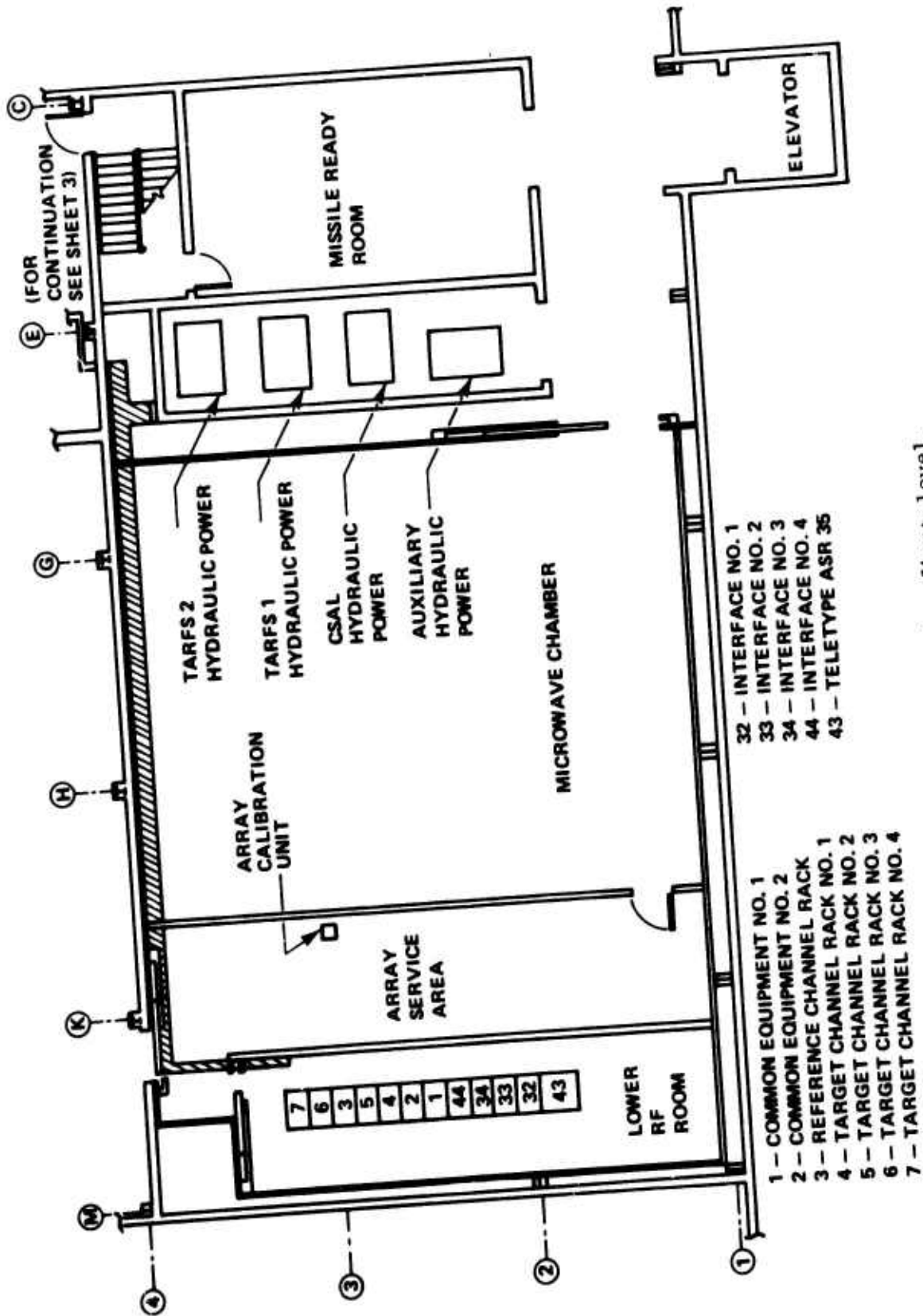


Figure 27. Plan view first level.

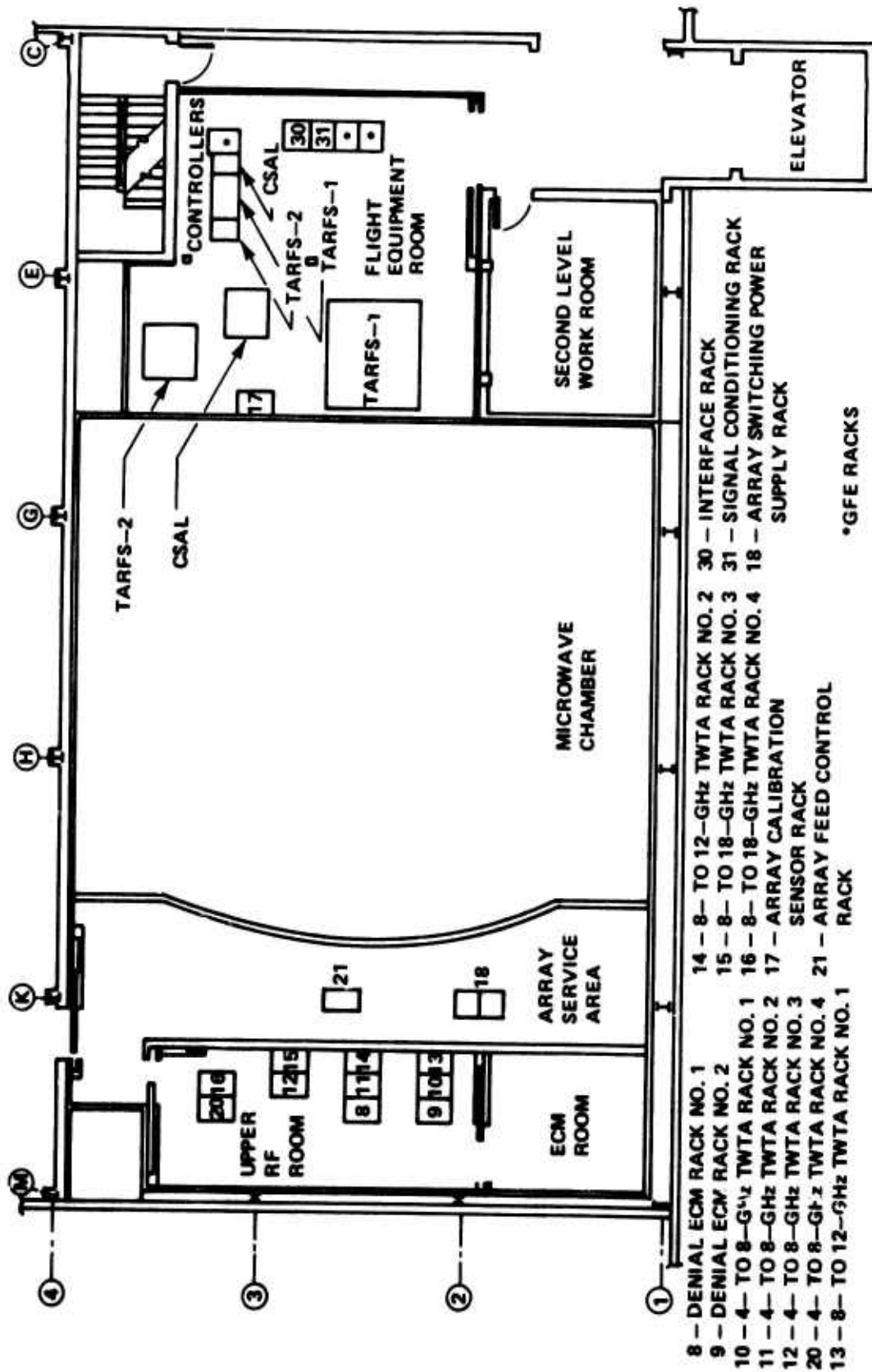
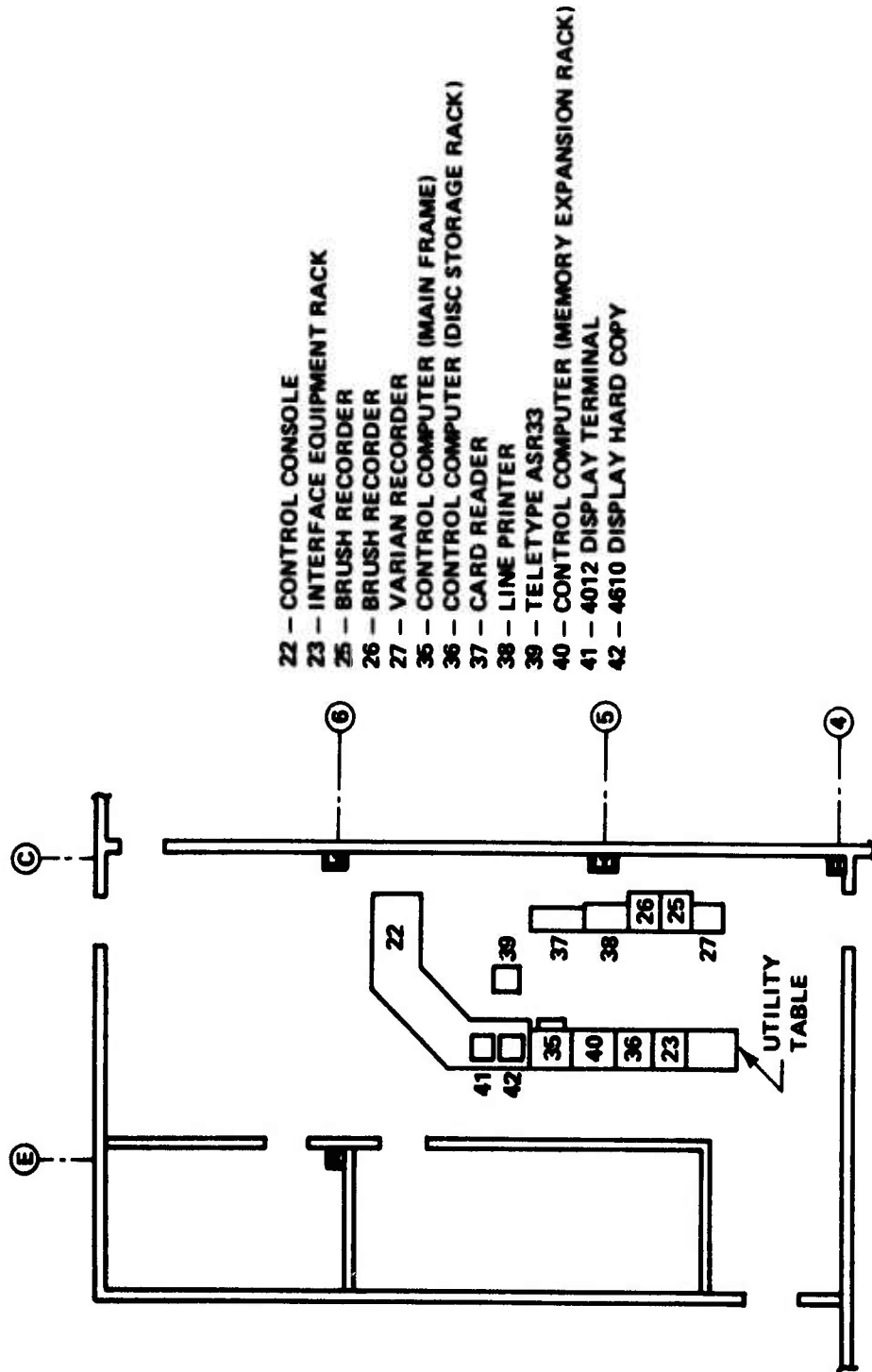


Figure 28. Plan view second level.



- 22 - CONTROL CONSOLE
- 23 - INTERFACE EQUIPMENT RACK
- 25 - BRUSH RECORDER
- 26 - BRUSH RECORDER
- 27 - VARIAN RECORDER
- 35 - CONTROL COMPUTER (MAIN FRAME)
- 36 - CONTROL COMPUTER (DISC STORAGE RACK)
- 37 - CARD READER
- 38 - LINE PRINTER
- 39 - TELETYPE ASR33
- 40 - CONTROL COMPUTER (MEMORY EXPANSION RACK)
- 41 - 4012 DISPLAY TERMINAL
- 42 - 4610 DISPLAY HARD COPY

Figure 29. RFSS control room.

array, (2) the ECM array, which has sixteen antennas distributed among the target array antennas, or (3) the electronic subsystems of a missile system being tested in the laboratory.

b. Lower RF Room

The lower RF room contains low-power RF generation and modulation equipment, and the interface equipment between (1) the master computer, located in the control room, and (2) the target array and RF generation equipment. A keyboard printer is also used in conjunction with the interface equipment, which contains six minicomputers.

Low-power RF signals are used as inputs to (1) high-power RF generation equipment, located in the upper RF room, and (2) guidance and fuze electronics of a guidance sensor mounted on TARFS-1. Five independent low-power RF signal channels, four target channels and a reference, are available in either C or X bands; two independent low-power RF signal channels are available at Ku-band.

The interface equipment receives signals from the master computer, computes control signals for the arrays and RF generation equipment, and sends signals to the master computer.

c. Upper RF Room

The upper RF room contains the high-power C-band, X-band, and Ku-band amplification equipment, and the DENIAL ECM generation equipment.

Four independent high-power amplification channels are available in C-band. Another two amplification channels cover X-band. Each of two additional channels cover either X or Ku-band. Each of the two DENIAL ECM generators covers the 4- to 8-GHz and 8- to 12-GHz bands. The high-power channels are usually routed to the four channels of the target array. The DENIAL ECM signals may be routed to (1) the ECM array, (2) channels 1 and 2 of the target array, or (3) subsystems of a missile system being tested in the laboratory.

d. Array Service Area

The array service area contains (1) the target array and ECM array feed system components and control electronics, (2) antenna mounting fixtures, which enable array antennas to be positioned, and (3) work platforms for service work behind the array.

e. Microwave Chamber

The shielded anechoic chamber (48 ft high × 48 ft wide × 40 ft long) simulates a free-space environment. The target and ECM antenna arrays are located on the south wall of the chamber. One primary aperture and two secondary apertures are located on the north wall. The primary aperture is centered on the longitudinal axis of the chamber. TARFS-1 is located at the primary aperture. The two secondary apertures are located above the primary aperture and provide additional space for open-loop sensor tests.

The target array and ECM array are located on the south wall of the chamber. The target array consists of 534 antennas located at a fixed radial distance from the intersection of TARFS-1 gimbal axes. The conical field-of-view provided by the target array is approximately 42 deg. The target array can transmit a maximum of four simultaneous independent signals and can also receive signals from an active guidance sensor.

On the target array, the apparent location (phase center) of radiation of a target is controlled by (1) selecting a triad of adjacent antennas which are to radiate and (2) controlling the relative amplitude and phase of the three radiated signals. The amplitudes and phases of the signals determine the phase-center location within the triad.

The polarization of signals transmitted from the target array is controllable. Each of the target array antennas consist of two orthogonal linearly polarized elements. Rotatable linear, left hand and right hand circular, or variations of elliptical polarizations are obtainable by the control of the relative amplitude and phase of the signals radiated by the two orthogonal elements of each antenna. Polarization and phase-center location are independently controllable.

The ECM array consists of 16 antennas distributed among target array antennas. Each of two independent ECM signals can be radiated from one of the 16 ECM antennas, or the two signals may be applied to different antennas. The radiated signal may be horizontally, vertically, or circularly polarized.

f. Aperture Rooms

The aperture rooms provide significant testing capability for general seeker characterization tests and related tests when closed-loop operation is not required. The aperture rooms provide the capability for integrating the seeker with associated simulation mechanical, electrical, and electronic interfaces; conducting certain open-loop testing against radiating source(s); determining seeker operational characteristics; and establishing required scaling, recording and data flow parameters. The aperture rooms can be used either for unique singular tests or as prerequisite to subsequent closed-loop tests in the flight equipment room. Typical aperture room configuration and interface with the RFSS facility is shown in Figure 30.

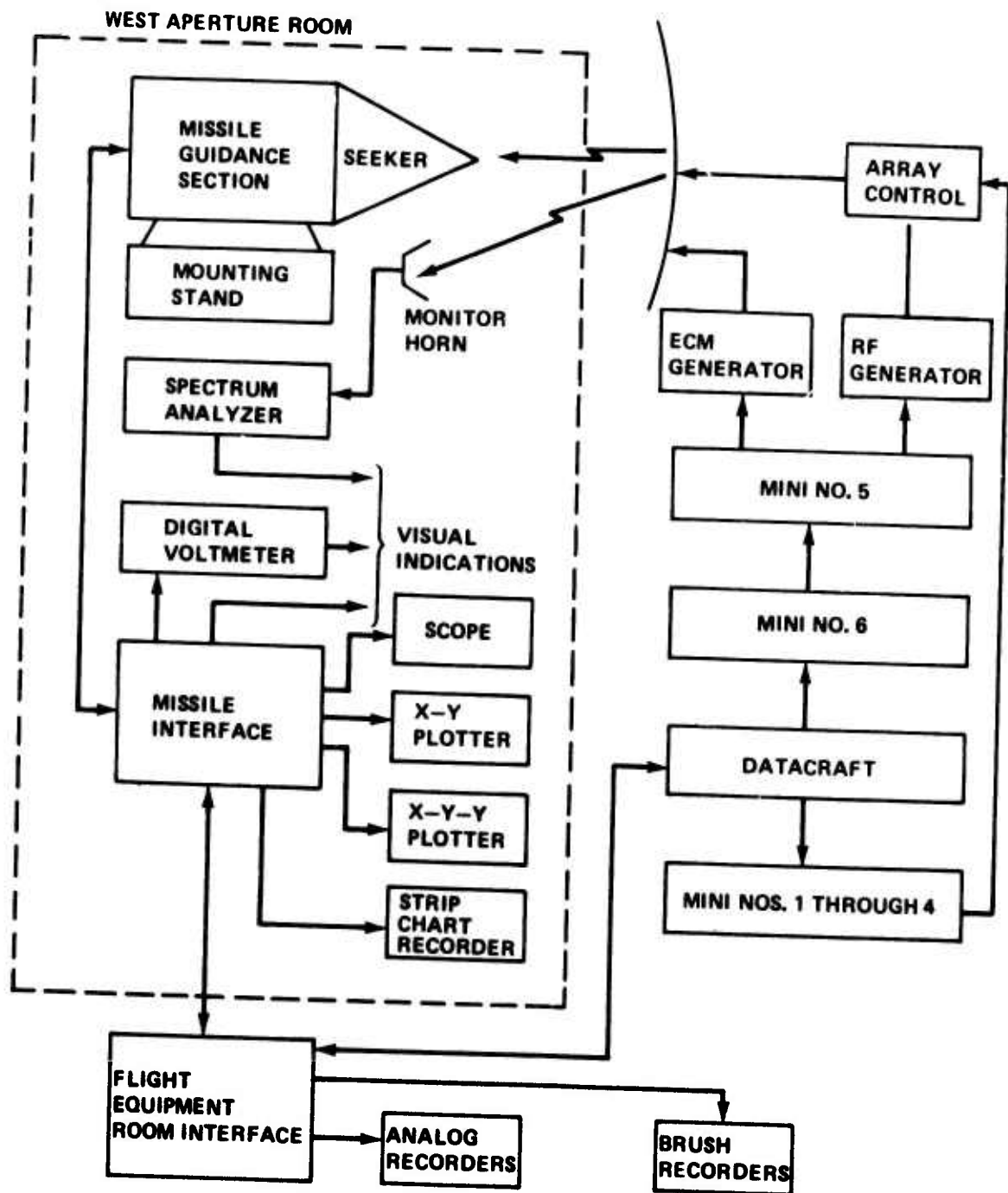


Figure 30. West aperture room representative interface configuration.

g. Flight Equipment Room

The flight equipment room contains hydraulic simulation equipment (the two TARFS and the CSAL) and interface equipment. The interface equipment connects or enables connections to be made among (1) the flight equipment, (2) the TARGS-1, -2 and CSAL control electronics, (3) the master computer, and (4) the MIRADCOM hybrid computer complex, (5) RFSS recording equipment, and (6) the RFSS and the two other simulation cells (EOSS and IRSS).

h. Hydraulic Room

The hydraulic room contains four hydraulic power supplies. Three power supplies serve the TARFS-1, TARFS-2, and CSAL. An auxiliary hydraulic power system (AHPS) provides power for missile flight hardware being tested in the flight equipment room.

i. Control Room

The control room contains the master computer, computer peripherals, the RFSS control, recording and display equipment, and test conductor's console. The master computer has two spare input/output channels to enable connections with the ASC hybrid computer complex.

3. Simulation Example

The use of RFSS is exemplified by the semiactive missile terminal guidance simulation that was developed as a part of the system demonstration. A functional diagram of the simulation is shown in Figure 31. Actual missile hardware is used for the semiactive seeker antenna, gimbals, and electronics. Special interfaces were fabricated to connect (mechanically, hydraulically, and electronically) the missile hardware to the RFSS.

The simulation is started by the test conductor at the weapon system and simulation control panels. The master computer generates the target and missile initial trajectories in space coordinates. The master computer then converts these space coordinates to RFSS coordinates and feeds the target and reference signal commands to the master/mini interface, and the missile commands to the flight equipment room interface.

The targets are energized and the missile seeker is enabled in a launch sequence identical to the real life situation.

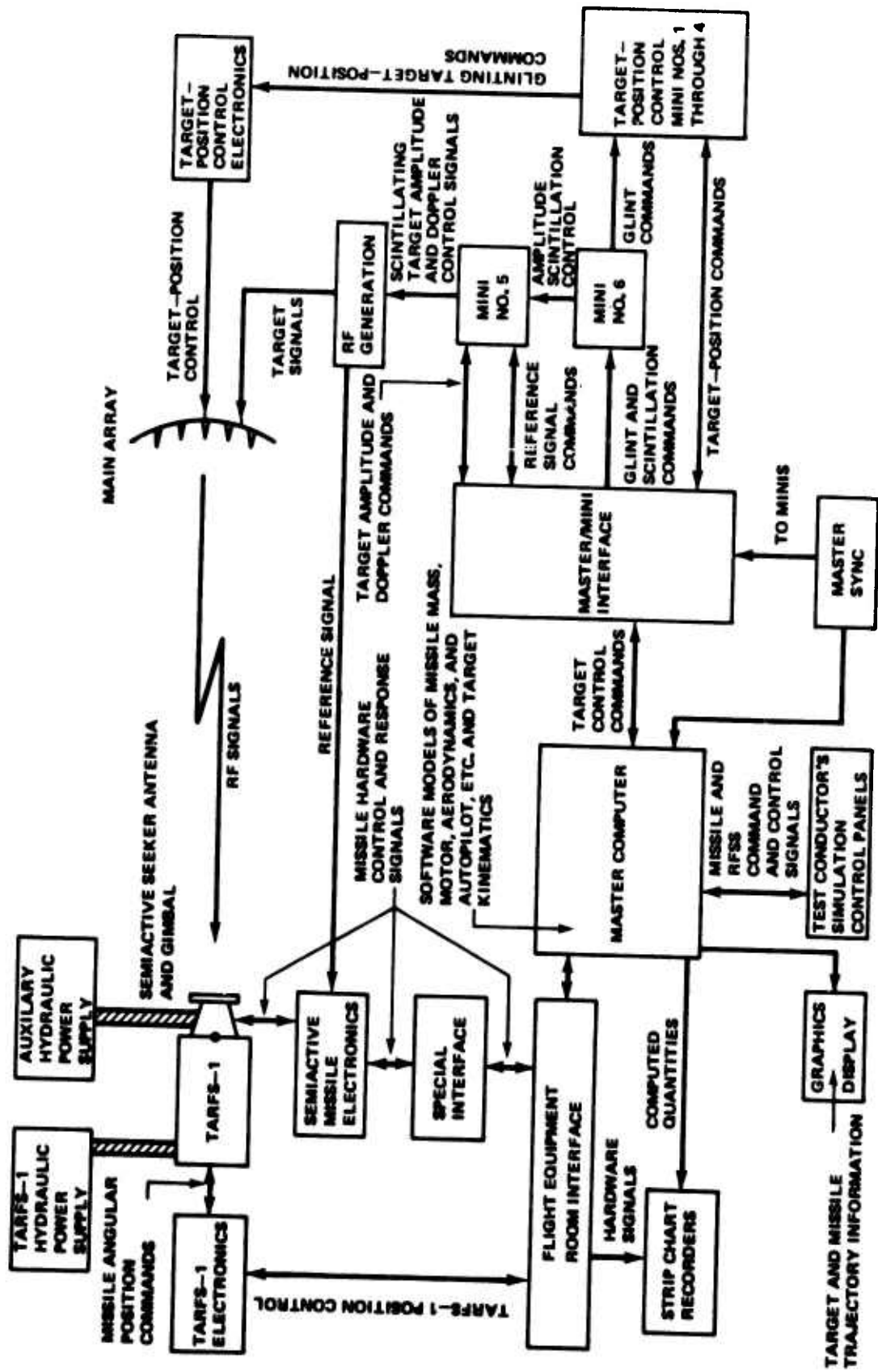


Figure 31. Semiactive missile simulation.

The target control and reference signal commands pass through the master/mini interface to six minicomputers. Mini Nos. 1 through 4 control the angular positions of four targets on the array. Mini No. 6 generates the target glint and scintillation update commands based upon resident software target models and current target-missile trajectory information. Mini No. 5 adds scintillation and doppler to the simulated target and develops RF generation hardware amplitude and frequency control signals.

The RF generation subsystem produces the target-reflected and reference signals. The target signal is coupled to the main array and radiated toward the seeker from controlled angular positions. The reference signal is transmitted to the missile electronics via coaxial cable or waveguide. The reference signal simulates the signal received by the missile directly from the illuminator.

The missile seeker receives the target signals from the main array and generates homing guidance signals. These guidance signals are coupled through the special interface and flight equipment room interface into the master computer. The master computer then generates new target and missile commands and updates both commands.

Meanwhile, the missile commands from the master computer have gone through the flight equipment room interface to the TARFS-1. These signals drive the TARFS-1 hydraulic gimbals to duplicate the missile-body angular motions that occur in actual flight. Thus, the proper angular position and rate environment is generated for the gimbals of the semiactive seeker.

The simulation is a closed-loop guidance simulation operating in real time with actual missile HWIL. The simulation starts at missile actuation and ends when the missile is at the "point of closest approach" to the target. The simulation timing is synchronized by a master synchronizer and runs at the speed set by the synchronizer. As a matter of interest, for simulations in which the missile transfer parameters are well-known, the RFSS master computer (Datacraft 6024) does not have the necessary storage capability to make use of these intricate and complex functions; hence, the existence of an interface of the RFSS master computer with the central hybrid computer complex.

Information recorded on the strip-chart recorders is the same information that is normally telemetered to the ground in an actual missile flight so that it can be directly compared with actual missile flight test data. In this manner, the simulation constants can be varied to "match" any desired flight test condition. In addition to the normal telemetered data, recordings are made of many other missile/target flight parameters such as seeker head pointing error, etc.

Up to four simultaneous independent targets can be simulated; each may have unique and independent radar signatures. The simulated targets may represent helicopters, aircraft, missiles, or surface RF emitters. Target angular motions as fast as 4000 deg/sec can be simulated.

B. Controls and Interfaces

The general layout of the control room is shown in Figure 32. RFSS control links and instrumentation are summarized in Tables 9 and 10. The performance of the TARFS and CSAL are summarized in Table 11.

C. Target Generation

The control range, resolution, and update rate of the RF signal parameters are summarized in Table 12. The target generation and array capability are summarized in Table 13.

The antenna array consists of 500 antennas located on the concave (front) surface of a spherical metal dish, which has a radius of curvature of approximately 40 ft and a dish diameter of 33 ft. The array provides the capability to transmit RF signals dynamically controlled in relative angular position, or to receive RF signals over a field of view of a approximately 42 deg as viewed by a sensor mounted on TARFS-1. The location of the apparent source of radiation of the RF signals is controllable up to within 0.3 mrad, with a working accuracy of at least 1.0 mrad. The nominal update rate of all target parameters is 1 kHz.

D. Software

Computer control of the RFSS is provided by one Datacraft 6024/1 computer, five Interdata Model 80 computers, and one Interdata Model 85 computer. The layout and interface of these control elements are shown in Figure 33. The basic capabilities of these computers are shown in Tables 14 and 15. Two fixed-head disc storage units are available with the Datacraft computer. The capabilities of the discs are shown in Table 16.

Computer control of RFSS checkout and operations is provided by approximately 50 special purpose programs. These programs control all target and test manipulations and provide for automatic data reduction. As required by specific tests, auxiliary software programs are developed and/or existing programs are modified by the RFSS software staff.

Additional computing and data storage capability is provided through data links with the ASC CDC 6600. Real time operation with the CDC 6600 in the loop is available if required.

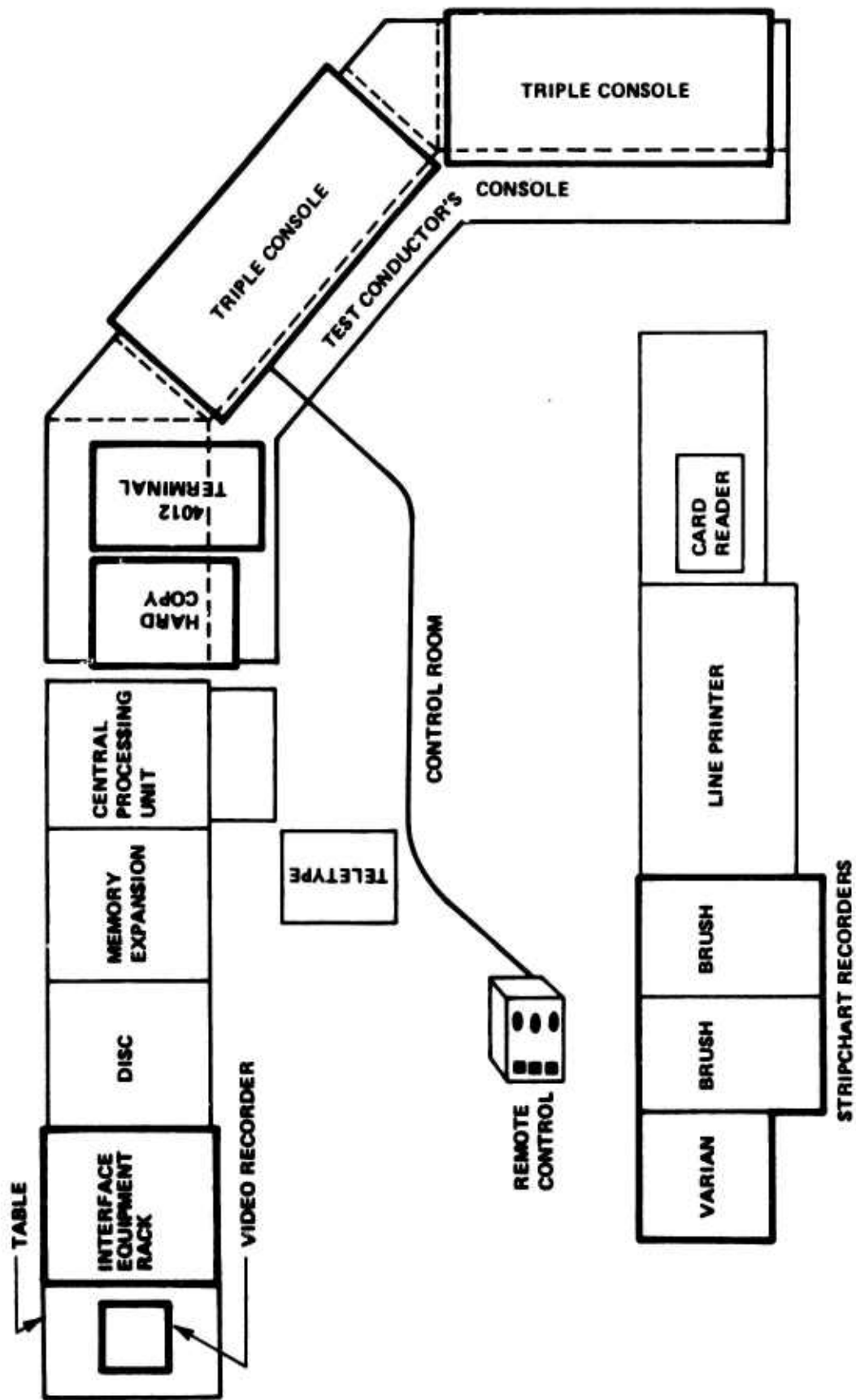


Figure 32. Control room layout.

TABLE 9. RFSS CONTROL LINKS

Area	Discrete	Patchable to	Analog	Patchable to
Flight Equipment Room 273	96-channel 0 to +5 V inputs command 96-channel 0 to +5 V output command	Datacraft	64-channel ± 10 V output 64-channel ± 10 V inputs	Analog room
	32-channel 0 to +5 V inputs command 32-channel 0 to +5 V output command	Analog room	24-channel ± 10 V outputs	Datacraft

TABLE 10. RFSS INSTRUMENTATION

Data Acquisition	Recording	Display
<p>Control Room 115</p>	<p>Varian Statos IV Electrostatic Recorder Recorder - 16 Analog Channels, 10 Discrete Events</p> <p>Brush Model 200 8 Analog - Channel Strip Chart Recorder (2 ea)</p> <p>TEK 4610 Hard Copy Unit Multiplexed to TEK 613 and TED 4012 Displays</p> <p>Sony AV-3650 1/2-Inch Video Recorder</p>	<p>TEK 613 Graphic Display</p> <p>TEK 4012 Terminal/Graphic Display</p> <p>2 - Closed Circuit TV Monitors of Flight Equipment Room Hardware</p> <p>Facility EMI Integrity Status</p> <p>Hydarulic and RF Generation Hardware Integrity Status RF Spectrum Display Unit</p>
<p>Flight Equipment Room 273</p> <p>Tustin X-1500 ADC - 12 128 Channel</p> <p>Lower RF Room (171)</p> <p>Upper RF Room (271)</p> <p>East and West Aperture Rooms (372, 371)</p>	<p>Direct Digital Link to Adjoining CDC 6600 Room Giving Access to Magnetic Tape and Disc as well as Standard Peripheral Recording</p> <p>1 - CDC Line Printer</p> <p>FR1900 Analog Tape, 14 Channels Available 7 Direct Record, 7 FM Record</p> <p>One Brush Model 200, 8 Analog Channel Strip Chart Recorders</p> <p>One Tridata Cartrifile</p> <p>One Recorder, 8 Analog Channels Ten Discrete Events</p>	<p>1 - Closed Circuit TV Monitor</p>

TABLE 11. TARFS AND CSAL PERFORMANCE STUDY

TARFS-1 SUMMARY		
Load limitations:		
Load size: 16 in. diameter, 60 in. long		
Load weight: 150 lb		
Performance Characteristics		
	Pitch/Yaw	Roll
Angular displacement	±50 deg	±50 deg
Load inertia	15 slug-ft ²	1.5 slug-ft ²
Position accuracy	±1.0 mrad	±1.0 mrad
Repeatability	±0.1 mrad	±0.1 mrad
Velocity	200 deg/sec	400 deg/sec
Acceleration	9000 deg/sec ²	40,000 deg/sec ²
Frequency response	13 Hz	30 Hz
TARFS-2 SUMMARY		
Load limitations:		
Load size: 10 in. diameter, 10 in. long		
Load weight: 50 lb		
Performance Characteristics		
Angular displacement	±80 deg	±50 deg
Load inertia	0.042 slug-ft ²	0.042 slug-ft ²
Position accuracy	±1.0 mrad	±1.0 mrad
Repeatability	±0.1 mrad	±0.1 mrad
Velocity	200 deg/sec	700 deg/sec
Acceleration	40,000 deg/sec ²	200,000 deg/sec ²
Frequency response	30 Hz	80 Hz
CSAL SUMMARY		
Parameter	Characteristics	
Load size (diameter)	From 3 to 24 in.	
Torque output (maximum)	±1000 ft-lb	
Rotational displacement	±45 deg	
Load inertia	0.02 slug-ft ²	
Position accuracy	±0.05 deg	
Torque accuracy	±5 ft-lb	
Maximum velocity	700 deg/sec	
Frequency response	50 Hz	

TABLE 12. CONTROL RANGE, RESOLUTION, AND UPDATE RATE OF RF SIGNAL PARAMETERS

Signal Parameter	Unit	Control Range	Resolution	Update Rate	Notes
Doppler shift	IF frequency synthesizer	±15 MHz	0.3 Hz	5 msec	This is relative (target-to-target) delay
Range (time) delay	Time delay generator	0 - 9.999999 msec	1 msec	1 msec	
Linear FM chirp	Chirp (LFM) generator	See Figure 8.2.2.2.1*	See Figure 8.2.2.2.1*	Master computer command	
Center frequency	Diversity programmer	4 to 18 GHz 2 targets 4 to 12 GHz 2 targets, ref	1 MHz	Pulse-to-pulse in diversity mode upon master computer command otherwise	Full range not under computer control without manual selection of filters. See Section 82.1
Power level (including scintillation)	High and low level attenuators Ref attenuator Fuse attenuator ECM attenuator	Target Channels: 0 to 130 dB Ref. Channel: 0 to 120 dB Fuse Channel: 0 to 60 dB ECM Channels: 0 to 60 dB 60 to 100 dB	0.5 dB 0.5 dB 1 dB 1 dB 40 dB	1 msec 5 msec 1 msec Master computer command Master computer command	
Pulse operation frequency	Low PRF generator High DAF generator	1 Hz to 100 Hz 100 Hz to 1.0 MHz	Resolution of period = 10 μsec Resolution of period = 0.1 μsec	5 msec	Max duty cycle 5% Pulse - 5 μsec pulse watts limit
Pulse code	Pulse code shift register	0 to 256 bits 0 to 1024 function of low PRF		Master computer command	
Pulse shape	Pulse shaper	Rise and Fall Time: 10 nsec to 100 nsec Width: 15 nsec to 40 msec pulse width 5 μsec max for 1 kW operation	0.1 nsec minimum 0.1 nsec minimum	Master computer command	Resolution is a function of the setting.
Denial ECM center frequency	ECM center frequency	4 to 12 GHz	2 MHz	10 msec	Master Computer Command
Denial ECM AM	ECM AM	0.5 to 150 MHz BW	Internal: 0.5, 1, 5, 10, 20, 150 MHz External: external source limit	Manual	
Denial ECM FM	DMC FM	Center frequency deviation ±800 MHz, 4 to 8 GHz ±1.6 GHz, 8 to 12 GHz Rate Sawtooth 1 kHz to 10 MHz 50 MHz to 50 MHz Sine 50 MHz Noise 0.5 to 50 MHz BW External 0 to 50 MHz 0.00015 Hz to 50 kHz	800 KHz 1.6 MHz	Master computer command Master computer command	
Noise Generator	Caussian and Binary		50 Hz Smoothly variable 0.5, 1, 5, 10, 20, 50 MHz External source limit Selectable sequence lengths	Master computer command Manual Manual Manual Manual	3 each

TABLE 13. SIMULATION FLIGHT PARAMETERS

Target Generation	Capability	Main Array
Frequency	2 to 18 GHz	42 deg field of view
Simultaneous targets	four at 2 to 12 GHz, two at 12 to 18 GHz	four targets
Reference	one	Polarization diversity
Scintillation	40 Hz to 40 dB	1-kHz update
Target velocity capability	0 to 20,000 ft/sec	534 elements
Relative velocity controllability	0.5 ft/sec with 5-Hz jockeying	Target accuracy: 2 to 12 GHz: 0.3-mrad linear polarization 0.5-mrad polar diversity
Waveforms	Pulse, CW, chirp	12 to 18 GHz: 1.0-mrad linear polarization 1.5-mrad polar diversity
Computer control	1 kHz update	
ECM	Capability	ECM Array
Stand-off jammers	Two	
Types of denial jamming	Spot, swept spot, blinking, and barrage jamming	16 elements over 42 deg field of view
Types of deception jamming	Velocity and range gate stealer	Polarization diversity
Jammer-to-signal ratio	Up to 50 dB (limited), 1 kW peak, 10-W CW)	Two simultaneous stand-off jammers
Jammer modulation	10% frequency, 100% amplitude	Fuze, Reference Signals
		One, 100 mW full modulation reference channel
		Hard coupled RF signals uplink and downlink equipment available
		Environment
		Programmable and controllable including ground clutter and multipath

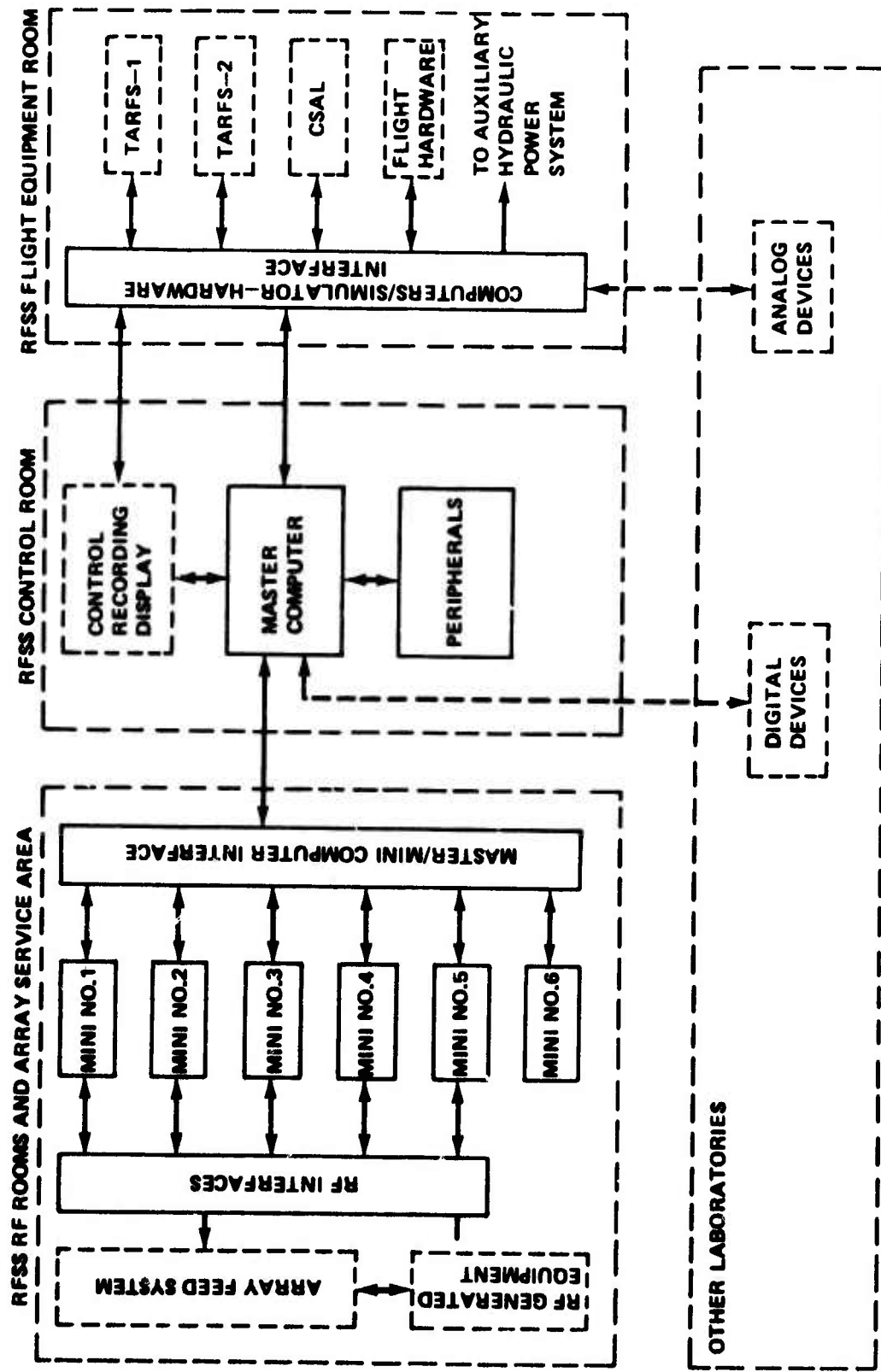


Figure 33. RFSS control elements.

TABLE 14. DATACRAFT 6024/1 CHARACTERISTICS

Memory Size	32,768 words
Word Size	24 bits plus memory parity
Registers	5 to 24 bit (3 may be used for indexing)
Addressing	
(Direct, indirect and indexing)	32,768
Cycle Time	600 nsec
Input/output capability	
ABC channels	8 provided (up to 14 possible)
Standard channel	1 provided (up to 28 possible)
Priority interrupts	
Internal	8 (standard)
External	24
Sense switches	4
CPU features	
Power fail shutdown and restart	
Program restrict/instruction trap	
Stall alarm	
Interval timer	
Address trap	
Scientific arithmetic unit (floating point)	
Bit processor	
Hardware bootstrap	

TABLE 15. BASIC FEATURES OF INTERDATA MODELS 80 AND 85 COMPUTERS

Instruction repertoire	127 instructions including multiply/divide fixed and floating point (131 instruction for Model 85)
Instruction word format	Full word (32 bits) and half word (16 bits)
Direct accessing	65,536 bytes
Data word length	8, 16, and 32 bits
Memory size	16K bytes
Access time	330 nsec
General registers	16 (15 useable for index registers)
Priority interrupts	8 (external)
Input/output	VIA selector channel (DMA) (two provided) (separate teletype input/output)
Additional model 85 features:	
Micro processor:	
Micro instructions	170
Control store memory (fixed)	4096 bytes 60 nsec access
Control store memory (dynamic)	4096 bytes 200 nsec access
Data word length	16 bits
Universal clock:	
Resolution	1 sec, 10 sec, 100 sec, 1000 sec (intervals)
Program control	Command, status, count, interval

TABLE 16. FIXED-HEAD-DISC SPECIFICATIONS

Rotational speed	1800 rpm
Average access time	16.7 msec
Transfer format	Serial
Transfer rate	134,400 words/sec
Storage	143,360 words
Number of heads/track	1
Number of tracks	32
Words per sector	112 plus end-of-sector word
Sectors per track	40

E. Missile Hardware/RFSS Hardware Integration

Each piece of program-related hardware that must be employed in the RFSS for testing must pass through an integration effort. Although there is no standard level of effort, as each program tends to be unique, the integration steps are standard and include the following:

- 1) Defining functional requirements.
- 2) Developing and reviewing a design concept.
- 3) Detailing the design (drawings and parts lists).
- 4) Releasing requests for procurements.
- 5) Receiving, expediting and inspecting parts.
- 6) Assembling drawer(s)/cable(s).
- 7) Checking out and integrating drawer(s)/cable(s).
- 8) Integrating the program hardware with the RFSS.

To date, levels of effort have ranged from kluges to dedicated racks and are usually specified by the customer.

IV. COST, SCHEDULING, AND PRIORITY

A. Cost Rationale

The estimation and presentation of a single daily cost for using each of the ASC simulation cells have many risks because of the misunderstanding which can arise when such figures are used at some future time and assumed to apply to specific tasks being considered at that time. The difficulty which surfaces then is that the basis for costs may have changed and the new cost estimates may not agree with the estimates previously presented, thus creating in the mind of the user a credibility gap which is extremely hard to bridge. For this reason, a discussion of how costs are developed in the ASC will be presented.

Within each of the ASC cells and within the ASC, simulation development proceeds through several stages associated with each of which are different manpower, computer time, and material/equipment requirements. These stages are development, integration and check-out, and utilization. The total cost to conduct a specific simulation task is the summation of costs to perform each of these stages. Since the stage at which AFATL would enter the ASC process is indeterminate at this time, it is almost impossible to provide "typical" costs for the development stage or the integration and checkout. These can only be properly estimated after extensive discussion and negotiation with the customer.

With these considerations in mind, it is believed that the best approach to provide some indications of the costs involved is to identify the cost of using the various cells under the present pricing structure and then discuss the variations.

Typical utilization costs are as follows:

1)	RFSS, open loop, stand along	
	In flight equipment room	\$4,640/day
	In aperture room	\$2,410/day
2)	RFSS, closed loop, stand alone	\$4,640/day
	In flight equipment room (assumes simplified all-digital simulation)	
3)	RFSS, closed loop, hybrid, with modeling support	\$5,180/day
	In flight equipment room	
4)	RFSS, any of above, but including use of aerolaader of TARFS-2 <u>add</u>	
	Aerolaader	\$800/day
	TARFS-2	\$800/day
5)	EOSS, open loop	\$1,608/day
6)	EOSS, closed loop, stand alone	\$1,608/day
7)	EOSS, closed loop, hybrid, with modeling support	\$2,148/day
8)	IRSS, open loop	\$1,360/day
9)	IRSS, closed loop	\$1,900/day

For each of the preceding costs, charges for use of the digital and hybrid computer resources must be added. The magnitude of these costs depends upon the number of resources used and the number of tests run per day and, therefore, cannot be easily estimated.

The costs outlined assume that the simulation models, software, and hardware (including interfaces) have been completed and the overall effort has reached the stage of production or data taking. This point in the process may have been reached under a variety of means, and AFATL may or may not have participated. In addition, the preceding costs are predicated upon the use of ASC personnel only. Should AFATL choose to actively participate in the effort, at any stage, the AAC would welcome such participation. The total cost will be reduced under these circumstances.

Once a particular simulation has been developed and used for production runs, the costs to reactivate that same simulation at a latter time will be minimal. Costs incurred are associated with remounting test hardware and interfaces, cell setup, and possible model changes, if any. In general, experience indicates the costs to be approximately \$15K to \$20K, depending upon the extent to which the preceding activities have to be performed.

In summary, costing a simulation job in the ASC cannot be done in a general context. The number of variables involved complicates the procedure to the point that a cost can be considered valid only if it is developed for a specific job with well-defined and thoroughly-understood requirements.

B. Scheduling and Priority

Resource scheduling and billing for a simulation job is handled by a scheduler program which runs on a PACER computer. The mechanics of the process requires that the simulation project leader manually schedule on the schedule board the resources required for specific periods of time. Conflicts are generally handled via negotiations among project leaders. Scheduling is normally done in advance for 2-week periods of time; the data are entered into the scheduler program and computer-generated schedules are produced which represents the schedule for the next 2 weeks.

In general, all jobs currently active in the ASC have equal priority as far as scheduling of resources are concerned. Exceptions to this rule would be based on such things as

- 1) A particular job having high national priority.
- 2) A job where simulation results are required on a high priority basis as an input to other efforts.
- 3) A job where availability of test hardware is limited to a short period of time.

Customer jobs are handled on the same basis as other jobs such that, barring the need to make exceptions, priorities and resource scheduling are handled on a first-come, first-served basis.

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