Martin-Marietta Aerospace Simulation & Test Laboratory

General

In Martin-Marietta's Simulation & Test Laboratory (STL), a wide variety of missile guidance and aircraft fire control systems are simulated, tested and evaluated. The STL consists of the following areas: 1) Man-in-the-Loop Simulation System, 2) Radar Guidance Simulation System, 3) Heliport Flight Operations, 4) Outdoor Lab & Range Operations, and 5) Radar Antenna Test Chambers. The STL is a separate complex and is shown in Figure 1. Only the Man-in-the-Loop Simulation System (MILS) will be described and consists of the simulation of: 1) the Advanced Attack Helicopter (AAH), 2) the A-10 aircraft, and 3) the F-16 aircraft. Basically, three different cockpits are used in conjunction with other common simulation elements. The purpose of the simulation system is to provide the same complex interaction as the aircraft between the crew, the aircraft and the avionics systems. Large dynamic, closed-loop, real-time, 6 degree-of-freedom systems are used which enable MMA to demonstrate the feasibility of the pilot or crew to efficiently and effectively perform target acquisition and air-to-surface weapon delivery using stabilized sensors with automatic tracking capability, various controls and displays, cueing information and assorted weapons. This is accomplished by experimental studies of equipment utilization, operating techniques, control functions and display symbology that can be performed during simulated mission flights against typical targets on a three-dimensional terrain model.

The simulation enables the pilot or crew seated in a cockpit to fly missions over a 80' by 40' terrain model using visual cockpit displays whose scenes are provided by sensors on the simulated aircraft. Figure 2 shows the simulation elements. The aircraft flight over the terrain model (European environment) is simulated by a 6 degree-of-freedom motion system that includes the terrain model. A large gantry containing two (2) television systems is suspended over the terrain model. The windscreen probe and TV represents the aircraft and can reproduce aircraft rotations, angular velocities and angular accelerations for three degrees of angular freedom. The sensor probe and TV represents the fire control system and provides a magnified small field-of-view scene.

The three degrees of translational freedom are obtained by moving the terrain model along a straight line horizontal path and by moving the probes and television systems both in a vertical direction and in a horizontal direction. The translations, velocities and accelerations are scaled according to the terrain model scale which is scaled at 225:1 for helicopter operations and 1200:1 for fixed-wing aircraft operation.

The simulation is controlled by a hybrid computer arrangement composed of three (3) Sigma 5 digital computers, six (6) EAI 231-RV analog computers and appropriate instrumentation, interface and peripheral equipment. A typical mission would have the aircraft as represented by the windscreen probe and TV located at some initial position with respect to a target area on the terrain model. The mission would be started and the pilot would fly the aircraft against the target (tanks, trucks, bridges, etc.) using the cockpit visual and instrument displays. As the flight progresses, the computers are used to control the aerodynamics and to process commands to the sensor probe and TV and to determine where it is looking, to handle operational mode logic and switching functions, to perform weapon delivery calculations, and to generate commands to position symbology on the visual displays. The mission is terminated when a weapon is released and breakaway is completed.

The cockpits can be located either on the 6 degree-of-freedom motion base or operated from 2 separate rooms which contain identical interface consoles. The MILS system is designed for less than 1 hour changeover from one aircraft system to another.

The following paragraphs describe the simulation elements.

Terrain Model

The terrain model (Figures 3 and 4) is 80' by 40' with a fiber glass surface which can be walked on for target changes. Three foot mirrors ring the terrain model for terrain extension. The terrain model has scales of 1200:1 and 225:1. Simulation parameters for 1200:1 are:

Slant range		100,000 ft.
Altitude		12,000 ft. (max) 84 ft. (min)
Lateral range	to	48,000 ft.
Longitudinal velocity	to	12,000 ft/s
Vertical velocity	to	7,200 ft/s
Lateral velocity	to	4,800 ft/s

The terrain model consists of mountains, plains, harbors, streams, ridges, forests, dams, tunnels, highways, railroads, bridges, airports, buildings, docks, etc. Topography is rolling hills modeled after West Germany. Choice of materials used in the manufacture of the terrain model was based on weather and sun resistance and, at the same time, a presentation of realistic targets to the sensors.

Lighting

The environments controlled in the terrain model room are lighting and temperature. The lighting is a combination of low ripple (1 percent maximum), fluorescent, and metal halide lighting. The low ripple system is provided by 750 watt incandescent lamps giving approximately 200 footcandles 36 inches above the floor. The fluorescent system provides 500 footcandles and may be reduced by increments of 50 footcandles. The metal halide system provides 2000 footcandles. Conditioned air is provided to maintain a temperature of $75°F \pm 5°$.

Longitudinal Transport Mechanism

The 3-D terrain model is mounted on 30 trucks, and 10 central trucks with compound bearings provide lateral guidance in addition to vertical guidance. The trucks allow translation of the assembly in a longitudinal direction on three tracks. The characteristics of the terrain model longitudinal drive assembly are listed below:

Displacement	±80 feet
Velocity	Accuracy at min ±1.0 percent at 0.01 ft/s Accuracy at max ± .05 percent at 10 ft/s
Acceleration	±10.0 ft/sec^2
Positioning	Accuracy ±0.1 inch Repeatability .02 inch max.
Small signal frequency response	3.0 cps
Weight of longitudinal drive system	24,000 lbs. static and rolling friction less than 250 lbs.

The 3-D terrain model is mechanized to simulate the longitudinal movement of the aircraft in flight; and, therefore, accounts for one degree of freedom.

Vertical and Lateral Transport Mechanisms

The remaining two degrees of translational freedom to simulate vertical and lateral movement of the aircraft are provided by a lateral carriage and a horizontal beam. The lateral carriage is free to translate laterally and is attached to a horizontal beam which is free to move in the vertical direction between two supporting columns. The operating characteristics of the lateral and vertical drive systems are:

Lateral and Vertical Drive Characteristics

	Lateral	Vertical
Displacement	38 ft	25 ft 7 in
Velocity		
Accuracy at minimum	+1.0 percent at 0.004	±1.0 percent at 0.006 ft/s
Accuracy at maximum	.05 percent at 4.0 ft/s	.05 percent at 6.0 ft/s
Accelerations	4 ft/s^2	6.0 ft/s^2
Positioning		
Accuracy	±.02 inch	±.02 inch
Repeatability	.005 in max	.005 in max
Small Signal frequency response	3.0 cps	3.0 cps

Windscreen Probe

This is an optical probe (Figure 5) to provide the pilot with an out-the-window presentation. It is a Scheimpflug corrected probe which has essentially an infinite depth of field. It also will allow low level (<100 ft) operation over the terrain model. The specifications are:

1. Fields of View — 50° circular
33.3° circular
12.5° circular

2. Minimum altitude — 10 mm ∿ 40 feet (1200:1)
3. Near focus — 25 mm ∿ 100 feet (1200:1)
4. Resolution — 2.3 arc min at 25% MTF
5. Servo Performance

	Displacement	Velocity
Roll	Continuous	360°/sec
Pitch	+ 25°, -90°	100°/sec
Yaw	Continuous	360°/sec

This probe and the sensor probe are mounted on the lateral carriage above the terrain model.

Sensor Probe

The sensor probe (Figure 5) is used to simulate a fire control system. It is a Scheimpflug corrected probe which has essentially an infinite depth of field allowing low level (<100 ft) operation over the terrain model. The specifications are:

	#1 Snout	#2 Snout
1. Field of View	6° circular	20° circular
	4° circular	13.3° circular
	1.5° circular	5° circular
2. Minimum Altitude:	20 mm ∿ 84 ft (1200:1)	20 mm
3. Near focus:	300 mm ∿ 1200 ft (1200:1)	300 mm
4. Resolution	17 arc seconds at 25% MTF	50 arc seconds at 25% MTF

5. Servo Performance

	Displacement	Velocity
Roll	Continuous	360°/sec
Pitch	+25°, -90°	100°/sec
Yaw	Continuous	360°/sec

When the windscreen and sensor probes are mounted on the lateral carriage, the longitudinal separation between entrance pupils of the two probes will be 12 inches.

High Resolution TV

Two 1200 line, 60 MHz high resolution TV systems (Figure 5) are used with these probes. Both systems have a variable line rate and bandwidth so that they can be used to simulate a system with any resolution up to

1200 lines with a linearity of less than 0.1%. A set of distribution amplifiers is included in the TV control console, and distribution amplifiers are included in each cockpit interface console. These distribution amplifiers are all differential to minimize 60 Hz interference. These systems can be used with Martin Marietta TV trackers. When used with the optical probes, these TV systems yield resolutions of 4.4 arc minutes for the windscreen probe at 50° field of view, and 17 arc seconds for the sensor probe at 1.5 degree field of view. The TV systems can also be electronically zoomed at a ratio of 4:1 in conjunction with the probes to provide a variety of fields of view.

Visual Display Systems

Two black and white, high resolution, high accuracy, infinity focus visual display systems provide a 50° field of view of the terrain model to the pilot through the windscreen of the cockpit. The optics for each system consist of 4 large diameter (up to 40") plastic refractive lenses. The scene is provided by a 25" Cathode Ray tube which can provide up to 1200 lines with linearity and geometric accuracy of less than 1% of picture height. The overall resolution is 4 Arc Minutes/Line Pair and a brightness of up to 25 footlamberts.

Special Effects Generator

A special effects generator provides low ceiling and limited visibility effects and provides a horizon and sky.

Computer Laboratory

The computers provide the means of calculating the equations of the mathematical implementation of missile or aircraft aerodynamic, kinematics, and autopilot. The computer laboratory (Figure 6) is the central control room where all data is normally gathered. The computers contain the computational elements listed below:

GDC Hybrid Computer Complement

Digital Computer

Sigma 5 - Triple CPU	
Memory size	160K words
Word length	32 bits
Memory cycle time	1.0μs
Arithmetic	Fixed point and floating point.

Analog Computers

231R-V's	
Number of consoles	6
Total number of amplifiers	1496
Quarter-square multipliers	276
Resolvers	30
Potentiometers - Servo Set	900
Potentiometers - Hand Set	140
Function generators	120

Hybrid Interface
(digital computer/231R-V)

Multiplying Digital to analog converters	56
Analog to digital converter channels	48

Peripheral devices - Sigma 5

2 card readers	400 & 1500 car/min
4 mag tapes	75 inches per sec 800 bits/inch
2 line printers	800 & 1000 lines/min 132 char/line
2 fixed head disk memories	6.0 Mbytes
1 disk pack	48 Mbytes

Control Consoles

Control consoles are used for translational and rotational drive control as well as lighting and closed circuit TV control. In general, the consoles provide mode of operation (velocity or position and manual or computer control), manage the general signal routing, and provide the outlets for availability of selected parameters to be measured. The control console has provisions for manually introducing a position or rate command for each of the six degrees of freedom, independently or simultaneously.

Crew Station Laboratory

The motion base building houses a 6 DOF motion base (Figure 7) and space for 2 fixed base operational cockpits. The motion base has the following specifications.

Payload	18,000 lbs.
Vertical travel	+33, -38 inches
Lateral travel	$\pm$58 inches
Longitudinal travel	$\pm$53 inches
Roll travel	$\pm$32 degrees
Pitch travel	+36, -31 degrees
Yaw travel	$\pm$32 degrees

AAH Cockpit

A tandem helicopter cockpit (Figure 7) has been configured as a YAH-64 Advanced Attack Helicopter. The cockpit consists of two sections, the rear being the pilot's position and the forward configured for the co-pilot/gunner position. The interior of both cockpit sections represents the proposed layout of the production version of the YAH-64 as of July 77.

The pilot's section is configured with a full complement of operational flight and engine instruments (engine instruments to be installed by Feb. 78). The primary fire control and visionics panels are operational with the balance of the panels configured as photo mockups.

The pilot's flight controls consist of cyclic, pedals, and collective assembly. The artificial feel system is programmable and has the capability to simulate any helicopter control system. The pilot's grip is identical to that for the YAH-64.

The cockpit interior is painted black, for compatibility with night vision goggles. The interior lighting is red and all instruments and panels are integrally lighted and dimmable. In addition, complete provisions have been made for installation of a Helmet Display and Sight System.

The co-pilot/gunner section is configured with a fully operational (simulated) Target Acquisition and Designation System (TADS). In addition, the primary fire control and visionics panels are operational with the remainder of the panels and instruments configured as photo mockups.

An aural simulation is also provided for the AAH. It simulates rotor and tail rotor sounds, turbine whine, weapon firing, and wind cues. The system is programmable and is driven by the aero-model software.

A-10 Cockpit

An A-10 cockpit (Figure 8) is available which can be installed on the motion base. This cockpit is a representation of A-10 aircraft number 11 (Tail No. 7500262) with all trainer applicable ECP's uo to May 9, 1977 incorporated. The approximate size of this cockpit is 11 feet long, 6 feet high and 5 feet wide. The cockpit interior represents the basic design of the A-10A aircraft. All instruments, indicators, gages, controls are located in the same position as in the A-10A.

A 20° FOV Helmet Mounted Display system and an A-10 Airborne Head-Up Display are installed in the cockpit. The A-10 cockpit has the same type of artificial control feel and aural simulation as the AAH. One of the visual display systems will be mounted on the A-10 cockpit.

F-16 Cockpit

A 2-seat F-16 cockpit is available and is scheduled to be modified to be installed on the motion base. Adequate instruments, displays and controls are provided for air-to-ground weapon delivery missions. An airborne F-16 Head-Up Display is installed for symbology cues. The F-16 uses the same aural simulation equipment as the A-10 cockpit with differences in drive signals. A visual display system will be mounted on the F-16 cockpit. The F-16 cockpit is shown in Figure 9.

Figure 1. Simulation and Test Laboratory

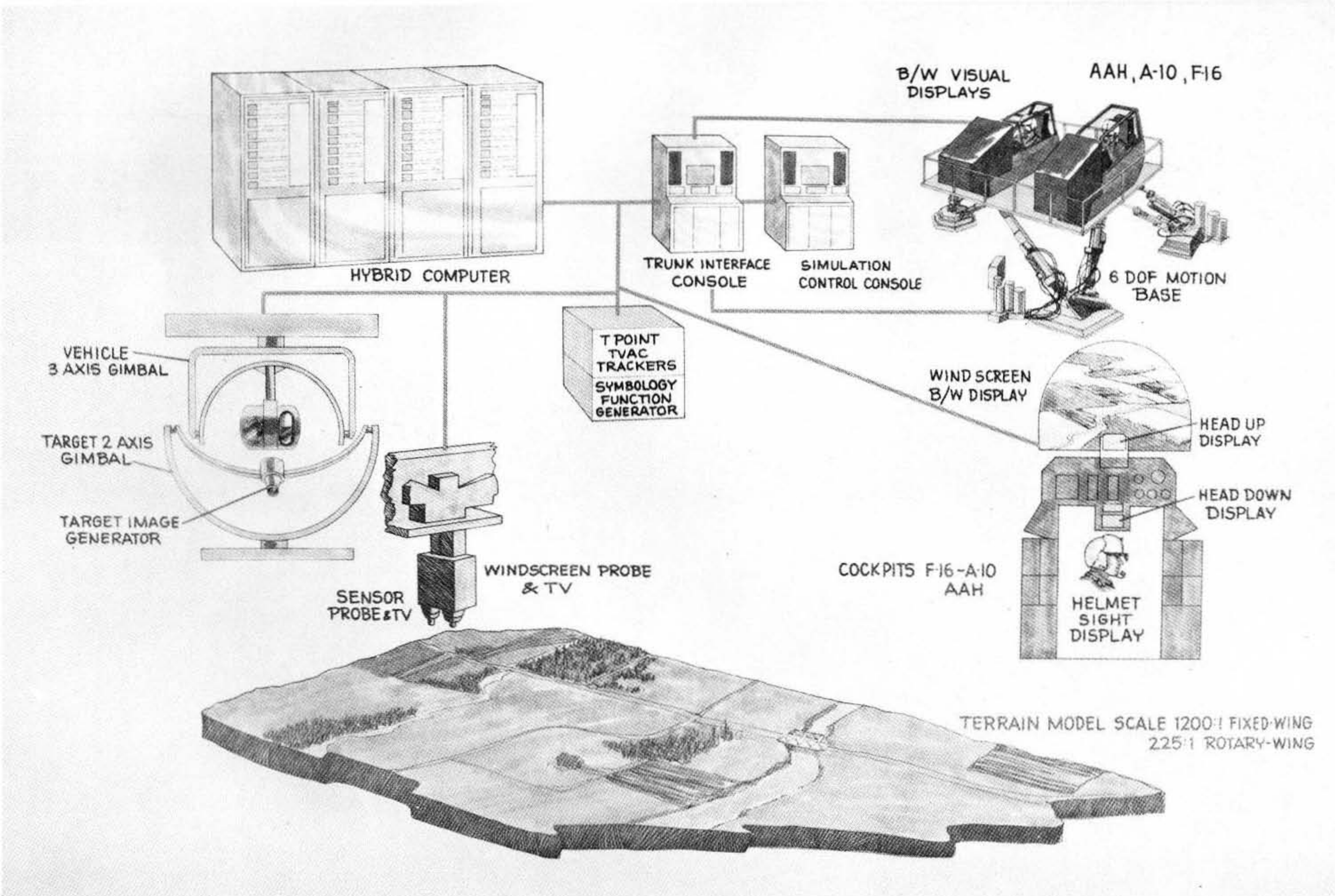

Figure 2. Simulation Elements

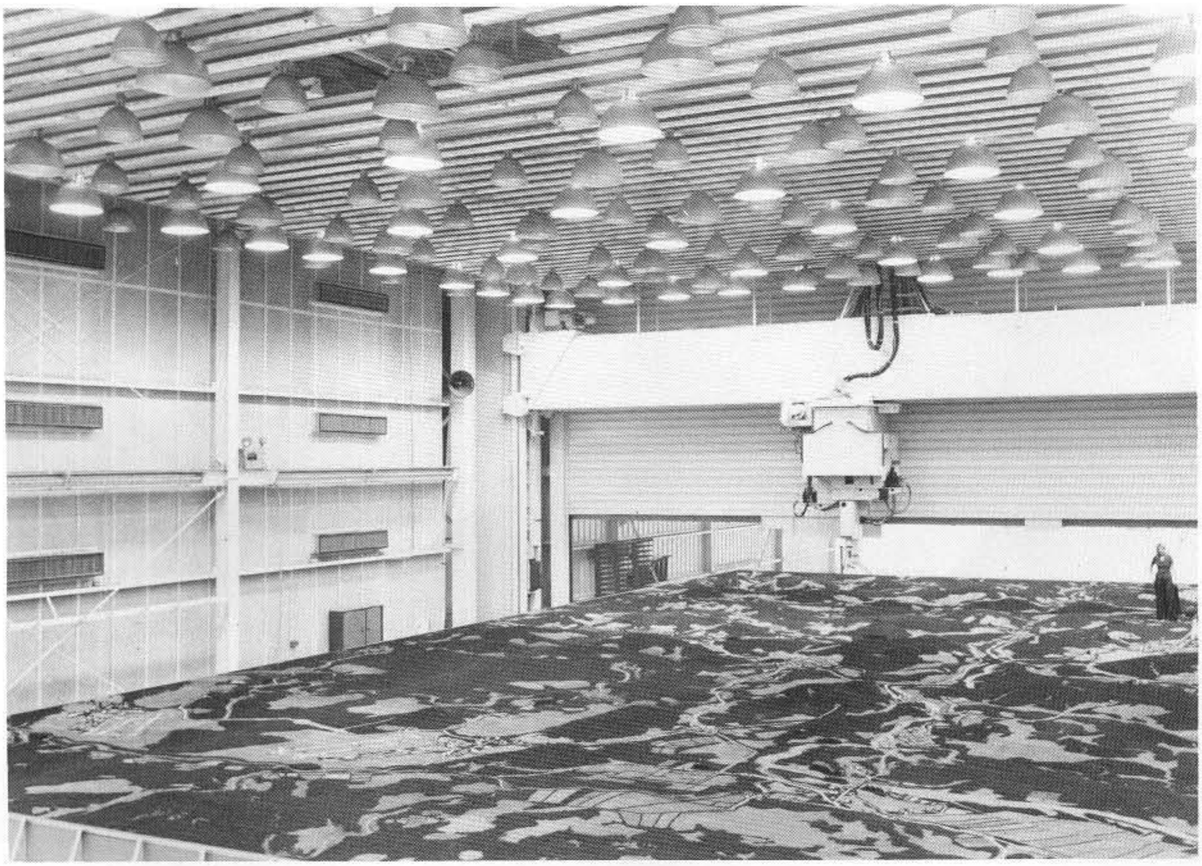

Figure 3. 80 x 40 ft Terrain Model

Figure 4. Terrain Model Closeup

Figure 5. Optical Probes and Televisions

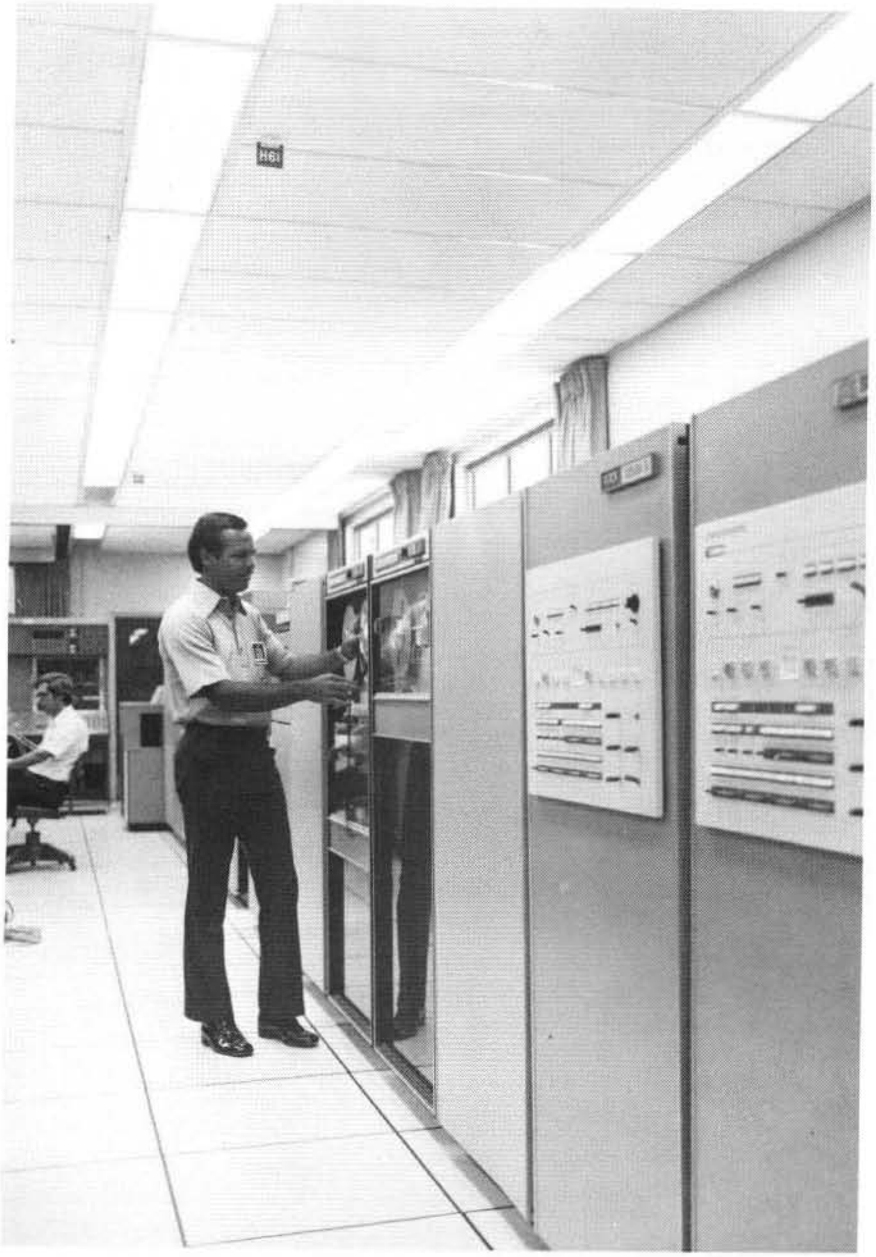

Figure 6. Computer Complex

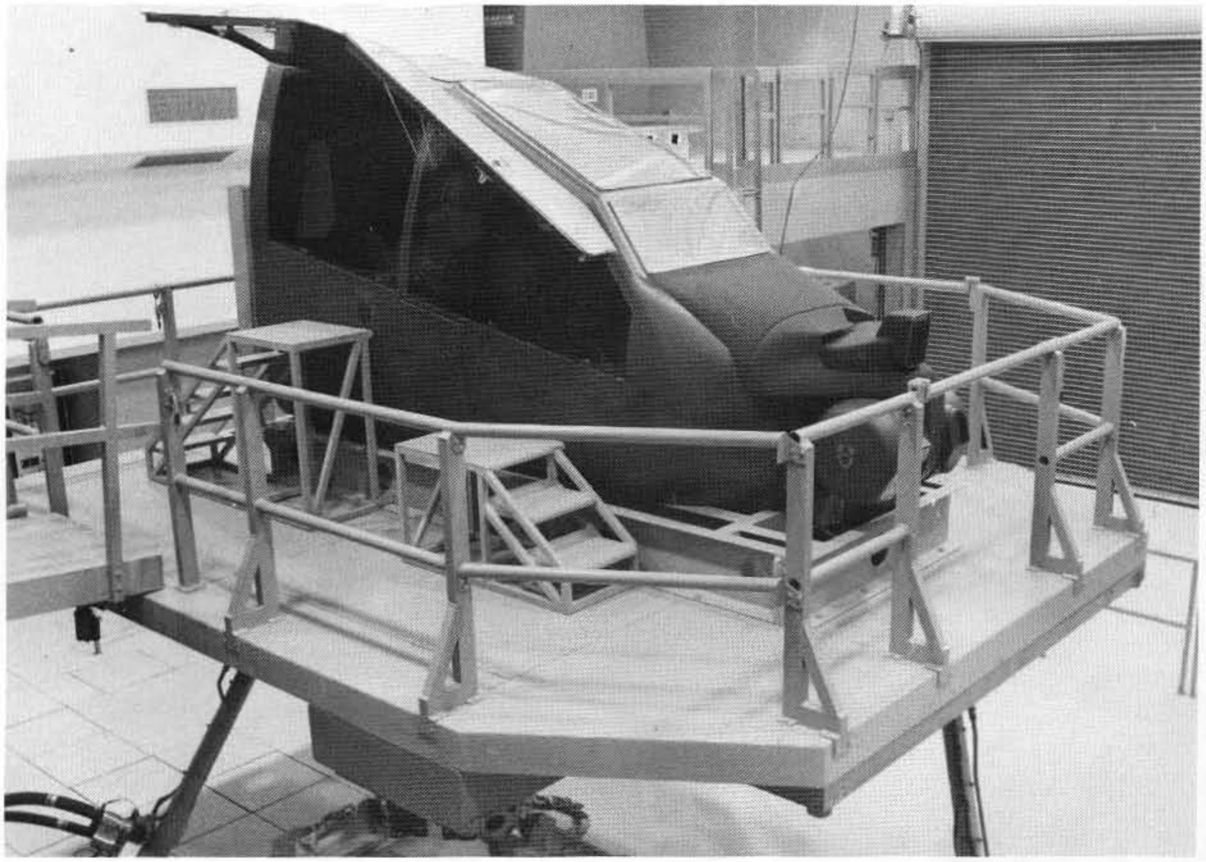

Figure 7. 6 DOF Motion Base and Cockpit

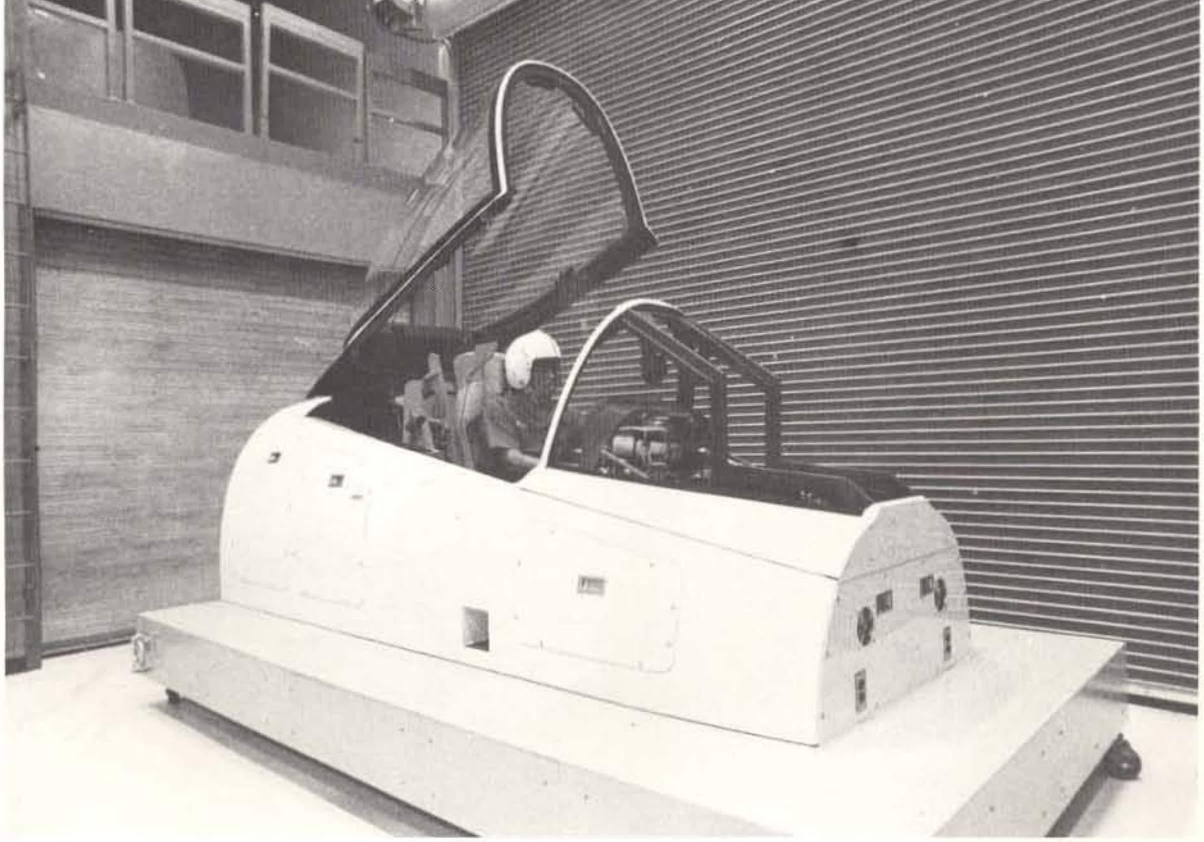

Figure 8. A-10 Cockpit