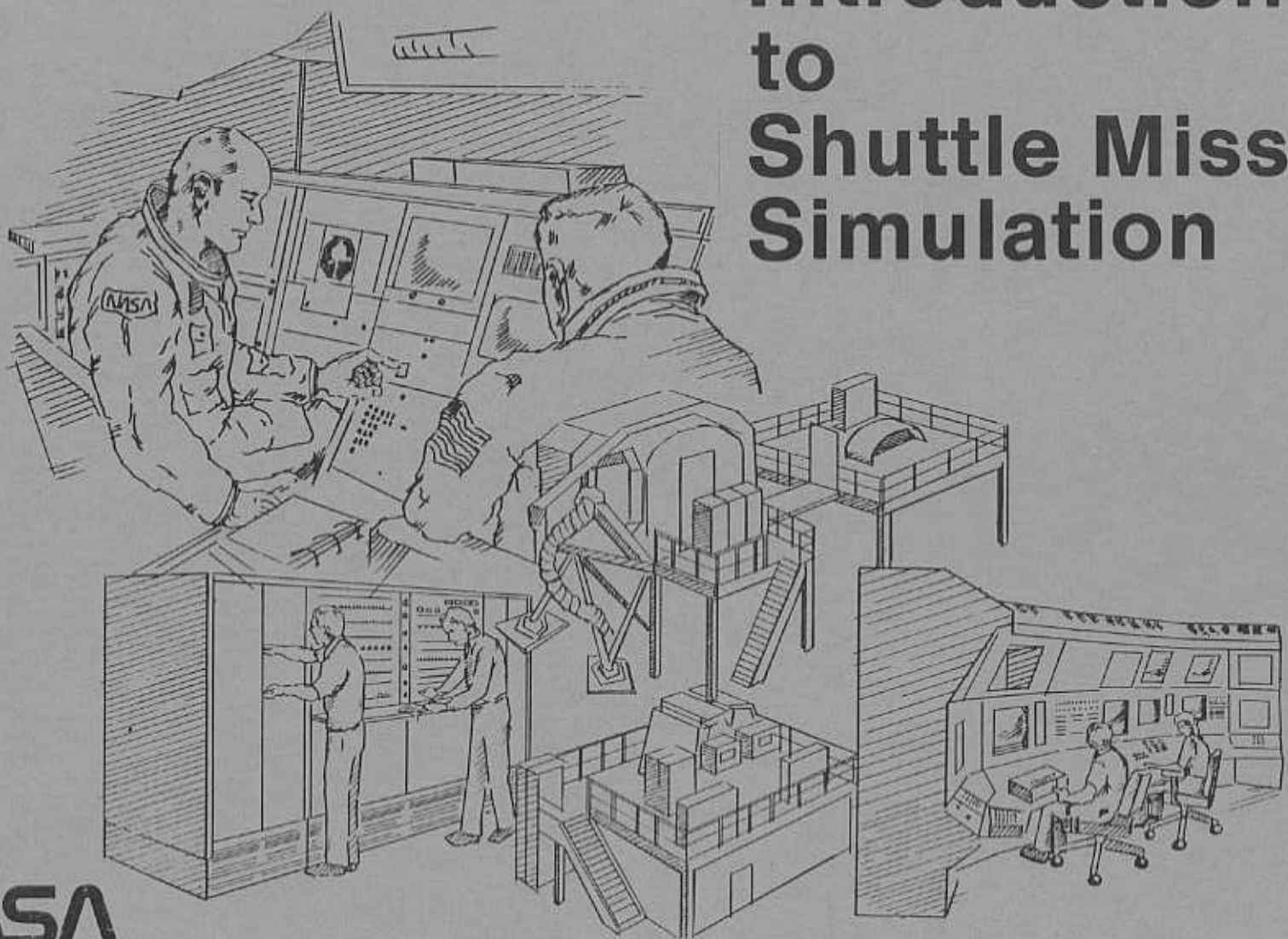


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Introduction to Shuttle Mission Simulation



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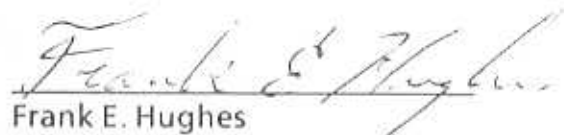
Introduction to Shuttle Mission Simulation

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Preface

This book provides a fundamental description of the Shuttle Mission Simulator (SMS) located at the NASA Johnson Space Center (JSC) for those who are unfamiliar with this simulator. It contains information concerning the SMS complex, its purpose and capabilities, the support computer facility, and the role of the SMS in integrated simulations. This book should be used as an SMS overview source and not as a detailed textbook. For detailed information concerning the SMS capabilities, refer to the SMS Statement of Work, Addendum A: SMS Design Control Specification.

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Introduction

Overview

The Shuttle Mission Simulator (SMS) is the prime training simulator for crew training in the Shuttle Program. It is the only high-fidelity simulator capable of training flight crews for all phases of a mission, from lift-off minus 30 minutes through rollout. This includes prelaunch checkout, ascent, aborts, on-orbit operations (including payload deployment and rendezvous), entry, landing, power down, and contingency operations. To support this high-fidelity requirement, the SMS uses real-world flight computers and associated support equipment and flight software, along with flight cockpit hardware (instruments, displays, and controls). In addition, visual, aural, and motion cues are provided by computer-generated out-the-window scenes, hidden speakers, and a motion platform.

The SMS complex consists of a fixed base crew station (FBCS), a motion base crew station (MBCS), two instructor stations, two operator stations, the Network Simulation System (NSS), the Spacelab Simulator (SLS), and its supporting instructor and operator station, and the supporting computer facility. The SMS occupies most of the north side of JSC building 5; the two crew stations, their support operator stations, and most of the computer complex are located in the high bay area, while the

instructor stations are located in the adjacent low bay area. See figure 1 for a layout of the SMS area.

Background

In the last 20 years, flight simulation has become the major method of training personnel for commercial, military, and space vehicle operations. Ever since the Mercury Program, flight simulation has proven to be the best and, in most cases, the only practical way of training astronauts for space flights. The SMS, designed for this purpose, is a major milestone in flight simulation sophistication and fidelity.

Constructed in 1976-77, the SMS has been operational since late 1978 and is expected to provide Shuttle crew training for the next 20 years. The complex is maintained and operated under the supervision of the Flight Simulation Division of the Data Systems and Analysis Directorate at JSC. The simulators were constructed and are presently supported by the Link Division of the Singer Company under NASA contract NAS9-1490. IBM and Rockwell International provide the prime and backup flight software, respectively. The approximate cost of the SMS is \$100 million (1980 dollars).

Facility Support

Except for the computer facility, there is no major support equipment dedicated to the operation of the SMS. Water, air conditioning, and electricity are supplied to the SMS through the normal JSC utility system (however, the electricity is "smoothed" by a small facility next to building 5 before being supplied to the SMS). An overhead crane is available for handling heavy equipment.

SMS support personnel include instructors, operators, engineers, and maintenance technicians. Although the number of people required to support the SMS depends on the particular simulation being performed (e.g., an integrated simulation involves more people than a nonintegrated one), over 600 people are involved in operating and supporting the SMS directly or indirectly.

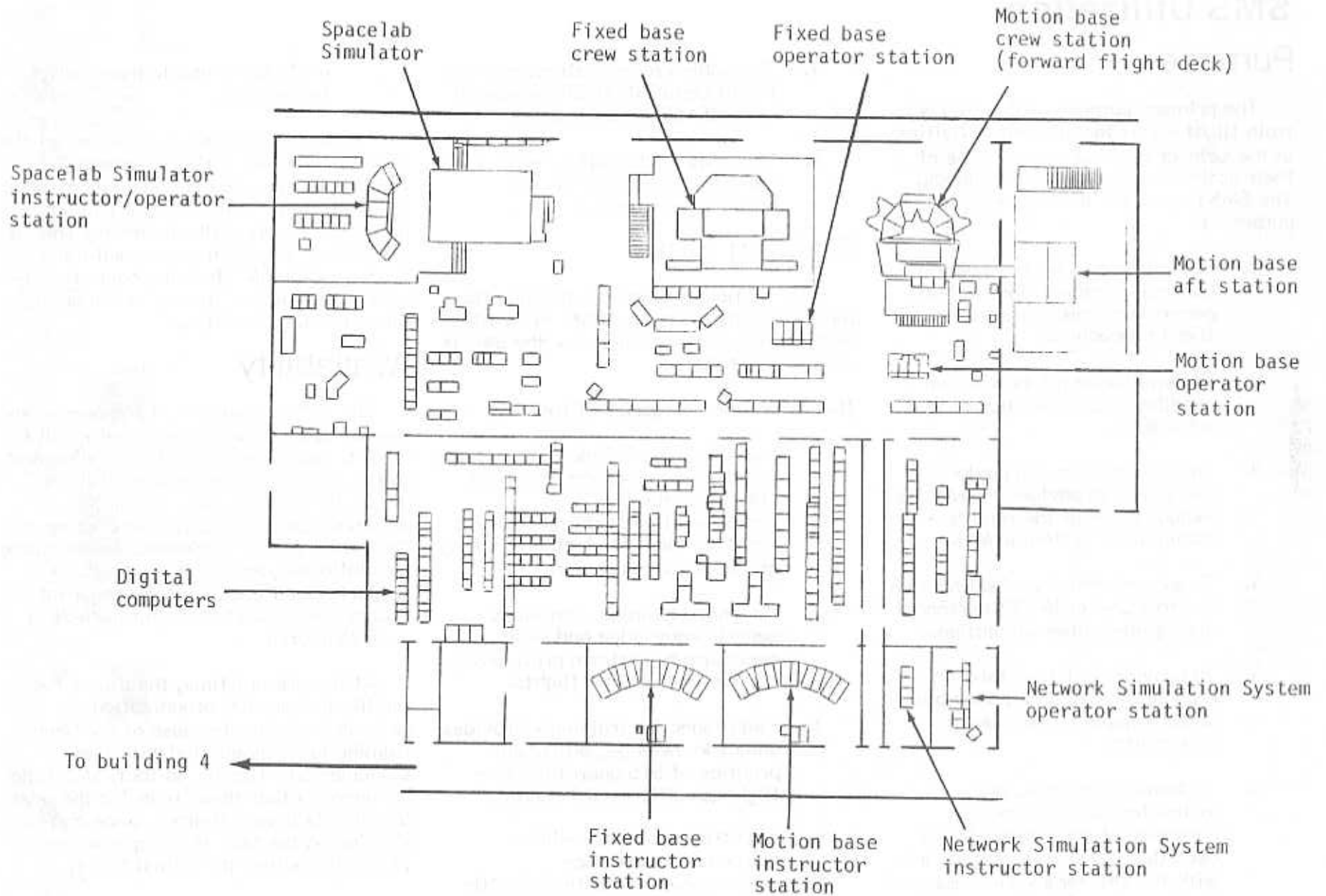


Figure 1. - Layout of the Shuttle Mission Simulator facility.

SMS Utilization

Purpose

The primary purpose of the SMS is to train flight crews for all their activities in the Orbiter flight deck and some of their activities involving the middeck. The SMS is used for the following specific purposes:

1. To train crews for normal and contingency operations in both generic and mission-specific flight procedures.
2. To familiarize pilots with the handling characteristics of the vehicle.
3. To train mission and payload specialists in payload operations, including use of the remote manipulator system (RMS).
4. To support training of all Mission Control Center (MCC) personnel during integrated simulations.
5. To provide real-time mission support by evaluating anomalies and developing contingency procedures.
6. To familiarize crews and instructors with all cockpit hardware of the Orbiter flight deck (location and function) and with the Orbiter's various support and avionics subsystems.

7. To enable crews, instructors, and Flight Data File (FDF) personnel to verify flight procedures.
8. To verify flight software through normal use of flight general purpose computers (GPC's).

Training Flow

This section outlines the training flow for astronauts from candidate to flight-ready status and describes how the SMS is used in this training.

There are four categories of training:

1. Basic training - Generic in nature; familiarizes new personnel with NASA and the Space Transportation System (STS) and prepares them for further training in individual assignments.
2. Advanced training - Provides generic knowledge and skills necessary to perform proficiently on "typical" Shuttle flights.
3. Flight-specific training - Provides unique knowledge, skills, and practice of STS operations in a flight-specific environment.
4. Recurring training - Allows astronauts to practice seldom-used but critical Shuttle operations to maintain their

proficiency and to learn new techniques.

The use of the SMS in three out of the four training categories (advanced, flight-specific, recurring) is indicative of its essentiality in the Shuttle training program. Figure 2 illustrates the role of the SMS in subject training, and table 1 compares the SMS training hours required of Shuttle pilots with required hours in other training facilities.

Availability

The SMS is operational 24 hours a day. Weekly activity schedules usually call for crew training during the first and second shifts, procedure verification training during the second shift, and SMS maintenance and modification during the third shift and on weekends. (During long simulations or real-time contingency support, flight crews may be required to occupy the crew stations for periods of over 24 hours.)

At the present time, the use of the facility by non-JSC organizations is extremely limited because of the heavy training loads associated with the scheduled STS flights. In fact, SMS time for anyone other than crews for the next few flights is very limited, since a crew's training on the SMS starts approximately 11 months before the actual flight.

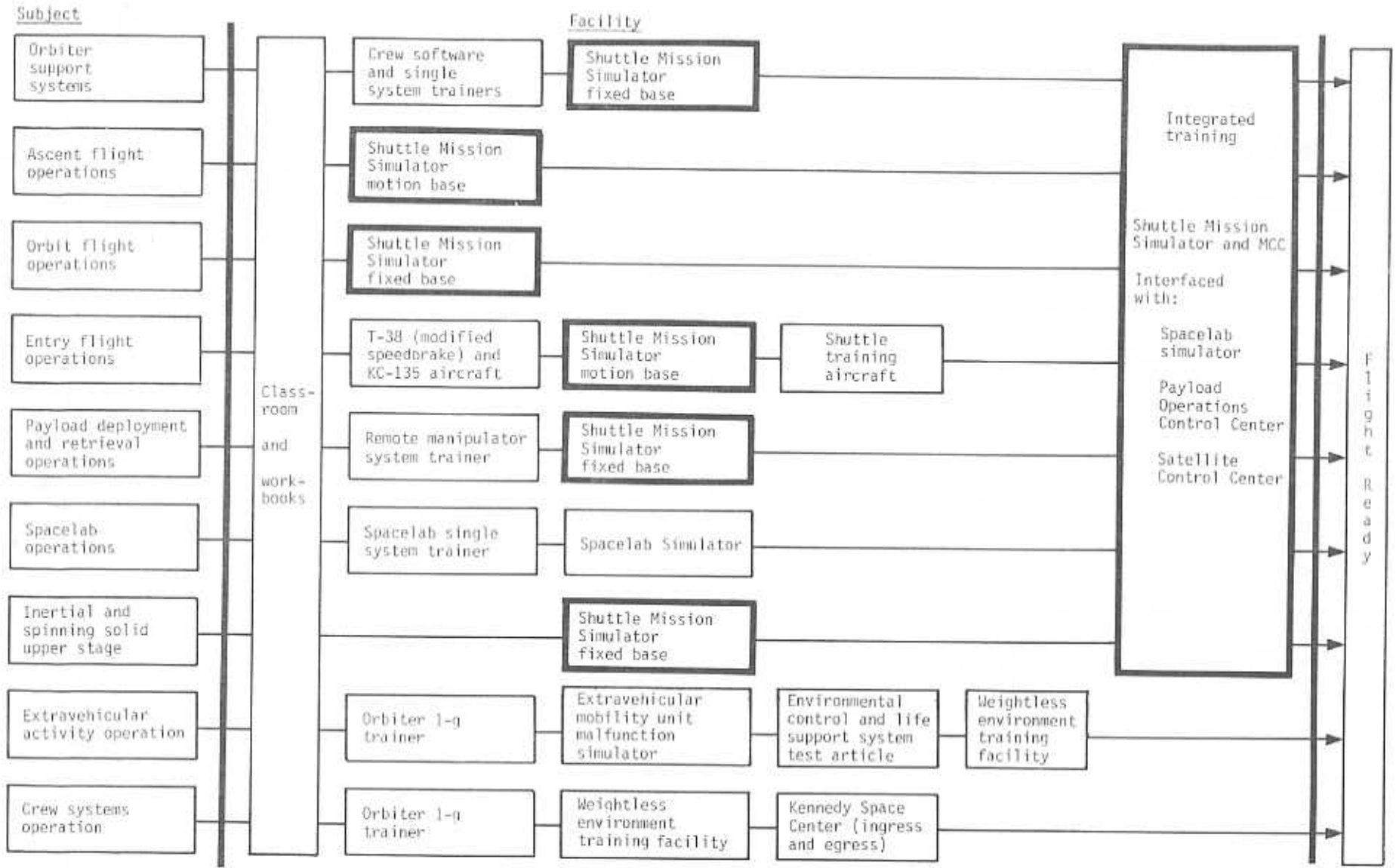


Figure 2. - Training flow and facility use.

TABLE I. - PILOT TRAINING REQUIRED HOURS

Subject	Shuttle Mission Simulator	Integrated simulations	Classroom and workbook	Single system trainer and crew software trainer	Shuttle training aircraft	1-g Trainer	Other *	Total
Orbiter systems			191 (0)	82 (0)				273 (0)
Ascent	60 (16)	0 (8)	13 (3)					73 (27)
Orbit	82 (20)	0 (48)	18 (2)					100 (70)
Entry	122 (20)	0 (8)	22 (0)		40 (20)			184 (48)
Payload operations	9 (3)**		15 (1)**	3 (0)**			10 (1)**	37 (5)**
Deployment & retrieval	12 (0)		17 (0)				18 (1)	47 (1)
Spacelab	14 (0)		39 (0)	14 (0)			24 (0)	91 (0)
Proximity operations	28 (32)		7 (2)					35 (34)
Crew systems			26 (0)	2 (0)		10 (37)	13 (8)	51 (45)
Total	273 (59)	0 (64)	285 (6)	87 (0)	40 (20)	10 (37)	23 (9)	718(195)

The numbers indicate generic hours; those in the parentheses indicate mission-specific hours.

*Includes ingress/egress training at KSC, KC-135 0-g plane, and SLS.

**Weighted average.

Capabilities

General

The SMS can simulate both the nominal operation and possible malfunctions of every support and avionics subsystem on the Shuttle. Not all simulation modules are of the same fidelity. For example, the integrated simulations for crew training involve the complete SMS capability (e.g., window scenes, aural cues, network tracking); whereas procedure verification sessions may involve none of the above.

Mathematical Models

The simulation of various subsystems is provided by mathematical models closely approximating the real-world performance of these systems. Approximately 56 math models of various complexities are included in the computers; they are modularly designed so that changes in the functions of simulated equipment or phases can be implemented easily. Table 2 lists the major subsystems simulated. Unlike engineering simulators, the SMS cannot simulate parameters for which there are no hard engineering data (such as high-frequency effector flutter and body flex). But as engineering data become available, they are incorporated into the math models if they affect the crew controls. The SMS software is designed to perform and respond just as the actual

vehicle does under normal conditions; extreme out-of-tolerance conditions may possibly result in inaccurate responses. The wiring and avionics in the SMS do not correspond exactly to flight configuration; they are modified as necessary for correct simulation response. Testing of the exact configuration of flight avionics and wiring is done in the Shuttle Avionics Integration Laboratory (SAIL).

Malfunctions

In order for the training to be realistic and meaningful, malfunctions were specified and included in the simulation software. The SMS has approximately 6800 malfunctions that can be activated from the instructor stations (see the section describing these stations). The malfunctions are divided into the following three types:

- M - malfunctions that may be applied to more than one of several identical components
- D - discrete malfunctions
- V - variable malfunctions in which parameters (e.g., leak rates, sensor biases) may be entered

The software is designed so that a malfunction in one subsystem may propagate (mathematically) through other subsystems.

Subsystem	Number of Malfunctions
Avionics	1000
Life Support	1000
Structures	1000
Thermal Control	1000
Electrical	1000
Other	1000
Total	6800

TABLE 2. - SIMULATED SUBSYSTEMS

<ul style="list-style-type: none"> Communication & nav aids <ul style="list-style-type: none"> Caution & warning Ku-band Microwave scanning beam Operational instrumentation Rendezvous radar S-band TACAN/radar altimeter (no atmospheric effects) UHF Computer interface <ul style="list-style-type: none"> Engine controller interface Formatting Main engine controller Master events controller Dynamics <ul style="list-style-type: none"> Atmospheric drag (below 150 km) Body bending Emphemeris Gravity Ground contact Mass properties Orbiter/target equations Wind (steady, gust, shear, turbulence) 	<ul style="list-style-type: none"> Electrical power <ul style="list-style-type: none"> Distribution Fuel cells Reactants storage & distribution Environmental control <ul style="list-style-type: none"> Atmospheric circulation Auxiliary power Freon loops Gas supply Space radiator Vent & purge Water coolant Flight control <ul style="list-style-type: none"> Automatic Control stick steering Manual direct Guidance & control <ul style="list-style-type: none"> Air data system Body-mounted sensors Controls & displays Star tracker Thrust/surface control 	<ul style="list-style-type: none"> Measurement processors <ul style="list-style-type: none"> Flight recorders Network signals Pulse code modulation master unit Timing unit Mechanical power <ul style="list-style-type: none"> Auxiliary power units Hydraulic system Mechanical systems <ul style="list-style-type: none"> Landing & braking Manipulator arm Payload bay doors Separation Propulsion <ul style="list-style-type: none"> External tank (fuel slosh) Main engines Orbital maneuvering Reaction control (no plume impingement effects) Solid rocket boosters Thrust controller Tracking network <ul style="list-style-type: none"> Voice communication Telemetry Tracking
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Fixed Base Crew Station

The fixed base crew station (FBCS) is the most critical element of the Shuttle training program. It is the only complete, high-fidelity simulated flight deck (forward and aft stations) available for mission training (figure 3 illustrates the forward flight deck). All controls and displays on the flight deck, and some on the middeck, are active. In addition, stowage is provided. During long-duration simulations, water and food can be provided to the FBCS.

Because the middeck is incomplete, most of the training for on-orbit crew systems (e.g., waste management, food preparation, EVA preparation) is done in the 1-g trainer in building 9A. A mockup GPC trainer, located in the middeck of the SMS, allows for the changeout of mockup components such as GPC's. The flight deck provides seating for the commander, the pilot, and two mission specialists.



Figure 3. - The forward station of the FBCS flight deck.

As part of the simulation, out-the-window scenes and aural cues are included for both the fixed base and the motion base crew station (refer to the section on visual and aural simulations for a summary of these capabilities).

The FBCS is located in the high bay area of building 5 (see figure 1) on an elevated platform (see figure 4). As with the actual vehicle, entrance to the flight deck is through an opening in the ceiling of the middeck.

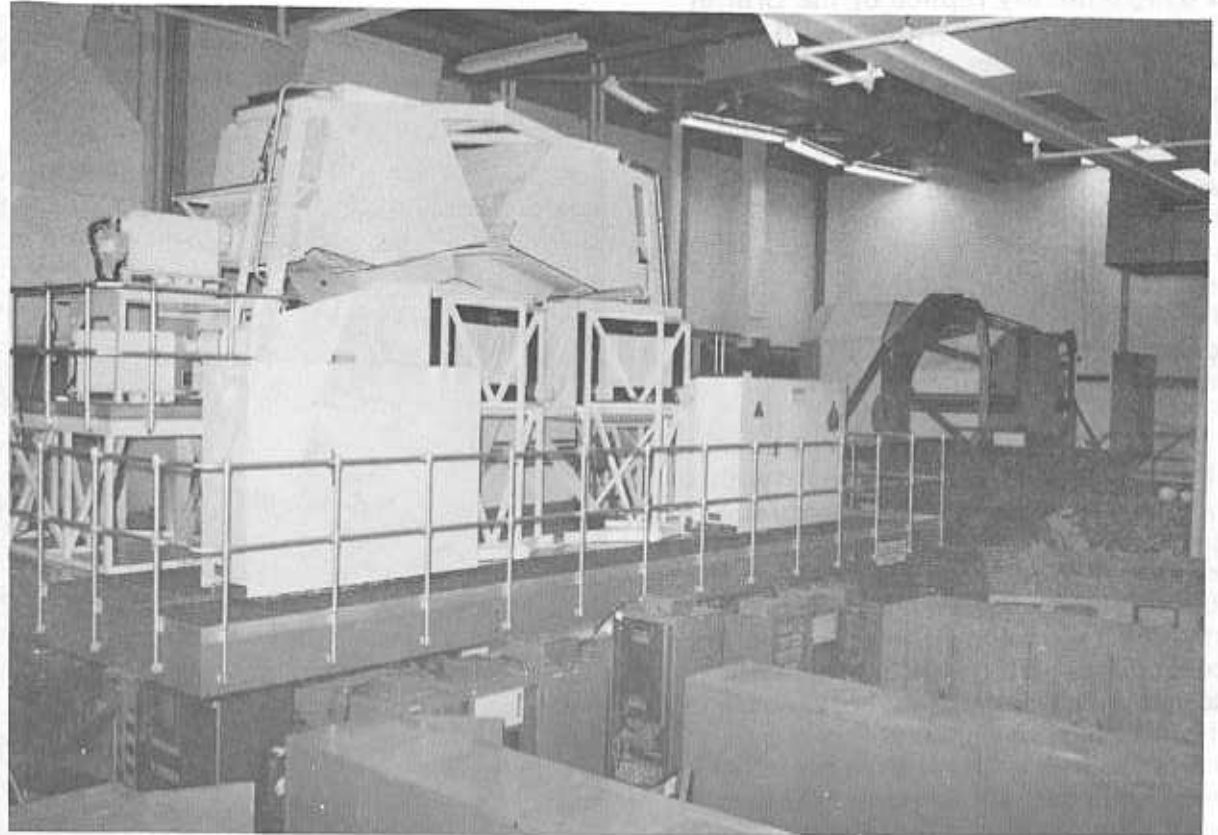


Figure 4.- The fixed base crew station.

Motion Base Crew Station

The motion base crew station (MBCS) is a high-fidelity replica of the Orbiter flight deck forward station, with seating for the commander, pilot, and two mission specialists. In addition, an aft station is connected to the forward cabin via a walkway. This aft station is expected to have a middeck added to it in the future. As with the FBCS, all controls and displays are active, and visual and aural cues are provided. As the name implies, the MBCS provides motion cues essential for an accurate simulation of launch, ascent, deorbit, entry, and landing.

The crew station is mounted on a platform and tiltrate assembly with six independent hydraulic servo-actuators (see figure 5) providing six degrees of freedom. Power is supplied by two 100-horsepower hydraulic pumps operating at 1200 psi. Table 3 shows the motion capabilities of the MBCS. The basic design philosophy of the motion base is that an onset motion cue is given to duplicate the actual flight acceleration associated with a maneuver and that, once the crew is alerted, the motion is washed out subliminally. The onset cue-shaping is obtained using a software-implemented second-order, low-pass filter for each of the six degrees of freedom. The filter inputs are scaled translational and angular accelerations, and the outputs are displacement commands to the platform to translate

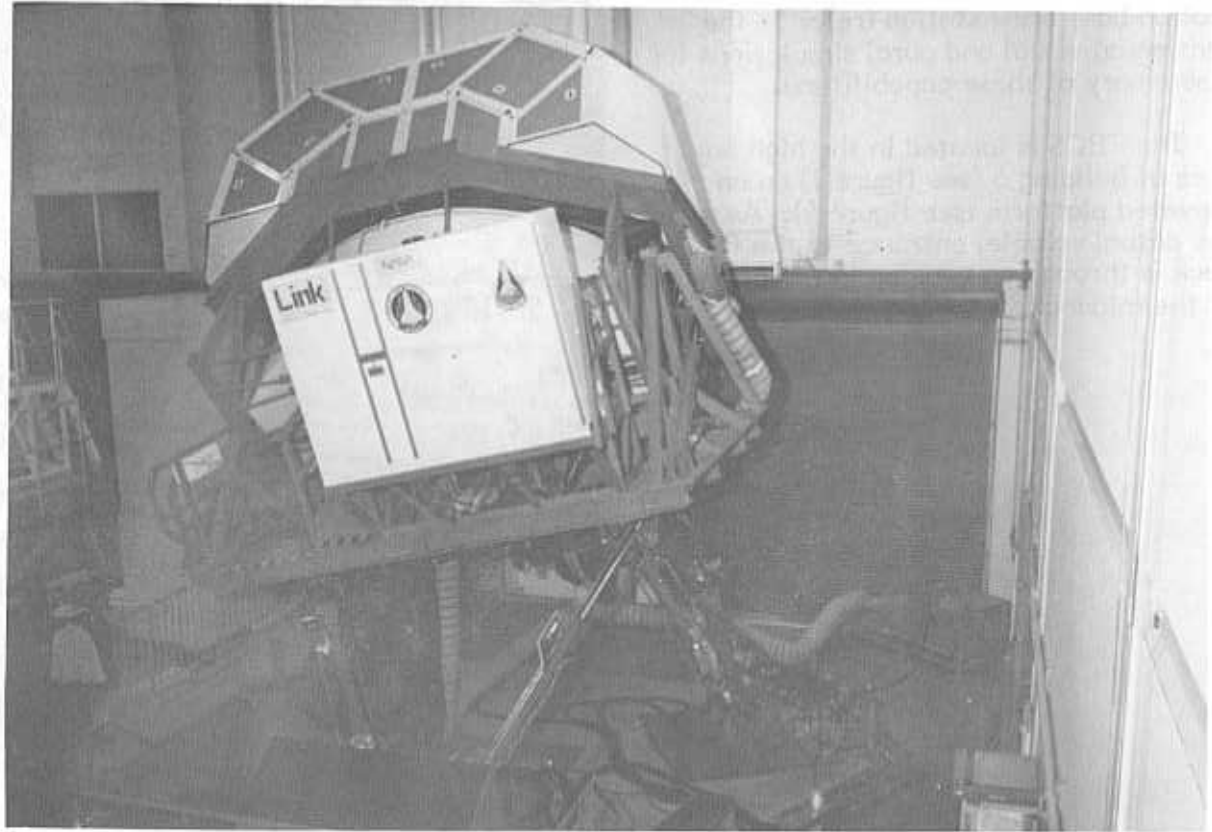


Figure 5.- The motion base crew station.

TABLE 3. - MOTION SYSTEM CAPABILITY

Rotation	Excursion, deg	Velocity, deg/sec	Acceleration, deg/sec ²
Pitch	+28.0 -26.5	15.0	50.0
Extended pitch	+80.0 -0.0	42.1 up 43.0 down	
Roll	\pm 18.5	15.0	50.0
Yaw	\pm 23.0	15.0	50.0
Displacement	Excursion, in.	Velocity, in/sec	Onset accel, g
Longitudinal	\pm 42.0	24.0	\pm 3
Lateral	\pm 42.0	24.0	\pm 3
Vertical	\pm 36.0	24.0	\pm 4

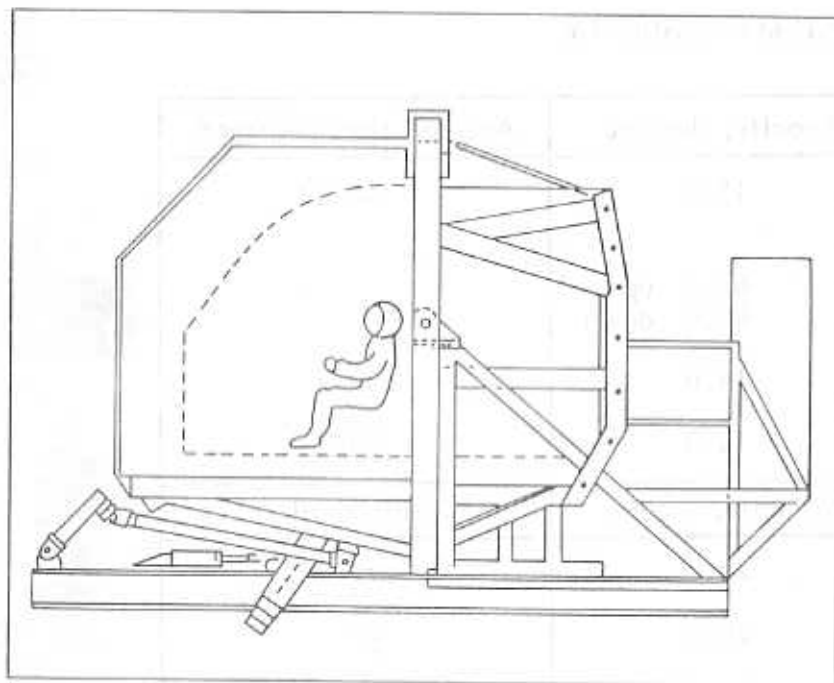


Figure 6.- The MBCS in neutral position.

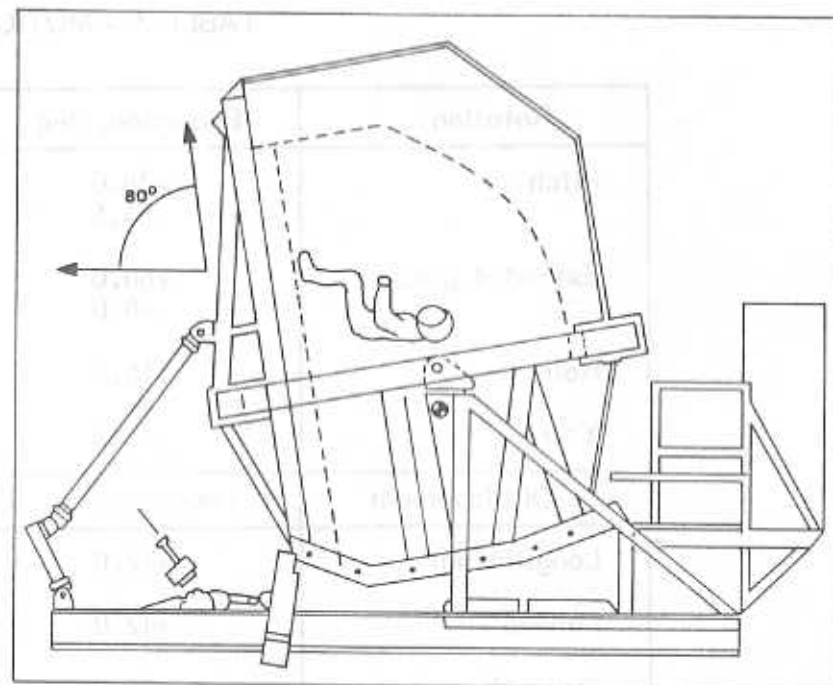


Figure 7.- The MBCS in 80° pitch.

and rotate. When the input is reduced to zero, the platform returns to its neutral position (see figure 6). Thus, platform displacements are proportional to the translational and angular accelerations of the vehicle, and simultaneous vehicle motion in multiple axes can be provided.

During launch and ascent simulations, the motion base is pitched up to its maximum 90 degrees (80 degrees from tiltframe, 10 degrees platform) to redirect the gravity vector toward the backs of the crewmembers in order to simulate the effect of launch g-forces (figure 7 illustrates this position). Sustained translation thrusting in the longitudinal or lateral axis is simulated by a subliminal rotation of pitch or roll to redirect the gravity vector in the appropriate direction. For example, to simulate thrusting for translation in the +Y direction, the crew station is rolled left to give the crewmembers the impression that they are being "pushed" against the left side of the cabin. In addition, accelerations associated with SRB staging, main engine cutoff, OMS and RCS burns, vehicle vibration, and wheel contact and rollout on landing are all provided.

The MBCS is located next to the FBSC in the building's high bay area. The system was designed with a safety factor of 4 and with numerous devices for the prevention of "runaway" conditions, including automatic shutoff. When the

system is in the neutral position, ingress and egress is through a conventional door at the rear of the crew station. An emergency hatch located above the aft part of the crew station permits exit when the MBCS is in a tilted position with the rear door blocked by the platform. The total weight of the moving machinery is over 21 tons.

Visual and Aural Simulations

Visual Capabilities

To enhance the high fidelity of the SMS, out-the-window scenes are provided by the digital image-generation system (DIG). To reduce downtime and costs associated with the preparation and changeout of visual models, the DIG was selected for the SMS over the more conventional rangebed, camera, and model system.

The DIG generates, processes, and displays scenes for all windows of the FBSC and the MBCS; no DIG scenes are generated for the spacelab simulator. It provides scenes for every phase of the mission, from prelaunch pad views to rollout on the runway. The views in the six forward windows of the two crew stations are in color, while those in the overhead and two aft windows of the FBSC are monochromatic (green hue). The simulated scenes (polar and equatorial missions) include the following major aspects:

- Earth scenes from an altitude of 20 feet to 1100 n. mi. These scenes include clouds and major land masses, a moving terminator, and simulation of the flight into and out of the Earth's shadow. (See figure 8 and 9 for DIG scenes.)

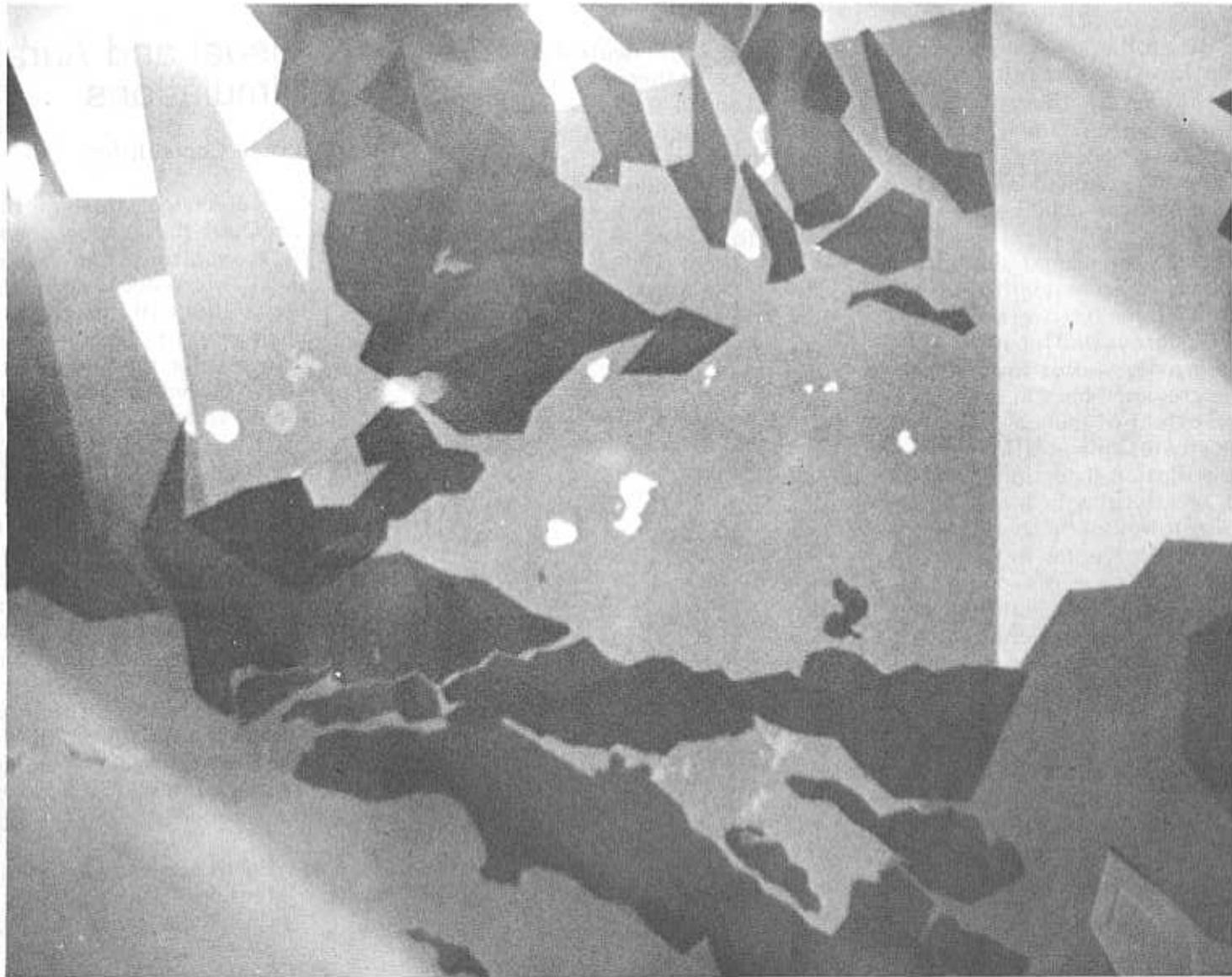


Figure 8. - A DIG scene of the Los Angeles area at bottom center.

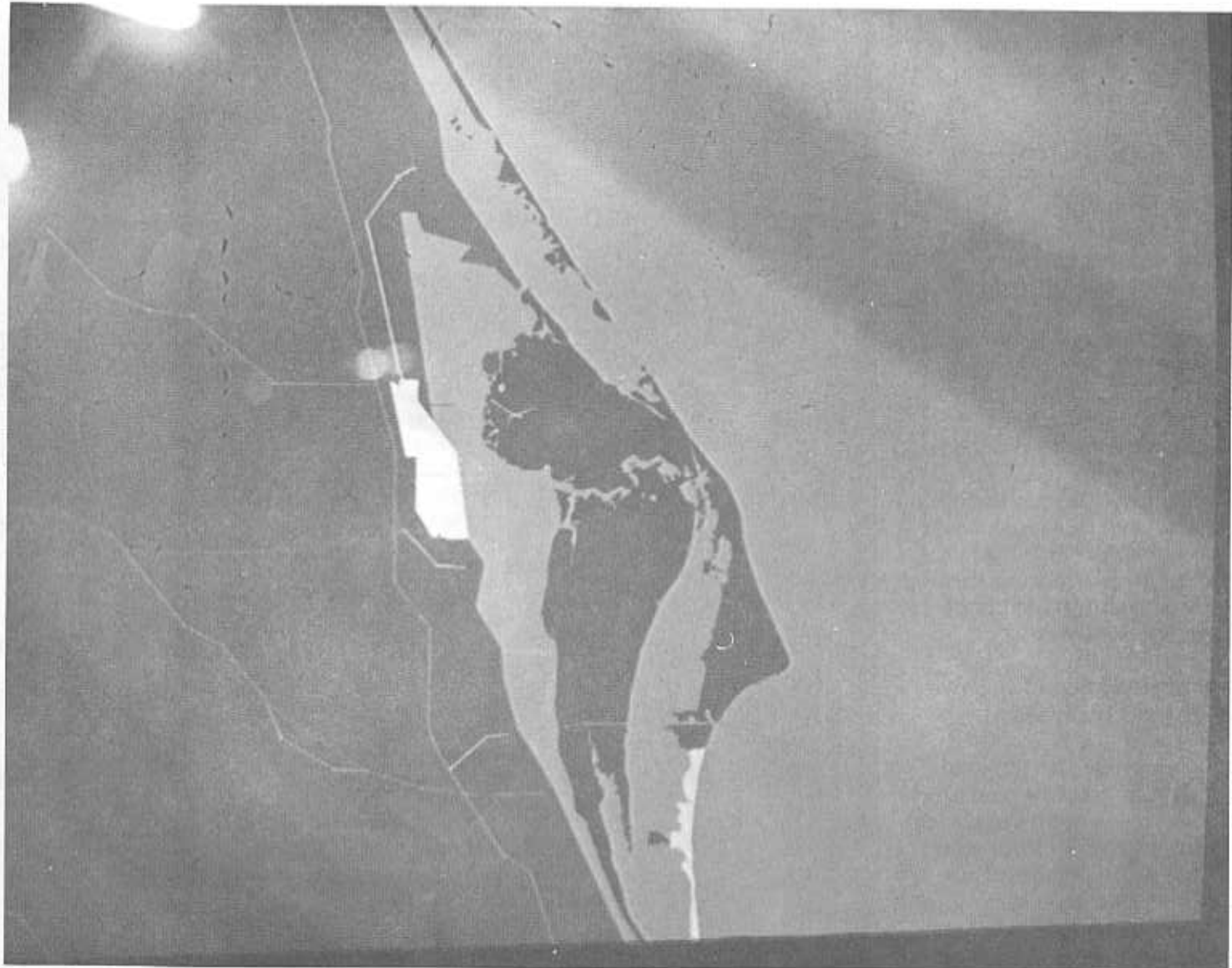


Figure 9 - A DIG scene of Cape Canaveral, Florida.

- Star field scenes (in forward and overhead windows only) containing 1000 stars, the Sun, and the Moon

Stars with magnitudes of +2 or brighter are positioned to a relative accuracy of ± 6 arc minutes, while other stars are positioned to an accuracy of ± 15 arc minutes. All major constellations are readily recognizable without apparent distortions.

- Rendezvous and docking scenes through the aft and overhead windows and on closed circuit TV (CCTV)

The visual simulator can handle a maximum of two moving targets at any given time. In targets are independent, free-floating targets that are selectable from about 15 choices in the software.

- Scenes of the payload bay in the two aft windows of the FBCS (see figure 10)

The scenes include the payload bay doors (which can be operated from the crew station), operation of two remote manipulator arms (RMA's) from the crew station (wrist, elbow, and shoulder movements), RMA jettison when applicable, payloads (fixed and moving), and parts of the Orbiter (wings, vertical stabilizer, aft pods). The scenes will take into account the different lighting conditions caused by the floodlights, the Sun, and the Earth's shadow.

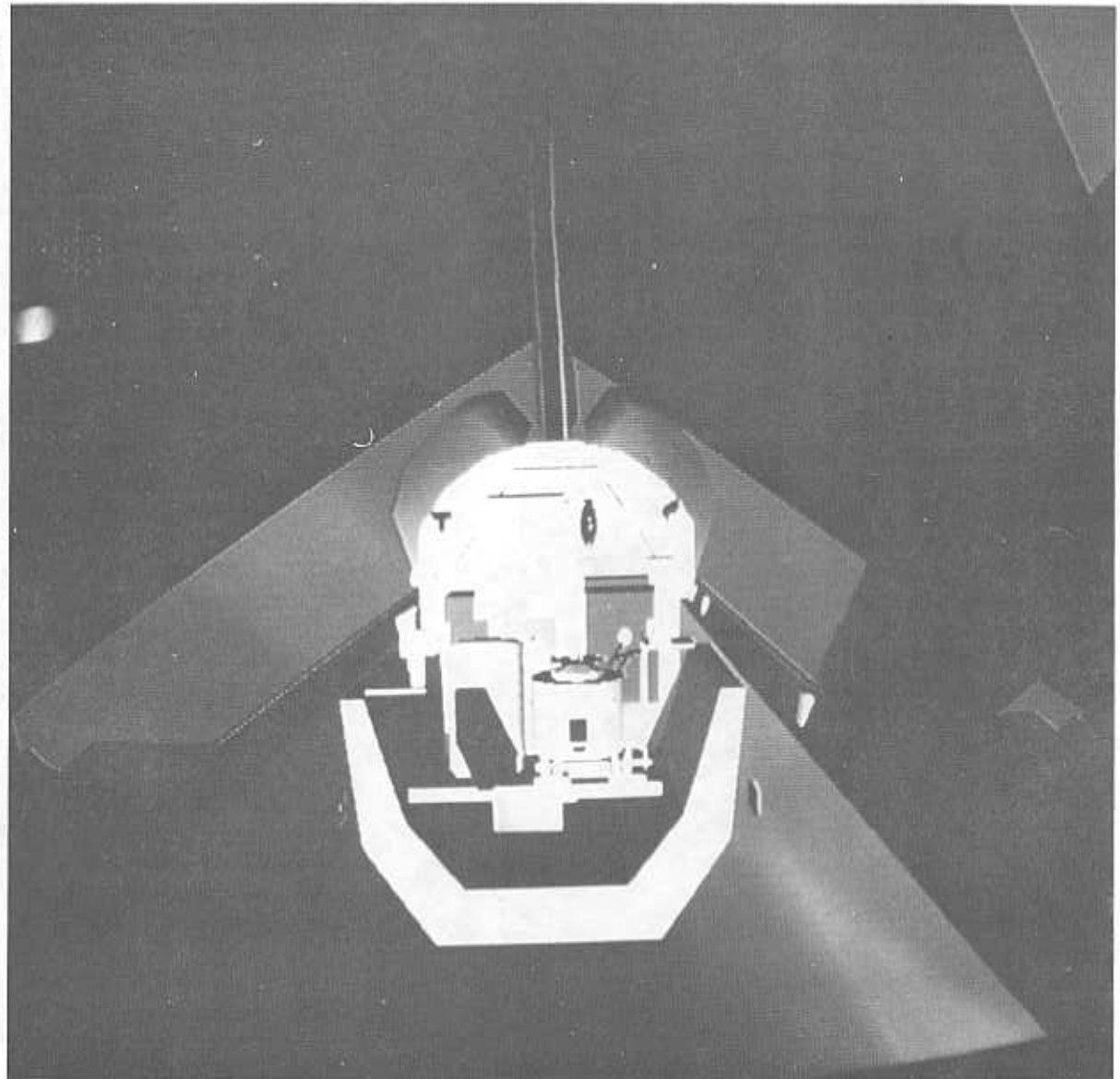


Figure 10.- A DIG scene of the payload bay.

- Views of payloads in the aft and overhead windows of the FBCS
Relative motion between the Orbiter and a payload (e.g., deployment of the payload assist module (PAM) can also be simulated.
- During lift-off, views of the launch service tower and KSC facilities in the forward windows of both crew stations
The external tank and SRB's also appear in those windows through staging.
- For approach, landing, and rollout, scenes of the runway, runway markings, buildings, and the surrounding terrain for the particular landing site (this includes low visibility conditions)
The landing sites available are KSC, Northrup Strip, Dakar, Edwards AFB, Rota Naval Station, Hawaii, and Kadena AFB. See figures 11-14 for digital image generated scenes of landing sites. Figures 15 and 16 illustrate actual runway approaches.

In addition to out-the-window scenes, the DIG also simulates black and white closed-circuit TV pictures taken from cameras in the cargo bay and on the (RMA's). Camera functions associated with picture quality, such as black and white stretch, and lens functions, such as focus and iris, are not simulated.

Designed and built by the Hughes Aircraft Company, the DIG uses a unique crystal light projection system to provide the high light output, sharp resolution, and wide field of view needed for an accurate visual simulation. All window scenes in both crew stations appear three-dimensional. The fields of view through the windows are as follows:

Six forward: 205° horizontally
 40° vertically

Two Overhead: 109° fore to aft
 30° inboard
 41° outboard

Two Aft: 70° vertically
(36° down;
 34° up)
 66° horizontal
(26° inboard;
 40° outboard)

The visual systems of the two crew stations can operate independently and are controlled from the operator stations. The attitudinal positions of the window scenes reflect the crew commands to move the vehicle.

Aural Capabilities

Aural cues are provided in both crew stations using strategically located and hidden loudspeakers. The sounds are

computer generated using the Link Poly-Voice Sound Synthesizer; the generated sounds are controlled at the operator stations. The volume, frequency spectrum, and direction of the generated sounds are perceptibly the same as those in the actual vehicle. The simulated aural cues include the sounds of onboard pumps, blowers, mechanical valves, aerodynamic vibrations, thruster firings, pyrotechnic explosions, gear deployment, and ground contact. Refer to the section on integrated simulations for a description of the voice communication simulation.

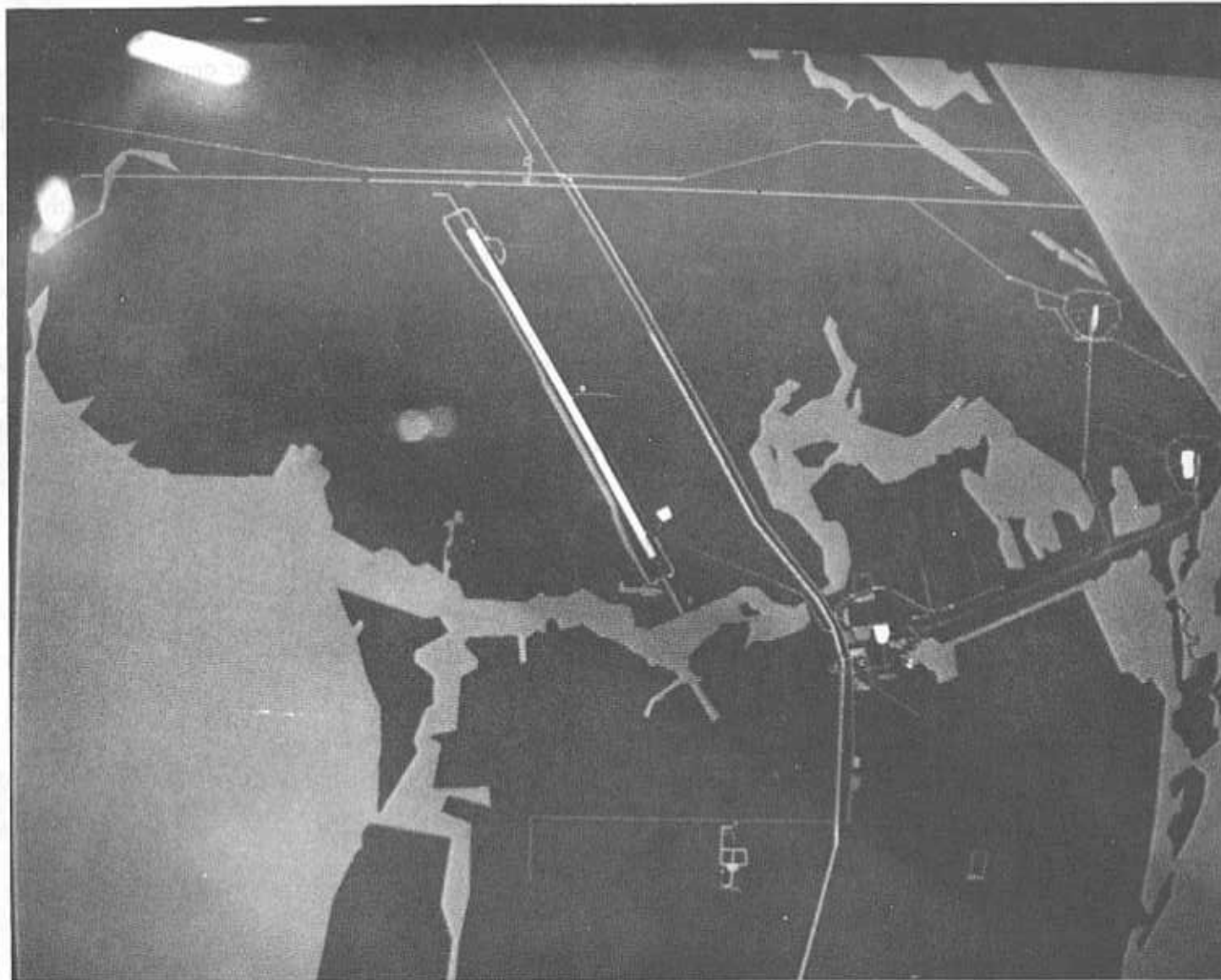


Figure 11.- A DIG overhead view of the KSC landing site.

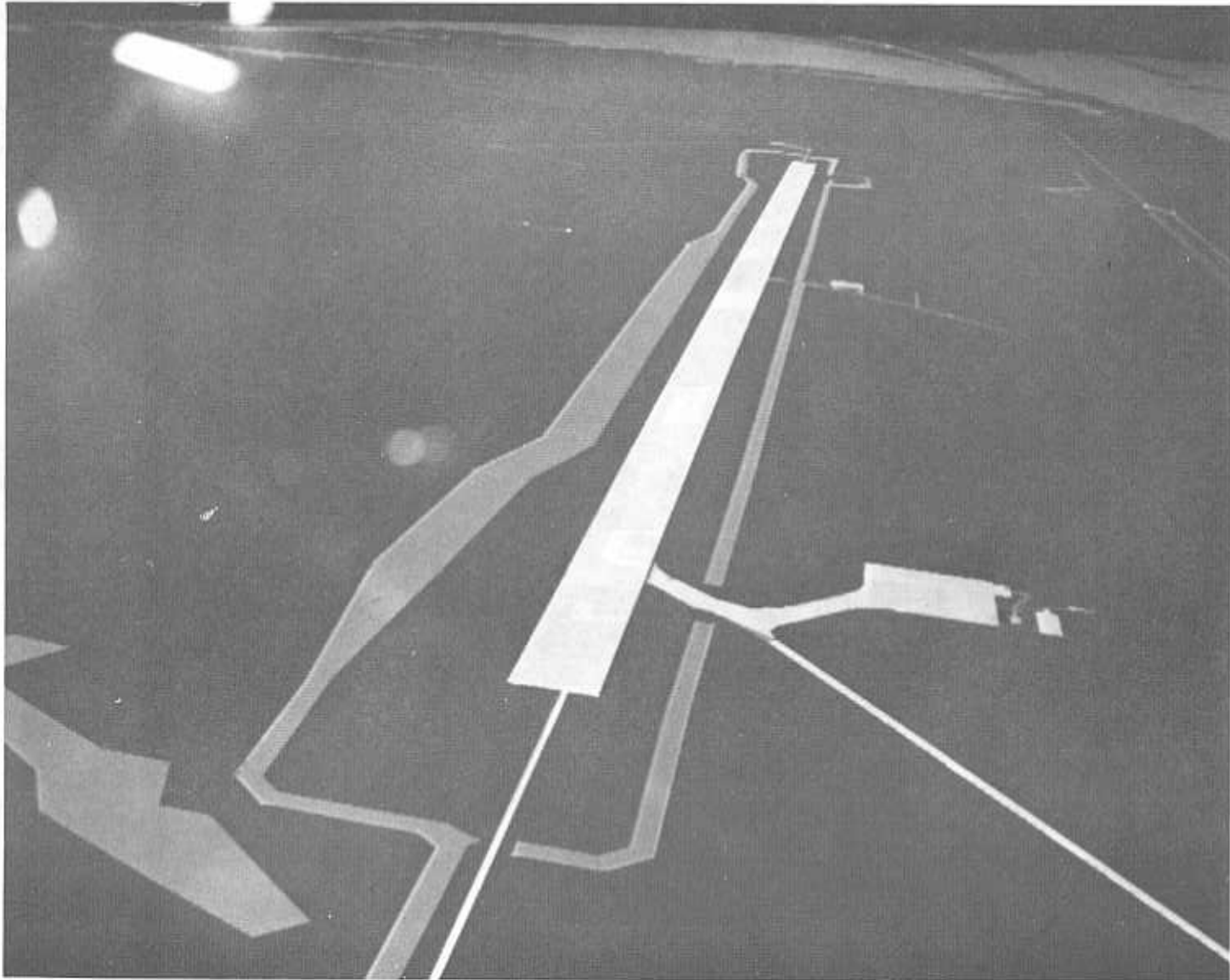


Figure 12.- A DIG scene of the final landing approach at KSC.

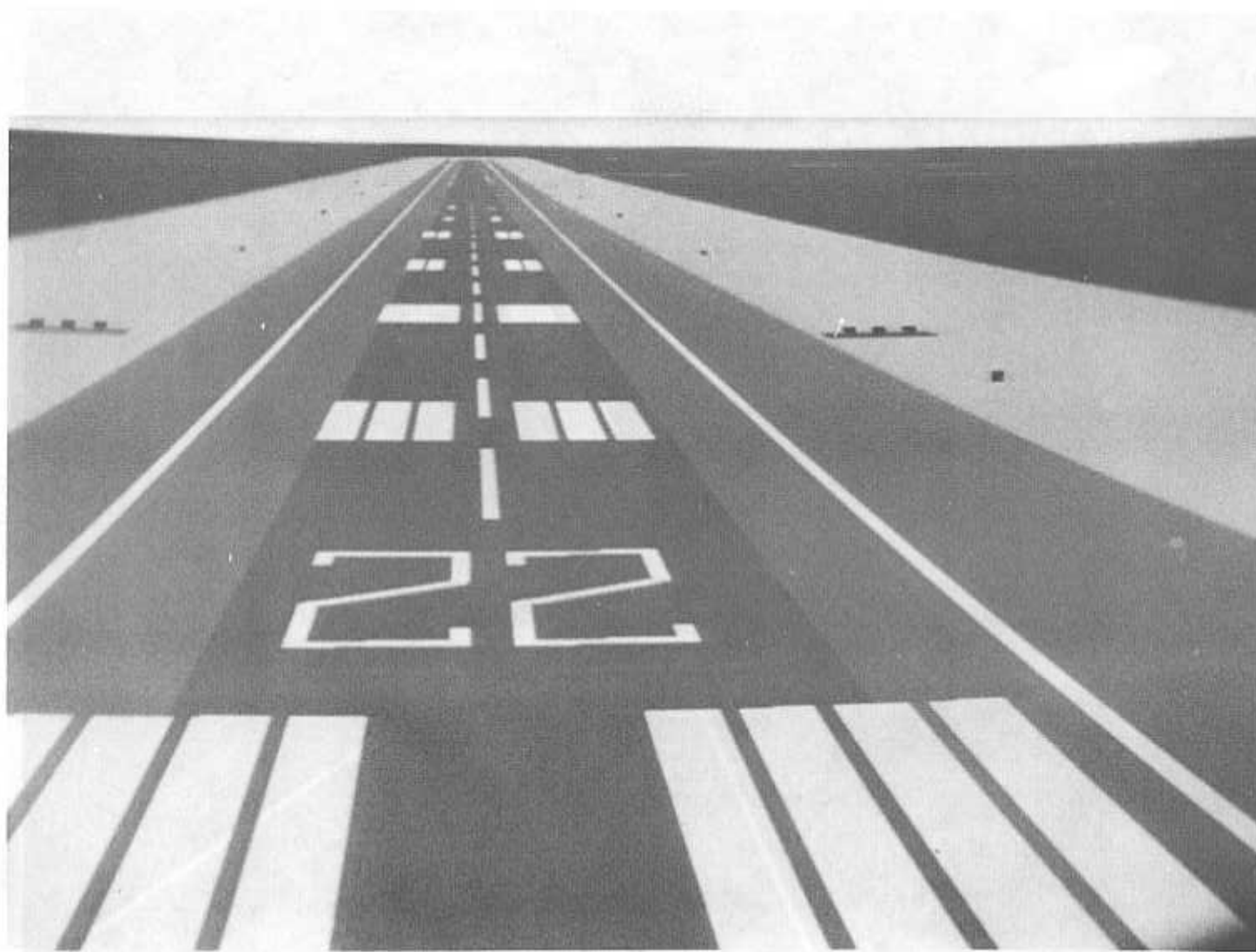


Figure 13.- A DIG scene of the final approach to runway 22 at Edwards AFB.

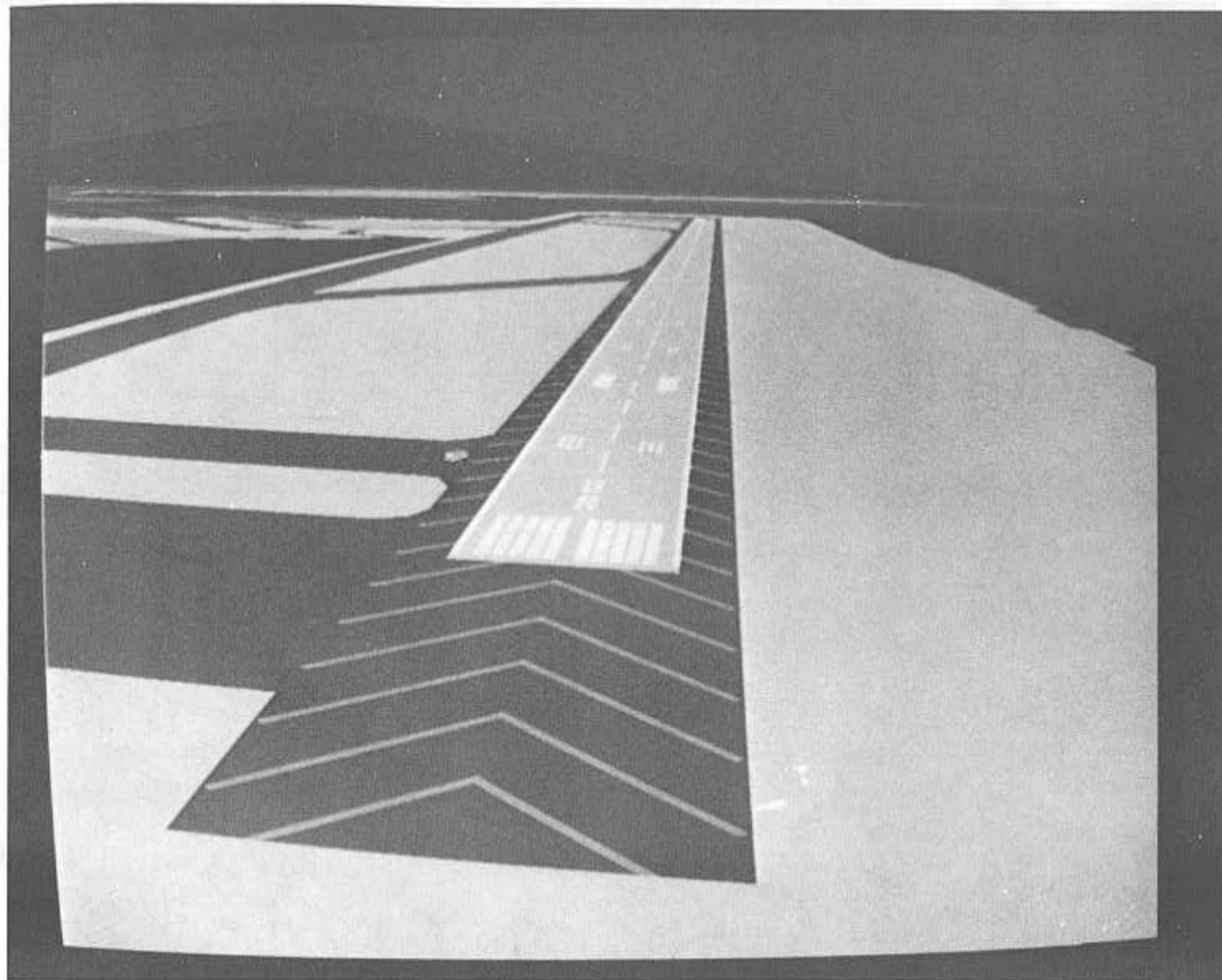


Figure 14.- The Hawaii landing site DIG scene.

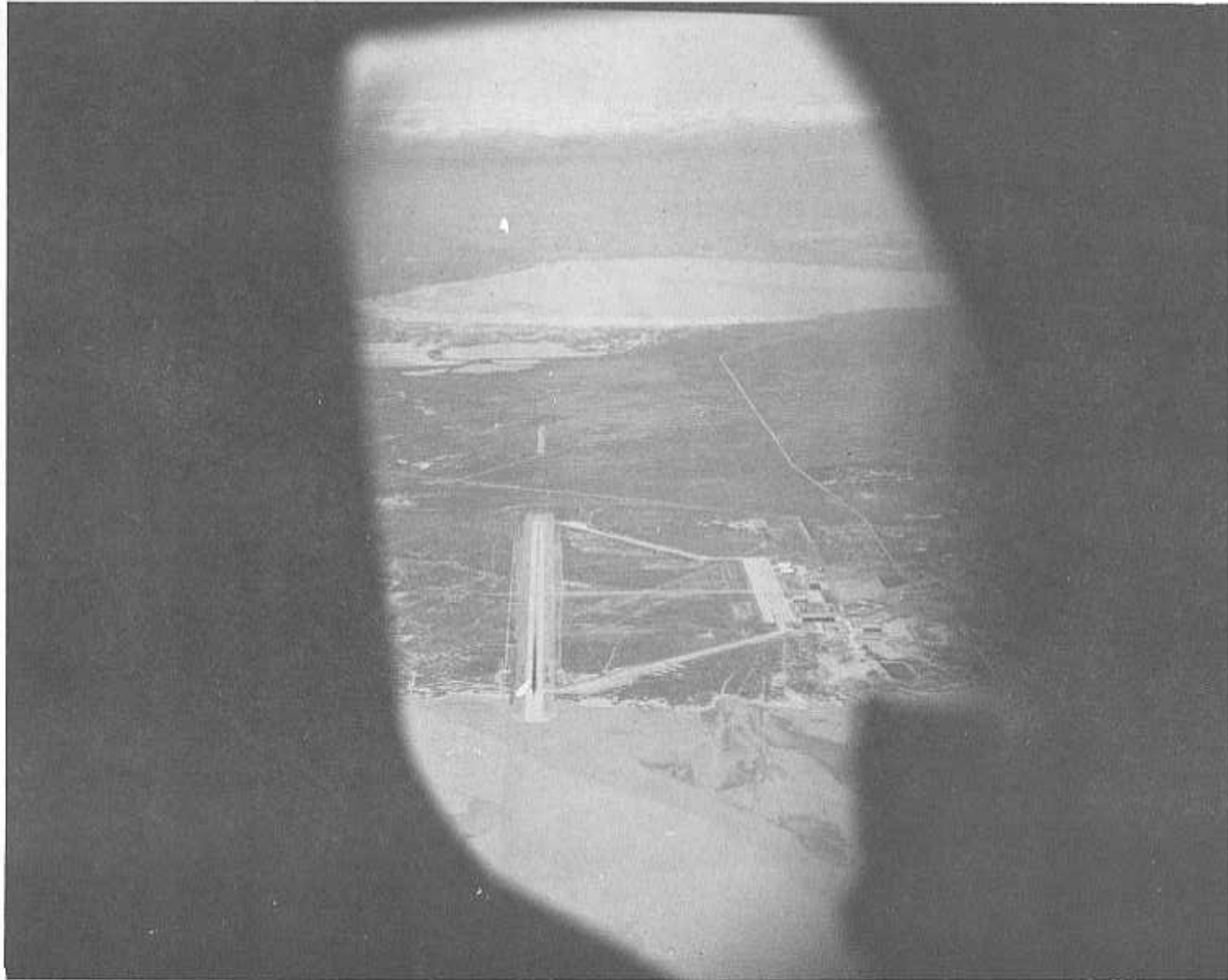


Figure 15.- The final approach to Edwards AFB as seen from STS-6.



Figure 16.- The KSC runway with the vehicle assembly building (VAB) in the background.

Computer Complex

The SMS digital computer facility occupies most of the floor space of the high bay area in building 5. (See the layout in figure 1.) It has the capability to serve the FBCS and MBCS simultaneously. The complex consists of the following interconnected computers:

Fixed base simulator	<u>18</u>
Host computer (UNIVAC 1100/44)	1
General purpose computers (IBM AP101)	5
Intelligent controllers (PE 8/32 and PE 3252)	12
Simulation interface device	
Visual system	
Crew/instructor/operator station	
Input/output	
Forward digital image generator	
Network simulation system	
Spacelab Simulator	
Payload	
Aft digital image generator	
Aft occlusion processor	
CCTV digital image generator	
CCTV occlusion processor	
Motion base simulator	<u>14</u>
Host computer (UNIVAC 1100/44)	1
General purpose computers (IBM AP101)	5
Intelligent controllers (PE 8/32 and PE 3252)	8
Simulation interface device	
Visual systems	
Crew/instructor/operator station	
Input/output	
Forward digital image generator	
Network simulation system	
Spacelab Simulator	
Payload	

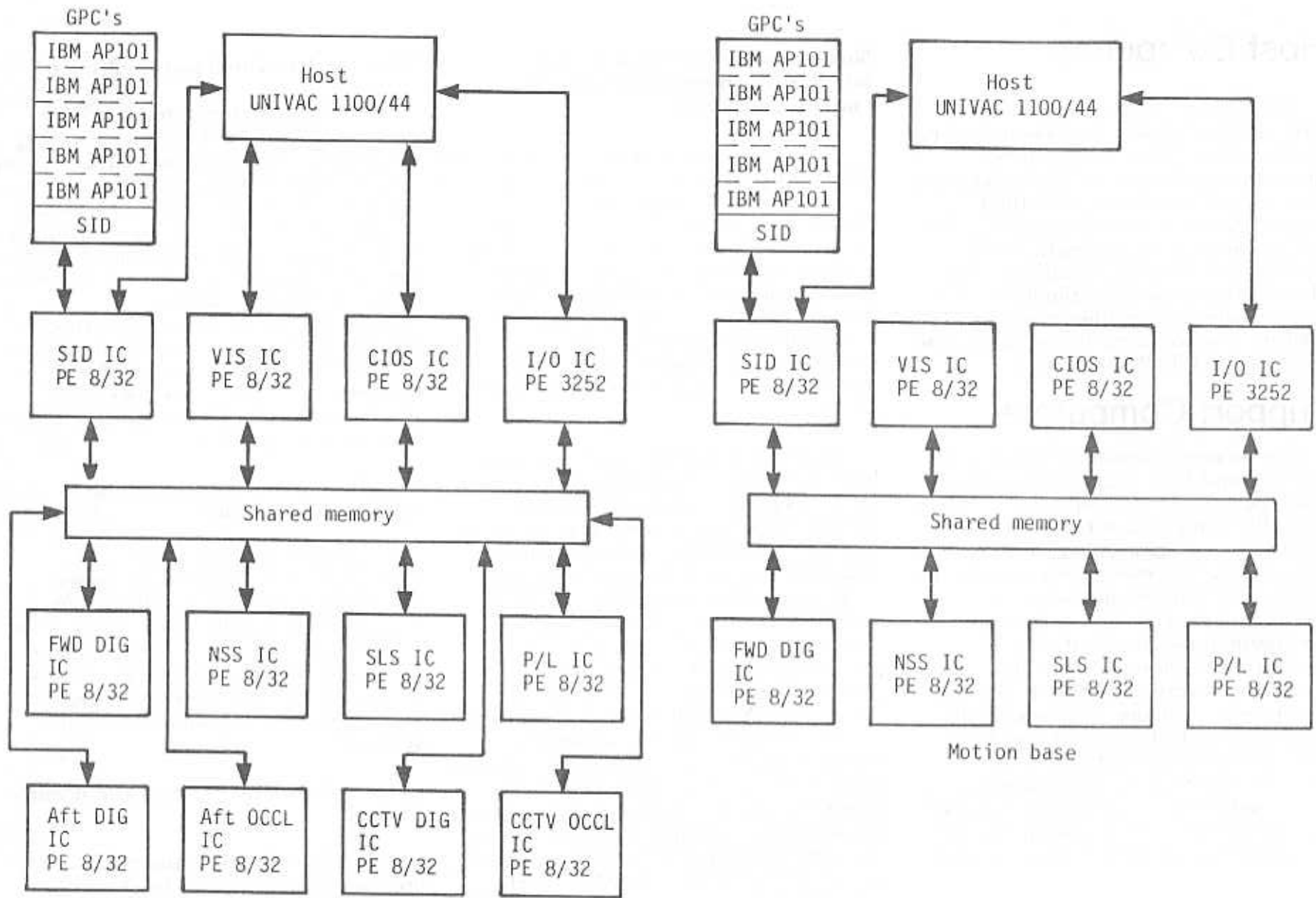


Figure 17.- The SMS computer network.

Host Computers

The host computers are two large-scale UNIVAC 1100/44 computers, which contain the majority of the simulation math models. Each computer is in a 4 by 2 configuration, with 4 computational arithmetic units (CAU's) and 2 input/output arithmetic units (IOAU). The UNIVAC 1100/44 is capable of executing an average simulation mix at approximately two million operations per second. One computer is assigned to each crew station (FBCS and MbCS).

Support Computers

The support computers consist of 20 8/32 Perkin-Elmer (PE) minicomputers, which gather and transfer data as well as house the math models for tracking, telemetry, and communication simulations. The execution capability of the PE 8/32 is approximately 350K operations per second. However, the input/output and computational capabilities of these units are not identical and vary according to the task performed. As figure 17 shows, all 20 intelligent controllers (IC's) interface with each other and with the host computers by transferring commands for flight control and other functions, sensor signals, Shuttle position and status, and other quantities required for simulation.

Simulation Interface Device and Intelligent Controller and General Purpose Computers

The simulation interface device houses the flight GPC's for the two crew stations and data-handling equipment that interfaces with the simulation interface device intelligent controller. The SID IC contains the reset points, data storage, and the applications software for the launch processing system. The SID models the performance of various peripheral devices onboard the Orbiter, such as the multiplexer/demultiplexers (MDM's).

Real GPC's must be physically present because they are too fast to be simulated by the UNIVAC. The GPC's are IBM API01 computers, which carry out all of the required data processing functions onboard the vehicle (e.g., flight control, malfunction detection, RM). The IBM API01 is a high-performance flight computer capable of processing approximately 350K operations per second. The difference between the Shuttle GPC's and the SMS GPC's is that the Shuttle GPC's have a nonvolatile memory and an iron ferrite core while the SMS GPC's have a volatile memory and a monolithic core. The SMS GPC's require continual power to avoid loss of memory. They are connected to the SID IC, which is then hooked to the UNIVAC, which simulates the MDM's. The Shuttle GPC's are connect directly to the MDM's.

Visual System Intelligent Controller

The visual system intelligent controllers consist of the forward DIG, CCTV DIG, CCTV occlusion processor, aft DIG, and aft occlusion processor. In this data base the "world" is represented by approximately 50 000 surfaces, with the Earth being represented by about 1600 triangular surfaces and the Sun and Moon by about 30 surfaces each. Transformation variables originating in the UNIVAC are processed by the visual PE 8/32's to generate scenes in the windows. Each computer generates images containing 920 raster lines with 8000 elements per line.

Crew/Instructor/Operator Station Intelligent Controller

As the name implies, the crew/instructor/operator station intelligent controller interfaces with three different stations and contains the software for the master controller and the Aydin and graphics CRT's (see the section on the instructor and operator stations for an explanation of these systems).

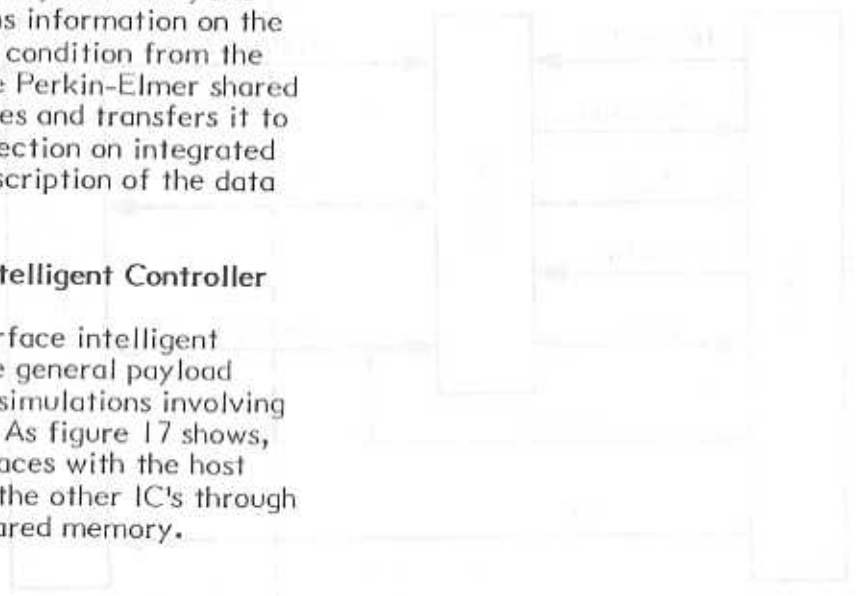
Network Simulation System Intelligent Controller

The Network Simulation System IC's are used to simulate the tracking and telemetry network during integrated simulations with the Mission Control

Center and during joint integrated simulations with remote sites. The computers contain mathematical models for ground track, voice, command, and telemetry. It obtains information on the Shuttle location and condition from the UNIVAC through the Perkin-Elmer shared memory and processes and transfers it to the MCC. See the section on integrated simulations for a description of the data flow.

Payload Interface Intelligent Controller

The payload interface intelligent controller houses the general payload models used for the simulations involving payload operations. As figure 17 shows, this computer interfaces with the host computers and with the other IC's through the Perkin-Elmer shared memory.



Integrated Simulations

The integrated simulation system is a complex of computers and software that simulate the Shuttle mission. It includes models for the Shuttle, the ground track, voice, command, and telemetry. The system is designed to provide a realistic simulation of the Shuttle mission, allowing for the testing of various mission scenarios and the optimization of Shuttle operations. The simulation is run on a central computer, with data being shared with other computers in the system. This allows for the simulation of the Shuttle mission in a realistic environment, providing valuable information for the Shuttle program.

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Integrated Simulations

The concept of integrating crew and flight control team simulations was first established during Project Mercury and has evolved through all manned flight programs since then. Currently, the integrated simulations involve the SMS and the MCC and joint integrated simulations involve the SMS, the MCC, and the Payload Operations Control Centers (POCC's).

These simulations are the "dress rehearsals" of the actual flight, characterized by a high-fidelity simulated mission environment which provides training in the interaction between the crew and MCC personnel, responses to stressful situations, flight replanning, validation of flight procedures and plans, ground uplinks, and evaluations of system performance.

Network Simulation System

The Network Simulation System (NSS) provides the voice and data link between the MCC, the POCC's, and the SMS during integrated and joint integrated simulations. The computers and two NSS operator stations are located in building 5 along with the rest of the SMS facility (see figure 1). The voice and data link between the two simulators, their respective instructor stations, and the MCC are all hardwired. It is only through the NSS that the simulators can be tied to

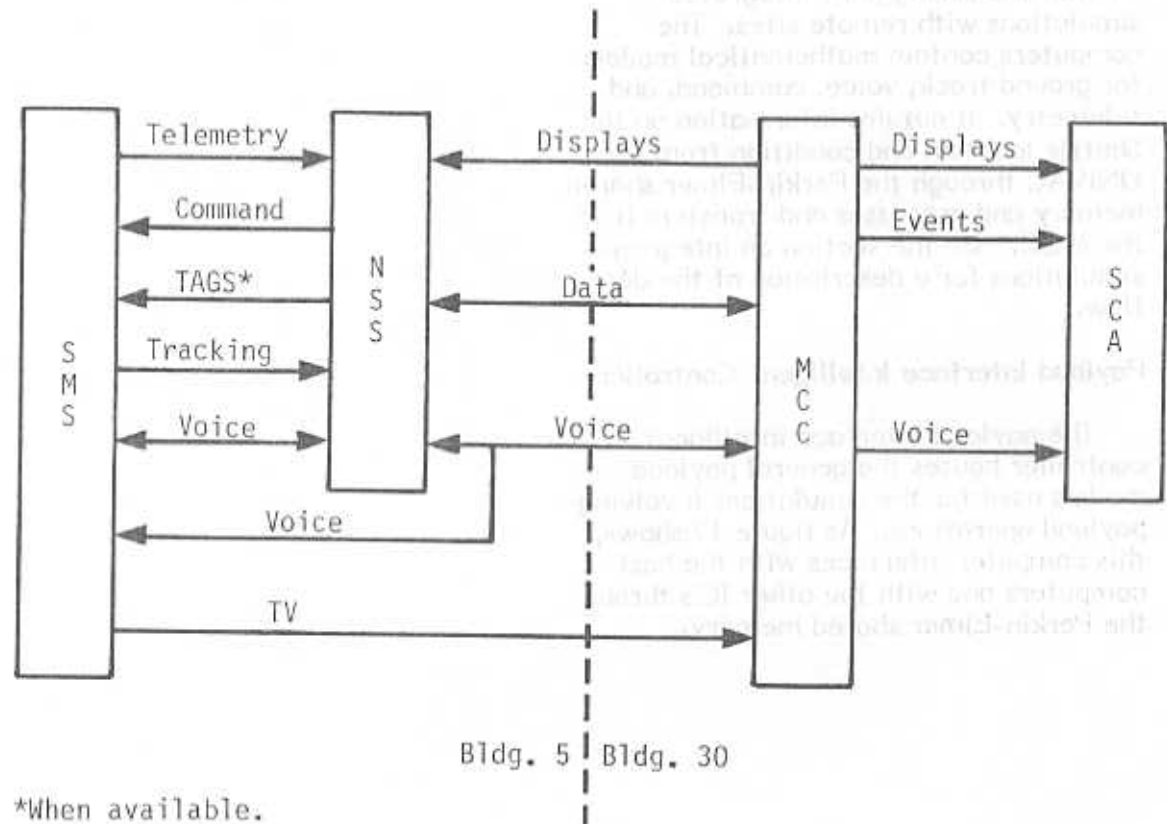


Figure 18.- Communications and data flow.

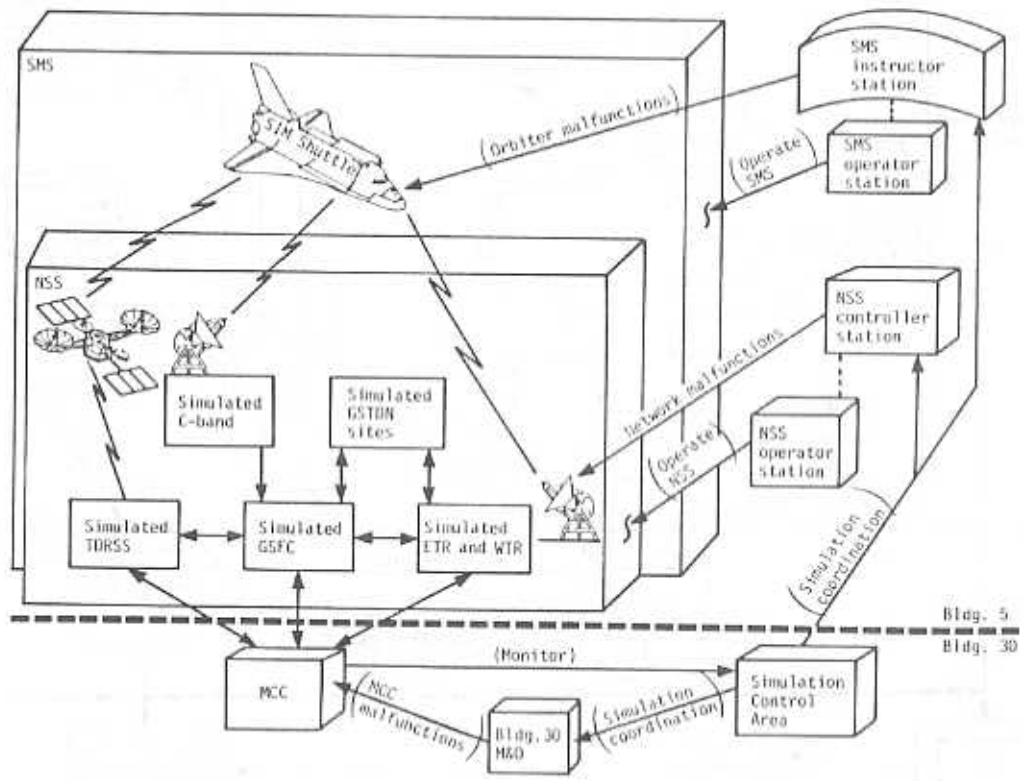


Figure 19.- The integrated simulation network.

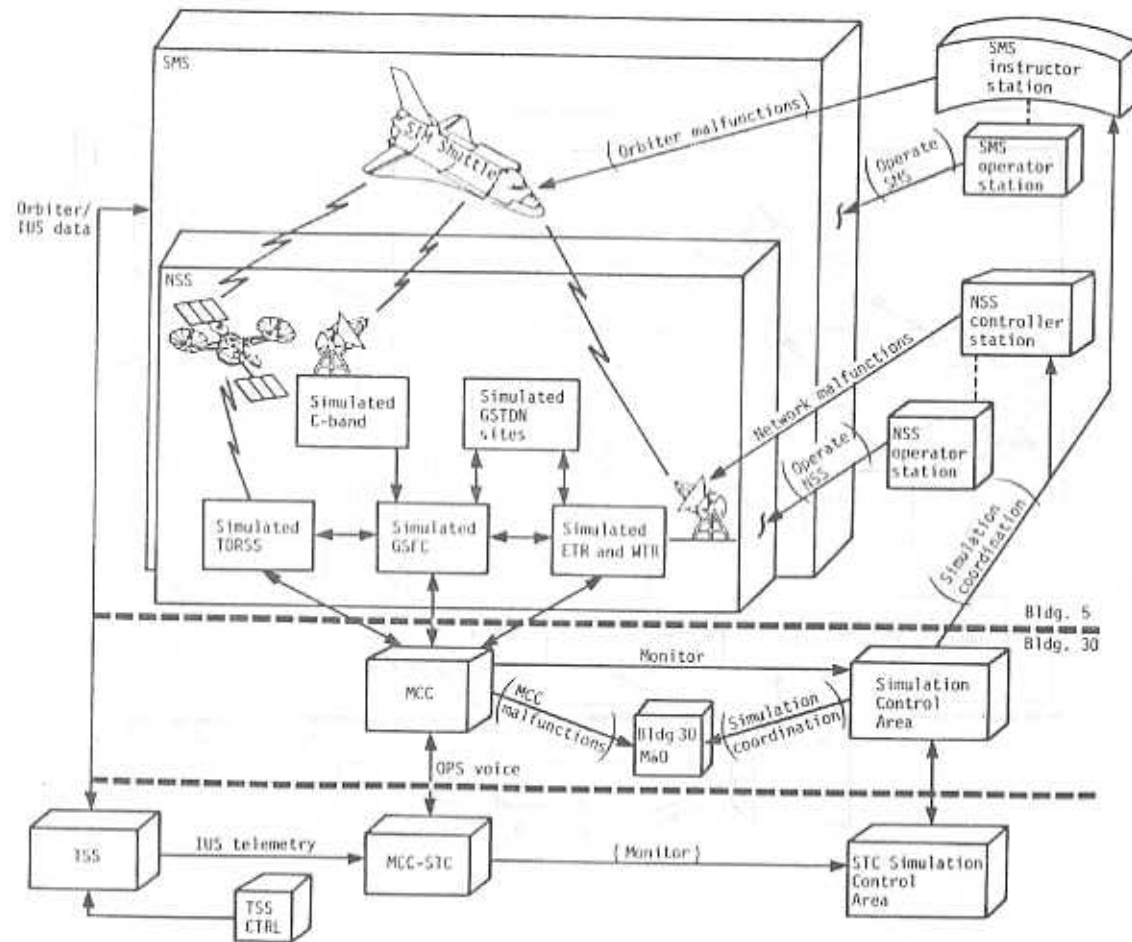


Figure 20.- The joint integrated simulation network.

the MCC, the POCC's, and any other remote sites. The NSS simulates both the Ground Spacecraft Tracking and Data Network (GSTDN) and the Tracking and Data Relay Satellite System (TDRSS).

See figures 18, 19, and 20 for diagrams of the communications flow, the integrated simulation configuration, and the joint integrated simulation configuration, respectively.

Simulation Control Area

The Simulation Control Area (SCA), located in a room adjacent to the Mission Operations Control Room (MOCR) in building 30, monitors, controls, and coordinates the integrated simulations. During those simulations, the SCA is manned by an eight-member instructor team which directly monitors the performance of the flight control team (see figure 21 for the SCA positions). In addition, the SCA personnel are responsible for planning the individual simulation sessions, preparing the simulation scripts which contain the malfunctions to be entered for each run, and debriefing the flight controllers and the crew after each run. There are four teams of SCA instructors, each headed by a simulation supervisor who directs the simulation sessions.

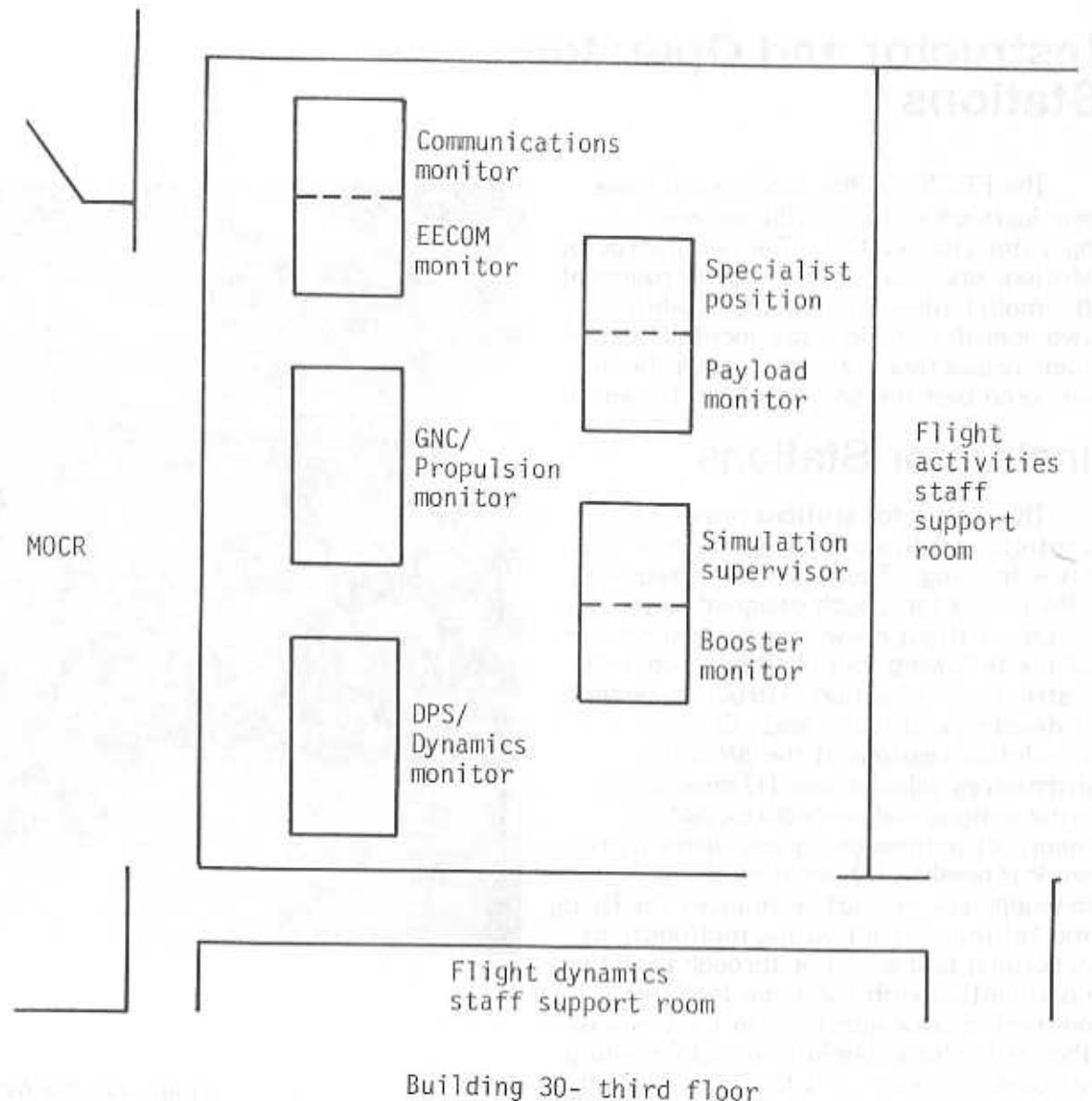


Figure 21. - Layout of the Simulation Control area.

Instructor and Operator Stations

The FBCS and the MBCS each have one instructor station (IS) and one operator station (OS). The two instructor stations are located in separate rooms off the main hallway in building 5, while the two operator stations are located next to their respective crew stations in the high bay area (see the SMS layout in figure 1).

Instructor Stations

The instructor stations provide the controls and displays necessary to effect crew training. There are seven teams of SMS instructors, each assigned to train a different flight crew. Each team consists of the following four positions: control instructor, navigation instructor, systems instructor, and team lead. During simulation sessions at the SMS, the instructors' jobs include (1) monitoring crew actions and procedures, noting incorrect actions and areas where more work is needed, (2) assisting in the development of pilot techniques for flying the Orbiter, (3) activating malfunctions according to a script or through real-time coordination with the team lead, (4) answering crew questions in the areas of the instructor's specialty and, (5) making simulated ground calls to the crew during nonintegrated simulations.

The instructor stations provide the capability to display, monitor, and control system status, switch positions, and flight



Figure 22.- The fixed base instructor station.

environment (e.g., wind speed and direction, barometric pressure, air temperatures). Figure 22 is a picture of the FBCS IS. The stations each have nine Aydin alphanumeric CRT's, five graphics CRT's, four display CRT's which monitor the four GPC CRT's in the crew station, a keyboard which can be activated from the operator station in order to control the four onboard CRT's, six communication control boards to control the various voice loops, three black and white TV monitors for viewing selected scenes in the forward, aft, and overhead windows (only forward visual for MBCS), a hardcopy machine for the Aydin and one for the graphics CRT's, and a CRT that monitors mission event times. Both simulator stations have three 8-channel, x-versus-time recorders and two x-y-y' recorders for recording and plotting data.

Displays can be called up on Aydin and graphics CRT's from any one of the keyboards, but only one assigned Aydin can be controlled interactively by each keyboard. The interactive Aydin is used for malfunction insertion, switch reconfiguration, and system status and flight environment changes. The SMS has a capability of approximately 6800 malfunctions, discrete and variable, which can be activated manually or automatically.

Operator Stations

The operator stations provide the controls and displays necessary to prepare the simulators for the training sessions and operate the facility during the training sessions. The operator stations for the two crew stations have identical controls and displays except that the MBCS OS also has controls and status indicators dedicated to the motion system.

In addition to controlling the operation of the SMS itself, the operator has the responsibility of preparing the simulators for each run. This includes entering "look and enters" which initialize quantities such as consumables and pressures, setting up the visual system, providing the proper displays for the graphics CRT's, and setting the system to the chosen reset point. The SMS has a standard set of reset points that correspond to different phases of a flight. Thus, training for discrete phases of a flight can be accomplished simply by resetting the simulator to the appropriate reset point. If any of the quantities that are defined by the reset point are not appropriate for the run, the operator can type in the correct data using the interactive CRT. The time required for a complete reset is about 2 minutes.

There are four other control modes to the SMS in addition to the reset mode. (1) The "run mode" simply means that the SMS is in "run" status. (2) The "data

store" mode allows the SMS to record data at a chosen point. (3) In the "freeze mode," the SMS is temporarily down and will not respond to crew or instructor inputs. The "freeze" status can be activated at both the OS and the IS and usually precedes and follows the reset mode. (4) The "step-ahead mode" allows the SMS to step ahead or back to a specific point in time. It is usually followed by the "freeze" mode before running. The simulation control modes are usually activated by the operator upon request by the team lead.

Conclusion

The Shuttle Mission Simulator represents a major advancement in mission simulators in terms of fidelity and completeness. It uses flight cockpit hardware, computers, and software which enable the SMS to simulate as closely as possible the actual vehicle. The ability of the simulator to perform integrated and joint integrated simulations with the MCC and POCC's allows for the simultaneous training of flight controllers and crews in a simulated flight environment. The SMS will be a major training device for the manned space program for the next two decades.

Acronyms

AFB	Air Force base	JSC	Lyndon B. Johnson Space Center	SAIL	Shuttle Avionics Integration Laboratory
CAU	computational arithmetic unit	KSC	John F. Kennedy Space Center	SCA	Simulation Control Area
CCTV	close-circuit television			SID	simulation interface device
CIOS	crew/instructor/operator station	MBCS	motion base crew station	SLS	Spacelab Simulator
CRT	cathode ray tube	MCC	Mission Control Center	SM/S	Shuttle Mission Simulator
DIG	digital image generator	MDM	multiplexer/demultiplexer	SRB	solid rocket booster
DPS	data processing system	MO	maintenance and operations	STC	Satellite Test Center
		MOCR	Mission Operations Control Room	STS	Space Transportation System
EECOM	Electrical, Environmental, Consumables, and Mechanical Systems	NSS	Network Simulation System	TAGS	text and graphics system
ETR	Eastern Test Range	OCCL	occlusion	TDRSS	Tracking and Data Relay Satellite System
EVA	extravehicular activity	OS	orbital maneuvering system	TSS	Telemetry Simulation System
FBCS	fixed base crew station	PAM	payload assist module	VIS	visual system
FDI	Flight Data File	P/L	payload	WTR	Western Test Range
FWD	forward	POCC	Payload Operations Control Center		
GNC	guidance, navigation, and control	PE	Perkin-Elmer		
GPC	general purpose computer	RCS	reaction control system		
GSFC	Goddard Space Flight Center	RM	redundancy management		
GSTDN	Ground Spacecraft Tracking and Data Network	RMA	remote manipulator arm		
		RMS	remote manipulator system		
IC	intelligent controller				
IOAU	input/output arithmetic unit				
IS	instructor station				

JSC-19081

Mission Operations Directorate
Training Division

- SMS - Shuttle Mission Simulator
- MCC - Mission Control Center
- MBCS - motion-base crew station
- FBCS - fixed-base crew station
- RMS - Remote Manipulator System
- CRT - cathode ray tube
- DIG - digital image generation
- CCTV - closed circuit television
- SID - simulation interface device
- NSS - Network Simulation System
- SLS - Spacelab Simulator

Shuttle Mission Simulator

Shuttle Mission Simulator

The Shuttle Mission Simulator (SMS) is located in building 5 at the NASA Lyndon B. Johnson Space Center, Houston, Texas. The SMS was developed to support flightcrew and flight controller training for the Shuttle orbital missions. Simulation capability provides for training activities in all facets of the Shuttle vehicle operations and in all systems tasks associated with the major flight phases: prelaunch, ascent, abort, orbit, rendezvous, docking, payload handling, undocking, deorbit, entry, approach and landing, and rollout. These systems include the Orbiter vehicle main engines, solid rocket engines, external tank, and support equipment and interfaces required to achieve the Shuttle objectives, including interface with the Mission Control Center (MCC).

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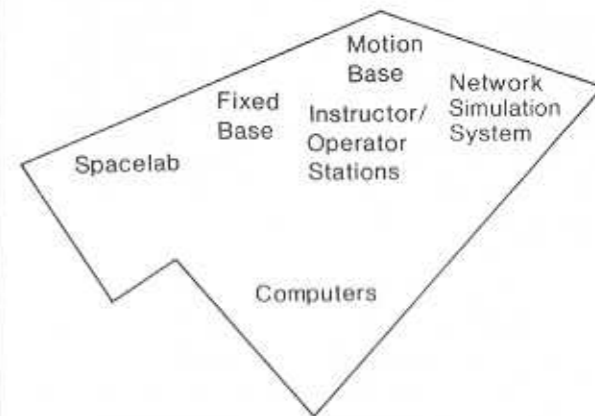
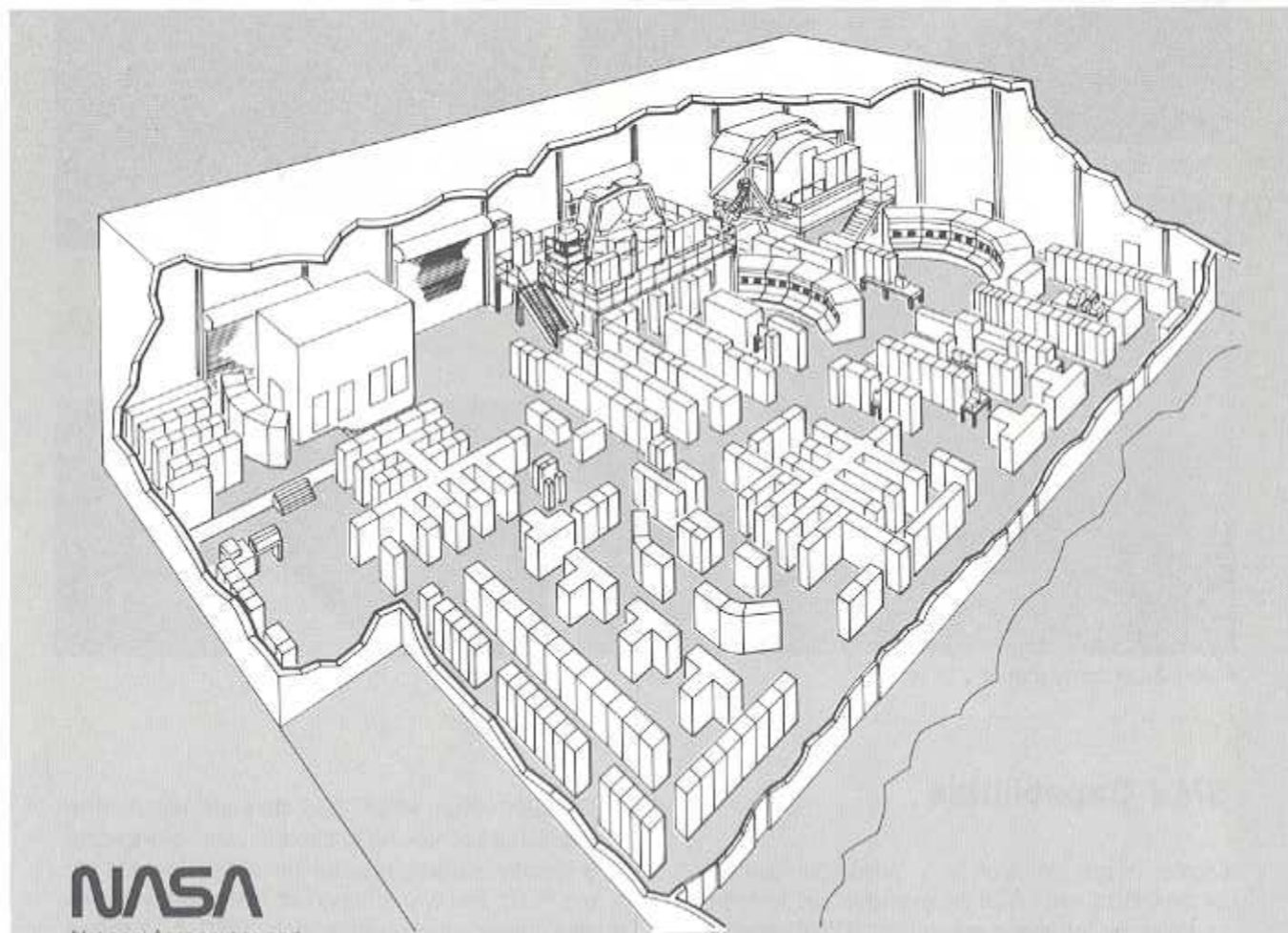


Diagram of SMS complex

NASA

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

Crew Stations

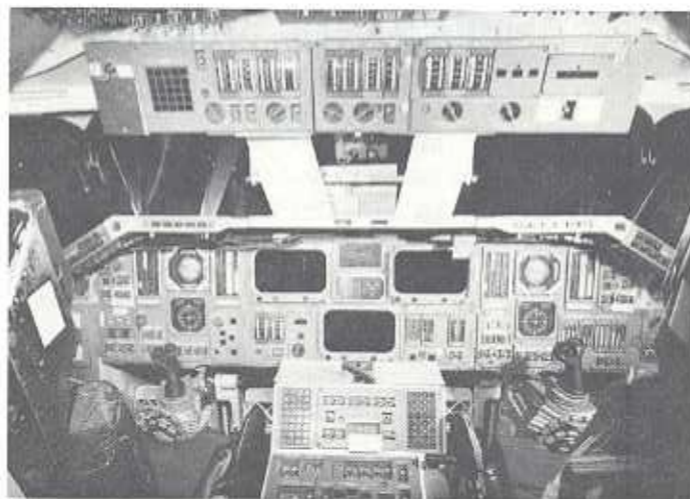
The major simulation devices constituting the SMS are two crew-station and instructor/operator-station complexes that allow parallel but independent training exercises involving flightcrews. The motion-base crew station (MBCS) and the fixed-base crew station (FBCS) will contain all the controls, displays, and consoles visible to and required by the crew in the performance of their flight duties. The MBCS and the FBCS have the same physical appearance, location, and function as in the actual flight vehicle.

Motion-base crew station — The MBCS is configured for Shuttle commander and pilot positions. It operates with motion cues supplied by a

modified six-degree-of-freedom motion system and provides motion cues appropriate to all mission phases including launch, descent, and landing. A specially designed tilt frame allows a 90° upward tilt to simulate the axial acceleration of lift-off and ascent. Normal ingress/egress for the MBCS is through a conventional rear located door.

Fixed-base crew station — The FBCS is sized and configured for commander, pilot, mission specialist, and payload operations crew positions. Included within the FBCS are the Remote Manipulator System (RMS), the navigation and rendezvous systems, and the payload accommodation system that will be configured to represent specific Shuttle payload flight requirements in the future. The FBCS is located on an elevated platform. Entrance to this station is through a hatch opening in the floor of the crew station as in the actual vehicle.

Instructor/operator consoles — Instructor and operator consoles have been designed to provide the capability to monitor simulation activities. Interactive cathode ray tube (CRT) display systems provide digital and graphic displays. The SMS monitoring and control activities allow either an individual or a full complement of instructors, operators, crew, and ground controllers to conduct a simulation. A simulation reset capability allows initialization to a mission state within any of the mission phases for specific training concentration. Simulation in either the MBCS or the FBCS may be tied to the MCC by the Network Simulation System (NSS) for integrated flight controller training. The NSS models the worldwide tracking and communications system, including the satellite links. The NSS also models the Orbiter telemetry and command systems. Actual Shuttle flight computers and flight software are used in the SMS to ensure effective training in data processing functions, systems monitoring, and flight control. The simulations are conducted in real time with extensive failure and perturbation capabilities.



Motion-base crew station



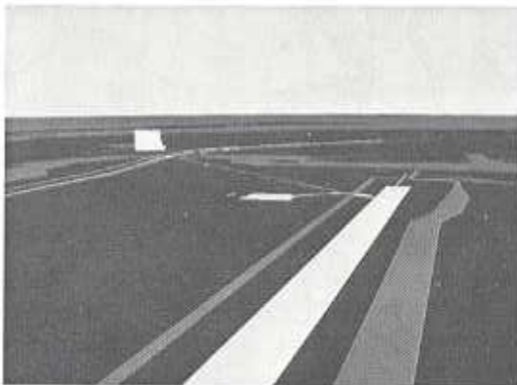
Fixed-base crew station

SMS Capabilities

Digital image generation — Visual simulations for the MBCS and FBCS are provided by four independent digital image generation (DIG) systems. These out-the-window scenes generated for the two crew stations include launch, insertion, on-orbit, special effects, and approach and landing.



Simulator cockpit



DIG scene

The Earth, Sun, Moon, and stars are included in the visual scenes. All cockpit forward windows in both crew stations may be simulated. In addition, the FBCS has two aft and two overhead windows and closed circuit television (CCTV) displays simulated. The aft DIG systems contain an occlusion controller and processor refinement to determine, process, and display the correct spatial

ordering of moving objects for aft window and CCTV fields of view. The CCTV enables viewing the payload through fixed cameras or through cameras mounted on remote manipulator arms. This feature is important for payload deployment and retrieval training for later Shuttle flights.

Auditory simulations — Auditory simulations are provided to correspond to the operation of on-board systems, aerodynamic noise, propulsion, and the functioning of landing gear doors, other mechanical devices, and ground contact. Voice communication corresponding to that of the actual mission is provided.

Computer facilities — The SMS computer facilities are comprised of two independent digital computer systems. Each system has a Univac 1100/40 host computer which contains a majority of the mathematical models for simulation. Fourteen minicomputers perform data collection and transfer as well as other functions. There are two simulation interface devices (SID's) that communicate with the flight computer systems. The flight computer systems consist of five IBM AP101 computers for each crew station. Four DIG computers and various input/output processors complete the basic computer system.

Supporting systems — The SMS will be interfaced with other simulators to duplicate various Shuttle missions. One of these, the Spacelab Simulator (SLS), simulates the laboratory module developed by the European Space Agency. Spacelab is the laboratory module carried in the Orbiter payload bay.

The SMS represents a major advancement in mission simulators in terms of sophistication, completeness, and magnitude of systems simulated. Its modular construction in both hardware and software should enable modifications to be made with relative ease for simulation of different missions and payloads. This simulator will be a major training device for the United States space program for the next two decades.