# SHUTTLE MISSION SIMULATOR REQUIREMENTS REPORT

## VOLUME I

REVISION A 3/23/73

SINGER
SIMULATION PRODUCTS

A DIVISION OF THE SINGER COMPANY • DEVELOPER AND MANUFACTURER OF THE LINK TRAINER SINCE 1929

SHUTTLE MISSION SIMULATOR

REQUIREMENTS REPORT

VOLUME I

REVISION A 3/23/73

J. F. Burke

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Principal Investigator
SMS Definition Study

This document is submitted in compliance with Line Item No. 3 of the Data Requirements List as Type I Data, Contract NAS9-12836

SINGER COMPANY
SIMULATION PRODUCTS DIVISION

# SHUTTLE MISSION SIMULATOR
# REQUIREMENTS REPORT

## VOLUME I

## REVISION A

Prepared by:

J. F. Burke
Principal Investigator
SMS Definition Study

Approved by:

C. Olasky
NASA Technical Manager
Contracting Officer's Representative

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SIMULATION PRODUCTS DIVISION

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## 1.0 Purpose

This statement of work defines the Contractor tasks required to produce a Shuttle Mission Simulator Complex which will be used to support the training of crew members and ground personnel for operating the Space Shuttle System which includes the Orbiter Vehicle, Main Engines, Solid Rocket Motors, External Tank, Air Breathing Engines for the Ferry mode of operation and support equipment and activities required to provide the Space Shuttle System objectives.

## 2.0 Scope

### 2.1 Contractor Tasks

The Contractor's tasks will consist of the design, development, production, installation, checkout and field support of one (1) Shuttle Mission Simulator complex which is defined to consist of two separate and distinct crew stations. These tasks will include the review of spacecraft changes and the incorporation of appropriate changes into the simulator hardware and software design, the generation of documentation for design, configuration management and training use by maintenance and instructor personnel after acceptance for each of the crew stations.

### 2.2 Program Definition

The SMS program for the purposes of this Statement of Work and the ensuing contract shall consist of four primary tasks:

1) Development of a Motion Base Crew Station
2) Development of a Fixed Base Crew Station
3) Spares Provisioning
4) System Support

The program shall be organized into a Work Breakdown Structure with each crew station defining the project level work packages. The project level work packages are divided into system work packages and lower levels. The Work Breakdown Structure will form the basis for the proposal, cost and schedules. Further definition of the requirements of the WBS concept are detailed in Exhibit 4.

The major program milestones which shall comprise the SMS program are tabulated in Figure 2.1.

2.2.1 Program Elements

The overall SMS program elements are shown on Figure 2.2 which defines the SMS program level specification tree. NASA shall be responsible for the management and coordination required to interface the Program at this level. The elements of the program and the interrelationships between are defined in the following paragraphs:

2.2.1.1 Facility & Facility Modifications

After ATP a Facility Modifications Requirements document shall be prepared by the SMS Contractor. (See Exhibit 2 for further instructions, reference DRL Line Item 37).

2.2.1.2 Simulation Computation Complex

The SMS Contractor shall be provided as GFP, the SMS Simulation Computation Complex (SCC). The SCC specification tree is shown in Exhibit (5). The Contractor shall utilize the equipment and software so provided as the computation complex of the SMS. The SCC consists of the equipment and software defined in Exhibit (3). Proposed expansion of the SCC if required to meet the SMS requirements shall be the responsibility of the Contractor. Preventive maintenance, scheduling, modification, and configuration control of the SCC equipment and specifications shall be proposed by the Contractor from computer acceptance until acceptance of the Motion Base Crew Station. Subsequent

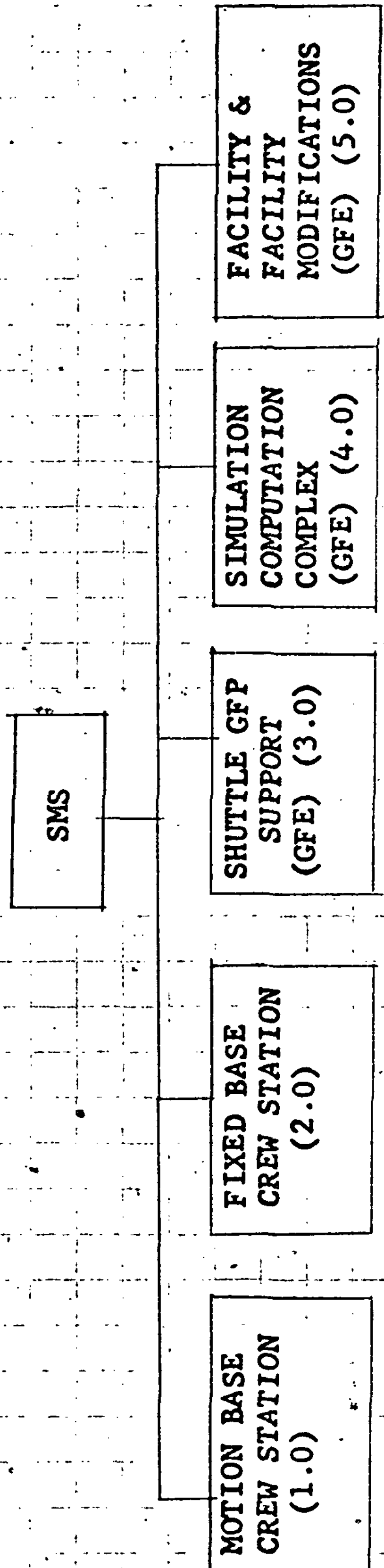


FIGURE 2-2 PROGRAM SPECIFICATION TREE

to the acceptance of the MBCS NASA will schedule the machine and utilize the complex Sixty hours per week. The SCC shall be located in Building 5 at JSC during the entire program.

SMS Authority to Proceed

SCC Availability

Bldg. 5 Modifications Complete

GFP Flight Hardware Availability

Motion Base Crew Station (MBCS)

- Authority to Proceed
- Preliminary Design Reviews
- Critical Design Reviews
- Installation at MSC
- Acceptance
- Post Acceptance Update
- Astronaut Training
- Systems Support
- Spares Provisioning

Fixed Base Crew Station (FBCS)

- Specification/ECP
- Authority to Proceed
- Preliminary Design Reviews
- Critical Design Reviews
- Installation at MSC
- Acceptance
- Systems Support
- Spares Provisioning

FIGURE 2.1 MAJOR PROGRAM MILESTONES

2.2.1.3 Shuttle GFP Support

The prime Shuttle Contractor (North American Rockwell) is responsible for providing data and equipment to NASA to support the SMS development and operations. The Shuttle Contractor support shall be as follows:

2.2.1.3.1 Shuttle Systems Data Support

The Shuttle Contractor shall provide vehicle data as required to allow the design and maintenance of the SMS in an up-to-date configuration which duplicates vehicle functions with a high degree of fidelity. This data shall include vehicle configuration, operations, avionics and flight crew interface data.

This data shall be used as the baseline design data for designing the SMS. An initial data package will be provided the SMS contractor at ATP. Data will continue to be provided after ATP and will be transmitted to the SMS Contractor through the NASA SMS Technical Manager. The SMS Contractor shall establish a Data Management capability to catalog, track, disseminate, evaluate and retrieve this data as specified in paragraph 7.0. A formal interface shall be established after ATP between the SMS Contractor and the NASA Technical Manager/Shuttle Prime Contractor to permit additional data request for missing, incompatible or incomplete data items to be obtained from the Shuttle Contractor.

2.2.1.3.2 Avionics Hardware and Software Support

High fidelity simulation of avionics subsystems is required for procedures development and crew and flight controller training. Therefore, flight-type hardware for simulation of such avionics equipment as computers, data buses, interface units, etc., may be necessary to effectively incorporate flight software characteristics into training simulators. If flight hardware or flight software is required to achieve this capability, it will be provided as GFP.

The SMS contractor shall specify the GFP Avionics equipment required. The specified equipment will be procured by NASA separately and provided as GFP to the SMS Contractor. Interface will be defined jointly by NASA and the contractor and the resulting definitions will be documented by Interface Control Documents (ref. DRL #32 of Exhibit 2). The GFP may be modified by agreement between the Contractor and the NASA SMS Technical Manager.

2.2.1.3.3 Hardware Support

Hardware to be provided in the SMS falls into one of three categories: (a) Flight fidelity hardware is required where there is an active instrumentation requirement; (b) Hardware of mockup fidelity may be provided where only stowage or crew-support equipment is necessary; and (c) Flight Simulator Hardware to be supplied GFP. The NASA shall specify the vehicle hardware which is to be supplied as GFP (Reference Exhibit 3). The GFP defined may be modified by agreement between the SMS Contractor and the NASA Technical Manager.

2.2.1.4 Motion Based Crew Station

For the purposes of this procurement, the Shuttle Mission Simulator shall consist of two crew stations, a Motion Base Crew Station and Fixed Base Crew Station. The Motion Base Crew Station shall be procured under the initial SMS contract. The specification tree for the Motion Base Crew Station (MBCS) is shown in Exhibit (5). The MBCS shall be a moving base simulator with a visual system which shall provide training for the Commander and Pilot work stations.

2.2.1.5 Fixed Base Crew Station

A modification to the basic SMS contract will be initiated by NASA subsequent to ATP to procure the FBCS. The specification tree for the FBCS is shown in Exhibit (5). The FBCS will be a fixed base simulator with visual which shall provide training for the Commander, Pilot, Mission Specialist, Payload Specialist and Orbit Work Stations.

2.2.2 Program End Items to be Provided

The Contractor shall provide the following end items:

a. One (1) Motion Base Crew Station - Hardware and software in accordance with the requirements of this SOW.

b. One (1) Fixed Base Crew Station - Hardware and software in accordance with the requirements of this SOW.

c. Computer Programs - Two (2) magnetic tape copies and a backup card deck for the simulator on-line and off-line software programs shall be provided at acceptance.

d. Documentation - Documentation in accordance with Exhibit (2), Data Management Specification for the Shuttle Mission Simulator.

e. Test Equipment - Unique Test Equipment required to meet the maintainability requirements as proposed by the Contractor.

f. Visual Graphic Masters - If applicable, masters of graphic material (e.g., film, slides, etc.) required for image generation which were generated during the program and are required for the production of first generation copies after acceptance.

g. Spares Provisions - Sufficient to support the SMS for one year after acceptance of each crew station.

h. Systems Engineering - For a period of six months after acceptance of each crew station to support maintenance and operations.

## 3.0 General Requirements

### 3.1 Performance

The Shuttle Mission Simulator shall be composed of two independent Crew Stations. The first Crew Station which shall be referred to as the Motion Base Crew Station (MBCS) shall be capable of providing training for the Commander/Pilot work stations. The second Crew Station which shall be referred to as the Fixed Base Crew Station (FBCS) shall be capable of providing training for all work stations located in the upper crew compartment of the Orbiter Vehicle.

The Motion Base Crew Station shall be delivered in a training configuration identical to the Shuttle System configuration for the First Manned Vertical Flight Test. The Fixed Base Crew Station shall be delivered in a training configuration identical to the Shuttle System configuration for the first vertical flight which incorporates the Aft Orbiter crew stations, i.e., the Mission Specialist, Payload Specialist and the Orbiter work stations.

Each Crew Station shall be capable of operating integrated but not simulataneously with MCC for the purpose of ground personnel training.

The SMS shall be capable of training flight crews to operate the space shuttle vehicle (SSV) and to become proficient in all facets of the vehicle's assigned missions. The MBCS shall be mounted on a six degree-of-freedom motion system which shall have the capability of being tilted to simulate vehicle launch. The FBCS shall be a fixed-base simulator capable of training all SSV Crew members. Visual systems shall be provided for the forward windows of the MBCS and all windows of the FBCS exclusive of the photographic stations.

The simulator shall be designed so that both modules can be operated at the same time on independent training exercises.

Both crew stations shall be capable of providing training in all tasks required during the following major flight operations.

a. Ascent
b. Orbit
c. Rendezvous
d. Deorbit
e. Entry
f. Approach and Landing
g. Ferry
h. Abort

In addition the FBCS shall provide training for the Rendezvous, Payload Operation and Docking and Undocking mission phases. Both crew stations shall be designed to provide training from ten minutes prior to lift-off until the orbiter comes to rest on the runway after landing.

The SMS shall faithfully duplicate all controls and displays utilized during manned operation of the SSV. In addition, the simulator shall operate in an integrated mode with MCC to provide full mission training.

## 4.0 Program Management Requirements

### 4.1 Organization Requirements

The contractor will establish a Shuttle Mission Simulator organization headed by a Program Manager and removed from other contractor programs to the extent necessary to prevent interference with a timely completion of the SMS program. The Program Manager shall have the responsibility and necessary authority for the accomplishment of the objectives of the SMS contract. The Program Manager shall have clearly demonstrated ability to deliver similarly complex systems on time and within contract cost. In order to accomplish the management-utilization and control of the GFP located at JSC, the contractor shall provide the necessary personnel located in the vicinity of JSC.

#### 4.1.1 Organization Plans

The contractor shall provide NASA with a current organization chart which clearly identifies the areas of responsibility for the performance of the various aspects of the SMS program. The organization chart shall identify responsibility at least to the Work Package Manager level. See Exhibit (2), Data Management Specification for the Shuttle Mission Simulator, DRL Line item 1.

#### 4.1.2 Key Personnel Changes, Contracting Officer

Prior to diverting or reassigning specified key personnel, the contractor shall notify the NASA Contracting Officer. See Exhibit (2), Data Management Specification for the Shuttle Mission Simulator, DRL Line item 1.

4.2 Program Plan Requirements

The contractor shall prepare and submit for NASA approval a Program Plan which shall be the single, authoritative summary document which the contractor shall use to delineate the manner in which the objectives of this Statement of Work shall be achieved. This Program Plan shall be agreed upon during contract negotiations. See Exhibit (2), Data Management Specification for the Shuttle Mission Simulator, DRL line item 1.

4.3 Industrial Safety Plan Requirements

As part of the Program Plan, the contractor shall prepare and submit for NASA approval a proposed Safety Plan for assuring proper attention and control on industrial and public safety matters. The Industrial Safety Plan shall be agreed upon during contract negotiations and be properly integrated with the Organizational Plans and Program Plan.

4.4 Subcontract Plan

As part of the program plan, the contractor shall prepare a Subcontract Plan which includes: the method of procurement, procurement schedules, and procedures by which control will be exercised over the subcontract effort. See Exhibit (2), Data Management Specification for the Shuttle Mission Simulator, DRL line item 5.

4.5 Data Management Plan

As part of the program plan the contractor shall prepare a Data Management Plan which will outline the contractor's planned method for management and control of data. (See Exhibit (2), for further instruction, Ref DRL line item 7).

4.6 Installation at MSC Plan

As part of the program plan, the contractor shall prepare an installation at MSC plan. (See Exhibit (2) for further instruction, Ref. DRL line item 42).

4.7 Monthly Technical Progress Report

The contractor shall prepare a Monthly Technical Progress Report which will describe the progress, significant accomplishments, major activities, and problems encountered during the reporting period. (See Exhibit (2) for further instructions, Ref DRL line item 4). The Monthly Technical Progress Report shall include a summary of all subcontracts (Ref DRL line item5).

4.8 SMS Baseline Management

Concurrent with the period of performance of this SMS contract, the actual Shuttle System will be developed, manufactured and tested. The contractor shall be responsible for reviewing and assessing all approved mission changes and configuration changes to the Shuttle System to determine the impact on the SMS configuration. NASA will provide the contractor with data for this purpose.

The contractor shall submit an Engineering Change Proposal (ECP) (reference Exhibit (2),DRL item 30) for each proposed SMS configuration change or modification that impacts the design, function, cost, for management and control of data. (See Exhibit (2), for further instruction, Ref DRL line item 7).

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As part of the program plan, the contractor shall prepare an installation at MSC plan. (See Exhibit (2) for further instruction, Ref. DRL line item 42).

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The contractor shall submit an Engineering Change Proposal (ECP) (reference Exhibit (2), DRL item 30) for each proposed SMS configuration change or modification that impacts the design, function, cost, or schedule of the SMS. Upon receipt of the ECP and its review with the contractor, NASA will reach a decision whether or not to incorporate the change or modification into the SMS. Prior to PDR, the SMS contract Statement of Work shall serve as the SMS baseline configuration. Approved changes from ATP to PDR shall be incorporated into the CEI and CPCEI documentation. From PDR to the termination of the program the end item specifications (Part I & Part II) shall be used as the SMS baseline configuration. The source of design data and assumptions made to arrive at this baseline shall be documented in the Data Book (reference Exhibit 2, DRL line item 34).

Subsequent to PDR, a formal Configuration Control Board consisting of NASA and SMS contractor personnel will convene semi-monthly to review and assess the impact of the change activity.

Each change shall be evaluated as to whether it can be incorporated into the defined program schedule. Changes which cannot be incorporated into the original schedule shall be designed, fabricated, and installed as a modification kit after acceptance of the initial delivered configuration. The modification kits shall be generated in accordance with Exhibit 2, DRL line item 23.

Due to the uncertainty of the change activity, for the purposes of bidding the review of data and preparation of ECP's shall be estimated as a level of effort of twenty man-years of systems engineering personnel spread over the entire program.

# 5.0 Program Control Requirements

## 5.1 Conference Requirements

The NASA will exercise program control through use of program planning documents, periodic reviews, cost reports, and such other management tools as may be required.

Monthly program reviews will be conducted as well as unscheduled meetings as required. The program reviews will alternate in location between the SMS contractor's facility and JSC.

### 5.1.1 Preliminary Design Review (PDR)

PDR(s) will be conducted with the SMS contractor by the NASA Technical and Work Package Managers and other NASA personnel and Shuttle contractors as deemed necessary by NASA prior to or early in the detail design phase. A PDR is the technical review of the basic design approach for an item of equipment or software to assure compatibility with the technical requirements as defined by the contract Statement of Work and the producibility of the design approach. The design approach will be documented by Contract End Item Specifications, (reference Exhibit(2), DRL item 40). The End Item Specifications will be supported by Engineering Design Reports (reference Exhibit(2), DRL item 22), Interface Control Documents (reference Exhibit (2), DRL item 32) and the Data Book (reference Exhibit (2), DRL item 34). This documentation shall be submitted prior to the review to enable adequate time for NASA review as defined in the DRL List of Exhibit (2)

These reviews will update the NASA requirements to be used by the contractor. Cost and schedule relationships which arise due to technical requirement changes will also be reviewed. The NASA approved changes shall be documented as the NASA baseline, implemented by the contractor, and placed under configuration control. The End Item Specifications shall serve as the basis for the baseline and appropriate changes shall also be implemented in the Contract Statement of Work. The contractor shall publish a plan for the PDR(s) (Reference DRL line item 35 , schedule and conduct the PDR(s) and publish a summary report (Reference DRL line item 39).

5.1.2 Critical Design Review (CDR)

CDR(s) will be conducted with the SMS contractor by the NASA Technical and Work Package Managers and other NASA personnel and Shuttle contractors as deemed necessary by NASA when the detailed design is essentially complete. The purpose of a CDR is to determine the compliance of the completed design with the technical requirements of the NASA baseline. Actions resulting from these reviews, in general, shall be completed prior to authorization to proceed with implementation of the contractor's overall detail design. A CDR shall result in authorization to the contractor to proceed with the release of detail design to Manufacturing, of test procedures, etc., and the appropriate revision or update of the NASA baseline documentation. The detail design will be documented by the End Item Specifications (Part II) (Reference Exhibit 2, DRL item 41).

Changes to the technical requirements which arise at the reviews shall be handled analogous to PDR changes procedures defined in paragraph 5.1.1 The contractor shall publish a plan for the CDR(s) (Reference DRL line item 36 ) schedule and conduct the CDR(s) and publish a summary report (Reference DRL line item 39).

5.1.3 Incremental PDR(s) and CDR(s)

Each total system review, i.e., PDR and CDR, will be a one-time review of either the overall design approach or the detail design with review results presented to a formal NASA review board. However, in order to allow design of the system and its various subelements to proceed in the most efficient manner and to allow initiation of long lead-time procurement and/or manufacturing to best support program requirements, review and authorization for individual elements of the overall system design will be granted on an individual basis. As the contractor proceeds with system design, NASA will monitor design progress. When the contractor and NASA agree that the design of a system or hardware element has progressed to the point where it is appropriate to proceed with detail design or to release detail design for manufacturing, an incremental review will be conducted on that system or hardware element to obtain NASA's authorization to proceed. The incremental reviews will be conducted in accordance with the PDR and CDR requirements as herein described. Upon completion of the Incremental Design Reviews and resolution of resulting action items, the NASA baseline shall be updated as appropriate.

The PDR and CDR shall be summary reviews of the Incremental PDR's and CDR's to ensure that the incremental reviews are compatible and the results satisfy program requirements.

5.1.4 Start of Acceptance Testing Review (SATR)

The SMS and all End Items ready for NASA's acceptance shall be documented by the contractor through a formal Start of Acceptance Testing Review (SATR). The contractor shall publish a plan for the SATR (Ref DRL line item 38 ), schedule and conduct the SATR and publish a summary report (Ref DRL line item 39).

5.1.5 Final Acceptance Review (FAR)

A Final Acceptance Review (FAR) will be conducted at the completion of NASA Acceptance Testing. The contractor shall publish a plan for the FAR (Ref DRL line item 43).

5.2 Configuration Control Requirements

The contractor shall prepare a configuration management plan See Exhibit (2) for further instructions, Ref.DRL line item 27.

5.2.1 Preparation of Engineering Change Proposals for Contract End Items

The contractor shall prepare proposed changes to contract end items. See Exhibit (2) for further instructions, Ref. DRL line item 30. Changes to requirements as defined by the contract Statement of Work which arise during the program due to the design reviews, data reviews, or NASA direction shall be documented by this method.

5.2.2 Review, Transfer and Turnover Package

The contractor shall provide NASA with review data concurrent with SMS acceptance. See Exhibit (2), for further instructions, Ref. DRL line item 13.

5.2.3 Interface Control Documents

The contractor shall prepare Interface Control Documents to define and control SMS interface. See Exhibit (2) for further instructions, Ref DRL line item 32.

5.2.4 Interface Revision Notices

The contractor shall prepare Interface Revision Notices to inform NASA of proposed changes to Interface Control Documents See Exhibit (2) for further instructions, Ref. DRL line item 33.

5.3 Schedule Requirements

The contractor shall prepare and submit, monthly, detailed milestone schedules that will accurately depict the progress of the program. See Exhibit (2) for further instructions, Ref. DRL line item 3.

5.4 Work Packages

The work packages/work tasks concept with significant milestone charts will be used by NASA for visibility of the total project. The work package/work task shall represent an identifiable and measurable area of effort that is consistent with the contractor's breakout of budget allocations, cost accumulation centers and scheduling practices expressed in terms of manhours and identified to schedule milestones. Milestone charts with associated manloading charts shall be included. See Exhibit (2) for further instructions, DRL line item 3.

5.5 Financial Control Requirements

The contractor shall prepare and submit monthly a detailed Financial Management Report in a NASA provided format, that will accurately depict the plans and actuals of the costs and manhours for this program consistent with the milestone schedules discussed in Paragraph 4.4 above. The Work Package identification concept will be used by NASA for visibility into the measurement of progress, as related to cost. See Exhibit (2) for further instructions, DRL line item 6.

5.6 Quality Assurance Program

The contractor shall develop, implement and maintain a quality assurance and inspection program in accordance with the approved Quality Assurance Plan. (See Exhibit (2) for further instructions, DRL line item 10)

5.7 NASA and Other Contractor Related Tasks

The contract will be managed by the Manned Spacecraft Center of NASA. The development of the simulator will require contact with other NASA contractors and Government organizations. The NASA will arrange the procedures for and will monitor these contacts.

## 6.0 Technical Requirements

### 6.1 System Engineering Requirements

The following documentation shall be generated by the Contractor's system engineering function for each of the end items which are the responsibility of the SMS Contractor.

#### 6.1.1 Engineering Design Reports

The SMS Contractor shall prepare overall design reports that provide detailed technical descriptions of the equipment to be provided. (See Exhibit (2) for further instructions, Ref. DRL Line Item 22).

#### 6.1.2 Modification Data

The SMS Contractor shall prepare a Modification Data Package for each modification authorized by the Contracting Officer. (See Exhibit (2) for further instructions, Ref. DRL Line Item 23).

#### 6.1.3 Drawings

The SMS Contractor shall prepare a complete set of SMS drawings, Form II. (See Exhibit (2) for further instructions, Ref. DRL Line Item 25).

#### 6.1.4 Drawing Index

The SMS Contractor shall prepare an index of all drawings and specification required for the SMS. (See Exhibit (2) for further instructions, Ref. DRL Line Item 26).

6.1.5 Data Book

The SMS Contractor shall prepare a document defining the data and assumptions which form the design base. (See Exhibit (2) for further instructions, Ref. DRL Line Item 34).

6.1.6 End Item Detail Specification

The SMS Contractor shall prepare End Item Specifications for the simulator in the format and content specified. (See Exhibit (2) for further instructions, Ref. DRL Line Items 40 and 41).

6.1.7 Specification Maintenance

The SMS Contractor shall prepare specification change notices and the specification change log pertainingthereto. (See Exhibit (2) for further instructions, Ref. DRL Line Item 28 and 29).

6.1.8 Interface Control Documents

The SMS Contractor shall prepare interface control documents to define and control SMS interface. (See Exhibit (2) for further instructions, Ref. DRL Line Item 32).

6.1.9 Interface Revision Notice

The SMS Contractor shall prepare Interface Revision Notices to inform NASA of proposed changes to Interface Control Documents (See Exhibit (2) for further instructions, Ref. DRL Line Item 33).

## 6.2 Design and Development Requirements

### 6.2.1 General Design Requirements

#### 6.2.1.1 Operability

##### 6.2.1.1.1 Reliability

The contractor shall establish and maintain an effective reliability program in accordance with MIL-STD 785 Requirements for Reliability Program (for Systems and Equipments).

Reliability of operation shall be of prime importance in the design and manufacture of the training device. All practical methods shall be employed to insure quality and reliability consistent with the state of the art. Reliability shall be integrated with maintainability efforts in order to achieve maximum availability in the most economical manner.

##### 6.2.1.1.2 Maintainability

The simulator shall be designed for ease of maintenance, accessibility for installation and removal of components, safety of personnel during operation, and minimum time for training problem setups. The following practices and equipment characteristics shall be adhered to:

a) Components which are functionally and physically interchangeable shall be of the same part number and shall be used wherever and as frequently as possible. Provisions shall be made to insure that components cannot be incorrectly installed.

b. All inspections, adjustment, service requirements, and replacements shall be accomplished using a minimum of tools or support equipment.

c. Standardized components requiring minimum of lubrication, adjustment, cleaning, and protection shall be used wherever standardization does not penalize the simulator in performance.

d. Wherever possible, sequential assembly and subsequent disassembly arrangement of detail parts shall be avoided.

e. Wherever possible, sequential alignment and calibration arrangements shall be avoided.

f. The functional units shall incorporate self-test capabilities where possible and particularly whenever electrical or electronic circuitry units, components, and detailed parts are employed. Simulator go-no-go self-test shall indicate in a direct reading form whether or not the simulator is operating within established operating limits. The indication shall be readily available to the instructor-operator or maintenance personnel. The possibility of doubt entering into the interpretation of go-no-go displays shall be excluded.

g. For maintenance purposes, functional units shall be arranged so that each may be isolated from the trainer and operated individually from suitable input devices while its output is measured with appropriate test equipment. Input and output test jacks shall be separate from the normal service connectors on the unit and shall be available for use while the unit is in service. Input and output test equipment characteristics shall be specified by the contractor.

h. The physical arrangement of components shall be such that they can be readily inspected, serviced, calibrated, and if required, adjusted without removing the component and with minimum disturbance to other parts. The degree of accessibility shall be commensurate with the frequency of inspection, servicing, or repair on the unit or detail part. Hermetically sealed units or units otherwise protected from specific hazards shall be exempted from this requirement.

6.2.1.1.2.1 Accessibility

Easily removable access panels shall be provided throughout the equipment as required for maintenance, inspection, test or modification. The degree of accessibility shall be commensurate with the required frequency of inspection or servicing. Such access shall be to an extent which will facilitate removal and replacement of parts. All covers, hinged access doors, or removable panels which must be removed or opened for inspection and maintenance purposes shall be secured by readily removable screws or quick-release mechanisms. Components which are subject to replacement or servicing shall not be permanently secured by riveting, welding, or other means which prohibit ready removal. The design shall provide for removal of failed components with minimum disturbance of nonfailed components.

6.2.1.1.3 Useful Life

The SMS shall be designed and constructed for an accumulated operating life (longevity) of not less than 30,000 hours.

6.2.1.1.4 Natural Environment

The SMS shall be designed to sustain no damage and be capable of satisfactory operation within the performance requirements of this specification after being subjected to the following natural environmental conditions:

a) Temperature - Minus 20 degrees F to plus 140 degrees F for 2 weeks and 25 degrees F to 105 degrees F for 3 years.

b) Altitude - Up to 35,000 feet for 25 hours and up to 6,000 feet for 3 years.

c) Humidity - Up to 90 percent relative humidity due to temperature changes.

6.2.1.1.5 Transportability

The SMS shall be designed to minimize preparation procedures for handling and transport. Features shall be incorporated in the equipment design to permit handling by forklifts and cranes; no special equipment shall be required. All cabinets are to be furnished with casters for ease in handling and relocation. Disassembly shall be held to the minimum required to provide adequate protection of the components, but shall not require the use of special tools or skills for reassembly. The largest single piece of equipment which cannot be disassembled shall not exceed a crated width of 7' 4", height of 8 feet, length of 16 feet and weight of 4,000 pounds.

6.2.1.1.6 Human Performance

Human performance criteria to support the SMS for optimum arrangement, lighting, colors, placarding, and equipment, shall be provided. Human factors requirements shall be applied to assure compatibility between man and the simulator. Unless otherwise specified herein, the human engineering requirements shall be in accordance with MIL-STD-1472.

6.2.1.1.7 Safety

The SMS shall be designed to insure maximum safety to personnel and equipment during training periods and maintenance operations.

6.2.1.1.7.1 Personnel Safety

The equipment design shall provide for the adequate protection of personnel and crewmembers at all times. Protective devices shall be incorporated to prevent accidental contact with primary supply voltages or rotating parts.

6.2.1.1.7.2 Equipment Safety

The SMS shall be designed for optimum equipment safety throughout, as specified herein.

a. Overload Protection - Overload protective devices shall be provided within the equipment for primary circuits and such other circuits as required for protection of the equipment from damage due to overload. These protective devices shall be located in such a manner as to be readily replaceable, either by direct location on the front panel or behind hinged doors or panels. (Except for off-the-shelf commercially available equipments.) Lamp indicators shall be used so that fuse failures are visually indicated. All overload protective devices shall be placed in the ungrounded side of the circuits.

b. Heat Dissipation - The SMS design shall provide for the adequate positioning and spacing of components whose operation involves the release of heat at appreciable rates. Location and spacing shall be such as to permit sufficiently rapid dissipation of heat to prevent excessive temperatures in their immediate environment. Such items shall be contained in cabinets or other suitable enclosures. Enclosures containing such heat dissipating components shall incorporate provisions for removal of heat energy released. Where rate of dissipation is too high to warrant reliance upon natural convection for cooling, forced ventilation shall be provided.

6.2.1.1.7.2.1 Equipment High Temperature Warning

When electronic equipment may be damaged due to high temperatures, an automatic high-temperature audible warning system shall be installed. Means shall be provided to cut-off the audible warning alarm after sounding, while the equipment is secured and allowed to cool down.

6.2.1.1.8 Dangerous Materials and Components

Materials and components shall not generate toxic or noxious gasses when exposed to excessive heat. Adequate handling procedures shall be provided for any components that may be hazardous through breakage, e.g., pressurized lamps or cathode ray tubes.

6.2.1.1.9 Induced Environment

The SMS shall be capable of operating in the following induced environment.

6.2.1.1.9.1 Operating Environment

The SMS system shall be capable of performing its intended functions within the specified performance requirements while operating under any combination of the environmental conditions specified below:

a. Temperature - +60° F to 85° F

b. Altitude - Zero to 2,500 feet

c. Relative Humidity - 30 to 80 percent

6.2.1.1.9.2 Conditioned Air

Conditioned, filtered, cooling air shall be furnished by the using site directly to training equipment at 70 plus or minus 5 degrees F, relative humidity 50 percent or less, at a differential pressure equal to 0.3 inch of water. The cooling air shall be supplied to the lower part of the equipment (under floor plenum) and exhausted out through the top into the room.

6.2.1.1.9.3 Acoustics

The noise level of operative training equipment parts shall be held to a minimum. Noise levels shall not be permitted to interfere with communications essential to efficient training.

6.2.1.1.10 Life Support

The contractor shall provide conditioned air to the spacecraft suit in order to maintain proper transfer of training. The conditioned air shall be oil free and shall not contain solid particles larger than 1 micron.

6.2.1.2 Facility Interface

6.2.1.2.1 Product Configuration

The general physical arrangement, product configuration and other design constraints such as floor space, floor loading, vibration, electrical power, air-conditioning, mechanical, and plumbing requirements shall be as delineated in the ICD. (Reference DRL Item #32).

6.2.1.2.2 Power Requirements

a. Three-phase 60 Hz 120v/208v power within limits as specified in paragraph 6.2.5.2.1 shall be furnished by NASA.

b. 400 Hz power - 115 volt single phase power within the limits specified in paragraph 6.2.5.2.1 shall be furnished by NASA.

c. 277/480 volt 3 phase 4 wire 60 Hz power shall be furnished by NASA.

d. Outlets - The SMS consoles and cabinets shall be equipped with contractor furnished 60 Hz, 115v power outlets to facilitate the use of testing equipment.

6.2.1.2.3 Cabling Requirements

All power distribution cables from facility power distribution points to the SMS shall be furnished by NASA at the installation site.

6.2.1.2.4 Air-Conditioning Requirements

The SMS Contractor shall interface with the GFP facility conditioned air (reference paragraph 6.2.1.1.9.2) in the following manner.

a. The SMS contractor shall supply the "boots" which direct the flow of air from the under floor plenum to those equipment cabinets requiring plenum air.

b. The cooling air capacity (CFM) and the cooling (BTU/HR) required by each unit shall be described in the applicable Interface Control Document.

6.2.1.2.5 Facility Layout

The SMS will be located at the Manned Spacecraft Center facility at Houston, Texas. It will be housed in the Mission Simulation Facility Building No. 5. It shall be designed for installation in the areas shown on FIG.6.2 -III. Additional dimensional information of the simulator space is shown on FIG. 6.2.-I and FIG.6.2 -II.

The flooring in the simulator area is of 8" thick reinforced concrete with cable troughs as shown on Section A-A of FIG. 6.2-I.

Flooring in the balance of the area is computer flooring 16 inches high with a 28 inch square panel grid.

Site modification shall be the responsibility of NASA. The Contractor will clearly define all modifications necessary for the installations including, but not limited to:

a) Filling of trenches

b) Floor leveling requirements to accommodate the motion base

c) Size and location of trenches from the hydraulic power room

d) Cutouts in the floor panels for equipment mounted on the computer flooring

F-398-8-A

e) Size and location of trenches from the Image Generation equipment.

f) Floor loading information

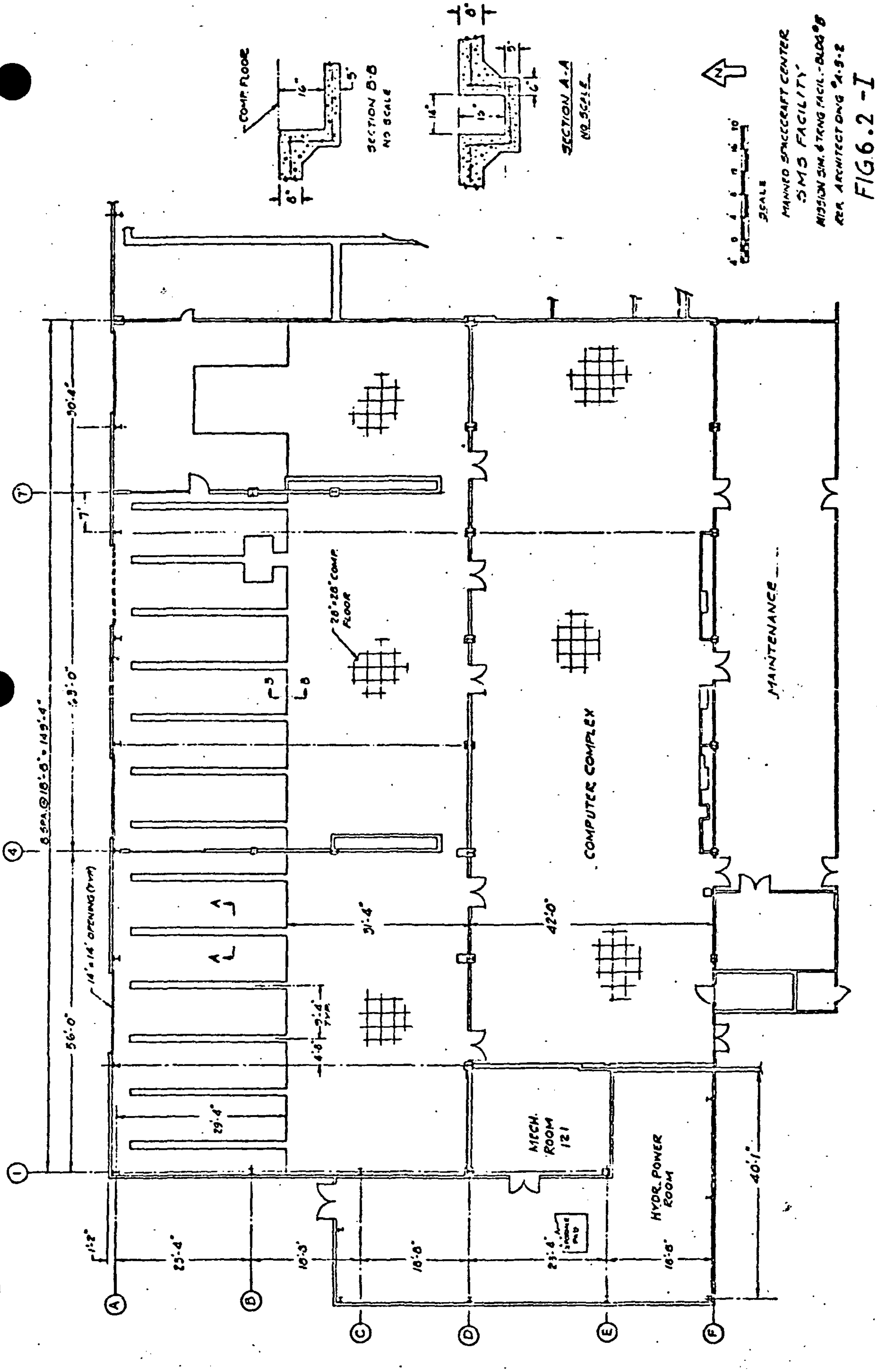
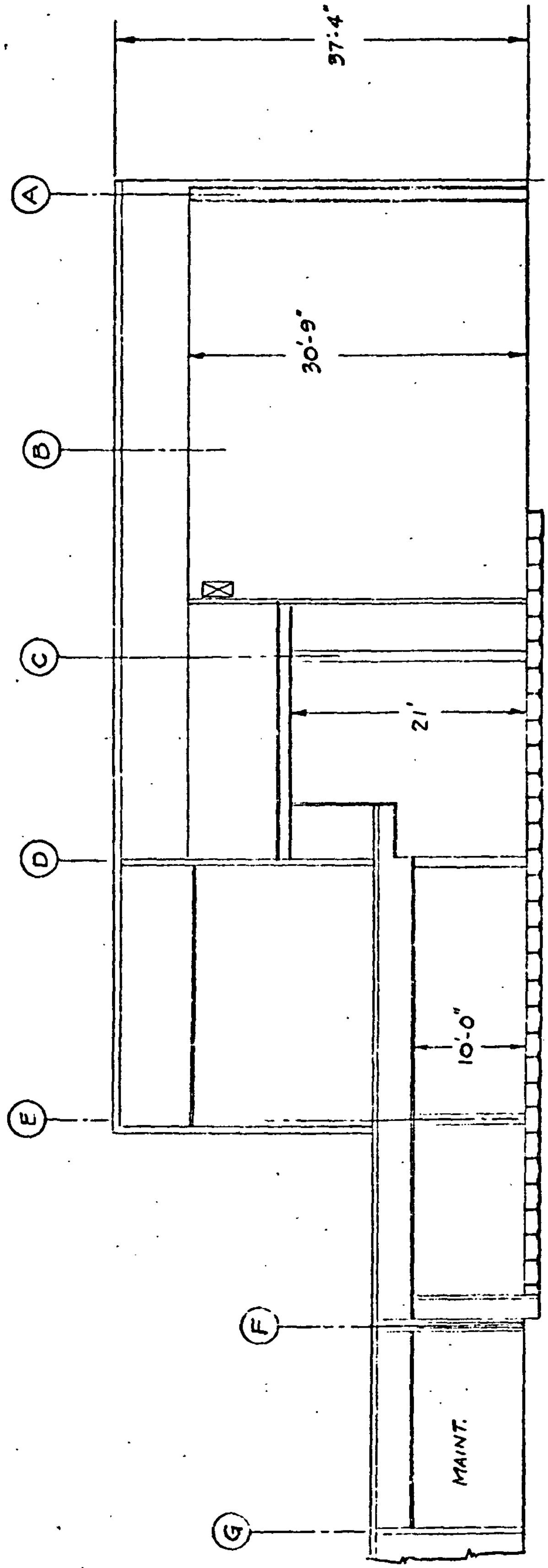
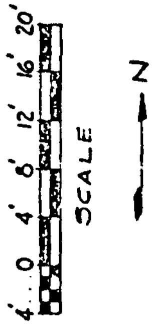

COMP. FLOOR
SECTION B-B
NO SCALE
SECTION A-A
NO SCALE
SCALE
MANNED SPACECRAFT CENTER
SMS FACILITY
COMPUTER COMPLEX
MAINTENANCE
28"x28" COMP. FLOOR
MECH. ROOM 121
HYDR. POWER ROOM
56'-0"
31'-4"
42'-0"
40'-1"
29'-4"

FIG 6.2 -I

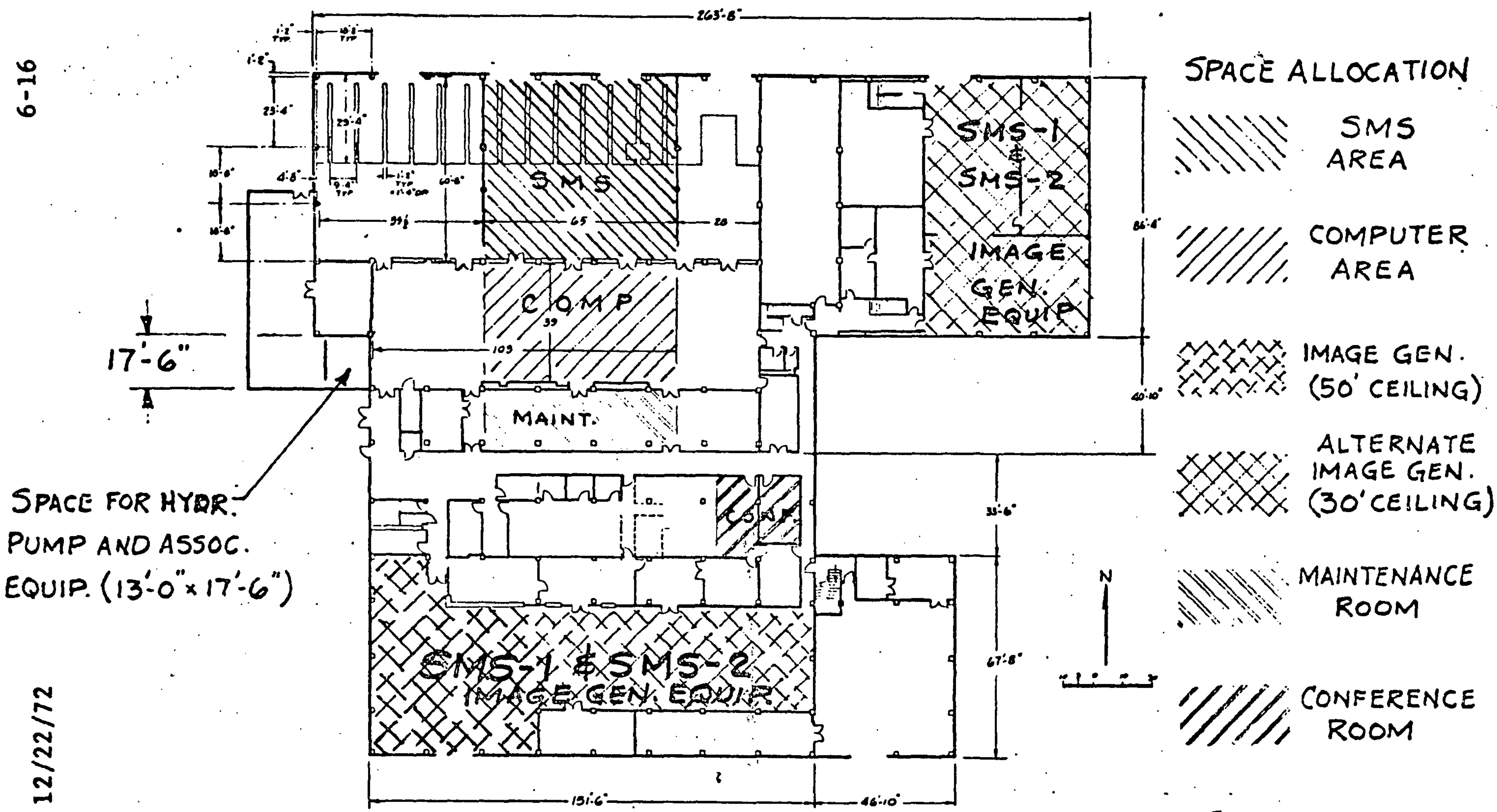



SMS FACILITY
TYPICAL CROSS SECTION
FOR CEILING HEIGHT

FIG 6.2.-II

12/22/72




SMS FACILITY
FIG 6.2.III

6.2.1.3 Design and Construction Standards

6.2.1.3.1 General Design Features

The SMS equipment shall simulate, as far as practical, those features of the SMS operations to be encountered by flight crews in the performance of their tasks. The configuration of the equipment shall provide for the requirements of the using site facilities and all specifications herein. Actual S/C hardware may be utilized but shall not require flight qualification. Features shall be incorporated in the design to permit ease of modifications necessitated by design changes in the actual vehicle. Emphasis shall be placed upon reliability, simplicity, minimum size, versatility, ease of maintenance, and minimum time for training problem setup. The design requirements of the SMS for simulation of the actual SMS subsystems shall be based upon data that describes the performance and physical characteristics of these subsystems. The SMS shall be designed to accept electrical cables and cooling air exhaust outlets that are contained in the subflooring at the using site. Cables for interconnecting components shall be compatible with the using site facilities. Any subsystems involving chemical reactants or pyrotechnics shall not be simulated with actual hardware.

6.2.1.3.1.1 Human Engineering

Unless otherwise specified herein, the human engineering requirements of the training equipment shall be in accordance with MIL-STD-1472 where applicable.

6.2.1.3.1.2 <u>Electrical Requirements</u>

The SMS equipment shall operate from the GFE power sources within the limits as specified in paragraph 6.2.5.2.

All electrical equipment and design shall comply with the National Electrical Code.

Batteries shall not be used as a part of, or in connection with, the power equipment. Automatic time-delay devices shall be used as required to prevent damage to circuits caused by loss of all power and/or power on sequence.

6.2.1.3.1.2.1 <u>Electric Motors</u>

Equipment utilizing electric motors larger than one horsepower shall be designed to operate from a 3-phase power supply.

6.2.1.3.1.2.2 <u>Wiring</u>

Stranded hook-up wire shall be used unless solid conductors are required to meet circuit conditions. Conductor size shall be sufficient to avoid deterioration in electrical properties of the wire from overheating. Bare hook-up wire shall not be used unless insulated wire is impractical because of circuit characteristics or shortness of wire runs. All wire shall conform to Specification MIL-W-16878, except that the polyanide jacket is not required.

6.2.1.3.1.2.2.1 <u>Electrical Connections</u>

In no case shall electrical connections depend upon wires, lugs, or terminals clamped between a metallic member and an insulated material. Where practicable, such connections shall be clamped between metal members such as an assembly of two nuts, two washers, and a machine screw. If such an assembly cannot be used, and maintenance of a tight connection depends upon the resistance of an insulating material of other than a ceramic or vitric nature to compressive stress or shear, such connection shall be securely soldered. Wherever bolts, screws, nuts, or studs are used in, or as part of, a radio-frequency circuit, connections shall be assembled by use of a lug. Specifically, soldered connections shall not be considered practicable at studs of molded phenolic capacitors, meter terminals, or relay contacts, unless such parts are designed for soldered connections.

6.2.1.3.1.2.2.1.1 Solderless Type Terminals

Solderless type terminals shall be used except for parts where wrapped, solder type or dip solder type terminations require solder connection. Spade type terminals shall be used on wiring at cable ends where frequent disconnection is required. For wire size AWG 22 and larger AWG numbers, pre-insulated type terminals may be used.

6.2.1.3.1.2.2.2 Access Wire Holes

Whenever wires are run through holes in metal partitions or shields less than 1/8 inch in thickness, the holes shall be equipped with suitable insulators for mechanical protection of insulation otherwise subject to abrasion. Panels, 1/8 inch or more in thickness, shall either have insulators or shall have the hole edges rounded to a radius equal to one-half the thickness of the material.

6.2.1.3.1.2.2.3 Wire Runs

Care shall be exercised in the running of hook-up wire to insure that it is not carried over or does not bend around any sharp corners or edges which might, in time, cut through the insulation. In order to prevent deterioration of the conductor by heat, care shall be taken to insure that wiring is not exposed to local temperatures appreciably above ambient temperatures and that the wiring cannot come in direct contact with heated parts.

6.2.1.3.1.2.2.4 Metallic Shielded Wire Runs

Conductors using metallic shielding unprotected by an outer insulation shall not be used.

6.2.1.3.1.2.2.5 Spare Receptacle Contacts and Terminals

A quantity of unused receptacle contacts and junction terminals shall be provided. The number of spare contacts shall be not less than 10 percent of the total quantity used, but in no case shall be less than two spare contacts per connector. This requirement shall not apply to equipment such as motors, indicating instrument, and meters where it is unlikely that additional circuits will ever be required. The 10 percent spare contacts on interconnecting cables shall be wired. Cabling between bays and racks of equipment shall contain approximately 10 percent unused spare capacity for future expansion.

6.2.1.3.1.2.2.6 Maximum Terminal Point Connections

The number of wires connected to any one binding post or terminal board stud shall be limited to four.

6.2.1.3.1.2.2.7 Ammeter Shunts

Ammeter shunts shall not be used as terminal lugs.

6.2.1.3.1.2.2.8 Terminal Strips

Terminal strips of low moisture absorption insulating material shall be used for junction of cables requiring infrequent disconnection or the joining of two or more cables at a common point. Adequate terminal spacing or barriers shall be employed to prevent breakdown or low leakage resistance under high humidity, including condensation.

6.2.1.3.1.2.2.9 Cabling

Conductors not placed in ducts or channels shall be bound into a cable and securely held by insulating clamps or other suitable means. Cables shall be supported a minimum of once every 24 inches to prevent abrasion from folding, vibration, or other mechanical damage, In addition, pulse, audio, video and radio-frequency signal carrying conductors that may undesirably couple such signals into other conductors shall not be bound into a cable. All video cables shall be continuous (without connectors) except for points essential to the video system. Cables between assemblies and units shall terminate in terminal lugs or connectors and shall be contained within extruded plastic or synthetic rubber tubing. Unless otherwise specified, all cables other than power distribution cables terminating in connectors or terminal strips which contain three or more conductors shall be provided with spare conductors as follows:

| Number of Live Conductors | Number of Spare Conductors |
|---|---|
| 3 to 5 | 2 |
| 6 to 12 | 3 |
| 13 to 20 | 4 |
| 21 or more | 5 conductors or 20 percent, whichever is greater |

6.2.1.3.1.2.2.10 Cable Grouping

Where practicable, interconnecting cables, except those cables contained under the raised flooring, shall be bound into cable groups. Each grouping shall be limited to an equivalent area of 12 square inches. When required to bend such cable groups, the radius of bend shall be not less than ten times the minimum thickness of the group.

6.2.1.3.1.2.2.11 Use of Conduit or Zipper Tubing

Where required, lightweight metallic conduit or zipper tubing shall be used for protecting electrical wiring from mechanical damage.

6.2.1.3.1.2.2.12 Conduit Fitting or Connectors

Conduit fittings or connectors of the water tight type shall be used for fastening either metallic conduit or insulating tubing to equipment or junction boxes where termination of wires in the conduit or insulating tubing is made to terminal strips or connections within the equipment or the junction box.

6.2.1.3.1.2.2.13 Size of Conduit

In determining the diameter of conduit to be used, the group of conductors that are to be installed shall be bundled together and the maximum diameter measured. The maximum diameter shall not exceed 75 percent of the internal diameter of the conduit to be used. Wires and cables within the conduit shall not be tied or fastened together.

6.2.1.3.1.2.2.14 Slack

Unless otherwise specified, wires and cables shall be as short as practicable. Sufficient slack shall be provided for the following purposes:

a. Allow repair of broken connections at terminal at least two times, except for sizes AN2, AN4, and larger where only one replacement is required.

b. Prevent mechanical strain on the wires, cable junctions and supports.

c. Permit free movement of shock and vibration mounted equipment.

d. Permit shifting of equipment in order to perform alignment, servicing, tuning, removal of dust covers, or changing of plug-in components or subassemblies while installed.

All underfloor power and signal cables measuring 20 feet or more in length point-to-point shall be at least 15 feet longer than point-to-point distance. All underfloor cables measuring less than 20 feet in length point-to-point shall be at least eight feet longer than point-to-point distance.

6.2.1.3.1.2.2.15 Wiring Practices

The following wiring practices shall be avoided:

a. Moisture-absorbent materials used as fill for clamps or adapters.

b. Tape or cord used for primary support.

Where continuous lacing or wrapping is used, it shall be in accordance with the requirements of NASA Handbook SP-5002.

6.2.1.3.1.2.2.16 Insulating Tubing

Insulating tubing shall be placed over each conductor solder terminal connection at each end of the cable. The tubing shall be installed in a manner to prevent slippage of the tubing from the connection.

6.2.1.3.1.2.2.17 Grounding

The following grounding methods shall be used:

a. A central ground point shall be provided that is located in the main power cabinet.

b. The simulator frame, signal and individual power grounds shall be isolated from each other within each unit. When it is required for circuit reasons to connect a specific power ground to a signal ground, the power ground shall be considered as a signal ground.

c. The simulator frame, signal and individual power grounds shall be common only at the central ground point for the entire system. Each ground shall be capable of being separated from the central ground point.

d. Each shield shall be grounded at one point only. preferably at the end where the signal originates. Signal shields shall be connected to power or chassis ground. Where it is desired to pass one or more shields through a connector, a shield ground wire shall be carried through each connector to the point where it connects to power or signal ground. One point only on each segment of each shield shall be connected to this shield ground wire.

6.2.1.3.1.3 Mechanical

Major components of the simulator shall be of modular construction such that installation assembly and disassembly can be accomplished without special equipment. The simulator shall have provisions for securing and locking items in place for shipping. Means for leveling each major component shall be provided. Each major component shall have provisions for lifting and moving by forklift or tow points for skidding the unit.

Simulator supporting structure shall be suitably reinforced to support the equipment during its normal use and to withstand jars, vibrations, and shock incident to shipment.

All parts, such as shafts, bearings, pistons, gears, valves, armatures, regulators, and controls shall have proper clearances and adjustments. They shall so work together that the simulator equipment will satisfy the stated requirements without unnecessary strains, vibrations and overheating. They shall be able to withstand the conditions incident to shipping, storage, installation and service.

6.2.1.3.2 Selection of Specifications and Standards

Unless otherwise specified, specifications and standards for materials, parts, and processes shall be selected using Standard MIL-STD-143 as a guide.

Where materials, parts, and processes are not covered by Government specifications, their selection will be at the option of the contractor with the restriction that selection shall meet the performance characteristics satisfactory for the intended use.

6.2.1.3.3 Materials, Parts and Processes

Materials that are not specified herein shall be sound, of uniform quality and conditions, and free from cracks, seams or defects which may adversely affect the appearance, strength, endurance or wear resistance of the finished part.

6.2.1.3.3.1 Noncritical Materials

Wherever practicable, noncritical materials shall be used in construction of the equipment.

6.2.1.3.3.2 Nonmetals

All nonmetals, such as wood, plastic, and fabric used in construction of the equipment shall be of the moisture and temperature resistant type.

6.2.1.3.3.3 Flame-Resistant Materials

Where practicable, flame-resistant materials shall be used. Where necessary to use flammable materials, they shall be of such characteristics that neither toxic nor corrosive fumes will be liberated if the material should burn. All flammable materials shall be brought to NASA attention prior to design approval.

6.2.1.3.3.4 Dissimilar Metals

Contact of dissimilar metals as defined in Specification MS 33586 shall be avoided wherever practicable. Where such contact is unavoidable, and if practicable, the metals shall be electronically insulated with paint, non-metallic washers, chemical films, or anodic coatings.

6.2.1.3.3.5 Gearing

The class of gear shall be determined according to its application. Except for commercially available gear boxes which are integral with motors, high-speed or heavily loaded geared transmissions shall include anti-friction permanently lubricated bearings.

6.2.1.3.3.6 Finishes and Protective Coating

Finishes and protective coatings shall be applied to all surfaces of the simulator to prevent corrosion and deterioration.

6.2.1.3.3.7 Crew Stations

The crew station interior colors shall duplicate the SMS vehicle interior.

6.2.1.3.4 Standard and Commercial Parts

Standard parts such as Air Force-Navy (AN), National Aircraft Standard (NAS), and Military Standard (MS) parts shall be used where practicable when they suit the purpose, and shall be identified on the drawing by their part number.

6.2.1.3.4.1 Commercial Utility Parts

Commercial utility parts, such as screws, bolts, nuts, washers, pins, rivets and similar small parts, having suitable properties may be used provided that:

a. They can be replaced by standard parts (MS or AN) without alteration.

b. The corresponding MS or AN standard part number is referenced in the part list and on the training device drawings.

6.2.1.3.5 Moisture and Fungus Resistance

Materials that are susceptible to damage or deterioration due to moisture or salt spray shall be avoided.

Materials that are nutrients for fungi shall not be used where it is practical to avoid them. Where nutrient materials are used and not hermetically sealed, they shall be treated with an acceptable fungicidal agent.

6.2.1.3.5.1 Corrosion of Metal Parts

Corrosion-resistant metals shall be used in the construction of the SMS wherever protective finishing is not practical. Where necessary to use ferrous materials to obtain certain functional or magnetic properties, such ferrous materials shall be protected against corrosion.

6.2.1.3.6 Interchangeability and Replaceability

Mechanical and structural interchangeability and replaceability shall conform to the requirements of Specification MIL-I-8500. Electrical and electronic interchangeability and replaceability shall conform to the requirements of MIL-E-5400. All parts having the same manufacturers part numbers shall be governed by the drawing number requirements of MIL-STD-100.

6.2.1.3.7 Workmanship

The SMS shall be constructed and finished in accordance with the requirements of MIL-STD-454. Particular attention shall be given to the following:

a. Freedom from blemishes, defects, burrs, and sharp edges

b. Accuracy of dimensions, radii of fillets, and marking of parts and assemblies.

c. Thoroughness of soldering, welding, brazing, painting, wiring, and riveting.

d. Alignment of parts and tightness of assemblies, screws, and bolts.

The SMS shall be thoroughly cleaned. Loose, spattered or excess solder, metal chips, and other foreign material shall be removed during and after final assembly.

6.2.1.3.8 Electromagnetic Interference

The generation of electromagnetic interference or the vulnerability of the SMS (except commercial off the shelf equipment) to interference shall be controlled within the limits of CE03,RE02 and CS06 of Table II of MIL-STD-461.

6.2.1.3.9 Identification and Markings

The SMS equipment shall be marked in accordance with the requirements of MIL-STD-130.

6.2.1.3.9.1 Cautionary Marking

In all instances where parts, subassemblies, assemblies and units of the spacecraft equipment are used in the SMS and these parts, subassemblies or assemblies, have been modified in any way for application to the SMS, such parts, subassemblies or assemblies shall be permanently marked with the following cautionary markings in a plainly visible position:

A WARNING: FOR TRAINER USE ONLY

6.2.1.3.9.2 Wiring

Each wire and cable installed between subassemblies, assemblies, and units shall be identified by imprinting on the wire, cable, or sleeve. This identification applies to those wires and cables normally subject to removal for maintenance or shipping, such as cables between cabinets. The imprinting shall be placed within 3 inches of each connection and shall be located so that shielding, ties, clamps, or supporting devices do not have to be removed to read the identification. Each wire shall be identified by a dual method of marking which designates the connection points at each end of the wire. A slash mark shall separate the two parts (portions) of the identification marking (For example, switch S-3 has one wire leading to terminal three of terminal board TB-1. The wire should be identified on the switch end as

S-3-1/TB-1-3). To facilitate this method of marking, at least every tenth terminal in all junction boxes shall be numbered. Where power wiring occurs in the junction boxes, the terminals shall be labeled as to the voltage and frequency. All plugs and connectors shall be assigned a reference designation in accordance with Standard USAS Y32.16. All wire marking shall be of sufficient size to be legible and shall be marked in permanent colors to provide suitable contrast with background wire, sleeve, or cable covering.

6.2.1.3.9.3 <u>Transformer Connections</u>

Transformer connections shall be clearly marked on the subassemblies near each connections or prominently labeled on the transformer itself.

6.2.1.3.9.4 <u>Control Panels</u>

The IOS control panel facilities, such as control switches, rheostats, indicators, jacks, sockets, and fuse holders, shall be marked with a suitable word, phrase, or abbreviation, indicating the use or purpose of the parts as well as their operational functions. The control panel markings shall be placed in appropriate positions adjacent to the part in a durable and legible manner. The Crew Station control panel markings shall be in accordance with S/C data.

6.2.1.3.9.5 <u>Electronic Parts Identification</u>

Where space permits electronic parts, such as capacitors, resistors, relays, transformers, and other circuit parts, shall be identified by reference designations stamped on the mounting adjacent to the subassemblies and assemblies. All subassemblies and assemblies shall be identified by reference designations stamped on the mounting adjacent to the subassemblies and assemblies. These identification symbols shall be the same that appear on the applicable circuit diagrams and shall be completely legible and located in a position to facilitate identification.

### 6.2.1.4 Software Design

#### 6.2.1.4.1 Simulator System Software

The Contractor shall design and implement a simulation structure that will utilize the capabilities and resources of the GFE Computer Complex and Operating System in an optimum manner. The Contractor shall also provide the facilities necessary to support time-sharing requirements for batch processing, remote job entry, and a data management system utilizing the GFE Computer Complex, in parallel with the simulator operation.

A high level compiler language shall be used in coding the application programs. The contractor shall evaluate and discriminately select the type of programming languages which should be implemented for the various control, application, and support software systems of the SMS. Factors that should be considered shall include, but not be limited to, data base communication, program linkages, simulation task structure linkages, operating system linkages and facilities.

The contractor shall ensure that efficient utilization is made of the facilities of the GFE operating system in the development of the data management system. Factors that should be considered shall include, but not be limited to, source file updates, variable load module creation, data set maintenance and integrity, object module/data base linkages.

6.2.1.4.2 Simulated Shuttle Systems Software

6.2.1.4.2.1 Structure

The SMS applications software shall be structured for ease of modification and load-making. Each program shall be modularized to allow replacement of any subsystems program module without destroying the integrity of a load configuration. (The modularization shall be accomplished relative to real world systems and subsystems, rather than for internal programming conveniences.) The capability to simultaneously load multiple program modules of a given subsystem into the computer shall exist. By this means, modification development and discrepancy clearance can be accomplished at the same time training is taking place.

6.2.1.4.2.2 Training Configurations

The training configurations for applications software shall be developed to permit the training modes described in Paragraph 6.2.1.4.4.5.

6.2.1.4.3 Modifications

The applications software modifications shall be accomplished without modification to the training configuration on a modular basis and shall reside until accepted for on-line training. The modular model under development shall have the capability of being brought on-line to either replace the equivalent accepted module or be added to a load configuration for checkout. During on-line development, test drivers shall be developed to expedite checkout of the modifications on a non-real time basis as spare computer time is available. This development shall normally be pursued at a terminal/CRT station. After this initial test phase is complete, the modification shall be tested with a compatible load configuration.

The test drivers shall be maintained in the off-line mass storage in a current configuration until simulator acceptance. Additional drivers shall be included as necessary to emulate the interface to allow checkout of the integrated configurations without actual tie-in to the other training stations.

The Data Management System (DMS) shall provide capabilities by means of data processing functions to control and status the hardware and software configuration of the simulator. The DMS shall also provide the summary of simulator complex utilization for various activities such as crew training time, preventive maintenance time and lost time.

6.2.1.4.4 Simulator Modes

6.2.1.4.4.1 Reset

The Reset mode shall provide the capability to select the set of desired initial conditions from the number of sets available. Twenty reset points shall be delivered with each crew station. The available sets of initial conditions shall be stored in mass storage and, on actuation of Reset Modes, the selected set shall be transferred to operating storage. The simulator shall be switched to Freeze mode on actuation of the Reset and remain in Freeze mode until another mode is selected. The latter requirement shall not disallow program executions necessary to establish stable and numerically correct values of initial conditions.

Separate parallel function mode controls shall be located at the instructor operator station and the MBCS station convenient to the instructor for which the control is applicable.

A CRT shall display the instructor option initial condition parameters. This display/control will be used by the instructor to, at his option, change the values to those selected upon the next reset. The number of parameters shall not exceed one CRT page and shall include Runway Heading, Landing Site, Barometric Pressure and Altitude, wind controls, Air Turbulence profile selection, magnetic variation, and Orbiter State Vector with respect to the Landing Site

6.2.1.4.4.2 Freeze

The Freeze mode shall hold all time dependent variables at the last values computed before actuation of the Freeze mode when actuated by other than Reset Mode. The exception stated under 6.2.1.4.2.1 shall apply for Reset Freeze mode.

Computer controlled entry into Freeze mode shall be included under conditions necessary to protect the safety of equipment and personnel. An Automatic Freeze Enable Control shall, when activated, freeze the problem under defined simulated conditions for which negative or no training value results. Return to the Operate mode, on actuation, shall be smooth and shall continue from the conditions existing when the Freeze mode was entered.

6.2.1.4.4.3 Operate

The Operate mode shall, when actuated, allow update of computed values, applicable to the computer load configuration.

6.2.1.4.4.3.1 Real Time

The Real Time mode shall enable operation of the simulator computations with a one-to-one relationship between actual and simulated time. All time-dependent parameters shall be computed at the rates characteristic of the time dependent real world relationships.

6.2.1.4.4.3.2 Slow Time

When actuated, the slow time mode shall displace the real time mode and maintain selectable rates of one-half, one-tenth, or one-twentieth real time. The ratios of slow time to real time shall be maintained at all subsystem levels.

6.2.1.4.4.4 Step-Ahead

The Step-Ahead mode shall contain means of selection of a point in time to which the simulation will be advanced or regressed as selected. The state vector of the simulated vehicle shall be within the Real Time mode tolerances at this new point in time. Degraded accuracy of simulated vehicle on-board subsystems shall be acceptable except that the errors shall be less than the errors existing if the on-board system were not changed in time from that time existing before step-ahead. Single iteration updates of these on-board systems shall be acceptable. For purposes of defining this mode, the simulated vehicle on-board computers are not considered part of the simulated vehicle on-board subsystems. The simulated vehicle on-board computers shall contain means of update to the accuracies of the Real Time mode at the selected time.

6.2.1.4.4.5 Training Modes

6.2.1.4.4.5.1 Motion Base Crew Station (MBCS)

The simulator shall contain the software necessary to allow operation of the MBCS independent of other training stations. The software shall be configured so training at this station is not degraded by simultaneous training at the Fixed Base Crew Station except that the capability for training Launch-Boost mode need not be provided for both stations simultaneously. Active training stations are the Commander and Pilot Stations with seating included to be used by the Mission and Payload specialists or the instructor/operators.

6.2.1.4.4.5.2 Fixed Base Crew Station (FBCS)

The simulator shall contain the software necessary to allow operation of the FBCS independent of other training stations. Active training stations are the Commander, Pilot, Mission and Payload specialists and the Remote Manipulator Station. The software shall be configured so training at this station is not degraded by simultaneous training at the MBCS, except for the Launch-Boost limitation noted in Paragraph 6.2.1.4.4.5.1.

6.2.1.4.4.5.3 MBCS/FBCS Integrated

Requirements for an MBCS/FBCS integrated mode are TBD.

6.2.1.4.4.5.4 MCC Integrated

The simulator shall contain the software necessary to allow any one of the configurations explained under 6.2.1.4.4.5.1, 6.2.1.4.4.5.2 or 6.2.1.4.4.5.3 to operate in an integrated mode with the Mission Control Center. See 6.2.5.8 for the integrated mode interface requirements. No more than one integrated mode involving the MBCS and the FBCS integrated with MCC shall be required at any one time.

6.2.1.4.4.6 Telemetry,Digital Command System and Trajectory Interface

The requirements for interface between the SMS stations and Mission Control are listed in Addendum B to this specification. These interface requirements are listed with paragraph cross-references to the specification. The simulation shall include all listed parameters transmitted at a rate of TBD KBS.

6.2.1.4.4.7 Simulated Malfunctions

The simulation shall include malfunctions. The requirements for simulated malfunctions for all SMS systems, are listed in Addendum B. The listing is not intended to exclude other possible malfunctions from the training inventory.

To clarify the malfunction description, the following definition of malfunction types is given:

Multiple Malfunction - Meaning that the malfunction may be applied to morethan one identical type subcomponent.

Discrete Malfunction - Meaning that the malfunction uses boolean logic for insertion/removal.

Variable Malfunction - Meaning that the malfunction modifies internally used multiplier coefficients for subsystem component functional changes and must return to the nominal value upon reset.

6.2.1.4.4.8 IOS Crew Station Display

Parameters internal to the simulation equations shall be provided to the IOS for instructor/system engineer monitoring. Provision shall be made to provide both crew station displays and true values to the IOS when malfunctions have been inserted to affect the crew instruments. The term "true value" is defined as the calculated value of the simulated system function parameter without consideration of signal conditioning for telemetry or display purposes.

6.2.2 Work Breakdown Structure/CEI Organization

The WBS structure for the SMS Complex is defined in Exhibit 4. The ensuing sections of the Design & Development requirements will define the requirements of each of these work packages. For brevity, when the requirements of analogous work packages for the MBCS and FBCS overlap or are identical, one set of requirements are stated and, if any differences exist, they are so noted.

The SMS Specification Tree, the Contract End Items and Computer Program Contract End Item Lists which comprise the SMS program are tabulated in Exhibit 5 for the SMS Program elements. The Contractor shall have the capability of adding to the list of Contractor provided equipment or computer programs if additional items are identified or are generated due to the uniqueness of the proposed design.

6.2.3 Crew Station Requirements (WBS#1.1 and 2.1)

6.2.3.1 Crew Station Hardware

6.2.3.1.1 General Description

The crew stations for the Shuttle Mission Simulator shall be contained in 2 compartments; one compartment shall be designated the Motion Based Crew Station (MBCS) and the other compartment shall be designated the Fixed Base Crew Station (FBCS).

6.2.3.1.1.1 Motion Based Crew Station (MBCS)

The MBCS shall contain the entire Pilot and Commander's stations and shall extend aft to include the Mission Specialist and Payload Specialist seats in their authentic locations. The forward section of this compartment shall be an authentic replica of the vehicle from a station at the front of the compartment, which will contain all forward equipment visible to the crew (i.e., glareshield, pedals, and window frames), aft to a station containing the vertical panels at the aft edge of the side consoles.

A readily removable"jump seat" shall be installed aft of the center console to permit an Instructor/Observer to monitor the crew actions. (Ref. Paragraph 6.2.4.1.4)

The flooring and pedestals shall extend aft to include the seat tracks and pedestals of the aft crew members seats. The aft bulkhead location and detail may be compromised to accommodate these aft crew members in a forward facing position. The shelves and panels at these aft stations shall be authentically located, with controls and displays which are functional for the missions of the MBCS operable as in the spacecraft. Non-functional items may be simulated to a lesser degree of fidelity. GFE linings shall be authentically placed with neatly blended linings covering the overhead and aft surfaces normally devoted to the RMS station and cupola.

The design shall permit removal of the complete crew station from the visual system as required to accommodate visual alignment.

The entire crew station and visual system shall be mounted on a tilt frame such that it can assume a nose-up attitude of a minimum of 90° from the level position for the launch phase of the mission training. This attitude may be achieved by the combined excursions of the motion system and tilt mechanism . An additional motion capability of ±10° of pitch, or ±12" of heave shall be provided when the crew station is in the 90° pitch attitude. The total payload shall be designed to withstand the performance requirements of the motion system while in any tilt attitude.

6.2.3.1.1.2 Fixed Base Crew Station (FBCS)

The Fixed Base Crew Station shall contain all five crew stations of the flight deck. All stations shall be authentic replicas of the vehicle stations in the spacecraft in areas visible to and affecting the crew members except that the orientation of the orbit station may be altered if deemed necessary to accomplish training in a 1 g environment. If deviations from the vehicle configuration are proposed in this area, the design and rationale of the crew station will be discussed in detail in the bidder's proposal.

The crew compartment shall be designed to permit removal from the visual display area to permit alignment of the visual system.

6.2.3.1.2 Cockpit Envelopes

The external appearance of the crew station modules need not resemble the flight vehicle. The overall size shall be as small as possible, consistent with economical structural and covering configurations which do not compromise space for equipment installations and cable routing. These modules shall be sectionalized as necessary to satisfy the transportability requirements of para. 6.2.1.1.5. The exterior shall extend only as far as necessary to include the visual effects of the window framing and to enclose the cabling, panel mounted equipment and stowage compartments of the respective stations. In a vertical plane the envelope shall include structure above the overhead panels for the MBCS and the outer frames of the cupola windows for the FBCS. The lower surfaces shall be defined by the structure beneath the lowest floor elevation of the upper deck.

6.2.3.1.3 Lighting

Lighting for each crew station shall duplicate in all respects (fixtures, controls and intensity) that found in the respective sections of the flight vehicle. The effects of lights located remotely from the simulated station envelope shall also be reproduced.

6.2.3.1.4 Interior Fidelity

The interior of the crew stations shall replicate that of the flight vehicle in those areas discernible to the crew members in the performance of their duties. Departures from replication are tolerated in the extension of the stations of the MBCS to accommodate the mission specialist/payload specialist positions although such extensions shall be designed to simulate the continuation of the forward compartment.

The replication shall include, but not be limited to the following:

MBCS

1) L. Console - aft panel
2) L. Console - fwd panel
3) Main Instrument Panel
4) Glareshield
5) Ctr. Pedestal - fwd
6) Ctr. Pedestal - aft
7) R. Console - fwd
8) R. Console - aft
9) Hand Controller - Rot.
10) Hand Controller - Transl.
11) Parking Brake Control
12) O'Hd Eyebrow Panel
13) O'Hd Center Panel

14) O'Hd Aft Panel

15) L. Console - vert. panel

16) R. Console - vert. panel

17) Rudder Control

18) Crew seats (2)

19) Linings

20) Windows & Frames

21) Lights

22) Pedestals

23) Air Cond. outlets

24) Simulated Floor Hatch

25) Mission Specialist Seat

26) Payload Specialist Seat

FBCS

1) All of the forward portion of the MBCS, plus the following equipment located aft of the side console vertical panels.

2) Lining

3) Lights

4) Air Outlets

5) Entrance Hatch

6) Mission Spec. Main Panel - side

7) Mission Spec. Overflow Panel - fwd

8) Mission Spec. Instrum. Panel - aft

9) Payload Monitor Main Panel

10) Payload Monitor Upper Panel

11) Orbit Station Side Console - L.H.

12) Orbit Station Side Console - R.H.

13) Orbit Station TV Receivers (2)

14) Orbit Station Controllers

15) Orbit Station Arm Rests

16) Orbit Station Headrests

17) Orbit Station Windows

18) Orbit Station Side vert. panels.

19) Floor Hatch

20) Crew Seats (2)

21) Payload Monitor Seat Track

6.2.3.1.4.1 Pilot/Commander Seats

The forward crew seats complete with cushions, harnesses, actuators and tracks shall be government furnished equipment. Pyrotechnics shall not be supplied. Controls essential to SMS training shall be fitted with loading devices which permit repeated operation. Position sensing switches shall be installed on all ejection controls to permit monitoring of the sequence of operation. Ejection simulation shall consist of activation of a solenoid operated thumper to provide a physical and audible cue to the crew member.

6.2.3.1.5 Ingress/Egress

Ingress to the crew compartments of the motion base crew station shall be thru a doorway in the aft bulkhead such that a walk-in capability exists with the crew compartment in a level attitude. Provision shall also be made to permit emergency egress when the crew station is in a tilt attitude.

Ingress/egress for the fixed base crew station shall be through a hatch opening configured to that of the spacecraft as viewed from the interior.

All hand-holds, steps, latching controls, decals and warning devices shall be simulated.

6.2.3.1.6 Environment

The crew station environment shall be controllable and capable of producing an environment similar to that prevailing in the actual flight vehicle in order to provide a comfortable training environment. With an ambient temperature of 70°F the heating/air conditioning system shall be capable of producing an ambient temperature of 65°F. to 85°F. in response to the crew station controls.

The ventilation system shall utilize the distribution outlets as they appear in the spacecraft with additional outlets as required to supplement the flow and eliminate hot spots.

6.2.3.1.6.1 Pressure Suit Environment

The simulator shall include provisions for complete crew training with pressure suits of the type worn in the spacecraft. All connections for ventilation, suit pressurization, oxygen and communications shall be made as in the spacecraft. Breathing quality air shall be used for suit ventilation and pressurization. It shall be filtered to exclude particles above .8 microns. The air system shall include the capability of controlling the suit inlet temperature as follows:

| Ambient Temp. | Temp.Control Setting | Suit Inlet Temp. |
|---|---|---|
| $65^oF$ | LOW | $60^oF \pm 5^o$ |
| $80^oF$ | HIGH | $90^oF \pm 5^o$ |

The system shall include provisions to limit the relative humidity of the air to a max. of 50% R.H. It shall be capable of maintaining the suit pressures at 3.5 psig with all suit ventilation controls set at maximum flow.

The system shall include safety relief valve(s) to preclude overpressurization of the suits. A readout of switches, gauges and controls associated with the ECLS systems shall be displayed on the CRT at the IOS as one of the Panel Display Pages. A regulating servo shall limit the rate of suit pressurization to preclude discomfort to the crew.

6.2.3.1.7 Stowage

Stowage provisions shall be included in the simulated crew stations to the extent of simulating appearance and access. The size of the compartments of the MBCS may be reduced to accommodate stowage of items essential to simulator purpose as defined at the mock-up review if such reduction is essential to economical incorporation of the tilt feature.

The stowage compartments of the FBCS shall duplicate those of the vehicle.

6.2.3.1.8 Layout Model

A full scale model of each crew station section shall be constructed prior to the establishment of firm requirements relative to overall layouts. These models shall be as complete as necessary to permit evaluation of the general layout and the installation of the following equipment:

MBCS (positioned on an outline of the motion platform)

a) Mockup of the crew compartment section to show the compartment size and shape
b) Steps, entrance and door
c) Window arrangement
d) Outline model of visual display enclosure
e) Visual display internal panels representing the display size and orientation

f) Crew compartment panels and consoles with prints of panel content

g) Crew seats and pedestals

h) Pedals

i) Hand controllers

j) Instructor Chair

k) Instructor panels

l) Steps and doors

m) Handrails

n) Structural frames as they affect access

o) Location of air conditioning outlets and supplemental lighting as required

p) Location of access panels

q) Location of electrical utility outlets

FBCS (positioned on outline of the raised platform)

a) Mockup of the crew compartment to show size and shape

b) Crew compartment panels and consoles with prints of panel content

c) Crew seats and tracks

d) Orbit station platform, headrest, etc.

e) Orbit station window arrangement

f) Visual display internal panels representing the display size and orientation

g) Outline model of visual display enclosure with support structure

h) Entrance hatch

i) Location of air conditioning outlets and supplemental lighting as required

j) Location of access panels

The models shall be constructed in a manner to be self supporting and need not be capable of supporting loads associated with transportation. Additional supporting framework and bracing may be employed as required, consistent with the goal of economical construction.

The models shall be painted to resemble the proposed color scheme. The additional framing shall be painted of a contrasting color to assist in identification and evaluation of the proposed configuration.

6.2.3.2 Controls & Display Hardware

6.2.3.2.1 General Requirements

The controls and displays associated with the SMS panels shall faithfully duplicate those of the operational equipment in appearance, location, color, action, and reaction to as high a degree as required for crew training. The functions performed by the simulator controls, however, shall generally be different from those in the spacecraft.

6.2.3.2.2 Console/Panel/Component

The controls and display devices contained in the simulator generally need not be constructed to rigid spacecraft environmental specifications. For example, the circuit breakers shall be remotely trippable and activated from the computer by Discrete Digital Bit Outputs rather than by causing a circuit overload, as might be the case in the operational equipment. Simulated controls and displays shall be identical to those of the spacecraft in appearance, feel, and in their functional interface with the men. Panel components shall be wired to connectors mounted on brackets attached to the back of the panels. These connectors shall mate with cables that connect the controls and displays to the DCE via the patch panel unit. Signal wires shall be grouped to minimize crosstalk between analog and digital signals.

6.2.3.2.3 Control Tolerances

All controls shall respond within plus or minus five percent of the corresponding Space Shuttle controls, i.e.:

a) Where a simulated Space Shuttle control is manually actuated against a spring, the spring constant and preload, if any, shall be duplicated in the SMS to within ±5% of the corresponding Space Shuttle control.

b) Where a Space Shuttle control exhibits an inherent or induced damping, such damping coefficient shall be duplicated in the SMS to within ±5% of the corresponding Space Shuttle control.

6.2.3.2.4 Display Tolerances

6.2.3.2.4.1 Analog and Digital Display Response Tolerances

The closed loop response time of analog and digital displays shall be as follows:

a. Shuttle Vehicle analog meters, displays, and indicators which respond to controls having time constants equal to or less than 0.20 second shall have time constants in the simulator of not more than 0.20 second. Shuttle Vehicle analog meters, displays and indicators that have a time constant greater than 0.20 second shall have simulated time constants within plus or minus five percent.

b. Digital indicators, status lights, flag indicators and video displays that respond to controls in less than 0.20 second in the Shuttle Vehicle shall not exceed 0.20 second in the SMS. Indicators which require longer than 0.20 second response shall respond in the simulator within plus or minus five percent of the corresponding Vehicle response.

6.2.3.2.4.2 Meter Display Tolerance

The meter display tolerances shall be as follows:

a. Overall display tolerances shall reflect mechanization error estimates.

b. Unless otherwise specified, all meters in the crew stations and on the IOS shall be plus or minus two percent full scale accuracy instruments.

c. Unless otherwise specified, the IOS repeater meters shall indicate within plus or minus three percent full scale of the corresponding crew station meters. Those displays that require better than three percent match within the normal operating range shall be hand trimmed to achieve the required match.

d. All digital displays that are driven from the digital section of the computer complex shall present exactly the computer data, either in the crew station or the IOS, or both.

6.2.3.2.5 Computer Control

The status of all panel switches and circuit breakers shall be continuously inputted to the computer through the DCE DI's. Panel displays such as caution warning and status light, flag indicators and numerical readouts shall be controlled by discrete digital outputs. The information outputted to the numerical readouts shall be in binary-coded decimal (BCD) form on a set of four lines, with conversion to the seven segment display being accomplished in the display hardware. Variable controls such as speed brakes, rudder pedals, and throttle shall interface with the computer through A/D converters. Instrument shall be computer controlled by D/A outputs.

6.2.3.2.6 Lighting

The SMS panel illumination shall duplicate that of the spacecraft. Necessary supplementary lighting shall be provided for use during service and repair. All panels which are normally electroluminescent in the real world shall be supplied with electroluminescent lighting in the simulator, with the nomenclature on all panels identical with that in the spacecraft.

6.2.3.2.7 CRT Displays

The crew station CRT displays shall operate in the simulator as in the spacecraft.

6.2.3.2.8 Flight Controls

All flight controls shall duplicate the actual spacecraft controls in dynamic feel, size, color and location. Computer controlled forces shall be applied to specific flight controls, when applicable.

### 6.2.4 Instructor-Operator Stations

Two IOS's shall be provided for the SMS. One station shall operate with the motion-based simulator; the other, with the fixed-base simulator. The IOS's shall be located outside the simulated cabin, and in close proximity to it. In addition to the two IOS's, a capability shall be provided for an instructor to observe the trainee's activity within the cabin of the motion-based simulator.

The IOS for the motion-based simulator shall permit monitoring of training exercises for all phases of flight except docking and payload handling. The fixed-base IOS shall accommodate instruction for all phases of the mission. The motion-based simulator would be used primarily to train the Commander and Pilot. It would also be used to train the Mission Specialist and Payload Specialist, but only in those duties required to assist the Commander and Pilot. The fixed-base simulator shall provide training associated with the entire crew cabin.

General Requirements

The IOS shall provide the instructors and operators a location from which to control the overall SMS operations and monitor flight crew performance. To accomplish these functions, the IOS shall:

a. Function as a master control for SMS training operations.

b. Provide all display data and present status of control available to the astronauts.

c. Provide supplemental displays of the Simulator Systems Status (i.e., SCC, DCE, etc.).

d. Provide a means to introduce malfunctions into and remove malfunctions from the SMS subsystem simulation programs.

e. Provide recording devices.

f. Provide instructor-operator capability to control voice communications with the astronauts.

g. Provide necessary controls to simulate inputs and/or commands from other space vehicles and/or ground control.

h. Provide readout of any data in digital storage via CRT type display.

i. Provide separate capability to monitor subsystem parameters existing on interface data streams.

j. Provide separate capability to introduce and clear telemetry faults.

k. Provide capability to monitor faulted and true values of telemetry.

l. Provide a TV monitor for the visual and TV displays available to the crew.

The fixed-and motion-based IOS's shall be located external to the crew station modules and as near as possible to provide optimum interface with the trainees.

The IOS console shall consist of vertical or inclined panels containing all controls, indicators, displays, recorders, instruments, lights and any other equipment necessary to set up, control and monitor the simulator training mission. As a minimum the instruments and the indicators specified herein shall be installed to permit convenient monitoring of the trainee by the instructor. Controls shall be provided to permit convenient control of the training situation by the instructor.

The IOS components shall be physically arranged to provide the instructor with the capability to monitor the trainees' activities. The display arrangement shall permit the instructor to completely control the mission and to evaluate the trainees' performance. The monitoring, controlling, and evaluating functions shall be accomplished through the use of both dedicated and multiplexed displays.

6.2.4.1 Motion-Based Simulator IOS

The IOS for the motion based simulator shall contain the necessary displays and controls to permit the instructor to monitor all training exercises associated with all phases of the SSV mission except docking and payload operations. The IOS shall be designed to be manned by two instructors; one for the Commander and one for the Pilot. When training is being conducted for one crew member, only one instructor shall be required to man the console.

In addition to the console, the IOS shall include:

a. One X-Y Recorder

b. Three eight-channel time history X-T recorders.

c. Two castered, fully adjustable, swivel armchairs.

d. One hard copy device

The instructor-operator console shall integrate five CRT display units, keyboard units, two visual system monitors, dedicated displays, a control panel used for functions not accomplished with the keyboard units, and an audio panel to provide the necessary communications functions. A shelf shall provide space for reference materials (manuals, mission plans, etc.) and for writing.

6.2.4.1.1. Dedicated Displays

The following instruments located in the forward crew cabin shall be repeated at the IOS to permit monitoring of the trainee's performance. The instruments shall be grouped in a configuration similar to the arrangement on the vehicle's instrument panel. The dedicated instruments shall be so positioned to provide a reference for both instructors.

a. Caution & Warning Indicators

b. Monitor, Center CRT

c. Monitor, Left-Center CRT

d. Flight Director Attitude Indicator (Commander)

e. Vertical Speed Indicator (Commander)

f. Barometric Pressure Altimeter (Commander)

g. Airspeed/Mach Number Indicator (Commander)

h. Acceleration Indicator (Commander)

i. Horizontal Situation Indicator (Commander)

j. Elapsed Time Meter (Commander)

k. Gimbal Position Indicator

l. Monitor, Right CRT

m. Monitor, Right-Center CRT

n. Flight Director Attitude Indicator (Pilot)

o. Vertical Speed Indicator (Pilot)

p. Barometric Pressure Altimeter (Pilot)

q. Airspeed/Mach Number Indicator (Pilot)

r. Radar Altimeter

s. Acceleration Indicator (Pilot)

t. Horizontal Situation Indicator (Pilot)

u. True Airspeed/Static Air Temperature Indicator

v. Elapsed Time Meter (Pilot)

w. Rudder Position Indicator

x. Elevon Position Indicator

The above repeater instruments shall accurately duplicate the readings or indications of their counterpart located in the crew cabin.

6.2.4.1.2 CRT Display/Keyboard Units

Each instructor position at the IOS shall be provided two CRT display units. In addition, a third CRT shall be located conveniently between the two instructors and shall be primarily used for the Event Time Monitoring function. Also, each instructor shall be provided a monitor on which he can view the visual scene presented to the trainee.

Each CRT shall have the capability of displaying alphanumeric or graphic data at any position of the IOS at the option of the instructor. Each of the five CRT's - two at the Commander instructor station, and two at the Pilot instructor station and the center CRT - shall have access to the same pool of CRT pages and shall be selected by the keyboard unit located at each instructor position. The CRT's shall operate independently but in parallel so that any available data can be shown on any CRT and any control action can be accomplished with any keyboard. The CRT display control shall enable an instructor to obtain a desired display and execute a given control action by depressing a limited number of keys.

The following CRT pages shall be provided:

a. Event Time Monitor

b. Panel Displays (excluding those provided by dedicated displays).

c. Energy Management Predictor.

d. Malfunction Insertion and Display.

e. Circuit Breaker Status

f. Crew Station Set-up Verification

g. Active Malfunctions and Tripped Circuit Breakers

h. Mission Parameters and Summary Display

i. Interface Data Stream and Telemetry Monitoring

j. Enroute and Approach Displays

k. System Schematic Displays

l. Programmed Demonstration

m. Training Exercise Display

n. Performance Monitor Display

o. External Environment

Each of the display categories shall be identified by a one or two character mnemonic. The first character being a letter to identify the category (e.g., E = Energy Management Predictor), and the second character - where there is more than one page in the category - denoting the page within the category.

The top line of the CRT shall always contain the following items:

a. A one-or two-character display mnemonic identifying the display.

b. Symbols indicating the ground station in contact with the vehicle; if none are in contact, LOS (Loss of Signal) is displayed.

c. Mission elapsed time (MET).

d. Simulated Greenwich mean time (GMT).

The space to the left of MET shall be used for a flashing display of mnemonics of the system page(s) in which astronaut activity has occurred during the previous five seconds. It shall be used as a signal to call up a system page, or to look at the Event Time Monitor display. The displays shall indicate the simulated time consisting of three digits for days and two digits each for hours, minutes, and seconds.

The CRT display system shall provide a minimum usable horizontal and vertical display size of 12 and 16 inches respectively. The system shall be capable of displaying 80 minimum small characters (0.17 inch) per horizontal line including spaces. A minimum of 60 lines of characters shall be displayed on a page. The capability of selecting two colors shall be provided. The display system shall also be capable of presenting alphanumerics, graphics, symbols, vectors and circles. The capability of presenting lines and circles in dot, dash, dot-dash, and as solid lines shall be provided. Provisions shall also be made for vectors and symbols to blink. The display shall also be rotatable, with the controls associated with image rotation being located at the IOS.

6.2.4.1.2.1 <u>Event Time Monitor</u>

A CRT located between the two instructors shall be used primarily for the Event Time Monitoring function. The display shall provide a chronological display of the most recent crew actions. Each of these lines shall contain the following data:

a. The name of the control manipulated.

b. The action taken. For a momentary switch, the new position shall be displayed; for a momentary switch, or continuous control, the direction of the most recent motion would be shown.

c. The time at which the action occurred.

d. The mnemonic of the system page involved.

The most recent crew action shall be displayed on the top line of the CRT. As the next action takes place, it will occupy the first line, and the previous action will occupy the second line. When the CRT page is filled, a new crew action shall cause the last line to be dropped.

6.2.4.1.2.2 Panel Displays

Panel displays shall be repeaters of spacecraft control positions and displays and also provide the functions of parameter override (reference paragraph 6.2.4.1.2.2.1) and parallel switch operation (reference paragraph 6.2.4.1.2.2.2). The repeater function shall enable the instructor to monitor trainee activities and to observe the reaction of the crew in rectifying errors and malfunctions and in performing their mission tasks.

Panel displays shall be categorized according to the major vehicle panels. Each category shall contain one or more display pages. Pages shall present to the instructor a display of the control and indicator positions presented in the cabin. Controls shall be displayed as follows:

a. Continuous Controls - This type of control shall be displayed as a vertical rectangle. The scale shall be located within the rectangle representing the range of the control. An index, This page intentionally left blank.

also located within the rectangle shall represent the indication of the control. The control shall be identified by its name.

b. Continuous Displays. This type of control shall be displayed the same as continuous controls.

c. Switches - A tabular listing of system switches shall be displayed. The listing shall include the switch name and all available switch positions. The symbol □ shall be placed to the left of the switch position prevailing in the vehicle; an asterisk (*) shall be placed to the left of the position selected by the instructor for parallel switch operation, or, in the case of display selecting switches for parameter display override.

d. Digital Displays - Those displays shall be presented in the same manner as in the vehicle. Commas, decimal points, and other symbols (e.g., N,S,E,W,+,-) shall be appropriately displayed.

e. Quasi Digital Displays (Flags) - Displays of this type shall be accomplished by a colored symbol.

6.2.4.1.2.2.1 Parallel Switch Operation

Provisions shall be made for parallel switch operation which will allow the instructor to override the position of switches in the crew station. However, the most recent command shall take precedence.

6.2.4.1.2.2.2 Parameter Display Override

Parameter display override controls shall be located at the IOS. These override controls shall provide a reading of the applicable parameter at the IOS only. The parameter display override shall be usable in two different ways: (1) to view a display selected by a switch position other than the one present in the Shuttle Vehicle, and (2) to view the true value of a malfunctioned display. When no override is commanded by the override control, the applicable IOS display shall repeat the same parameter and value as the appropriate crew station instrument.

6.2.4.1.2.3 Energy Management Predictor Display

This page shall provide a graphic display of the critical parameters associated with energy management. The display shall contain a symbol indicating the vehicles current state, and a second symbol which shall predict the vehicles future state. Predicted values of energy management parameters will be displayed in 30 second increments.

6.2.4.1.2.4. Malfunction Insertion and Display

This feature shall provide the instructor with the capability of entering malfunctions into any subsystem of the SSV and faults into the telemetry. Provisions shall be made for both automatic and manual insertion of malfunctions. Automatic insertion of malfunctions shall be a feature of the preprogrammed training exercises and shall require no action on the part of the instructor. The conditions for automatic malfunction insertion will be specifiable in terms of simulator/trainee events as well as in terms of time into mission.

Malfunctions shall be grouped on pages by system. The display page shall contain a mix of discrete and variable malfunctions, one malfunction per line. For a variable malfunction, the range and units shall be provided. The instructor shall be required to insert the desired value of the malfunction to be inserted. Provisions shall also be made for changing the value of a variable malfunction already in the simulator. Control of variable malfunctions shall be handled by means of the keyboard unit. Provisions shall be made to provide the instructor with a visual reference of the malfunctions (faults) which have been inserted into the simulator.

When automatic malfunction is in operation, the instructor shall have the capability of overriding a previously programmed malfunction whether it be active or programmed for future insertion.

6.2.4.1.2.5 Circuit Breaker Status

Tabular displays, organized by system or panel, or circuit breaker status, shall indicate for each circuit breaker its status: normal, permanently failed, or open.

The status of any circuit breaker shall be changed to permanently failed or temporarily failed by use of this display. Circuit breaker controls at the IOS shall enable the instructor the capability to include the following:

a. Permanently fail a circuit breaker.

b. Temporarily fail a circuit breaker.

c. Change from permanently failed to temporarily failed.

d. Change from temporarily failed to permanently failed.

Circuit breakers shall be displayed by panels. In some instances, it may be necessary to display a panel of circuit breakers on more than one page. Panels containing a limited number of circuit breakers may be grouped by panel on a single page.

6.2.4.1.2.6 Crew Station Setup Verification Display

The capability for the instructor to rapidly verify the proper position of crew station controls prior to initiating an exercise by displaying the difference between desired and actual positions of controls or a comparison of desired and actual shall be provided. In addition, the equipment status displays shall provide for a rapid and gross verification of correct operation and operational status of all SMS components and subsystems.

This display shall contain three columns headed "Control", "Desired Position", and "Actual Position". The names of up to (number TBD) controls whose desired and actual positions differ shall be displayed along with the desired and actual positions. The display shall be automatically called up when the simulator is reset to one of the reset points. The page shall remain displayed until the necessary corrections are made or overrided by the instructor.

6.2.4.1.2.7 Active Malfunctions and Tripped Circuit Breakers

This display shall provide, in one place, a listing of all active malfunctions and tripped circuit breakers. The instructor shall be able to clear malfunctions individually or simultaneously.

This display shall contain a listing of all the malfunctions, discrete or variable inserted into the simulator. The list shall also contain all tripped circuit breakers: those permanently failed by the instructor, and those temporarily failed. The instructor shall be able to delete a malfunction or modify a variable malfunction with this display in the same manner as the regular malfunction display, but he shall not be able to insert a malfunction with it. The instructor shall be able to change the status of a previously failed circuit breakers from permanently failed to temporarily failed and vice versa. Provisions shall be made to remove all active malfunctions simultaneously.

6.2.4.1.2.8 Mission Parameters and Summary Display

This display shall provide a summary of critical mission parameters. The parameters to be displayed shall be capable of being changed for different mission phases. The display shall provide:

a. Summary of up to (number TBD) critical parameters during a given phase of the mission. The format of the display shall be: each line shall contain the name of the parameter, its value, and the units in which the value is expressed. Mission parameters shall be categorized by mission phase which begins at one of the reset points provided. As the mission progresses, parameters shall be changed accordingly.

6.2.4.1.2.9 Interface Data Stream and Telemetry Monitoring

This display shall permit the values of any interface data stream telemetry subsystem parameters to be monitored. Telemetry faults can be inserted into any channel and both faulted and true values can be monitored. The CRT pages used for interface data stream shall be organized as follows:

a. Uplink Command Input

b. Uplink Command Summary

c. Telemetry Monitoring

d. Telemetry Malfunction Insertion

e. Interface Buffer Monitor

6.2.4.1.2.9.1 Uplink Command Input Page (UCIP)

This page shall provide the capability for an instructor to insert uplink commands into the training exercise while the simulator is running independently, or integrated with MCC. The command entries into the CRT shall be designed in such a manner to be compatible with the mission uplink command documentation. The page shall be formatted in such a manner that all entries required for the various types of commands are displayed on the page shall be line selectable. The format, units, and number of characters required for each entry shall be defined in the display format.

The last command entered for each type command shall be displayed in the input field. This display shall appear on all UCI pages which are being displayed on CRT's regardless of the one from which the command originated.

An error message shall be generated for illegal entries and remain for a period of ten seconds.

An override capability shall be provided to enable commands from the IOS to be processed regardless of the power configuration and/or signal strengths. The instructor shall be able to select or cancel the override by line input. Incorrect or garbled commands shall be displayed in a different format, e.g., hexidecimal.

6.2.4.1.2.9.2 Uplink Command Summary Page

A command summary page shall be provided which will display for each command entered during a training session the following data:

a. The code name for the command.

b. Status of the command (e.g., executed, ignored, in-process).

c. The vehicle up-link system, if redundant or multiple units are on-board, to which the command was addressed.

d. Originator of the command (MCC, UCIP or any other system capable of inserting uplink commands).

e. The GMT that the command was received in the simulated vehicle.

Incorrect or garbled commands shall be displayed in a different code format, e.g., hexidecimal.

All commands shall be recorded and available for display on the Uplink Command Summary page regardless of whether the page is active on the CRT at the time the command(s) were entered.

6.2.4.1.2.9.3 Telemetry Monitoring Page

Sequential pages shall be provided which will display and monitor all telemetry parameters organized by SSV systems. The telemetry data displayed shall repeat the parameter values which are being transmitted to the down-link equipment by the simulated vehicle system programs as modified by the malfunctions inserted in the bit stream pattern through the Telemetry Malfunction Page. The parameters shall be identified by their TM number and descriptive engineering terminology. The values of analog parameters shall be displayed in terms of engineering units used by the simulator programs, i.e., degrees - Rankine, volts, amps, pounds per square inch, etc. The values of discrete parameters shall be displayed as on/off, 1 or 0, primary or secondary, etc.

6.2.4.1.2.9.4 Telemetry Malfunction Insertion Page

This page shall enable the instructor to insert up to TBD malfunctions into the telemetry down-link data. This page shall be formatted in such a manner that each malfunction entered is tabulated in the order of insertion, and the following data associated with each malfunction measurement is displayed.

a. Telemetry measurement number.
b. Actual value (in engineering units)
c. Failed value
d. Type of malfunction
e. Malfunction value

The types of malfunctions which may be entered are as follows:

a. Static integer/discrete
b. Static bit pattern
c. Drift malfunction
d. Offset malfunction
e. Fixed value malfunction

The instructor entries shall be designed so that the allowable and required entries are annotated on the scratch pad line. Error messages shall be provided to inform the instructor of illegal operations.

6.2.4.1.2.9.5 Interface Buffer Monitor

Display Page(s) shall be provided to monitor the interface data in the transmitted and received format prior to being decoded for inputs and after packing and formatting for transmissions.

6.2.4.1.2.10 Enroute and Approach Display

The enroute and approach display shall provide the following types of horizontal and/or vertical profile flight paths depending on the mode of operation:

a. Enroute Display

b. Approach Display

c. Demonstration Maneuver Display

The display shall automatically switch to or from the approach mode when the vehicle position crosses a predetermined boundary for a selected approach area. The display shall portray a solid line plot denoting the programmed mission or maneuver and a dashed line shall represent the vehicle's path with an aircraft symbol representing the trainee's instantaneous position.

6.2.4.1.2.10.1 Enroute Mode

The enroute mode shall provide the instructor with a graphic presentation of the vehicle's flight path in relation to the desired flight path. This graphic presentation shall be provided for missions involving space operation as well as atmospheric (Ferry) flights. For space operation, the display shall present the actual orbit versus the desired orbit of the vehicle. During the rendezvous phase of the mission, the display shall provide the instructor with a graphic representation of the relative position of the target and the SSV together with the required parameters to effect a rendezvous. The instructor shall be provided with the necessary controls to rotate the display to provide the optimum viewing angle of the display.

For Ferry missions, the instructor shall be presented a graphic display of the vehicle's ground track compared with the desired ground track. The ground track of the course flown shall be corrected for map distortion. The display shall provide a graphic representation in terms of circles, call letters and channel or frequency of all surface facilities within the area of display.

The enroute mode shall operate at continuously variable scales from 1 inch equals 10 nautical miles to 1 inch equals 50 nautical miles as selected from the instructor's control panel. The control shall be graduated in 0.1 nautical mile increments and incorporate a positive lock to prevent inadvertant movement.

6.2.4.1.2.10.2 Approach Mode

The approach mode shall present a magnified display of the course flown in the approach area with respect to a simulated navigation facility normally located at the center of the chart. In this mode the recorder shall operate at varying scales from 1 inch equals 0.2 nautical mile, to 1 inch equals 10 nautical miles as selected by the instructor-operator's control. The control shall be graduated in 0.1 nautical mile increments, and incorporate a positive lock to prevent inadvertent movement. In the approach mode, radial lines and distance circles shall be visible on the display surface. These radial lines and distance circles shall be either projected or etched on the surface. The location of the area covered by the display system shall be determined by selection of any of the ILS Localizer, GCA, or

VOR approach facilities. When the simulator comes within the predetermined range of a selected navigational facility, the display system shall automatically switch to the approach mode and shift the selected facility to the center of the approach display. Dotted lines, aircraft symbols and solid lines shall be displayed as described above.

As the vehicle approaches to within ten miles from the airport the display shall automatically switch to a terminal mode. In this mode a split screen display shall be presented. The upper portion of the display shall provide an elevation versus range to touchdown point along an axis representing ten miles in length; the lower portion of the display shall present azimuth versus range to touchdown point. The displayed runway heading and glideslope shall be defined by the surface facility selected by the instructor.

6.2.4.1.2.10.3 Demonstration Maneuver Display

When a demonstration maneuver is selected, the mission display shall automatically display the flight path of the preprogrammed maneuver. Two separate plots shall be provided, one for the horizontal projection of the maneuver, and one for the vertical projection of the maneuver. As in the previous displays, the programmed maneuver shall be displayed as a solid line, and dotted lines with an aircraft symbol shall depict the trainee's position.

6.2.4.1.2.11 Systems Schematic Displays

Schematic displays shall be provided of the vehicle's systems. These displays shall be in sufficient detail for the instructor to analyze malfunctions which have been inserted into the training exercise. In addition, the display shall also provide a visual aid for instructional purposes.

6.2.4.1.2.12 Programmed Demonstration Displays

These displays shall contain a number of preprogrammed displays associated with the SSV missions. In this mode, the simulator shall fly the selected maneuver in an ideal manner. The system shall provide an additional submode in which the trainee can fly the same maneuver and be compared with the ideal demonstration. During the demonstration, the appropriate controls and indicators shall be driven as required to execute the maneuver. For each demonstration maneuver, data stored in the computer shall define:

a. Initial conditions

b. Demand parameter values for each part of a demonstration maneuver.

c. Demand rates of change for each part of a demonstration maneuver.

d. Parameter and value which will define termination of a demonstration maneuver.

Provisions shall be made for the instructor to retain the demonstration for future critique purposes or erasing the demonstration. The instructor shall be provided an indication of the recording time remaining, of the eight hours available, and the number of segments recorded. Provisions shall also be made to inform the instructor of any unsafe condition in the vehicle's configuration for the next segment of the training exercise.

6.2.4.1.2.13 Training Exercise Display

This display shall provide the instructor with a chronological listing of events which comprise a training exercise. A sufficient number of training exercises shall be provided with the delivery of the simulator to demonstrate this feature to the customer. In addition to providing a chronological listing of events, the display shall contain parameters and parameter tolerances which should be monitored by the instructor and any special instructions required.

The format of the page shall be displayed as follows:

a. Mission elapsed time

b. Event

c. Monitor

d. Remarks

Provisions shall be made for the instructor to retain the demonstration for future critique purposes or erasing the demonstration. The instructor shall be provided an indication of the recording time remaining, of the eight hours available, and the number of segments recorded. Provisions shall also be made to inform the instructor of any unsafe condition in the vehicle's configuration for the next segment of the training exercise.

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The format of the page shall be displayed as follows:

a. Mission elapsed time

b. Event

c. Monitor

d. Remarks

The instructor shall be provided the capability of making changes in the training exercise during the exercise. It shall not be necessary for an instructor to be knowledgeable about computer programming in order to prepare and insert programming statements. The preprogramming software shall enable the instructor to accomplish at least the following functions:

a. Determine the time in the mission when an event will occur.

b. Describe the event.

c. If desired, specify any malfunctions that should be automatically inserted during any of the tasks in the training exercise.

d. Identify those parameters to be monitored during a mission event.

e. Identify those demonstrations to be used in the training exercise and specify when they shall be replayed.

f. Specify standards or criteria for any simulator-variable profile on any of the tasks.

g. Monitor, display and record any performance information that is resident in the computer.

6.2.4.1.2.14 Performance Monitoring Display

This display shall provide the instructor with a tabular listing of all information relative to out of tolerance parameters. The display shall contain the following information:

a. The names of all parameters on which tolerances have been exceeded.

b. Allowable tolerance.

c. Percentage of time out of tolerance.

d. Maximum deviation and time of occurance.

For preprogrammed missions, the performance monitoring parameters shall be selected as part of the preprogrammed requirements. The instructor shall also be provided the capability of monitoring parameters on-line. Parameters requested on-line shall be categorized by mission phase and system.

To demonstrate the on-line request capabilities of the system, the contractor shall deliver the Performance Monitoring Display pages for the launch, on-orbit, and entry mission phases, and the Environmental Control System. For preprogrammed missions, the Performance Monitoring Display pages associated with the deliverable preprogrammed missions shall be provided.

Provisions shall be made for the instructor to request hard copy of the Performance Monitoring Display as well as a print-out rate if desired. Selectable printout rates shall be: every 5 seconds, every 30 seconds, every minute, or every two minutes.

6.2.4.1.2.15 External Environment Page

This page shall provide the capability for the instructor to insert or change the following environmental parameters:

a. Wind direction and speed

b. Altimeter setting

c. Outside air temperature

d. Rough air intensity

e. Cloud base and top

f. Visibility

6.2.4.1.2.15.1 Wind Direction and Speed

It shall be possible for the instructor to introduce any wind speed from 0 to 200 knots and any wind direction through 360 degrees. The wind velocity applied shall affect the course flown and shall produce a correct drift angle and a correct ground speed effect within the tolerances specified herein. Takeoff characteristics, aerodynamic characteristics, and build-up/drop-off rate for airspeed shall properly reflect the aircraft performance when the aircraft is subject to the same environment.

6.2.4.1.2.15.2 Altimeter Setting

The instructor shall be able to adjust altitude system to reflect any barometric pressure setting value from 28 through 32 inches of mercury in increments of 0.01 inch. Adjustment of the altimeter setting control shall affect the indicated altitude according to standard pressure altitude relationship charts. Setting of the flight compartment altimeter to correspond to that selected by the instructor-operator, the indicated altitude shall correspond to the selected field elevation $\pm 20$ feet when the simulator is on the ground.

6.2.4.1.2.15.3 Outside Air Temperature

Outside air temperature shall vary automatically with altitude to simulate the appropriate effect on performance. The instructor shall be able to vary the outside air temperature from $-50^{\circ}C$ to $+50^{\circ}C$. Variation from normal shall appropriately affect engine thrust and takeoff characteristics. Installation and compressibility errors shall be included.

6.2.4.1.2.15.4 Rough Air Intensity

The instructor shall be able to control the intensity of simulated rough air conditions. Rough air shall be entered through numerical values ranging from 0 (calm) through 10 (intense) in single digits. The effects of rough air introduced shall appropriately be reflected in affecting instruments, controls, visual and motion systems. The rough air control shall be functional at all airspeeds associated with atmospheric flight.

6.2.4.1.2.15.5 Cloud Base and Top

The instructor shall be provided the capability of determining the base and top of the cloud layer in the visual scene. The base of the cloud layer shall be variable from 100 ft. to 50,000 ft., tops from 2000 ft. to 60,000 ft.

6.2.4.1.2.15.6 Visibility

The instructor shall be able to introduce visibility into the visual scene. The visibility shall be variable from 0 nautical miles to 55 nautical miles in any increment.

6.2.4.1.3 Simulator Control and Display

Control of the simulator shall be from the IOS. The instructor shall be provided controls at his console for those functions not accomplished through the CRT display system. Since the IOS will be manned by one or two instructors depending on the training exercise, sufficient controls shall be available for either instructor to conduct a training exercise from his position. Controls and displays shall include the following functions:

a. Simulator Status
b. Operate Controls
c. Hand Controller Indicator
d. Inflight Refueling
e. IFF Transponder
f. Record/Playback
g. Communications Control
h. Lighting/Sound Controls
i. Graphic Control
j. Monitor Select
k. ILS/GCA Monitor
l. Console Speaker

6.2.4.1.3.1 Simulator Status

The instructor shall be provided a visual indication from which he can determine the status of the simulator and its associated subsystems. Status of the following subsystems shall be included: visual, power, DCE, computer, and motion. Indicators shall be provided to alert the instructor when maintenance is in progress. Lights shall also indicate when a subsystem is ready for simulator operation to commence. Indicators shall be provided to denote that the visual scene for a vehicle window is ready to be portrayed. The status of the visual system image generators shall also be displayed.

6.2.4.1.3.2 Operate Controls

Sufficient controls and indicators shall be provided to permit safe operation of the simulator. Controls shall be provided for operation of the simulator itself, the motion system and control loading system, and the visual system. Simulator controls shall be provided to operate the simulator at various speeds (normal, 1/2, 1/10, 1/20 speed). Controls shall also be provided which permits MCC to be integrated into the training exercise. An emergency stop switch appropriately identified, shall be provided which will remove all primary power from the simulator, and return the motion system, if it is activated, to a stowed position. The following special function controls shall also be included:

a. Automatic Freeze Disable

b. Freeze

c. Reset

d. Write-Reset

e. Step-Ahead

f. Safe-Store

6.2.4.1.3.2.1 Automatic Freeze Disable Control

This control when activated shall cause the simulator to be stopped automatically when defined simulator conditions have been exceeded. Parameters which have been exceeded shall be displayed on the CRT.

6.2.4.1.3.2.2 Freeze Control

Activation of this control shall cause the computer to enter the freeze mode. In this mode, integration and time varying functions shall be held constant.

6.2.4.1.3.2.3 Reset Control

Upon initiating a reset, the simulator should be initialized to a specific set of initial conditions. These conditions should be such that from reset the consumables, switch positions, on-board computer modes, and trajectory characteristics are representative of the mission planning documentation. Reset conditions shall be displayed on the CRT and the instructor shall have the option of changing parameters through the CRT keyboard.

6.2.4.1.3.2.4 Write-Reset Control

This control shall provide the capability to store, at instructor option, without interrupting the real time simulation, those values in memory which are required to reinitialize the simulator back to this point.

6.2.4.1.3.2.5 Step-Ahead Control

This control shall provide the capability to advance or retard the mission a preselected increment of time which is entered into the keyboard by the instructor. During this mode, the computer shall execute the required programs at least 40 times faster than real time.

6.2.4.1.3.2.6 Safe-Store Control

This control shall cause the simulator to periodically store, at least once every minute, without interferring with real-time simulation, those values in memory which are required to subsequently reinitialize the simulator back to this point. Sufficient safe store points shall be provided to cover a period of eight hours.

6.2.4.1.3.2.7 Motion System Controls

Operational control of the motion system shall be from the IOS. The following controls shall be provided:

a. Motion Ready Indicator

b. Motion ON-OFF

c. Control Loading ON-OFF

d. Tilt Control

6.2.4.1.3.2.8 Visual Control

The following controls shall be provided on the console to permit control of the visual system by the instructor.

a. "READY" light

b. "OPERATE" switch

Provisions for establishing the time of day of the visual scene, control of the visibility level of the visual scene, and the cloud content (cloud base and height) will be through the keyboard unit.

6.2.4.1.3.3 Hand Controller Indicator

The hand controller indicator shall consist of a series of tell-tale lights which will inform the instructor of hand controller activity. Three lights shall be provided to indicate the location at which the hand controller is being operated; Commander, Pilot, Orbital Maneuvering Station. Eight tell-tale lights shall indicate the following position of the translational hand controller: up, down, clockwise, counter-clockwise, forward, aft, left, and right. Directions of the rotational hand controller shall be displayed by the following six lights: positive pitch, negative pitch, positive yaw, negative yaw, positive roll, and negative roll.

6.2.4.1.3.4 In-Flight Refueling

In-flight refueling is associated with the Ferry phase of the SSV mission. The in-flight refueling phase of this mission will be simulated to a limited extent. Only the effects of on-loading fuel from the tanker will be part of the simulator program (e.g., increase in the fuel quantity guages for the ABES at a constant rate, change in the vehicle's CG as the fuel load increases). The instructor shall be provided an ON-OFF switch for controlling the inflight refueling program. A fuel quantity indicator shall also be provided to inform the instructor of the progress of the refueling operation.

6.2.4.1.3.5 IFF Transponder

The instructor shall be provided with the necessary indicators to appraise him of the position of switches and the code identifier inserted into the IFF panel in the simulator cabin. The numerical identification code to which the transponder is tuned shall be read out on the code identifier. Indicator lights shall be provided to indicate activation of the following switches:

a. Standby
b. Low sensitivity
c. Normal sensitivity
d. Emergency
e. Identification
f. Mode 3A ON
g. Microphone ON

6.2.4.1.3.6 Record/Playback

These controls, in conjunction with the keyboard, are used to record the trainee's performance and play it back at a subsequent time. The following controls shall be located at the IOS:

a. Operate
b. Record
c. Manual
d. Demonstrate
e. Playback
f. Stop

6.2.4.1.3.7 Communications Control

Each instructor shall be provided with a voice communication terminal which shall allow selective voice communication within the SMS complex as well as with facilities related to an integrated simulation. The instructor may select either simulated links, or select simulator-peculiar supplementary loops which shall provide direct communications with the crew station modules. The major functions of the communication control are:

a. Provide conference capability among the various operational positions of the simulator complex.

b. Provide communications between the crew station and instructors through simulated and non-simulated loops.

c. Provide communications between the simulator complex, MCC, and Mission Control Center Simulation Facility (MCCSF).

d. Provide communications between simulator instructors and the various support personnel. This shall include a network between the instructor and the various stations within the simulator complex, e.g., computer room, visual room, hydraulic room. Within the computer room, stations shall be provided at each major cabinet area.

Two loops which have no real-world counterparts, and are completely independent of software control, shall provide supplementary voice communications between the instructors and the crew station. One loop shall connect the IOS positions to the crew station modules independently of the MCCSF console communication system. It shall be selected by the instructor on an individual basis and shall require only simulator power in order to be "hot". The other loop shall be the astronaut loop and shall differ from the previous loop in the following ways:

a. Audio Select switch must be in the CCS position.

b. Selection is made by way of the CCS keyset.

c. Provides service to the MCCSF area as well as the IOS.

d. Require active CCS as well as simulator power.

6.2.4.1.3.8 Lighting/Sound Controls

Controls shall be provided at the IOS for the simulated sound, and the lighting of the instructor's console. Operation of the sound system shall be through an ON-OFF switch and a control for the intensity of the sound. The control panel lighting shall be varied through two controls; one for the intensity of the panel lights, and one for the intensity of the indicator lights. A capability shall be provided for testing the indicator lamps for operability. A lamp test shall be provided for each position at console, i.e., Commander instructor, and Pilot instructor.

6.2.4.1.3.9 Graphic Control

These controls provide the instructor with the capability to control the presentation on the graphic display or visual monitor. Control is also provided for manually changing from the enroute mode to the approach mode or vice versa, and varying the scale of the display being presented. Provisions shall also be made for selecting the center of the presentation from aircraft oriented to airport oriented. The following controls shall be provided as a minimum:

a. Enroute

b. Approach

c. Longitudinal Axis

d. Vertical Axis

e. Lateral Axis

f. Clockwise

g. Counterclockwise

h. Chart Scale

i. Airport Chart Select

j. Aircraft Chart Center

k. Airport Chart Center

6.2.4.1.3.10 Monitor Select

Provisions shall be made for the instructor to monitor the visual scene as portrayed at the various crew positions. Tell-tale lights shall illuminate when a visual scene is present in any of the crew position windows. The following controls shall be provided for the instructor to select the visual scene he wishes to view on the visual monitor located on his console:

a. Left side window

b. Left quarter window

c. Left forward window

d. Right forward window

e. Right quarter window

f. Right side window

6.2.4.1.3.11 ILS/GCA Monitor

Indicators and controls shall be provided for the instructor to monitor the approach and landing or to act as a ground controller on a GCA landing. The following shall be provided for the instructor to perform these functions:

a. Glide slope deviation indicator

b. Localizer deviation indicator

c. Range indicator

d. Heading indicator

e. Airspeed indicator

f. Localizer expanded scale

g. Glide slope expanded scale

h. Landing aid frequency control

6.2.4.1.3.12 Console Speaker

A speaker shall be located at the IOS. The necessary controls shall be provided to activate the speaker, and to control the intensity of the volume.

6.2.4.1.4 In-Cockpit Instructor Station

Provisions shall be made for an instructor station within the crew cabin of the motion-base simulator. This station will be occupied when the Mission Specialist and Payload Specialist's seats are not occupied. The instructor seat shall be portable and installed prior to a mission requiring an on-board instructor. Fittings shall be provided in the simulator to permit the installation and removal of the seat with a minimum effort and within a short period of time. The seat shall be located in the forward crew cabin, just aft of the center console.

Sufficient controls and indicators shall be provided to permit safe operation of the simulator. Controls shall be provided for operation of the simulator itself, the motion system and control loading system, and the visual system. Simulator controls shall be provided to operate the simulator at various speeds (normal, 1/2, 1/10, 1/20 speed). Controls shall also be provided which permits MCC to be integrated into the training exercise. An emergency stop switch, appropriately identified, shall be provided which will remove all primary power from the simulator, and return the motion system, if activated, to a stowed position. The simulator shall automatically be stopped when any of the preselected simulator parameters are exceeded. The instructor shall be provided an indicator to inform him that the simulator has been stopped for this reason. **The instructor shall be provided the capability of inserting any one of the 20 reset points from this position.**

6.2.4.1.5 Telemetry Operator Station

The Telemetry Operator Station serves to incorporate uplink commands and telemetry data into the training exercise. One Telemetry Operator Station shall be provided to serve both the fixed-base and the motion-base simulators. One operator shall be required at this station. This station shall consist of a CRT, a keyboard unit, and a communications control panel. A shelf of sufficient size shall be provided at this station for reference material and for writing.

6.2.4.1.5.1 CRT Display/Keyboard Unit

The CRT display/keyboard unit shall furnish the Telemetry Station operator with the necessary displays and controls to monitor mission performance and entering all data associated with the telemetry and interface data function. The CRT shall be capable of providing both alphanumeric and graphic data. Operation of the display keyboard unit shall be as described in 6.2.4.1.2, and the same keyboard action shall be used to select a display or modify a value stored in the computer. The top line of the CRT shall always contain the following data:

a. A one-or-two character display mnemonic identifying the display.

b. Symbols indicating the ground station in contact with the vehicle. If none are in contact, LOS shall be displayed

c. Mission elapsed time

d. Simulated Greenwich mean time

The following CRT pages, identical to those available at the Commander-Pilot IOS, shall be provided at the Telemetry Operator station. The telemetry operator shall be able to call up a page independent of the action at any other IOS.

a. Event Time Monitor

b. Panel Displays

c. Energy Management Predictor

d. Malfunction Insertion and Display

e. Circuit Breaker Status

f. Crew Station Setup Verification

g. Active Malfunctions and Tripped Circuit Breakers

h. Mission Parameters and Summary Display

i. Interface Data Stream and Telemetry Monitoring

j. Enroute and Approach Display

k. System Schematic Displays

l. Programmed Demonstration

m. Training Exercise Display

n. Performance Monitor Display

o. Environmental Control

A description of the above displays is contained in 6.2.4.1.2.

6.2.4.1.5.2 Station Controls

The Telemetry Operator Station will contain no controls associated with the operation of the simulator. A communications control shall be provided for the necessary communications with the trainee(s), other instructors and other personnel in support of the training exercise.

6.2.4.2 Fixed-Base Simulator IOS Complex

The fixed-base simulator IOS shall consist of five positions arranged into a composite station. Because of the number of instructors involved, the IOS complex shall be designed in modular form. One module shall consist of the Commander-Pilot IOS, a second module shall comprise the OMS IOS. This module shall be located adjacent to the Commander position of the Commander-Pilot IOS. The instructor assigned to the Commander will also operate this station. Located opposite the Commander-Pilot IOS, with the instructors of the two groups sitting back-to-back, will be the remaining IOS modules. One module shall be used for monitoring the activities of the Mission Specialist and Payload Specialist; the other for the telemetry operator. The telemetry IOS shall be used to service both the fixed-base simulator and the motion-base simulator. The design of the stations shall permit each position of the IOS complex to operate the trainer. In addition, the IOS complex shall be capable of operating as a unit for integrated crew training, and mission rehearsals integrated with MCC.

The IOS complex shall use CRT's and keyboard units as the principal means of controlling the training operation and to monitor crew performance. The CRT's shall operate independently but in parallel so that any available data can be shown on any CRT and any control action can be accomplished with any keyboard. The IOS shall be capable of being operated by one man, but can accommodate as many as four.

A shelf shall be provided at each IOS position and be sufficiently large to provide space for reference material and for writing.

In addition to the IOS consoles, the fixed-base IOS complex includes:

a. One X-Y Recorder

b. Three eight-channel time history X-T recorders

c. Four castered, fully adjustable, swivel armchairs.

d. CRT Hard Copy Device

6.2.4.2.1 Commander-Pilot IOS

The Commander-Pilot IOS for the fixed-base simulator shall be identical to the IOS for the motion-based simulator. The IOS shall include all the features and provide the instructor with the same capabilities offered in the motion-based simulator. The only changes in the two IOS's shall be in the area of the motion-tilt system. These controls shall be eliminated on the fixed-base IOS.

6.2.4.2.2 Orbital Maneuvering Station IOS

The OMS IOS shall be designed to be manned by one instructor. The IOS console shall consist of vertical or inclined panels containing all controls, indicators, displays, recorders, lights, and any other equipment necessary to set-up, control, and monitor the simulator training mission. As a minimum, the instruments and indicators specified herein shall be installed to permit convenient monitoring of the trainee by the instructor. Controls shall be provided to permit convenient control of the training situation by the instructor. A shelf shall be provided at the OMS IOS of sufficient size to provide space for reference material and for writing.

The OMS IOS shall consist of a CRT monitor for observing visual scenes presented on the aft visual system. In addition, two TV monitors shall be provided which are repeaters of those located at the OMS in the crew cabin.

6.2.4.2.2.1 CRT Display/Keyboard Units

The OMS IOS will be located adjacent to the Commander's position of the Commander-Pilot IOS. The OMS instructor shall be provided an alphanumeric CRT, and a monitor for observing the visual scenes presented at this station. A keyboard unit shall be located at the OMS IOS and shall operate in conjunction with the above CRT unit.

The keyboard/display unit shall operate identically to those described previously in 6.2.4.1.2, and the same keyboard action shall be used to select a display or modify a value stored in the computer. The top line of the CRT shall always contain the following data:

a. A one-or two character display mnemonic identifying the display.

b. Symbols indicating the ground station in contact with the vehicle; if none are in contact, LOS is displayed.

c. Mission elapsed time.

d. Simulated Greenwith mean time.

The following CRT pages, identical to those available at the Commander-Pilot IOS, shall be provided at the OMS IOS.

a. Event Time Monitor

b. Panel Displays (excluding those provided by dedicated displays).

c. Energy Management Predictor

d. Malfunction Insertion and Display

e. Circuit Breaker Status

f. Crew Station Setup Verification

g. Active Malfunctions and Tripped Circuit Breakers

h. Mission Parameters and Summary Display

i. Interface Data Stream and Telemetry Monitoring

j. Enroute and Approach Display

k. System Schematic Displays

l. Programmed Demonstration

m. Training Exercise Display

n. Performance Monitor Display

o. Environmental Control

A description of the above displays is contained in 6.2.4.1.2.

6.2.4.2.2.2 Dedicated Instruments

The following instruments located at the OMS shall be repeated at the IOS to permit the instructor to monitor the trainee's performance.

a. Right Boom Position Indicator

b. Left Boom Position Indicator

c. Camera Attitude Indicators

d. Camera Range Indicator

e. Camera Range Rate Indicator

f. Caution and Warning Indicators

g. Monitor 1

h. Monitor 2

6.2.4.2.2.3 Simulator Control and Display

The IOS control panel shall contain the necessary controls and indicators for operation of the IOS. The controls and indicators shall complement those functions accomplished through the CRT display system. Controls and displays shall include the following functions:

a. Operate Controls

b. Communications Controls

c. Visual Window Select Controls

d. Lighting/Sound Controls

Operation of the above controls shall be the same as those located on the Commander-Pilot IOS and are described in 6.2.4.1.3. A difference does exist in the Visual Window Select Controls.

The Visual Window Select panel shall provide the instructor with the necessary controls to select a scene being portrayed on one of the seven cupola windows. Selection of a cupola window to be displayed on the Visual Monitor shall be through a switch-light. Tell-tale lights located above the switch-lights shall indicate the cupola window at which a visual scene is being portrayed. The following switch lights, when activated, shall call up the appropriate cupola window scene on the visual monitor.

a. Left forward window

b. Left aft window

c. Aft window

d. Right aft window

e. Right forward window

f. Top aft window

g. Top forward window

6.2.4.2.3 Mission Specialist/Payload Specialist IOS

The MS/PS IOS shall be designed to be operated by one instructor. The instructor shall be provided with all the controls necessary to operate the simulator as a Part-Task trainer or in an integrated mode for complete crew training or for mission rehearsals integrated with MCC. The MS/PS IOS shall integrate two CRT display units, a keyboard unit, TV monitors, dedicated displays, a control panel for functions not accomplished with the keyboard unit, and an audio panel to provide the necessary communications functions. A shelf of sufficient size shall be provided at the station for reference material and for writing.

6.2.4.2.3.1 CRT Display/Keyboard Unit

The CRT display/keyboard unit shall furnish the MS/PS instructor with the necessary displays and controls to monitor the mission performance of the trainee(s). Either CRT display unit shall be capable of displaying both alphanumeric and graphic data. Operation of the display keyboard unit shall be as described in 6.2.4.1.2, and the same keyboard action shall be used to select a display or modify a value stored in the computer. The top line of the CRT shall always contain the following data:

a. A one-or-two character display mnemonic identifying the display.

b. Symbols indicating the ground station in contact with the vehicle. If none are in contact, LOS shall be displayed.

c. Mission elapsed time

d. Simulated Greenwich mean time.

The following CRT pages identical to those available at the Commander-Pilot IOS shall be provided at the MS/PS IOS. The MS/PS instructor shall be able to call up a page independent of the action at any other IOS.

a. Event Time Monitor

b. Panel Displays

c. Energy Management Predictor

d. Malfunction Insertion and Display

e. Circuit Breaker Status

f. Crew Station Set-up Verification

g. Active Malfunctions and Tripped Circuit Breakers

h, Mission Parameters and Summary Display

i. Interface Data Stream and Telemetry Monitoring

j. Enroute and Approach Display

k. System Schematic Displays

l. Programmed Demonstration

m. Training Exercise Display

n. Performance Monitor Display

o. Environmental Control

A description of the above displays is contained in 6.2.4.1.2.

6.2.4.2.3.2 Dedicated Displays

The following instruments located at the Mission Specialist and Payload Specialist's station shall be repeated at the IOS. (List TBD).

6.2.4.2.3.3 Simulator Control

The IOS shall contain the necessary controls and indicators for operation of the IOS. The controls and indicators shall complement those functions not accomplished through the CRT display system. Controls and displays shall include the following functions:

a. Simulator Status

b. Operate Controls

c. Communications Controls

d. Lighting/Sound Controls

e. Record/Playback Controls

f. Speaker Controls

Operation of the above controls shall be the same as those located on the Commander-Pilot IOS and are described in 6.2.4.1.3.

6.2.4.3 Simulator Status

A simulator status "morning readiness" check program shall be provided. This program shall enable operating personnel to determine if the simulator is ready for operation. The check shall utilize automatic sequencing through a series of standard static outputs utilizing the normal iteration rate of the simulator program. These tests shall enable the operator to ascertain visually that all subsystems of the simulator are performing properly. The subsystems shall include, but not necessarily be limited to: visual DCE, computer, and sound. Provisions shall be incorporated to step through the simulator diagnostic program incrementally to verify the desired output at each step. The program shall not require more than 30 minutes running time.

6.2.4.4 Classroom Terminals

Repeater terminals of the in-cabin CRT's and their associated keyboards shall be provided in a classroom. The terminals shall permit the trainees to monitor training exercises being conducted in the simulator. In addition, through the keyboard, the trainee shall be able to practice procedures for operation of the in-cabin CRT's.

6.2.4.5 Layout Mock-Up

A full-scale mock-up of the instructor-operator station(s) shall be constructed at the contractor's plant prior to establishment of firm requirements relative to the overall layout. Where major components are duplicated on the console (e.g., CRT displays) only one need to be modeled in detail. The model shall be as complete as necessary to permit evaluation of the general arrangement and installation of the following equipment as applicable.

a. Location of the instructor-operator station(s) with respect to crew compartment stations.

b. Instructor-operator flight compartment controls.

c. Full scale replica of all cabinets and panels including controls and indicators located in the instructor-operator areas.

d. Instructor chairs.

e. Lighting arrangement.

f. Sample of panel painting and engraving.

6.2.5 Ancilliary Equipment (WBS#1.3 and 2.3)

6.2.5.1 Aural Cue System

6.2.5.1.1 Cue Requirements

The sounds which are conspicuous in the SSV shall be simulated with respect to location, frequency content, amplitude, and rate of change. These sounds shall be appropriately simulated during all phases of simulated vehicle operation including, but not limited to, the following:

a) Ascent

b) Orbit

c) Rendezvous

d) Docking and Undocking

e) Payload Operation

f) Deorbit

g) Entry

h) Approach and Landing

i) Ferry Operation

j) Abort

The sounds to be simulated shall include, but not be limited to, the following:

a) Engine and Motor Operation

b) Hydraulic System Operation

c) Electrical System(s) Operation

d) Pressurization System Operation

e) Airconditioning System Operation

f) Landing Gear Operation

g) Speed Brake Deployment

h) Drag Chute Deployment

i) Airflow Noises

j) Structural Noises

k) Pyrotechnic Separation

l) Separation Noises

m) Fuel and Oxidizer Venting

n) Payload Bay Door Opening and Closing

o) Docking Ring Extension, Mating and Locking

p) Manipulator Arm Mating and Stowage

q) Cargo Latching and Unlatching

r) Caution and Warning Aural Cues

Each sound shall be independently adjustable before mixing into a total composite sound signal. The instructor shall have ON-OFF/volume control for the composite sound signal.

6.2.5.1.2 Operational Features

The aural cue system shall be a real time acoustic effects generator suited to the production of computer controlled sound effects. It shall be capable of producing both normal and abnormal sounds which are heard by the crew members in the MBCS and FBCS .

Each event to be synthesized shall be generated by producing acoustic signals characteristic of the proper frequency, timbre, density, and timing. The aural cue system shall also be capable of generating the directional aspect of each aural cue.

The blending of the various sounds shall be controlled by the simulator digital computer program as a function of parameters such as engine speed, airspeed, etc. The intensity of the composite audio for each crew station shall be controllable from the associated Instructor operator's station between the limits of "off" and "normal".

6.2.5.1.3 Test Features

Suitable diagnostic programs and automatic built-in test features for the aural cue system shall be provided. These features shall be controlled at the Instructor Operator Station.

6.2.5.1.4 Update Capability

The Aural Cue system design shall be such that changes or additions to the aural cues can be provided without major system change or hardware addition.

6.2.5.1.5 Software Drive Requirements

The software drive control of the aural cue system shall be capable of reproducing the required aural cues perceivable in the spacecraft at an iteration rate not to exceed 20 iterations per second.

6.2.5.2 Simulator Power Hardware

6.2.5.2.1 General

The contractor shall provide two power distribution systems, one for the Motion Base Crew Station and one for the Fixed Base Crew Station which shall interface with NASA furnished power sources having the following characteristics.

a) Three phase Y-connected, 4 wire, 120/208 VAC, with a maximum voltage variation of plus or minus 8%, with transient drops from a nominal 120/208 VAC of up to 15% for a 0.25-second duration, maximum frequency deviations of ±3%, and transient recovery time for frequency of not more than 3 seconds to return to nominal value.

b) 277/480 VAC 60 Hz, three phase power.

c) Single phase 115 VAC 400 Hz power.

6.2.5.2.2 Circuit Design

The Power Distribution System circuit design shall include an adequately fused main power switch to shut off all power to the SMS without disconnection from the power source. An indicator light shall be provided to indicate when primary power supply to the equipment is on. The SMS shall maintain normal uninterrupted operation for all voltage levels above 105 VAC.

The SMS power factor shall be greater than 85% and the unbalanced current between lines shall be less than 15% of the average of the current in each of the three legs.

Proper control logic shall be implemented to assure that the various power loads are sequenced into operation, reducing the surge current demands.

All power distribution circuits shall be adequately protected by circuit breakers. Additional protective devices shall comply with best commercial practices and the National Electrical Code. An emergency power-off system shall provide readily accessible switches located throughout the simulator. Activation of these switches shall remove all power to the simulator.

6.2.5.2.2.1 Utility Power

A 115 Volt, 60 Hz utility electrical power circuit, designed to operate from the main power supply unit shall be provided. The circuit shall be capable of operating while the remainder of the SMS power is off. The circuit shall contain the lights and utility outlets required for checkout and trouble shooting the equipment.

6.2.5.2.2.2 Elapsed Time Indicators

Elapsed time indicators shall be installed in the power supply equipment cabinets and shall give separate indications of the time that the main power is being supplied to the computers and each major subsystem of the SMS. The indicators shall have at least five digits in increments of one hour to give indication up to a total of 99,999 hours. Indicators shall not be required for the utility power circuit.

6.2.5.3 Central Timing Equipment (CTE)

6.2.5.3.1 CTE Function and Operating Modes

The CTE shall receive, generate and transmit continuous timing signals to various systems in the SMS complex. The equipment will have two operating modes: (1) "non-integrated", which shall be active when the SMS is in an independent mode; and (2) "integrated", which shall be active when the SMS is operating in an integrated mode with MCC.

6.2.5.3.2 GFP Signals

NASA shall supply a one minute pulse, as well as a 1 KHZ pulse to enable synchronization between time dependent elements of the complex.

6.2.5.3.3 Synchronization Requirements

6.2.5.3.3.1 SMS/MCC Integrated Mode of Operation

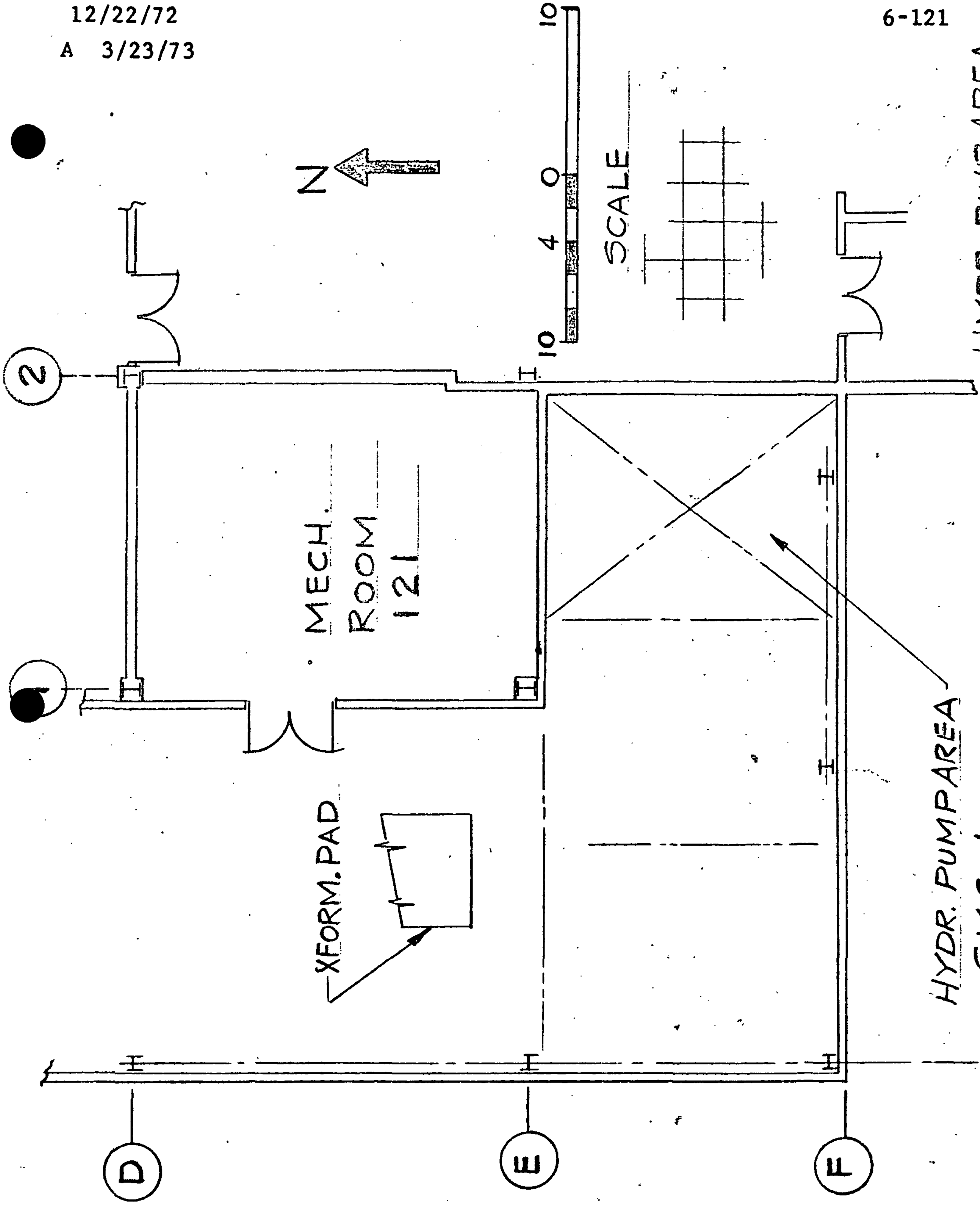
When the SMS and MCC are operating together, the simulation shall be synchronized by use of the minute pulse signal. Either the MBCS or the FBCS, but not both simultaneously, shall operate synchronized with MCC.

6.2.5.3.3.2 Internal SMS Synchronization

The contractor shall supply all timing signals other than the GFP signals to enable the SMS to function correctly. These signals shall include those required to interface the GFP flight hardware.

6.2.5.4 Hydraulic System Hardware

The hydraulic pump, motor, heat exchanger, reservoir and other equipment associated with the generation of hydraulic power shall be located in the area designated on FIG. 6.2 -III. The arrangement within this area shall be coordinated with NASA to accommodate power equipment for 2 additional simulators, thus a possible arrangement is shown on FIG. 6.2.5.4-1. The layout for this equipment with electrical power and water requirements, trenches, noise levels, and installation requirements shall be submitted with the proposal.




HYDR. PWR AREA
FIG. 6.2.5.4.-I

6.2.5.5 Interface Cabinets

Interface Cabinets, where required, shall be provided to enable ease of wiring modifications by means of patch panels. Patch panels shall be utilized as the interconnection point for interconnecting the data conversion equipment (DCE) with the SMS crew station, instructor-operator station, visual system, etc.

6.2.5.6 Intercommunications

The intercommunication stations shall be located so the operators at the consoles, crew station, and ancilliary equipment of the SMS shall be able to communicate with each other on a network basis.

Each instructor shall be provided with a voice communication terminal which shall allow selective voice communication within the SMS complex as well as with facilities related to an integrated simulation. The instructors may select either simulated links, or select simulator-peculiar supplementary loops which shall provide direct communications with the crew station modules. The voice terminal shall consist of an audio control panel and a communications selection switching unit.

6.2.5.7 Cabling

CFE cables shall be provided for interconnecting SMS equipment. A cable routing installation drawing shall be developed to specify proper routing of cables to avoid electromagnetic compatibility problems.

6.2.5.8 External Signal Interface

The Shuttle Mission Simulation is required to interface with a large number of devices in order to provide the various part task and fully integrated mission training functions.

These interfaces have been subdivided and categorized below according to work package breakdown.

The SMS contract shall satisfy these interface requirements, utilizing GFE where available, as identified in Exhibit (3), and provide Interface Control Documents defining detailed signal requirements.

6.2.5.8.1 Motion Base Crew Station Simulator Signal Interface

The following signal interfaces shall be provided for the Shuttle Motion Base Crew Station simulation.

a) MBCS/DCU/GSSC Interface

b) MBCS/Audio Communications Interfaces

c) MBCS/Central Timing Equipment Interface

d) MBCS/DCU Interface Software

6.2.5.8.1.1 MBCS/DCU Interface

The SMS/DCU GSSC Interface shall provide the capability of combining the Ground Support Simulation Complex and the SMS into one integrated training network.

Interface between the two buildings shall be accomplished by parallel-to-serial data transmission between computers. The GFE interface unit Digital Conversion Unit (DCU) uses a hard wire data line for serial bit transmission. Maximum data transmission rate for the

DCU ground line system is 40.8 Kbs. per line.

The data is simplexed for two-way communication. The message exchange rate is based on a 10 per second iteration rate.

The contractor shall provide the necessary hardware for interface with DCU. The SMS shall provide all trajectory data, configuration/mode data, communication system signal strengths, control functions for voice and data tape recorders, computer master timing, and telemetry data.

The update commands shall originate with MCC in the GSSC loop during integrated training sessions. Commands shall be insertable by the instructor in all modes of operation.

6.2.5.8.1.1.1 GSSC-to-SMS

The GSSC shall transmit 2360 bps to the SMS to provide up-link command data, trajectory data, Message identification, Validity tags, and computer status. The division of the data for each frame is as follows:

44 bits - DCU transmission/Validity data

48 bits - Packed Message ID discretes, computer status discretes, Message Validity tag. (Total 48 discretes)

144 bits - Packed Command Up-link words (6-24 bit words)

6.2.5.8.1.1.2 SMS to GSSC - Block 1 Data

The SMS shall transmit 19640 bps. to the GSSC to provide

Trajectory data, Time Tags, Computer Configuration/Mode data, Target information, Communication System signal strengths, Message ID, and validity tags. The division of the data for each frame is as follows:

44 bits - DCU transmission/Validity data.

32 bits - Message ID discretes and Computer Validity tags. (total 32 discretes)

64 bits - Time Tags

Each message exchanged between the SMS and the GSSC shall contain a message time tag. The data within the interface message shall be valid for the GMT of the message time tag. Whenever SMS or target vehicle state vector information is being transferred in an interface message, the inertial state vector shall be referenced to the time tag of that respective message. All time tags interface messages shall be referenced to the SMS RTCC Greenwich Meridian Time (RTCC-GMT) which is defined as a time measure of elapsed days, hours, minutes, seconds, and deciseconds at the Greenwich Meridian from midnight of December 31 of the year prior to the launch. The GMT at midnight of December 31-January 1 of the year prior to the launch is defined to be an RTCC-GMT of: DAYS-001:HRS-00MIN-00:SEC-00.0.

(64 bits of Multiple packed integer

96 bits - Computer Configuration/Mode discretes packed (Total 96 discretes)

128 bits - Communication/Recorder System data (28 bits packed discretes and 20-5 bits integer words packed)

96 bits - Communication data - Signal Strengths (3-32 bit floating point words)

928 bits - Trajectory data for Shuttle vehicle (29 - 32 bit floating point words)

No additional Transformations shall be required on SMS Trajectory parameters prior to formating for transmissions.

576 bits - Target data

(17 - 32 bit floating point words, 16 discretes packed and two 8 bit integer words packed). The target data shall be multiplexed and discrete codes provided to identify target vehicles. A maximum of four target data sets shall be required per second.

6.2.5.8.1.1.3 SMS to GSSC-Block 2 Data

Block 2 data shall consist of telemetry data information. The telemetry data transmitted shall be formatted identical to the shuttle real world PCM telemetry format. The measurements and the channel assignment, rate of samples per second bit distribution, and total system capacity shall be as specified in the ICD. (Reference Exhibit (2), DRL Item #32).

Telemetry data transmission shall be at a 10 per second iteration rate. Each frame of data transmitted shall consist of 12,800 bits of data.

6.2.5.8.1.2 MBCS Audio Communications Interfaces

All MBCS audio communication hard line interfaces will be accomplished through the MCCSF/CCS audio distribution network. Provision shall be made to interface (No. TBD) audio loops (audio pairs) with the MCCSF communication distribution system. Each audio line will be terminated at the interface with an isolation transformer. Provision shall be made to maintain proper impedance match and signal levels as specified in the appropriate ICD.

The audio loops which shall be provided are as follows:

a) Intercomm Loop

b) Air/Ground Link No. 1 (S-Band)

c) Air/Ground Link No. 2 (VHF)

d) Air/Ground Link No. 3 (VHF)

e) Utility Loop

6.2.5.8.1.3 MBCS Central Timing Equipment Interface

The MBCS shall include central timing equipment as specified in paragraph 6.2.5.3

This equipment shall be capable of synchronization by an internal timing reference for stand alone mode of operation and shall be capable of being synchronized from an external timing source reference when the MBCS is integrated to the MCC.

6.2.5.8.2 Fixed Base Crew Station Simulator Signal Interfaces

In addition to the Interface equipment identified in paragraph 6.2.5.8.1 above, it shall be the responsibility of the contractor to provide interface equipment for the FBCS when it is added to the SMS complex.

These interfaces shall permit operation of the MBCS and the FBCS as two independent entities and also provide for full mission simulation (FMS) using either the MBCS or the FBCS in integrated modes with MSSC.

However, the MBCS shall not be operated/integrated with MSCC while the FBCS is operated integrated with MSCC.

These additional interfaces shall include but not be limited to the following:

a) FBCS/Audio Communication Interfaces

b) FBCS/Central Timing Equipment Interfaces

c) FBCS/DCU Interface Software

6.2.5.8.3 External Interface Software

The SMS Interface program shall operate in association with the SMS/DCU Interface hardware to provide capability of combining the MBCS or the FBCS into one integrated training network.

Interface Software shall provide the necessary formatting and processing of data as specified in the appropriate ICD.

Modes of operation shall be as follows:

a) MBCS Non-Integrated

b) FBCS Non-Integrated

c) MBCS Integrated with MSCC, FBCS Non-Integrated

d) FBCS Integrated with MSCC, MBCS Non-Integrated

6.2.5.8.4 Interface Control Document Requirements

The contractor shall prepare Interface Control Documents to define and control the external interfaces of the SMS. These ICD's shall depict the physical and functional interface engineering requirements of a subsystem which affect the design or operation of a cofunctioning subsystem. These documents shall be used as design control documents delineating subsystem engineering data coordinated for purposes of (a) establishing and maintaining compatibility between cofunctioning sybsystems, (b) controlling interface designs, thereby preventing changes to system requirements which will affect compatibility with cofunctioning subsystems, and (c) communicating design decisions and changes to participating activities.

Each ICD shall delineate, as applicable

a) Configuration and interface dimensional data applicable to the envelope, mounting, and mating of the subsystem.

b) Complete Interface Engineering Requirements such as software, mechanical, electrical, electronic, hydraulic, pneumatic, optical, etc.

c) Other characteristics which cannot be changed without affecting design criteria.

6.2.6 On-Board Computer Simulation (WBS#1.4 and 2.4)

6.2.6.1 Data Processing and Software (DP&S)

6.2.6.1.1 Fidelity

The Data Processing and Software Subsystem on-board computers and Interface Equipment (DP&S) shall be simulated for all flight mission phases including ascent, orbital, deorbit, abort, and atmospheric flight, and for all modes, automatic and manual. Redundancy features and built-in test features of the DP&S which effect crew station or MCC displays shall be simulated.

The DP&S subsystem shall interface with other elements of the avionics system including the Dual Redundant Tape Readers, the IMU's and nav sensors, rate gyros, body mounted accelerometers, the air data system, Tacan Units, ILS Receivers, Radar Altimeters, manual controls, the flight control converter and the CRT Displays and Keyboards.

As presently defined, the DP&S subsystem includes two primary GN&C computers, one Backup GN&C computer, and two Auxillary computers used for performance monitoring and Payload Handling Functions.

In the Moving Base Crew Station Simulator, simulation of the two primary GN&C, the backup GN&C, and one auxillary computer shall be provided.

In the Fixed Base Crew Station Simulator, a simulation of all the DP&S computers shall be provided.

6.2.6.1.2 G.F.P. Integration

The DP&S OBC simulation shall include the capability to incorporate G.F.P. crew station display and control hardware equipment and OBC software as specified in Exhibit 3 and para. 6.2.6.1.3 below.

6.2.6.1.3 Flight Software

Hardware and software as required shall be provided to enable use of DP&S OBC flight software in the simulator without extensive modification. This flight software will be provided (G.F.E.) in source and object language format. The source language format will be HAL. The object language format will be the OBC assembly language and load module (binary format). Flight software will be provided on magnetic tape and paper tape.

6.2.6.1.4 Loading

The simulator shall include equipment required to load the flight software in the simulation computer. If pre-processing of the flight software is required, a suitable hard copy output device shall be provided for program listings.

6.2.6.1.5 Moding

The simulated DP&S OBC shall operate in conjunction with the simulator mode control functions such as freeze, reset, and non-real time, without degradation in performance.

6.2.6.1.6 Update

The capability to incorporate software changes to the DP&S programs shall be provided. Hardware equipment and software as required for conversion of changes to the DP&S software for incorportation into the simulator shall be provided. This equipment shall be compatible with that required for loading the programs.

6.2.6.1.7 Diagnostics

If flight hardware is used, Diagnostic program software to exercise and test this hardware shall be provided. This software shall include programs to determine the state of the OBC at a specific instant in time, i.e., a snapshot dump program.

6.2.6.1.8 Interface

Interface equipment to interface real world DP&S OBC hardware to the main simulation computer shall be provided. This equipment shall include buffering and interrupt handling equipment as required.

6.2.6.1.9 Debugging Tools/Equipment

Additional equipment shall be provided to enable rapid evaluation and test of real world DP&S OBC hardware. This equipment shall operate in conjunction with diagnostic programs to enable rapid fault isolation and repair capability.

6.2.6.1.10 Synchronization

The DP&S OBC shall operate in time synchronism with the main simulation computer, with the MCC in integrated modes, and with the PCM telemetry system. A 50 millisecond synchronization period is required.

6.2.6.1.11 Reset Requirements

The DP&S OBC shall have the capability to be rapidly reset and restarted at all normal mission oriented simulator reset points.

6.2.6.1.12 Redundancy Requirements

The dual redundancy features of the primary GN&C computers shall be simulated, including computer to computer intercommunication and backup control modes.

6.2.6.1.13 Simulated Malfunctions

Simulated malfunctions of the DP&S OBC shall be as specified in Addendum A.

6.2.6.2 Main Engine Controller Assemblies and Interface Systems

6.2.6.2.1 Fidelity

The Main Engine Controller Assemblies, including Digital Computers, Input Electronics, Output Electronics, Computer Interface Electronics, and power supplies, shall be simulated for all flight mission phases including ascent, orbital, deorbit, abort and atmospheric flight, and for all modes, automatic and manual. Redundancy features and built-in test features of the Main Engine Controllers which effect crew station or MCC displays shall be simulated.

The Main Engine Controllers shall interface with other elements of the Main Engine system including the Inflight Data Sensors, Limit Sensors, Control Sensors, Actuators, Igniters, On-Off Controls, the Data Bus Interface, and the Vehicle Data Recorder.

If flight hardware is used for simulation it shall be provided for the MBCS only. However, the design shall be implemented so that the flight hardware may be used by either the MBCS or the FBCS but not both simultaneously.

6.2.6.2.2 G.F.P. Integration

The Main Engine Controller simulation shall include the capability to incorporate G.F.P. crew station display and control hardware equipment and digital computer software as specified in Exhibit 3 and paragraph 6.2.6.2.3 below.

6.2.6.2.3 Flight Software

Hardware and software as required shall be provided to enable use of Main Engine Controller OBC flight software in the simulator without extensive modification. This flight software will be provided (G.F.E.) in source and object language format. The source language format will be the Main Engine Computer Assembly Language.

The object language format will be load module (binary format). Flight software will be provided on magnetic tape and paper tape.

6.2.6.2.4 Loading

The simulator shall include equipment required to load the flight software in the simulation computer. If pre-processing of the flight software is required, a suitable hard copy output device shall be provided for program listings.

6.2.6.2.5 Moding

The simulated Main Engine Controllers shall operate in conjunction with the simulator mode control functions such as freeze, reset, and fast time, without degradation in performance.

6.2.6.2.6 Update

The capability to incorporate software changes to the Main Engine Controller program shall be provided. Hardware equipment and software as required for conversion of changes to the Main Engine Controller software for incorporation into the simulator shall be provided. This equipment shall be compatible with that required for loading the programs.

6.2.6.2.7 Diagnostics

Diagnostic program software to exercise and test real world computer hardware and computer interface hardware shall be provided if flight hardware is used. This software shall include programs to determine the state of the OBC at a spsecific instant in time, i.e., a snapshot dump program.

6.2.6.2.8 Interface

Interface equipment to interface real world OBC hardware to the main simulation computer shall be provided. This equipment shall include buffering and interrupt handling equipment as required.

6.2.6.2.9 Debugging Tools/Equipment

Additional equipment shall be provided to enable rapid evaluation and test of real world OBC hardware. This equipment shall operate in conjunction with diagnostic programs to enable rapid fault isolation and repair capability.

6.2.6.2.10 Synchronization

The Main Engine Controllers shall operate in time synchronism with the main simulation computer, with the MCC in integrated modes, and with the PCM telemetry system. A 50 millisecond synchronization period is required.

6.2.6.2.11 Reset Requirements

The Main Engine Controllers shall have the capability to be rapidly reset and restarted at all normal mission oriented simulator reset points.

6.2.6.2.12 Redundancy Requirements

The redundancy features of the Main Engine Controllers computers shall be simulated, including computer to computer intercommunication and backup control modes.

6.2.6.2.13 Simulated Malfunctions

Simulated malfunctions of the Main Engine Controllers shall be as specified in Addendum A.

### 6.2.7 Simulation Computation Complex (WBS #1.5 and 2.5)

The contractor shall provide a simulation task structure that will interface with the operating system of the GFE Computer Complex. This task structure will have the capability to perform the simulation of one Motion Base Crew Station and one Fixed Base Crew Station of the SMS simultaneously. The contractor shall also provide the capability to perform local and remote time-sharing functions such as Batch processing and Data Management activities in parallel with the simulation tasks.

The contractor shall provide a minimum of 50 percent spare execution time and 25 percent spare in the remaining resources of the GFE Computer Complex. These percentages of spare shall exist during all operational activities of the GFE Computer Complex.

The resources of the GFE Computer Complex for which 25 percent is required are as follows:

Mass Storage (Disc, drum, large core memory)

Input/Output Time for all available channels

CPU Main Memory

Auxiliary Processor Execution Time

6.2.8 Digital Conversion Equipment (WBS #1.6 and 2.6)

6.2.8.1 Devices

Data Conversion Equipment shall be provided to permit the activation of the simulator stations and sampling of controls with sufficient accuracy and speed to minimize input/output signal errors and eliminate discernible discrete stepping of indicators and other appropriate outputs. Standards for form and format of input/output quantities shall be established for the computer side and simulator side of the interface. The interface system shall include analog-to-digital input conversion equipment, digital-to-analog output conversion equipment, discrete inputs, discrete outputs, digital inputs, digital outputs, digital-to-synchro outputs, etc., and necessary control equipment.

6.2.8.1.1 Computer Side

Standards shall be established for computer digital word formats and computational units considering necessary tagging of data, resolution of data, and the range of variables in order to optimize the computer input/output equipment design.

6.2.8.1.2 Simulator Side

The electrical or physical format of the data and conversion techniques shall be standardized to greatest extent possible. Standards shall be established for input/output quantities of the simulator side of the interface for identical parameters performing identical functions in different simulator areas.

6.2.8.2 DCE System Spare Capacity

Twenty-five percent of each input channel, output channel, and each type of interface equipment shall be provided as spare capacity. The input/output system includes the computer I/O and the interface multiplexers, analog-to-digital converters (A/D), digital-to-analog converters (D/A), and all signal distributers, converters and processors between the computer and the input source and output displays etc. This requirement is intended to provide direct expansion, i.e., without requiring additional channels and signal processors in the I/O and interface areas.

6.2.8.3 DCE System Growth Capability

The DCE system shall be designed to permit expansion of capacity without significant design changes to existing hardware and without obsoleting the existing equipment.

A capability for a 100 percent increase in the input/output channels and complete interface associated with the computation system shall be provided.

6.2.8.4 Real-Time Interface Equipment Diagnostics

Programs shall be provided which will enable on-line program control checkout of the simulator interface equipment. They shall be of an automated type requiring a minimum of operator effort and shall provide a hard copy of the test results. These programs shall perform the following tasks.

<u>Discrete input and output test</u>. The capability shall be provided to check the proper functioning of all the discrete input and output channels, including spares, in a closed-loop fashion. All disconnection and reconnection shall be accomplished under program control. The program, upon detecting a malfunction shall indicate to the operator the failing channel.

<u>Analog input and output test</u>. Tests shall be provided to exercise all of the analog input devices through their full range of operation. This shall be accomplished in a closed-loop fashion. All disconnection and reconnection shall be accomplished under program control. The tests shall be designed such that an accuracy limit can be specified by the operator. It shall test all converters, multiplexers, and demultiplexers, including spares, in the DCE system. All channels not functioning within the specified limits shall be indicated as such via on-line hard copy. A dynamic test of the analog output channels also shall be provided. This test shall enable the operator to vary the period and amplitude of the test signal to a specified channel via an on-line input device.

### 6.2.9 Visual System (WBS#1.7 and 2.7)

#### 6.2.9.1 Introduction

The Shuttle Mission Simulator complex will consist of a separate motion base crew station and a separate fixed base crew station. The motion base crew station contains the Commander/Pilot's station or forward work station and will be mounted on a six-degree-of-freedom motion system with a tilt capability to simulate launch conditions. The fixed base crew station contains the forward work station and the aft work stations and will be fixed base.

The Shuttle Mission is divided into the following mission phases:

1) Ascent Phase - Ten minutes prior to lift-off to orbit insertion (Main Engine Thrust Termination).

2) Abort Phase - There exists five abort phases during vertical launch: (a) SRM assist (launch commit to 30 seconds after lift-off), (b) orbiter glide (30 seconds to 86 seconds after lift-off), (c) orbiter powered return to site (86 to 300 seconds after lift-off), (d) orbiter once-around orbit (300 to 440 seconds after lift-off), and (e) orbiter abort to orbit (440 to 551 seconds after lift-off).

3) Orbital Operation Phase - This phase includes all orbital operations commencing with orbit insertion except those operations associated with rendezvous. For example, external tank separation, orbit changes, navigation updates, and performance monitoring. The altitude range varies from 50 n.m. to 500 n.m.

4) High and Low Altitude Rendezvous Phase - The purpose of

this phase is to fly to a co-orbit condition with another orbital vehicle. This phase includes: (a) orbital adjustment, i.e., correct phasing with rendezvous target, (b) coelliptic sub-phase, i.e., placing the orbiter at the desired terminal condition prior to initiating an intercept trajectory, (c) terminal sub-phase, i.e., placing the orbiter on an intercept trajectory with the target and perform tracking to achieve a station keeping condition and (d) station keeping sub-phase, i.e., maintaining a relative position in the near vicinity of the target vehicle. The altitude range is 50 n.m. to 500 n.m. and the maximum slant range between the two vehicles is 300 n.m.

5) Docking and Undocking Phase - The purpose of this phase is to move from/to a station keeping mode to/from a docking condition with the rendezvous target. The altitude range is 50 n.m. to 500 n.m. and the maximum slant range between the two vehicles is 10 n.m. This phase is entirely accomplished without the aid of the RMS arms.

6) Payload Operations - This mission phase exists only when the RMS is being utilized. The purpose of this phase is to guide and control the orbiter and the RMS as necessary to meet payload handling requirements. The following RMS maneuvers could be encountered: docking or undocking, payload deploy/retrieve, assembly of payload and the maintenance of payloads. The altitude range is 50 n.m. to 500 n.m.

7) Deorbit Phase - The purpose of this phase is to select a landing site and perform the deorbit maneuver. The altitude range varies from 500 n.m. to 400,000 ft.

8) Entry Phase - During this phase the orbiter angle of attack and bank angle is controlled in order to "fly out" the targeted crossrange and downrange within temperature, g-load and skip-out constraints. The transition maneuver, that is, the transition from spacecraft (high angle of attack) to aerodynamic flight (maximum L/D) is entirely accomplished in this phase. The altitude ranges from 400,000 ft. to 50,000 ft.

9) Approach and Landing Phase - The purpose of this phase is two-fold. Initially the terminal approach sub-phase the orbiter is flown with a maximum L/D to the 15° glideslope intercept following an optimal path dependent on energy available. Subsequently, the final approach sub-phase begins at an altitude of 10,000 ft., i.e., intercept of the 15° glideslope and is terminated at touchdown. The altitude ranges from 50,000 ft. to 25 ft.

Ferry Flight Phase - The purpose of this phase is to fly the vehicle from one airport to another. This phase includes: (a) taxi, (b) takeoff and climb, (c) cross-country, (d) in-flight refueling, and (e) approach and landing. The maximum ferry range is 400 n.m. without air to air refueling and the altitude ranges from 25 ft. to TBD ft. (at least 10,000 ft.).

6.2.9.1.1 Display

The forward work station display system for the MBCS & FBCS shall present color imagery at infinity. It is desirable that the forward work station display system provide the field of view filling all six windows to be viewed by the Commander and Pilot. (Three windows are shown in Figure 6.2.9-1. The remaining three are the mirror image). However, a display system providing the field of view filling all six windows to be viewed by either the Commander or Pilot, but not both simultaneously would be acceptable. In this case means to provide the necessary switching would be required. As a minimum, a limited field of view display system would be acceptable provided that:

a) simultaneous commander/pilot viewing is permitted via two limited field of view displays, and

b) the total field of view provided by both displays encompasses the six windows.

In particular, the Commander's field of view would include the three windows on the Commander's side of the vehicle plus a window on the Pilot side. The Pilot's field of view would be the mirror image of the Commander's field of view.

6.2.9.1.1.2 Aft Work Station

The aft work station contains four windows, i.e., one aft facing window, one overhead window and two side windows (see Figure 6.2.9.-2). It is desirable that the aft work station display system provide the field of view, filling all four windows to be viewed by the remote manipulator system operator. This display system will be provided only for the FBCS.

The aft work station display system shall present black and white imagery at infinity.

12/22/72

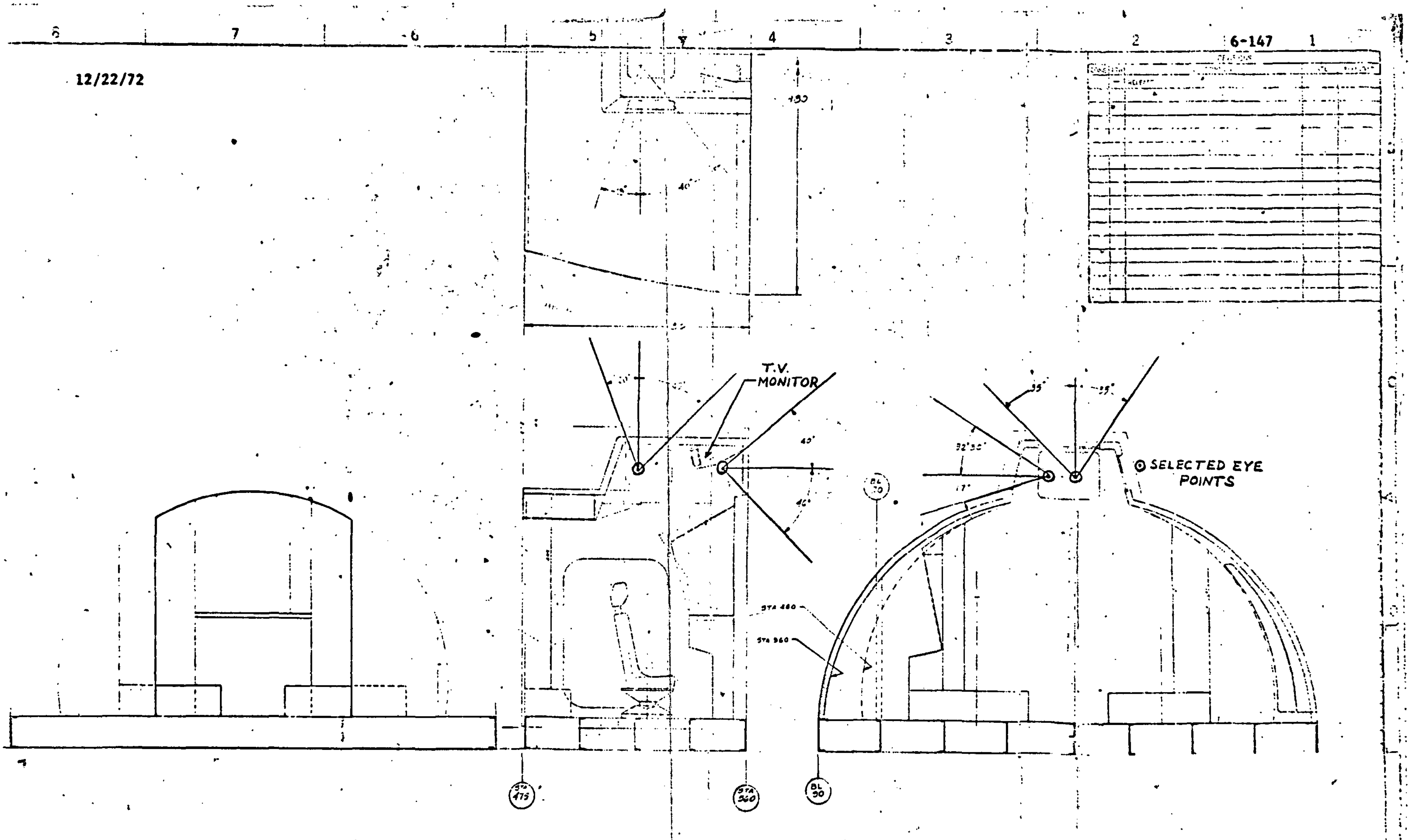
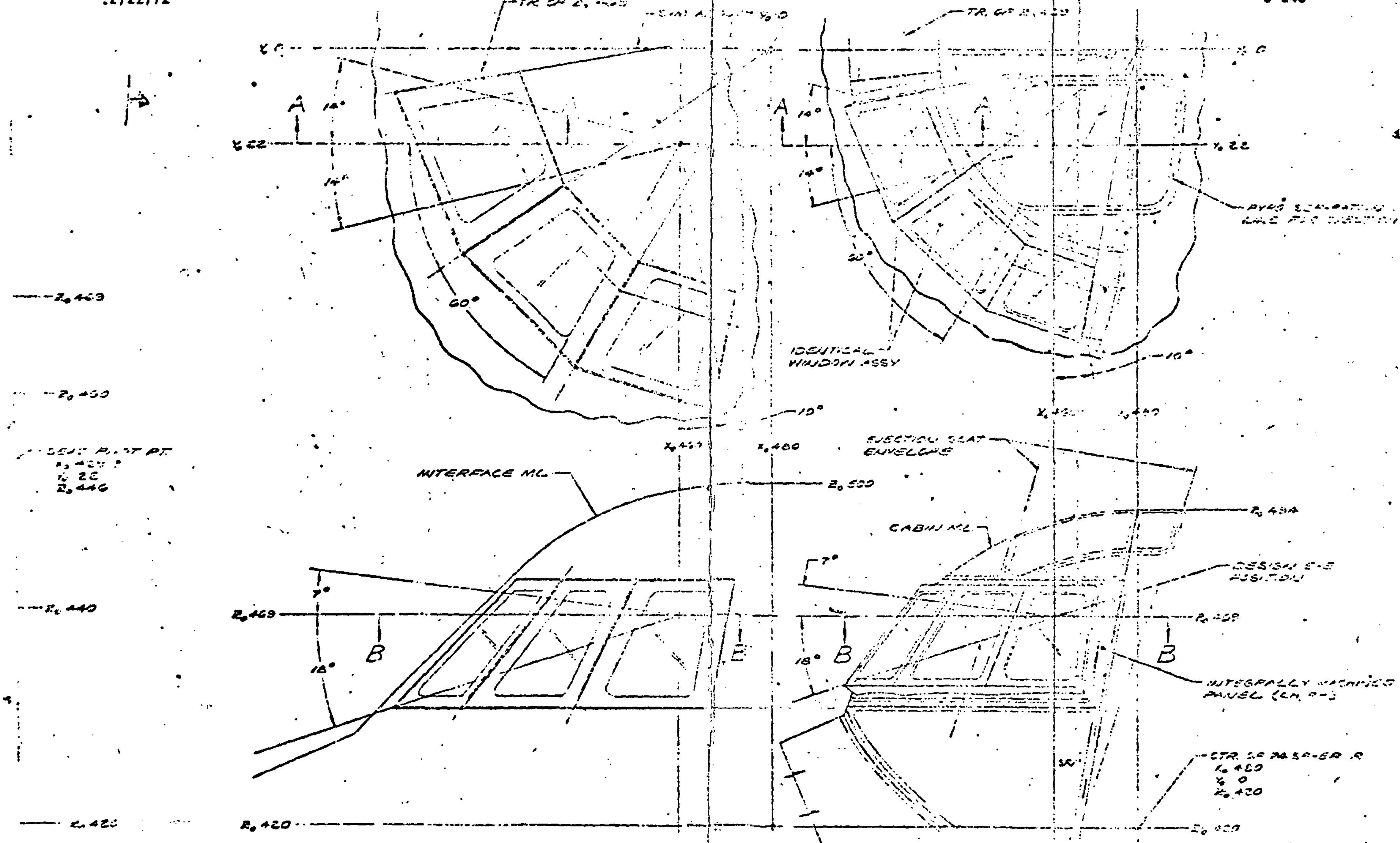



FIG. 6.2.9-2




FUS. OUTER STRUCTURE WINDOW CONFIG. SCALE 1/10

CABIN WINDOW CONFIG. SCALE 1/10

### 6.2.9.1.1.3 TV Monitors

There exists two TV monitors in the aft work station (see Figure 6.2.9-2). The images generated by the spacecraft TV cameras shall be simulated on the simulator TV monitors. This requirement exists only in the FBCS.

### 6.2.9.1.2 Image Generators

The image generators shall include the capabilities to provide the following scene elements:

a. Celestial bodies

b. Earth and horizon

c. Own vehicle

d. Target vehicles

e. Remote manipulation system arms.

6.2.9.2 Visual Performance Characteristics

6.2.9.2.1 General

The general performance characteristics which shall be provided in the design of the overall visual system as well as in the design of the individual elements shall be governed by the following considerations:

a. The mission phases to be simulated by the forward work station visual system for the MBCS and the FBCS are:

i) Orbital Missions - Ascent, abort, oribital operations, deorbit, entry, approach and landing and the take-off, cross country and approach and landing.

ii) Ferry Missions - Take-off, cross country and approach and landing. The visual simulation of the remaining phases of the ferry missions, i.e., taxiing and in-flight refueling are not required but if they can be provided with no increase in the visual system complexity they are desirable.

iii) FBCS Only - Rendezvous, docking and undocking, and payload operations.

iv) Time-Shared Mission Phases - Training for the ascent, abort, entry, approach and landing mission phases for orbital and ferry missions will not occur simultaneously on the MBCS and the FBCS so that unique equipment to these mission phases may be time shared.

In the normal ascent mission phase no visual requirements have been identified. However, visual scenes during ascent identical to those required for the applicable abort mode shall be provided in order to prevent transition problems. If the cost and complexity of the visual system can be reduced by eliminating some of the abort requirements during the normal ascent phase and still provide a satisfactory transition to the abort mode, such recommendations should be proposed.

Similarly no training requirements have been identified during the cross country phase of ferry mission, however a horizon and cloud cover is desired if it can be achieved with no increase in complexity.

b. The mission phases to be simulated by the aft work station visual system are: docking and undocking and payload operations

c. The basic performance characteristics of the visual simulation system, in particular the identification of the scenes which are required to be shown during each phase are shown in Table 6.2.9-1 to 6.2.9-5. The motion envelope requirements for which the visual system shall be designed are shown in Table 6.2.9-6.

| | ABORT PHASE | | | ORBITAL OPERATIONS PHASE | RENDEZVOUS PHASE | DOCKING & UNDOCKING PHASE | PAYLOAD OPERATIONS PHASE | DE-ORBIT PHASE | ENTRY PHASE | APPROACH & LANDING PHASE | FERRY PHASE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MODE #1,2 | MODE #3 | MODE #4,5 | | | | | | | | TAKEOFF | APPROACH & LANDING |
| ...ENAL HYDROGEN<br>...EN TANK | REQUIRED:<br>1) IN ATTACHED POSITION<br>2) DURING SEPARATION | REQUIRED:<br>1) IN ATTACHED POSITION<br>2) DURING SEPARATION | REQUIRED:<br>1) IN ATTACHED POSITION<br>2) DURING SEPARATION | REQUIRED<br>1) IN ATTACHED POSITION<br>2) DURING SEPARATION<br>3) VERIFICATION OF SAFE SEPARATION | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R |
| ...E FROM SRM<br>...INATION | REQUIRED:<br>1) EFFECT OF PLUME ONLY | REQUIRED t <109 SEC<br>1) EFFECT OF PLUME ONLY -<br>N/R t >109 SEC | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R | N/R |
| ... OF VEHICLE<br>...USE OF HEAD MOTION<br>...IPULATOR STATION<br>...) | N/R | N/R | N/R | N/R | N/R | REQUIRED | REQUIRED | N/R | N/R | N/R | N/R | |
| ...O BAY | N/R | N/R | N/R | N/R | N/R | REQUIRED:<br>1) DOCKING TUNNEL IN EXTENDED POSITION ONLY | REQUIRED:<br>1) DOCKING TUNNEL AND CARGO BAY DOORS DYNAMIC<br>2) PAYLOAD FROM STOWED POSITION TO DYNAMIC POSITION<br>3) TRUNION LOCATIONS VISIBLE EMPTY BAY<br>4) CARGO BAY FLOODLIGHTS ILLUMINATING CARGO BAY | N/R | N/R | N/R | N/R | N/R |

IMAGE CONTENT - "OWN VEHICLES" TABLE 1 of 5

Table 6.2.9-1

| | ABORT PHASE | | | ORBITAL OPERATIONS PHASE | RENDEZVOUS PHASE | DOCKING & UNDOCKING PHASE | DE-ORBIT PHASE | ENTRY PHASE | APPROACH & LANDING PHASE | FERRY PHASE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | MODE #1 | MODE #2 | MODE #3,4,5 | | | | | | | TAKEOFF | APPROACH & LANDING |
| HORIZON-INTERFACE BETWEEN TOP OF CLOUD LAYER AND SKY | NOT REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | NOT APPLICABLE | NOT APPLICABLE |
| HORIZON-INTERFACE BETWEEN EARTH AND SKY | REQUIRED | REQUIRED | REQUIRED | NOT REQUIRED | NOT REQUIRED | NOT REQUIRED | NOT REQUIRED | NOT REQUIRED | REQUIRED | REQUIRED | REQUIRED |
| CEILING HEIGHT | 100-50,000 FT. | 100-50,000 FT. | 100-50,000 FT. | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | 100-50,000 FT. | 100-50,000 FT. | 100-50,000 FT. |
| VISIBILITY | 1,300 FT. TO UNLIMITED | 1,300 FT. TO UNLIMITED | 1,300 FT. TO UNLIMITED | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | 1,300 FT. TO UNLIMITED | 1,300 FT. TO UNLIMITED | 1,300 FT. TO UNLIMITED |
| ILLUMINATION BY OWN VEHICLE LANDING LIGHTS | DESIRABLE | DESIRABLE | DESIRABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | DESIRABLE | DESIRABLE | DESIRABLE |
| TIME OF DAY | DAYLIGHT TO DARKNESS | DAYLIGHT TO DARKNESS | DAYLIGHT TO DARKNESS | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | DAYLIGHT TO DARKNESS | DAYLIGHT TO DARKNESS | DAYLIGHT TO DARKNESS |
| CLOUD COVER | NOT APPLICABLE | HOMOGENEOUS | HOMOGENEOUS | HOMOGENEOUS | HOMOGENEOUS | HOMOGENEOUS | HOMOGENEOUS | HOMOGENEOUS | HOMOGENEOUS | NOT APPLICABLE | NOT APPLICABLE |
| DAY/NIGHT TERMINATOR | NOT APPLICABLE | NOT APPLICABLE | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE |
| ONE LANDING STRIP: KSC. WITH FAA CATEGORY II RUNWAY MARKINGS AND LIGHTS | REQUIRED | REQUIRED | REQUIRED | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | NOT APPLICABLE | REQUIRED | REQUIRED | REQUIRED |
| NOSE OF VEHICLE OCCULTATION | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED |

IMAGE CONTENT - "EARTH SCENE AND HORIZON"

TABLE 2 of 5

TABLE 6.2.9-2

| | ABORT PHASE | | | ORBITAL OPERATIONS PHASE | RENDEZVOUS PHASE | DOCKING & UNDOCKING PHASE | PAYLOAD OPERATIONS | DE-ORBIT PHASE | ENTRY PHASE |
|---|---|---|---|---|---|---|---|---|---|
| | MODE #1 | MODE #2 | MODE #3,4,5 | | | | | | |
| CONSTELLATIONS | NOT REQUIRED | NOT REQUIRED | REQUIRED - QUANTITY ~88 | REQUIRED QUANTITY ~88 | REQUIRED QUANTITY ~88 | NOT REQUIRED | NOT REQUIRED | REQUIRED QUANTITY ~88 | NOT REQUIRED |
| NUMBER OF STARS | NOT REQUIRED | NOT REQUIRED | ≥ 1000 | ≥ 1000 | ≥ 1000 | SUFFICIENT NUMBER FOR ATTITUDE MOTION REFERENCE ONLY | NOT REQUIRED | ≥ 1000 | SUFFICIENT NUMBER FOR ATTITUDE MOTION REFERENCE ONLY |
| CONSTELLATION IDENTIFICATION | NOT REQUIRED | NOT REQUIRED | REQUIRED BY CONFIGURATION AND MAGNITUDE | REQUIRED BY CONFIGURATION AND MAGNITUDE | REQUIRED BY CONFIGURATION AND MAGNITUDE | NOT REQUIRED | NOT REQUIRED | REQUIRED BY CONFIGURATION AND MAGNITUDE | NOT REQUIRED |
| MOON (SYMBOLIC) | NOT REQUIRED | NOT REQUIRED | REQUIRED INCLUDING PHASES | REQUIRED INCLUDING PHASES | REQUIRED INCLUDING PHASES | REQUIRED INCLUDING PHASES | REQUIRED | REQUIRED INCLUDING PHASES | REQUIRED INCLUDING PHASES |
| SUN (SYMBOLIC) | NOT REQUIRED | NOT REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED | REQUIRED |
| PLANETS (FOUR BRIGHTEST) | NOT REQUIRED | NOT REQUIRED | REQUIRED | REQUIRED | REQUIRED | NOT REQUIRED | NOT REQUIRED | REQUIRED | NOT REQUIRED |

IMAGE CONTENT - "CELESTIAL BODIES" TABLE 3 of 5

Table 6.2.9-3

| | RENDEZVOUS PHASE | DOCKING AND UNDOCKING PHASE | PAYLOAD OPERATIONS PHASE |
|---|---|---|---|
| VISUALLY DETECT TARGET | 300 n.m. | 0 TO 10 n.m. (COLLISION POSSIBLE) | 0 TO 1 n.m. (COLLISION POSSIBLE) |
| SUBTENDED ANGLE AT WHICH TARGET ATTITUDE IS IDENTIFIABLE | NOT REQUIRED | $\geq 1.50°$ | $\geq 1.50°$ |
| QUANTITY OF SIMULTANEOUS TARGET VEHICLE | ONE TARGET | ONE TARGET | FIVE TARGETS. |
| MAXIMUM/MINIMUM SIZE | ANOTHER ORBITER: LENGTH = 111 FT., SPAN = 80 FT/SATELLITE: 100 INCH DIAMETER SPHERE | ANOTHER ORBITER: LENGTH = 111 FT., SPAN = 80 FT./SPACE STATION: CYLINDRICAL, LENGTH = 15 FT., DIAMETER = 15 FT. | ANOTHER ORBITER: LENGTH = 111 FT., SPAN = 80 FT./SATELLITE: 100 INCH DIAMETER SPHERE |
| TARGET VEHICLE MOVING PARTS | NOT APPLICABLE | N/R: | N/R: |
| TARGET LIGHTS, i.e., ACQUISITION, TRACKING AND ANTI-COLLISION LIGHTS ONLY | REQUIRED: SOME TARGET VEHICLE WILL HAVE NO LIGHTS. FOR TARGET VEHICLES THAT DO HAVE LIGHTS THEY WILL BE CONTROLLABLE AND THE LIGHTS WILL BE FIXED TO TARGET, HOWEVER, TARGET ATTITUDE IS A VARIABLE. | REQUIRED: SOME TARGET VEHICLES WILL HAVE NO LIGHTS. FOR TARGET VEHICLES THAT DO HAVE LIGHTS THEY WILL BE CONTROLLABLE AND THE LIGHTS WILL BE FIXED TO TARGET, HOWEVER, TARGET ATTITUDE IS A VARIABLE. | REQUIRED: SOME TARGET VEHICLES WILL HAVE NO LIGHTS. FOR TARGET VEHICLES THAT DO HAVE LIGHTS THEY WILL BE CONTROLLABLE AND THE LIGHTS WILL BE FIXED TO TARGET, HOWEVER, TARGET ATTITUDE IS A VARIABLE. |
| OWN VEHICLE LIGHTS ILLUMINATING TARGET VEHICLE | NOT REQUIRED | REQUIRED: (1) ILLUMINATION BY SPOTLIGHT FOR RELATIVE VEHICLE ATTITUDE REFERENCE, (2) ILLUMINATION BY FLOODLIGHT. SHADOWS ALSO REQUIRED. | NOT APPLICABLE - SEE IMAGE CONTENT - "REMOTE MANIPULATOR ARMS" TABLE 5 of 5 |
| SUN SHADOWS ON TARGET VEHICLE | NOT REQUIRED | REQUIRED | REQUIRED |
| VISUALLY DETECT PAYLOAD RETENTION FITTINGS | NOT REQUIRED | NOT REQUIRED | REQUIRED: RANGE = 0 TO 60 FT. |

<u>IMAGE CONTENT - "TARGET VEHICLE"</u> TABLE 4 of 5

Table 6.2.9-4

| | PAYLOAD OPERATIONS |
|---|---|
| PHYSICAL DIMENSION | LENTH = 50 FT. (TO END OF TERMINAL DEVICE)<br>DIAMETER = 8 INCH MAXIMUM |
| TERMINAL DEVICE MAXIMUM/ MINIMUM RANGE | 50 FT./10 FT. |
| VISUALLY DETECT DEGREES OF FREEDOM | REQUIRED: VISUALLY DETECT EACH DEGREE OF FREEDOM BY EFFECT OF CHANGE IN POSITION AND/OR ATTITUDE. ALSO, MOTION OF TERMINAL DEVICE FOR OPEN/ CLOSE TRANSITION |
| LIGHTS | REQUIRED: SIMULATION TO SIGNIFY BLINDING BY THE SPOTLIGHTS ON EACH ARM NEAR TERMINAL DEVICE BY SOME MEANS IS REQUIRED. SPOTLIGHT SHADOWS BY EITHER ARM OR OWN VEHICLE OR TARGET VEHICLE. |
| ARMS FIXED TO DOOR | REQUIRED: ALSO MOTION FROM FIXED POSITION TO OPERATIONAL POSITION AND VICE-VERSA. |
| VISUALLY DETECT ARM JETTISONING AND EXPLOSION | REQUIRED: AN EXPLOSIVE BOLT DEVICE IN CASE OF FROZEN JOINT MALFUNCTION |

IMAGE CONTENT - "REMOTE MANIPULATOR SYSTEM ARMS" TABLE 5 of 5

FIGURE 6.2.9-5

| | TRANSLATION | | ROTATION | | |
|---|---|---|---|---|---|
| | VELOCITY | ACCELERATION | DISPLACEMENT | VELOCITY | ACCELERATION |
| 1. ORBITAL PHASES | $25{,}500 \le V \le$ 28,000 fps | max AV = 1000 fps (burn time not specified) | all-attitude | minimum = $0.1^{\circ}$/sec maximum = TBD | $0 \le \|$ roll acceleration $\| \le 5^{\circ}/sec^2$ $0 \le \|$ pitch acceleration $\| \le 2.5^{\circ}/sec^2$ $0 \le \|$ yaw acceleration $\| \le 2.5^{\circ}/sec^2$ |
| 2. AERODYNAMIC PHASES | $140 \le V \le 600$ knots DESIGN TOUCHDOWN SINK RATE = 0-10 fps | $0 \le$ ACC. $\le 40$ ft/sec$^2$ | $-30^{\circ} \le$ bank angle $\le 30^{\circ}$ $-10^{\circ} \le$ slide slip $\le 10^{\circ}$ $-3^{\circ} \le$ pitch angle $\le 20^{\circ}$ | $0 \le \|p_B\| \le 20^{\circ}$/sec $0 \le \|q_B\| \le 5^{\circ}$/sec $0 \le \|r_B\| \le 5^{\circ}$/sec | $0 \le \|\dot{p}_B\| \le 1.5$ rad/sec$^2$ $0 \le \|\dot{q}_B\| \le 0.5$ rad/sec$^2$ $0 \le \|\dot{r}_B\| \le 0.5$ rad/sec$^2$ |
| 3. DOCKING MISALIGNMENT | Max relative velocity at docking = $\pm$ 0.5 fps | | Docking Angular Misalignment = $\pm 5^{\circ}$ Docking Roll Misalignment = $\pm 7^{\circ}$ | Max V at docking (active vehicle) = $\pm 1^{\circ}$/sec Max V at docking (passive vehicle) = $\pm 0.1^{\circ}$/sec | |

SHUTTLE MOTION PROFILE TABLE 6.2.9-6

d. There shall be no image discontinuity or interruptions, i.e., transition between models, color and size variations, appearance such as television to film or vice versa, since these would provide effective cues in the simulator which would be absent in the real world.

e. The accuracy of the system shall be adequate to permit measurements with the COAS, such that the inaccuracies due to the star and horizon position shall be less than half of the allowable measurement inaccuracy of $\pm 0.75^{\circ}$ or $\pm 45$ arc minutes.

f. The image generation system shall permit continuous simulation of any mission including abort and ferry phases.

6.2.9.2.2 Display

6.2.9.2.2.1 Forward Work Station

Display system parameters which shall be provided by the design are as follows:

a) Field of view filling all six windows simultaneously

b) Color

c) Infinity image, non-pupil forming

d) The head motion envelope shall be a 12-inch diameter sphere centered at the design eye such that within the sphere the distortion and brightness shall still satisfy the requirements.

e) Resolution (horizontal and vertical) 6 arc minutes at 5% modulation

f) Geometricdistortion (angular error between true position of image point and displayed position with respect to design eye) $\pm 1^{o}$

g) White field brightness, large area 8 ft. lamberts

h) Brightness variation anywhere in the field of view (i.e. $\frac{\text{minimum}}{\text{maximum}}$) .5 or greater

i) Ghosts (under maximum contrast conditions of the sun image against a star background. 100:1

j) Positional accuracy as measured for the COAS foreward window position with respect to the calculated line of sight:

navigational stars & celestial bodies $\pm 10$ arc minutes

horizon $\pm 10$ arc minutes

k) Contrast (minimum to maximum with 50% of the measured viewing channel at maximum brightness) 1:25

l) Collimation error (within head motion envelope) $\leq 40$ arc minutes

m) image matrix characteristics (if used)

1) image registration $\leq$ 25 arc minutes ov[er] central 70% of matrix edge

2) brightness matching $\pm$1 shade of gray

3) No loss of imaging at the mosiac edges will occur for head motion: horizontal $\pm$3 inch and vertical $\pm$2 inch.

6.2.9.2.2.2 <u>Aft Work Station</u>

Display system parameters which should be provided by the design are as follows:

a) Field of view filling all four windows simultaneously

b) Black and White

c) Infinity image, non-pupil forming

d) The head motion envelope shall be a volume that circumscribes the four 12 inch diameter spheres which are centered at each selected eye point (as shown in Figure 6.2.9-2 such that within this volume the distortion and brightness shall still satisfy the requirements.

e) Resolution (horizontal and vertical) 6 arc minutes at 5% modulation

f) Geometric distortion (angular $1^{o}$

error between true position of image point and displayed position with respect to the selected eye position for each window)

g) White field brightness, large area — 8 ft. lamberts

h) Brightness variation anywhere in the field of view (i.e., $\frac{\text{maximum}}{\text{minimum}}$) — .5 or greater

i) Ghosts (under maximum contrast conditions of the sum image against a star background) — 100:1

j) Contrast (minimum to maximum with 50% of the measured viewing channel at maximum brightness) — 1:25

k) Collimation error (within head motion envelope) — $\leq$ 40 arc minutes

l) Image matrix characteristics (if used)

1) image registration — $\leq$25 arc minutes over central 70% of matrix edge

2) Brightness matc hing — $\pm$1 shade of gray

3) No loss of imaging at the mosaic edges will occur for head motion: horizontal $\pm$3 in and vertical $\pm$2 inch.

6.2.9.2.2.3 TV Monitors

The two TV monitors will be monochromatic and capable of 525 scan lines. Each monitor will have the standard ON/OFF, brightness, contrast and test controls. In addition any of five TV cameras can be selected on any of the two TV monitors.

6.2.9.2.3 Image Generators

6.2.9.2.3.1 Celestial Bodies

6.2.9.2.3.1.1 Stars

The starfield is required during backup system IRU alignment employing a COAS and to provide information relative to spacecraft attitude motion. The starfield therefore is required to be simulated in both the forward and rear windows. The accuracy of positioning the navigation stars to be observed from the COAS when mounted on the front window positioning brackets should be within 10 arc minutes of the calculated line of sight. All stars with a magnitude -1 to +5, shall be shown and arranged to represent the major (88) recognized constellations. This will permit continuous training of the constellation identification under heavy workload conditions during simulated malfunctions. Approximately 1000 stars are required for identification of the constellations. In the rear windows it is not necessary to represent any constellations, nor to meet any positional accuracy requirements, however, approximately 100 stars distributed randomly such that they do not represent any constellation will be required to provide attitude motion references.

If virtual image point sources are not used to simulate the stars, the representation of a star may be provided by any other method that provides an apparent star diameter which does not exceed 6 arc minutes. Variation in star magnitude may be represented by variations in intensity.

6.2.9.2.3.1.2 Sun

A symbolic representation of the sun with true size and position (± 10 arc minutes) is required for use in backup navigation with the COAS. The brightness should be as high as feasible without excessive costs but not less than 12 ft. lamberts and appear white.

2.2.9.2.3.1.3 Moon

The requirements for the moon are identical to those for the sun, except that the brightness should be equal to 0.1 that of the sun and the color temperature may be shifted to aid differentiating from the sun. Continuous control of moon "phases" shall be provided.

6.2.9.2.3.1.4 Planets

The four brightest planets shall be shown as stars of suitable magnitude with location accuracy sufficient to provide COAS measurement accuracy of ±10 arc minutes over an eight hour training session.

6.2.9.2.3.2 Earth Scenes

6.2.9.2.3.2.1 General Requirements

Scenes of the earth are required for all altitude ranges from 24 ft. to 500 n.m. Switching of image generators if required will be done in a cloud layer. VFR and IFR approach and landings are required to be simulated. During VFR approach and landings it will be necessary to provide a high resolution, "real world" type of runway and surrounding area,

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so that the pilot may obtain confidence in his altitude and flight path judgements via the visual cues. Category II visibility conditions are the worst visibility conditions to be simulated.

6.2.9.2.3.2.2 Cloud Cover

Above 60,000 ft. the earth will always be covered by a homogeneous cloud cover. The radius of curvature of the overall disc will change as a function of altitude.

Below 60,000 ft. the cloud layer will have a variable thickness selectable by the instructor at the IOS station. The cloud layer top will vary from 2000 ft. to 60,000 ft. The cloud layer bottom will vary from 100 ft. to 50,000 ft. A cloud layer must always exist to provide non-calibratable altitude cues and to accommodate the necessary image generation changes from a homogeneous cloud cover earth scene to an earth scene consisting of terrain information.

6.2.9.2.3.2.3 Horizon

Above the homogeneous cloud cover the horizon is formed by the interface between the top of the cloud layer and the sky. During orbital flight when the navigation backup system is employed, the horizon is viewed from the COAS. Therefore, the horizon depression angle must be within $\pm 10$ arc minutes. The visibility limiting haze below the homogeneous cloud layer, will blend naturally into overcast forming a horizon.

6.2.9.2.3.2.4 Earth Scene Below Cloud Layer

Below the maximum altitude of 50,000 ft., the earth scene will contain the runway and other significant landmarks such that the pilot could visually confirm his location. Detail of the runway area shall increase as the simulated orbiter altitude decreases such that at approximately 10,000 ft. altitude (i.e., the altitude the pilot attains the 15$^{\circ}$ glide slope) the scene content will consist of natural and cultural features used by the pilot in executing a landing at a given runway at a particular airfield--features such as hills, prominent buildings, roads, bridges, bodies of water, etc. The airfield at KSC shall be simulated The airfield will have Category II runway markings and lights. No taxi or off runway scenes are required. Also the visual scene will be in color

As a minimum, a symbolic earth scene within the altitude range of 10,000 ft. to 50,000 ft. providing perception of velocity and the capability for unlimited translation and rotation shall be acceptable In this case different symbols would be required to represent the airfield and other significant landmarks such that the pilot could visually confirm his location. However, an earth scene content consisting of natural and cultural features is still required during the orbiter's flight below 10,000 ft. altitude and in the vicinity of the airfield. Therefore, a transition from a symbolic earth scene to a natural and cultural earth scene shall be provided where no image discontinuity or interruptions exist. Subsequent to transition, the horizontal display field of view shall be a minimum of $100^{\circ}$. In this case a horizontal and vertical display resolution of 11 arc minutes shall be acceptable.

6.2.9.2.3.2.4.1 Maneuver Range

The maneuver range within the simulated altitude range 50,000 ft. to touchdown shall be a 200n.m. square centered at the runway. The maneuver range within the simulated altitude range 10,000 ft. to touchdown shall be 20n.m.parallel to runway by 8 n.m. centered at the runway.

6.2.9.2.3.2.4.2 Visibility

Below the homogeneous cloud cover, a continuous range of visibility shall be provided from a 0 n.m. to the maximum visibility limit. The maximum visibility limit varies as a function of altitude between a ground range of 55 n.m. measured from nadir at a simulated altitude of 50,000 ft. to 3 n.m. at touchdown. The maximum visibility limits are derived so that approximately $1^{\circ}$ of the forward vertical field of view contains an earth scene at a 50,000 ft. altitude and visibility is provided beyond the ground near ground level. The maximum visibility function (i.e., linear, quadratic etc.) as a function of altitude is to be determined.

6.2.9.2.3.2.3 Earth Scene Above Cloud Layer

A textureless and patternless earth disc will be provided. Also a day/night terminator with controllable curvature and orientation is required. The visual scene will be black and white.

6.2.9.2.3.3 Spacecraft Exterior

6.2.9.2.3.3.1 Nose

The occultation of the out-of-the-window scene by the nose, as a function of the eyepoint position is required.

6.2.9.2.3.3.2 Wings

Depending on the final configuration of the Orbiter, it may be necessary to show the wings in the side and aft windows at the payload handling station. Since the wings will be far away, relative to the probable head position, the significance of variation in occultation as a function of head motion, is of lesser importance than the appearance of the structure. Therefore, the wing structure shall be included in the imagery.

6.2.9.2.3.3.3 Orbiter Aft Section

The aft section includes the payload bay and the tail assembly. It shall be imaged at infinity. The opening and closing of the payload bay doors shall be shown. The detail includes the trunnion locations in the payload bay and large areas of the body and tail. The latter may be shown in simple large uniform planes, with sun illumination areas. Letter and cargo or storage guideline paintings shall be shown.

6.2.9.2.3.4 <u>Lighting & Shadows</u>

Simulation of the lighting and shadows shall be provided to the extent defined below.

Required:

a. Light source position and axis

b. Radiation patterns - when significant

c. Illumination of all surfaces which are illuminated by the source

Illumination from:

a. Sun

b. Earth shine

c. Spotlights, on remote manipulator system arms

d. Floodlights on vehicle

e. Spotlight in docking hatch

Illumination levels shall be shown as follows:

Earth shine - low level

All other sources, or combinations thereof including the sun, but excluding the illumination from the spotlights at the end of the remote manipulator system arms-Medium level.

Spotlights at the end of the remote manipulator systems arms - highest level.

6.2.9.2.3.5 Occultation

Occultation of all surfaces and celestial bodies by all other celestial bodies and spacecraft, cargo and other vehicle surfaces shall be provided.

6.2.9.2.3.6 Time of Day

The time of day for any simulation task is variable and is selected by the instructor at the IOS station.

6.2.9.2.3.7 TV Cameras

There are five closed circuit TV cameras located at the following positions: Two TV cameras are located near the terminator of each remote manipulator arm, two TV cameras are located in the payload bay (i.e., fore and aft) and the fifth camera is mounted on the center-line of the docking axis at the docking port window. Any two may be monitored via a switch selected by the payload handling specialist. The TV cameras are used during docking and undocking and payload operations.

Simulation of the complete TV cameras subsystem shall be provided. This shall include the associated spotlights and floodlights, optical system (including varifocal operation) light level compensation and camera features (525 line monchromatic).

The images to be shown in each camera are those of the earth, the target vehicle, the sun and moon and the Shuttle vehicle and target vehicles. Stars and planets need not be shown. Moreover, portions of the vehicle will be seen via the closed circuit TV cameras, especially by those located at the ends of the remote manipulator system arms. Therefore, all vehicle surfaces that can be viewed from any point within the remote manipulator system arm envelope shall be included.

6.2.9.2.3.8 Remote Manipulator System Arms

The two remote manipulator system arms shall be simulated. Each of the seven degrees of freedom shall be visually detected by observing the effect of change in position and/or attitude. Also, open/close motion of the terminal device shall be simulated. The remote manipulator system arms shall be imaged at infinity. When the remote manipulator system arm(s) has malfunctioned, visual simulation shall be required for the explosive bolt operation and subsequent jettisoning of the arms.

6.2.9.2.3.9 Target Vehicles

Visual simulation of the removal and storage of target vehicles from the payload bay shall be simulated. The payload retention fittings shall be visually detected by the remote manipulator system operator within a line of sight range of 60 feet. The remote manipulator system operator shall be capable of viewing up to 5 target vehicles either in the payload bay or exterior to the orbiter.

The target vehicles will vary in size from another orbiter (i.e., length = 120 ft., span = 80 ft.) to a satellite (i.e., 100 inch diameter sphere). Portions of these shall be able to be shown in more than one position, e.g., the docking hatch on the other orbiter shall be either extended or retracted, but a dynamic transition need not be simulated. Target vehicles lights, that is acquisition, tracking, and anti-collision lights, fixed to the vehicle shall be simulated. The target vehicle will be an all attitude vehicle and must be visually detected up to 300 n.m. The attitude of the target vehicle must be identifiable to the observer when the target vehicle subtends an angle greater than $1.5^{\circ}$ with respect to the observer.

6.2.9.3 Visual and Motion Cue Coordination

Motion and visual cues are important in a number of critical mission phases and flight maneuvers. The visual scene provides essential control information, while cockpit motion cues permit the crew to anticipate some control requirements, and to assess the effects of others, before they are reflected either in the visual scene or in the cockpit instruments.

The alerting function of motion cues makes it essential that they be provided in the simulator in the same temporal relationship to the visual and instrument cues which they accompany in the aircraft. The perceptual limitations of the pilot permits some discrepancies to exist between the simulator and the aircraft, but these are relatively small, and are proportional to the normal time periods existing in the aircraft, between the occurrence of motion and visual cues. Therefore, the accuracy of visual and motion cue coordination shall be within 10% of the relationships measured in the aircraft itself.

6.2.9.4 Maintenance Features

A signal substitution panel shall provide the capability of operating the visual system without the SMS computer and DCE to aid in maintenance and to do the necessary calibration, e.g., positional accuracy. The following equipment shall be required: 525 line black and white monitor as a substitute for the payload handling station monitors, test image generators, e.g., resolution and color patterns, signal generators, optical measurement devices, e.g., for display brightness and resolution, etc., depending upon the visual system design.

6.2.9.5 IOS Monitor Features

Two types of visual monitoring requirements are required, one a repeat of the crew's visual scene, the other, a graphic and alphanumeric representation of significant system performance parameters.

1. Visual Scene Repeater. The repeat of the crew's visual scene is important since it provides the instructor with information in his display to be able to see the same spatial relationships and vehicle attitudes as observed by the crew in their visual scene.

2. Graphic Display. This display will provide a graphic representation of the performance required of the system in each relevant mission task and maneuver, and of the criteria established for acceptable performance of ground track, flight path, orbit, altitude, attitude and other similar parameters will be displayed in graphic form, to minimize requirements for instructor interpretation of discrete data.

Depending on the crew task, it will be necessary to display some parameters both graphically and numerically, to support monitoring of performance trends as well as diagnosis of specific sources of some trends. The required display system will permit alphanumeric and graphic data to be displayed at the same time on the same display.

Also, in addition to displaying desired and actual performance at the same time, the graphic display will be able to be viewed from any angle, regardless of the orientation of the crew to the task situation under consideration. This will permit the instructor to view the effects of crew performance from a point of view not available to the crew. The view of a docking exercise, for example, can be rotated so that it is seen at right angles to the crew's normal orientation.

It will also be possible for crew members to observe the repeated display to form a better understanding of the dynamics of many mission tasks.

6.2.9.6 Software Drive Requirements

The software for driving the visual system will reside in the SMS Computer Complex. The outputs derived from the SMS Computer Complex will be passed through the DCE as required by the visual system hardware. The visual simulation programs will be organized along logical lines corresponding to visual system hardware subsystems and will be readily identifiable by function. Iteration rates of the programs will be sufficiently high to prevent any noticeable "staircasing" of output signals in the visual systems.

The visual scene must appear in correct perspective when viewed from the Commander's nominal eye position and the pilot's nominal eye position and the rear window nominal viewing positions. In addition, the visual software will determine the positions and directions (i.e., line of sight) of the five remote manipulator system's TV cameras. Each TV camera will be treated separately as individual windows.

The visual system software will interface at a minimum with the following software programs:

a. orbiter equations of motion

b. external hydrogen-oxygen tank equations of motion

c. ephemeris system

d. target vehicles equations of motion

e. remote manipulator system

f. payload bay doors equations of motion

The Shuttle Mission Simulator shall be used with or without the visual system via a switch on the IOS.

The thickness of the cloud layer is selectable at the IOS (i.e., altitudes of cloud top and cloud bottoms), however, a software check is required such that the cloud layer of sufficient thickness will exist to accommodate the necessary image generation changes from a homogeneous cloud cover earth scene to an earth scene consisting of terrain information.

6.2.9.7 Visual Graphics

The contractor will furnish the customer the masters of the graphic material such that first generation copies may be generated after acceptance; for example, the original film if the visual system design includes film, the original model drawings if the visual system design includes a camera/model system and the original environment model on a mass storage device if the visual system design includes a computer image generation system.

## 6.2.10 Shuttle Systems Simulation Software (WBS #1.8.1 and 2.8.1)

### 6.2.10.1 Electrical Power System (EPS)

The EPS simulation shall be divided into three major divisions: Power Generation, Power Distribution, and Power Loading. The simulation shall have a response accuracy of ±5% of the steady-state telemetry or display parameter range for calculated values within one second after a transient occurrence and an accuracy of ±1% within two seconds. The long term simulation error after eight hours run shall be less than ±10% of the parameter measurement range.

During non-integrated modes of training, the Shuttle Mission Simulator shall provide realistic simulation of other docked vehicles or attached payloads electrical interface parameters. The control of these simulated interface parameters shall be provided to the IOS station. Mating of interface power cables, which is normally a manual crew operation, shall be accomplished either by setting an IOS control parameter or by the crew procedure of using a simulated power cable in the crew station area. Where handling of cables is considered of training value, the cables shall be provided. All power in the simulated cable shall be limited to that level required to simulate a mated connection.

6.2.10.1.1 Power Generation

6.2.10.1.1.1 Fuel Cell

The fuel cell simulation shall calculate all internal and interface parameters that correlate to the power loads and losses of the cell. These equations shall also calculate the reactant parameters that are instrumented on the liquid oxygen and liquid hydrogen cryogenic tanks. Mass property parameters shall be calculated for interface with the equations of Weights and Balances. Thermal parameters of the fuel cell and its cryogenic system shall be calculated for interface with the equations of the thermal systems of ECLSS, TCS and TPS. All logic of the control system for the start-up, run, and shut-down of the fuel cell and the cryogenic storage system shall be included for crew station inputs, simulated up-link commands, and internal electronic logic.

6.2.10.1.1.2 Charger-Battery

The Charger-Battery equations shall calculate all internal and interface parameters that correlate to the power loads and losses of the charger and the power loads and losses of the batteries. These equations shall account for internal power losses, all control logic between the charger and battery, and shall provide realistic battery output voltage levels as a function of battery state-of-charge, battery temperature, and battery current, internal impedance, and load. The charger simulation shall provide the logic of the real-world system for control of the rate-of-charge of the simulated battery.

The electrical load of the simulated charger, including efficiency, shall be calculated for interface with the Bus Loading equations. The thermal parameters of the charger and battery shall be calculated for interface with the equations of the thermal systems of ECLSS, TCS, and TPS. All logic of the control system for activation, run, and shut-down of both the charger and the battery shall be included for crew station inputs, simulated up-link commands, and internal switching logic.

6.2.10.1.1.3 Generator

6.2.10.1.1.3.1 APU Generator

The APU Generator simulation shall calculate all internal and interface parameters that correlate to the power loads and losses of the APU alternators. These equations shall account for all internal power losses, all control logic, and also provide a realistic output voltage level and frequency as a function of power input to the alternator. The thermal parameters of the alternators shall be calculated for interface with the thermal control systems of ECLSS, TCS, and TPS. All logic of the control system for activation, run, and shut-down of the alternator shall be included for crew station inputs, simulated up-link commands, and internal switching logic.

6.2.10.1.1.3.2 ABPS Generator

The ABPS Generator simulation shall calculate all internal and interface parameters that correlate to the power loads and losses of the ABPS alternators.

These equations shall also account for all internal power losses, all control logic, and also provide a realistic output voltage level and frequency as a function of power input to the alternator. The thermal parameters of the alternators shall be calculated for interface with atmospheric properties from EOM Aerodynamic Data. All logic of the control system for activation, run, and shut-down of the alternators shall be included for crew station inputs, simulated up-link commands, and internal switching logic.

6.2.10.1.2 Power Distribution System

6.2.10.1.2.1 AC Power Distribution

The AC Power Distribution equations shall calculate the voltage levels at all instrumented buses which have sensors for on-board display or for telemetry transmission. All loads shall be handled as resistive, non-capacitive, non-inductive loads. The equations shall provide an interface between the AC power generation equations, the bus loading equations, and all AC power using systems. All switching logic for the control of bus interconnection shall be handled by the power switching logic equations.

6.2.10.1.2.2 DC Power Distribution

The DC Power Distribution shall calculate the voltage levels at all instrumented buses which have sensors for on-board display or for telemetry transmission. All loads shall be handled as purely resistive loads. The equations shall provide an interface between the DC power generating equations, the bus loading equations, and all DC power using systems.

All switching logic for the control of bus interconnection shall be handled by the power switching logic equations.

6.2.10.1.2.3 Power Switching Logic

The power switching logic equations shall provide the calculation of the switching logic between the EPS buses and the electrical power sources. These switching logic equations shall take into account all inputs either from the crew station or by up-link command, and shall include all internal switching logic controls for the inter-network of buses. This system shall handle all switching logic of both AC and DC systems and shall include the logic of connecting the power sources to the bus network.

6.2.10.1.2.4 Power Control and Display

The Power Control and Display equations shall have two main functions: control of circuit breakers; and calculation of the Control and Display converter/signal conditioner power for activation of the crew station meters.

Circuit breaker control shall be provided for all Shuttle vehicle circuit breakers accessable to crew members. Simulated circuit breakers outside of the crew station shall be software functions.

The control of the circuit breakers shall include a simulation of circuit breaker response to overload conditions. On sensing overload conditions, provision shall be made to open the simulated circuit breaker. This capability shall exist for the (TBD) types of circuit breakers. For certain malfunctions, the manually controlled circuit breaker shall be opened by the insertion of the malfunction.

The simulation of the converters used for display and control purposes, shall be limited in fidelity to a go-no go logic. That is, with input power and the converter not malfunctioned, the converter output voltage shall remain constant regardless of the minor load fluctuations. Power available booleans shall be established for using systems so that the availability of control and display power is taken into account in simulation of crew station displayed parameters.

6.2.10.1.3 Power Loading

6.2.10.1.3.1 Transformer-Rectifier Units

The transformer-rectifier equations shall calculate all internal and interface parameters that correlate to the power loads and losses of the Transformer-Rectifier units. These equations shall also account for all internal power losses, all control logic and regulation, and also provide a realistic output voltage level as a function of power input to the unit. The thermal parameters of the transformer-rectifier units shall be calculated for interface with the thermal control systems of ECLSS, TCS, and TPS.

6.2.10.1.3.2 Inverter Units

The inverter equations shall calculate all internal and interface parameters that correlate to the power loads and losses of the inverter units. These equations shall account for all internal power losses, all control logic and phase relation, and also provide a realistic output voltage level as a function of power input to the unit. The thermal parameters of the inverter units shall be calculated for realistic interface with the thermal control systems of ECLSS, TCS, and TPS.

6.2.10.1.3.3 Bus Loading

The bus loading equations shall provide the interface between systems which use electrical power, both AC and DC, and the power distribution system. The program shall accumulate the electrical load of each using system, including the effect of supply voltage, on each bus in the electrical network.

Loading equations shall provide all transient loads that affect crew station display instrumentation. Minor electrical loads which do not cause motion of crew station display instrumentation shall be provided for by accumulated loading under control of the instructor.

6.2.10.2 Mechanical Power System

6.2.10.2.1 Auxiliary Power Unit

The auxiliary power unit simulation shall provide for the major areas of power generation by the turbines, the fuel supply, the power loads on the turbine, the fire protection system, and the lubrication system. The overall system response shall be within ± 5% of the steady state calculated value within one second, and ± 1% of the steady value within two seconds following a system transient. The long term accumulated simulation error after eight hours run shall be less than ± 2%.

6.2.10.2.1.1 Power Generation

The power generation equations shall calculate all internal and interface parameters required for the turbine engine combustion cycle. This shall include parameters of the catalytic reactor plates, the combustion chamber, and the exit ducting. These parameters shall include electrical heater loads, efficiency or reaction/combustion, temperature, pressure and the tachometer speed. Fuel consumption shall reflect the engine load.

6.2.10.2.1.2 Fuel Supply System

The fuel supply system shall calculate all internal and interface parameters required for storing, handling, conditioning, and control of the hydrazine fuel for the gas turbine. Among the items to be simulated are the He pressurization subsystem, the storage and handling of the liquid hydrazine fuel, the transformation of the liquid fuel to a gaseous state, the temperature control of the fuel lines, and the control logic of the valving. Parameters to be calculated shall include, but not be limited to, quantity remaining, flow rates, heat transfer, temperature, and pressure.

6.2.10.2.1.3 Power Loading

The APU power loading equation shall provide the summation of all loads, both mechanical and electrical, to the power generation equations. These loads shall include the electrical alternators, the hydraulic pumps, the fuel pumps, and the lube pumps. Efficiency of the gear drive system shall be taken into account.

6.2.10.2.1.4 Fire Protection System

The fire protection system shall provide all controls and logic associated with the storage and use of the $CO_2$ extinguishers and the logic of the fire detection components.

6.2.10.2.1.5 Lubrication System

The lubrication system shall calculate the interface parameters and control logic for the lube oil/water boiler heat exchanger, the lube oil/air cooler heat exchanger, and the lube oil circulation system.

6.2.10.2.1.6 Control & Display Logic Subsystem

The logic for the controls and displays of the APU shall be simulated to include both automatic and manual start up and shut down of the units. Controls and displays to the crew shall include simulation fidelity for sequencing of switches, circuit breakers, and logic sequencer units to open/close valves. Speed control shall be simulated to provide realistic parameters for crew displays and telemetry for start up and shutdown sequences.

Interfaces with the EPS, ECLSS, instrumentation, and TCS shall be incorporated into the simulation process.

6.2.10.2.2 Hydraulic Power System

The hydraulic system simulation shall provide for the five areas of the power unit, the reservoir and circulation pump, the hydraulic load, the logic involved with control and display of the fluid state, and the heat exchanger. The overall simulation response shall be within ±5% of the steady state value within one second and be within ±1% of the steady state value within two seconds following a system transient. The accumulated simulation error shall not exceed ±2% at any time.

6.2.10.2.2.1 Power Unit

The power unit simulation equations shall provide for all internal and interface parameters pertaining to the conversion of mechanical turbine shaft energy into hydraulic pump output. To be included in these equations shall be pump efficiency, flow rate, heat gained, pressure, and temperature of the fluid.

6.2.10.2.2.2 Reservoir and Circulation Subsystem

The hydraulics reservoirs, accumulators, heaters, and circulation pumps shall be simulated. The simulation shall include calculations of hydraulic fluid temperature, pressures, flow rates, oil viscosity, and quantity levels. The fluid circulation system shall include all pumps, valving, pressure regulators, and flow limiting orifices or check valves. All automatic valving control logic shall be simulated for realistic time and functional responses.

6.2.10.2.2.3 Power Loading

The power loading equations of the hydraulic system shall provide summation of the loads from all using hydraulic actuators to the reservoir and circulation system. The summation parameters shall include the effect of pressure levels to each actuator.

6.2.10.2.2.4 Control and Display Logic

The control and display logic simulation shall provide all hydraulic system control logic, whether electronic, mechanical, or hydraulic used for valve and pump control. The equations shall also provide those parameters for crew station meter display which include control and display power available booleans from the EPS control and display equations.

6.2.10.2.2.5 Heat Exchanger Unit

The heat exchanger simulation program shall provide interface equations and parameters for the air coolers, ECLSS coolant loops, the water boilers, and the hydraulic line/reservoir/accumulator electrical strip heaters. These equations shall relate generally to heat flow and temperature of the exchangers.

6.2.10.3 Main Propulsion System (Less Controller)

The Main Propulsion System shall be simulated with the fidelity required to provide realistic responses for all crew displays and telemetry data of the external tanks, lines, valves, pre-burner turbines, recirculation pumps, pre-burner feed pumps and helium pressurization system. The simulated system parameters shall include fuel flow rates, turbine rpm, temperatures, pressures, and thrust level output. Interface and internal parameters shall be generated for pressurization, re-pressurization, fill, dump, recirculation of fluids and gases, purge and drain, diffusers, anti-slosh rings, anti-vortex baffles. Controlling inputs from the crew station or from interface with the commands from the GN&C computers via the controller shall be provided to the simulated system. Stabilization of the simulated system following power level changes shall be similar to the real-world system for rate of response. The system shall have an accuracy of ±1% of the real world telemetry or display parameter range for calculated values within 1 second after a transient occurrence. Refer to Controls and Displays paragraph 6.2.3.2.4 for meter response requirement. Prior to liftoff, the start logic and thrust buildup characteristics shall be provided for quick response and stable operation while maintaining realistic sensor parameters. At liftoff and until thrust tailoff, the engine at an operational power level shall have an average accuracy of ±1000 lbs. thrust and 0.05% mass as referenced to the operational flight trajectory data. Upon command to shutdown, the thrust tailoff shall be simulated so that the total impulse from each engine averages the same power level of the engine at cutoff. Fuel consumption shall also reflect the intermediate time step, if required, to meet the above mass accuracy requirements.

6.2.10.4 Reaction Control System

The Simulation of the RCS requires realistic responses for all crew displays and telemetry data of propellant tankage, lines, reaction heaters, helium pressurization system, and engines. Controlling inputs from the crew station and GN&C computers shall provide realistic values and time response. The simulation shall have a response accuracy of $\pm$ 1% of the steady state telemetry or display parameter range within one second following a transient occurance. The long term simulation error after eight hours run shall be less than $\pm$ 1% of the parameter measurement range. In the manual attitude or translational control mode, the total specific impulse error for each jet shall be less than $\pm$ 100 lb-seconds. In the minimum impulse mode or a computer controlled engine firing mode the total specific impulse error shall be less than $\pm$ 1 lb-second. Instrumentation and mass errors are both limited to $\pm$ 1% of the measurement range or, in the case of mass of fuel remaining, the total tankage quantity.

This system shall be unaffected by operation in the Integrated and Non Integrated Modes of Operation with other trainers or data networks since there are no direct interface requirements.

The deployment of the RCS doors shall be simulated and hydraulic quantity usage supplied to the hydraulic power system. Power loads shall be supplied for the electrical power loading program.

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6.2.10.5 Orbital Maneuvering System

The Orbital Maneuvering System shall be simulated for realistic responses for all crew displays and telemetry data of the tanks, lines, valves, and helium pressurization system. The engine system shall be simulated to provide realistic display and T/M parameters for fuel flow rates, fuel and oxidizer dump, temperatures, pressures, and thrust level output. Controlling inputs from the crew station or from interface with the commands from the GN&C computers shall be provided to the simulated system. Stabilization of the simulated system following power level changes shall be similar to the real-world system for rate of response. The system shall have an accuracy of ± 1% of the real world telemetry or display parameter range for calculated values within 1 second after a transient occurrence. Refer to Controls and Displays paragraph 3.5.2.4 for meter response requirements.

The start logic and thrust buildup characteristics shall be provided for quick response and stable operation while maintaining realistic sensor parameters. After start and until thrust tailoff, the engine at an operational power level shall have an accuracy of ± 20 lbs thrust and 0.2% mass as referenced to the operational flight trajectory data. Upon command to shutdown, the thrust tailoff shall be simulated so that the total impulse from each engine averages the same power level of the engine at cutoff. Fuel consumption shall also reflect the intermediate time step if required to meet the mass simulation requirements.

The modular addition of fuel tanks in the cargo bay shall be simulated.

### 6.2.10.6 Air Breathing Engine System

The Air Breathing Engine System shall be simulated for realistic response for all crew displays and telemetry data of the fuel tanks, supply lines, valves, fuel controllers, and boost pumps. Simulation of the in-flight refueling system shall be under instructor control. The support equipment functions of the fire detection units and the fire extinguishing system shall be simulated. Controlling inputs from the crew station or from interface with the commands from the GN&C computers shall be provided to the simulated system. Stabilization of the simulated system following power level changes shall be similar to the real-world system for rate of response. The system shall have a general stability accuracy of ± 1% of the real world telemetry or display parameter range for calculated values within 1 second after a transient occurance.

The engine system shall be simulated to provide realistic display and T/M parameters for fuel flow rates, turbine rpm, temperatures, pressures, and thrust level output. Prior to take off, the start logic and thrust buildup characteristics shall be provided for quick response and stable operation while maintaining realistic sensor parameters. The engine shall have an accuracy of ± 2% of the total real world thrust range. The fuel remaining shall be accurate within ± 2% of the total real world fuel tank capacity. All other parameters shall have an overall accuracy of ± 4% of the real world system instrumentation range.

Simulation shall provide power available booleans to the EPS simulation for the alternators and also provide hydraulic pumping rates to the hydraulic power system.

The air breathing engines shall be simulated only when the engines are installed, Instrumentation providing crew displays or telemetry shall be simulated if not removed with the engine nacelles.

6.2.10.7 Solid Rocket Motor

The Solid Rocket Motors shall be simulated for realistic response for all crew displays and telemetry data of thrust, temperature, and pressures of the strap on booster, external tank retro rocket, and the separation rockets. The function of the fire detection units shall be simulated. Controlling inputs from the crew station or from interface with the commands from the GN&C computers shall be provided to the simulated system. Thrust vector control of the nozzle shall be accomplished by control inputs from the GN&C system. The system shall have a stability accuracy of $\pm$ 1% of the real world telemetry or display parameter range for calculated values within 1 second after a transient occurrence.

The engine systems shall be simulated to provide realistic display and T/M parameters for temperatures, pressures, and thrust level output. Prior to lift off, the start logic and thrust buildup characteristics shall be provided for quick response and stable operation while maintaining realistic sensor parameters. The engine simulated parameters shall have an accuracy of $\pm$ .05% of the predicted or design thrust and mass range. All other parameters shall have an overall accuracy of $\pm$ 2% of the real world system instrumentation range.

6.2.10.8 External Tank - ET

The External Tank System shall be simulated for realistic response for all crew displays and telemetry data for the separation logic controls and responses. Controlling inputs from the crew station shall be provided to the simulated system.

The simulation of the range safety system shall not be provided. Simulation of the effects of the solid rocket deorbit motor will be provided. Electrical power interface and simulation of the external tank batteries will be provided by the EPS simulation. The Main Propulsion Simulation will include the simulation of the fuel and oxidizer tanks, sensors, and valving.

6.2.10.9 Guidance, Navigation and Control

6.2.10.9.1 Aerodynamic Flight Control

6.2.10.9.1.1 Aerosurface Control

The elevon and rudder/speed brake aerosurface control systems shall be simulated. Aerosurface position commands from the primary and back-up flight control system, aerosurface positions and hydraulic flow rates shall be calculated and shall be made available for display and for other systems. Response of the simulated system (time constants, maximum overshoots, rate limits, etc.)shall not be detectably different from that of the real-world system, and shall not introduce detectable divergence from real-world response into the control dynamics closed loop, in nominal operation. By detectable divergence is meant any anomaly which may be perceived by the crew as such, either by feeling vehicle dynamic response, viewing cockpit meters, monitoring CRT readouts, or watching out-the-window visual. Discrepancies which are of too brief duration to be sensed by a human, or which are of so small a magnitude as to be within all applicable meter/display accuracy tolerances are not detectable. Simulated system response (open and closed loop) shall reflect hydraulic system malfunctions and electrical system malfunctions, if present. The role of hydraulic pressure monitors and other failure detection equipment in the real-world systems' redundancy management shall be simulated. The simulated control surfaces shall exhibit the same position limits as the real-world actuators.

6.2.10.9.1.2 Air Data

The air data system and angle of attack transducers shall be simulated. Simulated real-world data, on which simulated air data is based, shall be consistent with that used in the simulated aerodynamic equations.

6.2.10.9.2 Spacecraft Flight Control

The spacecraft flight control components' electrical loads and hydraulic flow rates (if applicable) shall be simulated. The simulated spacecraft flight control components shall reflect the effects of electrical power system and hydraulic system malfunctions. The performance of components shall reflect the effects of applicable control switch settings and other crew inputs.

6.2.10.9.2.1 MPS Thrust Vector Control

The simulated main propulsion system thrust vector control system shall calculate the position of the simulated main engine gimbals for displays, the equations of motion, and other systems. Parameters used for telemetry and on-board display shall be calculated. The simulated thrust vector control system shall exhibit the same position and rate limits as the real-world system. Simulated system response to transients shall not detectably differ from that of the real-world system. Thrust vector control response shall be simulated with sufficient accuracy as to not detectably degrade closed loop control-vehicle dymamics response in any applicable flight regime - as compared to real-world. The role of hydraulic pressure monitors and other failure detection equipment in real-world redundancy management shall be simulated.

6.2.10.9.2.2 SRM Thrust Vector Control

The simulated boost SRM Thrust Vector Control System shall calculate the direction of the thrust vector for each of the strap-on boost solid rocket motors, while those motors remain attached to the shuttle vehicle. Parameters used for thrust vector control system shall exhibit the same position and rate limits as the real-world system. The simulated thrust vector control response characteristics to input commands shall be sufficiently accurate as to not detectably degrade closed-loop control/vehicle dynamics response in any flight regime prior to separation. The role of failure detection equipment in real-world redundancy management shall be simulated.

6.2.10.9.2.3 OMS Thrust Vector Control

The simulated Orbital Maneuvering System thrust vector control system shall calculate the position of the simulated OMS engine gimbals for displays, the equations of motion, and other systems. Parameters used for telemetry and on-board display shall be calculated. The simulated thrust vector control system shall exhibit the same rate and position limits as the real-world system. OMS thrust vector control response shall not detectably differ from that of the real-world system. Simulated OMS thrust vector control response accuracy shall be adequate to ensure against degradation of control-vehicle dynamics closed-loop response in any applicable flight regime.

6.2.10.9.2.4 Star Trackers

Each of the on-board star trackers shall be simulated, and shall provide target azimuth and elevation angles when in tracking mode to the on-board computer. The simulated star tracker shall exhibit the same field of view in each scan or tracking mode as the real-world system. The simulated star tracker search mode shall operate at approximately the same speed as the real-world device. During simulator slow time mode, scan speed shall be reduced in the same proportion as the speed of other processes is reduced. Earth, solar and lunar interference effects shall be simulated. In tracking mode, identification of the star or planet being tracked, azimuth, and elevation from both ephermeris and simulated star tracker output shall be available for instructor display.

6.2.10.9.2.5 Horizon Sensors

Each of the on-board horizon sensors shall be simulated. The simulated horizon sensors shall provide the same parameters to the on-board computer as do the real-world devices. The simulated device shall exhibit the same field of view as the real-world device.

6.2.10.9.2.6 Body Mounted Rate Sensors

Each of the vehicle body mounted rate sensors shall be simulated. Its sensed rate shall be available for display, and other systems. Rate sensor accuracy shall be comparable to the accuracy of the real-world devices.

6.2.10.9.2.7 Body Mounted Accelerometers

Each of the vehicle body-mounted accelerometers shall be simulated. Its sensed acceleration shall be available for display and other systems. Simulated sensed acceleration from accelerometers shall include accelerations arising from location of the device at a position other than the vehicle center of mass, as well as acceleration of the vehicle center of mass.

6.2.10.9.3 Inertial Measurement Unit

Each of the on-board Shuttle Vehicle Inertial Measurement Units (IMU) shall be simulated. Each of the operating modes of the real-world IMU's shall be simulated. The simulated IMU's shall possess the same realignment capabilities as the real-world devices. The self-test capabilities of the actual IMU's shall be simulated. The IMU simulation shall draw power from the simulated Electrical Power System, and shall respond to Electrical Power System malfunctions in a similar fashion to the real-world IMU's. IMU power switching shall be simulated. The effects of non-nominal temperatures upon the IMU's shall be simulated. The IMU temperature control system shall be simulated, including its interface with vehicle Electrical Power System and Environmental Control System. The simulated IMU's shall respond to pertinent crew control inputs and switch settings, and shall calculate all IMU parameters which may be displayed to the crew in the actual vehicle. All parameters used in real-world telemetry shall be calculated. Each simulated IMU shall acquire its information on vehicle dynamics from the simulated equations of motion, and calculate from that information all parameters provided to the remainder of the Guidance, Navigation, and Control system by the actual IMU's. The instructor shall be provided capability to vary these paramters. The simulated IMU's shall be capable of operation in other than real time. Following a vehicle "step ahead", the simulated IMU's shall be rotated through the same angle as was the vehicle during the step-ahead. (If a Strapdown IMU is used, the IMU electronics shall be reset in an analogous fashion to represent the new attitude.)

6.2.10.10 Communications and Tracking

The Communications and Tracking system shall include the simulation of all subsystems providing these capabilities for the operational mission. All subsystems shall be simulated in a realistic manner within real world accuracies unless specifically stated otherwise. The individual subsystems to be simulated include: S-Band Antenna, VHF Antenna, L-Band Antenna, C-Band Antenna, UHF/VHF Antenna, S-Band FM Receivers, Wide Band Transmitter, DFI Transmitter, SGLS S-Band Transponder, ERTS USB Transponder, AM and FM VHF Transceiver, TACAN, ATC Transponder, ILS, Radar Altimeter and interface with switching logic for the above subsystems. The system shall provide the capability of simulating multiple ground stations representative of the stations to be used for communications and tracking. Only those ground stations meeting antenna pattern and selection requirements need be on line; however, all stations must be available from mass storage.

6.2.10.10.1 Navigation and Landing Aids

6.2.10.10.1.1 TACAN

The TACAN subsystem shall simulate the ground-based VORTAC/TACAN stations providing range and bearing information through the L-band antenna system and the on-board triple redundant TACAN receivers/transponders. Both search and lock-on modes shall be simulated. Computed accuracy of the bearing information shal be $\pm 0.1^{\circ}$. The distance information shall have an error of less than $\pm 0.2$ percent at the distance measured. The simulation shall include multiple stations and require the same procedure for acquisition and tuning as exists in the operational equipment. The maximum number of ground-based stations required at any one time shall be three (3); however, the capability of tuning to and receiving the correct response from any station simulating the real world location shall not be limited in the simulator. Aural identification shall be included in the simulation of each station. Radiation patterns of the ground stations shall be simulated including the radio horizon, maximum range and cone of confusion.

6.2.10.10.1.2 Instrument Landing System (ILS)

The ILS subsystem shall simulate the ground based and in-flight equipment used to provide relative azimuth (localizer) and relative elevation (glideslope) with respect to the runway. Distortion of the radiated pattern, including false nulls, shall be simulated under control of the instructor. Two glide slopes shall be simulated -- a steep and a nominal glide slope. The capability of selection of the glide slope and localizer by the instructor shall be included. If not otherwise selected, the ILS shall be the correct simulation of the prime landing site ILS system. The inner, middle and outer marker beacons shall also be simulated.

6.2.10.10.1.3 GCA Radar

Information normally available to a GCA operator shall be made available at the instructor console to allow the simulator instructor to serve as GCA operator at his discretion. Information displayed shall be in an easy-to-read form including distance from touchdown, cross track, and height over/under the glide path. This information shall be available for at least 0 to 7 n.mi. from touchdown.

6.2.10.10.1.4 ATC Transponder

The ATC Transponder subsystem shall provide discrete indications of status to the appropriate displays.

6.2.10.10.1.5 Radar Altimeter

The Radar Altimeter shall be simulated. The subsystem shall provide a measurement of transducer altitude above local simulated terrain to ± 1 ft. accuracy.

6.2.10.10.1.6 Microwave Landing System (MLS)

Simulation of the MLS system shall provide range, azimuth and elevation angle with respect to the runway landing center line. The simulated airborne antennas operating in the C or Ku bands shall provide coverage of ±45° in azimuth and ±30° in elevation with respect to the orbiter longitudinal axes. The system shall have accuracies corresponding to the real world equipment. If real world equipment accuracies are not available at the time of simulation contract, the system accuracy shall be within 1 ft. in altitude, 7 ft. in cross track, 0.5 ft./sec. in altitude rate, and 0.6 ft./sec. in cross track rate with update at 4 second intervals. Maximum range of the system shall be 20 n.m. for the C-Band and 2 n.m. for the Ku band.

6.2.10.10.2 Communications

6.2.10.10.2.1 S-Band System

The S-Band communication system shall be simulated for both air-to-ground and ground-to-air links. The simulation shall include equations to calculate the line-of-sight acquisition and distance between shuttle and acquired ground station. From this data and relative body position, attenuation of signal strengths shall be calculated to provide signal-to-noise levels for injection of noise into the audio communication link and AGC signal.

All automatic and manual switching logic shall be included in the simulation. Both crew station displays and telemetry data shall reflect realistic value and response rate for all instrumented parameters.

All telemetry data and video signals shall be transmitted for integrated simulator operation without interruption from loss-of-signal. A boolean shall be generated by the S-Band program signalling whether or not each ground station has acquired or lost communication for telemetry and video.

There shall be a minimum of two voice communication loops for integrated training. One loop shall provide direct communication with the crew without attenuation of signal by calculated signal-to-noise ratio. This loop will provide a means of communication with the crew station regardless of computer mode or operational state. A dedicated audio loop shall provide voice-with-noise dependent on the calculated signal-to-noise ratio for the S-Band communication link.

Voice transmission shall be provided in all computer modes of operation on the S-Band line when a ground station is acquired.

Command data shall be accepted by the simulation only when ground station control is possible. Instructor override of the requirement for ground station control shall be provided.

Instructor aids shall be provided to display the ground station names or numbers when the stations have acquisition of signal.

Wideband data simulation shall not be provided at a rate higher than the limits of the External Interface Equipment. Refer to Paragraph 6.2.5.8.

Doppler tracking and Pseudo Random Noise Ranging shall be simulated by providing the calculated range of the acquired station. Instructor control shall be provided for insertion of dispersion effects.

6.2.10.10.2.2 VHF System

The VHF communication system shall be simulated for both air-to-ground and ground-to-air linkage. The simulation shall include equations to calculate attenuation losses for signal-to-noise level injection into the audio communication line.

All automatic and manual switching logic shall be included in the simulation. Both crew station displays and telemetry data shall reflect realistic value and response rate for all instrumented parameters.

A dedicated audio loop shall be provided for VHF communication with the crew members. This loop shall have voice-with-voice dependent on the calculated signal-to-noise ratio.

Instructor aids shall be provided to display the acquired ground station names or numbers.

Acquisition of a ground station for communication shall be dependent on line-of-sight of station, signal attenuation, and on carrier frequency. Both ground station and shuttle transceiver must be set on corresponding frequencies. The IOS shall simulate the ground station system. Provision shall be made to provide the IOS with controls for station and frequency selection.

6.2.10.10.2.3 Audio Control Center

The Audio Control Center shall be simulated for all automatic and manual switching logic and crew displays. Telemetry data shall also be provided. Both crew station displays and telemetry data shall reflect realistic value and response rate for all instrumented parameters.

6.2.10.10.3 Rendezvous Tracking

A rendezvous target vehicle based TACAN system for each free flight target vehicle shall be simulated. This TACAN system simulation shall supply information only to the simulated GN&C computer in a form such that software derives range and range rate. Accuracy of the simulated TACAN system shall be ±300 ft. with a maximum range of 300 n.m. Both Search and Lock-on modes shall be simulated. Relative bearing information shall be obtained from the Star Tracker.

6.2.10.11 Instrumentation System

Both the Developmental and Operational instrumentation System shall be simulated for realistic response for all crew displays and telemetry data. Controlling inputs from the crew station or the command up-link shall be provided to the simulated system. The simulation method shall display correct control and sequential logic. Variable parameters such as instrumentation converter voltage outputs shall be simulated at a minimum fidelity level of two state values. Power available booleans for signal conditioning shall be established for sensors, transducers, signal amplifiers, and support of other system signal provessing.

The Caution and Warning System shall be simulated similarly to the other instrumentation. Signal conditioning and/or sensor power available booleans shall be provided by the Caution and Warning Program. Either out-of-tolerance booleans or variable parameter state conditions shall be furnished by the generating systems to the Caution and Warning Program for further processing prior to display.

6.2.10.12 Environmental Control/Life Support System (ECS)

The ECS simulation is divided into four major divisions: Atmosphere Revitalization and Monitoring; Thermal Control; EVA/IVA; and Water, Waste and Food Management. The simulation shall have a response accuracy of ± 5% of the steady-state or display parameters range within one second following a transient occurrence. Within two seconds this error shall be a maximum of ± 1%. The long term simulation error after an eight hour run shall be less than ± 10% of the parameter measurement range. Minimum response rate for this system shall be 200 milliseconds.

During non-integrated modes of training, the Shuttle Mission Simulation shall provide realistic simulation of other vehicle or unit thermal, atmosphere, gas distribution, and liquid management for interface with the ECS simulation program. The control of these simulated interface parameters shall be provided to the IOS station.

6.2.10.12.1 Atmosphere Revitalization and Monitoring

The simulation of the atmosphere shall calculate all internal and interface parameters that correlate to the mixture of gases between the crew station compartments. These compartments are to include the upper and lower crew station, the airlock, the payload (passenger carrying payload), and a docked vehicle. These equations shall also calculate the reactant parameters for usage from the nitrogen and oxygen tank. Mass property parameters shall be calculated for interface with the equations of Weights and Balances. Partial pressures of gases shall be calculated. Oxygen usage shall be calculated for exchange with the cryogenic simulation of the oxygen tanks. All logic for the control of values, regulators, and timing shall be simulated. Carbon dioxide concentration and removal shall be simulated for a manned vehicle. The number of crew members is to be controlled by the instructor at the IOS. All sensors and electronic loads shall be simulated for interface with the Caution and Warning System and the Electrical Power System. Atmospheric heating by electrical heaters or by the thermal control system is to be simulated.

Atmospheric temperature and partial gas pressures shall be required only for meter and telemetry purposes. Simulation of fire by malfunction entry shall cause the carbon dioxide level to increase, however, no smoke shall be generated in the crew stations. Circulation of the air conditioned atmosphere within the crew station shall not be under computer control.

6.2.10.12.2 Thermal Control

The simulation of the thermal control loops shall calculate all internal and interface parameters that are required to provide T/M and crew displays of the water/freon heat management. The simulation shall include heat loads, temperature, sublimation, and storage of the cold plates, cold walls, pumps, heat exchangers, chillers, and radiators.

The simulation shall include all electronic control logic for all water and freon control values and pumps. Heat loads/rates shall be provided to the thermal system from the TCS, EPS, Hydraulic system, and using equipment simulated on the cold plates.

During re-entry the system shall simulate the effect of the high heat environment. The walls of the crew station shall not require active cold wall simulation.

The cryogenic storage of the hydrogen and oxygen liquid/gases used for the fuel cell system shall be simulated for realistic display in the crew station or telemetry. The fidelity shall include simulation of heat flow, gas/liquid state calcuation, and flow usage as required by instrumentation.

6.2.10.12.3 Water, Waste and Food Management

Waste and Food Management shall not be simulated.

Water Management shall be simulated. The simulation shall calculate the amount of condensate and urine in storage and the amount of potable water available. Replenishment water from the fuel cell process shall be taken into account. Water usage by the thermal control shall also be accounted for.

Fixed usage rates for electrical power for waste and food management shall be included as variables under instructor control.

6.2.10.12.4 EVA/IVA

Simulation of the depressurization and repressurization of cabin, airlocks, and other mating vehicles shall be required. Refer to paragraph 6.2.10.12.1 Atmosphere Revitalization and Monitoring for simulation requirements for cabin gases.

The suit system shall be simulated for realistic crew displays and telemetry values of the simulated suit and conditioning system. Simulation includes ventilation, pressurization, oxygen and communications. The actual suit conditions shall be as defined in paragraph 6.2.3.1.6.1.

6.2.10.13 Payload Accommodation System

6.2.10.13.1 Interfaces

The simulation of the payload shall provide the capability of interface with simulated shuttle vehicle systems. The systems that have interfaces include the electrical power, telemetry data, command data, thermal and environmental control, communication, navigation data, caution and warning, venting and purge control, and payload instrumentation. For a particular payload a few, all, or none of the above systems may require interface.

6.2.10.13.2 Payload Structural Attachment

The simulated payload structural attachment subsystem shall simulate the attachment status of each of the mission payloads during all phases of any given shuttle vehicle space mission. The mass, inertia tensor (about its own mass center), and position of the center of mass of each attached payload shall be provided, in the shuttle vehicle mass properties coordinate system, for calculation of the simulated shuttle vehicle mass properties. This data shall reflect current attachment position and orientation of each attached payload. During payload manipulation, forces and torques exerted by the attachment fitting payload trunnion guides upon the payload and vehicle shall be simulated and be available to the equations of motion. Upon payload attachment release, the initial payload position and attitude shall be available to the equations of motion. Contact position and rate requirements and constraints of the attachment devices shall be simulated.

6.2.10.13.3 Payload Deployment and Retrieval Mechanism

The simulated dynamic state of the shuttle vehicle payload deployment and retrieval mechanism shall be maintained at all times during which the mechanism is not secured. Angular position and angular velocity of each joint shall be available for IOS display, program verification, and use by other systems. Joint positions and velocities shall be maintained within a tolerance of one-third of the mechanism control accuracy, and any other parameters which represent mechanism state shall exhibit comparable accuracy. The tachometers and potentiometers on each joint shall be simulated, and their outputs provided for the on-board computer and for display purposes. The drive motors and servo-actuator loops on each joint shall be simulated, and their open loop response characteristics shall be accurate to within the perception of the operator. The full dynamics and control loop shall be simulated with sufficient fidelity such that the entire arm exhibits closed loop response characteristics not perceptibly different from those of the real world system, with any payload mass of 2000 slugs or less, or with no grasped payload, and during either acceleration or deceleration of a payload, or during any other operational tasks. The simulated mechanism shall take into account power available, and shall provide electrical loads to the simulated electrical power system. Joint travel limits, torque limits, velocity limits, and runaway actuator controls and overrides shall be simulated. Redundant torque motors shall be simulated. Brakes on joint movement shall be simulated, and shall be actuated and released under the same conditions as the real-world subsystem. The manipulator checkout system shall be simulated, and shall possess the same capability to act as a backup manipulator control system as does the real world checkout system. Real-world manipulator deployment and manipulator jettison devices shall be simulated. The positions of the manipulator terminal device grasping bars shall be maintained, and the device response to operator control shall duplicate that of the real world system to within the perception of the operator. The simulator shall contain the simulation of a grasping-type terminal device. The design of the simulation shall permit the replacement of the grasping-type terminal device simulation with a different terminal device by modification following delivery with minimal impact. Realistic inputs to the simulated controls and displays shall be provided to operate the hand contact/engagement indicator and the berthing indicator. Position and orientation of wrist TV cameras and wrist floodlights shall be maintained.

6.2.10.13.4 Payload Doors

The positions of the simulated payload doors shall be maintained throughout all space flight phases of simulated shuttle missions. The simulated doors shall be segmentally operable in the same fashion as the real world doors. The simulated door latches shall be simulated to actuate by proximity sensing in a similar way to the real world latches, and shall exhibit a similar zip-fastener action. The powered hinges and their control shall be simulated, and door motion shall exhibit the proper rates, taking account of the current status of the hydraulic system. During opening or closing of doors and radiators, dynamic effects upon orbiter state shall be simulated. The structural and mechanical interface between the payload doors and the space radiators shall be simulated. The payload manipulator latches shall be simulated, and shall be actuated and controlled in a manner analogous to that of the real world system.

6.2.10.13.5 Rendezvous and Docking Sensor

The rendezvous and docking sensor which will be carried on some missions in the cargo bay shall be simulated.

6.2.10.13.6 Orbit Station

Each of the input parameters to the payload accommodation system from the payload handling station shall be obtained from the payload handling station hardware and distributed to the simulation software subsystems. Each of the output parameters from the payload accommodation system to the payload handling station shall be obtained from the simulation software and provided to the simulated station hardware. Provision shall be made for malfunction of station controls and displays. Parameter update rates shall be sufficiently high to prevent perceptible lag, but shall not be higher than those required or exhibited by the real world payload accommodation system.

6.2.10.13.7 Payload Bay Lighting

The simulation of the payload bay lighting shall be consistent with the current relay status and configuration of the orbiter electrical power system. This shall include all associated switches and circuit breakers. Each illuminated payload bay floodlight shall provide power load to the electrical power system. The control system of any floodlight which is capable of tracking a manipulator arm terminal device, or which may be otherwise reoriented, shall be simulated. The position and orientation of floodlights attached to the manipulator arms shall be simulated, and the orientation of all other floodlights shall be simulated.

6.2.10.13.8 Payloads

The attitude control jet systems of detached payloads shall be functionally simulated when they exist. Jet logic shall be simulated to the extent that reasonable deadband phase planes are exhibited, and that evident payload attitude rates and rate limits are reasonable. The instructor shall have the capability to control payload attitude command. Capability shall also be provided to automatically execute a limited number of maneuvers to preprogrammed fixed attitudes as a function of external command. Translational propulsion systems of detached payloads shall be functionally simulated when present and in operation. Such simulated systems shall provide realistic steady-state thrust forces and mass flows while thrusting, and realistic total impulses and mass loss over the duration of a burn. Guidance systems which target and perform translational burns shall be functionally simulated when they exist on detached payloads (e.g., the space tug). These guidance systems shall be simulated to the extent that displays which may be monitored by the crew (e.g., range, range rate, rendezvous targetting) required telemetry parameters, and required ground tracking data show no obvious anomalies during the interval in which they may be utilized. These payload systems shall be simulated in such a way to permit reconfiguration to a different payload by altering a minimal number of reset terms. Simulation of other payload on-board systems shall not be required at this time. Computer loading, in terms of core and time, shall not preclude addition of simulated payload electrical power, thermal control, telemetry, communication, instrumentation, command, television, purge and dump, configuration change, etc., systems for particular and/or generalized payloads at a later time. Such future simulations, if they exist, shall be assumed to be of no more than that accuracy and extent to provide realistic crew display response (value and time) for both commands and switching logic.

6.2.10.14 Miscellaneous Systems

6.2.10.14.1 Purge and Vent System

The Purge and Vent System shall be simulated only to the extent that crew displays and telemetered data are realistic. Conditions relating to the after-effects of the pre-launch air purge of compartments shall be required. All control logic shall be simulated for responses to the crew's manual control inputs.

Simulation of interfacing parameters to be used by the systems of ECS and TCS shall be provided as required.

6.2.10.14.2 Landing/Braking System

The simulation of the landing and braking system shall include nose wheel steering, wheel braking, antiskid control, wheel well doors, deployment/retraction, assembly for nose and main gear including uplocks and downlocks, landing gear oleo strut extension/compression, and nose wheel shimmy suppression at various landing speeds. The drogue chute brake system shall be simulated for deployment, normal drag forces, and release.

Interface parameters shall be established for the Visual Simulation, the Aural Cue, and the Motion System. Refer to simulation requirements for these systems for gear, brake, drogue chute, wheel shimmy, and touchdown. Hydraulic and electrical power usage parameters shall be generated for the Hydraulic Control System and the EPS loading programs.

6.2.10.14.3 Speed Brake System

The SpeedBrake System shall be simulated with realistic crew displays and telemetry data. Parameters shall be generated for interface with the aerodynamic simulation of drag force programmed and the Hydraulic Power simulation. Response of surface to manual control inputs shall be realistic for both rate and stability.

6.2.10.14.4 Ejection Seat Mechanism

Simulation of the ejection seat shall be provided only for logic of operation, crew display, telemetry, and preliminary motion. Ejection shall not be required.

6.2.10.14.5 Thermal Protection System

Simulation of the Thermal Protection System shall be provided for realistic displays on crew instruments and for telemetry instrumented data. Thermal rates and temperatures shall reflect realistic value and response rate.

Interfacing parameters shall be provided to the other thermal systems of Thermal Control System, Vent and Purge System, and the ECLSS.

6.2.10.14.6 Thermal Control System

Simulation of the Thermal Control System shall be provided for realistic displays on crew instruments and for telemetry instrumented data. Thermal rates and temperatures shall reflect realistic value and response rate.

Interfacing parameters shall be provided to the other thermal system of Thermal Protection System, Vent and Purge System, and the ECLSS.

6.2.10.14.7 Docking Mechanism

The simulated orbiter docking mechanism shall be operable only when successfully deployed. The operation of the guide cone, hydraulic attenuators, alignment rings, and capture latches shall be simulated when present. The simulated capture latches shall actuate under the same conditions as their real world analogs. Forces and moments exerted upon both vehicles by the guide cone, alignment rings and hydraulic actuators shall be simulated, and shall be similar to those which would be exerted by the real world analogs with the same vehicle relative states. Simulated docking latches shall be actuated under the same conditions as their real world analogs. Contingency or emergency separation and jettison provisions shall be simulated. Provisions shall be made for interface parameters in electrical power, telemetry data, command data, thermal and environmental control, communication, navigation data, caution and warning, venting and purge, and target vehicle instrumentation. For a particular target vehicle, a few, all, or none of the above systems shall require interface.

## 6.2.11 Simulator Applications Software (WBS #1.8.2 and 2.8.2)

### 6.2.11.1 Translation and Rotation Dynamics

#### 6.2.11.1.1 Vehicles

The vector position, vector velocity, and attitude of the simulated space shuttle vehicle shall be maintained in real-time (and other time frames as specified below), given body forces and moments, gravitational forces, and vehicle mass properties. Body angular rates and body linear accelerations shall be available for use in other systems, and for displays. Vehicle latitude, geographic longitude, altitude above reference ellipsoid, ground track heading azimuth, relative velocity magnitude, flight path angle, radius magnitude (boost/orbit/entry phases), inertial velocity magnitude (boost/orbit/entry phases), orbital elements (boost/orbit/entry phases), and time of next orbital sunrise/sunset (orbital phases) shall be calculated for other systems and displays. Entry in the preceding sentence need not include approach and landing. Capability shall be provided to maintain the above parameters, throughout all anticipated nominal and abort phases of Shuttle space and ferry missions, with or without payloads, and for each of the following configurations in the applicable regimes:

- Orbiter + external tank + boost SRM's
- Orbiter + external tank
- Orbiter + payload
- Orbiter

During the prelaunch phase, vehicle inertial position and velocity and vehicle attitude shall be maintained to within 200 feet, .015 ft./sec., and $10^{-3}$ degrees, respectively, of the real world values. Neither the position discrepancies, velocity discrepancies, nor attitude discrepancies shall change rapidly as to cause jitter or step changes perceptible by the crew. At boost cutoff, the simulated shuttle vehicle (without malfunctions) shall be within 1200 feet, 6 ft./sec., and 1/2 second of nominal cutoff position, velocity, and time. During the boost phase, the shuttle vehicle trajectory shall remain within the $3\sigma$ boost trajectory envelope. During orbital coast, the simulated vehicle state vector shall not diverge from the real-world state vector by more than 750 feet in position or .30 ft./sec. in velocity over one orbit, excepting errors due to the median orbital density profile specified in Section 6.2.11.1.1.4. Dispersions between simulated orbiter position and real-world nominal position following an automatically controlled deorbit burn shall be within nominal 3$\sigma$ dispersions, providing procedures (e.g., IMU alignment) are adhered to and no malfunctions are entered. The translational and rotational integration schemes (starting with linear and angular accelerations) used for boost and for entry-atmospheric flight shall be of equivalent accuracy. The simulated automatically controlled entry and transition trajectory shall be within the 3$\gamma$ trajectory envelope. The discrepancy between simulated vehicle attitude and IMU-derived attitude shall be within the IMU error limits when the IMU is not malfunctioned. Rotational dynamics shall be simulated to sufficient precision to permit proper control system response (e.g., reasonable values of and response to perturbation of TVC gimbal angles, reasonable frequency of and response to RCS firing, reasonable response to and values of aerodynamic control surface deflections, reasonable response to aerodynamic turbulence) and proper malfunction response (e.g., response to TVC gimbal hardovers or nulls). Provision shall be made for the simultaneous simulation of the translational and rotational state of as many as seven vehicles other than the space shuttle vehicle. The position and attitude of articles jettisoned during boost at dynamic pressures exceeding 2 $lb/ft^2$ (e.g., SRM's) shall be calculated so long as the danger of recontact with the remainder of the shuttle vehicle exists, taking into account gravitational forces, aerodynamic forces and moments, and residual thrust forces and moments. Provision shall be made to detect recontact with jettisoned articles. Accuracy of simulation of the dynamics of jettisoned articles shall be adequate to detect recontact. In the case of external tank jettison in orbit, position and attitude of the tank shall be maintained until such time as the tank is displaced from the orbiter by 40 n.mi.; taking account of gravitational forces, aerodynamic forces and moments, and tank deorbit SRM thrust forces and moments. During payload manipulation, translational and roational dynamics of the manipulated payload shall be simulated. Effects of manipulator operation upon both payload and orbiter dynamics shall be simulated. Relative position accuracy between the manipulator tip and the orbiter shall be maintained within the manipulator control system tolerances. Positions and attitudes of deployed payloads shall be maintained so long as required for visual or radio contact. Position and velocity of rendezvous targets or retrieval payloads shall be maintained when within rendezvous ranging distance of the orbiter. Attitudes shall be maintained when visually discernable. Translational and rotational dynamics of detached payloads and target vehicles shall reflect gravitational forces, aerodynamic forces and moments, payload propulsion forces and moments, and payload control forces and moments. Target vehicle attitude control jet moments shall be included in target vehicle rotational dynamics, when they exist.

Target vehicle or payload attitude control systems will be functionally simulated when they exist, and shall possess deadbands and rates similar to the properties of the real world vehicle. Target vehicle attitude control forces may be assumed, in the functional simulation, to act in perfect force couples (i.e., no resultant force). Simulation software design for target vehicle equations of motion shall include the necessary interface terms to obtain and include in vehicle dynamics no-zero resultant attitude control forces deriving from later payload-unique modifications which include a more elaborate attitude control simulation. Target vehicle translational propulsion forces shall be included in target vehicle translational dynamics, when a translational propulsion system exists on the target vehicle. Propulsive engines of target vehicles or detached payloads shall be simulated functionally to the extent that realistic steady-state thrust forces and mass flows are produced while thrusting, and realistic total impulses and total mass losses are produced over the duration of a burn. Target vehicle translational thrust force may be assumed, in the functional simulation, to act through the mass center (i.e., no resultant moments from a translational burn). Simulation software design for target vehicle equations of motion shall include the necessary interface terms to obtain and include in vehicle dynamics non-zero translational propulsion moments deriving from later payload-unique modifications which include a more elaborate target vehicle propulsion/TVC simulation. In the case of payloads or target vehicle possessing guidance systems which target and perform translational burns (e.g., the space tug), these guidance systems shall be functionally simulated to the extent that displays which may be monitored by the crew (e.g., range, range rate, rendezvous targetting), required telemetry parameters, and required ground tracking data show no obvious anomalies during the interval that they may be utilized. When performing extended station-keeping, the fidelity of simulation of gravitational and aerodynamic forces and moments upon the target vehicle and the integration of same to obtain position and attitude of the target vehicle shall be comparable in fidelity to that of the simulated orbiter. Aerodynamic properties, propulsion properties (thrust, number of jets, minimum impulse, etc.), and control parameters used in target vehicle or payload dynamics simulation shall be capable of being reset to the appropriate values for the particular payloads/vehicles present in a given mission. In particular, the orbiter target vehicle in a rescue mission shall reflect the aerodynamic properties of a space shuttle orbiter as faithfully as the "prime" orbiter, and shall reflect correct control behavior for an orbiter to within the perception of a crewman in another vehicle. Parameters such as range, range rate, orbiter-body-referenced azimuth and elevation, and orbital elements of targer vehicles or detached payloads shall be available for display. Reset parameters for each relevant vehicle shall include vector position, vector velocity, attitude, attitude rate, any past values required in integration schemes, etc. When the simulator is placed in "operate" after "freeze" or "reset", vehicle dynamics shall not exhibit any transients due to the mode change(s). Repeated changes of mode between "operate" and "freeze" shall not degrade the accuracy of the simulated dynamics. The simulated dynamics shall be capable of operating at full precision in non-real-time. Provisions shall also be made to operate the equations of motion in a "step-ahead" mode, wherein only gravitational and aerodynamic forces are simulated in maintaining translational dynamics and attitude/attitude rates are maintained unchanged with respect to local horizontal, in those mission phases where applicable (which shall not include boost or flight at dynamic pressure above 1 lb./ft.$^2$), at accuracy otherwise comparable to nominal operation.

6.2.11.1.2 <u>Orbiter Vehicle Configuration</u>

The translational and rotational dynamics of the orbiter vehicle shall be maintained in real-time in its operational space configuration, with varied payloads or without payload, and in its ferry configuration, whichever is applicable in a given situation. The translational and rotational dynamics of the orbiter vehicle shall be maintained when docked to another vehicle.

6.2.11.1.3 <u>Forces and Moments</u>

The simulated space shuttle equations of motion shall, at the proper times, reflect the forces and moments arising from the following effects:

- Gravity
- Aerodynamics (including ground effects)
- Boost SRM Thrust
- Main Engine Thrust
- ØMS Thrust
- RCS Thrust
- Air Breathing Propulsion System
- Ground Force
- Payload Manipulation
- Docking
- Venting and Dumping
- Separation

Earth gravitational force shall be simulated including the first three zonal harmonics (J2, J3, J4) and the first tesseral harmonic (J22) throughout all space mission phase, for the simulated shuttle vehicle, as well as all other simulated target vehicles. Earth gravitational force for ferry flights shall reflect a central force field, with gravitational parameter that of latitude 30$^{\circ}$N. Either gravitational model may be used for the approach and landing phase of orbital missions. During space missions, aggregate numerical error (round-off, etc.) in the calculations of gravitational force shall not exceed $10^{-5}\ \frac{ft.}{sec.^2}$. Aggregate error in the gravitational force calculations arising from all sources shall be comparable to uncertainty existing in the real world arising from the current values of the current tolerances upon the values of the coefficients of the gravitational potential function plus error arising from the neglect of higher-order harmonics (as calculated using current values for these harmonics). Gravity gradient torques shall be simulated during orbital coast for the orbiter vehicle and for station-keeping target vehicles. Given the current c.g. location, moments due to SRM, main engine, ØMS, and RCS thrust, and the ABPS shall be calculated. At such time as landing gear is in contact with the runway, the effects of forces and their associated moments exerted by the gear upon the remainder of the vehicle shall be simulated. During payload manipulation, forces and moments exerted by the manipulator arm upon the remainder of the vehicle shall be simulated. During docking, the forces and moments exerted by the docking mechanism upon both vehicles, and their effects, shall be simulated. Forces and moments arising from venting and dumping the external tank shall be simulated. Forces and moments of residual thrust and separation SRM's; upon the boost SRM's following staging shall be simulated. Forces and moments from the deceleration parachute system shall be included in total body forces and moments when applicable.

6.2.11.1.4 Aerodynamics

Aerodynamic forces and moments along and about all three axes upon the space shuttle vehicle shall be simulated at all altitudes below 275 n.mi. Aerodynamic properties of each of the space shuttle vehicle configurations specified in 6.2.11.1.1 & 6.2.11.1.2 (including docked configurations) shall be simulated at those times during which each is in existence. However, at altitudes below 300,000 feet, only those vehicle configurations which may reasonably be expected to exist on a nominal mission shall be simulated (e.g., no requirement exists for simulating payload bay door open effects below that altitude). Full capability for simulation of aerosurface control malfunctions shall be maintained in any case. Aerodynamic forces and moments shall reflect properly the effects of vehicle relative velocity, atmospheric density, and vehicle attitude. Vehicle relative velocity shall reflect the effects of winds, including gusts and turbulence, upon instructor request. Atmospheric density and speed of sound shall be calculated as a function of altitude, with provision for variation of temperature-dependent properties from standard day properties upon instructor request. A median density vs. altitude profile shall be used at altitudes in excess of 300,000 feet. Atmospheric density will be maintained within 2% of the appropriate nominal real-world value for all altitudes below 300,000 feet. Aerodynamic forces and moments and hinge moments arising from any control surface deflections, or any combinations thereof, shall be simulated. Aerodynamic forces resulting from individual landing gear deployment shall be simulated, when gear is not retracted. Ground effects upon aerodynamic forces shall be simulated. Damping derivatives shall be simulated where significant. Static and dynamic stability characteristics shall be realistically simulated. Proximity aerodynamic effects during separation from SRM's (and from external tank in sensible atmosphere) shall be simulated, for both the shuttle vehicle and the jettisoned object. Stall characteristics shall be realistically simulated, and vehicle behavior following a stall shall be approximately correct. Stall recovery techniques, when applied to the simulated orbiter, shall elicit proper response. Angle of attack, sideslip angle, dynamic pressure, mach number, and relative velocity shall be calculated for IOS displays, and for other systems. Orbital aerodynamic forces and moments shall be a function of vehicle attitude, dynamic pressure, and vehicle configuration. Aerodynamic data used in the simulator shall be tabulated and utilized in the same coordinate system(s) and under the same sign conventions as those used by the Shuttle vehicle prime contractor to supply data. A simulator program shall be supplied to read and translate into simulator format tape outputs of the NR Aero Data Bank Computer Program.

6.2.11.1.5 Coordinate Systems

An inertial, orthogonal, earth-center-fixed coordinate system shall be provided, and state vector(s) shall be maintained within this system through all phases of space missions, except perhaps final approach and landing. An orthogonal coordinate system fixed to the landing runway shall be provided, and orbiter state shall be available in this system throughout final approach and landing. An orthogonal, body-fixed coordinate system shall be provided, whose x-axis is parallel to the orbiter longitudinal axis and whose y-axis is parallel to the orbiter pitch axis. Body linear accelerations and angular rates shall be available for display in this system. A local vertical coordinate system shall be provided, whose z-axis is along the vehicle radius vector and whose x-axis is along local horizontal in the direction of motion. Vehicle attitude, in terms of pitch, yaw, roll rotations, shall be available for display in this system. Such other coordinate systems shall be provided as are required for trajectory verification, i.e., those coordinate systems utilized in reference trajectories.

6.2.11.2 Mass Properties

6.2.11.2.1 Vehicles

The total mass of the shuttle vehicle shall be maintained throughout all phases of space or ferry missions. For each integration of acceleration to obtain velocity performed by the translational equations of motion, a value of vehicle mass shall be provided which is within .05% during boost, and .3% during other flight phases, of the expected value of mass required to introduce zero error into the calculation of the amount of $\Delta V$ produced by body forces during that integration interval (as compared to real world vehicle $\Delta V$), excepting dispersions caused by malfunctions, instructor-entered dispersions, or crew-activity caused consumable or configuration deviations from normal. The location of the shuttle vehicle center of mass and the vehicle tensor of inertia shall be maintained in a body-fixed coordinate system throughout all mission phases. Shuttle center of mass during powered flight shall be maintained to sufficient precision to ensure that engine gimbal angles and control surfaces (as applicable) required to track the center of mass and to cancel aerodynamic moments shall not be perceptibly different than those of the real-world vehicle in nominal operation. During powered flight and entry, shuttle center of mass and inertia tensor shall be maintained within sufficient accuracy to provide vehicle TVC and aero-surface control response characteristics sufficiently similar to those of the real-world vehicle that error so introduced shall not be perceptible. During orbital coast, moments of inertia shall be maintained at all times within 1.0% of their nominal value, and products of inertia (if body axes are not exact principal axes) to within a tolerance equal to 5% of the smallest moment of inertia. At no time shall simulated mass properties change so abruptly as to be discernible by the crew as a "step" change, unless the real-world vehicle mass properties change abruptly at that point (e.g., staging). Mass Properties of jettisoned Boost SRM's and external tank shall be maintained for as long as dynamic simulation thereof is required to an accuracy consistent with the requirement to correctly detect recontact. Mass properties of detached payloads or target vehicles shall be represented by reset constants when no translational propulsion system is aboard and anticipated mass changes are less than 5% of total mass. Mass properties of detached payloads or target vehicles which possess a translational propulsion system or whose anticipated mass changes are greater than 5% of total mass shall be maintained within sufficient accuracy to provide accurate cues to the crews being trained, including visual and tracking cues while state for that vehicle is maintained. The reset generation and rest programs shall provide the capability to simulate the specific mass properties of each payload or target vehicle utilized in any given mission, given the necessary vehicle data for each vehicle simulated. Simulated mass properties shall be capable of operation at full precision in other than real-time. At the termination of "step-ahead" mode, shuttle mass properties shall be updated to reflect recalculated consumable mass properties. Target vehicle mass properties shall remain unchanged during step ahead.

6.2.11.2.2 Vehicle Configuration

The simulated space shuttle vehicle mass properties shall be capable of simulating vehicle mass properties for each of the following vehicle configurations:

- o Orbiter + external tank + boost SRM's
- o Orbiter + external tank

- Orbiter - space mission configuration without payloads
- Orbiter - space mission configuration with payload
- Orbiter - ferry mission configuration

When docked to a target vehicle, the mass properties of the docked configuration shall be simulated. The mass properties of the orbiter shall, at all times, include the mass properties of the current attached contents of the payload bay. Instructors shall have the capability of altering vehicle mass properties by specifying and changing simulated crew location.

6.2.11.2.3 Consumables

The simulated shuttle vehicle mass shall reflect changes in the mass of the boost SRM propellant on board, changes in the consumable mass in the MPS lines and the Helium Pressurization System, and changes in the mass of the contents of the following consumable tanks:

- ØMS tanks
- RCS tanks
- ABPS tanks
- Cryogenic tanks
- APU tanks
- Water system tanks
- GN2 tanks
- External tank LH2 tank
- External tank LØ2 tank

as required to meet previously stated accuracy requirements on total vehicle mass. Mass distribution parameters (center of mass, inertia tensor) for the consumable contents of each of the above shall be used as required to meet the previously stated accuracy requirements in the calculation of vehicle mass distribution parameters.

6.2.11.3 Ephemeris

6.2.11.3.1 Celestial Bodies

The apparent direction of the sun relative to the vehicle shall be maintained in an inertial coordinate system and shall include the effect of aberration. The direction of the moon relative to the vehicle shall be maintained. The direction of all stars detectable by the star tracker shall be available. Direction of Mercury, Venus, Mars, Jupiter and Saturn shall be maintained. Directions of these celestial bodies shall be maintained within the following tolerances:

| | |
|---|---|
| apparent sun | ±25 arc-seconds |
| moon | ±30 arc-seconds |
| stars | ±5 arc-seconds |
| planets | ±5 arc-seconds |

Occultation of the sun by the earth shall be determined. Capability to calculate these parameters in real-time for a period of 30 days following launch of a mission shall be provided. A non-real time program shall be capable of providing the real-time program with the necessary data for any launch date between November, 1976 and December, 1999.

6.2.11.3.2 Coordinate Transformations

The transformations between the Ephemeral Inertial Coordinate System and the Basic EØM Reference Inertial Coordinate System and the Earth-Fixed Georgraphic Coordinate System shall be maintained within sufficient accuracy to ensure that during simulation, when within seven days of the reset point last used, no axis of any of the above simulated systems will differ from the corresponding axis of the real-world system by more than 2 arc-seconds. Precision and nutation of the earth's equator shall be simulated as required by the above accuracies. None of the aforementioned transformations shall be updated in such a way as to cause a perceptible jump in the earth visual scene. The True Greenwich Hour Angle shall be maintained. At each time of state vector recalculation during simulation, when within seven days of the reset point last used, the simulated Greenwich Hour Angle shall be within 2 arc-seconds of the real world value. Changes in the above error between two iterations shall not cause perceptible jumps in the ground visual scene. Precession and nutation effects upon the hour angle shall be simulated as required to meet the above accuracy. Capability to calculate these parameters in real-time for the duration of any realistic mission launched at any time during the shuttle program shall be provided.

6.2.11.3.3 Displays

The Greenwich Hour Angle shall be available for display. Occultation of the sun by the earth shall be available for display.

## 6.2.12 Simulator Control Software (WBS #1.8.3 and 2.8.3)

### 6.2.12.1 Data Recording

The SMS shall have the capability of recording simulation data on external recording devices. This capability shall be of the types as follows.

#### 6.2.12.1.1 Plotters and Recorders

The capability of the plotters and recorders shall allow plotting of two(2) parameters against one another for each recorder, and shall allow recording of one(1) parameter against time per recorder channel. The plotting and recording system shall collect and record real-time parameters at the maximum parameter computation rate of the simulator. They shall be connected to digital/analog signals for concurrent and post-training analysis. The system shall use predefined data to format real-time retrieved parameter values for D/A channel output.

The predefined information for data definition shall be in selectable groups to be used at the discretion of the user, and these groups may be modified in real-time.

#### 6.2.12.1.2 Real-Time Print

The SMS shall have the capability of collecting and converting real-time simulation data for direct output to a hard copy device. The data to be output shall be in predefined selectable groups. The data group to be used shall be selected at the users discretion.

The rate of collection and the number of parameters to be collected shall be a function of the hard copy device speed.

#### 6.2.12.1.3 Logging

The SMS shall have the capability of collecting and outputting real-time simulation data to an external magnetic recording device. The data shall not be converted in real-time, but all conversions shall be post-processed by a non-real-time program for hard copy. The logging rate shall allow a maximum equivalent to the fastest simulator computation rate. The data to be logged shall consist of real-time data pool terms and all real-time input/output quantities. All logging shall procede through a common interface to insure the simplicity of new logging additions.

The types of logging to be active at any time shall be selectable. Data pool logging shall be controlled through predefined selectable groups which may be modified in real-time.

6.2.12.2 Real-Time Input/Output

Software support for real-time Input/Output shall be part of the Simulator Control Software package. This would include device access methods for real-time and non-standard devices. A set of macro instructions shall be provided to invoke various Input/Output options and sequences. The Input/Output software will interface with the data logging facility to provide logging as an option. Provision should be made to allow device independance through the use of dummy device reference and/or device substitution without application program modification.

6.2.12.3 Synchronous Simulation Program Processor

Simulation Control software shall provide for the execution of synchronous programs based upon the sequence and iteration requirements of the simulation.

6.2.12.4 Master Timing

The master timing program shall generate all required parameters for simulation clocks, event timers, and special time words.

This program shall initialize a mission dependent times capability to their proper values during resets and allow for uplink initialization capability, if necessary.

All crew station and IOS time displays shall be updated at a rate equal to the least displayable time unit for the appropriate clock.

6.2.12.5 Master Control

The Master Control program shall provide the primary interface with the operating system software. This program shall contain moding logic such as Reset, Freeze, Operate, Step-ahead, Write Reset, Safe Store, and Slow Time. It will also provide for the execution of asynchronous functions such as demand data reading, simulation phase control, and special task activation. The Master Control program shall also provide control over the execution of the Synchronous Simulation Program Processor to ensure proper time framing.

6.2.12.6 Advanced Training

Software packages shall be provided which will allow certain instructor functions to be carried out by the computer. The following paragraphs delineate the basic requirements of each package.

6.2.12.6.1 Automated Training

This package shall allow a training mission to be predefined and executed under control of the computer, while at the same time allowing the instructor full control to override the preprogrammed sequence.

This package shall allow for automatic insertion of malfunctions into the simulation problem based upon the passage of time or the occurrence of a specific event.

Specific off nominal conditions may also be introduced into the simulator problem.

6.2.12.6.2 Performance Comparison

This package shall monitor specific parameters and compare them against a nominal value for the parameters. It shall display optionally, true deltas, percentage of delta, excessive deviation from a predetermined value, etc.

These functions shall be applicable to all phases of the mission envelope, and shall be fully compatible with the functions of the automated training package.

Comparison results may be viewed on a CRT, output to a printer, or both. Deliverable Performance Monitoring pages are specified in paragraph 6.2.4.1.2.14.

6.2.12.6.3 Record Playback

A package shall be provided which will record in real-time, on magnetic tape or disc storage, selected inputs and internal simulation parameters. This data shall be of such a nature that it may be input to the simulation software and cause the trainer to reproduce the effects incurred during the recording process. The movement of instruments, readouts, indicators, motion base, visual and any controls that can be driven by the computer will be reproduced. Movement of switches, continuous controls, levers and any controls not driveable by the computer shall not be reproduced.

Upon completion of the playback, flight critical controls will be checked for acceptable positions to allow the simulator to "flyout" with the status it has at that time. Discrepancies between current controls and required "flyout" positions shall be noted on a CRT display or instructor station readouts.

Under no circumstances shall this package allow the simulator to "flyout" into a dangerous condition.

6.2.12.7 CRT Pages

CRT page programs shall be generated to support individual displays.

The CRT page programs shall have sufficient inherent programming power to allow new requirements for the CRT system to be satisfied by them rather than by the CRT interactive routines.

6.2.12.7.1 Malfunction Control

Malfunction insertion, deletion, and value display shall be CRT page program functions. The page program shall allow the symbolic malfunction name and natural unit values to be input, causing the malfunction to be introduced into the simulation problem. The deletion of the malfunction shall be accomplished with the simplest number of keyboard entries.

6.2.12.7.2 Setup Verification

CRT page programs shall exist which will allow the crew station controls to be checked for desired positions and deviations from desired position as indicated.

The page programs shall be generated in such a way that the crew station configuration can be verified in the fastest possible manner, (e.g. verification will be by panel, left to right, top to bottom).

6.2.12.7.3 Parameter Display

CRT page programs shall provide for the display of internal computer parameters. All common forms of data conversion, i.e. floating, integer, boolean, shall be provided.

CRT pages shall be able to access and display any data pool parameter currently core resident.

6.2.12.8 CRT Interactive System

A software package shall be provided which will coordinate the processing of CRT page programs and CRT keyboard inputs. In addition to supporting CRT page programming requirements, the CRT system software will support the functions delineated below.

6.2.12.8.1 CRT Hard Copy

Provide for placing on a hard copy device a snapshot of the current CRT display.

6.2.12.8.2 Look and Enter

Provide for operator access, display, and modification of any data pool parameter by symbolic name now present in the computer. This action shall be independent of any CRT page program supplied interface.

6.2.12.8.3 Graphics

Provide for the support and generation, under page program control, of graphic images on the CRT screen.

6.2.12.9 Operating System Interface

Interface with the operating system shall be provided to invoke operating system facilities and services. This interface may take the form of a set of macro or special purpose instructions available to the application for request of operating system facilities. The definition of standard interface conventions shall be made.

## 6.2.13 Support Software (WBS #1.8.4 and 2.8.4)

### 6.2.13.1 Operating System

The operating system shall provide for management of computer system hardware and software resources in a multijob environment. Specifically, the operating system shall support simultaneous part task simulation with concurrent batch and terminal processing. This will include servicing of external interrupts, real-time I/O, task switching on a priority basis, device allocation, time and data routing, and timing services. Facilities should exist for storage protection, terminal request processing, management of main storage contents, and central processing time.

### 6.2.13.2 Software Processors

The SMS shall have software processors to translate programmer generated card source into meaningful computer instructions. The software processor that will be required at a minimum is a program to edit CRT page program source into data and instructions useable by CRT hardware on one hand, and the CRT interactive processor on the other.

This editor shall accept a source language similar to an assembler language, provide for error notification and automate data pool linkages. The syntax, mnemonics, register useage, and so forth, shall be as compatible with the GFE assembler as possible.

6.2.13.3 Data Base Generator

The Data Base Generator shall create the simulator data pool and all associated listings. The Data Base Generator shall construct the linkages required between the data pool and the simulation programs. A cross reference of all symbols with associated program usage shall be created and maintained. A statistical analysis to determine which simulator programs are affected by a data base update, to compile a history of changes to the data pool, and use, or non-use, of symbols in the data base shall be required.

6.2.13.4 Reset Generator

The reset generator shall be a non-real-time program, or group of inter-related programs, which will generate a group of data to be used in initializing all data base requirements of all the SMS real-time simulation systems for several defined points.

The reset generator shall process input data of predefined values (mostly from mission planning documents) by checking for validity and completeness and perform any conversions or computations required. The result shall be outputs of suitable nature for initialization of simulator data base parameters.

The reset generator shall have the capability of updating existing reset points taken by the instructor in real-time (e.g. write reset and safe store).

6.2.13.5 On-Board Computer Support Software

The on-board computer support software shall generate all required listings and loadable flight program object code. The on-board computer support software shall generate all data sets required for simulated switching from one computer to another. Also, all patches required to the flight program shall be generated by the support software.

6.2.13.6 Utility Programs

Utility programs shall be provided for areas of software support outside those defined as simulation control, operating system, software processors, or applications software. These would include programs for hardware diagnostics, configuration control, debug support, and subroutine libraries.

6.2.13.6.1 Diagnostics

Diagnostic programs shall be provided for computer complex main frame, peripheral hardware and DCE. Routines shall be provided to exercise both standard and non-standard I/O devices and hardware interfaces. These programs shall be capable of running in a non-real-time stand alone environment. Output shall be in the form of failure reports and diagnostic messages pointing to specific functional and/or component failures.

6.2.13.6.2 Support Utilities (Plotting, Trace, Snapshots)

Programs supporting debug facilities such as XT plotting, program trace, and memory snapshots shall be provided. These facilities should be capable of supporting both real-time and off-line test environments.

6.2.13.6.3 Subroutine Library

Subroutine library routines shall be provided for support of standard system macros and should include support of standard trigonometric functions in Fortran or other high level languages.

6.2.13.7 Delog

The Delog program shall receive real-time log data as input and shall perform all formatting and conversions necessary for an easy to read and understandable hard copy.

6.2.13.8 Statistics Gathering System

The Statistics Gathering System shall, upon request, accumulate data as to the amount of memory and processor time used by the real-time simulation, the amount of input/output channel time used by the real-time simulation, the state of any non-simulation jobs in the act of processing, the amount of simulator downtime, and the total computer resource usage for all processing.

6.2.13.9 Automated Documentation

The SMS support software shall include packages that will allow for an automated documentation process. These packages will include automated flowchart generators for the computers assembler language, Fortran, as well as any other programming language used in support of the simulation complex.

Further documentation aids shall include programs to list elements of the data pool, software source, symbol useage cross references, reports concerning software changes, and DCE-data pool relationships.

6.2.13.10 Data Management System

The Contractor shall provide a data management system (DMS) which will interface with the operating system of the GFE Computer Complex. The DMS shall require minimum amount of manual intervention. In addition, the DMS shall utilize remote terminal capability as well as the peripheral equipment of the GFE Computer Complex in the performance of its services.

6.2.13.10.1 Configuration Control

The contractor shall provide data management programs which will maintain and status upon request the detailed configuration of the simulator hardware and software. Some of the activities that should be monitored by these programs are: print numbers, revision level, crew station modification and discrepancy report effectivity, modification pending incorporation, modifications incorporated, modifications awaiting parts, discrepancies outstanding, discrepancies cleared, and discrepancies awaiting parts. The DMS programs shall provide this configuration control for the following simulator components:

- Simulation Hardware
  - IOS
  - Supplementary Hardware
  - Crew Station(s)
    - Spacecraft Configuration
    - Variations from Spacecraft
  - Data Conversion Equipment
  - Visual System
  - Motion Base
  - Ancillary Equipment
- Simulation Software
  - Math Models
  - Application Software
  - Control Software
  - Support Software
  - Source Modules
  - Object Modules
  - Load Modules
  - Program Timing and Core Loading
- Quality Control

6.2.13.10.2 Simulator Complex Utilization

The DMS programs shall also provide a summary of the computer complex time utilized for various activities. This report should be divided at a minimum as follows:

NASA

Other Contractors

Preventive Maintenance

Data=Processing

Lost Time

Training Time

The DMS programs shall be designed to interface and operate in a time sharing mode. Report pages shall be available for interrogation by the inter-active terminals in Building 4, 5 and the off-site facility.

6.2.14 Systems Integration (WBS #1.9 & 2.9)

The contractor's plans to integrate and checkout the SMS software prior to integration with the equipment shall be defined for purposes of evaluation. The test documentation, drivers and results so generated by the contractor shall be deliverable at acceptance. Configuration control of the documentation and software shall be maintained during the duration of the program.

6.2.15 Demonstration, Installation & Test (WBS #1.10 & 2.10)

6.2.15.1 Factory Test and Demonstration

6.2.15.1.1 Layout Model

A layout model of the total SMS floor plan shall be provided. Scale shall be 3/8"/ft. minimum. This model shall be provided in conjunction with the models of the crew stations and IOS at the time of the simulator mockup review.

6.2.15.1.2 Factory Test

Prior to the installation of contractor built equipment at the NASA MSC facility, the various hardware systems shall be thoroughly tested and demonstrated at the factory.

Hardware for the following systems shall be tested and demonstrated to the extent specified herein:

1) Crew Station Hardware
2) Control and Display Hardware
3) Visual Hardware
4) Visual Graphics
5) Instructor Operator Station
6) Motion Hardware
7) External Interface Equipment
8) Aural System Hardware
9) Simulator Power Hardware
10) Simulator Timing Hardware
11) Hydraulic System Hardware

12) Anciliary Equipment

13) On-Board Computer Hardware
14) Data Conversion Equipment

Documentation describing the factory test set up, test methods, and test results for all hardware equipment shall be generated as specified in Exhibit (2).

Documentation to be prepared shall include comprehensive descriptions of the following as applicable:

1) Test methods and test equipment
2) Diagram of test set-up
3) Required results
4) Record of test results achieved.

6.2.15.1.2.1 Crew Station Hardware

Crew station hardware shall be tested to determine agreement with manufacturing drawings.

6.2.15.1.2.2 Control and Display Hardware

Prior to installation in the crew station, the panels, controls, and displays to be utilized in the crew stations of the simulator shall be tested to the point of determining agreement with mechanical drawings, and wiring,and cabling diagrams.

After installation in the crew stations, the panels, controls and displays shall be further tested to insure compatibility with interfacing cables and hardware.

6.2.15.1.2.3 Visual Hardware

The visual system shall be tested to determine agreement with drawings and wiring and cabling diagrams.

A signal substitution panel shall be provided to provide drive functions for the visual system.

This panel shall enable complete testing of the visual system in the absence of the computer control functions. Static, dynamic, and optical MTF tests shall be provided to verify visual system capabilities and specification compliance.

6.2.15.1.2.4 Visual Graphics

Visual graphic equipment (films, models, etc.) shall be tested to determine agreement with specification requirements. Films shall be tested for MTF. Film calibration and splicing equipment shall be provided as required.

Calibrated video test patterns provided for test of the video equipment shall also be tested using appropriate test equipment.

6.2.15.1.2.5 Instructor/Operator Station

Prior to installation in the IOS, panels, controls and displays to be utilized in the Instructor/Operator station shall be tested to the point of determining agreement with wiring and cabling diagrams. After installation in the IOS the panels, controls, and displays shall be further tested to insure compatibility with interfacing cables and hardware.

6.2.15.1.2.6 Motion Hardware

Prior to turn-on, the motion system shall be tested to insure agreement with mechanical drawings and wiring and cabling diagrams. Subsequent tests shall verify operation of the motion system under normal weight load conditions. These tests shall demonstrate the status and dynamic capabilities of the system in terms of accelerations, velocities, and excursions of the system.

6.2.15.1.2.6.1 Motion System Dummy Load

A load possessing the weight, moment of inertia and c.g. location of the actual payload shall be constructed and installed on the motion system platform to effect these tests.

6.2.15.1.2.7 External Interface Equipment

All SMS external Interface equipment shall be tested to insure agreement with wiring and cabling diagrams. Functional tests shall also be provided to verify operation of interface hardware prior to tie-in with the GFE computer and with the M.C.C.

6.2.15.1.2.8 Aural System Hardware

The aural cue system shall be tested to insure agreement with wiring and cabling drawings.

The sound amplitude and frequency response characteristics of the system also shall be demonstrated, using a test fixture if required as a substitute for computer control functions.

6.2.15.1.2.9 Simulator Power Hardware

Prior to power turn-on, the simulator power distribution and conversion hardware shall be tested to insure agreement with wiring and cabling diagrams. Subsequent tests shall verify operation of all power hardware under normal load conditions. Power-on and power-off sequencing shall be demonstrated.

6.2.15.1.2.10 Simulator Timing Hardware

The simulator central timing equipment shall be tested prior to shipment for operation in all modes by simulation of external sync and control inputs with the device driving all output loads to which it will be subject in the field. This shall include operation of any line driver outputs or line receiver inputs associated with the timing equipment which shall have equivalent terminated transmission line lengths in the test set-up.

6.2.15.1.2.11 Hydraulic System Hardware

The hydraulic system shall be tested to insure agreement with all design and specification control drawings. Additional tests to verify performance requirement shall be in conjunction with the motion system hardware.

6.2.15.1.2.12 Ancilliary Equipment

Interface cabinets and other interface equipment shall be tested to insure agreement with associated wiring and cabling drawings. Subsequent tests shall insure agreement with interfaced equipment including all crew station control and display, the IOS, motion, visual, etc.

6.2.15.1.2.13 On-Board Computer Hardware

On-board computer, computer interface, and display and control hardware for the Data Processing and Software Subsystem on-board computers, and the Main Engine Computers, which is incorporated into the SMS, shall be tested and demonstrated prior to integration with the main simulation computer.

6.2.15.1.2.14 Data Conversion Equipment

The data conversion equipment shall be tested to determine agreement with drawings and wiring and cabling diagrams. Functional tests shall also be provided to verify operation of the DCE prior to tie in with the interface hardware and with the main simulation computer.

6.2.15.2 On-Site Installation and Test

6.2.15.2.1 General

On-site installation and test, of all simulator hardware and integration with the GFE computer and DCE hardware and with computer software, shall be provided at NASA MSC. Hardware maintenance support shall be provided during the software test phase.

6.2.15.2.2 On-Site Hardware Installation, Integration and Test

The factory tested and demonstrated equipment shall be shipped to NASA MSC. Hardware installation and integration shall be accomplished in a timely manner. Any equipment which was not tested at the factory shall be thoroughly tested at MSC prior to integration with other equipment.

During and subsequent to on-site hardware installation and integration, tests shall be executed to re-verify hardware system operation. These tests shall be a selected sub-set of those required in paragraph 6.2.15.1 above, plus any additional tests required to verify external interface requirements which were not proven during the factory test phase.

6.2.15.2.3 System Test

System tests shall be executed subsequent to hardware installation and test and prior to execution of the ATP. A system test shall be the evaluation of performance parameters of a software-hardware system in an environment in which all programs are loaded in the simulation computer in near Final Form. The hardware shall be operational, and the simulator complex shall be capable of operation in an mission environment with a full reset capability. For each system, a system test document shall be generated which when executed, shall provide assurance that each system is fully operational.

6.2.15.3 Acceptance Test

The SMS contractor shall prepare detailed Acceptance Tests in accordance with Exhibit (2), DRL Line Item 12.

The simulator shall be submitted to NASA for acceptance testing along with a Start of Acceptance Test Review Plan (SATR) in accordance with Exhibit (2), DRL line item 38.

6.2.15.4 Acceptance Test

The simulator shall be submitted to NASA for acceptance testing along with a Start of Acceptance Test Review Plan (SATR).

Acceptance tests shall be performed on the simulator to demonstrate compliance of the integrated end item systems with the simulator specification requirements. All acceptance tests shall be executed using the same computer load. Acceptance Testing shall be divided into phases as follows:

1) Simulator Operations and Procedures
2) SMS System Tests
3) Mission Oriented Tests
4) Visual Graphics Tests
5) Visual System Tests

6.2.15.4.1 Simulator Operation and Procedure Tests

This phase of the acceptance tests shall be devoted to the initilization and operation of the SMS. Included shall be demonstration and operation of the simulator data acquisition system (CRT displays, recorders and the simulator control functions such as master control, master timing, malfunction insertion and display.)

6.2.15.4.2 System Acceptance Tests

This phase of the acceptance test is intended to verify the SMS systems. SMS systems such as EPS, RCS, GN&C, Main Engines, Communications, Performance Monitor, Caution and Warning, shall be tested in detail to verify proper operation.

The tests shall be designed such that each system is tested in the same manner of operation as would take place in real missions.

Interface programs such as telemetry, DCS, and the MCC trajectory interface program, shall also be tested to assure that data is being handled according to the appropriate Interface Control Documentation.

6.2.15.4.3 Mission Oriented Tests

For this phase the testing philosophy shall be to demonstrate that the SMS dynamically simulates the various aspects of the simulated mission environment. In addition to demonstrating a number of normal features to be encountered by the flight crew, a number of pre-selected malfunctions shall be entered and their effects observed.

6.2.15.4.4 Visual Graphics Tests

Tests shall be provided to insure agreement of visual system graphics (films, video test patterns, etc.) with their appropriate specification requirements. These tests shall include MTF tests and other tests as to verify accuracy of the graphic elements.

6.2.15.4.5 Visual System Tests

A comprehensive series of tests including system status and dynamic tests of the visual system shall be provided. These tests shall include the factory tests identified in paragraphs 6.2.15.2 plus additional integrated tests which include the main simulation computer, and D.C.E. equipment as required. Test programs shall be provided to permit driving the visual system at known rates for verification of the accuracy and dynamic response of the visual system under computer control.

6.2.16 Documentation (WBS #1.11 and 2.11)

The requirements associated with these work packages are defined in Section 7.0 in conjunction with Exhibit 2 and Exhibit 3.

6.2.17 Program Management (WBS #1.12 and 2.12)

The requirements associated with these work packages are defined in Sections 4.0 and 5.0.

6.2.18 Miscellaneous Hardware & Software (WBS#1.13 and 2.13)

There are no specific requirements for these work packages. They are intended for use by the Contractor to cover efforts which do not fall into any of the other work packages.

6.2.19 Motion System (WBS #1.14)

A six-degree-of-freedom motion system shall be provided for the MBCS. The motion system shall provide motion cues which would be perceived by the crew member in the actual Shuttle vehicle under the same conditions.

6.2.19.1 General Requirements

The physical motion system movement shall be determined by computations based upon six degrees of aircraft freedom. Motion system movement shall be correctly correlated with the motion of the simulated aircraft. All aircraft stability derivatives shall be accounted for in such a manner that aircraft movement in any degree of freedom shall correctly influence movement along or about the axis of the motion system. The sensations of motion shall be representative of the sensations experienced in the operational aircraft.

6.2.19.2 Degrees of Freedom

The physical movement of the simulated aircraft shall be along and about the X-axis (longitudinal and roll), along and about the Y-axis (lateral and pitch), and along and about the Z-axis (vertical and yaw). Motion shall be possible in any one degree of freedom independently or any combination thereof.

6.2.19.3 Detail Design Requirements

6.2.19.3.1 Hydraulic & Electromechanical Design

The motion system shall be controlled electrically and powered hydraulically. The hydraulic pumps shall be of the pressure-compensated variable volume type. Should a hydraulic control loading system be utilized, means shall be provided such that cockpit training with control loading only can be provided when the motion system is down for maintenance, as when a motion system pump or any actuator is removed from the hydraulic line. The following features shall be incorporated.

a. Pressure relief valves shall be installed in the system and shall open if the maximum design working pressure is exceeded. Replacement or recleanable filters shall be provided throughout the system as necessary to ensure reliable operation. Fine filters (5 micron nominal) shall be placed upstream of servo control valves. Additional filters on the pump case drain line and elsewhere shall be provided as necessary to ensure reliable operation. All filters shall be equipped with differential pressure switches to provide a remote indication (at the maintenance control panel) that the filter needs servicing. If the filter is equipped with a bypass, the differential pressure switch will actuate before the bypass opens (i.e., at a lower differential pressure). All filters shall be accessible for ease in servicing.

b. Permanent hydraulic line connectors shall be used wherever possible. Leakproof separable connectors shall be used as necessary to assist in sound installation and maintenance.

c. The design shall incorporate adequate provisions for maintenance operations, including draining, cleaning, bleeding and filling the hydraulic system. Shut-off valves and drain ports shall be provided as necessary for maintenance operations. The design shall include provisions for removal and replacement of any hydraulic actuator, including maintenance jack support and ease of access.

d. Inert gas accumulators shall be provided as necessary to assist flow requirements during worst-case maneuvers. Accumulator pressure drop during worst-case maneuvers shall not exceed 70% of the supply pressure.

e. Water-cooled heat exchangers shall be designed to operate with a maximum inlet temperature of 85°F for the cooling water. Air-cooled heat exchangers shall be designed to operate with a maximum inlet air temperature of 110°F.

f. All feedback elements shall be shielded from accidental damage.

g. An automatically operated access stairway (or ramp) shall be provided if necessary to ease personnel entry and exit into the simulator crew station. The access stairway shall be operable when the motion system is down for maintenance. Mechanization shall be determined at the layout model conference.

h. Hydraulic fluid (per MIL-H-5606B) shall have a minimum flashpoint temperature of 200°F. An oil temperature sensing gauge shall be provided with either an audio and visual overtemperature warning device. Excessive oil temperature shall automatically activate shutdown of the hydraulic system. A reservoir of adequate capacity for continuous maximum demand with a sight gauge shall be provided. Automatic shutdown of the motion system shall occur if the fluid level is too low for normal operation, or if system pressure drops below a predetermined value.

i. Cavitation shall not occur in the pump, control valves, or other components of the hydraulic system. The pressure pulses caused by the pump shall not excite resonance, nor shall the motion system excite resonance in the simulator or any portion thereof. Transient pressure pulses, such as may be caused by rapid closing of a valve, shall not cause damage to the hydraulic system. Chattering of valves shall not occur.

6.2.19.3.2 Motion and Control Loading System Controls

a. The control loading pump (if utilized) alone shall be used during normal maintenance operations or during training without motion. Controls at the instructor's station shall be provided to engage or disengage both the motion system and control loading system.

It shall be possible to deactivate the motion system pump(s), and activate the control loading pump, from the instructor's station. It shall not be possible to engage the motion system unless all interlocks are in a safe position; the motion system shall then be engaged when the control is activated by the instructor. The reverse sequence (control switch is activated, interlocks moved to safe position, motion system responds) shall not occur. Engaging or disengaging the system shall not result in rapid crew station movement. The motion system shall respond to engagement or disengagement in less than three seconds.

b. A key-operated switch shall be provided to facilitate isolating the pump motor circuits for maintenance. "Emergency Stop" switches shall be provided to shut down the hydraulic system. "Emergency Stop" switches shall be provided at the instructor's console, maintenance control panel, and in the crew station within reach of the pilot. The crew station switch shall not interfere with the simulator training function. When any "Emergency Stop" switch has been activated, the motion system shall remain inoperable until the instructor initiates the normal control switch starting sequence.

6.2.19.3.3 Maintenance Controls

A maintenance control panel shall be provided and located within view of the motion system. The panel shall provide controls to drive each actuator to any position desired by the operator without computer control If necessary, other actuators may move to allow a chosen actuator to be driven to a selected position. On-off and engage-disengage controls similar to those at the instructor's station, shall be provided. An "Emergency Stop" switch shall be located on the panel to shut down the system. A "mode" switch shall be provided for "maintenance" or "normal" operation. The "normal" position shall deactivate maintenance panel controls, except for the "Emergency Stop" control. The "maintenance" position shall deactivate instructor motion controls, returning full control to the maintenance operator. Visual status indicators of pressure, fluid contamination, temperature, control positions and other pertinent information shall be provided.

6.2.19.3.4 Floor Loading

The SMS contractor shall design the motion system support structure for the correct reaction mass composition, tie-down means and structure interface. The support structure shall be designed for installation in soil of 1500 pounds per square foot bearing capacity. Leveling of the motion system pads shall be solely the responsibility of the SMS contracto

6.2.19.4 Performance Requirements

6.2.19.4.1 Simulated Motions

The motion system movement shall be determined by computations based upon six degrees of vehicle freedom. The simulated motions shall optimize the tracking of the total acceleration vector of the simulated crew station, including changes in magnitude and direction. The frequency of simulation of new acceleration cues shall be maximized; during position washout, new acceleration cues shall be accepted in any direction, constrained only by the position and velocity limits of the system, and the threshold of perception of the crew member The motion system shall provide cues in multiple degrees of freedom. simultaneously, as demanded by the flight equations of motion. The acceleration cues of the simulator crew station shall not exceed the acceleration of the actual vehicle under the same conditions. Spurious motion cues shall at no time be noticeable to crew member.

a. As a minimum, the following motions shall be simulated: launch, launch abort, re-entry, buffets, stalls, dives, climbs, banks, rolls, vibration dynamics, touchdown attitude and impact, movements corresponding to brake application, landing gear strut dynamics, ground dynamics including runway rumble, movements corresponding to landing gear and external control surfaces extension or retraction, and movements corresponding to center of gravity or center of pressure movement. The envelope of movement shall be as large as possible so that full motion displacement is utilized.

b. Steady-state simulated vehicle pitch attitude shall result in a constant corresponding pitch attitude of the simulator. Entry into a coordinated turn shall result in roll and lateral motion to provide the onset cue; if the coordinated turn is held, the crew station shall imperceptibly return to a normal level position.

6.2.19.4.2 Payload Weight

The performance requirements for the motion system shall be met with the complete simulated forward crew station (including the pilot, commander and instructor), the forward visual system, and the structure and mechanism associated with the tilt feature which simulates the launch attitude of the vehicle. The performance requirements shall be met with the payload in both level and full tilt attitudes. Interlocks shall be provided in the system to minimize motion cues while the payload is in transition between the zero tilt and full tilt attitude.

6.2.19.4.3 Worst-Case Maneuvers

The motion system shall perform smoothly and without hunting at all times. The motion system shall be sized to perform the worst-case flight maneuvers the simulated vehicle will encounter.

6.2.19.4.4 Rough Air

The effects of rough air and wind buffet shall be appropriately reflected in the motion system.

6.2.19.4.5 Response

Motion system response to a step input shall occur in less than 0.05 seconds. Motion system response to a crew station control input shall occur in less than 0.15 seconds.

6.2.19.4.6 Excursions, Velocities and Accelerations

The motion system shall be capable of attaining the following minimum excursions, velocities and accelerations with the payload specified in 6.2.19.4.2.

| | | Excursion | Vel. | Accel. |
| --- | --- | --- | --- | --- |
| (1) | Pitch | $\pm 30^\circ$<br>$-20^\circ$ | $15^\circ$/sec | $\pm 50^\circ/sec^2$ |
| (2) | Roll | $\pm 22^\circ$ | $15^\circ$/sec | $\pm 50^\circ/sec^2$ |
| (3) | Yaw | $\pm 32^\circ$ | $15^\circ$/sec | $\pm 50^\circ/sec^2$ |
| (4) | Heave | +39"<br>-30" | 24"/sec | ±0.8g<br>(from normal 1g) |
| (5) | Lateral | ±48" | 24"/sec | ±0.6g |
| (6) | Longitudinal | +49"<br>-48" | 24"/sec | ±0.5g |

These excursions must be attainable within the normally operable motion envelope which excludes the soft stop and cushioned stroke of the actuators. These are not simultaneous requirements. The system must satisfy only one set of requirements at a time. The peak accelerations must be met from the normal operating position of the motion system. The system shall be capable of producing a continuous sinusoidal heave motion of 7½" peak to peak excursions at 1 Hertz.

6.2.19.4.7 Acceleration Onset

The motion system shall meet the following criteria, as a minimum governing onset cue capability.

| Movement | Onset Acceleration Rate | Maximum Acceleration |
| --- | --- | --- |
| Vertical | ±4g/sec | ±0.8g |
| Lateral | ±3g/sec | ±0.6g |
| Pitch | 300 degrees/sec$^2$/sec | ±60 degrees/sec$^2$ |
| Roll | 300 degrees/sec$^2$/sec | ±60 degrees/sec$^2$ |

The above requirements shall be met from the normal operating position of the motion system.

6.2.19.4.8 Frequency Response

The closed-loop performance of the motion system shall comply with the following:

| Frequency Range (Hertz) | Maximum Phase Shift (Degrees) | Motion Platform Position (Maximum Decibels) |
|---|---|---|
| 0.1 - 0.5 | $20^{\circ}$ | $\pm$ 1 db |
| 0.51 - 1.0 | $60^{\circ}$ | $\pm$ 2 db |
| 1.1 - 2.0 | $110^{\circ}$ | $\pm$ 3 db |

The above criteria apply to each degree of freedom. Resonance shall not occur from zero to five Hertz. Design provisions shall be incorporated to minimize activation of resonant frequencies above five Hertz.

6.2.19.5 Safety Requirements

a. Mechanical, electrical and hydraulic protective devices shall be provided to protect the crew member, operating personnel, observers, and maintenance personnel from injury. The motion system structural design shall be based on a minimum safety factor of 4:1.

Hydraulic actuators shall be equipped with redundant electrical limit switches to automatically shut down the motion system if overtravel occurs. A passive mechanical-hydraulic system shall automatically shut down the motion system when an electrical power failure occurs. When the motion system is shut down, the cockpit shall return to a level cockpit egress position at a safe rate of return. Mechanical and hydraulic energy-absorbing devices shall be provided to absorb the greatest kinetic energy the system can develop, in a manner not to compromise crew member safety, if runaway occurs.

b. When the system is shut down, all hydraulic fluid pressure shall settle to zero within three minutes. All hydraulic system components shall be pressure-rated at least 100% higher than the maximum working pressure of the system.

c. A warning sign shall be provided in a suitably prominent position and shall automatically illuminate when the motion and/or control loading systems are engaged.

d. Fail safe electrical interlocks shall be provided to prevent activation of the motion system in an unsafe condition. As a minimum, interlocks shall be provided on the entrance gate, access stairway, and within pressure pads underneath the motion system and on the entrance steps.

e. The access stairway or ramp shall be physically removed from the operating envelope of the motion system when the motion system is engaged. In the event of a main power failure, means shall be provided to automatically move the access stairway to the crew station position in less than thirty seconds.

f. At no time shall the motion system unexpectedly move rapidly. Engaging or disengaging the motion system shall not result in abrupt motion system movement. "Freezing" or release from a simulator "freeze" condition shall be smooth, even if control movements have been made during the "freeze" state.

g. In the event of an emergency, it shall be possible to rapidly evacuate the crew stations.

6.2.19.6 Synchronization

Cues provided by the motion system shall be properly synchronized with cues provided by the crew station displays. There shall be no noticeable time, position, velocity, or acceleration error between motion system cues and other cues.

6.2.19.7 Maintenance Features

In addition to the requirements of 6.2.19.3.3 the motion system shall include the following:

a. system transducers to permit reading voltage outputs directly without the need for demodulators.

b. adjustable jacks,with built in receptables on the motion platform,to permit removal of actuator assemblies without removing the payload.

c. fluid level indicators.

d. provisions for bleeding and lubricating the system.

e. provisions for checking each servo operationally without removing it from the system.

6.2.19.8 Software Drive Requirements

The motion system software shall employ axis systems compatible with the axis systems defined in the simulated vehicle. Accelerations, both translational and rotational shall be computed by software within these axis systems. Software considerations such as the stability deviations effect, center of gravity changes, or center of pressure movement shall be displayed at the motion platform through software acceleration changes. The acceleration of the simulator crew station in any degree of freedom shall not exceed the vehicle acceleration experienced under the same flight and configuration conditions. Environmental conditions such as rough air, wind and gusts shall be considered by software and reflected in the acceleration outputs employed by the motion system software.

6.2.19.9 Tilt Provisions

As part of the basic motion system a capability shall be provided to position the forward crew station in a vertical attitude to simulate sustained longitudinal accelerations. The crew station in this position shall provide motion cues to the crew which simulate the actual cues experienced during long term longitudinal accelerations.

The payload shall be positioned in the vertical attitude at a rate which will prevent injury to the crew members. Deceleration devices shall be employed at the extremes of position to preclude damage to the equipment. Locking devices shall be provided to achieve the stability required in each mode to permit full motion system operation.

Provisions shall be made to permit safe evacuation from the crew compartment when it is positioned in the launch attitude.

The total excursion in tilt shall be a minimum of $+105^{\circ}$ from level which may be achieved by the tilt mechanism plus the pitch capability of the motion system.

The tilt mechanism alone shall be capable of moving the payload at a rate of $40^{\circ}$/sec. for either positive or negative tilt.

## 6.3 Test Requirements

The SMS Contractor shall generate a General Acceptance Test Plan in accordance with Exhibit (2), DRL Line Item 11. The test requirements specified in paragraph 6.2.15 are considered to be the minimum acceptable and the plan shall demonstrate the courses of action to be taken to effect the required testing as well as any other deemed necessary by the Contractor.

## 6.4 Logistics Requirements

### a) Spares Provisioning

The contractor shall provide Spare Parts Provisioning sufficient to support the SMS for a period of one year after acceptance of each crew station.

The contractor shall publish an agenda for the Spare Parts Provisioning Guidance Meeting (Reference Exhibit (2), DRL line item 15), conduct the meeting, publish minutes of the meeting (Reference DRL line item 16), prepare a Spare Parts Provisioning List (Reference DRL item 21), and submit period reports on the Provisioning Program Status (Reference DRL item 17).

### b) Maintenance

The simulator shall be designed so that it can be maintained within the lowest possible level of maintenance available. The contractor shall develop detailed maintenance procedures and document them in a maintenance manual (See Exhibit (2) for further instructions, Reference DRL line item 18).

### c) Operations

The contractor shall prepare an Operations Manual to provide detailed instructions for operating all equipment which is not part of the flight compartment. (See Exhibit (2) for further instructions, Reference DRL line item 19).

### d) Software Logistics

The contractor shall provide the necessary documentation in the form of a Programmer's Reference Manual (Reference Exhibit (2), DRL item 31) to enable the NASA to maintain and modify the SMS software subsequent to acceptance.

e) Failure Evaluation and Analysis

The contractor shall perform an evaluation and analysis effort on all failures occurring on the SMS in order to determine high failure rate items and recommend proper corrective action. This effort shall continue for a period of six months after acceptance of each crew station.

## 6.5 Reliability and Quality Assurance Requirements

### 6.5.1 General

An organized quality assurance program shall be established by the SMS contractor in accordance with NPC200-3.

### 6.5.2 Responsiblity for Inspection

Unless otherwise specified in the contract or purchase order, the SMS contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, in the contract or order, the SMS contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

### 6.5.3 Facilities

The SMS contractor shall furnish any facilities, equipment or personnel that the Government may require to ensure that the training device meets the requirements of this specification.

### 6.5.4 Classification of Inspections

Inspections to be performed are classified as follows:

a) In-process inspection

b) Quality conformance inspection

6.5.4.1 In-Process Inspection

In-process inspection shall include such visual, electrical and mechanical examinations and testing of materials, subassemblies, parts and accessories (including purchased items) during the manufacturing process of the training device as may be required to assure conformance to all requirements of this specification.

6.5.4.2 Quality Conformance Inspection

Quality conformance inspection shall include visual, electrical, mechanical, and functional examinations and tests of the end item to assure conformance to all requirements of this specification.

## 6.6 Support Requirements

A team of engineering personnel shall be provided at the simulator site for a period of six months after acceptance of each crew station. The team shall be comprised of personnel selected on the basis of their experience in the various technical areas associated with the simulator. The team shall provide:

a. Training of operations personnel. This shall consist of on-the-job training for technically qualified personnel who are not familiar with this simulator.

b. Training of maintenance personnel. On-the-job training shall be provided for technically qualified personnel who are not familiar with this simulator.

c. Coordination of data requirements and hardware change control between the contractor's facility and on-site operation.

d. Spares coordination between the contractor's facility and the on-site operation.

The team shall form a part of the installation, checkout and testing crew.

The team shall be completely familiar with the Maintenance and Operation Manuals for the SMS prior to the on-site training period. Each member of the team shall be able to support training of NASA maintenance and operation personnel in the use of the manuals.

## 7.0 Documentation Requirements

The contractor's plans for the generation of the documentation tabulated in Exhibit 2 shall be defined for purposes of evaluation. The interpretation of requirements and division of work between work packages, and provisions and procedures which shall be made to accept and handle Shuttle Data during the life of the program shall be clearly defined in the Data Management Plan (Reference Exhibit 2, DRL item 7). A Data Manager at Houston shall be provided to interface with NASA and the Shuttle Contractors.

Exhibit 1

Applicable Documents to the

Shuttle Mission Simulator

Statement of Work

The following documents of the issue in effect on the effective date of the contract form a part of this specification to the extent specified herein.

Specifications

| | |
|---|---|
| Addendum 'A' | SMS Malfunction List |
| Addendum 'B' | MCC/SMS Interface Parameters |
| Addendum 'C' | Data Management Specification |
| Addendum 'D' | Government Furnished Property List |

Military

| | |
|---|---|
| MIL-E-5400 | Electronic Equipment, Aircraft General Specification For |
| MIL-I-8500 | Interchangeability and Replaceability of Component Parts for Aircraft and Missiles. |
| MIL-W-16878 | Wiring, Electrical, Insulated, High Temperature |
| MIL-STD-100 | Engineering Drawing Practices |
| MIL-STD-130 | Identification Marking of U.S. Military Property |
| MIL-STD-143 | Specifications and Standards, Order of Procedures |
| MIL-STD-461 | Electromagnetic Interference Characteristics Requirements for Equipment |
| MIL-STD-1472 | Human Engineering Design Criteria for Military Systems, Equipment and Facilities |
| NH5300.4(1B) | Quality Program Requirements for Aeronautical and Space System Contractors |
| MS-33586 | Metal, Definition of Dissimilar |

| | |
|---|---|
| NASA HDBK SP-5002 | Reliable Electrical Connections |
| Standard USAS Y32.16 | Reference Designations for Electrical and Electronics Parts and Equipments |
| NHB 8040.2 | Apollo Configuration Management Manual |
| MIL-STD-785 | Requirements for Reliability Program |
| NPC200-3 | Inspection System Provision for Suppliers of Space Materials, Parts, Components, and Services |
| MIL-STD-454 | Standard General Requirements for Electronic Equipment |

Exhibit 2

TO THE PERFORMANCE & DESIGN REQUIREMENTS SPECIFICATION

FOR THE

SHUTTLE MISSION SIMULATOR

DATA MANAGEMENT SPECIFICATION

## 1.0 General Requirements

### 1.1 Data Requirements and Description

1.1.1 The contractor shall prepare, maintain and/or submit data throughout the life of this contract in accordance with the Data Requirements List (DRL). Data submitted shall be in legible form and in the quantity of copies specified in the DRL.

1.1.2 The Data Requirement Descriptions(DRD's) define the content, format, and maintenance requirements for the data items. The DRD defines the minimum requirements that will be accepted for the documentation. Wording such as "...as a minimum" or "....included, but not limited to' permit the contractor to include data in addition to the listed requirements, where necessary, or to use existing documentation if appropriate.

1.1.3 Documents referenced on the DRL and associated DRD's are the issue in effect on the contract date of the DRL line item and shall form a part of the data requirement line item or DRD to the extent specified therein. In the event of conflict between the DRL/DRD requirements and documents referenced on the DRL or DRD, the DRL/DRD requirements shall govern.

1.1.4 The documentation requirements specified by the DRL shall not be altered as a result of a make or buy decision.

1.1.5 Where practicable, the Contractor's own internal documents shall be utilized to meet and/or supplement the requirements specified herein, e.g., internal documents shall not be retyped and printed on more expensive paper prior to submittal.

1.1.6 The Contractor shall participate in program data requirements reviews to assess the adequacy of Government and Contractor documentation efforts.

1.1.7 Any detail documentation generated with the normal course of the contracted work and not a part of the data required herein shall be made available in accordance with the "Data Requirements" clause of this contract.

1.1.8 References to data in the Contractors responses are permissible, providing the references are adequate and include such identification elements as title, number, revision, etc.

1.1.9 When a referenced document would only be applicable to a minor or limited extent, the Contractor shall make every effort to include applicable requirement(s) and avoid direct reference. All referenced documents shall be made readily available to the cognizant Center Agency upon request.

## 1.2 Classification and Categories of Data

### 1.2.1 Classification

Data required shall be categorized as follows:

Type 1 - Type 1 data shall be submitted to NASA for approval. Implementation of Type 1 documentation shall not proceed until after approval by NASA or until 20 days after receipt at NASA, provided notice of disapproval has not been received by the Contractor.

Type 2 - Type 2 data shall be submitted to NASA for coordination, surveillance, information, review and/or management control.

Type 3 - Type 3 data shall be retained by the Contractor and submitted to NASA upon request.

### 1.2.2 Categories of Data

Data prepared by the Contractor shall be categorized as follows:

Category

- MA - Program Management
- SC - Scheduling
- PC - Procurement and Contracts
- DM - Data Management
- CM - Configuration Management
- LS - Logistics
- MF - Manning and Financial

SE - Systems Engineering

RA - Reliability and Quality Assurance

TM - Test and Manufacturing

FA - Facilities

## 1.3 Data Identification

1.3.1 All data shall be organized into a series of numbered documents and shall reference the assigned contract number(s). All data delivered, except drawings and ECP's, shall be clearly marked with the DRL line item number that requires such delivery. Documents that satisfy the requirements of more than one line item shall reflect all applicable line item numbers. Successive issues or revisions of data shall be identified in the same manner as the basic issue. Types I and II documents shall be identified by MSC number to be assigned by the Center Data Manager (BM2) for MSC through the Contract Technical Manager. These numbers shall be entered in the upper right corner of the document cover as shown on the sample, Figure 1. This sample cover also illustrates the method of identifying the document to the DRD, the DRL, the DRL line item number, and the contract. Periodic progress reports, i.e., monthly, quarterly, will be identified by one basic MSC number and given separate identities in each series by their dates.

## 1.4 Subcontractor Data Requirements

1.4.1 The prime contractor shall state contractually to vendors and subcontractors that they make all requests for program data needed in the satisfactory accomplishment of their contracts to the prime contractor.

## 1.5 Data Right

1.5.1 During the period of the contract, NASA shall have the option of requiring any data prepared under this contract be delivered in a reasonable format and timely manner. Any such request for data in its existing format shall not be considered a request pursuant to the "Data Requirements" clause.

## 2.0 Detailed Requirements

### 2.1 Preparation of Data

2.1.1 DaData shall be prepared in accordance with the DRD specified by the DRL requirement. Unless otherwise specified by the DRD, the best industry and engineering practice shall be employed when preparing the data.

2.1.2 The reproduction and binding of all data required shall be done at the lowest feasible cost in accordance with Table XX of the Government Printing and Binding regulations.

### 2.2 Maintenance of Data

2.2.1 Revisions to documentation may be accomplished either by individual page revision or a complete reissue of the document with the exception of drawings which shall be revised in accordance with minimum Configuration Management Requirements (Reference DRD DM003TA).

### 2.3 Data Requirements Change Procedure

#### 2.3.1 MSC Initiated Change

2.3.1.1 New and/or revised data requirements will be incorporated by contract modification to which the new or revised DRL and/or DRD will be appended.

2.3.1.2 The Contractor shall notify the Contracting Officer in the event a data requirement is imposed by a contract modification and for which no DRL change page is appended. In such a case, the Contracting Officer will submit the required DRL/DRD changes, unless the data is a "one-time" requirement. Nothing herein shall be construed to relieve the Contractor of the responsibility to furnish data under the provisions of any contract modification in the event the appropriate DRL change pages are not appended or otherwise furnished.

2.3.1.3 DRL change identification will be accomplished by controlling each DRL page separately and by placing a change control symbol and date in the revision block at the top of each DRL page.

2.3.2 Contractor Initiated Change

2.3.2.1 Contractor proposed data requirement, or proposed changes to existing requirements shall be presented on a company controlled Document Change Notice (DCN).

2.3.2.2 Associated costs for preparing DCN's in response to MSC contract modifications will be evaluated and negotiated as an integral part of said modification.

2.4 Delivery and Distribution of Data

2.4.1 Data shall be delivered to NASA in accordance with the schedule presented in the DRL and with the following information:

a. All documentation delivered shall be clearly marked with the DRL line number requiring such delivery (except drawings).

b. Type I documents shall be marked, "Preliminary - NASA Approval Pending."

c. Approved Type I documents shall reflect NASA approval.

d. Type 1 documentation shall be submitted to NASA via most expeditious means.

e. All documentation shall be delivered to:

NASA Manned Spacecraft Center

Houston, Texas 77058

Attention: (Named) Contracting Officer

or

as further designated on a NASA approved Data Distribution List.

## 3.0 Order of Precedence

3.1 Where requirements of this Data Management specification and the requirements of a DRD or the DRL conflict, the following order of precendence shall prevail:

1. the DRL
2. the DRD
3. this Data Management Specification

SAMPLE COVER PAGE

SD 69-202

APOLLO APPLICATIONS CSM PROGRAM

MONTHLY PROGRESS REPORT

15 AUGUST 1969

for L. M. Tinnan
Program Vice President
Apollo Applications CSM

This document is submitted in compliance with L.I. No. 3, DRD MA-003T of SD69-211 as Type II Data, Contract NAS 9-99[illegible]

SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION

Figure 1

**Exhibit 2**

Data Requirements Specification for the

**Shuttle Mission Simulator**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER

# DATA REQUIREMENTS LIST (DRL)

(The Center Data Manager (Code JM2) will assign numbers in blocks d, 2, and 6.)

TELEPHONE NUMBER 713 483-6391.

ATTACHMENT NUMBER: a

EXHIBIT NUMBER: b

CONTRACT/RFP NUMBER: c

DRL NUMBER: d

PROJECT/SYSTEM: e Shuttle Mission Simulator

RESPONDENT: f

PREPARATION DATE: g 12/22/72

PAGE h

REVISION: i

| 1 LINE ITEM NO. | 2 DRD NUMBER | 3 TITLE | 4 OPR | 5 TYPE | 6 MSC DOCUMENT NUMBER | 7 FREQ. OF SUBM. | 8 INITIAL SUBMITTAL |
|---|---|---|---|---|---|---|---|
| 1 | MA-066T | PLAN, PROGRAM | | 1 | 2 | RT | SEE 9 |
| 2 | DM-003TB | REQUIREMENT FOR STANDARD METHOD OF INSERTING REVISED MATERIAL | | N/A | N/A | AR | SEE 9 |
| 3 | SC-001TB | MILESTONE SCHEDULES | | 2 | 2 | MO | SEE 9 |
| 4 | MA-067TA | REPORT, MONTHLY TECHNICAL PROGRESS | | 2 | 2 | MO | See 9 |

9. REMARKS (10 AS OF DATE; 11 COPIES: A TYPE, B NO.)

**Line item 1** — 9: First submittal due with Contractor's proposal. First revision to be submitted within 60 days after effective date of contract. Subsequent revisions to be submitted as released.

Reference paragraph 3.5.43 of the Specification.

10: — 11 COPIES: A Print, B 10

**Line item 2** — 9: This requirement is a requirement for changes and revisions, as necessary, to all other documents required by this DRL.

10: — 11 COPIES: A SEE, B 9

**Line item 3** — 9: First submittal due with Contractor's proposal. Cut-off date is the last day of the Contractor's Accounting Month. Due date is the 15th of the current month. First submittal due the 15th of the first month following ATP

Reference paragraph 4.4 of the Specification

10: 15/1 — 11 COPIES: A Print, B 10

**Line item 4** — 9: Outline of this report due with proposal. Cut-off date is the last day of the Contractor's Accounting Month. Due date is the 15th of the current month. First submittal due the 15th of the first month following ATP)

Reference paragraph 3.5.43.7 of the Specification

10: 15/1 — 11 COPIES: A Print, B 10

MSC DATA REQUIREMENTS LIST (DRL)
(CONTINUATION SHEET)

DRL NUMBER | REVISION | PAGE 2

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 5 | PC-002T | REPORT, SUBCONTRACT MANAGEMENT | | 2 | 2 | MO | See 9 |

9: To be submitted with REPORT,MONTHLY TECHNICAL PROGRESS, DRL line item 4. Cut-off date is the last day of the Contractor's Accounting Month. Due date is the 15th of the current month. First submittal due the 15th of the first month following ATP.
Reference paragraph 3.5.43.4 of the Specification.

10: 15/1 — 11 COPIES: A: Print, B: 10

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 6 | MF-008TB | REPORT, FINANCIAL MANAGEMENT | | 2 | 2 | MO | See 9 |

9: Block 10 - Cut off date is last day of Contractor's Accounting Month; due date is the 25th of the current month. (Reference NASA Form 533, Feb 67) First submittal due the 25th of the first month following ATP.
Reference paragraph 4.5 of the Specification

10: — 11 COPIES: A: Print, B: 10

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 7 | DM-010T | PLAN, DATA MANAGEMENT | | 1 | 2 | RT | See 9 |

9: First submittal due with Program Plan (DRL line item 1). Revision as released.
Reference paragraph 3.5.42 & 3.5.43.5 of the Specification.

10: — 11 COPIES: A: Print, B: 10

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 8 | | RESERVED | | 1 | 2 | RT | See 9 |

10: — 11 COPIES: A: Print, B: 10

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 9 | | RESERVED | | | | | |

MSC DATA REQUIREMENTS LIST (DRL)
(CONTINUATION SHEET)

DRL NUMBER | REVISION | PAGE 3

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 11 Copies A | B |
|---|---|---|---|---|---|---|---|---|---|
| 10 | RA-062TA | PLAN, QUALITY ASSURANCE | - | 1 | 2 | RT | See 9 | Print | 10 |
| 9 | First submittal due with program plan. Revisions as released.<br><br>Reference paragraph 4.6 of the Specification. | | | | | | | | |
| 11 | TM-056TA | PLAN, GENERAL ACCEPTANCE TEST | | 1 | 2 | RT | See 9 | Print | 10 |
| 9 | First submittal due with program plan, DRL line item 1. Revisions as released. Final submittal due with Acceptance Test Procedures.<br><br>Reference paragraph 3.5.41.3 of the Specification. | | | | | | | | |
| 12 | TM-057T | PROCEDURES, ACCEPTANCE TEST | | 1 | 2 | RT | See 9 | Print | 10 |
| 9 | First submittal due 45 days prior to scheduled test.<br><br>Reference paragraph 3.5.41.3 of the Specification. | | | | | | | | |
| 13 | CM-016TA | DATA PACKAGE, REVIEW, TRANSFER AND TURN-OVER | | 2 | 2 | OT | See 9 | Print | 2 |
| 9 | Data Package to be submitted at start of Acceptance Test.<br><br>Reference paragraph 4.2.2 of the Specification | | | | | | | | |
| 14 | LS-022T | DATA, VENDOR TECHNICAL | | 2 | 2 | OT | See 9 | Print | 2 |
| 9 | Due with Review, Transfer, and Turnover Data Package, DRL line item 13.<br><br>Reference paragraph 3.1.1.2 of the Specification. | | | | | | | | |

MSC DATA REQUIREMENTS LIST (DRL)
(CONTINUATION SHEET)

DRL NUMBER | REVISION | PAGE 4

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 15 | LS-023T | AGENDA, SPARE PARTS PROVISIONING GUIDANCE MEETING | | 1 | 2 | AR | See 9 |
| 16 | LS-024T | MINUTES, SPARE PARTS PROVISIONING GUIDANCE MEETING | | 1 | 2 | AR | See 9 |
| 17 | LS-025T | REPORT, PROVISIONING PROGRAM STATUS | | 2 | 2 | MO | See 9 |
| 18 | LS-026TA | MANUAL, MAINTENANCE | | 2 | 2 | RT | See 9 |
| 19 | MT-009TB | MANUAL, OPERATIONS | | 2 | 2 | RT | See 9 |

**15 — 9:** Submittal due 10 days prior to proposed meeting.

Reference paragraph 3.1.1.2 of the Specification.

11 COPIES: Print 10

**16 — 9:** Submittal due within 5 days of meeting.

Reference paragraph 3.1.1.2 of the Specification.

11 COPIES: Print 10

**17 — 9:** First submittal due within 60 days after Spare Parts Provisioning Guidance Meeting.

Reference paragraph 3.1.1.2 of the Specification.

11 COPIES: Print 10

**18 — 9:** First submittal due at start of acceptance testing.

Reference paragraph 3.1.1.2 of the Specification.

11 COPIES: Print 10; Repro 1

**19 — 9:** First submittal due at start of acceptance testing.

Reference paragraph 3.1.1.2 of the Specification.

11 COPIES: Print 10; Repro 1

12/22/72
Rev. A 3/23/73

MSC DATA REQUIREMENTS LIST (DRL)
(CONTINUATION SHEET)

DRL NUMBER | REVISION | PAGE 5

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 20 | | RESERVED | - | 2 | 2 | RT | See 9 |
| 21 | LS-028T | LIST, SPARE PARTS PROVISIONING | | 1 | 2 | MO | See 9 |
| 22 | SE-079TA | REPORTS, ENGINEERING DESIGN | | 2 | 2 | AR | See 9 |
| 23 | SE-080T | PACKAGE, MODIFICATION DATA | | 1 | 2 | RD | See 9 |
| 24 | | RESERVED | | 1 | 2 | RD | See 9 |

**20** — 9: (blank). 11 Copies: Print 10; Repro 1

**21** — 9: First submittal due within 60 days of Spare Parts Provisioning Guidance Meeting.

Reference paragraph 3.1.1.2 of the Specification.

11 Copies: Print 10

**22** — 9: Submittals due 15 days prior to Design Reviews (PDR, CDR).

Reference Paragraph 3.1.2.1.6.1,4.1.1 of the Specification.

11 Copies: Print 10

**23** — 9: Due within 30 days of release.

Reference paragraph 3.1.2.1.6.2 and 3.5.43.9 of the Specification.

11 Copies: Print 10

**24** — 9: (blank). 11 Copies: Print 2; Repro 1



1064

MSC DATA REQUIREMENTS LIST (DRL)
(CONTINUATION SHEET)

DRL NUMBER | REVISION | PAGE 6

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 25 | SE-082TA | DRAWINGS AND ASSOCIATED LISTS (FORM II) | | 2 | 2 | RD | See 9 |
| 9: Due within 30 days of release. Reference paragraph 3.1.2.1.6.3 of the Specification. | | | | | | | 11 Copies: Print 2, Repro 1 |
| 26 | SE-083T | DRAWING INDEX | | 2 | 3 | RT | See 9 |
| 9: First submittal due within 45 days after PDR. Revisions due as released. Reference paragraph 3.1.2.1.6.4 of the Specification. | | | | | | | 11 Copies: Print 10 |
| 27 | CM-017TB | PLAN, CONFIGURATION MANAGEMENT | | 1 | 2 | RT | See 9 |
| 9: First submittal due with Program Plan, DRL line item 1. Reference paragraph 4.2 of the Specification. | | | | | | | 11 Copies: Print 10 |
| 28 | CM-019T | NOTICE, SPECIFICATION CHANGE | | 1 | 2 | AR | |
| 9: Reference paragraph 3.1.2.1.6.7 of the Specification. | | | | | | | 11 Copies: Print 10 |
| 29 | CM-019T | LOG, SPECIFICATION CHANGE | | 2 | 2 | AR | |
| 9: Reference paragraph 3.1.2.1.6.7 of the Specification | | | | | | | 11 Copies: Print 10 |

MSC DATA REQUIREMENTS LIST (DRL)
(CONTINUATION SHEET)

DRL NUMBER | REVISION | PAGE 7

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 30 | CM-020T | PROPOSAL, ENGINEERING CHANGE | - | 1 | 2 | AR | |
| 9: Reference paragraph 3.5.43.9 and 4.2.1 of the Specification. | | | | | | | 11 COPIES A: Print B: 10 |
| 31 | TBD | MANUAL, PROGRAMMERS REFERENCE | | 2 | 2 | | See 9 |
| 9: Initial submittal due at the Start of Acceptance Testing. Reference paragraph 3.1.1.2 of the Specification. | | | | | | | 11 COPIES A: Print B: 10 |
| 32 | CM-022TA | DOCUMENT, INTERFACE CONTROL | | 1 | 2 | RT | See 9 |
| 9: Initial submittal due 15 days prior to Preliminary Design Review (PDR). Reference paragraph 3.1.2.1.6.8 and 4.2.3 of the Specification. | | | | | | | 11 COPIES A: Print B: 10 |
| 33 | CM-023T | NOTICE, INTERFACE REVISION | | 1 | 2 | AR | |
| 9: Reference paragraph 3.1.2.1.6.9 and 4.2.4 of the Specification. | | | | | | | 11 COPIES A: Print B: 10 |
| 34 | SE-084TA | DATA BOOK | | 2 | 2 | RT | See 9 |
| 9: Initial submittal due 15 days prior to Design Reviews (PDR, CDR). Reference paragraph 4.1.1, 3.1.2.1.6.5 and 3.5.43.9 of the Specification. | | | | | | | 11 COPIES A: Print B: 10 |

| MSC DATA REQUIREMENTS LIST (DRL) (CONTINUATION SHEET) | | | DRL NUMBER | REVISION | | | PAGE 8 |
|---|---|---|---|---|---|---|---|
| 35 | MA-069TA | PLAN, PRELIMINARY DESIGN REVIEW | - | 1 | 2 | RT | See 9 |
| First submittal due 15 days prior to PDR.<br>Reference paragraph 4.1.1 of the Specification. | | | | | | | COPIES: Print 10 |
| 36 | MA-070TA | PLAN, CRITICAL DESIGN REVIEW | | 1 | 2 | RT | See 9 |
| First Submittal due 15 days prior to CDR.<br>Reference paragraph 4.1.2 of the Specification. | | | | | | | COPIES: Print 10 |
| 37 | TBD | FACILITY MODIFICATIONS REQUIREMENTS | | 1 | 2 | | |
| First submittal due with Contractor's Proposal. First revision due 15 days prior to PDR. Subsequent revisions as released.<br>Reference paragraph 3.1.2.1.1 of the Specification. | | | | | | | COPIES |
| 38 | MA-072TA | PLAN, START OF ACCEPTANCE TESTING REVIEW | | 1 | 2 | RT | See 9 |
| First submittal due 15 days prior to SATR.<br>Reference paragraph 4.1.4 & 3.5.41.3 of the Specification. | | | | | | | COPIES: Print 10 |
| 39 | CM-024TA | REPORT, DESIGN REVIEW SUMMARY | | 1 | 2 | AR | See 9 |
| Submittal due within 10 days after PDR, CDR, and SATR.<br>Reference paragraph 4.1.1, 4.1.2 and 4.1.4 of the Specification. | | | | | | | COPIES: Print 10 |

MSC DATA REQUIREMENTS LIST (DRL)
(CONTINUATION SHEET)

| DRL NUMBER | REVISION | PAGE |
|---|---|---|
| | | 9 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 40 | SE-227T | SPECIFICATION, END ITEM (PART I) | - | 1 | 2 | RT | See 9 |

9 Initial submittal due 15 days prior to Design Review (PDR).

Reference paragraph 4.1.1 and 3.1.2.1.6.6 of the Specification.

11 COPIES: A Print, B 10

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 41 | SE-228T | SPECIFICATION, END ITEM (PART II) | | 1 | 2 | RT | See 9 |

9 Initial submittal due 15 days prior to CDR.

Reference paragraph 4.1.2 & 3.1.2.1.6.6 of the Specification.

11 COPIES: A Print, B 10

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 42 | MA-073T | PLAN, INSTALLATION AT MSC | | 1 | 2 | RT | See 9 |

9 First submittal due with Program Plan (DRL line item 1). Final due six weeks prior to start of installation.

Reference paragraph 3.5.4.3.7 of the Specification.

11 COPIES: A Print, B 10

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 43 | MA-074T | PLAN, FINAL ACCEPTANCE REVIEW | | 1 | 2 | AR | See 9 |

9 First submittal due 10 days prior to FAR.

Reference paragraph 4.1.5 of the Specification.

11 COPIES: A Print, B 10

## DATA REQUIREMENTS DESCRIPTION

The Data Requirements Descriptions are standard NASA DRD's utilized on the Skylab Simulator Program and as such will not be duplicated for this issue of the specification except for the following DRD's which are new or have been revised.

| DRL Line Item No. | Title |
|---|---|
| 6 | Financial Management Report |
| 31 | Programmers Reference Manual |
| 32 | Interface Control Document |
| 37 | Facility Modification Requirements |

| NATIONAL AERONAUTICS AND SPACE ADMINISTRATION<br>MANNED SPACECRAFT CENTER<br>DATA REQUIREMENT DESCRIPTION | DRL NUMBER - 32<br>LINE ITEM NUMBER - |
|---|---|
| 1. TITLE<br>Interface Control Document (ICD) | 2. NUMBER TBD<br>4. DATE 12/22/72 |
| 3. USE<br>Establish a means for defining and controlling interface requirements. | 5. ORGANIZATION<br>6. REFERENCES<br>7. INTERRELATIONSHIP |

*(The Center Data Manager (Code JM2) will assign numbers in block 2.)*

8. PREPARATION INFORMATION

8.0 Scope

This Data Requirement Description (DRD) establishes the requirements for preparation of Interface Control Documents (ICD's) which will define the physical and functional interfaces between the simulator and confunctioning equipment.

8.1 Definition

An Interface Control Document (ICD) depicts physical and functional interface engineering requirements of a subsystem which affect the design or operation of cofunctioning subsystems. These documents are used as design control document, delineating subsystem interface engineering

data coordinated for purposes of: (a) establishing and maintaining compatibility between cofunctioning subsystems; (b) controlling interface designs thereby preventing changes to system requirements which would affect compatibility with cofunctioning systems; (c)communicating design decisions and changes to participating activities.

8.2 References

Source of Requirements

(1) MIL-D-1000 drawings, engineering and associated lists
(2) MIL-STD-100 engineering drawing practices
(3) NASA approved contractors drafting manuals.

8.3 Brief of Requirements

A. Interface Control Documents shall be prepared in accordance with the requirements of MIL-D-1000.

B. ICD's shall delineate, as applicable, (a) configuration and interface dimensional data applicable to the envelope, mounting and mating of the subsystem; (b) complete interface engineering requirements, such as software, mechanical, electrical/electronic, hydraulic, pneumatic, optical, etc.; and (c) any other characteristics which cannot be changed without affecting the system design criteria.

C. ICD's shall be limited to interfaces affecting the prime contractors and the cognizant contracting agency.

8.4 Approval

ICD's are coordinated with all activities affected by the interface requirements and submitted to the cognizant government agency for appropriate action.

8.5 Schedule

ICD's are prepared and negotiated prior to the start of detail design drawings (CDR) so that controlled interface features will be incorporated into the design drawings.

8.6 Method of Revision

A. ICD's are revised by incorporating the changes into the vellum master.

B. Revisions are identified by an alpha change letter.

8.7 Requirements

The ICD's required shall include, but are not necessarily limited to, the following:

(1) Physical requirements

(a) Physical layout
(b) Floor loading/vibration limits
(c) Air Conditioning

(2) Power requirements

(a) Main power interconnect
(b) Power loading

(3) Equipment requirements

(a) Central timing equipment SMS/MCC

(4) Trajectory data link SMS/MCC

(5) Digital Command System SMS/MCC

(6) Telemetry SMS/MCC

(7) Voice Communications SMS/MCC

(8) Shuttle GFP Support

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
DATA REQUIREMENT DESCRIPTION

DRL NUMBER - 37

LINE ITEM NUMBER -

1. TITLE
Facility Modification Requirements

2. NUMBER
TBD

4. DATE
12/22/72

3. USE
To define the modifications required to Building 5.

5. ORGANIZATION

6. REFERENCES
paragraph 2.2.1.1 of the Specification.

7. INTERRELATIONSHIP

*(The Center Data Manager (Code JM2) will assign numbers in block 2.)*

8. PREPARATION INFORMATION

8.1 Scope

This document shall be used as the basis for defining the NASA provided modifications to Bldg. 5 at MSC to accommodate the SMS.

8.2 Content

The document shall describe the archictectural, mechanical, and electrical modifications required to accommodate the proposed design of the SMS into Bldg. 5. The requirements of the modifications shall be specified in sufficient detail to enable NASA to issue a statement of work to another contractor to accomplish the modifications.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
DATA REQUIREMENT DESCRIPTION

DRL NUMBER - 31

LINE ITEM NUMBER -

1. TITLE
Manual, Programmers Reference

2. NUMBER
TBD

4. DATE
12/22/72

3. USE
To serve as a training tool to enable NASA Software Modifications after Acceptance.

5. ORGANIZATION

6. REFERENCES
Paragraph 6.4.1 of the Specification

7. INTERRELATIONSHIP

*(The Center Data Manager (Code JM2) will assign numbers in block 2.)*

8. PREPARATION INFORMATION

8.1 Scope

This document shall define the software design conventions, procedures, debugging and documentation requirements utilized in the design and test of the SMS to the extent that NASA shall be able to modify and maintain the delivered software after acceptance.

8.2 Content

The manual will contain a description and where appropriate examples of the software design philosophy procedures and conventions which were used and are required to modify the SMS. At a minimum the following topics shall be described.

1. Program Structure
2. Data Base Management
3. Coding Conventions
4. Debug Procedures
5. Test Standards and Drivers
6. Software Configuration Control
7. Documentation Requirements
8. Integration Procedures
9. Catalogued Procedures

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
DATA REQUIREMENT DESCRIPTION

DRL NUMBER - 6

LINE ITEM NUMBER -

1. TITLE
Report, Financial Management
(NASA Form 533)

2. NUMBER

4. DATE
12/22/72

3. USE
The Contractor's Financial Management Report:
a. Serves as basic documenting of the "cost" and "manhours" as "forecast" and as "actually utilized for the entire contractual duration,time-phased by months.
b. * see below

5. ORGANIZATION

6. REFERENCES
**

7. INTERRELATIONSHIP
***

*(The Center Data Manager (Code JM2) will assign numbers in block 2.)*

8. PREPARATION INFORMATION
* b. This document substantiates the "need for funding" on the contract and supports the "approval-to-pay" the vouchers submitted by the contractor within the framework of the contract.

** Procedures for Reporting Cost Information From Contractors; "NHB 9501.2 March 1967, NASA Hdqrs. Para. 4.5 of the Statement of Work.

*** The "cost" and "manhours" are to be correlated, by-time to the "Milestones Schedules" and "Monthly Technical Progress Reports".

8.1 The manual referenced in block 6, serves as the basic guidelines and instructions for the preparation and submission of the Contractor's Financial Management Report. The formats for the Contractor's Financial Management Report, with appropriate work packages, as required for contract monitoring, are described below.

8.1.1 The Work Breakdown structure shall be in accordance with 8.2 which designates the Work Packages/tasks, that are to be evaluated, planned for, and priced, including the manhours required for each, consistent with the time-phased milestone schedules; whereas, both are to be reflected in monthly, or less frequent increments for the entire period of the contractual effort. Contractors will not deviate from this stipulated work packages/tasks breakdown structure without written approval from the NASA Contracting Officer.

8.1.2 Because of the relatively short duration of this contractual period and the essential need for effective forecasting of manhours and costs the NASA Form 533, Quarterly modified to Monthly Contractor Financial Management Report shall be used; whereas the complete financial plans and actuals will be reviewed,updated and submitted each month.

8.1.3 Attached is a copy of "Monthly (converted from quarterly) Contractor Financial Management Report" NASA Form 533. Also, attached is a copy of "Monthly Contractor Financial Management Report, NASA Form 533a, only the Instructions on the reverse side are applicable.

8.1.4 Prepare and submit NASA Form 533 (use as many sheets as necessary for adequate work package coverage, plus summary coverage) to arrive in the office of the addressee not later than the 25th calendar day of each month. Follow the applicable instructions on the reverse sides of both Form 533 and 533a. Particularly, attention is directed to the requirement that the forecast shall be reviewed and updated monthly and an adequate "Remarks" section shall be included with each monthly submission. The "Remarks" are to be brief, covering the significant aspects. Use is to be made of proper cross referencing to paragraph/section/page number or task in the Monthly Technical Progress Report or on the Monthly Milestones Schedule Charts to minimize duplication/wasted effort.

8.1.4.1 On all Work Package level sheets, the man-hours shall be expressed to the nearest man-hour, not rounded off to the nearest tens of thousand; likewise, dollars are to be epxressed to the nearest dollar, not rounded to the nearest tens of thousand. On the Summary Program level sheets, man-hours and costs may be rounded to the nearest hundred.

8.1.4.2 The Monthly Contractor Financial Management Report, NASA Form 533 (Modified from Quarterly), shall include the "reporting categories" as designated in the Contractor's approved Program Plan. The Form 533 shall be divided into basically five groups as shown:

a. Summary Program Level
b. Work Packages, Separately
c. Subcontracting - (Same detail as if it were prime, relatively)
d. Spares Provisioning
e. Proposed Changes - Awaiting Approval/Implementation. (DO NOT include these in Program Summary until "approved for implementation")

8.1.4.3 On the Work Packages where subcontracting effort is performed the subcontractor shall be identified and kept separated from the prime effort.

8.1.4.4 Spares, man-hours, materials, and direct cost, including storage and documentation, are to be kept separate in WBS No. 4.0.

8.1.4.5 In cases of conflicting instructions, those contained in the contract including DRD prevail. Omit Instructions 10 and 11 on 533a and Instructions 11 and 12b and c on 533.

8.1.5 Man-hours/costs are to directly identify/trace progress as reflected on the Milestone Schedule Charts. The schedules tell <u>what</u> is to be done.

8.1.6 Include a separate section of <u>charts</u> of "Manhours" and "Costs" by Program Summary Level and by Work Package, which clearly reflect the requirements, forecast by month to completion, and shows the "planned vs. actuals" as time passes. (Monthly rates and cumulative)

8.2 <u>Work Breakdown Structure</u>

8.2.1 The Work Breakdown Structure for the SMS Motion Base Crew Station is to be in accordance with the Work Package as indicated herein.

<u>Work Packages</u>

1.0 <u>SMS Motion Based Crew Station</u> - This work package is a composite of work packages 1.1 to 1.16 and as such defines the cost for the SMS FCSS.

1.1 <u>MBCS Crew Station</u> - Includes the design and manufacture of the SMS MBCS including controls and displays, primary and secondary structure, internal mockups and cabling and the design review mockup.

1.2 <u>MBCS Instructor-Operator Station</u> - Includes all the design and manufacturing effort of the MBCS IOS including structure, panels, displays and controls exclusive of visual and internal wiring. Software associated with IOS functions shall be costed in WBS 1.8.3.

1.3 <u>Ancilliary Equipment</u> - Includes all the design and manufacturing effort utilized in providing interconnecting cables, power supplies, aural cue equipment, communication equipment, external interface equipment, interface cabinets and other equipment not specified elsewhere in the WBS.

1.4 <u>On-Board Computer Equipment</u> - Includes all the design and manufacturing effort of the OBC equipment and interfaces as well as all software design and programming.

1.5 Computer Complex - This work package shall include all costs associated with maintaining, operating and modifying the TCSS.

1.6 Digital Conversion Equipment - Includes the effort to design and manufacture the digital conversion equipment as well as to modify the GFP DCE.

1.7 Visual System - Includes all the effort utilized in the hardware and software design and manufacturing of the MBCS Visual system including the structure to mount it on the motion system.

1.8 Software - This work package is a composite of work packages 1.8.1 to 1.8.4.

1.8.1 Shuttle System Simulation Software - This work package includes all the effort to design, document, code, and to test to the individual program component level the simulated shuttle systems, e.g., EPS, ECS, C&W, etc.

1.8.2 Simulator Applications Software - Includes the effort to design, document, code and to test to the individual program component level the simulator applications programs, e.g., Equations of Motion, Ephemeris, Aural, Motion, etc.

1.8.3 Simulator Control Software - Includes the systems effort to design, document, code and to test to the individual program level the simulator control programs, e.g., Master Control, CRT Processor, Advanced Training, etc.

1.8.4 Support Software - Includes the systems effort to design, document, code and to test to the program level, the support software programs, e.g., Reset Generator, Data Base Generators, etc.

1.9 Systems Integration - Includes the effort to test and document the software packages into an integrated simulator load exclusive of hardware/software integration.

1.10 Installation, Test and Checkout - Includes all effort (including development) utilized in installation, checkout and testing, both at factory and installation site. Also includes the design and manufacturing effort utilized in providing any special equipment for use in installation, checkout and testing.

1.11 Documentation - Includes all development, printing and distribution effort utilized in providing Documentation and/or Publications. System Engineering documentation which is a normal by-product of the design process, e.g., Engineering Drawings, CEI's, Engineering Reports, shall be bid in the appropriate WBS and only those efforts associated with the actual publication process included here, e.g., editing, re-typing, duplication and distribution.

1.12 Program Management - Includes all the effort directed toward and execution of the program management functions associated with the SMS MBCS. Also included in the WBS is the data review and ECP preparation effort.

1.13 Miscellaneous Hardware & Software - Effort which does not follow into any of the other work packages shall be costed here.

1.14 Spares Provisioning - Includes the effort associated with spares provisioning the MBCS for a period of one year after acceptance.

1.15 System Support - Includes the factory and on-site support to train the maintenance and operations personnel for a period of six months after MBCS acceptance.

1.16 Motion System - Includes all the effort utilized in the design and manufacturing of the SMS MBCS motion system.

2.0 Fixed Base Crew Station - This work package is a composite of work package 2.1 to 2.11.

2.1 FBCS Crew Station - Includes the design and manufacture of the SMS FBCS Crew Station including controls and displays, primary and secondary structure, internal mockups and cabling and the design review mockup.

2.2 FBCS Instructor Operator Station - Includes all the design and manufacturing effort of the FBCS IOS including structure, panels, displays and controls exclusive of visual. Software associated with IOS functions shall be costed in WBS 2.8.3.

2.3 Ancilliary Equipment - Includes all the design and manufacturing effort utilized in providing interconnecting cables, power supplies, aural cue equipment, communication equipment, external interface equipment, interface cabinets and other equipment not specified elsewhere in the WBS.

2.4 On-Board Computer System - Includes all the design and manufacturing effort of the OBC equipment and interfaces as well as all software design and programming.

2.5 Computer Complex - This work packages shall include all costs associated with maintaining, operating and modifying the TCSS.

2.6 Digital Conversion Equipment - Includes the effort to design and manufacture the digital conversion equipment as well as to modify the GFP DCE.

2.7 Visual System - Includes all the effort utilized in the hardware and software design and manufacturing of the FBCS visual system.

2.8 Software - This work package is a composite of work packages 2.8.1 to 2.8.4.

2.8.1 Shuttle System Simulation Software - This work package includes all the effort to design, document, code, and to test to the individual program component level the simulated Shuttle systems, e.g., EPS, ECS, C&W, etc.

2.8.2 Simulator Applications Software - Includes the effort to design, document, code and to test to the individual program component level the simulator applications programs, e.g., Equations of Motion, Ephemeris, Aural, Motion, etc.

2.8.3 Simulator Control Software - Includes the systems effort to design, document, code and to test to the individual program level the simulator control programs, e.g., Master Control, CRT Processor, Advanced Training, etc.

2.8.4 Support Software - Includes the systems effort to design, document, code and to test to the program level, the support software programs, e.g., Reset Generator, Data Base Generators, etc.

2.9 Systems Integration - Includes the effort to test and document the software packages into an integrated simulator load exclusive of hardware/software integration.

2.10 Installation Test & Checkout - Includes all effort (including development) utilized in installation, checkout and testing, both at factory and installation site. Also includes the design and manufacturing effort utilized in providing any special èquipment for use in installation, checkout and testing.

2.11 Documentation - Includes all development, printing and distribution effort utilized in providing Documentation and/or Publications. System Engineering documentation which is a normal by-product of the design process, e.g., Engineering Drawings, CEI's, Engineering Reports, shall be bid in the appropriate WBS and only those efforts associated with the actual publication process included here, e.g., editing, re-typing, duplication and distribution.

# Exhibit 3

To the Performance & Design Requirements

Specification For the

Shuttle Mission Simulator

Government Furnished Property List

This Exhibit defines the Government Furnished Property which shall be provided to the SMS contractor.

1) Simulation Computer Complex
   a) Computer Hardware & Peripherals
   b) Software
   c) Digital Conversion Equipment
2) Shuttle Data Package
3) Flight Software Data Plan
4) Flight Software Programs
5) Spacecraft Hand Controllers
   . Translational
   . Rotational
   . Remote Manipulator
6) Data Processing & Software System Equipment
   . Flight Computers
   . CRT's and Interface Units
   . Keyboards
   . Tape Loaders
   . Recorders
7) Crew Station Seats

# EXHIBIT 4

## SHUTTLE MISSION SIMULATOR

## WORK BREAKDOWN STRUCTURE

The SMS Program W.B.S. is divided into two project level sub-structures as shown in Figure E4-1. The lower level W.B.S. for the MBCS and the FBCS are shown on Figure E4-2 and E4-3 respectively. The software sub-structure for both the MBCS and FBCS is identical and is shown on Figure E4-4. Details on the composition and effort associated with each work package is described in Exhibit 2, DRL Item #6.

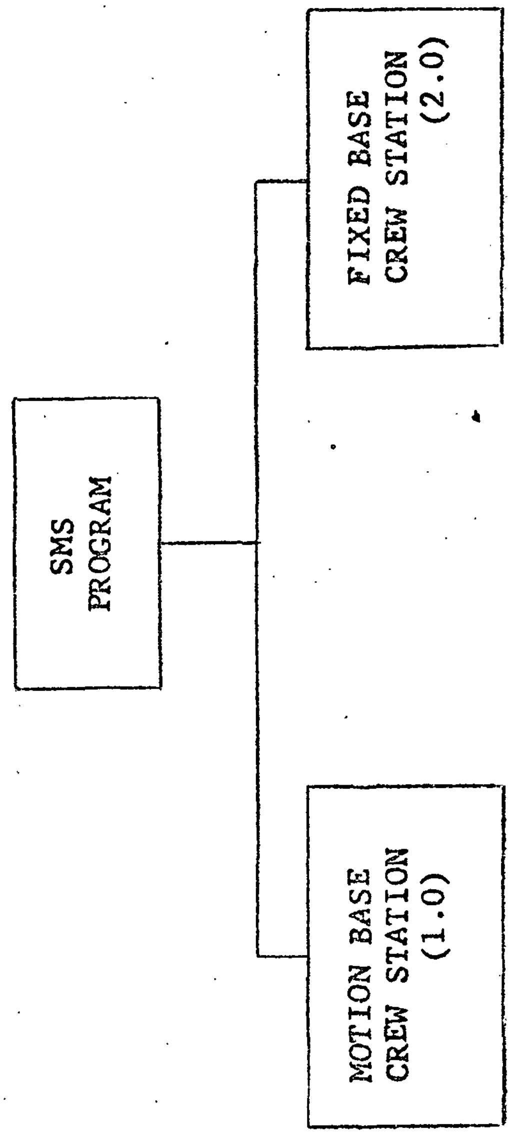


FIGURE E4-1 SMS PROGRAM WORK BREAKDOWN STRUCTURE (W.B.S.)

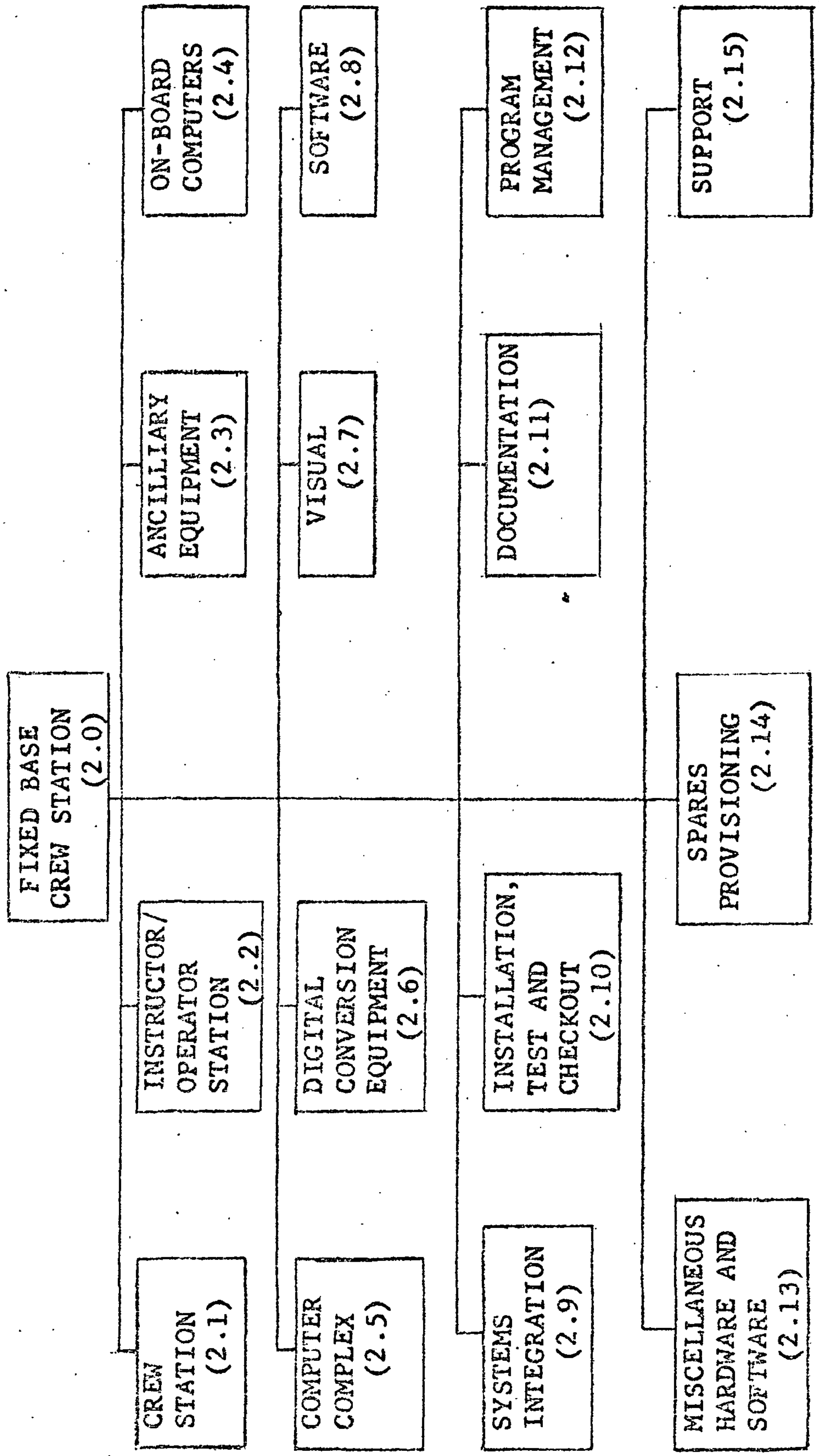


FIGURE E4-3 FBCS WORK BREAKDOWN STRUCTURE

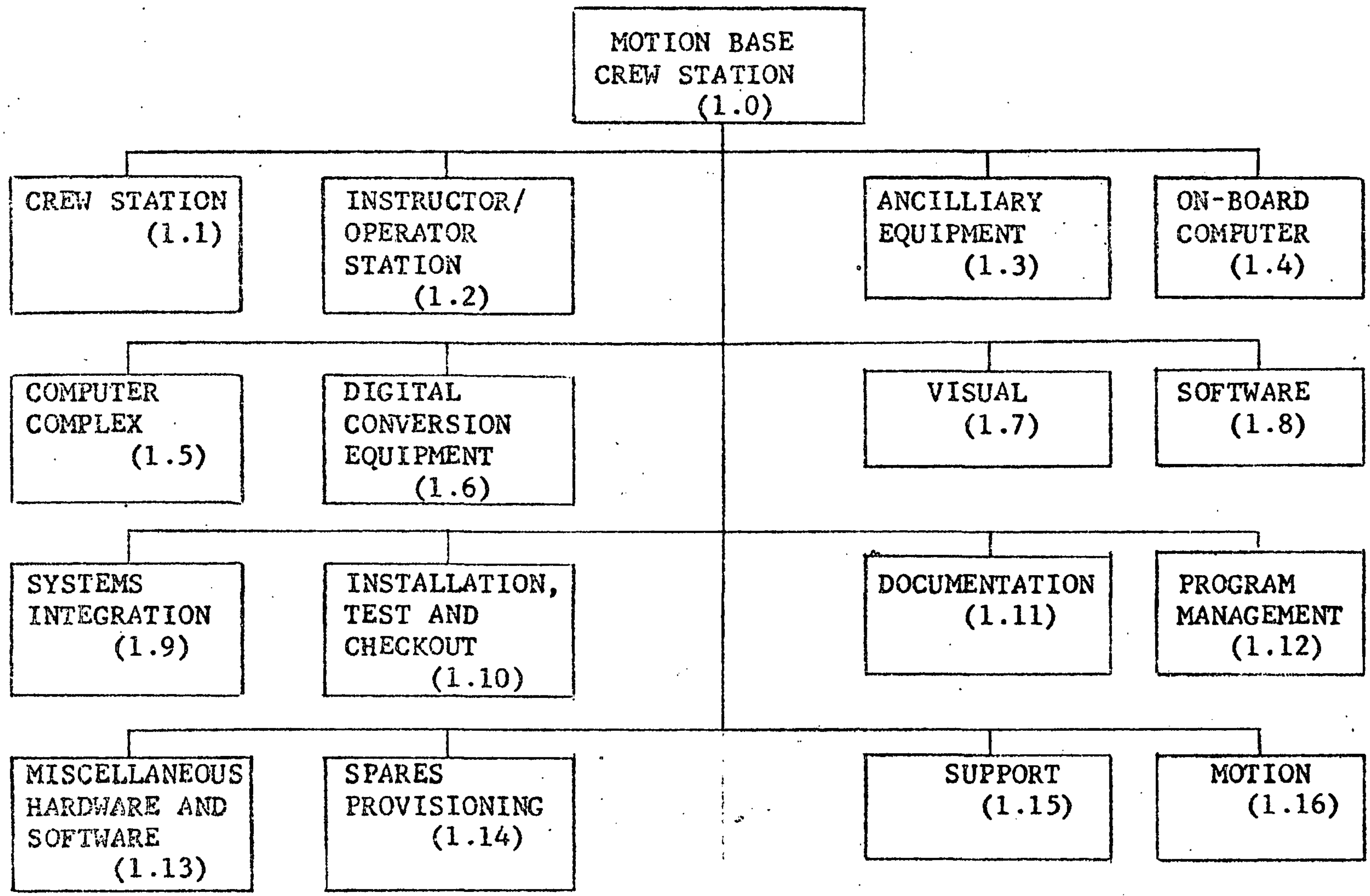


FIGURE E4-2 MBCS WORK BREAKDOWN STRUCTURE

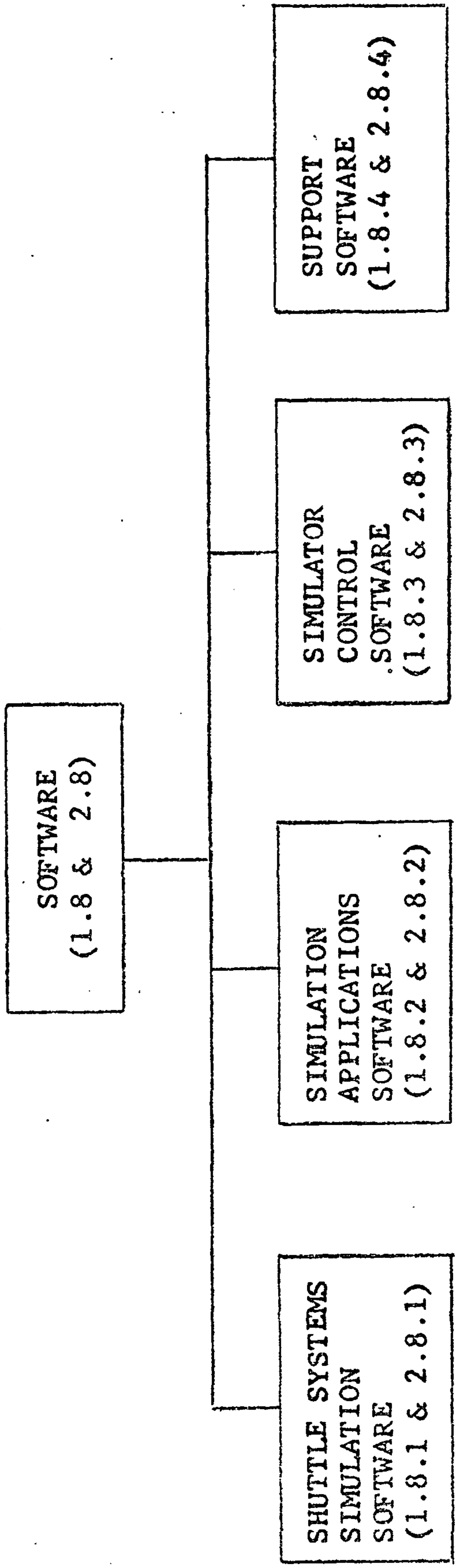


FIGURE E4-4 MBCS & FBCS SOFTWARE WORK BREAKDOWN STRUCTURE

# EXHIBIT 5

## SHUTTLE MISSION

## SIMULATOR SPECIFICATION TREE

The SMS specification tree from the program level down to the system CEI and CPCEI level are enumerated in Figures E5-1 to E5-7. Specification requirements due to the uniqueness of the Contractors design may require modification to this tree. Such changes if any are to be proposed.

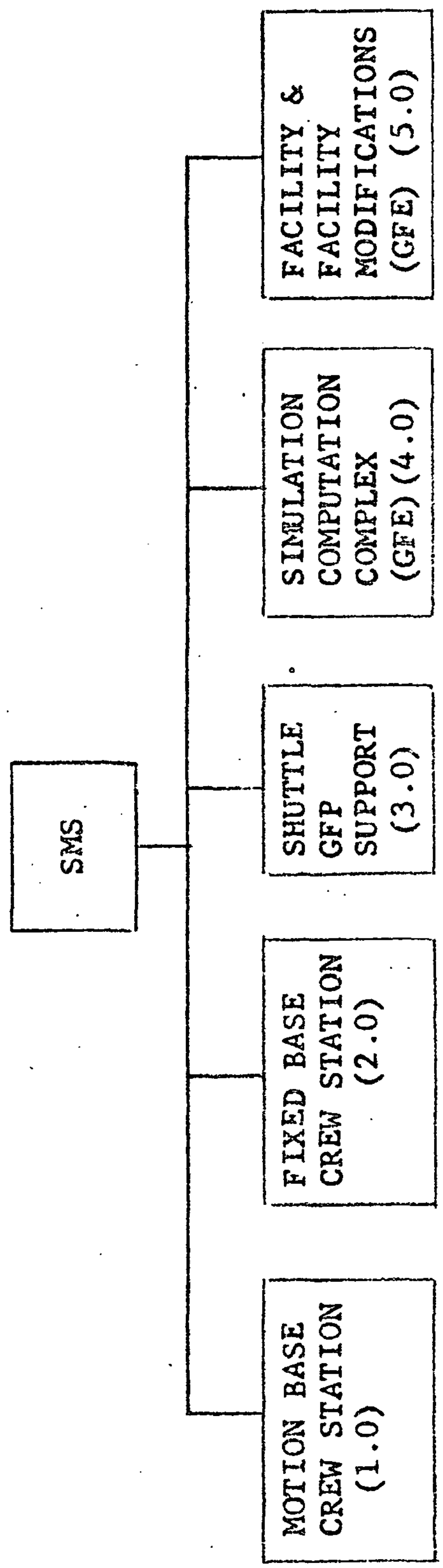


FIGURE E5-1 PROGRAM SPECIFICATION TREE

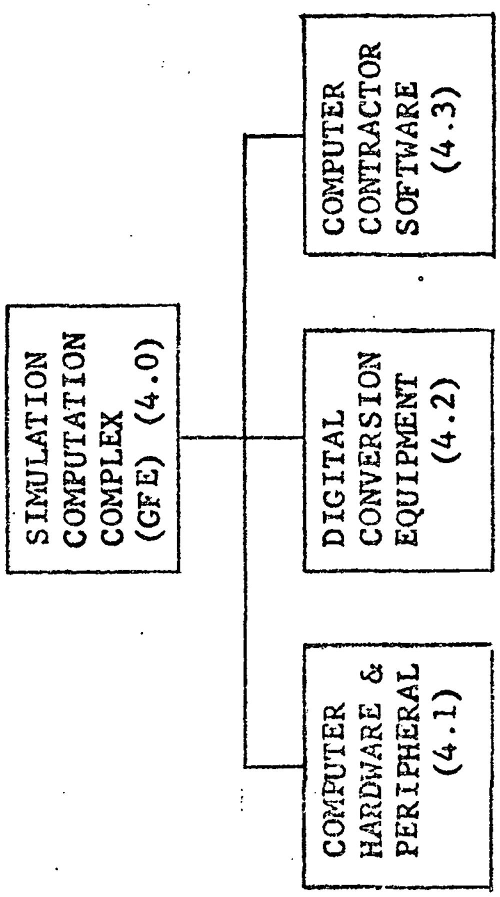


FIGURE E5-2 SIMULATION COMPUTATION COMPLEX SPECIFICATION TREE

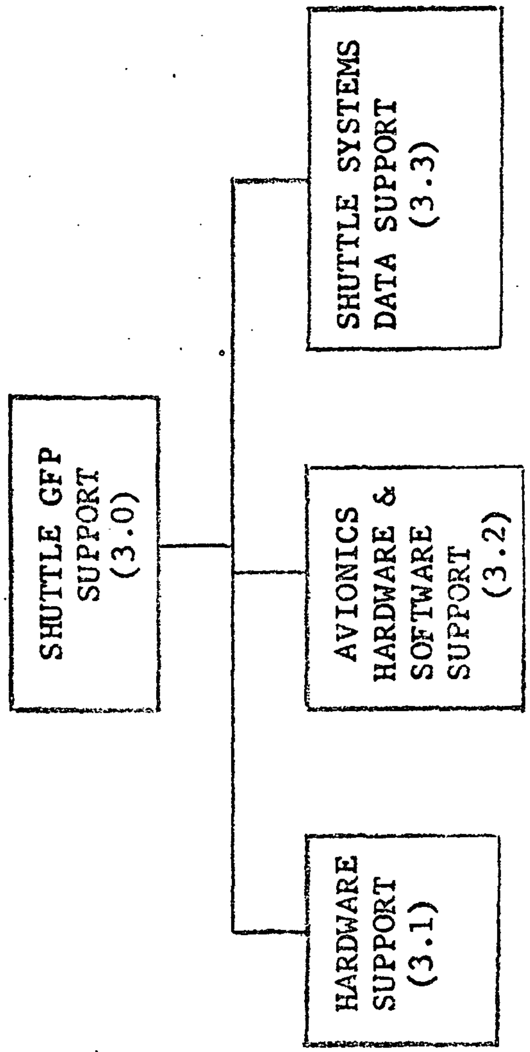


FIGURE E5-3 SHUTTLE CONTRACTOR SUPPORT SPECIFICATION TREE

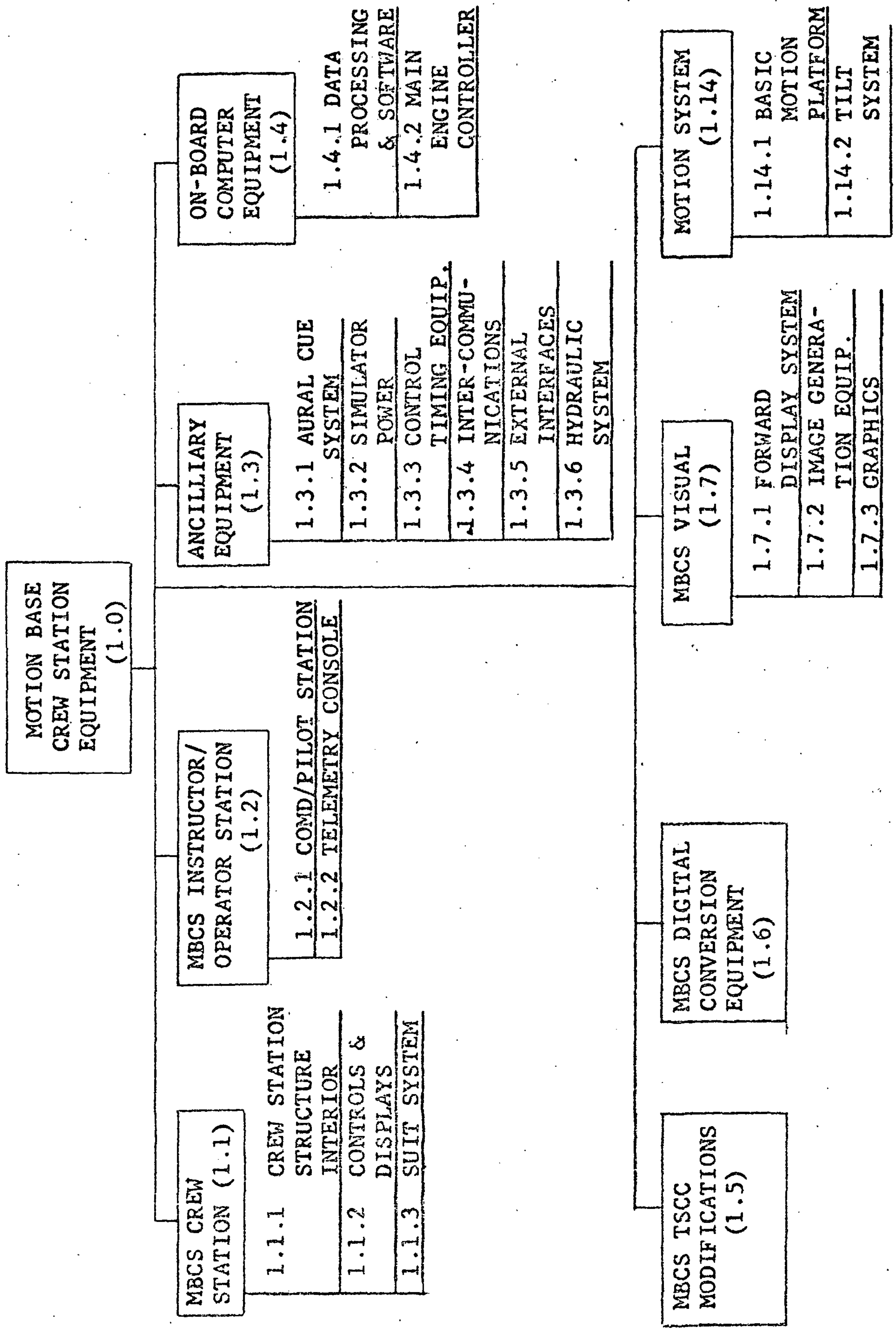


FIGURE E5-4 MBCS SYSTEM CEI SPECIFICATION TREE

- MOTION BASE CREW STATION SOFTWARE (1.8)
  - SHUTTLE SYSTEMS SIMULATION SOFTWARE (1.8.1)
    - 1.8.1.1 ELECTRICAL POWER SYSTEM
    - 1.8.1.2 MECHANICAL POWER SYSTEM
    - 1.8.1.3 MAIN PROPULSION SYSTEM
    - 1.8.1.4 REACTION CONTROL SYSTEM
    - 1.8.1.5 ORBITAL MANEUVER SYSTEM
    - 1.8.1.6 AIR BREATHING ENGINE SYSTEM
    - 1.8.1.7 EXTERNAL TANK SYSTEM
    - 1.8.1.8 GUIDANCE NAVIGATION & CONTROL
    - 1.8.1.9 COMMUNICATIONS & TRACKING
    - 1.8.1.10 OPERATIONAL INSTRUMENTATION
    - 1.8.1.11 DEVELOPMENT FLIGHT INSTRUMENTATION
    - 1.8.1.12 MISCELLANEOUS AIRCRAFT SYSTEMS
    - 1.8.1.13 ENVIRONMENTAL CONTROL SYSTEM
  - SIMULATOR APPLICATION SOFTWARE (1.8.2)
    - 1.8.2.1 EQUATIONS OF MOTION
    - 1.8.2.2 AURAL
    - 1.8.2.3 VISUAL
    - 1.8.2.4 MOTION
  - SIMULATOR CONTROL SOFTWARE (1.8.3)
    - 1.8.3.1 PROGRAM STRUCTURE
    - 1.8.3.2 SIMULATOR CONTROL
    - 1.8.3.3 INSTRUCTOR AIDS
  - SUPPORT SOFTWARE (1.8.4)

FIGURE E5-5 MBCS SOFTWARE CPCEI SPECIFICATION TREE

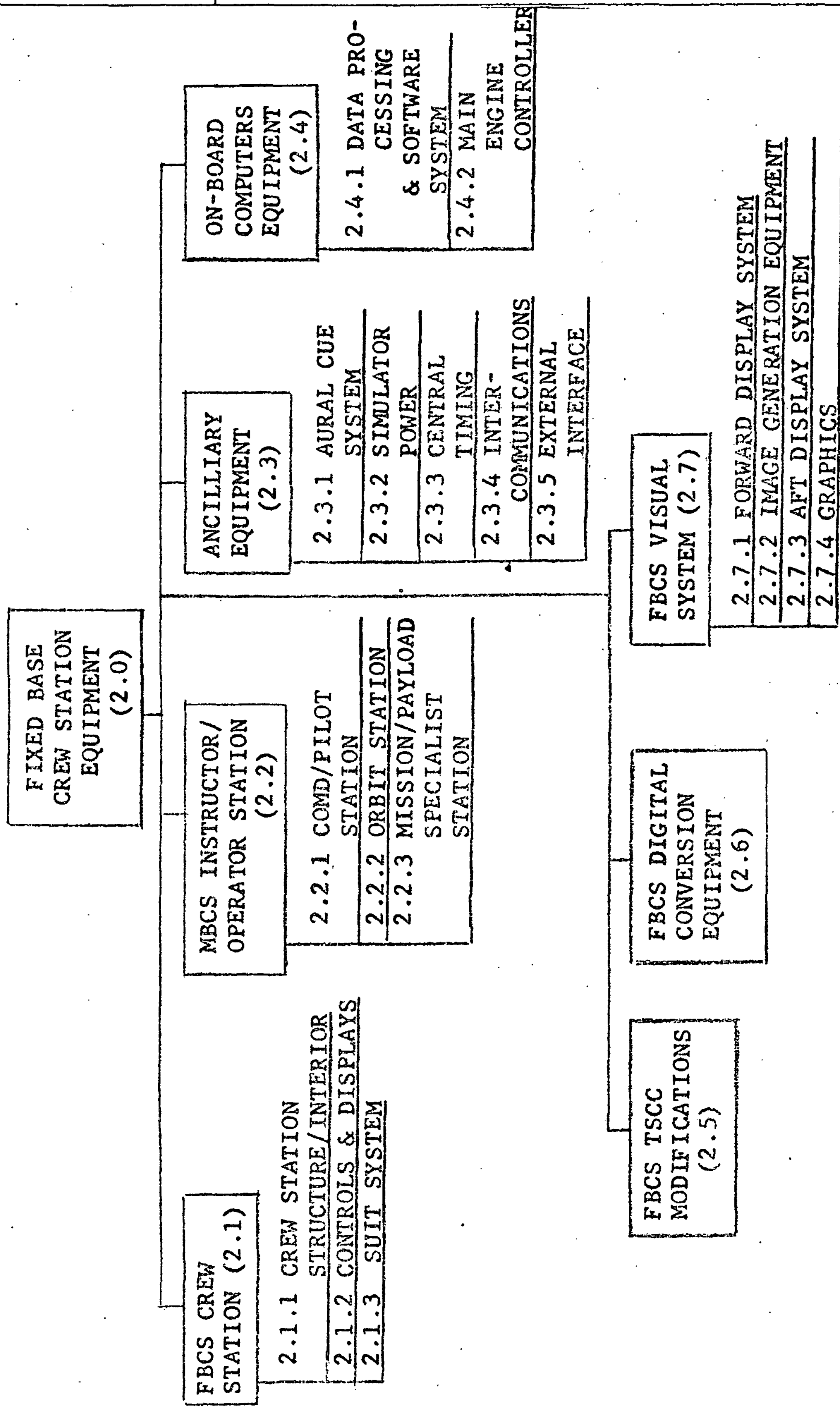


FIGURE E5-6 FBCS SYSTEM CEI SPECIFICATION

- FIXED BASE CREW STATION SOFTWARE (2.8)
  - SHUTTLE SYSTEMS SIMULATION SOFTWARE (2.8.1)
    - 2.8.1.1 ELECTRICAL POWER SYSTEM
    - 2.8.1.2 MECHANICAL POWER SYSTEM
    - 2.8.1.3 MAIN PROPULSION SYSTEM
    - 2.8.1.4 REACTION CONTROL SYSTEM
    - 2.8.1.5 ORBITAL MANEUVER SYSTEM
    - 2.8.1.6 AIR BREATHING ENGINE SYSTEM
    - 2.8.1.7 EXTERNAL TANK SYSTEM
    - 2.8.1.8 GUIDANCE NAVIGATION & CONTROL
    - 2.8.1.9 COMMUNICATIONS & TRACKING
    - 2.8.1.10 OPERATIONAL INSTRUMENTATION
    - 2.8.1.11 DEVELOPMENT FLIGHT INSTRUMENTATION
    - 2.8.1.12 MISCELLANEOUS AIRCRAFT SYSTEMS
    - 2.8.1.13 ENVIRONMENTAL CONTROL SYSTEM
    - 2.8.1.14 PAYLOAD ACCOMMODATION SYSTEM
  - SIMULATOR APPLICATIONS SOFTWARE (2.8.2)
    - 2.8.2.1 EQUATIONS OF MOTION
    - 2.8.2.2 AURAL CUE
    - 2.8.2.3 VISUAL
  - SIMULATOR CONTROL SOFTWARE (2.8.3)
    - 2.8.3.1 PROGRAM STRUCTURE
    - 2.8.3.2 SIMULATOR CONTROL
    - 2.8.3.3 VISUAL
  - SUPPORT SOFTWARE (2.8.4)

**FIGURE E5-7 FBCS SOFTWAE CPCEI SPECIFICATION TREE**

# Addendum A

# To the Performance & Design Requirements Specification For the Shuttle Mission Simulator Malfunction Requirements

This addendum defines the SMS Malfunctions which shall be designed into the SMS software. The types of malfunctions are defined in paragraph 3.4.1.2 of the specification.

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Electrical Power System

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.1 | Battery Capacity Degradation | Multiple - Variable |
| 6.2.10.1 | Battery Charger Output Bias Voltage | Multiple - Variable |
| 6.2.10.1 | Battery Charger Internal Short | Multiple - Variable |
| 6.2.10.1 | Battery Internal Plate Short | Multiple - Variable |
| 6.2.10.1 | Battery Output Short | Multiple - Variable |
| 6.2.10.1 | Battery Charger Voltage Sensor Bias | Multiple - Variable |
| 6.2.10.1 | Battery Charger Temperature Sensor Bias | Multiple - Variable |
| 6.2.10.1 | Battery 3rd Electrode Comparitor Bias | Multiple - Variable |
| 6.2.10.1 | Battery Heat Sink Degradation of Cool Plate | Multiple - Variable |
| 6.2.10.1 | Battery Charger Mode Relay Failed Last Position | Multiple - Discrete |
| 6.2.10.1 | Battery Charger Rate Relay Failed Last Position | Multiple - Discrete |
| 6.2.10.1 | DC Power Bus Short | Multiple - Variable |
| 6.2.10.1 | AC Power Bus Short | Multiple - Variable |
| 6.2.10.1 | Remote Controlled Circuit Breaker Failed Open | Multiple - Discrete |
| 6.2.10.1 | Transfer Power Relay Failed in Last Position | Multiple - Discrete |
| 6.2.10.1 | Battery Output Relay Failed in Last State | Multiple - Discrete |
| | | |
| | | |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Electrical Power System

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.1 | APU Alternator Output Relay Failed In Last State | Multiple - Discrete |
| 6.2.10.1 | Failure of GCU Voltage Sense Circuit | Multiple - Discrete |
| 6.2.10.1 | Failure of Nose Wheel GSE Relay in Last State | Multiple - Discrete |
| 6.2.10.1 | GSE AC Power Relay Failed In Last State | Multiple - Discrete |
| 6.2.10.1 | Failure of TR Unit | Multiple - Discrete |
| 6.2.10.1 | Short on Output of TR Unit | Multiple - Variable |
| 6.2.10.1 | Short on Nose Wheel Well Umbilical | Multiple - Variable |
| 6.2.10.1 | Short on Output of Fuel Cell | Multiple - Variable |
| 6.2.10.1 | Failure of Remote Power Controller | Multiple - Discrete |
| 6.2.10.1 | Loss of Phase Sensing on Invertors | Multiple - Discrete |
| 6.2.10.1 | Failure of Sequencer Logic | Multiple - Discrete |
| 6.2.10.1 | Failure of Inverter Input Power Relay In Last Position | Multiple - Discrete |
| 6.2.10.1 | Failure of Main DC Bus Tie Relay in Last Position | Multiple - Discrete |
| 6.2.10.1 | Short on Output of Inverter | Multiple - Variable |
| 6.2.10.1 | Short Between Main Power Buses - Not To Ground | Multiple - Discrete |
| 6.2.10.1 | Open Line Between Sequencer and Pyrodevice | Multiple - Discrete |
| | | |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Electrical Power System

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.1 | APU Alternator Open Winding | Multiple - Discrete |
| 6.2.10.1 | ABPS Alternator Open Winding | Multiple - Discrete |
| 6.2.10.1 | ABPS Alternator Output Relay Failed In Last State | Multiple - Discrete |
| 6.2.10.1 | EPS Crew Station Meter Failed | Multiple - Discrete |
| 6.2.10.1 | C&D Convertor Failed | Multiple - Discrete |
| 6.2.10.1 | Short On C&D Convertor Output | Multiple - Discrete |
| 6.2.10.1 | Failure of Sequencer/Batt Bus Relay In Last Position | Multiple - Discrete |
| 6.2.10.1 | Failure of Sequencer/ESS Control Bus Relay In Last Position | Multiple - Discrete |
| 6.2.10.1 | Leak In Cryo Line (LOX or LH) | Multiple - Discrete |
| 6.2.10.1 | Failure of Pressure Relief Valve | Multiple - Discrete |
| 6.2.10.1 | Failure of Circulation Pump | Multiple - Discrete |
| 6.2.10.1 | Failure of Circulation Pump Pressure Switch | Multiple - Discrete |
| 6.2.10.1 | Failure of Circulation Line Heater | Multiple - Discrete |
| 6.2.10.1 | Failure of Manifold Isolation Valve | Multiple - Discrete |
| 6.2.10.1 | Failure of ECLSS Supply Valve | Multiple - Discrete |
| 6.2.10.1 | Failure of $O_2$ Supply Valve | Multiple - Discrete |
| | | |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Electrical Power System

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.1 | Failure of $H_2$ Supply Valve | Multiple - Discrete |
| 6.2.10.1 | Failure of $O_2$ Purge Vent Heater | Multiple - Discrete |
| 6.2.10.1 | Failure of $H_2$ Purge VEnt Heater | Multiple - Discrete |
| 6.2.10.1 | Logic Failure In Startup Control | Multiple - Discrete |
| 6.2.10.1 | EPS Meter Failure | Multiple - Discrete |
| 6.2.10.1 | EPS Meter Function Select Switch Failure | Multiple - Discrete |
| 6.2.10.1 | EPS Meter Bias | Multiple - Variable |
| 6.2.10.1 | EPS Talkback Failure | Multiple - Discrete |
| 6.2.10.1 | Leak In Outer Case of LO/LH Tank | Multiple - Variable |
| 6.2.10.1 | Contaminant in KOH-Degradation | Multiple - Variable |
| | | |
| | | |
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| | | |
| | | |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Auxiliary Power System

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.2.1 | Failure of automatic start logic | Discrete-multiple |
| 6.2.10.2.1 | Failure of automatic shutdown logic | Discrete-multiple |
| 6.2.10.2.1 | Failure of lube pump | Discrete-multiple |
| 6.2.10.2.1 | Gear box mechanical failure - Overheat | Discrete-multiple |
| 6.2.10.2.1 | Speed control failure - Tach | Discrete-multiple |
| 6.2.10.2.1 | Loss of Helium Pressurant - Slowleak | Discrete-multiple |
| 6.2.10.2.1 | Loss of decomposition heater | Discrete-multiple |
| 6.2.10.2.1 | Loss of fuel line heater | Discrete-multiple |
| 6.2.10.2.1 | Loss of fuel tank heater | Discrete-multiple |
| 6.2.10.2.1 | Fire in APU Area | Discrete-multiple |
| 6.2.10.2.1 | Failure of decomposition heater thermostat | Discrete-multiple |
| 6.2.10.2.1 | Failure of fuel line heater thermostat | Discrete-multiple |
| 6.2.10.2.1 | Failure of Fuel tank heater thermostat | Discrete-multiple |
| 6.2.10.2.1 | Failure of He pressure regulator | Discrete-multiple |
| 6.2.10.2.1 | Rupture of hydrazine bladder tank - internal | Discrete-multiple |
| 6.2.10.2.2 | Ruptured line into water boiler | Discrete-multiple |
| 6.2.10.2.2 | Failure of Air Cooling fan in Off | Discrete-multiple |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Auxiliary Power System

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.2.2 | Failure of Water Boiler Valve in Open | Discrete-multiple |
| 6.2.10.2.2 | Failure of Ram Air Cooling Circulation Valve in Closed | Discrete-multiple |
| 6.2.10.2.2 | Failure of He Pressure Regulator in Auto | Discrete-multiple |
| 6.2.10.2.2 | Failure of Fuel Control Valve Off | Discrete-multiple |
| 6.2.10.2.2 | Failure of Control Preheat in Run | Discrete-multiple |
| 6.2.10.2.2 | Failure of Control Preheat in Preheat | Discrete-multiple |
| 6.2.10.2.2 | Failure of APU Selector Switch in Pos X | Discrete-multiple |
| 6.2.10.2.2 | Failure of APU Tachometer Meter | Discrete-multiple |
| 6.2.10.2.2 | Failure of APU Fuel Qty Meter | Discrete-multiple |
| 6.2.10.2.2 | Failure of APU Fuel Pressure Meter | Discrete-multiple |
| 6.2.10.2.2 | Failure of APU Tachometer Sensor for C/D | Discrete-multiple |
| 6.2.10.2.2 | Failure of APU Fuel Qty Sensor for C/D | Discrete-multiple |
| 6.2.10.2.2 | Failure of APU Fuel Pressure Sensor for C/D | Discrete-multiple |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Hydraulic Power System

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.2.2 | Failure of Circulation Pump in Auto | Discrete-multiple |
| 6.2.10.2.2 | Failure of Circulation Pump - Both | Discrete-multiple |
| 6.2.10.2.2 | Failure of Accumulator Bellows | Discrete-multiple |
| 6.2.10.2.2 | Failure of Hydraulic Pump A System | Discrete-multiple |
| 6.2.10.2.2 | Failure of Hydraulic Pump B System | Discrete-multiple |
| 6.2.10.2.2 | Failure of Hydraulic Spool Valve - 4 Way | Discrete-multiple |
| 6.2.10.2.2 | Failure of Strip Heater Thermostat | Discrete-multiple |
| 6.2.10.2.2 | Failure of Strip Heater | Discrete-multiple |
| 6.2.10.2.2 | Loss of fluid from broken manifold | Discrete-multiple |
| 6.2.10.2.2 | Leak in Check Valve to Accumulator | Discrete-multiple |
| 6.2.10.2.2 | Contamination in system - Low Flow Rate | Discrete-multiple |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: **Main Propulsion System**

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.3 | Failure of Repressurization ISOL Valves | Multiple - discrete |
| 6.2.10.3 | Failure of IND-SEL Switch | Multiple - discrete |
| 6.2.10.3 | Leak in Common He Manifold | Variable |
| 6.2.10.3 | Failure of He Blow Down Switch | Discrete |
| 6.2.10.3 | Failure of Self Sealing Disc Valve | Multiple - discrete |
| 6.2.10.3 | Failure of ECO Sensor | Discrete |
| 6.2.10.3 | Rupture of GOX pressure Manifold | Discrete |
| 6.2.10.3 | Rupture of GHY Pressure Manifold | Discrete |
| 6.2.10.3 | Failure of He Relief Valve | Multiple - discrete |
| 6.2.10.3 | Preburner Bearing Over heat | Multiple - discrete |
| 6.2.10.3 | Propellant Pump Failure | Multiple - discrete |
| 6.2.10.3 | Erratic Combustion - Diffuser Plate Rupture | Multiple - discrete |
| 6.2.10.3 | Throat Erosion | Multiple - variable |
| 6.2.10.3 | Preburner Overspeed | Multiple - variable |
| 6.2.10.3 | Failure of Flow Control Valve | Multiple - discrete |
| 6.2.10.3 | Sensor Failure | Multiple - discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: **Main Propulsion System**

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.3 | Outboard Fill and Dump Valve Failure | Multiple - discrete |
| 6.2.10.3 | Inboard Fill and Dump Valve Failure | Multiple - discrete |
| 6.2.10.3 | Pre valve Failure | Multiple - discrete |
| 6.2.10.3 | Leak in Engine He Supply Line | Multiple - variable |
| 6.2.10.3 | Failure of Recirculation Pump | Multiple - discrete |
| 6.2.10.3 | Failure of Emergency Vent Valve Switch | Multiple - discrete |
| 6.2.10.3 | Failure of Dump Valve | Multiple - discrete |
| 6.2.10.3 | Failure of Recirculation Valve | Multiple - discrete |
| 6.2.10.3 | Failure of Display Flag | Multiple - discrete |
| 6.2.10.3 | Failure of Pressure Switch | Multiple - discrete |
| 6.2.10.3 | Failure of Propellant Load Sensor | Multiple - discrete |
| 6.2.10.3 | Leak in Feed Line to Engine | Multiple - variable |
| 6.2.10.3 | Failure of Vent and Relief Valves | Multiple - discrete |
| 6.2.10.3 | Failure of MPS Press Meter | Multiple - discrete |
| 6.2.10.3 | Leak in He Supply | Multiple - variable |
| 6.2.10.3 | Failure of He Regulator - Open | Multiple - variable |
| 6.2.10.3 | Failure of Control Switch | Multiple - variable |

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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: **Reaction Control System**

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.4 | Loss of Catalytic Heater in Engine | Multiple - Discrete |
| 6.2.10.4 | Failure of Meter | Multiple - Discrete |
| 6.2.10.4 | Failure of Selector Switch | Multiple - Discrete |
| 6.2.10.4 | Failure of Flag Indicator | Multiple - Discrete |
| 6.2.10.4 | Failure of RCS Fuel Integrator | Discrete |
| 6.2.10.4 | Leak in Helium Pressure Manifold | Multiple - Discrete |
| 6.2.10.4 | Leak in Helium Pressure Sphere | Multiple - Discrete |
| 6.2.10.4 | Failure of Pressure Relief Valve | Multiple - Discrete |
| 6.2.10.4 | Failure of Pressure Regulator-HE | Multiple - Discrete |
| 6.2.10.4 | Failure of Propellant Tank Heater | Multiple - Variable |
| 6.2.10.4 | Failure of Propellant Line Heater | Multiple - Discrete |
| 6.2.10.4 | Failure of Engine Valve | Multiple - Discrete |
| 6.2.10.4 | Failure of Propellant Check Valve | Multiple - Discrete |
| 6.2.10.4 | Failure of Auto Engine Heater Control | Multiple - Discrete |
| 6.2.10.4 | Failure of Manual Engine Heater Control | Multiple - Discrete |
| 6.2.10.4 | Partial Failure of Catalytic Heater | Multiple - Variable |
| 6.2.10.4 | Degradation of RCS Nozzle Throats | Variable |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Reaction Control System

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.4 | Fire In Forward Hydrazine Storage Area | Discrete |
| 6.2.10.4 | Failure of Hydraulic System Forward Door | Multiple - Discrete |
| 6.2.10.4 | Failure of PC Sensor | Multiple - Discrete |
| 6.2.10.4 | Rupture in Hydrazine Tank Bladder | Multiple - Discrete |
| 6.2.10.4 | Leak in Hydrazine Supply Line | Multiple - Variable |
| 6.2.10.4 | Mechanical Jam on Forward Door | Multiple - Variable |
| 6.2.10.4 | Failure of Temperature Sensor | Multiple - Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Orbital Maneuvering

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.5 | Outboard Fill and Dump Valve Failure | Multiple - Discrete |
| 6.2.10.5 | Inboard Fill and Dump Valve Failure | Multiple - Discrete |
| 6.2.10.5 | Failure of Main Trim | Multiple - Discrete |
| 6.2.10.5 | Leak In Engine He Supply Line | Multiple - Variable |
| 6.2.10.5 | Failure of TVC Channel in Auto | Multiple - Discrete |
| 6.2.10.5 | Failure of Emergency Vent Valve Switch | Multiple - Discrete |
| 6.2.10.5 | Failure of Dump Valve | Multiple - Discrete |
| 6.2.10.5 | Failure of TVC Channel in Off | Multiple - Discrete |
| 6.2.10.5 | Failure of Display Flag | Multiple - Discrete |
| 6.2.10.5 | Failure of Pressure Switch | Multiple - Discrete |
| 6.2.10.5 | Failure of Propellant Load Sensor | Multiple - Discrete |
| 6.2.10.5 | Leak in Feed Line to Engine | Multiple - Variable |
| 6.2.10.5 | Failure of Vent and Relief Valves | Multiple - Discrete |
| 6.2.10.5 | Failure of OMS Meter | Multiple - Discrete |
| 6.2.10.5 | Leak in He Supply | Multiple - Variable |
| 6.2.10.5 | Failure of He Regulator - Open | Multiple - Variable |
| 6.2.10.5 | Failure of Control Switch | Multiple - Variable |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Orbital Maneuvering

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.5 | Failure of Repressurization ISOL Valves | Multiple - Discrete |
| 6.2.10.5 | Failure of IND-SEL Switch | Multiple - Discrete |
| 6.2.10.5 | Leak in Common He Manifold | Variable |
| 6.2.10.5 | Failure of He Blow Down Switch | Discrete |
| 6.2.10.5 | Failure of Quantity Remaining Integrator | Multiple - Discrete |
| 6.2.10.5 | Failure of Gauging Probe Sensor | Discrete |
| 6.2.10.5 | Rupture of Oxidize Pressure Manifold | Discrete |
| 6.2.10.5 | Rupture of Fuel Pressure Manifold | Discrete |
| 6.2.10.5 | Failure of He Relief Valve | Multiple - Discrete |
| 6.2.10.5 | Throst Erosion | Multiple - Variable |
| 6.2.10.5 | Sensor Failure | Multiple - Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Air Breathing System

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.6 | Failure of Fuel Tank Gauge | Multiple-Discrete |
| 6.2.10.6 | Failure of Fuel Control Valve | Multiple-Discrete |
| 6.2.10.6 | Failure of Boost Pump | Multiple-Discrete |
| 6.2.10.6 | Failure of Alternator Drive Unit | Multiple-Discrete |
| 6.2.10.6 | Failure of Hydralic Drive Unit | Multiple-Discrete |
| 6.2.10.6 | Failure of Fire Detection Unit | Multiple-Discrete |
| 6.2.10.6 | Failure of Lube Oil Heater | Multiple-Discrete |
| 6.2.10.6 | Failure of Fuel Tank Heater | Multiple-Discrete |
| 6.2.10.6 | Failure of Fuel Line Heater | Multiple-Discrete |
| 6.2.10.6 | Failure of Fuel Tank Vent Valves | Multiple-Discrete |
| 6.2.10.6 | Malfunction in Fuel Control System Causing Hot Start | Multiple-Discrete |
| 6.2.10.6 | Failure of Fuel Tank Drain Valve | Multiple-Discrete |
| 6.2.10.6 | Failure of Pump Pressure Switch | Multiple-Discrete |
| 6.2.10.6 | Foreign Object in Air Intake | Multiple-Discrete |
| 6.2.10.6 | Failure of Tachometer Feedback Loop | Multiple-Discrete |
| 6.2.10.6 | Failure of Temperature Sensors | Multiple-Discrete |
| 6.2.10.6 | Failure of Pressure Sensors | Multiple-Discrete |

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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Air Breathing Engine

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.6 | Meter Bias | Multiple-Variable |
| 6.2.10.6 | Meter Failure | Multiple-Discrete |
| 6.2.10.6 | Control Switch Failure | Multiple-Discrete |
| 6.2.10.6 | Display Flag Failure | Multiple-Discrete |
| 6.2.10.6 | Engine Inlet Icing | Multiple-Variable |
| 6.2.10.6 | Engine Fire | Multiple-Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Solid Rocket Motor

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.7 | Case Segment Burn Through | Multiple-Variable |
| 6.2.10.7 | Throat Erosion Factor | Multiple-Variable |
| 6.2.10.7 | Propellant Grain Checking | Multiple-Variable |
| 6.2.10.7 | Pressure Sensor Failure | Multiple-Discrete |
| 6.2.10.7 | Temperature Sensor Failure | Multiple-Discrete |
| 6.2.10.7 | Separation Rocket Failure | Multiple-Discrete |

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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: External Tank

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.8 | Failure of Separation Mechanism | Multiple-Discrete |
| 6.2.10.8 | Failure of Separation Avionics | Multiple-Discrete |
| 6.2.10.8 | Failure of Separation Battery | Multiple-Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Guidance, Navigation and Control (less computer)

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.9 | Avionics Bay Fire | Multiple-Discrete |
| 6.2.10.9.1.1 | Aerosurface Servo-Actuator Feedback Failure | Multiple-Discrete |
| 6.2.10.9.1.1 | Aerosurface Servo-Actuator Feedback Bias | Multiple-Variable |
| 6.2.10.9.1.1 | Aerosurface Actuator Null | Multiple-Discrete |
| 6.2.10.9.1.1 | Aerosurface Actuator Lube System Failure | Multiple-Variable |
| 6.2.10.9.1.1 | Aerosurface Display or Meter Failure | Multiple-Discrete |
| 6.2.10.9.1.1 | Aerosurface Deformity | Multiple-Variable |
| 6.2.10.9.1.1 | Aerosurface Jammed | Multiple-Variable |
| 6.2.10.9.1.2 | Air Data Probe Failure | Multiple-Discrete |
| 6.2.10.9.1.2 | Air Data Computer Power Loss | Multiple-Discrete |
| 6.2.10.9.1.2 | Angle of Attack Transducer Power Loss | Multiple-Discrete |
| 6.2.10.9.1.2 | Air Data/GNC Computer Interface Bit Failure | Multiple-Discrete |
| 6.2.10.9.1.2 | Air Data Meter or Display Failure | Multiple-Discrete |
| 6.2.10.9.1.1 | Aero Control Electrical Shorts or Failures | Multiple-Discrete |
| 6.2.10.9.2. | Spacecraft Flight Control Displays or Meters Failed. | Multiple-Discrete |
| [illegible] | Spacecraft Flight Control Displays or Meters Biased. | Multiple-Variable |
| 6.2.10.9.2 | Hand Controller Failed | Multiple-Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Guidance, Navigation and Control (less computer)

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.9.2.1 | MPS TVC Servo-actuator Feedback Failure | Multiple-Discrete |
| 6.2.10.9.2.1 | MPS TVC Servo-actuator Feedback Bias | Multiple-Variable |
| 6.2.10.9.2.1 | MPS TVC Actuator Nulls | Multiple-Discrete |
| 6.2.10.9.2.1 | MPS TVC Actuator Hardovers | Multiple-Discrete |
| 6.2.10.9.2.1 | MPS TVC Electrical Shorts | Multiple-Discrete |
| 6.2.10.9.2.1 | MPS TVC Attitude Error Signal Loss | Multiple-Discrete |
| 6.2.10.9.2.3 | OMS TVC Servo-Actuator Feedback Failure | Multiple-Discrete |
| 6.2.10.9.2.3 | OMS TVC Servo-Actuator Feedback Bias | Multiple-Variable |
| 6.2.10.9.2.3 | OMS TVC Actuator Nulls | Multiple-Discrete |
| 6.2.10.9.2.3 | OMS TVC Actuator Hardovers | Multiple-Discrete |
| 6.2.10.9.2.3 | OMS TVC Electrical Shorts | Multiple-Discrete |
| 6.2.10.9.2.3 | OMS TVC Attitude Error Signal Loss | Multiple-Discrete |
| 6.2.10.9.2.3 | OMS TVC Failed In Off | Multiple-Discrete |
| 6.2.10.9.2.3 | OMS TVC Failed in Auto | Multiple-Discrete |
| 6.2.10.9.2 | TVC Displays or Meters Failed | Multiple-Discrete |
| 6.2.10.9.2 | TVC Displays or Meters Biased | Multiple-Discrete |
| 6.2.10.9.2.4 | Star Tracker Deflection Coil Driver Failure | Multiple-Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Guidance, Navigation and Control (less computer)

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.9.2.4 | Star Tracker Sweep Generator Failure | Multiple-Discrete |
| 6.2.10.9.2.4 | Star Tracker Tracking Loop Error Signal Loss | Multiple-Discrete |
| 6.2.10.9.2.4 | Star Tracker Tracking Loop Error Signal Bias | Multiple-Variable |
| 6.2.10.9.2.4 | Star Tracker Mode Control Failure | Multiple-Discrete |
| 6.2.10.9.2.4 | Star Tracker Output Error Amplifiers Failed | Multiple-Discrete |
| 6.2.10.9.2.4 | Star Tracker Output Error Amplifiers Biased | Multiple-Variable |
| 6.2.10.9.2.4 | Star Tracker Output Error Amplifiers Noisy | Multiple-Variable |
| 6.2.10.9.2.4 | Star Tracker/GNC Computer Interface Bit Failure | Multiple-Discrete |
| 6.2.10.9.2.4 | Star Tracker Electrical Short | Multiple-Discrete |
| 6.2.10.9.2.5 | Horizon Sensor Optics Motor Failure | Multiple-Discrete |
| 6.2.10.9.2.5 | Horizon Sensor Motor Pickoff Failure | Multiple-Discrete |
| 6.2.10.9.2.5 | Horizon Sensor Motor Pickoff Bias | Multiple-Variable |
| 6.2.10.9.2.5 | Horizon Sensor Radiance Compensation Failure | Multiple-Discrete |
| 6.2.10.9.2.5 | Horizon Sensor Radiance Compensation Bias | Multiple-Variable |
| 6.2.10.9.2.5 | Horizon Sensor Output Error Amplifiers Failed | Multiple-Discrete |
| 6.2.10.9.2.5 | Horizon Sensor Output Error Amplifiers Biased | Multiple-Discrete |
| 6.2.10.9.2.5 | Horizon Sensor Output Error Amplifiers Noisy | Multiple-Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Guidance, Navigation and Control (less computer)

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.9.2.5 | Horizon Sensor/GNC Computer Interface Bit Failure | Multiple-Discrete |
| 6.2.10.9.2.5 | Horizon Sensor Electrical Short | Multiple-Discrete |
| 6.2.10.9.2.6 | Rate Sensor Fail Off | Multiple-Discrete |
| 6.2.10.9.2.6 | Rate Sensor Fail Maximum | Multiple-Discrete |
| 6.2.10.9.2.6 | Rate Sensor/GNC Computer Interface Bit Failed | Multiple-Discrete |
| 6.2.10.9.2.6 | Rate Sensor Electrical Short | Multiple-Discrete |
| 6.2.10.9.2.7 | Body-mounted Accelerometer Failed Off | Multiple-Discrete |
| 6.2.10.9.2.7 | Body-mounted Accelerometer Failed Maximum | Multiple-Discrete |
| 6.2.10.9.2.7 | Body-mounted Accelerometer/GNC Computer Interface Bit Failed | Multiple-Discrete |
| 6.2.10.9.2.7 | Body-mounted Accelerometer Electrical Short | Multiple-Discrete |
| 6.2.10.9.3 | IMU Stab Loop Failed Open | Multiple-Discrete |
| 6.2.10.9.3 | IMU Accelerometer Failed Off | Multiple-Discrete |
| 6.2.10.9.3 | IMU Accelerometer Failed Maximum | Multiple-Discrete |
| 6.2.10.9.3 | IMU Gimbal Angle Pickoff Failed | Multiple-Discrete |
| 6.2.10.9.3 | IMU Power Supply/Switching Failures | Multiple-Discrete |
| 6.2.10.9.3 | IMU Blowers Failed On | Multiple-Discrete |
| 6.2.10.9.3 | IMU Blowers Failed Off | Multiple-Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Guidance, Navigation and Control (less computer)

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.9.3 | IMU Heaters Failed On | Multiple-Discrete |
| 6.2.10.9.3 | IMU Heaters Failed Off | Multiple-Discrete |
| 6.2.10.9.3 | IMU Electrical Short | Multiple-Discrete |
| 6.2.10.9.3 | IMU Meters or Displays Failed | Multiple-Discretes |
| 6.2.10.9.3 | IMU Meters or Displays Biased | Multiple-Variable |
| 6.2.10.9.3 | IMU/GNC Computer Interface bit failed | Multiple-Discrete |
| 6.2.10.9.3 | IMU Gimbal Angle Pickoff Biased | Multiple-Variable |
| 6.2.10.9.3 | IMU Align Electronics Failed | Multiple-Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Communications

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.10 | Transmitter Select Logic Failure | Multiple-Discrete |
| 6.2.10.10 | Loss of Subcarrier | Multiple-Discrete |
| 6.2.10.10 | No PM Transmission on S-Band | Multiple-Discrete |
| 6.2.10.10. | No Uplink Voice in S-Band Voice Mode | Multiple-Discrete |
| 6.2.10.10 | No Downlink Voice in S-BD "Voice" Mode | Multiple-Discrete |
| 6.2.10.10. | VHF Voice Amplifier Malfunction | Multiple-Discrete |
| 6.2.10.10 | Malfunction of the Command Decoder | Multiple-Discrete |
| 6.2.10.10 | Failure of Speech Processor Amplifier | Multiple-Discrete |
| 6.2.10.10 | S-Band AGC Signal Lost Sig. Strength | Multiple-Discrete |
| 6.2.10.10 | S-Band Signal Strength Meter "Freezes" at Last Value | Multiple-Discrete |
| 6.2.10.10 | False S-Band "Caution" Signal | Multiple-Discrete |
| 6.2.10.10 | S-Band Antenna Heater Failed "On" | Multiple-Discrete |
| 6.2.10.10 | Voice Can't Get on Intercomm Line | Multiple-Discrete |
| 6.2.10.10 | PTT Circuit Fails "Open" | Multiple-Discrete |
| 6.2.10.10 | PTT Circuit Fails "Closed" | Multiple-Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: COMMUNICATIONS

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.2 | Failure of antenna select logic | Multiple-Discrete |
| 6.2.10.2 | Failure of VHF receiver AM | Multiple-Discrete |
| 6.2.10.2 | Failure of VHF transmitter AM | Multiple-Discrete |
| 6.2.10.2 | Failure of S-Band Transmitter | Multiple-Discrete |
| 6.2.10.2 | Failure of S-Band Receiver | Multiple-Discrete |
| 6.2.10.2 | Failure of VHF data MUX | Multiple-Discrete |
| 6.2.10.2 | Failure of VHF receiver FM | Multiple-Discrete |
| 6.2.10.2 | Failure of VHF transmitter FM | Multiple-Discrete |
| 6.2.10.2 | Failure of ground station | Multiple-Discrete |
| 6.2.10.2 | RF loss to antenna | Multiple-Variable Discrete |
| 6.2.10.2 | Failure of UHF receiver | Multiple-Discrete |
| 6.2.10.2 | Failure of UHF transmitter | Multiple-Discrete |
| 6.2.10.2 | Defective UHF antenna | Multiple-Discrete |
| 6.2.10.2 | TACAN Interrogator locked in search | Multiple-Discrete |
| 6.2.10.2 | Failure of audio cue generator TACAN | Multiple-Discrete |
| 6.2.10.2 | Channel Selector Failure - TACAN | Multiple-Discrete |
| 6.2.10.2 | Short in Unit | Multiple-Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: COMMUNICATIONS

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.2 | Loss of Range Phase Lock | Multiple-Discrete |
| 6.2.10.2 | Loss of Bearing Reference | Multiple-Discrete |
| 6.2.10.2 | Loss of Self Test | Multiple-Discrete |
| 6.2.10.2 | Loss of Range Rate Reference | Multiple-Discrete |
| 6.2.10.2 | Bias in Radar Altimeter | Multiple-Variable |
| 6.2.10.2 | Failure of Radar Transponder | Multiple-Discrete |
| 6.2.10.2 | Defective C Band Hoen | Multiple-Discrete |
| 6.2.10.2 | Failure of L Band Antenna Switch | Multiple-Discrete |
| 6.2.10.2 | Failure of ATC Transponder | Multiple-Discrete |
| 6.2.10.2 | Failure of Glideslope resolver | Multiple-Discrete |
| 6.2.10.2 | Failure of Localizer resolver | Multiple-Discrete |
| 6.2.10.2 | S-Band Phase Modulator Malfunction | Multiple-Discrete |
| 6.2.10.2 | S-Band Power Amplifier Malfunction | Multiple-Discrete |
| 6.2.10.2 | Audio Center Malfunction | Multiple-Discrete |
| 6.2.10.2 | VOX Failed "Closed" | Multiple-Discrete |
| 6.2.10.2 | VOX Failed Open | Multiple-Discrete |
| 6.2.10.2 | S-Band Frequency Modulator Failed | Multiple-Discrete |
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SYSTEM: Instrumentation

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.11 | Multiple Malfunction of RDM MUX | Multiple - Discrete |
| 6.2.10.11 | Tape Recorder is Failed in Stop | Multiple - Discrete |
| 6.2.10.11 | Pri PCM/DDAS is Failed | Multiple - Discrete |
| 6.2.10.11 | RASM 1 Malf'n | Multiple - Discrete |
| 6.2.10.11 | Multi-Malf For C&W Sensors | Multiple - Discrete |
| 6.2.10.11 | Fire Occurence | Multiple - Discrete |
| 6.2.10.11 | Emergency Annunciator Lights Fail On | Multiple - Discrete |
| 6.2.10.11 | C&W Subunit Caution Lights Failure | Multiple - Discrete |
| 6.2.10.11 | Emergency Subunit Lights Failure | Multiple - Discrete |
| 6.2.10.11 | Alert System Lights Failure | Multiple - Discrete |
| 6.2.10.11 | Emergency Unit Annunciator Lights Failure Off | Multiple - Discrete |
| 6.2.10.11 | Fire Sensor Test Switch Failure On | Multiple - Discrete |
| 6.2.10.11 | C&W DC/DC CONV #1 Failed | Multiple - Discrete |
| 6.2.10.11 | C&W Subunit Caution Master F/F Failed Set | Multiple - Discrete |
| 6.2.10.11 | C&W Subunit Master Alarm Output Failed | Multiple - Discrete |
| 6.2.10.11 | C&W Subunit Memory Recall Output Failed | Multiple - Discrete |
| 6.2.10.11 | Emergency DC/DC Converter Failed | Multiple - Discrete |

SYSTEM: INSTRUMENTATION

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.11 | Failure of Signal Conditioning Unit | Multiple - Discrete |
| 6.2.10.11 | Failure of Inst Convl +24V Output | Multiple - Discrete |
| 6.2.10.11 | Failure of Inst Bus A +24V Output | Multiple - Discrete |
| 6.2.10.11 | Failure of Inst Bus B -24 Pwr | Multiple - Discrete |
| 6.2.10.11 | Failure of Inst Bus A +5V Pwr | Multiple - Discrete |
| 6.2.10.11 | AM Display Xducer +24V | Multiple - Discrete |
| 6.2.10.11 | Hi-Level MUX Malfunction | Multiple - Discrete |
| 6.2.10.11 | Primary IB Electronics Failure | Multiple - Discrete |
| 6.2.10.11 | Lo-Level MUX Malfunction | Multiple - Discrete |
| 6.2.10.11 | Failure of Tape Recorder MAN/CMD Relays | Multiple - Discrete |
| 6.2.10.11 | Failure of Tape Motion Monitor Recorder | Multiple - Discrete |
| 6.2.10.11 | Failure of Selected Manual XMTR Control Relays | Multiple - Discrete |
| 6.2.10.11 | Failure of Selected Manual TR Control Relays | Multiple - Discrete |
| 6.2.10.11 | Primary Programmer Failure | Multiple - Discrete |
| 6.2.10.11 | XMTR A Real Time Telemetry CMD Failure | Multiple - Discrete |
| 6.2.10.11 | Xmitter C Malf. | Multiple - Discrete |
| 6.2.10.11 | Failure of XMTR MAN/CMD Relays | Multiple - Discrete |

SYSTEM: Instrumentation

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.11 | C/W Unit #2 Warning Master Flip/Flop Failed Reset | Multiple - Discrete |
| 6.2.10.11 | Rapid Delta P #1 Pressure Sensor Failed Off | Multiple - Discrete |
| 6.2.10.11 | Sig Cond Display Pri Converter Failed | Multiple - Discrete |
| 6.2.10.11 | Emergency Unit Fire Flip/Flop Failed | Multiple - Discrete |
| 6.2.10.11 | Audio Tone Generator Fails | Multiple - Discrete |
| 6.2.10.11 | Fire Tone Generator 1 Fails | Multiple - Discrete |
| 6.2.10.11 | C&W Power 1 Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | C&W Power 2 Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | Warning Test Switch Failure | Multiple - Discrete |
| 6.2.10.11 | Emergency Power 1 Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | Clear Memory Function Fails | Multiple - Discrete |
| 6.2.10.11 | Memory Recall Switch Fails | Multiple - Discrete |
| 6.2.10.11 | PPO2 Control Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | Signal Alert Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | PPO2 Monitor Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | Warning Tone Generator Fails | Multiple - Discrete |
| 6.2.10.11 | Caution Test Switch Failure | Multiple - Discrete |

SYSTEM: Instrumentation

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.11 | Fire Test Switch Failure | Multiple - Discrete |
| 6.2.10.11 | Gas Interchange Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | Condensate Tank Delta P Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | EVA LCG 1 Pump Delta P Switch Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | Cluster Pressure Sensor Output Failed | Multiple - Discrete |
| 6.2.10.11 | Sieve Gas Flow Sensor OutputFailed | Multiple - Discrete |
| 6.2.10.11 | Fire Sensor Control Sensor Fire Occurance | Multiple - Discrete |
| 6.2.10.11 | Emergency Fire Flip/Flop Failed Set | Multiple - |
| 6.2.10.11 | Emergency Unit Rapid ΔP Flip/Flop Failed Set | Multiple - Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Environmental Control

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.12 | 02 Line Leak Downstream from 120 Regs | Variable & Multiple-Discrete |
| 6.2.10.12 | N2 Line Leak Downstream from 150 Regs | Variable & Multiple-Discrete |
| 6.2.10.12 | 02 120 Reg Bias | Variable & Multiple-Discrete |
| 6.2.10.12 | Produce Variable Leak in 02 Tank Repress | Variable & Multiple-Discrete |
| 6.2.10.12 | Produce Variable Leak in N2 Tank | Variable & Multiple-Discrete |
| 6.2.10.12 | Sensor Failure | Multiple-Discrete |
| 6.2.10.12 | ECS - Battery Degradation of Cooling Efficiency | Multiple-Discrete |
| 6.2.10.12 | Fail Mole Sieve Compressor Off | Multiple-Discrete |
| 6.2.10.12 | Solenoid Valve Sieve Failed | Multiple-Discrete |
| 6.2.10.12 | PWR Interrupt to Selected Mole Sieve Timer | Multiple-Discrete |
| 6.2.10.12 | Condensate Tank Vent Heater Light Failed Off | Multiple-Discrete |
| 6.2.10.12 | Mole Sieve Bed Temp Display Failed | Multiple-Discrete |
| 6.2.10.12 | Mole Sieve Dew Point Temp Display Failed | Multiple-Discrete |
| 6.2.10.12 | Sieve Bed Gas Selector Vlv Sticks in Last Posn | Multiple-Discrete |
| 6.2.10.12 | Sieve Chx Water Separator Plates Clogged | Variable & Multiple-Discrete |
| 6.2.10.12 | Fail Mole Sieve Cycle Timer Off | Multiple-Discrete |
| 6.2.10.12 | Fail Mole Sieve Cycle Timer in Last Position | Multiple-Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Environmental Control

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.12 | Flow Restriction Malfunction Mole Sieve | Variable and Multiple-Discrete |
| 6.2.10.12 | Bakeout Hts Bed Sieve Failed | Multiple-Discrete |
| 6.2.10.12 | Logic Unit Transfer Failure | Multiple-Discrete |
| 6.2.10.12 | Pump Failure | Multiple-Discrete |
| 6.2.10.12 | Accumulator Coolant Leak | Variable and Multiple-Discrete |
| 6.2.10.12 | Radiator Coolant Leak | Variable and Multiple-Discrete |
| 6.2.10.12 | Heater Failed On | Multiple-Discrete |
| 6.2.10.12 | Heater Failed Off | Multiple-Discrete |
| 6.2.10.12 | Delta Pressure Sensor Failed Minimum | Multiple-Discrete |
| 6.2.10.12 | Radiator Bypass Valve Failed to Bypass Position | Multiple-Discrete |
| 6.2.10.12 | Radiator Bypass Valve Failed to Full Flow Pos. | Multiple-Discrete |
| 6.2.10.12 | Overload for RSS Control C/B | Multiple-Discrete |
| 6.2.10.12 | Heater Element Degradation | Variable and Multiple-Discrete |
| 6.2.10.12 | Controller Temp Bias | Variable and Multiple-Discrete |
| 6.2.10.12 | Pump Performance Degradation | Variable and Multiple-Discrete |
| 6.2.10.12 | Pump Switch Failure | Multiple-Discrete |
| 6.2.10.12 | Temp Sensor Failed Minimum | Multiple-Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Environmental Control

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.12 | Transfer Duct Fan Failed Off | Multiple-Discrete |
| 6.2.10.12 | TCS Failed - Producing Heat | Multiple-Discrete |
| 6.2.10.12 | TCS Failed - Producing Cool | Multiple-Discrete |
| 6.2.10.12 | Htr Group Duct Failed Off | Multiple-Discrete |
| 6.2.10.12 | Auto TCS Logic Fails All Htrs Off | Multiple-Discrete |
| 6.2.10.12 | Auto TCS Logic Fails All Heat Exch Fans Off | Multiple-Discrete |
| 6.2.10.12 | Relief Vlv in Lock Failed Closed | Multiple-Discrete |
| 6.2.10.12 | C&W Receives Erroneous PPO2 Control Signal | Multiple-Discrete |
| 6.2.10.12 | C&W Receives Erroneous Cluster Press Signal | Multiple-Discrete |
| 6.2.10.12 | Rad Htrs Failed in Last Position | Multiple-Discrete |
| 6.2.10.12 | Heat Exch Fan Failed in Last Position | Multiple-Discrete |
| 6.2.10.12 | Foul Heat Transfer Surface Chx Sieve | Multiple-Discrete |
| 6.2.10.12 | Sieve A/B Outlet PPCO2 Sensor Failure | Multiple-Discrete |
| 6.2.10.12 | Pri or Sec Cond Tank Dump Htrs Failed Off | Multiple-Discrete |
| 6.2.10.12 | Foul Heat Transfer Surface Chx Sieve | Variable and Multiple-Discrete |
| 6.2.10.12 | Fail Mole Sieve Cycle Timer Failure | Multiple-Discrete |
| 6.2.10.12 | Flow Restriction Malfunction Mole Sieve | Variable and Multiple-Discrete |

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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Environmental Control

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.12 | Controller DCS Control Off | Multiple-Discrete |
| 6.2.10.12 | Controller Manual Control Off | Multiple-Discrete |
| 6.2.10.12 | C&D Pump Failure | Multiple-Discrete |
| 6.2.10.12 | Radiator Bypass Valve Lock-up | Multiple-Discrete |
| 6.2.10.12 | Radiator Valve Control Short | Multiple-Discrete |
| 6.2.10.12 | Pump Inverter Switch Short | Multiple-Discrete |
| 6.2.10.12 | Vent Valve Failed Open | Multiple-Discrete |
| 6.2.10.12 | Solenoid Vent Valve Failed Open | Multiple-Discrete |
| 6.2.10.12 | Airlock Internal Hatch Leak Due to Improper Sealing | Multiple-Discrete |
| 6.2.10.12 | Compartment Pressure Relief Valve Failed Open | Multiple-Discrete |
| 6.2.10.12 | Wall Heaters Failed Off | Multiple-Discrete |
| 6.2.10.12 | Wall Heaters Failed On | Multiple-Discrete |
| 6.2.10.12 | Heat Exchanger Fan Failed On | Multiple-Discrete |
| 6.2.10.12 | Circulation Fan Failed On High | Multiple-Discrete |
| 6.2.10.12 | PPO2 Sensor Failed High | Multiple-Discrete |
| 6.2.10.12 | PPO2 Sensor Failed Low | Multiple-Discrete |
| 6.2.10.12 | Vent Valve Failed Open | Multiple-Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Environmental Control

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.12 | Bakeout Htr Bed Sieve Failed in Last Position | Multiple-Discrete |
| 6.2.10.12 | Fail Mole Sieve Compressor Off | Multiple-Discrete |
| 6.2.10.12 | Fail N2 Tank Press Transducer | Multiple-Discrete |
| 6.2.10.12 | Fail 02 Tank Press Transducer | Multiple-Discrete |
| 6.2.10.12 | Cabin Press Reg Assy Fails Open | Multiple-Discrete |
| 6.2.10.12 | Fill Valve Failed in Present Position | Multiple-Discrete |
| 6.2.10.12 | Fail 150 PSI N2 Reg Assy Closed | Multiple-Discrete |
| 6.2.10.12 | Fail 5 PSI N2 Reg Assy Closed | Multiple-Discrete |
| 6.2.10.12 | Fail 120 PSI 02 Reg Assy Closed | Multiple-Discrete |
| 6.2.10.12 | Fail 02 Fill Valve | Multiple-Discrete |
| 6.2.10.12 | Fail Pri N2 Supply Valve | Multiple-Discrete |
| 6.2.10.12 | Fail N2 150 PSI Press Transducer (TM & Display) | Multiple-Discrete |
| 6.2.10.12 | Primary Pump Failure | Multiple-Discrete |
| 6.2.10.12 | PPO2 Sensor Drift | Multiple-Discrete |
| 6.2.10.12 | 02N2 Controller Failed | Multiple-Discrete |
| 6.2.10.12 | Cabin Press Leak - Lock to Vacuum | V<br>Multiple-Discrete |
| 6.2.10.12 | Broken Water Separator Plates Sieve | Multiple-Discrete |

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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM:

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.12 | Condensate Tank Capacity Degradation | Variable and Multiple-Discrete |
| 6.2.10.12 | Heater Degradation | Variable and Multiple-Discrete |
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| 6.2.10.12 | Reg Control Valve Failed | Multiple-Discrete |
| 6.2.10.12 | Rad Control Valve Failed | Multiple-Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Payload Accommodation

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.13 | Structural Attachment Latch Failure to Engage/Release | Multiple - Discrete |
| 6.2.10.13 | Structural Attachment Latch Position Sensor Failure | Multiple - Discrete |
| 6.2.10.13 | Manipulator Joint Tachometer Output Failure | Multiple - Discrete |
| 6.2.10.13 | Manipulator Joint Potentiometer Output Failure | Multiple - Discrete |
| 6.2.10.13 | Manipulator Joint Tachometer Bias | Multiple - Variable |
| 6.2.10.13 | Manipulator Joint Potentiometer Bias | Multiple - Variable |
| 6.2.10.13 | Manipulator Joint Motor Input Command Failure | Multiple - Variable |
| 6.2.10.13 | Manipulator Joint Motor Servo Feedback Loop Failure | Multiple - Variable |
| 6.2.10.13 | Manipulator Joint Motor Failure On | Multiple - Discrete |
| 6.2.10.13 | Manipulator Joint Limit Switch Failure | Multiple - Discrete |
| 6.2.10.13 | Manipulator Joint Brake Failure to Unlock/Lock | Multiple - Discrete |
| 6.2.10.13 | Electrical Short or Failure | Multiple - Discrete |
| 6.2.10.13 | Temperature Sensor Failure | Multiple - Discrete |
| 6.2.10.13 | Wrist Light Loss | Multiple - Discrete |
| 6.2.10.13 | Manipulator Arm Jettison System Sensor Failures | Multiple - Discrete |
| 6.2.10.13 | Manipulator Joint Motor Overheat | Multiple - Discrete |
| 6.2.10.13 | Door in Latch Position Sensor Failures | Multiple - Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Payload Accommodation

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.13 | Manipulator-to-Door Latches Fail to Release/Engage | Multiple - Discrete |
| 6.2.10.13 | Door-to-Fuselage Latches Fail to Release/Engage | Multiple - Discrete |
| 6.2.10.13 | Latch Position Sensor Failures | Multiple - Discrete |
| 6.2.10.13 | Temperature Sensor Failure | Multiple - Discrete |
| 6.2.10.13 | Door Powered Hinge Hydraulic Motor Overheat | Multiple - Discrete |
| 6.2.10.13 | Door Powered Hinge Jackscrew Jam | Multiple - Discrete |
| 6.2.10.13 | Payload Handling Station Display or Meter Failure | Multiple - Discrete |
| 6.2.10.13 | Manipulator Arm Controller Failure | Multiple - Discrete |
| 6.2.10.13 | Floodlight Bulb Burned Out | Multiple - Discrete |
| 6.2.10.13 | Lighting System Electrical Short or Failure | Multiple - Discrete |
| 6.2.10.13 | Light Orientation System Failure | Multiple - Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Miscellaneous

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.14 | Failure of Vent Port Mechanical Orifice | Multiple-Discrete |
| 6.2.10.14 | Leak or Rupture in GN2 Feeder | Multiple-Discrete |
| 6.2.10.14 | Failure of Control Valve | Multiple-Discrete |
| 6.2.10.14 | Failure of Gear Position Indicator | Multiple-Discrete |
| 6.2.10.14 | Failure of Up Gear Lock | Multiple-Discrete |
| 6.2.10.14 | Failure of Down Gear Lock | Multiple-Discrete |
| 6.2.10.14 | Failure of Down Gear Indicator | Multiple-Discrete |
| 6.2.10.14 | Excessive Nose Wheel Shimmy | Multiple-Discrete |
| 6.2.10.14 | Failure of Drogue To Deploy | Multiple-Discrete |
| 6.2.10.14 | Failure of Drogue in Streamline | Multiple-Discrete |
| 6.2.10.14 | Excessive Brake Overheating | Multiple-Discrete |
| 6.2.10.14 | Failure of Anti-skid Control | Multiple-Discrete |
| 6.2.10.14 | Wet Runway | Multiple-Discrete |
| 6.2.10.14 | Ice on Runway | Multiple-Discrete |
| 6.2.10.14 | Failure of Gear Hydraulic Cylinder | Multiple-Discrete |
| 6.2.10.14 | Low Oleo Pressure | Multiple-Discrete |
| 6.2.10.14 | Failure of Landing Gear Heater | Multiple-Discrete |

ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Miscellaneous

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.14 | Failure of Hydraulic Split Rudder Cylinder Control Valve to Maximum Position | Multiple-Discrete |
| 6.2.10.14 | Mechanical Failure in Last Position | Multiple-Discrete |
| 6.2.10.14 | Electro-Mech Failure to Deploy Surface | Multiple-Discrete |
| 6.2.10.14 | Failure of Bonding Cement Through Cold/Heat Fatigue - Visual Inspection Required of RSI | Multiple-Discrete |
| 6.2.10.14 | Failure of Sensor | Multiple-Discrete |
| 6.2.10.14 | Hot Spot - Insulation Failure | Multiple-Discrete |
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ADDENDUM A - MALFUNCTIONS
VOLUME I

SYSTEM: Docking

| PARAGRAPH # | MALFUNCTION NAME | TYPE |
|---|---|---|
| 6.2.10.14 | Capture Latch Fails to Engage/Release | Multiple-Discrete |
| 6.2.10.14 | Docking Latch Fails to Engage/Release | Multiple-Discrete |
| 6.2.10.14 | Hydraulic Attenuator Leak | Multiple-Variable |
| 6.2.10.14 | Hydraulic Attenuator Mount Failure | Multiple-Discrete |
| 6.2.10.14 | Docking Mechanism Failures to Extend/Retract | Multiple-Discrete |
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# Addendum A - Malfunctions

## System On-Board Computer

| Paragraph # | Malfunction Name | Type |
|---|---|---|
| 6.2.6.1 | Primary GN&C OBC No. 1 Fail | Discrete |
| 6.2.6.1 | Primary GN&C OBC No. 2 Fail | Discrete |
| 6.2.6.1 | Backup GN&C OBC Fail | Discrete |
| 6.2.6.1 | Auxiliary Computer No. 1 Fail | Discrete |
| 6.2.6.1 | Auxiliary Computer No. 2 Fail | Discrete |

## Addendum A - Malfunctions

### System Main Engine Controller

| Paragraph # | Malfunction | Type |
| --- | --- | --- |
| 6.2.6.2 | Main Engine No. 1 Input Electronics No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Input Electronics No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Input Electronics No. 3 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Computer Interface No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Computer Interface No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Computer No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Computer No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Output Electronics No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Output Electronics No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Controller Power Supply No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 1 Controller Power Supply No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Input Electronics No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Input Electronics No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Input Electronics No. 3 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Computer Interface No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Computer Interface No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Computer No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Computer No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Output Electronics No. 1 Fail | Discrete |

## Addendum A - Malfunctions

### System Main Engine Controller

| Paragraph # | Malfunction | Type |
|---|---|---|
| 6.2.6.2 | Main Engine No. 2 Output Electronics No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Controller Power Supply No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 2 Controller Power Supply No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Input Electronics No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Input Electronics No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Input Electronics No. 3 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Computer Interface No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Computer Interface No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Computer No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Computer No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Output Electronics No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Output Electronics No. 2 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Controller Power Supply No. 1 Fail | Discrete |
| 6.2.6.2 | Main Engine No. 3 Controller Power Supply No. 2 Fail | Discrete |

# Addendum B

# To the Performance & Design Requirements

# Specification For the

# Shuttle Mission Simulator

# Telemetry Requirements

This addendum shall define the Telemetry parameters and their characteristics which shall be provided in the SMS. The list is presently undefined and will be included as the data becomes available.