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CRITERIA
FOR
PRELIMINARY DESIGN OF
ENGINE/STAGE TEST STAND 2-3

MASTER

20 JANUARY 1967

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CRITERIA
FOR
PRELIMINARY DESIGN OF
ENGINE/STAGE TEST STAND 2-3

Prepared by:

Space Nuclear Propulsion Office
U.S. Atomic Energy Commission
Washington, D.C.

Harold B. Finger, Manager

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INTRODUCTION

The AEC-NASA Space Nuclear Propulsion Office (SNPO) plans the construction of a nuclear rocket propulsion module test complex at the Nuclear Rocket Development Station (NRDS), Jackass Flats, Nevada. The Test complex will be known as Engine/Stage Test Stand 2 and 3, (E/STS 2-3).

The purpose of this test complex is to provide the capability for testing large NERVA engine systems (nominally rated at 250,000 pounds thrust) and other nuclear propulsion module flight systems. It is envisioned that this program will take place in two (2) phases. Initially, tests will be conducted predominantly oriented towards engine system development followed by development of other systems, leading ultimately to flight rating of a totally integrated nuclear propulsion module. A nuclear ground test propulsion module, which is described in further detail in Section III, will be used for this development program.

This document was originally prepared as a guide to the Architect-Engineer in the preparation of a Budgetary Study for the test complex preparatory to funding and design. It has been updated incorporating currently effective technical direction to further serve as functional criteria during preliminary design of the facilities.

The guide was prepared using characteristics of the nuclear ground test module with NERVA engine. Unless otherwise specified, the ultimate growth potential will be considered to be twice the quantities and rates given, except for maximum run time, which will be 45 minutes instead of 30 minutes. In general, requirements for the ground test module described in Section III shall be satisfied, and basic provisions incorporated for later expansion for growth modules described herein.

Abbreviations and terms commonly used herein:

<u>Abbreviation</u>	<u>Term</u>
AEC	U. S. Atomic Energy Commission
C/O	Checkout
E-MAD	Engine Maintenance Assembly and Disassembly
E/STS 2-3	Engine/Stage Test Stands at the Nuclear Rocket Development Station
GFE	Government Furnished Equipment
GH _e	Gaseous Helium
GH ₂	Gaseous Hydrogen
GSE	Ground Support Equipment
LH ₂	Liquid Hydrogen
LN ₂	Liquid Nitrogen
MAM	Module Assembly and Maintenance
MW	Molecular Weight
NASA	National Aeronautics and Space Administration
NERVA	Nuclear Engine for Rocket Vehicle Application
NGTM	Nuclear Ground Test Module
NPSP	Net Positive Suction Pressure
NRDS	Nuclear Rocket Development Station, Jackass Flats, Nevada
PFS	Propellant Feed System
PSOV	Propellant Shut-Off Valve
SNPO	AEC/NASA Space Nuclear Propulsion Office
T	Temperature, °R
T _c	Chamber Temperature
TCA	Thrust Chamber Assembly
TPCV	Turbopump Control Valve
W	Flow Rate

II

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III

NUCLEAR GROUND TEST MODULE DESCRIPTION AND CHARACTERISTICS

A. Scope

1. Purpose

The purpose of this section is to describe the Nuclear Ground Test Module (NGTM) as it is currently envisioned; including its components and subsystems, and their operating characteristics.

2. Assumptions

In the preparation of this document it has been assumed that all ground test module components and subsystems have been developed in the component test portion of the program external to the E/STS 2-3 complex. No extensive cold flow development or cold soak capabilities to simulate space environment of the module tank are envisioned at E/STS 2-3. It is further assumed that all basic components used in the engines are flight designed components when introduced into this facility and that engine development and flight readiness demonstration can be accomplished with a relatively small number of engine builds. Finally, it has been assumed that module flight systems development technology will generally follow engine development technology. Thus early testing at this facility will be primarily engine oriented, although the first propellant tanks will be NGTM tanks.

B. Objectives

The ultimate objective is to demonstrate flight readiness of the nuclear propulsion module flight systems, including the NERVA engine.

The prime objective of the engine portion of the test program to be conducted in E/STS 2-3 is to develop and demonstrate flight readiness of a nominal 250,000 lb. thrust NERVA engine. In order to accomplish these objectives, the following must be accomplished in the engine system test portion of the development program:

1. Investigate the controlled startup to the power range, evolving a suitable method for flight application.
2. Demonstrate the ability of the reactor, turbopump, nozzle, etc., to operate as a compatible engine system under altitude conditions for sufficient durations to be useful for flight application.
3. Investigate and define the engine steady state operating envelope.
4. Investigate and define the after-cooling requirements, evolving a suitable method for flight application.
5. Investigate restart capability after programmed cooldown.
6. Demonstrate engine gimbaling.

The prime objective of including the nuclear ground test module tank and flight module components and subsystems as elements to be hot tested concurrently with the engine is to permit maximum advantage to be taken as early as possible in the engine test program of data useful to the flight propulsion module systems development, including radiation effects due to close coupling.

C. System Description

The nuclear ground test module is a complete functional system that duplicates the flight nuclear propulsion module to the maximum extent practicable. All functional systems will eventually be the same as those for the flight vehicle with the exception of emergency (safety) systems and the structure and insulation of the module tank which will be modified as necessary to meet requirements peculiar to the ground test program and to preclude the necessity of operating the ground test module in a vacuum chamber. Figure III-1 shows the major features of the NGTM.

1. Module Propellant Tank

The liquid-hydrogen NGTM tank is a self-supporting welded-structure fabricated from formed-aluminum-alloy panels. This tank is comprised of a cylindrical section with an elliptical upper end and an elliptical-conical bottom. The propellant tank umbilical fittings are located in the lower skirt of the tank cylindrical section. The lower umbilical provides the interface for the propellant-fill and drain line, as well as for the gaseous-hydrogen, nitrogen, and helium line interconnect fittings. Any electrical power, instrumentation and control lines required

will

terminate in electrical umbilical fittings. (See Subsystems Equipment Bay for upper umbilicals).

2. Subsystems Equipment Bay

The subsystems equipment bay will ultimately contain all of the functional electrical, electronic, electromechanical, and mechanical equipment necessary for the operation and control of the basic ground test module with the exception of the PSOV and the fill-and drain-valve located at the lower end of the tank.

The umbilical for the operation, control, and monitoring of the NGTM is located on the periphery of the equipment bay.

The major subsystems in the equipment bay are as follows:

- (a) Measuring Subsystem
- (b) Telemetry Subsystem
- (c) Flight Control Subsystem
- (d) Flight Safety Subsystem
- (e) Electrical Subsystem
- (f) Propellant Tank Pressurization and Vent Subsystems
- (g) Docking Control Subsystem

3. Instrumentation Unit

In the early phases of testing, a simulated instrument unit will be used. As the program advances, an Instrument Unit (IU) will be integrated into the NGTM for simulated flight tests. It will be secured to the upper flange of the NGTM. This IU contains the electronic and control equipment required by the flight nuclear-propulsion module. The unit has its own umbilical fitting. This instrument unit is same diameter as the NGTM tank, is 36 inches high and has a weight of approximately 5000 pounds.

4. Environmental Enclosure

The environmental enclosure is mounted on top of the upper-most functional unit of the ground test module and provides shelter for the equipment located underneath. It also provides for a suitable environment for sensitive equipment in the instrument unit or equipment bay.

Access is provided for test equipment and entry of personnel. A handling ring, located at the lower end of the enclosure provides the mounting surface for the attachment of the enclosure to either the instrument unit or the equipment bay.

The enclosure is the same diameter as the NGTM, is 6'-10" high and has a weight of approximately 10,000 pounds.

5. Nuclear Rocket Engine

(a) Description

The ground test Nuclear Rocket Engine (NERVA) is a liquid hydrogen, turbopump-fed hot bleed cycle nuclear rocket engine designed to operate at a nominal thrust level of 250,000 pounds with a nozzle expansion ratio of 40:1.

The engine consists of the following sub-systems:

- (1) Propellant Feed Subsystem - This subsystem consists of the

turbopump assembly and all valves, lines and other components to provide the required flow of liquid hydrogen during engine startup, steady state operation, shutdown and cooldown.

(2) Nuclear Subsystem - This subsystem consists of a hydrogen cooled, graphite moderated, epithermal reactor capable of producing a nominal thermal power of 5000MW and conditioning hydrogen propellant to nominal exit temperature. A support structure, reflector, shield, core, control drums and associated components comprise this sub-system. The primary subsystem function is to provide controlled heat to the hydrogen propellant supplied by the Propellant Feed System to maintain desired nozzle chamber temperature and pressure.

(3) Thrust Subsystem - This subsystem consists of the pressure vessel, nozzle, nozzle skirt, thrust structure, thrust vector mechanism and associated components. Capability of transferring energy from the hydrogen propellant into propulsive thrust is provided by this subsystem.

(4) Pneumatic Subsystem - This subsystem consists of storage vessels, valves, lines and other components necessary to furnish gaseous hydrogen to all pneumatic operated actuators of the engine and to furnish pressurizing gas for the module propellant tank.

(5) Controls Subsystem - This subsystem consists of the engine programmer and associated assemblies and components required to control the engine operation and alignment. Engine power operation is accomplished by control of the basic variables of turbine drive flow and reactor reactivity. Alignment is controlled by a thrust vector controller which receives stage guidance system electrical signals and transmits these signals to the thrust vector mechanism actuators to control pitch and yaw orientation of the thrust vector.

(6) Diagnostic Instrumentation Subsystem - This subsystem consists of the necessary instruments, sensors, wire and harnesses to sense, measure, condition and route the electrical signals required to measure the desired engine parameters during all phases of testing.

(7) Electrical Distribution Subsystem - This subsystem consists of wire harnesses and electrical conditioning equipment to condition and deliver electrical energy as required within the engine system.

(8) Purge Subsystem - This subsystem consists of lines, valves and disconnects required to permit purging the engine system propellant flow passages.

(9) Safety Subsystem - This subsystem consists of anticriticality and operational subsystems which prevent inadvertant reactor criticality during engine system handling and operation.

Figure III - 3 presents an engine flow schematic. The engine assembly is shown on Figure III - 4, Figure III - 5 shows the maximum engine envelope for all items provided by AGC-REON, including the PSOV that is mounted on the Module Propellant Tank as well as the remote connectors at the engine-to-Module Propellant Tank remote interface. The engine envelope related to remote engine installation and removal operations are given in Figure III - 6. The engine weight is 33,176 pounds. Table III - 1 gives the estimated fluid conditions at the aft Remote Umbilical (Engine).

Reference B-27 presents a more complete description of the engine, subsystems, and components.

(b) Propellant Tank

The pressurizing gas for the stage propellant tank shall be hydrogen furnished from the reactor shield inlet plenum and combined with the pneumatic discharge from the actuators and valves. The pressurizing

gas shall be pressure-regulated. Estimated tank pressurant fluid conditions at the engine-tank interface are shown in Table III - 1.

(c) Engine Operation

(1) Pretest Operations - The NERVA engine as shown on Figure III - 4 will be transported remotely from the E-MAD Building to the test stand and remotely mated to the Module Propellant Tank employing the EIV-MCC. Remote removal and replacement of the PSOV from the Module Propellant Tank will also be performed remotely with the EIV-MCC. Functional checkout of all instrumentation, control and facility support systems used in the tests will be accomplished after the engine installation is made.

(2) Start Sequence - A typical engine start sequence of events is described in Table III - 2. In brief, at approximately 120 seconds prior to desired full power operation the reactor controls rods are turned to bring the reactor up to 1% power on a one second period.

The reactor is held at this power until full thrust is demanded. The propellant feed system is then activated and power and flow programmed through the bootstrap startup phase. At approximately $T_c = 1000^\circ R$, the temperature control loop is closed and is programmed to rise to full power steady-state temperature as shown in Figure 11 of Reference B-27.

(3) Steady-State Operation - A steady-state thrust level will be maintained by controlling chamber pressure and engine specific impulse will be established by controlling chamber temperature. Upon receipt of a suitable electrical signal, the engine thrust level may be changed to a different steady-state value in accordance with programmed inputs, within the limits of the performance, by modification of the chamber pressure while controlling to a limiting chamber temperature. Table III - 5 defines typical steady-state operating conditions within the engine.

(4) Shutdown - Cooldown Sequences - Following engine operation at power conditions, fluid flow is necessary through the propellant flow path to prevent overheating of engine components. The three types of shutdown-cooldown modes provided are normal, fast, and emergency modes.

a Normal - This is the usual mode used unless a malfunction situation exists. This mode can be accomplished either employing solely LH_2 from the Module Propellant Tank or by use of GH_2 and LN_2 from facility supplies after loss of engine TPA drive energy. The first option is the method used during engine flight operation and the second option is used only during ground testing.

The description of the ground test sequence, operational constraints, and fluid requirements is given in Table III - 3. Figure 14 of Reference B-27 shows typical shutdown-cooldown conditions as a function of time.

b Fast - This mode differs from the normal mode in that the programmed decrease of engine (reactor) power level is not used. This mode is used in cases of minor malfunctions in engine operation involving danger of damage to engine components, but not test facility or personnel. The T_c program provides a maximum chamber temperature decrease rate of $250^\circ\text{R}/\text{sec}$ compared to the $37^\circ\text{R}/\text{sec}$ rate for the normal mode.

c Emergency - This mode is used for malfunction conditions of a more serious nature than for the fast mode. The reactor is immediately scrammed from the operating power level and LH_2 is supplied from a facility source in a minimum time interval. After 14 seconds, GHe from a facility source is used to inert the system followed by LN_2 for the remainder of the cooldown period.

D. Other Considerations

1. Module Growth

Figure III - 1 shows the size of the basic ground test module to be utilized in the ground test program. In order to allow for advanced nuclear ground test modules, the E/STS 2-3 should be capable of accepting the greater length, 33 ft. diameter module and the larger 40 ft. diameter module shown in Figure III - 2. The facility shall not preclude the testing of a 50 ft. diameter tank.

2. Engine

Capability to test growth versions of the nuclear rocket engine should be provided in the design of E/STS 2-3 test complex. The growth version to be considered is a 10,000 MW engine capable of delivering 500,000 lb. thrust, with a liquid hydrogen flow rate of about 600 lb/sec. The engine will weigh on the order of 60,000 lbs.

Figure III - 6 shows the general layout and dimensions of this engine. Functionally it will operate in the same manner as the 5000 MW engine. It should be noted that the facility propellant storage capabilities will not be designed to meet testing of the growth engine. However, basic structures, emergency cooldown lines and propellant feed lines and safety considerations should consider the growth engine.

TABLE III - 1

UMBILICAL & LINE FUNCTION	FLUID	MAXIMUM PRESSURE (PSIA)	MAXIMUM MINIMUM TEMP. °R	FLOW RATE (lbs/sec)	CONNECTOR LINE DIA-METER (IN)	TOTAL OPERATIONAL QUANTITY (lb)
<u>INSTRUMENT UNIT UMBILICAL</u>		Not Determined				
<u>FORWARD UMBILICAL (SERVICE)</u>						
Environmental Enclosure Purge (a)	GN ₂	16	530	1.0	2	5,000
Plant Air	Air	120	530	-	1	---
Cooling Water (Equipment Bay Electronics)	Water	50	500	0.03	1	---
Air Conditioning (Equipment Bay, I.U. & Enclosure	Air	(b)	(b)		10	---
Cooling Water Return	Water	50	-	0.03	1	----
<u>FORWARD UMBILICAL (STAGE)</u>						
Propellant Tank Flight Vent	GH ₂	23 to 36	38	0.3	10	---
Emergency Vent	GH ₂	31 to 44	38	-	10	---
Propellant Tank Ground Vent	GH ₂	30 to 43	38	1.0	14	---
Chilldown & Fill Vent	GH ₂	30 to 43	530 to 38	10.0 to 40.0	14	---
Tank Purge Discharge	GN ₂	25	530	2.5	14	---
Accumulator Relief Vent	GH ₂	1,100	530	1.0	14	---
Sensing Pressure Vent	GH ₂	50	530	0.001	14	---
Ground Pressurization (c)	GH ₂	44	270	-	6	6,500
Fill Pressurization Safety Backup	GH ₂	46	530	8.0	6	2,100
Tank Purge	GH ₂	25	530	0.5	6	2,100
Pneumatic and Accumulator Tank Purge (a)	GHe	65	530	0.1	1	50

UMBILICAL & LINE FUNCTION	FLUID	MAXIMUM PRESSURE	MAXIMUM MINIMUM TEMP. °R	FLOW RATE (lbs/sec)	CONNECTOR LINE DIA- METER (IN)	TOTAL OPER. QUANTITY (lb)
Insulation Purge	GHe	15	530	0.01	2	1,000
Insulation Vacuum	Air	13 to .5	530	(5cfm to vac)	2	---
Connecting-Mode Simulation (d)	LH ₂	31 to 43	38	350	16	413,000
Connecting-Mode Circulation Vent	LH ₂	43	38	0.3	2	13,500
Accumulator Tank Fill, Dump & Purge	GH ₂	1000	530	1.0	1	100
Facility Vent Control & Purge	GHe	50	530	0.1	1	60
Pneumatic Tank Fill, Dump, & Purge	GHe	3500	530	0.5	1	60
Pneumatic Tank Pressure Relief	GHe	3600	530	-	1	---
<u>AFT UMBILICAL (STAGE)</u>						
Tank Fill						
Slow	LH ₂	22 to 44	38	10	12	240,000
Fast	LH ₂		38	100	12	
Topping (12 hr. hold)	LH ₂	16	38	0 to 5	12	10,000
Tank Purge (in.)	GN ₂	25	530	2.5	12	25,000
Emergency Radiation Shield	LN ₂	35	140	200	12	350,000
Tank Purge (Discharge)	GN ₂ & GH ₂	25	530	0.5	12	---
Tank Chillydown	LH ₂	35	38	10	12	50,000
Actuator Ground Control	GHe	500	530	0.01	1	60
Actuator Control Scavenge & Purge	GHe	500	530	0.01	1	---
Propellant Feed Line Purge	GHe	65	530	0.1	2	3,200

UMBILICAL & LINE FUNCTION	FLUID	MAXIMUM PRESSURE	MAXIMUM MINIMUM TEMP ^o R	FLOW RATE (lbs/sec)	CONNECTOR LINE DIA- METER(IN)	TOTAL OPERATIONAL QUANTITY (lb)
Thrust Structure/Engine Feed System Compt. Purge	GHe	65	530	0.3	2	200
Insulation Purge	GHe	15	530	0.1	2	1,000
Interstage Purge (not used on GTM)	GN ₂	-	-	-	2	---
<u>AFT REMOTE UMBILICAL(ENGINE)</u>						
Remote Actuator Supply	GN ₂	115	530	0.5	2	900
Engine Compartment/Duct Purge	GN ₂	65	530	50	10	45,000
Special-Purpose Purge	GHe	65	530	0.1	2	60
Turbine Inlet & Exhaust Purge	GHe	65	530	0.1	2	60
Turbopump Assembly Hot Purge	GHe	65	590	0.002	2	5,200
Pneumatic System Line Purge	GHe	65	530	0.1	2	60
Pneumatic Tank Fill & Dump	GH ₂	1200	530	1.0	2	35
Pneumatic Tank Purge	GHe	65	530	0.1	(same)	60
O ₂ Detector Line	O ₂	-	-	-	2	---
H ₂ Detector Line	GH ₂	-	-	-	2	---
Ground Test Cooldown	GHe	1250	530	165	8	20,000
	GH ₂	250	530	20	(same)	200
	LN ₂	500	530-140	230	(same)	70,000

GROUND TEST MODULE ID REQUIREMENTS

UMBILICAL & LINE FUNCTION		FLUID	MAXIMUM PRESSURE (PSIA)	MAXIMUM/ MINIMUM TEMP. °R	FLOW RATE (lbs/sec)	CONNECTOR LINE DIA- METER (In)	TOTAL OPERATIONAL QUANTITY (lb)
		GN ₂	250	530-140	105	(same)	450,000
		LN ₂	100	530-140	15 (Pulsed)	(same)	100,000
		LH ₂	250	50/38	90	(same)	10,000
Ground Test	Cooldown Circulation Vent	LH ₂	250	38	0.3	2	13,500
	Spare					8	
	Spare					2	
	Spare					2	
Insulation	Vacuum	Air	13.0 to 0.5	530	(5cfm to vac)	2	

- (a) No stage-mounted control valve provided-facility required
- (b) Air conditioning required to maintain 72° ± 2°F. relative humidity 50% maximum, in environmental enclosure and equipment bay and instrument unit; total volume, 9200 cu.ft.
- (c) Facility pressure regulator and solenoid-operated shutoff valve (to be actuated by stage-mounted pressure switch); regulator to be located in close proximity to upper umbilical.
- (d) Facility flowrate throttling valve required

TABLE III-2: Typical Start Sequence of Events

Order of Occurrence	Event
Upon receipt of suitable engine startup	Engine programmer started.
Upon receipt of signal from engine programmer	(a) Pneumatic system shutoff valve opened furnishing gas to the actuators. (b) Reactor control drum locks released. (c) Subpower reactor startup.
At approximately 1% of required full power	Power control loop is closed and power held constant until receipt of start thrust signal.
Upon receipt of start thrust signal from the propulsion module programmer (or facility control) to the engine programmer	Engine programmer provides signals for the following functions: (a) Propellant shutoff valve (TSOV) opened, and discharge shutoff valve (DSOV) are opened (b) Turbine power control valve (TPCV) programmed to control chamber pressure increase as described in Fig. II of Reference B-27. (c) Chamber temperature control loop closed and programmed to control chamber temperature increase as shown in Figure 14 of Reference B-27. (d) When reactor shield plenum pressure reaches preset value, pneumatic system shutoff valve closed. Actuator gas and tank pressurant then furnished from plenum.

TABLE III-3

Typical Programmed Shutdown-Cooldown Modes

I. FAST

Time After Initiation (Sec)	Fluid	Initial Flow Rate (#/Sec) and Press.	Supply & Amt.	Limits & Required Action
(1) 0-16	LH ₂	305 @ 1033 psia	3500# thru TPA	Ramp T _c at 250°R/sec max to <2000°R
(2) 16-600	LH ₂	90 @ 250 psia	10,000# * thru high press. dewar	Exponential LH ₂ flow decay. T _c not to exceed 1400°R.
(3) 600-610	GH ₂	200 @ 250 psia	200# *	T _c not to exceed 14000R.
(4) 610-2 days	LN ₂	105 @ 250 psia	450,000# *	T _c not to exceed 1400°R.
(5) 2-10 days	LN ₂	15 @ 100 psia	100,000# *	Cool to max. core temp. of 800°R.

II. NORMAL

(1) 0-100	LH ₂	305 @ 1033 psia	12,000# thru TPA	Ramp T _c at 37°R/sec max.
(2) 100-600	LH ₂	max - 100 P _c max - 130	5000# thru TPA	Pulse using TPA - T _c not to exceed 1400°R.
(3) 600-610	GH ₂	20 @ 250 psia	200# *	T _c not to exceed 1400°R.
(4) 610-2 days	LN ₂	105 @ 250 psia	450,000# *	T _c not to exceed 1400°R.
(5) 2-10 days	LN ₂	15 @ 100 psia	100,000# *	Cool to max. core temp. of 800°R.

* Facility supplied.

NOTE: Oxygen must be excluded from the reactor core when core temperature exceeds 800°R.

TABLE III-4: Emergency Shutdown-Cooldown Mode

Time After Initiation (Sec)	Fluid	Initial Flow Rate (#/Sec) and Press. Max.	Supply & Amt.	Limits & Required Action
(1) 0 sec				Scram the reactor from full power.
(2) 0-14 sec	LH ₂	140 @ 600 psia	1300	Exponential flow decay to T _c = 2625°R.
(3) 14-160 sec	GH _e	165 @ 1250 psia	20,000# *	T _c reduced to 1000°R.
(4) 160-600	LN ₂	230 @ 500 psia	70,000# thru high press. dewar *	T _c not to exceed 1400°R.
(5) 600-2 days	LN ₂	105 @ 200 psia	450,000# from low press. dewar *	T _c not to exceed 1400°R
(6) 2-10 days	LN ₂	50 @ 100 psia	100,000# *	to max core temp of 800°R Cool to max core temp of 800°R

* Facility supplied.

TABLE III-5
NERVA Engine Typical Steady-State
Fluid State Points

GENERAL DATA

5000 MW

625 P_c

LOCATION	Flow Rate lb/sec	Pressure PSIA		Temperature °R	
		Static	Total	Static	Total
1. TANK OUTLET	297		36.0		38.5
2. PUMP INLET	297				
3. PUMP OUTLET	297		1304.0		54.1
4. NOZZLE MANIFOLD	297		1264.0		54.1
5.					
6.					
7. NOZZLE TUBE OUTLET	266		864.0		156
8. REFLECTOR INLET	254		864.0		156
9. REFLECTOR OUTLET	254		803.0		324
10.					
11. SHIELD INLET	285		803.0		296
12. SHIELD OUTLET	285		785.0		317
13. CORE OUTLET	285		625.2		4500
14. NOZZLE CHAMBER	280		625.2		4500
15. MAIN NOZZLE EXIT	280		622.0		4426
16. HOT BLEED	6				
17. DILUENT BLEED INLET	12				
18. DILUENT HE EXIT					
19. MIXING ZONE OUTLET					
20. TPCV INLET					
21. TURBINE INLET	17		448		1659
22. TURBINE OUTLET			80		
23. TURBINE NOZZLE INLET					
24. TURBINE NOZZLE EXIT

NUCLEAR GROUND TEST MODULE
FIGURE III-1

FIG. III-2 GROWTH MODULE PROPELLANT TANKS

10,000MW ENGINE

FIGURE III - 7

IV

TEST PROGRAM AND OPERATIONS

A. Scope

This section will describe the test programs, the method of performing planned tests, the general operational philosophy and facility utilization, in order to recognize constraints imposed on the facility due to methods and philosophy of operation.

The following assumptions are made:

1. The nuclear rocket propulsion module defined in Section III is the article to be tested.

2. Each stand will be initially equipped with a ground test module tank which may be used to support several engine tests.

3. The nuclear propulsion module test program will progress generally as indicated in Table IV-1.

B. Description

1. Propulsion Module System

The test program at NRDS will evaluate the safety, reliability, compatibility, structural integrity, and flight readiness of the nuclear rocket propulsion module.

(a) Basic objectives are:

- (1) To demonstrate operational safety, functional capability and structural integrity of the propulsion module under 0 to 100 percent engine-thrust conditions.

- (2) To demonstrate the capability of the GSE to perform handling, checkout, and hot-engine operational functions.

(3) To demonstrate the capability of the propulsion module flight systems fulfill flight-profile requirements.

(4) To determine the reliability of the propulsion module to establish flight-test confidence factors.

(5) To confirm thermodynamic and radiation design criteria and the effects on the nuclear ground test module tank structure, insulation, and propellant resulting from radiation and cryogenic stresses during a hot-firing cycle.

(6) To conduct onboard open loop or passive tests of candidate subsystems simultaneously with the early engine tests; however, engine tests shall not be constrained thereby.

(7) To verify all propulsion module subsystems by onboard open loop or passive subsystems tests prior to system integration.

(b) Propulsion Module Test Sequence

Testing at the E/STS 2-3 Complex will be initially oriented primarily toward engine development objectives and will use a ground test module tank (designed and furnished by others). The ground test module tank will be used to support several engine tests. Later in the development program completely integrated propulsion module testing using a flight prototype tank (in lieu of the ground test module) will be the primary objective.

Typical sequences of operation:

Engine

(1) Assemble engine in the Engine Maintenance, Assembly and Disassembly (E-MAD) Building

(2) Mate engine and propulsion module tank at the test stands

- (3) Checkout test stand systems (I&C, support systems, etc.)
- (4) Integrated engine systems checkout
- (5) First firing (see test program)
- (6) Post-firing checkout (Facility systems and test article)
- (7) Subsequent firings (see test program)
- (8) Demate engine and return to E-MAD
- (9) Disassembly and post mortem in E-MAD
- (10) In the event of an engine malfunction during tests, it may be necessary to remove the engine remotely from the test stand to E-MAD for necessary repairs or replacements. Remote reinstallation of the engine in the E/STS 2-3 facility complex prior to continuation of the test program on that particular engine would follow.

Module

- (1) Receive and inspect propulsion module (less engine) and complete assembly work.
- (2) Transport to test stand
- (3) Lift the propulsion module tank (less engine) from horizontal to vertical attitude and place in test stand.
- (4) Mate engine
- (5) Hook-up, calibrate, and align
- (6) Integrated systems checkout
- (7) Simulated countdown
- (8) First-firing (see test program)
- (9) Post-firing checkout and cooldown
- (10) Repeat firing and post-firing cycle to test series completion
- (11) Demate engine and remove to E-MAD
- (12) Disconnect and remove remaining propulsion module from test stand, if maintenance or replacement is necessary.

2. Basic Module Test System Configuration

Engine System - The test engine will consist of a fully integrated engine system although the engine programmer will initially be operating open loop. All engine control functions and sequences will originate from facility control by manual and/or partially automatic control functions to meet the objectives of each individual test. The engine programmer will be monitored for proper functioning during the initial test series to ensure satisfactory operation prior to integration into the engine system as a primary control function.

Module Propellant Management System - The propellant management system consists of the pressurization, fill, vent and pneumatic control subsystems. In this test series the propellant management control system will be operating partially integrated. All pressurization and pneumatic control will be paralleled by equivalent facility capability. The propellant tank will be filled through the normal propulsion module fill procedures. The venting subsystem will be fully integrated; facility venting procedures will be utilized only as a redundant safety system. The pressurization system, at the option of the operator, may be operated open loop or closed loop, but controlled from facility sequencing which duplicates the pressurization requirements of the individual test. The supply will be safely vented and disposed of by facility systems.

Structures - The structural system in this test series will consist of a ground test propellant tank providing the basic elements and concepts which will be utilized in the design of a flight weight prototype tank. The ground test tank essentially provides a container for LH₂ to provide checkout

of propulsion module subsystems. The tank bottom configuration, internal baffling and vortex suppressor utilized in the tank will represent optimum configurations determined from prior cold flow and scale model test results. Propellant temperature and pressure profiles and distribution data will form a reference datum from which the configuration performance can be checked with predicted results from scale model testing.

Insulation - The nuclear ground test module will be insulated with cryo-insulated materials on the outside of the tank and propellant lines.

Flight Control - The flight control system will not be mounted on the propulsion module during the initial and early test series.

Electrical - The propulsion module electrical system will be mounted on the propulsion module but operated open loop during the initial test series. Input data will be supplied to the electrical system simulating specific required control functions. The output data from the electrical system will be monitored to verify system performance.

Telecommunications - In the first series of tests the telecommunications system will be partially installed, operated and utilized open loop to verify performance.

I. U. - The I. U. will not be mounted to the propulsion module during the initial test series.

Environmental - The environmental control systems will be installed and operated open loop to verify operation and check performance levels under the actual environment imposed by engine operation.

Flight Termination - The flight termination system will not be installed in the initial and/or early test series.

Docking Control - The docking control system will not be installed in the initial and/or early test series.

GSE - The flight GSE will be installed at the site and operated to afford checkout and operational performance of the equipment.

Facility - The facility will supply all requirements for the various subsystems of the propulsion module in order to meet the objectives of each individual test. As experience is gained with various propulsion module subsystems and performance levels attained, the subsystems will be integrated into the basic propulsion module and the corresponding facility support system will be utilized as a primary backup in the event of subsystem malfunction.

C. Test Programs

1. Typical tests for the engine system and for the propulsion module are described below:

(a) Engine Module Systems

(1) First Test Series: Cold Flow: Unfueled engine

a. Components (Engine)

(1) Engine programmer installed but not in control loop

(2) Pneumatic system installed but not in control loop

b. Components (Supporting)

(1) Shielded flight tank bottom on module tank

(2) High NPSP capability

c. Facility

- (1) Engine controls
- (2) Pneumatic fluid supply control systems for engine actuators and tank pressurization

d. Test objectives

- (1) Verify ground support equipment to be used on fueled engine No. 1
- (2) Check out the mechanical interfaces of engine to stand
- (3) Final check of all facility systems
- (4) Obtain and evaluate initial low flow regimes to check and verify engine bootstrap characteristics
- (5) Verification of fill and vent systems
- (6) Determination of baseline data and correlation of tank bottom and vortex configuration
- (7) Data acquisition and checkout of operating open loop systems:
 - ° Pressurization and pneumatic
 - ° Electrical
 - ° Telecommunications
 - ° Environmental
 - ° GSE
 - ° Engine Programmer

(2) Second Test Series

The flight type power termination system will be installed as a propulsion module subsystem and operated open loop to provide checkout

and operational integrity of the system under radiation environment.

The complete telecommunications will be operated open loop to provide system checkout.

a. Components (Engine)

- (1) Engine programmer installed but not in control loop
- (2) Pneumatic system installed but not in control loop

b. Components (Supporting)

- (1) Shielded flight tank bottom on module tank
- (2) High NPSP capability

c. Facility

- (1) Engine controls
- (2) Pneumatic fluid supply control systems for engine actuators and tank pressurization

d. Test Objectives

- (1) Low power flow and mapping tests
- (2) Transient starts and shutdown tests
- (3) Perturbation experiments
- (4) Final facility verification under hot operating conditions
- (5) Continued data acquisition on vent system
- (6) Continued verification and data acquisition on fluid dynamics of propellant tank (baffles, tank bottom, vortex suppressor)
- (7) Data acquisition for baseline data for propellant heating analysis and stratification

- (8) Continued data acquisition and checkout of subsystems operating open loop to verify performance prior to integration with propulsion module as primary systems.

(3) Third Test Series

In this test series partial integration of some propulsion module subsystem begins to take place; in addition, the prototype I. U. and flight control subsystems are added to the propulsion module and operated open loop.

It is anticipated that sufficient data acquisition has been accomplished on the electrical, telecommunications and flight termination subsystems to ensure the attainment of satisfactory operation for partial integration of the subsystem with the basic propulsion module to perform basic required sequencing functions.

a. Components (Engine)

- (1) Engine programmer installed but not in control loop
- (2) Pneumatic system installed but not in control loop

b. Components (Supporting)

- (1) Shielded flight tank bottom on module tank
- (2) High NPSP capability

c. Facility

- (1) Engine controls
- (2) Pneumatic fluid supply control systems for engine actuators and tank pressurization

d. Test objectives

- (1) Repeat the above and complete mapping and perturbation tests
- (2) Conduct restarts and cooldown variation tests
- (3) Conduct duration run-up to 30 minutes if all objectives above have been met
- (4) Data acquisition for propellant heating and stratification analysis
- (5) Continued data acquisition on subsystems operation and performance levels to ensure functioning prior to integration into basic propellant module.

(4) Fourth Test Series

In this test series full integration of the propellant management system, electrical system and telecommunications will take place, provided the performance levels have been satisfactorily achieved in the previous test series. The facility systems which have been supporting the basic functions of the above subsystems will be utilized as backup system for support in the event of subsystem malfunction.

a. Components (Engine)

- (1) Engine programmer installed but not in control loop
- (2) Pneumatic system installed but not in control loop

b. Components (Supporting)

- (1) Shielded flight tank bottom on module tank
- (2) High NPSP capability

c. Facility

- (1) Engine controls
- (2) Pneumatic fluid supply control systems for engine actuators and tank pressurization

d. Test objectives

- (1) Full power operation for 30 minutes duration
- (2) Investigate steady state operating map
- (3) Obtain engine/module tank thermal data
- (4) Data acquisition on propellant heat and stratification
- (5) Final checkout and operation of engine programmer
- (6) Continued data acquisition on partially and fully integrated propellant module system to ensure proper operation.

(5) Fifth Test Series

The major change in this test series is complete integration of all subsystems including the engine programmer. This series of tests represents the first fully integrated propulsion module operating independent of facility systems. The facility will represent a backup in the event of malfunction conditions.

a. Components (Engine)

- (1) Engine programmer in control loop
- (2) Malfunction recovery unit (safety system) installed but not in control loop
- (3) Pneumatic engine control system in control loop

b. Components (Supporting)

- (1) Modify shielding on tank bottom of module tank

c. Facility

- (1) Engine controls not in control loop - use as backup system
- (2) Propellant supply for 30 minutes
- (3) Pneumatic supply not in control loop - use as backup system

d. Test objectives

- (1) Full power operation and restart to full power for duration
- (2) Operate engine pneumatic supply system refilling bottles at full power
- (3) Operate engine programmer
- (4) Obtain engine/module tank thermal data
- (5) Check complete operation of all propulsion module systems to determine integration effectiveness

The remaining test series that are contemplated would be devoted to the development and qualification of prototype flight systems of the propellant module.

C. Other Considerations

1. Methods and Operating Philosophy

All tests will be performed in accordance with a test specification prepared by the cognizant design organization. Personnel at the test site will prepare test procedures which will be used by the test group to run a

particular test. All tests will be accomplished under the direction of a Test Director with an operating group in a central control point.

2. Facility Utilization

A typical operating schedule is shown below:

Month	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>
<u>Position 1</u>												
Installation & C/O	xxxxxx								xxxxxx			
Test		xxxxxx								xxxxxx		
Cooldown & Removal				xx							xx	
Decontaminate & Refurbish					xxxxxxxxxxxxxxxxxx							
<u>Position 2</u>												
Installation & C/O					xxxxxx							
Test						xxxxxx						
Cooldown & Removal							xx					
Decontaminate & Refurbish								xxxxxxxxxxxxxxxxxx				

TABLE IV-1

TEST SERIES	FACILITY VALIDATION	TEST SERIES NUMBER											
		1	2	3	4	5	6	7	8	9	10	11	12
TEST SYSTEMS*													
• ENGINE		②	②	②	③	②	③	②**	③	②**	③	②	③
• ENGINE PROGRAMMER		X	X	X	I	I	I	I	I	I	I	Q	Q
• PRESSURIZATION	X	X	X	X	I	I	I	I	I	I	I	Q	Q
• FILL, DRAIN & VENT	I	I	I	I	I	I	I	I	I	I	I	Q	Q
• ELECTRICAL	X	PI	PI	PI	I	I	I	I	I	I	I	Q	Q
• TELECOMMUNICATIONS	X	X	PI	PI	I	I	I	I	I	I	I	Q	Q
• FLIGHT TERMINATION			X	X	X	X	X		X		X	Q	Q
• ENGINE DESTRUCT	M	M	M	X	X	X	X		X		X	Q	Q
• AUXILIARY THRUST				X	X	X	X		X		X	Q	Q
• ATTITUDE CONTROL	M	M	M	M	PI	I	I		I		I	Q	Q
• ENVIRONMENTAL	PI	PI	PI	PI	I	I	I		I		I	Q	Q
I. U.													
• TELECOMMUNICATION				X	PI	I	I						
• GUIDANCE & CONTROL				X	PI	I	I		I		I	Q	Q
• FLIGHT CONTROL				X	PI	I	I		I		I	Q	Q
• COMMAND & TRACKING				X	PI	I	I		I		I	Q	Q
• ELECTRICAL				X	PI	I	I		I		I	Q	Q

I - INTEGRATED

X - NOT INTEGRATED

P - PARTIAL

Q - FLIGHT READINESS TEST

M - MASS SIMULATION

② - ② TEST POSITION

③ - ③ TEST POSITION

□ ENGINE TEST OBJECTIVES PRIMARY

○ INTEGRATED SYSTEMS TEST OBJECTIVES PRIMARY

• ALL NRDS TESTING WILL USE A BATTLESHIP TANK
& A SPECIAL INSULATION SYSTEM

** ENGINE PFRT

CREDIBLE ACCIDENTSA. Scope1. Purpose

The purpose of this section is to identify representative credible accidents which should be considered by the Architect-Engineer. Source terms pertinent to this work will be furnished by the Government. Nuclear considerations for siting the test complex will be in accordance with the criteria set forth in Section VI.C. of this document.

B. Objective

The objective of this section is to assure that the Architect-Engineer considers credible accidents which could cause serious damage within the complex and/or to other test facilities at NRDS. The siting of the test complex shall, to the extent feasible, considering economics and operational capability, minimize the possibility of such credible accidents. Further, neither test position within the complex shall suffer major damage from any accident at the other test position. All aspects of resulting fragmentation, ground and air shock waves, radioactive fallout, and fire hazards shall be considered.

C. Credible Accidents

Credible accidents which should be considered are:

1. Engine propellant system rupture and the release of liquid hydrogen for a time equal to the time required to close the tank shut-off valve.
2. Core meltdown, assuming 20% core vaporization, and resulting damage to the test position including rupture to the run tank.
3. Failure of the exhaust system.
4. Failure of a support system or support systems.

5. A reactor power excursion resulting in reactor pressure vessel rupture, nozzle loss, and scattering of core pieces to the exhaust duct, tank shield, engine compartment, and surrounding area.

6. Rupture of propulsion module tank with associated spillage of liquid hydrogen at the test position.

7. Major electrical fire and/or failure of primary ventilation system in control center during a run or with engine (shielded) on one test stand.

D. Other Considerations

The Architect-Engineer should not limit his analysis to the above postulated accidents but should investigate all reasonable credible sequences which might lead to such an accident.

VI

FACILITY REQUIREMENTS

A. General

The E/STS 2-3 facility will be comprised of two (2) separate test stands which are essentially identical and constructed as close together as possible, consistent with operational, functional, and safety requirements, as described elsewhere in these criteria. In addition, there shall be provided a common control area, propellant storage area, utility service connections, etc., as required and described elsewhere in this section.

A master plan for NRDS has been prepared and furnished to the Architect-Engineer for site familiarization and location of interfaces of this facility with existing and future site components.

1. Scope

(a) Purpose

The purpose of this section is to enumerate the functional and operational requirements which must be satisfied in planning the facility complex and determining the optimum facility configuration to meet these requirements at reasonable cost.

(b) Assumptions

(1) Existing utilities and road networks will be extended to the E/STS 2-3 complex.

(2) The test positions will be located west of the existing engine test stand (ETS-1) at the NRDS.

(3) Existing Administration & Engineering Building; Support Area, including Technical & Maintenance Machine Shops; and E-MAD Building will be used to support operations at the test complex.

(4) Planning of future facilities includes a Module Assembly and Maintenance Building for proposed module work. This building may be located in the proximity of the E/STS 2-3 complex.

2. Objectives

The objective is to provide two test stands for the developmental testing of nuclear rocket propulsion modules with power levels of at least 5,000 MW with a thrust of 260,000 pounds, and to provide a test complex which incorporates the following features:

(a) Sufficient operating fluids storage and systems capacity to test a propulsion module continuously for thirty minutes at full power, plus the required time for pre-firing cooldown, ramp to full power, normal shutdown time, post-firing cooldown time and fluids required for emergency or fast shutdown.

(b) So designed and constructed that the facility may be used, with minimum modifications and addition of fluid and gas storage, for testing propulsion modules continuously for forty-five minutes.

(c) Position accessible for on-stand continuous work one month after completion of testing on that position with the test article removed.

(d) Sited and oriented so that both test positions may be operated and/or be made ready for operation by a single crew.

(e) Sited and oriented so that the activities of one test position will not be affected by activities at the other position except that during test operations at one stand, personnel may be temporarily evacuated for the other should the power level of the test run so dictate.

(f) Common instrumentation and control and support systems wherever consistent with program requirements, safety and economy of original construction and operating costs.

(g) The basic structure shall be designed to accommodate a 10,000 MW engine producing 500,000 lb. thrust with minor modifications.

(h) Propellant piping system shall consider the 10,000 MW engine requirements, see Section III-D-2, and the design shall anticipate piping and equipment changes to provide for this engine.

3. Test Complex Description

(a) Test Stand

Each test stand shall be capable of supporting a propulsion module in a vertical position during full power operation with the nozzle exhausting downward. Control and instrumentation systems, exhaust systems, safety systems, nuclear shielding, propellant and inert fluid systems shall be provided in general accordance with other sections of this criteria. The acoustics of a 5,000 MW engine nozzle have not been established; however, acoustic data for the 1,000 MW KIWI nuclear reactor is provided in References 20 and 28 of these criteria to assist in the evaluation of this aspect of the test stand design.

Each test stand shall consist of foundations, module support structure with access provisions, safety features and interfaces with all necessary support systems. In addition to the two test stands, the complex will include a test control center, test stand electronics room, fluid storage areas, and all ancillary facilities properly located and suitably protected.

Each test stand shall be designed for Zone 3 seismic loadings as defined in the latest addition of the Uniform Building Code.

An intermediate radiation shield shall be provided in accordance with current nuclear criteria to limit the radiation that the engine upper thrust structure and the module tank bottom will see during ground tests.

The following criteria shall pertain to the shield design:

- a. The cross section and materials shall be in accord with current criteria.
- b. The outside diameter shall mate with the inside diameter of the cylinder facility shield and shall have an inside diameter of 173.5".
- c. The shield installation and removal must be compatible with the installation and removal of the engine and a one piece duct extension. The facility shield must be adjustable - ± 3 " from the nominal position.
- d. In order to preclude an additional shield to cover the pad, the shield shall be stored in a pit that is concentric with the test stand centerline; and with the top of the shield flush with the test pad level. The top surface of this shield shall be used for support of EIV track extension if required.
- e. The shield, in operating position, shall be hung from the test stand module support structure, and the shield assembly shall be capable of accepting an additional 60,000 lbs. load.
- f. The shield shall be capable of remote attachment and detachment from the structural support.
- g. Cooling, instrumentation and other services to the shield shall be provided as required with remotely operated connect-disconnect couplings.
- h. The shield may be segmented as necessary for flexibility and ease of installation and removal.
- i. The shield may be handled by either remotely operated equipment or infacility mechanisms located above the test stand pad level.

Future additional shielding (which is not a part of this design) may be installed if test requirements dictate. Cooling capability, and structural support for the future shielding shall be provided as a part of this design as follows:

- a. Cooling - 1,500 gpm at the structural support interface
(borated H₂O)
- b. Structural - 60,000 pounds - assume uniform distribution -
to a 360° support ring

(b) Test Control Center

The Test Control Center will be specifically designed to permit the following functions to be performed:

- (1) Safe personnel evacuation from the Test Control Center under the emergency conditions noted in Section V.
- (2) Direct and monitor transporter activities within the test area.

(3) Perform and control all fluid flow operations required for test operation, i.e., firing, cooling, chilldown, filling, draining, flaring, venting.

(4) Direct, control and monitor all cold flow, prefiring, static firing and post-firing tests of the propulsion module.

(5) Record and monitor all test data.

(6) Serve as center of operations for required test activities.

(7) Provide space for test operational and monitoring personnel to perform their duties safely and properly. An observation room for 40 people and office space for 40 to 50 people should be provided; however, should design of the control center due to operational requirements permit additional space for offices, it may be so utilized.

(c) Access Tunnels, Roads

Access tunnels and roads shall be provided for personnel and equipment moving to and between the test control center and each test stand. Access ways shall consider nuclear safety, explosion hazards, size and weight of equipments to be transported, routing of cabling, power and utility lines, and provision for future revision or expansion. Consideration should also be given to control of personnel access during hazardous conditions.

(d) Support Systems

The support systems for the test stands shall include fluid required for exhaust system, cryogenic and pressurizing gas storage with associated piping, instrumentation and controls, process water system including treatment storage and recovery facilities, electric power distribution and control systems, personnel and equipment access provisions, permanent facility components of the propulsion module instrumentation and control

systems, safety and fire protection systems, radioactive waste disposal system, facilities decontamination system, and all associated subsystems. Specific interfaces shall be established for each system between the propulsion module and the facility support system.

Support systems shall be designed for a maximum turnaround time of 30 days between successive 5000 MW thirty minute firings of the same propulsion module or between modules installed in either of the two test stands. Fluid storage capacities shall be such that reasonable allowances are made for transfer operational losses, delivery contingencies, cooldown of cryogenic components, purge and vent usages, etc.

The following specific requirements shall pertain to the systems indicated:

(1) Liquid hydrogen (LH_2) system - storage as close as practicable to the test stands with (a) provision to top (or refill) main tank during operation at the rate dictated by the propulsion module characteristics; (b) provision to supply pressuring gas to the main module tank during refilling and test operation; (c) provision for pushback of propellant from propulsion module tank to storage; (d) provision of separate high pressure storage for emergency engine cooldown, with associated piping and controls; (e) provisions for emergency dumping from the propulsion module; and (f) provisions for conversion of liquid hydrogen to gaseous hydrogen.

(2) Gaseous H_2 system - storage at optimum pressure to provide for LH_2 transfer requirements, reactor start and shutdown requirements, and other uses as module and facility operation dictate.

(3) Helium system - storage, piping, instrumentation, and control systems as required by the propulsion module test program with sufficient

allowance for purging, inerting and emergency cooldown.

(4) Nitrogen systems - a) liquid and gaseous nitrogen storage, transfer, instrumentation and control systems required by the operation of the test positions including, as warranted, high pressure pumps and vaporizers; b) provision for separate high pressure liquid storage for emergency engine cooldown with associated piping and controls.

(5) Process water system - a) treatment and pumping equipment utilizing existing supply insofar as practicable; b) storage reservoir; c) piping, controls and instrumentation for cooling and deluge systems using process water; d) ponding and recovery system, including coolers as warranted, if recovery system economically feasible.

(6) Electrical power system - a) connections to existing systems at NRDS; b) provisions for electrically independent emergency power; c) provisions for regulated essential power, electrically independent of utility power systems; d) necessary power monitoring, grounding, switching, and operating instrumentation and controls.

(7) Other support systems - a) deluge and fire protection systems; b) communication and area warning systems, external lighting, etc.; c) radiation and combustible gas detection systems; d) personnel and equipment access tunnels or roadways and surface parking areas; e) change room, first aid, and small parts storage areas; f) domestic water system; g) fill stations for fluid systems storage areas; h) vacuum system; i) propane system; j) railroads; k) propulsion module environmental control system; l) minimum support shop and storage areas; m) adequate sanitary facilities.

4. Studies

To achieve the objectives of the test complex, including support systems, it may be necessary to undertake various feasibility and economic

studies, including but not limited to, the following:

- (a) Siting
- (b) Test stand configuration
- (c) Utility requirements and existing utility features
- (d) Fluid storage and transfer systems,
- (e) Instrumentation and control system concepts
- (f) On-stand engine propellant tank mate and demating capability

5. Other Considerations

(a) Although the Architect-Engineer will not be responsible for the design of the following facilities, he should provide in his site planning for their location in the proximity of the test complex and access thereto:

(1) Module Assembly and Maintenance (MAM) Building

The MAM Building will be specifically design to permit the following functions to be performed:

- a. Receive and assemble module tank
- b. Raise and position module vertically in assembly stand
- c. Assemble the module with components that have been shipped separately
- d. Clean and inspect the assembled module
- e. Perform service and repair on components as required
- f. Perform checkout of module (less engine) systems and subsystems.
- g. Provide for placement of module in transporter.

The MAM building will, in general, be a counterpart to the E-MAD facility for module work. It will include a high bay area and a service pit for limited remote maintenance of systems, minimal shop area, and other support areas and support services as required to perform the above outlined operations.

VI-B. NUCLEAR ENVIRONMENT

1. Scope

(a) Purpose

The purpose of this section is to define the magnitudes of the sources of nuclear radiation from the propulsion module and its operation and to describe levels below which facility shielding must reduce radiation at various locations.

(b) Assumptions

(1) Analysis for heating and radiation protection of personnel and equipment shall be based on whichever of the following provides the more severe case:

2.7×10^7 Mw-sec (10,000 Mw for 45 min.) single run.

Two separate 9.0×10^6 Mw-sec runs within 30 days
(two runs of 5,000 Mw for 30 min.)

(2) The test stand will have the capability of testing a NERVA engine having no internal shield without over-exposure of the stand itself, and of testing a NERVA engine having a large internal shield without significant perturbations to the nuclear environment of the engine.

(3) A factor of 3 conservatism shall be applied to all operating neutron and gamma flux, dose rate, and heat generation calculations.

(4) A factor of 5 conservatism shall be applied to all shutdown radiation dose and dose rate calculations.

2. Objectives

The object of this section is to provide the basic nuclear information to be used in the design of the facility including radiation shield design.

3. Radiation Sources

(a) Operating and Shutdown Environment

The radiation model to be used in predicting the facility

environment of the engine is that given in the Criteria Supplement (C-RD). This radiation model is based on the current description of the NERVA reactor with no shield internal to the pressure vessel and minimum reflector thickness. Figures VI-B-1 and VI-B-2 show the approximate neutron and gamma leakage distributions, respectively, produced by this module at 5,000 Mw. The results for 10,000 Mw configurations are approximated by doubling the power distributions given in the radiation model.

(b) Released Fission Products

(1) The facility will be designed to be compatible with the release of gaseous and particulate fission products as specified in the Criteria Supplement (C-RD). These releases may be approximated by the following:

Particulate fission products whose fraction of the total fission product inventory is 5% for either 30-minute duration run at 5000 Mw or for 45 minutes duration at 10,000 Mw.

Gaseous fission products amounting to 6% of the gross fission product inventory for a 30-minute run at 5,000 Mw and 7.5% of the gross fission product inventory for a 45-minute run at 10,000 Mw.

It will be assumed that the rate of escape of gaseous fission products from the engine is proportional to the inventory of that nuclear species. Thus:

$$\frac{dN(t)}{dt} = R - KN(t)$$

where: R = rate of fission product formation
KN(t) = the fission product escape rate
N(t) = number of fission products in the engine at time (t) after full power operation is achieved.

The integral of fission product escape of each nuclear species is given in the Criteria Supplement (C-RD) so that the time of escape can be determined.

(2) Plateout of fission products in the duct will be assumed to be 1% of the gaseous fission products in the exhaust.

(3) Distribution of fission products will otherwise be assumed to be such as to provide conservative shield design.

Figure VI-B-2

4. Flight Radiation Environment Simulation

(a) Engine Environment Simulation

The environment of the engine components above the internal engine shield is represented in Figures VI-B-3 and VI-B-4 respectively for full power neutrons and gamma rays respectively for 5000 Mw operation. These data also apply to the 10,000 Mw engine if multiplied by 2; e.g. = 0 direction. Facility contributions to the engine environment from scatter and capture phenomena shall be limited to 25% of the levels shown. Thus a flight nuclear environment for the engine will be simulated within 125% of anticipated magnitudes.

(b) Criticality Interactions

The design of the facility shielding shall be such as to limit perturbations to the criticality of the reactor to less than \$0.50 of that predicted in space.

(c) Propellant Tank Environment Simulation

The test complex shielding shall be designed to limit increase in radiation level to the propellant tank to 25% of those predicted for space. The facility will accommodate shielding to be supplied with the test article which can vary exposure of the tank bottom.

5. Limitations to Test Stand Environment

(a) Radiation Damage to the Test Stand

Operating and shutdown radiation intensities as well as accumulated dose rate to any permanent test facility components will be identified. Radiation damage to components as well as neutron activation and fission product contamination to test stand components will be evaluated. Local shielding or modification of planned shields will be considered as preferable alternatives to specification of radiation hardened equipment or excessive replacement of non-radiation hardened equipment. Radiation levels to which facility components will be subjected will in any event be limited to such levels that will not impair their normal functions.

FIGURE VI B 2 Flight environment

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS PER INCH

GRAPH Dose Rate (RAD/HR)

FIGURE VI - B - 6 *Fig. 31*

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS PER INCH

FAST NEUTRON FLUX (E.N. 0.4 Mev) (NEUTRONS/CM²/SEC)

THESE DATA WERE OBTAINED FROM A CALCULATION OF THE NEUTRON FLUX IN THE CORE OF A REACTOR. THE CALCULATION WAS MADE BY THE METHOD OF DIFFERENTIAL EQUATIONS. THE RESULTS OF THE CALCULATION ARE GIVEN IN THE FOLLOWING TABLE.

DISTANCE ABOVE CORE MIDPLANE (CM)

VI-B-7

(b) Access Requirements

Access to various parts of the facility and the remainder of the test site is required as specified in Table VI-B-1. This table has been developed with the objective of minimizing exposure to operating personnel. Only the most restrictive cases are included in the table.

In the case of any credible accident including those defined in Chapter V, the entire E/STS 2-3 facility will be restricted with the exception of the control center in which personnel exposure shall not exceed a rate of 2.5 Mr/hr. Moreover, capability will be provided for evacuation of personnel from the control center one hour after any incident without accumulating integrated doses in excess of 3R.

It is possible that strict adherence to the data given will impose unreasonable constraints on the facility design. Areas in which significant savings might result from modest relaxation of the requirements of Table VI-B-1 will be identified for further consideration.

TABLE VI-B-1

PERSONNEL ACCESS REQUIREMENTS

LOCATIONS	All Power Operations	10 ² * Mw Seconds		3 x 10 ⁵ * Mw Seconds		3 x 10 ⁶ * Mw Seconds		9 x 10 ⁶ * Mw Seconds		2.7 x 10 ⁷ * Mw Seconds		MCA	Time After Engine Removed
	Shield	Shld	Unshld	Shld	Unshld	Shld	Unshld	Shld	Unshld	Shld	Unshld		
Other NRDS Facilities	U	U ₀	U ₇	U ₀	U ₃₀	U ₀	U ₈₀	U ₀	U ₂₅₀	U ₀	U ₄₀₀	U ₁₀	U ₀
<u>Peripheral Work Zones</u>													
MAM	R	U ₀	U ₇	N ₃	N ₃₀	N ₁₀	N ₈₀	N ₃₀	R	N ₃₀	R	R	U ₀
Complex Control Gate	R	U ₀	U ₇	N ₃	N ₃₀	N ₁₀	N ₅₀	N ₃₀	R	N ₃₀	R	R	U ₀
Control Emergency Exit	R	U ₀	U ₇	N ₃	N ₃₀	N ₁₀	N ₇	N ₃₀	R	N ₃₀	R	See Text	U ₀
Main Complex Substation	R	U ₀	U ₇	N ₃	N ₃₀	N ₁₀	N ₈₀	N ₃₀	R	N ₃₀	R	R	U ₀
Water Storage	R	U ₀	U ₇	N ₃	N ₃₀	N ₁₀	N ₈₀	N ₃₀	R	N ₃₀	R	R	U ₀
<u>Control Center Zone</u>													
Parking/Personnel Ent.	R	U ₀	U ₇	N ₃	N ₀	N ₁₀	N ₈₀	N ₁₀	R	N ₃₀	R	R	U ₀
Equipment Unloading Ent.	R	U ₀	U ₇	N ₁₀	R ₀	N ₆₀	R ₈₀	M ₂₀	R	--	R	R	U ₀
Building Interior	U	U ₀	U ₇	U ₀	U ₀	U ₀	U ₀	U ₀	U ₀	U ₀	U ₀	U ₀	U ₀
<u>Forward Support Zone</u>													
Fluid Fill Station	R	U ₀	U ₇	N ₁₀	R	N ₆₀	R	M ₂₀	R	--	R	R	U ₀
Fluid Storage Area(s)	R	U ₀	U ₇	N ₁₀	R	N ₆₀	R	M ₂₀	R	--	R	R	U ₀
Elec. Dist. Point	R	U ₀	U ₇	N ₁₀	R	N ₆₀	R	M ₂₀	R	--	R	R	U ₀
Vaporizers	R	U ₀	U ₇	N ₁₀	R	N ₆₀	R	M ₂₀	R	--	R	R	U ₀
Ejector Fluid Gen.	R	U ₀	U ₇	N ₁₀	R	N ₆₀	R	M ₂₀	R	--	R	R	U ₀
Camera Bunker	R	U ₀	U ₇	N ₁₀	R	N ₆₀	R	M ₂₀	R	--	R	R	U ₀
<u>Test Stand Zone</u>													
Exterior Pad	R	U ₀	N ₂₀	N ₂₀	R ₁	N ₁₄₀	R	N ₂₈₀	R	--	R	R	U ₃₇₀
Umbil. Arm - Upper	R	U ₀	N ₂₀	N ₂₀	R ₁	N ₁₄₀	R	N ₂₈₀	R	--	R	R	U ₃₇₀
Umbil. Arm - Lower	R	U ₀	N ₂₀	N ₂₀	R	N ₁₄₀	R	N ₂₈₀	R	--	R	R	U ₃₇₀
Umbil. Term - Elec.	R	U ₀	N ₇	N ₂₀	R	N ₁₄₀	R	N ₂₈₀	R	--	R	R	U ₃₇₀
Umbil. Term - Fluid	R	U ₀	N ₇	N ₂₀	R	N ₁₄₀	R	N ₂₈₀	R	--	R	R	U ₃₇₀
Elec. Term Room	R	U ₀	U ₇	U _{0.1}	U ₇	U _{0.1}	U ₇	U _{1.0}	U ₇	U _{1.0}	U ₇	R	U ₃₇₀
Elec. Substation	R	U ₀	U ₇	U _{0.1}	U ₇	U _{0.1}	U ₇	U _{1.0}	U ₇	U _{1.0}	U ₇	R	U ₃₇₀
Adjacent Stand Pad	R	U ₀	U ₇	U ₈₀	U ₈₀	U ₈₀	U ₈₀	U ₁₀₀	R	U ₁₀₀	R	R	U ₀

TABLE VI-B-1 (Cont'd)

PERSONNEL ACCESS REQUIREMENTS

- U - Unlimited access, no restriction; less than 2-1/2 mr/hr.
- N - Normal controlled access, less than 100 mr/hr.
- M - Maximum planned exposure for time-critical tasks; less than 3 R/hr.
- R - Restricted access, no planned exposure; greater than 3 R/hr.

NOTES: Only the most restrictive cases are included in this table.

These criteria do not necessarily provide for facility component protection due to radiation.

Subscripts denote times after shutdown in hours, except engine removal.

-- - No requirements

10² Mw-sec Engine Calibration
 3 x 10⁵ Mw-sec 5000 Mw 1 min.
 3 x 10⁶ Mw-sec 5000 Mw 10 min.
 9 x 10⁶ Mw-sec 5000 Mw 30 min.
 2.7 x 10⁷ Mw-sec 10,000 Mw 45 min.

C. Siting

1. Scope

(a) Purpose

It is the intent of this section to present siting requirements based on existing nuclear safety, technology, quantity-distance criteria for stored gases and propellants, operating plans and philosophy and the impact of meteorological considerations on the siting and design.

(b) Assumptions

(1) The nuclear safety parameters for site personnel and the general public will not exceed those stipulated in AEC Manual, Chapter 0534 and Section VI-B of these criteria.

(2) The hazards associated with storing and using high energy propellants shall be considered in siting and designing facilities. Where oxidizers and fuels such as liquid oxygen and propane or alcohol are used, their storage, handling and use shall be in accordance with sound engineering principles and experiences within the government and particularly NASA, gained from previous operations. Where liquid hydrogen is used, the design of storage, handling and using facilities shall be based on probabilities of occurrence of leaks, fires, deflagration and pressurization failures predicated on operational experiences peculiar to development of large diameter stages.

(3) Wind conditions during a test will carry radioactive contaminants from the test stand to other facilities and to offsite inhabited areas. The effect of this radioactive fallout upon design of facilities within the E/STS 2-3 complex and increased requirements for washdown, shielding,

interrupted operations, etc., shall be considered and the most economical tradeoffs sought. Meteorological data for NRDS is provided in Section VII, Site Information.

(4) Layout of the site shall take advantage of shadow shielding from the terrain or shadow shields to help reduce separation of functionally related facilities where practical and economical. Also, consideration shall be given to locating facilities in relationship to topographical features to insure good drainage, economical construction and safety for personnel in the event of an excursion, explosion or deflagration on the test stand or at the storage or fill areas.

2. Objectives

It is the objective of this section to provide the Architect-Engineer with basic considerations to be used in site selection and layout of roads, railroads and site plans for facilities.

3. Nuclear Siting Considerations

(a) The siting of facilities will be consistent with the nuclear and operational considerations as presented in Sections V and VI-B.

(b) Radiation-Exposure Limitation Requirements

Calculations generated as a result of the siting and design of the facilities must account for all sources of radiation such as direct, air and structure scatter, exhaust clouds, and local fallout.

4. Non-Nuclear Siting Considerations

(a) General

The operational relationships of each facility within the complex should be considered carefully. Functionally related facilities should be located as close together as possible to facilitate communications, reduce construction and operating costs. Every

effort shall be made to take advantage of any thermal radiation or blast protection provided by the natural terrain, when siting each facility. This should be done with the object of either reducing ground-line distances between them to a minimum, or avoiding excessive cut-and-fill expense, or both. Complex location should be such as to take advantage of meteorological considerations and reduce fall-out interference with other activities at NRDS.

(b) Test Stands

The depth of the exhaust duct cavity will probably require considerable excavation, particularly since horizontal access from grade into the cavity must be provided for drainage and installation, and maintenance of equipment. Siting of each test stand shall be such as to minimize the cost of excavation. It is desirable to make the EIV trackage and the transporter roadway to each test stand as short as possible consistent with the nuclear parameters mentioned above. The associated longitudinal gradients shall be minimized to the extent possible, but not more than 10% for the PMT roadways or 5% for the EIV railroads. Turns in the roadways shall be kept to a minimum, and the radius of curvature of necessary turns shall be kept maximum, not less than 100' for the PMT roadways nor 400' for the EIV railroads.

The adjacent test stand must be located a sufficient distance from the test stand containing the fueled and pressurized module so that it will not sustain more than a 2% probability of impact from fragments from a failed module tank. Further, separation distances and designs of adjacent facilities and equipment will be such as to prevent damage in the event of the hydrogen fire associated with a module tank rupture. Propellant, coolant and gaseous lines from the support areas will be located to provide as much shadow shielding as possible.

(c) Control Center (CC)

Because of the need to minimize line losses on hard-line data transmission, the separation distance between the Control Center and the electronics rooms in the test stands should be small as possible. Access and egress for the control center should be as direct as possible and not routed through or by hazardous or large scale operational activities in the complex.

(d) Gas Storage Area

This area should be located so as to reduce lengths of pipe lines to the test stand; however, the location of the gas storage shall be such as to minimize the effect of thermal radiation from the engine test exhaust plume or thermal or blast effects from a module tank pressure rupture.

Access to the area for maintenance or refilling operations should be planned so as to reduce or eliminate operational interferences such as the liquid hydrogen filling operations or those associated with the control center. Further, the layout and location of the Gas Storage Area shall provide for approximately 100% expansion capability for future storage vessels, converters and pressure vessels to accommodate 10,000 MW, 45 minute run operations.

(e) Cryogenics Storage Area

This area shall be located so that it will not be subjected to damage due to thermal radiation from an on-stand hydrogen fire. Connecting line ruptures shall be considered in the layout of the storage area. Nearby facilities should be sufficiently separated from the storage dewars so as to preclude thermal damage to them. The access for the liquid hydrogen fill trucks shall be planned so that interference with other activities is minimized.

The storage area and fill stations shall be located and planned to provide for expansion capability sufficient to meet the needs of the future 10,000 MW engine running for 45 minutes.

(f) Ejector Fluid Generation and Storage Area

This area shall be located so as to provide minimum length pipe runs to the test stands. The generator fuel and oxidizer storage vessels (if rocket engine type generator is selected) shall be carefully located so as to preclude damage from module tank ruptures and

hydrogen fires either on-stand or at the Cryogenic Storage Area.

The area shall be sized to accommodate a steam accumulator-type system for the ejector working fluid with expansion capability sufficient to meet the needs of the future 10,000 MW engine running for 45 minutes.

(g) Vent Gas Disposal Area

The Vent Gas Disposal System shall be located so as to best serve the needs of the test stands, Gas Storage Area, and the Cryogenics Storage Area within the complex. The location shall provide adequate separation from other operations and facilities. Further, the system shall safely dispose of gases considering the effect of prevailing winds on the exhaust plume from the disposal system. The Architect-Engineer shall determine the optimum method for safe disposal of gases.

D. Instrumentation and Control Systems

1. Scope

(a) Purpose

The purpose of this section of the I&C criteria is to define the general constraints relating to, the performance requirements of, and such other information as necessary to the preparation of a performance specification for the design of an instrumentation and control system for the test facilities. Whereas this document establishes design concepts, criteria and performance goals as a substantive guide to the Architect-Engineer, it does not limit the latter to strict adherence to the specific engineering procedures, techniques and systems herein described providing the performance capabilities of the designed system are at least equivalent to the herein-described systems both in performance and relative cost, and in addition represents a high level of engineering achievement and is consistent with proven state of the art and practices.

(b) Assumptions

The following assumptions relate to the system design of the instrumentation and control systems for E/STS-2 and E/STS-3:

(1) The Control Center shall be located no more than 700 feet from either test stand.

(2) The Instrumentation and Control Systems herein defined consist of the following subsystems which are proximally described and shall be designed to function as integrated, highly reliable and readily maintainable overall Instrumentation and Control Systems. The total number of channels for acquiring diagnostic and control data for each test stand is 1500 nominally.

a. Data Acquisition Subsystem

A subsystem which is capable of acquiring the engineering data from transducers or other equivalent sensors, transmitting this data to suitable terminating and control centers for conditioning, calibrating, scaling, linearizing, displaying, and recording of 1500 analog signals and discrete signals and continuously generated data channels correlated with time for an

integrated time period of as much as one hour. Data channelization, processing and display is not required on a simultaneous total capacity basis and will be defined specifically under sub-paragraph 3 of this section.

b. Control Subsystem

The control subsystem is a separate and independent subsystem which provides the necessary control, monitoring and intelligence functions necessary to the operation of the test item and the test facilities. The control subsystem is composed of the facility control and the test control & simulation system (TCSS). There shall be no direct inter-connection between the control subsystem and the data acquisition subsystem except thru isolation amplifiers or isolators which provide outputs for recording and/or monitoring purposes. Termination panels, power supplies, controls for switching, activation, etc. shall be physically and electrically separated to avoid inadvertent interaction or detrimental influence. Detailed design considerations and criteria are defined under sub-paragraph 3 of this section.

c. Facility Support Subsystems

The facility support subsystems include Safety, Communications, Closed Circuit TV, Photographic, and Power subsystems as defined in sub-paragraph 3.

2. Objectives

(a) Performance

The objectives of the Instrumentation & Control System are to provide an efficient and reliable means of acquiring the data necessary to the development and testing of nuclear rocket engines and modules and associated equipments in an economical and straightforward manner. In order to accomplish these objectives, the I&C system must be of high stability, repeatability and dependability while maintaining the high order of accuracy and flexibility for application essential to such a system. These criteria dictate that field and time-proven techniques be employed using equipments and components that have previously demonstrated performance capabilities in similar applications.

(b) Environmental Requirements

The following environmental conditions are applicable to all instrumentation and control systems, subsystems and equipments to be furnished and installed at E/STS 2-3:

Temperature:

Controlled Facilities	-	+55°F to +80°F
Uncontrolled Areas	-	0°F to 150°F

Pressure - 12 psia to 15 psia

Humidity (Relative):

Controlled Facilities	-	10% to 60%
Uncontrolled Facilities	-	0% to 100%

Sunshine:

Unprotected equipments	-	105 watts/sq.ft. total
		50 to 80 watts/sq.ft. above 7800
		Angstroms (long ultra violet)

Wind Velocities:

Operating (Unprotected)	-	70 mph
Not operating (Unprotected)	-	70 mph - gusts to 100 mph

Precipitation:	- 4.0 in/hr
Sand and Dust:	
Operating (Unprotected)	- Particles 10^{-4} to 1.0 mm diam. blown by 70 mph winds
Non Operating (Unprotected)	- Particles to 1/4" diam. with gusts to 100 mph
Fungus Growth	- Present at temperatures above 60°F and 60% R.H.

The above specifications pertain to all equipment installed; operating and non-operating; protected or unprotected; according to location, installation, and configuration as applicable.

Due consideration of environmental conditions shall also be given to transportation to the site by air and ground means, handling, storage and packaging.

Electrical equipment which is to be operated in potentially explosive atmospheres shall be provided with means of preventing ignition of the atmosphere.

Equipment may be required, in some instances, to operate in an inert atmosphere of 99% nitrogen and 1% other gases.

Shock - Equipment subject to bench servicing may be subjected to one inch flat drops and four inch pivot drops onto a hard surface, either operating or non-operating and unpackaged.

Certain equipments located on and in the Test Stand will be subjected to shock and vibration and designed accordingly.

Sound pressure in the vicinity of the Test Stands may be as high as 170 db $\pm$ 5 db at 0 to 10,000 cps. Appropriate attenuation at other locations is to be considered due to distance and type of structure.

Radio frequency interference - Equipment may be subjected to RF interference of 135 db above 1 microvolt from 150 Kc to 25 Mc.

Magnetic interference - Equipment may be subjected to magnetic fields of 10^{+5} Webers per square meter at 60 cps and/or 400 cps and electric fields of 100 volts/meter at 60 and/or 400 cps.

Nuclear radiation - Equipments shall operate satisfactorily in nuclear environments as described in Section VI-B and the Budgetary Study.

3. System Description

A. Data Acquisition Subsystem for E/STS 2-3 (Figure VI-D-1)

1. Design Concepts

a. The design concepts for E/STS 2-3 envision a test system that allows recording of 1500 channels of data. Low level data is defined as 0 to ± 100 millivolts at typical full scale values of ± 5 , ± 10 , ± 20 and ± 100 MV, and high level as 0 to ± 5 volts full scale.

b. Transmission of these data to the first point of treatment will be over suitable cables and conductors of as short a length as is consistent with good facility design to a termination point described as the Control Point Termination Room, with the exception of cabling for thermocouple reference junctions and impedance matching devices.

c. Reference junctions for thermocouple measurements, impedance matching devices and similar devices will be located in the Test Stand Electronics Room. Provision will also be made as regard to layout space including access and penetration details for 200 channels of signal conditioning and amplifiers of closed loop analog control functions for each Test Stand. This TCSS hardware and design will be provided by others, however, the A&E contractor will take cognizance at the various interfaces with the instrumentation system.

d. The channels of data transmitted to the Control Point Building (Control Center) from each test stand will be terminated in suitable signal conditioners. Distribution from the signal conditioners will be such that a total of 1200 digital channels may be processed for data acquisition and control at any one time and simultaneously from either or both test stands to include recording, display multiplexing, amplification digitizing, digital recording and computation. Three hundred will be recorded or displayed as analog data.

e. Control Center Electronics Room - The following functions will be performed in this room (signal conditioning):

Calibration insertion

Excitation of transducers

Bridge completion when impractical to accomplish
on transducers and balance

Amplification where required

Span and scale adjustments

Multiplexing of diagnostic data not required for quick
look monitoring and/or control (i.e., where parallel display and recording
is not required).

It should be noted that essentially all signal conditioners and associated electronics are located in the control building with the exception of thermocouple reference junctions and certain control channels which will be defined and provided by others. This description defines the conceptual approach as a "low level system" with analog data transmitted to the control building prior to signal treatment except as noted.

The signal conditioners and appropriate electronics for the 200 TCSS channels will be installed at a later time by others in the space available in the test stands. In order to accommodate these TCSS channels, cabling, terminations, equipment and associated control building space must

be provided. These latter space requirements will be defined by the government.

f. The exact numbers of channels, computer modules, sub-subsystems components, etc. are not intended as an engineering constraint in the performance of the B-1 Task scope of work in that distribution may be more efficiently and economically accomplished in other combinations, even to the extent of minor modifications to the total numbers specified. Deviations from the totals specified must be presented to the Government for review and approval at the earliest possible stage of engineering. Similarly, the selected detailed design I & C contractor, shall not be constrained to the modular breakdown proposed in the performance specification in order to fully capitalize on state-of-the-art progress at the time of system commitment. It is the express intent of a modular configuration, that the instrumentation and control subsystem incorporate the means and capacity for multiple routing of critical operational and control channels, to preclude loss of information or system perturbational degradation.

g. The numbers of channels to be displayed and recorded, insofar as specific treatment is concerned, is as follows and relates to the shared portion of the data acquisition sub-system:

(1) a total of 30 channels of digital display will be selectable. These displays will be appropriately distributed to operating consoles and graphic display units.

(2) at least 1200 channels of continuous digital data will be tape recorded with a total of 200 of the 1200 to be on-line computed data with respect to linearization, scaling, etc., including conversion to engineering units.

(3) a total of 300 channels will be available from the amplifier output patch for simultaneous display and recording on or near the various control room consoles including a capacity for the direct writing recording of 72 of these channels.

(4) 96 channels of direct wiring recording capacity will be provided for test limit monitoring and 24 channels for diagnostic data review. These channels will be patchable to the appropriate locations as needed.

(5) a total of 240 channels of event recording capacity are to be provided. The location and distribution of these channels in the control building will be specified at a later date.

h. A capability for the simultaneous presentation or plotting of three sets of cross plot data will be provided utilizing computed parameters such as integrated power mass flow, chamber temperatures,

pressures, etc. The presentation or plots may be digital or analog using electro mechanical or electronic devices as determined by system integration and economic considerations.

l. Automatic channelization, pre and post test calibration will be provided for all continuous measurement channels with the capability of inhibiting these functions required to assure the integrity of the facility with the Test Control and Simulation System (TCSS) channels.

m. The guide-line to the number of calibration steps required in accomplishing the above is that sufficient number of steps should be utilized to assure that the channel in question is adequately calibrated throughout its usable range; and that both 0% and 100% calibration points would require neither 0 or full scale count of the digitizing system. Over-ranging of the measurement channel shall be considered in digital scaling.

n. No requirement exists for computerizing channel gain, filter selection or control of multiplexer sampling rates.

The approved conceptual approach to the Instrumentation and Control system performance does not alter the design criteria with respect to performance and accuracy as specified. It is desired that as the work progresses continual evaluation of the performance of this system be carried on in conjunction with cognizant vendor's and equipment suppliers so that any obstacle to the achievement of the design goals can be brought to the attention of the Government. The wording and intent of the approved Procurement Document shall also require that the successful design contractor be cognizant of these guidelines in order that all

potential problems will be recognized in a timely manner.

o. In addition to the above, the Control Center Electronics Room will contain necessary maintenance and test equipment. The Control Center is defined as the space allocated for display and monitoring of data for actual test operations and the originating point of control. The Control Center will be located as close to the test stand facilities as operational safety and other considerations will permit.

p. It is intended that each test stand will have separate controls and control monitoring consoles, but that the associated digital data system and data recording systems will be common. In this latter connection, it is also desired that the digital data system and data recording systems can be apportioned to each test stand by a switching and patching system in order to facilitate setup and checkout of both stands concurrently. Tests of propulsion modules will not be conducted on both stands simultaneously, however, simultaneous partial checkout of the stands will be provided for.

q. The Control Center will contain, but not be limited to, the following I & C equipments:

(1) Control Room Equipments

Control consoles - E/STS 2-3

Lead Instrumentation Engineer Consoles

Monitoring Presentations - meter or strip charts

for trend data - original monitors

Operational Controls

Events Indicators

Timing Indicators

(2) Computer Room Equipment

Control computer system including input-output devices, power supplies, patch racks, line printer, magnetic tapes, displays, etc; this computer will be a general purpose control computer capable of on-line control and monitoring of facility, stage and engine control functions; and off-line analysis of facility, stage and engine control system performance.

(3) Data Recording Room -- Analog*

Magnetic Tape Recorders - FM (0 to 10⁴ KC) and
Direct (0 to 20 KC)

Strip Chart Recorders - Direct writing, multiple
channel and signal channel

Oscillographic Recorders - Direct writing

Channel Multiplexers

Patching and Switching Controls

*All 1500 channels must be recorded on either analog or digital magnetic tapes. Generally, narrow band data will be recorded as digital data on magnetic tape and wide band data will be recorded on analog magnetic tape. Patching will permit, however, redundant recording of narrow band data on analog magnetic tapes where required. Numbers of each type to be defined later.

(4) Data Recording Room - Digital*

Sample Digitizers - Capacity 30,000 samples/sec

Resolution - 1 part in 9,999

Digital Magnetic Tape Recorders and Playback

75 in/sec--556 or 800 pulse packing density

to be decided later

Tape Search and Control

Digital Display Registers

Switching and Patching Controls

(5) Termination and Cabling

(a) Cable termination racks shall be furnished at each end of cable runs.

(b) Termination racks shall be provided such that access is available on each side of dual racks installed back to back.

(c) Termination points will be minimized to the extent practicable.

(d) Cable entry to terminal racks from cable raceways shall be from below the terminal rooms if practicable.

(e) Terminal racks shall be provided with section doors to provide protection against inadvertent disturbance of connections. Control termination racks and cabinets shall be distinctively marked and shall be lockable.

(f) Terminal room subvaults or cable entries shall provide pull areas for cable additions and modifications. Cable raceways to be constructed with pull boxes (manholes) every 1000' or at direction change as

applicable--no angle turns in duct run. Ducts or cable trays to be restricted to 50% fill with normal lay and sloped to drain sump at either end - 1% minimum grade maintained thru manholes and duct runs. No power circuits are permitted in these cable raceways or terminal boxes.

(g) Cable entries and exits to equipment racks shall be from floor plenums or ;under special circumstances from above.

r. Measurement Capacity - 1500 channels of continuous information for 60 minutes.

(1) Engine Measurement and Control Allocation - 540

Channels

Displacement	55
Acceleration	30
Strain	70
Pressure	75
Differential Pressure	55
Speed and/or Counters	2
Temperature	175
Flow	3
Other	75 (Includes necessary refer- ence channels and events*)

* Multiple coordinated events may be combined on a single channel.

(2) Stage Measurements and Control Allocation - 565

Channels

Displacement	15
Vibration	30
Strain	150
Pressure	35
Temperature	200
Flow	5
Miscellaneous	80 (Voltage, current, frequency, neutronics)
Events*	50

(3) Test Stand Facilities and Control Allocation -

395 Channels

Strain	60
Pressure	70
Differential Pressure	60
Vibration	20
Temperature	120
Flow	20
Miscellaneous	20 (Voltage, current, frequency, neutronics)
Events*	<u>25</u> 395

t. System Characteristics (exclusive of transducers)

(1) Accuracies

Class A - ± 0.1 to 0.2% of full scale

Class B - $\pm 1.0\%$

Class C - $\pm 5\%$

The time base shall provide at least 1.0 millisecond resolution at an accuracy of $\pm .001$ milliseconds. Priority diagnostic and control accuracies generally Class A. Others Class B or C.

(2) Diagrams

Narrow Band Channels to 5 cps - 1300 ea.

Wide Band Channels to 3.0 KC - 200 ea.

(3) Sampling Rates - Non-aliasing

Variable from 1 sample/10 seconds to 2000 samples/sec/channel

Generally the order of 10, 20, 40 and 100 samples/sec/channel for run data

u. Transducer Types (Typical)

Pressure, Flow (ΔP) 4 arm bridge type strain gages

Vibration Piezoelectric-Variable Reluctance and Strain

Position Linear Voltage Differential Transformers and Swept Potentiometers*

Strain Compensated half bridges with bridge completion networks

Temperature

Tungsten/Tungsten Rhenium Thermo-
couples

Chromel/Alumel Thermocouples

Copper/Constantan Thermocouples

Resistance Thermometers

Flow

Turbines and Counters (Frequency),

Venturis, Orifices and Nozzles

Acceleration

Variable Reluctance Piezoelectric,
and Strain

Neutronics

Ion Chambers

*Swept Potentiometers will not be used in vibration prone installations.

v. Final data reduction and bulk processing of data is not an integral part of this system design; however, due consideration must be given to formatting, taping and playback to assure compatibility with standardized large scale automatic data processing equipments. Quick look data processing shall be provided for conversion of raw data to engineering units for both in-line and off-line recordings, tabulations, plottings and display.

w. Growth Potential -- Physical space in equipment rooms, cable raceways, etc., shall accommodate a growth of 50% in capacity without requiring construction changes. Power, air conditioning and other utilities shall be designed to permit modular addition where required to support the specified growth potential. Installed duct work, conduit, etc., shall be sized to accommodate a 50% increase in load.

x. Standardization is required to the extent practicable from an operational, maintenance and system performance viewpoint. Flexibility and interchangeability shall be utilized to the maximum extent consistent with performance requirements.

y. Electrical Grounding -- System design shall provide completely independent instrumentation and power system grounds of not more than 0.5 ohms to ground at 10 volts. Joining of the two systems shall be possible at one point in the two systems and inter-connection is to be located only in the Control Center. Multiple grounds are prohibited. Building and equipment cabinets grounding shall be in accordance with approved practices. Ref. VI-D-25.

z. Noise and Cross Talk Consideration

(1) All systems, including power and instrumentation cabling, terminal boxes, controls, etc., shall be designed and installed with maximum practical physical and electrical separation to avoid mutual coupling, and cross talk.

(2) Shielding shall be provided for all signal wires and termination with an additional outer shield for cables consisting of multiconductor groups.

(3) Insulation of all signal channels shall be of high quality and not less than 5,000 megohms per 1000 ft. at 500 volts. Measurements shall be made after line charging and shall be stabilized prior to reading.

B. TCSS (This paragraph provided for information purposes only)

1. TCSS is provided by others and consists of necessary electronics and controls for operating the test item and associated hardware. Appropriate information displays and control functions shall be provided in

the Control Center Control Room, for rapid assimilation and evaluation of operational parameters.

2. Control functions shall be suitably integrated with their respective information display in a coordinated, human engineered fashion.

3. Controls will be provided for start, shutdown, and manual control of the engine system during operation. Normally, all operations will be controlled by the ground test master programmer (specialized on-line digital computer), with override capabilities. In addition, an automatic shutdown capability will be provided with predetermined and variable operational limits in the event of test stand or test item malfunction. It is not expected that manual control will be exercised during periods of rapid transients or when complex control operations on interrelated parameters are required.

4. All remote controls, either for manual or automatic operation, and related test facilities functions will be located in appropriate test operations consoles.

5. Control function simulators shall be provided for exercising and checking out the various control systems both in the normal and malfunction modes of operation. Test articles, simulators and checkout equipment will be furnished by others, as will the control system (TCSS) itself. Interconnecting TCSS cabling or provision for same, console space, control racks space and necessary hardware space will be specified to the Architect-Engineer by others, except that the tunnel portion of this cabling will be by the Architect-Engineer.

6. Control functions shall be designed in the fail safe mode in the event of system or test item malfunction which renders further control capability inoperable.

7. Interfaces with the Data Acquisition Subsystem and Facilities Support subsystems shall provide isolation circuitry to prevent intra-subsystem interactions.

8. Control servo loops shall be contained entirely within the Test Stand Electronics Room for optimum response characteristics.

Remote status and follow-up indicators with set point and demand controls shall be located in the Control Room. Circuitry shall minimize transients when switching from indicated to demand control. Function and ramp generators shall be provided as variable demand controls. Switching transients shall be minimized utilizing comparator gates which prevent humping of control circuitry.

9. Separate control circuitry shall be provided for each Engine/Stage Test Stand including separate control consoles. Test item controls peculiar to each test stand shall be furnished as separate circuitry and control consoles. A typical control room layout is shown in Figure VI-D-1.

C. Facilities Control Subsystem

1. The facilities control subsystem comprises all the necessary functions required in support of the engine/propulsion module tests which are not a part of the TCSS. The channels designated for this subsystem are a part of the basic 1500 channels described under measurement capacity.

2. The facilities control subsystem shall provide local and/or remote control of motors, pumps, valves, and all facility items. Shared facilities shall be displayed on a common display panel under the control of the common facilities control position.

3. Manual operation or locally controlled operators shall be used where feasible. The loading and unloading of cryogenic liquids and gases at facility storage areas shall be accomplished by manual operations with local controls. Local and remote controls shall be provided for emergency dumping of cryogenic liquids thru permissive control of the Control Center. Process vessels, transfer piping, high pressure headers, pumps, turbines, steam generators, gas systems associated with the test operations shall be operated from the Control Center Control Room.

4. All remotely operated valves shall be provided with remote indicators for full-open and full-closed positions and proportional position where applicable.

5. All transducers, actuators, etc., located along pipelines shall be of weather-proof construction whether sheltered or not. Purging or deactivating as applicable capability shall be provided on all fixtures and equipments located in areas requiring explosion-proof installations, if suitable Class I Group B equipment is not available.

6. Safety interlocks shall be provided where necessary to protect personnel and equipment.

7. Controls shall be provided for operation and monitoring of radiation shields, exhaust duct and associated systems including seals and system interfaces.

8. Typical facilities control elements include, but are not limited to the following:

Test Stand Flow Piping Systems

LH₂ Supply and Storage - Level, mass flow rate & capacity

GH₂ Actuation and Supply

Purging Systems

Purging Cooling Gas System

Emergency LH₂ Coolant Supply

D. Facility Support Sub/system

1. Safety Sub/subsystem

The purpose of the safety sub-subsystem is to provide a fail safe, reliable and efficient means of protecting personnel and property against the following types of hazards:

a. Fire

Unsafe oxygen levels

Combustible and/or explosive mixtures

Radiation hazards

Adverse meteorological conditions

b. Analyzer and detection sniffers or sensors shall be strategically located throughout the E/STS 23 complex for the purpose of detecting fire, adverse oxygen concentrations for life support and industrial safety, combustible gas concentrations and radiation levels. Quantitative information and alarms will be transmitted from designated stations to the Control Center for recording and display on the safety console and other designated operational consoles associated with their respective subsystems.

c. Alarm conditions or pre-set warning limits for all systems, including hydrogen leak-detection, will be displayed as visual and audible indications on the safety console and in addition, where appropriate, on the related section of the control and/or facilities consoles. In addition to the automatic safety sensors, manually operated emergency alarm initiating switches shall be strategically located within and about the complex. Each indicator will be capable of being reset from the safety console position. Visual alarm readouts will be provided as flashing red lights and an audible alarm until acknowledged by the safety monitor / engineer, after which time the audible alarm will be silenced and the visible alarms will remain as steady state red indicators until reset. Reset action will clear only when the alarm

condition is ended, otherwise the same sequence will be reinitiated.

d. All alarm indicators will be equipped with two lamps to preclude errors due to burnout. The audible alarm will resound in a pre-set time unless the alarm condition is cleared. Each alarm system will contain a separate audible alarm of different and distinguishable pitch. Alarm squelch shall be provided in every case.

2. A graphic display panel shall be provided which clearly indicates the location and nature of the alarm condition. The display will also clearly show the status of area control indicators used to control personnel and vehicular traffic throughout the complex. Purge status indicators showing various system purge conditions will also be clearly displayed on the graphic display panel.

3. It is required that realistic orientation be utilized in the display but not necessarily to scale of construction in order to minimize the panel size. The control of the panel should be such that, at the safety monitor's option by closing a spring return switch, that only indicators of single system indicator will show, i.e., oxygen content or radiation levels, independently to facilitate rapid review and assimilation of each systems status during pre-firing checkouts. Normally, all alarm indicators will be in the operational mode simultaneously.

4. The safety console will contain an over-ride on the communications system for emergency oral instructions to all personnel within the complex. The safety monitor will also have communications via radio link to remotely located personnel and equipment sites.

a. The fire protection sub-subsystem will consist of a test stand deluge and automatic sprinkler system, fire hydrants, fire

detectors and local fire alarm boxes. The fire protection system for equipment room and floor plenums will consist of CO₂ system rather than water systems with appropriate personnel alarms and delayed triggering in order to permit evacuation of personnel from the endangered area. Capability for the remote operation and monitoring of this subsystem shall be provided at the safety console with command operation restricted to unmanned areas only.

No inter-connections or interface will be permitted between the fire protection subsystem and the other portions of the safety subsystem other than the fire protection subsystem. NBFU code requirements will be used as a guide.

b. A multi-point oxygen detection sub-subsystem will be required, details of which will be dependent on the final configuration of the facility. The following is typical of a possible requirement:

(1) Monitoring duct and shield oxygen concentration prior to exhausting hydrogen.

(2) Monitoring oxygen content of the test stands and steam generators, ducts, shields, etc., for personnel and industrial safety.

(3) Monitoring the atmosphere within the engine compartment to assure that purging operations have been adequate. The oxygen detection subsystem will consist of multi-point rapid response analyzers with associated alarms and concentration display meters located on the safety console. Status indicator for each analyzer will be displayed in appropriate positions on the safety display panel. In addition, parallel outputs from the engine and stage areas will be displayed in the respective segments of the control consoles. All of the above data

is to be recorded at the Control Center data room on multi-channel direct writing recorders. Tentative specifications for the oxygen analyzers are as follows:

Temperature Range - 20°F - 500°F with possible peak temperatures of 5000°F.

Pressure Range - 14.7 psia - 1.0 psia with possible fluctuations to 20 psia at 1/2 cps.

Vibration and Shock - $\pm .2$ in. at 5 - 50 cps with peaks to 30 g's.

Detection Range - 0% - 6% by volume for engine and duct analyzers. Room and steam generator areas - 0 - 25%.

Accuracy - $\pm 2\%$ of full scale. , ,

Radiation Environment Expected.

Time Response - 90% of O₂ content within 15 sec. after a step change from safe to unsafe concentrations.

Analyzer Pump Locations - Use of filters, etc., will consider the possible radiation contamination and consequent hazards to personnel prior to and after tests. Consideration shall be given to the coordinated positioning of radiation detection monitors in conjunction with other equipments and sensors.

(4) Combustible Gas Sub-subsystem Detection - A multi-point combustible gas detection system shall be provided consisting of remote analyzers monitoring the engine, stage, duct, test stand area, flare stack, fill stations and storage farms. Displays and alarms shall be as specified under oxygen concentration analyzers. Performance specifications are essentially identical to those of the oxygen concentration analyzers with the following exceptions:

Range - Analyzers to be operable from 0% - 100% of the lower explosive limit of hydrogen mixtures at corresponding test cell pressures,

i.e., atmospheric, duct pressures, etc.

(5) Radiation Hazards - Radiation monitors will be provided to adequately advise area personnel of hazardous radiation levels. Depending on the proximity to the test item, monitors shall be provided of appropriate sensitivity.

(a) Airborne particulate and gas monitors will be provided with beta and gamma sensitivities of 1×10^{-6} to 1×10^{-1} microcuries per cubic centimeter.

(b) Neutron monitors will be provided to detect both thermal and fast neutrons in the range of 10^{-1} to 10^{-5} neutrons per square centimeter per second. These detectors will operate suitably in gamma radiations up to 10^4 rads/hr.

(c) Radiation sensors, alarms, indicators and reset controls will be essentially as described for oxygen concentration and other hazard alarm systems.

(6) A meteorological sub-subsystem shall be provided to monitor current weather conditions to include wind direction, velocity, barometer pressure and relative humidity. Meteorological parameters will be displayed on the safety console and all parameters will be recorded at the data recording room.

(7) Communications Sub-subsystem

An interphone and public address system shall be provided to support installation and checkout of the test stand including all facilities, instrumentation and control necessary to the conduct of test operations. A minimum of 15 networks shall be provided such that they may be operated individually or in concert as operational requirements dictate. Patching and switching of networks shall be under the control of the communications control console. Each intercom station shall be provided with a call or ring alarm circuit to the communications controller in order

to request connection to the appropriate network. Networks shall be fixed prior to commencement of an actual test and no patching or switching will be accomplished during this period.

(a) Selected intercom networks shall be patchable to the recording center in the Control Center.

(b) All interphone systems will utilize dual jacks for plug-in of head sets as well as panel mounted speakers where required with individual minimum level set volume controls. Circuits will be balanced and loaded so that insertion of interphones to networks will not result in volume or quality disturbance to the system. Disconnection will automatically reconnect load resistors of line impedance values. Side tone circuits will be employed to assist personnel in maintaining proper levels on the line in addition to the usual line equipment.

(c) Radio frequency single side band communications will be provided for outlying stations and such other facilities as necessary to conduct the mission.

(d) A public address system will be provided which interfaces with the safety command control system. The PA system will consist of a main amplifier with terminal amplifiers as necessary in high level noise locations to assure that all personnel can hear operational and all announcements above ambient noise and operation levels.

(e) Cabling, grounding, and installation practices will be in accordance with good engineering practice and essentially as described under the data acquisition system.

(f) Emergency battery power will be provided to operate the interphone/PA system for a period of two hours.

(g) System design will assure maximum flexibility of communications control and provide the means for maintaining reliable, unambiguous communications. Generally, standard practices and specifications will prevail using proven, modular systems, suitable for the purpose.

(8) T.V. Subsystem

A closed circuit TV subsystem will be provided to permit visual observation of activities on the engine/stage test stand and within the test stand area complex. Black and white, color, and IR (infra red) TV systems will be employed.

(a) Areas will be monitored for personnel safety, equipment function and observation of test firings. The monitoring location will be adjacent to the control room and in the control room as necessary to conduct operations and control of the missions. Up to six scenes will be displayed simultaneously with switching provided on the test conductors console for display of any two of the six scenes.

(b) The following specifications apply to the closed circuit TV system:

Scene illumination - 10 to 10,000 foot lamberts

Video - outputs at 9-21" monitors and 10-8" monitors. Recording of two selected video channels on wide band video recorders is required.

(c) Picture characteristics:

Scanning rate - not less than 1000 lines/frame

Resolution - 600 lines

2:1 interlace

30 frames/sec.

9 distinguishable shades of gray with scene

brightness of 20 ft. lamberts using amf/1.5 lens on an EIA test pattern

Non-linearity-less than 2% - vertical or horizontal

Synchronization - 60 cps EIA standards

(d) Camera requirements:

Automatic electronic vidicon protection with

lens cap

Focal lengths 10 to 300 mm

Remote operating controls

Pan $\pm 160^\circ$

Tilt $\pm 45^\circ$

Focus 4 ft. to infinity

Remote switching and patching capability

(e) Camera locations

Tank and fill station areas

Engine/Stage test item

System test stand area

Duct pit

Environmental conditions as stated earlier, including radiation, acoustical noise and vibration as applicable.

(9) Photographic Subsystem

The photo system will provide complete cinema and still photographic coverage of essential E/STS 2-3 activities. The system will contain remotely operated bunkered photo stations containing the following camera types:

<u>Frames/Sec</u>	<u>Field of View</u>	<u>Running Time</u>	<u>Film</u>	<u>Sound</u>
100	70'	60 min.	B/W 16 mm, IR	No
24	30' & 350'	90 min.	Color	Yes
1000	70'	60 min.	B/W, IR	No
100	70'	60 min.	Infra Red	No

(a) Timing marks initiated by the timing system will be recorded on the edge of each camera film using neon bulbs or equivalent as follows:

50 pps serial time code for 24 fps and 100 fps cameras

500 pps serial time code for 1000 fps cameras

Scene Ambient Illumination

for 1000 fps cameras - 4,000 - 10,000 foot candles

for 24 and 100 fps cameras - 400 to 10,000 foot candles

Environmental conditions are as specified earlier.

(b) Lenses and periscopes shall be of good photo-instrumentation quality and suitable for the purpose. Resolution of all optics shall be 70 lines/mm averaged over the entire field. Minimum lens aperture f 3.5. Periscopes shall not degrade the optical characteristics of the camera systems.

(c) Joint usage of camera stations is desired to the extent practicable for viewing E/STS 2-3.

(d) Camera controls for starting and stopping shall be remoted to the instrumentation control console located in the control room of the Control Center. All other necessary controls and monitors shall be located on the photo control panel.

(e) Locally operated controls shall also be provided at the individual camera stations.

(f) Cameras shall be automatically operated in sequence to assure complete coverage of a test run. Malfunction and status circuitry shall be provided as necessary.

(g) Camera stations shall be accessible to personnel to provide fastest possible recovery of film after a test operation.

E. Timing Subsystem

The timing system time references throughout the test complex including time base information to all data recording media (strip chart and event recorders, magnetic tape; analog and digital), photographic film and oscillograms, etc., and includes necessary visual displays to assist in the conduct of the tests.

Time readout shall be capable of the following:

1. Range time - time of day in seconds starting at 12:00 AM (midnight) and recycling the following midnight. This time format is used for all data acquisition, control and recording of the mission.
2. Time of day - local time in hours, minutes and seconds (Hms) based on a 24 hour clock countdown time, run time and hold time may be derived from either of the two basic time formats.
3. The timing system will be compatible with the existing ETS-1 timing system presently in operation at NRDS.

F. Power Subsystem

1. The power subsystem shall provide operational power to the entire Instrumentation & Control system and their associated sub-subsystems.
2. The essence of the power subsystem is the provision of highly reliable, stable and efficient power and power distribution to all equipments and components.
3. In general, good engineering practice will prevail and all power distribution will conform with NEMA and the National Electric codes.
4. System specifications are as follows:

(a) AC Power

Secondary power - 120/208 volts, 3 phase, 4 wire

Voltage Regulation - $\pm 10\%$ (steady state)

Frequency Regulation - ± 1 cps (steady state)

Line to Line Imbalance - Voltage $\pm 2.5\%$ maximum; Load
 $\pm 10\%$ maximum

Harmonic Distortion - Not to exceed 5%

System Power Factor - Not less than 90% lagging

Conduits sized for 50% expansion.

(b) DC Power

28 Volts D.C. $\pm .5\%$ w/battery backup

5. Power distribution for the Instrumentation and Control system will be considered as critical power which excludes all service type loads such as lighting, air conditioning, non-essential mechanical equipment, etc. The operational concept for these power systems requires that the commercial power source and the emergency (back up or standby) power source operate in parallel with sufficient capacity to allow a 50% load expansion such that the failure of either individually will not result in a loss of power. During actual test operations, it is desired that the instrumentation and control load be electrically and physically isolated such that transient commercial or standby power will not result in a disturbance to the I & C system load.

6. Quick acting control relays for under voltage, over voltage, reverse current and fault currents and of tolerance frequency will be provided for the E/STS 2-3. Power transfer from one system to the other will be permitted during test operation; however, the necessary control capability will be provided to operate from either separately or both in parallel as required by specific operational programs.

7. Critical control circuits essential to emergency shutdown, scram or safety will be isolatable from the main power system and will be capable of operating from separate battery-driven or propane turbine motor generator sets with sufficient capability to function through any AC powerless internal within the emergency cooldown and shutdown cycle.

emergency cooldown and shutdown cycle,

8. The Government will provide a 69 KV Ring Bus System with a thru feed to E/STS 2-3 with appropriate sectionalizing switches, OCB's, etc., to assure reliable and continuous power for E/STS 2-3 and the NRDS site from either or both commercial power sources and/or a size diesel generator of 69KV, 11 megawatt capacity standby and emergency power station located in the vicinity of E/STS 2-3 and capable of operating in parallel on the 69 KV Ring Bus. It is thus intended that short of a catastrophic situation, that the maximum off power condition will be 30 sec. or less. In this event, the I & C Power System which will be provided with a stored energy motor generator system, will continue as uninterrupted, transient free power throughout the entire operation.

9. Consideration will be given and provision made for the installation of a prime mover for either the stored energy motor generator or the emergency battery power system in the event that the battery power requirement is economically impractical and insufficient to fulfil emergency shut down requirements. Detailed requirements for this emergency cycle will be provided at a later date; however, the emergency cooldown and shutdown cycle can last ten days (240 hours).

10. Critical parameters of the power system performance will be recorded in the control room recorder room.

11. Power system status indicators, malfunction controls and alarms will be provided on the instrumentation control console.

FIGURE VI-D-1 - TYPICAL DATA ACQUISITION SUBSYSTEM

TYPICAL CONTROL ROOM LAYOUT
FIGURE VI-D-3

E. Exhaust System

1. Scope

(a) Purpose

The purpose of this section is to describe the exhaust system requirements and to present sufficient information to enable the Architect-Engineer to make preliminary test stand configuration layouts, prepare a detailed procurement specification, and to prepare cost estimates. The final definition of the exhaust system will be determined by analyses and model testing of concepts. The A & E will consider various exhaust systems, will select the most economical necessary to satisfy the operational and safety requirements, and will prepare preliminary test stand configuration layouts and prepare cost estimates consistent with the exhaust system selected. The test stand configuration shall not preclude the future installation of an exhaust duct for a 10,000 MW engine.

(b) Operational and Safety Requirements

The following requirements must be satisfied.

(1) Altitude pressure simulation at the nozzle and turbine exit must be provided.

(2) Controlled removal of exhaust effluent from engine and turbine must be provided.

(3) Combination of H_2 -Air in the exhaust duct during any operating condition including startup and shutdown is prohibited with a wind of 10 MPH directed into the exhaust duct.

(4) Combination of H_2 -Air in the exhaust duct during an abrupt stoppage of hydrogen flow from the exhaust nozzle is prohibited, with a wind of 35 MPH.

At this time an abrupt stoppage will be defined as not more than 100 PSI change in chamber pressure in 200 milliseconds.

(5) The exhaust system will operate without damage through 100 cycles of operation.

(6) The NES shall be capable of being placed in an onstream condition any time during a five minute period preceeding initiation of hydrogen flow within (15 seconds) demand.

(7) With an engine chamber of 500 PSIA or greater the NES shall be capable of supplying a sufficiently low nozzle back pressure to permit the nozzle to flow full without the ejector operating for a period of 30 minutes. The system shall be capable of supplying a low back pressure at partial power engine operation for up to 20 minutes.

(8) During post run period the NES shall handle the shutdown fluids as described in Tables III-3 and III-4.

(9) Turbine Exhaust Flow

The turbine will exhaust within an exit diameter of 109 inches or 2" larger than the 106.97 nozzle exit diameter illustrated on AGC Drawing No. 7926, 8-26-66.

(10) The 125 inches gas jet diameter gimballed dimension is a maximum for all gas flow leaving the engine, and all tolerances are minus. This dimension includes engine vibration and engine deformation caused by vacuum, temperature and multiple usage.

2. Objectives

An exhaust system will be defined that is the most economical in terms of construction, operation and logistics and will provide for all the necessary requirements. The exhaust system shall consist of a primary diffuser and a single stage secondary ejector system that will provide for a back pressure no greater than 2 psia during the start, run and shutdown operating envelopes of the engine. These envelopes are presented in Section III. The exhaust system shall accommodate an engine with a 40:1 area ratio exhaust nozzle having an exit flow diameter of 107 inches (109 inches including turbine exhaust). The exhaust system should operate satisfactorily with the engine gimbaling + 1 1/2° (3° cone) with a gimbal station located 304 inches from the exit plane of the nozzle; at a maximum velocity of travel of 0.25 degrees per second, and at a maximum acceleration of travel of .01 degrees per second². Consideration of the design of the NES will assume that gimbaling will occur during only the maximum power engine operation conditions.

3. System Description

It is envisioned that the exhaust system will contain a chamber surrounding the nozzle or attached to the engine. The exhaust system will consist of a vertically oriented primary diffuser followed by a subsonic 90° elbow and a single stage ejector.

On the basis of system costs, storage costs, logistics and overall fluid costs, steam is to be considered as the primary candidate for ejector fluid. Other fluids will be considered. Only storage in liquid state will be considered for the working fluids. Consideration can be given to any means of economically supplying the working fluid, i.e. gas generators, accumulators, etc.

Initial studies of the exhaust system have indicated that the exhaust system will self-pump when the engine is operating at chamber pressures above 500 psia, and will provide back pressure of less than 2 psia at the nozzle exit. Therefore, maximum operation of the ejector system to provide altitude simulation will be required only during the engine startup and shutdown phases. During the engine pre-fire period, full power operation and post-shutdown period, a purge system or valve system shall be provided to prevent any combination of H_2 -Air in the exhaust duct. It has been estimated that ejector fluid flow requirements equal to $1/2$ of the maximum fluid flow necessary for pumping will provide adequate purge during full power operation. Therefore, the use of the ejector system will be considered as the purge system. The emergency cooldown system as discussed in Section III will also be considered separately or in combination with the ejector system as a purge system.

4. Other Considerations

With respect to exhaust assembly system installation and removal, the design is to be such as to permit manual installation with provisions for subsequent removal by remote methods for maintenance and possible replacement. Consideration will also be given to decontamination of the exhaust assembly in a forward area in the event of a nuclear accident.

The instrumentation for the exhaust system will consist of the sensors and other components required to sense and transmit parameters such as pressure, temperature, flow, vibration and strain through suitable cables and connectors to interface with the test stand.

With respect to water coolant, only treated water should be used for all internal flow conditions. The entire exhaust system shall be self-draining. There should be no leakage of coolant water into the engine chamber or exhaust duct.

There can be no external leakage of GH_2 or exhaust gases from the exhaust system.

VII
SITE INFORMATION

Section VII consists of meteorological, geological, and site data, and will be transmitted as an attachment to this criteria.

VIII

GOVERNMENT STANDARDS

A. Mandatory Requirements

To extent feasible the requirements of the National Aeronautics & Space Administration's Facilities Publication NPC 325-1, "Manual of Design Criteria and Construction Standards", will be incorporated into the design and construction of E/STS 2-3.

Minimum safety standards which must be satisfied are as follows:

1. General Safety

(a) Safety Code for building construction, ASA-A10.2 or other standards which provide equal or greater protection than A10.2.

2. Fire Protection

(a) National Fire Codes (NFPA)

(b) Union Building Code (PC)

3. Radiation Protection

(a) Permissible levels of radiation exposure, AEC Manual Chapter 0524

4. Health Protection

(a) National Plumbing Code, ASA-A408.

(b) AWWA Standards and specifications for water supply, treatment, distribution system and storage equipment, materials and procedures.

(c) Public Health Service Drinking Water Standards, P.H. Reports 61:371. Reprint No. 2697.

(d) State and local Public Health Codes which cover sanitation.

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29. Report NSP-64-15, RIFT NRDS Facilities Requirement Development, Status Report, dated March 15, 1965, Especially with reference to section 3.1, pg. 77, Vacuum Deflector and Open Deflector Concept.

"Section IX Quality Assurance

9.1 General

The objective of the criteria shall be to provide that the contractor will be responsible for and shall implement a quality program in accordance with MIL-Q-9858A which shall include the submittal of a Quality Program Plan for approval. This Plan will automatically be a part of the work statement and will describe functionally the management of this effort with particular emphasis on review of engineering and procurement documents, surveillance of subcontractors, and control of manufacturing processes.

The 'Guidelines For Quality Control,' Section 2 of Volume IV of Report No. 66-21-RE(D) dated May, 1966, apply with the following additions:

9.1.1 Drawings and Documents

Design drawings and related documents will be reviewed during the design phase in conjunction with 30%, 70%, and 100% design review meetings for proper consideration of inspection techniques and inclusion of quality requirements. These drawings and documents will be signed off by Quality Assurance. ?

9.1.1.1

The engineering drawing shall incorporate as a minimum:

- a. Tolerances
- b. Nondestructive testing requirements with definitive symbols
- c. Welding symbols
- d. Special process parameters
- e. Critical, major and minor characteristics

9.1.1.2

The quality control section of each design document shall provide for as a minimum:

- a. Control of special processes
- b. Mock-ups where accessibility or unique technique is a factor
- c. Special tests to verify material properties that are limiting to the design

9.1.2 Procurement

The procurement packages shall include reference to all drawings and related documents, latest revision. These packages will be signed off by design Quality Assurance and submitted to the Project Director for approval.

9.1.3 Suppliers

Quality Assurance approval will be obtained for suppliers based on either his quality history or a reported survey of his facilities."

9.2 Structural Standards

The Contractor shall adhere to standards specified in Section 3, Volume IV, Kaiser Report No. 66-21-RE(D). Structural Design Specification, SNPO-C-1 shall be utilized for structural items not covered by the aforementioned report.

9.3 Material Standards

The Contractor shall adhere to standards specified in Section 4, Volume IV, Kaiser Report No. 66-21-RE(D).