SYSTEM DESIGN
SPECIFICATION
BRAYTON ISOTOPE POWER
SYSTEM (BIPS)
FLIGHT SYSTEM (FS)
AND
GROUND DEMONSTRATION SYSTEM (GDS)

SC-76-311742A

June 14, 1976

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SYSTEM DESIGN
SPECIFICATION
BRAYTON ISOTOPE POWER
SYSTEM (BIPS)
FLIGHT SYSTEM (FS)
AND
GROUND DEMONSTRATION SYSTEM (GDS)

1. INTRODUCTION

This document provides the system design specification for ground demonstration, development, and flight qualification of a Brayton Isotope Power System (BIPS). This specification defines the requirements for both a BIPS conceptual Flight System (FS), and a Ground Demonstration System (GDS).

1.1 Purpose

The purpose of this specification is to define in detail, DOD, NASA, AiResearch, and subcontractor performance, design, development, environmental, test, and operational criteria for the BIPS FS and GDS systems.

1.2 Scope

This specification encompasses all essential design, development, and test requirements for the BIPS FS and GDS. Appropriate cross-reference is provided in the following sections of this specification to define applicable requirements to both systems being designed, or as appropriate to either the FS or GDS system.

Paragraphs herein preceded by a single asterisk(*), indicate requirements applicable to both the BIPS FS and GDS segments. Paragraphs preceded by a double asterisk(**) indicate a requirement applicable to the BIPS FS only. Paragraphs with no identifying asterisk are applicable to the GDS only.

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A general categorization of the two systems is as follows:

BIPS FS - The flight system is an isotope heated thermodynamic conversion electrical power source for spacecraft utilization, wherein 500 to 2000 W_e is required. The system is to be designed for spacecraft launch by a Department of Defense Space Transportation System (DOD STS) Space Shuttle Vehicle (SSV), and where applicable transferred into geosynchronous orbit by an Interim Upper Stage (IUS) system segment.

BIPS GDS - A ground demonstration system designed to simulate, for ground test purposes, as closely as possible the BIPS FS. The GDS shall be performance and endurance tested to verify system design objectives.

As an aid to specification interpretation, a listing of commonly used abbreviations and acronyms is provided by Table B17331, Rev. 1.

TABLE B17331, REV. 1
BIPS PROGRAM

ABBREVIATIONS AND ACRONYMS

A		E	
ABS	Auxiliary Battery System	ECS	Emergency Cooling System (for HSA)
ACS	Auxiliary Cooling System (for HSA)	EHS-D	Electrical Heat Source - Dynamic
ACS	Attitude Control System	EHS-S	Electrical Heat Source - Static
AEC	Atomic Energy Commission (now ERDA)	ELS	Eastern Launch Site
AEC PR	Atomic Energy Commission Procurement Regulation	EMS	Material Specification (AiResearch Term)
AIRPHX	AiResearch, Phoenix	EQM	End of Mission
AIRLA	AiResearch, Los Angeles	ESD	Electronic System Division (of Air Force Systems Command)
AFSCF	Air Force Satellite Control Facility	ET	External Expendable Tank
AM	Amplitude Modulation	EPS	Electrical Power System
AOA	Abort-Once-Around	ERDA	Energy Research and Development Administration (Formerly AEC)
ASE	Airborne Support Equipment	EVA	Extravehicular Activity
ARS	Atmospheric Revitalization Subsystem	F	
ATO	Abort-To-Orbit	F	Fahrenheit Degrees
ATCS	Active Thermal Control Subsystem	FBS	Flight Battery System Required for Start in Orbit
a/o	Atomic Percent	FIB	Fuel Impact Body
B		FM	Frequency Modulation
BCL	Battelle Columbus Laboratory	FMA	Failure Mode analysis
BOM	Beginning of Mission	FMEA	Failure Modes and Effects Analysis
BIPS	Brayton Isotope Power System	FMECA	Failure Modes, Effects and Criticality Analysis
BRU	Brayton Rotating Unit	FPR	Federal Procurement Regulation
C		fps	Feet per Second
C	Celsius (Centigrade) Degrees	FS	Flight System
CCAFS	Cape Canaveral Air Force Station	FSA	Fuel Sphere Assembly
CCD	Configuration Control Document	FSAR	Final Safety Analysis Report
CCTV	Closed Circuit Television	FSE	Flight Support Equipment
CFM	Cubic Feet per Minute	FSEC	Fairchild Space and Electronics Company
C.G. or CG	Center of Gravity	FUO	Follow-up Output
CO2	Carbon Dioxide	FT	Feet, Foot
CRT	Cathode Ray Tube	FWW	Food, Water and Waste Management
CSI	Control Servo Input	G	
D		g	Acceleration Due to Gravity
DAS	Data Acquisition System	GDS	Ground Demonstration System - PCS + EHS-S
db	Decibel	GE	General Electric, Valley Forge
DC	Direct Current	GET	Ground Elapsed Time
DCS	Demonstrator Cooling System	GFE	Government Furnished Equipment
Delta-V or ΔV	Velocity Change in Feet per Second	GMS	Gas Management System
DOD	Department of Defense	GMT	Greenwich Mean Time
DOD STS	Department of Defense Space Transportation System	GN2	Gaseous Nitrogen
E		GN&C	Guidance, Navigation and Control
EAI	Engineering Assembly Instructions	GSE	Ground Support Equipment
EAFB	Edwards Air Force Base	GTC	Ground Test Console (a STE/GSE item)
EPFS	Electrically Powered Flight System (PCS + EHS-D)		
ECLS	Environmental Control and Life Support		

BIPS PROGRAM

H

HIP	Hot Isostatic Press
HS	Heat Source (Same as and replaced by IHS)
HSA	Heat Source Assembly (Does <u>not</u> include EHS or HSS. Does include HSHX, structure, insulation, ACS and ECS.)
HRHX	Heat Rejection Heat Exchanger (Radiator simulator for GDS)
HSHX	Heat Source Heat Exchanger
HSIS	Heat Source Insulation System
HSS	Heat Source Simulator (Same as and replaced by EHS)
HTGR	High Temperature Gas Cooled Reactor

I

IBFS	Isotope Brayton Flight System
IBGDS	Isotope Brayton Ground Demonstration System (PCS + EHS-S)
IHE	Isotope Handling Equipment
IHS	Isotope Heat Source
IMU	Inertial Measurement Unit
IUS	Interim Upper Stage
IVA	Intra Vehicular Activity

J

JPL Jet Propulsion Laboratory
 (Pasadena, California)

JFC Johnson Space Center (Houston)

K

KB	Keyboard
Kbaud	Code Elements per Second in 1000's
Kbps	Bits per Second in 1000's
KSC	Kennedy Space Center
KW _e	Kilowatts Electrical
KW _t	Kilowatts Thermal

L

LASL	Los Alamos Scientific Laboratory
LCC	Launch Control Center
LES 8/9	Lincoln Experimental Satellite (No. 8 and 9)
LF	Load Factor
LH2	Liquid Hydrogen
LiOH	Lithium Hydroxide
LO2	Liquid Oxygen
LPS	Launch Processing System

M

M	Meters
MARSCOM	Materials Review and Selection Committee
MBR	Mini-Brayton Recuperator
Mini-BRU	350 to 2100 Watts Electrical Brayton Rotating Unit
MCC	Mission Control Center
MDM	Multiplexer-Demultiplexer

M

MECO	Main Engine Cut-Off
MHW	Multi-Hundred Watt (AEC/GE IHS Technology)
MHZ	Megahertz
MM	Millimeters
MMD	Mean Mission Duration
MOS	Mission Operation System
MR	Milliradians
MSS	Mission Specialist Station
MW	Molecular Weight

N

NA	Not Applicable
NASA LeRC	National Aeronautical and Space Administration Lewis Research Center
NRA	Nuclear Research and Applications, Division of ERDA (formerly SNS)

0

OBP	Orbiter Processing System
OHA	Operational Hazard Analysis
ORNL	Oak Ridge National Laboratory
OMS	Orbital Maneuvering Subsystem

P

PCL	Power Conversion Loop (Use of PCS preferred)
PCM	Pulse Code Modulation
PCR	Payload Changeout Room.
PCS I	Power Conversion System (HSA + BRU + MBR + Heat Sink + Controls + Piping and structure
PCS II	Power Conversion System (HSA + BRU + MBR + Radiator + Controls + Piping and Structure
PGHM	Payload Ground Handling Mechanism
PHA	Preliminary Hazard Analysis
PLC	Parasitic Load Control System
P/L	Payload
PLCC	Payload Control Center
PLH	Payload Handling
PLM	Payload Management
POP	Perpendicular to Orbit Plane
PSAR	Preliminary Safety Analysis Report
PSC	Power Supply Console (for RHS)
PSC	Procurement Specification (AiResearch Term)
PSE	Peculiar Support Equipment
PSS	Payload Specialist Station
PSSR	Preliminary System Safety Review
PICS	Plutonium Isotope Containment Shield

Q

QA Quality Assurance

TABLE BL7331, REV. 1
BIPS PROGRAM

ABBREVIATIONS AND ACRONYMS
(CONTD)

R		V	
RCS	Reaction Control System	VAB	Vehicle Assembly Building
RCS	Radiator Cooling System	VAFB	Vandenberg Air Force Base
REM	Roentgen Equivalent Man	VDC	Volts Direct Current
RF	Radio Frequency	VHF	Very High Frequency
RM	Remote Manipulator	VRE	Voltage Regulator Exciter
RMS	Remote Manipulator System		
RSS	Root Sum Square		W
RTLS	Return to Launch Site	w/o	Percent by Weight
RTG	Radioisotope Thermoelectric Generator		
RTS	Remote Tracking Station		
S			
SAMSO	Space and Missile System Organization		
SNS	Space Nuclear Systems (now NRA)		
SMAB	Solid Motor Assembly Buildup		
SRB	Solid Rocket Booster		
SRM	Solid Rocket Motor		
SSP	Space Shuttle Program		
SSME	Space Shuttle Main Engine		
SSS	Space Shuttle System		
SSPP	System Safety Program Plan		
SSV	Space Shuttle Vehicle		
STDN/ TDRSS	Space Tracking and Data Network/Tracking Data Relay Satellite System		
STE	Special Test Equipment		
STS	Space Transportation System		
SURVSATCOM	Air Force Survivable Communication Satellite (now AFSATCOM III)		
T			
TACB	Temperature of Cabin		
TBD	To Be Defined		
TDRS	Tracking and Data Relay Satellite		
TECO	Thermo Electron Corporation		
TES	Teledyne Energy System (formerly Teledyne Isotopes)		
TIT	Turbine Inlet Temperature		
TV	Television		
U			
ULT	Ultimate Loads		
USAR	Updated Safety Analysis Report

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*2. APPLICABLE DOCUMENTS

*2.1 Government Documents

The following documents of the issue in effect on the date specified form a part of this specification to the extent specified herein. When the documents noted are referenced in this specification, revision letters and issue dates are omitted. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this document shall be the superseding requirements.

Specifications

Military

MIL-B-5087B 31 Aug 1970	Bonding, Electrical and Lighting Protection for Aerospace Systems
MIL-E-6051	Electromagnetic Compatibility Requirements, Systems
MIL-E-8983B 2 July 1973	Electronic Equipment, Aerospace Ex- tended Space Environment, General Specification for
MIL-P-9024G (USAF) 6 June 1972	Packaging, Materials Handling and Transportability, System and System Segments, General Specification for
MIL-T-21200L 2 July 1973	Test Equipment for Use with Electronic and Electrical Equipment, General Specification for
MIL-W-83575 (USAF) 1 March 1973	Wiring Harness, Space Vehicle, Design and Testing

Other Government Activity

JSC 07700 Volume XIV, Rev. D 26 Nov 1975	Space Shuttle System Payload Accommodations
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Specifications (Contd)

Other Government Activity (Contd)

SS-STG-100 Volume 3, Code 07868 15 Jan 1976	System Specification, Performance and Design Requirements for the Department of Defense Space Transportation System, Volume 3, Interim Upper Stage, Basic Requirements for
SAMSO-LVR-0001 21 July 1975	USAF Payload - Orbiter Electrical EMC Specification
SE-R-0006B TBS	NASA-MSFC Requirements for Materials and Processes
SP-R-0022 Sept 1974	Specification, Vacuum Stability Requirements of Polymeric Material for Spacecraft Applications
SN-C-0005 TBS	Specification, Contamination Control Requirements for the Space Shuttle Program

Standards

Military

MIL-STD-129F 30 Mar 1973 Change 1 20 May 1974	Marking for Shipment and Storage
MIL-STD-130D 05 Mar 1971 Change 3 01 Aug 1973	Identification Marking of U.S. Military Property
MIL-STD-461A 01 Aug 1968 Change 6 03 July 1973	Electromagnetic Interference Characteristics, Requirements for Equipment
MIL-STD-1246A 18 Aug 1967	Product Cleanliness Levels and Contamination Control Program
MIL-STD-1472B 31 Dec 1974	Human Engineering Design Criteria for Military Systems Equipment and Facilities

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Standards (Contd)

Military (Contd)

MIL-STD-1522 (USAF) 01 July 1972	Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Vehicles
MIL-STD-1539 (USAF) 01 Aug 1973	Electrical Power, Direct Current, Space Vehicle Design Requirements
MIL-STD-1540A (USAF) 15 May 1974	Testing Requirements for Space Vehicles
MIL-STD-1541 (USAF) 15 Oct 1973	Electromagnetic Compatibility Requirements for Space Systems
MIL-STD-1542 (USAF) 15 Apr 1974	Electromagnetic Compatibility (EMC) and Grounding Requirements for Space System Facilities

Industry

DO-160 (RTCA)	Environmental Conditions and Test Procedures for Airborne Electronic/ Electrical Equipment and Instruments
IEEE STD-100-1972	IEEE Standard Dictionary of Electrical and Electronic Terms (see Note 1)

Drawings

Interface Control Drawings
TBD

Other Publications

Manuals

AFETRM 127-1 Volume 1 1 Sept 1972	Range Safety Manual
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Handbooks

MIL-HDBK-5B 15 Aug 1974	Metallic Materials and Elements for Aerospace
MIL-HDBK-23 3 June 1974	Structural Sandwich Composites

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Other Publications (Contd)

SAMSO Standards (Formerly SAMSO Exhibits)

SAMSO-STD-73-2C 03 Sept 1974	Electronic Parts, Materials, and Processes for Space and Missile Applications, Standard Control Program for
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Miscellaneous Documents

NASA TM X-64627 15 Nov 1971	Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development
NASA KSC GP-863 Rev. 1 02 Feb 1973	General Criteria for Design of New Equipment and Facilities to be Utilized at KSC
KMI 1710-1B 09 Oct 1970	KSC Safety Program
NASA TBS	Safety Policy and Requirements for Payloads Using the Space Transportation System
SNS-1, Rev. 1 28 February 1975	Quality Assurance Program Requirements for Space Nuclear Systems
SNS-2 17 June 1974	Reliability Engineering Program Requirements Publication

2.2 Non-Government Documents

The following documents of the issue in effect on the date specified form a part of this specification to the extent specified herein. When the documents noted are referenced in this specification, revision letters and issue dates are omitted.

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Specifications

AiResearch

QC-048, Rev. 4
1 Oct 1974

General Quality Program Plan

Other Documents

75-311274B
15 Mar 1976

Brayton Isotope Power System
Configuration Control Document

76-311737
10 Feb 1976

Specification Requirements Summary
Brayton Isotope Power System (BIPS)
Ground Demonstration System (GDS)

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*3. DESIGN REQUIREMENTS

The Brayton Isotope Power System (BIPS) Flight System (FS) and Ground Demonstration System (GDS) design requirements shall be as defined herein. Design requirements described in the following sections/paragraphs of this specification are based primarily on applicable requirements extracted from NASA Document JSC07700, Volume XIV, Space Shuttle Payload Accommodations, and DOD STS Document SS-ST5-100, Volume 3, System Specification, Performance and Design Requirements for the Department of Defense Space Transportation System. System configuration is further defined by AiResearch Configuration Control Document 75-311274.

System Definition

The basic BIPS is a space power energy system utilizing a closed Brayton dynamic system to convert 4800 W_e energy BOM, from an isotope heat source, to produce 1300 W_e useful power BOM. The electrical power will be provided at 120 vdc. The BIPS segment will be carried into geosynchronous orbit as part of the spacecraft payload of an Interim Upper Stage (IUS) system segment of a DOD STS Space Shuttle Vehicle (SSV).

General Description - The BIPS shall be an integrated combination of components, subsystems, and equipment, which comprise the FS, or GDS, defined as follows:

BIPS FS - consists of the following major components/
subsystems or elements:

- (a) Mini-BRU (Brayton Rotating Unit)
- (b) Recuperator
- (c) Radiator (circular)
- (d) Heat Source Assembly (HSA) (containing the Nuclear Isotope Heat Source)

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- (e) Refractory Plenum (part of Mini-BRU)
- (f) Multi-Foil Insulation
- (g) Bellows/Ducting Assemblies
- (h) Support Structure
- (i) Control System
- (j) Working Fluid
- (k) Ground Support Equipment

BIPS GDS - consists of the following major components/subsystems or elements. Items preceded by a Δ indicate those components that are different, or in addition to the FS:

- (a) Mini-BRU (Brayton Rotating Unit)
- (b) Recuperator
- Δ(c) Heat Rejection Heat Exchanger
- Δ(d) Heat Source Assembly (HSA) (containing the Electric Heat Source)
- (e) Refractory Plenum, (part of Mini-BRU)
- (f) Multi-Foil Insulation
- Δ(g) Bellows/Ducting Assemblies
- (h) Support Structure
- Δ(i) Control System
- Δ(j) Working Fluid
- (k) Ground Support Equipment
- (l) Space Simulation System

A summary of similarities and differences between the GDS and FS is presented in Table 3-1.

The following BIPS GDS components shall be provided as GFE hardware. Also listed is the applicable Government supplier/subcontractor:

TABLE 3-1
SIMILARITIES AND DIFFERENCES
BETWEEN THE BIPS GDS AND THE BIPS FS

SUB-SYSTEM	CONFIGURATION	MATERIALS	PERFORMANCE	WEIGHT
MINI BRU	Identical except for instrumentation (Added for GDS tests)	Identical	Identical	Identical (38 pounds)
MBR	Similar except for instrumentation (Added for GDS tests) and size (MBR used in GDS tests is oversize since it has been optimized for three HSAs rather than two). The same basic design can be incorporated into a smaller version optimized for the 2 HSA flight system.	Identical	FS optimized for 2 capsule operation; GDS optimized for 3 capsules	Less for flight system (134/106 pounds)
HSA	Identical except for: 1) Instrumentation (added for GDS tests), 2) EHS power leads (for GDS), 3) Gas management valve (used only in HSA for FS for venting helium generated by isotope decay), and 4) Auxiliary cooling valve (used for venting cover gas from insulation - the GDS will utilize system which will permit reinjection of cover gas; FS ACV will be one-shot mechanism, probably actuated by radio command).	Identical except for external support housing and end domes (stainless steel for GDS; Beryllium for FS) and as noted under "configuration"	Identical	Similar; FS predicted to be somewhat lighter, primarily because Beryllium will replace stainless steel for housing.
RADIATOR	GDS will utilize a liquid to gas HRHX to simulate the space radiator of the FS	GDS HRHX - copper; FS - radiator - aluminum or Beryllium or Lockalloy	HRHX will simulate space radiator	(FS ~80 pounds) in Beryllium
CONTROLS	GDS: All circuits breadboarded; circuit boards to be plug-in type; no hybridizing; ease of accessibility and reliability prime considerations. Parasitic load and load drivers convection cooled. FS: All circuits hybridized; packaged for minimum volume, weight. All cooling by radiation	TBD	Identical	Flight System lighter due to hybridizing electronic components (FS ~ 10 pounds)
BELLOWS AND DUCTS	Identical except HRHX ducting for GDS different from radiator ducting of FS. FS has two more low temperature bimetallic joints. (HRHX inlet/outlet ducting). GDS has 15 more weld joints than FS.	Identical	Identical	Basic system without cooler and radiator identical. (FS ~27 pounds)
STRUCTURE	Identical except GDS uses vac tank support in place of radiator for FS. Radiator/ component support structure interface ring is identical to FS interface ring.	GDS uses all aluminum. FS uses Lockalloy and Beryllium	Identical	FS lighter structure (FS ~ 32 pounds)
INSULATION	Identical except for additional instrumentation penetrations	Identical	6 to 8% higher thermal loss in GDS (300 to 400 watts) due to instrumentation penetrations.	Identical (18 pounds)

- NOTES: (1) Although intended to be "identical" in many instances, lessons learned from GDS, performance and endurance tests may lead to changes in flight system components and/or configuration.
- (2) For test purposes, GDS will incorporate a number of additional valves, gas supply systems, and protective devices.
- (3) GDS loop will contain two turbine bypass shutoff valves and a pressure relief valve for development testing protection; FS will not.
- (4) GDS loop will contain a one-way check valve in compressor inlet to eliminate the possibility of reverse flow during startup. Possibility of removing check valve from FS will be investigated during GDS testing.
- (5) GDS loop will not be as well sealed as the FS because of extensive instrumentation and greater number of potential leak paths. For this reason, an He-Xe tank will be connected to GDS loop. A pressure regulator will control inlet pressure into closed loop and provide replenishment of working fluid to compensate for leakage. The FS will be sealed after initial charging.
- (6) Flight monitoring system will be included in GDS to a limited degree. Transducers selected for flight, and some associated electronics, will be included in GDS test.

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<u>Component</u>	<u>Supplier/Subcontractor</u>
(a) Mini-BRU	AiResearch-Phoenix
(b) Recuperator	AiResearch-Los Angeles
(c) HSA/EHS	General Electric
(d) Power Supply Console	General Electric

*3.1 General Requirements

**3.1.1 Definition of Terms

The BIPS FS, when spacecraft mounted, shall perform in conjunction with the Space Shuttle System (SSS) segment of the DOD STS. The SSS segment is comprised of the Space Shuttle Vehicle (SSV) and associated ground operations capability at the Eastern Launch Site (ELS), including the Kennedy Space Center (KSC). The SSV, also known as the Space Shuttle or Shuttle, is a manned vehicle designed to operate in low-earth orbits. SSV elements are a reusable Orbiter vehicle, the Space Shuttle Main Engines (SSMEs), an expendable external tank (ET) containing propellants for the SSMEs, and two solid rocket boosters designed for retrieval, refurbishment, and reuse.

**3.1.1.1 IUS Vehicle

The IUS vehicle is an expendable stage that leaves the Orbiter and places the spacecraft, including attached systems such as the BIPS FS, in extended earth orbits or in planetary mission orbits. It includes the; stage structure, solid rocket motors, reaction control system, avionics for guidance, navigation and control, telemetry, tracking and command communications, instrumentation, data

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management equipment, and required electrical power and electrical cabling. The IUS vehicle also includes the stage to spacecraft/BIPS FS interfaces.

**3.1.2 Mission Duration

The BIPS shall be capable of operation for the duration specified in 3.1.3 after being deployed aboard the spacecraft. The BIPS shall be capable of remaining in the Orbiter payload bay attached to the spacecraft, which is in turn attached to the IUS, before deployment for a time consistent with pre-launch, launch, ascent, and orbital operations. The BIPS shall (a) be capable of remaining attached to the spacecraft in the payload bay for a minimum of three orbital periods, and (b) also be compatible with abort, descent, and post-landing operations. Specifically, a cooling system consistent with an aborted mission lasting (TBD) upon detachment from GSE to reconnection of GSE cooling shall be defined.

**3.1.3 Life Requirements

The BIPS shall be designed to operate at required performance characteristics for a life, L , of seven years with a mean mission duration (MMD) of five years where:

$$MMD = \int_0^L R dt$$

and

R = probability of producing design
power at time, t

Notwithstanding this requirement, AIRPHX has established a more stringent objective of $R = 0.95$ after 5 years operation. Analyses shall be conducted to identify prelaunch, launch, and operational phase failure modes.

3.1.4 DC Power Characteristics

The designation dc power characteristics applies to voltages in a direct-current, two-wire or ground return system.

3.1.4.1 Nominal DC Voltage

The nominal dc voltage magnitude is 120 volts.

3.1.4.2 Distortion

Distortion is the rms value of the superimposed alternating voltage.

3.1.4.3 Distortion Factor

The dc distortion factor is the ratio of the dc distortion to the average dc voltage.

3.1.4.4 Distortion Spectrum

The distortion spectrum quantifies dc distortion in terms of the amplitude of each frequency component. The distortion spectrum includes the components resulting from amplitude and frequency modulation as well as harmonic and nonharmonic components of the ac waveform.

3.1.4.5 Electrical Power Characteristics

The electrical power characteristics include values and limits of voltage and frequency parameters, and include related characteristics pertinent to electromagnetic compatibility requirements as well as those designated in ac and dc subcategories. These characteristics are representative of steady and transient states experienced in system operation during all phases of operation.

3.1.4.6 Electric Power System

The electric power system is that group of connected generation, distribution, protective and conversion equipments active in supplying electric power to utilization equipments.

3.1.4.7 Electromagnetic Compatibility

The capability of systems and associated equipment to perform at specified levels in the total electromagnetic environment.

3.1.4.8 Frequency

Frequency is equal to the reciprocal of the alternation period of the fundamental of the ac voltage. The unit of frequency is the number of alternations per second of the ac voltage and is designated Hertz (Hz).

3.1.4.9 Overvoltage and Undervoltage

Overvoltage and undervoltage are those voltages which exceed the combined steady state and surge limits and are usually terminated by the action of protective devices. Although generally short lived, they differ from surges in the sense that, if left unchecked, they would continue indefinitely at their fixed magnitude or until some breakdown in operation was precipitated. Overvoltage and undervoltage can exist indefinitely at values slightly exceeding steady state limits but within the trip limits of the generator protection circuits. They are generally due to loss of regulator control, to unbalance, or to faults, i.e., causes other than those producing surge voltages.

3.1.4.10 Ripple Amplitude

The ripple amplitude is the maximum value of the difference between the average and the instantaneous values of a pulsating unidirectional wave (see 2.1, IEEE Standard).

3.1.4.11 Steady State

A steady state condition of the characteristics is one in which the characteristic shows only negligible change throughout an arbitrarily long period of time.

3.1.4.12 Utilization Equipment

Utilization equipment is that which receives power from the electric power system. It may be an individual unit, a set of equipments or a complete subsystem receiving power through common equipment terminals or power converters.

3.1.4.12.1 Utilization Equipment Terminals

Utilization equipment terminals through which the electric power system is connected to the utilization equipment are attached to the equipment or are immediately adjacent to the equipment itself. Power interconnections within the utilization equipment are excluded.

3.1.4.13 Voltage Surge

The voltage surge is defined as a transient departure of the peak values of voltage from the peak instantaneous value of the steady state voltage, persisting for periods in excess of 500 microseconds, followed by recovery to within peak values corresponding to steady state. Surges are caused by load changes, switching or power interruptions elsewhere in the system, and are not expected to activate protection equipment.

3.1.4.14 Voltage Spike

The spike is a transient of total duration normally less than 500 microseconds and is superimposed on the otherwise unaltered instantaneous voltage. Spikes may be characterized here in the time domain in terms of voltage with parameters of duration risetime and energy. They may also be characterized equivalently in terms of Fourier component amplitudes as a function of frequency. Spikes are not expected to activate protective equipment.

3.1.4.15 Reference Ground

The primary spacecraft structure is the reference ground for the dc electrical power system. In some instances, it may be possible to utilize as ground the negative polarity wiring of the dc system.

3.1.4.16 Power Sensitivity

Power sensitivity of utilization equipment is the ratio of incremental output changes to incremental input changes for specified output performance quantities and specified voltage or frequency input-power changes (see IEEE Standard, 2.1).

**3.1.5 Interface Requirements

The BIPS shall be designed for compatibility with physical, mechanical, electrical, and functional interfaces with the spacecraft/IUS segment. In addition, the BIPS, spacecraft mounted, shall be capable of launch on the IUS, when mounted in the payload section of the Space Shuttle. Interface requirements are further defined in JSC07700, Volume XIV, and SS-STS-100.

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**3.1.5.1 Structural/Mechanical Interface

The BIPS shall be capable of structurally mating with the spacecraft, which in turn is mated to the IUS retention system at payload attachment locations. The BIPS shall be capable of being deployed, when structurally attached to the spacecraft, which is in turn attached to the IUS, by the Orbiter equipment defined in JSC07700, Volume XIV. BIPS design shall not require the use of handling points for deployment from the Orbiter by the IUS.

The BIPS, when structurally mounted to the spacecraft, shall be capable of withstanding, without failure, IUS and Shuttle-imposed ultimate environments of load, pressure, temperature, acoustics, humidity, shock and vibration (defined in Section 3.4 herein) in vertical, or horizontal positions, during all phases of operations, including abort, as defined in JSC07700, Volume XIV. Design margins shall equal or exceed MIL-STD-1540 margins.

The BIPS support structure shall be designed to minimize dynamic responses of the BIPS. Coincidence of the BIPS natural frequency with the spacecraft, IUS, and Orbiter natural frequencies should be avoided.

**3.1.5.2 Electrical Power Interface

Electrical power for pre-launch monitoring and initial BIPS startup (if required), during deployment as the orbiter spacecraft payload, shall be provided by the spacecraft or IUS electrical system.

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**3.1.5.3 BIPS-FS/Spacecraft Interface

TBD (Figures 3-1, 3-2)

**3.1.5.4 BIPS FS Interface Loads

The BIPS FS spacecraft interface will be designed to support loads resulting from operational environmental conditions imposed on the BIPS FS/spacecraft vehicle combination. Load factors for estimating these loads are summarized in 3.5.4.2.3. These estimated loads shall be verified by dynamic load analysis.

The BIPS FS when mounted to the spacecraft will be compatible with the worst loads imposed by the IUS vehicle and Shuttle. The loads are based on a fully cantilevered BIPS FS unless approved provisions are made to accept part loads through another path to the Orbiter.

**3.1.5.5 Thermal Interface

The BIPS FS design and operations is such that heat transfer between the BIPS FS and spacecraft is minimized. The interface design provides a thermal resistance of at least 20 degrees Fahrenheit/watt at each attach point. The effective emittance at the interface is less than 0.02.

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TBD

STRUCTURAL INTERFACE (LIGHT SPACECRAFT)

FIGURE 3-1

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TBD

STRUCTURAL INTERFACE (HEAVY SPACECRAFT)

FIGURE 3-2

**3.1.5.6 Positioning Interface

The BIPS FS structural interface with the spacecraft is designed to accommodate preferred angular positioning and access for ground operations within the indexing capability of the standard interface.

**3.1.5.7 Command and Control

Provisions are made in the BIPS design to accommodate the receipt of critical commands from the spacecraft, Orbiter or launch center. Provisions shall also be made to provide telemetry data to the spacecraft, Orbiter or directly to the ground launch control center, if required.

**3.1.5.8 BIPS FS System Ground Interface

The BIPS FS/spacecraft system shall be compatible with interfacing Eastern Launch Site (ELS) facilities, support equipment, and items of the Space Shuttle System (SSS). The system shall also be compatible with the DOD ground network. Use of the Launch Processing System (LPS) on-line and off-line shall be considered.

**3.1.5.8.1 Launch Site Facility Interface

The BIPS FS segment shall be compatible with interfacing facilities and non-BIPS FS support equipment at the ELS, which is comprised of the KSC and the Cape Canaveral Air Force Station (CCAFS). Appendix II of SS-STC-100, Volume 3, defines the ground operations concepts that shall be considered. The ELS interfacing facilities may include:

- (a) System processing facilities consisting of (1) a storage area, (2) an IUS vehicle and ASE assembly maintenance and checkout bay, (3) a BIPS FS spacecraft mating and integration area. Items (2) and (3) may be in one area or facility.
- (b) Shuttle facilities comprised of the (1) Orbiter Processing Facility (OPF), (2) Vehicle Assembly Building (VAB), (3) Launch Pad and Towers, (4) Payload Changeout Room (PCR), (5) Payload Ground Handling Mechanism (PGHM), (6) Launch Control Center (LCC), and (7) Landing Area (LA).

**3.1.5.8.2 Launch Site Peculiar Support Equipment (PSE)

The BIPS FS shall be compatible with the interfacing PSE at ELS, which may include: (a) environmental, power, and fluid service PSE; (b) umbilicals and connectors; (c) Shuttle Launch Processing System; (d) special test equipment; (e) RF test equipment; (f) Shuttle payload cannister for sealed transport; (g) displays and controls for various items of PSE. The system should also be compatible with interfacing ground handling equipment which includes: (h) special handling fixtures; (i) cranes in each facility, and (j) payload transporter and towing equipment. Incompatibilities, if any, shall be brought to the attention of the Government.

*3.2 Functional Requirements

*3.2.1 Operating Characteristics

The basic BIPS system shall be capable of any electrical power output from 500 to 2000 W_e . The Mini-BRU rated power output range is 350 to 2146 W_e . The alternator is designed for a three-phase full-wave 120-vdc rectifier load.

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Power delivered shall be variable from 0 to 100 percent of power system output with a response time of 20 milliseconds. This may be accomplished with a parasitic load.

****3.2.1.1 Additional Operational Objectives**

Although not required for BIPS GDS design, the following additional operational objectives shall be considered in BIPS FS design:

- (a) Capability of providing partial power during launch to parking orbit
- (b) Capability of providing partial power during boost to final orbit or flight path
- (c) Ability to withstand spin-stabilized orbital transfer and operate throughout system lifetime on a spin-stabilized spacecraft.

***3.2.2 Performance Characteristics**

The BIPS GDS performance cycle shall be as shown on Figure 3-3 for all state-point conditions. This reference cycle is based on the GDS components shown on Table 3-1. GDS performance is based on predicted performance of the Mini-BRU, recuperator, and HSA, which will be GFE from NASA, and using an assumed thermal loss of 20 percent in lieu of 12 percent predicted for the BIPS FS, since instrumentation penetrations through the insulation give heat losses not applicable to the FS. System performance shown is for the same heat input and power output as the FS. Independent variables available to attain this performance are the coolant temperatures and gas inventory.

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BIPS GDS AT 4800 W_t

FIGURE 3-3

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TABLE 3-1

BIPS-GDS COMPONENT OUTLINE

Mini-BRU

- o 1600°F turbine inlet temperature (working fluid is Xe-He, M = 83.8)
- o Single shaft turbine, Rice alternator, and compressor supported on foil bearings with compressor bleed cooling
- o Alternator cooled by compressor discharge, output voltage is for a 3-phase 120 vdc rectifier
- o Refractory metal turbine plenum (Columbium Alloy C-103)

Recuperator

- o Hastelloy X construction with gold alloy braze
- o Fin/plate counterflow design

Radiator Simulator (Heat Rejection Heat Exchanger-HRHX)

- o Inlet and outlet conditions equivalent to a space radiator with 390 degree equivalent sink temperature

Heat Source

- o Electrically heated heat source simulator (EHS)

Heat Source Assembly (HSA)

- o Columbium Alloy C-103 heat source heat exchanger (HSHX)
- o Auxiliary Cooling System - Helium short circuit of HSHX Multi-Foil insulation
- o Emergency Cooling System - Melting of HSHX Multi-Foil insulation (alternatives have been identified).

Insulation

- o High temperature Multi-Foil insulation
- o Twenty percent heat loss from HSA, turbine, and hot interconnecting ducting to allow for instrumentation penetration through the insulation, etc.

Controls

- o Motor start inverter
- o Parasitic load
- o Speed control
- o Voltage regulator
- o Power Supply
- o Rectifier/filter

Piping and Structure

- o Ducting
- o Bellows
- o Support structure

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The BIPS FS performance cycle shall be as shown by the system flow schematic of Figure 3-4 for all state-point design conditions and operating parameters. This reference cycle is based on the FS components shown on Table 3-2.

The FS and GDS requirements are similar with the essential difference being that a space radiator shall be used for the FS system rather than the heat rejection heat exchanger used for the GDS.

****3.2.3 Weight**

The system weight goal for the 4.8 kW_t input FS is 450 pounds.

****3.2.4 Envelope**

Design flexibility in size and shape of the BIP FS shall be a prime consideration. This shall include the ability to adapt the flight system radiator to the shroud shape, and consideration for utilization of radiator interior space for other components. Consideration shall also be given to specific interface requirements of Paragraphs 3.1.5.3 and 3.1.5.4.

Analyses shall be conducted to determine size, length, and routing arrangement of interconnecting ducting to minimize heat loss and pressure drop consistent with system design requirements.

Design objective shall be to provide an FS envelope 60 inches in diameter and TBD inches in length.

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FLOW SCHEMATIC AND ESTIMATED PERFORMANCE
FOR THE 4800 W_t ERDA BIPS FS
FIGURE 3-4

TABLE 3-2

BIPS-FS COMPONENTS

Mini-BRU

- o 1600°F turbine inlet temperature (working fluid is Xe-He, M = 83.8)
- o Single shaft turbine, Rice alternator and compressor supported on foil bearings with compressor bleed cooling
- o Alternator cooled by compressor discharge
- o Refractory metal turbine plenum (Columbium C-103)

Recuperator

- o Hastelloy X construction with gold alloy braze
- o Fin/plate counterflow design

Radiator

- o Material [Be, aluminum alloy or Lockalloy (alloy of Al and Be)]
- o Cylindrical design, offset fin/tube geometry
- o Sink temperature, 390°R
- o Micrometeoroid survival, 0.99 (assumed)
- o Used as part of a low gage pressure vessel to contain an inert gas for protection of the C-103 and multifoil insulation from launch to orbit.

Heat Source

- o ERDA Multi-Hundred Watt (MHW) heat source, (advanced ERDA HS concepts will also be investigated)
- o Electrically heated heat source simulator (EHS) for FS checkout

Heat Source Assembly (HSA)

- o Columbium Alloy C-103 Heat Source Heat Exchanger (HSHX)
- o Auxiliary Cooling System - Helium short circuit of HSHX Multi-Foil insulation
- o Emergency Cooling System - Melting of HSHX Multi-Foil insulation (alternatives have been identified)

Insulation

- o High temperature Multi-Foil insulation
- o Eight percent heat loss from HSA (Goal)
- o Two percent heat loss from turbine and hot interconnecting ducting (Goal)

Controls

- o Motor start inverter
- o Parasitic load
- o Speed control
- o Voltage regulator
- o Power supply
- o Rectifier/filter

Piping and Structure

- o Ducting
- o Bellows
- o Support structure (Beryllium or aluminum alloy)
- o Radiator is used as part of the support structure

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****3.2.5 Separation Velocity Rate**

The BIPS FS as spacecraft mounted shall withstand an IUS vehicle induced longitudinal relative velocity imparted to the spacecraft during separation of 0.25 ft/sec.

****3.2.6 Pre-Flight Conditioning**

TBD

****3.2.7 Ground Contamination**

The BIPS FS shall be designed so as to minimize contamination of the spacecraft, IUS vehicle, Orbiter, and the spacecraft mating and integration area. This includes, but is not limited to, control or elimination of contamination from manufacturing, testing, handling, materials outgassing, leakage, mechanical system operation, and venting.

****3.2.8 Thermal Characteristics**

The BIPS FS segment shall be compatible with spacecraft, IUS vehicle, and orbiter characteristics as defined in JSC07700, Volume XIV. The system should be designed to meet the thermal margins of MIL-STD-1540 throughout all phases of ground and flight operation.

****3.2.8.1 Prelaunch**

The BIPS FS while spacecraft mounted and installed in the orbiter payload bay during prelaunch will be provided thermally conditioned air or purge gas to the bay at between 45° and 100°F.

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**3.2.8.2 Orbiter Bay

The BIPS FS as spacecraft attached will be subjected to the following in-orbit condition in the payload bay:

- (a) The payload bay may be open within 0.5 to 1.5 hours after shuttle launch
- (b) Upon reaching parking orbit the Orbiter may be oriented to assist in maintaining spacecraft-BIPS FS temperature
- (c) The payload bay inner wall temperature will be maintained between 40°F and 150°F during ascent.

*3.2.9 Structural Safety Factors

The BIPS shall be capable of sustaining design limit loads without detrimental deformation and still function. The BIPS also shall be capable of sustaining design ultimate loads without failure. The system shall meet the safety factors of MIL-STD-1522, KMI-1710.1B, and 3.6.8.1 of AFETRM 127-1, during ground operations. At a safe distance from the Orbiter, the flight safety factors may be reduced to 1.0 for limit load and 1.25 for ultimate load.

**3.2.10 Installation and Access

The BIPS FS design shall not preclude separate installation to the spacecraft with the Orbiter in the vertical or horizontal position. Normal installation in the Orbiter is at the launch pad with

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the BIPS FS spacecraft attached to the IUS vehicle. The BIPS FS shall be physically accessible up to final cargo bay closeout. When the Orbiter is at the launch pad, the BIPS FS shall be capable of being removed, replaced and returned to launch ready status.

3.3 DC Power Requirements

3.3.1 General

3.3.1.1 System Equipment Compatibility

The characteristics defined herein shall be maintained at the U/E terminals during the operation of all expected combinations of power source, distribution and utilization equipment. System operating modes outside the conditions defined by this standard will be permitted only when specifically authorized.

3.3.1.2 Power Interruption

Due to conditions of bus transfer, voltage may be between zero and the steady state limits for a period no greater than fifty milliseconds, and within the limits of Figure 3-5 following this interruption. Interruptions resulting from overvoltage and undervoltage or overcurrent may be followed by bus transfer or by power restoration delays as determined by the particular application.

3.3.1.3 Conformance Tests

Tests for conformance of the electric system to the characteristics stipulated in this standard shall be defined as part of the procurement specifications to which this document is applicable, and shall be subject to the approval of the procuring activity.

3.3.2 Detail

3.3.2.1 DC Power Characteristics

DC power characteristics are those of a direct-current, two-wire or ground return system having a nominal voltage of 120 volts.

3.3.2.1.1 Steady State

- o DC Voltage Magnitude - The dc voltage shall be within 110 to 125 volts.
- o DC Distortion - The dc distortion factor shall not exceed 0.025 nor shall the dc distortion spectrum exceed the limits shown in Figure 3-6. The ripple amplitude shall not exceed 2.5 volts (peak).

3.3.2.1.2 Transient

- o Voltage Surge - The maximum value of the dc voltage surge shall not exceed the limits shown in Figure 3-5.
- o Voltage Spike - The system electromagnetic compatibility aspects of voltage spikes shall be controlled by MIL-STD-6051.

3.3.2.1.3 Overvoltage and Undervoltage

The dc overvoltage values shall not exceed the upper limits shown in Figure 3-7, and the dc undervoltage shall be restored to its steady state limits within 5 seconds after exceeding the lower limit of Figure 3-5. Interruption following the period of these overvoltages or undervoltages shall be as specified in 3.3.1.2 (see also 3.1.4.9, 3.1.4.12, and 3.1.4.13).

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DISTORTION (RIPPLE) SPECTRUM OF DC VOLTAGE

FIGURE 3-8
(SEE 3.3.2.1.1)

****3.4 Design and Construction**

***3.4.1 Parts, Materials and Processes**

Selection of parts, materials and processes shall be in accordance with SAMSO Standard 73-2C. Polymeric materials should be in accordance with NASA SP-R-0022. Electronic equipment should be in accordance with MIL-E-8983 except for manual control interfaces, if required. Electrical wiring harnesses should be in accordance with MIL-W-83575. The electrical system should be in accordance with MIL-STD-1539 (USAF). System test equipment design should be guided by MIL-T-21200. General criteria for design of new equipment and facilities to be utilized at KSC should comply with NASA KSC GP-863. Design strength allowables should be as defined in MIL-HDBK-5 and MIL-HDBK-23.

***3.4.2 Structural Design Criteria**

***3.4.2.1 General Design**

The design shall provide for sufficient strength, rigidity, and other characteristics to survive critical conditions within the envelope of mission requirements. The system shall survive those conditions in a manner that does not reduce the required probability of the successful completion of the mission. The system design shall be guided by the critical flight conditions wherever practicable. The non-flight conditions and environments shall influence the design to a minimum extent.

***3.4.2.2 Design Environment**

The environmental phenomena corresponding to each design condition shall statistically include all factors that can influence the design, typically include thermal, vibration, shock and acoustics, in addition to quasistatic and dynamic loads.

*3.4.2.3 Misalignment and Dimensional Tolerance

The design shall consider the effects of allowable structural misalignments, control misalignments, and other permissible and expected dimensional tolerances for loads, load distributions, and structural adequacy.

*3.4.2.4 Dynamic Loads

The system shall be designed to meet all requirements for all quasi-static and transient dynamic load phenomena expected in each design environment. Dynamic loads include the effects of spacecraft structural flexibilities, damping, and coupling of structural dynamics with the control system and the external environment.

*3.4.2.5 Vibration and Acoustical Effects

The dynamic effects of the vibrational and acoustical environments shall be accounted for in design.

*3.4.2.6 Thermal Stresses

Required strengths shall be based upon the combined effects of thermal stresses with the appropriate load stresses. Thermal stresses shall be based on the applied temperatures, heating rates, etc., and shall be considered limit values.

*3.4.3 Material Properties

*3.4.3.1 Sources

Material strengths and other mechanical and physical properties may include AiResearch or subcontractor test values when approved by

the procuring agency. Strength allowables and other mechanical properties shall be appropriate to the loading conditions, design environments, and stress states for each system element.

*3.4.3.2 Values

Allowable material strengths used in design shall reflect the effects of load, temperature, and time associated with the design environment. These values shall be consistent with overall system reliability requirements.

*3.4.4 Strength Requirement

3.4.4.1 Limit Loads

The system shall be designed to have sufficient strength to withstand simultaneously the limit loads, maximum operating pressures, applied temperature and other accompanying environmental phenomena for each design condition without experiencing detrimental deformation.

*3.4.4.2 Ultimate Loads

The system shall be designed to withstand simultaneously the ultimate loads, maximum operating pressure, applied temperature and other accompanying environmental phenomena for each design condition without failure or collapse.

**3.4.4.3 Safety Margin

The margin of safety shall be minimal, positive, and shall be determined by analysis and/or test at design ultimate levels and design limit levels, at the temperatures expected for all critical conditions when applicable.

*3.4.5 Stiffness Requirements

*3.4.5.1 Limit Loads

The system shall experience no detrimental deformations at limit loads and pressures in the expected operating environments.

*3.4.5.2 Ultimate Loads

Structural deformations shall not precipitate structural failure or collapse during any design conditions and environments at loads less than ultimate loads.

*3.4.5.3 Dynamic Elasticity

The system properties shall be such as to:

- (a) Prevent all detrimental instabilities of coupled vibration modes.
- (b) Minimize detrimental effects of loads and dynamic response which are associated with structural flexibility.
- (c) Minimize adverse interaction between system structure and the spacecraft.

*3.4.6 Thermal Requirements

Critical thermal effects, including heating rates, temperatures, thermal stresses and deformations, and changes in the physical and mechanical properties of the materials, shall be included in system design.

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*3.4.6.1 Insulation

Where insulators are used for thermal protection and are integral with a load-carrying substructure, the mechanical and thermal properties of the insulator shall be defined over the entire range of operating temperatures together with the structural performance in the expected operating environment.

**3.4.7 Contamination

The system and its ancillary equipment shall minimize and control contamination of the spacecraft IUS vehicle, and Orbiter and shall not violate the Orbiter payload bay cleanliness level (100,000 class) while in the Orbiter payload bay. This includes control of contamination from materials outgassing, gas leakage and operation. Contamination control should comply with SN-C-005.

*3.4.7.1 Materials

To minimize contamination, organic/polymeric materials shall be selected according to NASA Specifications SP-R-0022, and SE-R-006.

**3.4.7.2 Protective Covers and Shrouds

The design of the BIP FS shall not restrict or limit the use of ejectable covers for the contamination protection of spacecraft surfaces. The BIPS FS spacecraft interface design shall not preclude installation of a spacecraft shroud or other equipment to maintain a cleanliness level of Class 10,000 or better around the spacecraft.

3.4.7.3 Particulates

Surfaces of the system spacecraft mounted to the IUS vehicle within the Orbiter payload bay shall have a particulate surface cleanliness visibly clean under normal factory lighting. The measured cleanliness should be equal to or less than 300 per MIL-STD-1246 or NASA SN-C-005, Level 300.

*3.4.8 Electromagnetic Interference/Compatibility

The system shall be designed for electromagnetic compatibility in accordance with MIL-STD-1541, SAMSO-LVR-001, and MIL-STD-1542. The system shall be designed to meet the magnetic field limits of RE04, and the electric field limits of RE02, MIL-STD-461. A structural electrical bond path should be provided between the BIPS FS and spacecraft structure. The structural interface joint impedance should be in accordance with Class R of MIL-B-5087. Connectors used to interface with the spacecraft should be of the pokehome type, using crimp bonding between the wires and the pin/socket interconnects, and should comply with the requirements of 3.6 of MIL-W-83575.

*3.4.9 Other Design Considerations

*3.4.9.1 Transient Effects

An analyses shall be conducted of the system start up and transient behavior to assure they are within system component design capability. Transient analysis shall be conducted to determine extent to which thermal stresses are imposed on the system components. Various means of scheduling speed, load and system pressure shall be investigated. The design shall accommodate transient effects while minimizing operating penalties and risks.

*3.4.9.2 Heat Sink

Trade-off studies shall be conducted of heat sink designs considering proven state-of-the-art, that fulfill performance and endurance requirements and the costs of fabrication and testing. Trade-off studies shall consider a spectrum ranging from a low cost liquid cooled radiator simulator to a space radiator including cold wall vacuum test chamber. Preliminary design approaches and recommended specific choices shall be prepared for procuring activity approval.

3.4.9.3 Control System - BIPS GDS

Detail design shall be established for the BIPS GDS controls including circuit schematics, circuit diagrams, detailed part tests, assembly drawings and wiring diagrams. High reliability shall be designed into the control system by employing the methods of component derating (voltage, current temperature and stress) and critical circuit redundancy. Inputs from transient analysis task of 3.3.9.1 shall be used.

3.4.9.4 Structure Design - BIPS GDS

Detail design shall be performed as required to prepare manufacturing drawings and specifications for ducting, bellows, valves, bimetallic joints, supporting structures, thermal insulation and other required components of the BIPS GDS. The detail design shall encompass the selection of materials used ranging from aluminum and stainless steel in the cold end to superalloys and refractory metals in the hot end.

3.4.9.5 Materials Compatibility - GDS

A development plan shall be prepared defining bimetallic joining and reflecting material and configuration selections required to integrate the GFE components into the system design. The plan shall be such that the bimetallic joining is developed to a satisfactory level to be used in fabrication of the BIPS GDS. It shall also provide for the necessary materials compatibility and properties studies relating to outgassing and possible degradation of components, coating behavior and other materials investigations required for succesful long term operation of the system.

3.4.9.6 Heat Source Analysis BIPS - GDS

The necessary heat source analysis and design shall be performed consistent with using electrical heat sources either supplied as GFE or procured by AiResearch from a subcontractor. If subcontractor procured, the design must simulate the physical and thermal characteristics of an MHW isotope heat source. The subcontractor shall also include a design of the heater power supply(s) and system control interfacing. The design and/or materials selection used in the electrical heat sources either procured or GFE shall be such that they are compatible with the intended service in the HSA.

**3.4.10 Nameplate and Product Marking

Each system component and higher levels of assembly shall be marked and serialized for identification in accordance with MIL-STD-130.

*3.4.11 Workmanship

All parts and assemblies of the system should be fabricated and finished in a manner that satisfies the workmanship requirements of

of MIL-STD-454. All details of workmanship concerned with the fabrication and installation of equipment shall be controlled such that the complete system is of sufficient quality to ensure proper operation, safety and service life.

****3.4.12 Interchangeability**

Any two components bearing the same part number shall possess such functional and physical characteristics as to be equivalent in performance and durability and shall be capable of being changed, one for another, without alterations or special calibration procedures of adjoining items. Where two components are not functionally interchangeable they should not be physically interchangeable.

****3.4.13 Safety**

The system shall be capable of being stored, handled, transported, installed, loaded or unloaded and checked out in a safe condition at all times prior to launch and during abort post-landing operations. The system shall be capable of safe operation during pre-deployment check-out, deployment from the Orbiter and post deploy while still in the vicinity of the Orbiter. The system shall be capable of having all safety critical items monitored from the spacecraft.

The design shall also meet the requirements contained in TBD NASA Safety Requirements Document.

****3.4.14 Hazards**

All potential hazards to the spacecraft that could be created by the system should be eliminated, minimized, or controlled by:

- (a) The hazard reduction procedure sequence per NASA Document TBD
- (b) By appropriate design features and/or procedures, as required.

*3.4.15 Human Performance/Engineering

The system should satisfy the human engineering criteria of MIL-STD-1472 as applicable.

**3.5 Environmental Requirements

The natural and induced environments that the BIPS FS will be subjected to when spacecraft mounted are defined in the following paragraphs. Consideration is given to environments applicable at interface structure points as related to spacecraft, IUS vehicle, and SSV.

The design should consider the attenuation or amplification of the environment between the spacecraft attachment and BIPS. The space shuttle provides an induced environment as benign or more benign than existing launch vehicles. If, however, the environment as defined herein is applied directly to payloads it could impose unduly severe requirements for a particular payload.

**3.5.1 Natural Environments

The following natural environmental criteria shall be considered in the BIPS design.

3.5.1.1 Atmospheric(a) Pressure

Surface	12.36 to 15.23 psia (85219.2 to 105007.2 N/m ²)
35,000 Feet	3.28 psia (22614.8 N/m ²) minimum

(b) Temperature

Surface (Sheltered Uncontrolled)	Minus 23°F (-31°C) to 150°F (66°C)
35,000 Feet (10,668 m)	Minus 65°F (-54°C) nominal

**3.5.1.2 Fungus

The design shall utilize non-fungi nutrient materials, since temperatures above 68°F (20°C) and relative humidities above 75 percent are conducive to high growth rates of fungi (including mold) and bacteria.

**3.5.1.3 Humidity

For design purposes, 0 to 100 percent relative humidity at the temperature extremes defined herein shall be the consideration. Detailed definition of extreme surface humidity is provided as follows:

- (a) High Temperature/High Vapor Concentration - The following extreme humidity cycle of 24 hours should be considered in design: 3 hours of 99°F (37.2°C) air temperature at 50 percent relative humidity and a vapor concentration of 9.7 gr/ft³ (22.2 g/m³); 6 hours of decreasing air temperature to 76°F (24.4°C) with relative humidity increasing to 100 percent (saturation); 8 hours of decreasing air temperature to 70°F (21.1°C), with a release

of 1.7 gr of water per cubic foot of air (3.8 grams of water as liquid per cubic meter of air), humidity remaining at 100 percent; and 7 hours of increasing air temperature to 99°F (37.2°C) and a decrease to 50 percent relative humidity.

- (b) High Temperature/Low Vapor Concentration - A vapor concentration of 2.1 gr/ft³ (4.8 g/m³), corresponding to a dew point of 32°F (0.0°C) at an air temperature of 100°F (37.8°C) and a maximum relative humidity of 26 percent at an air temperature of 70°F (21.1°C) remaining 20 hours of each 24 hours for 10 days.
- (c) Low Temperatures/Low Vapor Concentration - A vapor concentration of 0.9 gr/ft³ (2.1 g/m³), with an air temperature of 11°F (-11.7°C) and a relative humidity between 98 and 100 percent for a duration of 24 hours.

**3.5.1.4 Lightning - TBD

**3.5.1.5 Ozone

The design shall consider an environment containing ozone at a surface maximum 3 to 6 parts per hundred million (phm); 35,000 feet (10,668 m) maximum 100 phm.

Total oxidant concentrations may infrequently reach 60 phm for 1 to 3 hours during a 24-hour period. Levels increase with altitude to maximum value of 1100 phm near 98,000 feet (29,870 m).

**3.5.1.6 Salt Spray

The design shall consider exposure to a salt spray environment of 1.0 percent by weight of salt (NaCl) solutions for 30 days.

**3.5.1.7 Sand and Dust

Design consideration shall be given to accommodate exposure to sand/dust equivalent to 140 mesh silica flour with particles velocity up to 500 feet per minute and a particle density of 0.25 grams per cubic foot.

**3.5.2 Space Environments

Space shall be considered as being an altitude greater than 48.6 nautical miles, (295,000 ft, 90 Km).

**3.5.2.1 Pressure

For design guidance pressure values are provided as follows:

<u>Altitude</u>	<u>Max P. (Torr)</u>	<u>U.S. Standard Atmosphere</u>	<u>Min P. (Torr)</u>
48 n. mi (90 Km)		1.24×10^{-3}	
70 n. mi (130 Km)	1.4×10^{-5}	1×10^{-5}	8×10^{-6}
100 n. mi (185 Km)	2.2×10^{-6}	1.54×10^{-6}	4.7×10^{-7}
110.7 n. mi (205 Km)		1×10^{-6}	
1200 n. mi (2225 Km)	approximately 1×10^{-11} , in either case		

Highest pressure at orbital altitudes would be the maximum pressure at lowest orbital altitude (70 n. mi) and lowest pressure at orbital altitudes would be the minimum pressure at the highest orbital altitude (1200 n. mi).

**3.5.2.2 Solar Radiation (Thermal)

Temperature extremes for items exposed to space environments cannot be categorically defined. When determining these extremes analytically, use the following data:

<u>Environmental Parameter</u>	<u>Design Value</u>
Solar Radiation	443.7 Btu/ft ² /hr (1398.76 W/m ²)
Earth Albedo	30 percent
Earth Radiation	77 Btu/ft ² /hr (243 Wm ²)
Space Sink Temperature	0° Rankine

**3.5.2.3 Solar Radiation (Nuclear)

The natural nuclear radiation environment in terrestrial space which should be considered in design consists of:

- (a) Galactic cosmic radiation
- (b) Geomagnetically trapped radiation
- (c) Solar flare particle events

These elements are further defined as follows:

**3.5.2.3.1 Galactic Cosmic Radiation (Mainly Protons)

Composition

85 percent protons
13 percent alpha particles
2 percent heavier nuclei

Energy Range

10^7 to 10^{19} electron volts
(The predominant range is 10^9 to 10^{13})

Flux (Outside Earth's magnetic field)

0.2 to 0.4 particles/cm²/steradian/sec

Integrated Yearly Rate

Approximately 1×10^8 protons per sq. cm.

Integrated Yearly Dose

Approximately 4 to 10 rads

**3.5.2.3.2 Geomagnetically Trapped Radiation (Protons, Electrons)

Energy

Electrons > 0.5 MeV
Protons > 34 MeV

Peak Electron Flux: > 10^8 electrons per sq cm per sec

(Omnidirectional)

Peak Electron Flux Altitude:

Approximately 1900 n mi at equator

**3.5.2.3.3 Solar Flare Particle Events

Composition:

Energetic protons and alpha particles

Occurrence:

Sporadically and lasting for several days

Particle Event Model: (free space)

Refer to Section 2.4.3 of NASA TMX 64627

$$\begin{aligned}
 & 7.25 \times 10^{11} T^{-12} & 1\text{MeV} \leq T \leq 10\text{MeV} \\
 & -P(T)/67 \\
 \text{Protons: } N_p(>T) = & 3.54 \times 10^{11} E & 10\text{MeV} \leq T \leq 30\text{MeV} \\
 & -P(T)/73 \\
 & 2.64 \times 10^{11} E & T > 30\text{MeV} \\
 \text{Alphas: } N_d(>T) = & N_p(>T) & T < 30\text{MeV} \\
 & 7.07 \times 10^{12} T^{-2} & T \geq 30\text{MeV}
 \end{aligned}$$

Where $N_p(>T)$, $N_d(>T)$ = protons/cm², alphas/cm² with energy $>T$

$P(T)$ = particle magnetic rigidity in mV

$$P(T) = \frac{1}{Ze} [T(T + 2m c^2)]^{1/2}$$

Ze = 1 for protons, 2 for alphas

$m c^2$ = 938 MeV for protons, 3728 MeV for alphas

For near-earth orbital altitudes the above free-space event model must be modified since the earth's magnetic field deflects

some of the low-energy particles that would enter the atmosphere at low latitudes to the poles.

****3.5.2.4 Nearby Nuclear Burst**

TBD

****3.5.2.5 Meteoroids**

The meteoroid model encompasses particles of cometary origin in the mass range between 1 and 10^{-12} grams for sporadic meteoroids and 1 to 10^{-6} grams for stream meteoroids.

Average Total Environment:

Particle Density	0.5 g/cm^3
Particle Velocity	20 km/sec
Flux Mass Models	

$$(1) \text{ For } 10^{-6} \leq m \leq 10^0 \log Nt = -14.37 \\ -1.213 \log m$$

$$(2) \text{ For } 10^{-12} \leq m \leq 10^{-6} \log Nt = -14.339 \\ -1.584 \log m - 0.063 \\ (\log m)^2$$

Nt - no. particles/ m^2 /sec of mass m or greater

m = mass in grams

Defocusing factor for earth, and if applicable, shielding factor are to be applied.

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**3.5.3 Induced Environment

The following induced environments, as applicable, shall be considered in the BIPS design. The following environmental reservations shall be considered in designing to these requirements:

- (a) The environments, as defined, apply to the interface between the Orbiter and the integrated BIPS/spacecraft/IUS carrier combination; the effect on the BIPS must be evaluated by appropriate analysis.
- (b) The environments described are the maximum/minimum expected values for which the space shuttle is designed. In many cases it may be desirable and cost effective for the BIPS payloads to be designed and/or qualified to less severe environments. Such decisions are the prerogative of the designer provided that the desired safety objectives are met.

**3.5.3.1 Ground Handling

**3.5.3.1.1 Ground Temperature

The temperature in the Orbiter Processing Facility (OPF) building areas assigned for BIPS/spacecraft payload processing and checkout will be controlled to $75 \pm 3^{\circ}\text{F}$ ($24 \pm 1^{\circ}\text{C}$). While the payload bay doors are closed, the Orbiter payload bay atmosphere will be controlled by conditioned air during prelaunch operations until 80 minutes prior to Orbiter cryogenics loading. At this time GN2 will be supplied to provide an inert payload bay atmosphere through lift off.

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*3.5.3.1.2 Ground Shock

During handling the BIPS equipment may experience as much as a 20g terminal sawtooth shock pulse of an 11 millisecond duration in each of three orthogonal axes (6 directions). All BIPS components shall be designed to withstand this basic design shock spectrum.

*3.5.3.1.3 Acceleration (Hoist Loads)

The design shall accommodate hoist loads of 2g vertical within a plus or minus cone angle of 20 degrees.

*3.5.3.1.4 Vibration (Handling and Transportation)

The vibration spectrum that the BIPS is expected to experience during ground handling and transportation is a minimum of four (4) sweeps at 1/2 octave per minute at the following levels (sinusoidal motion).

2-5 Hz	at	1.0 inch (25.4 mm) double amplitude
5-26 Hz		1.3g peak
26-50 Hz		0.036 inch (0.91 mm) double amplitude
50-100 Hz		5g peak

**3.5.4 Flight Environment

3.5.4.1 Pressure and Venting

The Orbiter payload bay will be vented during the launch and entry phases, and will operate unpressurized during the orbital phase of the mission. The payload bay pressures to which the BIPS will be exposed during ascent and entry are shown in Figures 3-8 and 3-9.

ORBITER PAYLOAD BY INTERNAL PRESSURE
HISTORIES DURING ASCENT

FIGURE 3-8

ORBITAL PAYLOAD BAY INTERNAL PRESSURE
HISTORIES DURING ENTRY

FIGURE 3-9

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The payload bay level of cleanliness maintained at preflight will be retained for launch through orbital insertion. Any purging, other than that provided by normal payload bay depressurization, shall be accomplished by the payload. Payload bay purge parameters are presented in Table 3-5 for the various mission phases, from liftoff to landing, and purge system sequencing is shown in Figure 3-10. The payload purge system is presented schematically in Figure 3-11.

****3.5.4.2 Vibration and Shock**

****3.5.4.2.1 Vibration**

The Space Shuttle Vehicle will be subjected to fluctuating pressure loading on its exterior surfaces by engine exhaust generated acoustic noise and flow generated aerodynamic noise during powered ascent into orbit. These fluctuating pressure loads will be the principal sources of structural vibration. Actual vibration input to the BIPS will depend on the transmission characteristics of the support structure and interactions between the BIPS/spacecraft structure, spacecraft/IUS structure, and IUS/SSV structure interface.

The principal vibration levels the BIPS will experience are dependent upon the dynamic response to the SSV vibration of the components that make up the BIPS payload when in the payload compartment.

Peak random vibration levels estimated for the various interface points, to be considered in the design are as follows:

TABLE 3-5

PAYLOAD BAY WALL THERMAL ENVIRONMENT

Condition	Design Minimum	Design Maximum
Prelaunch	+40°F (4.5°C)	+120°F (49°C)
Launch	+40°F (4.5°C)	+150°F (65.5°C)
On-Orbit (doors closed)	See C&D	See A&B
Entry and postlanding	-100°F (-73°C)	+200°F (93.5°C)
<p>Heat leak criteria into or out of a 100°F (37.5°C) constant payload are as follows:</p> <p>A. Total bay heat gain, average ≤ 0 Btu/ft² hr (0 Watt/Meter²)</p> <p>B. Heat gain, local area ≤ 3 Btu/ft²-hr (9.5 Watt/Meter²)</p> <p>C. Total bay heat loss, average ≤ 3 Btu/ft²-hr (9.5 Watt/Meter²)</p> <p>D. Heat loss, local area ≤ 4 Btu/ft²-hr (12.6 Watt/Meter²)</p>

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MISSION PHASE

PAYLOAD BAY VENT POSITIONS

REMARKS

	<u>PURGE SPIGOTS CLOSED</u>	<u>PURGE SPIGOTS OPEN</u>	
VAB	CLOSED	PURGE POSITION - VENT #6	} PURGE PLUS ΔP
TRANSFER TO PAD (W/PURGE)	CLOSED	PURGE POSITION - VENT #6	
PAD (NON-CRYO P/L)	CLOSED	PURGE POSITION - VENT #6	
PAD (CRYO P/L)	PURGE POSITION - VENT #5	PURGE POSITION - VENT #6	
T - 4 SECONDS	CLOSE ALL VENTS		} PAYLOAD BAY ACOUSTIC SUPPRESSION
LIFT-OFF (T - 0)-	ALL VENTS CLOSED		
T + 10 SECONDS	ALL VENTS OPENED TO FULL POSITION		} ASCENT VENTING
ORBIT INSERTION	ALL VENT FULL OPEN		
ON-ORBIT	ALL VENT FULL OPEN		} MOLECULAR VENTING
PRE-ENTRY PREPARATION	CLOSE ALL VENTS		
ENTRY (HIGH HEAT ZONE)	ALL VENTS CLOSED		} ENTRY
@ 75,000 ± 5,000 FT (22.86 KM)	ALL VENTS OPENED TO FULL POSITION		
POSTLANDING PURGE	CLOSED	PURGE POSITION - VENT #6	} DESCENT VENTING
TRANSFER TO OPF (W/PURGE)	CLOSED	PURGE POSITION - VENT #6	
OPF (DURING PURGE OPS)	CLOSED	PURGE POSITION - VENT #6	
TRANSFER - OPF TO VAB (PURGE)	CLOSED	PURGE POSITION - VENT #6	

PAYLOAD BAY VENT SEQUENCING

FIGURE 3-10

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PAYLOAD BAY PURGE SYSTEM

FIGURE 3-11

Peak Random Vibration Levels

- (a) Shuttle/IUS Vehicle Payload Interface - $0.1 \text{ g}^2/\text{Hz}$
(90 to 275 Hz) this is an estimated response for an unloaded interface structure. Actual response should be lower due to mass of payload.
- (b) IUS Vehicle-Spacecraft Interface - $0.125 \text{ g}^2/\text{Hz}$
(100 to 1000 cps) recommended for conceptual design.
- (c) BIPS-Spacecraft Interface - $0.1875 \text{ g}^2/\text{Hz}$ (900 to 1400 Hz) G.E. estimate based upon their LES 8/9 and Mariner J/S experience.

Additional design information related to estimated random vibration and appropriate exposure durations for the SSV cabin and mid-fuselage payload interface due to the fluctuating pressure loads are shown in Figure 3-12. The mid-fuselage/payload interface vibration environment is based on the response of unloaded interface structure; therefore, should be considered the upper limit of the probable IUS interface vibration. The actual vibration levels experienced by specific components of payloads will generally be different from those shown in Figure 3-12, since the vibration inputs at the SSV/IUS interface will be reduced by the addition of the BIPS/spacecraft. In addition, vibration transmitted to the BIPS/spacecraft components will be modified by the payload carrier support structure. An analysis of the combined system shall be made to determine the vibration experienced by the BIPS. If desired, some degree of attenuation of vibration at specific frequencies may be achieved by special attention to the means of attaching the payload carrier to the Orbiter.

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PLEASE NOTE

ACTUAL VIBRATION INPUT TO PAYLOADS WILL DEPEND ON
TRANSMISSION CHARACTERISTICS OF MIDFUSELAGE-
PAYLOAD SUPPORT STRUCTURE AND INTERACTIONS WITH
EACH PAYLOAD'S WEIGHT, STIFFNESS, AND C.G.

THESE LEVELS ARE TYPICAL OF LIFTOFF, TRANSONIC AND MAX Q FLIGHT

· RANDOM VIBRATION AT MIDFUSELAGE MAIN LONGERON PAYLOAD
ATTACH POINTS INTERFACE AND IN CABIN

FIGURE 3-12

**3.5.4.2.2 Shock

The BIPS design shall consider the principal sources of shock which may occur during SSV launch and ascent, and as a result of IUS vehicle deployment. The principal source of shock will occur due to utilization of pyrotechnic devices on the IUS vehicle such as those used for BIPS/spacecraft separation from the IUS vehicle.

The principal shock levels the BIPS will experience are dependent upon the dynamic response of the payload to the Pyrotechnic explosions with the payload in the deployed configuration.

The following design shock levels shall be considered applicable to the BIPS design:

Peak Shock Levels

BIPS/Spacecraft/IUS Vehicle Interface

The shock response spectra gives a dynamic response of 115 g's at the IUS/spacecraft interface, with a "Q" equal to ten for a 100 cps system. Although the response of the BIPS to the shock at the IUS-spacecraft interface cannot be defined, it will be greatly attenuated due to the remoteness of the BIPS from the interface.

**3.5.4.2.3 Preliminary Shock and Vibration Design Criteria

As noted in Paragraphs 3.5.4.2.1 and 3.5.4.2.2, the actual shock and vibration levels the BIPS will be subjected to are dependent upon the dynamic response of the payload to the principal sources of excitation.

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Total definition is not available at this time related to the IUS support structure interface between either the SSV or the spacecraft, however, there are certain system dynamics criteria to be satisfied in order to maintain shock and vibration responses of the BIPS within acceptable structural design levels. These include:

- (a) The support structure of the cantilevered BIPS/spacecraft/IUS shall be designed to avoid coupling fundamental frequencies of the payload with fundamental frequencies of the SSV. The fundamental frequencies of the cantilevered payload should be at least two times greater than the fundamental frequencies of the shuttle in order to avoid this interaction. The fundamental frequency of the shuttle is predicted to be between 3 to 13 cps; therefore, the fundamental of the cantilevered payload should not be less than 26 cps.
- (b) The support structure of the discrete masses of the BIPS should be designed to avoid coupling of the fundamental frequencies of the cantilevered payload with the rigid body fundamental frequencies of the discrete masses of the BIPS. This means the fundamental frequencies of the BIPS components should not be less than 60 cps.

The limits of the fundamental frequencies of the cantilevered payload and BIPS components are defined by (a) and (b) above. However, it is desirable to maintain the upper limits of the natural frequencies no higher than necessary to satisfy (a) and (b) in order to minimize the dynamic response of the BIPS components to shock and vibration. The cascade of components that make up the cantilevered payload should respond to shock as a succession of simple systems so long as each succeeding structure has a low mass relative to the structure which supports it. It is anticipated that this is the case with the BIPS.

The BIPS FS components, HSAs, Mini-BRU and mounting pads shall be designed to a minimum limit loading of 50 g's. The BIPS interface structure, struts, beams, etc. shall be designed to a minimum limit loading of 25 g's. The design criteria of providing sufficient stiffness to the BIPS interface structure to maintain the BIPS component natural frequencies above 60 cps should result in high strength. It is anticipated that this built in strength should be in excess of 25 g's. This limit loading will satisfy requirements for all other loadings such as pre-launch environment, launch environment, operational environment and in the case of an abort mission the crash landing requirement.

The 50 g acceleration loading requirement provides increased structural integrity for the BIPS components and mount pads. This is necessary to compensate for a lower degree of mounting redundancy than the interface support structure (beams and struts). In the case of statically determinate mounted component such as the recuperator, failure of a single mount could result in component failure, whereas the interface structure is a redundant system that can tolerate a number of member failures without critical results.

****3.5.4.3 Acoustics**

The BIPS design shall consider the estimated payload bay acoustic spectra generated by the SSV engine exhaust and by aerodynamic noise during atmospheric flight as shown in Figure 3-13. The estimated time history of the payload bay noise level is shown in Figure 3-14. The data presented in these figures are based on an empty payload bay and may be modified by the addition of payloads such as the BIPS/spacecraft/IUS vehicle. The sound pressure levels are overall spatial averages.

ANALYTICAL PREDICTIONS MAXIMUM ORBITER PAYLOAD BAY
INTERNAL ACOUSTIC SPECTRA

FIGURE 3-13

ORBITER PAYLOAD BAY INTERNAL ACOUSTIC TIME HISTORY

FIGURE 3-14

Aerodynamic noise during entry is significantly less than shown by Figure 3-13 for liftoff through ascent. Acoustic levels during ascent at maximum dynamic pressure (Q) (See Figure 3-14) is generally 5 dB lower for 50 percent of the flights. Only one percent of the flights is expected to experience 135 dB.

The predictions of the Orbiter payload bay internal acoustic environment are based on the current mid-fuselage and payload bay door design. These predictions will be progressively refined and ultimately confirmed during future tests. Additional reduction in the acoustic level experienced by the payload may be achieved, in specific cases, by such means as added insulation or shrouds (payload chargeable).

****3.5.4.4 Acceleration**

The BIPS design shall consider the design limits established for a multiple payload (BIPS/spacecraft/IUS Vehicle) as defined by Sections 7.4 and 7.5 of JSC 07700, Volume XIV. For design purposes, maximum g's that will be encountered in the axial and transverse directions (relative to the shuttle axis) are presented in Table 3-6.

****3.5.4.5 Thermal Environment**

Determination of temperature environments which the BIPS payload will experience in the SSV payload bay requires knowledge of the specific mission environment from boost through entry, the type of thermal control provided in the SSV, payload bay, and payload thermal characteristics. To determine this information requires detailed knowledge of the SSV and payload design, as well as the specific in-flight orientations which probably will vary for each different mission objective. To initiate thermal design and integration, the following data shall be used as a guide and should include detailed analysis as required.

TABLE 3-6

MAXIMUM PAYLOAD LINEAR G-LOADS
AND ANGULAR ACCELERATIONS

Condition	Axial or Transverse	Linear G Load	Augmented Acceleration Rad/sec ²
Entry and landing	Axial	+1.06	--
Bost	Axial	-3.3	--
Crash	Axial	+9.00 -1.50	-- --
Landing	Transverse	+2.8	--
Lift-Off	Transverse	-1.5	--
Crash	Transverse	+4.5 -2.0	-- --
Entry and landing	Axial	--	+0.25 -0.25
Landing	Axial	--	+1.25 -0.75

**3.5.4.5.1 Payload Bay Environment

The BIPS design shall consider the SSV payload bay thermal environment. The shuttle payload bay thermal design environment is summarized in Table 3-5 for the case of no payload heat addition or removal.

For transient periods of launch (TBD), entry, and post-landing (touchdown + 30 minutes) the typical variation of the payload bay wall temperature and heat loads are illustrated in Figures 3-15 and 3-16 for the boundary cases of no heat transfer to or from the payload (adiabatic) and for constant temperature (infinite sink) payloads. Figure 3-15 provides payload bay wall temperature and Figure 3-16 provides heat loads or heat fluxes on payloads. The payload and payload bay locations where data are given are illustrated in Figure 3-17. A schematic diagram of the payload bay surfaces construction is presented on Figure 3-18.

A 10 ft (3048 mm) diameter x 60 ft (18,288 mm) long cylindrical payload was used to establish the data. At the beginning of entry, with the payload bay doors closed, a payload bay wall temperature of 70°F (21.1°C) was assumed.

For the on-orbit condition, typical values for temperatures and heat rates are given in Figures 3-19 (payload bay doors closed) and 3-20 (payload bay doors open). The data provided in Figure 3-20 are for an empty bay condition and for a cylindrical payload in the bay. The payload properties are $\epsilon = 0.80$ and $\alpha/e = 0.40$.

ENTRY THERMAL ENVIRONMENT (1 of 4)

$X_0 = 582 \text{ TO } 760$

FIGURE 3-15

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ENTRY THERMAL ENVIRONMENT (2 of 4)
 $X_0 = 760 \text{ TO } 919$

FIGURE 3-15

ENTRY THERMAL ENVIRONMENT
 $X_0 = 919$ TO 1191

(3 of 4)

FIGURE 3-15

ENTRY THERMAL ENVIRONMENT
 $X_0 = 1191$ to 1307

(4 of 4)

FIGURE 3-15

FIGURE 3-16

PAYLOAD BAY WALL AND PAYLOAD DATA POINT LOCATION

FIGURE 3-17

Payload bay surfaces

FIGURE 3-18

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ON-ORBIT THERMAL ENVIRONMENT WITH PAYLOAD BAY DOOR CLOSED

FIGURE 3-19

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DATA POINT LOCATION (See Figure 14-4) PORT STBD	BOTTOM TO SUN		TOP TO SUN		PORT SIDE TO SUN		TAIL TO SUN
	T	Q	T	Q	T	Q	T	Q
X = 582 TO 760								
1	-117 (-82.78)	2.015 (0.6357)	171 (77.22)	48.851 (15.4111)	-6 (-21.11)	19.384 (6.1151)	-210 (-134.44)	0.0
2	-111 (-79.44)	3.608 (1.1382)	209 (98.33)	72.664 (22.9865)	+3 (-16.11)	23.546 (7.4281)	-215 (-137.22)	0.0
3	-105 (-76.11)	8.871 (2.7985)	198 (92.22)	66.688 (21.0381)	+4 (-15.56)	23.643 (7.4587)	-212 (-135.56)	0.0
4	-47 (-43.89)	16.101 (5.0794)	150 (65.56)	37.568 (11.8576)	-3 (-19.44)	19.722 (6.2217)	-210 (-134.44)	0.0
X = 760 TO 919								
1	-130 (-90.00)	2.445 (0.7713)	156 (68.89)	51.360 (15.2026)	-10 (-23.33)	23.354 (7.3675)	-214 (-136.67)	0.0
2	-125 (-87.22)	4.354 (1.3736)	188 (86.67)	73.155 (23.0783)	0 (-17.78)	28.718 (9.0597)	-244 (-153.33)	0.0
3	-87 (-66.11)	10.690 (3.3724)	175 (79.44)	64.969 (20.502)	-7 (-21.67)	26.805 (8.4562)	-244 (-153.33)	0.0
4	-58 (-50.00)	16.026 (5.0557)	130 (54.44)	37.564 (11.8503)	-8 (-22.22)	23.728 (7.4855)	-235 (-148.33)	0.0
X = 919 TO 1191								
1	-150 (-101.11)	2.421 (0.7638)	163 (72.78)	52.279 (16.4925)	-10 (-23.33)	23.058 (7.2741)	-283 (-175.00)	0.0
2	-143 (-97.22)	4.340 (1.3691)	194 (90.00)	73.440 (23.1682)	-1 (-16.33)	28.264 (8.9165)	-296 (-182.22)	0.0
3	-100 (-73.33)	10.632 (3.3541)	180 (82.22)	65.552 (20.6797)	0 (-17.78)	28.378 (8.9524)	-294 (-181.11)	0.0
4	-70 (-56.67)	15.855 (5.0018)	137 (59.33)	38.629 (12.1863)	-7 (-21.67)	23.438 (7.3940)	-280 (-173.33)	0.0
X = 1191 TO 1307								
1	-150 (-101.11)	1.834 (0.5766)	166 (74.44)	46.532 (14.6797)	0 (-17.78)	23.120 (7.2937)	-281 (-173.89)	0.0
2	-132 (-91.11)	3.203 (1.0105)	200 (93.33)	70.737 (22.3155)	-9 (-22.78)	21.555 (6.8000)	-250 (-156.67)	0.0
3	-87 (-66.11)	10.520 (3.3188)	181 (82.78)	65.186 (20.5643)	-10 (-23.33)	21.674 (6.8375)	-248 (-155.56)	0.0
4	-80 (-62.22)	11.695 (3.6894)	170 (76.67)	48.046 (15.1571)	-16 (-26.67)	17.773 (5.6069)	-273 (-169.44)	0.0

T - TEMPERATURE, -°F (°C)

Q - ORBITAL AVE. ABS. SOLAR + EARTH HEAT FLUX, -Btu/hr-sqft - (Watts/sq cm x 10⁻³)

ON-ORBIT THERMAL ENVIRONMENT EMPTY PAYLOAD BAY

FIGURE 3-20

3.5.4.5.2 Payload Bay Entry Environment

For normal thermal condition at touchdown + 30 minutes, the GSE purge for interstitial cooling will be provided to the payload bay so that the temperatures shown in Figure 3-15 represent the maximum predicted values and would gradually decrease to ambient conditions as indicated in Figure 3-21 for the boundary cases of no heat transfer to or from payload (adiabatic) and constant temperature (infinite heat sink). The effect of continuing heat soak to the payload bay beyond touchdown + 30 minutes is also given in Figure 3-21.

*3.5.5 BIPS Contamination Control

The BIPS shall be designed to insure that a minimum of cross contamination may occur during system operation, as related to potential cross contamination of other system segments such as the spacecraft, IUS vehicle, or Space Shuttle.

Materials shall be selected for low outgassing characteristics. Selection criteria shall be 1 percent total mass loss and 0.1 percent volatile condensable material (VCM).

**3.5.6 Nuclear Effects

The BIPS design shall consider the requirement to survive the following levels of nuclear radiation emanating from the detonation of a nuclear war head in TBD space. Measures shall be taken to provide hardening sufficient to assure system survival against this threat.

ENTRY THERMAL ENVIRONMENT PAYLOAD
BAY AIR TEMPERATURE

FIGURE 3-21

*3.6 Safety/Reliability/Quality

*3.6.1 Safety

The design shall consider the ultimate requirements of nuclear flight safety as it relates to the BIPS. Packaging arrangements materials selection, and failure modes shall be considered to assure that the design reflects minimum ultimate nuclear risks in a flight system.

A system safety program shall be conducted to provide assurance that the following safety criteria will be considered:

- (a) Isotopic fuels and radioactive products, emanating from fuel or fuel by-products will not provide any undue safety hazard to personnel or the environment during normal operation, or in the event of foreseeable accidents.
- (b) All other potential hazards to personnel or system components will be identified and controlled.
- (c) Assurance of payload compatibility with spacecraft, IUS vehicle, and SSV as related to safety.

*3.6.2 Reliability and Quality

The design shall consider the necessary quality and reliability assurance associated with design, fabrication and testing of the BIPS. The Quality Assurance and Reliability plans, will use as general guidelines the objectives of ERDA Documents Quality Assurance Program Requirements for Space Nuclear Systems, SNS-1, Rev. 1, dated February 28, 1975, and Reliability Engineering Program Requirements Publication,

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SNS-2 dated June 17, 1974, specifically modified for the GDS with the intent of establishing background data for the subsequent FS effort. QA and Reliability plans have been prepared and approved by ERDA.

Unless otherwise specified, all quality assurance requirements shall be the responsibility of AiResearch. Tests shall be conducted at AiResearch facilities, subcontractor's facilities, or any commercial laboratory acceptable to the ERDA.

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*4. BIPS GDS AND FS TESTS

*4.1 General

This section establishes requirements for verification of the performance and design requirements of Section 3 herein. Test plans/procedures will be developed, as applicable, for GDS and FS testing, and will be submitted to the procuring activity for approval. Approval by the procuring activity shall constitute authority to proceed with testing. Satisfactory completion of all required testing shall be based on approval by the procuring activity of test reports and data submitted. Tests required for GDS and FS development and evaluation are discussed in the following paragraphs.

4.2 BIPS GDS Tests

A detailed test plan which defines the overall GDS test program shall be prepared and submitted to the ERDA for review and approval. The test plan shall define detailed test objectives, test facility functional requirements, system components, controls and instrumentation, special test equipment, and data to be obtained. Appropriate reference shall also be provided relative to anticipated development testing on weld joints, bellows, ducting, control system, materials, and insulation. A detailed summary of test requirements are included in AiResearch Report 76-311737, BIPS Specification Requirements Summary.

4.2.1 Performance Test

A system performance test shall be performed to establish and verify the mode of operation and to verify performance data.

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The GDS shall be optimized to operate at 1300 watts(e) output and a complete performance mapping should be performed at that power level. In addition, it is highly desirable that the testing program demonstrate, if possible, the capability of the system technology to provide flexibility of power output in the range of 500 to 2000 watts(e) with minimum redesign and reconfiguration. A series of startup and shutdown tests shall be performed in considerable depth, and data will be taken to permit comprehensive cycle evaluation and loss analysis. Measurements will be taken at all of the key thermodynamic cycle state points as well as at selected metal and insulation system temperatures.

A detailed performance test procedure shall be prepared for ERDA review and approval. A formal test report shall be prepared upon test completion that summarizes test results.

4.2.2 Endurance Test

Upon completion of the performance test, a 1000 hour endurance test shall be conducted. In conjunction with component tests and performance tests the endurance test shall be used to provide a lifetime assessment of the potential flight system (FS). Factors to be assessed include:

- (a) FMEA substantiation
- (b) Life limiting factors
- (c) Potential system lifetime
- (d) Detect basic design deficiencies which may exist in the original configuration including synergistic effects

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- (e) Detect weaknesses in test facility design which could prevent economical long duration tests
- (f) Determine precise costs for testing (\$/hr for endurance testing).

A detailed endurance test procedure shall be prepared for ERDA review. A formal test report will be prepared upon test completion that summarizes test results.

4.2.3 Overall Test Objectives

The GDS objectives specified below, shall demonstrate ability of the system to meet the basic design requirements of Section 3 with strong emphasis placed upon sufficient data acquisition to support the FS design.

Specific test objectives are:

- (a) The accumulation of operational time and data
- (b) The test of components and subsystems under simulated operating conditions.
- (c) Verification of performance at design point, off design, and in transient regimes
- (d) Verification of subsystems reliability and safety characteristics
- (e) Demonstration of prototype life capability.

**4.3 BIPS FS Tests

TBD.

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**5. PREPARATION FOR DELIVERY

5.1 Packaging

Packaging of the BIPS FS equipment for delivery to the procuring agency shall be prepared in accordance with the detailed provisions of AiResearch Specification (TBD). This specification shall be developed in accordance with the applicable sections of Specification MIL-P-9024.

5.2 Marking

5.2.1 Marking for Shipment

Marking for shipment shall be in accordance with MIL-STD-129.

5.2.2 Special Instructions

Special instructions shall be provided for use during receiving inspection, installation and operation. If non-obvious characteristics require that special handling be used, the procuring agency shall be notified under separate cover and a removable instruction tag shall be attached. Attachment shall be to the shipping container or to the article as appropriate.

6. NOTES AND DEFINITIONS

6.1 Definitions

6.1.1 Abort

Abort is the termination of the mission due to failure of the SSV or a payload.

6.1.2 Design Condition

A phenomenon, event, time interval, or combination thereof important in structural design. It may involve a specific point in time or integrated effects over a period of time in terms of physical units such as pressure, temperature, load, acceleration, etc.

6.1.3 Detrimental Deformation

Deformations, either elastic or inelastic, resulting from the application of loads, pressures and temperatures, which prevent any portion of the structure from performing its intended function, or which reduce the probability of successful completion of the mission.

6.1.4 Deployment

Unless otherwise specified, this refers to deployment of the IUS/spacecraft/BIPS combination from the Orbiter.

6.1.5 Failure

A rupture, collapse, or seizure, an excessive wear, or any other phenomenon resulting in an inability to sustain design loads, pressures, and environments without detrimental deformation, or inability to perform its intended function, or a reduction in the probability of successful mission completion.

6.1.6 Loads

6.1.6.1 Limit Load

The maximum load expected to act on a structure in the expected operating environments.

6.1.6.2 Ultimate Load

The product of the limit load and the ultimate factor of safety. It is the maximum load which the structure must withstand without rupture or collapse in the expected operating environments.

6.1.7 Load Factor

The acceleration to be used for design at a specified operational condition; expressed in g's for linear acceleration, in rad/sec sq. for angular acceleration.

6.1.8 Margin of Safety

The increment by which the allowable load (i.e., ultimate or limit) exceeds the applied load for a specific design condition, expressed as a fraction of the applied load.

6.1.9 Orbiter

The second stage of the Space Shuttle system and flight vehicle which goes into earth orbit with the payload, and provides support to the payload.

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6.1.10 Payload

Any item charged against the weight performance capability of the shuttle. Refers to the IUS vehicle, ASE, spacecraft, BIPS and other necessary support items which are mission peculiar.

6.1.11 Payload Bay

Refers to that volume in the Orbiter available for the stowage of payloads (IUS and spacecraft/BIPS) during ascent and re-entry.

6.1.12 Reaction Control System (RCS)

The thruster and propulsion portion of the altitude control system. Includes the RCS propellant feed system.

6.1.13 Safety Factor

A multiplying factor used to account for design uncertainties which cannot be analysed or otherwise accounted for in a rational manner.

6.1.14 Spacecraft

Any hardware to be delivered by the IUS vehicle.

6.1.15 Stiffness

Structural resistance to deflection under an applied force or torque.

6.1.16 TBD

To be determined and made a part of the specification.

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6.1.17 Useful Life

The interval beginning with manufacture of a specific hardware item and ending with completion of its specific mission.