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Hitchhiker

Customer Accommodations & Requirements Specifications

HHG-730-1503-06

1992

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Goddard
Space Flight Center
Greenbelt, Maryland

NASA
HITCHHIKER

Hitchhiker

Customer Accommodations & Requirements Specifications

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NASA HITCHHIKER

Goddard
Space Flight Center
Greenbelt, Maryland

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Changes* to

HITCHHIKER CUSTOMER ACCOMMODATIONS AND
REQUIREMENTS SPECIFICATIONS
HHG-730-1503-06

Change No.	Date	Nature of Change	Initials

*Recipients of the original distribution of this document will automatically receive changes. Others can request changes in a memo to the SSPP Customer Support Office (CSO), Code 740.3, NASA/GSFC, Greenbelt, Maryland 20771.

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SECTION-1

1. INTRODUCTION

In 1984, NASA Headquarters established projects at the Goddard Space Flight Center (GSFC) and the Marshall Space Flight Center (MSFC) to develop quick-reaction carrier systems for low-cost "flight of opportunity" or secondary payloads on the Space Transportation System (STS). One of these projects is the Hitchhiker (HH) Program. GSFC has developed a family of carrier equipment known as the Shuttle Payload of Opportunity Carrier (SPOC) system for mounting small payloads such as HH to the side of the Orbiter payload bay. The side-mounted HHs are referred to as Hitchhiker-G (HH-G). MSFC developed a cross-bay "bridge-type" carrier structure called the Hitchhiker-M (HH-M). In 1987, responsibility for the HH-M carrier was transferred to and is now managed by the HH Project Office at the GSFC. The HH-M carrier now uses the same interchangeable SPOC avionics unit and the same electrical interfaces and services developed for HH-G.

1.1 PURPOSE

National Aeronautics and Space Administration (NASA) has created this document to acquaint potential HH system customers with the facilities NASA provides and the requirements which customers must satisfy to use these facilities.

This publication defines interface items required for integrating customer equipment with the HH carrier system. Those items such as mounting equipment and electrical inputs and outputs; configuration, environmental, command, telemetry, and operational constraints are described as well as weight, power, and communications. The purpose of this publication is to help the customer understand essential integration documentation requirements and to prepare a Customer Payload Requirements (CPR) document.

1.2 CPR DOCUMENT

The customer shall prepare a CPR document (appendix E) which specifies all interface requirements and parameters. The CPR contains thermal, mechanical, electrical, attitude control, alignment, test and checkout, contamination control, mission operations, and shipping and handling requirements. It also includes customer-prepared interface drawings and schematics. The document defines which of the available carrier services and interfaces the customer needs and is requesting. Requirements over and above those noted here need specific authorization by the HH Project Office. They shall be documented in the CPR document as deviations from standard interfaces and services.

1.3 HH PROJECT ORGANIZATION

The HH Program is managed by the Carrier System Division of the NASA Headquarters Office of Space Flight and implemented by the GSFC HH Project Office which is part of the GSFC Shuttle Small Payloads Project (SSPP).

1.4 POINTS OF CONTACT

Key points of contact within the HH Program and Project Offices, as well as their telephone numbers follow.

Hitchhiker Program Office

NASA Headquarters, Code MK
Washington, DC 20546

Facsimile: (202) 426-8953

Program Office: (202) 453-1889

Hitchhiker Project Office

Code 740
Goddard Space Flight Center
Greenbelt, MD 20771
(301) 286-8799

Facsimile: (301) 286-2376
GSFCMAIL: TGOLDSMITH

Project Office: (301) 286-8799

Customer Support Office: (301) 286-6760

Hitchhiker Reimbursable Payloads

NASA Headquarters, Code MC
Washington, DC 20546
(202) 453-2300
Facsimile: (202) 426-6318

1.5 HH PAYLOAD MANIFESTING

In 1987, NASA redefined Space Shuttle payload categories as follows. Primary payloads weigh more than 8,000 pounds each; their requirements may determine Shuttle mission parameters such as orbit altitude and inclination. Secondary payloads are accommodated in space remaining after manifesting the primary payloads; weighing less than 8,000 pounds each, their requirements can not determine major mission parameters. Secondary payloads such as HH will be manifested under a system to be described later. Tertiary payloads are accommodated in space remaining after manifesting primary and secondary payloads; these currently consist of Get Away Special (GAS) payloads already in the GAS queue.

Potential HH customers should submit a Request for Flight, Form 1628 (Figures 1.1, 1.1a, and 1.1b) through the appropriate Headquarters discipline office and arrange to be included in the office priority list. Department of Defense (DOD) HH customers should contact the United States Air Force/Space Systems Division Code CLP.

NASA
National Aeronautics and Space Administration

Request for Flight Assignment

Form Approved O. M. B. No. 2700-0040
CONTROL NO. *(MC Use)*

Note.- Please read and detach instructions before completing this request.

TO	National Aeronautics and Space Administration Customer Services Code MC Washington, DC 20546	FROM	DEVELOPMENT COMPANY/AGENCY NAME AND ADDRESS PRINCIPAL CONTACT *(Name and Phone, incl. Area Code)*

I-BASIC PAYLOAD AND FLIGHT DATA

1. PAYLOAD TITLE

2. PAYLOAD OBJECTIVES

3. CATEGORY

☐ a. U.S. COMMERCIAL ☐ b. DOD ☐ c. NASA ☐ d. FOREIGN COMMERCIAL
☐ e. FOREIGN GOVERNMENT ☐ f. OTHER U.S. GOVT. ☐ g. JEA/OTHER

4. FLIGHT INFORMATION *(Check at least one in items 1-4)*

1 ☐ a. SHARED ☐ b. DEDICATED
2 ☐ a. CARGO BAY ☐ b. MIDDECK *(Specify locker volume):* ____________
3 ☐ a. ATTACHED ☐ b. DEPLOYABLE ☐ c. RETRIEVAL ☐ d. REVISIT/SERVICE
4 ☐ a. KSC ☐ b. VLS

5. CARRIER

☐ a. PAM D ☐ b. PAM DII ☐ c. IUS
☐ d. MPESS ☐ e. HITCHHIKER-G ☐ f. HITCHHIKER-M
☐ g. SPACELAB *(Specify; e.g., LM&P)* __________ ☐ h. OTHER *(Specify)* __________

II-PAYLOAD REQUIREMENTS

6. PAYLOAD ORBIT REQUIREMENTS

☐ a. 160NM ALTITUDE/28.5 INCLINATION ☐ b. 160NM ALTITUDE/57 INCLINATION
☐ c. OTHER: (1) NM ALTITUDE _____ ; (2) DEGREES INCLINATION _____ ☐ d. ORBIT INSENSITIVE

7. PAYLOAD LAUNCH REQUESTED *(Total launch(es) and date(s)) (Enter month and year only)*

a. NUMBER OF LAUNCHES ____________

b. FIRST LAUNCH *(Scheduled, stand-by, or short-term call-up)* ____________

c. SUBSEQUENT LAUNCH(ES) ____________

____

d. MINIMUM INTERVAL REQUIRED BETWEEN LAUNCHES ____________

NASA FORM 1628 SEP 86 *(Formerly STS Form 100)*

FIGURE 1.1
NASA FORM 1628

II-PAYLOAD REQUIREMENTS *(Continued)*

8. UNIQUE PAYLOAD CONSTRAINTS *(e.g., launch window, late servicing, early access, etc.)*

9. REMOTE MANIPULATOR SYSTEM REQUIRED	10. PAYLOAD MISSION DURATION REQUIRED
☐ a. YES ☐ b. NO	☐ a. YES *(Indicate hours/days)* ______ ☐ b. NO

III-PAYLOAD REQUIREMENTS CHARACTERISTICS
(The term payload refers to all customer provided equipment and associated carrier)

11. LAUNCH	a. WEIGHT *(LB/KG)*	b. MAX. DIAMETER *(IN/CM)*	c. MAX. LENGTH *(IN/CM)*	d. CG *(IN/CM)*
12. LANDING	a. WEIGHT *(LB/KG)*	b. MAX. DIAMETER *(IN/CM)*	c. MAX. LENGTH *(IN/CM)*	d. CG *(IN/CM)*

IV-QUESTIONNAIRE AND SERVICE REQUIREMENTS

DESCRIPTION	YES a.	NO b.
13. HAS EARNEST MONEY BEEN SUBMITTED?		
14. DOES YOUR ORGANIZATION REQUIRE COPIES OF STANDARD STS DOCUMENTATION?		

15. SERVICES *(List any anticipated special services required)*

16. REMARKS

17. TYPED NAME AND TITLE	18. SIGNATURE	19. DATE

FIGURE 1.1a

NASA FORM 1628 (Cont'd)

GUIDELINES FOR COMPLETION OF NASA FORM 1628
(Formerly STS Form 100)

A completed NASA Form 1628 enables a payload developer to inform NASA of his or her intentions to use the National Space Transportation System (NSTS). Information contained in this form permits NASA to become familiar with general payload requirements and develop a preliminary STS cargo manifest which assigns the identified payload to a particular orbiter flight.

This form should be completed for a single payload entity rather than for individual experiments which would fly on a common carrier. Instructions listed below are intended to assist the payload developer in completing this form.

1. Payload Title.- Enter the name you plan to use when referring to your payload.

2. Payload Objectives - Identify the major objectives for this payload program. For example, "This payload will map the surface of Venus using radar from orbiting spacecraft. Instruments will include imaging radar and microwave radiometers."

3. Category.- Select the appropriate customer category by placing an "x" in the proper box.

4. Flight Information.- Select at least one category for each item listed. For example, a company requests a launch to deploy its satellite and a later launch to service it, in which the spaces designated as "Cargo Bay," "Deployable," and "Revisit/Service" would be checked.

5. Carrier.- Specify the type of carrier or upper stage required for the payload. Upper stage options are PAM-D, PAM-DII, IUS, TOS, SCOTS, IRIS, UNIQUE STAGE, HITCHHIKER-G, HITCHHIKER-M, SPACELAB (+ CONFIGURATION), MPESS, PALLET, SPOC, SPAS, SPECIAL STRUCTURE, etc.

6. Payload Orbit Requirements.- Select the desired orbit for your payload. If item 6c, "Other" is selected, please identify both the degree altitude and inclination.

7. Payload Launch Requested (Total launch(es) and date(s).

a. Number of Launches.- Enter the total number of flights required for this payload program.

b. First Launch.- Enter the desired date for the first flight of this payload.

c. Subsequent Launch(es).- List the requested flight date for each additional launch.

d. Minimum Interval Required Between Launches.- If you have requirements for a specific number of days, weeks, months or years between your payload launches, identify the spacing timeframe.

8. Unique Payload Constraints.- List any unique requirements for your payload. Identify launch window constraints, experiment operating time, satellite checkout time, etc.

9. Remote Manipulator System Required.- Place an "x" in the appropriate box for use of Remote Manipulator System.

10. Payload Mission Duration Required.- If your payload requires a certain number of operating days in order to obtain the proper data, please indicate the number of hours and/or days required.

Payload Characteristics.- The term payload refers to all customer-provided equipment and associated carriers. Using U.S. or S.I. (Metric) measurement units, enter launch and landing weight, diameter and length of the payload as well as the center of gravity, if known, in items 11 and 12.

Questionnaire and Service Requirements. Items 13 and 14 are self-explanatory. List in item 15 any anticipated optional services required. Optional services are tasks performed for a charge using the existing capabilities of NASA. Some examples of optional services which would be listed in this block are: extravehicular activity, non-standard altitude and inclination, payload retrieval packages, etc.

16. Remarks.- Enter any further comments that concern your payload program.

17,18 and 19.- This request is to be signed by an official within the company who can authenticate the information provided. NASA payloads require the signature of an Associate Administrator.

NOTE.- If you need any additional assistance in completing this request, mail your inquiries to the address shown on the face of the form, or call (202) 453-2347.

FIGURE 1.1b

NASA FORM 1628 (Cont'd)

1.6 SPACE SHUTTLE HH ACCOMMODATIONS

HH payloads are accommodated on the Space Shuttle, which is operated by the NASA Headquarters Office of Space Flight. HH payloads are flown under the Space Shuttle Secondary Payload Program. The STS categorizes secondary payloads into two types: the Small Payload Accommodations (SPA) class payload and the Standard Mixed Cargo (SMC) class payload.

SPA class can be accommodated in the Space Shuttle with a minimum lead time of 11.5 months between manifesting and launch. SPA payloads are accommodated in bay positions two or three of the Orbiter, connect electrically to the SPA harness, and have restrictions regarding crew activity and other Space Shuttle functions which require analysis and planning.

SMC class payloads generally use the Orbiter Standard Mixed Cargo Harness (SMCH) and have more flexibility regarding bay location, crew activity, planning, and etc. SMC payloads have a minimum manifesting lead time of 19 months. SPA and SMC classes are shown in Table 1.1.

Table 1.1

Small Payload Accommodations (SPA) and
Standard Mixed Cargo (SMC) Payload Classes

	Small Payload	Standard Mixed
Orbiter Electrical Harness	SPA	SMCH
Total Payload Power (28VDC)*	1.4kw	1.75kw
Nominal Total Energy (Kwh/day)*	6	12.5
Crew Control Panel	SPA Switch Panel	Standard Switch Panel
Payload Bay Locations	2-8, 12, 13	2-12
Manifesting Lead Time (JSC)	11.5 months	19 months
Minimum HH Processing Time	15 months	23 months

* Includes Carrier Requirements of 75-125 W (1.8 - 3.0 Kwh/day)

HH carriers are designed to interface with either the SPA harness or the SMCH and can fly as either SPA- or SMC-class payloads. Each Orbiter has a single SPA harness to service a payload in bay positions two or three. A SPA Switch Panel (SPASP) in Aft Flight Deck (AFD) position A6 provides for crew control of a SPA payload. Each Orbiter also has four SMCH cable sets which can be connected to payloads anywhere in the payload bay. Each SMC payload will be connected to one-half of a Standard Switch Panel (SSP). SPA power is obtained through a tap on one of the SMCH power lines and is restrained by the requirements of any SMC payload connected to that line.

HH-M payloads are equipped with electrical connectors on either end of the bridge for connection to either a SPA or SMCH harness.

1.7 TRANSPORTATION AND INTEGRATION COSTS

HH is considered an extension of the basic Space Shuttle services. It is provided at no cost to NASA organizations (non-reimbursable organizations) for standard transportation and integration services. The standard HH integration service covers HH Project costs for a payload requiring no optional services or hardware. Additional integration costs are billed to the customer organization.

Reimbursable customers provide NASA with funds to cover transportation costs as well as standard and optional HH integration costs.

The Office of Space Flight (Code MC) has developed a preliminary policy for reimbursable HH payloads as follows:

The standard HH mounting "slot" accommodates any payload equipment which can be mounted in a canister or on a 25-inch mounting plate and attached to a HH side-mount or cross-bay carrier. The current charge factor per slot for customer payloads wishing to purchase space on a HH carrier on a shared basis is .0078. The FY1990 price for an entire shuttle payload is \$142M. The charge per HH slot is therefore .0078 x \$142M or \$1.108M. This charge covers shuttle transportation costs and standard GSFC integration services as deferred in this document for a one-slot payload. Payloads requiring more than one slot are charged an integral multiple of the above fee. Fractional slot payloads are not allowed. Shuttle fees are adjusted for inflation.

Customers requiring a dedicated HH carrier may be accommodated under the standard Shuttle Mixed Cargo Pricing Policy. GSFC integration charges for dedicated payloads are individually negotiated.

Customers desiring to use Hitchhiker services as part of the customer's primary payload or on the customer's dedicated flight will pay GSFC integration charges to be individually negotiated. Contact NASA Headquarters, Code MC for current pricing policy.

In cases where GSFC and the customer identify optional GSFC activities required by the customer, these will be priced on a case-by-case basis and are funded by the customer organization.

Transportation costs for secondary payloads, including HH, have not been determined at this time. It is anticipated that the secondary payload transportation price will be weight-oriented and based on the mixed cargo price. Reimbursable customers should contact NASA Headquarters, Code MC for current information regarding pricing. Discipline offices of non-reimbursable secondary payloads are charged for their payload weight against their allocation of secondary payload space. Accordingly, a "chargeable weight" will be developed for each HH customer payload.

Payloads sponsored by NASA discipline offices do not pay transportation costs. During the development of the Payload Integration Plan (PIP) with JSC and KSC, optional transportation services associated with a particular customer may be identified and estimated.

The current estimated weights (in lbs.) of various HH carrier equipment which could be used on a given mission are as follows:

Adapter Beam Assembly (ABA)		163.0
HH-G 50"x60" Plate (SPOC)		370.0
HH-G 25"x39" Plate		50.0
Avionics Unit (Beam Mount)		182.0
- Avionics	127.0	
- Plate	50.0	
- Bolts, etc.	5.0	

Sealed 5 ft^3 Canister		153.8
HMDA Canister		234.5
HMDA w/ Window Canister		258.3
HH-M Carrier		2165.0
- HHBA	1434.6	
- STP-1 MPE	323.4	
- STP-1 Cables	144.9	
- STP-1 Bolts	21.1	
- Avionics Assy	241.0	
(Avionics 127.0)		
(Plate & Misc. 114.0)		

	SEALED	HMDA
Canister w/ Blankets	67.0	67.0
Bridge Brkts & Bolts	15.0	15.0
Ground Strap	0.2	0.2
Lower End Plate (LEP)	29.4	29.4
Lower IEC	7.0	7.0
Battery Vent	1.3	1.3
End Plate Bolts	4.0	4.0
Upper End Plate	24.0	—
Upper IEC	6.0	—
HMDA	—	75.5
HMDA Blankets & Sht. Mtl.	—	15.5
HMDA EMP	—	11.0
HMDA Cable from LEP	—	2.0
HMDA Relay Box	—	6.7
Total	153.9	234.6
HMDA Window		18.9
Window Retainer		4.9
Total (HMDA w/ Window)		258.4

The following method is used for calculating chargeable weight:

Chargeable weight consists of the weight of all customer-supplied flight equipment plus the weight of any dedicated carrier equipment specifically required to accommodate the experiment such as canisters or mounting plates. An assessment for the pro-rata share of the common equipment is also required. Weight of attachment fittings (ABA or trunnion attachment fittings) is not included in chargeable weight.

Common equipment for the HH-G payload consists of the avionics unit and its adapter plate (182 pounds). A HH-G experiment which (with any support equipment) is mounted on one half of a ABA will be charged for 1/3 of the common equipment. Customers requiring more than the nominal one-experiment space will be charged for the appropriate pro-rata share in increments of 1/3. The common equipment charge will not be changed if NASA subsequently decides to fly less or more than the nominal number of customers on a particular carrier.

All anticipated charges, optional activities, and chargeable weights associated with a customer payload will be identified by GSFC when the CPR document is reviewed. Prices are calculated using an inflation factor dependent on the time of launch. The estimates given in the CPR are actual ("real year") prices based on the costing launch date.

1.7.1 Integration Cost

The integration costs consist of the cost of a package of normal services defined in Section 3 of this document covering GSFC activities in support of all HH payloads. In addition to the normal services, optional GSFC integration services may be required. Anticipated GSFC optional services will be identified and estimated. Finally, JSC and KSC may impose optional service costs for special activities required by a particular payload. Any such anticipated charges will also be identified and estimated during GSFC evaluation of the customer's requirements.

If you need more information regarding integration costs, contact the HH Project Office.

SECTION-2

2. THE HITCHHIKER CARRIER SYSTEM

The HH carrier system implements various modular hardware in mounting customer equipment in the payload bay. HH-G customer equipment is mounted in canisters, on small mounting plates, or directly to the Orbiter adapter beams. HH-M customer hardware is mounted to the HH bridge using standard canister hardware, small experiment mounting plates, or custom-mounting equipment. The standard avionics unit forms a part of both the HH-G and HH-M configurations. This unit provides the electrical interface between the Orbiter and up to six customer units. The weights of the various carrier units and their maximum customer weight capacities are shown in Table 2.1. Actual allowable customer weight depends on detailed analysis of actual mounting configuration and center of gravity. Table 2.1. also shows the weights of the GAS-type beam (attachment hardware for HH-G) and Keel Trunnion attachment hardware (used with HH-M). The attachment hardware weight is not counted in determining reimbursement to NASA for transportation cost.

Table 2.1
HH Carrier Equipment Capacities

Carrier Equipment	Carrier Weight (lbs)	Maximum Customer Weight (lbs)	Mounting Surface
Sealed Canister (insulated top plate)	160	200	19.75" Dia.
Sealed Canister (uninsulated top plate)	140	200	19.75" Dia.
Motorized Door Canister	235	170	19.75" Dia.
HH-G Small EMP	50	300	25" x 39"
HH-G Large (SPOC) EMP	370	330	50" x 60"
HH-G Direct Mount	-	700	20" x 40"
HH-M Side Mounting Plate (Experiment) (No Brackets)	61	250	25.6" x 39.5"
HH-M Small Top Mounting Plate (Exp.)	70 (Est.)	600	33.38" x 27.7"
HH-M Large Top Mounting Plate (Exp.) (No Brackets)	170 (Est.)	500	55.9" x 33.38"

Table 2.1 (Cont'd)

Avionics Unit (includes mounting plate & mounting hardware)	236	–	–
HH-M (includes avionics unit, mounting plate and standard MPE)	2165	1200	Custom-mounted

Attachment Hardware	Weight
HH-G GAS Beam, Bays 2-8, 12, 13	170 lbs.
HH-M Bridge Attachment Fittings for Bay 2	365 lbs.
HH-M Bridge Attachment Fittings for Bay 3	418 lbs.

2.1 MECHANICAL SUPPORT SYSTEMS

HH-G and customer hardware will be side-mounted to the Orbiter payload bay longeron and frame attachment points using GAS-type adapter beams. HH-G carrier components are illustrated in Figure 2.1. The large SPOC plate structural assembly is illustrated in Figure 2.2. The configuration shown in Figure 2.2 is available but is not recommended because of the difficulties encountered in handling and mounting.

Existing HH-G equipment is designed to be mounted on the starboard side of the cargo bay in bay locations 2 or 3. These locations are indicated in Figure 2.3 which shows the forward-most available positions in the bay for the GAS adapter beam mounting as well as the X-axis station numbers associated with these positions.

Figure 2.4 depicts an example of a typical structural configuration for HH-G payloads. Figure 2.5 shows a sideview of a typical HH-G payload mounting.

All plates that are to be side-mounted to the Orbiter are parallel to the X-Z plane. The X axis is along the long axis of the Orbiter; positive towards the tail. The Y axis is across the payload bay positive towards the starboard (right) wing. The Z axis completes the coordinate system and is positive moving "up" from the bottom of the Orbiter payload bay. See Figure 2.6.

The dynamic envelope of the cargo bay defines the maximum permitted extent of thermal and dynamic distortions of payload equipment. A maximum static design radius of 88 inches has been established for customer hardware (Figures 2.7 and 2.8). The maximum dynamic envelope radius is 90" (Figures 2.7 and 2.8). The maximum extent of payload equipment out from the sides of the mounting plates (along the Orbiter $\pm$ X directions) is mission-dependent. It will normally, however, be restricted to the width of the mounting plate to prevent interference with Orbiter Integration Ground Support Equipment (GSE).

The following subsections describe the various mechanical accommodations available with the HH-G system.

Hitchhiker-G Carrier Components

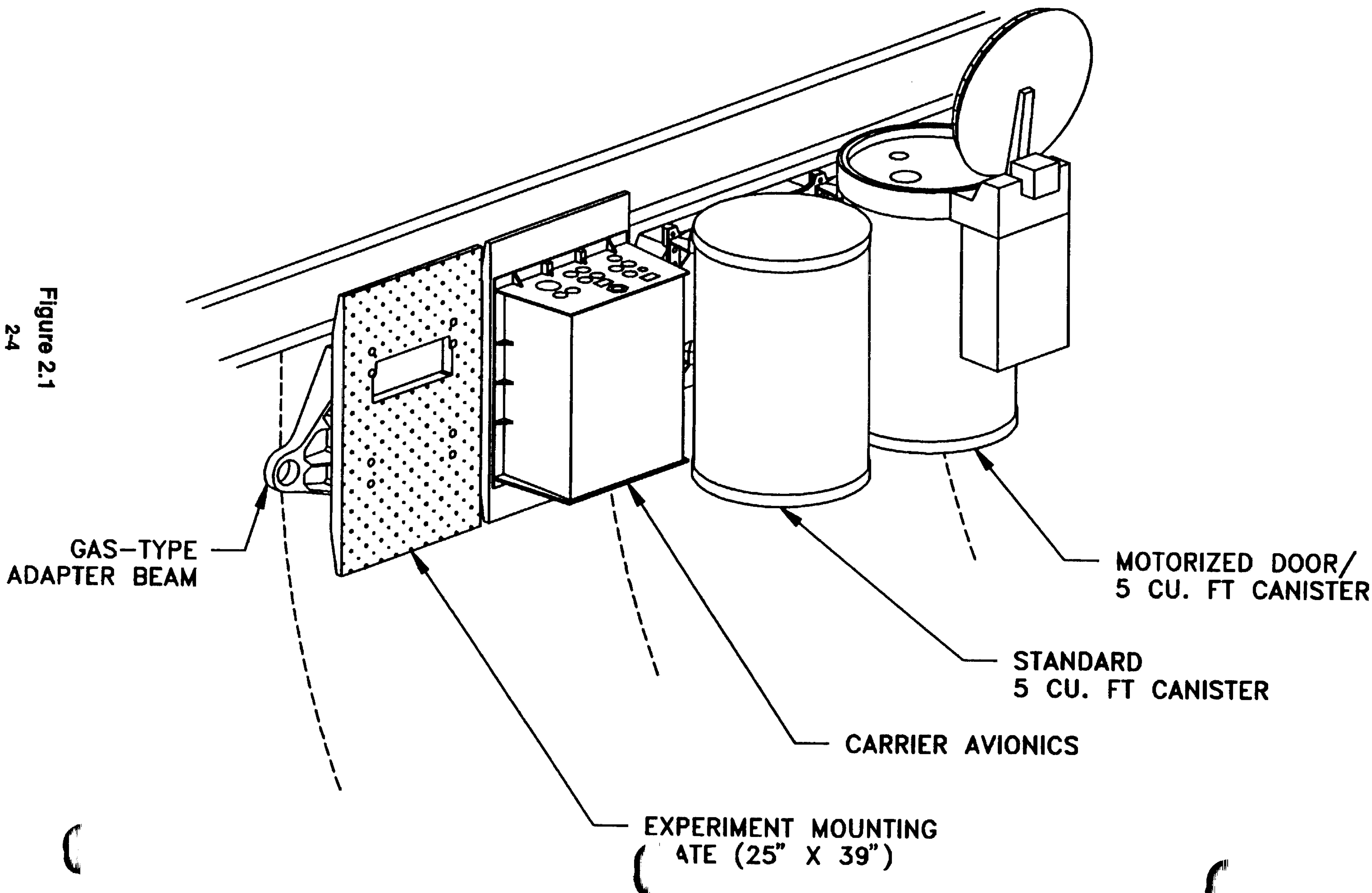


Figure 2.1

Hitchhiker-G SPOC Plate Structural Assembly

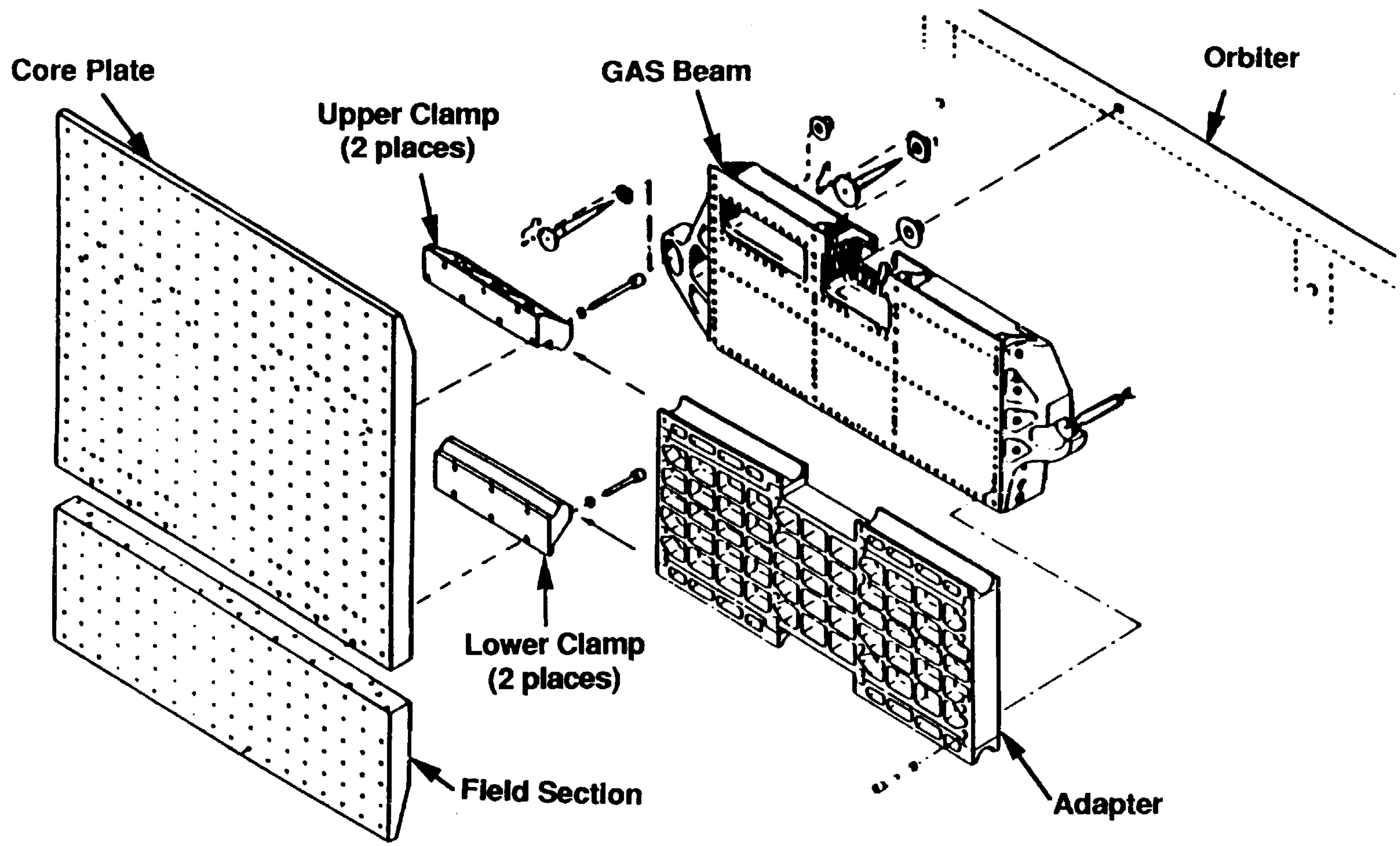


Figure 2.2

Hitchhiker-G
Available Sidewall Mounting Locations

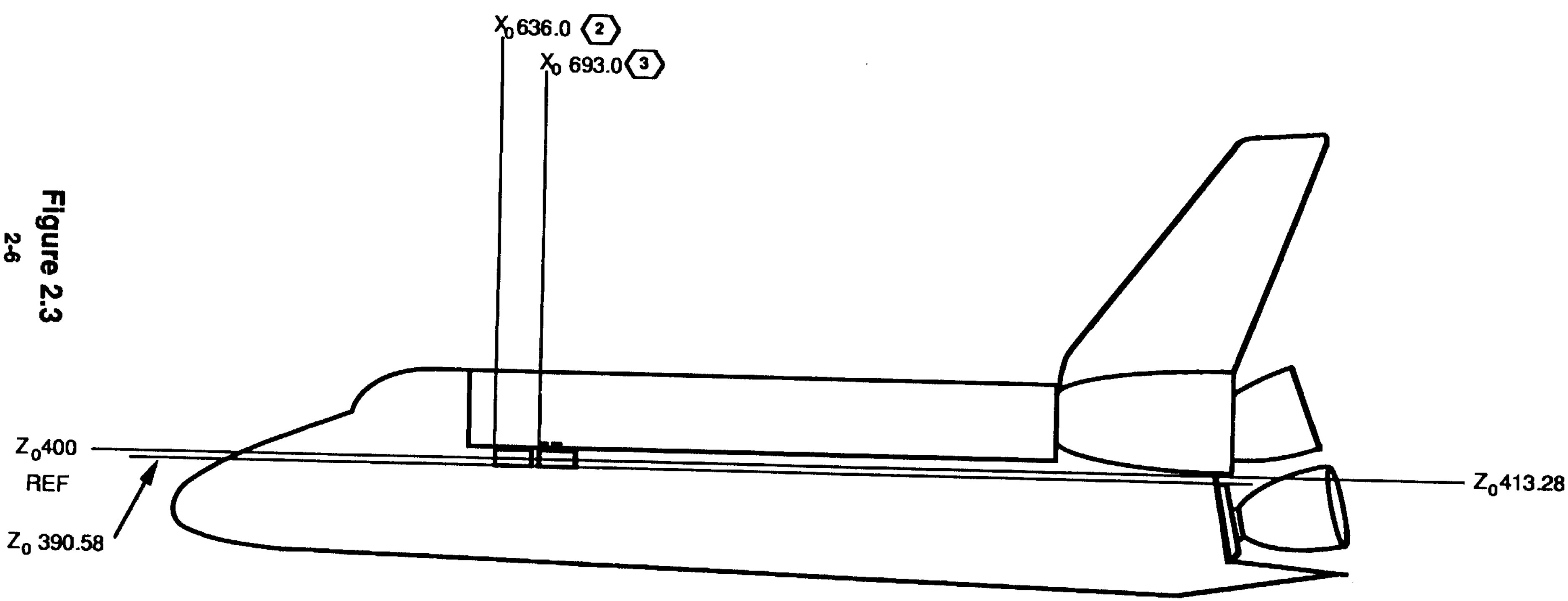


Figure 2.3

Hitchhiker-G Typical Structural Configuration

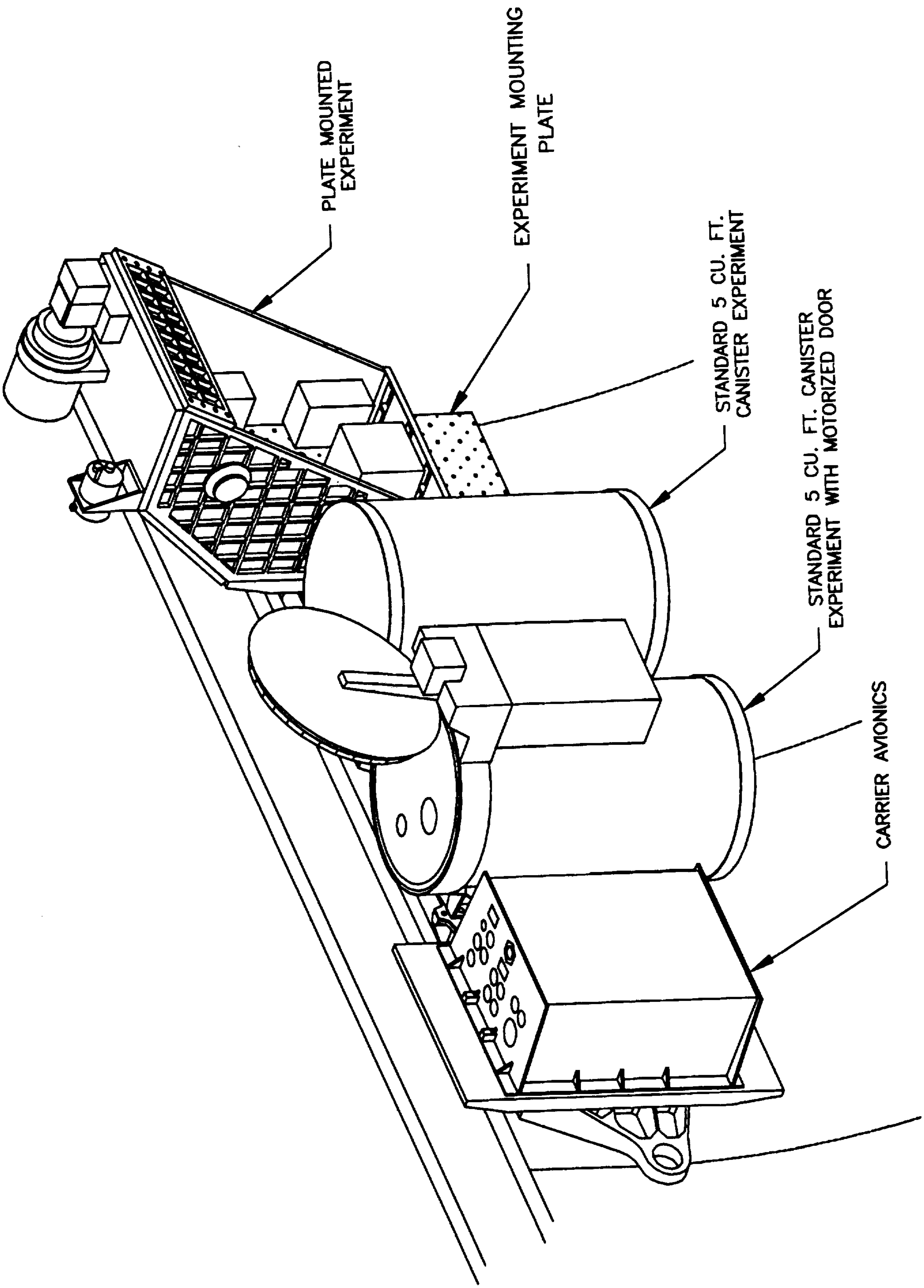
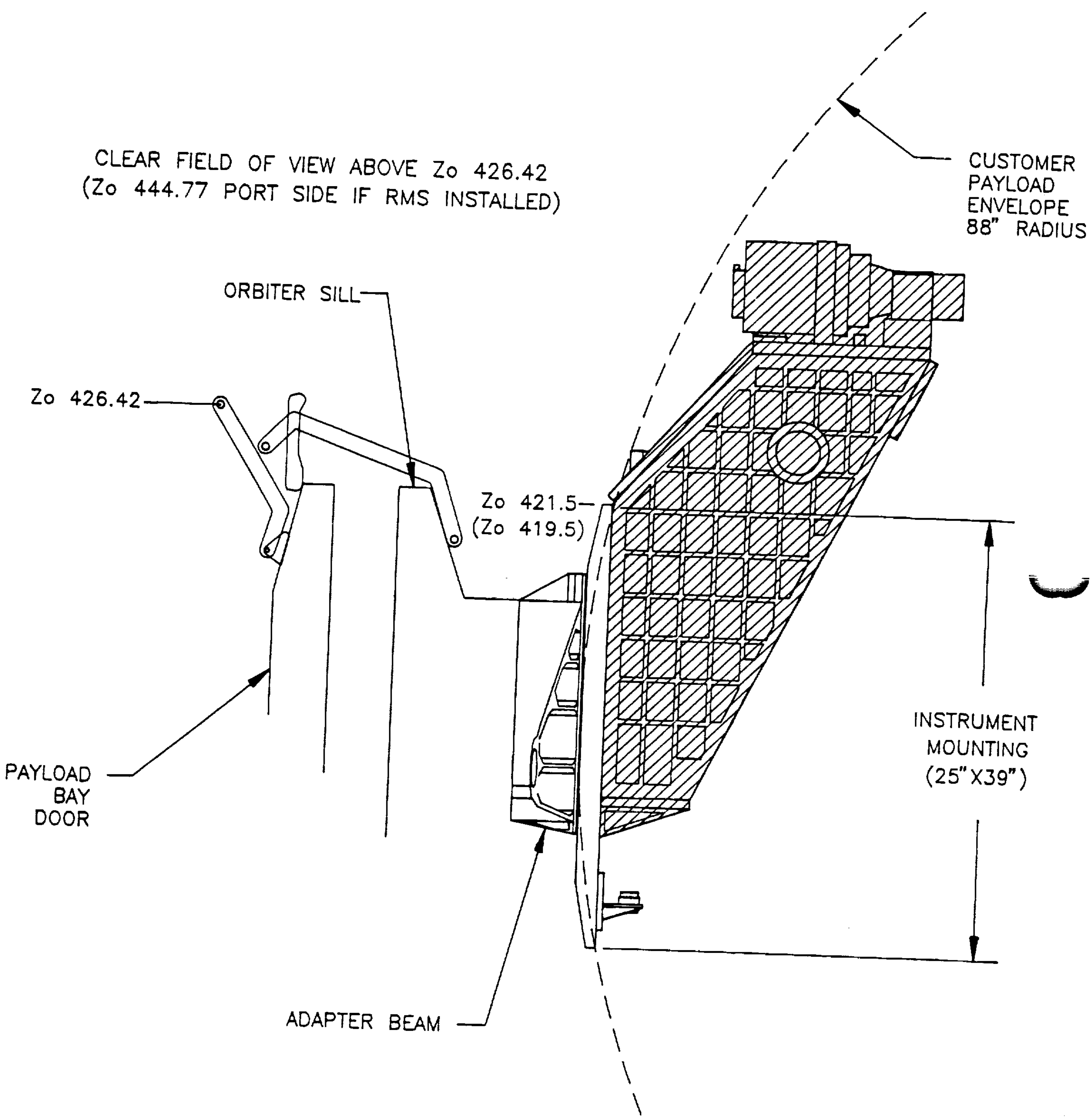


Figure 2.4

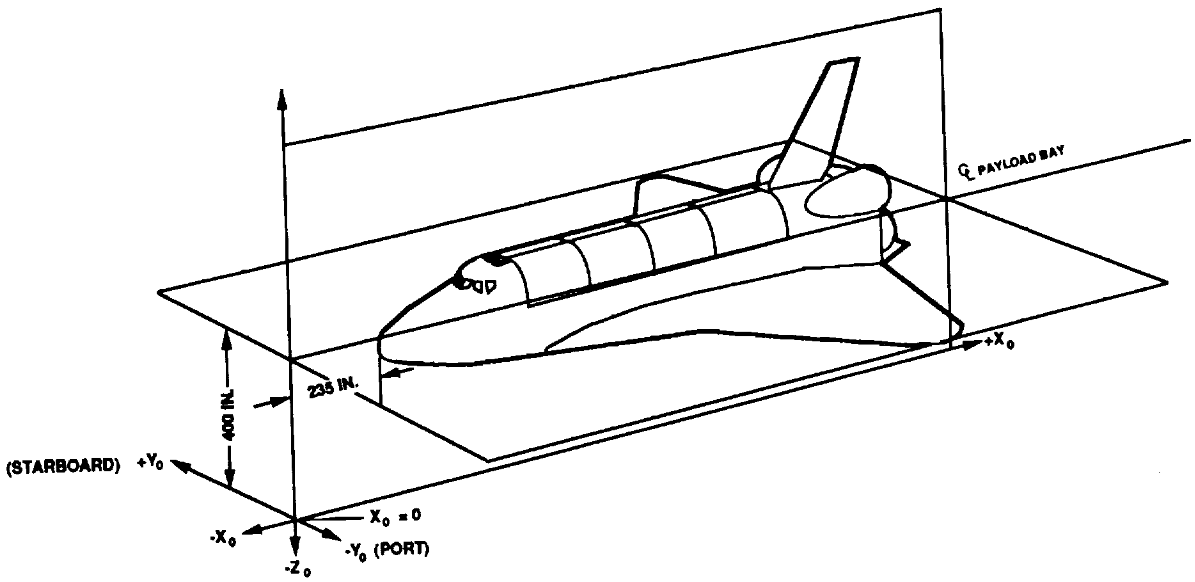
Hitchhiker-G Payload Mounting Concept (Sideview)



NOTE: Zo Coordinate in parenthesis indicates lower mounting position.

Figure 2.5

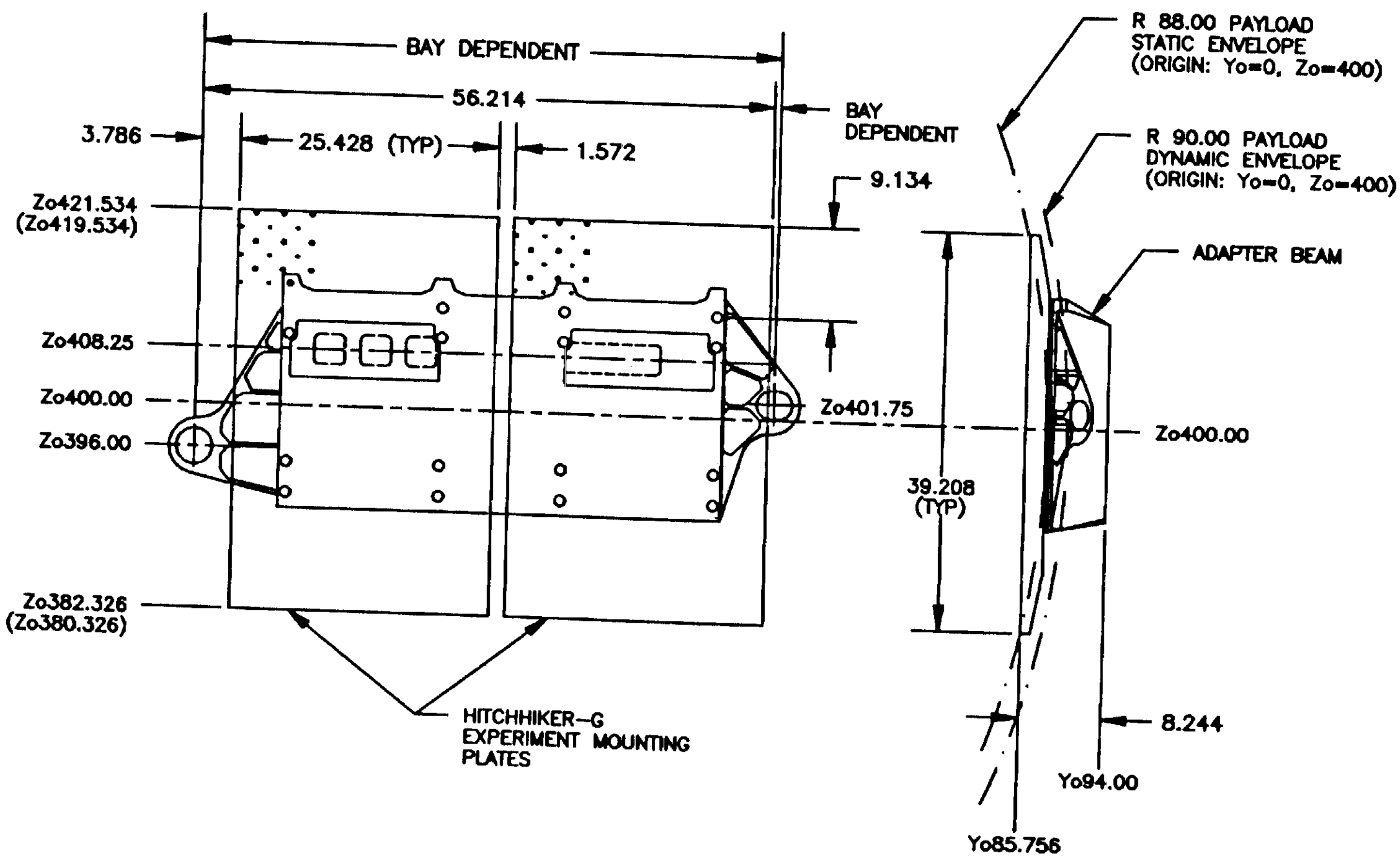
Orbiter Coordinate System



ORIGIN:	IN THE ORBITER PLANE OF SYMMETRY, 400 INCHES BELOW THE CENTER LINE OF THE PAYLOAD BAY AND AT ORBITER X STATION = 0.
ORIENTATION:	THE X_0 AXIS IS IN THE VEHICLE PLANE OF SYMMETRY. PARALLEL TO AND 400 INCHES BELOW THE PAYLOAD BAY CENTER-LINE. POSITIVE SENSE IS FROM THE NOSE OF THE VEHICLE TOWARD THE TAIL.
	THE Z_0 AXIS IS IN 0THE VEHICLE PLANE OF SYMMETRY, PERPENDICULAR TO THE X_0 AXIS POSITIVE UPWARD IN LANDING ATTITUDE.
	THE Y_0 AXIS COMPLETES A RIGHT-HANDED SYSTEM.
CHARACTERISTICS:	ROTATING RIGHT-HANDED CARTESIAN. THE STANDARD SUBSCRIPT IS 0 (e.g. X_0)

Figure 2.6

Maximum Payload Static and Dynamic Envelopes
Small Mounting Plate Layout



NOTE: Zo coordinates in parenthesis indicate lower mounting position.

Figure 2.7

Maximum Payload Static and Dynamic Envelopes
SPOC Plate Layout

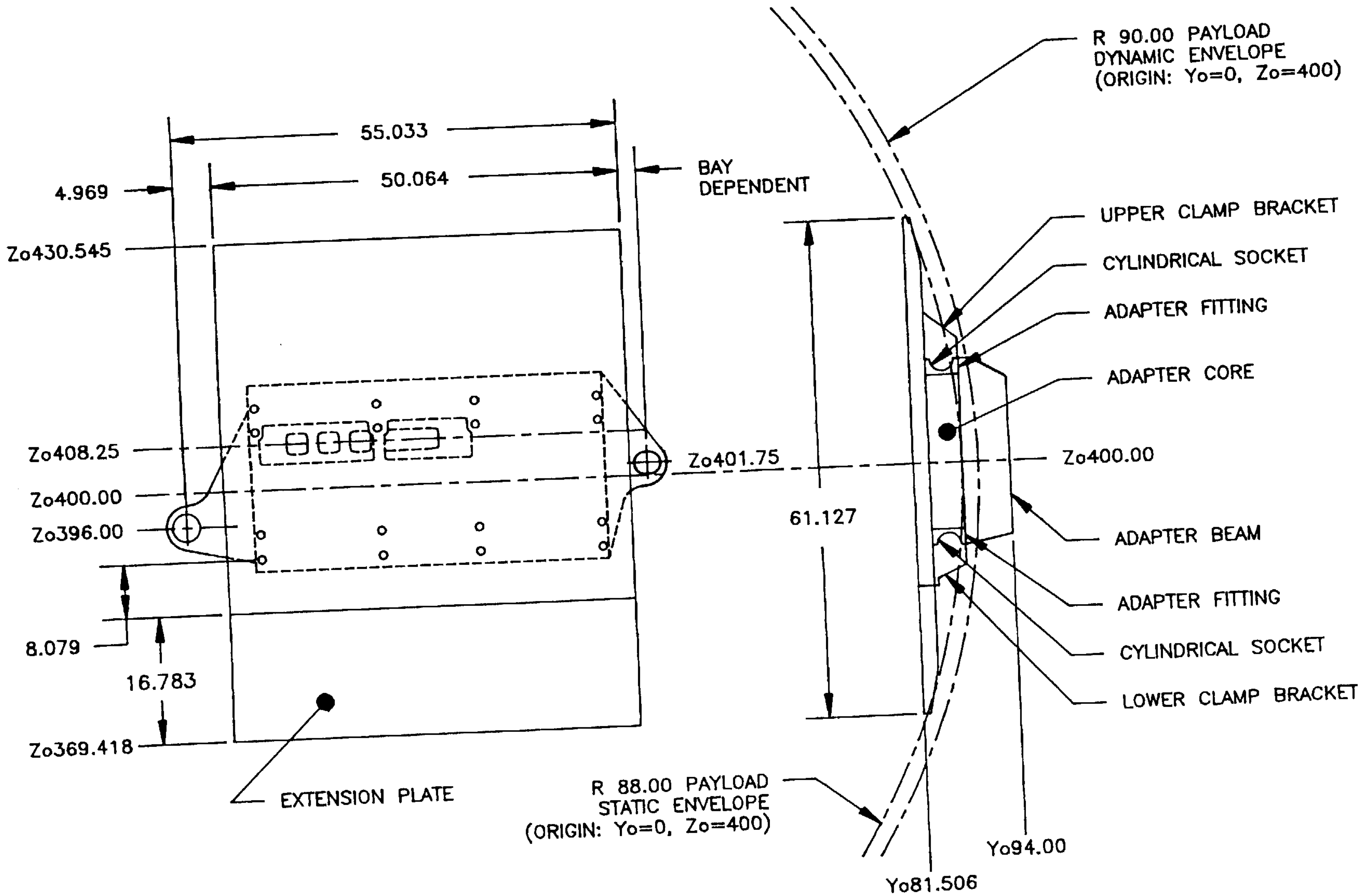


Figure 2.8

2.1.1 HH Canister

The HH canister is an adaptation of the canister developed by the GAS Program. It is mechanically very similar to a GAS canister and offers the customer the simplest mechanical accommodation in the HH-G system. It is available as a completely closed canister (Figure 2.9) or with an opening lid known as the Hitchhiker Motorized Door Assembly (HMDA) (Figure 2.10). Figure 2.11 shows the canister mechanical and electrical components. Figure 2.12 illustrates the field-of-view restrictions for payloads using the HMDA. Canister extensions to facilitate additional payload volume are available as an optional service and will be considered on a case-by-case basis.

Use of the standard container facilitates safety. The container provides for internal pressure which can be varied from near vacuum to about 1 atmosphere absolute. It also provides thermal protection for the experimental apparatus. The sides of the container may be thermally insulated or may be uninsulated with a white paint surface. The top may be insulated or not, depending upon the customer requirements. The bottom of the container is always insulated.

The experiment mounting plate, which is also the upper end plate of the canister, provides a standardized mounting surface for customer hardware. Any payload venting will be through the experiment mounting plate. The HMDA uses a different experiment mounting plate and similar, but different, payload venting.

The weight the canister can support depends upon whether it is mounted for a HH-G or HH-M configuration. For the HH-G configuration, the canister is qualified to support 200 lbs. of payload weight. The HH-M configuration is qualified to carry a total of 400 lbs. for the canister carrier weight and payload weight. If the canister carrier weight to support a payload increases, then the payload weight that can be flown is reduced. For example, a standard insulated canister with end plates weighs about 140 lbs., this would limit the payload to 260 lbs. If the payload required the MDA, then the payload weight allowed would be reduced by the weight of the MDA.

2.1.1.1 Container Construction. The standard container is made of aluminum. There is white paint or multilayer insulation on the exterior. The top may or may not be insulated depending on the particular Shuttle mission and needs of the experimenter. The circular top and bottom end plates are 5/8" thick aluminum.

The bottom 3" of the container is reserved for HH-G interface equipment such as interface harnesses and venting systems. This volume is in addition to the 5-cubic foot space available to the experimenter.

The container is a pressure vessel capable of:

a. maintaining about 1 atmosphere absolute pressure at all times, (dry nitrogen or dry air),

b. evacuation during launch and repressurization during re-entry.

c. evacuation prior to launch.

Hitchhiker Sealed Canister

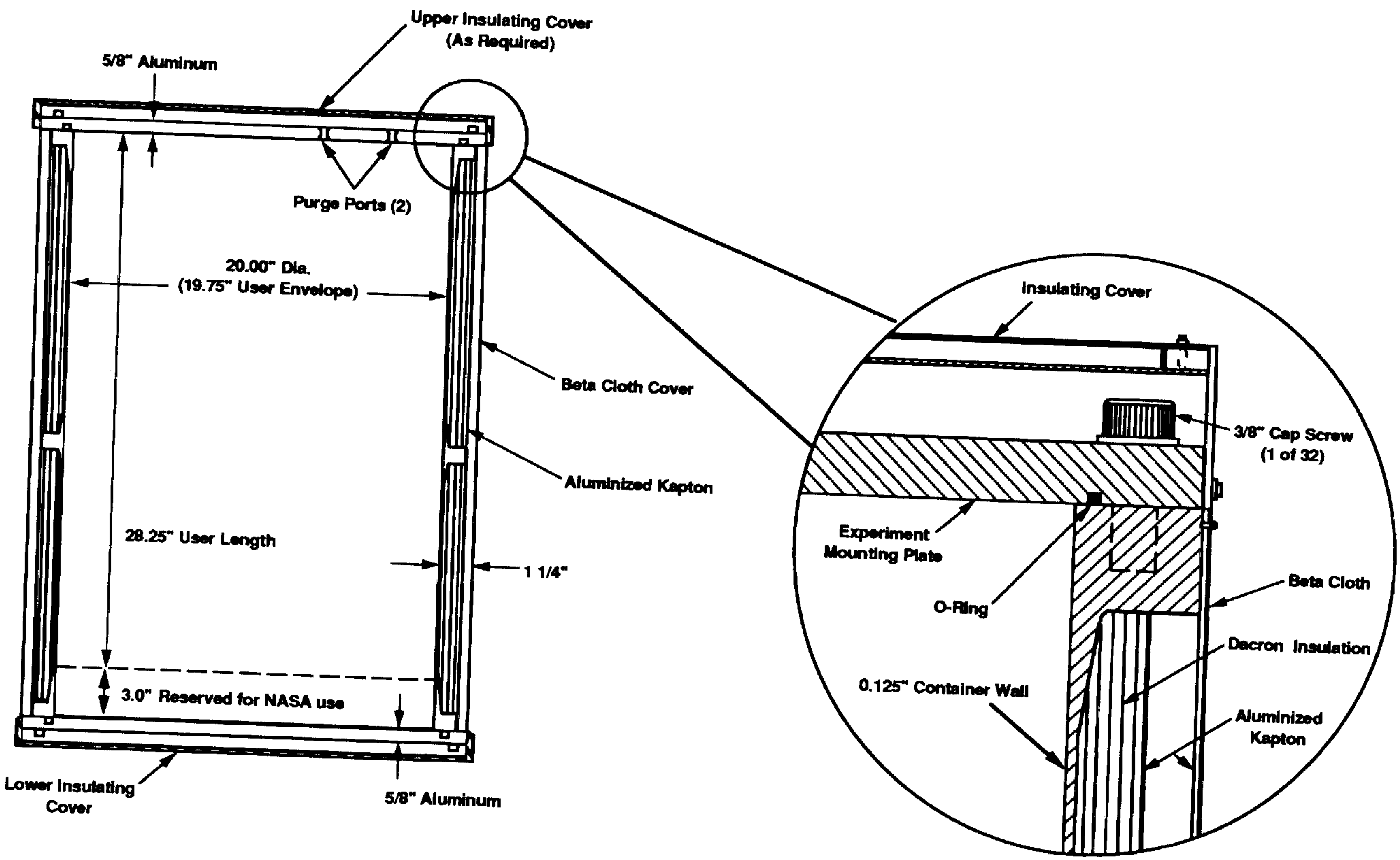


Figure 2.9

Hitchhiker Motorized Door Canister

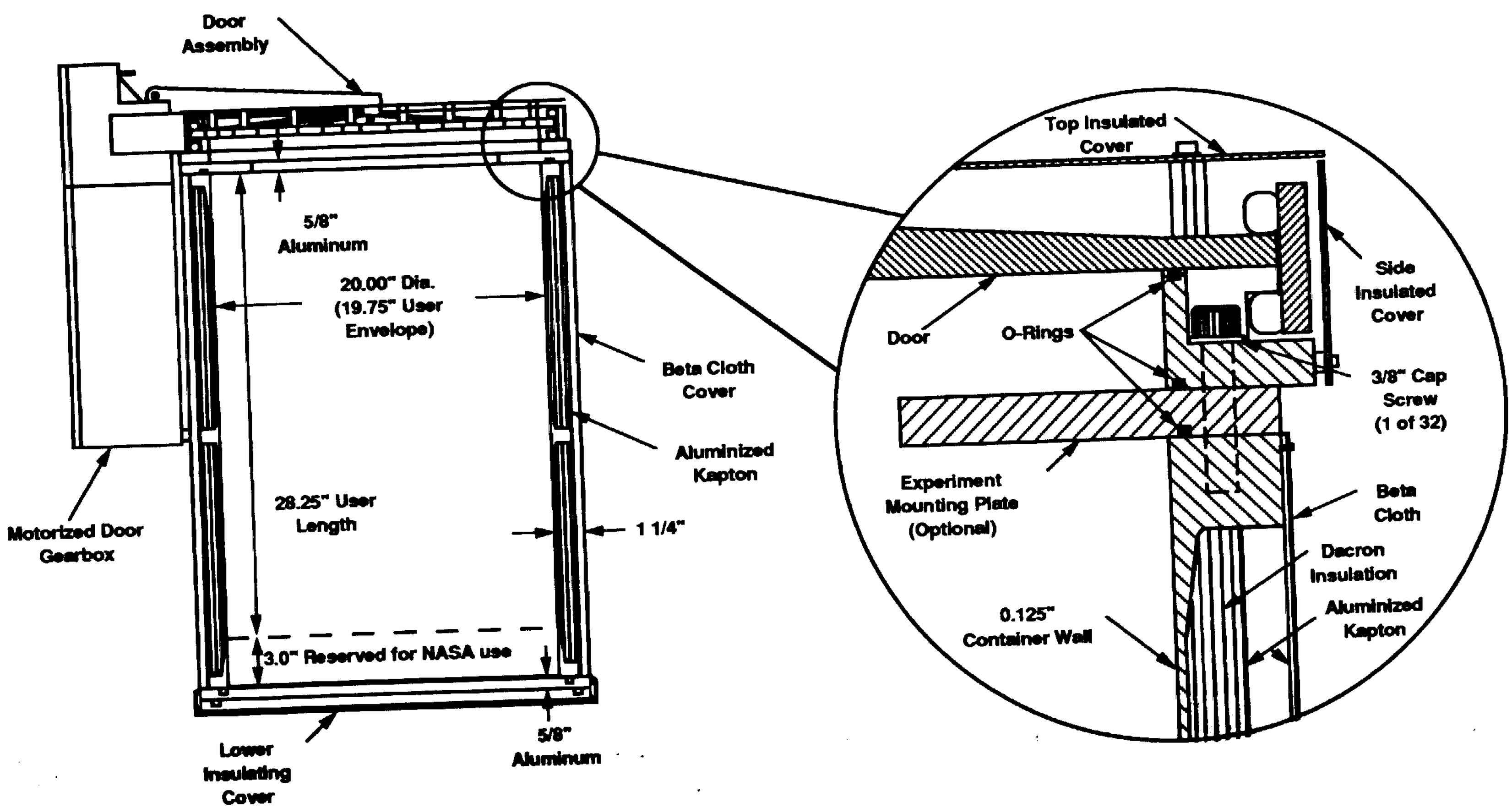


Figure 2.10

Hitchhiker Canister
Mechanical and Electrical Components

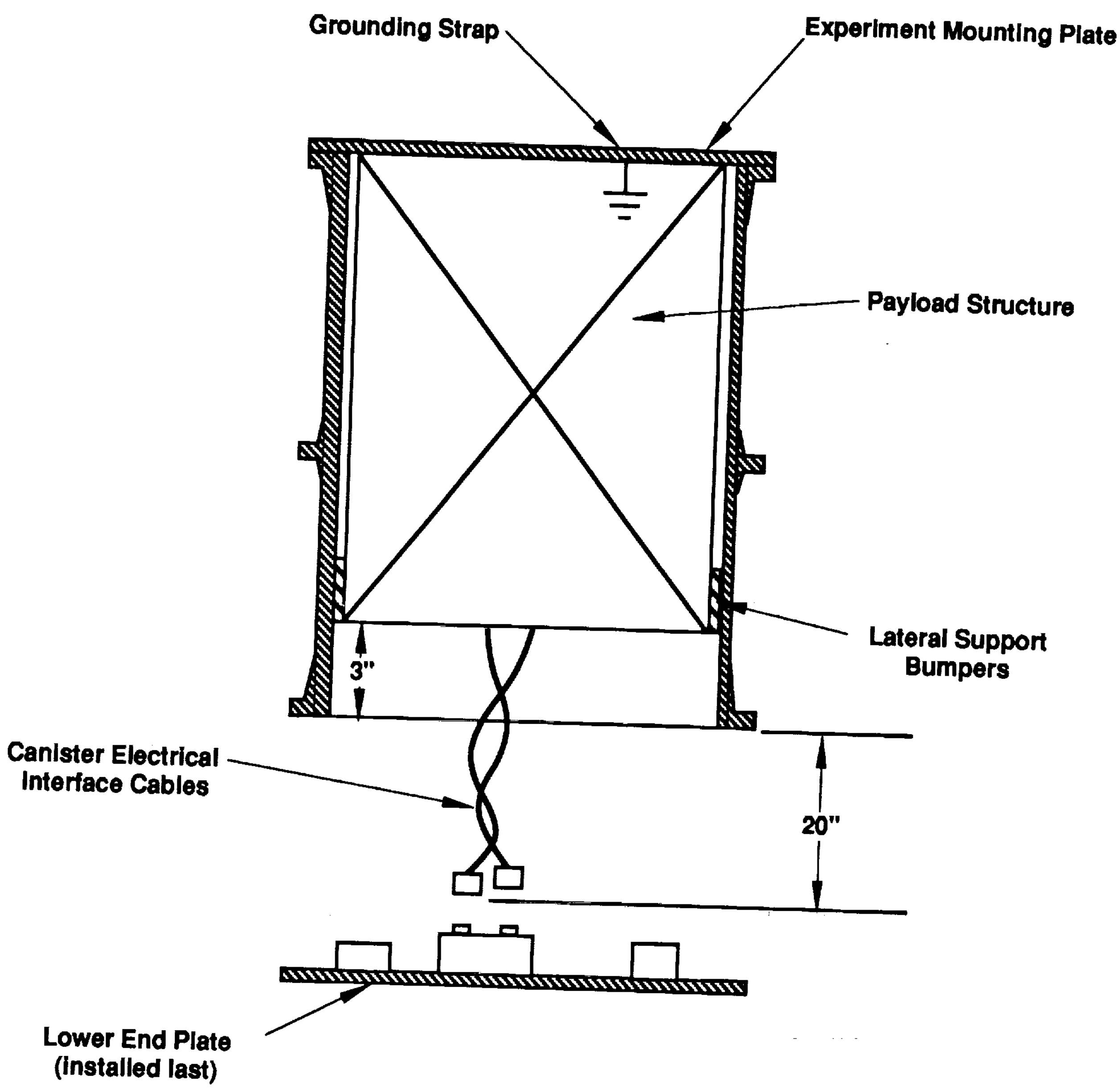
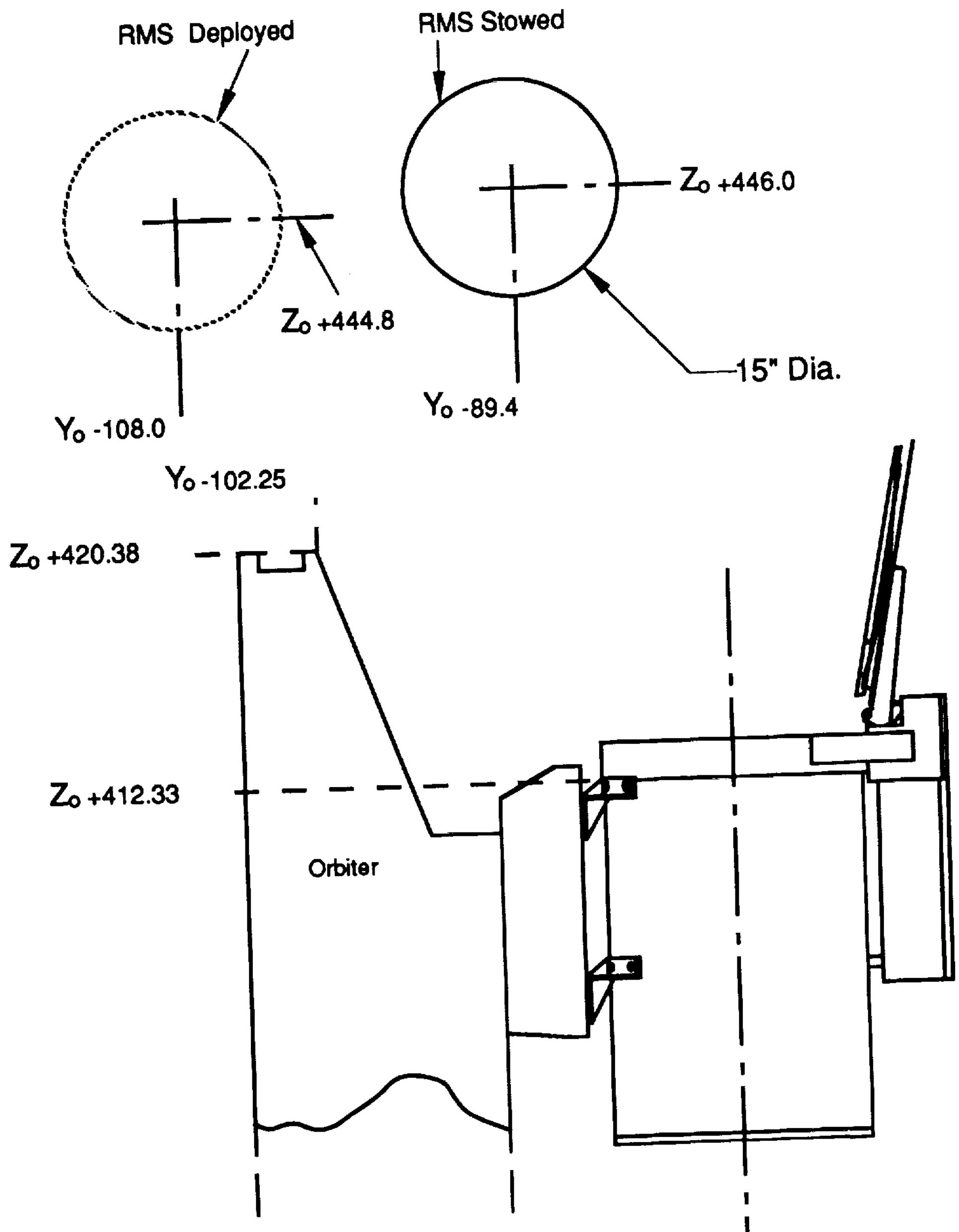


Figure 2.11

Hitchhiker-G Canister Mounting To Orbiter

View Looking Forward - Port Side



Canister With Opening Lid Showing Mount And Field-of-View Restriction Imposed By RMS

Figure 2.12

2.1.1.2 Sealed Canister Experiment Mounting Plate

The sealed canister upper end plate (see Figure 2.13) serves four purposes:

a. it seals the upper end of the standard container,
b. it provides a mounting surface for the experimental equipment,
c. it can act as a thermal absorption or radiation surface, and
d. it provides accommodations for experiment box venting when required.

The inner surface of the plate has a hole pattern adaptable for mounting a variety of hardware. Forty-five stainless steel, internally threaded inserts exist for experiment mounting purposes. The experimenter may use any of them in any combination required. The inserts do not go through the plate. They will accept #10 - 32 UNF machine screws to a depth of 0.31 inches. The HH Project will provide the screws. The Project is responsible for approving the structural dimensions of the experiment interface and the number and location of mounting screws.

The line from the center of the plate through the two purge ports will always be positioned toward the starboard (right) side of the Orbiter, perpendicular to the Orbiter centerline.

The canister will be purged with dry nitrogen, or dry air, as specified by the customer. Two purge ports are shown on the experiment mounting plate (see Figure 2.13). At least one of these must be unobstructed to allow purged gas to flow through the canister.

The customer must provide a grounding strap from the payload to the experiment mounting plate. Any mounting hole on the experiment mounting plate may be used for grounding.

If safety considerations require that a battery box or other component be vented, it can be plumbed to a special pressure-relief valve turret (illustrated in Figure 2.14). Since the turret can be rotated 360°, the experimenter can pick the most convenient orientation within the plumbing circle shown in Figure 2.13. If no turret is required for the payload, this area will be completely clear and will not affect payload mounting.

The customer must provide attachment points on the bottom of the payload structure for lifting in the inverted orientation by means of a crane and sling. The sling must be provided by the customer. Customers may not alter the mounting plate unless changes have been negotiated with the HH Project Office.

Hitchhiker Sealed Canister

Standard Experiment Mounting Plate (Upper End Plate)

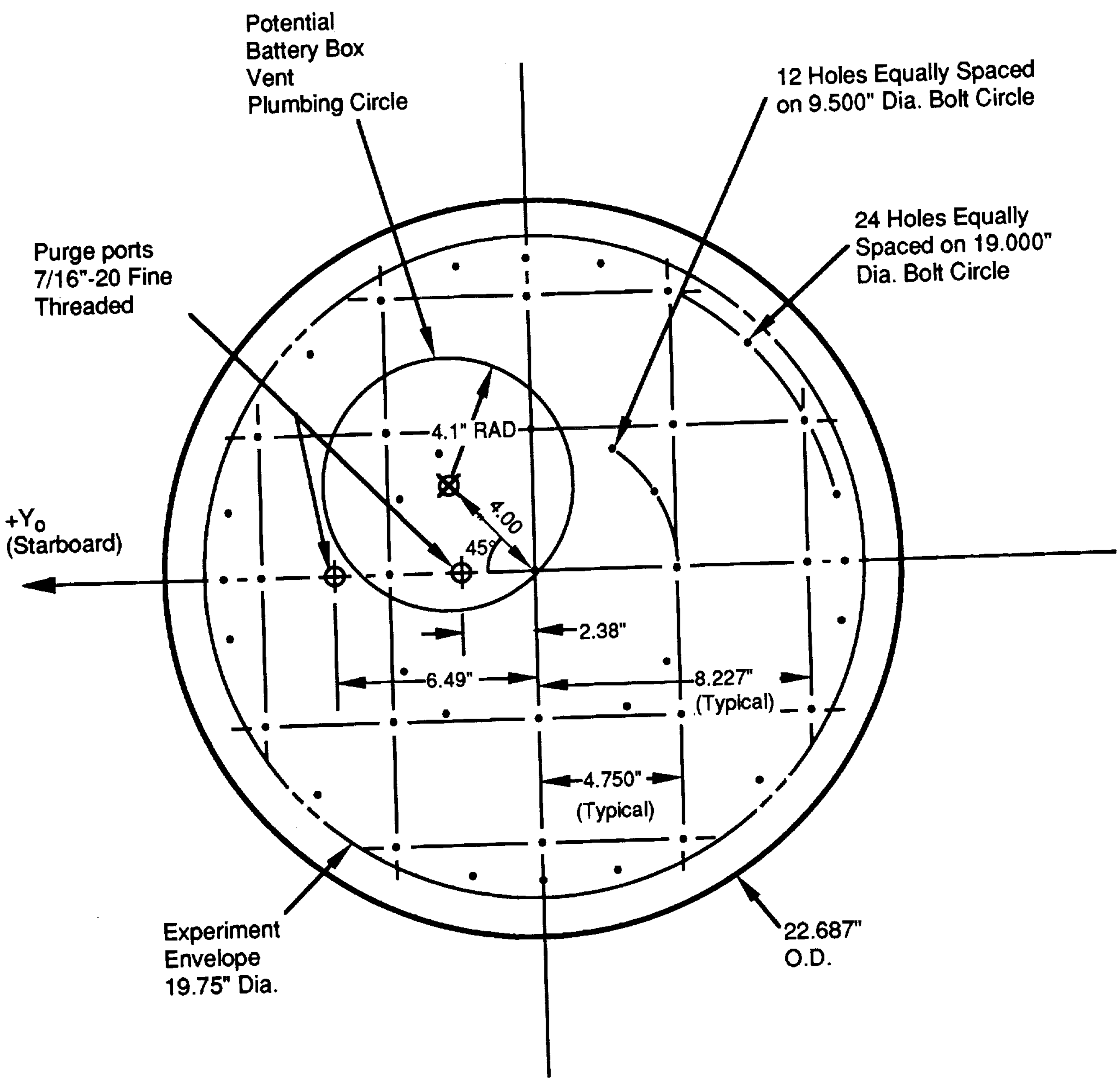


Figure 2.13

Hitchhiker Sealed Canister

Battery Vent Turret Interface

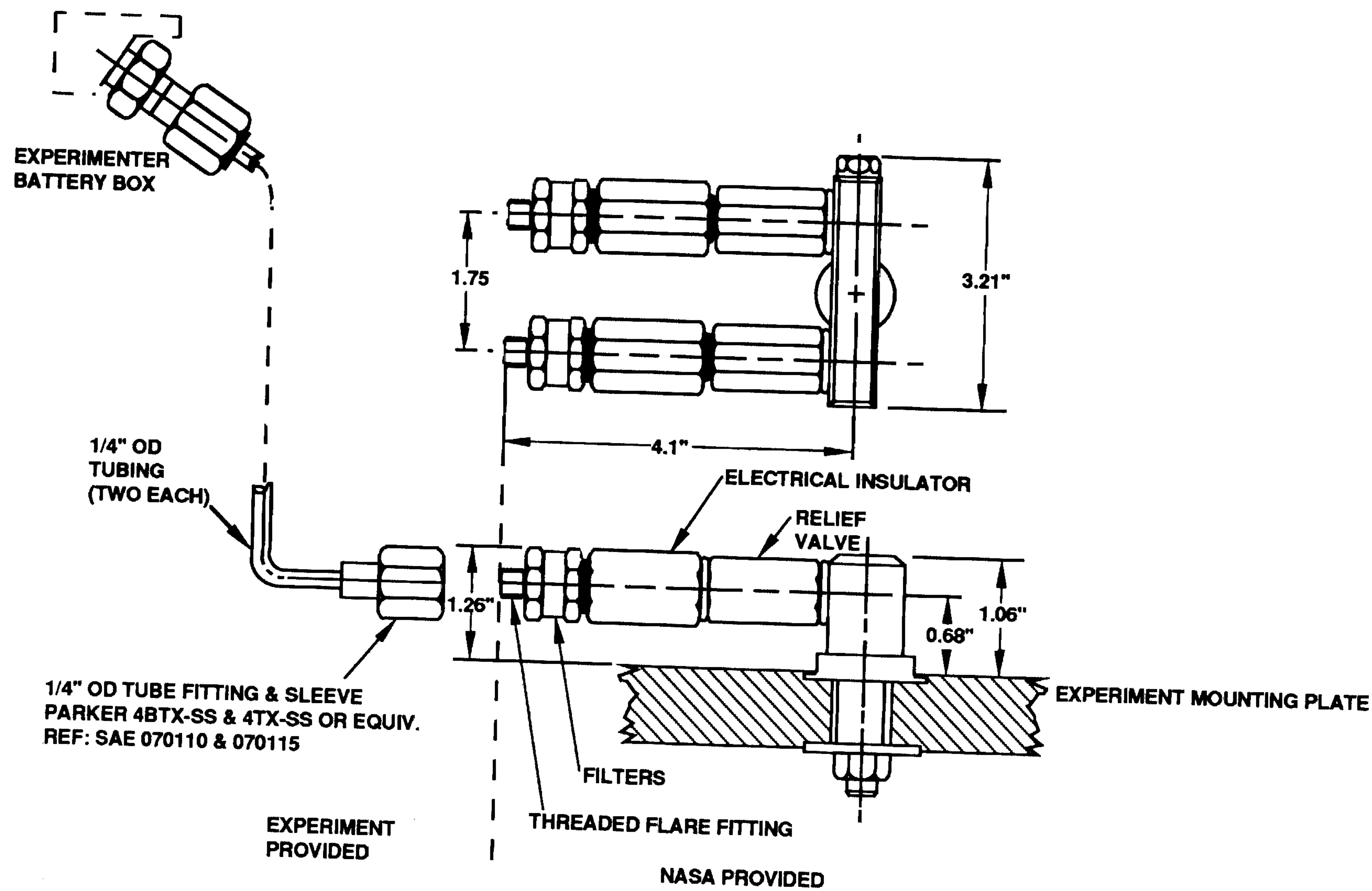


Figure 2.14

2.1.1.3 Opening Lid Canister. A canister may be fitted with a HMDA if the customer payload requires a field of view or exposure to the space environment. The door is opened and closed by ground command as required. The HMDA is capable of maintaining a 15 psi differential (psid) pressure or evacuated environment similar to the standard canister. It is possible to eject packages from a HMDA canister; however, the interface and safety requirements are considerably beyond the scope of this document and must be defined and approved on a case-by-case basis.

HMDA canisters are normally equipped with redundant pressure-relief valves which act to reduce the pressure to less than 1 psid during ascent. Once in orbit, a ground command may be used to open a vent valve and reduce the pressure to less than 0.1 psid prior to opening the door. HMDA canisters normally return with internal vacuum.

The mounting provisions for the opening lid canister are shown in Figure 2.15. Because the contents of the canister are exposed when the door is open, the materials, safety, and Electro-Magnetic Interference (EMI) considerations are essentially the same as for plate-mounted hardware.

For safety considerations, a pressure-relief valve turret designed for use on the HMDA Mounting Plate is available to vent battery boxes or other components (see Figure 2.17). Four venting locations have been provided to accommodate battery box orientation requirements. If no turret is required for the payload, this area will be completely clear and will not affect payload mounting.

Multiple interlocks are provided to prevent the door from opening prior to or during ascent. However, in the event of an in-flight door failure, the contents of the canister must be designed to allow safe descent and landing with the door open. The customer is responsible for designing and providing any thermal treatment of exposed surfaces.

2.1.1.4 Canister Orientation. A canister will always be mounted with the experiment mounting plate facing out of the payload bay. There are, however, two different container ground handling orientations. First, during insertion of a payload into the container and the subsequent checkout and transportation, the container's major axis will be vertical. Second, after the container is installed in the Orbiter bay, the container's orientation will become Orbiter dependent, i.e., the major axis of the container will be perpendicular to that of the Shuttle.

Care should be taken in experiment design to assure that systems that are sensitive to ground orientations, such as wet cell batteries, are properly oriented in the experiment. The customer should inform the HH staff of any special payload orientation requirements which must be met prior to installation in the Orbiter.

2.1.1.5 Lateral Load Support. Because the experiment structure will be cantilevered from the experiment mounting plate, radial loads at the free end of the experiment structure must be supported by at least three equally spaced bumpers between the experiment structure and the canister. Figure 2.18 illustrates one possible bumper design configuration.

The customer is responsible for providing bumpers as part of the experiment hardware. Bumper design should be in accordance with the following guidelines:

a. A minimum surface area of 4 in^2 (2" x 2") should be used for each bumper pad.

b. The bumper face should have a 10-inch radius so that it will fit snugly when adjusted against the 20-inch diameter container.

c. Where the bumper contacts the container wall, it should be faced with a resilient material at least 1/8 inch thick to protect the container. If the container is to be evacuated, select a non-outgassing material such as viton. If the bumper face is not round, every corner should have a minimum radius of 0.40 inches.

d. It is very important to provide a positive locking device for the bumpers. Do not depend on friction or a set screw alone to hold them in place.

e. After installing the payload in the container, bumper adjustment should be easily accessible from the open lower end of the container.

2.1.1.6 Center of Gravity (CG) Considerations. To minimize the amount of analysis required for a particular mission, the composite CG of a canister and payload must be constrained within certain limits. The CG envelope is shown in Figure 2.16.

Opening Lid Canister
Experiment Mounting Plate

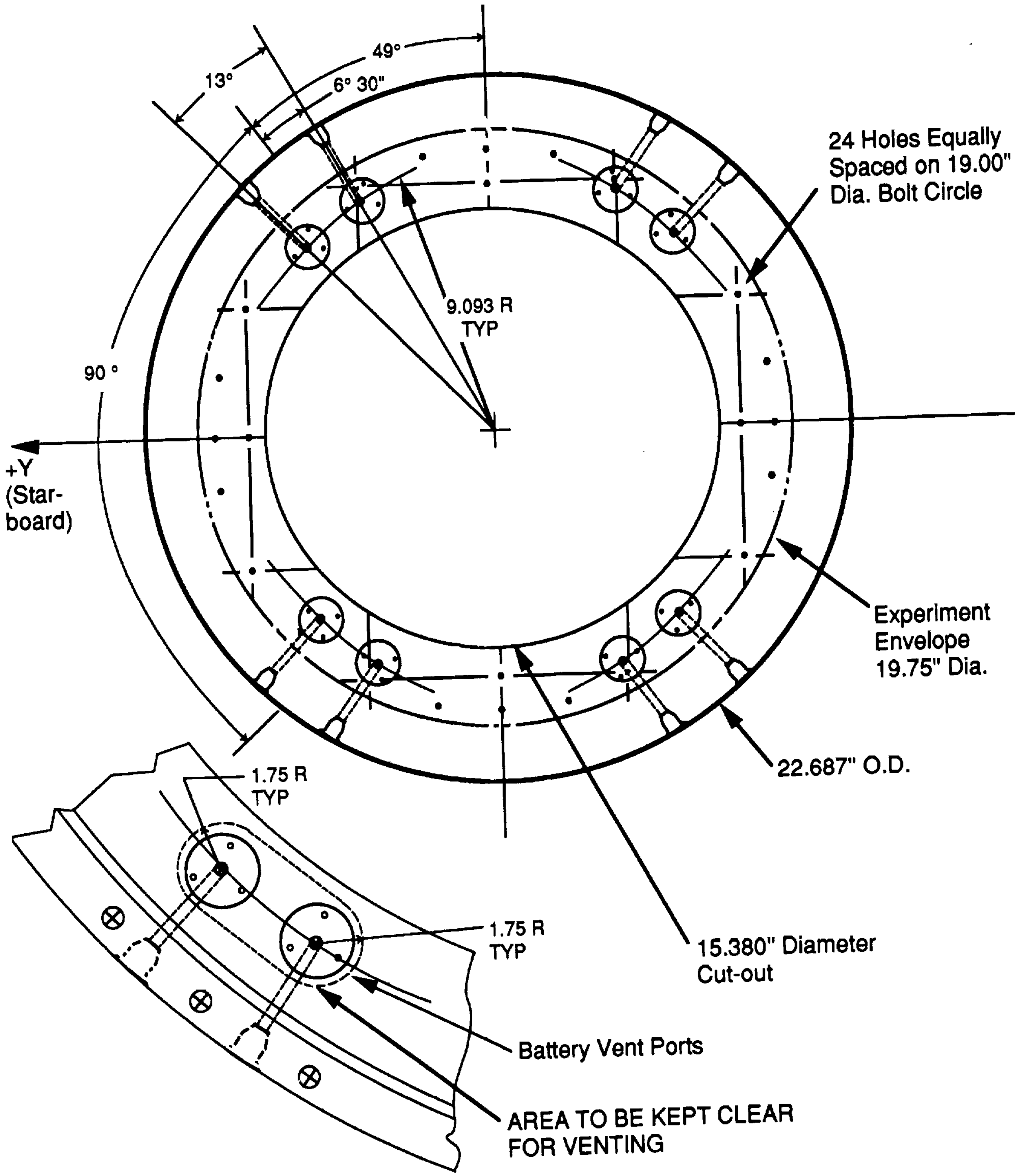
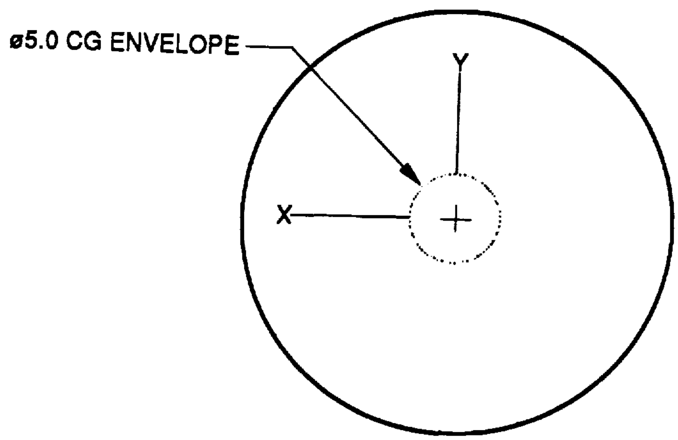


Figure 2.15

Canister CG Envelope
Adapter Beam or Bridge Mounting



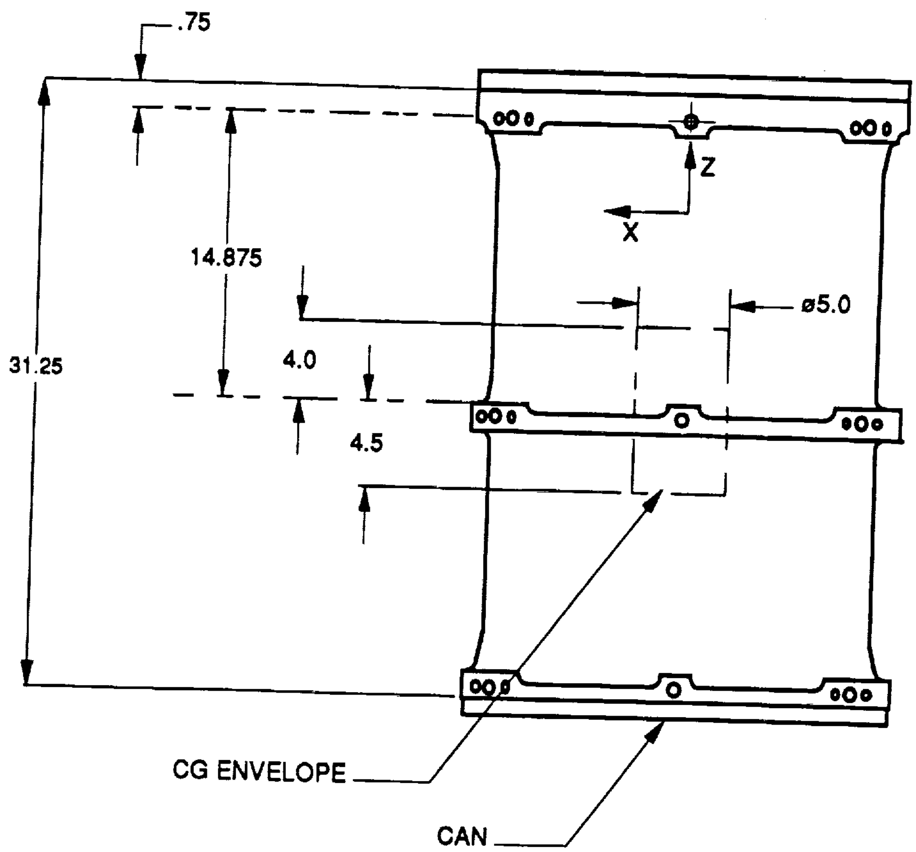


Figure 2.16

Hitchhiker Motorized Door Canister
Battery Vent Assembly

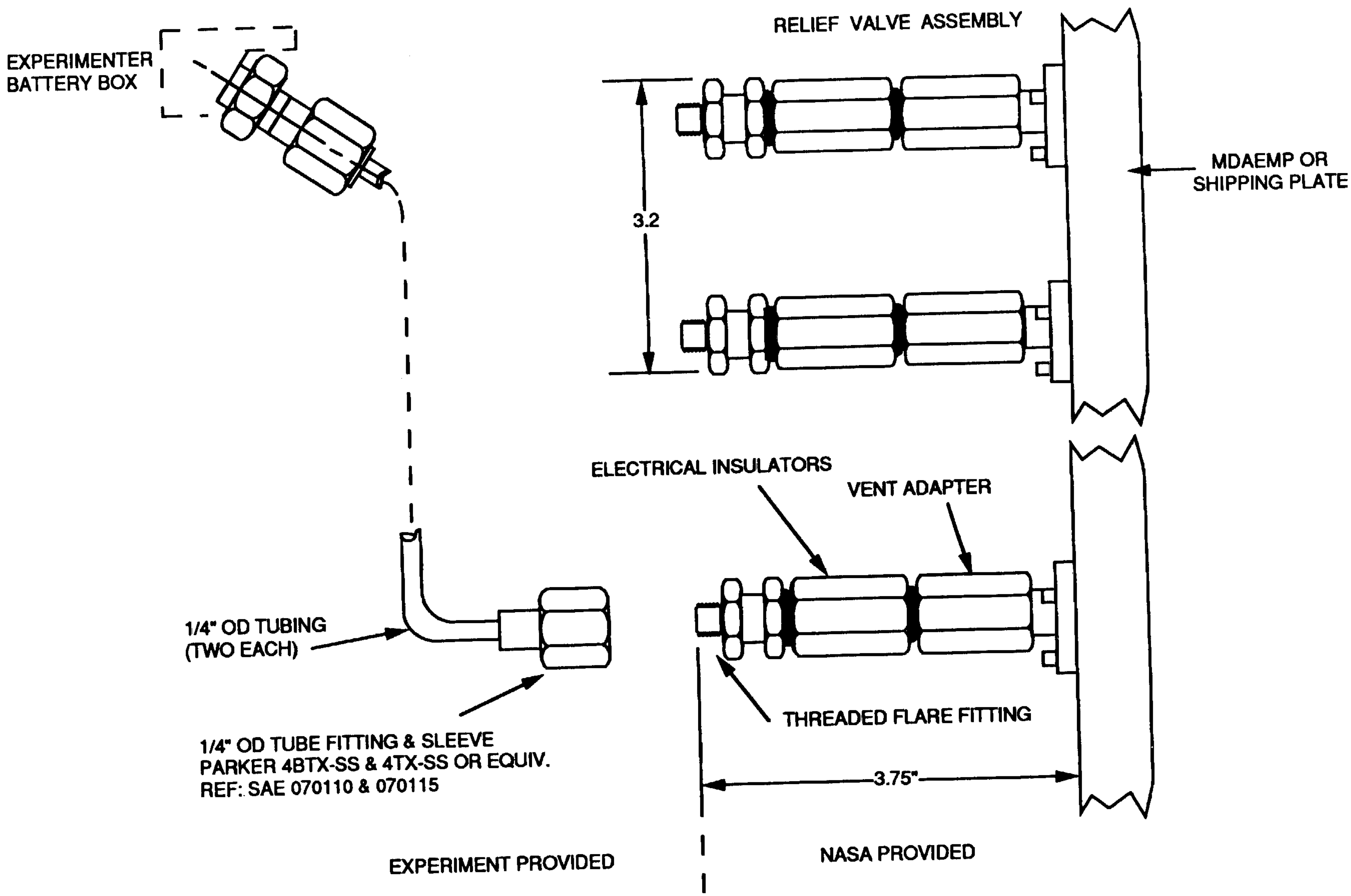


Figure 2.17

Bumper Design Example

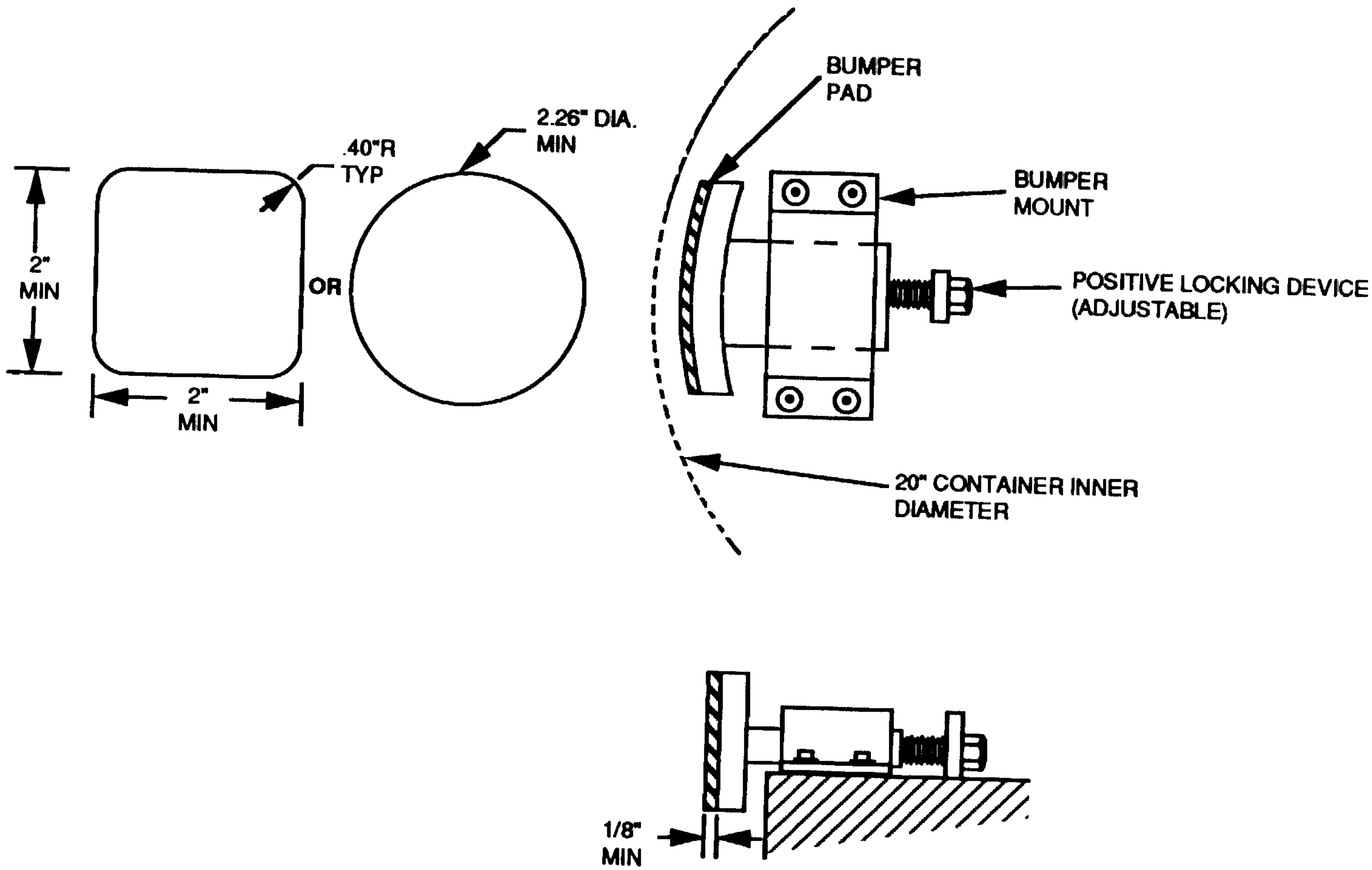


Figure 2.18

2.1.1.7 Customer Emblems. HH customers may attach a logo or emblem to the exterior of their equipment. Emblems may also be attached to the exterior of canisters containing customer equipment. The canister emblems should be on a .010 inch Lexan sheet 11 inches square. Emblem artwork must be submitted to GSFC for NASA approval. Materials used for emblems must meet all Space Shuttle payload bay materials requirements.

2.1.2 PLATE MOUNTING

Experiment packages which are not best suited for the canister approach may be mounted on a plate (see Figure 2.19). A small HH-G plate is capable of supporting experiment packages of up to 150 pounds, mounted on an area 25" x 39". Customer equipment is attached to the core plate using a grid hole pattern on 2.756" (70-mm) centers with 3/8" - 24 UNF stainless steel bolts. The bolts are supplied by the HH Project. A similar matrix of #10 - 32 mounting bolt locations will be used by the HH staff to route interface cables as well as intercomponent harnessing and plumbing. The experiment structural dimensions and attachment points at the mounting plate interface must be reviewed for acceptance by the HH Project. Figure 2.2 illustrated the large SPOC plate (50" x 60"), however as mentioned in Section 2.1, its use is not recommended.

2.1.2.1 Experiment Package Integrity. The package must be designed, fabricated, inspected, analyzed, and tested to demonstrate the ability to constrain, or to contain, the elements of the experiment package during launch, flight, and landing. All customer equipment shall be designed to withstand limit acceleration load factor limits as stated in Section 3.1.1.3.2. Also refer to Random Vibration Verification Levels given in Section 3.1.1.5.3 (Table 3.6) .

2.1.2.2 Experiment Package Volume. Specific volume restrictions other than those provided in Section 2.1 are not generally placed on customer equipment since the equipment mass and CG location are the controlling factors. In general, the experiment CG should be located as close to the mounting interface as practical. The complexity of the weight/CG relationship, the possibility of multiple customers per plate, manifesting considerations, and other factors require that the HH-G staff perform accommodation assessments on a case-by-case basis. Guidance will be provided to determine specific equipment design and accommodation details as part of the normal mechanical interface documentation exchange.

Hitchhiker-G Experiment Mounting Plate

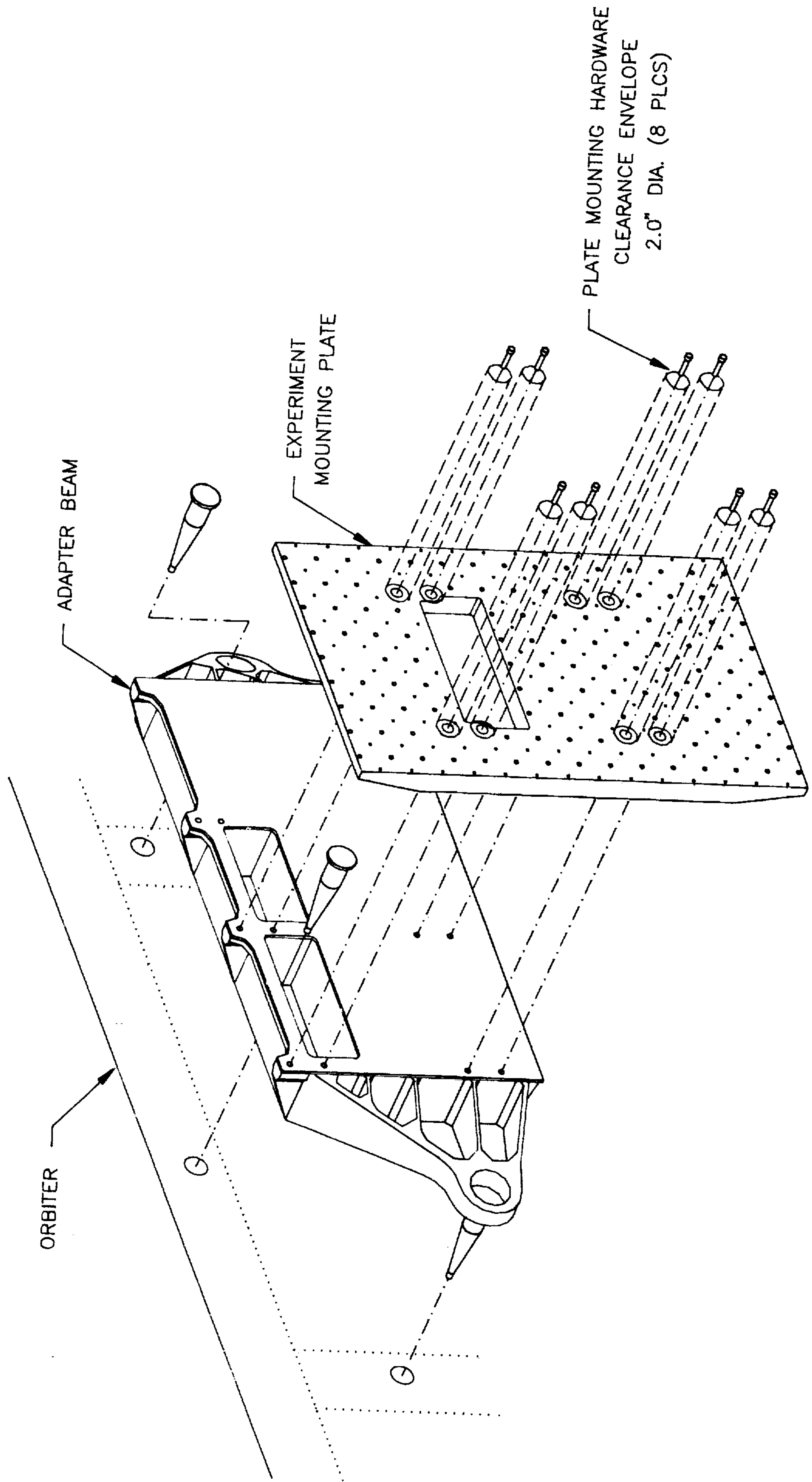


Figure 2.19

2.1.2.3 Mounting Bolt Loading Limitations. The mounting bolts must be included in the payload stress and fracture analysis (see Section 3.0). Bolt strength and material data will be supplied by the HH Project.

2.1.3 Direct Mounting of Experiment Package

The maximum weight-carrying configuration in the current HH-G system is accomplished by mounting the customer's flight unit directly to the Adapter Beam Assembly (ABA). This mode will accommodate up to 700 pounds but requires detailed case-by-case analysis and approval. The mounting hardware between the experiment package and the ABA will be supplied by the HH Project. The available experiment mounting locations are noted in Figure 2.20.

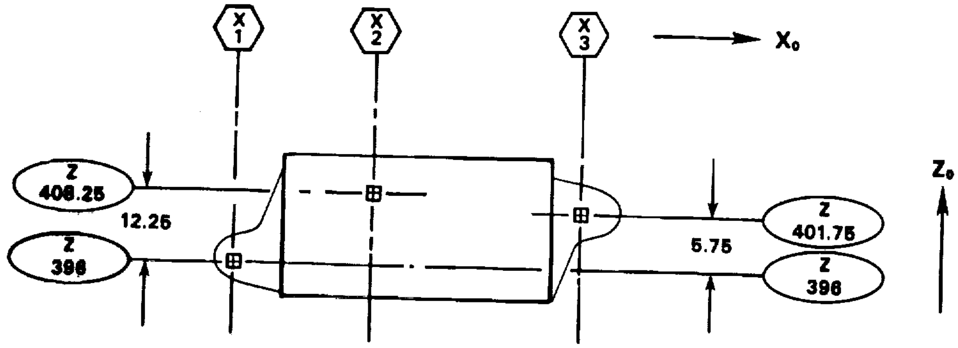
2.1.3.1 Experiment Package Integrity. See 2.1.2.1 for design considerations.

2.1.3.2 Experiment Package Volume and Mounting Limitations. The experiment volume in the direct mount configuration can be somewhat higher than in the plate mount setup; however, it is similarly restricted as described in subsections 2.1.2.2 and 2.1.2.3. The HH staff provides assistance in adapting customer hardware to the ABA interface and defining CG and volume restrictions. Direct-mount payloads are normally designed to be mounted on the adapter beam after the beam is installed in the Orbiter. The mounting scheme must be simple and involve captive fasteners. In the event that a payload is designed to mount on the beam prior to Orbiter installation, adequate access to the longeron bolts must exist. Special lifting equipment for hoisting the payload/beam combination must also be provided.

2.1.4 HH-M Structure

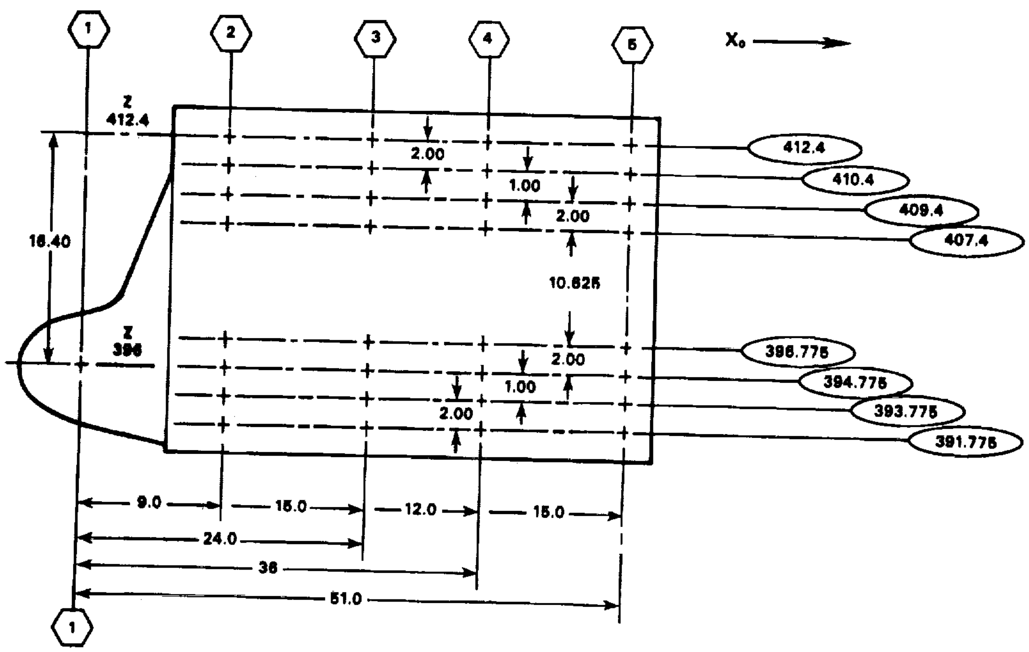
The HH-M cross-bay carrier is implemented using a truss structure (Figure 2.21) called the Hitchhiker Bridge Assembly (HHBA). The HHBA is similar to other Mission Peculiar Experiment Support Structure (MPESS) structures used on Spartan, GAS, Materials Science Laboratory (MSL), and other NASA payload programs and consists of an upper support structure and a lower support structure. The lower structure is normally attached to the upper structure at the launch site. During integration and transportation to the launch site, the upper structure is mounted on a special dolly (see Figure 2.22) which allows easier access and handling.

Adapter Beam Mounting Interfaces



X	X AXIS BAY							
	1	2	3	4	5	6	7	8
1		636.0	693.0	750.0	807.0	863.0	919.0	979.5
2		649.0	715.0	776.90	833.0	892.5	951.0	1011.40
3		693.0	750.0	807.0	863.0	919.0	979.5	1040.0

Longeron Bolt Access Locations



X	X AXIS BAY							
	1	2	3	4	5	6	7	8
1		636.0	693.0	750.0	807.0	863.0	919.0	979.5
2		645.0	702.0	759.0	816.0	872.0	928.0	988.5
3		660.0	717.0	774.0	831.0	887.0	943.0	1003.5
4		672.0	729.0	786.0	843.0	899.0	955.0	1015.5
5		687.0	744.0	801.0	858.0	914.0	970.0	1030.5

Adapter Beam Mounting Locations

Figure 2.20

Hitchhiker-M Payload

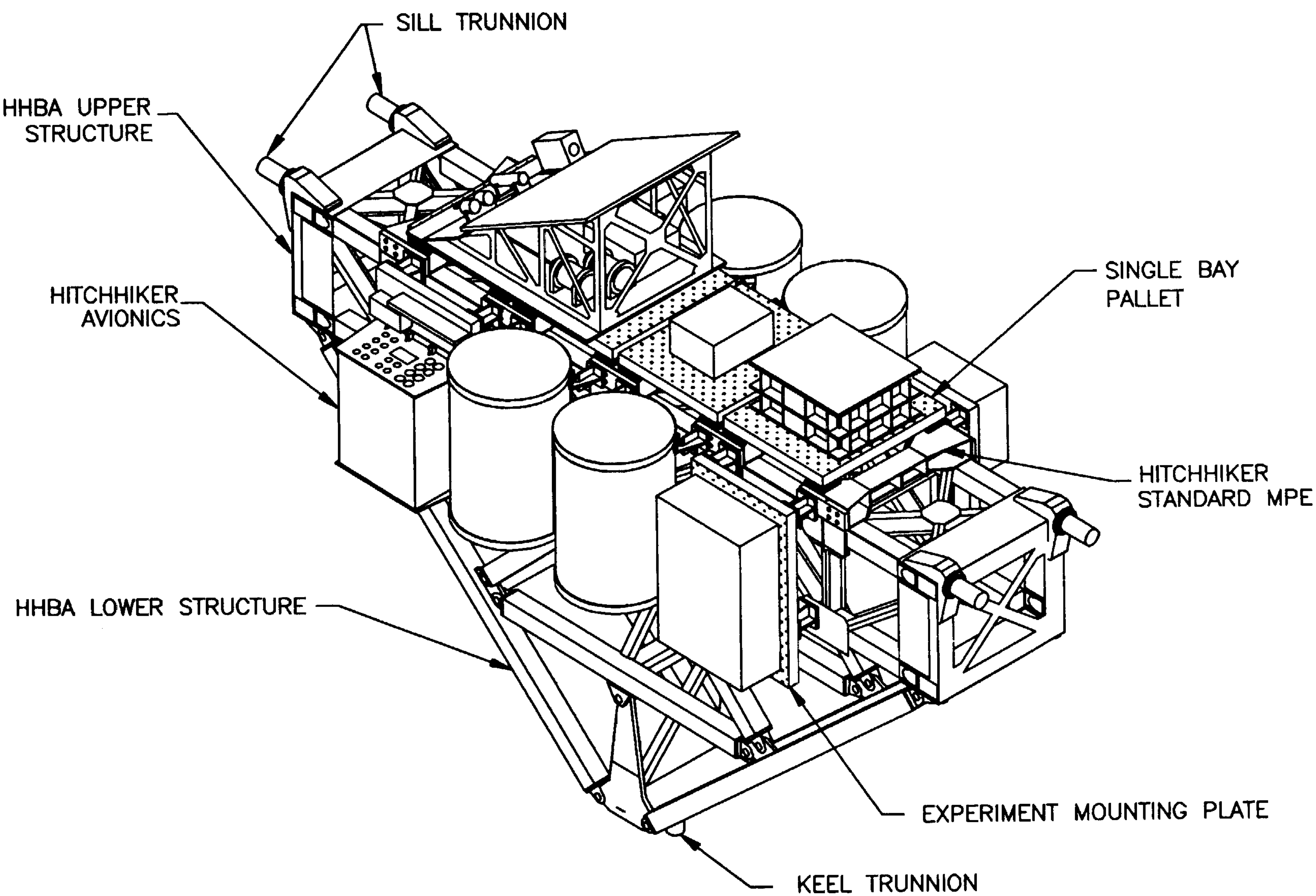


Figure 2.21

HHBA Upper Structure on Shipping Dolly

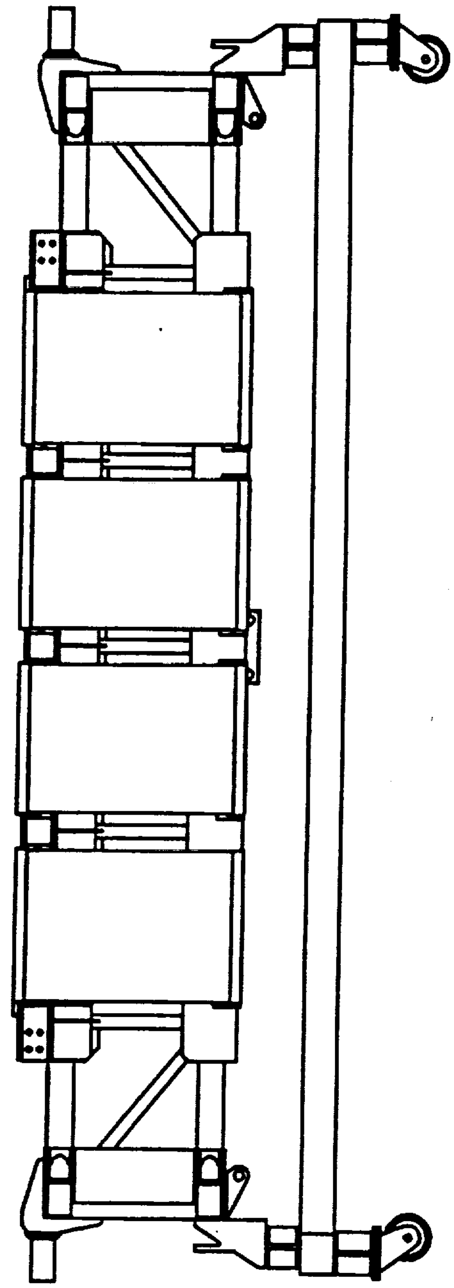


Figure 2.22

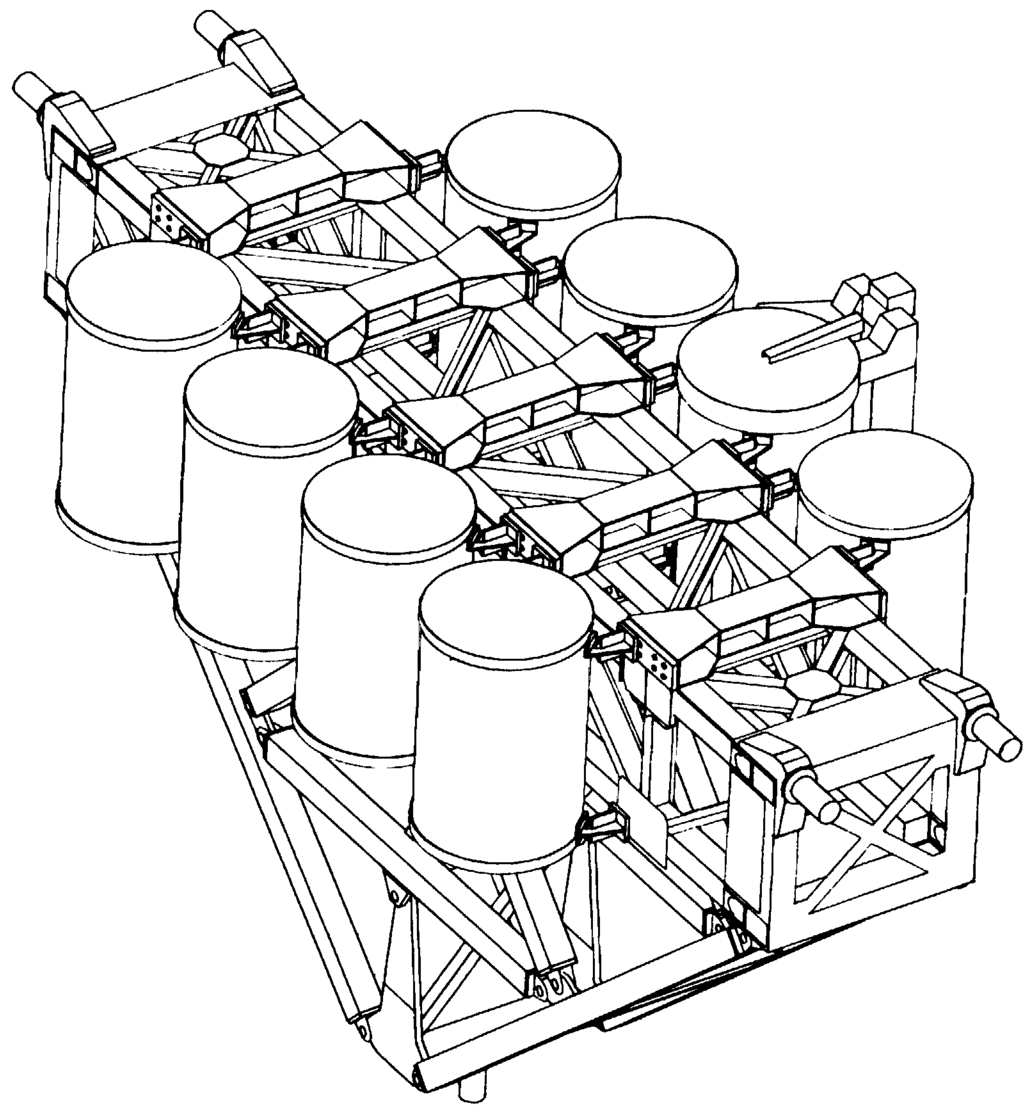
2.1.4.1 Standard HHBA. Attachment of payload equipment to the HHBA is done by means of special Mission Peculiar Equipment (MPE), structure elements which can be attached to the HHBA in five different locations spaced 28.20 inches apart across the top and sides of the structure. The standard MPE has eight positions on the sides of the HHBA for side experiment mounting plates and canisters. However, one experiment mounting plate position is reserved for the HH avionics. Of the remaining seven positions, three can be used for side experiment mounting plates or canisters. The other four positions can only be used for canisters. The HHBA and MPE are un-insulated and can experience large temperature deviations during a mission. For this reason, special mounting brackets are used to attach the plates and canisters to the MPE. The brackets provide thermal isolation and allow for thermal expansion when plates or canisters are temperature controlled.

The top of the MPE structure has positions for two sizes of top plates. It will accommodate two large top plates, four small top plates or combination thereof.

2.1.4.2 HH-M Canisters. Canisters identical to those specified for HH-G can be used with the HH-M. The canister is rotated 90 degrees about the Z axis in the HH-M case. All possible canister locations are shown in Figures 2.23, 2.24, and 2.25. Figure 2.23 shows the HH-M Canister Locations. Figure 2.24 shows the HH-M Canister and Mounting Plates , and Figure 2.25 shows the HH-M Canister highlighting the Y-Axis Coordinates and Field-of View Restrictions.

2.1.4.3 HH-M Side Mounting Plates. The HH-M side mounting plates (shown in Figure 2.26) are functionally identical to, although not interchangeable with, the small HH-G mounting plates. The plates are 25" x 39" and can support up to 250 pounds. The "Y" and "Z" axis coordinates of these plates and the field-of-view restrictions are shown in Figure 2.27.

Hitchhiker-M Canister Locations



NOTE:

The Avionics will use one of the side plate locations as shown in Figure 2.26.

Figure 2.23

Hitchhiker-M Canister and Mounting Plates

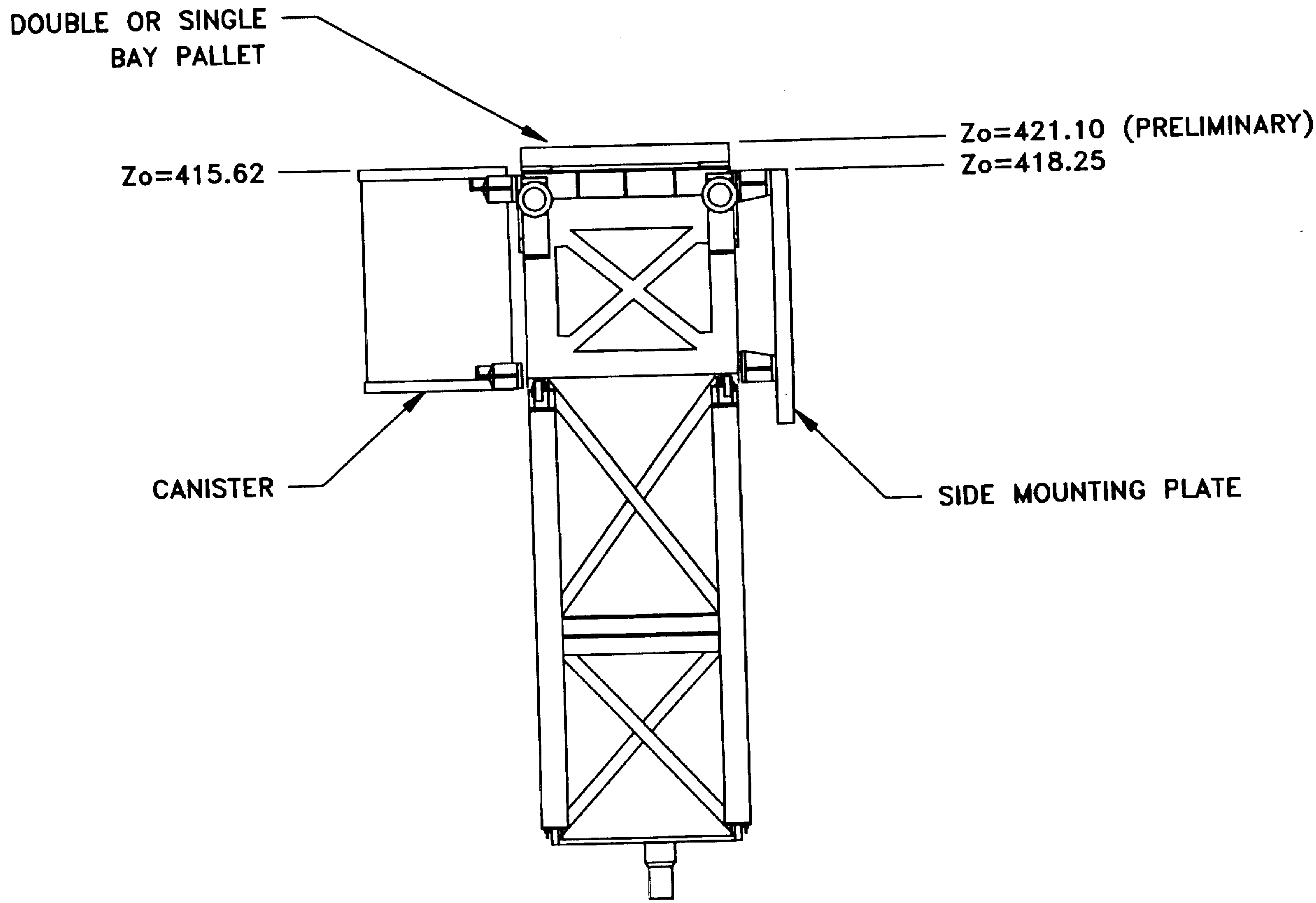


Figure 2.24

Hitchhiker-M Canister
Y-Axis Coordinates and Field-of-View Restrictions
(Looking Aft)

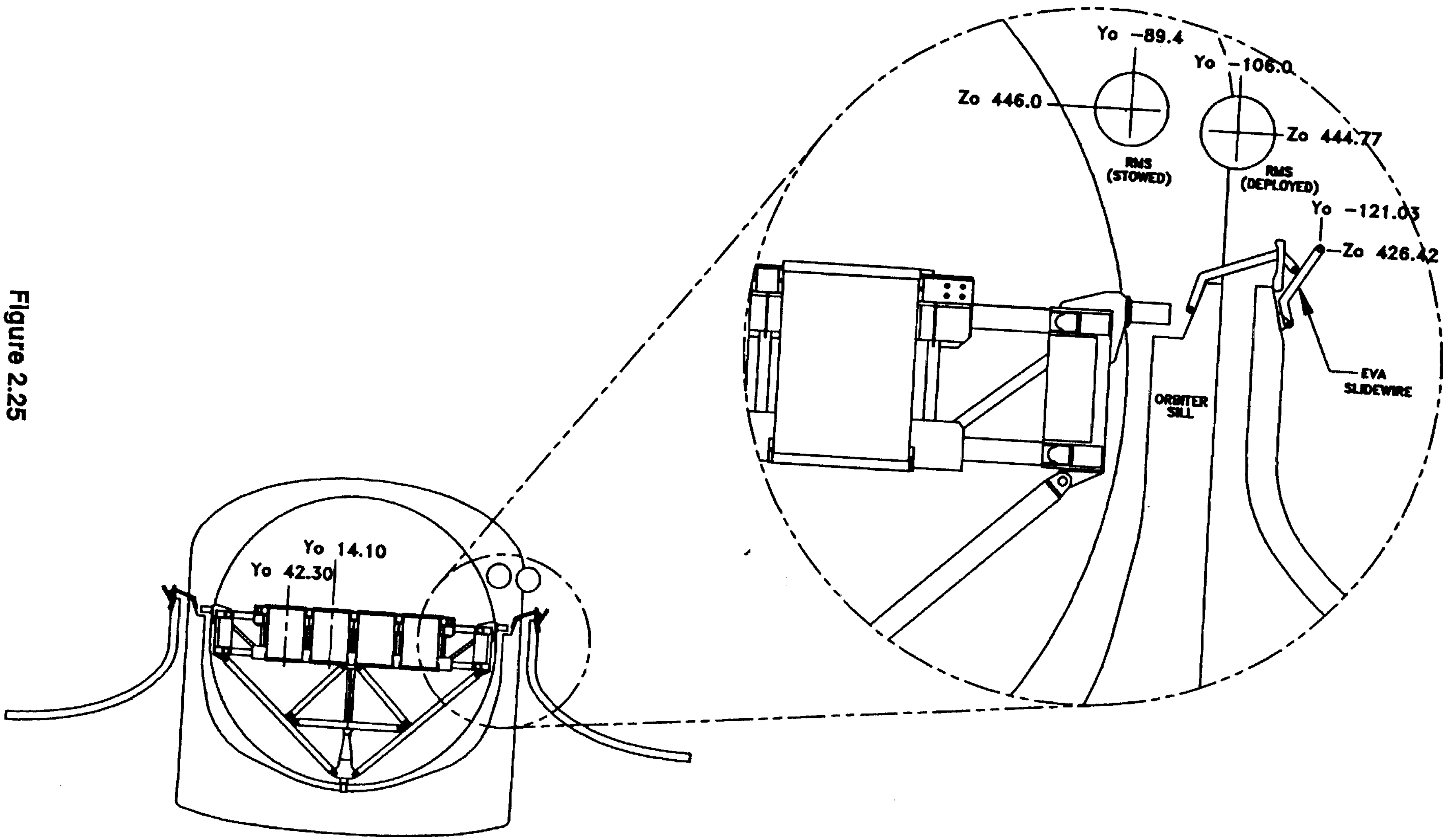


Figure 2.25

Hitchhiker-M Mounting Plate Locations

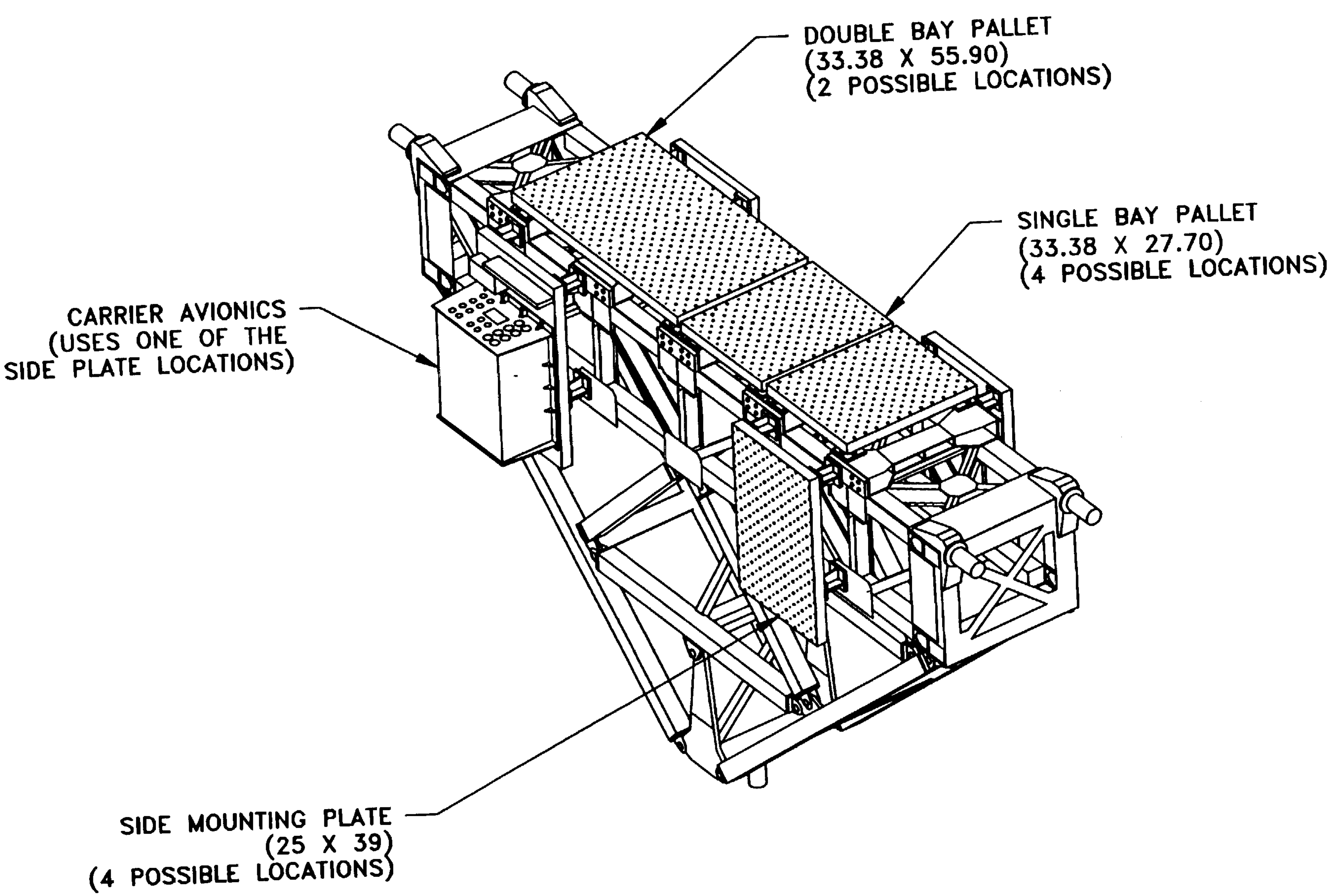


Figure 2.26

Hitchhiker-M Mounting Plate

Y-Axis Coordinates and Field-of-View Restrictions (Looking Aft)

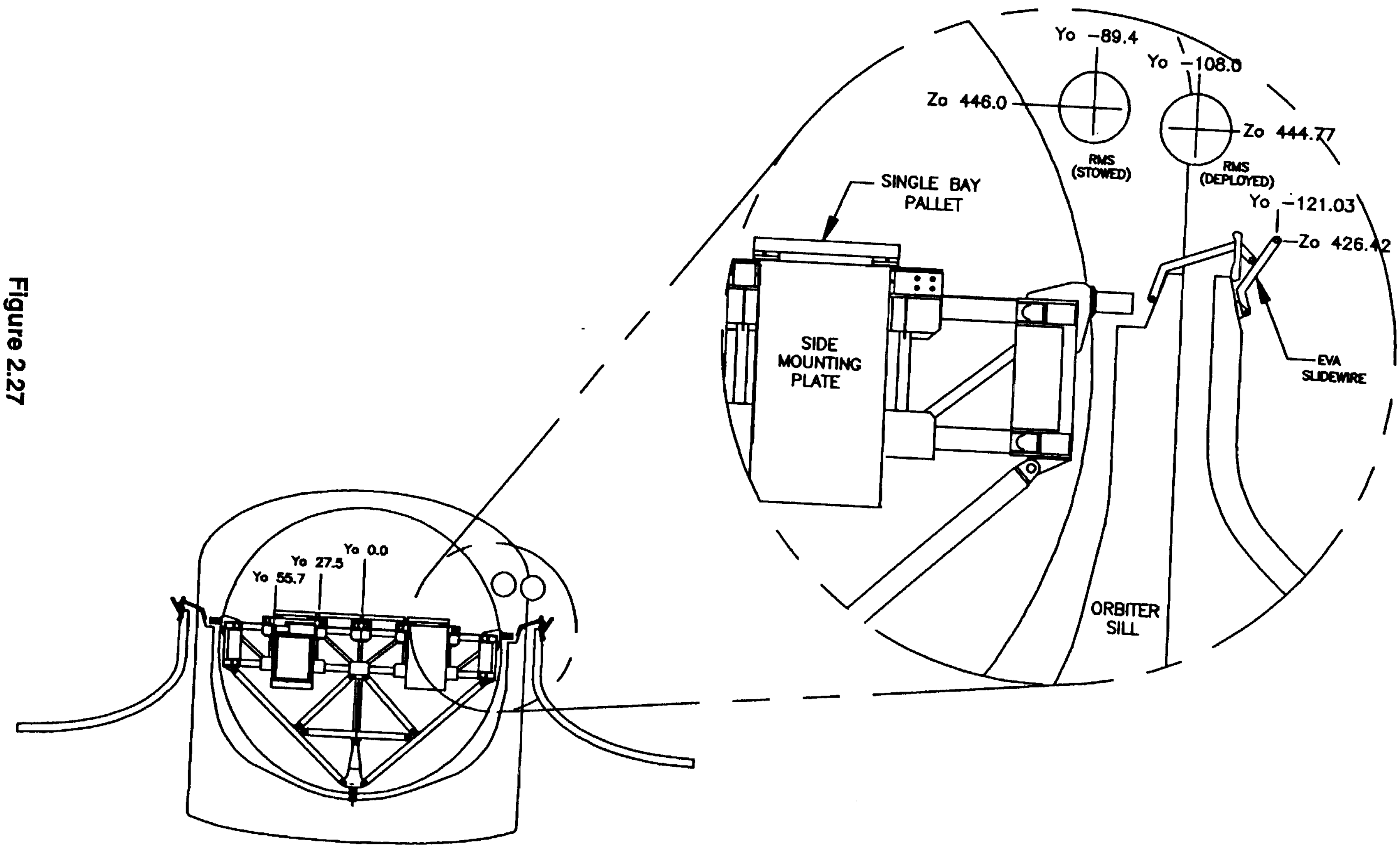
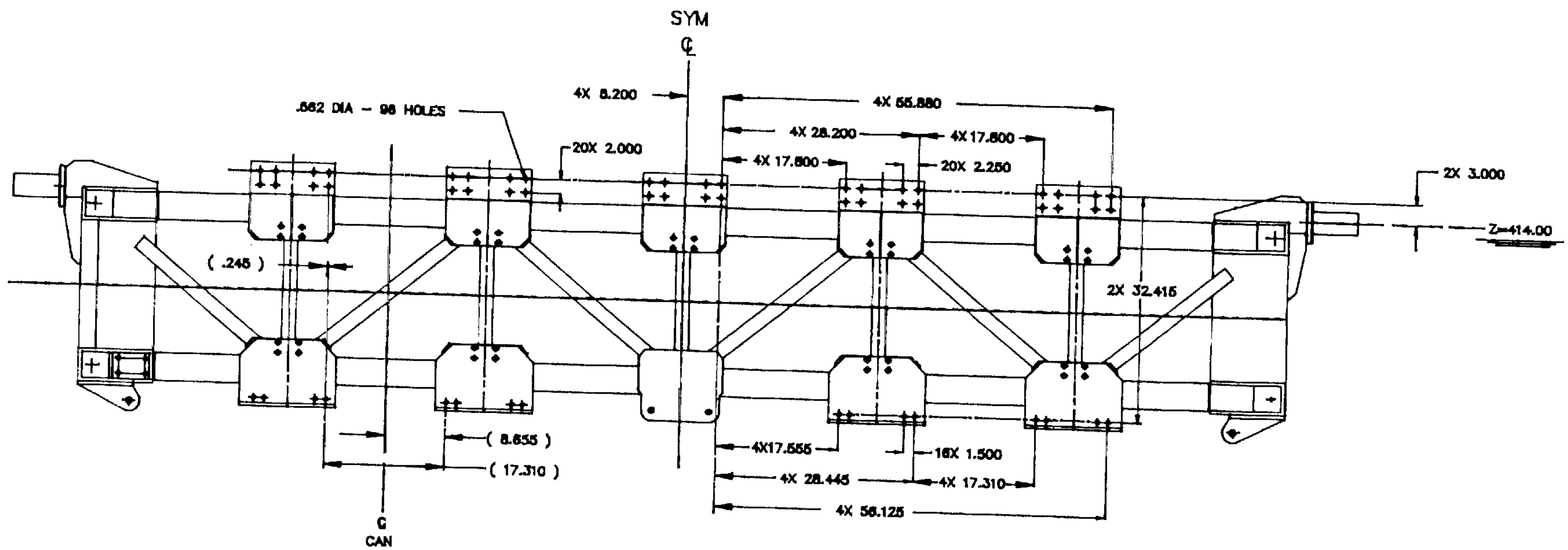


Figure 2.27

2.1.4.4 HH-M Top Mounting Plates. The HH-M proposed top mounting plates are also shown in Figure 2.26. Their field-of-view restrictions are shown in Figure 2.27. These plates are 25" wide (y direction) by 36" long (x direction) and can support up to 300 pounds. These plates are in the preliminary design phase at time of publication.

2.1.4.5 HH-M Direct Mounting. Large/heavy customer equipment which is not suitable for accommodation on the standard plates or canisters may be attached directly to existing HH MPE or may be attached to the structure by means of new customer-unique MPE, provided by GSFC as an optional service. Hardware mounting locations are shown in Figure 2.28. In either case, the customer's structural design must safely accommodate larger differential temperature changes between his/her equipment and the carrier. Proposals for direct mounting should be sent to the HH project for evaluation.

Hitchhiker-M Experiment Mounting Interface
(Side Mount)



NOTE:

The X numbers (i.e., 4X, 20X, etc.) indicate the number of occurrences of this dimension over the entire structure, two halves both near side and far side.

Figure 2.28

2.2 THERMAL CONSIDERATIONS

Although the Orbiter has a fluid loop heat exchanger for payloads, manifesting and engineering difficulties with its use are extensive. The HH carrier and customer equipment, therefore, rely on heater/thermostat type thermal control systems which depend on radiation for removal of heat. Generally, thermal design of the customer thermal control system is a customer responsibility as described below. Safety of payloads must not be affected by loss of heater power. Payloads must be safe to land 40 minutes after payload bay door closure, occurring anytime during the mission.

2.2.1 Thermal System Design (Canister)

There are presently four options available to HH canister customers:

1. Fully insulated canister
2. Insulated canister without upper-insulating end cap.
3. Uninsulated canister with bottom insulating end cap.
4. Opening lid canister (uses insulated canister).

The first three options pertain to a sealed HH canister, while the fourth refers to the opening lid canister. The three canister insulation options for the sealed canister are intended to offer a wide range of heat rejection capabilities depending on customer requirements. Customers using the uninsulated canister option must perform the thermal analysis and provide the thermal control systems (heaters, thermostats, internal surface coatings, insulation, etc.) required for their instruments.

The first option, a fully insulated canister, would be the best choice for customers with relatively low power requirements. This option minimizes heater power needed to maintain operational temperature levels at cold Orbiter orientations. It does not, however, allow for large power dissipations on a continuous basis. The steady-state average canister temperature for various Shuttle attitudes and customer payload power levels is given in Figure 2.29. The corresponding Orbiter attitudes are defined in Figure 2.30. The canister temperatures from Figure 2.29 can be used as boundary conditions to calculate customer instrument temperature levels using techniques described in "GAS Thermal Design While U Wait" which is the appendix to Get Away Special Thermal Design Summary, GSFC-732-83-8.

Fully Insulated Canister and Uninsulated Canister

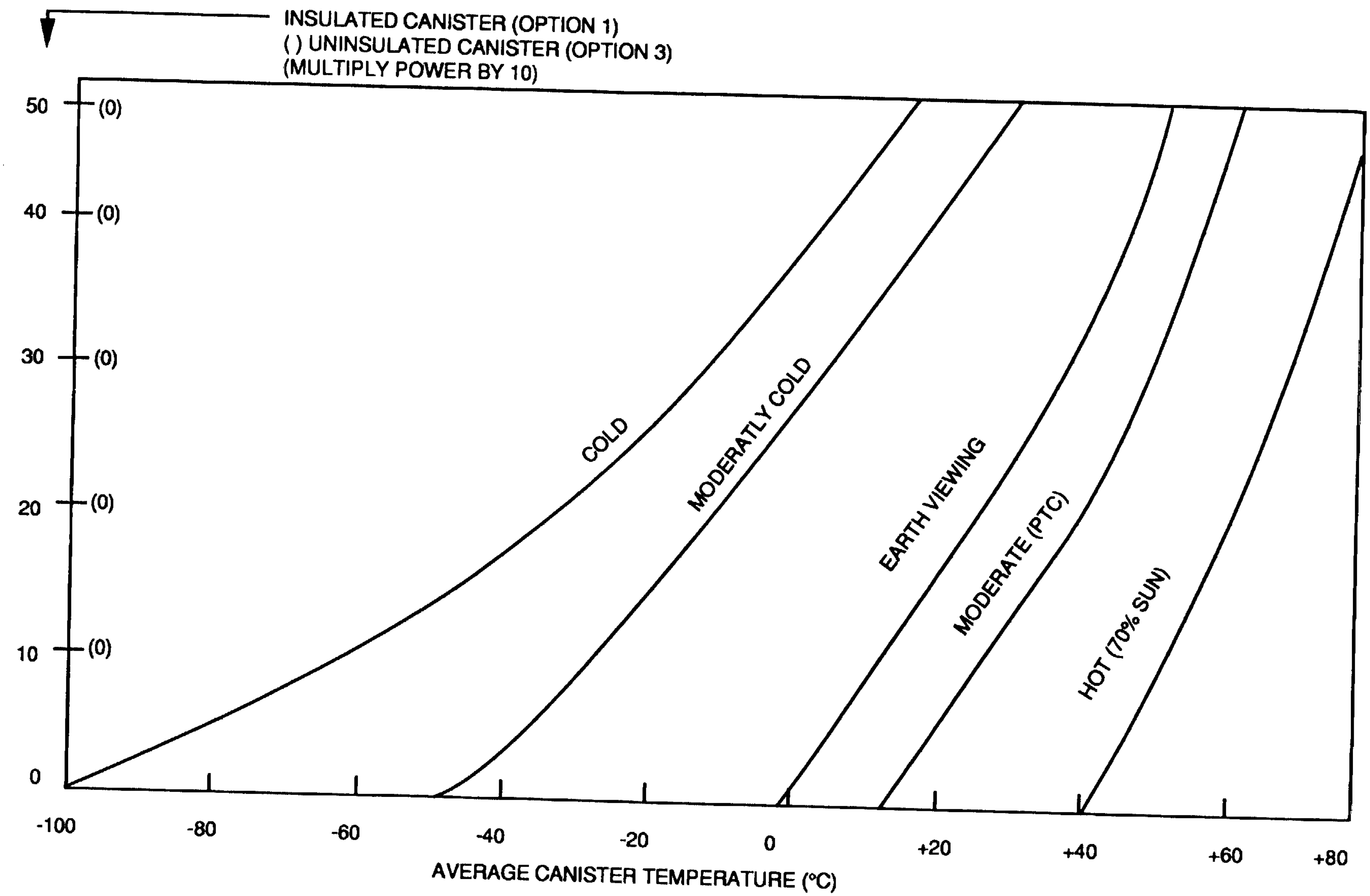
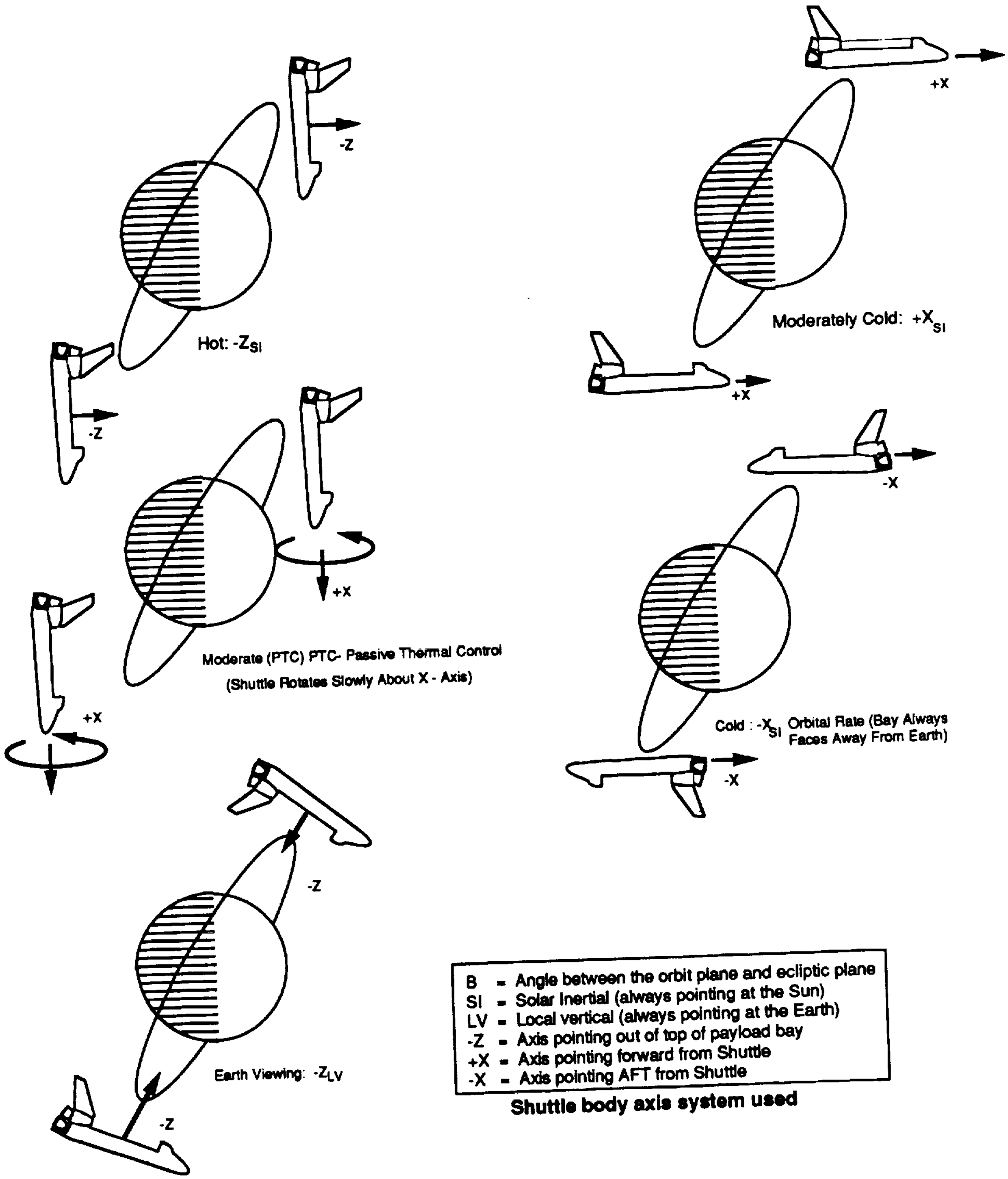


Figure 2.29

Typical Orbital Thermal Attitudes

(70% Sun, B=35°, and Altitude = 150 n.mi. (278km.)



B	=	Angle between the orbit plane and ecliptic plane
SI	=	Solar Inertial (always pointing at the Sun)
LV	=	Local vertical (always pointing at the Earth)
-Z	=	Axis pointing out of top of payload bay
+X	=	Axis pointing forward from Shuttle
-X	=	Axis pointing AFT from Shuttle

Shuttle body axis system used

Figure 2.30

The majority of the Shuttle missions flown to date have had the Earth-viewing attitude as the base one with excursions to other attitudes as required. Generally speaking, customer thermal designs should be tailored to this case, yet be flexible enough to withstand the other attitudes as well. The time-dependent or transient behavior of the canister should be considered as well, since its effects are usually favorable. For example, a fully insulated 160 pound canister with a 200 pound customer payload takes over 48 hours to cool from 20 degrees C to 0 degrees C in the Earth-viewing attitude. Heater requirements calculated on a steady-state basis would, therefore be much higher than that determined using a transient analysis.

Option 2 offers an increased heat rejection capability over option 1, as shown in Figure 2.31. The canister top plate exterior surface is coated with silver teflon (a = .15, E = .75) and acts as a radiator while the rest of the canister is insulated. Increased heater power, however, is required in order to maintain minimum temperature levels in cold Orbiter orientations. Transient response time is lower as well, with the canister cooling from 20 degrees C to 0 degrees C in 24 hours with the same conditions as the previous example. Finally, temperature gradients between the top and sides of the canister are more pronounced with this option. The curves shown in Figure 2.31 are average canister temperatures and do not show this effect.

Option 3 is available to customers requiring a large heat rejection capability. In this case, the side walls of the canister are painted white (a = .32, E = .86) and are allowed to radiate directly to the Shuttle bay and space. The average container temperature for various conditions is given in Figure 2.29. Power levels higher than those shown can be accommodated for short time periods depending on customer thermal design. However, large temperature gradients can be realized along with high power levels. Therefore, special attention should be given to the thermal design if Option 3 is selected. Also, large heater power levels are required to maintain minimum temperature levels even in the Earth viewing case. Transient response times are reduced as well, with the canister temperature cooling to 0 degrees C in less than 10 hours in the previous example.

Insulated Canister without Insulated Endcap (Option 2)

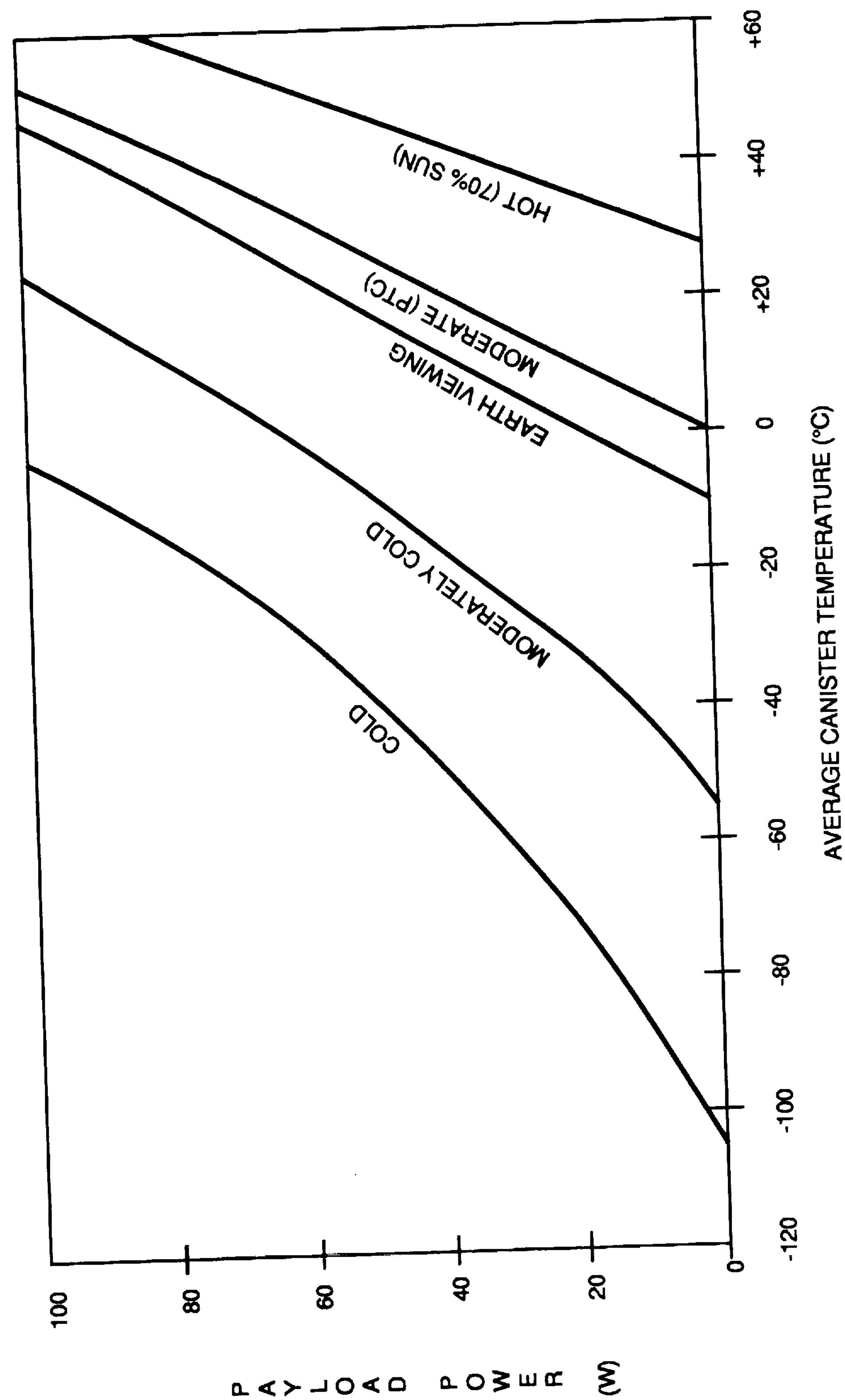


Figure 2.31

Option 4 refers to the opening-lid canister. When the lid is closed, the canister thermal behavior is approximately the same as that of the fully insulated canister (Option 1). When open, thermal behavior is heavily dependent on the customer payload thermal design, especially the exposed upper portion of the instrument. It is suggested that customers using this option pay particular attention to their thermal design, due to the increased complexity resulting from the opening lid. Thermal information for customers with opening-lids can be found in "Thermal Design Guide for Get Away Special/Motorized Door Assembly Users."

GSFC provides all exterior thermal insulation and coatings for canisters except for the top surface of an HMDA customer payload.

The temperatures listed for each orientation are approximate, and may vary somewhat (approx. +/- 10°C) depending on the Shuttle orbital attitude and beta angle (angle between the Shuttle orbit plane and the sun). All orientations shown were flown on STS-3, with the exception of the bay-Earth orientation, which was flown on STS-2.

Experimental data were obtained from the GAS Flight Verification Payload (FVP) on the flight of STS-3. Table 2.2 lists the steady-state temperature predictions and results for both hot and cold cases for the inside portion of the FVP. The experimental results are averages of thermistors or nodes at the indicated locations. The flight results listed are the hottest and coldest levels actually attained. They are not, however, the worst possible hot or cold case temperatures since steady-state conditions were not attained.

TABLE 2.2

CONTAINER AND PAYLOAD FLIGHT STEADY STATE THERMAL RESULTS
(Temperatures In °C)

FROM GAS VERIFICATION PAYLOAD

	HOT CASE		COLD CASE	
LOCATION	PREDICTED	ACTUAL	PREDICTED	ACTUAL
Top Plate	48.0	32.0	-20.6	-2.5
Container Sides	49.2	32.0	-19.1	-3.0
Bottom Plate	49.9	34.0	-19.5	-3.0
Battery	52.3	31.0	-5.7	+1.0
Tape Recorder	52.9	35.0	0.0	+4.0
Power	13.0W	13.0W	34.0W	13.0W

Note: Actual flight thermal levels did not reach steady-state conditions.
The levels are the maximum and minimum temperatures that were reached.

Table 2.3 shows external environmental thermal levels for steady-state conditions of the GAS container. It includes both predicted and actual flight thermal levels. Steady-state temperatures were not attained for the tail-to-sun, extreme cold case, which, therefore, is omitted from the table. The two predicted values for the adapter beam hot case correspond to two absorptivity values. The higher absorptivity value gives a better hot case correlation.

Additional thermal design information can be found in the Get-Away-Special Thermal Design Summary (X-732-83-8).

TABLE 2.3
GAS CONTAINER EXTERNAL THERMAL LEVELS AT
STEADY STATE

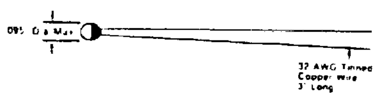
	PREDICTIONS °C	FLIGHT °C
Adapter Beam (Hot-Bay to Sun)	+37 to +46	+45 to +50
Adapter Beam (Cold-Nose to Sun)	-78	-40
Bottom Cover (Hot-Bay to Sun)	+63	+63 to +65
Bottom Cover (Cold Nose to Sun)	-76	-45 to -50
Top Cover (Bracket) (Hot-Bay to Sun)	+31	+25 to +35
Top Cover (Bracket) (Cold-Nose to Sun)	-73	-47 to -52

2.2.2 Thermistors

Three thermistors are available for all plate experiments. Opening can experiments have no thermistors except for one mounted on the base plate. Closed can experiments have one thermistor available and one mounted on the base plate. Additional thermistors may be available through negotiation with the HH project.

These thermistors, Yellow Springs Instrument Company (YSI) 44006 type or equivalent (see the manufacturer's specification sheet on the following page), are supplied by the HH Project for connection to appropriate pins on J2, as outlined in Tables 2.4 and 2.5. This interface configuration allows monitoring of up to three temperatures when customer payload power is on or off. The thermistor interface between customer and carrier is shown in Figure 2.32.

YSI PRECISION THERMISTOR



RESISTANCE VERSUS TEMPERATURE —80° to +150°C

TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES
−80	3558K	−50	441.3K	−20	78.91K	+10	18.79K	+40	5592	+70	1990	+100	816.8	+130	376.4
79	3296K	49	414.5K	19	74.91K	11	17.98K	41	5389	71	1928	101	794.6	131	367.4
78	3055K	48	389.4K	18	71.13K	12	17.22K	42	5193	72	1868	102	773.1	132	358.7
77	2833K	47	366.0K	17	67.57K	13	16.49K	43	5006	73	1810	103	752.3	133	350.3
76	2629K	46	344.1K	16	64.20K	14	15.79K	44	4827	74	1754	104	732.1	134	342.0
75	2440K	45	323.7K	15	61.02K	15	15.13K	45	4655	75	1700	105	712.6	135	334.0
74	2266K	44	304.6K	14	58.01K	16	14.50K	46	4489	76	1648	106	693.6	136	326.3
73	2106K	43	286.7K	13	55.17K	17	13.90K	47	4331	77	1598	107	675.3	137	318.7
72	1957K	42	270.0K	12	52.48K	18	13.33K	48	4179	78	1549	108	657.5	138	311.3
71	1821K	41	254.4K	11	49.94K	19	12.79K	49	4033	79	1503	109	640.3	139	304.2
−70	1694K	−40	239.8K	−10	47.54K	+20	12.26K	+50	3893	+80	1458	+110	623.5	+140	297.2
69	1577K	39	226.0K	9	45.27K	21	11.77K	51	3758	81	1414	111	607.3	141	290.4
68	1469K	38	213.2K	8	43.11K	22	11.29K	52	3629	82	1372	112	591.6	142	283.8
67	1369K	37	201.1K	7	41.07K	23	10.84K	53	3504	83	1332	113	576.4	143	277.4
66	1276K	36	189.8K	6	39.14K	24	10.41K	54	3385	84	1293	114	561.6	144	271.2
65	1190K	35	179.2K	5	37.31K	25	10.00K	55	3270	85	1255	115	547.3	145	265.1
64	1111K	34	169.3K	4	35.57K	26	9605	56	3160	86	1218	116	533.4	146	259.2
63	1037K	33	160.0K	3	33.93K	27	9227	57	3054	87	1183	117	519.9	147	253.4
62	968.4K	32	151.2K	2	32.37K	28	8867	58	2952	88	1149	118	506.8	148	247.8
61	904.9K	31	143.0K	−1	30.89K	29	8523	59	2854	89	1116	119	494.1	149	242.3
−60	845.9K	−30	135.2K	0	29.49K	+30	8194	+60	2760	+90	1084	+120	481.8	+150	237.0
59	791.1K	29	127.9K	+1	28.15K	31	7880	61	2669	91	1053	121	469.8		
58	740.2K	28	121.1K	2	26.89K	32	7579	62	2582	92	1023	122	458.2		
57	692.8K	27	114.6K	3	25.69K	33	7291	63	2497	93	994.2	123	446.9		
56	648.8K	26	108.6K	4	24.55K	34	7016	64	2417	94	966.3	124	435.9		
55	607.8K	25	102.9K	5	23.46K	35	6752	65	2339	95	939.3	125	425.3		
54	569.6K	24	97.49K	6	22.43K	36	6500	66	2264	96	913.2	126	414.9		
53	534.1K	23	92.43K	7	21.45K	37	6258	67	2191	97	887.9	127	404.9		
52	501.0K	22	87.66K	8	20.52K	38	6026	68	2122	98	863.4	128	395.1		
51	470.1K	21	83.16K	9	19.63K	39	5805	69	2055	99	839.7	129	385.6		

YSI 44006

RESISTANCE 10,000 OHMS @25°C

Interchangeability: ±0.2°C (See Tolerance Curves).

Max. Operating Temp: 150°C (300°F).

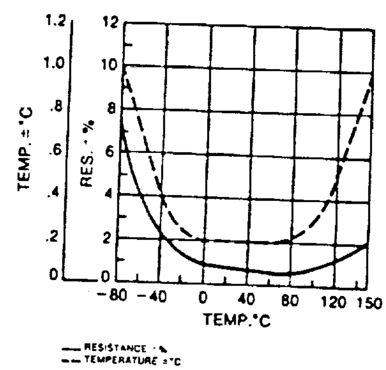
Time Constant, Max: 1 sec. in well stirred oil, 10 sec. in still air. Time constant is the time required for a thermistor to indicate 63% of a newly impressed temperature.

Dissipation Constant, Min: 8mW/°C in well stirred oil, 1mW/°C in still air. Dissipation constant is the power in milliwatts to raise a thermistor 1°C above surrounding temperature.

Color Code: Black epoxy body, blue end.

Storage Temperature: -80° to +120°C (-112° to +250°F).

Tolerance Curves: The following curves indicate conformance to standard resistance temperature values as a % of resistance, and as a maximum interchangeability error expressed as temperature.



WARNING

Use heat sinks when soldering or welding to thermistor leads.

MANUFACTURER'S SPECIFICATION SHEET
FOR YSI PRECISION THERMISTORS

Thermistor Interface to Carrier

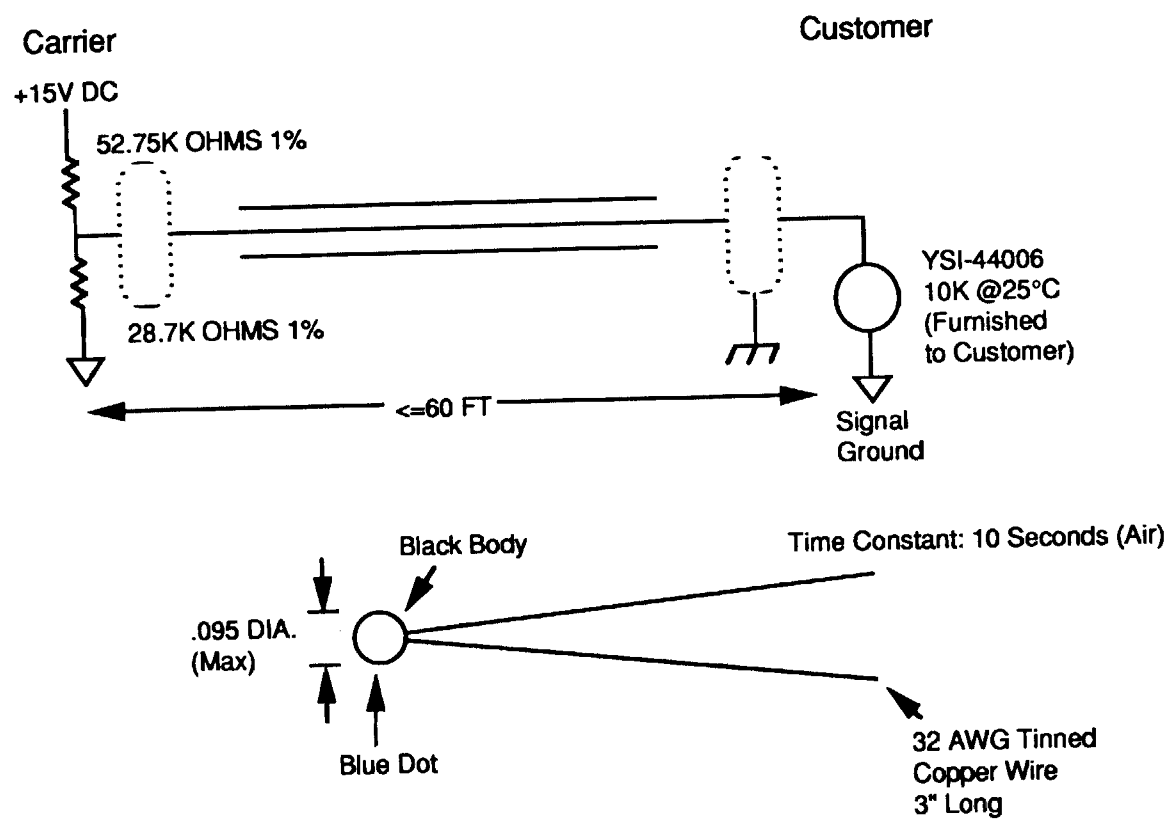


Figure 2.32

2.2.3 Customer Thermal Responsibilities for Plate Mounting

In general, the customer is responsible for the thermal design of a plate-mounted experiment system. This design will encompass the plate and its attachments to the GAS beam and Orbiter or to the HH bridge. Normally, in order to avoid problems with thermal/mechanical stress, a customer will want to provide good thermal conduction between his/her equipment and the HH mounting plate. On HH-G, the mounting plate has poor thermal conduction to the GAS beam. On HH-M, mounting plates are thermally isolated from the cross-bay structure by means of special hardware which allows for thermal expansion. The HH-G GAS beam is attached to the Orbiter with hardware which also provides thermal isolation and allows for expansion.

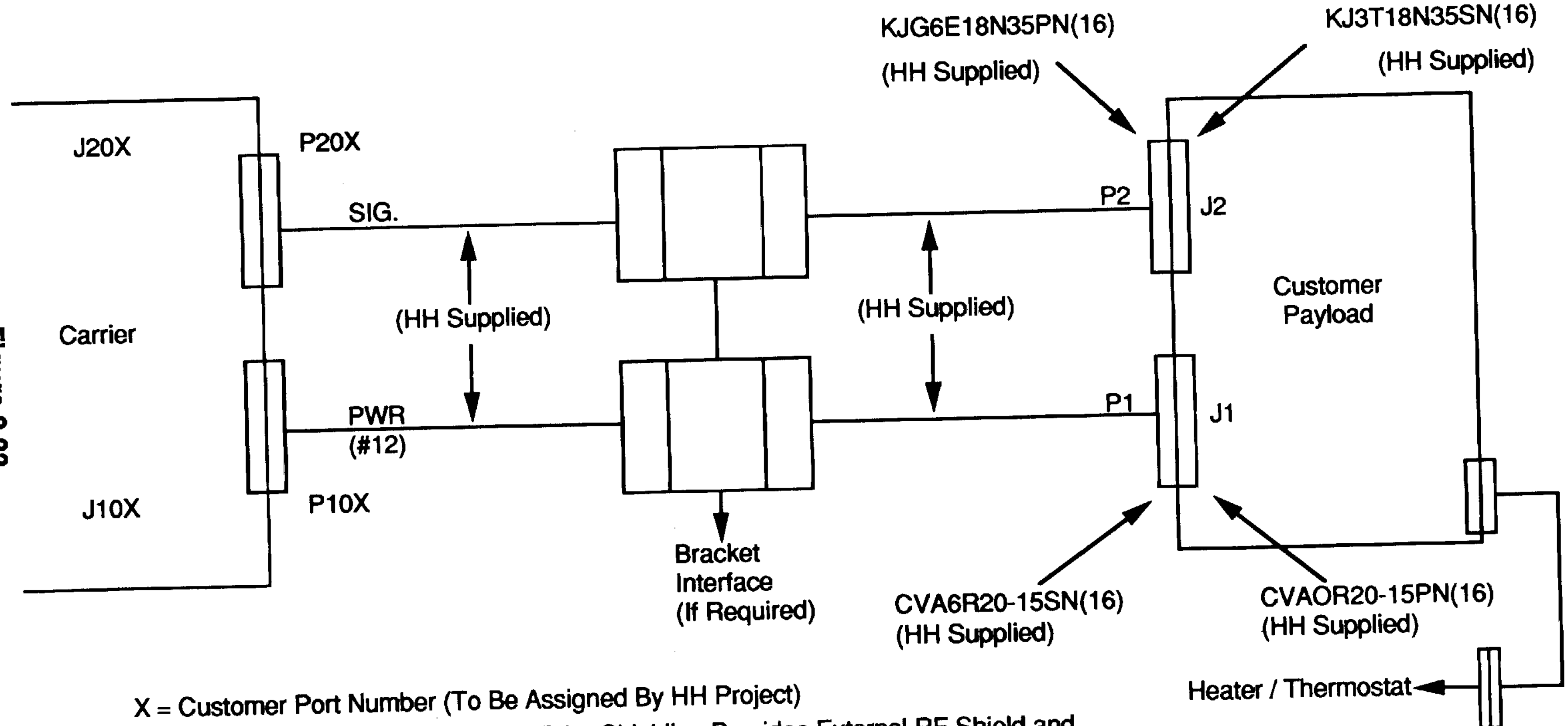
GSFC will supply the customer with thermal model data on the Orbiter plates and their attachments. GSFC will also supply insulation for the backs of plates and a custom-designed sheet to cover the unoccupied front surface of plates. GSFC will supply a standard heater system on the back of the HH-G or HH-M small plate consisting of a 140-watt heater(0°C thermostat) and one thermistor. The customer may use this system by providing a cable to connect the thermal system to power from his customer port. The customer will provide GSFC with thermal model data on all plate-mounted hardware and will also provide copies of his/her thermal design and analysis for GSFC review. Additional information may be found in the SPOC Thermal Design Handbook.

2.3 ELECTRICAL/POWER SUPPORT SYSTEMS

2.3.1 Electrical/Power System Design

The electrical interfaces for plate mount and canister customers differ slightly. Figure 2.33 and Table 2.4 give plate mounting details. Figure 2.34, 2.35, and Table 2.5 provide details on the canister mount. Figure 2.35 shows the Motorized Door Canister with the control and monitoring interface. Each of the two 12 gauge 28V power lines is protected by a 20A fuse (vacuum derated to 10A). Customers must provide consistent wiring and fusing within their payloads. Prior to using a smaller gauge wire for power service, an appropriate smaller fuse must be used to provide protection from fire hazard. Table 2.6 shows acceptable wire and fuse sizes.

Hitchhiker Standard Interface Cables
(Plate Mounted Customer)



X = Customer Port Number (To Be Assigned By HH Project)

Optional Semi-Rigid Convolute Tube Shielding Provides External RF Shield and Mechanical Protection on Power and Signal Cables

NOTE: The designation 'P' means this connector is on the end of a cable. The designation 'J' means this connector is a chassis mount connector. The designation of Pin or Socket for a connector is contained in the part number for each connector.

Figure 2.33

TABLE 2.4

SPOC PLATE ELECTRICAL INTERFACE CONNECTORS

ID	PIN (NOTE 3)	TYPE (NOTE 2)	FUNCTION
POWER CONNECTOR J1: (NOTE 4)			
+28A	A	C	+28V POWER CIRCUIT A
RETA	B	C	POWER RETURN (NOTE 1)
+28B	C	C	+28V POWER CIRCUIT B
RETB	D	C	POWER RETURN (NOTE 1)
+28HTR	E	B	+28V HEATER POWER
RETH	F	B	HEATER POWER RETURN (NOTE 1)
FRMGND	G	B	FRAME GROUND
SIGNAL CONNECTOR J2: (NOTE 4)			
PCMAD	1	A	PCM ANALOG DATA
PCMINDX	41	A	PCM INDEX PULSE
SIGGND	2	A	SIGNAL GROUND
PCMCLK	42	A	PCM BIT RATE CLOCK
PCMENA	32	A	SERIAL DIGITAL ENABLE A
PCMENB	33	A	SERIAL DIGITAL ENABLE B
PCMDATA	3	A	SERIAL DIGITAL DATA A
PCMDATB	8	A	SERIAL DIGITAL DATA B
THER1	14	A	THERMISTOR 1
THER2	15	A	THERMISTOR 2
THER3	16	A	THERMISTOR 3
SHIELD	6	A	SHIELD FOR COMMAND AND DATA SIGNALS
RD+	21	A	RECEIVE DATA ASYNC + FROM SPOC
RD-	22	A	RECEIVE DATA ASYNC - FROM SPOC
SD+	23	A	SEND DATA ASYNC + TO SPOC
SD-	24	A	SEND DATA ASYNC - TO SPOC
BLCMD1	17	A	BI-LEVEL/PULSE COMMAND 1

TABLE 2.4 (Cont'd)

SPOC PLATE ELECTRICAL INTERFACE CONNECTORS

ID	PIN (NOTE 3)	TYPE (NOTE 2)	FUNCTION
BLCMD2	18	A	BI-LEVEL/PULSE COMMAND 2
BLCMD3	19	A	BI-LEVEL/PULSE COMMAND 3
BLCMD4	20	A	BI-LEVEL/PULSE COMMAND 4
SCMDCLK	10	A	SERIAL COMMAND CLOCK
SCMDENV	11	A	SERIAL COMMAND ENVELOPE
SCMDDAT	12	A	SERIAL COMMAND DATA
METMIN	40	A	MET/MET ONE MINUTE PULSE
IRIGMET+	30	A	IRIG-B MET (MET) +
IRIGMET-	31	A	IRIG-B MET (MET) -
FRMGND	49	A	FRAME GROUND
KUMRCLK+	34	A	CUSTOMER GENERATED MR CLOCK +
KUMRCLK-	35	A	MR CLOCK -
KUMRDAT+	43	A	CUSTOMER GENERATED MR DATA +
KUMRDAT-	44	A	MR DATA -
KUMRSHLD	25	A	SHIELD FOR KU SIGNALS
UNDTSP1+	61	D	UNDEDICATED TSP 1 +
UNDTSP1-	66	D	UNDEDICATED TSP 1 -
UNDTSPS1	54	A	SHIELD FOR UNDEDICATED TSP 1
UNDTSP2+	62	D	UNDEDICATED TSP 2 +
UNDTSP2-	63	D	UNDEDICATED TSP 2 -
UNDTSPS2	55	A	SHIELD FOR UNDEDICATED TSP 2
UNDTSP3+	56	D	UNDEDICATED TSP 3 +
UNDTSP3-	57	D	UNDEDICATED TSP 3 -
UNDTSPS3	48	A	SHIELD FOR UNDTSP3
UND4	58	A	UNDEDICATED 4
UND5	59	A	UNDEDICATED 5
UND6	60	A	UNDEDICATED 6
UND7	64	A	UNDEDICATED 7
UND8	65	A	UNDEDICATED 8
UNDS	53	A	SHIELD FOR UNDEDICATED 4-8
MDAOC	52	A	RESERVED
MDASTP	51	A	RESERVED

TABLE 2.4 (continued)

NOTE 1: POWER RETURN PINS B, D AND F MAY BE CONNECTED TOGETHER WITHIN PAYLOAD.

NOTE 2: WIRE TYPE DESIGNATIONS:

A 22 GA

B 16 GA

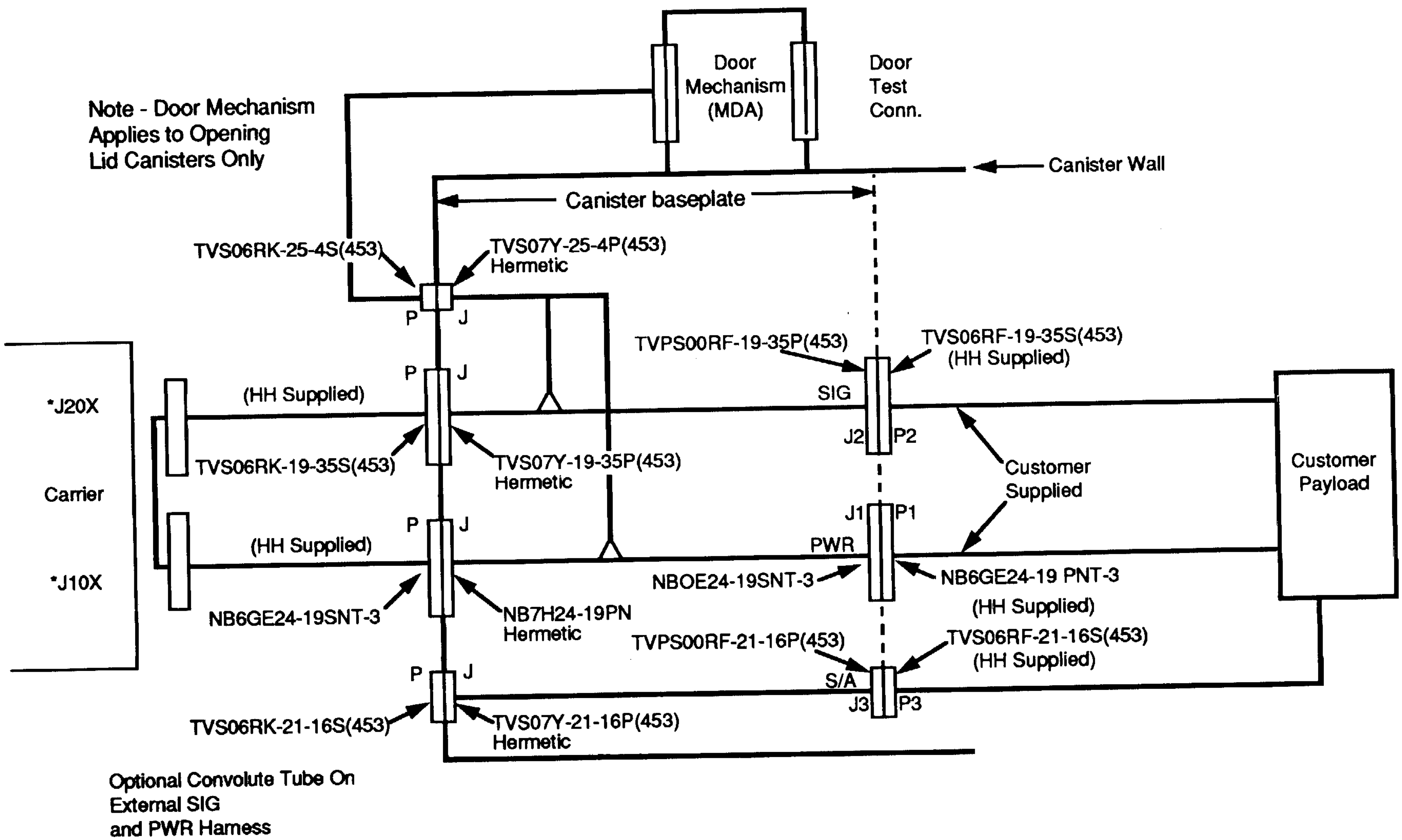
C 12 GA

D 26 GA

NOTE 3: CUSTOMER WILL MAKE NO CONNECTIONS TO UNUSED PINS

NOTE 4: THE DESIGNATIONS "J1" AND "J2" IN THIS TABLE INDICATE THE PIN OUT FOR A CHASSIS MOUNT CONNECTOR MOUNTED TO A PARTICULAR SCIENTIFIC EXPERIMENT. THE HH-PROVIDED CONNECTING CABLE WILL BE TERMINATED IN CONNECTORS WITH A DESIGNATION OF "P1" AND "P2" BUT WILL HAVE THE IDENTICAL PIN-OUT AS SHOWN IN THIS TABLE.

Hitchhiker Standard Interface Cables
(Canister Customer)



Note:
X = Customer port number (To Be Assigned By HH Project)
Note 1 on Figure
2.33 applies in full to this drawing

Figure 2.34

Hitchhiker Motorized Door Canister
Control and Monitoring Interface

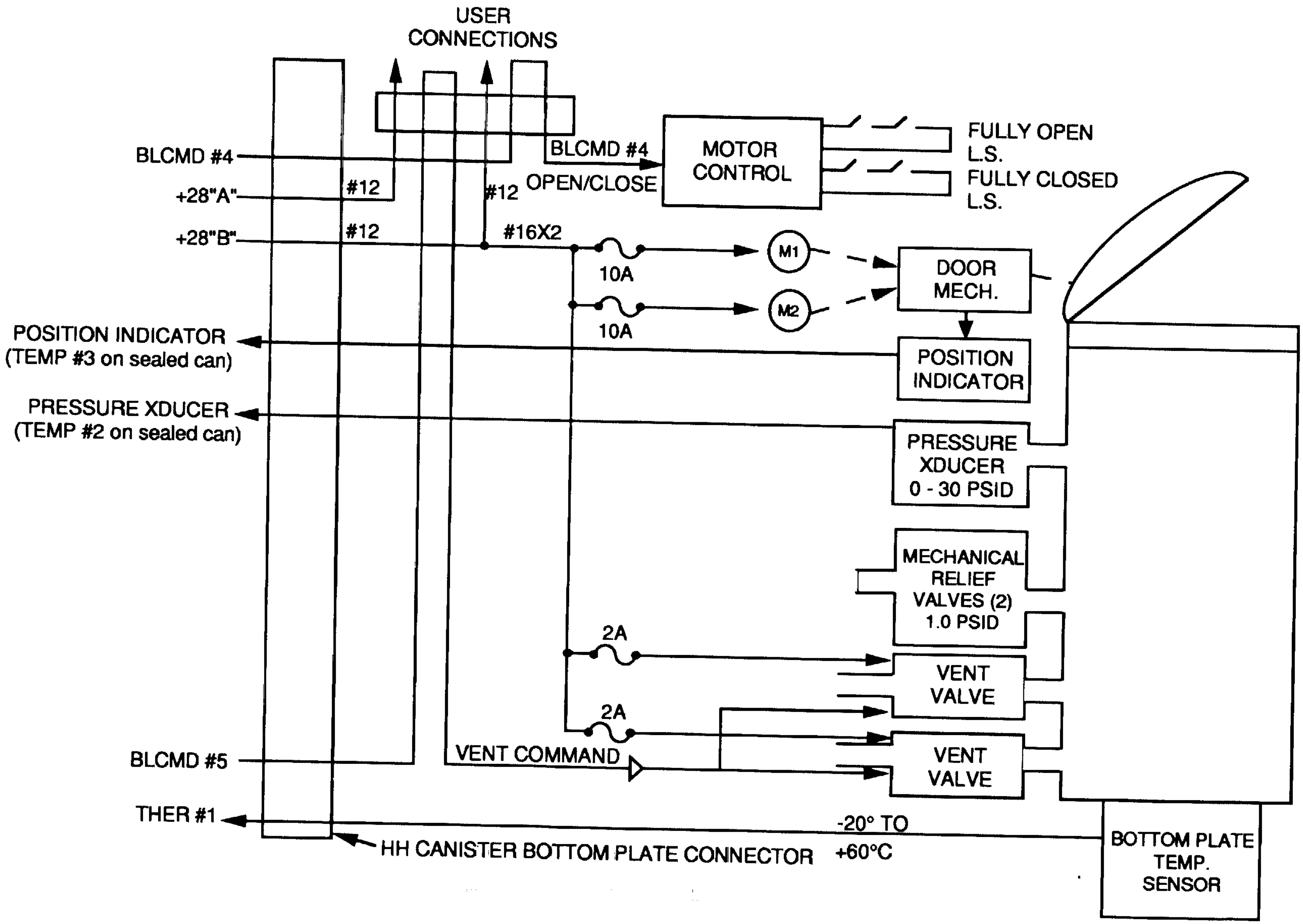


Figure 2.35

TABLE 2.5

CANISTER ELECTRICAL INTERFACE CONNECTORS

ID	PIN(NOTE 3)	TYPE(NOTE 2)	FUNCTION
POWER CONNECTOR P1:			
+28A	A	C	+28V POWER CIRCUIT A
RETA	B	C	POWER RETURN (NOTE 1)
+28B	C	C	+28V POWER CIRCUIT B (NOTE 5)
RETB	D	C	POWER RETURN (NOTE 1)
+28HTR	E	B	+ 28V HEATER POWER
RETH	F	B	HEATER POWER RETURN (NOTE 1)
FRMGND	G	B	FRAME GROUND
SIGNAL CONNECTOR P2:(NOTE 4)			
PCMAD	1	A	PCM ANALOG DATA
PCMINDX	41	A	PCM INDEX PULSE
SIGGND	2	A	SIGNAL GROUND
PCMCLK	42	A	PCM BIT RATE CLOCK
PCMENA	32	A	SERIAL DIGITAL ENABLE A
PCMENB	33	A	SERIAL DIGITAL ENABLE B
PCMDATA	3	A	SERIAL DIGITAL DATA A
PCMDATB	8	A	SIERAL DIGITAL DATA B
THER1	14	A	THERMISTOR 1 (NOT WIRED TO PLD) (NOTE 6)
THER2	15	A	CANISTER PRESSURE (NOT WIRED TO PLD)
THER3	16	A	MDA DOOR POSITION 0-5 V (NOTE 7)
SHIELD	6	A	SHIELD FOR COMMAND AND DATA SIGNALS
RD+	21	A	RECEIVE DATA ASYNC + FROM SPOC
RD-	22	A	RECEIVE DATA ASYNC - FROM SPOC
SD+	23	A	SEND DATA ASYNC + TO SPOC
SD-	24	A	SEND DATA ASYNC - TO SPOC
BLCMD1	17	A	BILEVEL/PULSE COMMAND 1
BLCMD2	18	A	BILEVEL/PULSE COMMAND 2
BLCMD3	19	A	BILEVEL/PULSE COMMAND 3

TABLE 2.5 (continued)
CANISTER ELECTRICAL INTERFACE CONNECTORS

ID	PIN(NOTE 3)	TYPE(NOTE 2)	FUNCTION
BLCMD4	20	A	BILEVEL CMD 4/OPEN CLOSE MDALID (NOTE 8)
BLCMD5	65	A	PRESSURE VALVE
SCMDCLK	10	A	SERIAL COMMAND CLOCK
SCMDENV	11	A	SERIAL COMMAND ENVELOPE
SCMDDAT	12	A	SERIAL COMMAND DATA
GMTMIN	40	A	GMT/MET ONE-MINUTE PULSE
IRIGGMT+	30	A	IRIG-B GMT (MET) +
IRIGGMT-	31	A	IRIG-B GMT (MET)-
FRMGND	49	A	FRAME GROUND
KUMRCLK+	34	A	CUSTOMER-GENERATED MR CLOCK +
KUMRCLK-	35	A	MR CLOCK -
KUMRDAT+	43	A	CUSTOMER-GENERATED MR DATA +
KUMRDAT-	44	A	MR DATA -
KUMRSHLD	25	A	SHIELD FOR KU SIGNALS
UNDTSP1+	61	D	UNDEDICATED TSP 1 +
UNDTSP1-	66	D	UNDEDICATED TSP 1 -
UNDTSPS1	54	A	SHIELD FOR UNDEDICATED TSP 1
UNDTSP2+	62	D	UNDEDICATED TSP 2 +
UNDTSP2-	63	D	UNDEDICATED TSP -
UNDTSPS2	55	A	SHIELD FOR UNDEDICATED TSP 2
UNDTSP3+	56	A	UNDEDICATED TSP 3+
UNDTSP3-	57	A	UNDEDICATED TSP 3-
UNDTSPS3	48	A	SHIELD FOR UNDEDICATED TSP 3
UND4	58	A	UNDEDICATED 4
UND5	59	A	UNDEDICATED 5
UND6	60	A	UNDEDICATED 6
UND7	64	A	UNDEDICATED 7
UND8	65	A	UNDEDICATED 8
UNDS	53	A	SHIELD FOR UNDEDICATED 4-8
MDAOC	52	A	MDA DOOR OPEN/CLOSE SIG TO MDA

TABLE 2.5 (continued)

NOTE 1: POWER RETURN PINS B, D, AND F MAY BE CONNECTED TOGETHER WITHIN PAYLOAD

NOTE 2: WIRE TYPE DESIGNATION:

A 22 GA

B 16 GA

C 12 GA

D 26 GA

NOTE 3: CUSTOMER WILL MAKE NO CONNECTIONS TO UNUSED PINS

NOTE 4: THE DESIGNATIONS "P1" AND "P2" IN THIS TABLE INDICATE THE PIN-OUT FOR A CABLE-MOUNTED CONNECTOR. A CANISTER EXPERIMENT WOULD NEED THIS TERMINATION TO INTERFACE TO THE CANISTER BASEPLATE CONNECTOR (DESIGNATED AS "J1" AND "J2"). THE PINOUTS ARE IDENTICAL FOR EITHER "J" OR "P" DESIGNATED CONNECTORS. CONNECTOR PAIR J3/P3 IS A SAFE AND ARM CONNECTOR WHOSE USE IS NOT A STANDARD SERVICE. THE PIN-OUT IS NOT INCLUDED.

NOTE 5: 28V B POWER CIRCUIT SHARED WITH MDA MOTORS - MAY CONTAIN EXCESS EMI DURING DOOR MOTOR OPERATION

NOTE 6: THERMISTOR 1 IS LOCATED ON CANISTER BOTTOM PLATE

NOTE 7: PIN 16 (MDA DOOR POSITION) MAY ONLY BE CONNECTED TO HIGH-RESISTANCE (100 K OHMS) LOAD WITHIN PAYLOAD IF MDA IS FLOWN

NOTE 8: PIN 20 BLCMD 4 TO BE CONNECTED TO PIN 52 (MDA OPEN/CLOSE CONTROL) UNLESS PAYLOAD HAS OTHER PROVISION FOR GENERATING 28V 10MA SIGNAL TO OPEN DOOR (IF MDA IS FLOWN)

TABLE 2.6

CIRCUIT PROTECTION REQUIREMENTS

MIN. WIRE GAUGE (IN A BUNDLE OF 20 WIRES)	MAX. FUSE SIZE (A)	MAX. LOAD (A)	TYP. FUSE VOLTAGE DROP
26	3	1.5	.163
24	5	2.5	.102
22	6	3.0	.102
20	7	3.5	.101
18	10	5.0	.098
16	14	7.0	.076
14	15	7.5	.116
12	20	10	.16

Six electrical interfaces are provided via six standard sets of cables and connectors. Two additional sets are reserved for system use. These provide up to 500W of 28VDC power to each interface and 50W of "Survival Heater Power." In addition to providing this type of interface during on-orbit operations, the HH has provisions for a transparent bi-directional data path between the customer's payload and the Customer Ground Support Equipment (CGSE). This type of interface allows the customer to maintain autonomous control over his/her payload.

The characteristics of the power will be the same as Orbiter power (see excerpts from Vol. XVI, ICD 2-19001, Appendix H of this document) except for higher source resistance due to the added carrier wiring. It is important to note that, while power is switched to each experiment through the HH avionics, no EMI filtering is provided. Customers will see the EMI environment specified in Appendix H and are expected to meet all EMI requirements by providing filtering with each experiment. Each power interface will consist of 28 VDC +/- 4 VDC power supplied via dual 12 gauge 10A circuits. Each of the dual circuits can be switched in through independent contacts of a Double-Pole Single Throw (DPST) relay (Figure 2.36). Each power interface will have independent current measurement capability. This data is available to the customer either in real-time or post-fight when specified as a requirement. Figure 2.37 provides a schematic drawing of the HH-G customer power interface. Customer signal ground must be isolated from chassis (case) ground for dc at a minimum resistance of 10K ohms, although there is no limitation on capacitative connection between signal ground and case. The 28V return must be isolated from both signal ground and case by a minumum resistance of 10K ohms. **This requirement cannot be waived.**

Tables 2.7 and 2.8 provide the detailed characteristics of the electrical system interfaces. A switch panel is used for carrier and experiment power activation and de-activation and may be used to provide a safety inhibit to a customer's hazardous function if required.

2.3.2 DC Power Ripple and Transient Limits (For Payload Main Circuit Only)

See Appendix H of this document.

TABLE 2.7

CUSTOMER ELECTRICAL INTERFACES AND SERVICE SUMMARY

1. 28 VDC (+/- 4 VDC) POWER (DUAL 10A CIRCUITS)
2. ASYNCHRONOUS INTERFACE (BI-DIRECTIONAL, 1200 BAUD)
3. SERIAL COMMAND (CLOCK/DATA/ENVELOPE) CAN ALSO FUNCTION AS INDIVIDUAL BI-LEVEL 0, +5V COMMANDS (3 EACH).
4. BI-LEVEL OR PULSE 0, +28V COMMAND (4 EACH)
5. IRIG-B MET AND MET ONE-MINUTE PULSE
6. MEDIUM-RATE KU-BAND DATA (16 Kb - 1.4 Mb/s TOTAL, CLOCK/DATA INTERFACE)

ITEMS 2, 3, 4, and 6 CAN BE INTERFACED TO CUSTOMER GSE

ITEMS 2 AND 6 ARE "TRANSPARENT" INTERFACES

TABLE 2.8
HITCHHIKER ELECTRICAL ACCOMMODATIONS

	TOTAL HH AND CUSTOMER PAYLOADS MAX	SINGLE CUSTOMER PAYLOAD PORT MAX
POWER (28 +/- 4DC)	1300W	500W
ENERGY (KWH)	60	10**
LOW-RATE DOWNLINK	6000 b/s	960 b/s*
MEDIUM-RATE DOWNLINK	1.4 Mb/s	1.4 Mb/s***
SERIAL COMMAND CHANNELS	6	1
BI-LEVEL COMMANDS	24	4

* NOMINAL INFORMATION RATE OF ONE STANDARD ASYNCHRONOUS CHANNEL. ANY COMBINATION OF FIVE 1.2k BAUD CHANNELS MAY BE DOWNLINKED SIMULTANEOUSLY.

** NOMINAL 1/6 ALLOCATION

*** BY MISSION REQUIREMENTS

Customer Power Interface

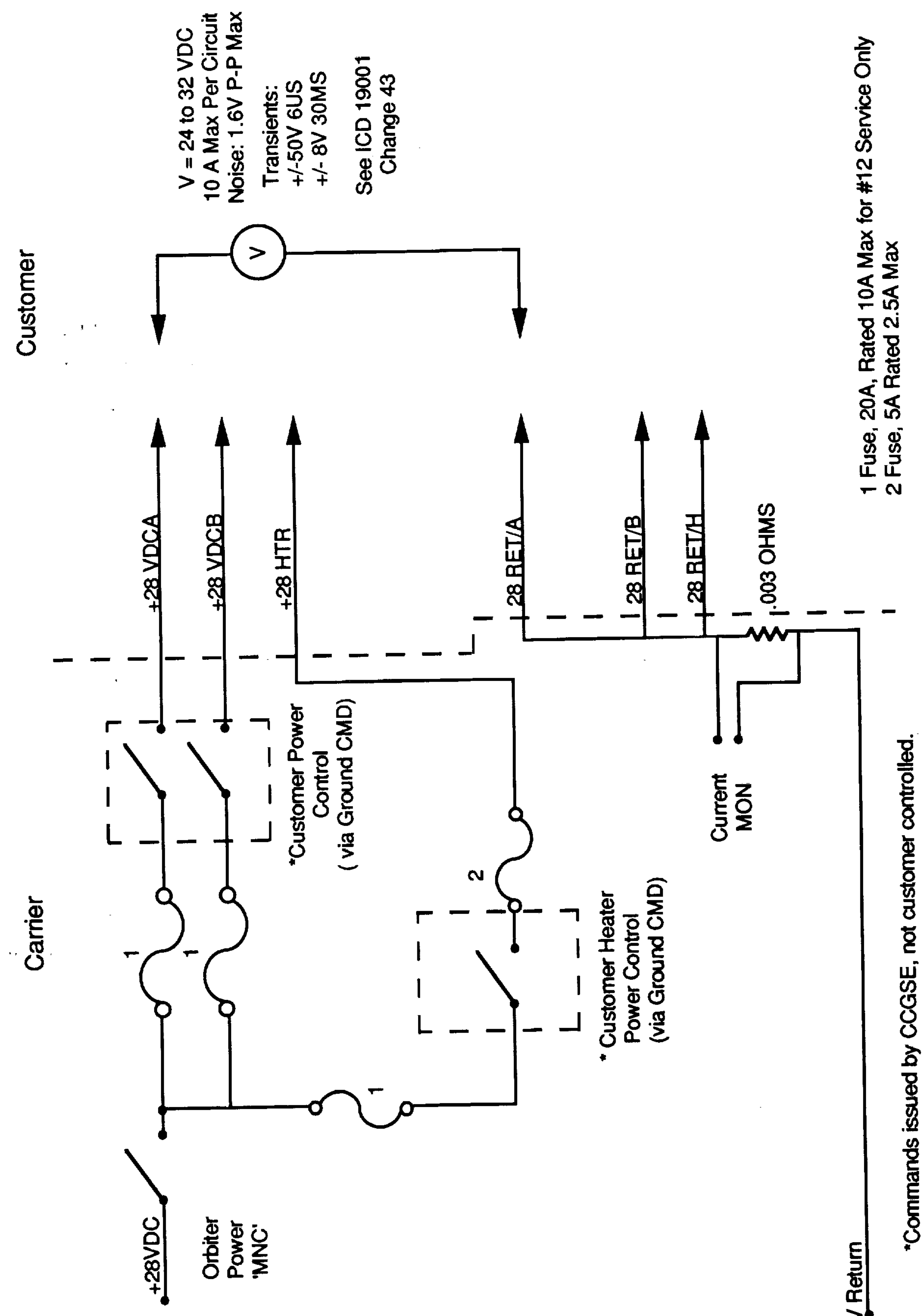
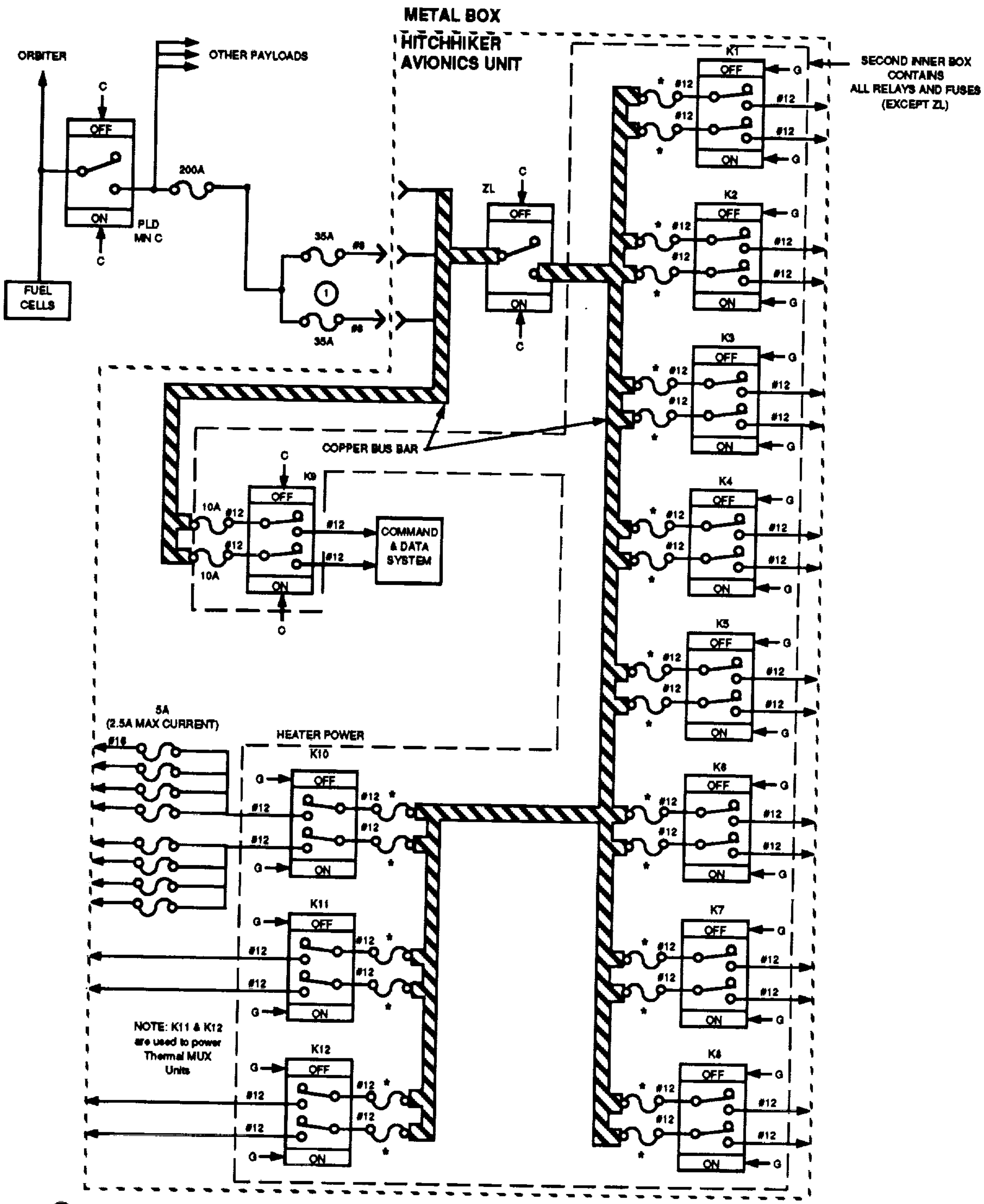


Figure 2.36

Hitchhiker Avionics Unit - Power Distribution



1. SMALL PAYLOAD HARNESS ONLY

C - CREW COMMAND (SWITCH PANEL)

G - GROUND COMMAND

* - 20A FUSE, VACUUM DERATED 50% (MAX CURRENT 10A)
FUSES TO COPPER BUS BAR ARE CONNECTED THROUGH 20 AWG BUS WIRES

Figure 2.37

2.4 COMMAND AND COMMUNICATION SUPPORT SYSTEM

2.4.1 Transparent Data System

Figures 2.38 through 2.43 illustrate the transparent data system available to the customer through HH. The figures present the command, low-rate and medium rate data flows. The data communications interface generally remains unchanged from the customer's point of view independent of whether the payload is at the customer's facility, at the integration facility, or during flight operations. All commands issued by the CGSE have the general format shown in Figure 2.40. Some ground data processing functions may have optional service charges for reimbursable customers. Contact the Project Office for details.

HITCHHIKER TRANSPARENT DATA SYSTEM

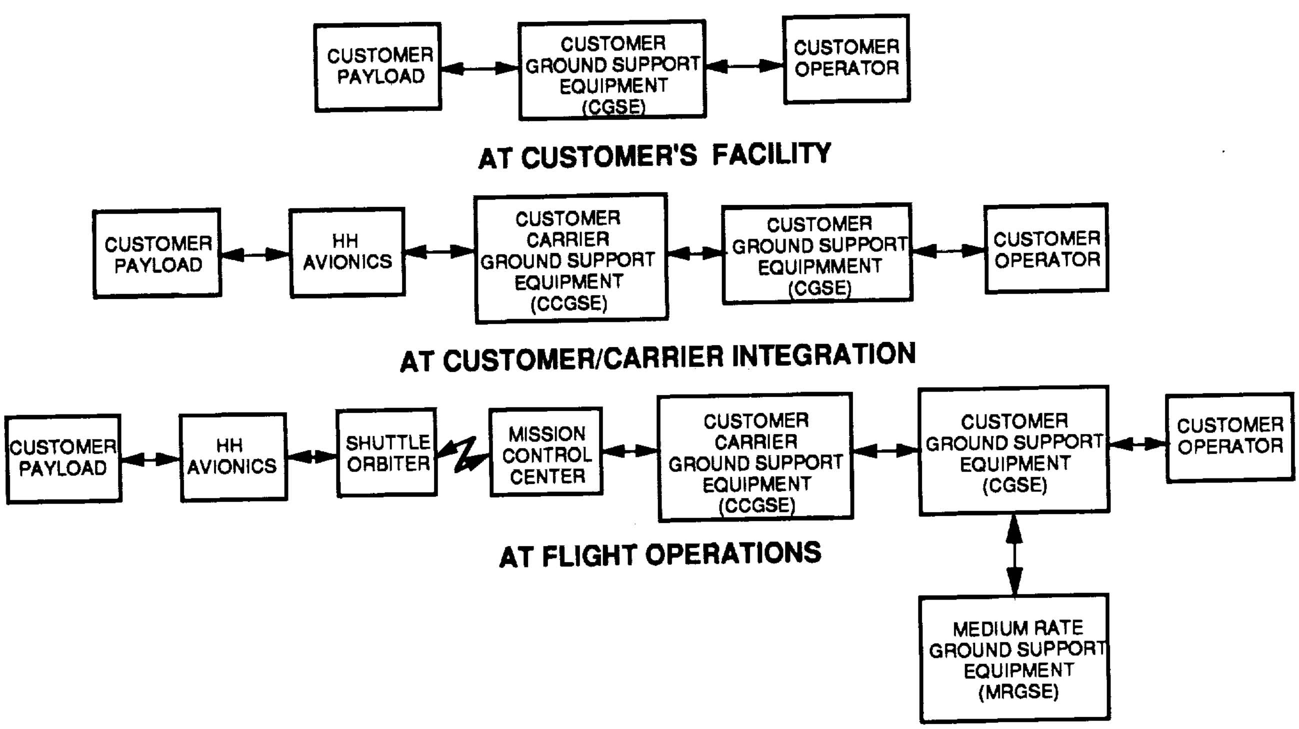
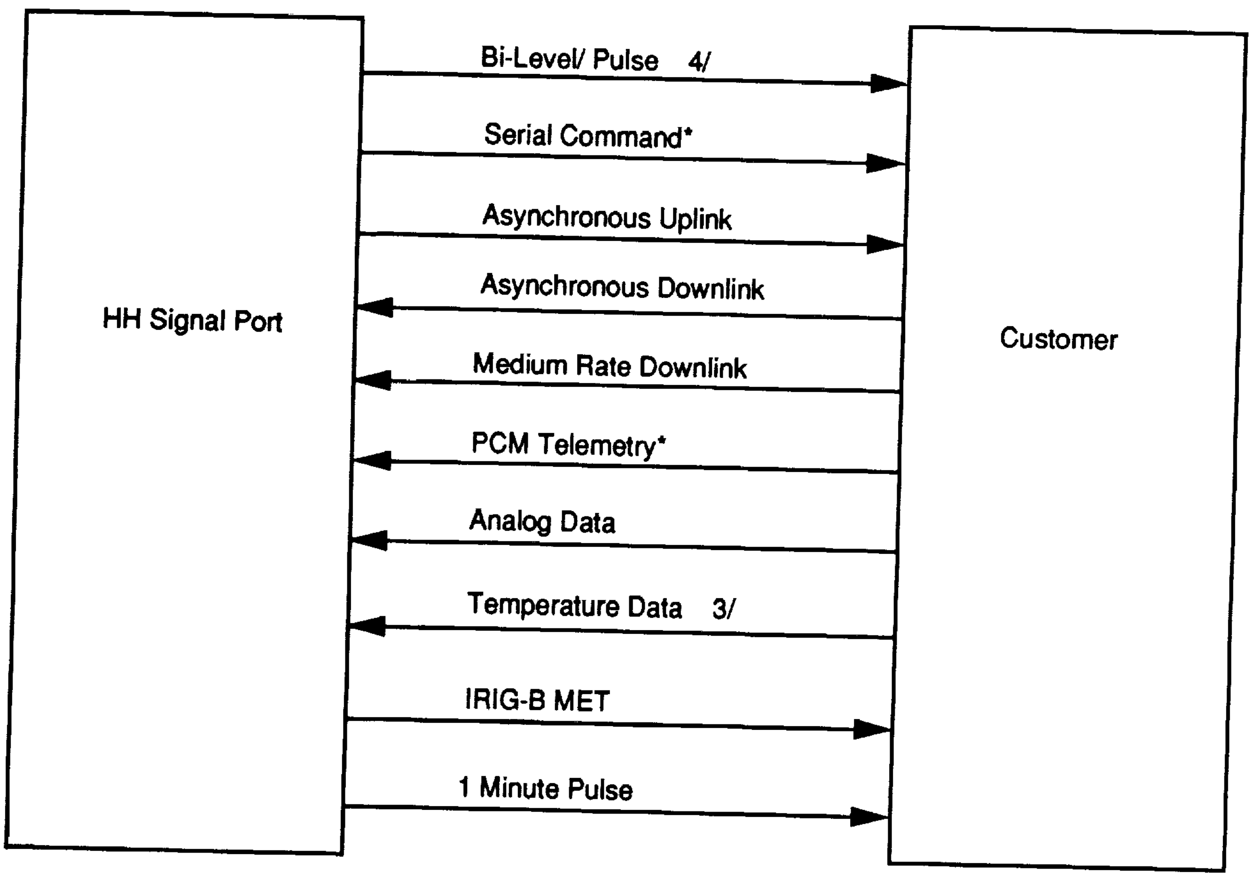


FIGURE 2.38

Hitchhiker Signal Port to Customer Interface



* Not recommended for use with new equipment

Figure 2.39

Customer Asynchronous Message Format - General

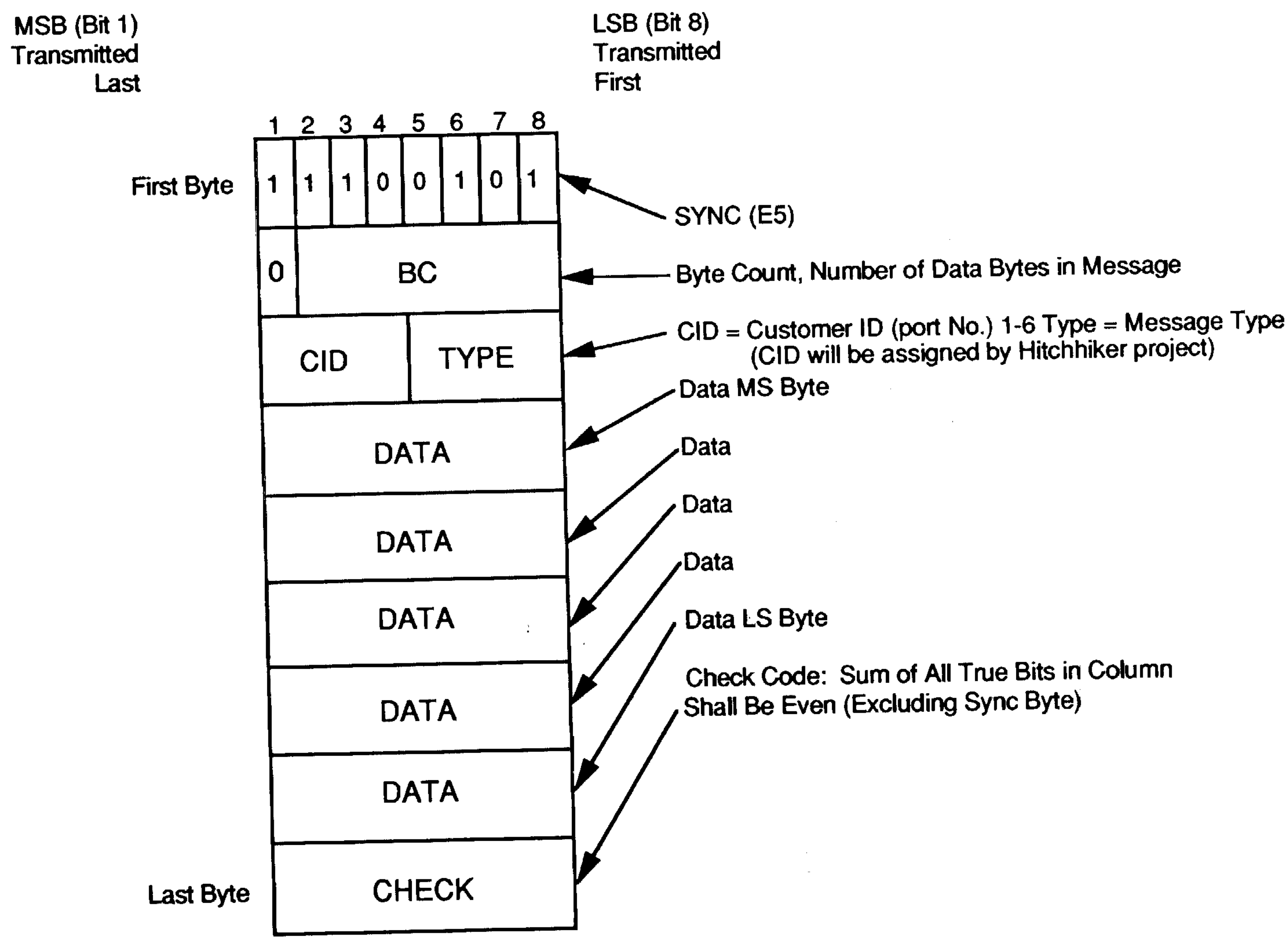


Figure 2.40

Customer/Carrier Ground Support Equipment (CCGSE)

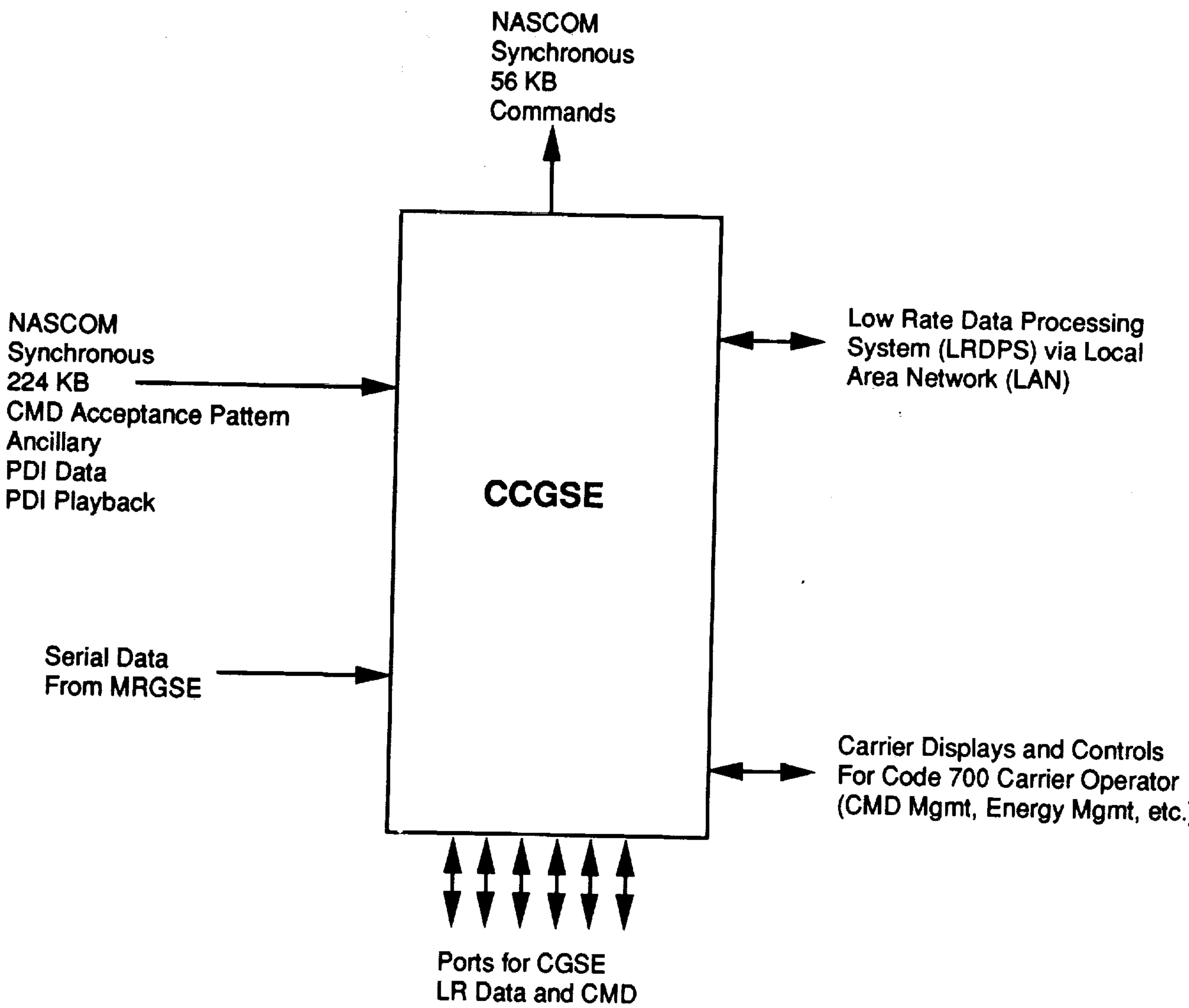


Figure 2.41

Hitchhiker Command Flow

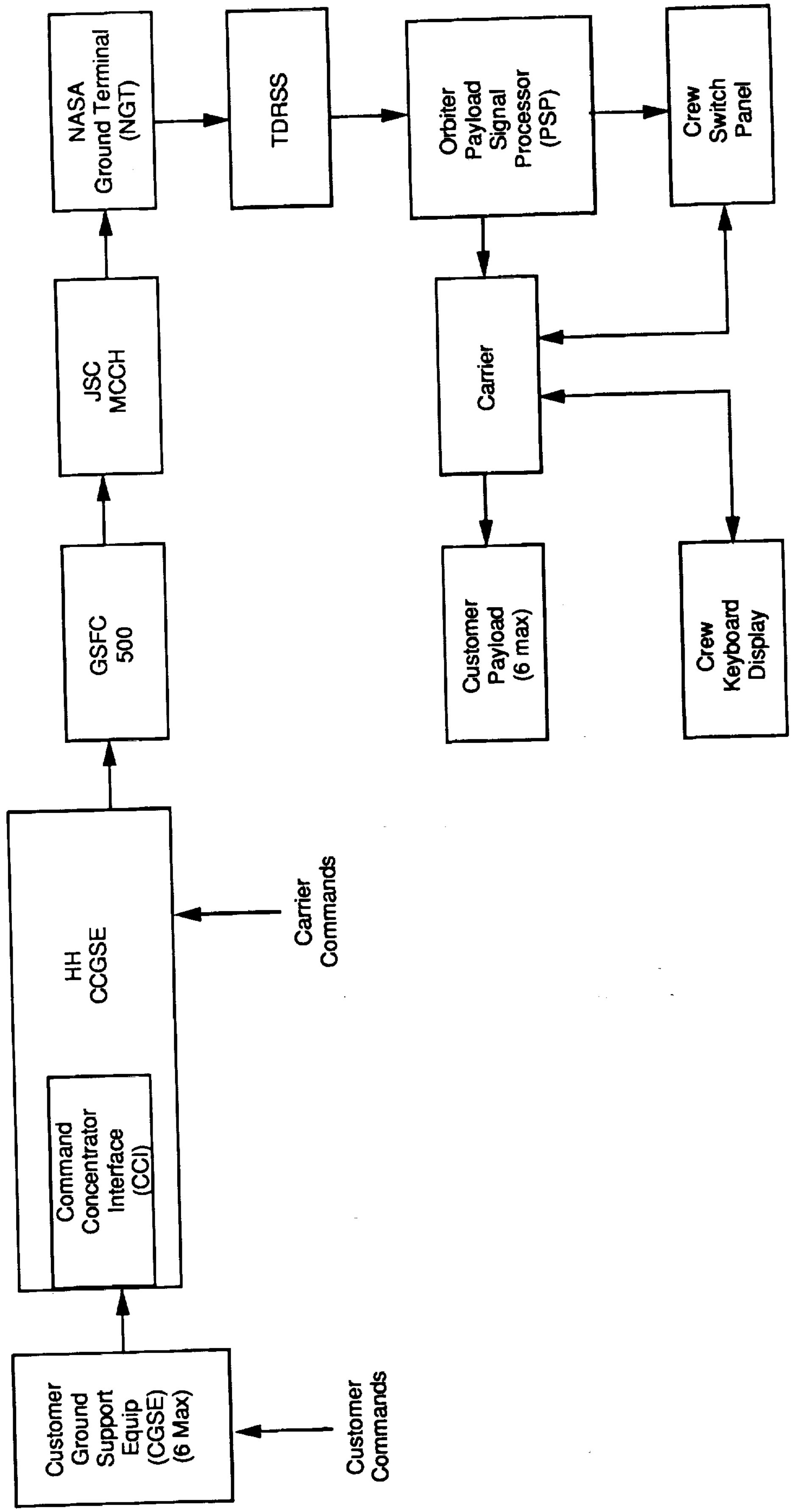


Figure 2.42

Hitchhiker Medium Rate Data Flow

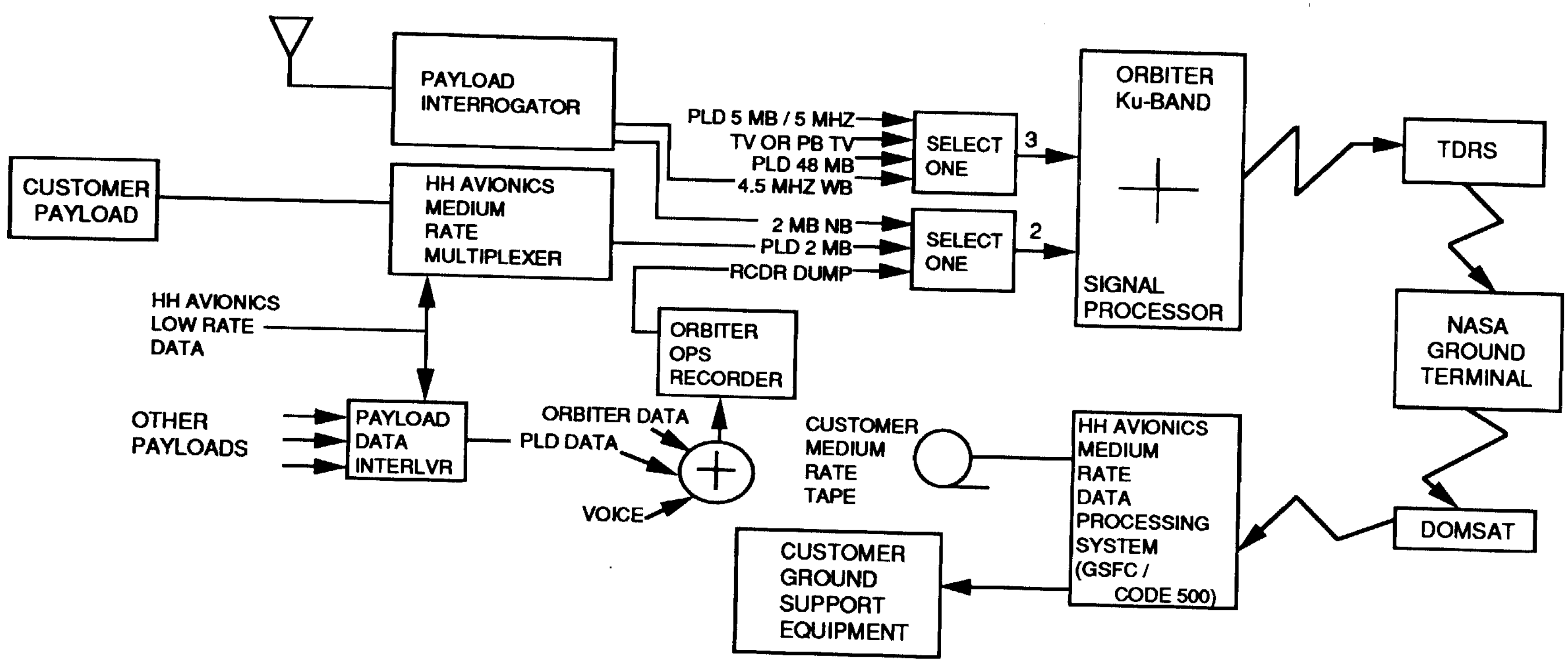


Figure 2.43

Hitchhiker Low Rate Data Flow

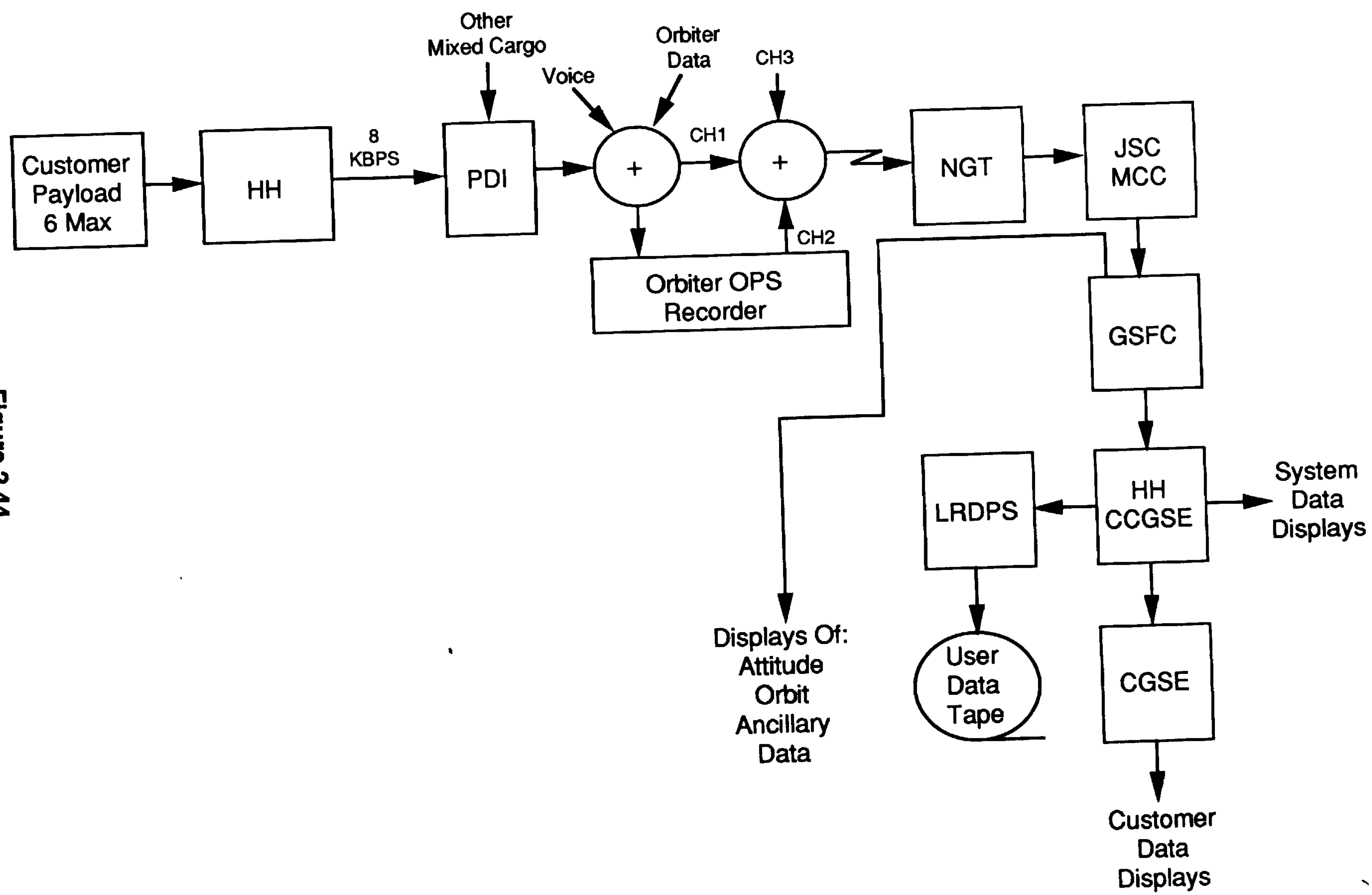
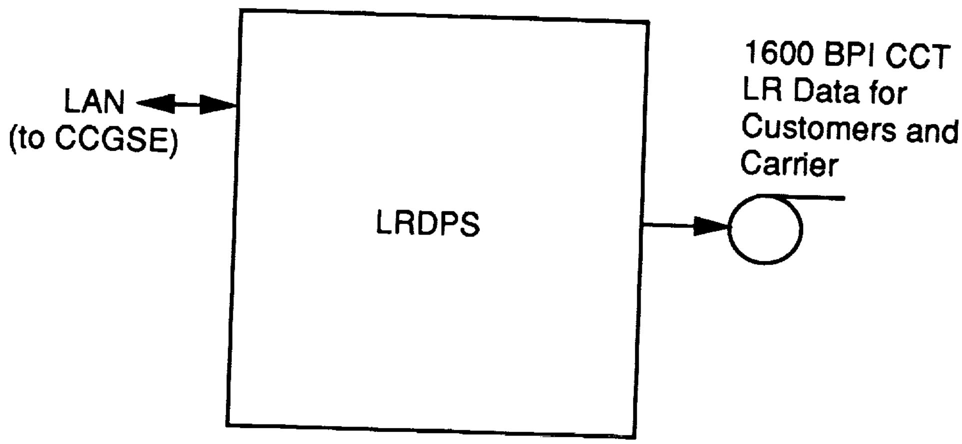


Figure 2.44

Low Rate Data Processing System (LRDPS)



Medium Rate Data Processing System (MRDPS)

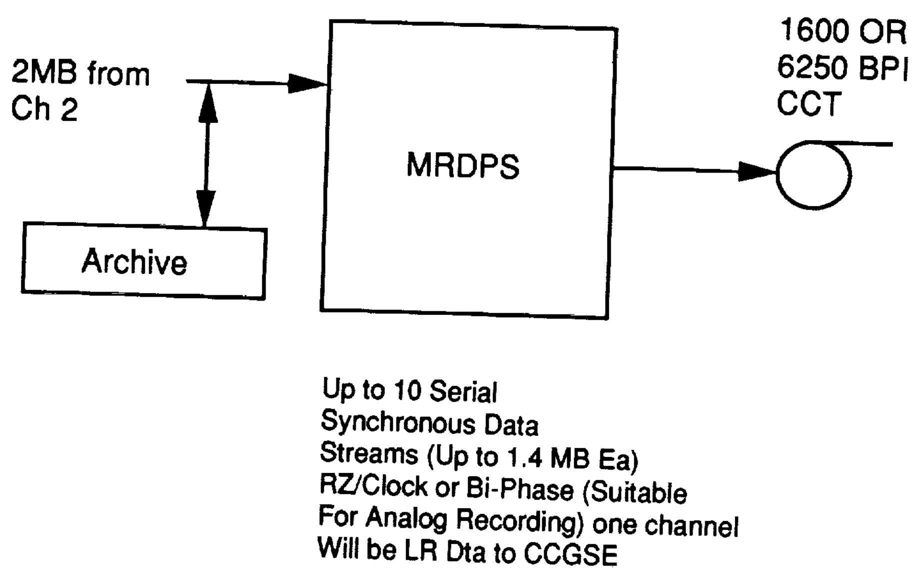
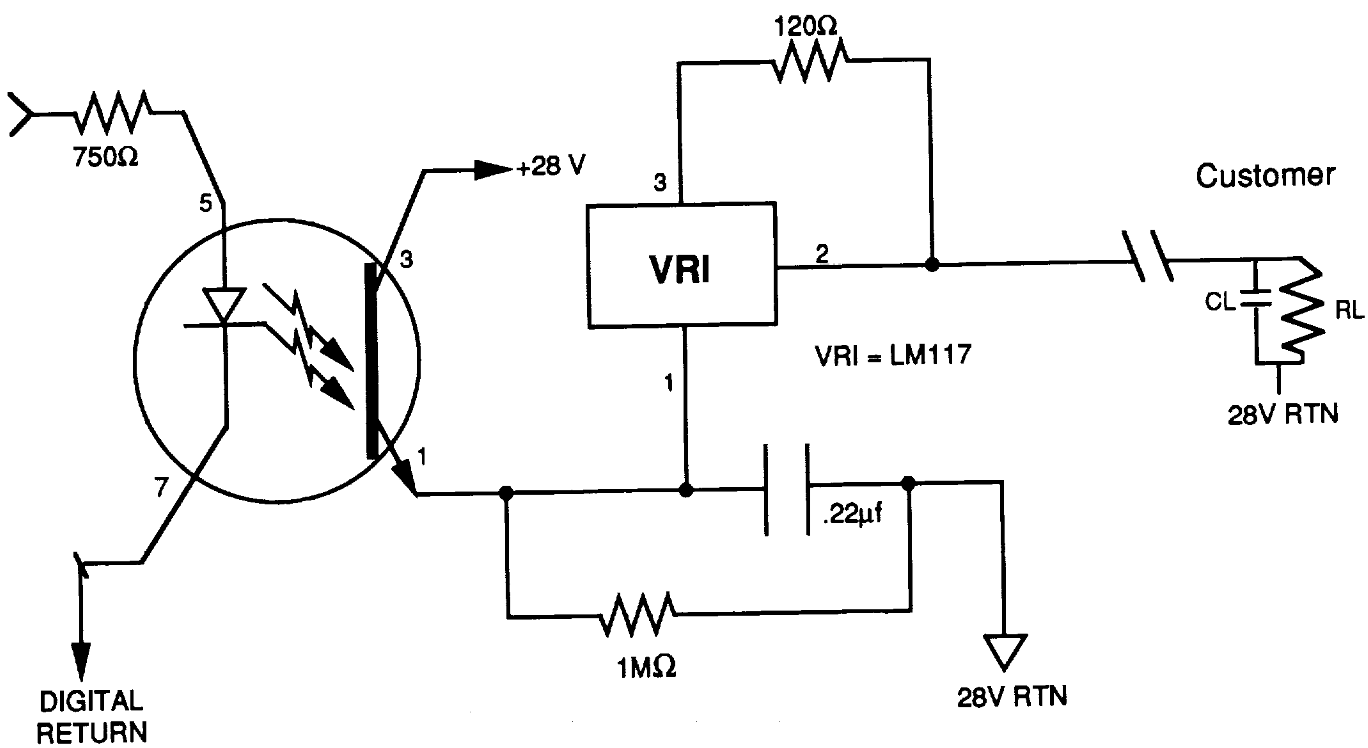


Figure 2.45

2.4.2 Bi-Level Command System

Signals that traverse the bi-level command interface may be set to ØV (false) or +28V (+19.5 to +32V) (true), or may be pulsed from false to true and back to false. There are four bi-level signals per interface. Figure 2.46 illustrates the customer bi-level command interface while Figures 2.47 and 2.48 show the command formats. Only one of the four signals may be affected by any one command.

CUSTOMER BI-LEVEL COMMAND INTERFACE



RL = 3.2K OHMS Min. (Customer Power On or Off)
RL = 10K Ohms Max, (Source 10ma Max; Sink 0)
CL = 1500 PF Max,
VT = 26 +/- 7V
VF = 1.5 +/- 1.5V
VNOISE = 1.6 V P-P (Max.)
TR = TF= 10 Microsec(Min)
TR = TF= 100 Microsec (Max)
T1 = 50 +/- 30 MS (Pulse Mode)

FIGURE 2.46

Customer Message Format for 28 Volt Bi-Level Commands

1	2	3	4	5	6	7	8
1	1	1	0	0	1	0	1
0	0	0	0	0	0	0	1
CID				0	0	1	1
S4	S3	S2	S1	R4	R3	R2	R1
CHECK							

S1-S4 Set Bi-Level 1-4 True = 28V
R1-R4 Reset Bi-Level 1-4 to False = 0V
RN and SN Simultaneously True = Error, No Action
Type = 3, Byte Count = 1. Any Bi-Level Command Lines Not Selected by Ones in SN, RN Will Not Be Affected

Customer Line Numbers

Only One Bi-Level Line May be Set/Reset by a Single Command.

Note: 28 volt bi-level and 28 volt pulse commands use the same 4 wires per customer interface (17,18,19,20).

Figure 2.47

Customer Message Format For 28 Volt Pulse Commands

1	2	3	4	5	6	7	8
1	1	1	0	0	1	0	1
0	0	0	0	0	0	0	1
CID				0	1	0	1
0	0	0	0	P4	P3	P2	P1
CHECK							

P1 -P4+ 1 PULSE BI-LEVEL LINE 1-4 SETS SELECTED BI-LEVEL LINES(S) ON CUSTOMER PORT CID TO TRUE (+28V) FOR 20- 80 MILLISECONDS THEN RETURNS LINE TO FALSE (OV). STATES OF ANY BI-LEVEL COMMAND LINES NOT SELECTED BY ONES ARE NOT AFFECTED. CUSTOMERS DESIGN MUST BE CAPABLE OF WITHSTANDING CONTINUOUS +28V ON ANY BI-LEVEL LINE WITH NO DAMAGE IN EVENT OF SOFTWARE FAILURE. TYPE =5, BYTE COUNT =1

CUSTOMER LINE NUMBERS

ONLY ONE LINE MAY BE PULSED BY A SINGLE COMMAND.

NOTE: 28 VOLT PULSE AND 28 VOLT BI-LEVEL COMMAND USE
THE SAME 4 WIRES PER CUSTOMER INTERFACE (17,18, 19, 20)

Figure 2.48

2.4.3 Serial Command System

The serial command interface consists of one signal set containing clock, data, and envelope, per customer interface. Signals that traverse this interface have voltage levels that are ØV and 5V for false and true conditions, respectively. The complete command, including sync, byte count, CID/type, and checksum, will be transferred to the user. The signal characteristics are shown in Table 2.9. The maximum number of data bytes is 4 (see Figures 2.49 and 2.50). Figure 2.49 shows the customer asynchronous CGSE format for serial commands. Figure 2.50 shows the customer serial command interface. The serial command signal is provided to support existing customer hardware and is not recommended for new flight equipment.

TABLE 2.9
DISCRETE OUTPUT LOW (DOL)/CARRIER-TO-PAYLOAD
ELECTRICAL INTERFACE CHARACTERISTICS
(SPOC SERIAL COMMAND INTERFACE)

PARAMETER	DIMENSION	CHARACTERISTICS OF CARRIER/PAYLOAD INTERFACE	NOTES
Type		Single-Ended	
False ("0")	min volt max volt	-0.5 +0.5	(1) (4) (1) (4)
True ("1")	min volt max volt	+4.0 +6.0	(1) (4) (1) (4)
Ripple & Noise	Milli-max volt	400	
Rise/Fall Time (10 to 90%)	min Microsec max Microsec	1 20	(2) (1)
Bit Rate	bps	125 +/-25	

TABLE 2.9 (Cont'd)

PARAMETER	DIMENSION	CHARACTERISTICS OF CARRIER/PAYLOAD INTERFACE	NOTES
Transfer	Direct Coupled	Grounded at Carrier	
Source Impedence (Carrier)	max ohm	min ohm 100	30
Load Impedence (Payload)	min ohm max ohm	600 4K	(3)
Capacitance	max Pico-Farad	3500	Payload not to exceed 1500
Pwr Off Impedence	Payload shall exceed 600 w/pwr off		min ohm10K (+6 VDC)
Current Drive Current Sink	Milliamp Milliamp	10 (Logic "1") -10 (Logic "0")	+/- 0.5 volts
Overvoltage Protection	Max volt	± 32	

TABLE 2.9 (Cont'd)

PARAMETER	DIMENSION	CHARACTERISTICS OF CARRIER/PAYLOAD INTERFACE	NOTES
Fault Voltage Emission	Max volt	± 15	
Fault Current Limitation	Max Milliamp	± 20	
Power-Ground Isolation	Megohms	10	

Table 2.9 NOTES

(1) Reference Signal Ground

(2) 400 ohm $\pm 5\%$ in parallel with 5 nanofarad $\pm 0\%$ load

(3) An open input shall not result in an ambiguous logic state

(4) 0.2 millisecond state uncertainty maximum following power up

Customer Message Format for Serial Commands

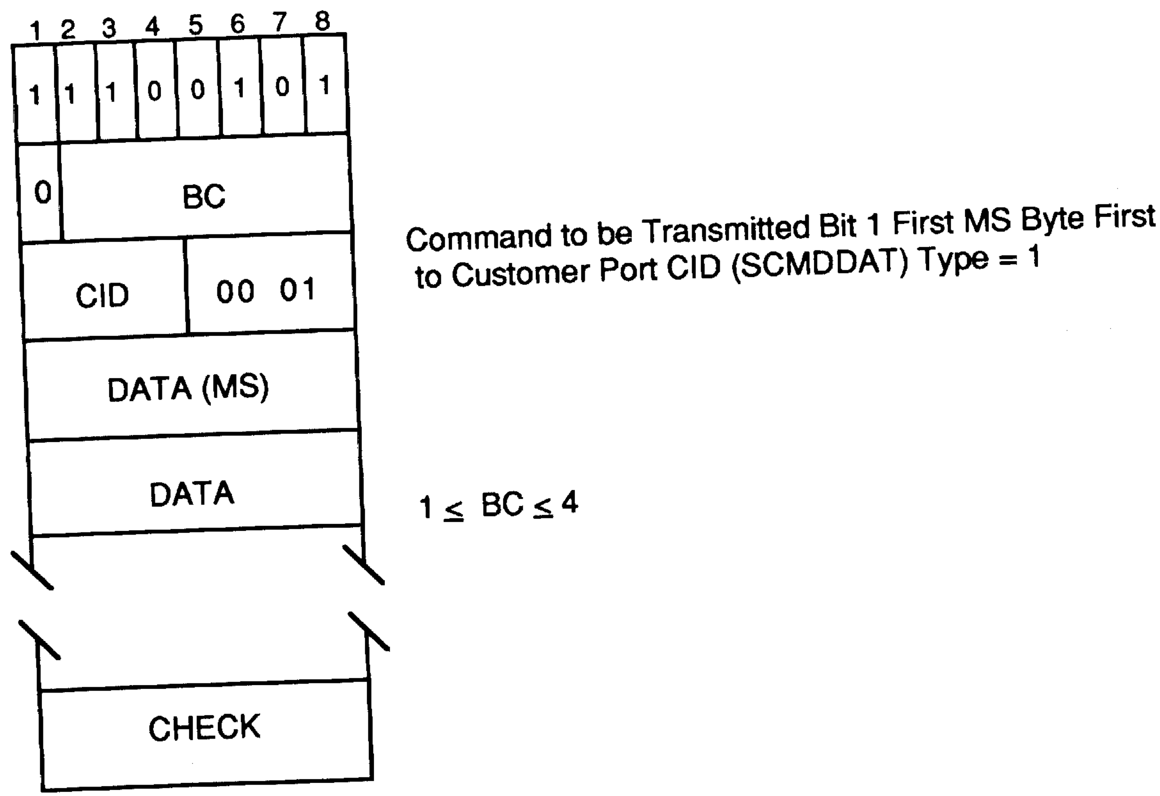
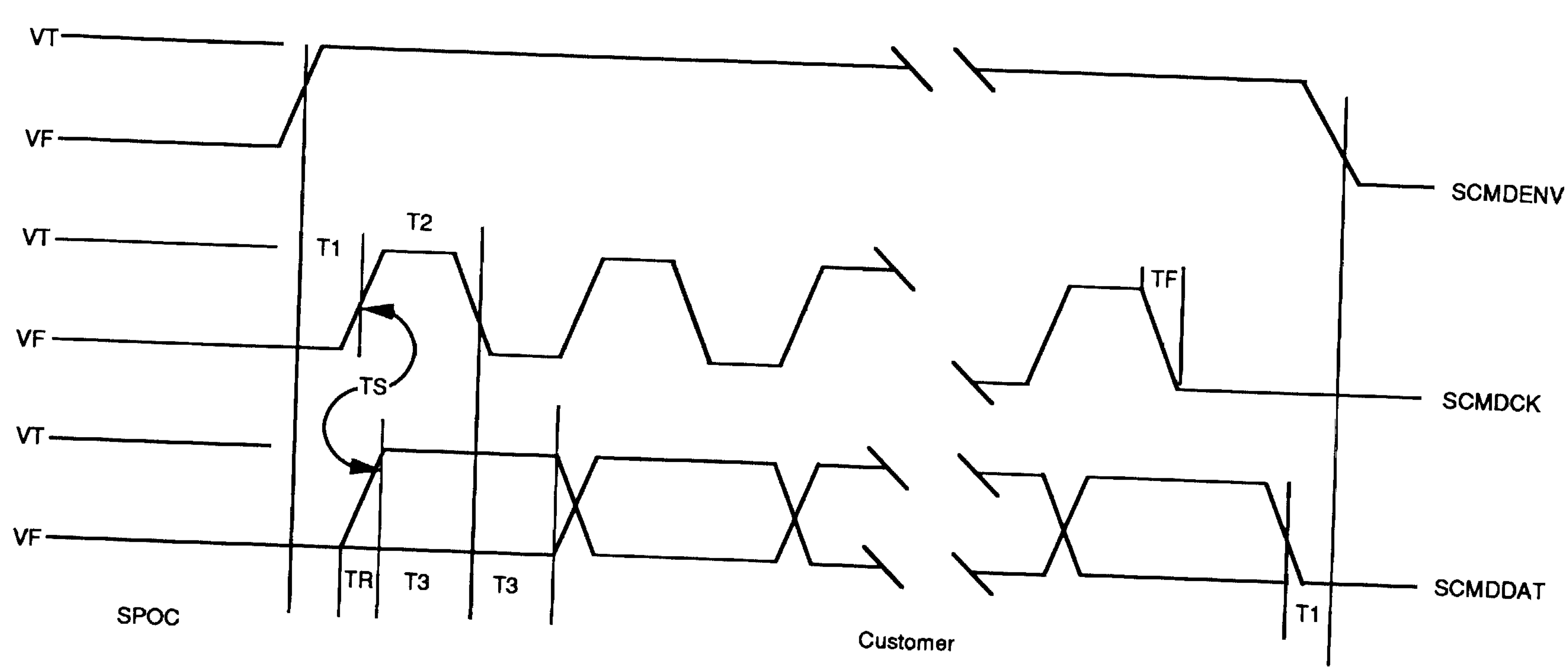
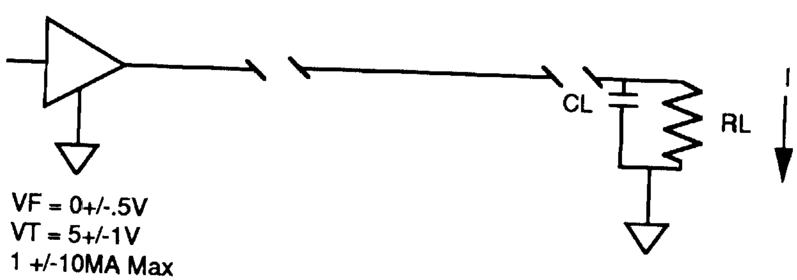


Figure 2.49

Customer Serial Command Interface





TS = Setup Time From Data
to Clock = 33+/-5 Microsec
T1 = 8 MS Min
T2 = 3 MS Min
T2 = 5 MS Max
T3 = 3 MS Min
TR = 1 Microsec Min
20 Microsec Max
TF = Same as TR
CL = 1500 PF Max
RL = 600 OHMS Min
(Payload Power On or Off)
RL = 4K OHMS Max
(Open Input Shall Read As False)

Figure 2.50

2.4.4 Asynchronous Uplink

The asynchronous uplink is used to transmit customer asynchronous command messages and Mission Elapsed Time (MET) messages to the payload.

The customer message format for asynchronous commands is shown in Figure 2.51. The format of the asynchronous MET message is shown in Figure 2.52. The format of the synchronize to met commend is shown on Figure 2.53. One receive data (RD) signal is available through each HH port.

The interface operates at 1200 baud asynchronous data rate. The signal format is shown in Figure 2.54 where each signal contains one start bit, eight data bits (no parity), and one stop bit. The uplink messages may originate from the CCGSE or from CGSE. The transport delay between CGSE and the customer's payload is nominally 2 to 20 seconds. The transport delays are due to latencies introduced by the number of CGSEs issuing commands, the networks, JSC Mission Control Center (MCC) and uplink delays. The delay does not account for retrying a command because of command uplink failure.

Customer CGSE's are connected to the CCGSE via the Command Concentrator Interface (CCI) referenced in Figure 2.42. This device places some limitations on user command thru-put, especially for long "back to back" experiment command strings.

In reference to the HH Command Flow, the following three elements apply:

1. The presence of a 1200-baud CGSE/CCI line does not mean that the user can continuously pump commands at this rate. The maximum command string length is 119 bytes. User minimum Delay Time (DT) between command strings sent by its CGSE to the CCGSE CCI is:

   DT = (Number of active command lines) * (400 milliseconds).

   This had been derived from extensive testing of the current CCI properties. The CCI has a single buffer for encoding user commands for its interface to the CCGSE computer. This buffer is called CCI Block Buffer. The CCI also has six Input Buffers to store user input commands for the CCI/CGSE Command Interfaces.

It takes the CCI 400 milliseconds to encode one of the six user Input Command Buffers into the CCI Block Buffer and transfer it to the CCGSE computer. It will take twice as long, on average, to process two user Input Buffers. If user does not enforce a delay of DT milliseconds between long command strings, a CCI overflow can occur placing the CCI into an unpredictable state.

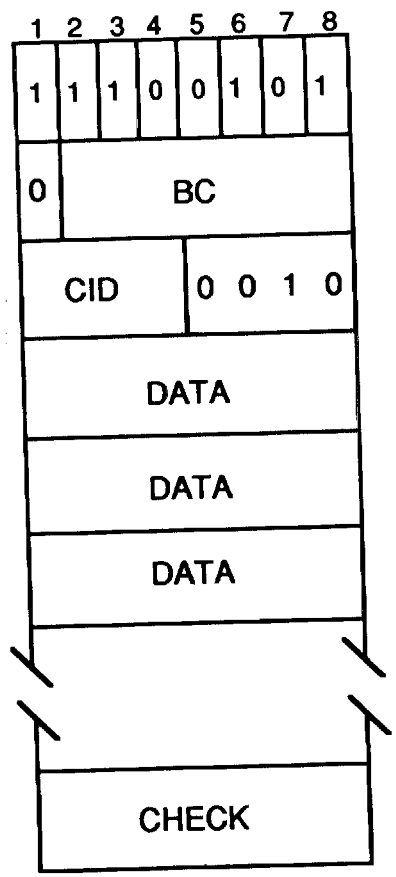
2. Once a CCI Command Block is transmitted to the CCGSE computer, the CCGSE Command Subsystem places the block into a unique user command queue. This queue will not be the subject of command transmission for the time Tmin = 6 seconds and until a previously transmitted command block is acknowledged by SPOC avionics in telemetry.

   The user is advised to hold its long command strings in its own CGSE for DT time rather than using the CCGSE to stage its long command strings.

   Command string staging is of significant overhead for the CCGSE. Suggested average separation between long strings of Universal Asynchronous Receiver Transmitter (UART) commands with two active command lines is 800 milliseconds.

3. Note that the CCGSE "round-robin" prioritization of users can improve the CCGSE processing of long and short command strings generated by two concurrent users.

Customer Message Format for Asynchronous Commands



Entire Message Including Sync and
Check Bytes to be Transmitted to
Customer Port CID
RD Asynchronous on Pins 21 & 22.
Type = 2

Format of CGSE Message Identical

Figure 2.51

Customer Message Format For MET

1	2	3	4	5	6	7	8
1	1	1	0	0	1	0	1
0	0	0	0	0	1	0	0
CID				0	1	0	0
D1	D2	D3	D4	D5	D6	D7	D8
D9	D10	H1	H2	H3	H4	H5	H6
0	M1	M2	M3	M4	M5	M6	M7
0	S1	S2	S3	S4	S5	S6	S7
CHECK							

Figure 2.52

D1-200 DAYS	H1-20 HOURS	M1-40 MIN	S1-40 SEC
D2 -100	H2-10	M2-20	S2-20
D3-80	H3-8	M3-10	S3-10
D4-40	H4-4	M4-8	S4-8
D5-20	H5-2	M5-4	S5-4
D6-10	H6-1	M6-2	S6-2
D7-8		M7-1	S7-1
D8-4			
D9-2			
D10-1			

4 BYTES

Command to be transmitted to customer payload asynchronous port at a time other than MET second 1 or 59. The 4 bytes of time data will be filled in by the SPOC avionics using Orbiter supplied time. When sent by the customer, the 4 bytes are "don't care" and may contain anything. CGSE command with dummy data initiates transmission of MET command, type=4.

Customer Message Format for Synchronized MET

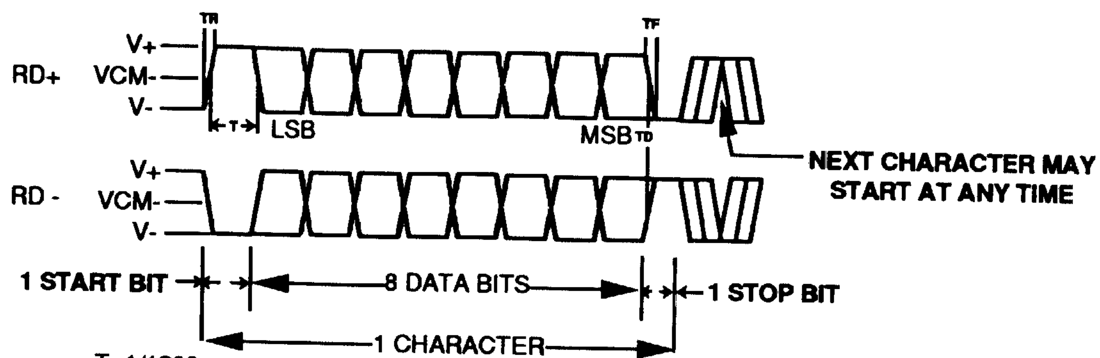
1	2	3	4	5	6	7	8	
1	1	1	0	0	1	0	1	
0	0	0	0	0	1	0	0	Byte Count
CID				0	1	1	0	Subcommand Type 6
D1	D2	D3	D4	D5	D6	D7	D8	
D9	D10	H1	H2	H3	H4	H5	H6	
0	M1	M2	M3	M4	M5	M6	M7	
0	S0	S0	S0	S0	S0	S0	S0	
CHECK								Checksum

Notes:
1. Unless MET is within ±5 seconds of the new minute, the next minute represented by the minute pulse is sent via the RS-422 Asynchronous Interface.
   If MET is within 5 seconds of the new minute, then the time sent to the customer is the <u>NEXT</u> minute, not the upcoming minute.

2. This command is not implemented in some HH avionics. Check with HH project for availability.

Figure 2.53

Customer Asynchronous RD Interface



T=1/1200 sec
VCM +1V< = V+ < = VCM +2.5V
VCM-1V> = V- >= VVCM-2.5V
-3V<=VCM+/- <=+3V WRT SIG. GND.
T R = TF = .5US
SLEW RATE = 40V/US MAX
CHARACTER RATE = 120 C/S MAX, 100 C/S NOM
TD = DIFFERENTIAL TIME DELAY = 10NS MAX

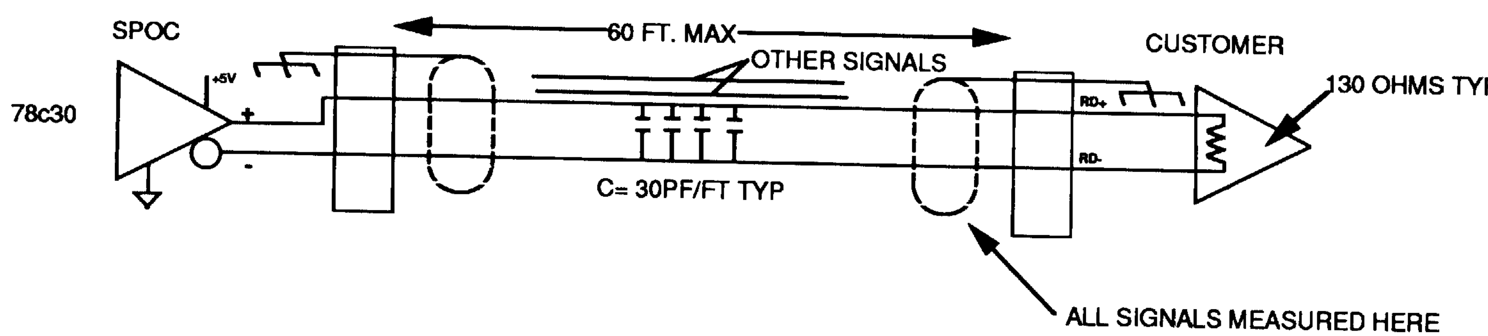


Figure 2.54

2.4.4.1 Orbiter Computed Data. A future capability is planned for transferring the output of payload-related Orbiter processes to the payloads. The Orbiter-computed data and Orbiter/payload-related processes available to support payloads are defined in the following paragraphs.

2.4.4.2 Orbiter State Vector/Attitude Data. Capability to transfer Orbiter state data to payloads is planned. The data to be transferred consists of the Orbiter state/vector attitude relative to Greenwich true of date Cartesian or Aries mean of 1950, Cartesian coordinate system, and Orbiter attitude rates about the Orbiter body axes.

2.4.4.3 Time Tag Accuracy. Under error-free on-orbit conditions, the MET shall be within plus or minus five milliseconds of the time at which the state vector or attitude is calculated.

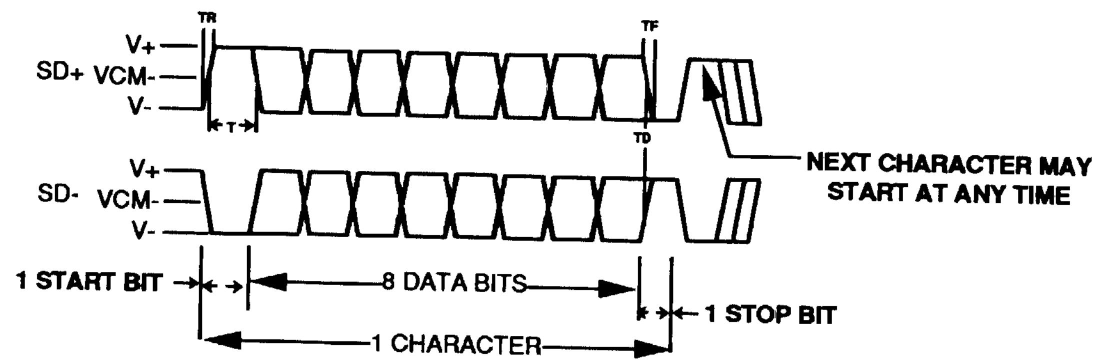
2.4.4.4 Transport Lag. The Orbiter state vector/attitude message shall be output from the General Purpose Computer (GPC) no later than five seconds past the MET time tag of the data. However, errors occurring in the Orbiter Data Processing System (DPS) and Guidance, Navigation, and Control (GN&C) sensors may cause occasional degradation of this interface.

2.4.5 Asynchronous Downlink

One asynchronous Send Data (SD) signal per interface that operates at 1200-baud asynchronous and has a similar message pattern (one bit start, 8 data bits, and one stop bit) as the uplink interface is available through the HH interface. (See Figure 2.55).

The downlink can support continuous 1200-baud transmission which will be routed to the customer's GSE via the CCGSE to CGSE interfaces. Downlink messages do not currently have a format requirement. Nominally, the transport delay between customer payload and customer GSE is 5 to 15 seconds. The standard HH carrier arrangement can simultaneously downlink any five asynchronous downlink channels selected by command. Planned modifications to the carrier will enable us to transmit more simultaneous data streams if some users do not require the continuous 1200-baud service. Therefore, users not requiring the full 1200-baud rate should interrupt transmission rather than transmitting fill.

Customer Asynchronous SD Interface



VCM +1V< = V+ < = VCM +2.5V
VCM-1V> = V- >= VVCM-2.5V
-3V<=VCM+/- <=+3V WRT SIG. GND.
T = .8333 MS (1200 BAUD)
VCM+ = VCM- (+/-50MV)
TR = TF = 1µS MAX   INPUT Z = 130 OHMS +/-10%
TD = DIFFERENTIAL TIME DELAY = 5NS MAX

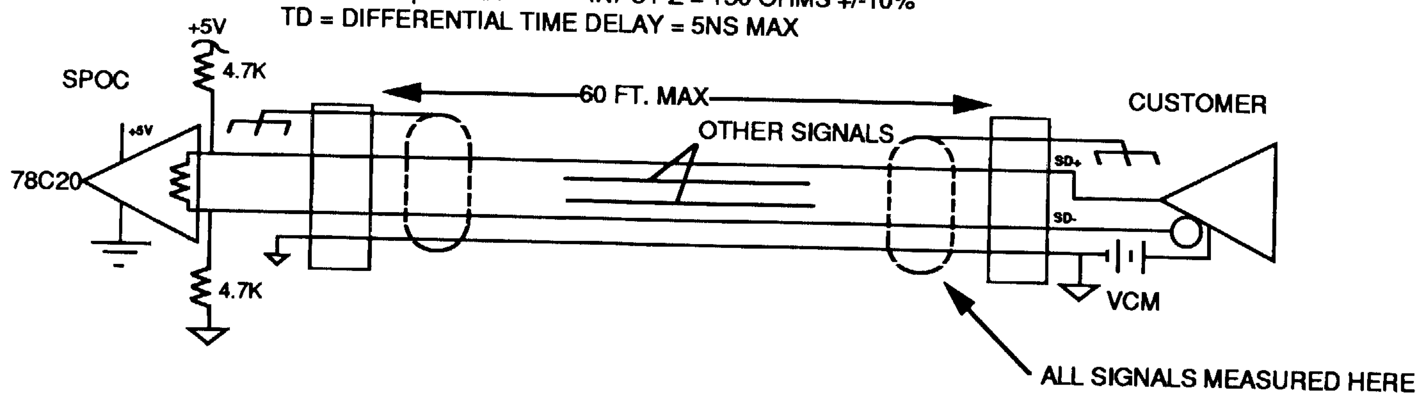


Figure 2.55

2.4.6 Medium-Rate Ku-Band Downlink

The carrier contains a Medium-rate Multiplexer (MRM) capable of multiplexing up to six simultaneous customer-provided serial-bit non-return to zero (NRZ) data signals into a single serial 2MB/s bit-stream for transmission via channel 2 of the Orbiter Ku-band Tracking and Data Relay Satellite System (TDRSS) signal processing system. The combined input rate to the MRM from all HH experiments cannot exceed 1.4 MB/s. This effectively limits customer downlink rates if the MRM is accepting data from more than one source. As previously shown in Figure 2.43, channel 2 is not available for exclusive use of HH data but is shared with dumping of the Orbiter's tape recorder and the payload interrogator. In addition, use of the medium-rate system requires the TDRSS as well as deployment and pointing of a steerable antenna on the Orbiter which cannot be used in certain attitudes or orbit positions. In general, Ku-band medium-rate service should be available approximately 50 percent of the time during a typical flight.

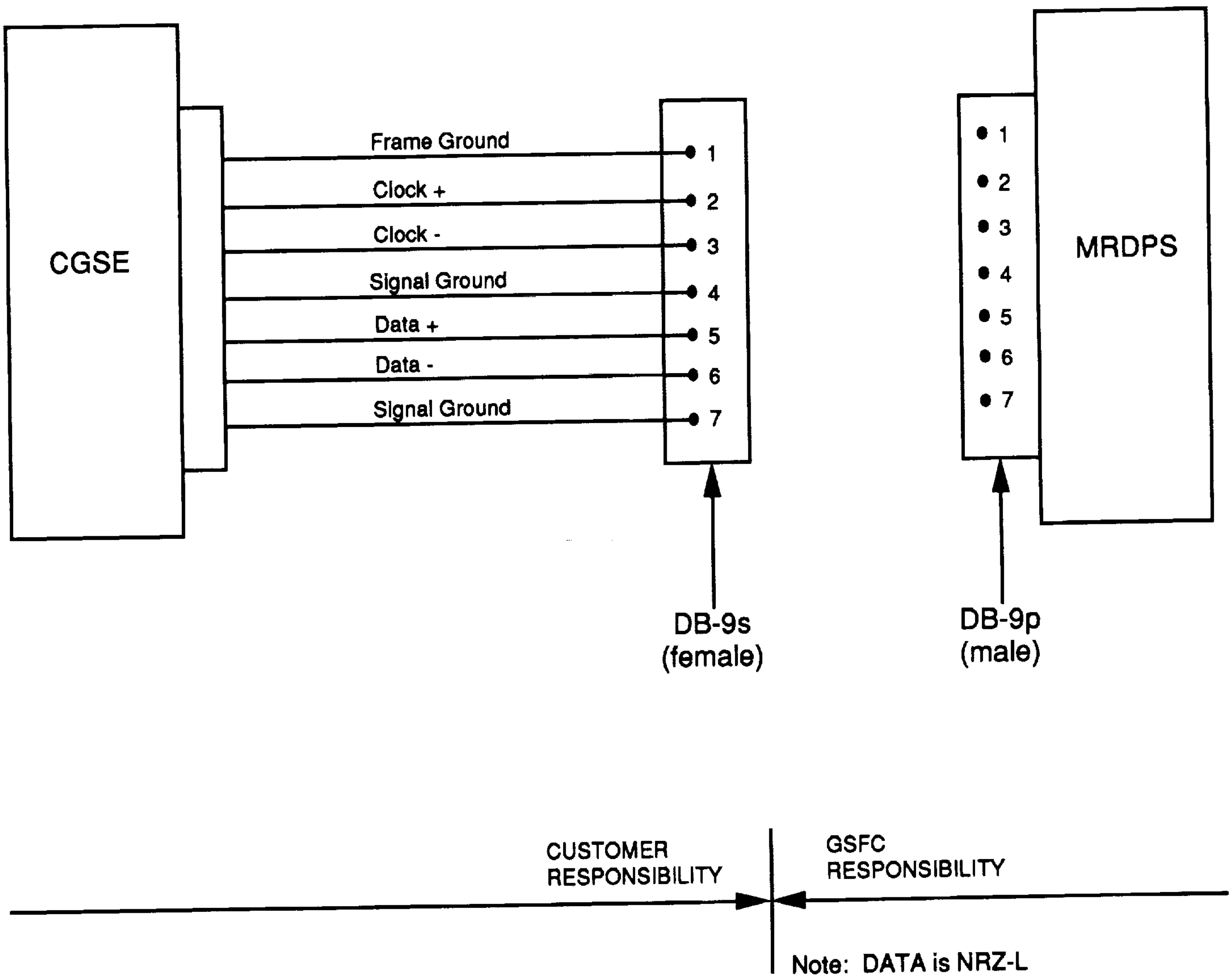
Each customer-supplied input data stream must be continuous and stable within 1 percent of its assigned data rate during the customer's data-take periods. If the customer's desired information is discontinuous or event-oriented, then the data stream supplied by the customer may be discontinuous with the clock stopping between periods of valid data. Alternately, the customer's equipment may transmit continuous clock but discontinue transmitting valid frame synchronization patterns. Each valid data period must be proceeded by no less than 4 data frames of leader telemetry (to provide for synchronizing GSFC and customer ground equipment) prior to the first frame of required data (assuming the customer's GSE can synchronize within one frame of data). Since the MRM contains data buffers for each customer, each data period must be followed by at least 66 bytes of clock to flush the buffer. The main purpose of discontinuous data is to avoid generating magnetic tapes of data which are not desired since a considerable amount of tape is involved at the higher data rates. Customer data during valid data periods must consist of a continuous series of data frames each containing a fixed integral multiple of 8 bits but no more than 8,192 bits. Each data frame must contain a fixed synchronization pattern of at least 24 bits to be specified by the customer. The pattern FAF320 (hexadecimal, most significant bit and byte first) is recommended. The remaining format of the data frames can be determined by the customer as desired; however, the following considerations should be taken into account. Each data frame should contain a frame number that does not repeat for at least 256 frames as well as time information adequate for the customer's needs; it should also contain provision for error detection if necessary to meet the customer's goals.

During testing and flight operations, the Medium-Rate Data Processing System (MRDPS), referenced in Figure 2.43, will decommutate the multiplexed signal and regenerate the customer's clock and data for use by the CGSE. This data interface is shown in Figure 2.56. The clock will generally be at a slightly higher bit rate than the onboard customer supplied clock. The ground clock and data will stop momentarily periodically to equalize the average data rate.

The data bit error rate is expected to be generally no worse than 10^{-5}; however, there will be periods of dropout and deteriorated data especially near the ends of TDRSS coverage periods. The data delay will be several hundred bytes plus approximately 2 seconds. The CGSE must be designed to obtain and maintain synchronization and otherwise operate in a satisfactory manner under these conditions.

The electrical interfaces and timing for the medium-rate system are shown in Figures 2.57, 2.58, and 2.59. Data signals are connected to CGSE by means of a transparent interface. Data return on the ground can be either by NRZ-L serial data and clock interface identical to Figures 2.57, 2.58 and 2.59 or post mission by Computer Compatible Tape (CCT). The CCT format is shown in Appendix C and will be frame synchronized data sets if the customer uses a fixed-frame length. GSFC engineers can assist customers in the design of prospective medium rate (MR) telemetry formats. Again, the customer's medium-rate ground data interface is shown on Figure 2.56.

Customer Medium Rate Ground Data Interface



NOTE: Suggested Cable length is 30 feet.

Figure 2.56

Medium Rate Customer Interface

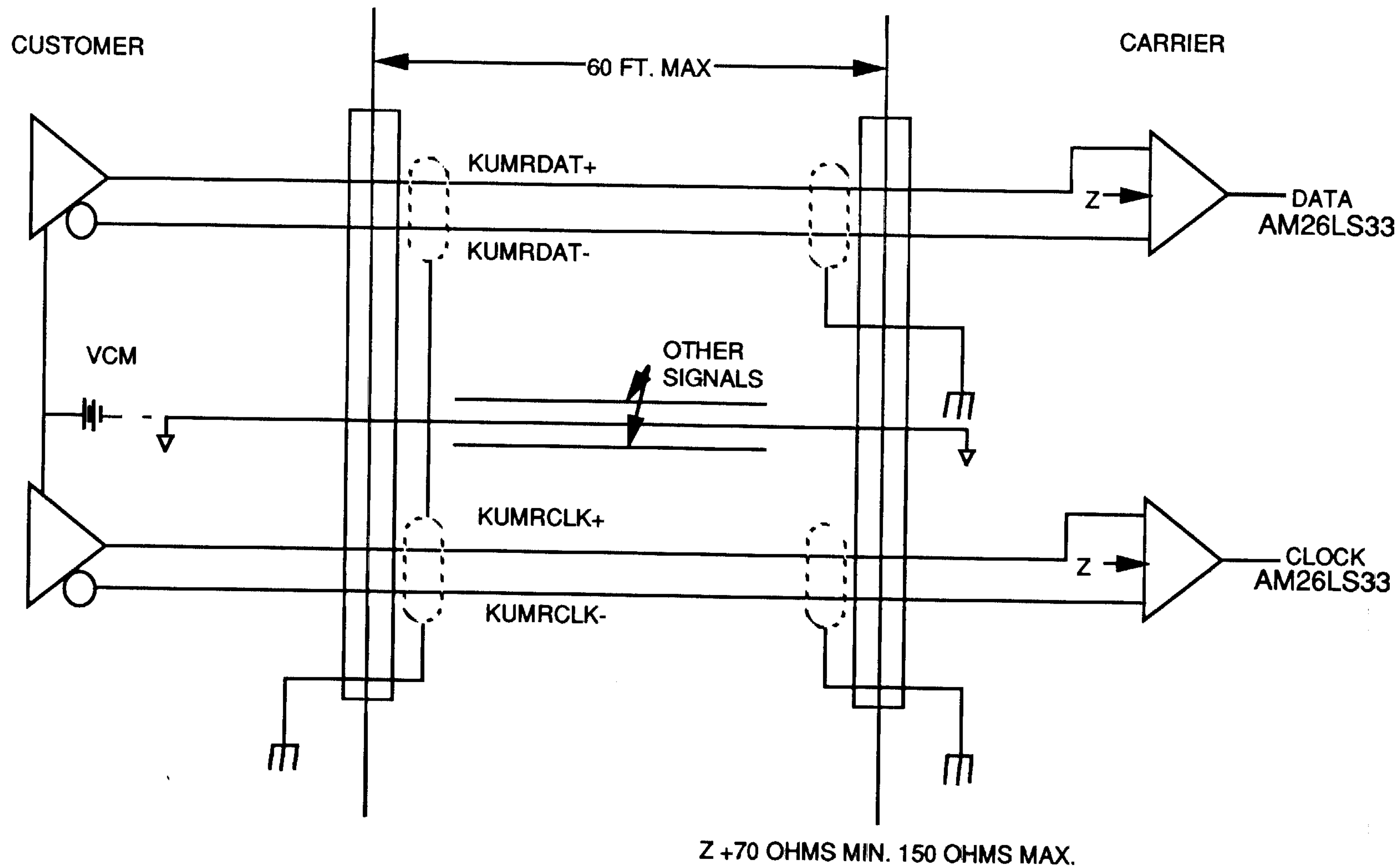
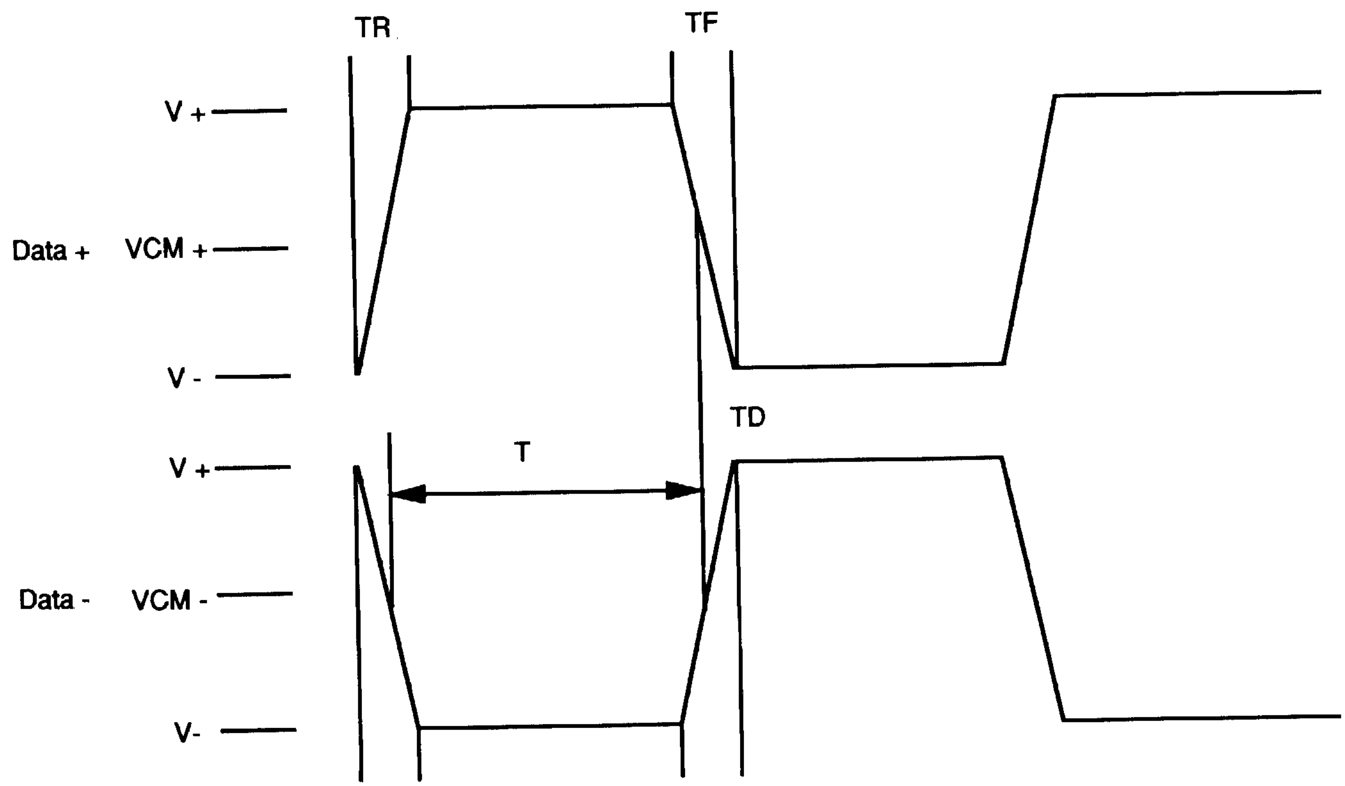


Figure 2.57

Medium Rate Customer Data



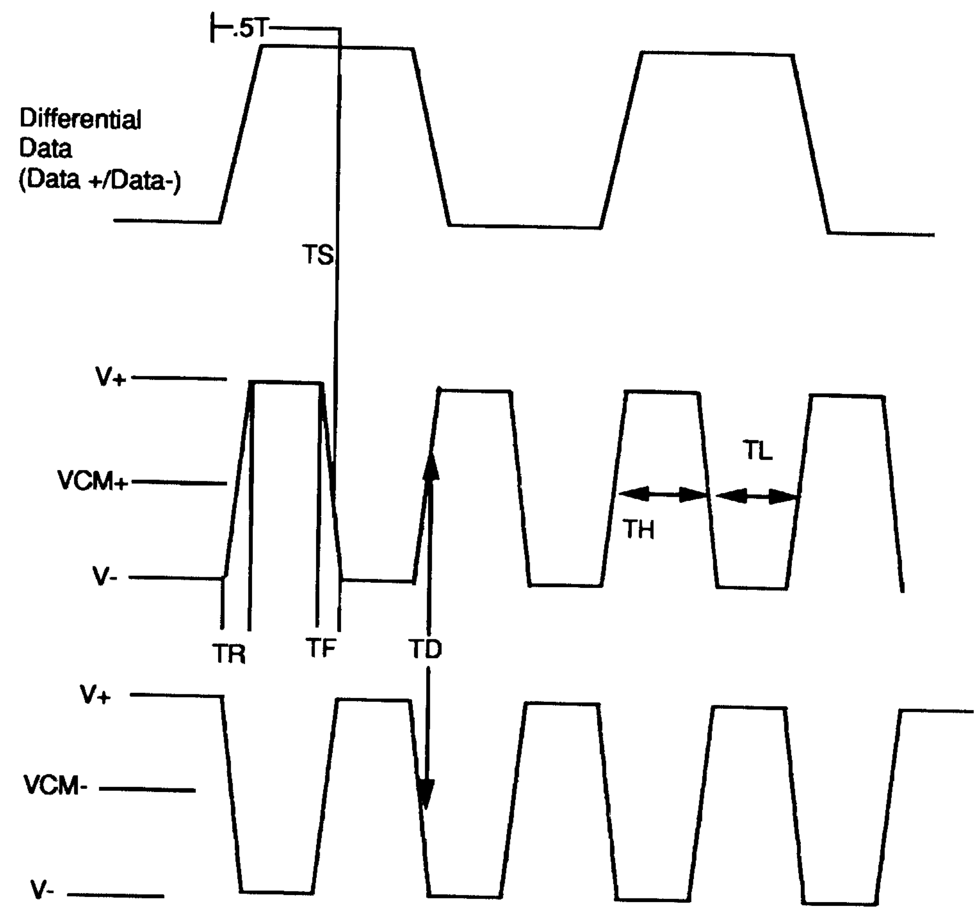
Required: VCM+ = VCM- +/-50MV, Then VCM+ = VCM- = VCM
Required: VCM + 1 volt ≤ V + ≤ VCM + 2.5V
Required: VCM' - 1 volt ≥ V - ≥ VCM - 2.5V
Required: -3 volts ≤ VCM ≤ + 3 volts with respect to signal ground
TR ≤ TF ≤ 1US

} For Data + and Data- Lines

T = Baud Period = 1/Baud Rate   Baud Rate = TBD
T = Differential Time Delay = 10 MS Max
Baud Rate Stability ≤ 0.1%

Figure 2.58

Medium Rate Customer Clock



Required: VCM+ = VCM- +/-5CMV, Then VCM+ = VCM- = VCM

Required: -3 V VCM + 3 V with respect to signal ground
VCM + 1 Volts ≤ V+ ≤VCM + 2.5 Volts
VCM - 1 Volts ≥ V- ≥VCM - 2.5 Volts
Baud Rate = 1/T

} For Clock+ and Clock- Lines

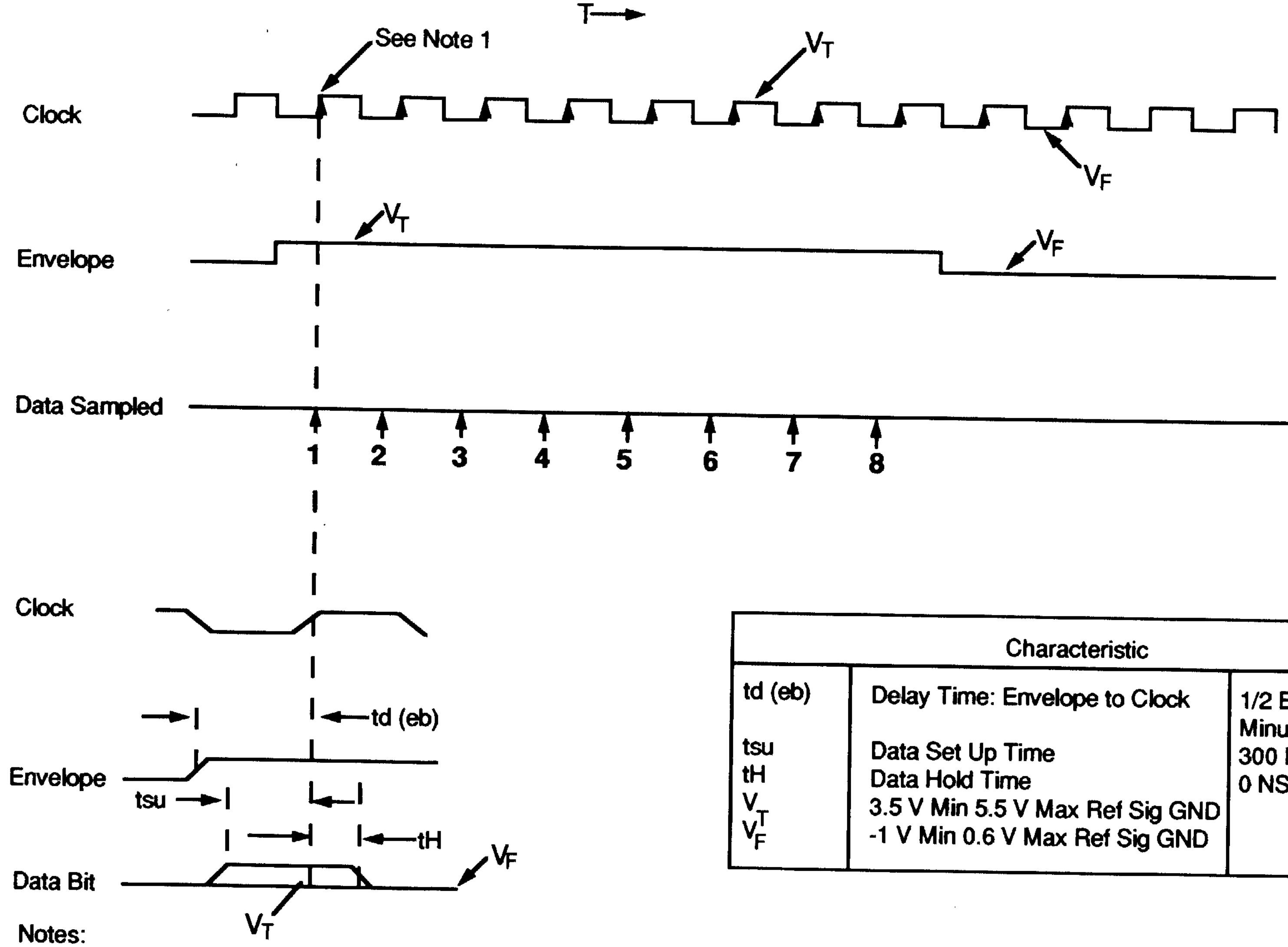
T = TH + TL = Baud Period TH/TL = 1 +/- .15
TD = Differential Delay = .05T< = 20 NS
TS = Clock Skew = +/- .15T Max from Middle of Data Bit
TR = TF<.1T<1µS Measured Between 10% and 90% Amplitude
Baud Rate Stability +/-.1% or Better

Figure 2.59

2.4.7 Pulse Code Modulation (PCM) Telemetry

A five-wire interface (continuous clock, data 1, data 2, envelope 1, envelope 2) is available for Pulse Code Modulation (PCM) telemetry interfaces. This five-wire interface is only available by special negotiations with the HH Project, and if the bandwidth is available. The CCGSE can extract PCM data and send it to the CGSE. See Section 2.4.9 for a discussion of the interface. The wave forms and electrical interfaces are shown in Figures 2.60 and 2.61. A continuous clock controls transmission of data on both of the two data lines. The envelope signals indicate the times at which data is being accepted on the respective data lines. Data is accepted in multiples of 8 bits and the envelope pulses will be an integral multiple of 8 bits in length. The clock rate (and bit rate) will be nominally 8 KB/S for HH. The sample timing for channels 1 and 2 is controlled by a mission-unique read-only memory and will be negotiated on a mission-unique basis with each user of the PCM data interface. The PCM five-wire interface is provided to maintain compatibility with existing equipment and is not recommended for new flight equipment.

PCM Digital Interface Waveforms

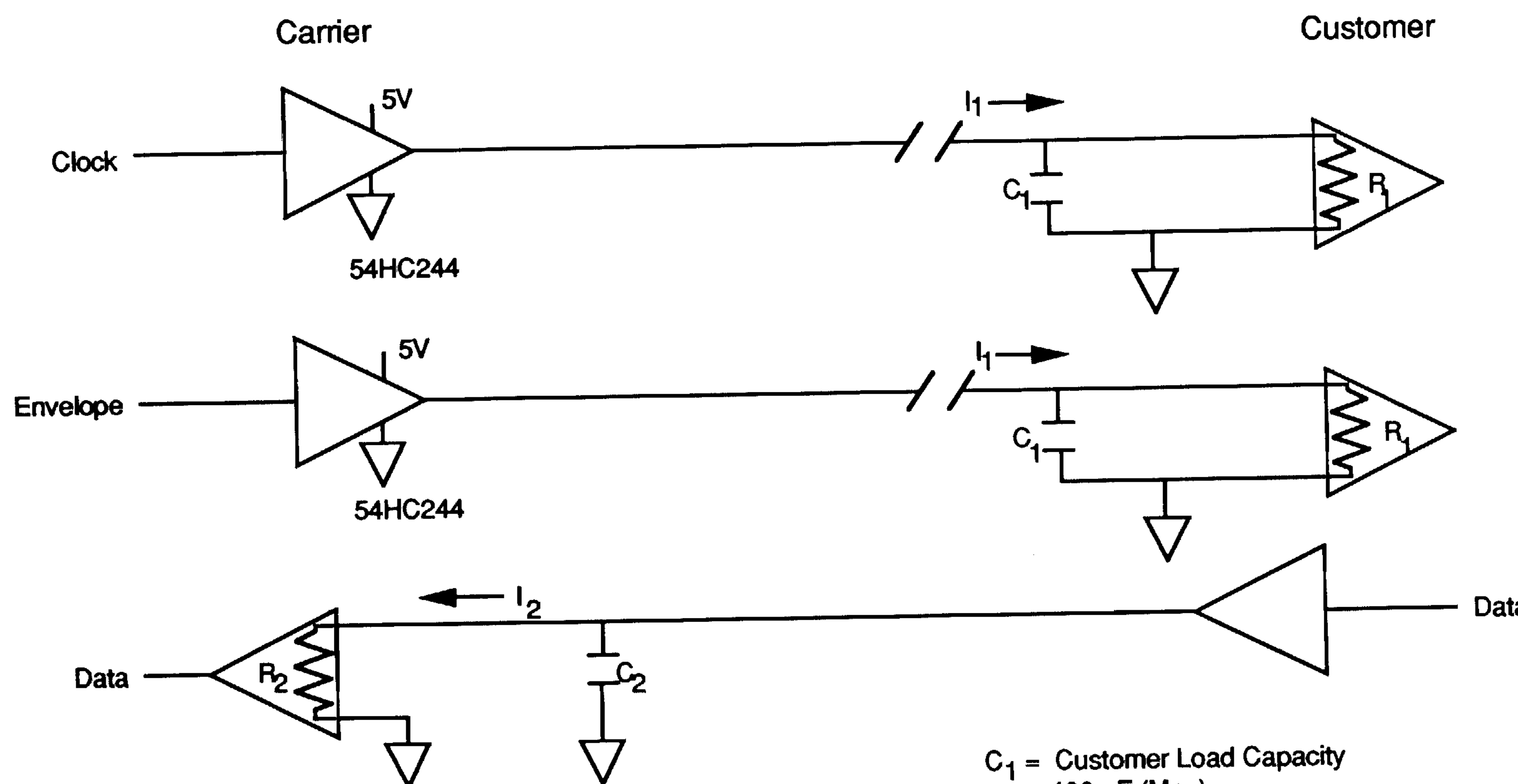


	Characteristic	
td (eb)	Delay Time: Envelope to Clock	1/2 Bit Period Minus 520 NS
tsu	Data Set Up Time	300 NS (Min)
tH	Data Hold Time	0 NS (Min)
V_T	3.5 V Min 5.5 V Max Ref Sig GND	
V_F	-1 V Min 0.6 V Max Ref Sig GND	

Notes:
1) Data Bits
   On the Leading Edge of Clock as Shown. Bit 1 (First Bit Out) Should Be Most Significant Bit.

Figure 2.60

Customer PCM Data Interfaces



C_1 = Customer Load Capacity
100 pF (Max)

I_1 = Customer Load Current
Source or Sink 1 MA (Max)

C_2 = Customer Load Capacity
1000 pF (Max) Inc. Cable

I_2 = Carrier Load Current
Source or Sink .4 MA (Max)

Figure 2.61

2.4.7.1 Analog Data. One analog data line is provided in each standard interface. This line is sampled at a rate of approximately 15 Hz. Voltages in the range of -0.06 to 5.04 volts are converted to 8-bit values (00 and FF, respectively). Voltages slightly below -0.06 or above 5.04 volts will be transmitted as 00 or FF (i.e., no foldover occurs). An index pulse on a separate wire occurs once per sample and can be used to advance a customer-supplied analog multiplexer to allow multiple parameters to be sampled over the single analog line. Several (typically three) of the multiplexer's inputs should be connected to known fixed voltages (e.g., +5.10, zero, +2.50) to allow the customer's ground equipment to determine synchronization with the returned sample sequence. Analog interfaces are shown in Figure 2.62.

Customer Analog Data Interfaces

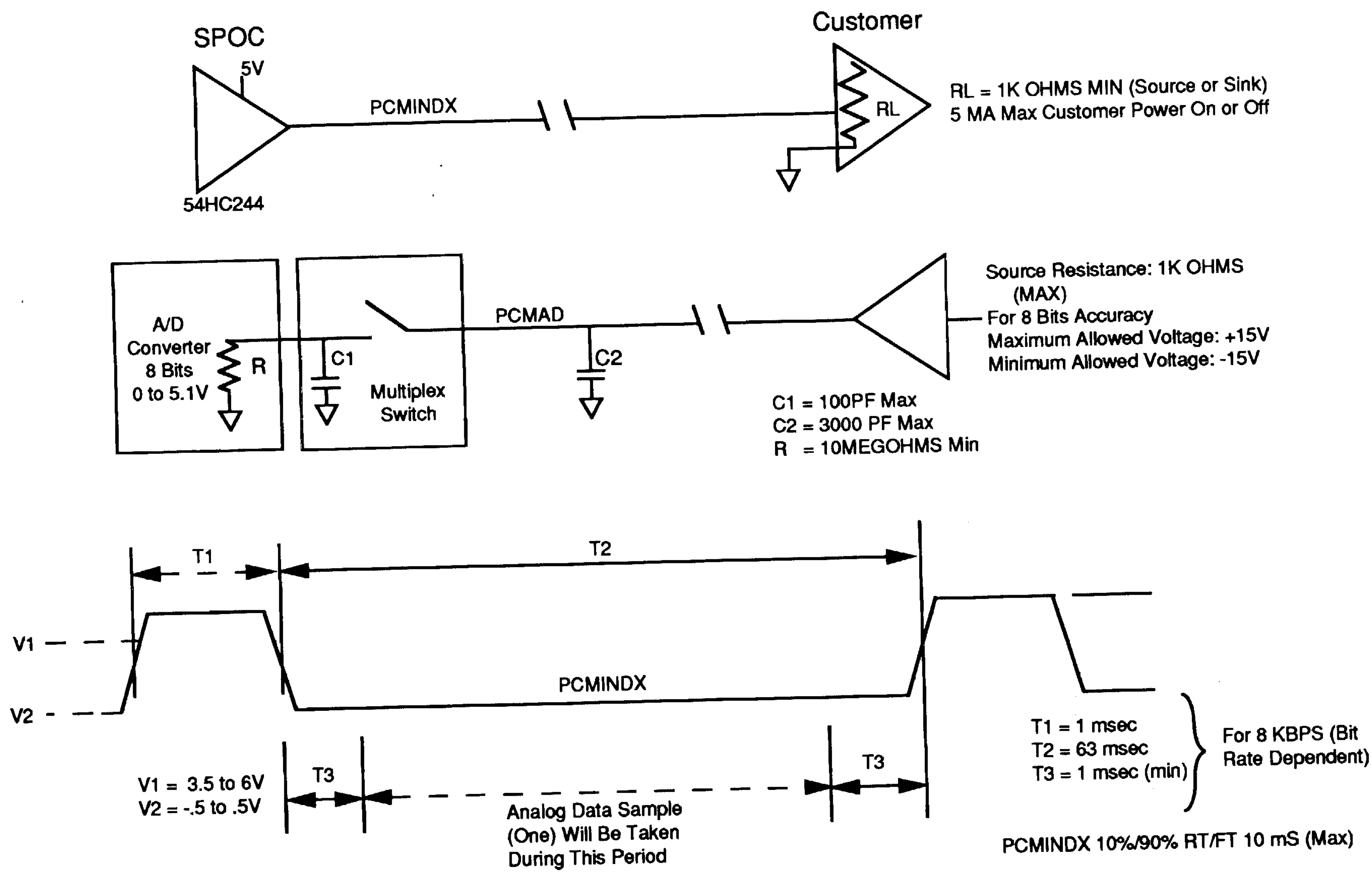


Figure 2.62

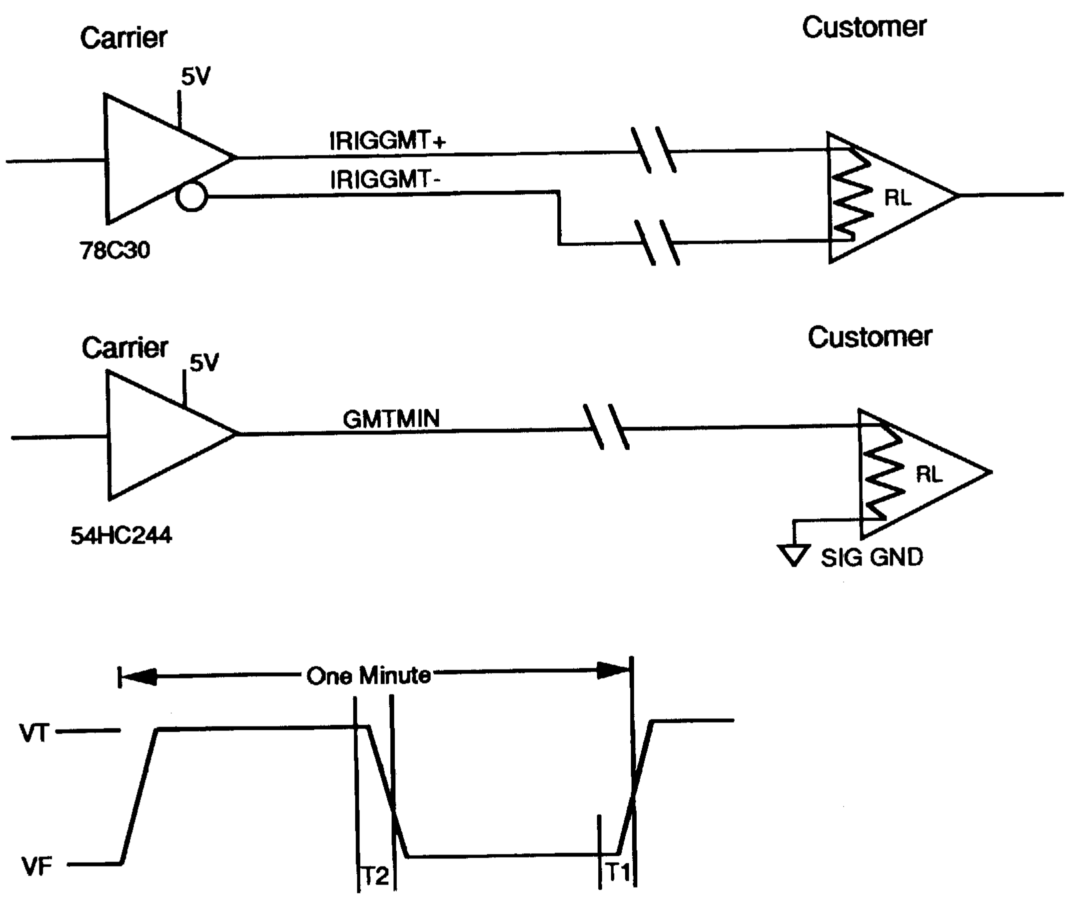
2.4.7.2 Temperature Data. As provided in each interface, three additional analog data lines (Figure 2.32) are sampled at approximately .5 Hz (-0.06 - +5.04v, 8 bits) and are provided with a regulated power source and resistor network. These are intended for connection to YSI 44006(see Section 2.2.2) thermistors to be supplied by GSFC and installed inside the customer's flight equipment by the customer. These networks and thermistors allow temperatures in the range of -20 to +60 degrees C to be measured without requiring the customer equipment to be operating. If all the thermistor lines are not required for temperatures, they may be used by the customer to measure other parameters such as: canister temperature, bottom plate temperature, canister pressure, and door position (if door is present).

2.4.8 Inter-Range Instrumentation Group, Type B (IRIG-B) MET Signal

Orbiter MET in IRIG-B format will be distributed to each interface. This signal is maintained to within 10 milliseconds (ms) and consists of a 100 Pulse Per Second (PPS) Pulse-Width-Type PCM signal giving days, hours, minutes, and seconds, once each second. In addition, there will be a MET minute signal; Transistor-Transistor Logic (TTL) levels, nominal square wave 1 ppm; edges traceable to MET within 10 ms. The customer timing interface is shown in Figure 2.63. Greenwich Mean Time (GMT) may be used in place of MET on some HH missions.

In general, post mission data tapes supplied by the HH Project will have time indications which can be interpreted to within 10 seconds. Real-time data transmitted to customer's GSE can usually be tagged by the customer's software to within 10 seconds. Therefore no time signals may be necessary at the customer's payload if time knowledge to within 10 seconds is adequate. If it is necessary to have time knowledge within the customer's payload, the MET minute signal can be used to reset a customer one-minute clock to 10 milliseconds accuracy. If the customer is using the asynchronous command channel, day-hour-minute-second time may be sent to the customer's payload periodically to update an on-board clock to within 3 seconds. This may be used in conjunction with the above minute pulse to obtain maximum accuracy. The IRIG time signal may also be decoded to obtain day-hour-minute-second time to within 10 milliseconds but is recommended only for existing designs because of the larger number of electronic parts required for decoding.

Customer Interfaces for Time



RL = 75 + /-5 OHMS
VT = (IRIG+)-(IRIG-) = +2.0 to 5.0V
VF = (IRIG+)-(ITIG-) = -2.0 to -5.0V
TR = TF = 50 Microsec (Max)

RL = 1K OHMS Min (Source or Sink)
5 MA Max True or False
Customer Power On or Off

VT = +3.5 to +6.0V

VF = -5.0 to +.5V

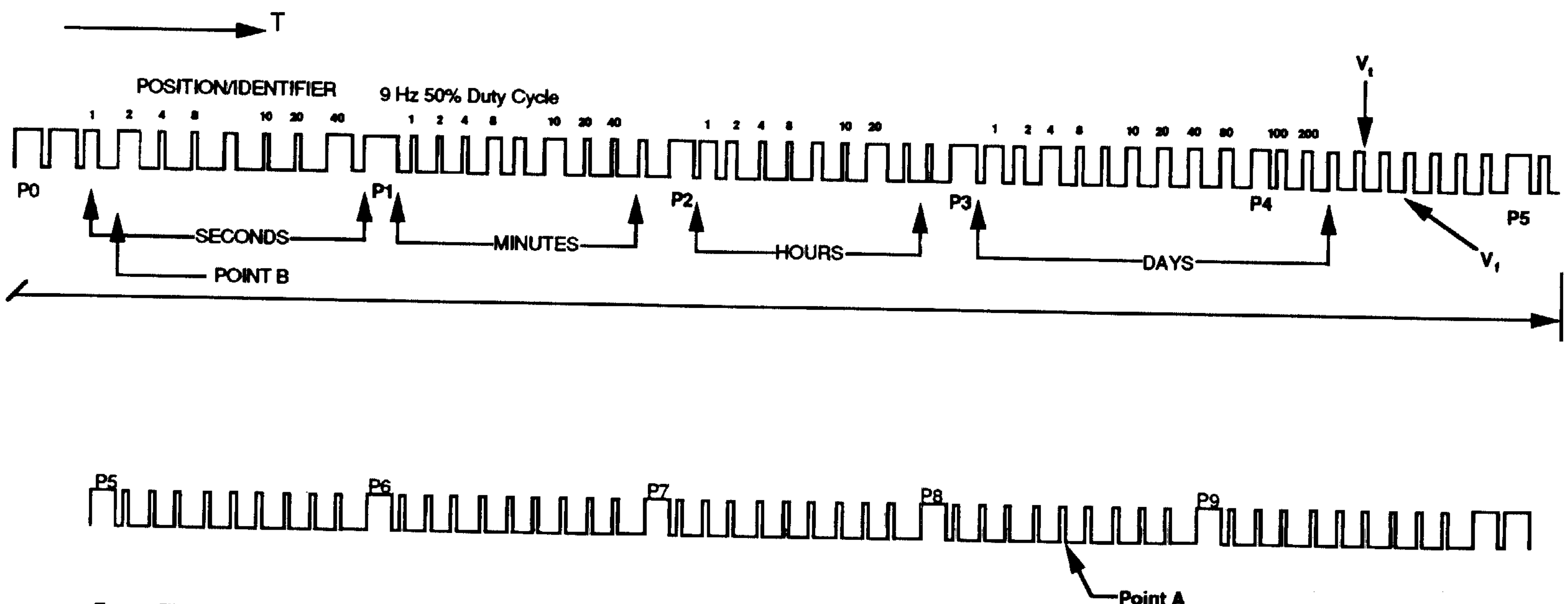
TR = TF = 2.0US

TI = Offset Between Rising Edge and GMT Second 0.00 = TBD +/-TBD

T2 = Offset Between Falling Edge and GMT Second 30.00 = TBD +/-TBD

Figure 2.63

MET Output Format



Frame Time - 1 Second
100 PPS (10 ms between pulses)
BCD
"On Time" Ref - Leading Edge
Position Identifier - 8 ms Duration +50 Microseconds
Binary 0-2 ms Duration + 50 Microseconds
Binary 1-5 ms Duration + 50 Microseconds
Time at Point A-5 Days, 21 Hours, 18 Minutes, 42.75 Seconds
Time at Point B-5 Days, 21 Hours, 18 Minutes, 42.02 Seconds

Note: The IRIG B Format is modified such that the "Straight Binary Seconds" which begin at Index Count 80, will not be generated. The IRIG format will be unmodulated with a 100 PPS output rate and a resolution of 10 milliseconds. The IRIG B Format code will be transmitted with least significant bit being transmitted first.

Figure 2.64

The signal characteristics of this interface are described in paragraph 8.2.10 of JSC 07700 Vol. XIV Attachment 1 (ICD 2-19001) SHUTTLE ORBITER/CARGO STANDARD INTERFACES, Rev. K dated January 15, 1991. This paragraph follows:

> [8.2.10.1.1] GMT (in HH Application, MET). The absolute time data, at any given time during a seven-day mission, shall not deviate by more than +/- 10 milliseconds from the ground station MET Reference Time Standard and shall be synchronized with the ground MET at certain times during a mission, subject to mission procedural constraints to prevent unacceptable time base perturbations. The accuracy of these time updates shall be +/- 5 milliseconds. The Master Timing Unit (MTU) frequency offset and drift rates shall constrain the time error growth rate to a maximum of +/- 10 milliseconds per 24 hours.

The MET output format shall be modified IRIG-B as shown in Figure 2.64. The electrical interface characteristics were previously shown in Figure 2.61.

2.4.9 CGSE Interface

Overall communication between the customer's payload and their ground support equipment are shown in Figure 2.65. The CCGSE provides the customer with (1) the command interface between the CGSE and the customer payload, (2) low-rate customer payload data as telemetered by the HH avionics, and (3) Orbiter ancillary data. The CCGSE provides two asynchronous data lines for these purposes.

The CCGSE will accept command requests from the CGSE over a 1200 baud RS-232-C link or a 1200 baud RS422 link. These commands will be screened by the CCGSE for criticality, formatted for the HH avionics, packaged for the appropriate transmission mode (network or Space Shuttle simulator), and transmitted. The CCGSE will verify that the commands were accepted by the HH avionics. It will not, however, monitor the telemetry to determine if the payload responded to the commands. Commands that are rejected by the networks or HH avionics will be retransmitted upon the direction of the CCGSE operators. The CCGSE will perform limited health and safety checks for the customer payload such as monitoring customer payload power currents and temperatures.

Hitchhiker/Customer Communications

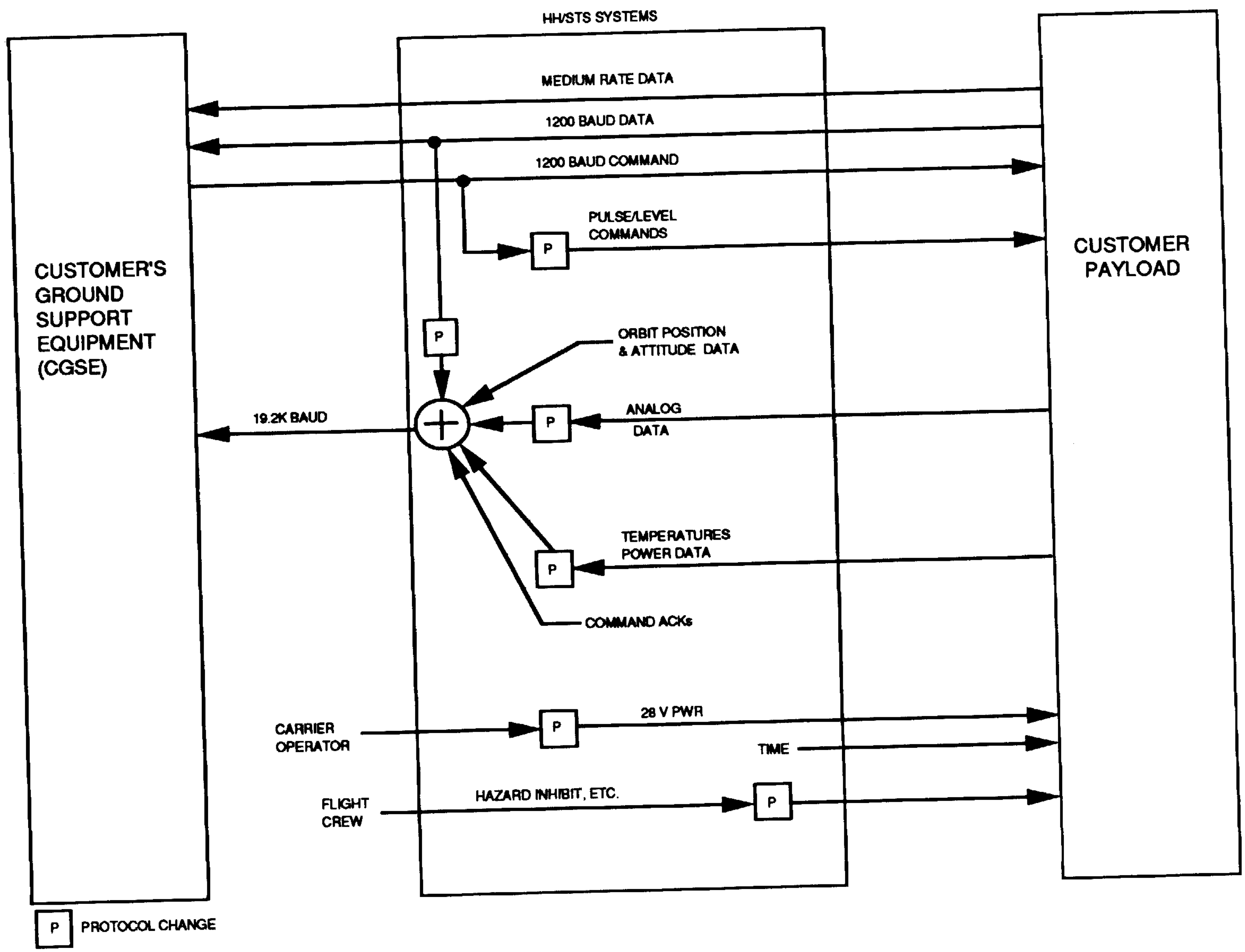


Figure 2.65

The CCGSE will extract payload asynchronous downlink data and send it in near real-time to the CGSE. The CCGSE can provide this data in two modes:

(1) Customer 1200-baud, asynchronous data identical to downlink data received from customer's payload except that any time gaps between characters may not be preserved. The electrical interface can be RS422 (Figure 2.55) or alternately RS-232 C.

2) Reformatted customer data in blocks with additional intermixed blocks of ancillary information transmitted in 19.2 K-baud synchronous format over an RS-232 C connection.

The CCGSE can send a subset of the Orbiter's ancillary data to the CGSE. These data are transmitted over a 19.2 K-baud asynchronous RS-232-C line. If the rate and/or format of the Shuttle Orbiter auxiliary data changes, the message format and line rates used for the CCGSE will change appropriately. A summary of the RS-232-C lines and rate requirements and uses are presented in Table 2.10.

The following paragraphs define in detail the data transferred between the CCGSE and CGSE and the electrical interfaces supported by the CCGSE.

For formatted data, an RS-232 port is provided for the transmission of Space Shuttle-related data, HH system ancillary data, customer energy data, command acknowledgements, CCGSE blocked payload data from one or more HH asynchronous ports and payload PCM data. The aggregate data rate of all the multiplexed data (including overhead) will not exceed 75 percent of the data line baud rate.

TABLE 2.10

CCGSE - CGSE COMMUNICATION

LINE #	LINE	CHARACTERISTICS	FUNCTIONCOMMENTS
1	FULL DUPLEX, 1200 BAUD, NO ECHO, 1 START, 1 STOP, NO PARITY, RS422 OR RS232	CCGSE RECEIVE SIDE: CGSE COMMAND MESSAGES CCGSE SEND SIDE: RAW PAYLOAD DATA FROM SPOC ASYNCHRONOUS SEND DATA PORT.	1 LINE PER CID
2	HALF DUPLEX, 19.2K BAUD, NO ECHO, 1 START, 1 STOP, NO PARITY, 8 BIT DATA RS232	MULTIPLEXED DATA MESSAGES OF ANY OF THE FOLLOWING TYPES: 2 - CUSTOMER ASYNC DATA 3 - CUSTOMER ANALOG DATA 4 - HH ANCILLARY DATA 5 - CUSTOMER COMMAND COMPLETION 6 - CUSTOMER COMMAND LINK STATUS 10 - SHUTTLE ANCILLARY DATA (ORBIT/ATTITUDE) 14 - CUSTOMER PCM-B DATA 15 - CUSTOMER PCM-A DATA	1 LINE PER CID IF UTILIZATION RATE EXCEEDS 75% OF BAUD RATE, A SECOND LINE WILL BE REQUIRED

Whenever the data rates are predicted to exceed the 75 percent threshold, another RS-232 line will be provided. In this case, the assignment of data type transferred over each line will be negotiated by the Project. The user may reconstruct each data stream by grouping data of similar types.

HH system ancillary messages consist of data telemetered by the HH avionics. They include the payload temperatures, relay states, current load, user analog data, and energy usage. The frequency and content of this message is dependent upon the mission-peculiar HH telemetry format. Currently, the message is transmitted approximately once every 4 seconds assuming a nominal 8 kb/sec telemetry rate.

A 1200-baud asynchronous port is provided for direct transfer of customer payload asynchronous downlink data. Customer data are transmitted to the CGSE without any data reformatting. One 1200-baud asynchronous port will be provided for each HH asynchronous port used.

All data, with the exception of customer payload asynchronous data, transferred to the CGSE from the CCGSE will be formatted into messages as shown previously in Figure 2.58. Each user will be assigned a Customer Identification (CID) by the HH Project. The customer will be issued multiple CIDs if the payload uses more than one HH port.

PCM and customer payload asynchronous data transferred between the CCGSE and CGSE will be packetized and received asynchronously. No attempt is made to simulate the timing relationship between data bytes as sampled on-board by the HH avionics or between the various independent data streams. No retransmission of data is provided.

The Space Shuttle orbit and attitude messages will contain data extracted from the Shuttle Ancillary Data blocks sent to the CCGSE by the Shuttle MCC. No conversion of the data will be performed.

Asynchronous downlink payload telemetry data are available in one of two modes: (1) transmitted over a dedicated 1200-baud, asynchronous port without any framing by the CCGSE, or (2) multiplexed with Shuttle orbit and attitude data and HH ancillary data. In the second mode, the CCGSE will place payload data originating from unique HH asynchronous ports into individual messages. In either case, no attempt is made to synchronize the data within the messages.

The CGSE may issue payload commands using the command line provided by the CCGSE. Commands are formatted as if they were being issued directly to the payload. The CCGSE will hold and release the commands after 119 command data bytes have been received (the maximum command string length) or when a time gap between commands is detected. After transmission by the CCGSE, the CCGSE issues an optional command acknowledgment message indicating the number of commands successfully transmitted to the HH avionics. Upon receipt of this message, the CGSE may issue another set of commands. If the CGSE does not opt for the command completion message, the CGSE should verify the receipt of the commands by the payload prior to transmitting more commands. Failure to do so may result in the loss of commands because the command link is slower than the aggregate command rate of all the users. In fact, transmission delays of 10-20 seconds may be common in operations because of additional delay in the networks and MCC.

2.4.9.1 CCGSE-CGSE Physical Interface Requirements. The asynchronous interfaces provided for the transmission of HH ancillary data, formatted payload data, Shuttle orbit and attitude data are RS-232-compatible. The interfaces for customer payload asynchronous telemetry and command generation are RS-232 or RS-422-compatible. Some of the characteristics of the lines and usage were defined in Table 2.10. Refer to Tables 2.11 and 2.12 for connector types and pin assignments.

The customer must negotiate with the HH Project to determine the exact configuration requirements for a particular mission.

Table 2.11

PIN DESIGNATION

FOR
RS-422 ASYNCHRONOUS SERIAL COMMAND
MESSAGES AND UNFORMATTED DATA
(EGSE OR CGSE TO SPOC CCGSE)

Pin Number	Function	Comments
1	Frame Ground	Connector Type -
2	(+) Transmit Dta	25-Pin Male
3	Signal Ground	Suggested Part
4	(-) Transmit Data	Sources
5	Signal Ground	(Male Connectors)
6	(+) Receive Data	1. AMPHENOL
7	Signal Ground	P/M 0325PV
8	(-) Receive Data	2. TRW 'Cinch'
9	Signal Ground	P/M DB-25P
10-25	N/C	or MIL-SPEC
		M24308/4-3

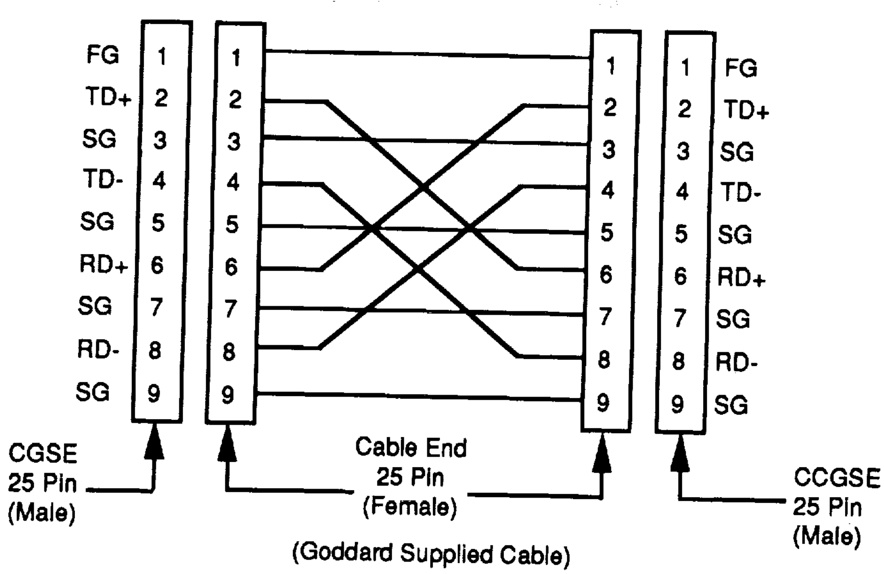


Table 2.12

PIN DESIGNATION

FOR

RS-232 ASYNCHRONOUS SERIAL FORMATTED PCM DATA

AND

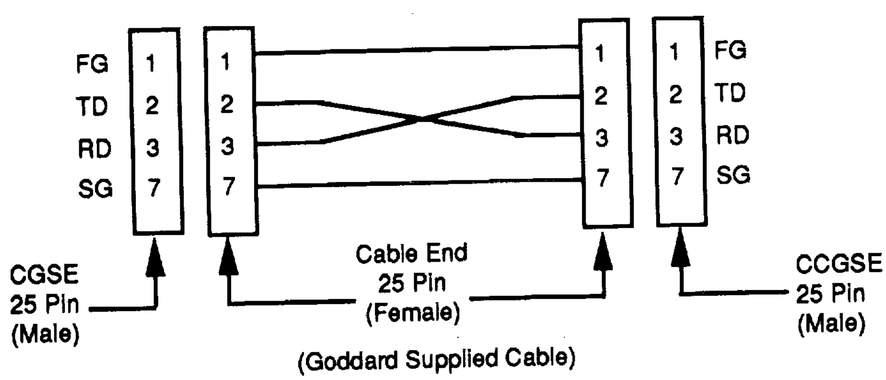
SPOC ANCILLARY AND STS ORBIT/ANCILLLARY DATA

OR

CGSE TO SPOC CCGSE SERIAL COMMAND MESSAGES AND UNFORMATTED DATA

Pin Number	Function (CCGSE)
1	Frame Ground (FG)
2	Transmit Data (TD)
3	Received Data (RD)
4 - 6	N/C
7	Signal Ground (SG)
8 - 25	N/C

The Serial Interface Circuit will use the "Null Modem" configuration, shown in Figure below.



2.4.9.2 CCGSE-CGSE Telemetry Interface. The CCGSE can provide HH telemetry and payload telemetry to the CGSE. The following sub-sections describe the format of the data transferred. No data interpretation or conversions are performed by the CCGSE. All data of a given type are transferred in a time-sequential order.

1. Unformatted Customer Payload Asynchronous Downlink Data

The customer may receive the payload asynchronous data in real time in a "transparent" manner. The data are bursted to the CGSE over a 1200-baud line as they are received by the CCGSE. These data are transmitted over the asynchronous CGSE command line. No attempt is made to synchronize this stream with any other data stream. No attempt is made to maintain the data sampling timing relationship within a stream.

2. Formatted Customer Asynchronous Downlink Payload Data (Type 2)

The customer may receive asynchronous payload data in real time multiplexed with other HH telemetry over one CCGSE-CGSE RS-232 line. The CCGSE throughputs the data without attempting to synchronize to the payload data.

The CCGSE formatted messages contain a maximum of 120 bytes of payload data and contain the HH time code of the telemetry frame containing the last data byte transmitted within the message. This data message format is shown in Table 2.13. The CCGSE schedules transmission of these blocks upon the filling of the data fields within the message or after one second if the message is not empty. If these messages are multiplexed with other message blocks, the timing between messages is erratic. Note that it is possible to receive a block with "no data bytes" if a sync error is encountered.

TABLE 2.13

CCGSE FORMATTED ASYNCHRONOUS DATA MESSAGE STRUCTURE

Byte	Bits	Function	Content
1	1-8	Synchronization	E5 (Base 16)
2	1-8	Number of data bytes in message	$0 \leq N \leq 120$
3	1-4	Customer Identification (CID)	$1 \leq CID \leq 6$
3	5-8	Message type	2
4-5	1-8/1-8	Binary day of MET from SPOC PCM frame containing last payload data byte (DD)	$0 \leq DD \leq 366$
6-9	1-8/1-8	Milliseconds of day from SPOC PCM frame containing last payload data byte. Treated as a 32-bit integer (M)	$0 \leq M \leq 86399999$
10	1	SPOC minor frame sync loss indicator 1 = sync loss during data collection	0/1
10	2	MCU frame sync loss indicator 1 = sync loss during data collection	0/1
10	3	MCU encountered data overrun if set to 1	0/1
10	4	MCU encountered parity error if set to 1	0/1
10	5-8	Spare	0'S
10+N	1-8	Payload data	0-255
11+N	1-8	Exclusive OR of bytes 2 through (N+10)	0-255

3. Customer Analog Data (Type 3)

The customer may receive data from its analog channel assigned by the HH mission. The CCGSE format the data into message blocks as shown in Table 2.14. The data are tagged with the HH time code (MET) of the minor frame containing the last byte of user data transmitted within the message. No attempt is made to synchronize the data within the sequence of analog samples. This message is scheduled for transmission to the CGSE every HH major frame. It is multiplexed with other ancillary and command acknowledgment messages, hence the timing between the messages is erratic. However, the time for messages of the same time is in ascending order.

4. HH Ancillary Data Message (Type 4)

The CCGSE will provide HH avionics ancillary data messages which contain information such as temperature data, bus voltage, relay states, etc. The format of the HH ancillary data messages is defined in Table 2.15. The time field is the HH time code of the minor frame from which the last data byte was sampled.

TABLE 2.14

CCGSE FORMATTED PAYLOAD ANALOG DATA STRUCTURE

Byte	Bits	Function	Value
1	1-8	Synchronization	E5(Base 16)
2	1-8	Number of data bytes in message	32
3	1-4	Customer Identification (CID)	$1 \leq CID \leq 6$
3	5-8	Message type	3
4-5	1-8/1-8	Binary day of year from SPOC PCM frame containing last byte of multiplexer data transferred (DD)	$0 \leq DD \leq 366$
6-9	1-8/1-8/ 1-8/1-8	Milliseconds of day from SPOC PCM frame containing last byte of analog data transferred (M)	$0 \leq M \leq 86399999$
10	1	SPOC minor frame sync loss during data collection if set	0/1
10	2-8	Spare	0
11-42	1-8	Analog data	0-255
43	1-8	Exclusive OR of bytes 2-42	0-255

TABLE 2.15
CCGSE ANCILLARY DATA MESSAGE STRUCTURE

Byte	Bits	Function	Content
1	1-8	Synchronization	E5 (Base 16)
2	1-8	Number of data bytes in message	10
3	1-4	Customer Identification (CID)	$1 \leq$ CID ≤ 6
3	5-8	Message type	4
4-5	1-8/1-8	Binary day of year	$0 \leq$ DD ≤ 366
6-9	1-8/1-8/1-8/1-8	Milliseconds of day	$0 \leq$ M ≤ 86399999
10	1	HH minor frame sync loss indicator (1=Loss)	0/1
10	2	MCU sync loss indicator (1=Loss)	0/1
10	3	SPOC analog channel sync loss (1=Loss)	0/1
10	4-8	Spare	0
11	1-8	Current drawn by user in counts (as telemetered)	0-255
12	1-8	Relay status as telemetered	0-255
13	1-8	Heater bus status	0-255
14	1-8	Thermistor #1 reading in counts	0-255
15	1-8	Thermistor #2 reading in counts	0-255
16	1-8	Thermistor #3 reading in counts	0-255
17	1-8	Energy usage as computed by MCU in counts (Sample 1)	0-255
18	1-8	Bus voltage as sampled by MCU in counts (sample 1)	0-255
19	1-8	Energy usage as computed by MCU in counts (sample 2)	0-255
20	1-8	Bus voltage as sampled by MCU in counts (sample 2)	0-255
21	1-8	Exclusive OR of bytes 2-20	0-255

5. Shuttle Orbit and Attitude Data Messages (Type 10)

The customer may receive the Shuttle orbit and attitude parameters as they are received by the CCGSE from the Calibrated Ancillary System (CAS). No attempt is made to convert the data values. The time field is contained in the Shuttle ancillary data block received from the CAS. Table 2.16 depicts the default format and content of the message. The frequency of the message is approximately once a second. The customer may negotiate with the Project for the inclusion of other data found in the Shuttle ancillary data block.

Algorithms for converting the quaternions in these messages to RA/DEC of the Z axis or orbiter R,P,Y angles are given in Appendix G.

TABLE 2.16

SHUTTLE ORBIT AND ATTITUDE DATA MESSAGE STRUCTURE

Byte	Bits	Function	Value
1	1-8	Synchronization	E5(Base 16)
2	1-8	Number of data bytes in message, excluding header and checksum	92
3	1-4	Customer Identification (CID)	$1 \leq CID \leq 6$
3	5-8	Message type	10
4-5	1-8/1-8	Binary day of year computed from Primary Source MET	$0 \leq DD \leq 366$
6-9	1-8/1-8/ 1-8/1-8	Milliseconds of day computed from Primary Source MET	$0 \leq M \leq 86399999$
10	Spare		
11-18	All	X-Component of current Shuttle position vector in IBM floating point. M50 coordinate system.	
19-26	All	Y component of current Shuttle position vector IBM floating point. M50 coordinate system.	
27-34	All	Z component of current Shuttle position vector in IBM floating point M50 coordinate system.	
35-38	All	X component of velocity vector in IBM floating point. M50 coordinate system.	
39-42	All	Y-component of velocity vector in IBM floating point. M50 coordinate system.	
43-46	All	Z component of velocity vector in IBM floating point. M50 coordinate system.	
47-54	All	Time Tag associated with current state in IBM floating point.	

TABLE 2.16 (Cont.)

Byte	Bits	Function	Value
55-58	All	M50 to measured body quaternion element 1 in IBM floating point	
59-62	All	M50 to measured body quaternion element 2 in IBM floating point	
63-66	All	M50 to measured body quaternion element 3 in IBM floating point	
67-70	All	M50 to measured body quaternion element 4 in IBM floating point	
71-74	All	M50 WRT LVLH quaternion element 1 in IBM floating point	
75-78	All	M50 WRT LVLH quaternion element 2 in IBM floating point	
79-82	All	M50 WRT LVLH quaternion element 3 in IBM floating point	
83-86	All	M50 WRT LVLH Quaternion Element 4 in IBM floating point	
87-102	All	Vernier Jet Data	
103	1-8	Exclusive OR of bytes 2-102	

TABLE 2.16 (Cont)

VERNIER JET DATA

Bytes 87-102

Up to 16 Samples of Orbiter Vernier Thruster Data in Time Sequence

Bit 1 = 0	Valid Sample
Bit 1 = 1	Fill (No valid sample)

Bit 2 Spare

Bits 3-8 Vernier Jet Data
1 = Jet Firing
0 = Jet Not Firing

BIT	JET	POSITIONPLUME DIRECTION
3	F5L	FWD-LeftDown/Left
4	F5R	FWD- RightDown/Right
5	L5D	AFT-LeftDown
6	L5L	AFT-LeftLeft
7	R5R	AFT-RightRight
8	R5D	AFT-RightDown

6. Payload PCM Data Messages (Type 14/15)

The customer may receive its contribution to the PCM telemetry (see sub-section 2.4.7) stream. The CGSE will format the data into message blocks shown in Table 2.17. The time field is the HH time code associated with the minor frame from which the last data byte was extracted. This data may be multiplexed over the asynchronous line used for Shuttle auxiliary data or transmitted over a dedicated line. The exact details must be negotiated with the HH Project.

TABLE 2.17

CCGSE FORMATTED PAYLOAD PCM DATA MESSAGE STRUCTURE

Byte		Bits	FunctionContent
1	1-8	Synchronization	E5 (Base 16)
2	1-8	Number of PCM data bytes in message, starting byte 11 to end not incl. check sum	$1 \leq N \leq 255$
3	1-4	Customer Identification (CID)	$1 \leq CID \leq 6$
3	5-8	Message Type	15 (PCM A) or 14 (PCM B)
4-5	1-8/1-8	Binary Day of Year	$0 \leq DD \leq 366$
6-9	1-8/1-8/ 1-8/1-8	Milliseconds of day	$0 \leq M \leq 86399999$
10	1	HH-G Sync loss indicator (1 = loss)	0/1
10	2-8	SPARE	
11	1-8	PCM Data	
*		*	
*		*	
*		*	
10+N	1-8	PCM Data	
N+11	1-8	exclusive OR of bytes 2 through N + 10	0-255

2.4.9.3 CCGSE-CGSE Command Messages. Messages are exchanged between the CCGSE and CGSE for payload commanding and command acknowledgment.

1. CGSE Command Messages

The CGSE CCI will buffer the commands for transmission to the HH avionics in a burst. The commands are not released by the CCGSE CCI until either (1) 100 milliseconds have elapsed between command messages or (2) the maximum of 119 bytes have been transferred. This maximum is the longest command message that can be transmitted to the avionics.

2. CCGSE Command Acknowledgement (ACKS) Messages (Types 5/6)

These messages are multiplexed with the HH system ancillary data messages, Shuttle orbit and attitude data messages, etc. All messages are optional.

The CCGSE will originate messages if errors are detected in the command data link. The messages indicate the error and the number of commands rejected by the CCGSE because of the error. The format of the messages is shown in Tables 2.18 and 2.19. These messages are transmitted from the CCGSE to the CGSE on the 19.2k baud link. The time in these two messages is the CCGSE computer GMT time when the message was generated.

TABLE 2.18

CCGSE COMMAND COMPLETION STATUS

MESSAGE STRUCTURE

Byte	Bits	Function	Value
1	1-8	Synchronization	E5 (Base 16)
2	2-8	Number of data bytes in the message, excluding header and checksum	2
3	1-4	Customer Identification (CID)	$1 \leq CID \leq 6$
3	5-8	Message type	5
4-5	1-8/1-8	Binary day of year	$1 \leq DD \leq 366$ (Note 1)
6-9	1-8/1-8/ 1-8/1-8	Millisecond time of day	$0 \leq M \leq 86399999$
10	1-8	Spare	0
11	1-8	Number of commands transmitted	
12	1-8	Number of commands accepted by SPOC	
13	1-8	Exclusive OR of bytes 2-12	0-255

Note 1: This time is the CCGSE computer GMT time.

TABLE 2.19
CCGSE DATA LINK STATUS
MESSAGE STRUCTURE

Byte	Bits	Function	Value
1	1-8	Synchronization	E5 (Base 16)
2	2-8	Number of data bytes in message, from bytes 11 to end not including check sum	2
3	1-4	Customer Identification (CID)	$1 \leq CID \leq 6$
3	5-8	Message Type	6
4-5	1-8/1-8	Binary day of year	$1 \leq DD \leq 366$ (Note 1)
6-9	1-8/1-8/ 1-8/1-8	Millisecond time of day (M)	$0 \leq M \leq 8639999$
10	1-8	Spare	0
11	1-8	Number of command bytes accepted or rejected	$1 \leq M \leq 120$
12	1-8	Status indicator (no bits set = received CMD without errors)	
	Bit #1	- CGSE shipped too many bytes in command message	
	Bit #2	- Parity error in transmission between CGSE-CCGSE	
	Bit #3	- Data overrun	
	Bit #4	- Framing Error	
	Bit #5	- Invalid CID	
	Bit #6	- Checksum Error	
	1-8	Exclusive OR of bytes 2 through 12	0-255

Note 1: This time is the CCGSE computer GMT time.

TABLE 2.20

CCGSE AIA DATA MESSAGE STRUCTURE

Byte	Bits	Function	Content
1	1-8	Synchronization	E5 (Base 16)
2	1-8	Number of data bytes in message from byte 11 to end not including checksum	73 or 14 (Note 2)
3	1-4	Customer Identification (CID)	0
3	5-8	Message Type	0
4-5	1-8/1-8	Binary day of the year (GMT)	0<=DD<=366
6-9	1-8/1-8/1-8/1-8	Milliseconds of day (GMT)	0<=M<=86399999
1	1-8	Spare	0
11-83	1-8/all	73 bytes of Alternative AIA or MCU subcom Data (Note 1)	0-255
84	1-8	Exclusive OR of bytes 2-83	0-255

Notes: 1. The 73 byte data field contains:

9 byte header + 64 byte AIA frame or
9 byte header + 16 byte status + 48 byte MCU subcom

The header and status fields contain information internal to the CCGSE for the CCGSE use only.

2. When the data field contains 14 bytes, it is a status message internal to the CCGSE.

2.4.10 Crew Control (CC)

The CC system provides a second method (independent of the ground command system) for controlling the flow of power to the customer payloads and, thus, ensures that power could be removed from the payload even in the event of any single failure. Since two independent commands (crew and ground) are required to apply power to a customer payload, two inhibits are present to prevent a hazardous payload function from occurring during ascent or descent. Additional crew control functions can be used to inhibit a hazardous payload function during on-orbit operations.

CC of the carrier power system (see Figure 2.34) is implemented using the first two switches S1 and S2 (DS1 and DS2 indicate the state of S1 and S2) of the SPASP or normally the first two switches of the SSP (see Figure 2.66). The carrier can be assigned to either half of the SSP and if assigned to the other half, S13 and S14 (DS13 and DS14 indicate the state of S13 and S14) would be used. The remaining switches can be assigned to a customer function with a negotiated electrical interface. Switch panel control is normally provided only to inhibit a hazardous function or provide a crew controlled function which must be synchronized with some other crew activity such as Orbiter attitude control. The use of the SPASP or SSP is determined by NASA based on the STS manifesting rules. The available switch and indicator characteristics are shown in Figure 2.67. The SSP cargo switching and fusing interface schematic is shown in Figure 2.68 (sheet 1 & 2).

2.4.11 Undedicated Connections in Standard Interface

Some Twisted Shielded Pair (TSP) and single wires in each interface are undedicated and may be connected by mission unique jumper plugs to the following:

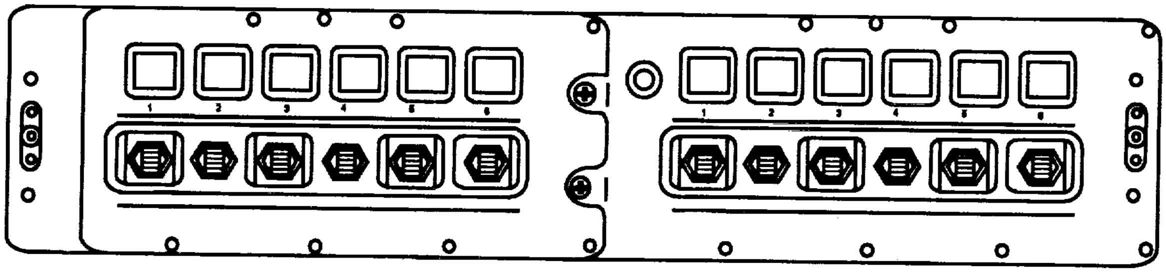
1. CC (Switch Panel)

2. Undedicated wires in a second standard interface port assigned to the same customer.

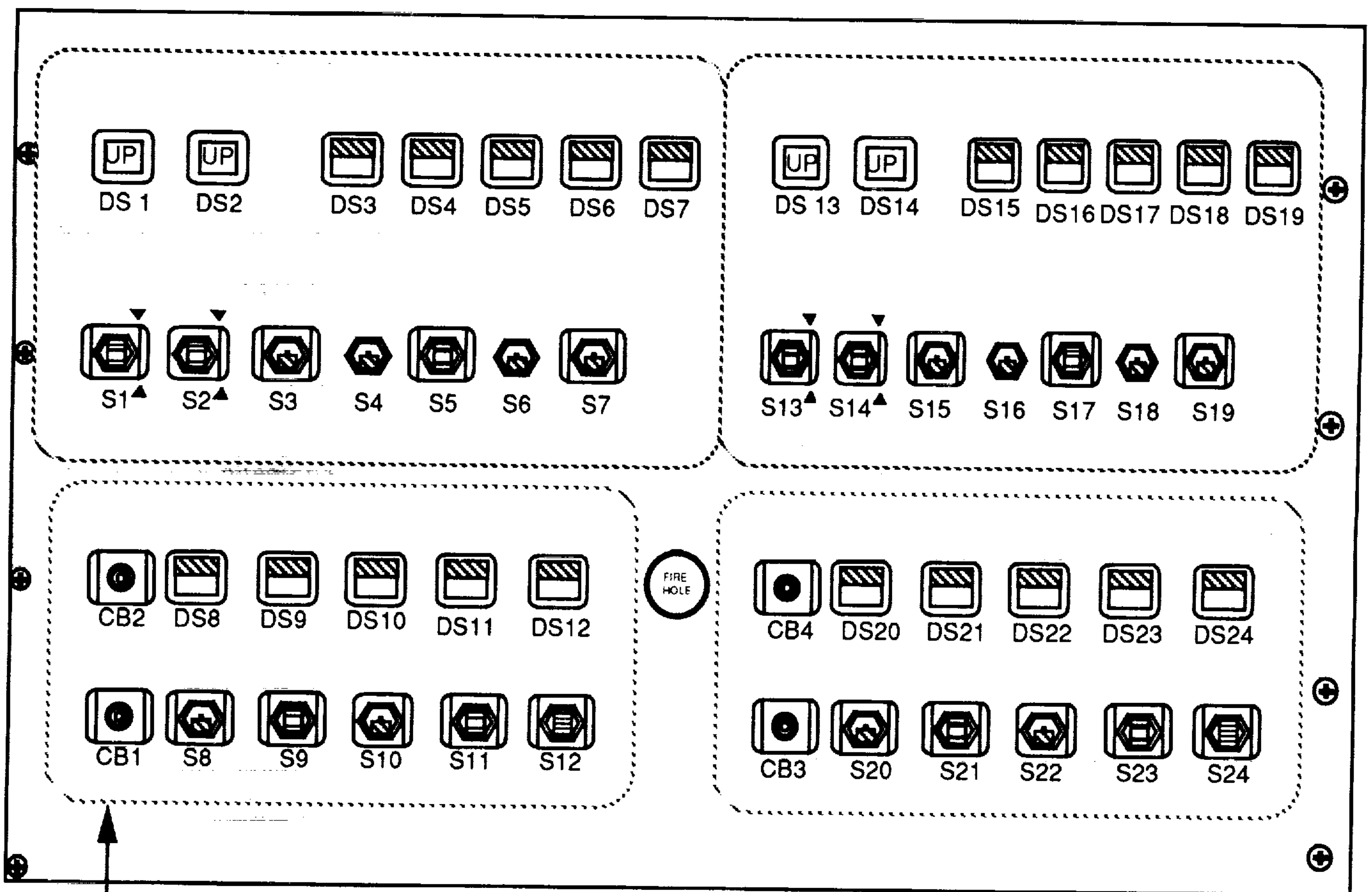
3. Other function as negotiated.

Use of the special connections may result in conflicts between customer payloads on the same flight and may therefore reduce manifesting possibilities and flight opportunities for each customer.

Switch Panels



SMALL PAYLOAD ACCOMMODATION SWITCH PANEL (SPASP)
S1, S2, DS1, DS2- RESERVED FOR CARRIER USE

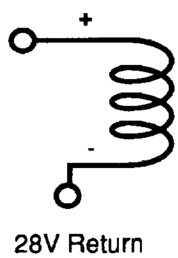


MARKING OF OVERLAYS TO BE DONE BY NSTS PER INDIVIDUAL CUSTOMER REQUIREMENTS.
(OVERLAY WILL COVER COMPONENT DESIGNATORS.)

STANDARD SWITCH PANEL (SSP)
S1, S2, DS1, DS2 OR S13, S14, DS13, DS14 RESERVED FOR CARRIER USE

Figure 2.66

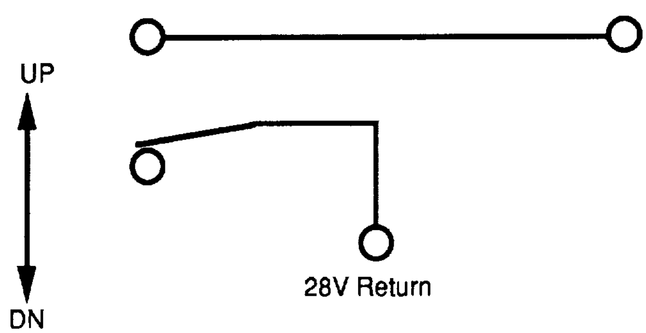
SPASP or SSP Switch and Indicator Characteristics



Coil Resistance
28.0 ± 3 K Ω

On = Gray = 18 to 32 VDC
Off = Stripes = 0 to 5 VDC

SPASP or SSP Mechanical Indicator

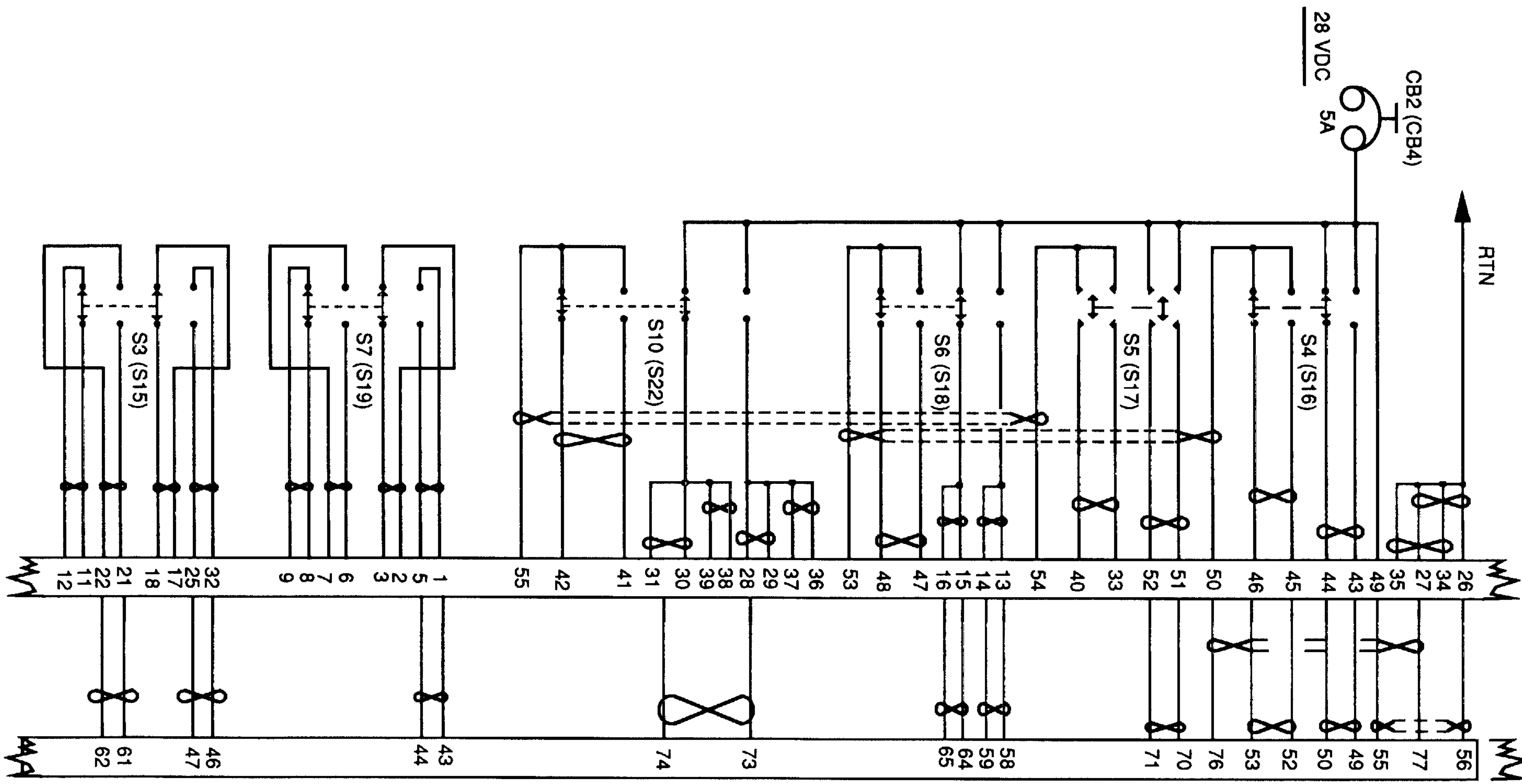


SPASP Switch (TYP 6 Places)

Resistance: 5 Ω MAX
Maximum Current: .1 AMP (dc only)
Minimum Current required to drive indicator:30 ma
Maximum Voltage: 32 VDC
Total available for customers: 4 (SPA), 10 (SMC)

Figure 2.67

SSP Cargo Element Switching And Fusing Interface Schematic (Sheet 1 of 2)



P1409
OR
P1411
OR
P1413
OR
P1415

NOTES: 1. SX (LEFT HALF OF SSP)
(SX) (RIGHT HALF OF SSP)

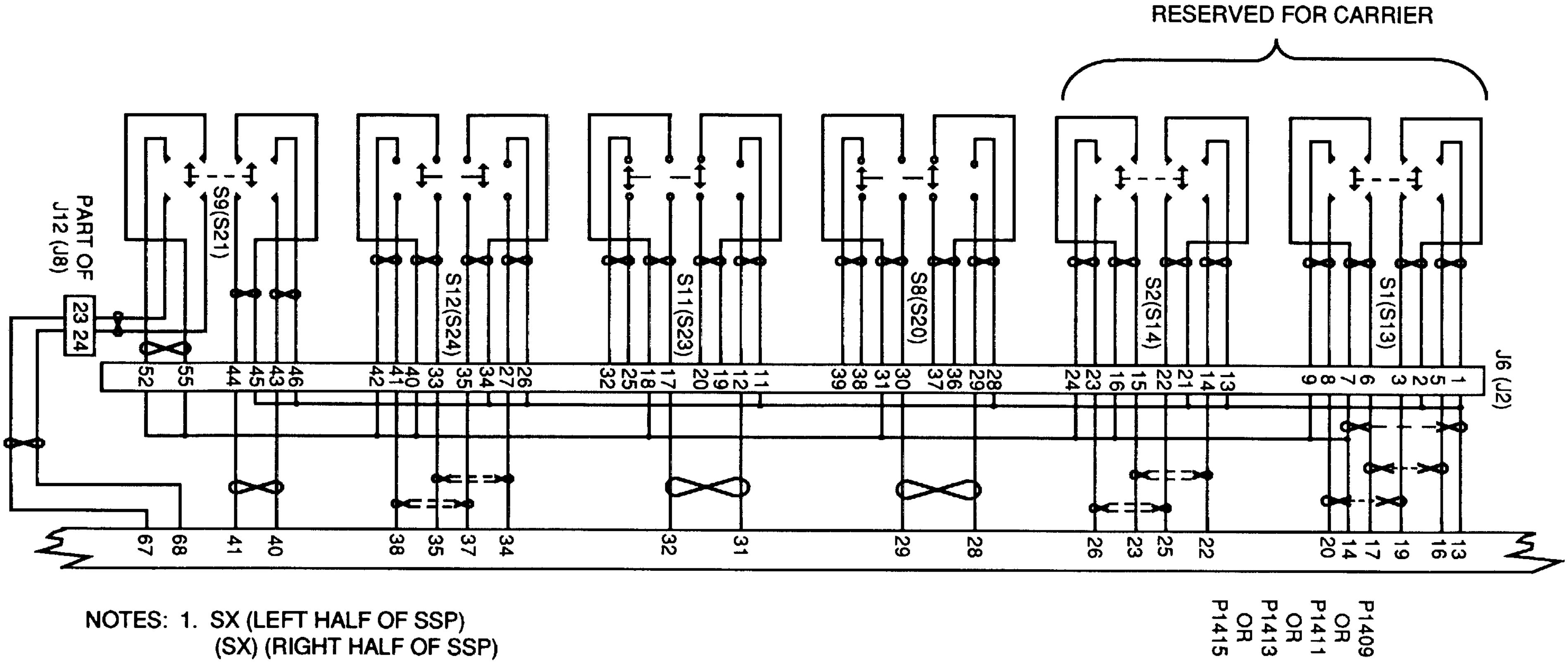
2. POSITION OF SWITCH WIPER CORRESPONDS TO POSITION OF SWITCH BAT HANDLE (E.G., MOVING HANDLE UP MOVES WIPER UP (LEFT) ON THIS DRAWING)

O MAINTAINED

▼ MOMENTARY

Figure 2.68

SSP Cargo Element Switching And Fusing Interface Schematic (Sheet 2 of 2)



NOTES: 1. SX (LEFT HALF OF SSP)
(SX) (RIGHT HALF OF SSP)

2. POSITION OF SWITCH WIPER CORRESPONDS TO POSITION OF SWITCH BAT HANDLE (E.G., MOVING HANDLE UP MOVES WIPER UP (LEFT) ON THIS DRAWING)

● MAINTAINED

▼ MOMENTARY

Figure 2.68 (continued)

2.4.12 Orbiter CCTV Interface

A special interface can be provided on SMC payloads to allow the display of a customer payload generated TV signal in the crew cabin. This signal can also be recorded on-board or transmitted to the ground. The signals are standard National Television Standard Committee (NTSC) (EIA RS170/RS330) color or black and white television signals transmitted on a differential interface. Details of the CCTV interfaces and services can be provided by the project office.

SECTION-3

3. CUSTOMER/NASA RESPONSIBILITIES

3.1 CUSTOMER RESPONSIBILITIES

Customer responsibilities in the development of a HH mission begin early in the flight system development phase and continue throughout the post-mission phase. The following subsections describe the customer responsibilities throughout the planning/development phase, pre-mission phase, mission operations phase, and post-mission phase. (See milestone schedule on page 3.25.)

3.1.1 CUSTOMER PLANNING/DEVELOPMENT RESPONSIBILITIES

During the planning/development phase, the customer is responsible for the activities described in the following subsections.

3.1.1.1 Programmatic Responsibilities. The customer must:

a. Conduct all pre-planning activities with the HH Project Office at the GSFC, Greenbelt, MD.
b. Prepare the HH CPR Document (Appendix E) for GSFC review and approval.
c. Designate what services they require.

3.1.1.2 Mechanical Responsibilities. Prior to implementation, the customer must submit a structural integrity verification plan for approval by the HH Project Office. This plan addresses the specific manner in which the various design, analysis, and test requirements of this section will be satisfied, and defines which of the documents and reports listed in Table 3.1 will be delivered to the HH Project Office for review. The customer may request an exception to a specific requirement provided that sufficient technical rationale accompanies the request. The request should be presented as part of the plan; it will be evaluated concurrently.

Once the structural integrity verification plan has been implemented, the customer is responsible for providing a structural integrity verification report, which presents the results of all analysis and test activities described in the verification plan. The structural integrity verification report (due at L-13 months) is referenced in the Hazard Report section of the customer safety data submittal. This cross-referencing is used to document the completion of a particular hazard control verification activity.

TABLE 3.1

STRUCTURAL INTEGRITY VERIFICATION PLAN
DELIVERABLES

Miscellaneous:	Complete Parts and Materials List
	Complete Payload Assembly and Interface Control Drawings
Analyses:	Detailed Stress Analysis
	- including finite element model
	Fracture Control Analysis
	- including certification of Nondestructive Evaluation (NDE) inspections
	Thermal Analysis
	Pressure Profile Analysis
Test Reports:	Random Vibration Test
	Structural/Strength Qualification Test
	Modal Test
	- modal survey, sine test, etc.
	Acoustic Test
	Mass Properties Measurements
	Thermal Test
	Other Payload-Specific Tests to meet requirements

The customer may be exempted from a specific requirement by the HH Project Office. Only the applicable analyses and tests from the above list should be included as deliverables in the structural integrity verification plan and report.

3.1.1.2.1 Standards. The customer is responsible for using design analysis, fabrication, inspection, assembly and testing practices consistent with commonly accepted aerospace industry standards and specific NASA requirements.

3.1.1.2.2 Drawings. The customer is responsible for providing the drawings and other information required for GSFC to produce the mechanical interface control drawings (MICD). These drawings will be controlled by GSFC; any proposed changes after initial release will require the approval of both parties. The type of mechanical interface control drawing information required is listed in Table 3.2.

The MICD is a vital document since it states the mutual customer-NASA understanding in all mechanical interface areas such as:

a. Hole location tolerances
b. Hole diameter tolerances
c. Interface plane flatness
d. Interface plane finish
e. Interface thickness

In addition, two sets of final detail fabrication and assembly drawings shall be provided to the GSFC for review and reference. If the customer submits a 3-D autocad model, GSFC will incorporate it into the integrated payload autocad model used for illustrations and studies of access and field of view requirements.

3.1.1.2.3 Exposed Corners, Edges, and Protrusions. Customer hardware shall be designed to minimize the likelihood of personal injury from contact with sharp corners, edges, protrusions, or recesses. In general, this means rounding exposed edges and corners to a minimum radius of 0.03 inches. Edges and corners that present a safety hazard or may be potentially damaging to other equipment during usage shall be suitably protected or rounded to a minimum radius of 1/2 inch. Protrusions, which for operational reasons cannot be made safe, shall be covered with a protective device.

3.1.1.2.4 Mass Properties. The weight, center of gravity, moments and products of inertia (about the component cg) of each component shall be provided in the CPR document. The basis for these numbers shall also be provided (i.e., estimated, calculated from fabrication drawings, or actually measured). The customer shall clearly state what contingency, if any, exists. Mass properties shall be reported using the following units: inches, pounds, and slug-ft^2.

TABLE 3.2

MECHANICAL INTERFACE CONTROL DRAWING

REQUIRED INFORMATION

a. Component Dimensions

b. Envelopes
* Static
* Thermal
* Dynamic

c. Coordinate System
* Origin
* Orientation

d. Mass Properties
* Weight, C.G.
* Basis (% Est, Cal, Act)
* Inertias

e. Attachment Details
* Number, Location
* Reaction Directions

f. Instrument Field of View
* Origin
* Size
* Shape

g. Radiator Field of View
* Origin
* Size
* Shape

h. Electrical Connectors
* Location
* Type
* Identification

i. Electrical Grounding Detail

j. Fluid Service
* Type
* Frequency
* Location
* Details

k. Radioactive Sources
* Strength
* Location
* Type

l. Ground Handling Points
* Location
* Details
* MRDPS
* Orientation

m. Optical Alignment Details

n. Access Areas
* Identification
* Location
* Size

o. Doors and Appendages
* Location
* Size
* Mass
* Duty Cycle

p. Remove/Install Pre/Post Item Locations
* Size
* Function

q. Ordnance/Actuator Details
* Location
* Type
* Function

r. Notes
* Safety Precautions
* Special Provisions
* Test Configurations
* Shipping/Storage
* Cleanliness
* Materials

3.1.1.3 Design Requirements

3.1.1.3.1 Equipment Integrity and Factors of Safety. All customer equipment shall be designed to withstand the launch, operational, reentry, and landing environments of the Shuttle without failures, leaking hazardous fluids, or releasing equipment and loose debris or particles that could damage the Space Shuttle or cause injury to the crew. The customer equipment shall be subjected to structural testing at 1.25 times the limit loads and show positive margins of safety by analysis at 1.4 times the limit load for all ultimate failure modes such as material fracture or buckling. Alternatively the customer may qualify the equipment by analysis alone by showing positive margins of safety at 2.0 times the limit loads for material yield and 2.6 times the limit loads for ultimate failure modes. This technique is pending JSC approval on a case-by-case basis. Complex structural interfaces or elements may be required to undergo structural testing. Customers choosing to perform structural verification by analysis should review their qualification plans with GSFC early in their program for approval. Pressure vessels, lines, fittings, and sealed containers shall be designed in accordance with NSTS 1700.7B.

3.1.1.3.2 Limit Acceleration Load Factors. In Table 3.3 are generalized design limit load factors for HH payload/instrument structures. These loads envelope the worst case steady state, low frequency transient, and higher frequency vibroacoustic launch and landing load environment. Refined design loads may be supplied when the payload/carrier configuration has been established. Final flight limit loads will be derived from the Shuttle Coupled Flight Loads Analysis performed for the Space Shuttle mission the customer is manifested on. Smaller, nonstructural components and assemblies should be designed using the tertiary assemblies/component loads given in Table 3.3.

The load factors are in g's and rad/sec/sec. All loads should be considered as positive and negative, simultaneous, and in all possible combinations. All accelerations should be applied through the payload's center of mass using the Shuttle coordinate system. Any thermally induced loading shall be combined with the above loads. On orbit thermal loading must also be considered.

GSE must be designed using a factor of safety of 5.0 for ultimate failure.

3.1.1.3.3 Vibration Frequency Constraints. All customer-supplied equipment shall have a lowest natural frequency of 35 Hz or greater when mounted to GSFC hardware. It is desirable to have the lowest natural frequency above 50 Hz. The customer is responsible for demonstrating satisfaction of this requirement.

TABLE 3.3

HITCHHIKER PAYLOAD/INSTRUMENT STRUCTURE
DESIGN LIMIT LOAD FACTORS

Load Factor, G			Angular Accleration rad/sec^2		
NX	NY	NZ	Rx	Ry	Rz
±11.0	±11.0	±11.0	±85	±85	±85

HITCHHIKER TERTIARY ASSEMBLY/COMPONENT
DESIGN LOAD FACTORS

Weight lb	Load Factor, G
<20	40
20-50	31
50-100	22

The above load factor shall be applied in most critical direction with 30% of the load factor applied in the remaining two directions.

3.1.1.3.4 Acoustic Noise and Random Vibration. All customer equipment shall be designed to withstand the vibroacoustic environment of the Shuttle without failure. If the customer chooses to perform an acoustic test, the levels given in Table 3.4 should be used. Payloads on the HHBA will normally be subjected to an acoustic test during integration. General Shuttle component random vibration test specifications are listed in Table 3.6 of the test requirements section 3.1.1.5.3.

3.1.1.3.5 Materials. Allowable mechanical properties of structural materials shall be obtained from MIL-HDBK-5D. Only the materials with high resistance to stress corrosion cracking listed in Table I of the latest version of MSFC-SPEC-522 shall be used. See Appendix B of this document.

3.1.1.3.5.1 Non-Metallic Materials. Use of non-metallic material shall be restricted to those materials which have a maximum collectable volatile condensable material content of .1% or less and a total mass loss of 1.0% or less. NASA-GSFC will provide the customer a list of approved materials for use in the thermal/vacuum environment upon request.

3.1.1.3.6 Thermal Blanket Attachment Requirements

There are no formal requirements for structural attachment of thermal blankets. Specific attachment methods are determined on a case-by-case basis depending on payload design, possible contamination constraints, availability of attachment hardware, etc. Typically a combination of various methods is used to attach the blankets to the payload. One mechanical fastener is required as an attach point for thermal blanket grounding.

3.1.1.4 Analysis Requirements

3.1.1.4.1 Structural Analysis Requirements. The customer is required to perform stress analysis in sufficient detail to show that the design FS described in paragraph 3.1.1.3.1 are met or exceeded and that positive MS of zero or greater can be shown for both yield and ultimate stress conditions, i.e.,

$$MS = \frac{\text{Allowable Stress}}{\text{(F.S.) (Actual Stress)}} - 1 \geq 0$$

Stress analysis shall use methods and assumptions consistent with standard aerospace practices. Buckling, crippling, and shear failures shall be considered ultimate failures. Allowable material stresses shall be taken from MIL-HDBK-5D. When alignment of components is critical to performance, it is suggested that the material micro-yield allowable be used in lieu of the 0.2% offset yield allowable.

TABLE 3.4
RECOMMENDED ACOUSTIC LEVELS *
HITCHHIKER PAYLOADS (01/90)

One Third Octave Center Frequency (Hz)	Noise Level (dB) re: .00002 Pa	
	Protoflight	Acceptance
25	122.0	119.0
32	125.0	122.0
40	128.0	125.0
50	130.5	127.5
63	131.5	128.5
80	132.0	129.0
100	132.0	129.0
125	132.0	129.0
160	131.5	128.5
200	130.5	127.5
250	130.0	127.0
315	129.0	126.0
400	128.0	125.0
500	127.0	124.0
630	126.0	123.0
800	124.5	121.5
1000	123.0	120.0
1250	121.5	118.5
1600	119.5	116.5
2000	118.5	115.5
2500	116.0	113.0
3150	114.5	111.5
4000	112.5	109.5
5000	111.0	108.0
6300	109.0	106.0
8000	107.5	104.5
10000	106.0	103.0
Overall	142	139

Test Duration 60 sec

* Assumes HH payload not in an annulus region

3.1.1.4.2 Structural Modeling Requirements. The customer is required to submit a test-verified finite element math model to GSFC for each customer-supplied payload or component which has demonstrated, or is expected to have, a lowest natural vibration frequency of less than 50 Hz when mounted to a rigid interface between the carrier and the component. All finite element models delivered to GSFC must demonstrate mathematical validity by showing that the model contains six rigid body frequencies of value .001 Hz or less. The math model should contain as few degrees of freedom as necessary for accurate simulation of frequencies and mode shapes under 50 Hz but in all cases must be limited to no more than 300 degrees of freedom. Specific details with regard to the form and content of a finite element math model that is to be submitted to GSFC will be agreed upon between the payload and GSFC on a case by case basis. A finite element math model is not required for components with lowest natural frequencies above 50 Hz, unless deemed necessary by GSFC.

Payloads having a lowest natural frequency greater than 50hz must, however, provide an analysis, either classical or finite element, that confirms the result of the testing described in 3.1.1.5.2. Test verification of math models can be achieved by performing a modal survey test on the payload.

3.1.1.4.3 Fracture Control. A fracture control program is required for all customer equipment mounted on plates or in canisters with opening lids. Since canisters without opening lids provide essential containment of all customer equipment, the requirements of fracture control are generally satisfied if the payload does not include any pressure vessel or other hazardous equipment. The customer is responsible for providing a Fracture Control Implementation Plan which describes in detail how the requirements of the General Fracture Control Plan for Payloads Using the STS, 731-0005-83 Rev. B, will be satisfied. The fracture control program implemented by the customer shall provide assurance that no catastrophic hazards to the Shuttle Orbiter or crew will result from the initiation or propagation of flaws, cracks, or crack-like defects in customer structure during its mission lifetime, including fabrication, testing, and service life. In addition, all customer structural fasteners must comply with GSFC S-313-100 (11/89) Fastener Integrity Requirements. The plan must be approved by GSFC prior to implementation. It will normally be included as part of the structural integrity verification plan described earlier.

3.1.1.4.4 Pressure Profile. Table 3.5 and Figures 3.1, 3.2, and 3.3 define the Orbiter cargo bay internal pressure history to be used by payloads for design and venting analyses. Orbiter cargo bay vent door opening occurs at altitudes between 70,000 and 94,000 feet. The repressurization rate of the cargo bay will not exceed 0.3 psi/sec during descent.

The pressure profiles given pertain to plate-mounted equipment. The pressure profiles for canister-mounted hardware may be different depending on the configuration.

3.1.1.5 Test Requirements

3.1.1.5.1 Structural Test Requirements (Qualification by test). The customer is required (for exceptions see paragraph 3.1.1.3.1) to perform strength testing of all components sufficient to demonstrate that no detrimental permanent deformation or ultimate failures occur when loads are imposed on the structure such that every primary load carrying member experiences a stress equal to a minimum of 1.25 times the limit stress. The limit stress is the highest stress produced by any one of the combinations either design limit acceleration load factors in paragraph 3.1.1.3.2 or the refined loads supplied by HH project. To satisfy this requirement, it is not necessary to impose the precise externally applied load factors in a single test. The imposed load may be artificial and may be imposed in a number of different load cases, each one of which produces the required stresses in only a portion of the structure, as long as the net result is the required stresses in all primary load-carrying members. The test load may be applied by pulling on the structure with discrete forces, by the application of a linear acceleration field (centrifuge) or by subjecting the instrument to a below-resonant frequency sine dwell or sine burst vibration test.

3.1.1.5.2 Natural Frequency Verification Test. All customer-supplied equipment shall have its lowest cantilevered natural frequency verified by test if the predicted natural frequency is below 100 Hz. Acceptable tests for verifying natural frequencies include modal survey and sine sweep vibration. Large payloads with natural frequencies less than 50 Hz may be required to undergo modal survey testing to recover both structural mode frequencies and mode shapes.

TABLE 3.5

ASCENT CARGO BAY PRESSURE AND DECAY RATE

ATTACHMENT 1 (ICD 2-19001) Change

Time	Maximum Cargo Bay Pressure	Minimum Cargo Bay Pressure	Maximum Rate of Depressurization
10	14.45	14.20	0.155
20	13.20	12.50	0.255
30	11.25	10.00	0.360
35	10.05	8.90	0.510
38	9.40	8.20	0.735
39	9.15	7.60	0.760
40	8.95	7.20	0.760
41	8.70	6.80	0.760
45	7.75	5.70	0.640
48	7.20	5.10	0.570
49	7.05	4.90	0.575
50	6.90	4.70	0.550
51	6.60	4.50	0.520
52	6.10	4.30	0.455
55	5.35	3.65	0.355
60	4.30	2.70	0.273
65	3.50	2.00	0.225
70	2.70	1.40	0.195
80	1.30	0.60	0.150
90	0.60	0.20	0.115
100	0.25	0.10	0.075

Note:
- a. Pressure in psia
- b. Rate of depressurization in psi/second
- c. Time in seconds from lift-off

3.1.1.5.3 Random Vibration. All customer flight equipment must be tested in order to qualify it for the Shuttle vibroacoustic environment. Table 3.6 below is a generalized vibration specification for Shuttle equipment. In some cases a more refined specification will be supplied once the payload/carrier configuration has been established. The HH project may waive this requirement in some instances such as reflown or contained hardware. New designs must be tested to qualification levels, reflown on previously qualified hardware may be tested to acceptance levels. A proto type unit may be used for qualification testing.

TABLE 3.6

GENERALIZED SHUTTLE COMPONENT RANDOM VIBRATION

(50 lbs. or less)

Frequency (Hz)	ASD Level (G^2/Hz)	
	Qualification	Acceptance
20 20-50 50-600 600-2000 2000	.025 +6 dB/oct .15 -4.5 dB/oct .025	.0125 +6 dB/oct .075 -4.5 dB/oct .0125
Overall	12.9 G_{rms}	9.1 G_{rms}

The test may be modified and the acceleration spectral density level reduced for components weighing more than 50 pounds by using the following formula:

dB reduction = 10LOG(W/50)

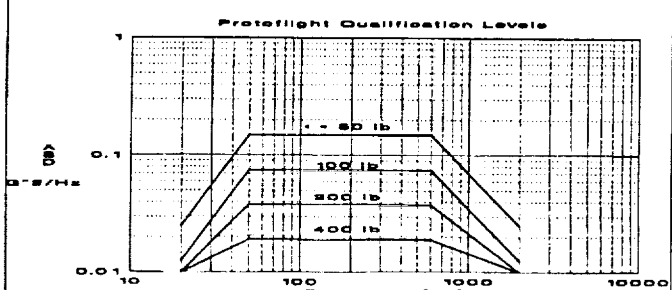
$ASD_{(50\text{-}600Hz)}$ = .15•(50/W) for protoflight

$ASD_{(50\text{-}600 Hz)}$ = .075•(50/W) for acceptance

Where W = component weight

The slopes shall be maintained at +6 and -4.5 dB/oct for components weighing up to 125 pounds. Above this weight, the slopes shall be adjusted to maintain an ASD level of 0.01 G^2/Hz at 20 and 2000 Hz.

For components weighing over 400 pounds, the test specification shall be maintained at the level for 400 pounds.



Vibration test duration is one minute in each of the three orthogonal axes.

3.1.1.5.4 Typical Test Sequence. The satisfaction of the above test requirements can often be satisfied by a single visit to a vibration test facility depending on the mass and stiffness of the payload. A typical test of this type would include:

1. A sine sweep test to verify the natural frequency,

2. A sine burst test to perform strength testing, and

3. A random vibration to qualify the payload for vibroacoustic environment.

This test sequence would typically be repeated in each axis. It must be remembered, however, that the sine burst applies a force field in a single axis whereas the design load factors occur in all three axes simultaneously.

Orbiter Cargo Bay Internal Pressure Histories During Ascent

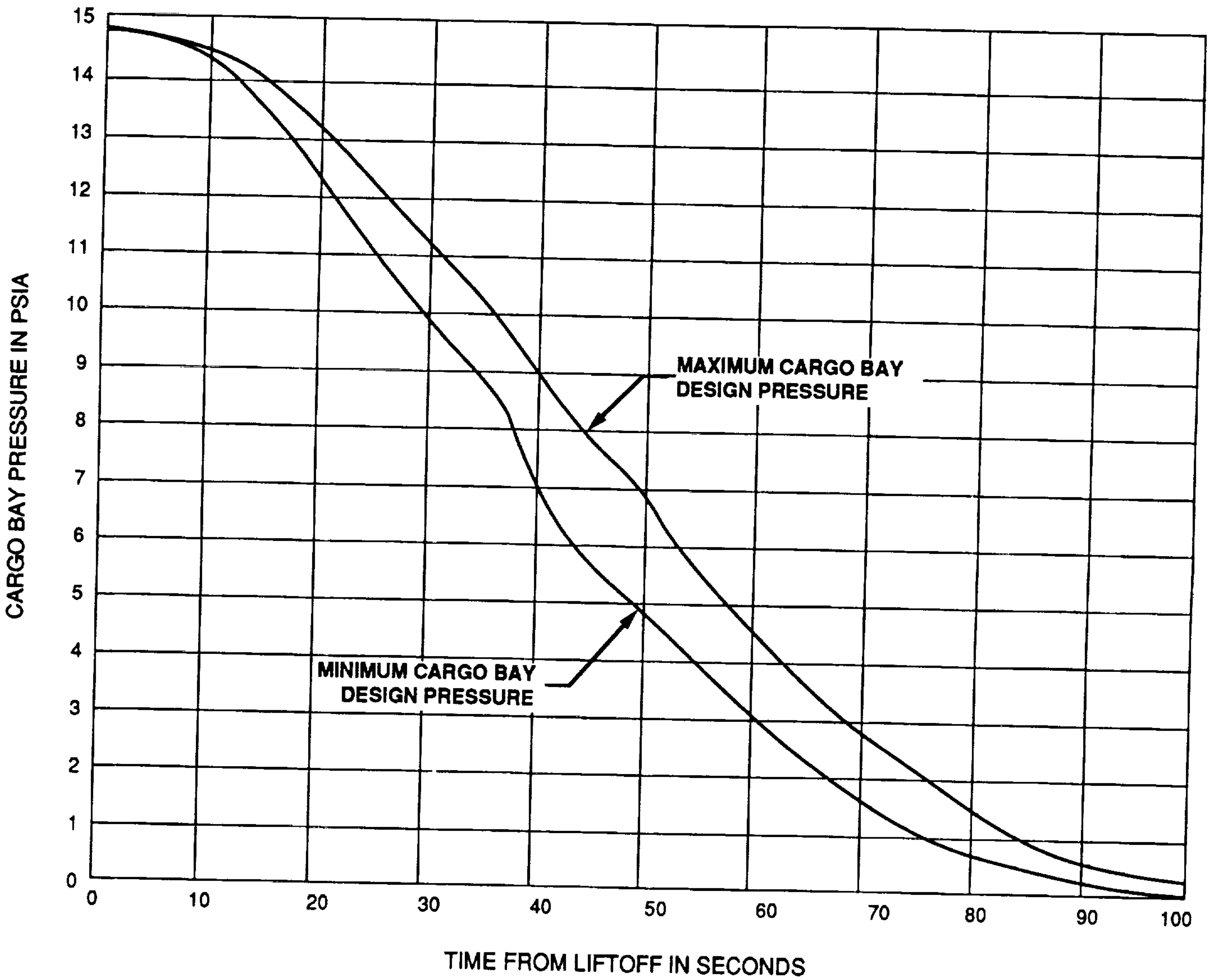


Figure 3.1

MAXIMUM CARGO BAY PRESSURE DECAY RATE DURING ASCENT

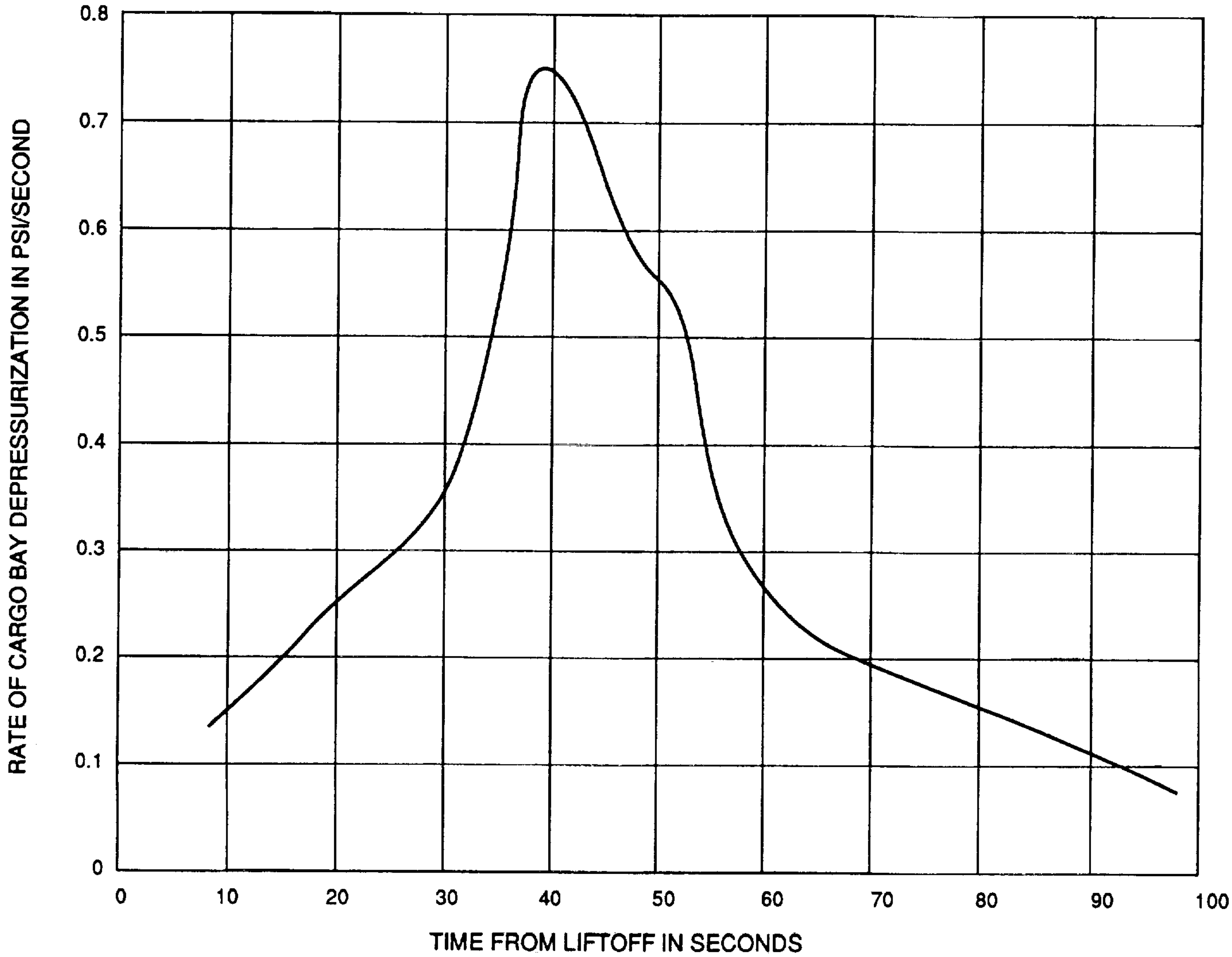
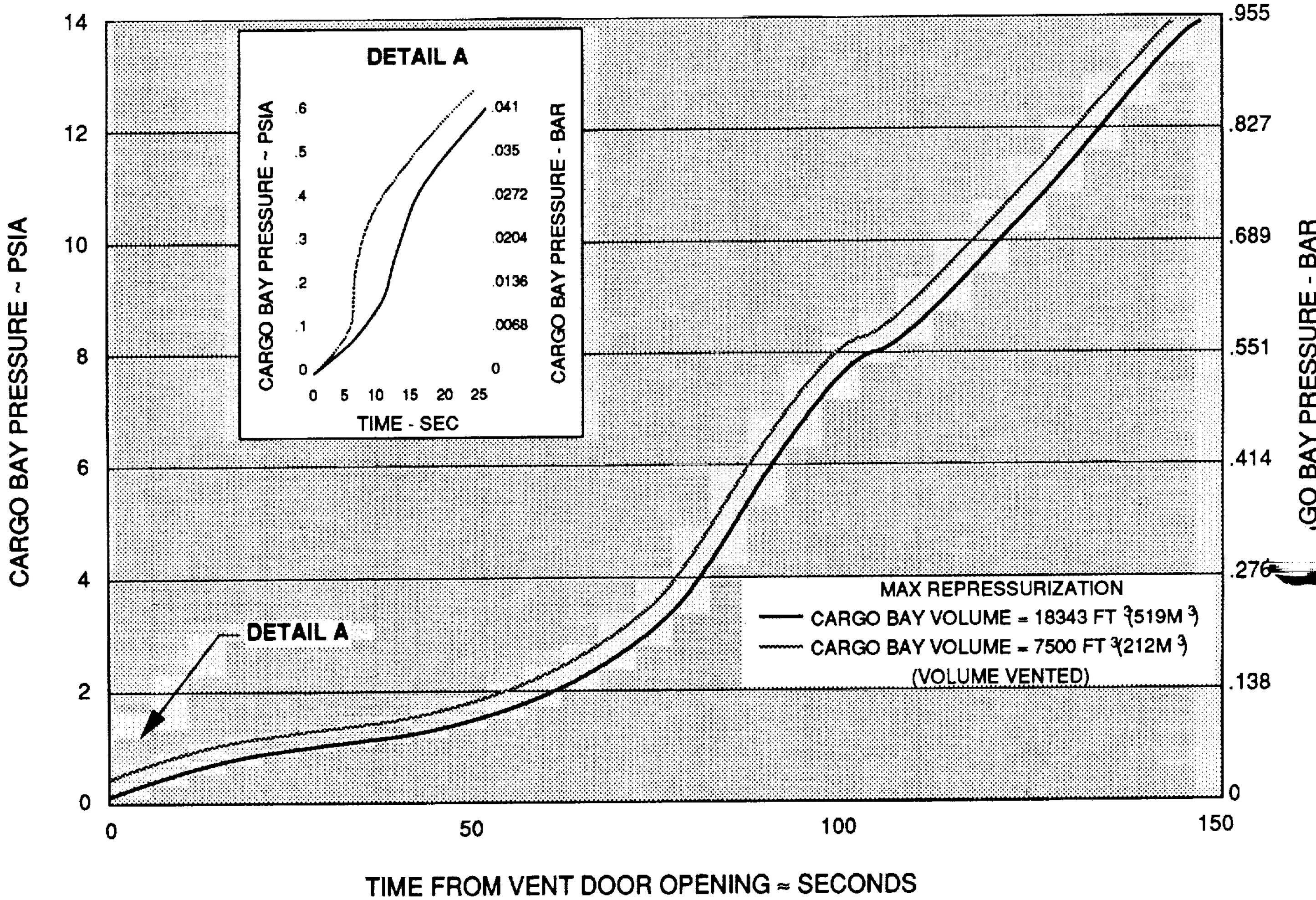


Figure 3.2

MAXIMUM CARGO BAY ENTRY REPRESSURIZATION RATE



(NASA /JSC PSEUDO TRAJECTORY, MAXIMUM
DYNAMIC PRESSURE (375/450) ~ PSF)

ENTRY PHASE CARGO BAY INTERNAL PRESSURE VALUES, TO BE USED FOR PAYLOAD DESIGN

Figure 3.3

3.1.1.6 Electrical Responsibilities

a. Certify that the requirements presented in ICD-2-19001, Section 7.2 and 10.7, pertaining to EMI control have been met. Payloads will be subjected to high levels of radiation from the Orbiter transmitter and must not interfere with the Orbiter or other payloads. Experiments will also undergo conducted and radiated susceptibility tests and transient tests, per Reference #8 in Appendix J.

b. Interfacing Circuits Schematic

c. Power Distribution Schematic showing compliance with requirements for fusing and wire size.

3.1.1.7 Thermal Responsibilities. The customer must provide required thermal analysis, design data, descriptions of all surface coatings and insulation, and a thermal math model of the payload. The customer design is to provide heaters, thermostats, blankets, and coatings to maintain the payload temperature within the required range.

3.1.1.8 Materials and Safety Responsibilities.

a. Submit a list of all materials (see Appendix B) used in the payload design to confirm the absence of hazardous agents or materials with poor structure, outgassing, and contamination characteristics.

b. Certify that the requirements of NSTS 1700.7B have been satisfied. Control of any items of a hazardous nature must be demonstrated, documented, and reviewed (pressure vessels, explosive devices, radioactive sources, exposed high temperature or high voltage, electromagnetic radiation, moving parts, any other personnel or equipment hazard.

3.1.2 CUSTOMER PRE-MISSION RESPONSIBILITIES

The customer is required to meet the following responsibilities during the Pre-Mission Phase.

a. Provide all required testing procedures and documentation to demonstrate compliance with the Space Shuttle safety requirements as described in this document (Appendix A and elsewhere). Confirm proper operation of the customer thermal, mechanical, and electrical systems. Provide documentation and analysis of such tests already conducted by the customer.

b. Provide all necessary thermal coatings, blankets, inter-element cables, plus handling and shipping equipment.

c. Provide electrical ground support equipment for generating commands and providing necessary real-time data displays. This requirement is waived if the customer has minimal command/data requirements.

d. Provide all operational plans, procedures, equipment, and personnel for operating the customer payload and supporting GSFC test and operations staff during pre-flight testing and simulations.

e. Provide transportation as required of all customer equipment and personnel to the KSC or other locations for integration of the customer's payload into the Orbiter and to the GSFC for all system reviews and simulations.

f. Provide personnel support to NASA at the location designated to integrate the customer equipment to the Orbiter.

g. Provide support to NASA in systems testing to confirm proper operation of the integrated payload and the absence of interference between customer payloads.

h. Provide all Mechanical Ground Support Equipment (MGSE) required to ship flight and non-flight hardware to GSFC, KSC, or other locations for HH integration.

i. Provide personnel to support a mechanical receiving inspection and verification that all customer provided flight hardware conforms to the specifications agreed upon in the mission unique Mechanical Interface Control Drawing (MICD).

j. Provide all MGSE, personnel and procedures required to handle flight equipment for mechanical integration to the HH system. Customer supplied MGSE, lift slings and fixtures, shall be proof loaded prior to use to a minimum of 2.0 times the rated working load. Written, dated, and signed test reports shall be provided, and if a hazard is identified, the condition shall be corrected prior to further use. These reports shall be supplied to the HH Project for approval. Following the load test, all ground handling equipment shall have a tag permanently affixed identifying the equipment, stating the rated capacity, the next scheduled load test due date, and a quality control indication assuring that the above information is correct. After this certification the MGSE shall not be disassembled or used for any other purpose.

k. Provide all necessary plans, personnel, and equipment required to support payload servicing and closeout operations at the Orbiter Processing Facility (OPF) and the pad if required.

l. Provide all requirements for space, power and air conditioning for the CGSE as well as electrical interface requirements.

3.1.3 MISSION OPERATIONS RESPONSIBILITIES

The customer is responsible for providing all operations plans, procedures, and personnel for operating the customer payload and ground support equipment as well as supporting the GSFC operations staff during all mission activities.

3.1.4 POST-MISSION RESPONSIBILITIES

The customer is responsible for providing planning, material, and personnel support to NASA at the locations designated to "safe" the payload, remove the customer equipment from the Orbiter, and, subsequently, deintegrate from the HH system.

3.2 HH AND/OR SPACE SHUTTLE ORGANIZATIONAL RESPONSIBILITIES

The joint responsibilities of the HH Project and the JSC Space Shuttle Program Office (SSPO), and those that are solely of the Shuttle, are described as follows. These responsibilities roughly parallel the mission development from planning to post-mission operations. NASA will:

a. Provide services and interfaces as agreed in the approved CPR document.

b. Provide standard HH carrier and ground equipment as defined in this document including flight interface cables and customer interface connectors (customer to carrier). (The customer will provide unique box-to-box cables.)

c. Provide integration (with customer support) of the customer equipment to the HH carrier.

d. Develop all necessary integrated documentation, plans, procedures, and software.

e. Conduct systems testing (with customer support) to confirm proper operation of all integrated payloads and the absence of interference between customers.

f. Conduct EMI testing of the complete payload to confirm compliance with the Shuttle EMI requirements.

g. Perform integration of the payload into the Orbiter; provide launch, flight, re-entry, and landing of the Orbiter; remove the payload after the mission.

h. Provide mission compatibility analysis to determine the compatibility of customer requirements with the Shuttle and HH capabilities and with the other customer payloads and non-HH mixed cargo payloads on the same mission.

i. Provide mission management to control and decide multi-payload issues such as safety-related issues and the resolution of conflicts for mission resources between payloads.

j. Provide computer-compatible tapes of the customer low-rate data and standard orbit, attitude, and ancillary data for test purposes and for flight-acquired data.

k. Provide computer compatible tapes of customer medium-rate data and standard orbit, attitude, and ancillary data for test purposes and for flight-acquired data. See Appendix C for details of data products formats.

3.3 GSFC RESPONSIBILITIES

The HH Project Office at the GSFC is solely responsible for the following activities in the development and operations of an HH mission. The office will:

a. Act as NASA's single point of contact for all customers participating in the HH Program.

b. Provide all integrated payload documentation.

c. Provide the customer with the outline for the HH CPR document and conduct review and approval of the document.

d. Provide the thermal fluxes and thermal descriptions of the areas near the customer payload. For canister customers, provide external insulation on the sides and bottom of canister if required. Provide thermal models, insulation, and heater system for plates.

e. Provide the customer with connectors that are to be used on the customer side of the electrical/signal interface.

f. Conduct tests on the integrated payload to confirm compliance with EMI requirements.

g. Provide customer facilities at GSFC as described in Appendix D. Some data services are optional extra cost services for reimbursable customers.

3.4 PAYLOAD REQUIREMENTS DOCUMENTATION

As indicated in subsection 2.3, the customer is required to prepare a CPR document and present it to GSFC for approval. The HH Project Office will provide an outline of this document to the customer for use in the preparation of the document. The document will address the following areas:

a. Mechanical Interface Definition
b. Thermal Interface Definition
c. Electrical Systems Requirements
d. Operations Requirements
e. Safety Data Package
f. Ground Handling Requirements and Procedures
g. Materials List

3.5 HH MANIFESTING SCENARIO

A list of the steps that occur during the development of the customer's payload for flight as a HH mission follows:

a. The customer studies this Customer Accommodations and Requirements Specifications (CARS) document to determine if suitable accommodations are possible on HH carriers.

b. The customer prepares the CPR document (see outline in Appendix E) specifying desired accommodations and services and submits CPR to GSFC for review.

c. The customer consults with GSFC concerning acceptability of requirements.

d. The customer's organization submits Form 1628 -- Request for Flight (see Figures 1.1 and 1.1a) through the appropriate NASA Headquarters discipline office (see Table 3.7) to the NASA Office of Space Flight, Customer Services Division. Form 1628 requests accommodation on a HH-G or HH-M carrier and specifies the weight of the customer's equipment. Customer submits deposit if reimbursable.

TABLE 3.7

NASA HEADQUARTERS SECONDARY PAYLOAD DISCIPLINE OFFICES

Discipline Office	Office Code
NASA-Sponsored Payloads:	
Space Science	S
Shuttle Advanced Technology	MD
Space Technology	RS
Commercialization	CC
Space Station Technology	MS
Discipline Office	Office Code
Reimbursable Payloads	
USA Domestic	CC[1]
Foreign	XI[1]
DOD	MC[2]

1) Reimbursable customers should contact Code MC for pricing.
2) DOD Customers should contact USAF Space Systems Division USAF/SSD/CLP.

e. The customer discusses manifesting requirements with the discipline office official responsible for developing the discipline office secondary payload priority list and arranges to be included in the priority list at a satisfactory priority. These lists are updated periodically, so the customer needs to ensure that adverse changes in priority do not occur subsequent to the initial list.

f. The customer visits GSFC for a payload accommodation conference and detailed discussions of requirements and interfaces. GSFC approves requirements document.

g. The customer prepares and submits phase 0/1 safety data package.

h. JSC and GSFC, with customer support, perform phase 0/1 safety review.

i. GSFC and NASA Headquarters determine which customer payloads should be combined on a single HH carrier. HH-G customer equipment may be carried on a HH-M carrier if acceptable to customer and of benefit to NASA. GSFC prepares a summary payload description. GSFC and JSC begin preparation of the integrated payload documentation.

j. NASA Headquarters, JSC, GSFC, and the discipline offices assign the payload to a Space Shuttle flight based on the Summary Payload Description requirement.

k. Customer submits Phase 2 Safety Package. GSFC submits integrated payload Phase 2 Safety Packages including all customer data and applicable carrier data. JSC, KSC, GSFC, and the Customer perform payload Phase 2 flight and ground handling safety reviews.

l. Customer delivers flight hardware, Phase 3 safety data. GSFC performs customer equipment-to-carrier integration and testing. GSFC submits data for Phase 3 safety reviews. Phase 3 reviews conducted.

m. Payload is delivered to launch site, post-ship checks and servicing performed. Customer signs safety certificate.

n. Payload integrated into Orbiter, integration test performed, Shuttle is launched, flown, landed, deintegrated. Customer equipment returned to customer.

o. Customer data products sent to customer.

3.6 OPERATIONS OVERVIEW

The timeline presented in Figure 3.4 outlines the implementation process for payload development. HH customer payloads will be delivered to GSFC where they will be electrically and mechanically integrated into the carrier. System checks and EMI tests will then be performed using CGSE and personnel. Following these activities, the integrated payload will be shipped to the launch site where it will be unpacked, inspected, and integrated into the Shuttle Orbiter in the OPF or on the launch pad. Protective covers will be removed and an Orbiter Integration Test (OIT) will be performed by Launch Site personnel with assistance from the HH and customer organization teams. The OIT is intended only to verify Orbiter interfaces and will be supported by a subset of the carrier ground equipment. Some remote transmission of customer data to GSFC may be possible depending on requirements.

The Orbiter will then be transported to the Vehicle Assembly Building (VAB) where the Orbiter is mated to the liquid and solid fuel rockets. Then the Orbiter is taken to the launch pad. Final countdown tests will be performed with generally no testing or access to the HH.

Once on orbit, the payload bay doors will be opened and flight operations activities will begin. Typical cargos will include one or more spacecraft to be launched into higher orbit using a Payload Assist Module (PAM) or similar upper stage rocket booster. Up to four primary payloads can be accommodated in addition to the HH. If all four are flown, the HH will be sharing power with one of the primary payloads and available power for HH operations may, therefore, be limited during portions of the flight. Many communications spacecraft cannot stand operation of the Ku band transmitter because of the presence of sensitive receivers; therefore, use of the Ku band system is restricted until such spacecraft have been launched.

Orbiter attitudes during a flight may contain more than 30 minutes of bay-to-sun attitude at a time, up to one hour of bay-to-space at a time, and indefinite periods in bay-to-Earth or Passive Thermal Control (PTC - - slowly rotating along the axis perpendicular to sun line). HH payloads must be designed to withstand at least these minimum thermal attitude requirements which might be increased on any given flight depending on HH or other payload observing requirements.

MILESTONE SCHEDULE FOR HITCHHIKER PAYLOADS

STANDARD SERVICES	DATE TO BE COMPLETED
CUSTOMER ORGANIZATION SUBMITS FORM 1628	L-24 MONTHS
CUSTOMER SUBMITS CPR TO GSFC/SSPP	L-24 MONTHS
CUSTOMER ACCOMMODATION MEETING AT GSFC	L-23 MONTHS
CUSTOMER SUBMITS PRELIMINARY SAFETY DATA AND STRUCTURAL INTEGRITY VERIFICATION PLAN	L-20 MONTHS
CUSTOMER SUBMITS STRUCTURAL INTEGRITY VERIFICATION REPORT	L-13 MONTHS
CUSTOMER SUBMITS FINAL SAFETY DATA	L-6 MONTHS
CUSTOMER HARDWARE DELIVERED TO GSFC	L-6 MONTHS
CUSTOMER/CARRIER INTEGRATION COMPLETED	L-4 MONTHS
HITCHHIKER PAYLOAD SHIPPED TO LAUNCH SITE	L-3 MONTHS
HITCHHIKER PAYLOAD INSTALLED IN ORBITER	L-2 MONTHS
LAUNCH	L-0 DAYS
CUSTOMER EQUIPMENT RETURNED	L+1 MONTH

FIGURE 3.4

Following or in-between, primary cargo operations attitude maneuvers may be scheduled in support of HH observations. These maneuvers must not result in any impact to flight planning such as requiring excessive crew activity or use of propellants; in addition, they must not violate the constraints of any primary cargo. In general, a relatively small number of maneuvers consuming a relatively small amount of total time (hours) within the previously described thermal attitudes will probably be acceptable.

The Orbiter attitude control system employs vernier thrusters operating in a "bang-bang" mode around a deadband which can be as small as +/- six arc minutes (+/- .1 degree). Additional errors can be introduced by misalignment between the payload and the Orbiter reference frame and by drift in the gyro system. The gyro system is updated approximately twice a day by use of Orbiter star trackers. These updates require the Orbiter to point at the chosen star for several minutes. Attitude maneuvers are generally performed by means of crew inputs to the Digital Autopilot (DAP) which can be with reference to Aries mean of 1950 (A50), True Of Date (TOD), or Local Vertical/Local Horizontal (LVLH). The DAP can also be used to scan the Orbiter pointing reference at rates of as little as .008 degrees per minute.

During on-orbit operations, CGSE may be used to send commands to the customer payload as well as display customer data for use of the customer. Attitude, orbit position and ancillary data will be available in real time for use by CGSE as well as via NASA-provided displays.

The doors will generally be closed several hours prior to reentry. Following landing at KSC or Edwards Air Force Base (EAFB), cooling air will be provided within about 15 minutes. Considerable temperature rise in the ambient air still occurs during the landing process. If landing occurs at a location other than KSC (which occurs frequently), the Orbiter is carried by ferry aircraft to KSC for deintegration. Minimal, if any, access is possible at the initial landing site. Following return of the Orbiter to the KSC OPF, the payload will be removed and shipped to GSFC for deintegration. All data products should be available within 30 days of landing.

In preparing for the flight operations, each customer will need to develop a plan describing operations of his payload as a function of MET during the flight. In connection with this he/she will eventually develop a computer file in a format to be specified by GSFC. This file will contain at least the payload's power and energy requirements, required relationship of any operations to orbit position, targets, day/night, crew activity, attitude, etc. and will be used to generate a MET sequenced data base of trajectory driven parameters as shown in Figure 3.5.

Hitchhiker Operations Data Base

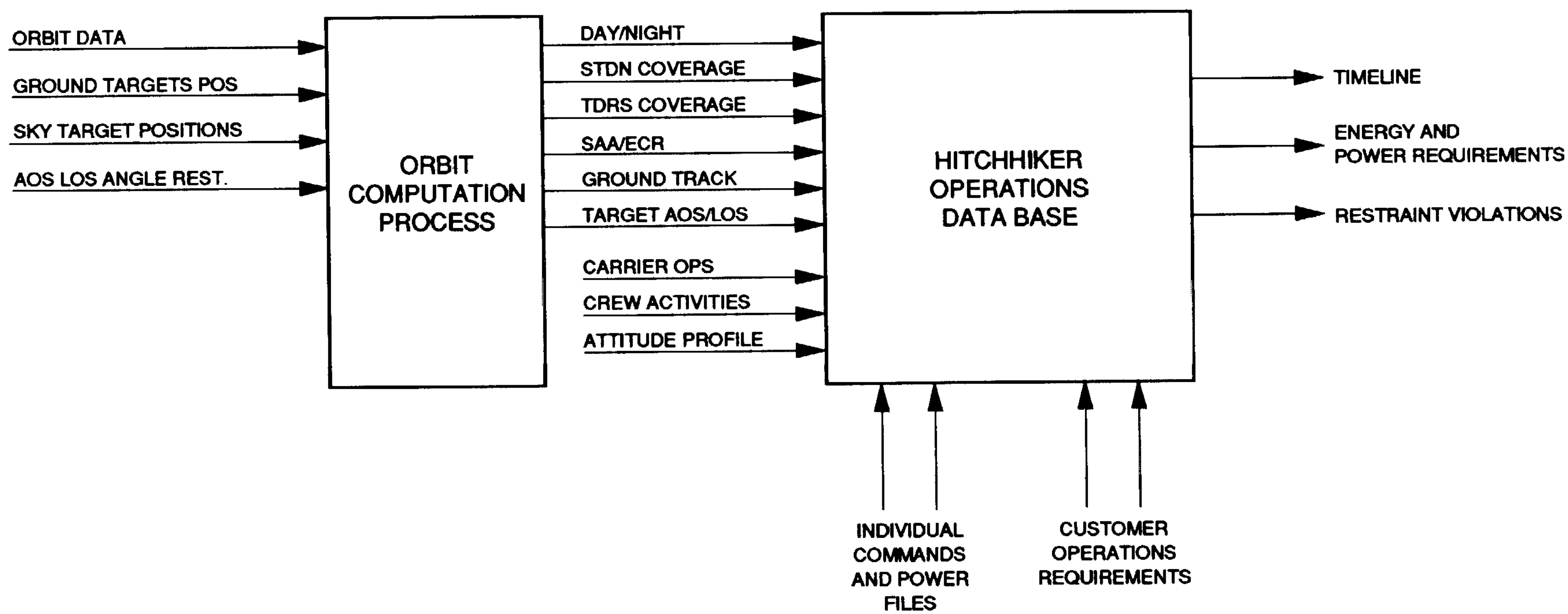


Figure 3.5

Additional files defining the predicted attitude profile, crew activities, and carrier operations will be generated and finally merged with the customer files to produce the HH Timeline which will be available as a printout and also for access by computer terminal prior to and during the flight. The timeline will be used by customer, HH and JSC operations staff to execute the mission operations. The data base also allows generation of the HH mission power and energy profile which is used by JSC to develop the complete Orbiter power, energy, and consumable (fuel cell hydrogen/oxygen) predictions. The timeline also defines HH requirements for medium-rate telemetry, command activity, unique attitude requirements, unique restraints on Orbiter operations (such as water dumps), or other requirements on crew or other payload operations. During the flight, the data base may be updated to accommodate contingency replanning and actual trajectory.

APPENDIX-A

APPENDIX A
PAYLOAD SAFETY REQUIREMENTS

1. OVERVIEW

All payloads using the STS must meet certain design and operational requirements prior to being considered "safe". Payloads must not be capable of generating or sustaining any failure mode that will result in a hazard to the flight and ground personnel, the STS, GSE, and other payloads. A hazard is defined as the present of a potential risk situation caused by an unsafe act or condition that could disable or cause damage to the Orbiter, its crew, ground processing facilities or personnel during pre- and post- launch activities. Basic requirements for payload safe design and operation are provided for in the following NASA documents:

NSTS 1700.7B (or current issue*) - Safety Policy Requirements for Payloads Using the Space Transportation System (STS), January 1989.

SAMTO HB S-100, KHB 1700.7 Revision A (or current issue*) - Space Transportation System Payload Ground Safety Handbook.

All payloads must comply with the guidelines set in these documents.

This section summarizes information from NSTS 1700.7B to aide the customer in understanding the requirements and guidelines that must be followed in order to obtain safety certification for their payload. This section is not a substitute for NSTS 1700.7B which takes precedence and must be adhered to by the customer for their payload. KHB 1700.7, Revision A, is the governing document for the GSE and ground operations.

* Current issue includes all future changes and revisions.

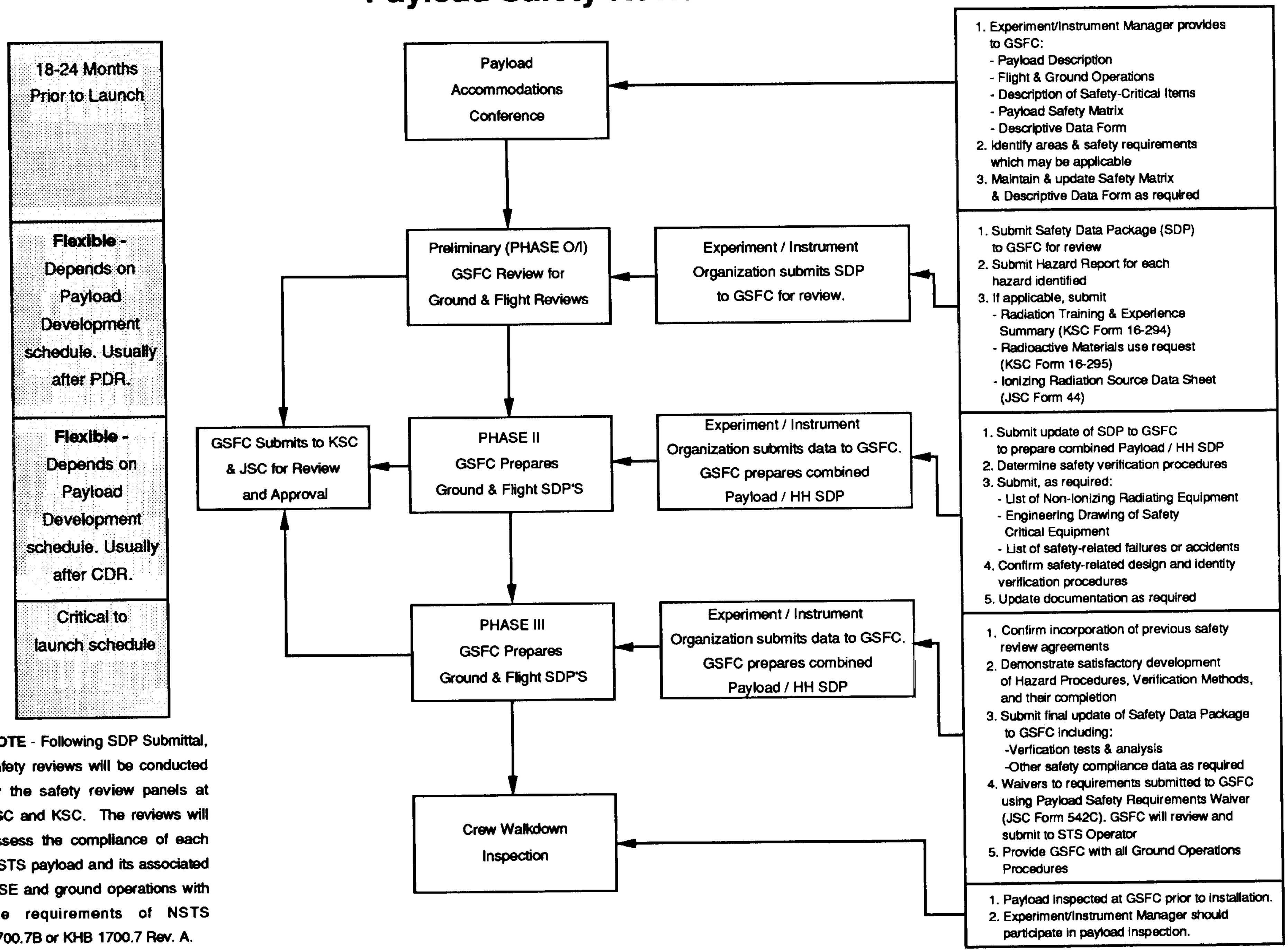
2. RESPONSIBILITIES

A customer representative should be designated as the technical point of contact between GSFC and the customer. This representative is called the Payload Manager. The Payload Manager is responsible for assuring the safety of his payload and to implement the requirements of NSTS 1700.7B and KHB 1700.7, Revision A. GSFC, acting as the responsible "payload organization," interfaces with the NSTS on behalf of the group of individual payload elements or experiments under its control. GSFC will assign a Mission Manager who will be the single technical point of contact for GSFC and interface with the Payload Manager. The HH Project Safety Manager will support the NASA Mission Manager in the safety review process.

3. SAFETY REVIEW PROCESS

The safety review process between the customer, GSFC, and the STS begins 18-24 months prior to launch with the development of safety-related information as part of the Payload Accommodations Conference. The review process culminates just prior to launch with the Final Safety Inspection. Aspects of safety-related issues extend into flight operations as well. Figure A.1 represents an overview of the safety review process.

Payload Safety Review Process



NOTE - Following SDP Submittal, safety reviews will be conducted by the safety review panels at JSC and KSC. The reviews will assess the compliance of each NSTS payload and its associated GSE and ground operations with the requirements of NSTS 1700.7B or KHB 1700.7 Rev. A.

Figure A.1

4. PAYLOAD HAZARD ANALYSIS

A hazard analysis is the technique used to systematically identify, evaluate and resolve hazards. Typically, such analyses assess the entire system and its interfaces. Results of the hazard analysis leads to one or more of the following:

- Improved payload safety design,
- Development of controls to mitigate hazards,
- Establishment of acceptable risk levels.

There may be many factors contributing to a hazard, however, there are basic hazard groups that are applicable to HH payloads. Those hazard groups and representative examples of their causes and effects are summarized in Table A.1. Figure A.2 provides an overview of the hazard analysis process.

TABLE A.1

BASIC HAZARD GROUPS, CAUSES, AND EFFECTS

HAZARD TYPE	DEFINITION	POSSIBLE CAUSE	POSSIBLE EFFECT
COLLISION	PAYLOADS AND/ OR ELEMENTS BREAK LOOSE AND IMPACT STRUCTURES, OTHER PAYLOADS, OR GROUND PERSONNEL	STRUCTURAL FAILURE PROCEDURAL ERROR, INADEQUATE GROUND HANDLING EQUIPMENT	PENETRATION OF PAYLOAD, PERSONNEL INJURY
CONTAMINATION	RELEASE OR ACCUMULATION OF PARTICULAR MATTER OR THE PLACEMENT OF THE WRONG MATERIAL IN A CONTAINER	LEAKAGE, SPILLAGE, OUTGASSING, ABRASION, IMPROPER CLEANLINESS PROCEDURES, INAPPROPRIATE MATERIALS USAGE	DEGRADED ATMOSPHERE OR EQUIPMENT OPERATION, PERSONNEL INJURY
CORROSION	STRUCTURAL DEGRADATION OF METALLIC AND NON-METALLIC EQUIPMENT	LEAKAGE, MATERIAL INCOMPATIBILITY, ENVIRONMENTAL EXTREMES, SHORT CIRCUITS	MECHANICAL FAILURES, PREMATURE WEAR, SEIZURE
ELECTRICAL SHOCK	ELECTRICAL CURRENT PASSING THROUGH ANY PORTION OF THE BODY	HUMAN ERROR, PROCEDURAL ERROR, EQUIP. FAILURE STATIC DISCHARGE, SHORT CIRCUIT	PERSONNEL INJURY
EXPLOSION	VIOLENT RELEASE OF ENERGY DUE TO OVERPRESSURI-ZATION	SUSCEPTIBLE EQUIP., BATTERIES, PUMPS, MOTORS, BLOWERS, GENERATORS, LASERS, ETC.	PAYLOAD DAMAGE, PERSONNEL INJURY
FIRE	RAPID OXIDATION OF PAYLOAD ELE-MENT COMBUSTIBLES FLAMMABILITY OF MATERIALS	FUEL AND OXIDIZER EXPOSED TO IGNI-TION SOURCE	PAYLOAD DAMAGE, PERSONNEL INJURY

TABLE A.1 (Cont'd)

RADIATION	EXPOSURE (HUMAN OR EQUIP.) TO: IONIZING RADIA-TION, UV OR IR LIGHT, LASERS, ELECTROMAGNETIC OR RF-GENERATING EQUIPMENT	LEAKY OR INADEQUATE SHIELDING	DEGRADED OR DAMAGED PAYLOAD OR EQUIP. PERSONNEL INJURY
TEMPERATURE EXTREMES	EXPOSURE TO ABNORMAL TEMP. EXTREMES (HOT OR COLD)	INSULATION BREAK-DOWN, SHORT CIR-CUITS, SEAL LEAKS PLUMBING FAILURES PROCEDURAL ERROR, HUMAN ERROR	DEGRADED OR DAMAGED PAYLOAD OR EQUIPMENT, PERSONNELINJURY
INJURY AND ILLNESS	PAYLOADS BREAK LOOSE AND IMPACT GROUND PERSONNEL AND RELEASE OF TOXIC MATERIALS	PROCEDURAL ERROR, INADEQUATE GROUND HANDLING EQUIPMENT LEAKAGE OR SPILLAGE OF TOXIC MATERIALS	PERSONNEL INJURY, PAYLOAD PENETRATION DEGRADED ATMOSPHERE OR EQUIPMENT OPERATION

Hazard Analysis Process

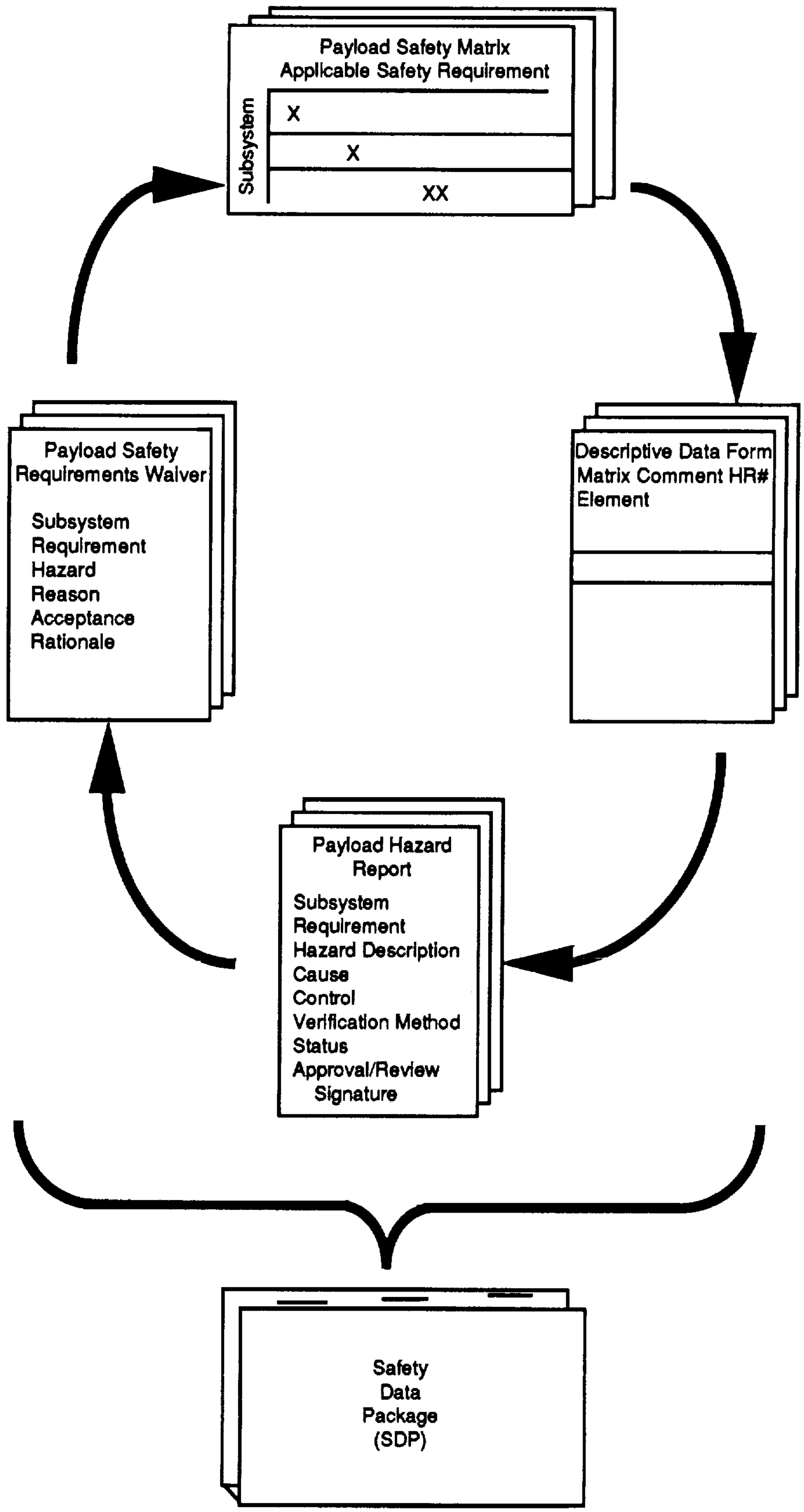


Figure A.2

4.1 PAYLOAD SAFETY MATRIX

The initial version of the Payload Safety Requirements Applicability Matrix is required early in the safety review cycle and should be kept up to date throughout the development process. This form and the Payload Ground Safety Requirements Applicability Matrix documents are used to foresee and assess interrelationships between the basic hazard groups and subsystems contained in the payload. Examples of these forms are presented in Figures A.3 and A.5.

NSTS PAYLOAD SAFETY REQUIREMENTS APPLICABILITY MATRIX

PAYLOAD: DATE: PHASE: PAGE___ OF___

NHB 1700.7B REQUIREMENTS

GENERAL REQUIREMENTS

NHB 1700.7B REQUIREMENTS	200 GENERAL	201 HAZARDOUS FUNCTIONS	203 RETRIEVAL OF PAYLOAD	204 HAZARD DETECTION/SAFING	205 CONT. RETURN/RAPID SAFING	206 FAILURE PROPAGATION	207 REDUNDANCY SEPARATION	211 DESTRUCT SYSTEMS	213.3 LIGHTING	214 VERIFICATION	215 HAZARDOUS OPERATIONS	216 SERIES PAYLOAD	216 REFLOWN HARDWARE	217 PLANNED EVA	218 PAYLOAD COMMANDING	220 CREW HABITABLE
PAYLOAD APPLICABILITY	X	X			X	X	X			X						

SPECIFIC PAYLOAD HAZARDS

202.1 SOLID PROPELLANT	202.2 LIQUID PROPELLANT	202.3 DEPLOYMENT/JETTISON	202.4 PLANNED EXTENSION	202.5 RF RADIATION	208.1, 2, & 3 STRUCTURES	208.4 PRESSURE SYSTEMS	208.5 SEALED COMPARTMENTS	209.1 HAZARDOUS MATERIALS	209.2 FLAMMABLE MATERIALS	209.3 OFFGASSING MATERIALS	210 PYROTECHNICS	212.1 IONIZING RADIATION	212.2 NONIONIZING RADIATION	212.3 LASERS	213 ELECTRICAL SYSTEMS	213.2 BATTERIES	219 FLAMMABLE ATMOSPHERES
HAZARD REPORT REFERENCE NUMBER																	

PAYLOAD ELEMENT OR SYSTEM

	IMPLEMENTATION PERSONNEL	DATE	PAYLOAD ORGANIZATION PERSONNEL	DATE
PREPARED BY:				
REVIEWED BY:				
APPROVED BY:				

JSC Form 1090 (Rev Jul 89) Previous Editions Are Obsolete

Figure A.3 Payload Safety Matrix A-9

NSTS PAYLOAD SAFETY REQUIREMENTS APPLICABILITY DESCRIPTIVE DATA			PAGE____OF____
PAYLOAD:			DATE:
			PHASE
MATRIX ELEMENT REFERENCE NO.	HAZARD REPORT NUMBER	HAZARD TITLE	

JSC Form 1090A (Rev Oct 88) Previous Editions Are Obsolete

Figure A.4 NSTS Payload Safety Requirements Applicability Descriptive Data Form

4.2 DESCRIPTIVE DATA FORM

Similar to the Payload Safety Matrix, the Payload Safety Requirements Applicability Descriptive Data Forms are required early in the safety cycle and must be continually updated. These forms (Figure A.4 and A.6) are completed for each subsystem having a "X" in any corresponding hazard group box on the Payload Safety Matrix. The Descriptive Data Forms provide a listing of the hazard groups applicable to each subsystem and cross-references each hazard to the applicable technical requirement from NSTS 1700.7B and KHB 1700.7, Revision A. Upon completion of the Payload Safety Matrix and the Descriptive Data Form, the customer has a comprehensive list of all the payload safety hazard issues that must be addressed in order for the payload to be granted safety certification.

STS PAYLOAD GROUND SAFETY REQUIREMENTS
APPLICABILITY MATRIX

DATE: ____________

1. PAYLOAD:	2. PAYLOAD ORGANIZATION:
3. PHASE:	4. PAGE OF

6. KHB 1700.7 REQUIREMENTS — PAYLOAD AND GSE

5. PAYLOAD AND GSE ELEMENTS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG	7. SAFETY ANALYSIS BY: (NAME, ORG, INITIAL)
	4.1.2.1 TRAINING	4.1.2.2 CERTIFICATION	4.1.2.3 PHYSICAL EXAM	4.1.3 HAZARDOUS OP-TOP REQ'D.	4.1.4 SAFETY INSPECTION REQ'D.	4.1.5 SAFETY EQUIPMENT REQ'D.	4.1.6 TOOLS	4.1.7 PHOTOGRAPHY	4.2.1 HUMAN FACTORS	4.3.1 BIOMEDICAL	4.3.2 ELECTRICAL	4.3.3 PRESSURE/VACUUM	4.3.4 RADIATION	4.3.5 ORDNANCE	4.3.6 MECH/ELECTROMECH.	4.3.7 PROPELLANTS	4.3.8 CRYOGENICS	4.3.9 MATERIALS	4.4.1 METEOROLOGICAL	4.4.2 HAZARDOUS ATMOSPHERE	4.5.1 HOISTING & HANDLING	4.5.2 TRANSPORTERS												

8. LEGEND:

- NOT APPLICABLE
- APPLICABLE: NO HAZARD IDENTIFIED
- APPLICABLE: HAZARD IDENTIFIED
- WAIVER REQUIRED

9.	IMPLEMENTATION PERSONNEL	DATE	PAYLOAD ORGANIZATION PERSONNEL	DATE
PREPARED BY:				
REVIEWED BY:				
APPROVED BY				

GSFC-302-SS-04A (4/83)

(SEE INSTRUCTIONS ON REVERSE SIDE OF GSFC-302-SS-078)

Figure A.5

10. STS PAYLOAD SAFETY REQUIREMENTS APPLICABILITY DESCRIPTIVE DATA

MATRIX ELEMENT	COMMENTS	H/R #

GSFC-302-SS-02B (2/83)

Figure A.6 STS Payload Safety Requirements Applicability Descriptive Data

4.3 PAYLOAD HAZARD REPORT

Following the completion of the safety analysis and identification of potential hazards, a Payload Hazard Report must be completed. This report is to be completed for each hazard identified on the Descriptive Data Form. Each hazard report should stand alone. Data required to understand the hazard, the hazard controls, and safety verification methods should be attached to the report. When functional diagrams are supplied, the pertinent information shall be clearly identified, (e.g., controls, inhibits, monitors, etc.).

Information for Phase II and Phase III Hazard Reports, is to be submitted to the HH Safety Manager. This data is included in a Payload/HH combined SDP.

The hazard report is used to track hazards identified throughout the lifecycle of the payload. It contains NASA review and approval signatures, acknowledging the possibility of hazard occurring, and the result rationale that has been reviewed in accordance with NASA standards. Figure A.7 represents the Payload Hazard Report.

PAYLOAD HAZARD REPORT		No.
PAYLOAD		PHASE
SUBSYSTEM	HAZARD GROUP	DATE
HAZARD TITLE		

APPLICABLE SAFETY REQUIREMENTS	HAZARD CATEGORY	
		Catastrophic
		Critical

DESCRIPTION OF HAZARD
HAZARD CAUSES
HAZARD CONTROLS
SAFETY VERIFICATION METHODS
STATUS OF VERIFICATION

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III		

JSC Form 542B (Rev Nov 82) NASA-JSC

Figure A.7 Payload Hazard Report

4.4 PAYLOAD SAFETY NONCOMPLIANCE REPORT (WAIVER)

A waiver request form (as shown in Figure A.8) must be submitted for noncompliance. This request will be returned to GSFC for review in such cases when safety requirements cannot be met. The Mission Manager will negotiate with the STS on behalf of the customer concerning the acceptability of the waiver request. Should the waiver be denied, the customer must meet the requirement through design changes to the payload or run the risk of having the payload denied the opportunity for flight on the STS.

PAYLOAD SAFETY NONCOMPLIANCE REPORT	NO.	DATE

TITLE (Brief reference to noncompliance)

PAYLOAD IDENTIFICATION (Include reference to applicable payload element, subsystem, and/or component)

APPLICABLE REQUIREMENT

DESCRIPTION OF NONCOMPLIANCE (Specify how the design or operation does not meet the safety requirements.)

HAZARD OR HAZARD CAUSE (Include reference to Payload Hazard Report)

REASON REQUIREMENT CANNOT BE FULFILLED

RATIONALE FOR ACCEPTANCE (Define the design feature or procedure used to conclude that the noncompliance condition is safe. Attach applicable support data, i.e. drawings, test reports, analyses, etc.)

APPROVAL SIGNATURES			
PAYLOAD ORGANIZATION			DATE
WAIVER APPROVAL		DEVIATION APPROVAL	
EFFECTIVITY		EFFECTIVITY	
STS OPERATOR	DATE	STS OPERATOR	DATE

JSC Form 542C (Rev Mar 83)

Figure A.8 Payload Safety Noncompliance Report

4.5 ADDITIONAL SAFETY REQUIREMENTS

Depending on the design of the payload and its operating characteristics, the customer may be required to submit the last version of additional forms such as:

a. Radiation Training and Experience Summary
(Figure A.9)
b. Radioactive Materials Use Request
(Figure A.10)
c. Ionizing Radiation Source Data Sheet
(Figure A.11A and A.11B)
d. Training and Experience Summary Non-Ionizing Radiation Users
(KSC Form 16-450) (Figure A.12)
e. Non-Ionizing Radiation Protection Source Questionnaire
(KSC Form 16-453) (Figure A.13)

It is important to address and identify special safety requirements and document them as soon as possible. These requirements may include:

a. Special handling or testing during installation or removal of the payload
b. Special environments during certain mission phases
c. Special flight operations.

RADIATION TRAINING AND EXPERIENCE SUMMARY (IONIZING RADIATION)

Note: (Complete unshaded sections of Form only) (Please type/print legibly, prepare original and one copy)
(Instructions for completion on reverse)

I. GENERAL INFORMATION

NAME/TELEPHONE NUMBER	DATE OF BIRTH	ORGANIZATION/MAILCODE OR ADDRESS	AUTHORIZATION NUMBER

SOCIAL SECURITY NO.	TYPE OF USER	SYSTEM/DEVICE TO BE USED
	☐ AREA RADIATION OFFICER ☐ MAINTENANCE ☐ USER ☐ OTHER ☐ USE SPVR/CUSTODIAN	

II. TRAINING *(Use supplemental sheets as needed)*

TYPE OF TRAINING	WHERE TRAINED	DURATION	ON-THE-JOB	FORMAL COURSE
A. PRINCIPLES AND PRACTICES OF RADIATION PROTECTION			☐ YES ☐ NO	☐ YES ☐ NO
B. RADIOACTIVITY MEASUREMENT STANDARDIZATION AND MONITORING TECHNIQUES AND INSTRUMENTS			☐ YES ☐ NO	☐ YES ☐ NO
C. MATHEMATICS AND CALCULATIONS BASIC TO THE USE AND MEASUREMENT OF RADIOACTIVITY			☐ YES ☐ NO	☐ YES ☐ NO
D. BIOLOGICAL EFFECTS OF RADIATION			☐ YES ☐ NO	☐ YES ☐ NO

III. EXPERIENCE *(Use supplemental sheets as needed)*

A. RADIOACTIVE MATERIALS ☐ YES ☐ NO *(Describe below)*

RADIONUCLIDE	MAXIMUM AMOUNT	LOCATION	TYPE OF USE	DURATION

B. ACCELERATOR OR X-RAY EQUIPMENT ☐ YES ☐ NO *(Describe below)*

TYPE	MAXIMUM ENERGY	LOCATION	TYPE OF USE	DURATION

IV. REFERENCE DOCUMENTS

I HAVE READ AND UNDERSTAND APPLICABLE PORTIONS OF THE FOLLOWING:

KHB 1860.1	☐ YES	☐ NO	
NRC REGULATIONS, 10 CFR 19 AND 20	☐ YES	☐ NO	☐ N/A
KMI 1860.1 *(If applicable)*	☐ YES	☐ NO	☐ N/A
ESMCR 160–1 *(If applicable)*	☐ YES	☐ NO	☐ N/A
FLORIDA REGULATIONS, CHAPTER 10D-56	☐ YES	☐ NO	☐ N/A

SIGNATURE OF APPLICANT ______________ DATE ______

V. AUTHORIZATIONS

HEALTH PHYSICS	DATE	KSC RADIATION PROTECTION OFFICER	DATE
ESMC RADIATION PROTECTION OFFICER *(If applicable)*	DATE	CHMN. KSC RADIATION PROTECTION COMMITTEE	DATE

Figure A.9 Radiation Training and Experience Summary

RADIOACTIVE MATERIAL USE REQUEST

(Prepare in original and four copies)

FROM (NAME) *(Please print)*	OFFICE CODE	DATE	REF. NUMBER *

TO:
KSC RADIATION PROTECTION OFFICER (RPO)
VIA
HEALTH PHYSICS SECTION (OMEHS)

1. RADIOACTIVITY REQUIREMENTS

A. ELEMENT AND ISOTOPE	B. PHYSICAL FORM
C. TOTAL QUANTITY REQUIRED (MC OR UNITS)	D. ESTIMATED ACTIVITY PER EXPERIMENT (MC OR UNITS)

E. WASTE CONCENTRATIONS & AMOUNTS	LIQUID	SOLID

2. TITLE OR BRIEF DESCRIPTION OF PROPOSED PROJECT

3. PROPOSED PROCEDURE (INCLUDING SPECIAL PRECAUTIONS)

		3A. LICENSE NO.	3B. NRC ☐ STATE OF
4. LOCATION OF USE	BUILDING NUMBER	ROOM NUMBER	AREA ZONE NUMBER

5. USERS	6. PERIOD COVERED BY REQUEST FROM ______ TO ______

7. HEALTH PHYSICS EQUIPMENT REQUIREMENTS

ORIGINATOR	SUPERVISOR'S SIGNATURE

APPROVALS

SIGNATURE (OMEHS HEALTH PHYSICS)	DATE
SIGNATURE (KSC RADIATION PROTECTION OFFICER)	DATE
SIGNATURE (CHAIRMAN RSC)	DATE

ORIGINAL – RSC COMMITTEE COPY 2 KSC RPO COPY 1 HEALTH PHYSICS

* *Supplied by Health Physics Section.*

KSC FORM 16-295NS (REV. 5/77)

Figure A.10 Radioactive Material Use Request

IONIZING RADIATION SOURCE DATA SHEET
SPACE FLIGHT HARDWARE AND APPLICATIONS
Lyndon B. Johnson Space Center

Complete Items 1 through 10 and Part A for radioisotope sources and Part B for ionizing radiation-producing equipment.

IDENTIFICATION

1. PAYLOAD DESIGNATION/EXPERIMENT	2. STS NO. AND/OR LAUNCH DATE
3. SOURCE USING ORGANIZATION	4. ADDRESS
5. CONTACT	6. TELEPHONE
7. PAYLOAD SPONSOR/MANAGER	8. ADDRESS
9. CONTACT	10. TELEPHONE

PART A. RADIOISOTOPE SOURCES

I. SOURCE DESCRIPTION

1. ISOTOPE	2. TOTAL QUANTITY (MILLICURIE) *(Include determination date.)*	3. NUMBER OF SOURCES*

4. CHEMICAL FORM	5. PHYSICAL STATE
6. SOURCE SEALED ☐ Yes ☐ No	7. IDENTIFICATION NOS.
8. MANUFACTURER	8. ADDRESS

II. SOURCE USE DATA

1. PURPOSE:
- ☐ EXTERNAL CALIBRATION
- ☐ INFLIGHT CALIBRATION
- ☐ OTHER *(Describe)*
- ☐ CREW INVOLVEMENT/REQUIREMENTS *(Include nominal and contingent situations.)*

III. SOURCE DIAGRAM

DETAILS ON SEALING, TECHNIQUES AND DIMENSIONS:

JSC Form 44 (Rev Oct 81)

*List individual source quantity.

Figure A.11 Ionizing Radiation Source Data Sheet

IV. TEST DATA

1. DATA SOURCE LEAK TESTED	2. RESULTS (MICROCURIE)

3. THERMO-VACUUM QUALIFIED TO:

		DATE
______ MM HG	______ DEGREE C.	

V. PRE-FLIGHT TRANSFERS

1. LOCATIONS WHERE SOURCE IS TO BE USED OR STORED AND APPROXIMATE DATES

A. LOCATIONS	B. DATED FROM	TO

2. SOURCE CUSTODIAN/RADIATION SAFETY OFFICER	TELEPHONE

VI. POST-FLIGHT DISPOSITION

OUTLINE REQUIREMENTS:

PART B. IONIZING RADIATION PRODUCING EQUIPMENT

I. EQUIPMENT CHARACTERISTICS

1. TYPE OF RADIATION PRODUCED:

2. MAXIMUM ENERGY LEVEL	3. OPERATING ENERGY LEVEL
4. DURATION OF OPERATION	5. NO. OF UNITS
______ HOURS TOTAL, ALL UNITS	6. PULSED UNIT DUTY CYCLE

II. RADIATION CHARACTERISTICS

1. RADIATION INTENSITY OF FLIGHT CONFIGURED UNIT	2. SECONDARY RADIATIONS PRODUCED	
	ENERGY LEVEL	TYPE
______ RAD/HR @ ______ METERS	______ KEV	

III. EQUIPMENT USE DATA

1. CREW INVOLVEMENT/PROCEDURES:

2. RADIATION PRODUCTION WARNING SYSTEM:	3. SAFETY INTERLOCK SYSTEM:
☐ Yes *(Describe)* ☐ No	☐ Yes *(Describe)* ☐ No

NASA-JSC

Figure A.11A Ionizing Radiation Source Data Sheet (Cont'd)

TRAINING & EXPERIENCE SUMMARY
NON-IONIZING RADIATION USERS

(PLEASE TYPE/PRINT LEGIBLY)

(NOTE - COMPLETE UNSHADED SECTIONS OF FORM ONLY)

I. GENERAL INFORMATION

A. NAME	B. DATE OF BIRTH	C. ORGANIZATION/MAIL CODE	D. REFERENCE NO.

E. SOC.SEC.NO.	E. TYPE OF USER	F. SYSTEM/DEVICE TO BE USED
	☐ AREA RADIATION OFFICER ☐ MAINTENANCE ☐ OPERATOR ☐ OTHER	

II. TRAINING *(USE SUPPLEMENTAL SHEETS AS NEEDED)*

TYPE OF TRAINING	YES	NO	WHERE TRAINED	DURATION
A. Biological Effects				
B. Radiation Protection				
C. Other				

III. EXPERIENCE *(USE SUPPLEMENTAL SHEETS AS NEEDED)*

TYPE OF EXPERIENCE	LOCATION	DURATION
A.		
B.		
C.		
D.		

IV. REFERENCE DOCUMENTS

I have read and understand the following:

A. KMI 1860.1	☐ Yes	☐ No	
B. KHB 1860.2	☐ Yes	☐ No	
C. 29 CFR 1910.97	☐ Yes	☐ No	
D. ESMC Regulation 160-1 *(If Applicable)*	☐ Yes	☐ No	☐ N/A

Signature of Applicant   Date

V. AUTHORIZATIONS

HEALTH PHYSICS	DATE
KSC RADIATION PROTECTION OFFICER	DATE
ESMC RADIATION PROTECTION OFFICER (IF APPLICABLE)	DATE
CHMN. KSC RADIATION PROTECTION COMMITTEE	DATE

Figure A.12 Training and Experience Summary Non-Ionizing Radiation Users Form

NON-IONIZING RADIATION PROTECTION SOURCE QUESTIONNAIRE

(PLEASE TYPE/PRINT LEGIBLY)

ORIGINATOR	ORG/MAIL CODE	PHONE	DATE
SUPERVISOR	ORG/MAIL CODE	PHONE	DATE

DEVICE/SYSTEM DESCRIPTION

(USE SUPPLEMENTAL SHEETS AS NEEDED)

TYPE

☐ RADIOFREQUENCY/MICROWAVE ☐ LASER/OPTICAL

MANUFACTURER AND YEAR

MODEL AND SERIAL NO.

FREQUENCY/WAVELENGTH

MAX. POWER OUTPUT

PULSE WIDTH

REPETITION FREQ

USE LOCATION(s) SITE(s)

INTENDED USE(s)

ANTENNA DATA	ASSOCIATED OPTICS
TYPE AND QUANTITY	LENSES
DIMENSIONS	FILTERS
GAIN	OTHER

RADIATION PROTECTION CONTROLS EMPLOYED/IDENTIFIED

KSC FORM 16-453 (REV. 4/81)

Figure A.13 Non-Ionizing Radiation Protection Source Questionnaire

5. SAFETY DATA PACKAGE (SDP)

A Flight Safety Data Package (SDP) and a Ground SDP is prepared for each payload. The Flight SDP is limited to payload design and flight operations and the Ground SDP focuses on ground hazards that might exist during pre-launch and post-landing periods. The preliminary SDP is prepared after the Payload Accommodations Conference. After final GSFC approval, the Project Manager will submit the Phase 0/I Flight SDP to the STS Payload safety review panel at JSC and the Ground SDP to the review panel at KSC for approval. Phase II and III SDPs will be prepared and submitted by GSFC with inputs from the payload organization. The following chart provides an example outline for the SDP.

EXAMPLE FLIGHT SAFETY DATA PACKAGE (SDP) OUTLINE

SECTION

I. Table of Contents

II. Acronyms Abbreviations

III. Figures and Diagrams

1.0 INTRODUCTION

1.1 Objectives

1.2 Applicable Documents

1.3 Concept

1.4 Operational Scenario

2.0 PAYLOAD DESCRIPTION

2.1 Overall Payload Description

2.1.1 Structural

2.1.2 Electrical

2.1.3 Cryogenics

2.1.4 Radiation

2.1.5 Pyrotechnics

2.1.6 Pressure System

2.1.7 Materials

2.1.8 Thermal

2.2 Hitchhiker Hardware Description

2.2.1 Mounting Plate

2.2.2 Adapter Beam

2.2.3 Canister

2.2.4 HH Avionics

2.3 Flight Operations

3.0 FLIGHT SAFETY ASSESSMENT AND VERIFICATION

3.1 General

3.2 Integrated Payload/HH Hazard Analysis

3.3 Payload Verification

APPENDIX A - HAZARD REPORTS

A similar outline should be followed for the Ground SDP and include ground operations.

APPENDIX-B

APPENDIX B

MATERIALS

1. OVERVIEW

As part of the System Safety Process, GSFC Materials Engineers review all materials used in HH payloads for freedom from stress corrosion cracking and to determine their potential flammability, toxicity, and offgassing[1] characteristics. Materials are also reviewed to determine their outgassing[2] and contamination characteristics so that scientific data degradation is minimized. (Note: A good rule to follow in meeting materials requirements is to house hardware in sealed containers.)

2. MATERIALS REVIEW PROCESS

a. Complete the appropriate forms applicable to your payload at a relevant point in the design process.

b. Submit completed forms to the HH Project Office, which will forward them to the HH Materials Engineer for review.

c. If any questions arise during the Materials Engineer's review, you will be contacted by telephone.

d. The Materials Engineer will document his findings at the completion of his review and forward them to you through the HH Project Office.

(Note: Some findings may require the submission of a material sample for test by GSFC or recommend an alternate material for one that is unacceptable for use.)

1. Offgassing - The emanation of volatile matter of any kind from materials into a manned pressurized volume.

2. Outgassing - The emanation of volatile materials under vacuum conditions resulting in a mass loss and/or material condensation on nearby surfaces.

3. LIST OF CANDIDATE MATERIALS

For the immediate needs of the HH and SPOC, we have generated lists of materials which, if used prudently, can form the basis of an acceptable materials design. It should be noted that while the materials listed are considered "acceptable" for space use, successful performance is not ensured without having an appropriate technical merit review by materials engineers. Nor does it assure that the selected material will not be used improperly.

This selection was based on certain criteria for polymers and metals in light of the referenced documents. Limitations regarding outgassing of polymers and the stress corrosion cracking of metals are of major concern to Shuttle payloads. In addition, test results such as flammability may not be readily available in the manufacturers' literature and may require further testing at JSC.

It is required that the selection of materials used in the design of payload structures, support brackets, and mounting hardware complies with the stress corrosion cracking criteria of the latest version of MSFC-SPEC-522. Acceptable materials taken from MSFC-SPEC-522B are given in Table B.1. Other materials need to have a Materials Usage Agreement (MUA) submitted for approval.

Refer to NASA Ref. Pub. 1124, August 1987, for lists of materials which have been tested for outgassing and have met the acceptable criteria. This criteria is that a maximum 1% Total Mass Loss (TML) and a maximum of 0.10% Collected Volatile Condensable Materials (CVCM) is acceptable. For materials that are not included, the Materials Branch of the GSFC, Code 313 should be contacted to determine their outgassing values.

Wherever more stringent outgassing criteria are needed, such as near sensitive optics, the CVCM value of 0.01% should be used. A list of these materials is included in Table B.2. Most of these materials will cure at room temperature and those that require an elevated temperature cure are indicated by an asterisk (*). In addition, those materials considered to be "non-flammable" per JSC/White Sands Test Facility (WSTF) data are indicated by a (1).

In using materials for space flight applications, several general precautions should be considered:

a. The use of electroless nickel on flexible members is not recommended due to its brittle nature.

b. Metal platings used as a corrosion protection film, should be at least 200 x 10^{-6} inches thick.

c. When the recommended Brayco oil and greases are used, a barrier film should be properly applied for prevention of lubricant creep.

d. The use of Ray Chem Spec 44/ or 55 wire is not prohibited, although it is classed as flammable. It is highly recommended that Teflon TFE (MIL-W-22759/11-12) or Kapton polyimide (MIL-W-81381/9-12) be used throughout the Program. Neither are flammable.

e. When using dry solid film lubricants and metal platings, allowance must be made for the lubricant thickness. Sputtered MoS_2 does not change the dimension to any significant degree.

f. Formulate plans for controlling the particulate and Non-Volatile Residue (NVR) contaminants around optics.

g. Use care in mixing and curing polymeric materials.

h. Use proper identified and dated (shelf life) materials at all times.

i. Use the proper primer with paints, conformal coatings, and potting compounds.

j. Flammability data is available on a limited number of materials as shown in Table B.2.

As a final note, these attached lists should be considered as a starting point and do not negate the use of other materials. It is not the intent of these lists to limit the use of materials to a select group but rather to assist the customer by listing those which have been used in previous space projects. Selected materials should be submitted for approval through the project office on forms shown in Figures B-1 through B-6.

TABLE B.1

MATERIALS LIST ENCLOSURE

MSFC-SPEC-522B
ATTACHMENT A

ALLOYS WITH HIGH RESISTANCE TO STRESS CORROSION CRACKING

STEEL ALLOYS

ALLOY	Condition
Carbon Steel (1000 Series)	Below 180 ksi UTS
Low Alloy Steel (4130, 4340, D6AC, etc.)	Below 180 ksi UTS
Music Wire (ASTM 228)	Cold Drawn
1095 Spring Steel	Tempered
HY 80 Steel	Tempered
HY 130 Steel	Tempered
HY 140 Steel	Tempered
ASP 11	Aged
200 Series Stainless Steel (Unsensitized) (1)	All
300 Series Stainless Steel (Unsensitized) (1)	All
400 Series Ferritic Stainless Steel (404, 430, 444, etc.)	All
Nitronic 32 (2)	Annealed
Nitronic 300 (2)	Annealed
Nitronic 40 (formerly 21-6-9) (2)	Annealed
A-286 Stainless Steel	All
AM-350 Stainless Steel	SCT 1000 and Above
AM-355 Stainless Steel	SCT 1000 and Above
AM-362 (Almar 362) Stainless Steel	3 Hrs. at 1000°F
Carpenter 20Cb Stainless Steel	All
Carpenter 20Cb-3 Stainless Steel	All
Custom 450 Stainless Steel	H1000 and Above
Custom 455 Stainless Steel	H1000 and Above
15-5PH Stainless Steel	H1000 and Above
PH15-7Mo Stainless Steel	CH900
17-7PH Stainless Steel	CH900

(1) Including weldments of 304L, 316L, 321, and 347

(2) Including weldments.

TABLE B.1 (Cont'd)

ALUMINUM ALLOYS

WROUGHT		CAST	
ALLOY (1)	TEMPER (2)	ALLOY (3)	TEMPER
1000 Series	All	319.0, A319.0	As Cast
2011	T8	333.0, A333.0	As Cast
2024 Rod, Bar	T8	355.0, C355.0	T6
2219	T6, T8	356.0, A356.0	All
2618	T6	357.0	All
3000 Series	All	B358.0 (Tens-50)	All
5000 Series	All (4), (5)	359.0	All
5000 Series	All	380.0, A380.00	As Cast
7049	T73	514.0, (214)	As Cast
7149	T73	518.0, (218)	As Cast (5)
7050	T73	535.0 (Almag 35)	As Cast
7075	T73	A712.0, C712.0	As Cast
7475	T73		

(1) Including weldments of the weldable alloys.

(2) Including mechanically stress relieved (TX5X orTX5XX) tempers when applicable.

(3) The former designation is shown in parenthesis where significantly different.

(4) High magnesium alloys 5456, 5083, and 5086 should be used in controlled tempers (H111, H112, H116, H117, H323, H343) for resistance to SCC and exfoliation.

(5) Alloys with magnesium content greater than 3.0 percent are not recommended for high temperature application, 66°C (150°F) and above.

TABLE B.1 (Cont'd)

COPPER ALLOYS

Condition

CDA No. (1)	(% Cold Rolled) (2)
110	37
170	AT, HT (3)
172	AT, HT (3)
194	37
195	90
230	40
422	37
443	10
510	37
521	37
524	0
606	0
619	40 (9% B phase)
619	40 (95% B phase)
638	0
655	0
688	40
704	0
706	50
710	0
715	0
725	40
752	50

(1) Copper Development Association alloy number.

(2) Maximum percent cold rolled for which SCC data is available.

(3) AT - Annealed and precipitation hardened.
HT - Work hardened and precipitation hardened.

TABLE B.1 (Cont'd)

NICKEL ALLOYS

Alloy	Condition
Glass Seal 52 CR (51Ni-49Fe)	All
Invar 36 (36Ni-64Fe)	All
Hastelloy B	Solution Heat Treated
Hastelloy C	All
Hastelloy X	All
Incoloy 800	All
Incoloy 825	All
Incoloy 901	All
Incoloy 903	All
Inconel 600 (1)	Annealed
Inconel 625	Annealed
Inconel 718 (1)	All
Inconel X-750	All
Monel K-500	All
Ni-Span-C 902	All
Rene' 41	All
Unitemp 212	All
Waspaloy	All

TABLE B.1 (Cont'd)

MISCELLANEOUS ALLOYS

Alloy	Condition
Beryllium S-200C	Annealed
HS 25 (L605)	All
HS 188 (1)	All
MP 35N	Cold Worked and Aged
MP159	Cold Worked and Aged
Titanium 3A1-2.5V	All
Titanium 5A1-2.5SN	All
Titanium 6A1-4V	All
Titanium 10Fe-2V-3A1	All
Titanium 13V-11Cr-3A1	All
Titanium IMI 550	All
Magnesium M1A	All
Magnesium LA141	Stabilized
Magnesium LAZ933	All

(1) Including weldments

TABLE B.2

MATERIALS WITH LOW OUTGASSING AND FLAMMABILITY DATA AVAILABLE

ADHESIVES, CONFORMAL COATINGS (C.C.) AND POTTING COMPOUNDS

Armstrong A-12; 3A/2B	epoxy(1)	adhesive
Armstrong A-31; 6A/4B	epoxy(1)	adhesive
Epon 828/TETA; 10A/1B	epoxy(1)	adhesive,C.C.
Epon 828/Versamid 140; 70A/30B	epoxy(1)	adhesive,C.C.
Hysol 11C; 1A/1B	epoxy	adhesive
Crest 3135/7111; 1A/1B	epoxy	adhesive
Stycast 2850/Cat. 9; 10A/0.3B	epoxy	adhesive
Stycast 2057/Cat. 9; 100A/6B	epoxy	potting
Stycast 2651MM/Cat. 9; 100A/6.5B	epoxy	adhesive,potting
Hysol C2-4259/3401	epoxy	potting
Conathane EN21; 100A116B	polyurethane	adhesive,C.C.,potting
Uralane 5753LV; 1A/5B	polyurethane	C.C.,potting
Solithane 113/300 Formula #4 or #21	polyurethane	C.C.,potting
P.R. 1660L; 25A/100B/8 Cab-0-Sil	polyurethane	adhesive,potting
DC93500; 10A/18	silicone	adhesive,potting,C.C.
RTV 566; 0.1% Cat.	silicone	adhesive,potting,C.C.
RTV 567; 0.5% Cat.	silicone	adhesive,potting.C.C.
RTV 142	silicone	adhesive

WIRE AND CABLE WITH TEFLON

(MIL-W-22759/11; MIL-W-22759/12) or Kapton polyimide

MIL-W-81381/9-12	(1)

SHRINK TUBING

Chemfluor Teflon*	(1)
ThermoFit 400 Teflon*	(1)
ThermoFit TR218 Kynor/Viton*	(1)
ThermoFit TFE-R Teflon*	(1)

TABLE B.2 (Cont'd)

ELECTRICAL CONNECTORS/FEEDTHROUGHS	
AMP-Feedthrough term block 204307-6-70-39	epoxy
Appleton Connector Red/Black Phenolic/Fiberglas	
Bendix Connector PT07H-14-19P Green	
Cannon Connector MS3476 Black Phenolic	
Cannon Connector C-16 MS C-40M 39569	silicone
Cannon Connector PV6G24831/SWC16 Red	silicone
DAP Connector Insert DDM 24W7P	
Deutsch Connector 6825 RM04-4428	silicone
ELECTRICAL SHIELDS	
Eccosorb MF112 Fe filled epoxy	
Eccosorb MF113 Fe filled epoxy	
Cho-Seal 1217 Ag filled fluorosilicon 125*	
Cho-Seal 1221 Ag filled silicone aerospace 200*	
FILM AND SHEET MATERIALS	
Cellulose acetate butyrate 200 micron purple film	
Cronar polyester transparency film	
Genotherm HT unplasticized PVC clear film	
Mylar LA616 film	
Kapton H-film	(1)
Polychrome 8 mil film	
Tedlar 150-30 CC black film	
Ormalon TG 4030 neutral Teflon or glass cloth-heat barrier film	
Beta Marquisette woven fiberglass,Style 2530	
Fairprene VS0080 black Viton A sheet	(1)
Fluoroglas 389-7 beta cloth/PTFE coated	(1)
Cho-Therm 1677 white fluorosilicone-thermal control	
Dacron mesh E2A polyesternetting - thermal blanket	
Dacron mesh 15320 polyester netting - thermal blanket	
G401500 Ag/Teflon film	(1)

TABLE B.2 (Cont'd)

FOAMS

P-65 polyether urethane foam white methyl alcohol wash
Absafil F1200/20 glass fibers
Skybond R1 7271-12 or 18 rigid polyimide
Zerefil F700 vinyl/20 glass fibers
Scott polyester urethane 100 TPI methyl alcohol wash*

LUBRICANTS

Brayco 815Z oil	(1)
Brayco 601, 602, and 603; RP, MS and Zn grease	(1)
Aplezon L and N; grease	
Rulon A,B,C,J,LD and 123; Teflon/fiberglass solid	
MoS_2 -filled vespel grade, SP3	

THERMAL INTERFACE CONTROL MATERIALS

Eccobond 57C; 1A/1B, Ag filled epoxy adhesive
Hysol K-16; 3A/1B, epoxy adhesive
Cho-Therm 1677 white fluorosilicon* (1)
Cho-Therm 1671 white silicone*
G-9042 white silicone thermal grease (1) (2)
G9052 black silicone (2)
BrayCo 3L-38-Zn fluorocarbon grease (1) (2)
McGhan NVSIL 2946, two part silicone
McGhan NVSIL CV2942
Eccosil 4954

FACING TAPE AND CABLE TIES

Stur-D-Lace 18DH - scoured	
Temp Lace 230 Teflon	(1)
Ty-Rap Ty25M Tefzel	(1)
Ty-Rap Ty307 Teflon	
Velcro midtemp Nomex polyimide fastener	

TABLE B.2 (Cont'd)

CIRCUIT BOARDS	
Nema G-10 Mica/Cell55 (RCA)	
Micaply PG 418T polyimide fiberglass (MCA)	(1)
602 Teflon/fiberglass (ATL)	(1)
Duroid 5870 Teflon/fiberglass (ROG)	(1)
Duroid 5880 Teflon/fiberglass (ROG)	(1)
Multilayer board - MIL-P-55617, 55636, 13949	
LAMINATES	
*Hercules 2002 M graphite fiber reinforced polyers, GFRP	
*Gy70/X-30 GFRP	(1)
*Gy 70/5208 orGy70/5209 GFRP	(1)
Hexcel-F174-120 glass cloth/polyimide prepreg.	
KG098 Teflon/fiberglass (MMM)	
Narmco 8517 epoxy/glass	
T300/934 GFRP	(1)
LABELS AND MARKING INKS	
Scotchcal 8001 and 8009 - aluminum labels (3M)	
Scotchcal 8005 photosensitive film (3M)	
Wornow Cat-L-Ink 50-100/Cat. 9/50-900 white	
MOLDING COMPOUNDS	
Acrylafil G47/20 styrene/acrylonitrile/fiberglass	
AF 1006 acryl butadiene styrene	
CF 1006 styrene/fiberglass	
Dapon M - C2580-11B FR-FMC	
DF 1006-polycarbonate/fiberglass	
GF 1006-polysulfone/fiberglass	
JF 1006-polysethersulfont/fiberglass	
Lexan 500-polycarbonate	
Noryl EN26	
Stycast 0005 polystyrene	(1)
Teflon PFA-TE 9704	(1)
Tefzel	(1)
Vespel SP-5 polyimide/glass fiber	(1)

TABLE B.2 (Cont'd)

PAINTS	
Chemglaze Z306 black	(1)
GSFC - 01550 white resin/ZRO	
RTV 602 Dev. 764-1A white (GSFC)	(1)
RUBBERS/ELASTOMERS	
ECD 006 and 487-90 perfluoroelastomer	(1)
Fluron FS005 Viton red	(1)
Gor-Tex carbon doped expanded Teflon	(1)
Kalrez 1050 or 3018 perfluoroelastomer	(1)
Mosites 1059 Fluorel fluoracarbon	(1)
Parker O-Ring S-383-70 red silicone	
Parker O-Ring V-747-75 Viton E6G	(1)
Viton B	
TAPES	
3M 415 Scotchpar - 2 sided	
3M X-1255 Kapton - 2 sided*	
3M Y-9460 Kapton transfer	
3M Y-967 Kapton transfer	
G400201 A1/Teflon	(1)
G406400 A Kapton	(1)
3M Y9339 A1 flil	(1)
3M 420 Lead foil	(1)
3M 425 Al foil	(1)
3M 5 polyester	
Mystik 7375 Tedlar	(1)
Mystik 7420 Copper foil	(1)
Temp-R-Tape Kapton	(1)

TABLE B.2 NOTES

NOTE: (1) - Considered non-flammable per JSC/WSTC data.
* - Other than Room Temperature (RT) cure.
(2) - Migrates when heated sufficiently.

NONMETALLIC MATERIALS IDENTIFICATION AND USAGE LIST

PAGE ______

REV ______

CONTRACT NO ______

ELEMENT LOCATION

[ ] ORBITER CABIN [ ] ORBITER CARGO BAY

[ ] AIRLOCK [ ] SPACE LAB HABITABLE AREA

[ ] SEALED CONTAINER

HARDWARE ELEMENT ______

CONTRACTOR ______ PREPARED BY ______ PHONE ______ GSFC MATLS EVALUATOR ______ DATE RECEIVED ______

PRESSURE ______ MEDIA ______ TEMP RANGE ______ PHONE ______ DATE EVALUATED ______

PART DWG NUMBER	MATERIAL	DESCRIPTION SPEC	MFGR	AREA (mm²)	WT (KG)	THK (mm)	NONMETALLIC MATERIAL IDENTIFICATION					USAGE APPLICATION	GSFC EVALUATION		
							FLAMMABILITY	ODOR	TOXICITY	TVS	RATING SOURCE		A	NA	SA

PROCEDURE FOR COMPLETING NONMETALLIC MATERIAL IDENTIFICATION AND USAGE LIST

All nonmetallic materials listed on drawings or parts lists must be entered on this list.

Hardware Element - Enter name of element for which sheet applies. Example: Motor, signal generator, control panel, harness

Hardware Element Location - Check location for hardware element, either Orbiter Cargo Bay, Spacelab Habitable Area, Orbiter Cabin, or Airlock

Pressure - Enter pressure of hardware element when in operation (i.e., 14.5 psia, vacuum). If element is presssurized to higher pressure, enter maximum pressure of element

Media - Enter media of hardware element. Air, oxygen, nitrogen, vacuum, etc.

Temperature Range - Enter operating temperature range for element

Part No Drawing - Enter part number/drawing number which calls out material, including materials listed on parts list

Material Nomenclature - Enter trade name of material. Example: RTV 732

Description Specification - Enter material description specification number. Example: Silicone, MIL-A-46146

MFGR - Enter manufacturer of material. Example: Dow Corning Corporation.

Area - Enter exposed surface area of material in square millimeters

Weight - Enter weight of material

Thickness - Enter thickness of material

Material ratings - Enter information as found in Government reference and other documents.

Rating Source - Enter source of rating. Example: RTV 732-MSFC-HDBK-527, odor data from JSC 02681

Usage Application - Enter brief description of usage application. Example: RTV 732 - used to bond silicone rubber

GSFC Evaluator's Comments: A = approved, NA = not approved; SA = see attached document for further comments

Figure B-1 Non-Metallic Materials Identification and Usage List

GSFC SPACECRAFT INORGANIC[1] MATERIALS LIST

SPACECRAFT ________ SYSTEM/EXPERIMENT ________ GSFC T/O ________

CONTRACTOR ________ ADDRESS ________

PREPARED BY ________ PHONE ________ DATE PREPARED ________

GSFC MATERIALS EVALUATOR ________ PHONE ________ DATE RECEIVED ________ DATE EVALUATED ________

ITEM NO	MATERIAL IDENTIFICATION[2]	CONDITION[3]	APPLICATION[4]	EXPECTED ENVIRONMENT[5]	GSFC EVALUATION[6]		
					A	NA	SA

NOTES

(1) List all inorganic materials (metals, ceramics, glasses, liquids) except bearing and lubrication materials which should be listed on form GSFC 18-59C.

(2) Give name of material, identifying number, manufacturer.
E.g., Aluminum 6061-T6
Electroless nickel plate, Enplate Ni-410, Enthone, Inc.
Fused silica, Corning 7940, Corning Glass Works.

(3) Give details of the finished condition of the material, heat treat designation (hardness or strength), surface finish and coating, cold worked state, welding, brazing, etc.
E.g., Heat treated to R_c 60 hardness, gold electroplated, brazed
Surface coated with VDA and MgF_2
Cold worked to Full Hard condition and welded by TIG process, electroless nickel plate.

(4) Give details of where on the spacecraft the material will be used (component) and its function.
E.g., Electronics box structure in attitude control system, not hermetically sealed.

(5) Give the details of the environment the material will experience as a finished S/C component, both in ground test and in space. Exclude vibration environment. List all materials with the same environment in a group.
E.g., T/V: -20°C/+60°C, 2 weeks, 10^{-5} torr, UV
Storage: up to 1 year at RT
Space: -10°C/+20°C, 2 years, 150 mi. alt., UV, electron, proton

(6) Evaluator's comments to be filled in by GSFC evaluator. A = approved, NA = not approved, SA = see attached document for further comments.

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Figure B-2 GSFC Spacecraft Inorganic Materials List

GSFC SPACECRAFT POLYMERIC[1] MATERIALS LIST

SPACECRAFT ______ SYSTEM/EXPERIMENT ______ GSFC T/O ______

CONTRACTOR ______ ADDRESS ______

PREPARED BY ______ PHONE ______ DATE PREPARED ______

GSFC MATERIALS EVALUATOR ______ PHONE ______ DATE RECEIVED ______ DATE EVALUATED ______

AMOUNT CODE		
Area, cm^2	Vol., cc	Wt., gm
1. 0-1	A 0-1	a 0-1
2. 2-100	B 2-60	b 2-50
3. 101-1000	C 61-500	c 51-500
4. >1000	D >500	d >500

ITEM NO	MATERIAL IDENTIFICATION[2]	MIX FORMULA[3]	CURE[4]	AMOUNT CODE	EXPECTED ENVIRONMENT[5]	REASON FOR SELECTION[6]	GSFC EVALUATION[7] A	NA	SA

NOTES

(1) List all polymeric (organic) materials total systems except lubrication materials which should be listed on form GSFC 18-59C.

(2) Give name of material, identifying number, manufacturer.
E.g., Epoxy, Epon 828, Shell Chem., Co.

(3) Provide proportions and name of resin, hardener (catalyst), filler, etc.
E.g., 828/V140/Silflake 135 as 5/5/38 bwt.

(4) Provide cure cycle details.
E.g. 8 hrs @ RT + 2 hrs @ 150°C

(5) Provide the details of the environment the material will experience as a finished S/C component, both in ground test and in space. Exclude vibration environment. List all materials with the same environment in a group.
E.g., T/V: -20°C/+60°C, 2 weeks, 10^{-5} torr, UV
Storage: up to 1 year at RT
Space: -10°C/+20°C, 2 years, 150 mi. alt., UV, electron, proton

(6) Provide any special reason(s) why the material was selected. If for a particular property, please give the property.
E.g., Cost and availability
RT curing and low expansion

(7) Evaluator's comments to be filled in by GSFC evaluator. A = approved, NA = not approved, SA = see attached document for further comments.

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Figure B-3 GSFC Spacecraft Polymeric Material List

GSFC SPACECRAFT LUBRICATION LIST

SPACECRAFT ________ SYSTEM/EXPERIMENT ________ GSFC T/O ________

CONTRACTOR ________ ADDRESS ________

PREPARED BY ________ PHONE ________ DATE PREPARED ________

GSFC MATERIALS EVALUATOR ________ PHONE ________ DATE RECEIVED ________ DATE EVALUATED ________

ITEM NO	COMPONENT TYPE, SIZE, MATERIAL(1)	COMPONENT MANUFACTURER & MFR. IDENTIFICATION	PROPOSED LUBRICATION SYSTEM & AMT. OF LUBRICANT	TYPE & NO. OF WEAR CYCLES(2)	SPEED, TEMP., ATM. OF OPERATION(3)	TYPE OF LOADS & AMT.(4)	OTHER DETAILS(5)	GSFC EVALUATION(6)		
								A	NA	SA

NOTES

(1) BB = ball bearing, SB = sleeve bearing, G = gear, SS = sliding surfaces, SEC = sliding electrical contacts. Give generic identification of materials used for the component, e.g., 440C steel, PTFE.

(2) CUR = continuous unidirectional rotation, CO = continuous oscillation, IR = intermittent rotation, IO = intermittent oscillation, SO = small oscillation ($<30°$), LO = large oscillation ($>30°$), CS = continuous sliding, IS = intermittent sliding.
No. of wear cycles. A(1-10^2), B(10^2-10^4), C(10^4-10^6), D($>10^6$)

(3) Speed: RPM = revs./min., OPM = oscillations/min., VS = variable speed
CPM = cm/min. (sliding applications)
Temp. of operation, max. & min., °C
Atmosphere: vacuum, air, gas, sealed or unsealed & pressure

(4) Type of loads: A = axial, R = radial, T = tangential (gear load). Give amount of load.

(5) If BB, give type and material of ball cage and number of shields and specified ball groove and ball finishes. If G, give surface treatment and hardness. If SB, give dia. of bore and width. If torque available is limited, give approx. value.

(6) Evaluator's comments to be filled in by GSFC evaluator. A = approved, NA = not approved, SA = see attached document for further comments.

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Figure B-4 GSFC Spacecraft Lubrication List

GSFC SPACECRAFT MATERIALS PROCESSES LIST

SPACECRAFT ______ SYSTEM/EXPERIMENT ______ GSFC T/O ______

CONTRACTOR ______ ADDRESS ______

PREPARED BY ______ PHONE ______ DATE PREPARED ______

GSFC MATERIALS EVALUATOR ______ PHONE ______ DATE RECEIVED ______ DATE EVALUATED ______

ITEM NO.	PROCESS TYPE[1]	CONTRACTOR SPEC. NO.[2]	MIL., ASTM, FED., OR OTHER SPEC. NO.	DESCRIPTION OF MAT'L. PROCESSED[3]	SPACECRAFT/EXP. APPLICATION[4]	GSFC EVALUATION[5]		
						A	NA	SA

NOTES

(1) Give generic name of process, e.g., anodizing (sulfuric acid).

(2) If process is proprietary, please state so.

(3) Identify the type and condition of the material subjected to the process.
E.g., 6061-T6

(4) Identify the component or structure of which the materials are being processed.
E.g., Antenna dish

(5) Evaluator's comments to be filled in by GSFC evaluator. A = approved, NA = not approved, SA = see attached document for further comment.

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Figure B-5 GSFC Spacecraft Materials Processes List

MATERIAL USAGE AGREEMENT	C	USAGE AGREEMENT NO.:	REV.	PAGE OF

PROJECT:	SYSTEM:	SUBSYSTEM:	ORIGINATOR:	ORGANIZATION/CONTRACTOR

PART NUMBER(S)	USING ASSEMBLY(S)	ITEM DESCRIPTION	ISSUE

MATERIAL DESIGNATION	MANUFACTURER	SPECIFICATION	PROPOSED EFFECTIVITY

MATERIAL CODE			LOCATION	ENVIRONMENT		
THICKNESS	WEIGHT	EXPOSED AREA	HABITABLE ☐	PRESSURE PSIA	TEMPERATURE, °F	MEDIA
			NONHABITABLE ☐			

APPLICATION

RATIONALE:

ORIGINATOR:	PROGRAM MANAGER:	DATE:

MATERIALS APPLICATIONS EVALUATION BOARD DISPOSITION

	DATE	APPROVE	REJECT	DEFER	MAEB MEMO NR.
CHIEF:					EFFECTIVITY
SECRETARY:					

REMARKS:

Figure B-6 Material Usage Agreement Form

APPENDIX-C

APPENDIX C
DATA PRODUCTS AND FORMATS

1. LOW-RATE DATA PROCESSING SYSTEM (LRDPS) CUSTOMER TAPE

This appendix describes the LRDPS, its data products, and formats. The LRDPS records SPOC user data subsets and generates user tapes. The LRDPS supports up to six simultaneous users receiving data from the CCGSE. The final product of the LRDPS is a tape (or tapes) of files, each file containing one data type. The files are time-ordered according to the time in the user message. The LRDPS shall delete any duplicate timed user data subsets. A separate tape (or tapes) shall be generated for each user. The tape can contain any of the following files:

a. Directory file (mandatory) - contains a list of all the files on the tape, as well as, the start and stop times of each file. (See Table C-1 for directory format)
b. CCGSE formatted asynchronous data message
c. CCGSE formatted payload analog multiplexer message
d. CCGSE (carrier) ancillary data message
e. CCGSE orbiter ancillary data message
f. CCGSE formatted customer ancillary data message
g. CCGSE formatted payload pulse code modulation (PCM)-A data message
h. CCGSE formatted payload PCM-B data message
i. CCGSE Data Link Status message
j. CCGSE Command Completion Status message

Table C-2 shows the file characteristics for each of the above file types.

TABLE C-1
USER DIRECTORY RECORD FORMAT

byte #		use
1-8	-	flight I.D.
9	-	space (unused)
10-17	-	user I.D.
18	-	space (unused)
19-27	-	file name
28	-	space
29-37	-	data type
38	-	space (unused)
39-41	-	day of year start time
42	-	: (colon)
43-44	-	hour
45	-	: (colon)
46-47	-	minutes
48	-	: (colon)
49-50	-	seconds
51	-	space (unused)
52-54	-	day of year stop time
55	-	: (colon)
56-57	-	hour
58	-	: (colon)
59-60	-	minutes
61	-	: (colon)
62-63	-	seconds
64-80	-	spare

Note: All data are ASCII characters

Table C-2

USER DIRECTORY RECORD FORMAT FILE CHARACTERISTICS

DATA TYPE	FILE EXT.	FILE FORM	RECORD TYPE	RECORD LENGTH (BYTES)
DIRECTORY	.DIR	FORMATTED	FIXED	80
ASYNCHRONOUS	.ASY	UNFORMATTED	VARIABLE	MAX 132, MIN 11
ANALOG MULT.	.ANA	UNFORMATTED	FIXED	43
ANCILLARY	.SPO	UNFORMATTED	FIXED	84
ANCILLARY	.STS	UNFORMATTED	FIXED	103
ANCILLARY	.USR	UNFORMATTED	FIXED	21
	.A	UNFORMATTED	VARIABLE	MAX 266, MIN 12
PCM	.B	UNFORMATTED	VARIABLE	MAX 266, MIN 12
STATUS	.LNK	UNFORMATTED	FIXED	13
STATUS	.CMD	UNFORMATTED	FIXED	13

The directory file is identified by the file name USERDATA.DIR and is always the first file on the tape. The specific user is defined before each mission, however, the file extensions will be consistent with those in Table C-2.

Figure C.1 depicts a typical tape layout and its file structure. Table C-1 Describes the User Directory Record Format.

The tapes will be standard 9-track, 2400-foot, 1/2-inch-wide magnetic tapes with a density of 1,600 bits per inch. They will be formatted according to the American National Standards Institute (ANSI) magnetic tape standards. Our reference for the ANSI standard is the VAX/VMS Magnetic Tape User's Guide (Volume 4A) of the VAX VMS software documentation. Figure C.2 depicts how files cross tape boundaries. Notice the first tape volume is terminated by an End of Volume (EOV) marker, instead of an End of File (EOF) marker. Therefore, if multifile/multivolume configurations are generated, they will be done according to this ANSI standard.

Typical Tape Layout And File Structure

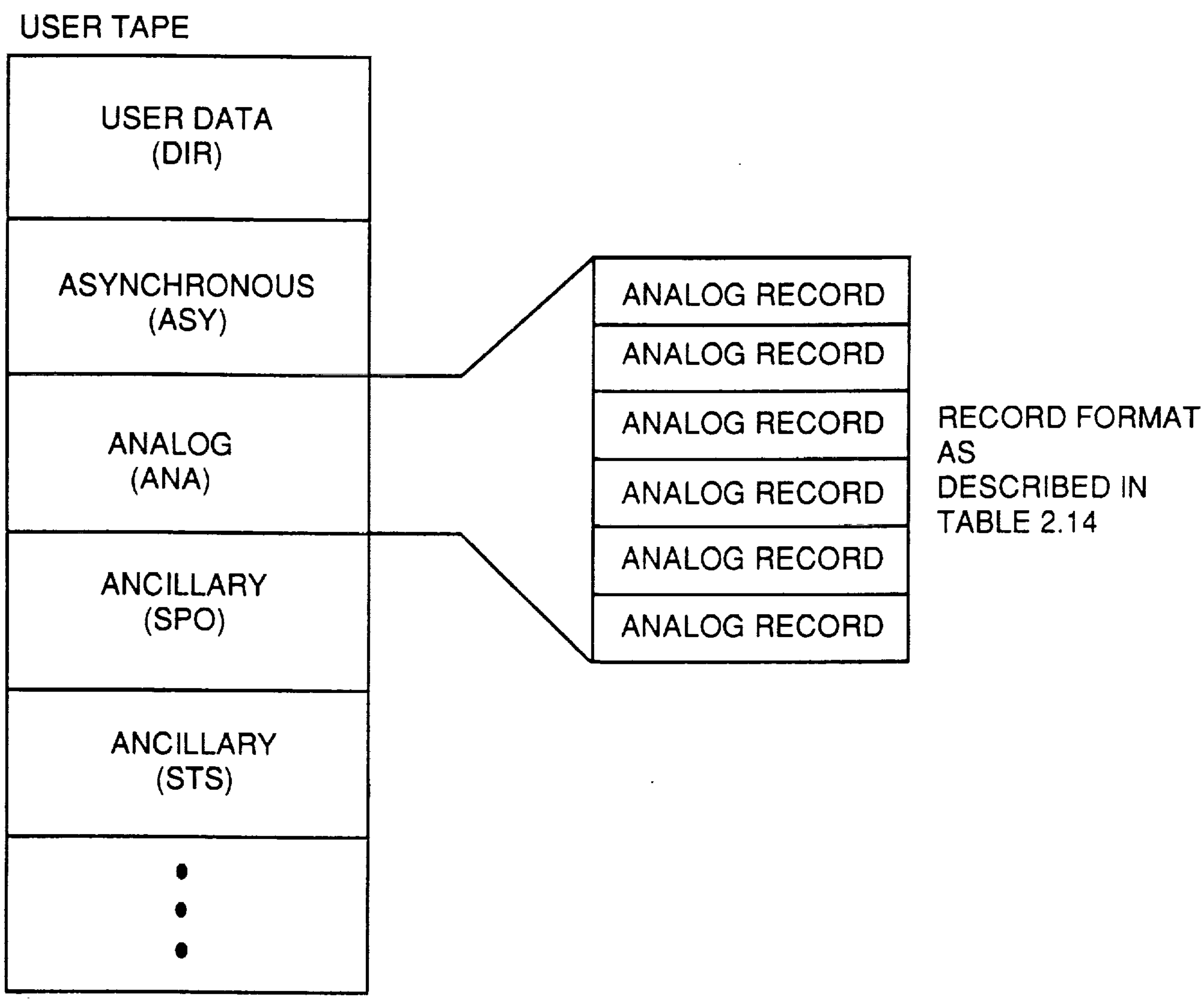
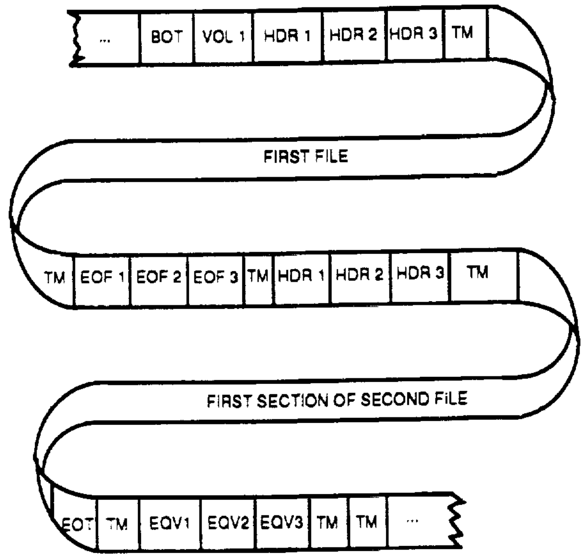


Figure C.1

User Directory Record Format



ANSI-LABELED MAGNETIC TAPE

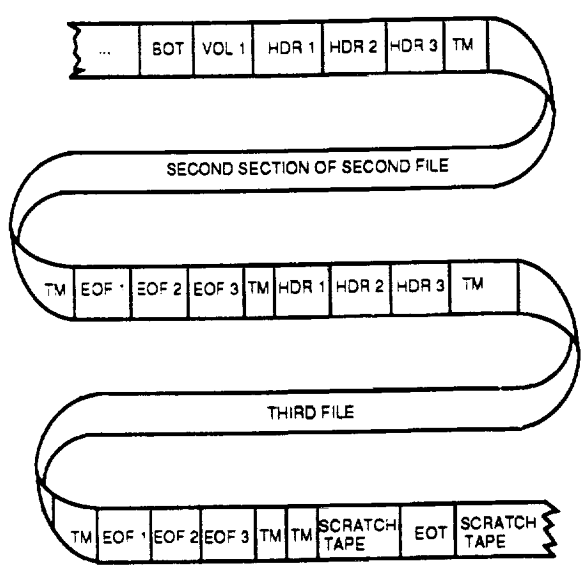


Figure C.2

2. Medium Rate Data Processing System (MRDPS) CUSTOMER TAPE

This appendix contains the description of the SPOC Customer Medium-Rate Tape (CMRT) Format, which is used to transfer the payload data from the SPOC MRM data streams to the customers.

The MRM can merge up to 10 data streams into one composite stream, with a composite data rate of 2.0 mbps. The MRDPS receives the data from NASCOM, passes it through a Medium-Rate Demultiplexer (MRDM) and into separate Frame Synchronizer Units (FSUs) and produces CMRTs. These CMRTs will be shipped to the customers for their data processing and analysis. The CMRT format described in detail in Reference 1.

2.1 CMRT Identification

CMRTs are physically identified on the external tape label, as well as being part of the tape file header records.

2.2 CMRT File

Each CMRT shall contain at least one file of data records from a payload data stream(s). Up to eight channels of the ten MRM data may be included in one CMRT file as one User Group. Each file shall contain a file header record as the first record of the file, and zero or more data records. All CMRT data records shall consist of an integral number of 32-bit words, i.e., integral multiples of 4 bytes. The last data record for each channel in a CMRT file may be shorter than the other data records of the file. The CMRT files shall be terminated with an EOF marker. CMRT files shall be fully contained on a physical CCT. The CMRT recording density shall be 6,250 characters per inch (cpi). The CMRT layout is as shown in Figure C.3. The end of each CMRT will be indicated by two EOF tapemarks.

2.3 CMRT Records

Each CMRT file contains a file header record followed by data records, if any. These two types of records are described in this section and the standard record structure is shown in Figure C.4.

A CMRT file header record is always the first record of each CMRT file. It contains information identifying the SPOC mission payload, the physical identification of the tape, and the date and time the file recording was started. The format of this record is shown in Figure C.5. Details of this record format are given in Section 4.1 of Reference 1.

A CMRT data record consists of an 8-byte record header and an integral number of frames of telemetry data. Each data record contains telemetry data from one MRM channel. A CMRT data record is variable in size, depending upon the payload frame length and the number of frames in the record, with a maximum size of 32,768 bytes. Users desiring a specific record size compatible with their data handling system should negotiate with MRDPS personnel as soon as possible. In each file, the final data record for each MRM channel may have fewer frames resulting in a shorter data record. The structure of a standard CMRT data record is shown in Figure C.6, and a detailed description is included in Section 4.2 of Reference 1.

Reference 1. Interface Agreement Document (IAD) for SPOC CMRT format, IPD-II AD/0186, July 1986.

CMRT Layout

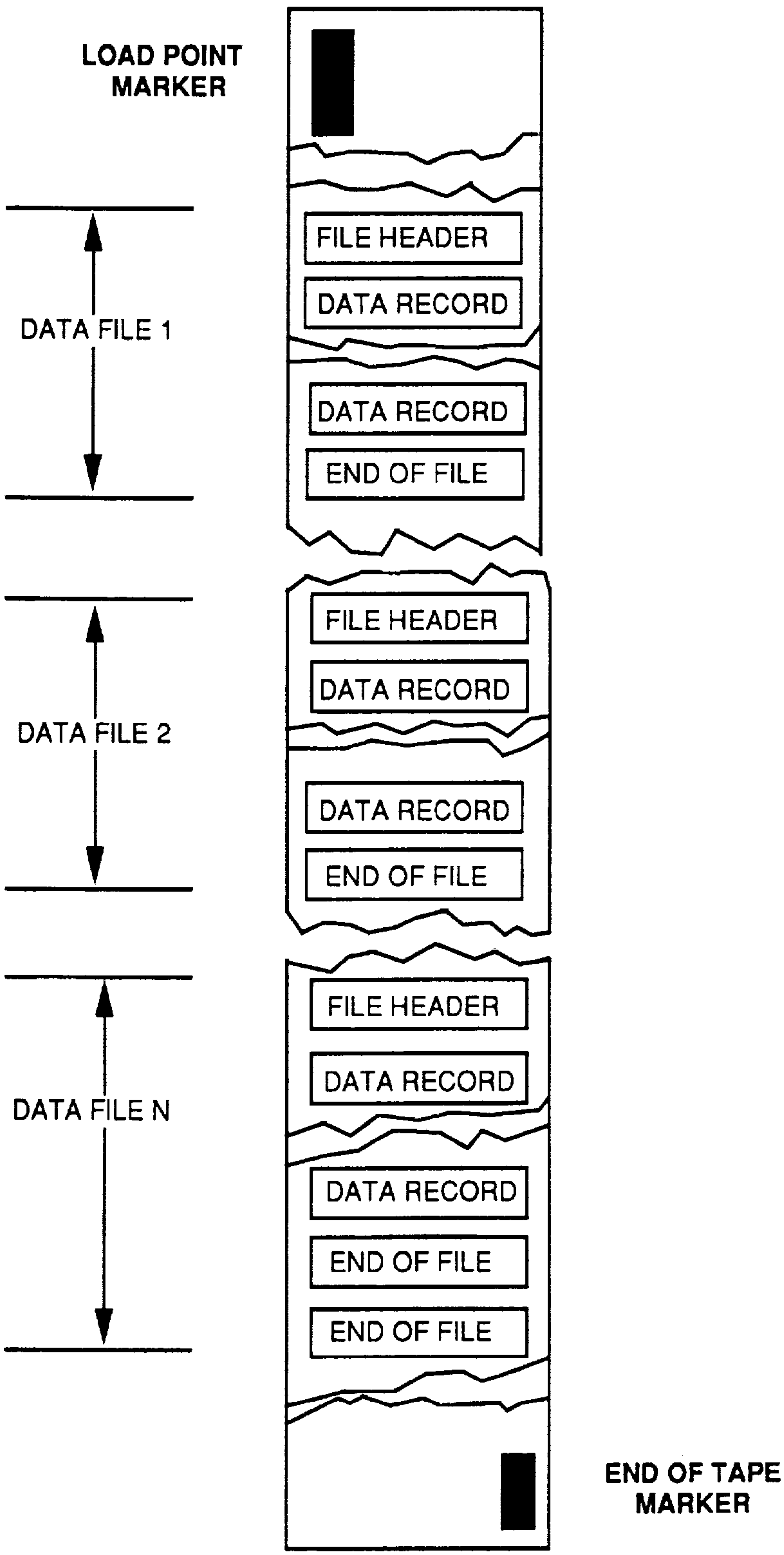


Figure C.3

Standard Structure of a CMRT Record

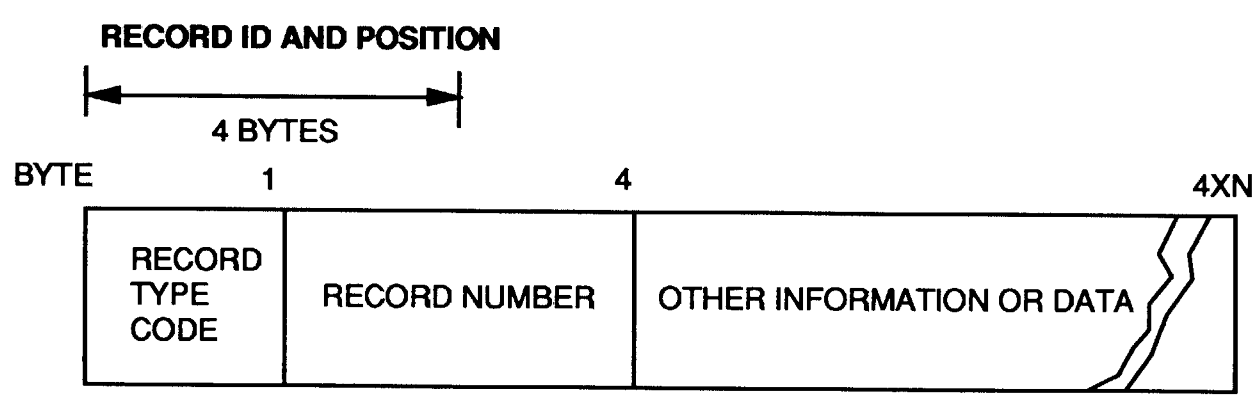


Figure C.4

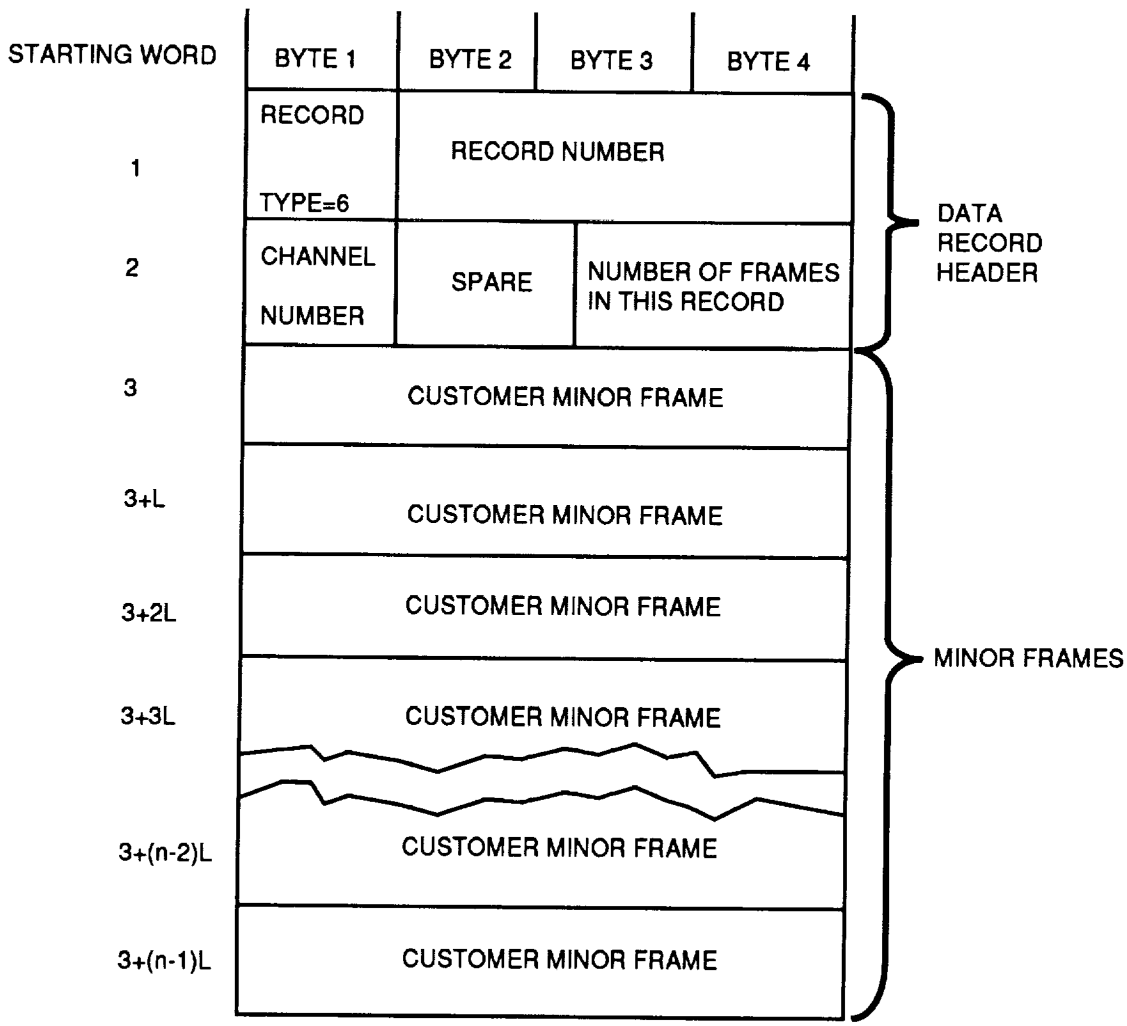
Structure Of A Standard CMRT File Header

WORD	BYTE 1	BYTE 2	BYTE 3	BYTE 4
1	RECORD TYPE - S	RECORD NUMBER =1		
2	SPOC PAYLOAD ID			
3	MISSION TIMELINE VERSION		MERDAPS VERSION NUMBER	PARAMETER FILE VERSION
4 5	CMRT TAPE ID		CMRT FILE NUMBER	SPARE
6 7	CMRT INVENTORY NUMBER			SPARE
8-10	CMRT FILE CREATION DATE AND TIME			SPARE
11	REAL-TIME / PLAYBACK MODE		PROCESSING MODE CODE	
12	CCT DRIVE ID		CMAT FILE REPROCESSING COUNT	
13	MAXIMUM CMAT RECORD SIZE IN BYTES		SPARE	
14	USER GROUP ID			
15-16	SOFTWARE VERSION DATE		SPARE	
17-19	MISSION START (LAUNCH) - DATE AND TIME			
10-32	SPARE			
33-xx	CHANNEL ID	SPARE	MINOR FRAME SIZES IN BYTES	
(xx+1)-64	SPARE			

THE VALUE OF XX DEPENDS UPON THE NUMBER OF CHANNELS IN USER GROUP.

Figure C.5

Structure Of A Standard CMRT Data Record



L is the length of the CMRT minor frame in 32-bit words.
n is the number of minor frames in the record.

Figure C.6

APPENDIX-D

APPENDIX D
OPERATIONS FACILITIES

1. OVERVIEW

Figure D.1 shows an overview of the Attached Shuttle Payloads (ASP) operations facilities for supporting the HH missions. The Shuttle/POCC Interface Facility (SPIF) supports the interface of the ground system to the STS.

The Flight Dynamics Facility (FDF) provides mission analysis and planning capability. It also supports the HH mission operations by providing analysis of received Orbiter orbit, attitude, and ancillary data. Displays generated as a result of this analysis are provided within the mission operations area.

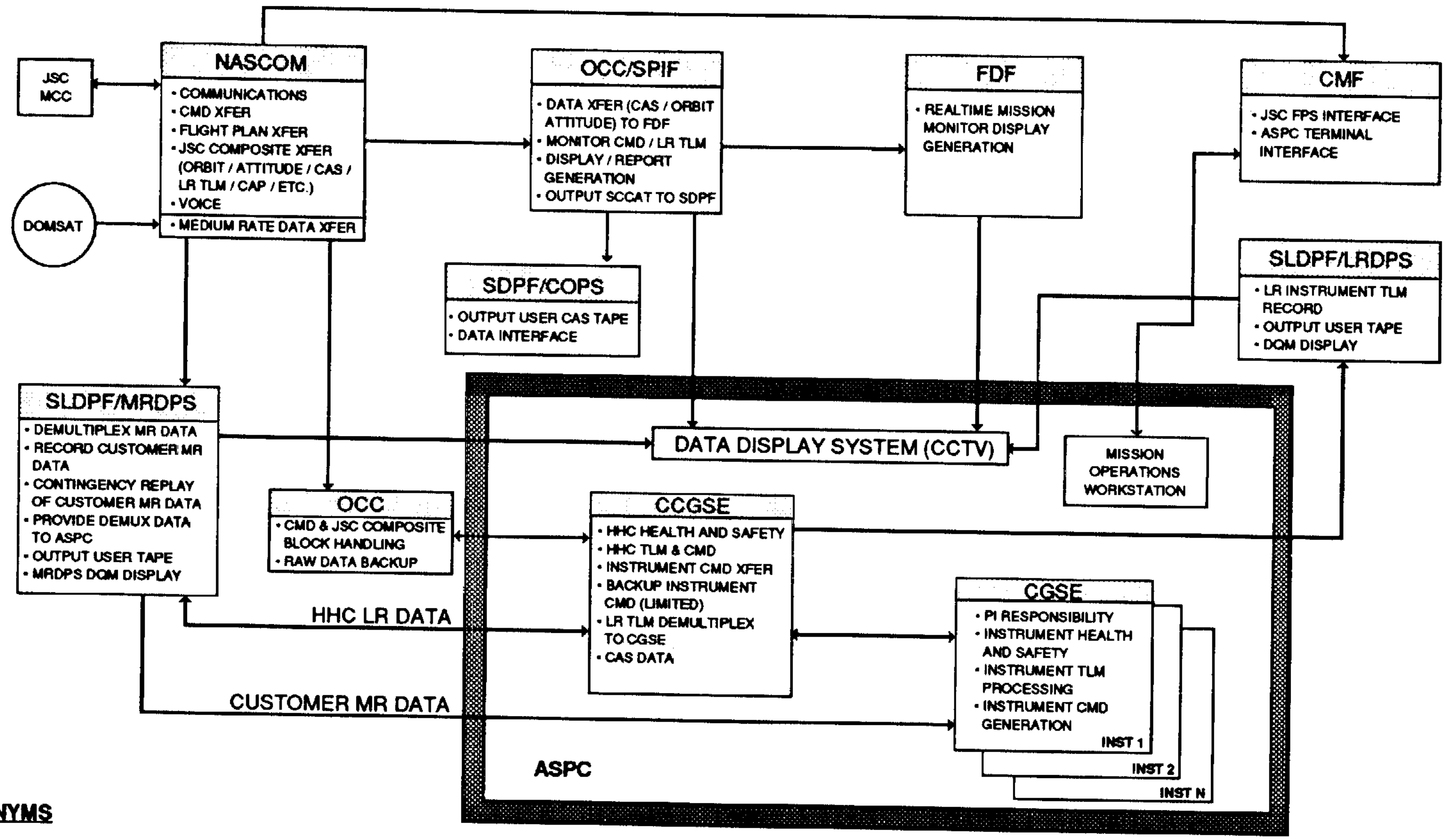
The Mission Planning System (MPS) provides an interface with the JSC Flight Planning System (FPS).

The Sensor Data Processing Facility (SDPF) produces User Calibrated Ancillary Data Tapes (UCAT) post mission. These contain JSC calibrated Orbiter ancillary data which is edited and time-ordered. The CCGSE provides SPOC command and telemetry processing functions, and interfaces customer-provided CGSE to the ground system to enable payload command and telemetry functions. The Medium-rate Data Processing System (MRDPS) provides receipt, recording, demultiplexing, and data quality monitoring of downlinked medium-rate data. The individual payload data streams following demultiplexing are provided to CGSE for customer specific payload data processing. The low-rate data are recorded within LRDPS within the Attached Shuttle Payload Center (ASPC).

Various Orbiter orbit, attitude, and ancillary displays, together with SPOC displays produced by the CCGSE and FDF displays are provided within the mission operations area of the ASPC. This area houses the CCGSE and CGSE systems.

Both HH and customer personnel are located within this area, and access to various FDF and other supporting mission operations capabilities are provided.

Attached Shuttle Payloads Operations Facilities



ACRONYMS

ACQ	ACQUISITION
ASPC	ATTACHED SHUTTLE PAYLOAD CENTER
CAP	COMMAND ACCEPTANCE PATTERN
CAS	CALIBRATED ANCILLARY SYSTEM
CCGSE	CUSTOMER CARRIER GROUND SUPPORT EQUIPMENT
CCTV	CLOSED CIRCUIT TELEVISION
CGSE	CUSTOMER GROUND SUPPORT EQUIPMENT
CMD	COMMAND
CMF	COMMAND MANAGEMENT FACILITY
COPS	CAS OUTPUT PROCESSING SYSTEM
DOMSAT	DOMESTIC SATELLITE
DQM	DATA QUALITY MONITOR
FDF	FLIGHT DYNAMICS FACILITY
FPS	FLIGHT PLANNING SYSTEM
JSC	JOHNSON SPACE CENTER
HHC	HITCHHIKER CARRIER
LR	LOW RATE
LRDPS	LOW RATE DATA PROCESSING SYSTEM
MCC	MISSION CONTROL CENTER
MR	MEDIUM RATE
MRDPS	MEDIUM RATE DATA PROCESSING SYSTEM
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NASCOM	NASA COMMUNICATIONS NETWORK
OCC	OPERATIONS CONTROL CENTER
PI	PRINCIPAL INVESTIGATOR
POCC	PAYLOAD OPERATIONS CONTROL CENTER
SCCAT	SPIF/COPS CALIBRATED ANCILLARY TAPE
SDPF	SENSOR DATA PROCESSING FACILITY
SLDPF	SPACELAB DATA PROCESSING FACILITY
SPIF	SHUTTLE /POCC INTERFACE FACILITY
TLM	TELEMETRY
XFER	TRANSFER

Figure D.1

2. COMMAND AND TELEMETRY PROCESSING CAPABILITIES

The CGSE has primary responsibility for providing the payload command and telemetry processing functions. Payload commands may also be executed from the CCGSE, but this is less convenient and is primarily for contingency purposes. The CCGSE provides the normal mode for commanding the SPOC avionics. In addition, limited capability for commanding the SPOC via the GAS Autonomous Payload Controller (APC) is available to the crew. The capability is primarily for activation and deactiviation of the SPOC, disabling the main customer power bus, and "safing" a payload in a contingency situation.

Commands initiated by the CGSE together with any commands from the CCGSE are transmitted from the ASPC to the MCC at JSC. Following execution of standard MCC command management functions, the commands are uplinked to the Orbiter and SPOC via the TDRSS network (TN).

A number of command acknowledgement capabilities exist within the system. The CCGSE can optionally issue a command acknowledgement message to the CGSE. This indicates the number of commands successfully transmitted to the SPOC avionics. The STS also generates a Command Acceptance Pattern (CAP) which indicates successful passage of the command block through the MCC. The CAPs are processed by the SPIF for auditing purposes. In addition, the CAPs are provided to the CCGSE for processing. The status of this CAP processing is available to the CGSE. However, if a customer requires direct indication that a command reached the payload and was correctly performed, it is necessary to receive appropriate payload telemetry and provide required processing within the CGSE.

Low-rate data downlinked via the Payload Data Interleaver (PDI) is transmitted to GSFC within the JSC composite data stream. This data stream includes Orbiter orbit and attitude data, various STS ancillary data and the PDI. The low-rate data from this data stream are processed by the CCGSE to extract the SPOC and individual payload data streams. The CCGSE also extracts various Orbiter ancillary data for processing and display. The SPOC data is evaluated for SPOC health and safety by the CCGSE.

The payload data are recorded by the ASPC and distributed to the CGSE for payload specific processing. The recorded data are processed post-mission to provide the low-rate production data tapes. Payload health and safety, and quicklook analysis functions are performed by the CGSE. The CGSE may receive only the payload data providing an unchanged interface from that used during payload development, or optionally may receive the payload data with various additional ancillary data. These ancillary data include various STS ancillary data extracted by the CCGSE, SPOC status as processed by the CCGSE, and the CCGSE command acknowledgement message.

The medium-rate data are downlinked to GSFC via the TN and the Domestic Satellite (DOMSAT). The data are then forwarded via a multiplexer-demultiplexer to the MRDPS. Following receipt by the MRDPS, the data are recorded and de-multiplexed to extract the individual payload data streams. These data streams are provided to the CGSE for quicklook analysis purposes. Each CGSE will receive its medium-rate data via a dedicated line. Low-rate data multiplexed within the medium-rate data stream will also be extracted and provided to the ASPC for CCGSE processing and distribution. These data will only be utilized if the low-rate data are not available from the PDI. The data quality of the medium-rate data received is monitored and the status of this processing is provided to the ASPC. If required for operational purposes, medium-rate data already recorded may be played back to support CCGSE processing. This would be performed on a non-interference basis with real-time operations. Following the mission, the medium-rate data are processed to provide Computer Compatible Tape (CCT) for delivery to the customer.

The JSC composite data stream is also received by the SPIF. This facility extracts various Orbiter orbit and attitude information, and STS ancillary data; it also formats the data for Closed Circuit T.V. (CCTV) display and hardcopy. These displays are made available to SPOC and customer operations personnel within the mission operations area. The SPIF also provides the Orbiter orbit and attitude data to the FDF for more extensive processing. In addition, the SPIF supports the STS interface by providing several other services. These include the capability to uplink hardcopy to the Orbiter via the Text and Graphics system (TAGS) and data facsimile services. Access to CAPS information will be provided by the ASP ground system. Note, the TAGS and CAPS systems are future capabilities.

The FDF supports the SPOC and customer operations personnel providing pre-mission analysis and planning, information package generation, and mission planning and monitoring. The pre-mission analysis and planning function develops a science events listing for payload operation based on an evaluation of the various constraints. The customer personnel use these listings to verify science acquisition capability. The information packages provide a range of hardcopy outputs containing science timelines and other associated summary tables. During the mission, the FDF updates mission plans and processes the Orbiter orbit and attitude data obtained from the SPIF to prepare a range of CCTV displays and hardcopy. The displays include alphanumeric information, world map plots, and other graphical displays. This display information is provided within the ASPC enabling rapid assimilation of required data.

The MPS provides an electronic interface with JSC for the transfer of FPS data. Received flight plans are distributed within the ASP complex.

APPENDIX-E

ATTACHMENT E.1
NASA HITCHHIKER PROGRAM
CUSTOMER PAYLOAD REQUIREMENTS (CPR)

HITCHHIKER PROGRAM

CUSTOMER PAYLOAD:

CUSTOMER:

DATE:

CUSTOMER APPROVAL:

NASA APPROVAL:

Payload Manager	Date	HH Mission Manager	Date
Payload Organization	Date	HH Project Manager	Date

APPENDIX E

NASA HITCHHIKER PROGRAM

CUSTOMER PAYLOAD REQUIREMENTS (CPR)

1. INTRODUCTION

This accommodation plan defines the agreement between NASA/GSFC and the HH customer concerning the unique information needed for the preparation, flight and disposition of the payload. The general plans for the handling of HH payloads are described in the HH CARS.

Appropriate information from this accommodation plan will be used to prepare all necessary documents required by the NSTS.

In addition, signature of this CPR sheet (see Attachment E.1) by the Payload Manager is his/her certification that this payload contains no items having commercial value that will be used for commemorative purposes and financial gain.

Customer data is given in Table E.1.

TABLE E.1
CUSTOMER DATA

CUSTOMER PAYLOAD NAME:____

CUSTOMER PAYLOAD ACRONYM:______________________________________

CUSTOMER NAME, ADDRESS, AND TELEPHONE NUMBER:_______________________

____

____

NAMES AND PHONE NUMBERS OF CUSTOMER CONTACTS:

ELECTRICAL: ____

THERMAL: ____

MECHANICAL:____

CALENDAR INTERVAL DURING WHICH FLIGHT IS REQUESTED:____________________

EARLIEST DATE AT WHICH QUALIFIED PAYLOAD WILL BE AVAILABLE: _______________

2. PAYLOAD DESCRIPTION

2.1 MISSION OBJECTIVES

A brief description of the mission objectives of this payload follows:

2.2 PHYSICAL DESCRIPTION

The payload consists of physically separate assemblies which are listed in Table E.2. For each assembly the weight, size, and field of view (if any) requirements are given, along with allowable ranges for operating and nonoperating (storage) temperatures and average power dissipation. Photographs or detailed drawings of each assembly are enclosed. The mounting requirements are either "Standard canister," "Opening-lid canister," "Plate", or "Direct". Figure E.1 is a sketch showing the assemblies and any cables interconnecting the assemblies, the location of the Carrier standard electrical interconnects, the location of surfaces requiring fields of view, and the location of any items requiring access such as purge ports or "red-tag" covers.

2.3 PAYLOAD FUNCTIONAL DESCRIPTION AND METHOD

The following is a brief functional description of the payload describing methods, techniques, and hardware elements used to obtain the mission objectives.

TABLE E.2

PAYLOAD ASSEMBLIES

		SIZE						TEMP	
ASSEMBLY	WEIGHT	X (In)	Y (In)	Z (In)	MOUNT	PWR	FOV	STG	OP

(CUSTOMER SUPPLIED DRAWING)

FIGURE E.1
PAYLOAD GENERAL ARRANGEMENT

2.4 OPERATIONAL SCENARIO

A brief description of the necessary operations scenario to achieve the payloads mission objectives follows: (Customer provides description.)

3. PAYLOAD REQUIREMENTS FOR CARRIER STANDARD SERVICES

3.1 CARRIER TO PAYLOAD ELECTRICAL INTERFACES

The payload will meet the standard electrical interface requirements (including connectors, pin assignments, impedences, signals, levels, etc.), specified in the CARS. This payload will require _____ of the standard interface connections or "ports". For each of the ports, a copy of Table E.3 must be filled in to show which of the standard electrical services will be required by the payload. Unused services will be left open circuited in the payload unless other termination is required by GSFC.

3.2 CARRIER TO PAYLOAD MECHANICAL INTERFACES

The payload will meet the standard mechanical interface requirements specified in the CARS. Mechanical drawings and other documentation will be supplied in sufficient detail for GSFC to perform user accommodation studies and ultimately draft the MICD. Section 2 of CARS addresses most of the information required for accommodation studies. The MICD Requirement Information List in Section 3.1.1.3.2 of the CARS lists the data required for inclusion on the MICD.

TABLE E-3

STANDARD AVIONICS PORT REQUIREMENTS

PORT NUMBER:	________	
NUMBER OF BILEVEL COMMANDS (4 MAX) (2.4.2):	________	
NUMBER OF THERMISTORS (3 MAX) (2.4.7.2):	________	
ASYNCHRONOUS UPLINK (2.4.4):	________	CPS
ASYNCHRONOUS DOWNLINK (2.4.5):	________	CPS
MEDIUM RATE KU-BAND DATA RATE (2.4.6):	________	KB/S
ANALOG DATA (2.4.7.1):	________	
IRIG-B GMT (2.4.8):	________	
GMTMIN (2.4.8):	________	
CREW PANEL SWITCHES (2.4.10):	________	
ORBITER CCTV INTERFACE (2.4.12):	________	
PORT TO PORT INTERCONNECT REQUIRED (2.4.11):	________	
POWER CIRCUIT A - AMPS MAX:	________	AMPS
POWER CIRCUIT B - AMPS MAX:	________	AMPS
POWER CIRCUIT HTR-AMPS MAX:	________	AMPS
TOTAL ENERGY REQUIRED A&B:.	________	KWH
OTHER (DEFINE):	________	

3.3 CARRIER TO PAYLOAD THERMAL INTERFACES

The customer will meet the standard thermal interface requirements specified in Section 2.2 of the CARS. A description of the thermal design concept for the payload follows:

3.4 CUSTOMER SUPPLIED GROUND SUPPORT EQUIPMENT (CGSE)

The payload will require customer-supplied and operated GSE to provide controls and displays for the payload during integration of payload to carrier, system tests, and flight operations as specified in Table E.4.

3.5 OPERATIONS REQUIREMENTS

On-orbit operations for this payload are defined in the form of "cycles"; a cycle is one activation or power-on operation followed by an operating period and then by a de-activation or power-off operation. Table E.5 shows general operations requirements and the characteristics of each operating cycle. The range of acceptable orbit inclinations and attitudes is given as are the duration, any attitude requirements, and requirements for orbit day or night. The maximum power, average power, and energy requirements are given for each cycle. The total number of commands expected to be transmitted is shown along with requirements for low-rate (LR) or MR data coverage in minutes.

TABLE E.4

CUSTOMER GROUND SUPPORT EQUIPMENT (CGSE)

WEIGHT: .... ______ Lbs.

NUMBER OF ASSEMBLIES: .... ______

POWER REQUIRED (WATTS TOTAL): . ... ______ Watts

FLOOR SPACE REQUIRED: .... ______ Sq.Ft.

CGSE WILL GENERATE UPLINK COMMANDS: .... ______

CGSE WILL RECEIVE LOW-RATE CUSTOMER DATA: .... ______

CGSE WILL RECEIVE MEDIUM-RATE DATA: .... ______

CGSE WILL RECEIVE ATTITUDE DATA: .... ______

NUMBER OF STANDARD 15A 115VAC 60-HZ OUTLETS REQUIRED: ... ______

TABLE E.5

PAYLOAD OPERATIONS REQUIREMENTS

TOTAL OPERATING TIME REQUIRED: .... ______

ORBIT INCLINATION RANGE: .... ______

TOTAL NUMBER OF OPERATION CYCLES: .... ______

ORBIT ALTITUDE RANGE: .... ______

TOTAL ENERGY (KWH): .... ______

PAYLOAD OPERATING CYCLES

CYCLE	DURATION	ATTITUDE	DAY/NIGHT	MAX PWR	AVG PWR	ENERGY	CMDS	DATA

SPECIAL OPERATIONS REQUIREMENTS OR RESTRICTIONS:

3.6 GROUND OPERATIONS REQUIREMENTS

This payload will require answers related to handling and ground services as defined in Table E.6.

TABLE E.6

GROUND OPERATIONS REQUIREMENTS

MAXIMUM AND MINIMUM ALLOWED STORAGE TEMPERATURES: .... ______

MAXIMUM AND MINIMUM ALLOWED RELATIVE HUMIDITY: .... ______

CLEANLINESS REQUIREMENT FOR PAYLOAD INTEGRATION AND TESTING: .. ______

CUSTOMER SUPPLIES GROUND SUPPORT EQUIPMENT REQUIRED TO SERVICE PAYLOAD. (EXCLUDING CGSE IN SECTION 3.4): .... ______

REQUIREMENTS FOR GASES OR LIQUIDS: .... ______

REQUIREMENTS FOR PAYLOAD SERVICING AT LAUNCH SITE: .... ______

REQUIRMENTS FOR ACCESS DURING ORBITER INTEGRATION: .... ______

REQUIRMENTS FOR ACCESS ON LAUNCH PAD: .... ______

REQUIRMENTS FOR POST-LANDING ACCESS: .... ______

ANY OTHER SPECIAL REQUIREMENTS FOR HANDLING AT INTEGRATION AND TEST OR LAUNCH SITE: .... ______

SIZES AND WEIGHTS OF ITEMS REQUIRED FOR SHIPMENT TO INTEGRATION OR LAUNCH SITES (EXCLUDING CGSE OF Table E.4):

ITEM	SIZE	WEIGHT

3.7 SAFETY

Table E.7 requires a "no" or "yes" answer to items related to payload safety. Details of items identified "yes" are also given.

TABLE E.7

PAYLOAD SAFETY RELATED ITEMS

a. CONTAINS PRESSURIZED VOLUME(S): .... ______
b. CONTAINS RADIOACTIVE MATERIAL: .... ______
c. CONTAINS LIGHT OR RF SOURCE: .... ______
d. EXTERNAL ELECTRIC OR MAGNETIC FIELDS: .... ______
e. EXTERNAL ELECTRICALLY CHARGED SURFACE: .... ______
f. EXTERNAL HOT OR SHARP SURFACE: .... ______
g. CONTAINS TOXIC MATERIAL (E.G., HG, BE): .... ______
h. CONTAINS OUTGASSING MATERIAL: .... ______
i. VENTS FLUIDS OR GASES: .... ______
j. CONTAINS CRYOGENS: .... ______
k. HAS MOVING EXTERNAL PARTS: .... ______
l. CONTAINS EXPLOSIVE DEVICES: .... ______
m. CONTAINS OR GENERATES EXPLOSIVE OR FLAMMABLE MATERIAL OR GAS: .. ______
n. CUSTOMER SUPPLIED GSE CONTAINS RADIOACTIVE MATERIAL, LIGHT OR RF SOURCES, PRESSURIZED VOLUME: .... ______
o. ANY OTHER HAZARD: .... ______

DESCRIPTION OF IDENTIFIED HAZARD(S):

3.7.1 SAFETY MATRIX

The Payload Safety Matrix and Descriptive Data Form contained in Appendix A, figures A.4, A.5, A.6 and A.7 should be used to provide an estimate of payload safety hazards. The intent of the forms is to assist in tabulating identified hazards associated with payloads and GSE. Directions for preparing these forms are given in Appendix A, page A-10 for the Payload Safety Matrix and A-13 for the Descriptive Data Form.

4. PAYLOAD REQUIREMENTS FOR OPTIONAL SERVICES

This section will contain descriptions and estimated costs for any optional services to be provided.

APPENDIX-F

APPENDIX F

THERMAL BLANKET REQUIREMENTS

1. INTRODUCTION AND SUMMARY

The intent of this Appendix is to provide the principle investigators for Shuttle-borne experiments enough information to design and fabricate insulation systems to protect scientific instruments from Shuttle environmental temperature extremes. While special requirements occasionally dictate the localized use of a foam or batt insulation, the great majority of payloads will be insulated with Multi-Layer Insulation (MLI) discussed in this section. Special requirements, however, occasionally dictate localized use of a foam or batt insulation.

A typical MLI contains 10 to 50 layers of a metallized film, with alternating layers of a low-density spacer material. MLI relies on low-contact conduction between layers, low-gas conduction in the vacuum environment, and highly reflective metal surfaces to minimize both conduction and radiation heat transfer. This information is intended primarily for the experimenter with relatively little spacecraft experience who is adapting a near-room-temperature laboratory or sounding rocket-class instrument for flight on the Shuttle.

The information provided has been compiled from existing data sources, including the Shuttle Payload Accommodations Handbook (Reference 1*), a Lockheed study of MLI insulation (Reference 2*), and from Grumman insulation data and fabrication procedures developed over a period of years in support of the Apollo lunar landing vehicle.

2. REQUIREMENTS FOR HH APPLICATION

2.1 TEMPERATURE EXTREMES

During pre-launch checkout, launch, and re-entry, the temperature of a payload insulation system is not under the experimenter's control. Since the multilayer insulation is composed of many very light-weight layers of aluminized film and spacer material, its temperature will closely follow the Shuttle bay environment temperature. The highest environment temperature reached in any of these mission phases occurs during re-entry when vents allow air in to minimize the pressure differential across the Shuttle structure. This has been established in Reference 1 as 80°C.

This criteria, along with flammability, has led to the selection of aluminized polymide (Kapton) as the standard insulation material for Shuttle payloads. Kapton is not flammable, and does not shrink or degrade at temperatures up to approximately 400°C. On-orbit, the insulation outer layer temperature depends upon the properties of the external coating and on the orientation of the surface to the sun and the Earth. Typically, insulation outer layer surface temperatures are expected to fall in the -160°C to 90°C range.

* See subsection F.3 for references

2.2 HUMIDITY

Aluminized Kapton is irreparably damaged by liquid water. Water dissolves the vapor-deposited aluminum which provides the high-radiation reflectance necessary for an efficient insulation system. Normal humidity levels of 30 to 50 percent existing in the laboratory or in the Shuttle bay during ground checkout will not harm the insulation system. The main consideration of exposure to normal humidity prior to thermal vacuum testing or flight is that it will require sufficient time in a vacuum to desorb the water molecules from the blanket before optimum blanket performance is reached. High humidity may be experienced during landing, so insulation systems should be inspected prior to re-use. In any application where high humidity, or indeed actual condensation on the MLI blanket is anticipated, consideration should be given to the use of gold-coated Kapton rather than the standard aluminized Kapton.

2.3 LAUNCH AND RE-ENTRY PRESSURE TRANSIENTS

Sufficient vent paths must be provided in the insulation system to prevent a pressure differential from tearing individual layers or ballooning the entire assembly away from the payload. The launch profile is the critical pressure transient, since typically, the blanket is only moderately restrained (by tape, velcro, or stand-offs) to resist motion away from the payload. To minimize lost mission time, the MLI venting system must allow rapid inner-layer venting and, hence, a rapid attainment of high effectiveness. An increasing external pressure during re-entry is less significant, since it will usually only result in slight compression of the blanket against the payload structure. Care must be taken in the design of the MLI system however, to allow repressurization of the experiment cavity.

2.4 OFF-GASSING CONSTRAINTS

Any payload to be flown on the Shuttle must be designed to meet off-gassing criteria. The concern is that a molecular cloud in the vicinity of the Shuttle, plus actual condensation of off-gassed molecules on optical surfaces, can greatly degrade experiments. The primary NASA criteria is to require use of materials that exhibit less than a 1% TML, and .1% collected Volatile Condensible Material (VCM) when heated to 125°C for the NASA standard test described in Reference 3 (see subsection F.3).

2.5 GROUNDING

A relatively new criteria imposed on Shuttle payloads is the grounding of the insulation system. Since the multiple alternating layers of spacer and metallized film can act as a large capacitor covering essentially the entire payload, NASA requires layer-to-layer grounding to avoid electrostatic charge buildup.

2.6 EXTERNAL COATING REFLECTANCE

NASA has established the goal of minimizing reflections off payload surfaces that could hamper the astronaut's visibility, affect crew tasks, or degrade neighboring experiments. Therefore, although specular reflecting surfaces are not forbidden, it is desirable to use diffuse reflecting external surfaces on insulation blankets. Paints and cloth coverings are generally diffuse, but a commonly used external layer is a thicker (2 mil) layer (for handling protection) of aluminized Kapton (Kapton side out), and this is a primarily specular surface. Another common surface used to obtain a low-solar absorptivity is silver-coated Teflon (Teflon side out), which can be obtained in either specular or diffuse versions. Until a firm criteria is established, the acceptability of specular outer surfaces will probably be determined by each Shuttle vehicle manager, based on the experiments and anticipated crew tasks for that flight.

An important design consideration for external blankets is the so-called "greenhouse" effect. This occurs when the outermost layer is semi-transparent to solar energy (beta cloth, plain Kapton). If the next outermost layer has a lower temperature, then the solar energy absorbed in the layer will result in a high-layer temperature and the energy will be re-radiated equally from both sides of the layer. Therefore, when a semi-transparent outermost-layer is used, the next layer should be one-side aluminized Kapton with the Kapton side out so that the energy absorbed in this layer is primarily re-radiated to the outer layer and then to space.

2.7 FLAMMABILITY

This is an extermely important criteria requiring controlled testing of any new materials contemplated for Shuttle use. Fortunately, non-flammable materials are available that are completely acceptable for MLI systems. These are aluminized Kapton for the reflective layer and various dacron and glass nets for the separator.

2.8 ACCELERATION, VIBRATION, AND ACOUSTIC ENVIRONMENTS

MLI systems are extremely light (.1 lb/ft^2). Hence, they are relatively easy to secure to the payload to survive the Shuttle acceleration, vibration, and acoustic environments during launch and re-entry. These design criteria are fully discussed in Reference 1 (see subsection F.3).

2.9 WEIGHT

The maximum weight of the payload MLI systems is not a Shuttle requirement but must be considered for standoff design and cost. The experimenter should estimate a realistic blanket-performance goal. By making use of the relatively simple design approaches and fabrication techniques discussed in this report, it is possible to obtain the highest effectiveness for a given blanket weight.

2.10 OTHER FACTORS

There are a number of mission unique-factors the experimenter must consider. These include installation time, on-orbit access, post landing access, and re-usability.

3. REFERENCES

1. Space Shuttle System Payload Accommodation, JSC07700 Volume XIV, Revision F.

2. NASA CR-134477 "Thermal Performance of Multi-layer Insulation", Lockheed Final Report, April 1974.

3. NASA Reference Publication 1014 "An Outgassing Data Compilation of Spacecraft Materials", January 1978.

4. Stimpson, L.D., and Jaworski, W., "Effects of Overlaps, Stitches and Patches on Multilayer Insulation", Progress in Astronautics and Aeronautics, Volume 31, 1973.

5. NASA SP 5027 "Thermal Insulation Systems", 1967.

6. Holmes, V.L., et. al., "Measurement of Apparent Thermal Conductivity of Multilayer Insulations at Low Compressive Loads", AIAA Paper 72-367, 1972.

APPENDIX-G

APPENDIX G

ALGORITHMS FOR ATTITUDE CONVERSIONS
SIMPLIFIED CALCULATION OF SHUTTLE BODY AXIS ATTITUDES USING M50 QUATERNIONS

1. INTRODUCTION

This appendix outlines simplified equations that can be used to calculate Shuttle body axis attitudes using M50 body quaternions in the Shuttle downlink. Both an analytical background and a simplified set of equations that can be used by a programmer will be provided. In addition, a sample personel computer (PC) program in BASIC is provided for reference in Table G.1.

2. ANALYTICAL APPROACH

NOTE: This section is an exerpt from the document titled: Payloads Mathematical Specifications, CSC/SD-85/6024, Prepared for NASA under Contract NAS5-27888, July, 1985.

A vector in Shuttle body axis coordinates, V_{by}, can be expressed as:

$$V_{by} = \{A_s\}_{M50} V_{M50}$$

where:

$\{A_s\}_{M50}$ = Attitude matrix relative to the Mean-of-1950 System (M50)

V_{M50} = Vector in M50 coordinate system

then,

$$\begin{aligned} V_{M50} &= \{A_s\}_{M50}^{-1} V_{by} \\ &= \{A_s\}_{M50}^{T} V_{by} \end{aligned}$$

NOTE: Since $\{A_s\}_{M50}$ is orthogonal, its inverse is equal to the transpose.

The attitude matrix $\{A_s\}_{M50}$ can be constructed from the Shuttle M50 body quaternion as follows:

$$\{A_s\}_{M50} = \begin{pmatrix} A11 & A12 & A13 \\ A21 & A22 & A23 \\ A31 & A32 & A33 \end{pmatrix}$$

where: $A11 = q1^2 + q2^2 - q3^2 - q4^2$

$A12 = 2(q2q3 - q1q4)$

$A13 = 2(q2q4 + q1q3)$

$A21 = 2(q2q3 + q1q4)$

$A22 = q1^2 - q2^2 + q3^2 - q4^2$

$A23 = 2(q3q4 - q1q2)$

$A31 = 2(q2q4 - q1q3)$

$A32 = 2(q3q4 + q1q2)$

$A33 = q1^2 - q2^2 - q3^2 + q4^2$

and (q1, q2, q3, q4) are the elements of the Shuttle M50 body quaternion.

For the i^{th} Shuttle body axis:

$$(i)_{M50} = (Ali^{-1}, A2i^{-1}, A3i^{-1})^T_{M50}$$

Hence $$(RA_i)_{M50} = \left(\mathrm{Tan}^{-1} \frac{A2i^{-1}}{A1i^{-1}{}_{M50}}\right)$$

And $$(Dec_i)_{M50} = \left(\mathrm{Tan}^{-1} \frac{A3i^{-1}}{\sqrt{(Ali^{-1})^2 + (A2i^{-1})^2}}\right)$$

Where $(RA_i)_{M50}$ = Right Ascension of the i^{th} body axis of the Shuttle in the M50 system

$(Dec_i)_{M50}$ = Declination of the i^{th} body axis of the Shuttle in the M50 system.

* The Shuttle M50 Pitch/Roll/Yaw attitudes can easily be calculated by forming the matrix {K} as follows:

$$\{K\} = \{A_s\}_{M50}\,\{R\}^{-1}$$

where $\{R\}$ = Identity matrix

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

and therefore = $\{R\}^{-1} = \{R\}^{T} = \{R\}$

Hence:

$$\{K\} = \{A_s\}_{M50}$$

Then, the Pitch, Roll, and Yaw using a 2-3-1 Euler rotation can be calculated:

$$\mathrm{Pitch}_{M50} = \mathrm{Tan}^{-1}(-K13/K11) \qquad 0 \leq p < 2$$

$$\mathrm{Roll}_{M50} = \mathrm{Tan}^{-1}(-K32/K22) \qquad 0 \leq R < 2$$

$$\mathrm{Yaw}_{M50} = \mathrm{Sin}^{-1}(K12) \qquad -\pi/2 \leq Y \leq \pi/2$$

To calculate the Shuttle body axis Pitch, Roll, Yaw attitudes in the LVLH coordinate system, one needs to form the {K} matrix as above and repeated here again:

$$\{K\} = \{A_s\}_{M50} \{R\}^{-1}$$

Where {R} = a matrix formed using the Shuttle position vector (r) and velocity vector (v) in the M50 coordinate system. The position and velocity vectors are obtained from the Shuttle ancillary downlink.

and

$$\{R\} = \begin{bmatrix} U_1^T \\ U_2^T \\ U_3^T \end{bmatrix}$$

where

$$U_1 = U_2 \ X \ U_3$$

$$U_2 = \frac{-(r \ X \ v)}{r \ X \ v}$$

$$U_3 = \frac{-r}{r}$$

Since the {R} matrix is orthogonal, then

$$\{R\}^{-1} = \{R\}^T$$

Hence:

$$\{K\} = \{A_s\}_{M50} \{R\}^T$$

Then, the Pitch, Roll, and Yaw body axis attitudes in the LVLH system can be calculated using a 2-3-1 Euler rotation as follows:

$Pitch_{LVLH}$	=	Tan^{-1} (-K13/K11)	$0 \leq P < 2$
$Roll_{LVLH}$	=	Tan^{-1} (-K32/K22)	$0 \leq R < 2$
Yaw_{LVLH}	=	Sin^{-1} (K12)	$-\pi/2 \leq Y \leq \pi/2$

3. PC PROGRAMMING APPROACH

Simple computer programming approach using quaternions to calculate Shuttle attitudes in: M50 Right Ascension and Declination; M50 Pitch/Roll/Yaw; and LVLH Pitch/Roll/Yaw.

Step 1

Obtain the Shuttle M50 body quaternion (Q1, Q2, Q3, Q4)

Set radians to degrees constant:

RTOD = 57.2957795

Note: If high precision is required, it is suggested that double precision be used.

Step 2

Calculate the elements of the matrix $\{A_s\}$ as follows:

```
A11 = Q1**2+Q2**2-Q3**2-Q4**2
A12 = 2.*(Q2*Q3-Q1*Q4)
A13 = 2.*(Q2*Q4+Q1*Q3)
A21 = 2.*(Q2*Q3+Q1*Q4)
A22 = Q1**2-Q2**2+Q3**2-Q4**2
A23 = 2.*(Q3*Q4-Q1*Q2)
A31 = 2.*(Q2*Q4-Q1*Q3)
A32 = 2.*(Q3*Q4+Q1*Q2)
A33 = Q1**2-Q2**2-Q3**2+Q4**2
```

Step 3

Calculate RA and Dec of each Shuttle axis in degrees using the transpose of matrix $\{A_s\}$ as follows:

X Shuttle M50 Body Axis (Out Nose):

```
RAX = ATAN2(A12/A11)*RTOD
IF(RAX.LT.0.0)RAX=RAX+360.0
DECX=ATAN2(A13/SQRT(A11**2+A12**2))*RTOD
```

Y Shuttle M50 Body Axis (Out Right Wing):

```
RAY=ATAN2(A22/A21)*RTOD
IF (RAY.LT.0.0)RAY=RAY+360.0
DECY=ATAN2(A23/SQRT(A21**2+A22**2))*RTOD
```

Z Shuttle M50 Body Axis (Out Bottom of Fuselage):

```
RAZ=ATAN2(A32/A31)*RTOD
IF(RAZ.LT.0.0)RAZ=RAZ+360.0
DECZ=ATAN2(A33/SQRT(A31**2+A32**2))*RTOD
```

-Z Shuttle M50 Body Axis (Up Out of Payload Bay):

```
RANZ=RAZ+180.0
IF(RANZ.GE.360.0)RANZ=RANZ-360.0
DECNZ=-DECZ
```

Step 4

Calculate the M50 Pitch/Roll/Yaw using a 2-3-1 Euler rotation:

```
PITCH=ATAN2(-A13/A11)*RTOD
IF(PITCH.LT.0.0)PITCH=PITCH+360.0
ROLL=ATAN2(-A32/A22)*RTOD
IF(ROLL.LT.0.0)ROLL=ROLL+360.0
YAW=ARSIN(A12)*RTOD
(Note: Yaw defined between -90 and +90)
```

Step 5

To calculate the LVLH Pitch/Roll/Yaw Shuttle body axis attitudes using the 2-3-1 Euler rotation, obtain the Shuttle position (R1, R2, R3) and velocity (V1, V2, V3) vectors in M50 from the Shuttle ancillary downlink.

Step 6

Calculate the {R} matrix:

```
RMAG=SQRT(R1**2+R2**2+R3**2)
U3X=-R1/RMAG
U3Y=-R2/RMAG
U3Z=-R3/RMAG
RXVX=R2*V3-R3*V2
RXVY=R3*V1-R1*V3
RXVZ=R1*V2-R2*V1
RXVMAG=SQRT(RXVX**2+RXVY**2+RXVZ**2)
U2X=-RXVX/RXVMAG
U2Y=-RXVY/RXVMAG
U2Z=-RXVZ/RXVMAG
U1X=U2Y*U3Z-U2Z*U3Y
U1Y=U2Z*U3X-U2X*U3Z
U1Z=U2X*U3Y-U2Y*U3X
```

Step 7

Using the transpose of {R}, calculate the {K} matrix where:

$$\{K\} = \{A_s\}_{M50}\,\{R\}^T$$

and

$$\{R\}^T = \begin{pmatrix} U1X & U2X & U3X \\ U1Y & U2Y & U3Y \\ U1Z & U2Z & U3Z \end{pmatrix}$$

and

$\{A_s\}_{M50}$ was calculated before

Hence the code to calculate {K} is:

```
K11=A11*U1X+A12*U1Y+A13*U1Z
K12=A11*U2X+A12*U2Y+A13*U2Z
K13=A11*U3X+A12*U3Y+A13*U3Z
K21=A21*U1X+A22*U1Y+A23*U1Z
K22=A21*U2X+A22*U2Y+A23*U2Z
K23=A21*U3X+A22*U3Y+A23*U3Z
K31=A31*U1X+A32*U1Y+A33*U1Z
K32=A31*U2X+A32*U2Y+A33*U2Z
K33=A31*U3X+A32*U3Y+A33*U3Z
```

Step 8
Calculate the LVLH Shuttle body axis Pitch/Roll/Yaw attitudes using a 2-3-1 Euler rotation:

```
PITCH=ATAN2(-K13/K11)*RTOD
IF(PITCH.LT.0.0)PITCH=PITCH+360.0

ROLL=ATAN2(-K32/K22)*RTOD)
IF (ROLL.LT.0.0)ROLL=ROLL+360.0

YAW=ARSIN(K12)*RTOD
```

(Note: since JSC normally represents yaw positive, then add 360 if negative)

```
IF(YAW.LT.0.0)YAW=YAW+360.0
```

4. GSFC CONTACT

If there are additional questions or problems, these can be directed to:

Deputy Project Manager
NASA/GSFC, Code 740.3
Greenbelt, Maryland 20771
(301) 286-4271 (FTS 888-4271) (FAX 301-286-2376)

TABLE G.1

PC PROGRAM IN BASIC FOR CALCULATING SHUTTLE BODY AXIS ATTITUDE

```
10 REM PROGRAM (IN BASIC) TO CALC ATTITUDE FROM
20 REM FROM M50 SHUTTLE BODY QUATERNIONS
30 RTOD#=180#/3.14159265#
40 PRINT "INPUT Q1"
50 INPUT Q1#
60 PRINT "INPUT Q2"
70 INPUT Q2#
80 PRINT "INPUT Q3"
90 INPUT Q3#
100 PRINT "INPUT Q4"
110 INPUT Q4#
120 PRINT
130 PRINT "THE INPUT QUATERNION IS"
140 PRINT Q1#,Q2#,Q3#,Q4#
150 REM
160 REM PART I : CALCULATE RIGHT ASCENSION AND DECLINATION IN M50
170 REM
180 PRINT
190 PRINT
200 PRINT "THE RIGHT ASCENSION AND DECLINATION IN M50 IS"
210 PRINT
220 PRINT
230 REM CALCULATE MATRIX A
240 A11#=Q1#^2+Q2#^2-Q3#^2-Q4#^2
250 A12#=2#*(Q2#*Q3#-Q1#*Q4#)
260 A13#=2#*(Q2#*Q4#+Q1#*Q3#)
270 A21#=2#*(Q2#*Q3#+Q1#*Q4#)
280 A22#=Q1#^2-Q2#^2+Q3#^2-Q4#^2
290 A23#=2#*(Q3#*Q4#-Q1#*Q2#)
300 A31#=2#*(Q2#*Q4#-Q1#*Q3#)
310 A32#=2#*(Q3#*Q4#+Q1#*Q2#)
320 A33#=Q1#^2-Q2#^2-Q3#^2+Q4#^2
330 REM THEN TRANSPOSE MATRIX A AND CALC RA+DEC FOR EACH
```

TABLE G.1 (Cont'd)

```
340 REM SHUTTLE BODY AXIS (INCLUDING X, Y, Z, AND -Z)
350 REM -Z=UP OUT OF SHUTTLE BAY
360 REM  X=OUT NOSE OF SHUTTLE
370 REM  Y=OUT RIGHT WING
380 REM  Z=OUT THE UNDERSIDE OF SHUTTLE FUSELAGE
390 RAX#=ATN(A12#/A11#)*RTOD#
400 IF A11#<0 THEN RAX#=RAX#+180#
410 IF A11#>0 AND A12#<0 THEN RAX#=RAX#+360#
420 DECX#=ATN(A13#/SQR(A11#^2+A12#^2))*RTOD#
430 PRINT "RA  +X (DEG)=",RAX#,"DEC  +X (DEG)=",DECX#
440 RAY#=ATN(A22#/A21#)*RTOD#
450 IF A21#<0 THEN RAY#=RAY#+180#
460 IF A21#>0 AND A22#<0 THEN RAY#=RAY#+360#
470 DECY#=ATN(A23#/SQR(A21#^2+A22#^2))*RTOD#
480 PRINT "RA  +Y (DEG)=",RAY#,"DEC  +Y (DEG)=",DECY#
490 RAZ#=ATN(A32#/A31#)*RTOD#
500 IF A31#<0 THEN RAZ#=RAZ#+180#
510 IF A31#>0 AND A32#<0 THEN RAZ#=RAZ#+360#
520 DECZ#=ATN(A33#/SQR(A31#^2+A32#^2))*RTOD#
530 PRINT "RA  +Z (DEG)=",RAZ#,"DEC  +Z (DEG)=",DECZ#
540 RANZ#=RAZ#+180#
550 IF RANZ#>=360# THEN RANZ#=RANZ#-360#
560 DECNZ#=-DECZ#
570 PRINT "RA -Z (DEG)=",RANZ#,"DEC -Z (DEG)=",DECNZ#
580 PRINT
590 PRINT
600 REM PART II : CALCULATE M50 PITCH/ROLL/YAW USING 2-3-1 EULER SEQ
610 REM CALCULATE THE K MATRIX AS FOLLOWS:
620 REM             T
630 REM  K = (A)  (R)
640 REM      ( 1  0  0 )
650 REM  R = ( 0  1  0 )
660 REM      ( 0  0  1 )
670 REM        T
```

TABLE G.1 (Cont'd)

```
680 REM R = (R)
690 REM SINCE R=IDENTITY MATRIX, THEREFORE MATRIX K = MATRIX A
700 REM USING A 2-3-1 ROTATION CALCULATE PITCH/ROLL/YAW (M50)
710 REM WHERE 0<=PITCH<360, 0<=ROLL<360, AND -90<=YAW<=90
720 REM HOWEVER, YAW IS MODIFIED TO BE BETWEEN 270 AND 90 GOING THRU 0
730 PITCH#=ATN(-A13#/A11#)*RTOD#
740 IF A11#<0 THEN PITCH#=PITCH#+180#
750 IF A11#>0 AND -A13#<0 THEN PITCH#=PITCH#+360#
760 ROLL#=ATN(-A32#/A22#)*RTOD#
770 IF A22#<0 THEN ROLL#=ROLL#+180#
780 IF A22#>0 AND -A32#<0 THEN ROLL#=ROLL#+360#
790 REM ACTUALLY YAW#=ARCSIN(A12#)*RTOD# , BUT MY PC BASIC DOESN'T
800 REM HAVE THE ARCSIN, HENCE THE RADICAL CALCULATION
810 YAW#=ATN(A12#/(SQR(1#-A12#^2)))*RTOD#
820 IF YAW#<0 THEN YAW#=YAW#+360#
830 PRINT
840 PRINT "SHUTTLE M50 PITCH/ROLL/YAW (2-3-1 EULER SEQ)"
850 PRINT
860 PRINT "PITCH (DEG)=",PITCH#,"ROLL (DEG)=",ROLL#,"YAW (DEG)=",YAW#
870 PRINT
880 PRINT
890 REM
900 REM PART III : CONVERT ATTITUDE TO LVLH PITCH/ROLL/YAW IN A
910 REM  2-3-1 EULER SEQUENCE
920 REM
930 REM INPUT ORBIT POSITION AND VELOCITY VECTORS(FT AND FT/SEC)
940 PRINT "INPUT R1"
950 INPUT R1#
960 PRINT "INPUT R2"
970 INPUT R2#
980 PRINT "INPUT R3"
990 INPUT R3#
1000 PRINT "INPUT V1"
1010 INPUT V1#
```

TABLE G.1 (Cont'd)

```
1020 PRINT "INPUT V2"
1030 INPUT V2#
1040 PRINT "INPUT V3"
1050 INPUT V3#
1060 PRINT "THE INPUT RADIUS VECTOR (FT) IS"
1070 PRINT R1#,R2#,R3#
1080 PRINT
1090 PRINT "THE INPUT VELOCITY VECTOR (FT/SEC) IS"
1100 PRINT V1#,V2#,V3#
1110 PRINT
1120 PRINT
1130 REM NOW CALCULATE THE R MATRIX USING THE R AND V VECTORS
1140 RMAG#=SQR(R1#^2+R2#^2+R3#^2)
1150 U3X#=-R1#/RMAG#
1160 U3Y#=-R2#/RMAG#
1170 U3Z#=-R3#/RMAG#
1180 RXVX#=R2#*V3#-R3#*V2#
1190 RXVY#=R3#*V1#-R1#*V3#
1200 RXVZ#=R1#*V2#-R2#*V1#
1210 RVMAG#=SQR(RXVX#^2+RXVY#^2+RXVZ#^2)
1220 U2X#=-RXVX#/RVMAG#
1230 U2Y#=-RXVY#/RVMAG#
1240 U2Z#=-RXVZ#/RVMAG#
1250 U1X#=U2Y#*U3Z#-U2Z#*U3Y#
1260 U1Y#=U2Z#*U3X#-U2X#*U3Z#
1270 U1Z#=U2X#*U3Y#-U2Y#*U3X#
1280 REM WE NOW HAVE R=(U1,U2,U3) MATRIX
1290 REM       ( U1X#   U1Y#   U1Z# )
1300 REM  R =   ( U2X#   U2Y#   U2Z# )
1310 REM       ( U3X#   U3Y#   U3Z# )        T
1320 REM NOW HOWEVER TAKE THE TRANSPOSE OF R = R
1330 REM
1340 REM   T  ( U1X#   U2X#   U3X# )
1350 REM  R  = ( U1Y#   U2Y#   U3Y# )
```


C·4

TABLE G.1 (Cont'd)

```
1360 REM      ( U1Z#   U2Z#   U3Z# )
1370 REM                        T
1380 REM NOW CALCULATE THE K MATRIX = (A) (R)
1390 K11#=A11#*U1X#+A12#*U1Y#+A13#*U1Z#
1400 K12#=A11#*U2X#+A12#*U2Y#+A13#*U2Z#
1410 K13#=A11#*U3X#+A12#*U3Y#+A13#*U3Z#
1420 K21#=A21#*U1X#+A22#*U1Y#+A23#*U1Z#
1430 K22#=A21#*U2X#+A22#*U2Y#+A23#*U2Z#
1440 K23#=A21#*U3X#+A22#*U3Y#+A23#*U3Z#
1450 K31#=A31#*U1X#+A32#*U1Y#+A33#*U1Z#
1460 K32#=A31#*U2X#+A32#*U2Y#+A33#*U2Z#
1470 K33#=A31#*U3X#+A32#*U3Y#+A33#*U3Z#
1480 REM IN A 2-3-1 ROTATION CALC PITCH/ROLL/YAW
1490 PITCH#=ATN(-K13#/K11#)*RTOD#
1500 IF K11#<0 THEN PITCH#=PITCH#+180#
1510 IF K11#>0 AND -K13#<0 THEN PITCH#=PITCH#+360#
1520 ROLL#=ATN(-K32#/K22#)*RTOD#
1530 IF K22#<0 THEN ROLL#=ROLL#+180#
1540 IF K22#>0 AND -K32#<0 THEN ROLL#=ROLL#+360#
1550 YAW#=ATN(K12#/(SQR(1#-K12#^2)))*RTOD#
1560 IF YAW#<0 THEN YAW#=YAW#+360#
1570 PRINT
1580 PRINT "SHUTTLE LVLH PITCH/ROLL/YAW (2-3-1 EULER SEQ)"
1590 PRINT
1600 PRINT "PITCH (DEG)=",PITCH#,"ROLL (DEG)=",ROLL#,"YAW (DEG)=",YAW#
1610 PRINT
1620 PRINT "DONE"
1630 REM TEST EXAMPLE : INPUTS ARE Q1=.2209538, Q2=.4641501, Q3=.8537468,
1640 REM  Q4=-.0828158,  R1=-16732867, R2=-12040024, R3=7815002.5,
1650 REM  V1=11329.191, V2=-21052.605, V3=-8160.598
1660 REM TEST EXAMPLE : RESULTS ARE RA+X=119.624,DEC+X=17.481
1670 REM                    RA+Y=36.305 ,DEC+Y=-20.274
1680 REM                    RA+Z=172.015,DEC+Z=-62.703
1690 REM                    RA-Z=352.015,DEC-Z=62.703
```

TABLE G.1 (Cont'd)

```
1700 REM      M50 PITCH=212.502, ROLL=353.456, YAW=56.009
1710 REM     LVLH PITCH=179.339, ROLL=269.727, YAW=1.739
1720 END
```

APPENDIX-H

Appendix H

Excerpts from Vo. XIV, ICD 2-19001

SHUTTLE ORBITER/CARGO STANDARD INTERFACES

REVISION K

AUGUST 1, 1991

NOTE: The complete volume XIV document may be obtained from NASA/JSC, Customer Service Center, Code TB15, Houston, TX 77058.

Additional limitations apply to any payload transmitter (contact Project Office).

Excerpts from Vol. XIV, ICD 2-19001: Shuttle Orbiter/Cargo Standard Interfaces, Revision K, January 15, 1991 (using paragraph and figure numbers from that document).

7.3.7 DC Power Ripple and Transient Limits

Ripple and transient limits for electrical power provided by the Orbiter at the indicated interfaces shall not exceed the voltage values specified in the following paragraphs.

During normal equipment operation, for both ground power and fuel cell power, voltage transients of opposite polarity shall not occur simultaneously on the positive and return dc power busses.

7.3.7.1 Inflight DC Power Bus Ripple

Inflight DC power bus ripple at the interface shall not exceed 0.9 volts peak-to-peak narrowband (30 Hz to 7 kHz) falling 10 dB per decade to 0.28 volts peak-to-peak at 70 kHz, thereafter remaining constant to 400 MHz.

The momentary coincidence of 2 or more signals at any one frequency shall not exceed the envelope defined as 1.6 volts peak-to-peak (30 Hz to 7 kHz), falling 10 dB per decade to 0.5 volts peak-to-peak at 70 kHz, thereafter remaining constant to 400 MHz.

Under the conditions of a passive payload (resistive simulation of load), the ripple on the power supplied shall not be greater than 0.8 volts peak-to-peak broadband (DC to 50 MHz); no discrete frequency shall exceed 0.4 volts peak-to-peak. This condition shall apply at the mid-body power interface only.

7.3.7.2 Inflight DC Power Transients

Inflight DC power transients on the Orbiter DC power busses at the cargo element interface (measured common-mode) shall not exceed the voltage envelope of Figures 7.3.7.2-1 and 7.3.7.2-2.

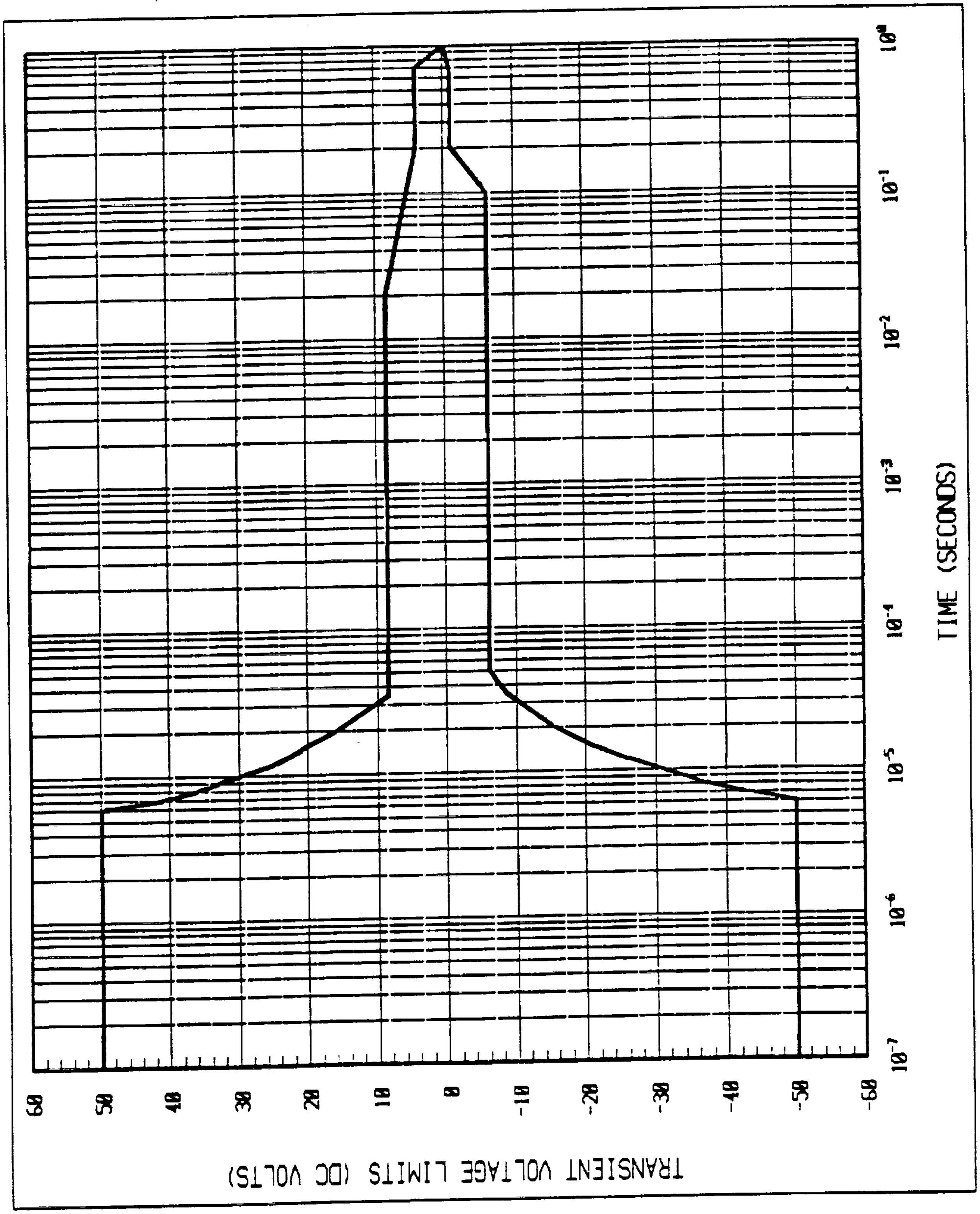


FIGURE 7.3.7.2-1 INFLIGHT DC POWER TRANSIENTS (MEASURED LINE-TO-STRUCTURE) AT ALL CARGO ELEMENT POSITIVE DC POWER INTERFACES

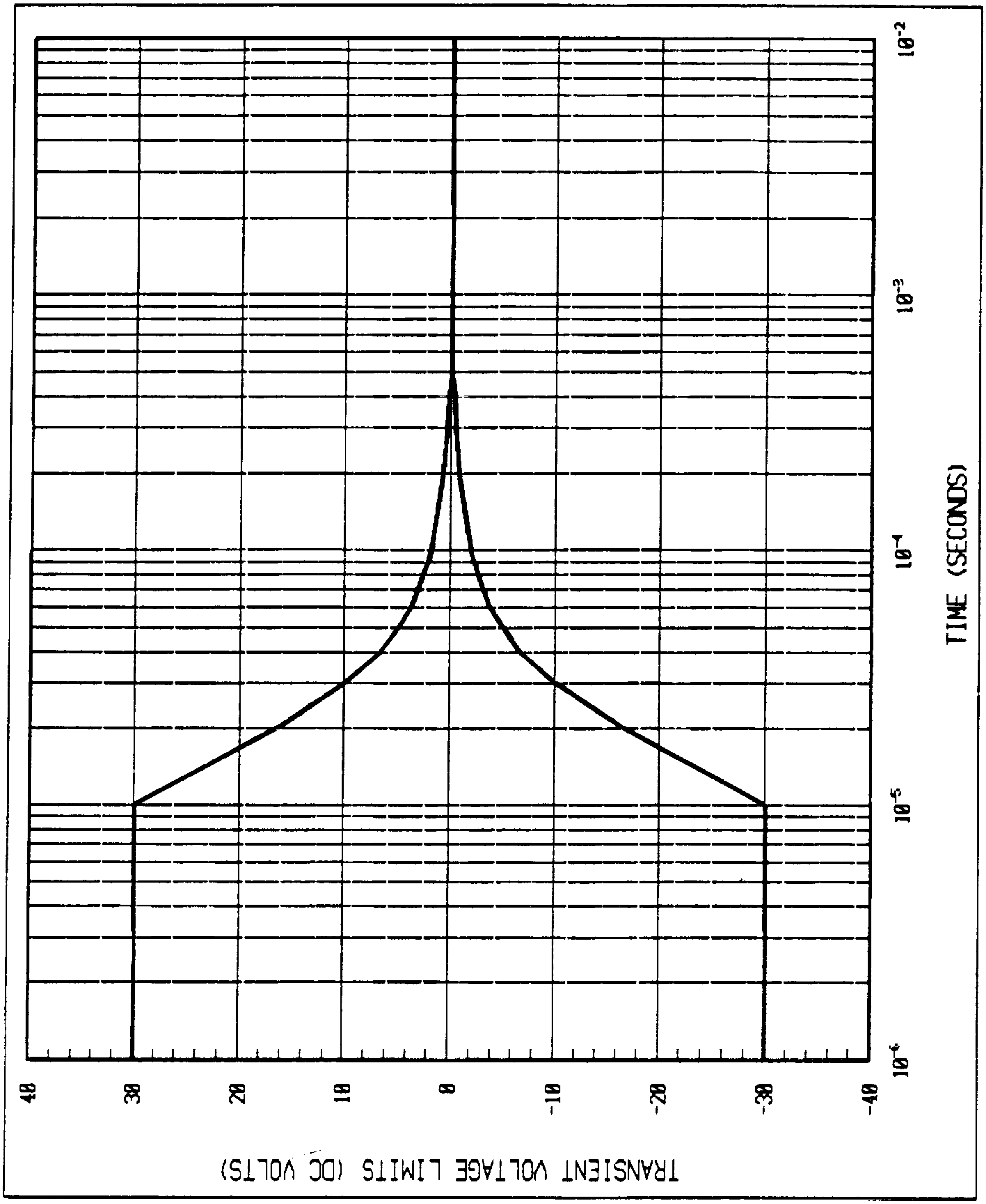


FIGURE 7.3.7.2-2 INFLIGHT DC POWER TRANSIENTS (MEASURED LINE-TO-STRUCTURE) AT ALL CARGO ELEMENT DC POWER RETURN INTERFACES

7.3.7.2.2 Hydraulic Circulation Pump and PRI and Cabin and Aux PL Busses

Hydraulic circulation pump produced transient voltages on the PRI PL Bus, Aux PL A, Aux PL B and the Cabin PL Bus, at the payload design interfaces, shall not exceed the voltage envelope of Figure 7.3.7.2.2-1. Payload design shall accommodate sawtooth transient oscillations, having a maximum amplitude of 4 volts peak-to-peak on the PRI PL Bus, Aux PL A, Aux PL B and the Cabin PL Bus, at the cargo element interface. The oscillation has a base frequency between 500 and 700 Hz and contained within the inner envelope shown in Figure 7.3.7.2.2-1. These bus voltage transients (caused by activation of the hydraulic circulation pump connected to that bus) may occur at any time during on-orbit operations, plus activation at touchdown, and shall not be subjected to pre-flight scheduling.

7.3.7.3 Common-Mode Voltage

Common mode voltage, as used here, is defined as the voltage drop across two points of Orbiter structure caused by a current through the impedance between those two points. The common-mode voltage for the longest Cargo Bay dimension (Station Xo585 to Xo1307 bulkhead) shall not exceed 0.3 volts peak-to-peak, when measured in the time domain with an instrument bandwidth of at least 50 MHz (linear function). This is inclusive of the DC component which may exist in the vehicle structural members. Voltages measured at discrete frequencies shall not exceed 0.15 volts peak-to-peak.

Transient excursions shall be limited to $\pm 50 \times 10^{-6}$ volt-seconds with rise and fall rates not greater than 56 volts/microsecond; peak voltage shall not exceed ± 2 volts when measured between station Xo585 and Xo1307 bulkhead.

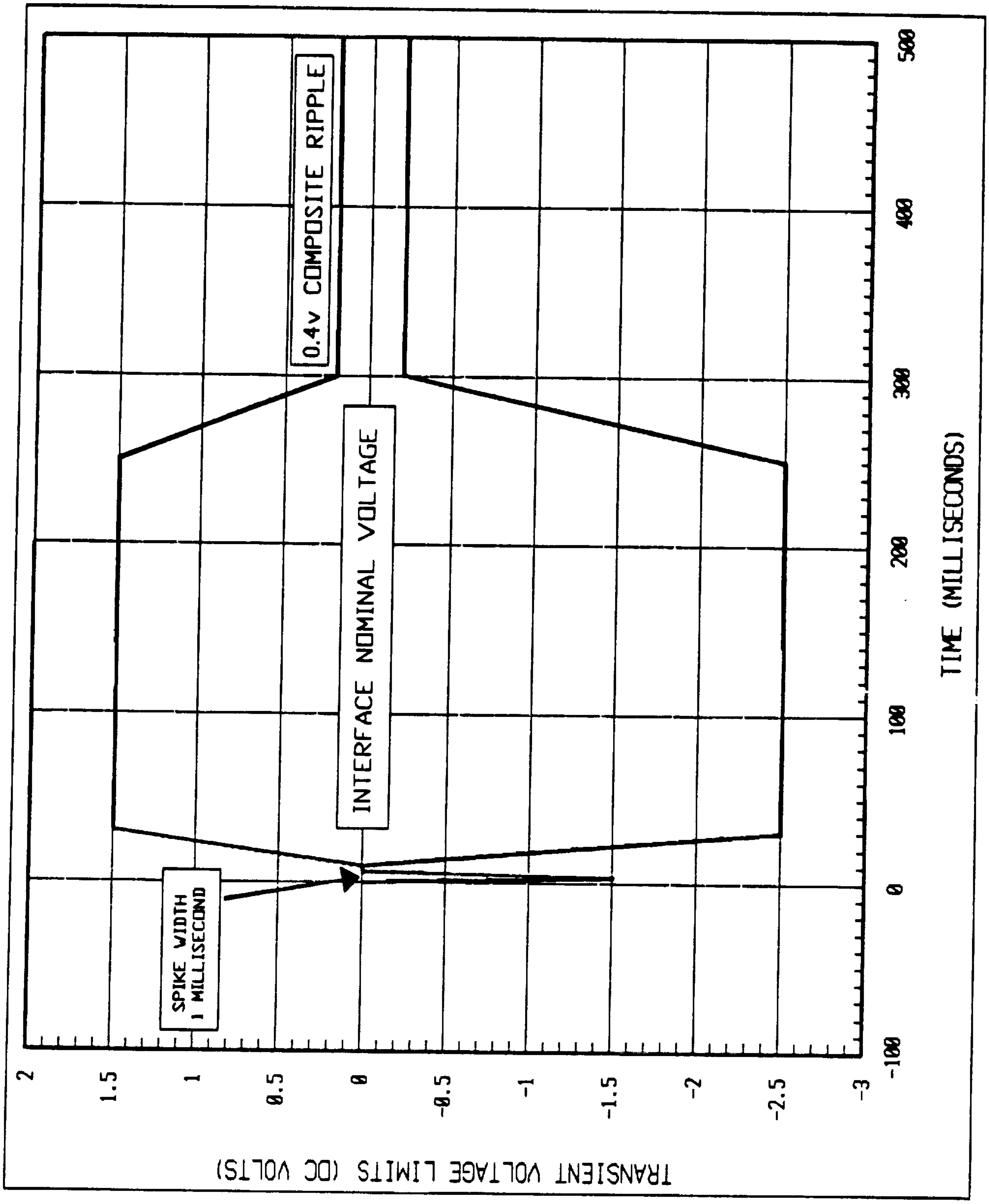


FIGURE 7.3.7.2.2-1 TRANSIENT VOLTAGE ON THE PRI PL BUS, AUX PL A, AUX PL B AND THE CABIN PL BUS AT THE CARGO ELEMENT INTERFACE PRODUCED BY OPERATION OF THE HYDRAULIC CIRCULATION PUMP

10.7.3 Cargo-Produced Interference Environment

10.7.3.1 Cargo-Produced Conducted Noise
The Cargo-generated conducted emission limits, applicable to all DC and AC power interfaces, shall be as follows in the subparagraphs below.

10.7.3.1.1 DC Power
The DC power line conducted emissions shall be limited to the levels indicated in Figure 10.7.3.1.1-1.

The cargo-generated spikes produced on DC power lines by switching or other operations shall not exceed the limits defined in Figure 10.7.3.1.1-2 when fed from a source impedance close to but not less than the values defined in Figures 10.7.3.1.1-3 and 10.7.3.1.1-4. (The use of a battery cart is preferable to regulated DC power supplies.) Rise and fall times shall be greater than 1.0 microsecond.

10.7.3.2 Cargo-Produced Radiated Fields

10.7.3.2.1 Magnetic Fields

10.7.3.2.1.1 AC Magnetic Fields
The generated AC magnetic fields (applicable at a distance of 1 meter from any payload equipment) shall not exceed 130 dB above 1 picotesla (30 Hz to 2 kHz) falling 40 dB per decade to 50 kHz.

10.7.3.2.1.2 DC Magnetic Fields
The generated DC magnetic fields shall not exceed 170 dBpT at the payload envelope. This limit applies to electromagnetic and permanent magnetic devices.

10.7.3.2.2. Electric Fields

10.7.3.2.2.1 Unintentional Radiated Electric Fields
The unintentional radiated electric fields shall not exceed the levels defined in Figures 10.7.3.2.2.1-1 and 10.7.3.2.2.1-2 except that the broadband emissions for cargo equipment in the cargo bay shall be limited to 70 dB above 1 microvolt/meter/MHz in the frequency range of 1770 MHz to 2300 MHz. Narrowband emissions shall be limited to 35 dB above 1 microvolt/meter from 1770 MHz to 2300 MHz, excluding any payload intentional transmitters.

10.7.3.2.2.3 Electrostatic Discharges
Electrostatic discharges shall not occur within the cargo bay unless they are isolated from the AFD and cargo bay gaseous environment (hydrogen-oxygen mixture) and are shielded by the Cargo to satisfy the requirements of Paragraphs 10.7.3.2.1.1, 10.7.3.2.1.2, and 10.7.3.2.2.1.

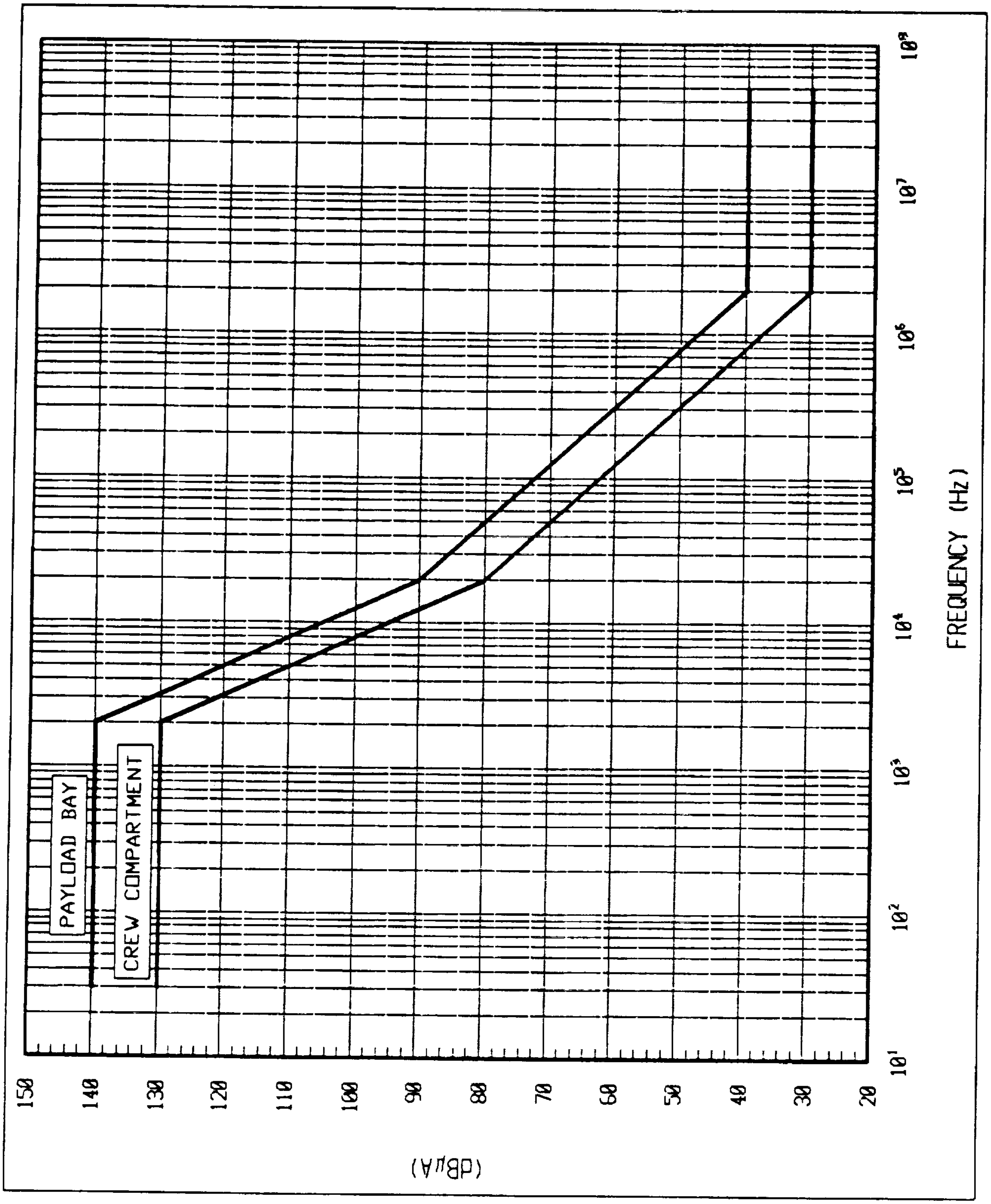


FIGURE 10.7.3.1.1-1 CARGO ALLOWABLE CONDUCTED NARROWBAND EMISSIONS

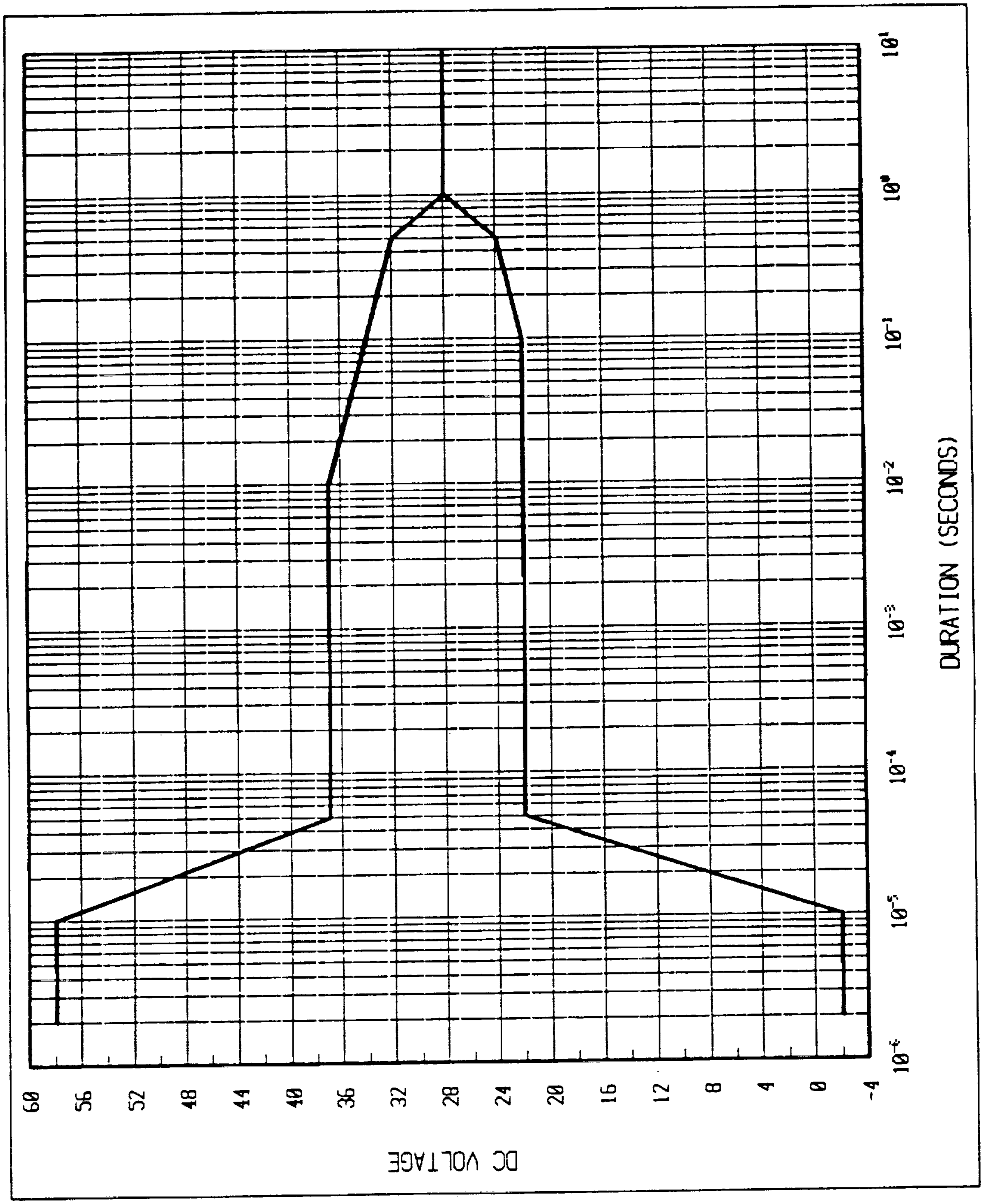


FIGURE 10.7.3.1.1-2 LIMIT ENVELOPE OF CARGO GENERATED TRANSIENTS (LINE-TO-LINE) ON DC POWER BUSSES FOR NORMAL ELECTRICAL SYSTEM

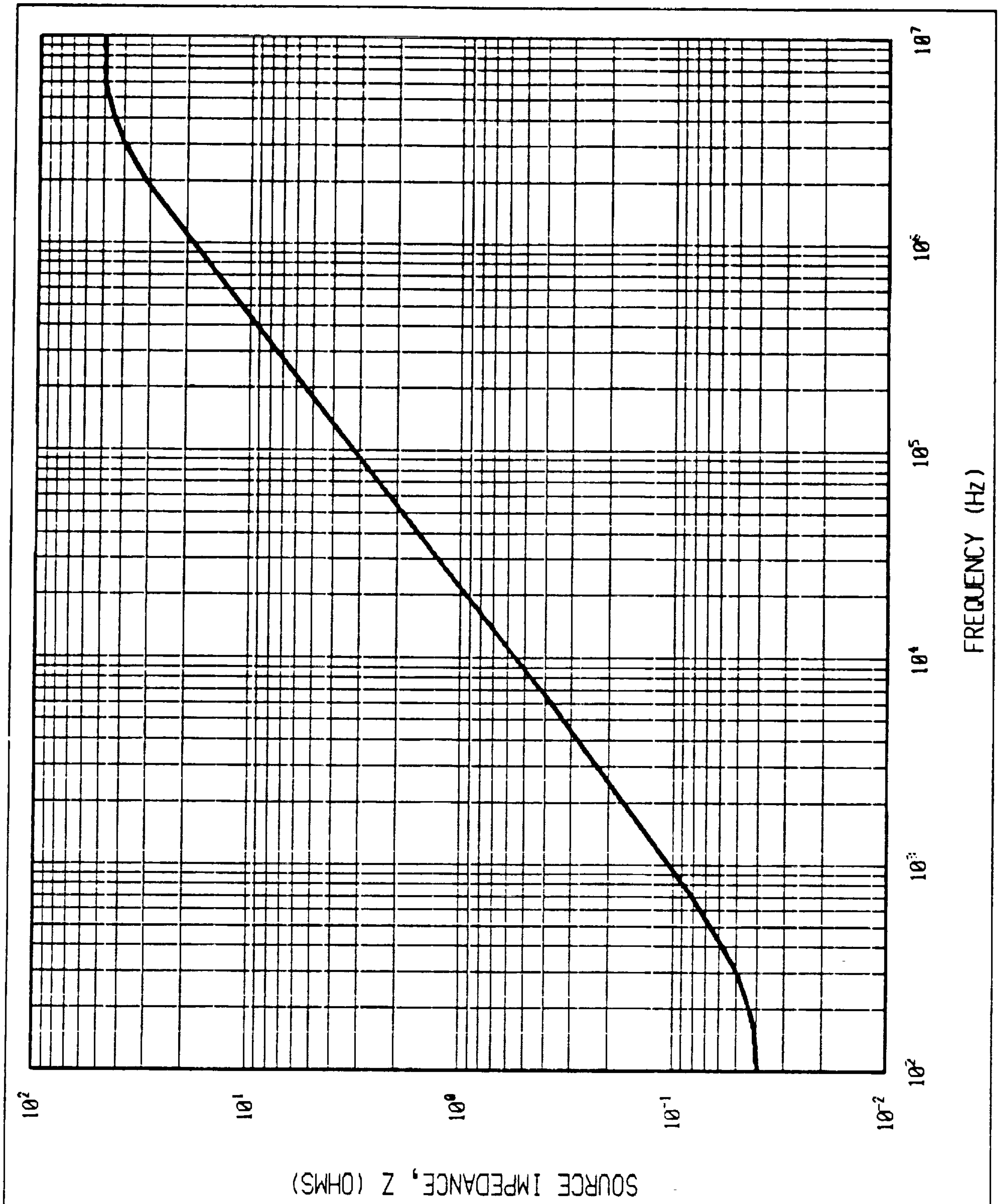


FIGURE 10.7.3.1.1-3 ORBITER DC POWER SOURCE IMPEDANCE (GROUND POWER)

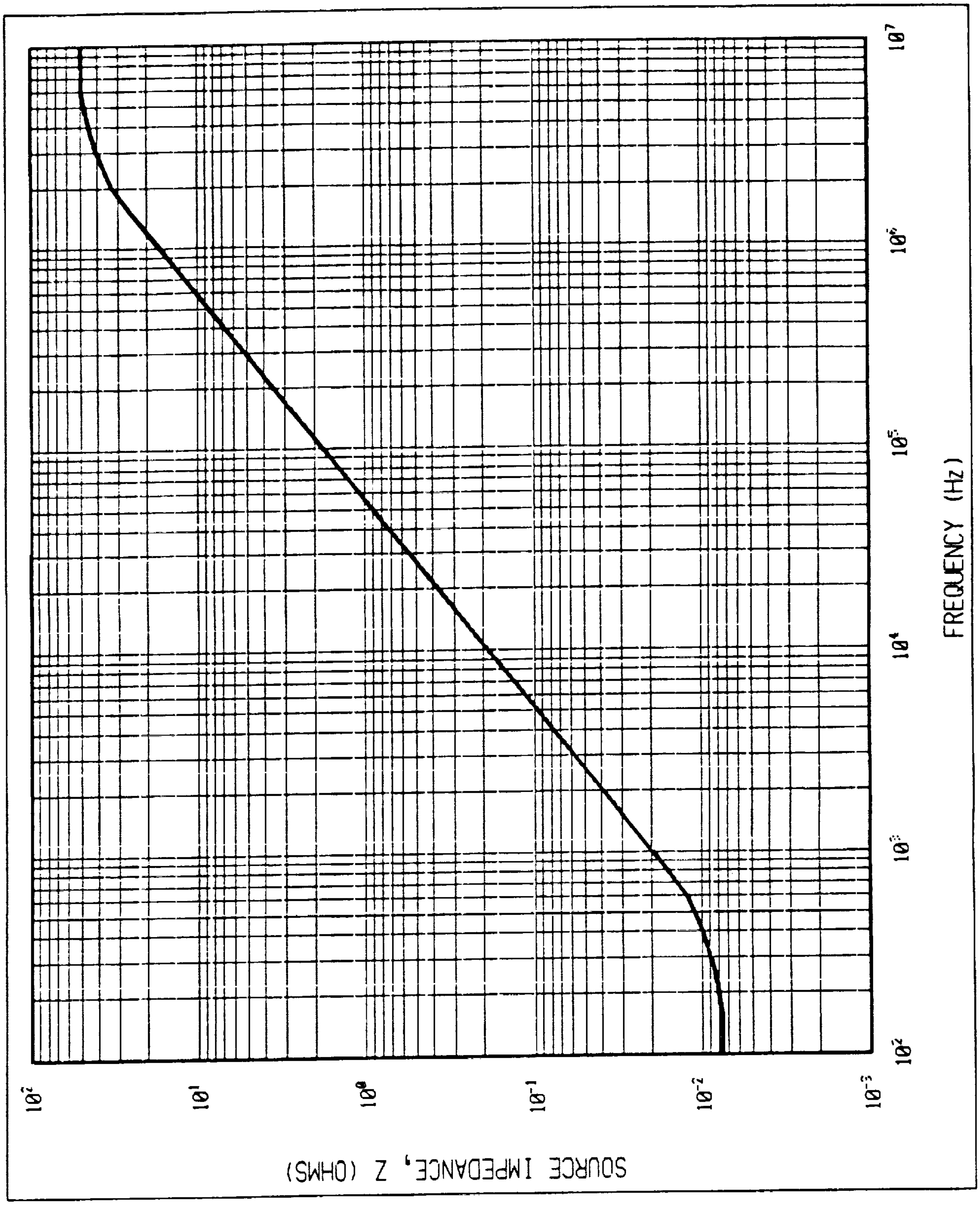


FIGURE 10.7.3.1.1-4 ORBITER DC POWER SOURCE IMPEDANCE (IN FLIGHT)

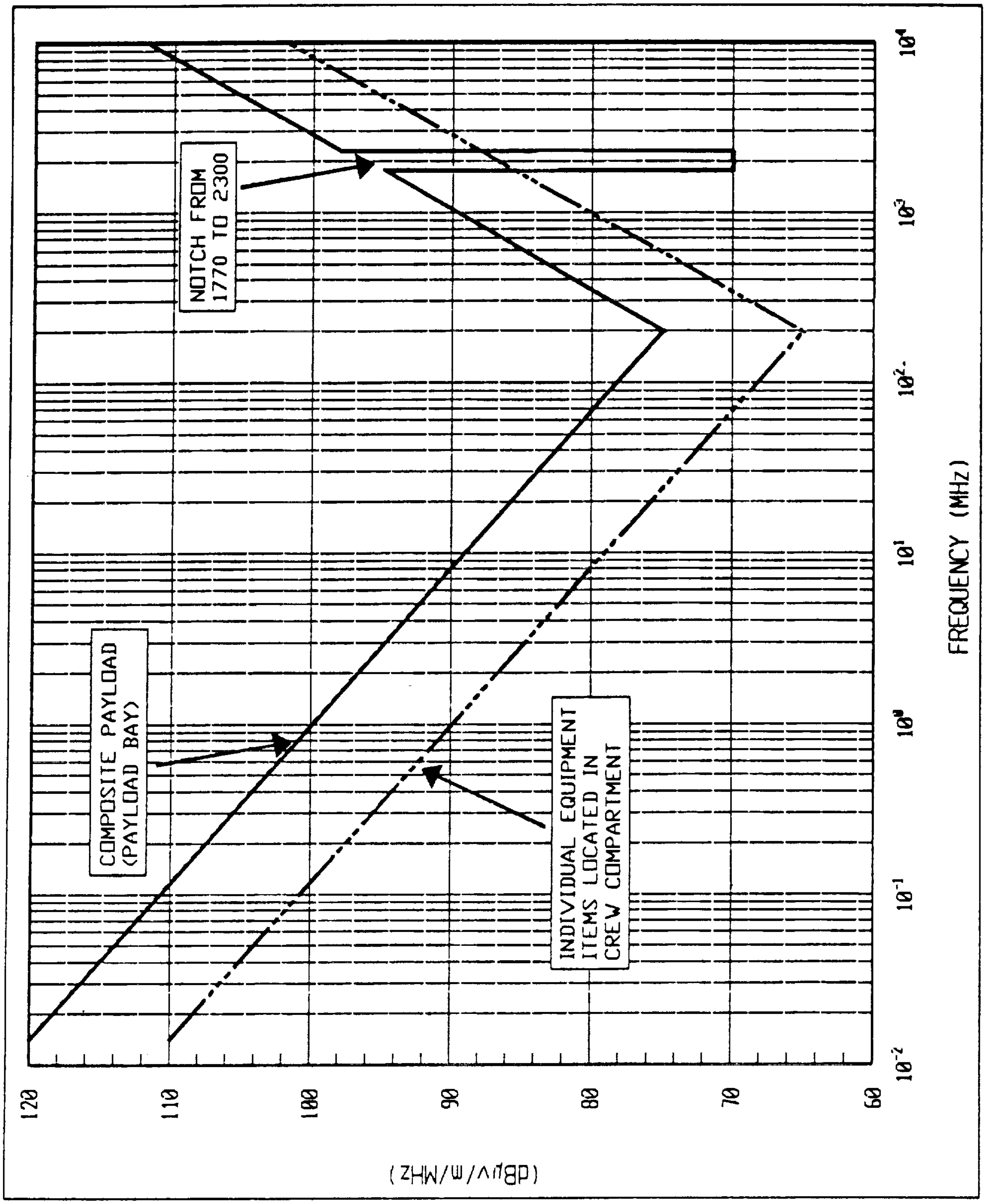


FIGURE 10.7.3.2.2.1-1 CARGO ALLOWABLE UNINTENTIONAL RADIATED BROADBAND EMISSIONS

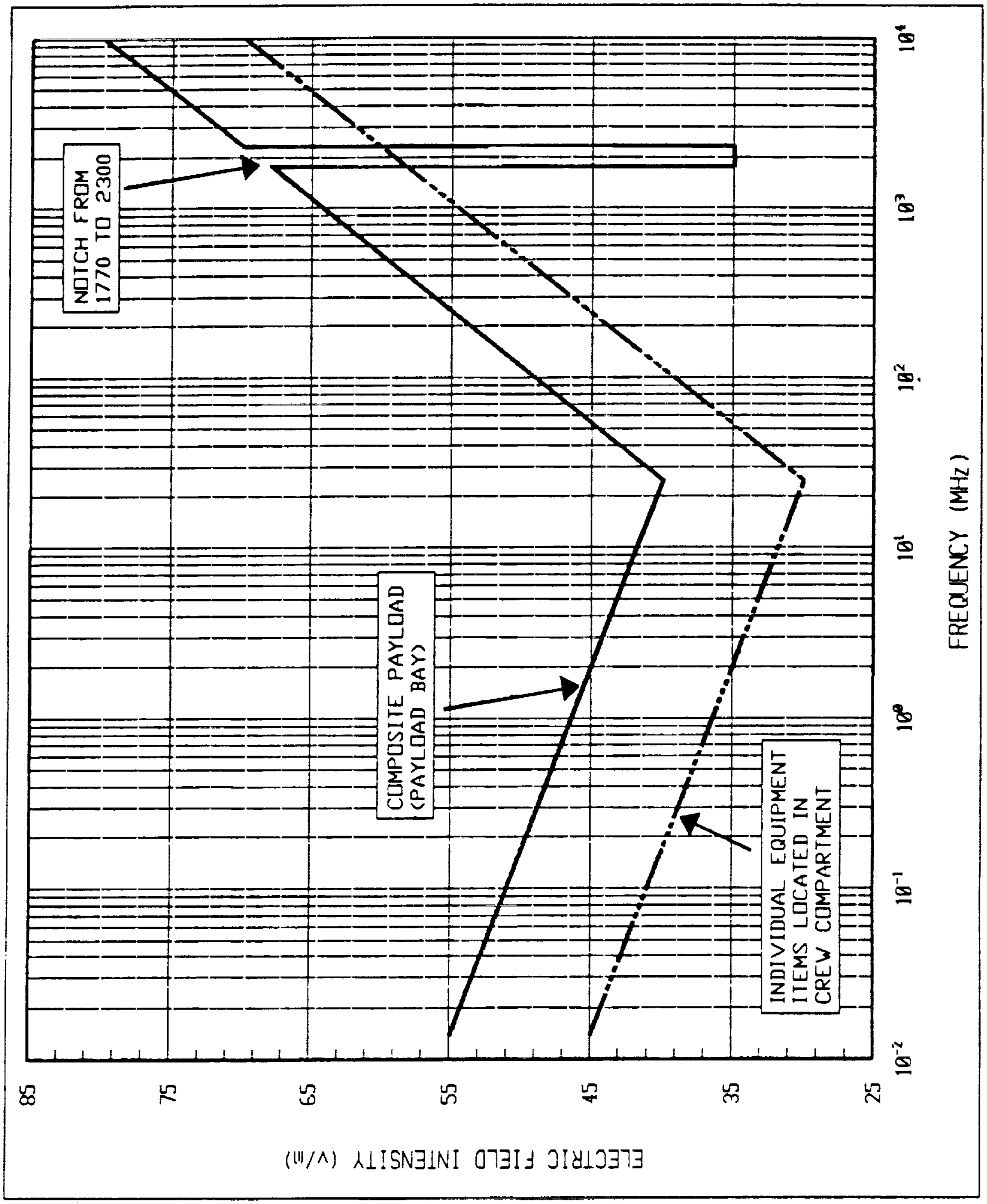


FIGURE 10.7.3.2.2.1-2 CARGO ALLOWABLE UNINTENTIONAL RADIATED NARROWBAND EMISSIONS

APPENDIX-I

APPENDIX I
APPLICABLE DOCUMENTS

JSC

1. JSC-02681, Rev. J, NON-METALLIC Materials Design Guidelines and Test Data Handbook, July 1982

2. JSC-20545, Rev. A, Simplified Design Options for STS Payloads, April 1988

3. NSTS-22648, Flammability Configuration Analysis for Spacecraft Applications, October 1988

4. NSTS 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System, January 1989

5. NASA Reference Publication 1124-2, Outgassing Data for Selecting Spacecraft Materials, November 1990

GSFC

6. S-313-100, GSFC Fastener Integrity Requirements, November 1989

7. GSFC-731-0005-83, Rev. B, General Fracture Control Plan for Payloads Using the Space Transportation System, November 1988

8. GEV-STS, General Environmental Verification Specification for STS and ELV Payloads, Subsystems, and Components, January 1990

9. GSFC SPOC Thermal Design Handbook, September 1985

MSFC

10. MSFC-SPEC-522A, Design Criteria for Controlling Stress Corrosion Cracking, November 1977

APPLICABLE DOCUMENTS (Cont'd)

KSC

11. KHB 1700.7, Rev. A, STS Payload Ground Safety Handbook, December 1984

OTHER

12. MIL-HDBK-5F, Metallic Materials and Elements for Aerospace Vehicle Structures, November 1990

13. EIA-232-D, Interface Between Data Terminal Equipment and Data Circuit Terminating Equipment Employing Serial Binary Data Interchange, Electronic Industries Association, January 1987

These documents may be acquired by contacting the Hitchhiker Project/Customer Support Office (See Page 1-2).

APPENDIX-J

APPENDIX J
LIST OF ACRONYMS AND ABBREVIATIONS

A	Amps
ABA	Adapter Beam Assembly
ACKS	Acknowledgement
AFD	Aft Flight Deck
AIA	Avionics Interface Assembly
ANSI	American National Standards Institute
APC	Autonomous Payload Controller
APOCC	Attached Payloads Operations Control Center
ASP	Attached Shuttle Payloads
ASPC	Attached Shuttle Payload Center
Aux	Auxiliary
b/s	Bits Per Second
Baud	Typically one bit per second
BBXRT	Broad Band X-Ray Telescope
BC	Byte count
BPI	Bits Per Inch
CAP	Command Acceptance Pattern
	Crew Activity Plan
CARS	Customer Accommodations and Requirements Specifications
CAS	Calibrated Ancillary System
CC	Crew Controller
CCGSE	Customer/Carrier Ground Support Equipment
CCI	Command Concentrator Interface
CCT	Computer Compatible Tape
CCTV	Closed Circuit TV
CG	Center of Gravity
CGSE	Customer Ground Support Equipment
CH	Channel
CID	Customer Identification
CMD(S)	Command(s)
CMF	Command Management Facility
CMRT	Customer Medium Rate Tape
CPR	Customer Payload Requirements

LIST OF ACRONYMS AND ABBREVIATIONS (Cont'd)

CRT	Cathode Ray Tube
CSR	Customer Support Room
CVCM	Collected Volatile Condensable Material
dB	Decibel
°C	Degrees Centigrade
DAP	Digital Autopilot
DC	Direct Current
DEC	Declination
	Digital Equipment Corporation
DCL	Digital Command Language
Dia.	Diameter
DOD	Department of Defense
DOL	Discrete Output, Low Level
DOMSAT	Domestic Communication Satellite
DPS	Data Processing System
DPST	Double-Pole Single Throw
DT	Delay Time
e.g.	such as
EAFB	Edwards Air Force Base
EGSE	Electrical Ground Support Equipment
EMI	Electro-Magnetic Interference
EOF	End of File
EOV	End of Volume
FDF	Flight Dynamics Facility
FM	Frequency Modulated
FOT	Flight Operations Team
FOV	Field of View
FPS	Flight Planning System
FS	Factor of Safety
FSU	Frame Synchronizer Unit
FT	Foot/Feet
FVP	Flight Verification Payload
G, g	Gravity
Ga.	Gauge
GAS	Get Away Special

LIST OF ACRONYMS AND ABBREVIATIONS (Cont'd)

GMT	Greenwich Mean Time
GN&C	Guidance, Navigation and Control
GPC	General Purpose Computer
GSTDN	Ground Spaceflight Tracking and Data Network
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HH	Hitchhiker
HH-G	Hitchhiker-G
HH-M	Hitchhiker-M
HMDA	Hitchhiker Motorized Door Assembly
Hz	Hertz
IAD	Interface Agreement Document
ICD	Interface Control Document
i.e.	that is,
I/F	Interface
IPD	Information Processing Division
IRIG-B	Inter-Range Instrumentation Group, Type B
JSC	Johnson Space Center
K	Kilo, Thousand
Kb/s	Kilo bits/second
KHz	Kilo Hertz
KSC	Kennedy Space Center
KUSP	Ku Band Signal Processor
KWHR	Kilowatt-Hour
LAN	Local Area Network
lbs.	pounds (Weight)
LEP	Lower End Plate
LR	Low Rate
LRDPS	Low-Rate Data Processing System
LRGSE	Low Rate Ground Support Equipment
LVLH	Local Vertical/Local Horizontal
Max	Maximum
Mb/s	Mega bits per second
MCC	Mission Control Center

MCCH	Mission Control Center Houston
MDM	Multiplexer De-Multiplexer
MET	Mission Elapsed Time
MGMT	Management
MGSE	Mechanical Ground Support Equipment
MHz	Megahertz
MICD	Mechanical Interface Control Drawing
Min	Minimum
MLI	Multi-Layer Insulation
mm	millimeter
MOD	Mission Operation Division
MPE	Mission Peculiar Equipment
MPESS	Mission Peculiar Equipment Support Structure
MPS	Mission Planning System
MR	Medium Rate
MRDM	Medium-Rate De-Multiplexer
MRDPS	Medium-Rate Data Processing System
MRGSE	Medium Rate Ground Support Equipment
MRM	Medium Rate Multiplexer
MS	Mass Storage
	Margin of Safety
ms	Millisecond
MSFC	Marshall Space Flight Center
MSL	Materials Science Laboratory
MTR	Magnetic Tape Recorder
MTU	Master Timing Unit
MUA	Material Usage Agreement
MUX	Multiplexer
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications
NDE	Nondestructive Evaluation
NGT	NASA Ground Terminal (TDRS)

LIST OF ACRONYMS AND ABBREVIATIONS (Cont'd)

NRZ	Non-Return to Zero
NSP	Network Signal Processor
NSTS	National Space Transportation System
NTSC	National Television Standard Committee
NVR	Non-Volatile Residue
OIT	Obiter Integration Test
O.D.	Outside Diameter
OPF	Orbiter Processing Facility
OPS	Operations
PAM	Payload Assist Module
PC	Personel Computer
PCM	Pulse Code Modulation
PDI	Payload Data Interleaver
PI	Principal Investigator
PIP	Payload Integration Plan
POCC	Payload Operations Control Center
PPS	Pulse Per Second
PSAT	Predicted Site Acquisition Table
PSID	Pounds-Per-Square-Inch Differential
PSP	Payload Signal Processor
PTC	Passive Thermal Control
PWR	Power
RA	Right Ascension
RD	Receive Data
Rev.	Revision
RF	Radio Frequency
RTN	Return
RMS	Remote Manipulator System
RT	Real-Time
SAA	South Atlantic Anomaly
SD	Send Data
SDP	Safety Data Package
SDPF	Sensor Data Processing Facility
SMC	Standard Mixed Cargo

SMCH	Standard Mixed Cargo Harness
SPA	Small Payload Accommodations
SPASP	SPA Switch Panel
SPIF	Standard Payload Interface Facility
SPOC	Shuttle Payload of Opportunity Carrier
SQ	Square
SSP	Standard Switch Panel
SSPO	Space Shuttle Program Office
SSPP	Shuttle Small Payloads Project
STS	Space Transportation System
TAE	Transportable Applications Executive
TAGS	Text and Graphic System
TBD	To Be Determined
TBS	To Be Supplied
TCL	TAE Control Language
TDRSS	Tracking and Data Relay Satellite System
TN	TDRSS Network
TLM	Telemetry
TML	Total Mass Loss
TOD	True of Date
TSP	Twisted Shielded Pair
TTL	Transistor-Transistor Logic
TV	Television
UART	Universal Asynchronous Receiver Transmitter
UCAT	User Calibrated Ancillary Data Tapes
UNF	United States National Fine
US	United States, Microsecond
VAB	Vehicle Assembly Building
VCM	Volatile Condensible Material
VDC	Volts Direct Current
VF	Voltage False
VMS	Virtual Memory System
VNoise	Voltage Noise

LIST OF ACRONYMS AND ABBREVIATIONS (Cont'd)

VT	Voltage True
WSTF	White Sands Test Facility
W	Watts
YSI	Yellow Springs Instrument Co.