NASA
National Aeronautics and
Space Administration

Space Transportation System

User Handbook

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User Handbook

JUNE 1977

TABLE OF CONTENTS

1 — Management and procedures

2 — Flight systems

3 — Launch and landing site operations

4 — Flight operations

Appendixes

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ERRATA

Space Transportation System User Handbook
July 1977

Appendix A, pages A-2 and A-5. Reference to the following documents under part 4 should be deleted:

STS Flight Planning, JSC-11803.

Communications and Data Systems Integration (CADSI) End-to-End Configuration Book, JSC-10074

Training and Simulations, JSC-11805

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NASA-JSC

INTRODUCTION

The Space Transportation System now being built will provide easier access to space for a wider range of users than ever before. This handbook is the beginning of a concentrated effort by NASA to explain and provide routine space operations.

As you need additional information in selected areas, you will find references to additional documents and organizations to support your inquiries In the United States, you should make initial contacts for planning and address questions of a general nature to the Space Transportation Systems Operations Office, Mail Code MO, National Aeronautics and Space Administration, Washington, D.C. 20546; telephone (202) 755-2344, Federal telecommunications system 755-2344. If you are outside the U.S., you should address initial inquiries to the Office of International Affairs, Mail Code I, National Aeronautics and Space Administration, Washington, D.C. 20546.

Initially, you will want to scan the major parts of this handbook from cover to cover. The table of contents provides an insight into the elements of the Space Transportation System. The mini-contents on the tab pages identify in more detail the subjects of each part. The cross-referenced index (following the appendixes) locates more specific topics.

Certain parts of this document will be more useful to one type of user than another. The individual user (if you are a typical experimenter) will find most helpful the sections in part 2 describing the major payload carriers. These sections also provide you with additional references to organizations to contact for assistance and guidance. In contrast, major users, who have broad interests or specific applications for the Space Transportation System (such as commercial communications satellites), will be interested in all parts of the handbook.

Users having special needs can use the index as a guide to that type of specialized information. For example, those users requiring active command and control function will want to review carefully the section on the Payload Operations Control Center. As another example, users having hardware best suited for manned extravehicular operation will find the EVA section helpful.

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Management and procedures

Flight systems

Launch and landing site operations

Flight operations

Appendixes

Management and procedures

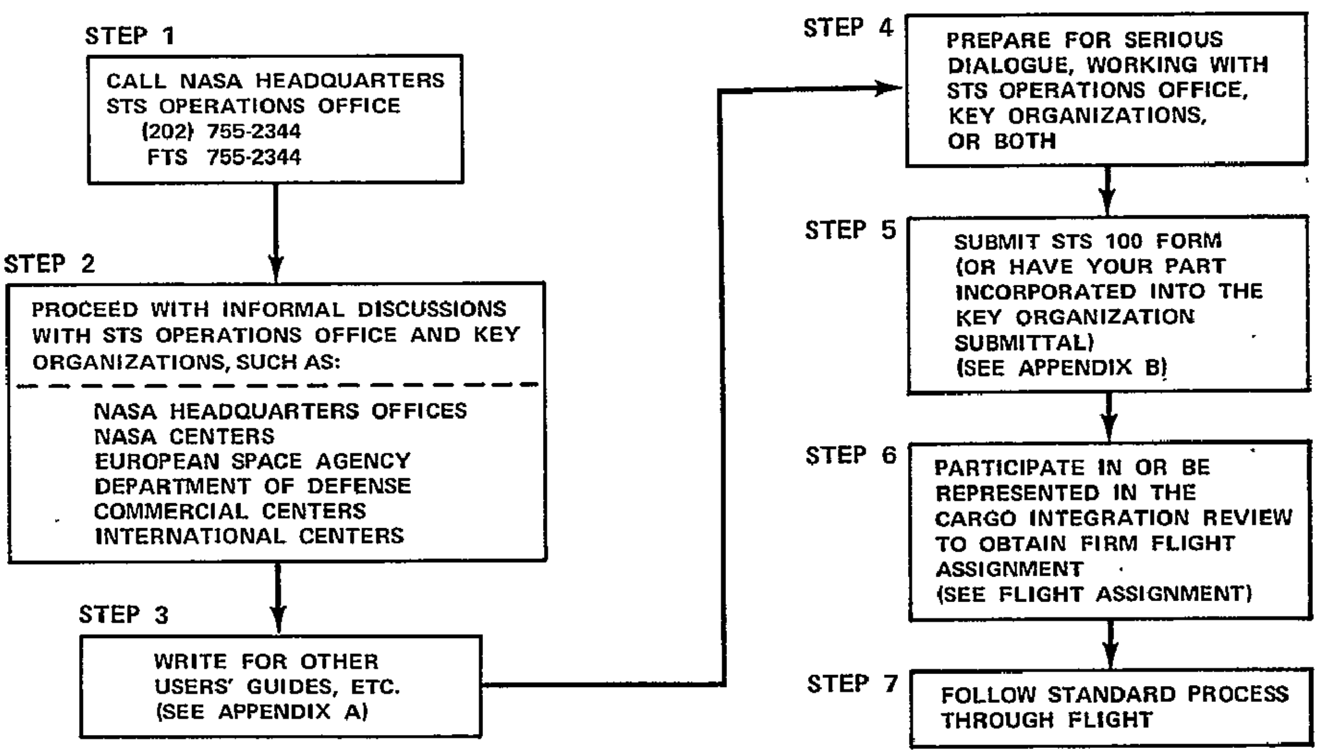
THE USER INTERFACE

Users of space in the Space Transportation System operations era will come from many sources. Within the United States, the NASA Centers will sponsor programs using the Space Transportation System (STS). Other civilian governmental agencies and the Department of Defense will conduct continuing space programs. International participation will come both from individual experimenters and from organizations such as the European Space Agency. Commercial activities of a domestic and international nature will be prevalent.

The commercial utilization of space is being encouraged and commercial firms are also expected to become user representatives for single investigators.

The NASA use of the STS to conduct investigations in space will be programed by NASA Headquarters. General program projections will be published, followed by proposal solicitations for investigations on future flights. Universities, nonprofit organizations, and industrial firms are encouraged to respond to the specific solicitations. Current common contractual arrangements with organizations and principal investigators will apply (rather than user charges).

The prospective user's first act should be to call the STS Operations Office at NASA Headquarters to obtain the latest planning in his area of interest. This will result in advice on how to proceed to the next step and with whom. Experimenters will work with a key organization that interfaces with the STS organization; therefore, the individuals can devote their total energies to their own experiments. Major commercial, defense, and other similar users will interface directly with STS operations. European Space Agency (ESA) member states should first contact that organization (European Space Agency, 8-10, Rue Mario Nikis, 75738-Paris Cedex 15, France) regarding ESA-funded experiments.



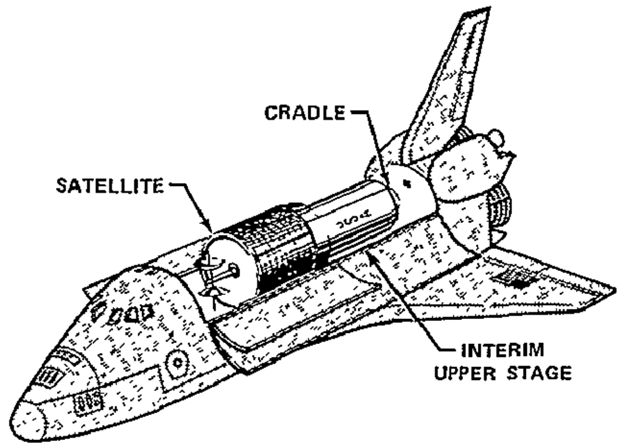
STANDARD SYSTEMS

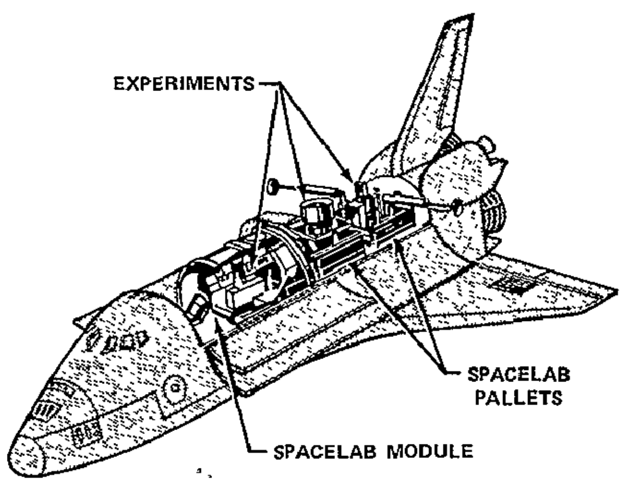
The key to opening this new era of routine space operations — both on the ground and in orbit — is the Space Shuttle system. The Orbiter vehicle can accommodate many standard or unique payloads in its large cargo bay. And it will deliver to orbit the other elements of the Space Transportation System (STS).

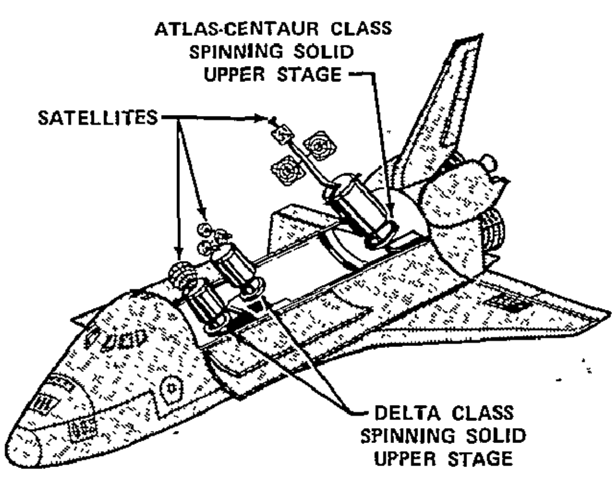
Two kinds of upper stages will be used to deliver satellites beyond the Orbiter's Earth orbit. Satellites headed for geosynchronous, elliptic, and higher circular orbits or destined for deep space can use the large, solid interim upper stage. Satellites of the Delta or Atlas-Centaur weight and volume class can use spinning solid upper stages to effect a smooth transition from existing expendable launch vehicles.

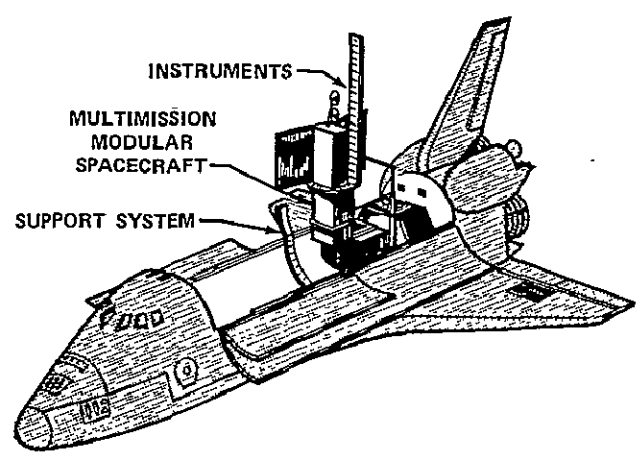
The Spacelab is an international project being undertaken by the European Space Agency. Its hardware components are a pressurized module (with a shirtsleeve working environment) and open equipment pallets (exposed to the space vacuum). For any one flight, the Spacelab hardware can be arranged as a module only, module with pallet, or pallets only. The single-pallet mode (without module) will also share flights with other payloads.

Free-flying standard spacecraft now include the Multimission Modular Spacecraft and the Long Duration Exposure Facility. These satellites, designed to be reused, will be able to support a wide variety of operational or research instruments.









STANDARD USE

In the user's planning for STS operations, the key words are "standard" and "adaptable." Standard plans and equipment, using standardized interfaces — both human and hardware — a few basic types of flights, and a stock set of flight phases are the foundation of the Space Transportation System.

The user can select among several options in equipment, thereby tailoring a flight to his own needs. The experiment hardware (together with its unique support equipment) interfaces with a total hardware and procedural system On orbit, many operational adaptations of standard procedures and techniques are possible.

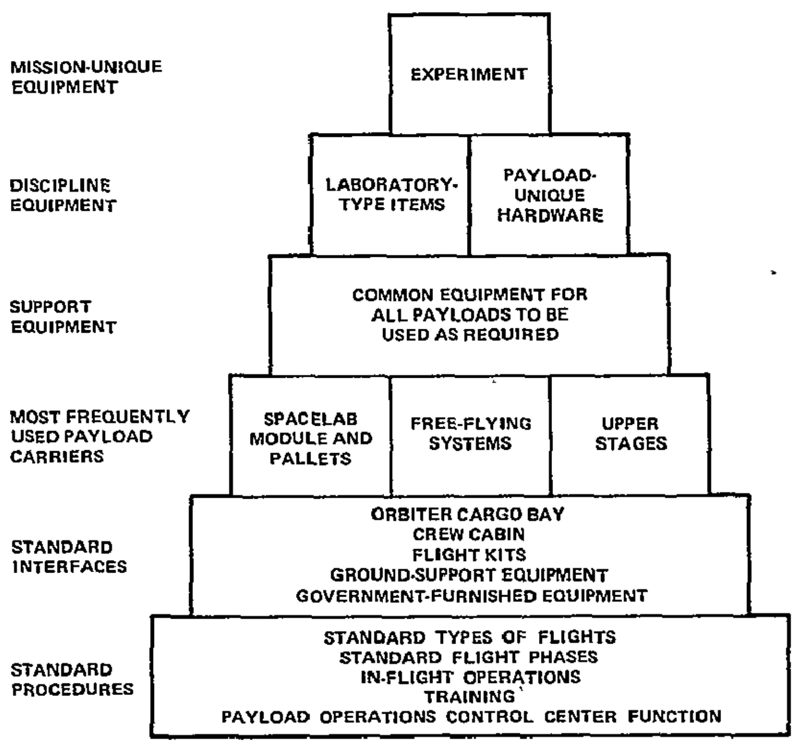
The payload carriers (Spacelab and upper stages), plus the Orbiter, form the basic inventory of STS hardware. Each has its own set of established interfaces to accommodate experiments.

A variety of support equipment is available to payloads as needed. Users are encouraged and helped to design payloads that are compatible with this in-stock equipment. This hardware is more fully explained in part 2. Provisions also exist for a commercial user to lease or purchase equipment.

The standardized flight types (or purposes) are payload deployment, on-orbit servicing of satellites, payload retrieval, and on-orbit operations with an attached payload. At times, more than one flight purpose may be combined in a single flight, depending on the combination of payloads. The user will be assigned a flight that fits his defined purpose.

The routine flight phases are prelaunch, launch, in-orbit, deorbit, entry. and landing, and postlanding. Specific flight phases that are adaptable to payload needs on each flight are various orbital maneuvers, rendezvous, deployment, retrieval, and on-orbit servicing.

Because of the standardized concepts, users are now able to plan and concentrate on the design and effectiveness of their own payloads, assured that those payloads will be compatible with the chosen element of the Space Transportation System.



FLIGHT ASSIGNMENT

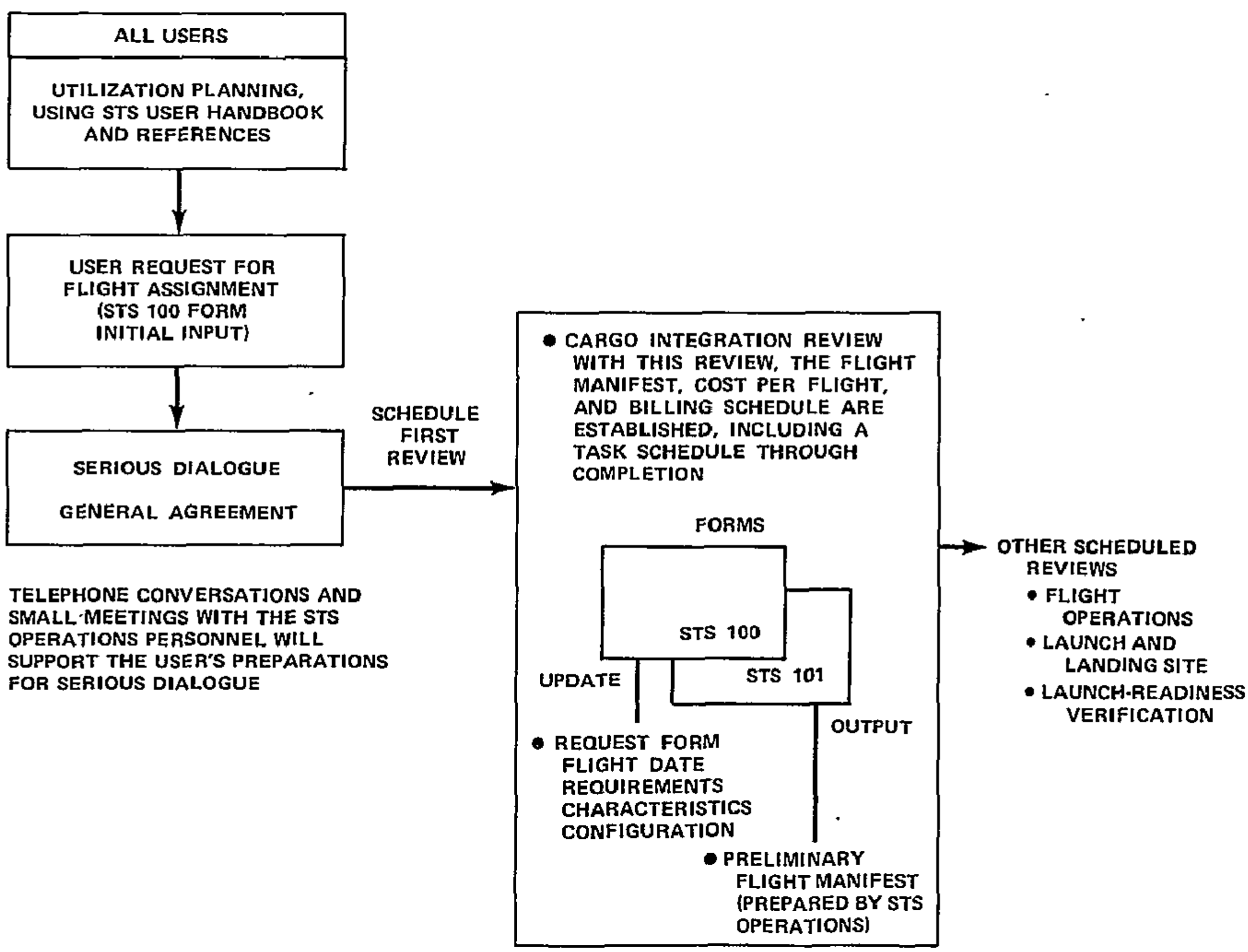
The basic steps in initiating a request and finalizing a firm flight assignment are summarized in the accompanying figure. The necessary form (STS 100) is in appendix B.

The NASA Headquarters STS Operations Office in Washington, D.C., after being contacted by an interested potential user, will assist user preparations for serious dialogue with one of its staff, with other NASA Headquarters personnel, or with assistance from a NASA field installation.

With the completion of the first formal review, the user becomes part of a standard planning and implementation process. This gives the user insight into how his needs will be met, who his operating interfaces will be along the way, and what inputs from him will be necessary during the implementation process.

In many cases, small users will be assisted or represented by management or engineering organizations (commercial, government, etc.) in dialogue with the STS operations personnel.

A schedule of tentative flight assignments is in appendix B. It will be updated periodically.



USER CHARGES

The overall objective of the pricing policy is to encourge full use of the Space Transportation System. A key part of this policy is guaranteeing a fixed price during the early years of STS operations: NASA offers this fixed price in contract-year dollars from now through fiscal year 1983 (ending Sept. 30, 1983). After that date, prices will be adjusted annually.

Additionally, the policy results in a price that permits economical transition from existing expendable launch vehicles to the STS. Finally, the STS pricing policy will reimburse NASA the cost to operate the STS, and it has provisions to ensure price stability over the life of the STS Program.

User charges for a specific flight will be negotiated within a fixed price schedule for all NASA-provided flight hardware and services. The price will be based on the projected cost of both flight operations and use of hardware. (The price schedule will be adjusted periodically to account for inflation; the Bureau of Labor Statistics index for compensation per hour, total private, will be the escalator used to escalate the price to the year of payment.)

Costs for services are included in the STS Reimbursement Guide (JSC-11802).

Basic charges

The price for exclusive use of an entire Orbiter (excluding Spacelab, interim upper stage, etc.) depends on the class of users. The price ranges are shown in the accompanying table, in which costs are expressed in constant fiscal year 1975 dollars.

The price charged the non-U.S. Government users (whether domestic or foreign) is designed to recover a fair share of the total operations costs and of the U.S. Government's investment in fleet, facilities, and equipment. The pricing structure is consistent with current U.S. policy on launch assistance to foreign countries and international organizations.

The price charged civilian agencies of the U.S. Government and participating foreign government users is designed to recover a fair share of total operations costs. The pricing structure is consistent with current policy on use charges for expendable launch vehicles.

The price charged the Department of Defense (DOD) class takes into consideration an exchange of costs between the NASA and the DOD for each providing accommodations to the other at their respective launch sites.

Users with an exceptional new use of space or a first-time application of great value to the public are considered a separate classification within the defined user classes. The price charged these users for a dedicated, standard Shuttle flight will be the additive cost of conducting one additional flight during the overall STS Program. This so-called "additive cost" is estimated to be $9 to $12 million. The STS Exceptional Program selection process will determine which payloads qualify for this user class. In all instances, the NASA Administrator will be the selection official with final authority on the decision.

All prospective users, regardless of class, must pay NASA $100 000 earnest money before contract negotiations for a flight begin. This nonrefundable earnest money will be applied to the user's first payment.

Price per dedicated Shuttle flight[a]
[fiscal year 1975 values]

User	Cost $ millions
Private: domestic, foreign	19.0 to 20.9
Foreign government	19.0 to 20.9
Government: U.S. civil, participating foreign	16.1 to 18.0
Department of Defense	12.2
Exceptional program	9 to 12

[a]For Shuttle only.

The basic billing schedule for all users begins 33 months before the planned launch date. Users who contract for Shuttle services on shorter notice (1) will pay a higher total cost and (2) will have to pay on an accelerated schedule. This accelerated payment schedule will be used for short-notice contracts unless some offsetting advantages accrue to the U.S. Government in an accelerated launch schedule. (In that instance, the Government may waive some or all requirements.) The schedule for both normal and accelerated payments is shown in the table.

A request for Shuttle services made less than 1 year before a flight is handled on a space-available basis or as a short-term callup option. Generally, if NASA can accommodate the user of a dedicated flight, the user's only additional costs will be those shown on the accelerated-payment schedule.

The NASA will make no charges after the flight except those negotiated in the contract as extra services.

Several price and schedule options are available to users for a fee.

1. Users with flights after Oct. 1, 1983, can contract now for a fixed price (in contract-year dollars). The fee for this option is $1 million (in 1975 dollars), payable at the time the $100 000 earnest money is paid. All funds will be applied to the user's first payment. Under this option, the user will be assured that the flight cost will be the then-current price plus 8 percent compounded annually from October 1983 to the planned date of launch. This option provides the user the advantage of a fixed price beyond the initial 3-year fixed-price period.

2. Users can contract for a guaranteed launch date within a specified 90-day period by paying an additional fee of $100 000, payable at the time the $100 000 earnest money is paid. This $200 000 will be applied to the user's first payment.

3. The "floating launch date" affords users some flexibility in choosing a launch date. The user schedules a tentative launch date at least 33 months away. Then, when the user notifies NASA of a desired launch date, a firm launch schedule will be negotiated. This option costs 10 percent of

Payment schedule

Contract initiation	Payment due, %: Months before launch						Total, %
	33	27	21	15	9	3	
Nominal schedule (more than 33 mo before launch date)	10	10	17	17	23	23	100
Accelerated schedule (months before launch date)							
27 to 32		21	17	17	23	23	101
21 to 26			40	17	23	23	103
15 to 20				61	23	23	107
9 to 14					90	23	113
3 to 8						122	122

the flight price in effect when the contract is negotiated and the fee must be paid at that time. This cost is in addition to other charges and is NOT applied to later payments due. If the user requests a launch date less than 12 months in advance, short-term callup fees also apply. This option permits a user who expects to need a launch at some uncertain time in the future to contract for a flight without specifying a launch date; thus, no postponement fees result.

All the preceding options require that the contract be made at least 3 years before launch. Users who are already on a 3-year payment schedule have the option of requesting a launch date sooner than negotiated and changing to the accelerated-payment schedule. Users who exercise this option must pay any back fees, so that they will be charged the same total cost as users who contract late. (The only exception would be if earlier payments had been lower because of adjustments for inflation that occurred after those payments were made.) For example, a user on a 33-month schedule who had already made two 10-percent payments and then decided on a launch date 15 months away would owe 41 percent (the difference between the 20 percent already paid and the 61 percent due on the accelerated-payment schedule).

Users can postpone a flight one time at no additional cost if the notification is made more than 1 year before the scheduled flight date. Subsequent postponements or postponements occurring less than 1 year before the planned launch will cost 5 percent of the flight price plus an occupancy fee (explained in the next section). Any time a user cancels a flight, the cost is 10 percent of the flight price plus an occupancy fee. The occupancy fee affects only users of shared flights (described in the next section). If postponement causes a payload to be launched in a year when a higher price has been established, the new price will apply.

Other services available to users at a negotiable additional charge include revisit and retrieval, use of Spacelab or other special equipment, use of flight kits to extend the basic Shuttle capability, use of upper stages, extravehicular activity by the flight crew, unique payload/Orbiter integration and testing, payload mission planning (other than for launch, deployment, and reentry phases), extended time on orbit, payload data processing, and possible special training. Special user requirements at the launch site that may incur additional user costs must be negotiated separately with the launch site organization.

Shared-flight charges

The basic charges are for a dedicated, single-user Shuttle flight. With NASA approval, a user of a dedicated flight may apportion and sublet STS services to other users, provided those users satisfy STS requirements. The price of integrating additional payloads will be negotiated.

For a payload that will not require an entire flight capability and that can share the cargo bay with others, the cost to the user will be a fraction of the dedicated-flight price, calculated as follows.

1. The payload weight is divided by the Shuttle payload weight capability at the desired inclination to find the weight load factor. The figures shown as examples are for a 160-nautical-mile (296-kilometer) orbit.

Inclination, deg	Weight capability lb (kg)
28.5	65 000 (29 484)
56	57 000 (25 855)
90	37 000 (16 783)
104	30 000 (13 608)

2. The payload length is divided by the length of the cargo bay, 60 feet (18.29 meters), to find the length load factor.

3. The load factor (length or weight, whichever is greater) is divided by 0.75 to determine the cost factor.

4. The calculated cost factor is multiplied by the price of a dedicated Shuttle flight (for the user's class) to determine the price for that payload.

For comparison, the fractions of a dedicated-flight price for payloads that currently are flying on expendable launch vehicles are: Delta class payloads, 1/3; Atlas-Centaur class payloads, 2/3; Titan class payloads, full flight price.

Users of shared flights who want to cancel or postpone a flight will be required to assume a fair share of the risk that NASA may be unable to find other suitable payloads to complete the cargo. The philosophy is that the user should bear any additional cost caused by schedule changes requested by the user. However, the user will not be penalized if the NASA can recover those costs from other users. Shared-flight users who require a short-term callup (or an accelerated launch schedule of less than 1 year) must pay a load factor recovery fee, which depends on how long before launch the option is exercised and on the availability of other payloads for the flight. A user paying this fee will still be flying for less than a dedicated flight would cost. Similarly, the occupancy fee for delayed or canceled flights depends on the time remaining before launch and on the availability of substitute payloads. In the event that substitute payloads cannot be found, the occupancy fees can be substantial. Therefore, users should make every effort to plan payload programs so that a launch need not be postponed or canceled less than a year before launch.

Shared-flight users who have paid fees in excess of the first payment due will receive credit on later payments.

A 20-percent discount will be given to shared-flight users who agree to fly on a space-available (standby) basis. The NASA will provide launch services within a prenegotiated period of 1 year and the user will be notified 60 days before launch.

User charges do not apply to investigations conducted under contracts awarded in response to NASA solicitations for experiments or, when appropriate, awards based on unsolicited proposals. Potential users who wish to be placed on the mailing list for announcements of opportunities for submitting proposals for experiments or investigations in space should contact the Office of Planning and Program Integration, Mail Code O, National Aeronautics and Space Administration, Washington, D.C. 20546.

Small self-contained payloads

Self-contained payloads that require no Shuttle services (power, deployment, etc.) and that are for research and development purposes will be flown on a space-available basis, provided they weigh less than 200 pounds (91 kilograms) and occupy less than 5 cubic feet (0.14 cubic meter) of space. The price will not exceed $10 000 (in 1975 dollars) and will be a minimum of $3000 with the exact amount negotiated on the basis of size and weight. If any Shuttle services are required, the price will be individually negotiated. Earnest money for this type payload is only $500.

TERMS AND CONDITIONS

Use of the Space Transportation System involves certain terms and conditions imposed on both the user and NASA. Some of the more important ones are summarized here.

• Reflight guarantee. For non-U.S. Government users, a reflight guarantee is included in the flight price. Other users can buy reflight insurance. The following services are provided under this guarantee.

1. The launch and deployment of a free-flying payload into a Shuttle-compatible mission orbit if the first attempt is unsuccessful through no fault of the user and if the payload returns safely to Earth or if a second payload is provided by the user.

2. The launch of an attached payload into its mission orbit if the first attempt is unsuccessful through no fault of the user, if the payload is still in launch condition or if a second payload is provided by the user.

3. The launch of a Shuttle into a payload mission orbit for the purpose of retrieving a payload if the first retrieval attempt is unsuccessful (this guarantee applies only if the payload is in a safe retrievable condition).

This reflight guarantee will not be applicable to payloads or upper stages required to place payloads into orbits other than the Shuttle mission orbit.

Other conditions of STS use include the following.

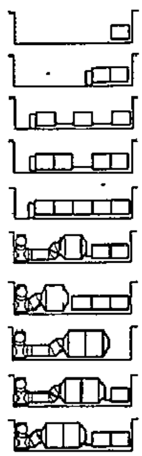
• Damage to payload. The price does not include a contingency or premium for damage that may be caused to a payload through the fault of the U.S. Government or its contractors. The U.S. Government, therefore, will assume no risk for damage or loss of the user's payload; the users will assume that risk or obtain insurance protecting themselves against such risk.

• Revisits and retrieval services. These services will be provided on the basis of estimated costs. If a special dedicated Shuttle flight is required, the full price will be charged. If the user's retrieval requirement is such that it can be accomplished as part of a scheduled Shuttle flight, the user will pay only for added flight planning, unique hardware or software, time on orbit, and other extra costs incurred by the revisit.

• Patent and data rights. NASA will not acquire rights to a non-U.S. Government user's inventions, patents, or proprietary data that are privately funded or that arise from activities for which a user has properly reimbursed NASA. However, in certain instances, NASA may obtain assurances that the user will make available the results to the public on terms and conditions reasonable under the circumstances. The user will be required to furnish NASA sufficient information to verify peaceful purposes and to ensure Shuttle safety and compliance with law and the Government's obligations.

• Launch schedule. For users of a dedicated flight, 3 years before the desired launch date NASA will identify a launch time within a 3-month period. One year before the flight, firm payload delivery and launch dates will be negotiated with NASA. For shared-flight users, 3 years before the flight the desired launch date will be identified within a 90-day period. One year before the flight, a payload delivery date and a desired launch date will be coordinated among the shared-flight users and negotiated with NASA.

STS service options and use charges

Option	Cost to user, $ millions[a]		
	Foreign and commercial	U.S. Government and participating	Department of Defense
STS elements			
Shuttle	KSC: 19.0 to 20.9 VAFB: 20.0 to 21.9	16.1 to 18.0	12.2
Spacelab 		TO BE PROVIDED	
Interim upper stage Two-stage Twin stage Planetary Planetary pioneer			
Spinning solid upper stage Delta class Atlas-Centaur class			
Payload Operations Control Center at GSFC JPL JSC			
Optional negotiable services			
Flight kits Support equipment Analytical flight planning Special training/simulation Other			

[a]In 1975 value.

Management and procedures

2

Flight systems

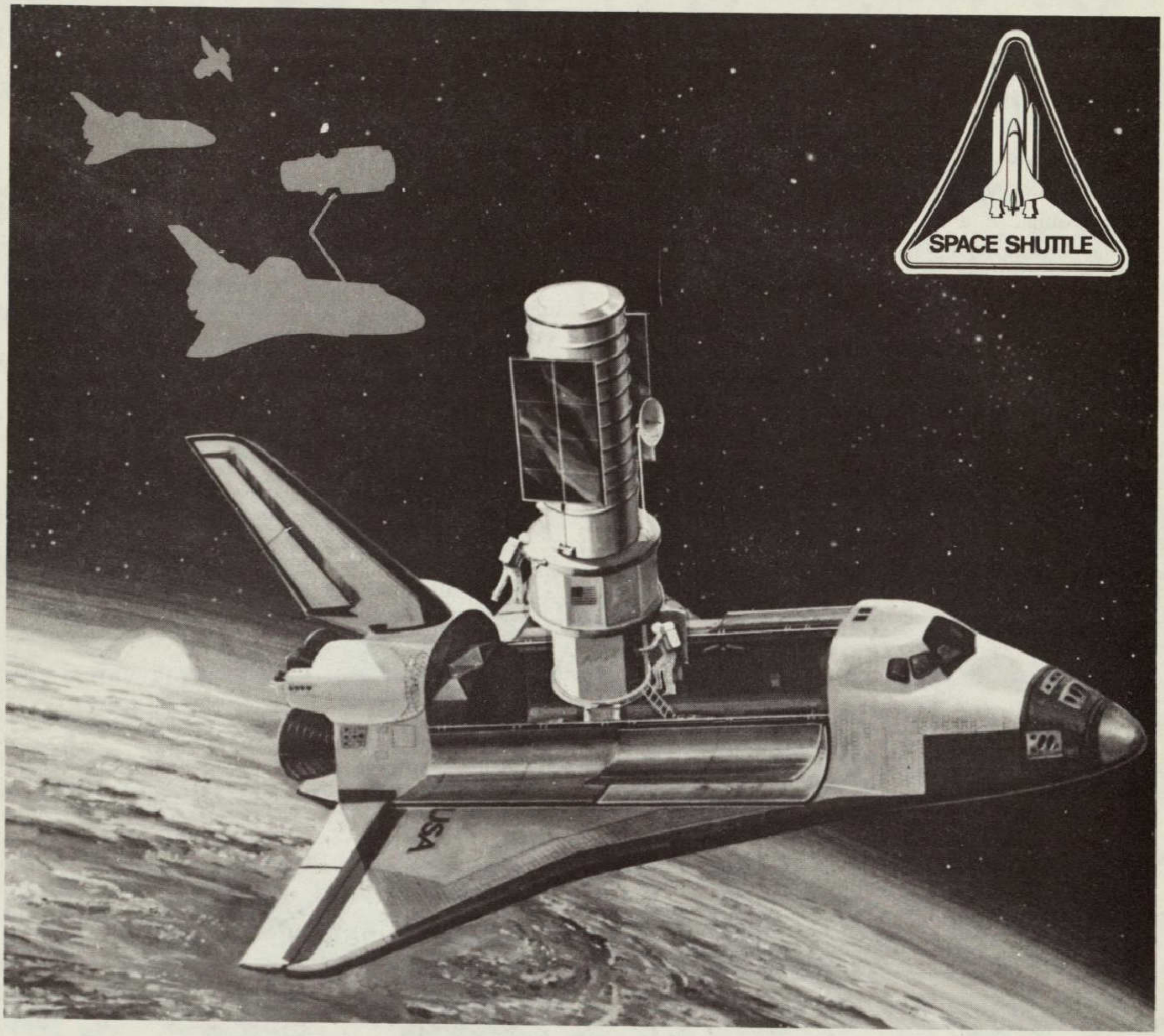
Launch and landing site operations

Flight operations

Appendixes

Flight systems

SHUTTLE SYSTEM



Shuttle system hardware and capabilities of importance to the user are summarized in this section. They include induced environments, and payload accommodations, such as attachments, the remote manipulator subsystem, electrical power availability, fluid and gas utilities, environmental control, communications links, data handling and displays, guidance and navigation systems, flight kits, and extravehicular activity provisions.

Users who expect their experiments to fly on a payload carrier (Spacelab, a propulsion stage, or a free-flying satellite) should refer to the section for that carrier. In those instances, the experiment will be integrated with the payload carrier and will not have a primary interface with the Space Shuttle Orbiter.

Possible design and accommodations changes will be made available to users as soon as is practical (Space Shuttle System Payload Accommodations, JSC-07700, Volume XIV). Any resulting payload modifications are the responsibility of the user.

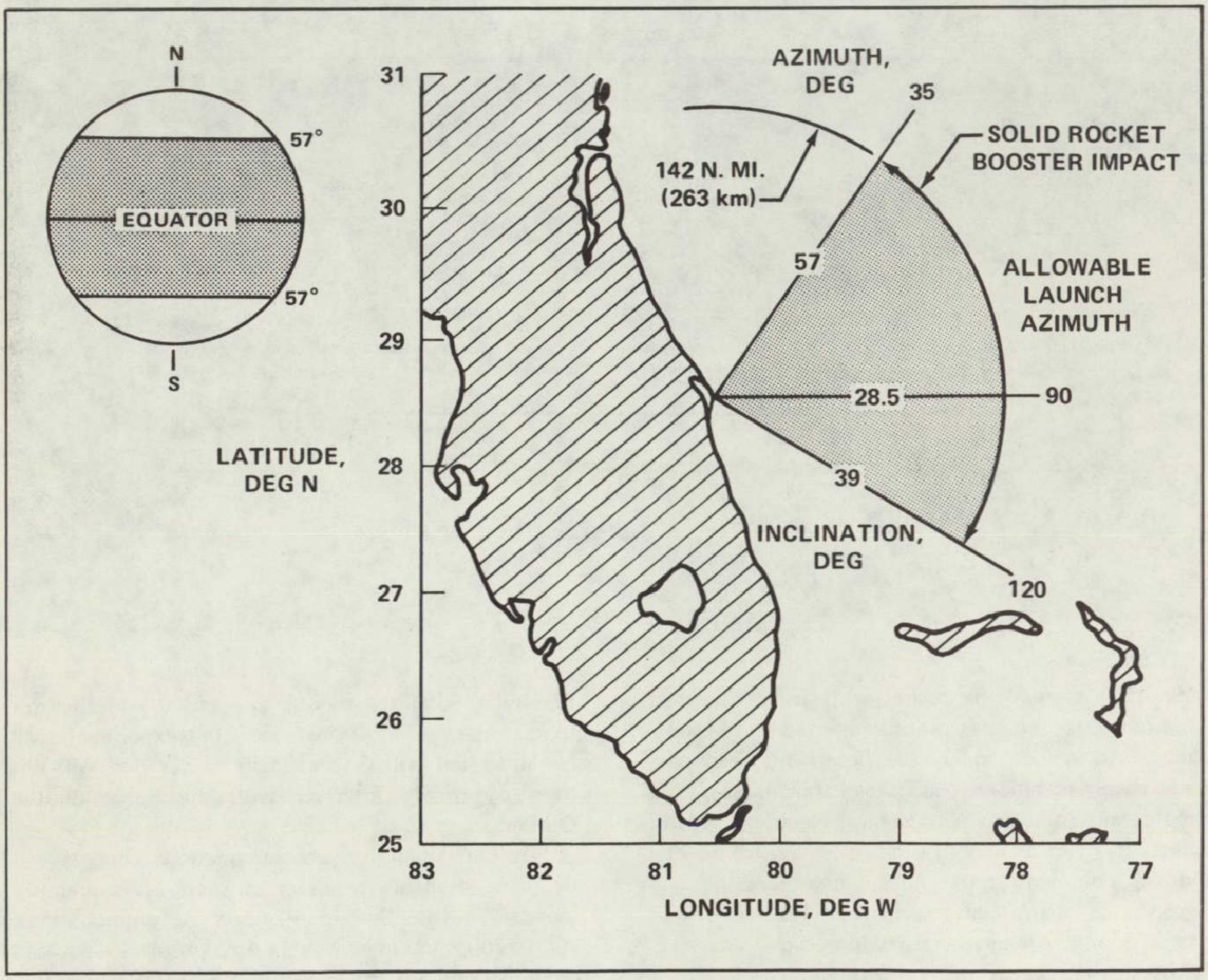
Performance capability

Launch limits

Operational flights will be launched from the NASA John F. Kennedy Space Center (KSC) in Florida beginning in 1980. Orbital inclinations of 28.5° to 57° can be obtained with cargo weights as shown for circular and elliptic orbits.

Individual figures for circular orbits illustrate both delivery-only missions and missions on which delivery and on-orbit rendezvous are needed for retrieving or servicing a payload. The reaction control subsystem (RCS) propellant loading is 3100 pounds (1406 kilograms) for a flight without rendezvous and 4900 pounds (2223 kilograms) with rendezvous. The orbital maneuvering subsystem (OMS) delta-V reserves are 22 ft/sec (6.7 m/sec) and 42 ft/sec (12.8 m/sec) for no-rendezvous and rendezvous, respectively.

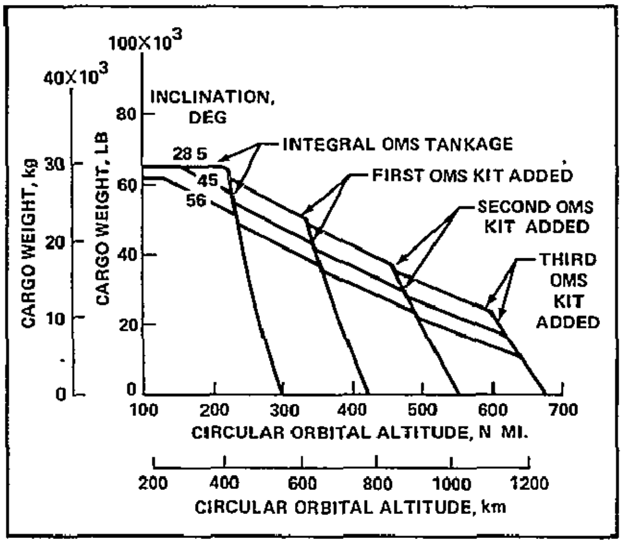
Altitudes and weights for elliptic orbits are shown for inclinations near the extremes. For no-rendezvous missions with an orbital perigee of 100 nautical miles (185 kilometers), the RCS propellant loading is 3100



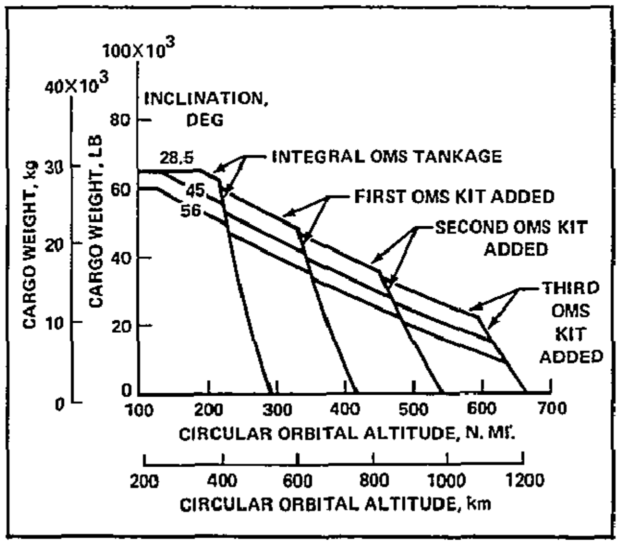
Launch azimuth and inclination limits from KSC in Florida. The inset globe illustrates the extent of coverage possible when launches are made from KSC.

pounds (1406 kilograms) and the on-orbit OMS delta-V reserve is 22 ft/sec (6.7 m/sec). These figures apply for all orbit inclinations possible from KSC.

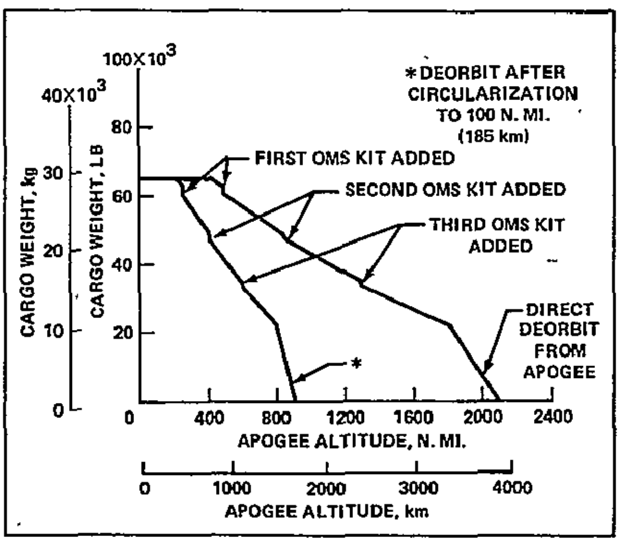
The integral OMS tanks on the Orbiter are sized to provide a 1000 ft/sec (305 m/sec) delta-V with a 65 000-pound (29 483-kilogram) cargo. As many as three extra OMS kits can be installed in the cargo bay for increased operational flexibility.



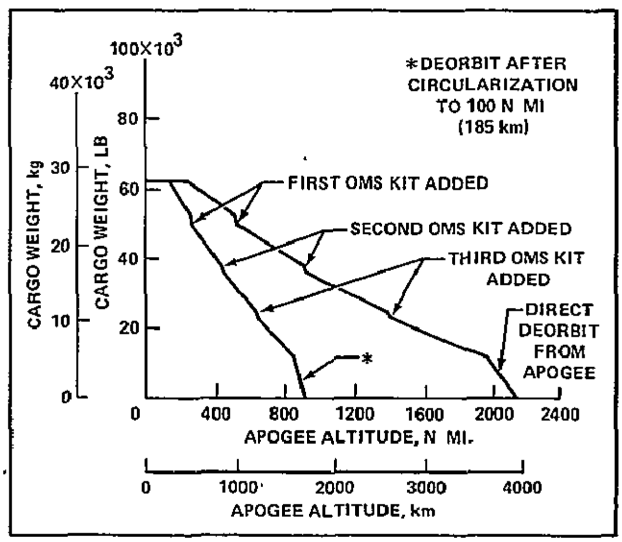
Maximum cargo weights at various circular orbital altitudes for flights with delivery only.



Maximum cargo weights for delivery and rendezvous flights in circular orbit.



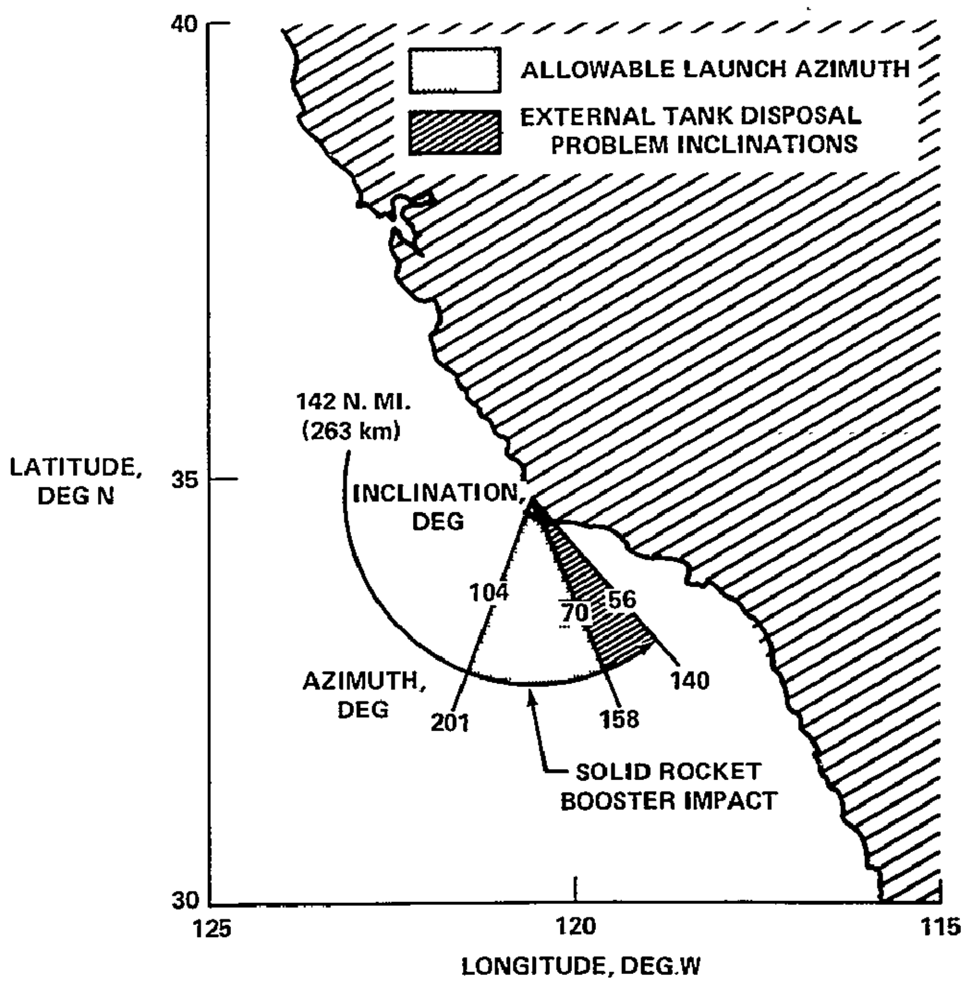
Maximum cargo weights in elliptic orbit at an inclination of 28.5°. The orbital perigee is 100 nautical miles (185 kilometers).



Cargo weight limitations in various elliptic orbits at an inclination of 55°. The orbital perigee is 100 nautical miles (185 kilometers).

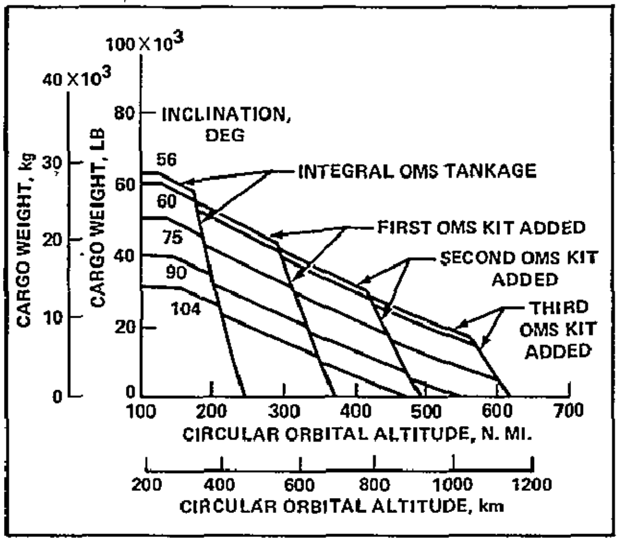
High inclination orbits from VAFB

Operational flights will also be launched from Vandenberg Air Force Base (VAFB) in California beginning in 1982. Higher orbital inclinations (56° to 104°) than from KSC can be obtained with cargo weights and orbital altitudes as shown for circular and elliptic orbits. For circular orbits, both delivery-only flights and those on which delivery and on-orbit rendezvous are needed can be accomplished. The RCS propellant loading is 3100 pounds (1406 kilograms) without rendezvous and 4900 pounds (2223 kilograms) with rendezvous. The OMS delta-V reserves are 22 ft/sec (6.7 m/sec) for flights without rendezvous and 42 ft/sec (12.8 m/sec) for rendezvous flights. Elliptic orbits at a maximum inclination of 104° provide delivery only. Propellant loading with delta-V reserves are the same as for circular delivery-only flights.

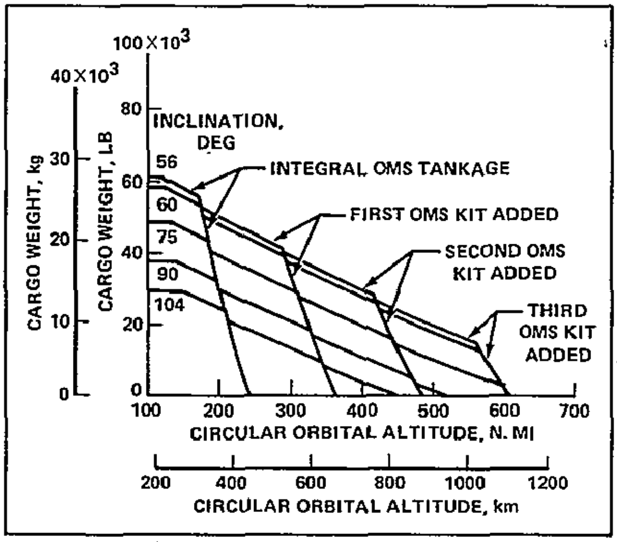


Launch azimuth and inclination limits from VAFB in California.

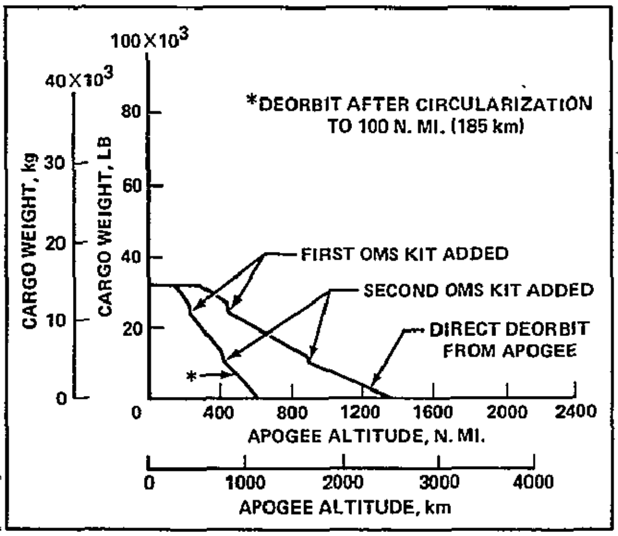
Shuttle cargo weight capability decreases rapidly as the inclinations become greater. Sun-synchronous orbital inclinations (97° to 99°), for example, will require one or more OMS kits, depending on the desired orbital altitude and cargo weight.



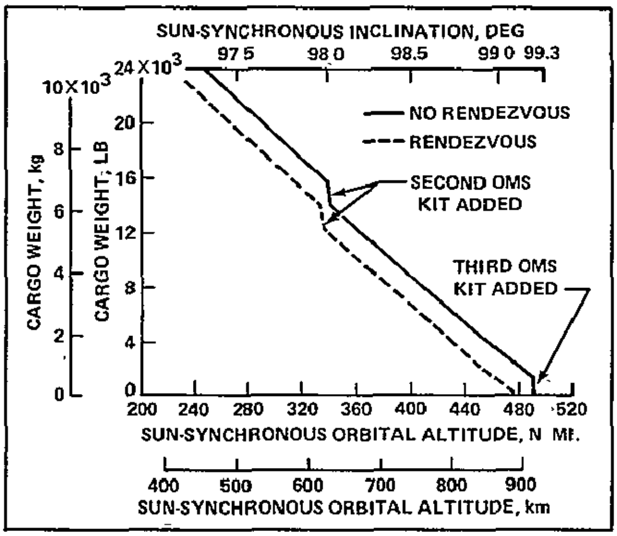
Maximum cargo weights at various circular orbital altitudes for flights with delivery only launched from VAFB.



Weight limits on delivery and rendezvous flights launched into circular orbit from VAFB.



Maximum cargo weights on high-inclination launches from VAFB into elliptic orbit. The orbital perigee is 100 nautical miles (185 kilometers).

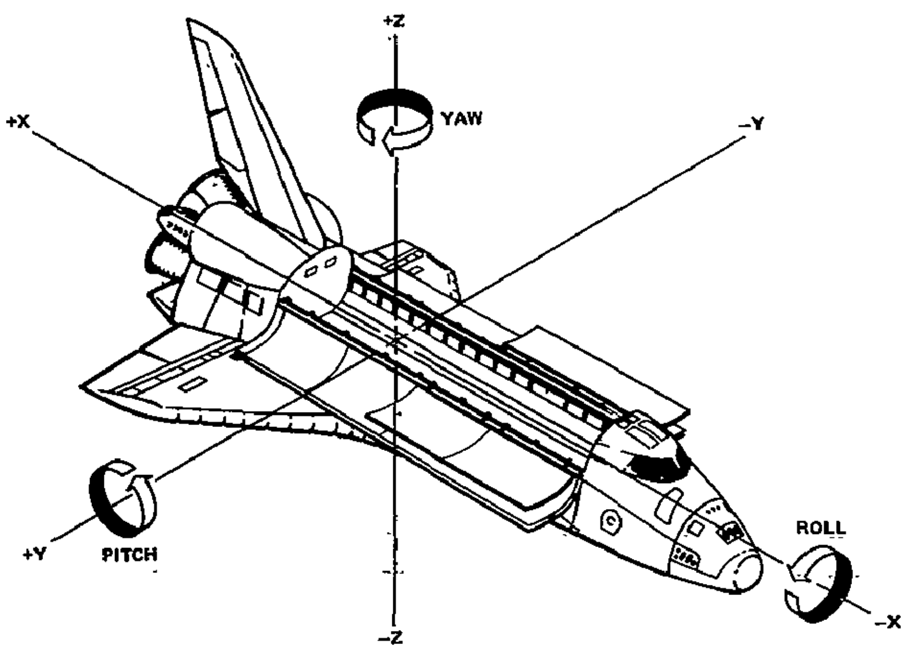


Cargo weights compared to altitudes in sun-synchronous orbits.

Free-drift Orbiter mode

Estimates of the on-orbit acceleration levels, velocity increment makeup, and altitude decrease resulting from atmospheric drag on the Orbiter in a free-drift mode of operation are illustrated. The drawings show which axis of the spacecraft is perpendicular to orbit plane (POP) in the three attitude orientations. The ballistic numbers (BN's) are based on a 200 000-pound (90 718-kilogram) Orbiter having drag coefficient of 2.0.

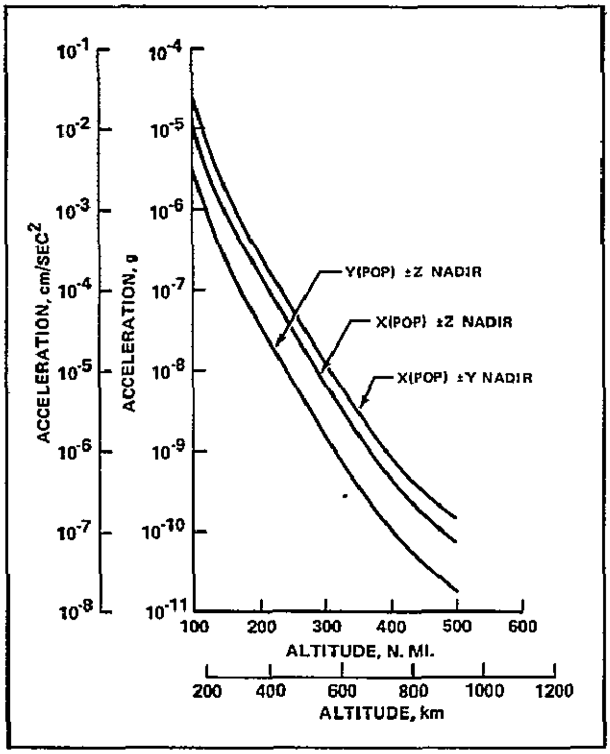
Typical experiment observation times for two possible free-drift modes are shown for a set of sample assumptions and cases at an orbital altitude of 250 nautical miles (463 kilometers). The results assume a sensor clear field of view of 90° cone (45° half cone) and a sensor interference limit of 14° above the Earth line.



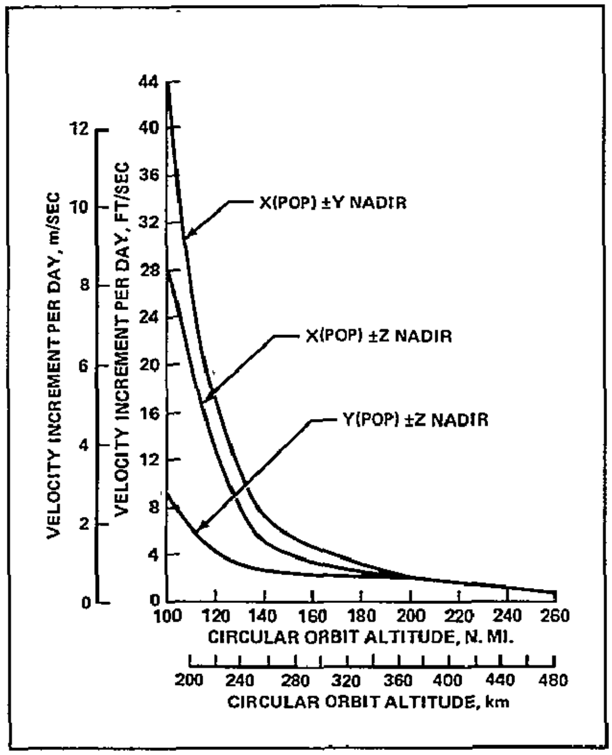
Observation parameters for selected free-drift modes

Flight mode		Maximum gimbal rates, deg/sec		Maximum observation time, min
		Pitch or yaw	Roll	
Gravity gradient stabilized	Y-POP, X-nadir	0 064	0.045	< 13.6
	Z-POP, X-nadir	0.045	0.064	> 50.7[a]
Quasi-inertial (selected inertial attitude/attitude rate	Y-POP	+0.048, –0.034	0.034	< 50.7[a]
	Z-POP	0.034	+0.048, –0.034	> 50.7[a]

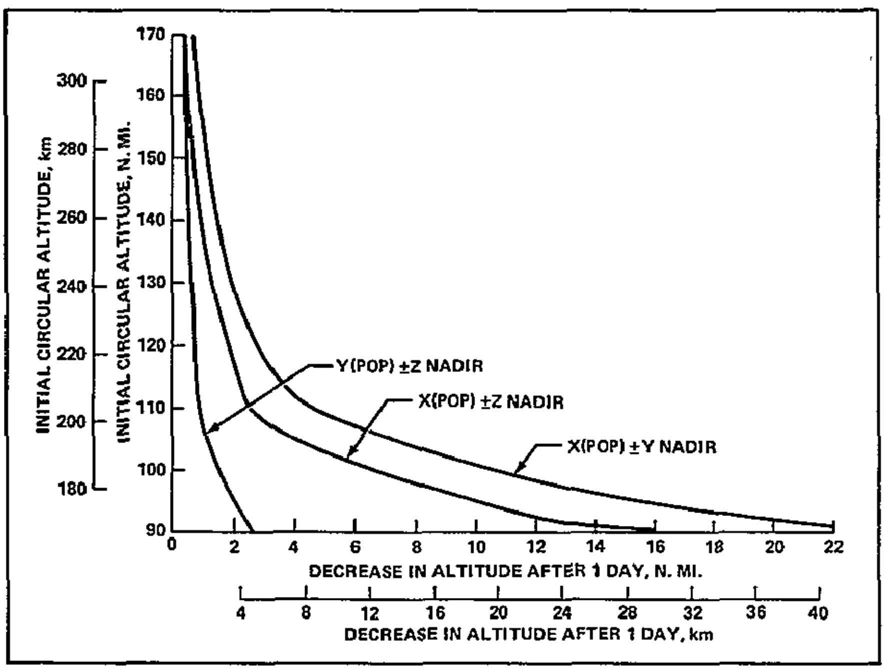
[a]Limited by Earth inteference.



Effects of atmospheric drag on the Orbiter.



Drag makeup delta-V increment in circular orbit.



Effects of drag on the Orbiter in low-Earth circular orbit.

On-orbit pointing and stabilization

The Orbiter is capable of attaining and maintaining any specified inertial, celestial, or local (vertical) Earth reference attitude. For payload pointing by use of the vernier thrusters, the Orbiter flight control system provides a stability (deadband) of ±0.1 deg/axis and a stability rate (maximum limit cycle rate) of ±0.01 deg/sec/axis. When using the primary thrusters, the Orbiter provides a stability of ±0.1 deg/axis and a stability rate of ±0.1 deg/sec/axis.

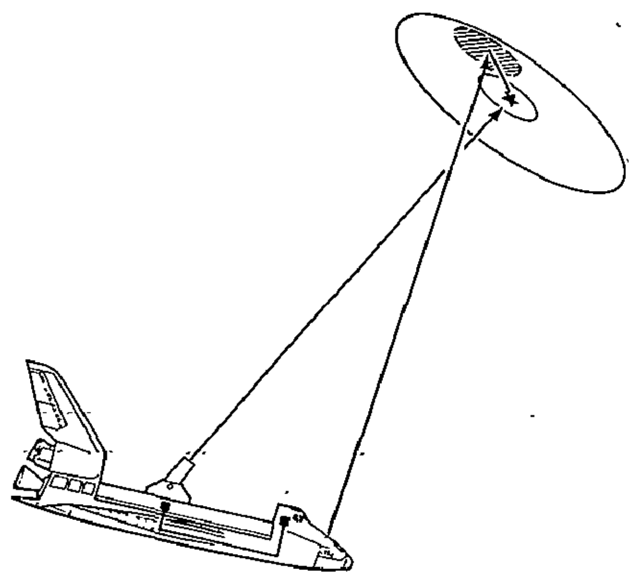
The Orbiter capability to point a vector defined in its inertial measurement unit (IMU) navigation base axes (using the Orbiter IMU for attitude information) is summarized in the accompanying table. The duration of continuous pointing within a specified accuracy is primarily dependent upon the IMU platform drift.

With augmented pointing systems and procedures, however, the pointing duration may be restricted by operational constraints such as thermal or communication considerations. Typical Orbiter RCS maximum acceleration levels during maneuvering and limit cycle pointing control are also shown. These figures are for single-axis (one degree of freedom) maneuvers, based on an Orbiter with 32 000 pounds (14 515 kilograms) of cargo.

Total (half-cone angle) pointing accuracy using Orbiter IMU

Reference	Half-cone angle pointing accuracy (3 sigma), deg[a]	Pointing accuracy degradation rate (3 sigma), deg/hr/axis	Duration between IMU alignments, hrs
Inertial and local vertical	±0.5	0.105	1.0
Augmented inertial	±0.44	0	NA
Earth-surface fixed target	±0 5	0 105	0 5

[a]Mechanical and thermal tolerances may degrade pointing accuracy as much as 2°.



Typical Orbiter RCS maximum acceleration levels

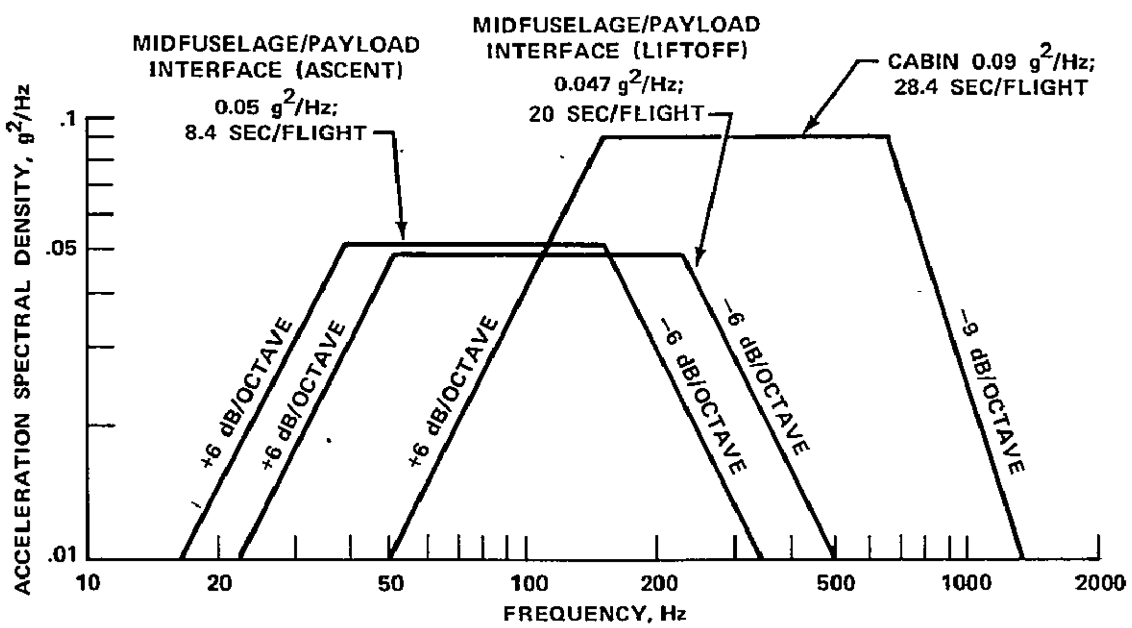
RCS system	Translational acceleration, ft/sec² (m/sec²)					Rotational acceleration, deg/sec²			
	Longitudinal		Lateral	Vertical					
	+X	−X	±Y	+Z	−Z	± Roll	+ Pitch	− Pitch	± Yaw
Primary thruster	0.6 (0 19)	0.5 (0.16)	0.7 (0.22)	1.3 (0 40)	1.1 (0.34)	1.2	1.4	1.5	0.8
Vernier thruster	0 0	0 0	0 007 (0 0021)	0 0	0.008 (0.0024)	0 04	0.03	0.02	0.02

Induced environments

Payload environments will vary for specific missions and will also depend on the spacecraft involved (type of free-flying system or Spacelab configuration, for example). Therefore, data in this section are general in nature. The figures represent recommended design qualification test levels.

Vibration caused by noise

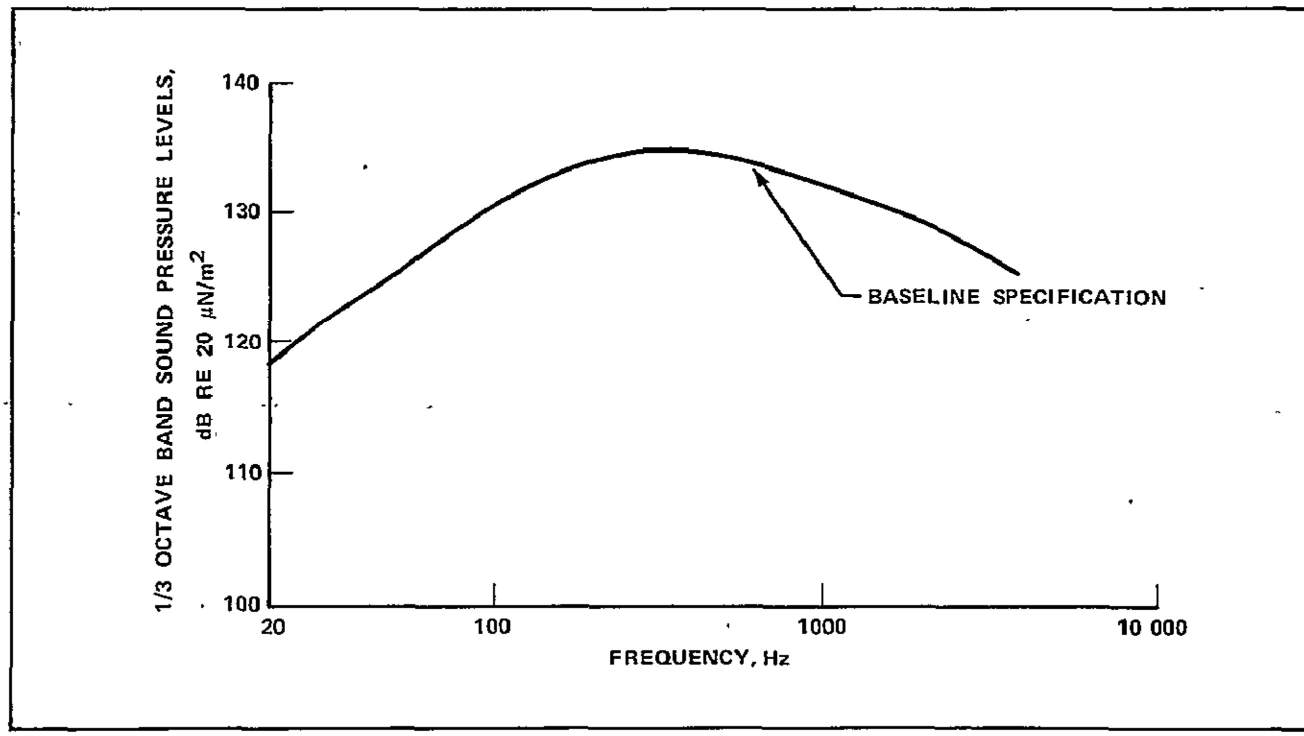
The Orbiter is subjected to random vibration on its exterior surfaces by acoustic noise (generated by the engine exhaust) and by aerodynamic noise (generated by airflow) during powered ascent through the atmosphere. These fluctuating pressure loads are the principal sources of structural vibration. Actual vibration input to payloads will depend on transmission characteristics of midfuselage payload support structure and interactions with each payload's weight, stiffness, and center of gravity.



Random vibration at midfuselage main longeron payload attachment points interface and in the cabin. These levels are typical of liftoff, transonic flight, and flight at maximum aerodynamic pressure.

The estimated random vibration and appropriate exposure durations for the cabin and midfuselage to payload interfaces caused by the fluctuating pressure loads are shown in the figure on the preceding page. The levels shown are typical of lift-off, transonic flight, and performance at maximum aerodynamic pressure. The midfuselage/payload interface vibration environment is based on the response of unloaded interface structure and should be considered the upper limit. The vibration inputs at the interface will be reduced by addition of the payload and support structures between the interface and payload component.

Vibration resulting from acoustic spectra is generated in the cargo bay by the engine exhaust and by aerodynamic noise during atmospheric flight. These predicted maximums are illustrated. The data presented are based on an empty cargo bay and may be modified by the addition of payloads, depending on their characteristics. Aerodynamic noise during entry is significantly less than on ascent.



Analytical prediction of maximum Orbiter cargo bay acoustic spectra.

Thermal control

During ground operations, the thermal environment of the cargo bay is carefully controlled by purging. While the Orbiter is on the ground, the cargo bay can be controlled within the limits shown in the table. Air-conditioning and purge requirements are defined by analysis for each launch.

During the ascent trajectory, the Orbiter construction and insulation limit the Orbiter induced heat loads on the payload. At 600 seconds after launch, the Orbiter is in the on-orbit phase and the cargo bay doors can be opened.

In space, with the cargo bay doors open, heating of payload components is based on the thermal, thermophysical, and geometric characteristics of each component. Additional factors influencing the incident thermal environment are launch date and hour, vehicle orientation, and orbital attitude. A detailed analysis of each payload may be necessary before thermal design and integration. For preliminary calculations, the optical properties of the cargo bay liner, Orbiter radiators, and insulated forward and aft bulkhead surfaces are as follows, where α is absorption and ϵ is emissivity.

Cargo bay liner	$\alpha/\epsilon \leqslant 0.4$
Radiator surface	$\alpha/\epsilon = 0.10/0.76$
Forward and aft bulkheads	$\alpha/\epsilon \leqslant 0.4$

Ground purge capability

Parameter	Location			
	Before launch pad		Postlanding and runway to OPF[a]	Transfers (VAB[b] to OPF, VAB to pad, OPF to VAB)
	Noncryogenic payload	Cryogenic payload		
Gas type	Air/GN_2[c]	GN_2	Air	Air
Temperature range, ±2° F (±1.1 K) (at T–0 umbilical inlet)	45 to 100 (280 to 311)	45 to 100 (280 to 311)	45 to 100 (280 to 311)	65 to 85 (291 to 303)
Flow rate, lb/min (kg/min)				
Spigots closed	110 (50)	364 (165)	115 (52)	115 (52)
Spigots open				
Spigots	150 (68)	150 (68)	136 (62)	136 (62)
Manifold	110 (50)	215 (97)	101 (46)	101 (46)
Total (spigots open)	260 (118)	364 (165)	220 (100)	220 (100)
Supply pressure, psig (N/m^2)	2.5 (17 235)	10 (68 940)	2.0 (13 788)	2.0 (13 788)

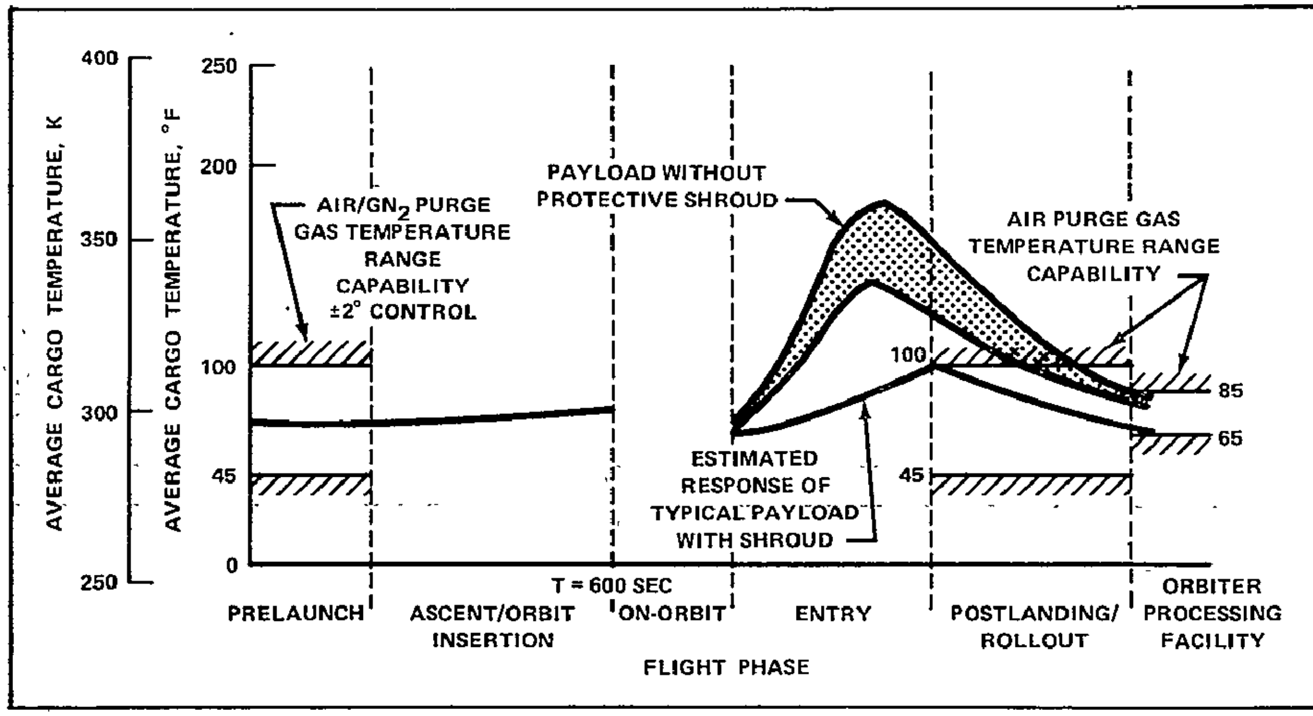
[a]OPF = Orbiter Processing Facility.

[b]VAB = Vehicle Assembly Building.

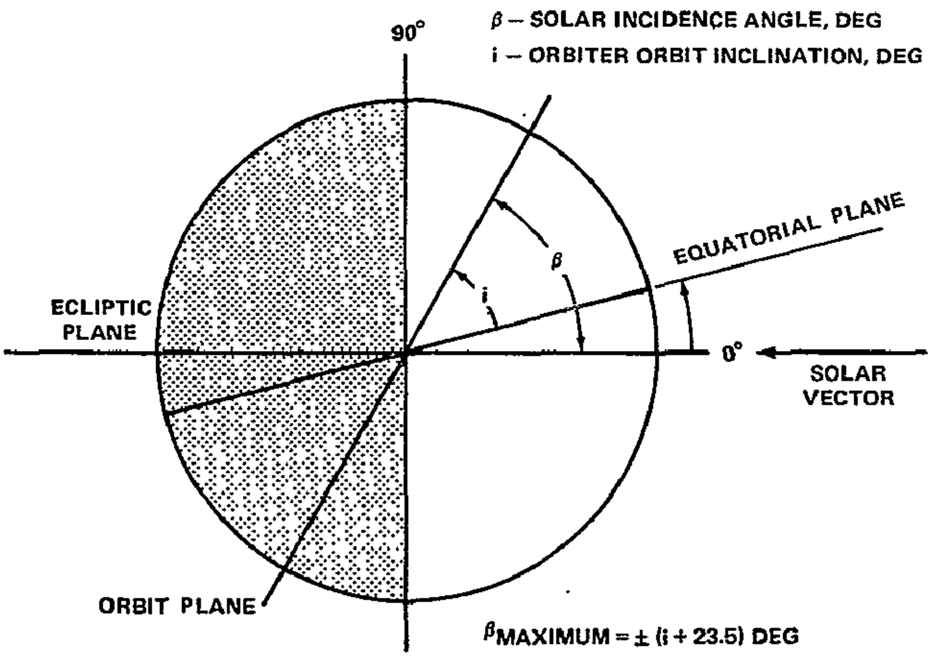
[c]Initiate gaseous nitrogen (GN_2) purge 80 min before cryogenic tanking of the Shuttle system to inert cargo bay

The Orbiter is designed for attitude hold capabilities as shown on the following page. During the 3-hour thermal conditioning periods, the vehicle rolls at approximately five revolutions per hour (barbecue mode) about the X-axis with the orientation of the X-axis perpendicular to the Earth-Sun line within ±20°, or it can be oriented at preferred thermal attitudes. On-orbit thermal conditioning lasting as long as 12 hours (before the deorbit maneuver) is allocated for missions on which the thermal protection subsystem temperatures exceed the design limits associated with a single-orbit mission.

Cargo temperatures for a typical flight, with emphasis on the entry phase, are shown in the figure.



Cargo bay thermal environment during the phases of a typical flight.



β range, deg	Orbiter orientation	Hold capability, hr	Preentry thermal conditioning requirements, hr
0 to 60	Any	⩾160	⩽12
60 to 90	Other than 3-axis inertial holds	Cycles of 6-hour holds followed by 3 hours of thermal conditioning for worst thermal attitudes	⩽7
	3-axis inertial holds	⩾160	⩽12

Orbiter attitude hold capabilities for various vehicle orientations.

Payload limit load factors

Payload structure and substructure must be designed with the appropriate margin of safety to function during all expected loading conditions, both in flight and during ground handling. The limit load factors at the payload center of gravity are shown in the accompanying table. The recommended margin of safety to apply to these limit load factors is 1.4. Emergency landing loads shall be carried through the payload primary structure at its attachment fittings. Preliminary design criteria for emergency landing conditions (ultimate design accelerations) for linear g are, along the X-axis, +4.5 to −1.50; along the Y-axis, +1.50 to −1.50; and along the Z-axis, +4.5 to −2.0.

The emergency landing design accelerations are considered ultimate; therefore, a 1.0 margin of safety should be applied.

Limit load factors[a]

Condition	Load factor		
	X-axis	Y-axis	Z-axis
Liftoff	-0.1 -2.9	1.0 -1.0	[b]1.5 [b]-1.5
Booster staging	-2.7 -3.3	.2 -0.2	-0.3 -0.3
Entry	1.06 -0.02	1.25 -1.25	2.5 -1.0
Landing	1.0 -0.8	0.5 -0.5	[b]2.8 [b]2.2

[a]For 65 000 lb (29 484 kg) up and 32 000 lb (14 515 kg) down.

[b]Angular accelerations of 10 rad/sec^2 applied from front cradle support to free end of spacecraft.

i.e. $N_Z = +2.75 + \frac{10\Delta X}{386}, N_Z = -2.75 - \frac{10\Delta X}{386}$

Landing shock

Landing shock is another factor that must be considered in payload structure design. Rectangular pulses of the following peak accelerations will be experienced.

Acceleration, g peak	Duration, msec	Applications per 100 flights
0.23	170	22
.28	280	37
.35	330	32
.43	360	20
.56	350	9
.72	320	4
1.50	260	1
		125

Consideration should be given to analyzing the landing shock environment in lieu of testing, because the g levels are relatively low in comparison to the basic design shock.

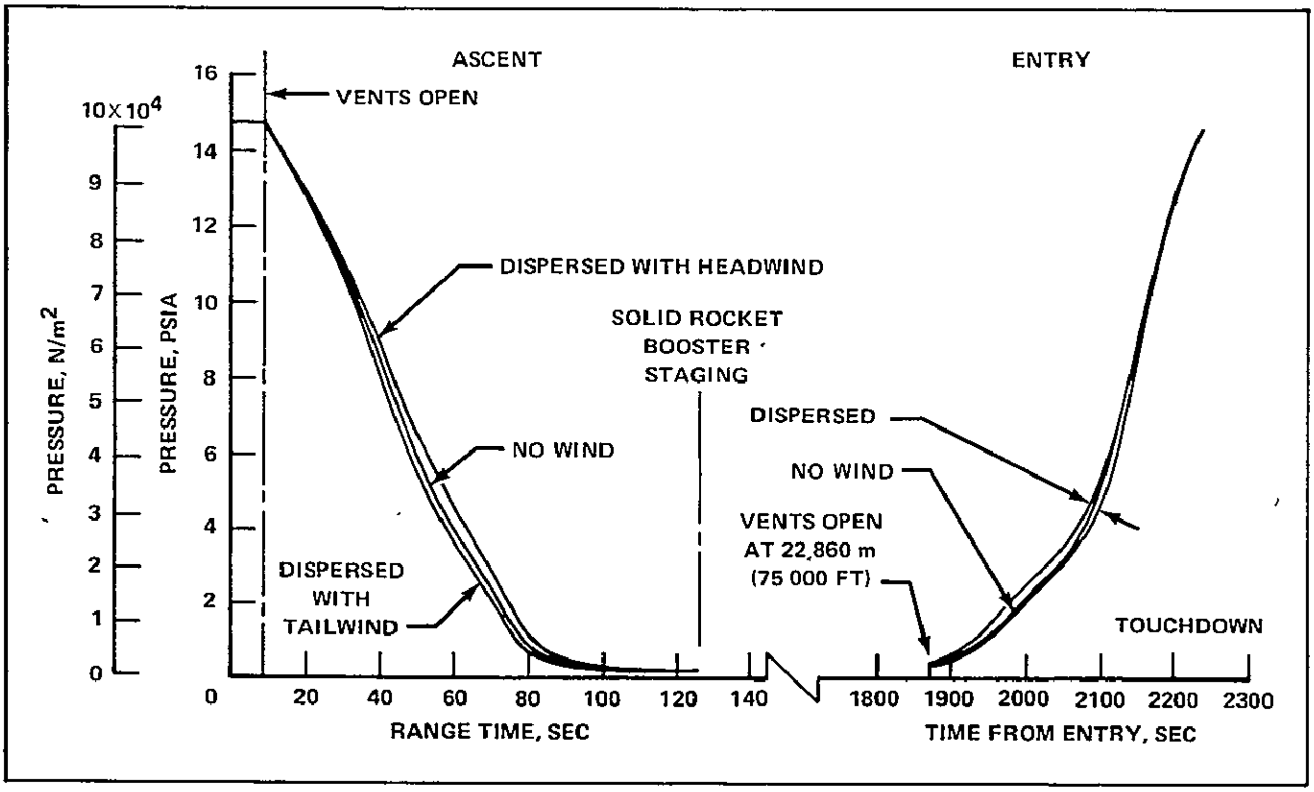
Testing must be performed only on those items not covered in a static structural stress analysis.

Pressure and venting

With the vents open, the cargo bay pressure closely follows the flight atmospheric pressures. The payload vent sequencing is as follows.

Prelaunch	Closed (vent no. 6 in purge position)
Lift-off (T = 0)	Closed
T + 10 seconds	All open
Orbit insertion	All open
On orbit	All open
Preentry preparation	All closed
Entry (high heat zone)	All closed
Atmospheric (75 000 ±5000 feet (23 ± 1.5 kilometers)) to landing	All open
Postlanding purge	Closed (vent no. 6 in purge position)

During the orbital phase, the cargo bay operates unpressurized. Pressures for other flight phases are shown in the figure.



Cargo bay internal pressure.

Contamination control

Contamination control systems as well as various techniques to eliminate or minimize contamination are provided by the Orbiter design and standard flight plans. The sensitivity of most payloads to contamination is recognized and each mission can be tailored to meet specific requirements. Before lift-off and after landing, the cargo bay is purged and conditioned as specified in the description of thermal controls. At launch and during early ascent, the cargo bay vents are left closed to prevent exhaust products and debris from entering the bay. During final ascent and through orbit insertion, the cargo bay is depressurized and the payload is generally not subjected to contaminants. (The payload vent sequencing is shown in the previous section.) On orbit there are three major sources of contamination: reaction control subsystem vernier firings, dumping of potable water, and release of particulates and outgassing. Predicted column density and return flux contributions are shown in the table.

During deorbit and descent, the cargo bay vents are closed to minimize ingestion of contaminants created by the Orbiter systems. During the final phase of reentry, the vents must be opened to repressurize the Orbiter. To help prevent contamination during this phase, the vents are located where the possibility of ingestion is minimal.

Predicted column density and return flux

Source	Number column density, molecules/cm^2			Return flux, molecules/cm^2/sec		
Outgassing (a) and (b)	$<10^{12}$ after 10 hr			$<10^{12}$		
				Values at 253 n. mi. (435 km)		
Vernier RCS	Aft -Z	Aft Y	Forward X/Z	Aft -Z	Aft Y	Forward Y/Z
(a)	4.4×10^{14}	2.0×10^{14}	3.9×10^{12}	7.6×10^{12}	3.4×10^{12}	6.6×10^{10}
(b)	1.8×10^{14}	8.1×10^{13}	2.7×10^{12}	3.2×10^{12}	1.4×10^{12}	4.6×10^{12}
Flash evaporator				378 n.mi (700 km)	235 n. mi. (435 km)	108 n. mi. (200 km)
(a)		5.6×10^{12}		8.4×10^{8}	2.4×10^{12}	1.3×10^{12}
(b)		5.6×10^{12}		8.5×10^{8}	2.4×10^{10}	1.3×10^{12}
Leakage						
(a)		2.2×10^{13}		1.2×10^{10}	3.7×10^{11}	1.9×10^{13}
(b)		3.5×10^{13}		2.0×10^{10}	5.6×10^{11}	3.1×10^{13}

[a] Zero degree line-of-sight (in the $+Z_o$ direction) originating at X_o 1107.

[b] 50° off of +Z towards $-X_o$ (forward) originating at X_o 1107

Electromagnetic compatibility

In general, close adherence to accepted electromagnetic compatibility design requirements will ensure compatibility of payloads with the Orbiter. The payload-generated, -conducted, and -radiated emissions are limited to the levels specified here.

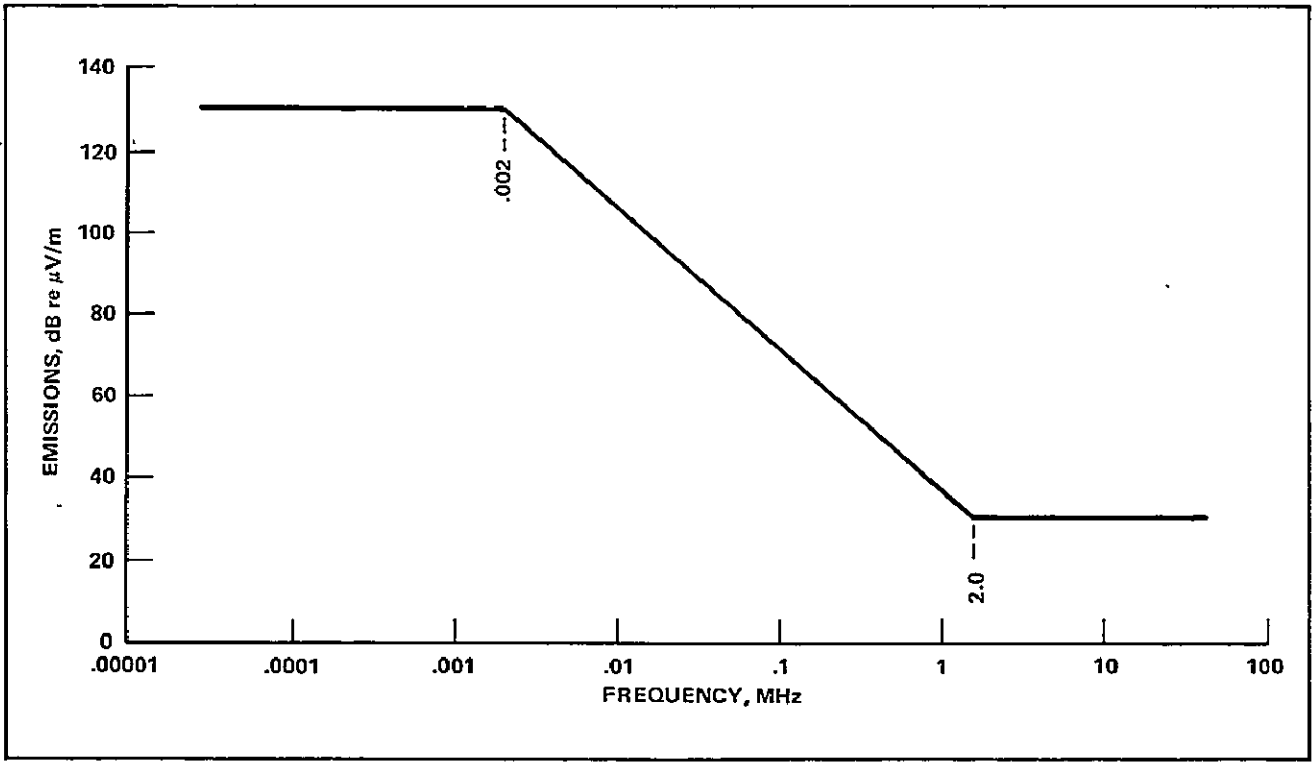
The limits to power line narrowband emission levels shown in the figure may be exceeded when the payload is operating from a dedicated fuel cell, provided the radiated electric field emission limits shown are met.

The magnetic fields (applied at a distance of 1 meter) generated shall not exceed 130 decibels above 1 picotesla (30 to 2 hertz), falling 40 decibels per decade to 50 kilohertz. The dc field shall not exceed 160 decibels above 1 picotesla.

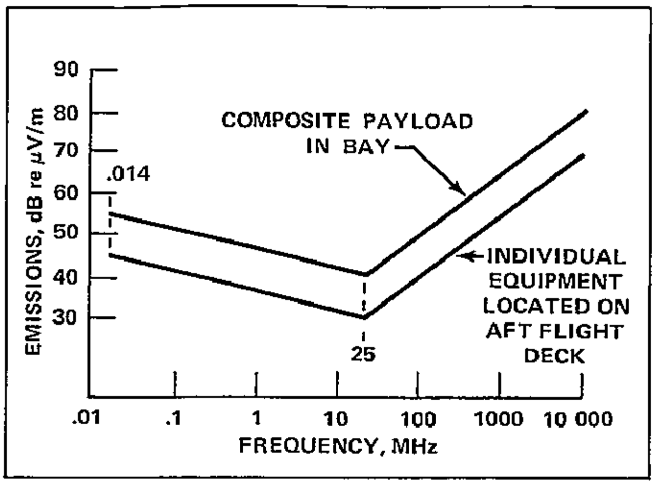
The maximum radiated electric fields, applied at a distance of 1 meter, both for narrowband and broadband emissions, are shown. In addition, for payload equipment in the cargo bay, broadband emissions shall be limited to 70 decibels above 1 μV/m/MHz in the frequency range of 1770 to 2330 megahertz; narrowband emissions shall be limited to 25 decibels above 1 μV/m from 1770 to 2300 megahertz, excluding the payload-intentional transmissions.

Electrostatic discharges are not permitted within the cargo bay unless they are contained and shielded by the payload.

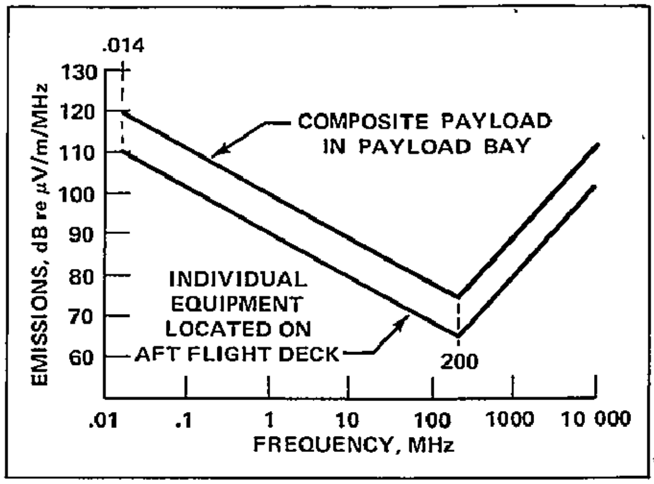
Payload-generated power by single event switching or operations occurring less than once per second shall not generate transients 300 X 10^{-6} volt-seconds above or below normal line voltage when fed from a source impedance as shown. Peaks shall be limited to ±50 volts, and rise and fall times shall not be less than 1 microsecond.



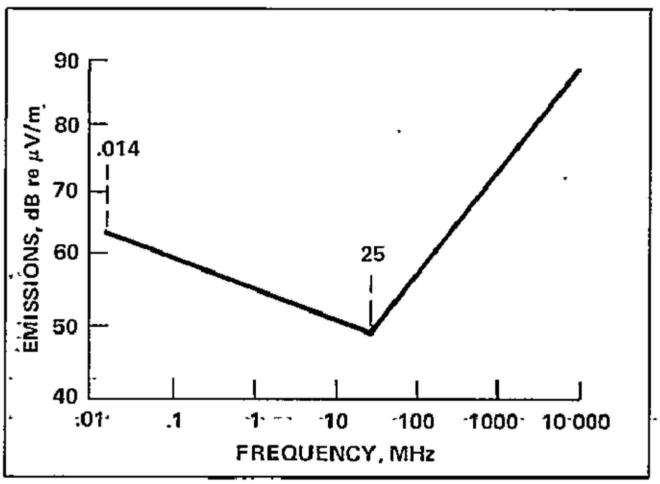
Payload allowable conducted narrowband emissions.



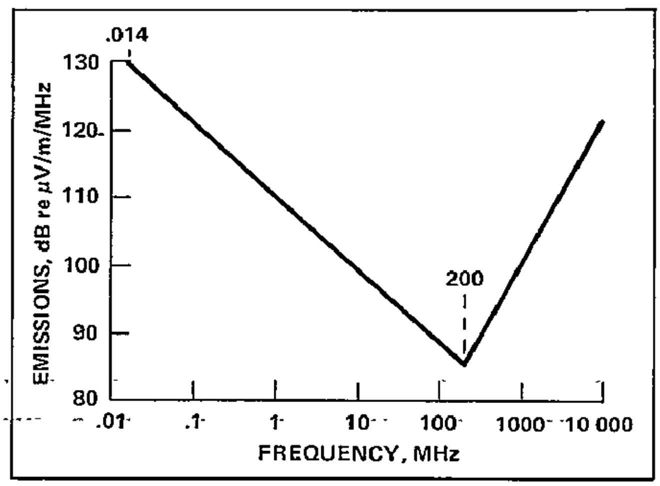
Payload allowable radiated narrowband emissions.



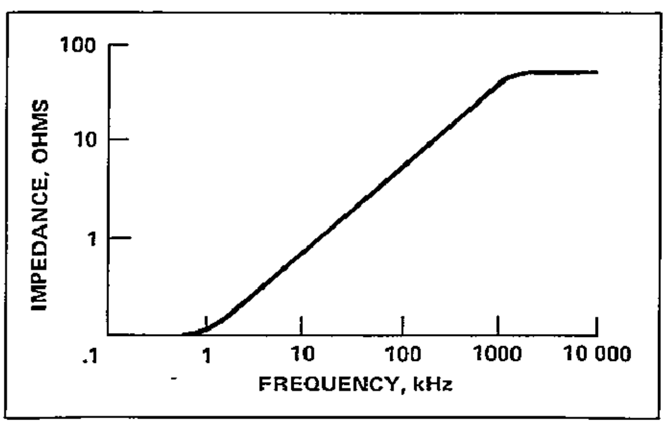
Payload allowable radiated broadband emissions.



Shuttle-produced narrowband emissions in the cargo bay.



Shuttle-produced broadband emissions in the cargo bay.



Orbiter dc power source impedance.

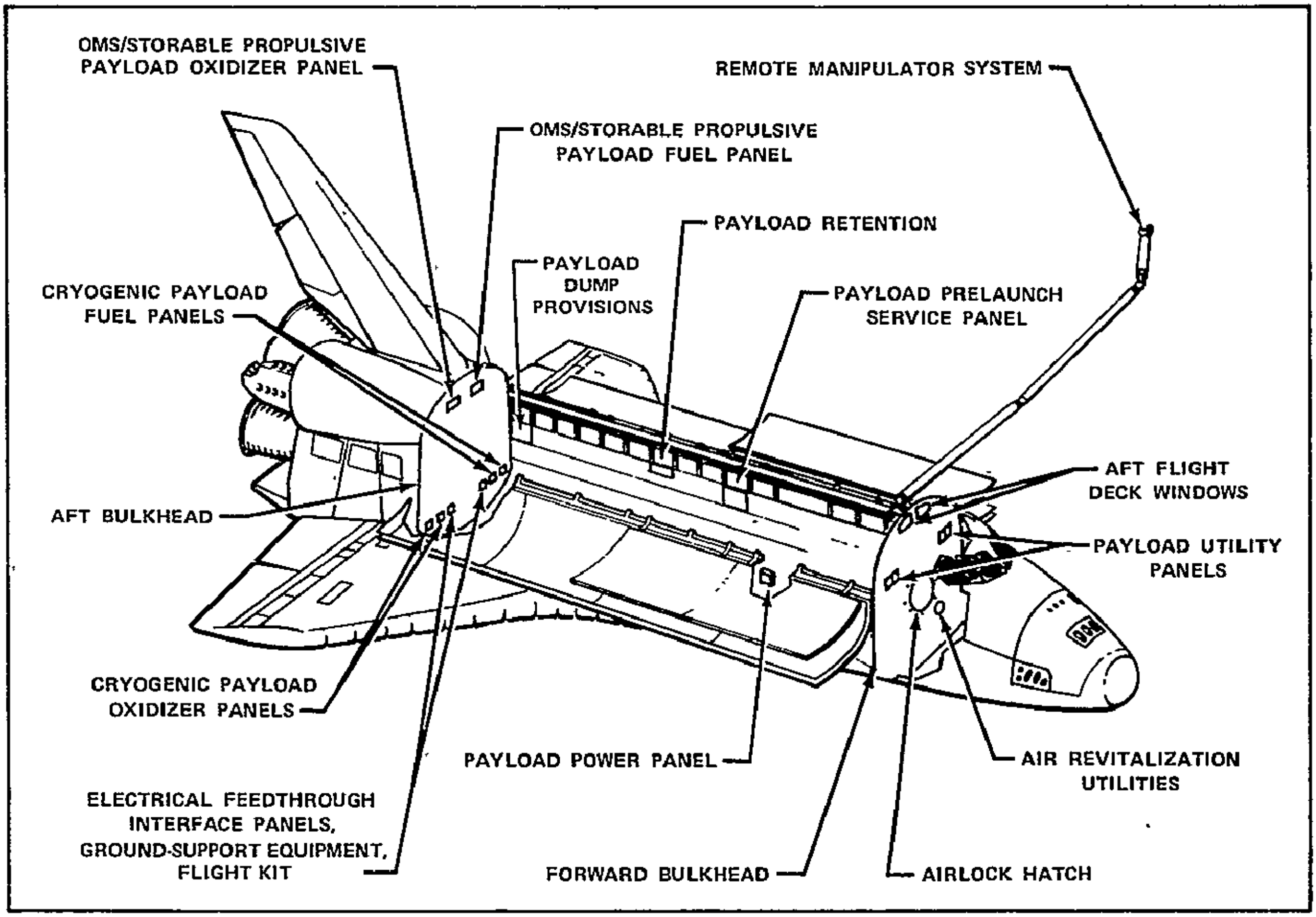
Payload accommodations

The Orbiter systems are designed to support a variety of payloads and payload functions. The payload and mission stations on the flight deck provide space for payload-provided command and control equipment for payload operations required by the user. Remote control techniques can be managed from the ground when desirable. When used, the Spacelab provides additional command and data management capability plus additional pressurized work area for the payload specialists. The following supporting subsystems are provided for payloads.

- Payload attachments
- Remote manipulator handling system
- Electrical power, fluids, and gas utilities
- Environmental control
- Communications, data handling, and displays
- Guidance and navigation
- Flight kits
- Extravehicular activity (EVA) capability when required

Payload accommodations are described in detail in the document Space Shuttle System Payload Accommodations (JSC 07700, Volume XIV).

All payloads have one or a combination of interfaces with the Orbiter vehicle. The vehicle is designed to provide adequate standard interfaces that can be used by or adapted to most potential payloads. Basic types of interfaces are summarized in the figure. Additional support systems and flight kits are also available to accommodate payloads.

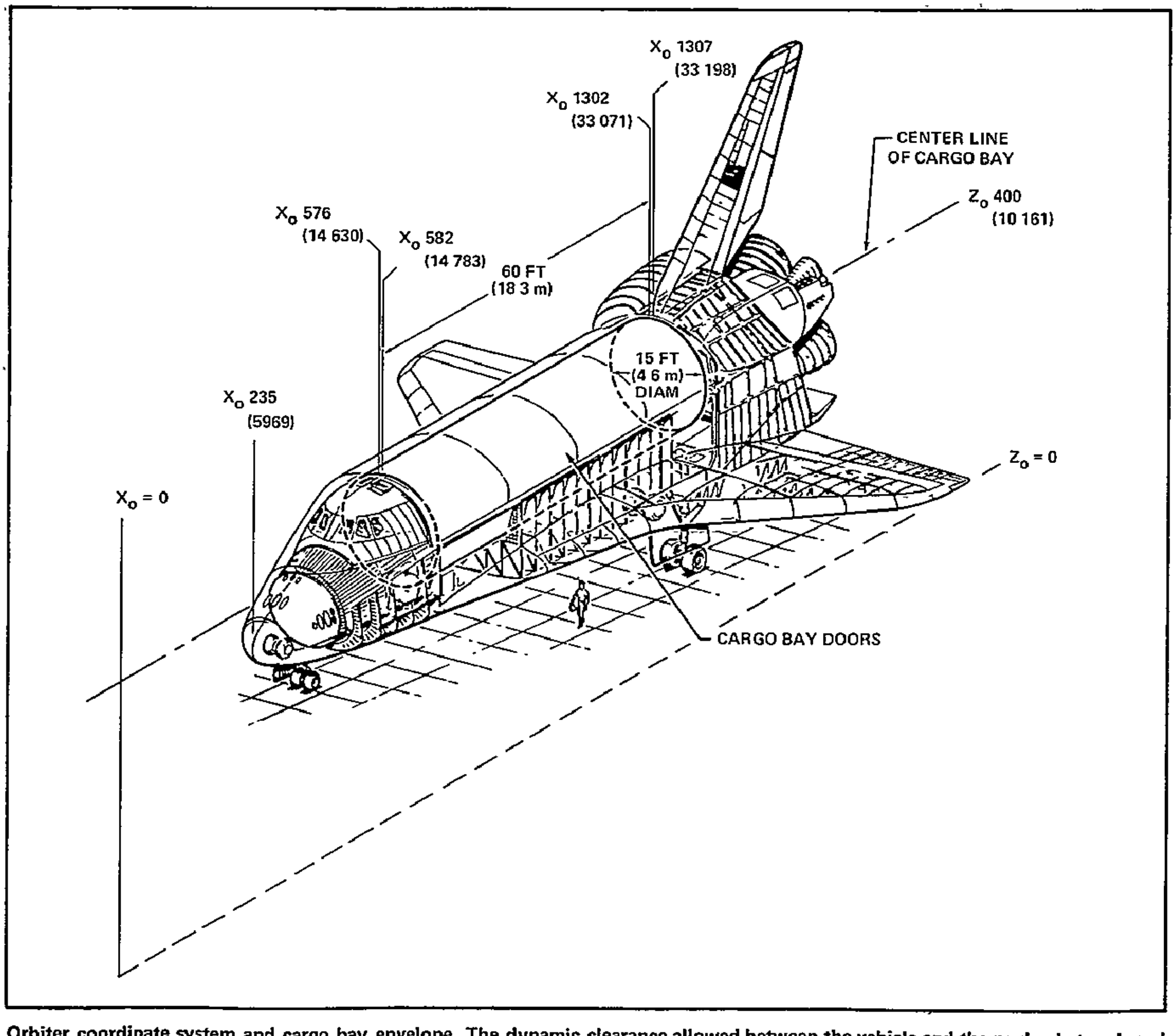


Principal Orbiter interfaces with payloads.

Envelope available to payload

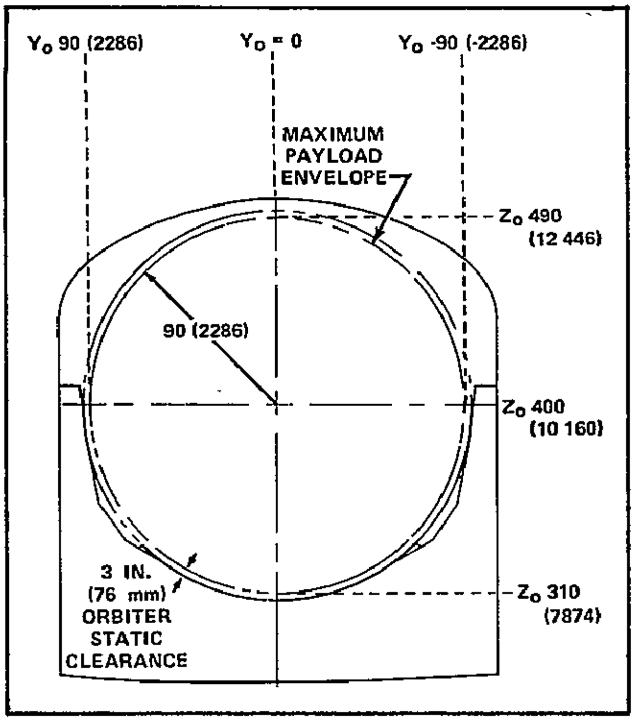
Payload accommodations are provided in two general areas of the Orbiter: the cargo bay and the aft flight deck in the cabin. The dimensions and envelope of the bay are illustrated, along with the structural and payload coordinate systems. The Orbiter stations (in inches with millimeters in parentheses) are included for reference.

The cargo bay is covered with doors that open to expose the entire length and full width of the cargo bay. The usable envelope is limited by items of supporting subsystems in the cargo bay that are charged to the payload volume.

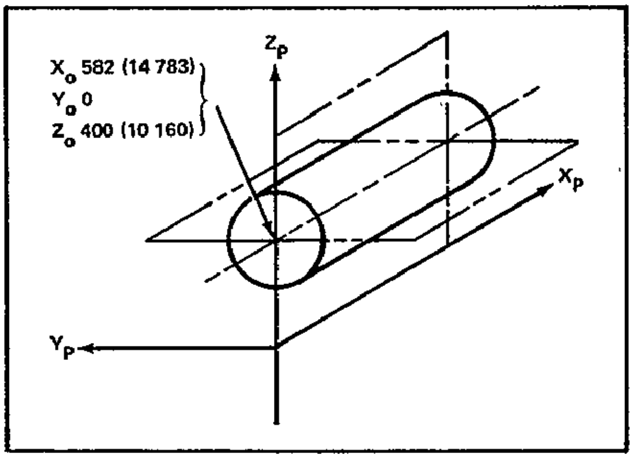


Orbiter coordinate system and cargo bay envelope. The dynamic clearance allowed between the vehicle and the payload at each end is also illustrated.

The payload clearance envelope in the Orbiter cargo bay measures 15 by 60 feet (4572 by 18 288 millimeters). This volume is the maximum allowable payload dynamic envelope, including payload deflections. In addition, a nominal 3-inch (76-millimeter) clearance between the payload envelope and the Orbiter structure is provided to prevent Orbiter deflection interference between the Orbiter and the payload envelope.

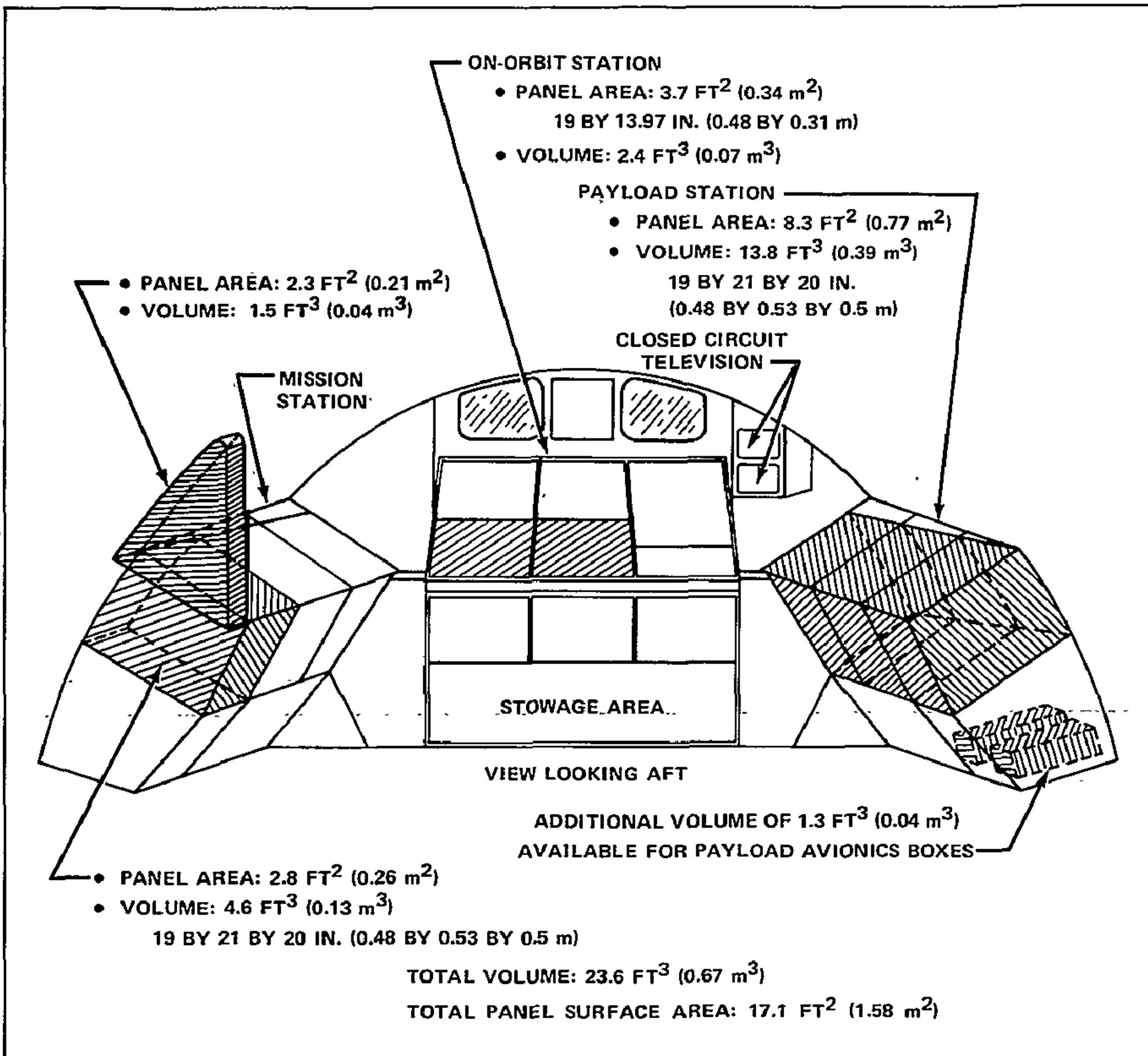


View of payload envelope looking aft.



Payload coordinates, showing relationship to Orbiter station on each axis.

The payload space on the aft flight deck is intended primarily for control panels and storage.



Area available for payload equipment or controls in the Orbiter aft flight deck.

Cargo bay liner and shrouds

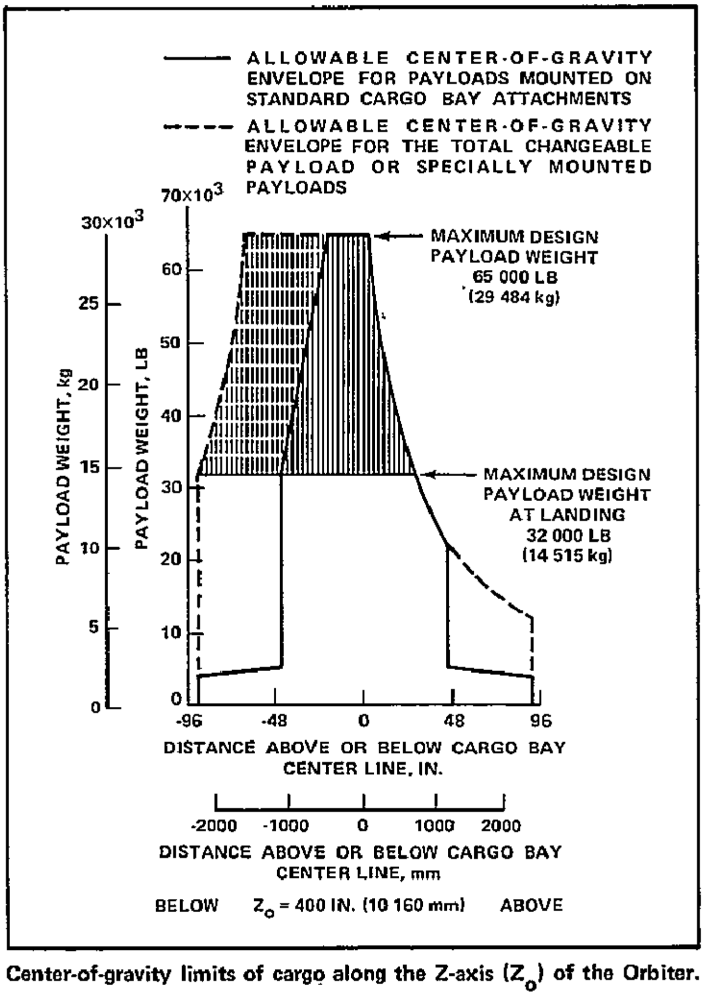
The cargo bay has been designed to minimize contamination of critical surfaces. Use of nonmetallic materials has been limited to those with low outgassing characteristics. Those areas that cannot be readily cleaned can be isolated from sensitive payload surfaces by the installation of a cargo bay liner, which does not intrude into the payload envelope.

Payloads that require additional protection from contamination can be provided with a shroud. It is considered part of the payload and is contained within the payload envelope of the cargo bay.

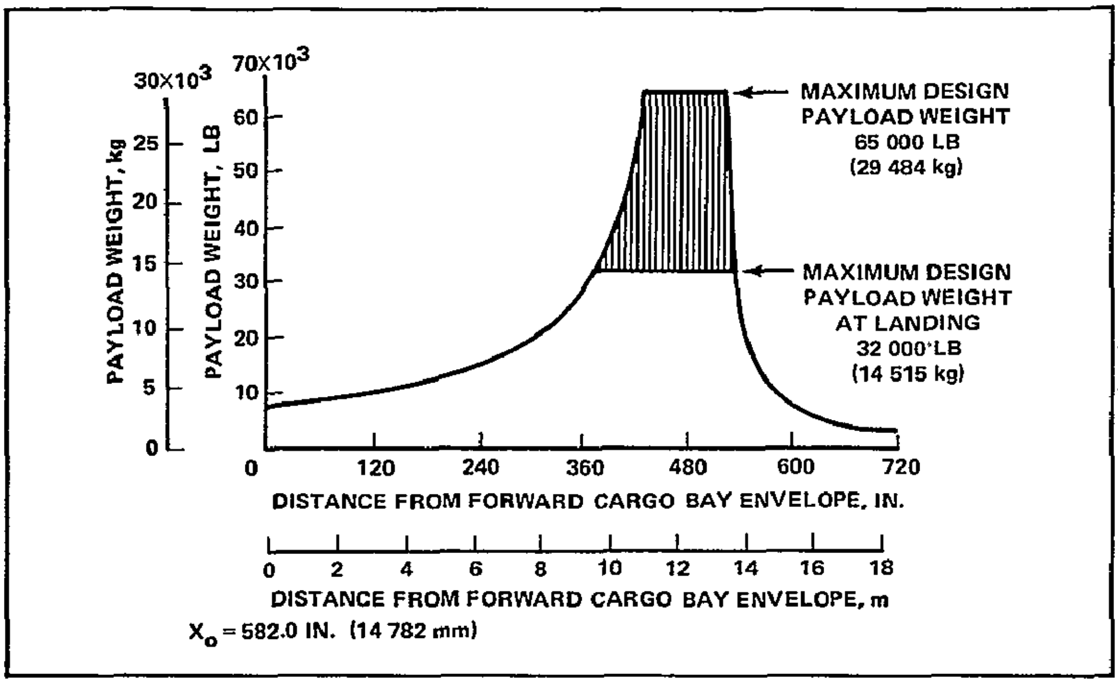
Weight and center of gravity

The location of the cargo center of gravity is critical during aerodynamic flight. Weight and center-of-gravity calculations must take into account all items of supporting subsystems charged to the payload. Cargo center-of-gravity envelopes for each axis of the Orbiter are shown in the figures. During normal landings and abort operations the center of gravity must fall within these envelopes. Out-of-envelope conditions are permissible during launch and space flight. However, the conditions must be correctable before reentry or in the event of an abort on launch.

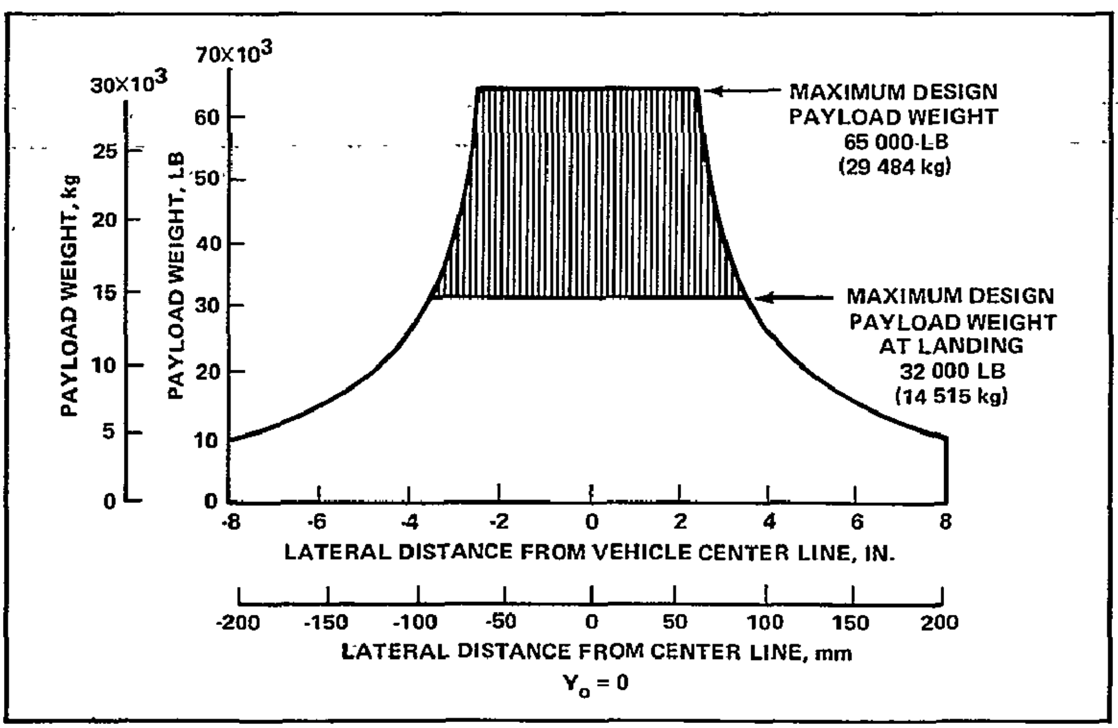
Each proposed out-of-envelope condition will be evaluated individually.



Center-of-gravity limits of cargo along the Z-axis (Z_0) of the Orbiter.



Payload center-of-gravity limits along the X-axis (X_o) of the Orbiter.



Allowable center-of-gravity envelope along the Orbiter Y-axis (Y_o).

Communications, tracking, and data management

Voice, television, and data-handling capabilities of the Orbiter support onboard control of the payload or, when desirable, remote control from the ground. The Orbiter communications and tracking subsystem provides links between the Orbiter and the payload. It also transfers payload telemetry, uplink data commands, and voice signals to and from the space networks. The provisions in the Orbiter for communications, tracking, and data management are flexible enough to accommodate most payloads.

Links through the Orbiter are outlined in the table. Communications capabilities, including those that bypass the Orbiter, are described in more detail in part 4.

The data processing and software subsystem of the Orbiter furnishes the onboard digital computation necessary to support payload management and handling. Functions in the computer are controlled by the mission specialist or a payload specialist through main memory loads from the tape memory. The stations in the Orbiter aft flight deck for payload management and handling are equipped with data displays, CRT's, and keyboards for onboard monitoring and control of payload operations.

Orbiter avionics services to payloads

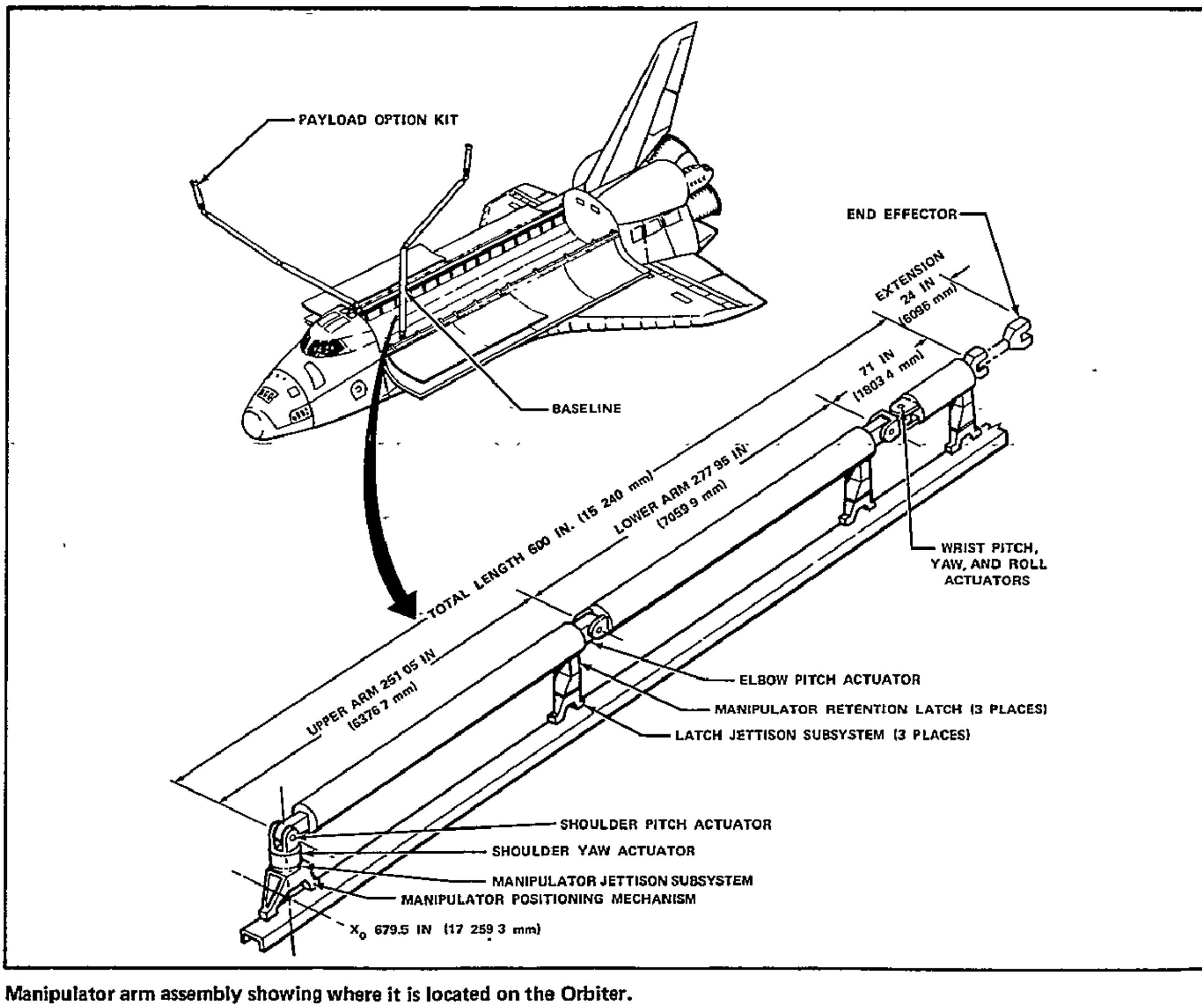
Function	Direct or through Tracking and Data Relay Satellite		Hardline		Radiofrequency link	
	Payload to ground via Orbiter	Ground to Payload via Orbiter	Orbiter to attached payload	Attached payload to Orbiter	Orbiter to detached payload	Detached payload to Orbiter
Scientific data	X	X		X		
Engineering data	X	X		X		X
Voice	X	X	X	X	X	X
Television	X		X	X		
Command		X	X		X	
Guidance, navigation, and control		X	X	X	X	
Caution and warning	X			X		X
Master timing			X			
Rendezvous					X	X

Deployment and retrieval

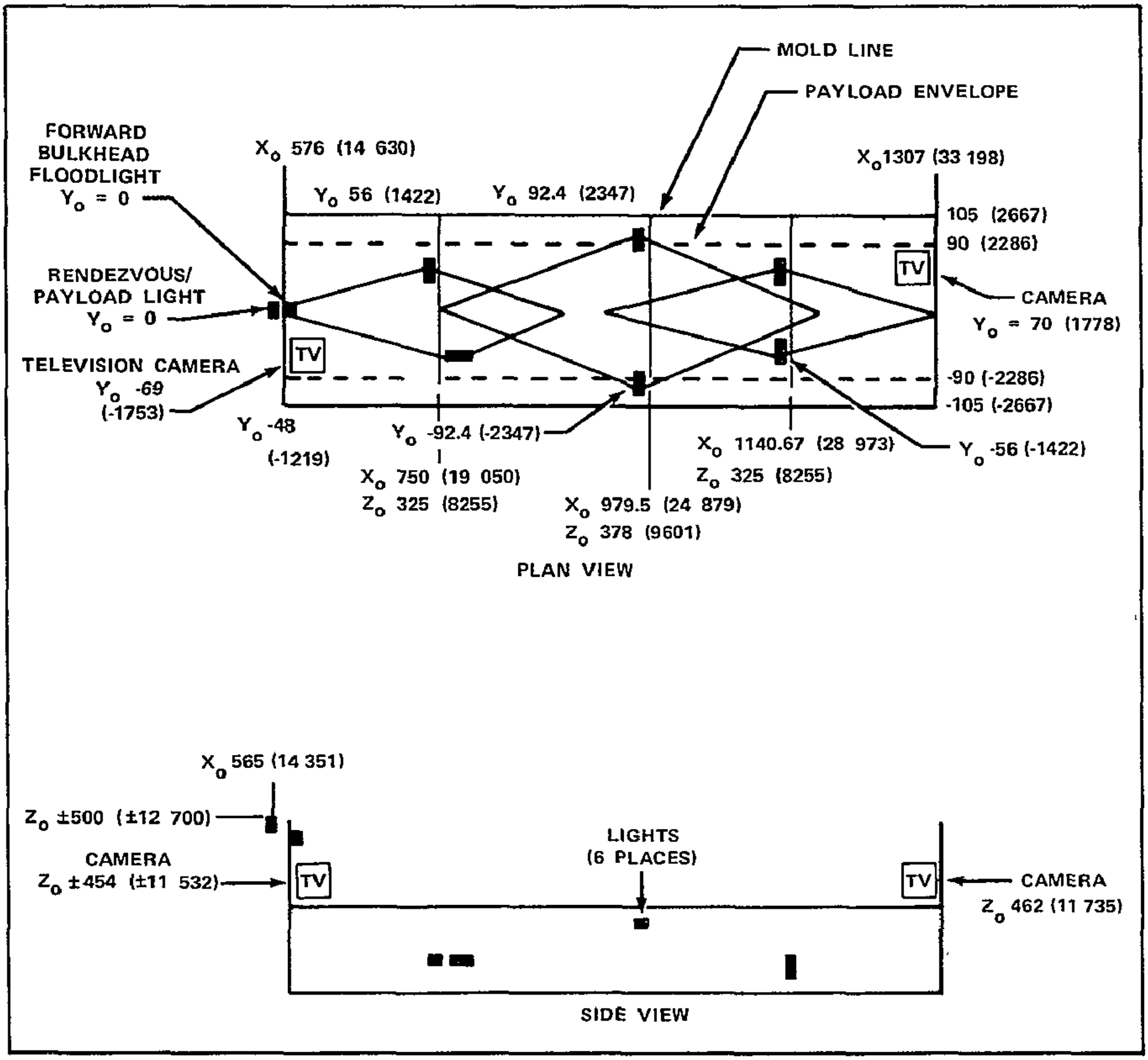
The deployment and retrieval of payloads will be accomplished by use of the general purpose remote manipulator system. Deployment can also be accomplished with a tilt/spin table.

One manipulator arm is standard equipment on the Orbiter and can be mounted on either the left or the right longeron. A second arm can be installed and controlled separately for payloads that require handling with two manipulators. Manipulators cannot be operated simultaneously. However, the capability exists to hold or lock one arm while operating the other. Each arm is associated with remotely controlled television cameras and lights to provide side viewing and depth perception. Lights on booms and side bulkheads provide sufficient illumination levels for any task that must be performed in the cargo bay. Payload retrieval involves the combined operations of rendezvous, stationkeeping, and manipulator arm control.

Handling of upper stages is discussed in the section describing those systems.



Manipulator arm assembly showing where it is located on the Orbiter.

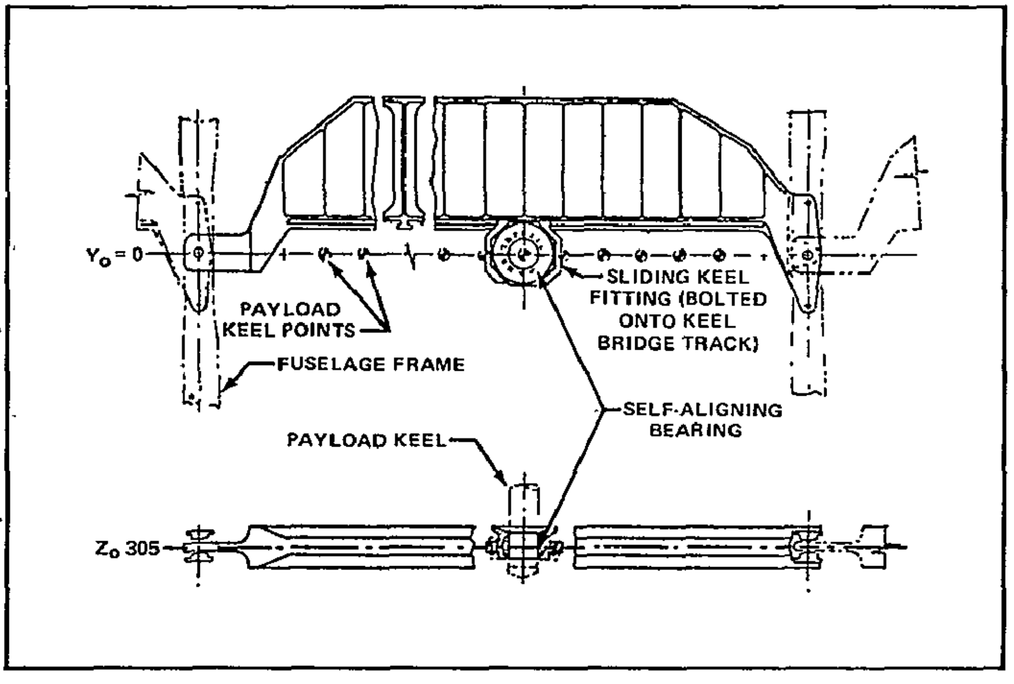


Locations of lights and television cameras are shown in relationship to the overall structure of the cargo bay. Orbiter stations are shown for reference. Dimensions are in inches (millimeters).

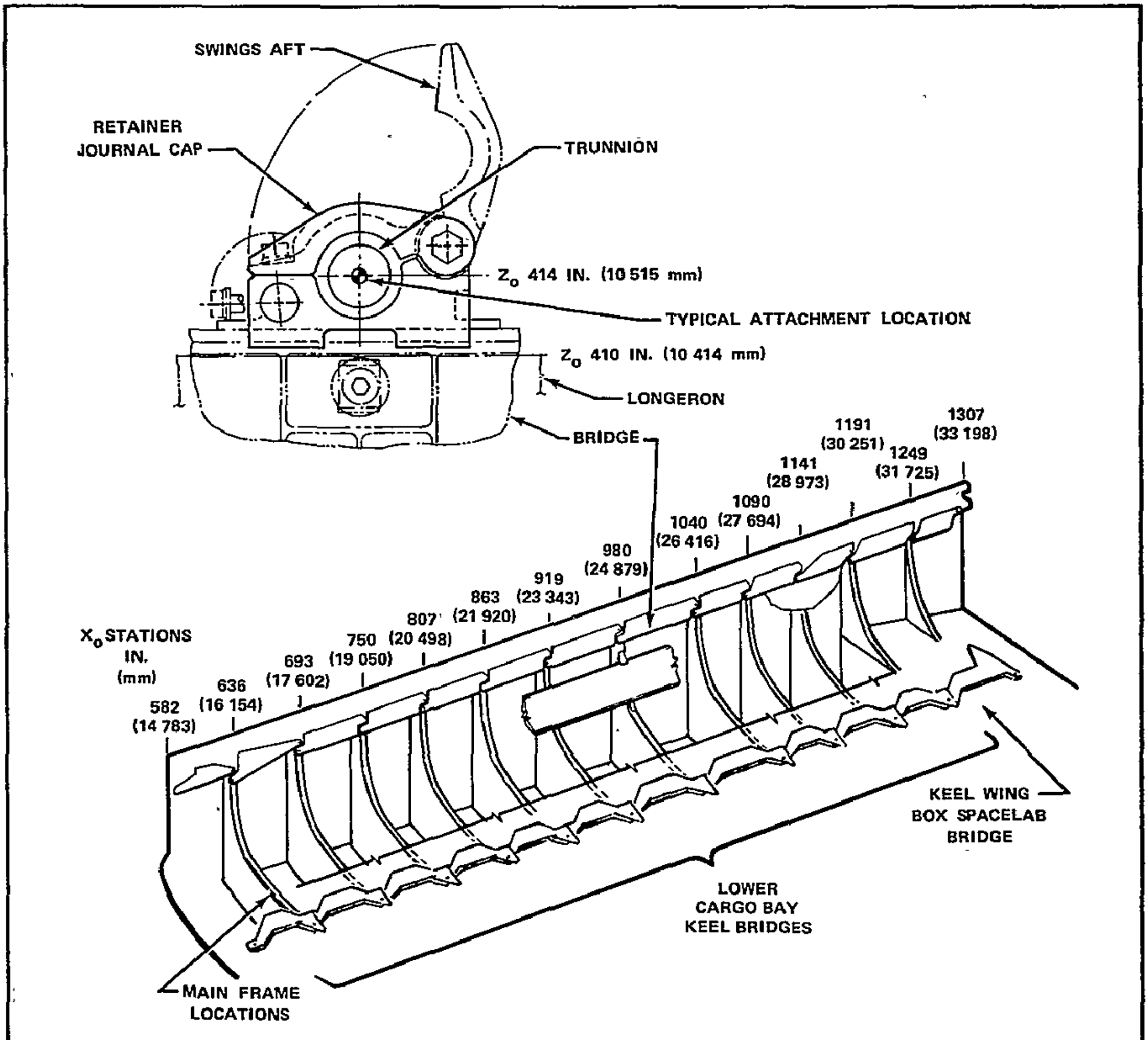
Structural Interfaces

Numerous attachment points along the sides and bottom of the cargo bay provide structural interfaces in a multitude of combinations to accommodate payloads. Thirteen primary attachment points along the sides accept X- and Z-axis loads. Twelve positions along the keel take lateral loads. Vernier locations are provided on each bridge fitting.

The fittings are designed to be adjusted to specific payload weight, volume, and center-of-gravity distributions in the bay. The fittings to attach payloads to the bridge fittings are standardized to minimize payload changeout operations. To further minimize payload operations involving the Orbiter, standard payload handling interfaces have been provided.



Keel bridge and attachment interface.



Payload structural attachment locations for use as required by various types of payloads. Detail of a standard fitting that holds the payload onto the bridge is also shown.

Electrical interfaces

Electrical power is provided to the payload from three fuel cells that use cryogenically stored hydrogen and oxygen reactants. The electrical power requirements of a payload during a flight will vary. During the 10-minute launch-to-orbit and the 30-minute deorbit-to-landing phases (when most of the experiment hardware is on standby or turned off), 1000 watts average to 1500 watts peak are available from the Orbiter. In orbit, as much as 7000 watts average to 12 000 watts peak can be provided to the payload.

For the usual 7-day flight, 50 kWh (180 megajoules) of electrical energy are available to payloads. If more energy is needed, flight kits can be added as required by the flight plan. Each kit contains enough consumables to provide 840 kWh (3024 megajoules). These are charged to the payload mass and volume.

Each of three fuel cell powerplants provides 2 kilowatts minimum and 7 kilowatts continuous, with a 12-kilowatt peak of 15 minutes duration every 3 hours.

Payload power interface characteristics are shown in the table.

Payload power interface characteristics

Flight phase	Interface	X_o station	Voltage range	Power available, kW		Peak power time limits	Comments
				Maximum continuous	Peak		
Ground operations (GSE power)	Primary payload bus	693	27 to 32	1.0	1 5	15 min/3 hr	Normal checkout, limited to 5200 Btu/hr (1523 W)
			27 to 32	6	TBD	15 min/3 hr	Orbiter powered down, without radiator kit
			27 to 32	7	12	15 min/3 hr	Orbiter powered down, with radiator kit
	Auxiliary payload A	693 Aft flight deck	25 5 to 32 25.7 to 32	0 4	25 amp	2 sec	Circuits automatically open when 25 amp is reached; power can be restored by switching off and on
	Auxiliary payload B	693 Aft flight deck	25.5 to 32 25.7 to 32	0.4	25 amp	2 sec	
	Aft payload B	1307	28 to 32	1 5	2	15 min/3 hr	Power can be used simultaneously with primary and auxiliary payload buses
	Aft payload C	1307	28 to 32	1.5	2	15 min/3 hr	
	Right GSE payload panel	1307	TBD	TBD	TBD	TBD	GSE power via T-0 umbilical independent of Orbiter
	Cabin payload bus	Aft flight deck	25.7 to 32	0.35	0.42	15 min/3 hr	Normal checkout; total power on aft flight deck (ac or dc) not to exceed 750 W continuous or 1000 W peak
			25.7 to 32	0.75	1	15 min/3 hr	Orbiter powered down
	ac 2 or ac 3	Aft flight deck	115 ± 5 ac	690 VA (3-phase)	1000 VA	2 min/3 hr	Orbiter powered down

Payload power interface characteristics – Concluded

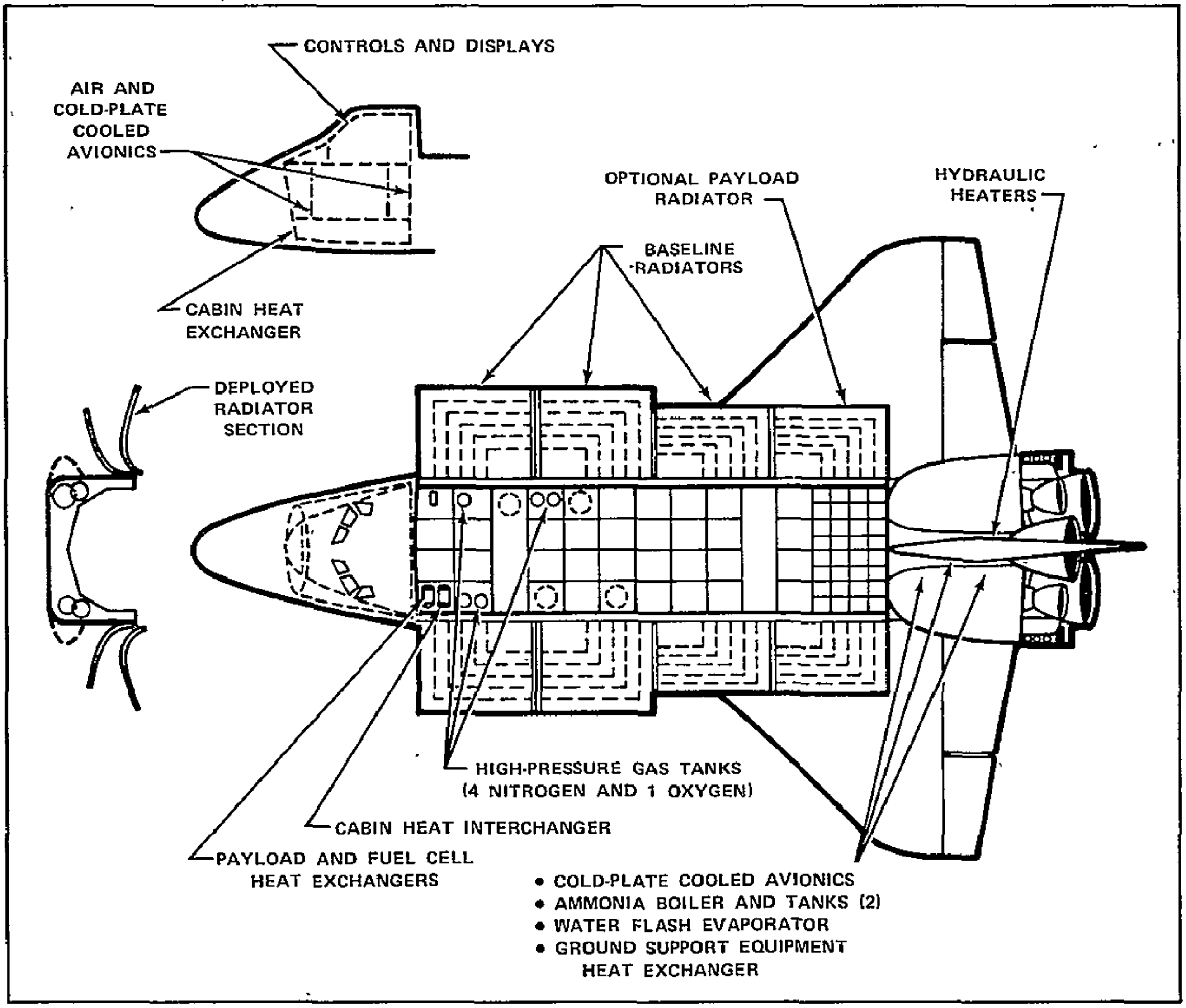
Flight phase	Interface	X_o station	Voltage range	Power available, kW		Peak power time limits	Comments
				Maximum continuous	Peak		
Prelaunch, ascent, descent, and postlanding	Primary payload bus	693	27 to 32	1	1 5	2 min/phase	Any active thermal control subsystem configuration
	Auxiliary payload A	693 Aft flight deck	25.5 to 32 25.7 to 32	0.4	25 amp	2 sec	Power may be used simultaneously
	Auxiliary payload B	693 Aft flight deck	25.5 to 32 25.7 to 32	0.4	25 amp	2 sec	Dedicated fuel cells not available
	Aft payload B	1307	24 to 32	1	1.5	2 min/phase	
	Aft payload C	1307	24 to 32	1	1.5	2 min/phase	
	Cabin payload bus	Aft flight deck	24.2 to 32	0.35	0.42	2 min/phase	Total power on aft flight deck (ac or dc) not to exceed 350 W continuous or 420 W peak
	ac 2 or ac 3	Aft flight deck	115 ± 5 ac	350 VA	420 VA	2 min/phase	During prelaunch and descent, ac power not available
On-orbit payload operations	Primary payload bus	693	27 to 32 27 to 32	7 6	12 TBD	15 min/3 hr 15 min/3 hr	With radiator kit; dedicated fuel cell mode; Orbiter powered down Without radiator kit; dedicated fuel cell mode or time-share Orbiter bus with 3 fuel cells operating; Orbiter powered down Peak voltage can be as large as 39 V for power loads less than 2 kW on a dedicated fuel cell
	Backup	693	26.3 to 32	5	8	15 min/3 hr	Time shared power; one fuel cell failed
	Auxiliary payload A	693 Aft flight deck	25.5 to 32 25.7 to 32	0.4	25 amp	2 sec	Power can be used simultaneously with all buses
	Auxiliary payload B	693 Aft flight deck	25.5 to 32 25.7 to 32	0.4	25 amp	2 sec	Total power on aft flight deck (ac or dc) not to exceed 750 W continuous or 1000 W peak
	Aft payload B	1307	24 to 32	1.5	2	15 min/3 hr	
	Aft payload C	1307	24 to 32	1.5	2	15 min/3 hr	
	Cabin payload bus	Aft flight deck	24.2 to 32	0.75	1	15 min/3 hr	
	ac 2 or ac 3	Aft flight deck	115 ± 5 ac	690 VA (3-phase)	1000 VA	2 min/3 hr	

Environmental control

Cooling services are provided to payloads by the Orbiter. Prelaunch and postlanding thermal control is provided by ground support systems. In orbit, the primary Orbiter heat rejection is by use of radiators on the cargo bay doors. The payload heat exchanger is designed so either water or Freon 21 can be selected as a cooling fluid, according to the needs of the payload. The payload side of the heat exchanger has two coolant passages; either or both can be used. Coolant is provided to the payload at 40° to 45° F (278 to 280° K). Fluid circulation through the payload side of the heat exchanger must be supplied as part of the payload. A water flash evaporator is used to supplement the radiator cooling capacity. During ascent and descent, when the cargo bay doors are closed and the radiators are ineffective, cooling is provided by the water boilers.

Payload heat rejection available

Flight phases	Capability, KW		Description
	Aft flight deck	Cargo bay	
Prelaunch, ascent, descent, postlanding (cargo bay doors closed)	.35 .42	1.52 NA	Average 2-min peak
On orbit without radiator kit (cargo bay doors open)	.75 1.00 .35	5.90 5.65 6.30	Average Peak for 15 min each 3 hr Minimum for aft flight deck, maximum for cargo bay
On orbit with radiator kit (cargo bay doors open)	.75 1.00 .35	8.10 7.85 8.50	Average Peak for 15 min each 3 hr Minimum for aft flight deck, maximum for cargo bay



Orbiter environmental control subsystem.

Optional flight kits

A group of flight kits to provide special or extended services for payloads can be added when required. They are designed to be quickly installed and easily removed. The major flight kits are as follows.

- Oxygen and hydrogen for fuel cell usage to generate electrical energy
- Life support for extended missions
- Added propellant tanks for special on-orbit maneuvers
- Airlocks, transfer tunnels, and docking modules
- A second high-gain antenna
- Additional radiator panels for increased heat rejection
- Additional storage tanks

These flight kits are considered part of the payload and, as such, are charged to the payload weight and volume allocation. The most significant payload weight increase results from the additional energy kits. The extra tanks may result in a significant volume penalty as well.

Extravehicular activity

Capability for extravehicular activity (EVA) is available on every Space Shuttle flight.

Payload EVA falls into three categories: planned before launch in order to complete a mission objective; unscheduled but decided upon during a flight in order to achieve payload operation success or advance overall mission accomplishments; or EVA involving contingency measures necessary to get any payload items out of the way of the cargo bay doors.

Equipment and consumables required for unscheduled and contingency EVA's are included on every Orbiter flight. Planned payload EVA is a user option.

Planned EVA can provide sensible, reliable, and cost-effective servicing operations for payloads. It gives the user the options of orbital equipment maintenance, repair, or replacement without the need to return the payload to Earth or, in the worst case, to abandon it in space. Therefore, the EVA capability can help maximize scientific return.

All EVA operations will be developed using the capabilities, requirements, definitions, and specifications set forth in Shuttle EVA Description and Design Criteria (JSC-10615).

Standard tools, tethers, restraints, and portable workstations for EVA are part of the Orbiter baseline support equipment inventory. The user is encouraged to make use of standard EVA support hardware whenever possible to minimize crew training, operational requirements, and cost. Any payload-unique tools or equipment must be furnished by the user.

Crewmembers using extravehicular mobility units (spacesuits and life support systems) can perform the following typical tasks.

- Inspection, photography, and possible manual override of vehicle and payload systems, mechanisms, and components
- Installation, removal, or transfer of film cassettes, material samples, protective covers, instrumentation, and launch or entry tiedowns
- Operation of equipment, including tools, cameras, and cleaning devices
- Cleaning of optical surfaces

• Connection, disconnection, and storage of fluid and electrical umbilicals

• Repair, replacement, calibration, and inspection of modular equipment and instrumentation of the spacecraft or payloads

• Deployment, retraction, and repositioning of antennas, booms, and solar panels

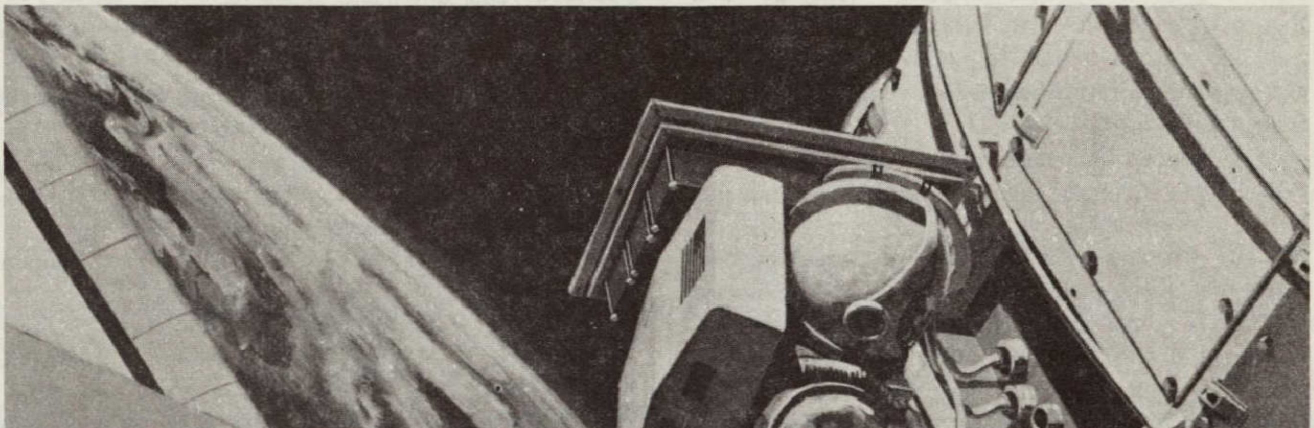
• Attachment and release of crew and equipment restraints

• Performance of experiments

• Cargo transfer

These EVA applications make it possible to demechanize operational tasks and thereby reduce design complexity (automation), simplify testing and quality assurance programs, lower manufacturing costs, and improve the probability of success. Given adequate restraints, working volume, and compatible man/machine interfaces, the EVA crewmembers can accomplish almost any task designed for manned operation on the ground.

Additional EVA capability is provided by the manned maneuvering unit, a propulsive backpack



Crewmembers performing representative type of extravehicular activity in support of a payload.

device (using a low-thrust, dry, cold gas nitrogen propellant), which enables a crewmember to reach areas beyond the cargo bay. The unit has a six-degree-of-freedom control authority, an automatic attitude hold capability, and electrical outlets for such ancillary equipment as power tools, a portable light, cameras, and instrument monitoring devices. Because the unit need not be secured to the Orbiter, the crewmember can use it to "fly" unencumbered to berthed or free-flying spacecraft work areas, to transport cargo of moderate size such as might be required for spacecraft servicing on orbit, and to retrieve small, free-flying payloads that may be sensitive to Orbiter thruster perturbation and contamination (the unit's own propellant causes minimal disturbances with no adverse contamination).

The manned maneuvering unit is normally carried only on those missions having requirements for it.

The following general constraints should be considered in early planning if a payload is expected to require EVA. These limitations are general in nature and, in certain circumstances, variations may be possible.

- EVA operations are normally performed by two EVA-trained crewmembers; however, one-man EVA is also possible
- Planned EVA periods should not exceed one 6-hour duration per day (excluding the time required for preparation and post-EVA activities); this does not preclude multiple shorter EVA's
- EVA may be conducted during both light and dark periods
- EVA will not be constrained to ground communications periods
- An EVA egress path into the cargo bay, 4 feet (1219 millimeters) minimum length, must be available adjacent to the airlock outside hatch; payloads that infringe into this area must be capable of being jettisoned to allow for contingency EVA operations
- The size of the airlock, tunnel adapter, and associated hatches limits the external dimensions of packages that can be transferred to or from payloads to 18 by 18 by 50 inches (457 by 457 by 1270 millimeters)
- Payloads requiring EVA operations must have access corridors and work areas large enough to allow the EVA crewmember to perform the required tasks safely and with adequate mobility – a translation path requiring the EVA crewmember to use mobility aids must be at least 43 inches (1092 millimeters) in diameter; additional volume is required when abrupt changes in the direction of travel are required; tasks requiring extensive body and arm manipulation require a working envelope 48 inches (1219 millimeters) in diameter
- EVA support equipment, loose payload components, and umbilicals must be firmly secured or tethered at all times during EVA operations to prevent loss, damage, or entanglement
- Payload components susceptible to inadvertent physical damage or contamination by an EVA crewmember should be protected or located away from EVA workstations and translation paths
- EVA is an acceptable mode of operation in low-Earth-orbit radiation zones if flight planning constraints inhibit planning around them

SAFETY AND INTERFACE VERIFICATION

All payloads using the Space Transportation System will be subject to a uniform set of basic safety and interface verification requirements. The verification system is designed so that the user will not need to duplicate or repeat verifications already made.

Payload safety requirements

The safety requirements, developed by the NASA Headquarters Office of Space Flight, will be tailored to the identified hazard potential of the payload. The Payload Safety Guidelines Handbook (JSC-11123) has been developed to assist the user in selecting design options to eliminate hazards.

The intent of the safety policy is to minimize active involvement of the STS, both at the design level and during actual flight, without compromising safety. The exact method of implementing payload safety will be negotiated between the payload supplier and the STS organization.

The STS safety policy requires that the basic payload design assure the elimination or control of any hazard to the Orbiter, crew, or other payloads. The requirements are not intended to assure a high probability of mission success.

The payload supplier is responsible for assuring the safety of any hardware proposed for use in the STS. In turn, the STS organization will plan cargoes to minimize hazards created by interaction among payloads and between a payload and the STS.

Safe payload operation with a minimum dependence on the Orbiter and its crew is an STS goal. The payload supplier must identify all potentially hazardous operating sequences. Hazardous situations that require a rapid response should, if possible, be corrected by automatic systems that are part of the payload.

The STS provides a limited capability for display and subsequent command of payload parameters. Therefore, use of this capability should be limited to safety conditions that cannot or logically should not be handled by design or operational provisions. The status of safing systems and the indication of anomalous conditions occurring within a payload that do not meet these criteria should be handled in the same manner as general payload telemetry and command and control; i.e., by ground control or through the Orbiter payload station.

The same basic safety approach applied to attached payloads should also be used for those that are to be deployed and retrieved. Configuring payloads for safe retrieval should, if practical, be performed by ground control.

The payload design must preclude propagation of failures from the payload to the outside environment. In addition, safety-critical redundant subsystems must be arranged to minimize the possibility of failure of one affecting the other.

Previous manned space-flight standards for flammability, offgassing, and odor of materials have been reduced somewhat for payloads carried outside the Orbiter cabin (either in other pressurized areas or in the open cargo bay). The Orbiter cabin provides smoke detection, fire suppression, atmospheric scrubbing, and a trace gas analyzer, which mitigate the hazards from flammability and offgassing.

The major goal is to design the payload for minimum hazard by including damage control, containment, and isolation of potential hazards. Hazards that cannot be eliminated by design must be reduced as much as possible and made controllable through use of safety devices as part of the system, subsystem, or equipment.

Payload interface verification requirements

Testing and interface verification of flight hardware is greatly simplified by the reuse of proven systems (Spacelab, Long Duration Exposure Facility, or Multimission Modular Spacecraft) or by the flight of identical expendable items (interim upper stage and spinning solid upper stage). The users will not need to repeat the verification process that the standard flight systems must undergo as part of their development. This will significantly reduce the time and cost of interface verification for the user.

The payload accommodation interfaces for the Space Shuttle system have been defined in the document, Space Shuttle System Payload Accommodations (JSC-07700, Volume XIV). Interface verification requirements are defined in Space Shuttle System Payload Interface Verification – General Approach and Requirements (JSC-07700-14-PIV-01). The latter document requires that new hardware projects have a verification program planned to assure that the necessary verification requirements of the respective interfaces are met before the payload is installed in the Orbiter.

Users of the standard payload carriers will assess their payload to determine if new or unique configurations require verification before flight. This assessment and necessary verification will be accomplished in conjunction with the STS operations organization.

Few or no additional verification requirements are anticipated for payloads that are reflown; however, some assessment of the payload should be made to assure that configuration changes to the payload or cargo do not create a new interface that would require preflight verification.

The term "payload" describes any item provided by the user having a direct physical or functional interface with the Space Shuttle system.

Payload verification plans shall be submitted to JSC for review and concurrence of the verification methods for safety-critical interfaces. When necessary, the verification methods for the safety-critical interfaces will be negotiated with the responsible payload organization to achieve an acceptable verification that will ensure a safe system. These safety-critical interface verification methods shall be subject to appropriate management control within the Space Transportation System.

A verification plan should contain the following information:

1. Scope.
2. Applicable documents.
3. Interface verification requirements and methods matrix, identifying specific direct (physical or functional) payload interfaces with the Orbiter and defining the verification method (test, demonstration, etc.) for each specific interface.
4. Safety-critical interface verification method synopsis.
5. Verification requirement waivers (these must be negotiated with JSC).

6. Verification requirement deferrals (i.e., deferral until installation in the Orbiter, until flight, etc.). These deferrals will have to be negotiated in the same way as waivers.

7. Schedule for plan submittal and required approval date.

8. Schedule for payload interface verification testing program and specific dates for safety-critical interface verification tests.

Equipment suitable for interface verification testing is available at the launch site. The cargo integration test equipment (CITE) at KSC is capable of both payload-to-payload interface testing for mixed cargoes and cargo-to-Orbiter testing. The CITE simulates the Orbiter side of the interface in form, fit, and function.

At the completion of the interface verification process, but before the payload is installed in the Orbiter, a certificate of compliance confirming interface compatibility shall be prepared by the using payload organization and submitted to the Shuttle system organization. The certificate of compliance documentation shall include all interface verification requirement waivers, noncompliances, and deferrals; this documentation will become a permanent part of the payload data package.

SPACELAB

Spacelab is a versatile, general-purpose orbiting laboratory for manned and automated activities in near-Earth orbit. The primary program objective is to provide the scientific community with easy, economical access to space. Involvement of ground-based scientific personnel in direct planning and flight support is an integral part of this program.

The Spacelab, built in Europe with European funds to joint U.S. and European requirements, is carried by the Space Shuttle and remains attached to the Orbiter during all phases of the mission. The overall physical characteristics of most importance to users of the Spacelab are summarized here.[a] All accommodations are described in more detail in the Spacelab Payload Accommodations Handbook (European Space Agency SLP/2104).

Services to the Spacelab payload in excess of those included in the Orbiter and Spacelab baselines are available as user options as needed. Appropriate care must be taken to ensure that all items are included in payload flight planning.

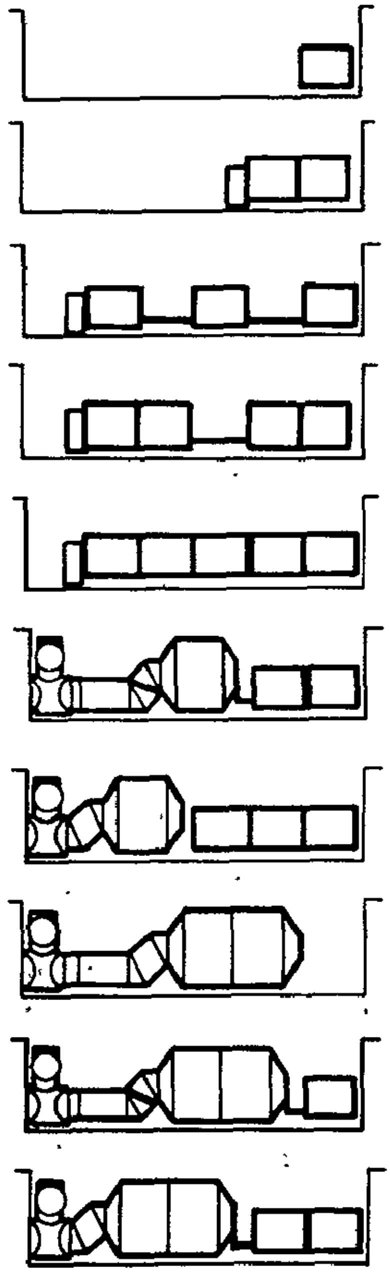
The Spacelab consists of module and pallet sections used in various configurations to suit the needs of a particular mission. The pressurized module, accessible from the Orbiter cabin through a transfer tunnel, provides a shirtsleeve working environment. The module consists of one or two cylindrical segments, each 13 feet 4 inches (4060 millimeters) in diameter and 8 feet 7 inches (2694 millimeters) long, and two end cones. The forward end cone is truncated at the diameter required to interface with the crew transfer tunnel. Spacelab subsystem equipment is located in the core segment, leaving about 60 percent of the volume available for experiments; all of the experiment segment is available for experiments.

Pallets accommodate experiment equipment for direct exposure to space. Each standard pallet segment is 9.8 feet (3 meters) long. Two or three can be connected to form a single pallet train, supported by one set of retention fittings. When no module is used, a cylindrical "igloo," mounted on the end of the forward pallet, provides a controlled, pressurized environment for Spacelab subsystems normally carried in the core segment.

In addition to the basic hardware inventory, the Spacelab Program provides a selection of mission-dependent equipment that can be flown according to the requirements of a particular mission.

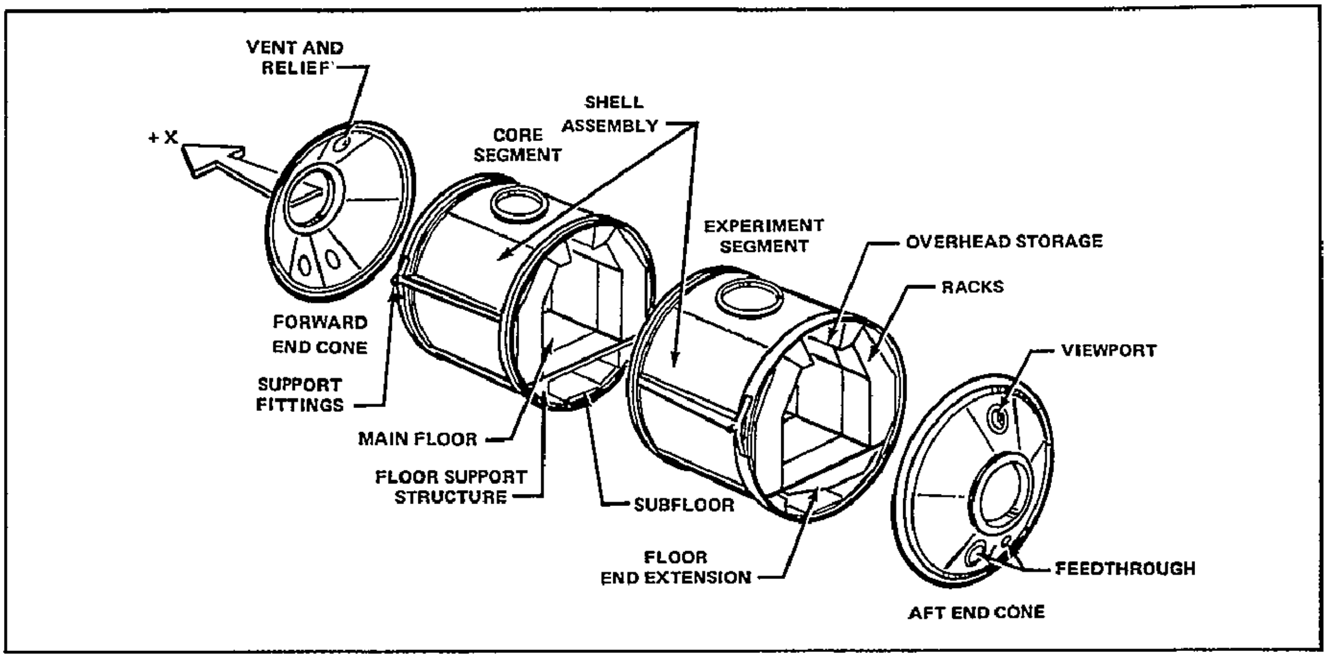
esa

european space agency

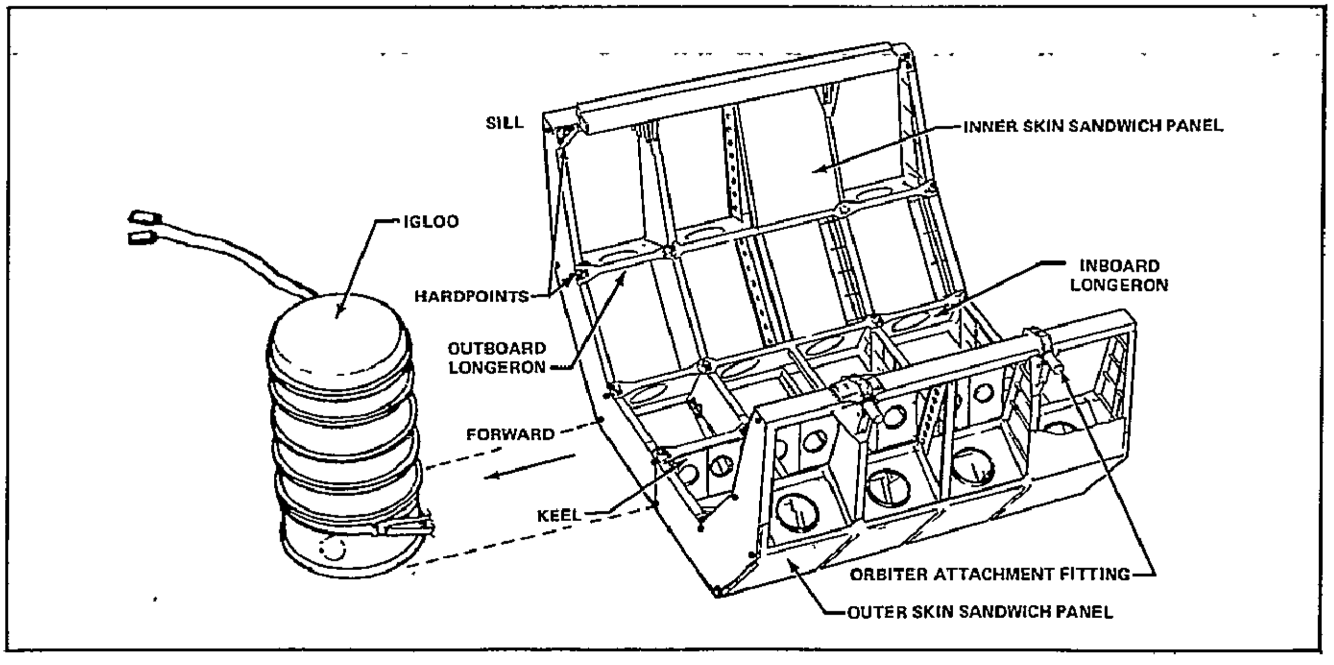


[a]Spacelab is in a developmental phase and the system characteristics described in this section may change in detail as

When the module is used, primary control of scientific equipment will be from the module itself. A Payload Operations Control Center (POCC) on the ground will function in a support and advisory capacity to onboard activity. In a pallet-only configuration, equipment is operated remotely from the Orbiter aft flight deck or from the POCC.



Overall configuration of the module showing both the core and experiment segments.

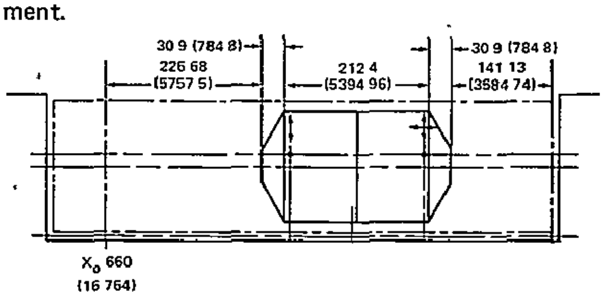


Pallet segment and igloo.

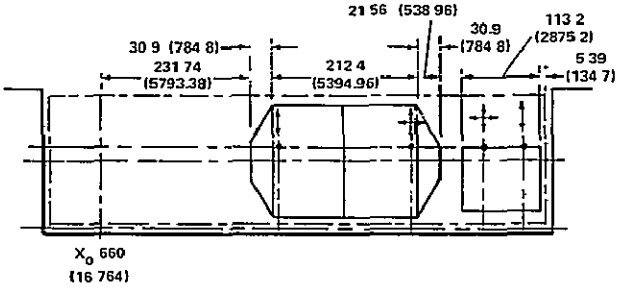
Basic configurations

Eight basic flight configurations have been designed to meet most user needs. (The Spacelab hardware, however, allows other flight configurations by combining appropriate hardware elements.) In each illustration the forward Orbiter attachment point (X_0) is shown. Dimensions are in inches with millimeters in parentheses. Arrows, if they do not mark dimensions, indicate the load-carrying direction of attachment fittings. The standard configurations are as follows.

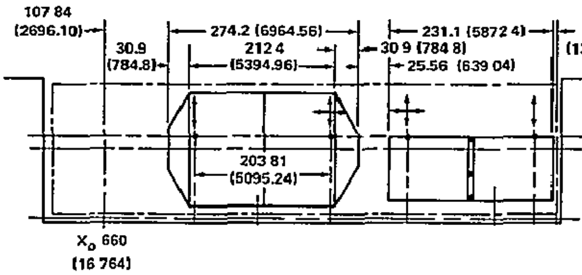
• Long module. The long module consists of core and experiment segments. This configuration, without pallet, provides the largest pressurized volume for Spacelab payloads with 784 cubic feet (22.2 cubic meters) available for payload equipment.



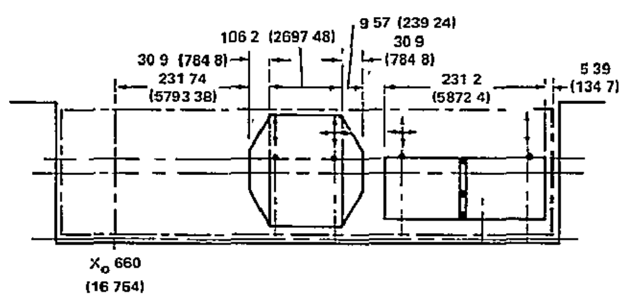
• Long module/one pallet. In this configuration, 184.1 square feet (17.1 square meters) of surface mounting area are available on the pallet. The pallet length is 9.4 feet (2.88 meters). (In exceptional instances, payloads can overhang at both ends of a pallet.) The inside dimensions of the module are given in the description of the long module.



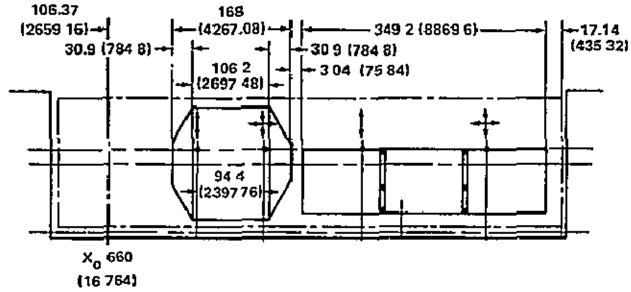
• Long module/two pallets. This configuration increases the space-exposed mounting area by connecting two pallets in a train. The two pallets provide 368.1 square feet (34.2 square meters) of mounting area and a pallet length of 19.3 feet (5.87 meters).



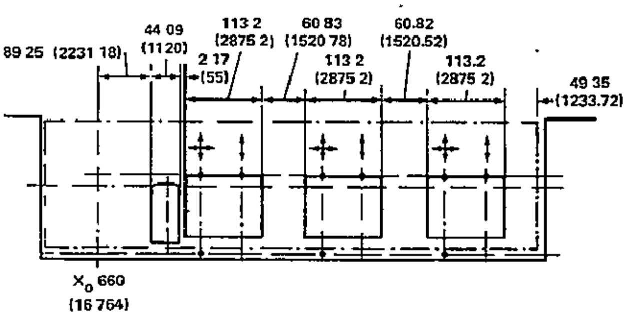
• Short module/two pallets. This pallet configuration is the same as the one described previously except that a short module has replaced the long one. This configuration also provides a pallet length of 19.3 feet (5.87 meters).



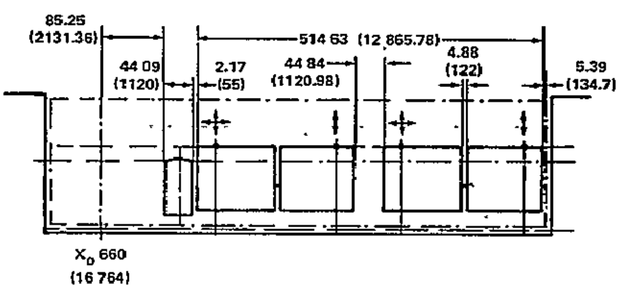
• Short module/three pallets. This configuration offers the largest pallet area if both module and pallet are required for a single mission. The usable pallet length is 29.1 feet (8.87 meters) with a mounting surface of 552.2 square feet (51.3 square meters). The volume available to payload equipment inside the short module is 268.4 cubic feet (7.6 cubic meters).



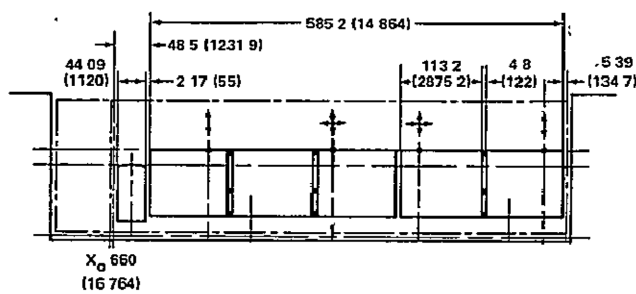
• Pallets only, independently suspended (28.3 feet (8.63 meters)). This configuration consists of three independently suspended pallet segments spread along the length of the cargo bay. The total surface mounting area is 552.2 square feet (51.3 square meters).



• Two pallets plus two pallets. This configuration, consisting of two independently suspended pallet trains, is well suited for a number of astronomy missions. It provides a maximum mounting area for payloads of 736.2 square feet (68.4 square meters). The length available to payloads is 38.5 feet (11.74 meters).



• Five pallets. This configuration provides the longest possible experiment platform for Spacelab payloads requiring exposure to the space environment. The surface mounting area is 920.3 square feet (85.5 square meters) and the usable length is 48.8 feet (14.86 meters). The configuration consists of independently suspended pallet trains separated by a dynamic clearance gap.



Payload mass

A wide range of payload mass capabilities exists. Maximums depend on configurations, mission-dependent Spacelab equipment, and other factors. The actual mass available to payloads for any given configuration of Spacelab and Orbiter hardware will be limited by the launch/landing mission capabilities of the Shuttle and the specific load-carrying capabilities of Spacelab. The information provided here will help users to determine the mass available for the total payload to meet specific mission needs.

The mass available to Spacelab and its payloads is limited by the maximum Orbiter landing mass (although for a wide range of orbits, the Orbiter load-carrying capability is considerably greater at launch than at landing). The landing masses listed in the accompanying table are about 885 pounds (400 kilograms) less than those for launch. Consumables, primarily fuel in the energy kit, account for the difference.

Hardware and consumables that must always be flown in a given Spacelab configuration comprise the Spacelab mission-independent mass budget. The total control mass for each standard configuration is shown in the accompanying table. The following categories are included.

• Spacelab subsystem equipment. These items are essential for the operation of Spacelab and are always flown. Included in this category are all of the structure, the environmental control system, power systems, data-handling systems, and the like.

- Mission-independent equipment furnished by NASA. The transfer tunnel and trace gas analyzer (for all configurations with module) and forward utility connections are in this category.
- Orbiter support equipment. This is necessary for Spacelab operation and is charged to the Orbiter payload. In this category are Orbiter heat rejection subsystem components not included in the Orbiter baseline, tankage and consumables for Spacelab power in excess of 50 kWh (180 megajoules), Orbiter payload attachment fittings in excess of four, and hardware for attaching the extravehicular activity (EVA) airlock to the tunnel and to the Orbiter cargo bay.

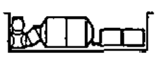
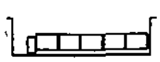
The remainder of the mass capability is available for payloads. Included is all equipment hardware, whether actually located in the Spacelab or the Orbiter, as well as any user-provided special displays, controls, service panels, or the like. Spacelab mission-dependent equipment is also charged to the payload mass allocation. It comprises hardware that is not an integral part of the basic Spacelab but can be added to meet the requirements of a particular mission. The following categories are included.

- Common payload support equipment
- Experiment consumables
- Crewmembers in excess of four
- Any additional mission-dependent Orbiter support equipment, such as EVA equipment above the Orbiter baseline, reaction control subsystem tankage and propellant for special Spacelab payload pointing requirements, orbital maneuvering subsystem kits and propellant required by the Spacelab payload, additional electrical energy kits, second Orbiter remote manipulator system, and extra hardware and consumables required for missions longer than 7 days.

Each of the many possible configurations will have a different total mass. The control masses listed in the table represent the maximum mission-dependent equipment that can be flown in each configuration.

The total mass available for both payloads and mission-dependent equipment is listed for each configuration. However, actual mass capability is further limited by structural limitations of various components. Additional localized constraints exist, such as mass-supporting capabilities of racks and hardpoints.

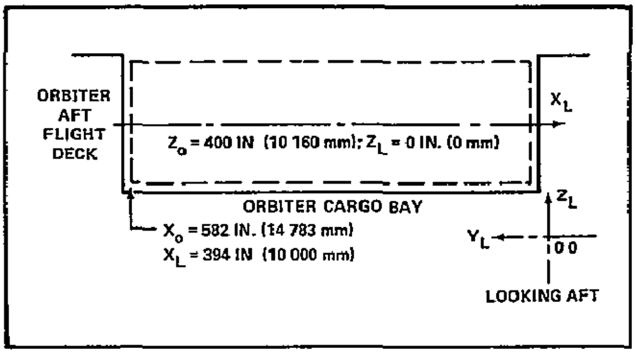
Mass allocation to Spacelab and payloads

Configuration	Total mission-independent Spacelab mass, lb (kg)	Mass of 100 percent mission-dependent equipment, lb (kg)	Mass available to payload and mission-dependent equipment, lb (kg)
	14 211 (6446)	2646 (1200)	14 066 (6380)
	16 182 (7340)	2976 (1350)	13 614 (6175)
	17 031 (7725)	3174 (1440)	12 765 (5790)
	14 941 (6777)	2006 (910)	14 414 (6538)
	15 790 (7162)	2116 (960)	13 717 (6222)
	8 369 (3796)	1164 (528)	20 613 (9350)
	9 129 (4141)	1190 (540)	19 564 (8874)
	10 357 (4698)	1301 (590)	18 263 (8284)

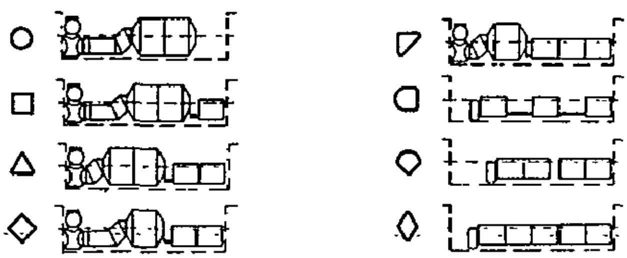
Center of gravity

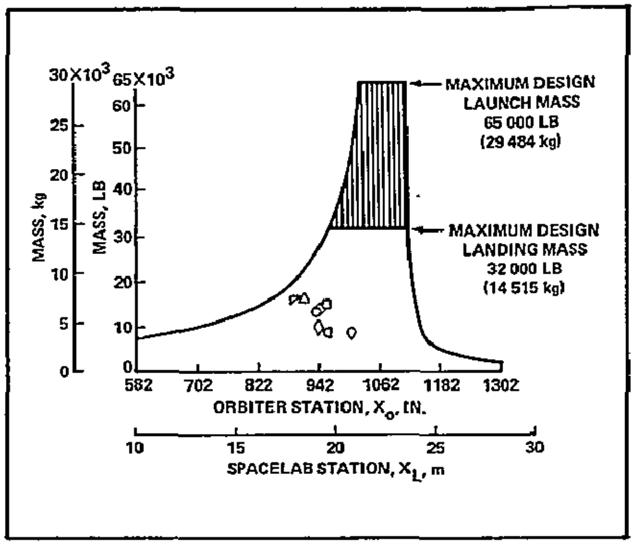
The Orbiter imposes stringent center-of-gravity constraints on the Spacelab. The center-of-gravity locations shown apply to specific locations of Spacelab in the cargo bay. Other locations are possible.

To establish the overall center of gravity of a combined Spacelab and its payload, the masses and centers of gravity for individual hardware and consumable items must be combined according to the requirements of a particular mission.

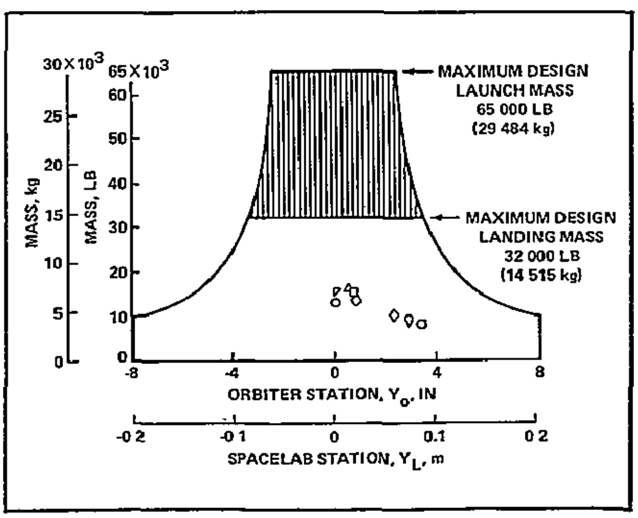


Coordinate system for Spacelab. The axes of the Spacelab are indicated by subscript L.

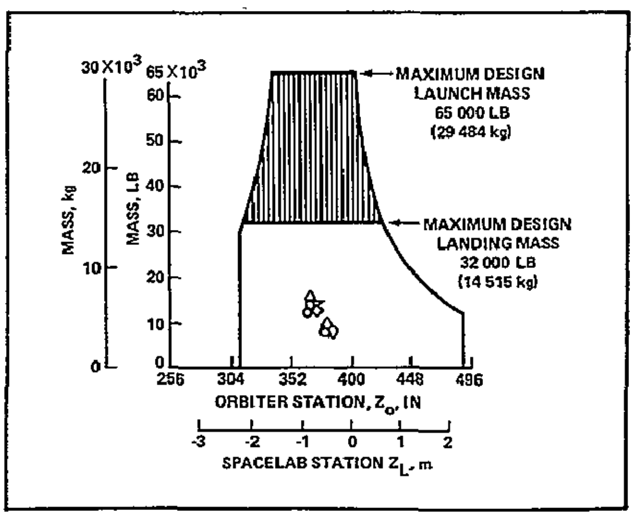




Center-of-gravity locations of basic Spacelab configurations along the X-axis. The forward end of the Orbiter cargo bay is at the left of the scale.



Basic Spacelab center-of-gravity locations along the Y-axis.



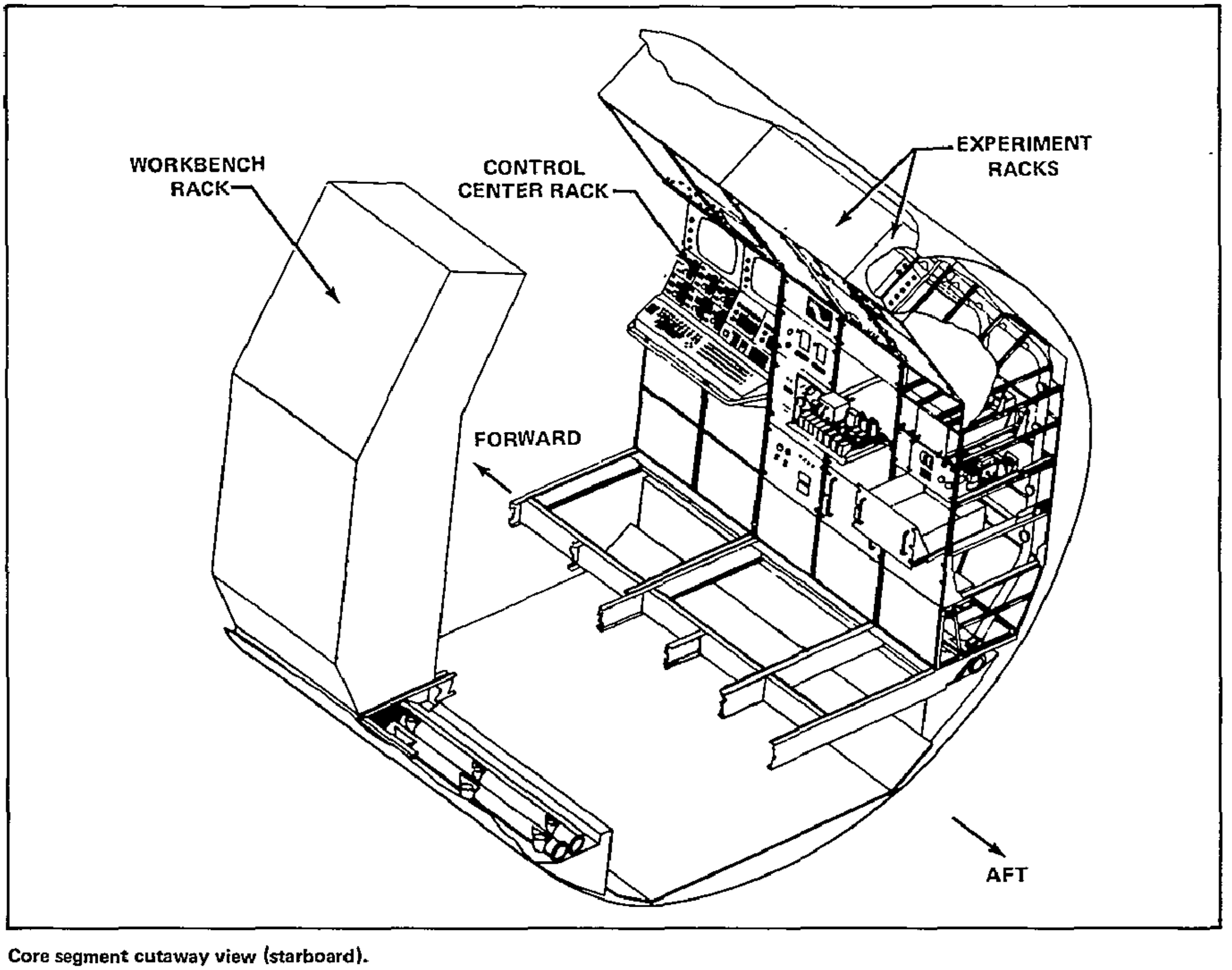
The Z-axis center-of-gravity locations of basic Spacelab configurations.

Module segments

Modules for all flight configurations contain the same basic internal arrangement of subsystem equipment; the main difference is the volume available for experiment equipment installation. Although subsystem equipment is located in the core segment, about 60 percent of the volume is available for experiments.

The interior design provides flexibility to the user. The floor, designed to carry racks with installed equipment, is in segments. The floor itself consists of a load-carrying beam structure and is covered by panels on the main walking surface. Except for the center floor plates, the panels are hinged to allow underfloor access, both in orbit and on the ground.

Mission-dependent experiment racks are available for experiments, experiment switching panels, remote acquisition units, intercom stations, and similar equipment. The standard 19-inch (483-millimeter) racks can accommodate laboratory equipment. As many as two double and two single racks can be installed in the core segment, four double and two single in the experiment segment. If experiment racks are replaced by stand-alone experiment equipment, the same attachment points must be used.



Core segment cutaway view (starboard).

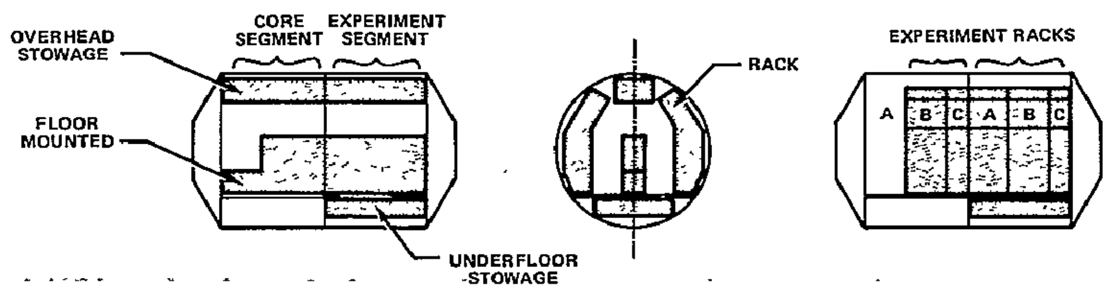
A detailed breakdown of the available volume inside the module is shown in the illustration. The listed values for the racks are available usable volume. The overhead volume indicates the volume available inside the mission-dependent storage containers (eight are provided in the baseline equipment).

The center-aisle volume is the maximum envelope available for payload equipment mounted on the floor without effect on crew habitability and safety requirements. The underfloor volume is available for payload use only in the experiment segment. If the racks are not used, the volume they would occupy is available for other experiment equipment.

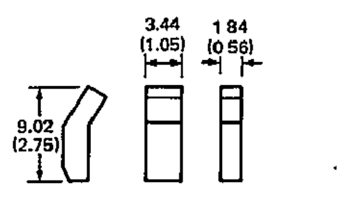
The module interior is sized and shaped to allow optimum task performance by crewmembers in a weightless environment. The module can accommodate as many as three payload specialists working a 12-hour shift. For shift overlap, as many as four can be accommodated for an hour. The cabin air temperature is maintained between 64° and 81° F (291 and 300 K). The airflow is directionally controllable and is between 16.5 and 39.6 ft/min (0.084 and 0.201 m/sec).

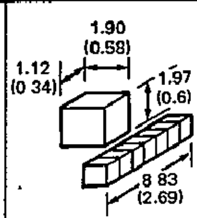
Foot restraints, handholds, and mobility aids are provided throughout the Spacelab so that crewmembers can perform all tasks safely, efficiently, and in the most favorable body position. The basic foot restraint system is identical in Orbiter and Spacelab.

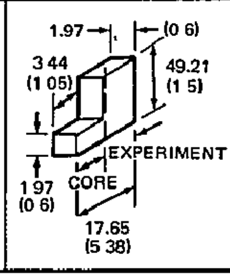
Fixed handrails and handholds are distributed throughout the habitable area, such as along the standard racks and along the overhead utilities/storage support structure.

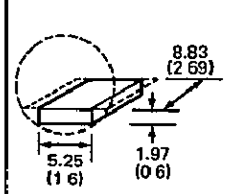


Segment	Volume inside racks, ft³ (m³)						Ceiling, ft³ (m³)	Center aisle, ft³ (m³)	Subfloor, ft³ (m³)	Total, ft³ (m³)
	Left side			Right side						
	A	B	C	A	B	C				
Core	–	61.8 (1.75)	31.78 (0.9)	–	61.8 (1.75)	31.78 (0.9)	28.25 (0.8)	52.97 (1.5)	–	268.39 (7.6)
Experiment	61.8 (1.75)	61.8 (1.75)	31.78 (0.9)	61.8 (1.75)	61.8 (1.75)	31.78 (0.9)	28.25 (0.8)	85.46 (2.42)	91.11 (2.58)	515.59 (14.6)







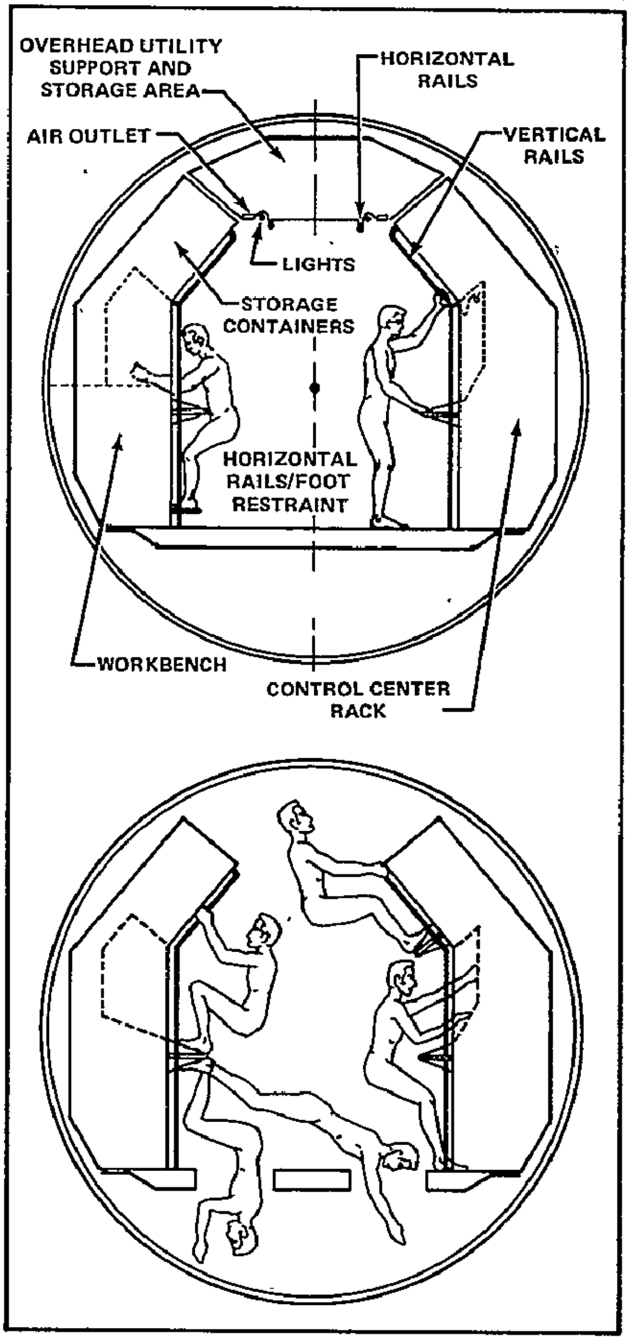


Approximate volume available for payload equipment in the module experiment racks, overhead and underfloor areas.

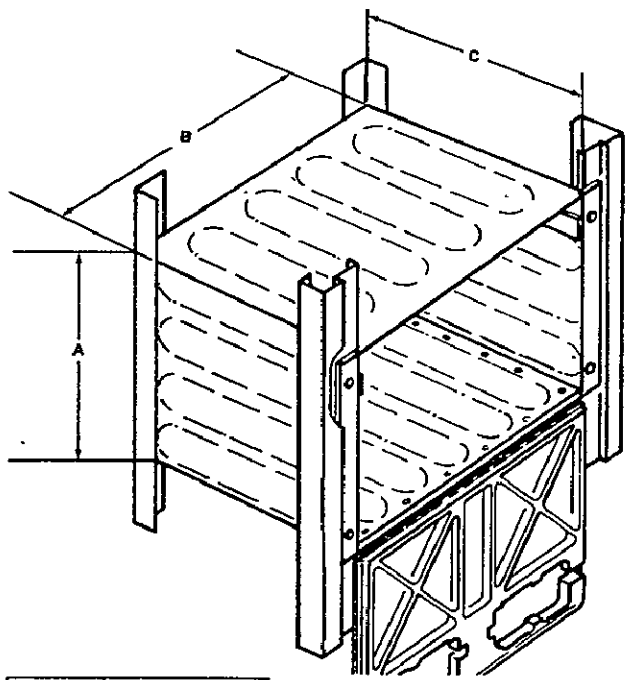
In addition to handrails, the overhead structure contains lights and air ducts. The nominal illumination level in the module is 200 to 300 lumens/m². At the workbench, it is 400 to 600 lumens/m². Individual lights can be turned off as necessary.

A workbench in the core segment is intended to support general work activities rather than those associated with a unique experiment. One electrical outlet (28 volts dc, 100 watts) is available to support experiment equipment. Also associated with the workbench are such items as wipes for housekeeping tasks, writing instruments and paper, and a stowage pouch with individual compartments, allowing easy removal of single items without disturbing other stowed equipment.

Stowage containers at the workbench, the racks, and in the ceiling provide storage space for experiment hardware, spare parts, consumables, and other loose equipment. Each ceiling container has a volume of 4.24 cubic feet (0.12 cubic meter) and a loading capacity of 79.4 pounds (36 kilo-



Primary crew working area (looking forward) and examples of the many possible working positions.



Location	Dimension, In. (mm)		
	A	B	C
Workbench and racks	13 31 (338)	17 56 (446)	19 53 (496)
Ceiling	13 39 (340)	22.83 (580)	23 62 (600)

Typical workbench, ceiling, or rack stowage container.

grams). Workbench and rack containers are smaller, having a volume of 2.65 cubic feet (0.075 cubic meter) and a load capacity of 49.4 pounds (22.4 kilograms). A grid pattern of mounting holes inside the container is provided for attachment of internal restraints. The container door can be fastened open. Two workbench containers will be available for payload use on most missions; eight ceiling and four rack containers are exclusively for experiment use. In a long-module configuration, there is room for 14 ceiling containers, but only 8 are provided as baseline hardware. The optical window takes the space of at least five (depending on space required for payload activities) ceiling containers. The airlock requires the space of six containers.

Rack and ceiling containers can be converted to accommodate as much as 331 pounds (150 kilograms) of film in plastic foam protective carriers.

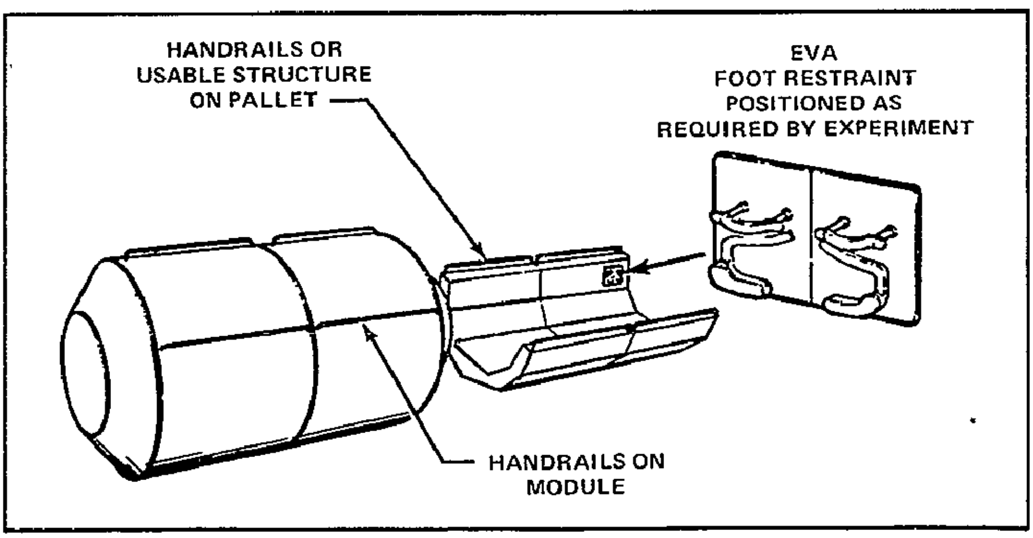
A range of standard equipment (such as tools and contingency maintenance items), stowed in the workbench containers, is used to support Spacelab activities but will also be available for experiment use. In addition, a tool and maintenance assembly, with a utility box for stowage, will include off-the-shelf tools, specially designed tools, and maintenance items.

Utility straps and bungees are provided so that crewmembers working on orbit can temporarily restrain equipment at various locations throughout Spacelab.

The transfer tunnel connecting the Spacelab module and the Orbiter enables crew and equipment transfer in a shirtsleeve environment. Mobility aids are installed in the tunnel. The lighted tunnel has the same internal atmosphere as the Spacelab module. It has a minimum of about 3.28 feet (1 meter) clear diameter, sufficient for a box with dimensions of 1.84 by 1.84 by 4.17 feet (0.56 by 0.56 by 1.27 meters) and a crewmember (including one equipped for EVA) 76.77 inches (1.95 meters) tall and with a maximum elbow width of 2.46 feet (0.75 meter). The tunnel can also be used for ground access to the Spacelab while it is still horizontal.

For EVA, Spacelab provisions allow a crewmember in a pressure suit to move through the EVA hatch (the Orbiter personnel airlock in the Spacelab tunnel adapter, or the docking module, depending on the mission configuration), up the end cone of the module, over the module, down the aft cone, and along the pallet.

The size of the airlock and associated hatches limits the external dimensions of a package that can be transferred to payloads to 2.95 feet (0.9 meter) in diameter and 4.59 feet (1.4 meters) long.

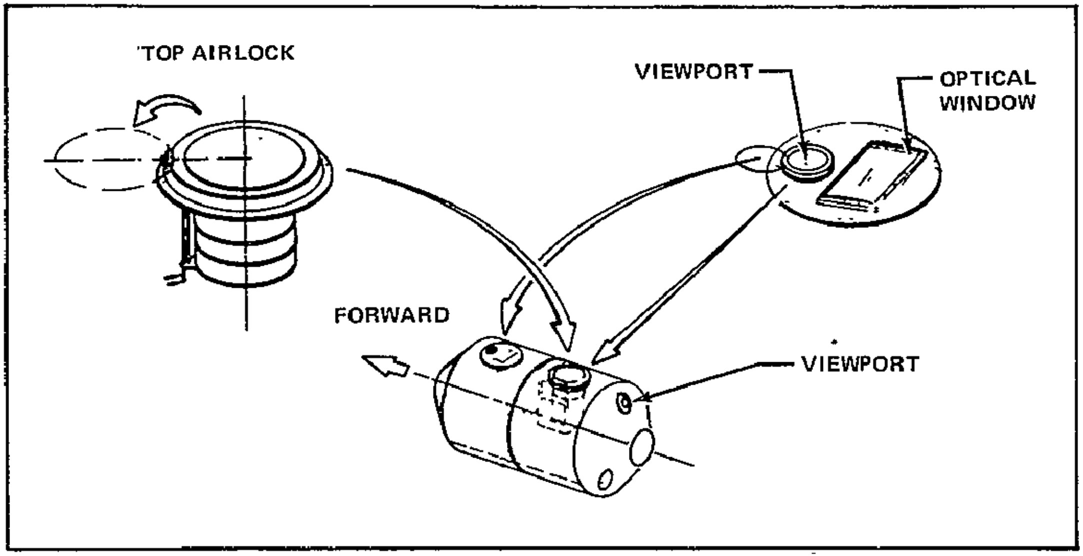


Mobility aids and restraints for EVA.

Common payload support equipment

The common payload support equipment, which are mission-dependent items, includes a top airlock and an optical window/viewport assembly. Each can be flown as needed. Locations for installation of these items on the module are shown in the figure.

A flanged cutout of 51.18 inches (1300 millimeters) internal diameter in the top of each cylindrical segment of the module is for installation of the airlock or optical window/viewport. Both openings are sealed with coverplates if not needed.



Common payload support equipment for module.

Airlock for experiments

The airlock enables experiments to be exposed to a space environment. Experiments are mounted on a sliding platform parallel to the airlock axis. This platform can be extended into space, where it is protected by a removable thermal shield. Experiments can be observed through an inner hatch window 5.9 inches (15 centimeters) in diameter that provides a 120° viewing angle. The platform can also be pulled back into the Spacelab module for experiment mounting and checking (both on orbit and on the ground). The inner hatch can be completely detached for payload installation and access. All controls are manual.

A control panel on the outside of the cylindrical shell provides for monitoring the airlock operations. Monitoring and display of airlock status are also provided by the command and data management system. Electrical and mechanical interfaces prevent dangerous operations sequences.

The platform, when extended into space, penetrates the Orbiter cargo bay envelope (as does the outer hatch). To preclude a critical situation if the retraction or hatch mechanism malfunctions, both the sliding platform and hatch are capable of being jettisoned.

The dynamic envelope available for experiments is illustrated on the next page. Lamps inside the airlock may protrude into this envelope, but can be removed if a voluminous experiment is flown.

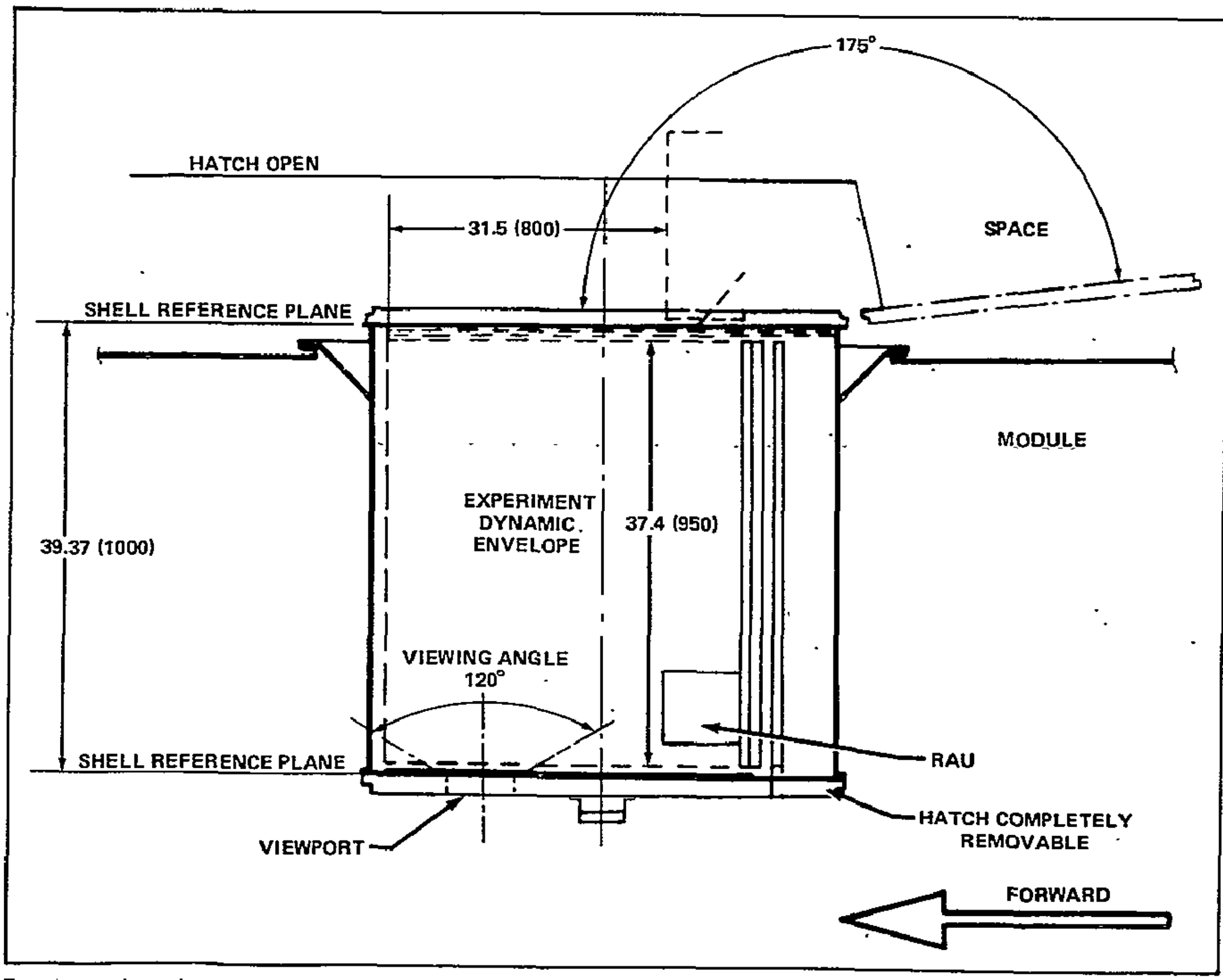
The top airlock is 3.28 feet (1 meter) in diameter and the same length. It is designed to carry an experiment or experiments with a total mass of 220 pounds (100 kilograms) during launch and descent.

Experiments will be bolted on the platform on two parallel channel bars 19.69 inches (500 millimeters) apart and 12.2 inches (310 millimeters) aft of the airlock axis. This interface allows a variety of convenient experiment attachments. For experiment mounting and checkout, the platform can be extended into the module 2.3 feet (0.7 meter). For ground operations, however, the extended platform must be supported by a special kit because the drive mechanism is not designed for one-g full-load operation.

After the outer hatch is opened, the experiment platform can be extended any distance up to 3.15 feet (0.96 meter). A thermal shield closes the airlock opening, protecting the airlock interior and the module from thermal exposure. In certain circumstances, thermal constraints may require that the platform always be extended for experiment operation.

Heaters are incorporated for thermal control of the airlock structure and seals. The exact power at any time will depend on the particular mission operating conditions. The airlock is able to absorb some experiment-generated heat, but the experimenter has the responsibility to provide thermal control for the experiment.

The removable thermal shield prevents excessive heating from solar radiation or Earth albedo at the airlock cavity. Two holes in the cylindrical shell of the airlock (opposite the top surface of the platform) are for payload-provided feed-throughs and cooling lines (e.g., to use the experiment heat exchanger).



Experiment dynamic envelope of the airlock, showing dimensions in inches and millimeters.

Power connectors are provided at the platform for 28 volts dc primary, 200 watts; and 115/200 volts ac, 400 hertz/three-phase, 3 amperes.

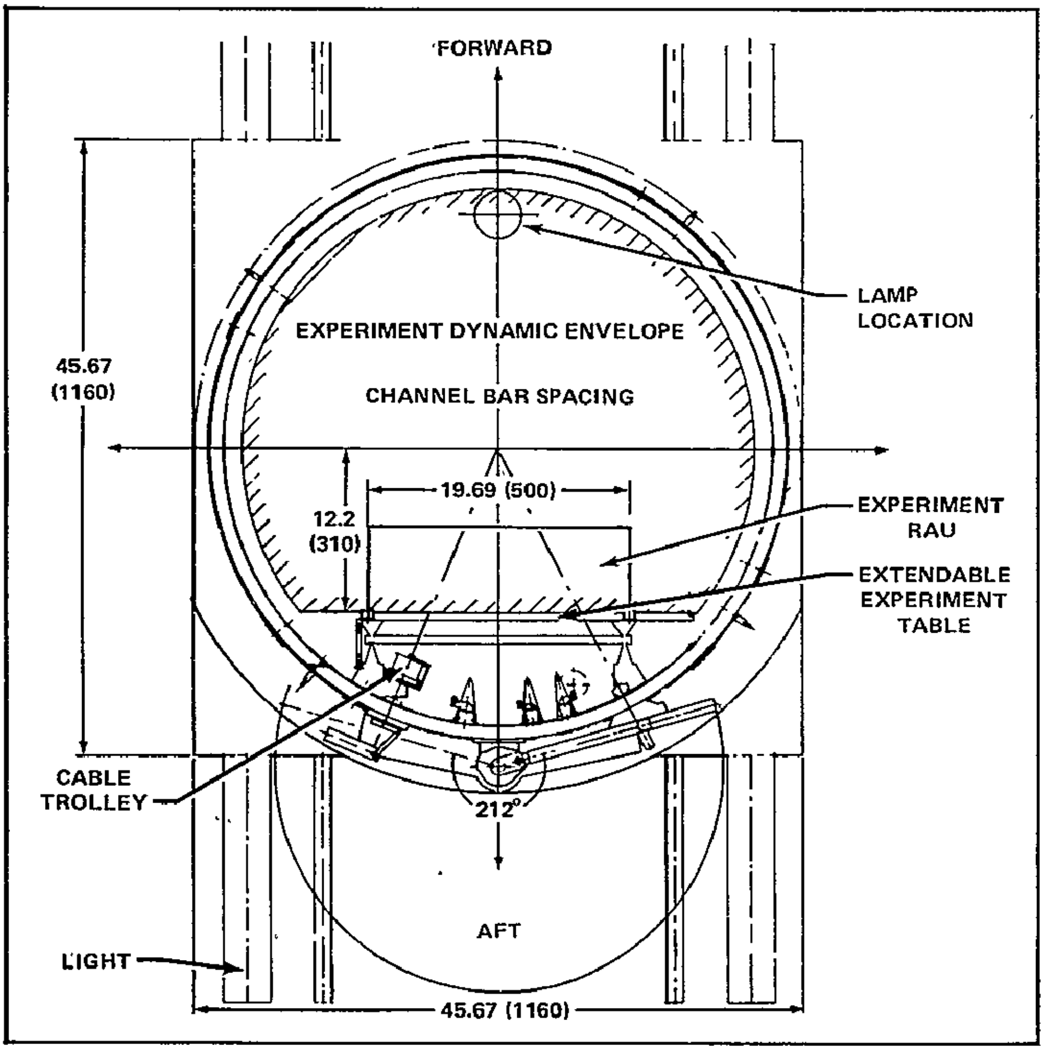
Experiment data handling and control can be performed either by the command and data management subsystem (by use of an experiment remote acquisition unit (RAU) mounted on the airlock platform) or by hardwired lines through the airlock shell to payload equipment in the module.

A flexible cable harness connects the platform with feedthrough connectors in the airlock shell; thus, experiment equipment can be checked while the platform is pulled into the module.

Inside the airlock, illumination is 100 lm/m^2 (controlled from the airlock control panel).

Seven repressurization cycles per 7-day flight for the experiments can be accommodated by the basic environmental control subsystem nitrogen resources. Additional repressurizations will depend on usage of nitrogen by the environmental control and life support subsystem.

The top airlock can be mounted into a single-segment module; however, planned or contingency ground operations (those requiring late access to the module) may prevent use of the airlock in the core segment.



View up into top airlock. Dimensions are shown in inches with millimeters in parentheses.

Optical window and viewport

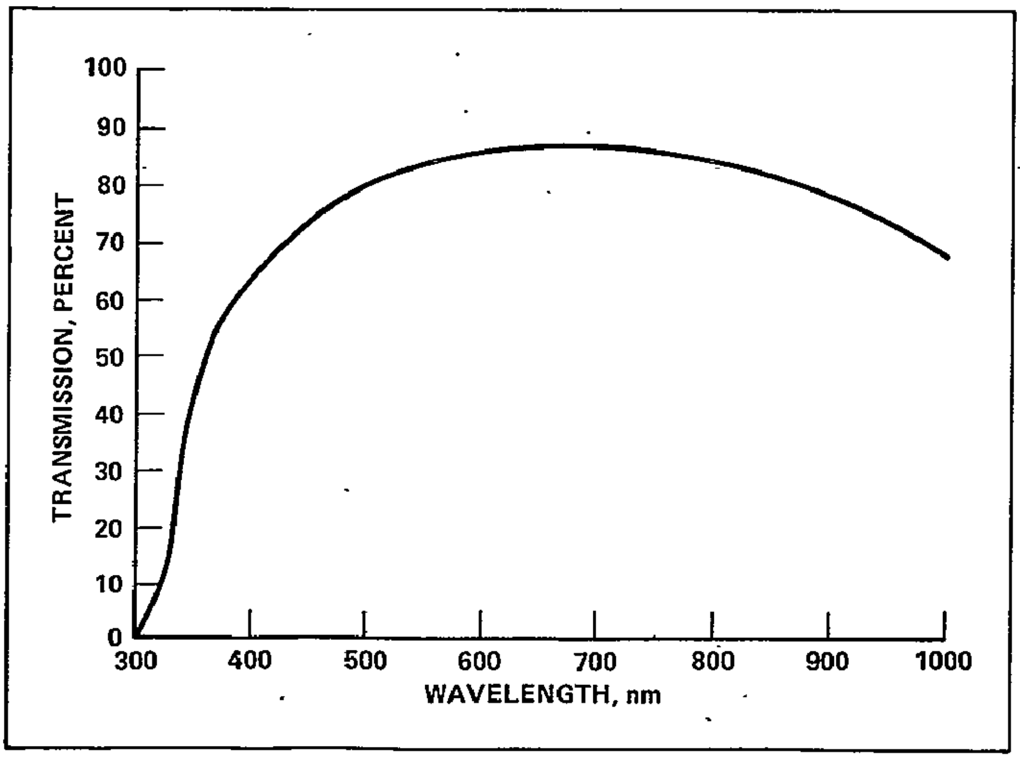
The optical window (adapted from the Skylab S190A window) consists of a single rectangular pane of BK-7 glass measuring 16.14 by 21.65 inches (41 by 55 centimeters) and having a thickness of 1.61 inches (4.1 centimeters). It is enclosed in a molded seal and supported by a flexible spring system in an aluminum frame. An automatic heating system controls window temperatures to minimize thermal gradients across the glass and to prevent condensation. This power use is charged to payload and mission-dependent equipment.

When the window is not in use, a manually operated cover protects the glass outside from radiation, meteoroid impact, contamination, etc. A removable glass safety shield inside protects the window from impacts and provides a redundant pressure seal.

The window transmission characteristics are shown in the figure. Some other optical characteristics are as follows.

Parallelism	2 arc-seconds
Reflectance	2 percent on inside; 4 percent on outside
Seeds and bubbles	Total area 0.1 $mm^2/100\ cm^3$ of glass; maximum dimension of single imperfection, 0.76 millimeter
Surface quality	60 to 40 or better (as defined in MIL-13830)

Wavefront variation is an optical performance criterion that affects distortion, resolution, and contrast. Some preliminary measurements for different possible viewing conditions are listed in the



Transmission characteristics of S190A window.

table. The measurements were made using a laser beam with a wavelength of 632.8 nanometers and refer to a circular area 2.99 inches (7.6 centimeters) in diameter.

Wavefront variation through window

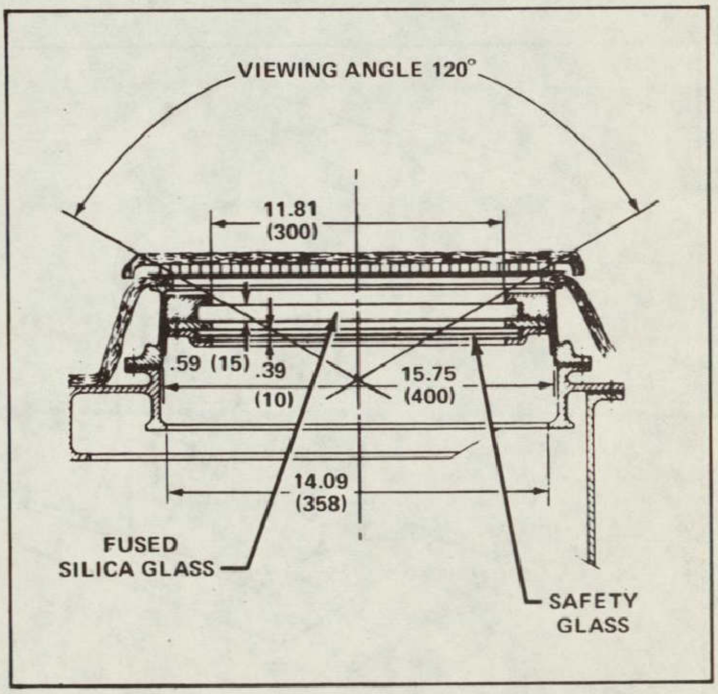
Viewing conditions	Wavefront variation, nm (root mean square)	
	Best fitting plane	Mean deviated plane
Deep space	⩽ 13	⩽ 26
Earth	⩽ 13	⩽ 25
Sun[a]	⩽ 53	⩽ 180

[a]There may be some constraints on Sun viewing because of thermal stresses in the window glass.

Viewports can also be installed as part of the window assembly. Each consists of two panes 11.81 inches (30 centimeters) in diameter, the outer one of quartz glass and the inner pane of safety glass. Optical characteristics are shown in the table. Experiment-mounting capability can be provided on the interface flange.

Optical characteristics of viewport

Spectrum	Transmission, percent
Ultraviolet, 200 to 300 nm	0.01
Visible range, 400 to 700 nm	65
Infrared, 800 to 1200 nm	10



Viewport design. Dimensions are in inches and millimeters.

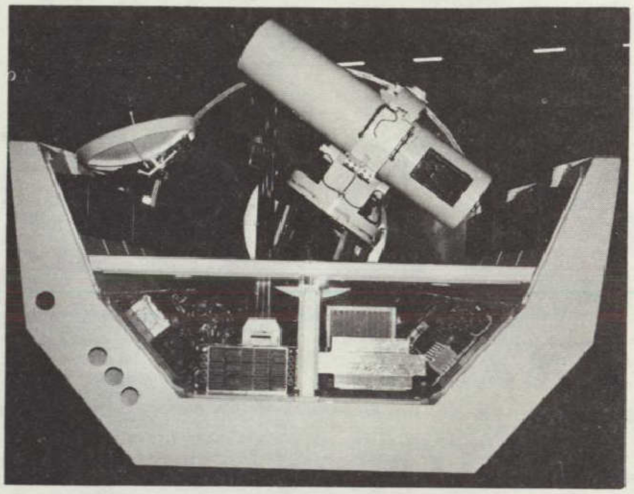
Pallet structure

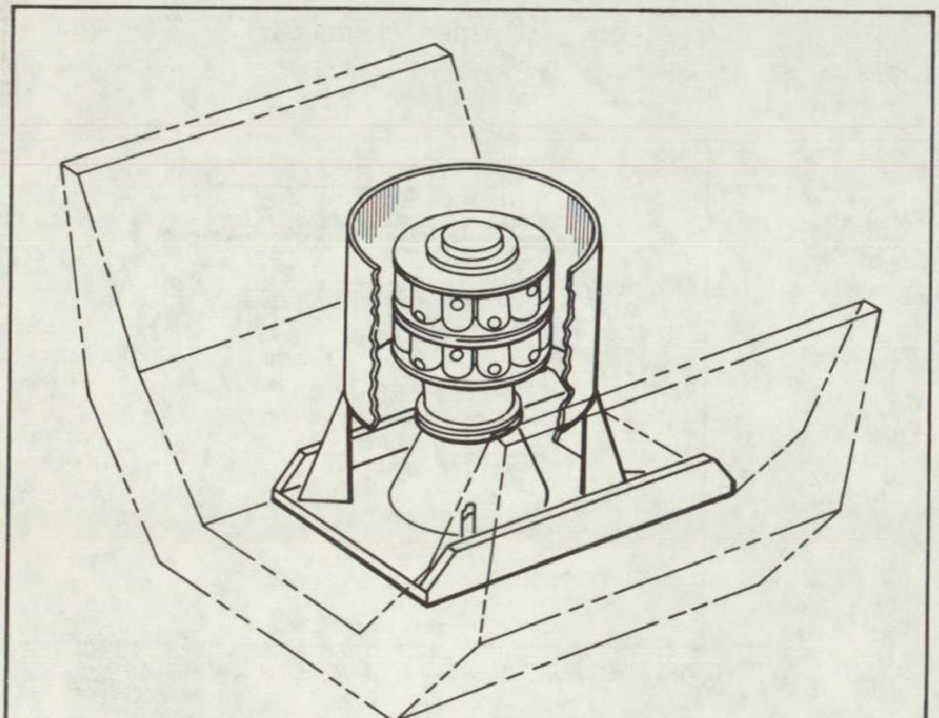
The standard U-shaped pallet segments are of aeronautic-type construction covered with aluminum panels. These panels can be used for mounting lightweight payload equipment. A series of hardpoints attached to the main structure of a pallet segment allows mounting of heavy payload items.

The pallet provides basic services, such as:

- Subsystem and experiment electric power buses
- Experiment power distribution boxes
- Subsystem and experiment data buses
- A subsystem RAU and as many as four RAU's for experiments
- Thermal insulation blankets
- Cold plates and thermal capacitors
- Plumbing

In a pallet-only configuration (one to five pallets with no module), the Spacelab subsystem equipment that is ordinarily in the module is installed in the igloo. The igloo, pressurized to 1 standard atmosphere (101 325 N/m^2), has a usable volume of 77.69 cubic feet (2.2 cubic meters). The internal temperature is compatible with commercial aviation and military equipment requirements. The equipment igloo weighs approximately 1410 pounds (640 kilograms).



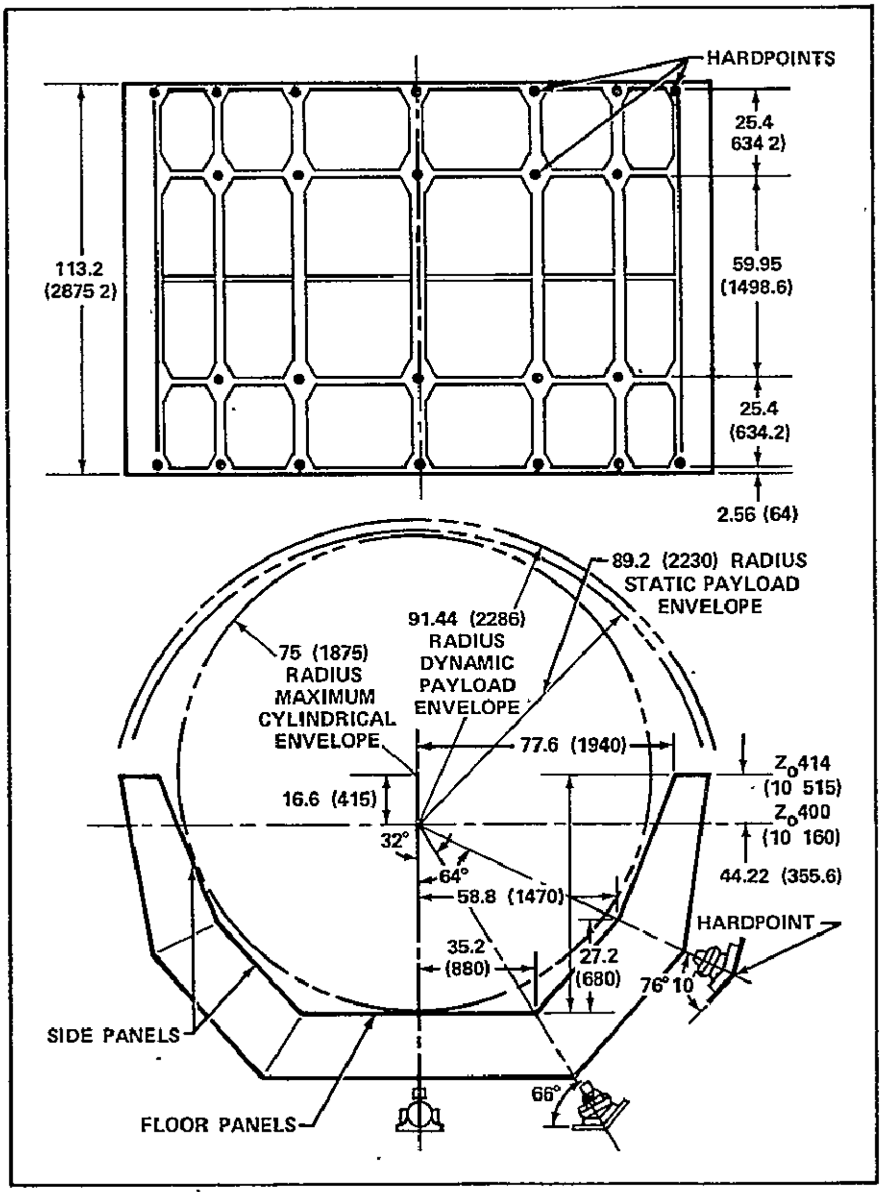


Representative experiment mounted on a pallet.

The following list is representative of items the igloo contains.

- Three computers
- Two input/output units
- A mass memory
- Two subsystem RAU's
- An emergency power box
- An experiment and a subsystem inverter (each 400 hertz)
- A power control box
- A subsystem power distribution box
- A remote amplifier and advisory box
- A multiplexer
- A subsystem interconnecting station

On the ground, access to the igloo interior is through a removable bulkhead.



Hardpoints and envelope for pallet payloads.

Instrument pointing subsystem

An instrument pointing subsystem (IPS) can provide precision pointing for payloads that require greater pointing accuracy and stability than is provided by the Orbiter. The IPS can accommodate a wide range of payload instruments of different sizes and weights.

The gimbal system is attached to the payload when on orbit; and performs the control maneuvers required by the observation program.

During ascent and descent, the payload is physically separated from the IPS to avoid imposing flight loads from the IPS to the payload. The payload is supported by the payload clamp assembly, which distributes the flight loads of the payload into the pallet hardpoints. The payload clamp assembly is capable of mounting and distributing the load of a nominal 4410-pound (2000-kilogram) payload and the IPS into a single unmodified pallet without exceeding safe loading conditions.

The IPS provides three-axis attitude control and stabilization for experiments. The typical payloads, whose characteristics are shown in an accompanying table, are used as design reference payloads except when a requirement specifically states otherwise. Pointing and stabilization characteristics are summarized in the other table.

During orbital operations, the IPS is capable of continuous operation in full solar illumination or in a completely shadowed configuration.

Overall control of the IPS during normal operations is exercised from the Spacelab control console using the keyboard and display of the command and data management subsystem. The flight operating software is capable of interfacing, through the Spacelab subsystem, with the Orbiter data-handling system. The IPS control system uses this Spacelab subsystem for all normal operations. Emergency retraction or jettison is exercised from a separate IPS control panel located on the Orbiter aft flight deck.

Characteristics of nominal payloads with IPS

Parameter	Large payload	Small payload
Mass, lb (kg)	4410 (2000)	440 (200)
Dimensions, ft (m)	(2 by 4)	(1 by 1.5)
Moment of inertia about payload center of gravity, kgm^2		
About axis perpendicular to line of sight	1200	20
About line-of-sight axis	1000	25
Center of gravity offset from center of rotation of gimbal axes, ft (m)		
Along line of sight	6.6 (2.5)	4.9 (1.50)
Perpendicular to line of sight	1 (0.30)	0.33 (0.10)

Attitude control of the payload is based on rate-integrating gyro error signals processed within the Spacelab computer to generate command signals. The rate-integrating gyro package is on the outer gimbal; therefore (aside from distortion or flexures occurring within the payload), it can maintain the payload as an inertially stabilized platform.

To correct for gyro drift and to provide an absolute attitude reference, a package of optical sensors is also included. In a stellar mission, this would consist of three star trackers; in a solar mission, one star tracker would be replaced by a solar sensor.

The IPS provides the following interfaces across the gimbal system for use of payloads.

- Wiring for four independent 800-watt peak (15 minutes maximum) power loads at 28 volts dc; one of the four sets of wiring is capable of carrying 115 volts, ac, 400 hertz
- Wiring for three remote acquisition units
- Ten coaxial cables, each adequate for transmission of the Orbiter high data rate of the Ku-band signal processor

IPS pointing and stability characteristics

Parameter	Requirement	Goal	Comment
Pointing accuracy, arc sec			
Line of sight	2	0.8	1 sigma
Roll	40	15	1 sigma
Quiescent stability error, arc sec			
Line of sight	1	0.33	1 sigma
Roll	3	1.6	1 sigma
Crew motion disturbance[a] error, arc sec			
Line of sight	3	1	Peak
Roll	10	4	Peak
Stability rate			
Line of sight, arc min/sec	1	—	Peak
Roll, arc sec/sec	130	—	Peak
Line of sight, arc sec/sec	—	5	rms
Roll, arc sec/sec	—	25	rms
Pointing range, rad			
Line of sight	3.14 (or π)	N/A	
Roll	±3.14 (or π)	N/A	
Slewing rate, deg/sec	2.5		Maximum

[a]Corresponds to a typical wall push-off by a crewmember.

Utility connections

Utility lines and routing from the Orbiter to the Spacelab interface are provided by the Orbiter. Experiment-dedicated lines allow experiment equipment (both in the module and on a pallet) to be connected with experiment-supplied equipment in the Orbiter aft flight deck. Utility lines from the interfaces must be provided as part of the experiment.

In a pallet-only configuration, utility lines dedicated to experiments are routed to an electrical interface plate on the first pallet.

When both module and pallet are used, utility lines are routed from feedthrough connectors in the module's aft end cone through a utility support structure to the pallet. One of the two feedthrough plates is for experiment utilities and the other for Spacelab subsystem utilities. The feedthrough plate and utility support structure can accommodate at least 100 twisted shielded pairs (American Wire Gauge (AWG) 24)), 20 coaxial cables, two 5-kilowatt powerlines (AWG 8), and two fluid lines for experiments. Connectors and utility lines must be provided with the experiments.

Inside the module, experiment signal lines can be routed between experiment equipment (e.g., racks, airlock, items in the center aisle, window, etc.), to the feedthrough connectors in the aft end cone, and to the connector bracket (which is the interface to experiments from the Orbiter) on the subfloor of the core segment. The cabling must be provided as part of the experiment hardware.

Routing of experiment signal lines is also possible between racks on the same and on opposite sides of the module. However, other experiment powerlines can be routed only between racks on the same side.

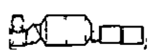
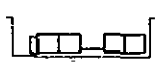
On a pallet, experiment utilities will normally be routed on top of the inner pallet panels.

Payload resources summary

The accompanying tables summarize the principal resources available to payloads using the Spacelab. All accommodations are described in more detail in the Spacelab Payload Accommodation Handbook.

Calculating power available to a payload is more complex than estimating mass or volume, because it depends on several other factors. Power for experiment use depends on the power consumption of the basic Spacelab subsystems and is also a function of the use of mission-dependent

Electrical power and energy resources for payloads

Configuration	Parameter		
	Energy available to payload during flight, kWh (MJ)[a]	On-orbit power at electrical power distribution subsystem interface, kW[b]	
		Maximum continuous	Peak[c]
	123.2 (443.5)	2.5	6.9
	59.2 (213.1)	2.0	6.4
	55.2 (198.7)	2.0	6.4
	65.2 (234.7)	2.1	6.5
	62.2 (224)	2.1	6.5
	457.6 (1647.4)	4.6	9.4
	455.6 (1640.2)	4.6	9.4
	453.6 (1633)	4.5	9.3

[a]From basic 890 kWh (3204 MJ) Orbiter supply. Additional energy is available only by decreasing the mass capacity for experiments

[b]With operation of mission-dependent nondiscretionary equipment. In addition, figures for all module configurations assume approximately 1 kW of power is available because some discretionary subsystem and mission-dependent equipment is not powered.

[c]15 minutes duration for 3-hour intervals.

equipment. Therefore, no attempt has been made to provide a detailed power budget. To establish an accurate mission power budget, an extensive time-lining effort is required after basic experiment accommodation and functional requirements are fixed. In addition, the energy budget has to be considered. A maximum amount of power is available to the experiments if no discretionary subsystem or mission-dependent equipment is used, and a minimum amount of power is available if all the discretionary subsystem and mission-dependent equipment have been selected.

The command and data management subsystem is largely independent from the Orbiter. It provides data acquisition command, formatting, display, and recording. Communication with ground stations is through the Orbiter's communication system. The communications network and data-handling procedures for all STS payloads are described in part 4.

Heat rejection capabilities and module atmosphere aspects

Parameter	Configuration	
	Module	Pallet
Atmosphere		(Igloo)
Nominal total pressure, bar (N/m^2)	1.013 ± 0.13 (101 300 ± 13 000)	1.096 (9600)[a]
Partial oxygen pressure nominal, bar (N/m^2)	.220 ± 017 (22 000 ± 17 000)	.035 (3500)[b]
Partial carbon dioxide pressure nominal, bar (N/m^2)	.0067 (670)	
Cabin air temperature, °F (K)	64 to 81 (291 to 300)	95 (308)[c]
Minimum humidity (dewpoint), °F (K)	43 (279)	
Maximum relative humidity, percent	70	
Maximum allowable internal wall temperature, °F (K)	113 (318)	
Air velocity in habitable area, ft/sec (m/sec)	0.33 to 0.66 (0.1 to 0 2)	
Total heat transport capability,[d] kW	8.5	8.5
Prelaunch/postlanding power,[d] kW		
GSE connected		
Orbiter powered down	Same as operational phase	
Orbiter powered up	1.5	1.5
Ascent/descent	1.5	1.5
Peak heat rejection capability[d]		
For payload power peaks during operational phase, kW	12.4	12.4
Minimum interval between peaks, min	165	165

[a]Maximum gaseous nitrogen differential pressure.

[b]Minimum gaseous nitrogen differential pressure.

[c]Maximum internal temperature.

[d]Available to payload and Spacelab subsystems.

Command and data-handling resources

Payload data acquisition	
Housekeeping and low rate scientific data (to computer via RAU's)	
Number of remote acquisition units (RAU's) of basic system	8
Maximum number of RAU's (extension capability)	22
Number of flexible inputs (analog or digital) per RAU	128
Analog: resolution of analog/digital conversion, bit	8
Discrete: number of inputs addressable as group	16
Number of serial pulse code modulation inputs per RAU	4
Clock rate, Mb/sec	1
Maximum number of words transferred per sample	32
Word lengths, bit	17
Maximum basic sampling rate, Hz	100
Data rate of transfer RAU/computer (including overhead), Mb/sec	1
Wideband scientific data	
Number of experiment channels of the high rate multiplexer (HRM)	16
Minimum data rate of HRM input channels, kb/sec	64
Maximum data rate of HRM input channels, Mb/sec	16
Number of closed circuit television video input channels	1
Number of 4.2-MHz analog channels	1
Data transmission to ground	
Nominal data rate for housekeeping and low rate scientific data from subsystem and experiment computer, kb/sec	64
Maximum data rate for wideband scientific data (via TDRSS), Mb/sec	50
Maximum data rate of high rate digital recorder (HRDR) bridging TDRSS noncoverage periods, Mb/sec	32
Storage capability of HRDR, bit	3.6×10^{10}
Payload command capability	
Telecommand rate from ground via Orbiter, kb/sec	2
Number of on/off command outputs per RAU	64
Number of serial pulse code modulation command channels per RAU	4
Clock rate, Mb/sec	1
Maximum number of words per command	32
Word length (including parity bit), bit	17
Payload data processing and displays	
Data processing	
Word length, bit	16
Speed (Gibson mix), operations/sec	350 000
Floating point arithmatic, bit	32 (24+8)
Mass memory, Mbit	131
Display: alphanumerical display screen (tri-color diagonal, in. (cm)	12 (30.5)

Mission scenarios

In order to orient the user in the uses of Spacelab, the results of a number of Spacelab conceptual mission studies are described in the following pages. Included are types of missions, their goals, and basic experiment equipment. These descriptions can be used for planning purposes, but none has been specifically approved as a NASA mission. For missions supporting specific disciplines in basic science or technology, NASA will provide specialized research and development facilities and equipment.

These Spacelab missions will concentrate on intense, short-term investigations and will, therefore, complement those long-term observations programs that use free-flying satellites. Payload operations studies have been directed at providing the greatest scientific return from each mission while most effectively using the resources of the Spacelab, the standardized experiment equipment, the individual experimenter's equipment, and the expertise of the crew. The payload specialist, trained by the user and working with ground-based scientists and technicians, is an integral part of the plan.

The modular design of the Spacelab and of the specialized experiment equipment permits their repeated use in long-range program planning. They provide broad flexibility to accommodate the diverse needs of both large and small users. The available equipment, as well as the number of planned missions, can be varied in response to user interests and requirements. The equipment can be used as part of mixed payloads as well.

Three levels of user involvement in these specialized missions are defined.

1. The user provides the complete experiment unit, both the facilities and the detectors or samples.

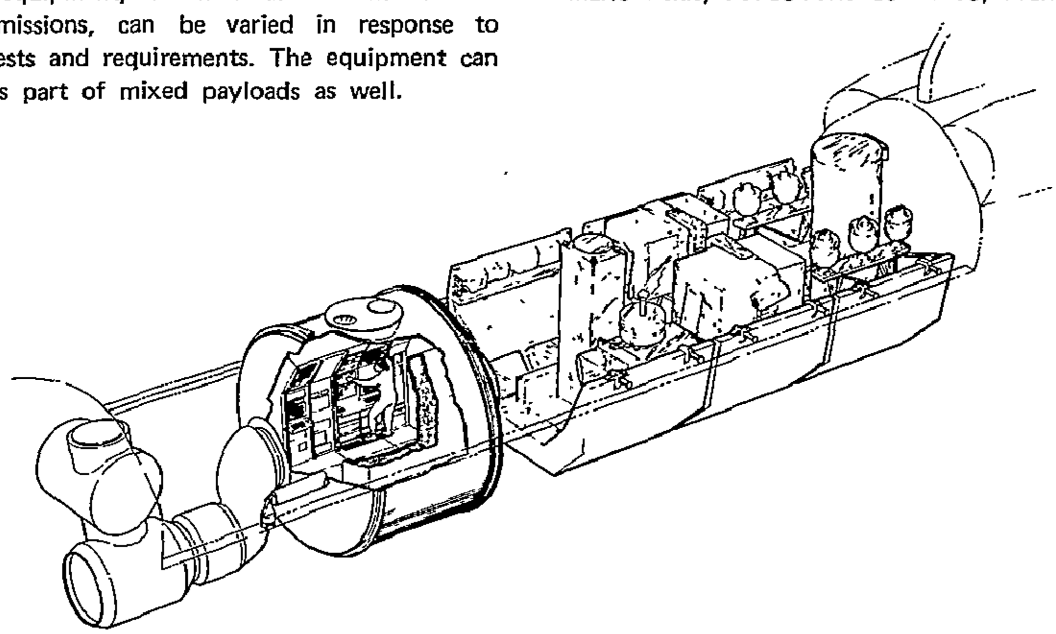
2. The user provides only the experiment, which will be accommodated by standardized, NASA-provided equipment.

3. The user receives data generated on a mission (such as Earth observations images or tapes), but provides no actual experiment or hardware.

Planned missions will involve space processing, advanced technology, Earth viewing, life sciences, astronomy, astrophysics, solar physics, and terrestrial physics. Sources of information about these specific missions are listed with the description of each.

For all missions, NASA will manage Spacelab operational activities. These include experiment integration, payload specialist training, checkout, flight operations, refurbishment, and data acquisition, preliminary processing, and distribution.

Additional information about the Spacelab Program in general is available in the United States from the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Mail Code NA01, Marshall Space Flight Center, Ala. 35812; Telephone (205) 453-4610; FTS 872-4610. In Europe, Spacelab information is available from the European Space Agency, 8-10 Rue Mario Nikis, 75738-Paris Cedex 15, France.



Astrophysics payloads

The astrophysics payloads (APP) project involves a set of instruments that will be used to investigate a wide range of long-term scientific problems in astrophysics, including the following.

- Origin and future of matter
- Nature of the universe
- Life cycle of the Sun and stars
- Evolution of solar systems

The small instrument pointing system (SIPS) has been designed to meet the 1 arc-second accuracy with sub-arc-second stability pointing needs of many ultraviolet, optical, and infrared instruments.

Thermal and contamination control is provided by a thermal canister.

During periods when optical and ultraviolet observations may be affected by the light backscattered from gas clouds in the vicinity of the Orbiter, it will be operated in a free-drift mode. The instrument pointing systems will compensate for attitude variations.

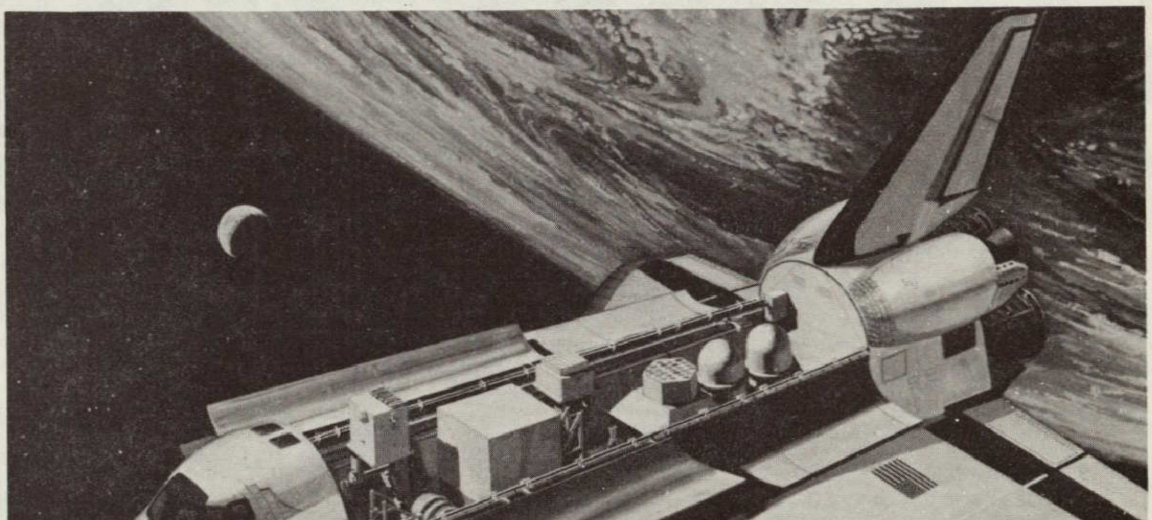
Parallel control capability of the APP instruments allows the payload specialist to react to unexpected mission events, while ground-based experiment operations in the Payload Operations Control Center (POCC) supplement the payload specialist's usual activities.

Experiments will be controlled and monitored by the payload specialist on the Orbiter aft flight deck. Experiments will be controlled from the POCC during rest periods for the payload specialist.

Real-time data will be provided to ground-based experimenters.

Preprogrammed observation sequences will be used and the payload specialist will be able to continuously monitor the computer-controlled operations by use of a status panel and readout system.

Many mission objectives can be met in 7 days, although major problems will require multiple or extended flights. One exception is data from the



Spacelab high-energy astrophysics observatory configuration.

gamma-ray spectrometer, which is expected to meet approximately 50 percent of its objectives in a 7-day flight. For the planned studies of solar evolution, all instruments except one are expected to attain mission objectives through use of 7-day flights. The medium-energy gamma-ray detector is expected to observe approximately 60 percent of its targets. Because of these exceptions, missions of 20 or more days are being considered.

The initial APP flights will be launched from KSC into a 216-nautical-mile (400-kilometer) circular orbit at an inclination of 28°. Two APP missions are tentatively scheduled for late 1981 and late 1982. More information about the APP flights is available from the Office of Space Science, Mail Code S, National Aeronautics and Space Administration, Washington, D.C. 20546.

Typical astrophysics instrumentation and mounting configuration

Instrument	Configuration	
	Origin and future of matter studies	Stellar evolution studies
Ultraviolet photometer/polarimeter	1/2 SIPS	1/2 SIPS
High-resolution ultraviolet spectrograph	1/2 SIPS	1/2 SIPS
Narrow field imaging telescope and objective spectrograph	1/2 SIPS	
X-ray detector/counter	Instrument pointing system	Instrument pointing system
High-resolution gamma ray spectrometer	Pallet	
Extreme ultraviolet imaging telescope		1/2 SIPS
Small infrared cryogenic telescope		1/2 SIPS
Medium-energy gamma ray detector		Pallet
Cosmic radiation electron detector/spectrometer		Pallet

Solar physics payloads

The Spacelab solar physics payloads (SPP) missions involve instruments designed to obtain data that will be used to understand the fundamental physical processes of energy production in the solar interior, the transport of this energy through the solar atmosphere, and its ultimate dissipation through radiation, acceleration of plasma, and the solar wind.

The emphasis of the early SPP missions will be on solar/terrestrial interactions. The two specific areas identified for initial investigation are the solar wind/Sun interface and high-energy acceleration processes.

More specifically, the investigation of the solar wind/Sun interface has the following objectives.

- Define boundary conditions to the solar wind in the lower corona
- Confirm solar wind emission from regions of open magnetic field
- Evaluate energy deposition and magnetic field divergence
- Evaluate solar wind modulation processes
- Evaluate terrestrial consequences to the observed coronal variations

The objectives of the study of high-energy acceleration processes of the Sun are summarized as follows.

- Observe particle acceleration sites to define particle acceleration processes
- Observe outer corona for trapping of high-energy particles and sites of energy dissipation
- Correlate acceleration processes with stressed solar magnetic fields to develop a predictive capability for impulsive events
- Correlate impulsive events and energetic particle emission with terrestrial effects

These objectives reflect the problem-oriented approach of the SPP. Instruments for these missions can be accommodated on a five-pallet configuration.

The SPP will be controlled either from the payload station on the Orbiter aft flight deck or the Payload Operations Control Center (POCC) on the ground. Experimenters and mission operations personnel on the ground will be able to assist the payload specialist with unexpected changes in observables on the solar disk. Primary control of all instruments will be assigned to the payload specialist, who will be trained to provide assistance with the analysis of malfunctions and to conduct critical mission operations in order to remedy the malfunctions.

Operationally equivalent controls and displays will be employed aboard the Orbiter and in the POCC. Experimenters will be provided with real-time data to assure maximum instrument use and productivity.

Two fully operational software packages will be available to provide for an interchange of the primary and secondary mission objectives of the flight. Ground-based computer capacity will supplement the Spacelab computer capabilities where required.

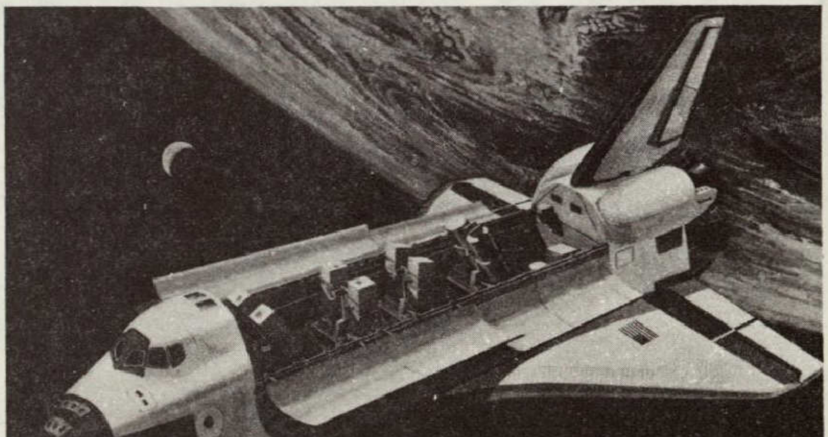
The orbit chosen for the SPP flights is a 254-nautical-mile (470-kilometer) circular one at 33° inclination launched from KSC near the winter solstice. A preliminary schedule has been prepared for launches in 1981 and 1982. Integration and testing is expected to take about 6 months before each flight and launch site activities will require another 2 months.

Although the standard 7-day flight will meet the minimum mission objectives, three-dimensional observations of solar phenomena are best conducted over a period comparable to the, 27-day solar rotation period. Therefore, flights of 15 days or longer are likely.

More information about the SPP flights is available from the Office of Space Science, Mail Code S, National Aeronautics and Space Administration, Washington, D.C. 20546.

Typical solar physics instrumentation

Instrument	Study	
	Solar wind/Sun	Acceleration processes
X-ray telescope	X	X
White light coronograph	X	X
Ultraviolet scanning spectrometer	X	
X-ray spectrometer/ spectrograph		X
Extreme ultraviolet and X-ray spectrometer	X	
Extreme ultraviolet monitor		X
Extreme ultraviolet spectroheliograph	X	X
Hard X-ray collimator		X
Helioscope		X
Hard X-ray spectrometer		X
Solar gamma ray telescope		X



Solar physics laboratory configuration in Orbiter.

Manned physics laboratory

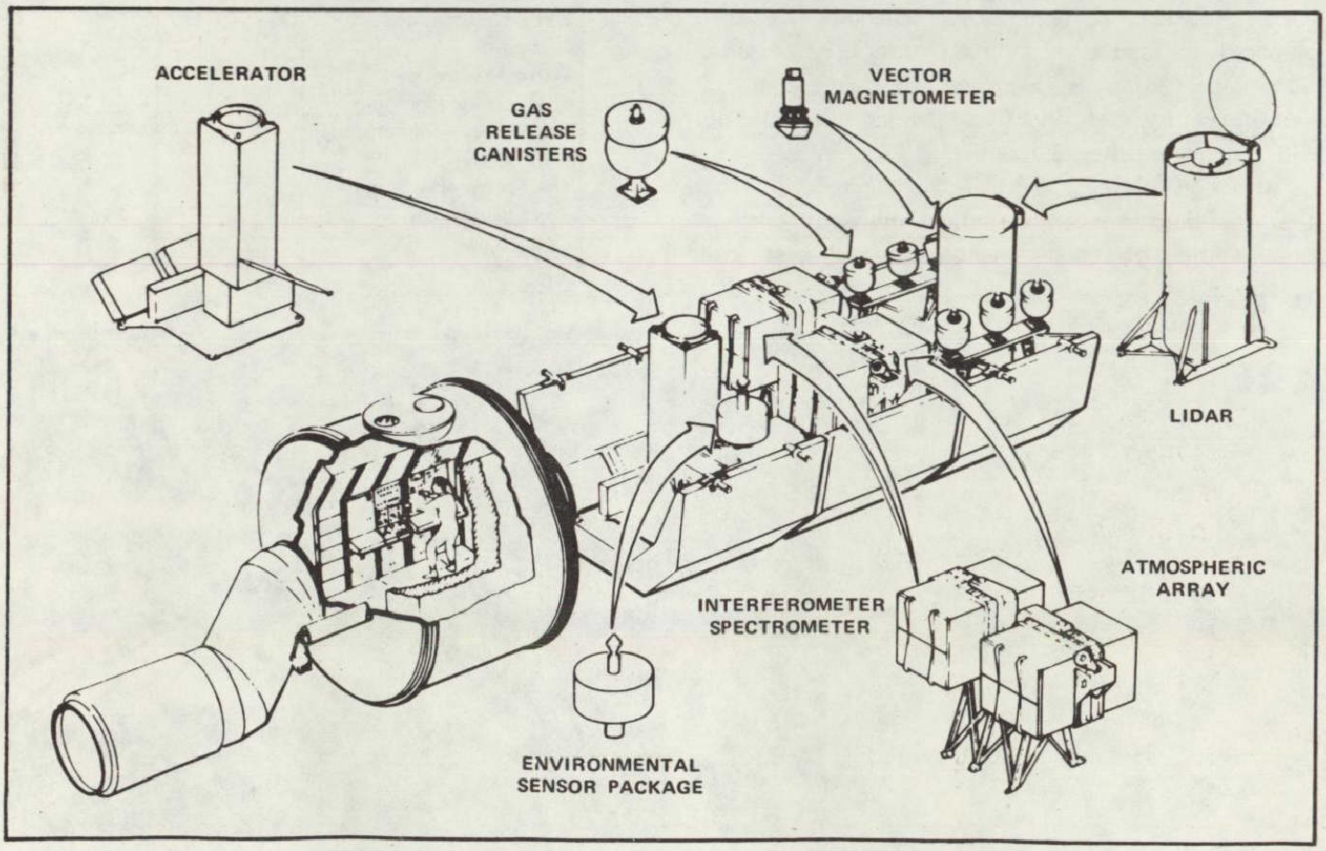
A dedicated Spacelab will be used for the atmosphere, magnetosphere, and plasmas-in-space (AMPS) project, which consists of a manned physics laboratory for conducting a large variety of scientific experiments and observations.

The objective of the AMPS project is to assist in developing a comprehensive understanding of the region surrounding the Earth. This involves studying the Earth's electric and magnetic field system, energetic particle and electromagnetic wave interactions, physical processes associated with the motion of bodies in rarefied plasmas, and the chemistry and dynamics of the upper atmosphere.

A number of basic instruments have been defined to support experimentation in this area of physical investigation. The instruments and the experiments that they support are shown for two typical flights.

Representative flight requirements

Requirement	Used	Allowable
Payload mass, kg	3448	5500
Center of gravity	Within limits	
RCS propellant, kg	1829	2851
OMS propellant, kg	9814	10 530
Electrical energy, kWh	229	391
Peak electrical power, kW	4.0	8.0
Average power, kW	2.1	3.8
Maximum computer load, instructions	50 000	64 000
Maximum computer throughput, thousand operations/sec	<100	320
Maximum data rate, Mbits/sec	6.4	50

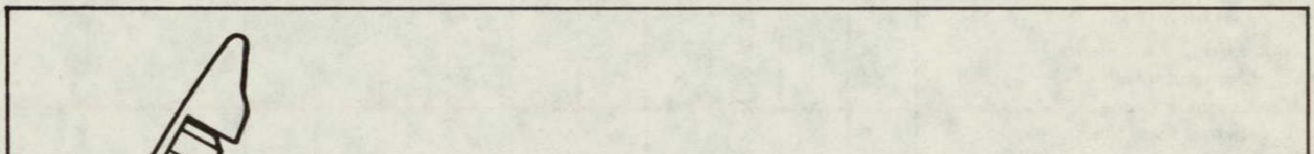


Equipment location for representative initial flight of this specialized laboratory.

Engineering analyses and design layouts show that the instruments for both flights can be accommodated and serviced in the short module/ three-pallet Spacelab configuration. Operational analyses show that the experiments can be conducted within the constraints of the Spacelab and STS, as is illustrated for one flight. Operational procedures for two experiments are also shown.

Representative experiment instrument complement

Instruments	Experiments: Beam characteristics	Spacecraft neutralization	Beam plasma interactions	Acoustic gravity wave	Gas cloud dynamics	Environmental observations	Minor constituents	Ozone density	Solar radiation
Active instruments									
Gas release				X	X				
Electron accelerator	X	X	X						
Supporting instruments									
Vector magnetometer	X	X	X						
Level 1 diagnostics	X								
Level 2 diagnostics	X	X	X						
Quartz crystal microbalance						X			
Atmospheric array									
Lidar								X	
Optical band imager	X	X		X	X				
Infrared radiometer							X		
Infrared interferometer							X		
Environmental sensor package	X	X	X			X		X	
Solar flux monitor									X



Proposed measurement of atmospheric constituents on an early AMPS flight.

The AMPS flight system and its operation are designed to complement the STS command, control, and communications network. Ground support is provided for activity replanning, payload hardware performance assessment, fault isolation assessment of scientific data, and the like. The scientific flight crew, therefore, can concentrate on scientific observations and make on-the-spot decisions.

Controls and displays have been designed to provide direct crew involvement with the investigations. A high degree of standardization with minimum changes from flight to flight is stressed. Extensive use is made of Spacelab keyboard and cathode-ray tube (CRT) interfaces with the experiment computer to control instruments and support equipment. Some special controls and displays are incorporated to provide flexibility. Both automated and manual controls are included in the flight system to enhance the crew's ability to make decisions and adjustments during the experiments.

Flight plans, crew procedures, crew training procedures, and flight data file material will be in modular form to provide flexibility and limit changes needed from flight to flight.

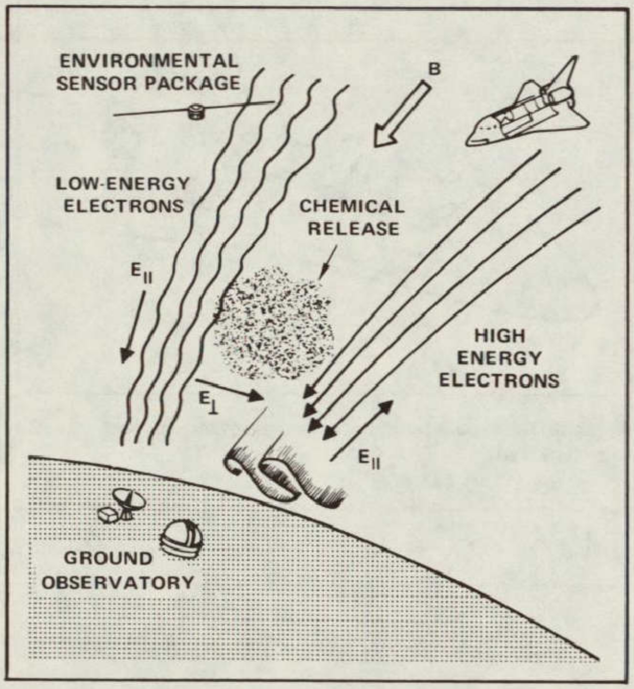
Second flight experiment instrument complement

Instruments	Experiments									
	Low-altitude conductivity modification	Plasma flow	High-frequency wave interactions	Long-delay echoes	Minor constituents	D-region composition changes	Oxygen variation	Neutral composition near aurora	Ozone changes at high latitude	Solar flux calibration
Active instruments										
Radiofrequency sounder			X	X						
Chemical gas release	X									
Test body		X								
Supporting instruments										
Magnetometer	X	X	X	X						
Langmuir probe	X	X	X							
Neutral mass spectrometer		X	X							
Ion mass and distribution	X	X	X							
Atmospheric array										
Lidar					X	X		X	X	
Optical band imager	X	X						X		
Ultraviolet-visible spectrometer					X	X	X	X	X	
Cryogenic limb scanner					X				X	
Cryogenic infrared interferometer					X	X		X	X	
Environmental sensor package	X		X	X		X		X	X	
Solar flux monitor										X

The AMPS concept assumes that each new item of equipment will be qualified for flight before it becomes part of the equipment inventory.

Detailed analytic models will be developed and refined by incorporating data from all ground tests and from the early flights. These models will be used to analytically verify the flight readiness of subsequent payload assemblies. This process is aimed at reducing the test program in later flights. Analytic models will include dynamic, structural, thermal, contamination, and electromagnetic interference.

More information about the AMPS project can be obtained from the Office of Space Science, Mail Code S, National Aeronautics and Space Administration, Washington, D.C. 20546.

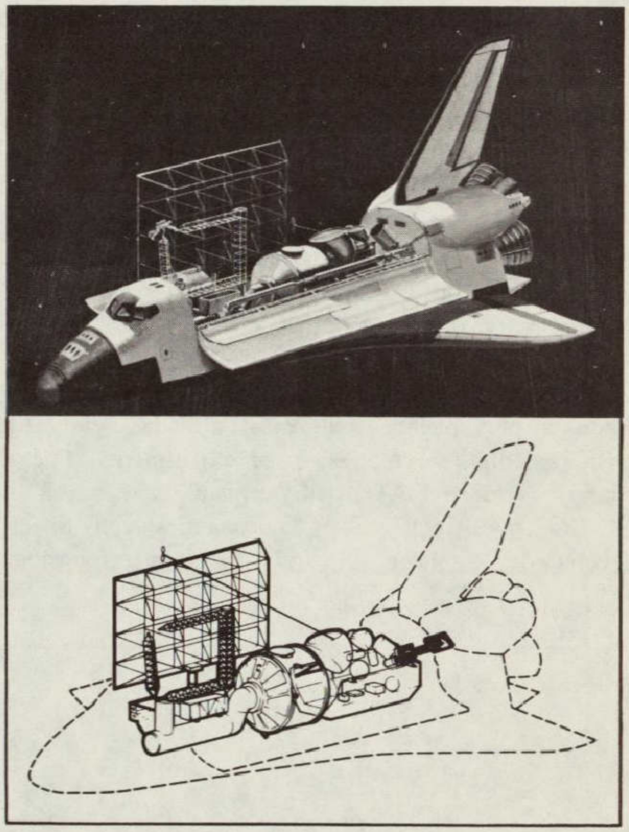


A proposed experiment is the thermite release of barium at high latitudes. This causes substantial conductivity increases, leading to the downward acceleration and dumping of high-energy electrons and the upward acceleration of low-energy electrons. Electric fields both along $E_{\parallel}$ and perpendicular $E_{\perp}$ to the magnetic field B will be generated.

Advanced technology laboratory

The advanced technology laboratory (ATL) is a Spacelab mission with emphasis on technology objectives. It represents the space research laboratory of the 1980's, providing the researcher with vacuum conditions, null gravity, a benign environment, the recovery of experiment equipment, and quick-response space research.

The ATL provides a new dimension in the development of spaceborne systems: the flight test. It is an organized, systematic approach for continuing and extending research and technology efforts into space.



Two views of a large power element integrated into a module-and-pallet configuration.

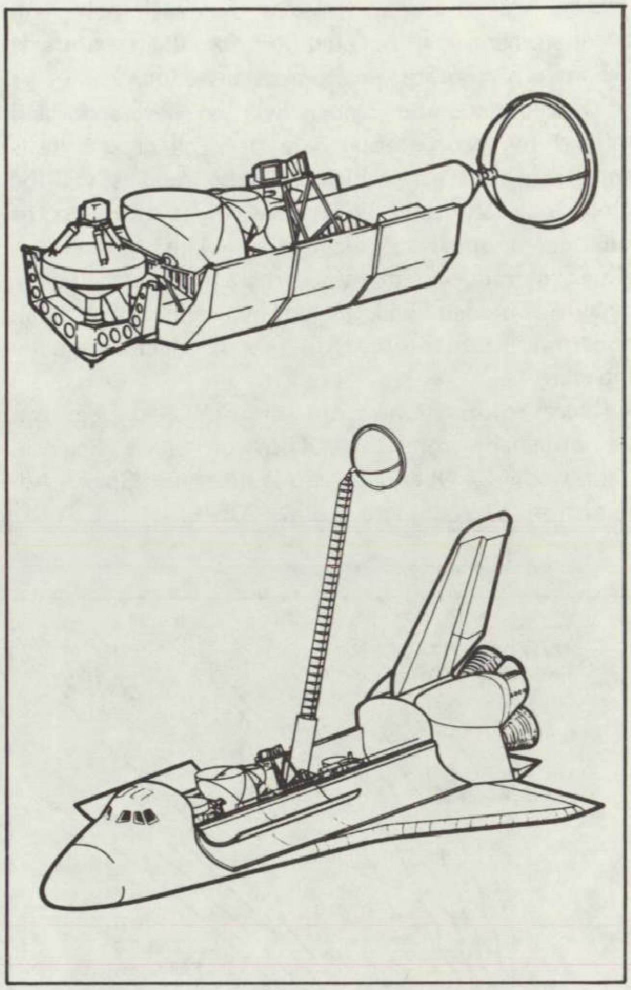
The ATL offers several advantages to users: it provides system and subsystem developers the capability to conduct economical testing under actual flight conditions; it extends the capabilities of the ground-based research laboratory into space and permits participation by onboard specialists; it offers the capability to develop techniques, sensors, systems, or subsystems to establish the technical base for future systems; and it allows users to retain control of their experiments.

Accommodations of ATL are identical to those of Spacelab. A typical configuration, composed of a short module and two pallets, is illustrated. A representative set of advanced space research experiments is integrated in this arrangement.

Pallet-only configurations are also possible for experiment hardware better suited to those configurations. Equipment, such as that shown in an accompanying figure, has been devised to remove experiments from canisters and deploy those experiments at a sufficient distance to neutralize the Orbiter's influence. For example, a large antenna can be deployed from its canister and operated; then, when the experiment is completed, it can either be refurled and stowed in the canister for return to Earth, or it can be jettisoned.

The operational flexibility afforded by the various configurations – module only, pallets only, or module plus pallets – will meet a wide variety of requirements for creative space experiments. Flight durations for the ATL will normally be 7 days.

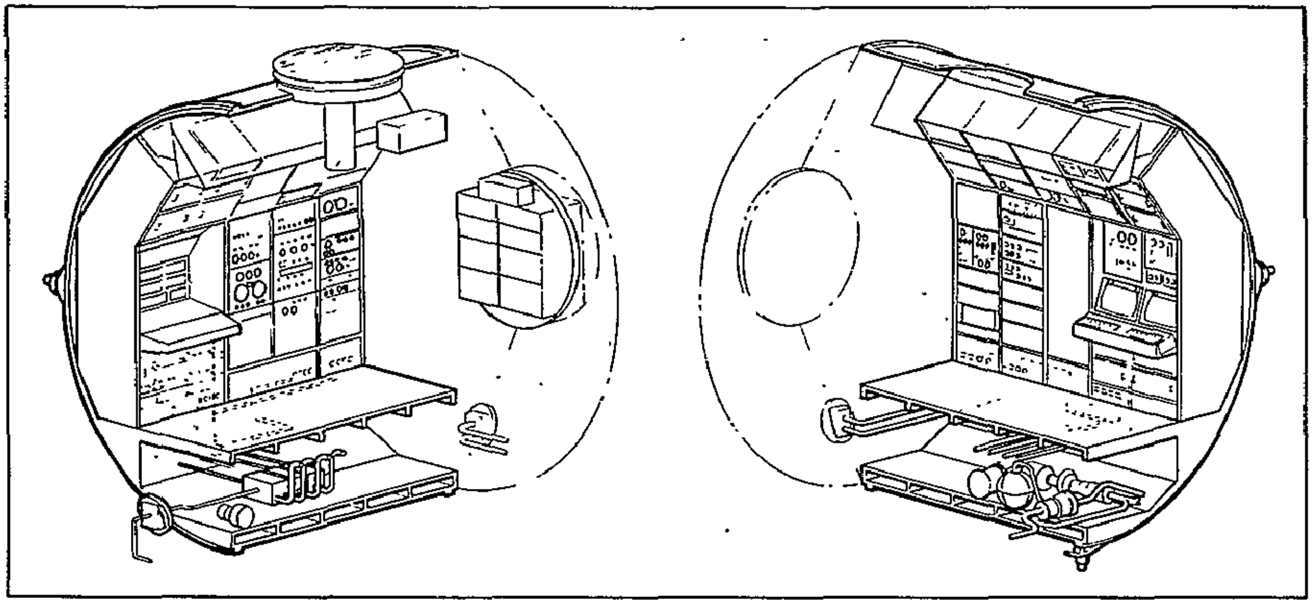
The NASA Office of Aeronautics and Space Technology sponsors the ATL, and is responsible



Antenna in a pallet-only configuration shown both stowed and deployed.

for the necessary integration and mission management effort. Some experiment development is funded by that office and flight assignments are made for other promising technology experiments. The ATL project office provides integration and interface program planning data to candidate researchers and to support experiment evaluation by the Office of Aeronautics and Space Technology. It can also plan and implement payloads after they have been selected. The ATL project office provides an experimenter with a single point of contact for detailed integration, schedules, and experiment planning information. Modest documentation is required.

More information about the advanced technology laboratory is available from the Office of Aeronautics and Space Technology, Shuttle/Spacelab, Mail Code RS, National Aeronautics and Space Administration, Washington, D.C. 20546, telephone (202) 755-8505, FTS 755-8505.



Representative module interior for the advanced technology laboratory.

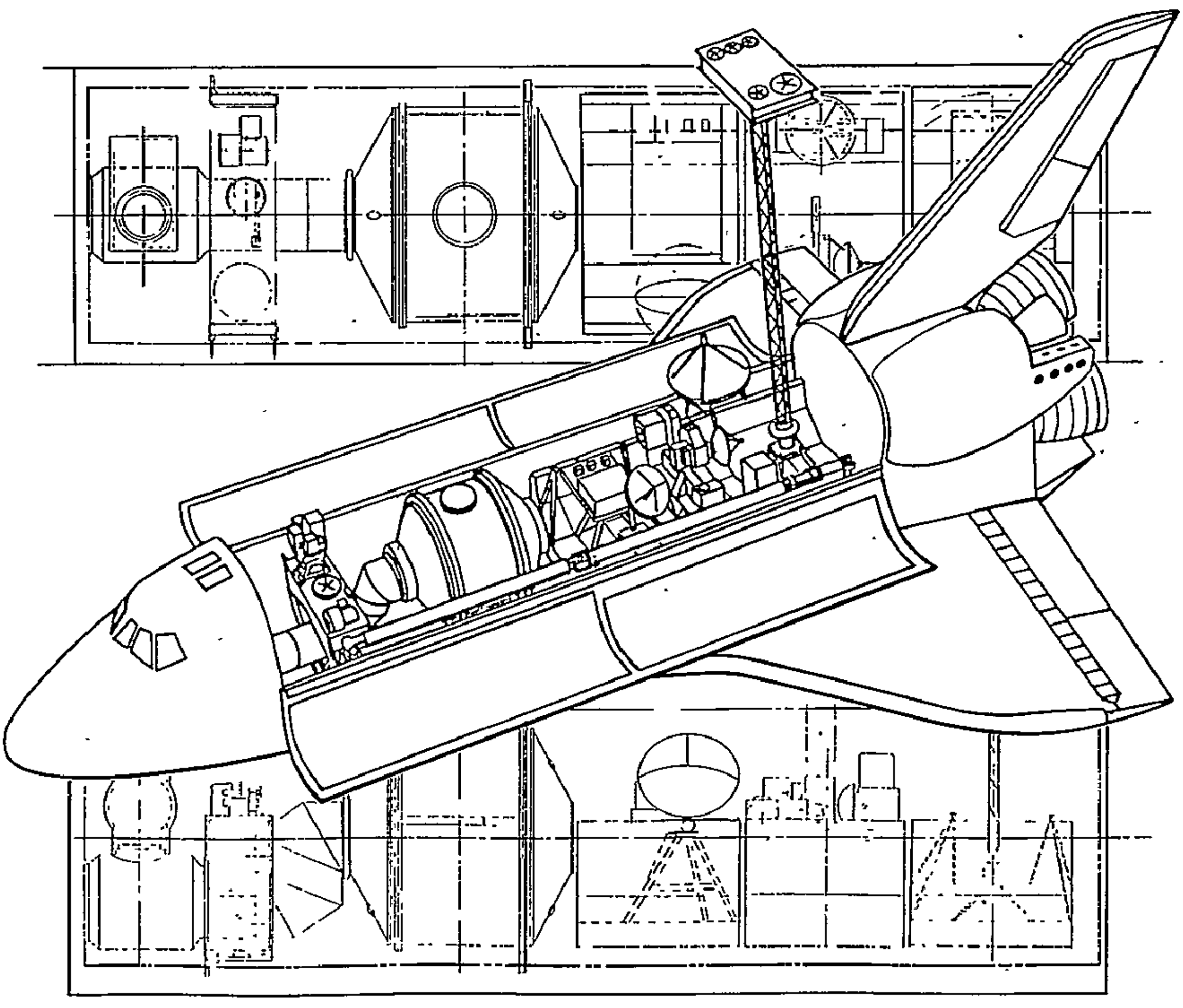
Earth-viewing application laboratory

The Earth-viewing application laboratory (EVAL) planned by NASA is a Shuttle/Spacelab project that utilizes elements of the Space Transportation System, experiment carriers, support equipment, and sensor instruments to carry out missions in the disciplines of Earth resources, communications and navigation, Earth and ocean dynamics, weather and climate, and environmental quality/pollution.

Missions and experiments that address technique development, sensor development, application development, and operational data collection are roles for EVAL flights. In technique development, early investigations of underlying scientific principles are examined to determine the best method for obtaining operational data on subsequent Shuttle or satellite flights. The major technique developments anticipated on initial EVAL flights are multiparameter radar signatures for various phenomena.

Sensor development missions are intended to provide the engineering evaluation required to finalize sensor design for future space missions. In this manner, incremental buildup of the sensor can be accommodated and performance verification and calibration can be accomplished.

The EVAL can also be used for application development missions in which a prototype end-to-end applications system is exercised to demonstrate operational potential.



Finally, EVAL can serve as an operational platform to perform applications missions and acquire information for operational resource managers. This role can have immediate human impact and be of significant monetary value to the ultimate user.

Payloads for EVAL will be planned to take advantage of common equipment requirements and derive synergistic benefits from combining mutually compatible experiments on the same flight. This characteristic, plus the frequent flight opportunities offered by the STS, will contribute significantly to controlling the cost of development programs.

Further enhancement of Earth-viewing projects will accrue from the unique resources provided by the Shuttle and Spacelab. These include onboard data processing, accurate pointing and vehicle stability, timely recovery of hard-copy data and mission hardware, broad capabilities for orbital placement, and rapid turnaround of hardware and software. Another key resource, of course, will be the presence of people on orbit, where they can participate directly in mission and experiment operations, assist real-time data reduction, and provide flexibility in real-time responses to unplanned targeting opportunities and nonnominal conditions.

Development of EVAL payloads involves programmatic planning by the NASA Office of Applications and the eventual determination of flight assignments. Early assessment of candidate missions will be done in cooperation with the Office of Space Flight to determine their compatibility with the capabilities and resources available from the Shuttle and Spacelab. The NASA Goddard Space Flight Center has been assigned the responsibility for developing the EVAL payloads. A Payload Operations Control Center is available for on-orbit experiment monitoring, evaluation, and control.

Inquiries from those interested in participating in the EVAL project are actively encouraged, although implementation plans for these flights are still tentative. Information is available from the Assistant Associate Administrator for the Office of Applications, Mail Code EB, National Aeronautics and Space Administration, Washington, D.C. 20546.

Specific EVAL missions being considered

Earth resources	• World crop survey • Vegetation stress • Urban planning • Timber inventory • Mineral survey • Water inventory
Weather and climate	• Cloud climatology • Ozone mapping • Solar energy monitoring • Atmospheric X-ray emission • Weather modification
Earth and ocean dynamics	• Crustal motions • Geomagnetic fields • Sea surface temperature • Ocean currents • Ocean waves • Geoid measurements
Environmental quality/ pollution	• Stratospheric pollution • Tropospheric trace constituents • Radiative flux changes • Thermal balance • Water pollution
Communication and navigation	• Electromagnetic mapping • Data collection • Search and rescue • Propagation effects • Laser communications

Life sciences experiments

The project for in-orbit life sciences payloads is being developed by the NASA Office of Space Science to use the Spacelab to conduct research in the null gravity and altered environments (radiation, acceleration, light, magnetic fields, etc.) of space. The Shuttle/Spacelab presents a unique capability to perform numerous experiments in all fields of life sciences; i.e., biomedicine, vertebrates, man/system integration, invertebrates, environment control, plants, cells, tissues, bacteria, and viruses. Broad objectives are to use the space environment to further knowledge in medicine and biology for application to terrestrial needs, as well as to ensure human well-being and performance in space.

The project is structured for the widest participation from the public and private sectors and is characterized by low-cost approaches, many flight opportunities, short experiment turnaround times, provisions for qualified investigators to fly with their experiments, and maximum use of existing or modified off-the-shelf hardware.

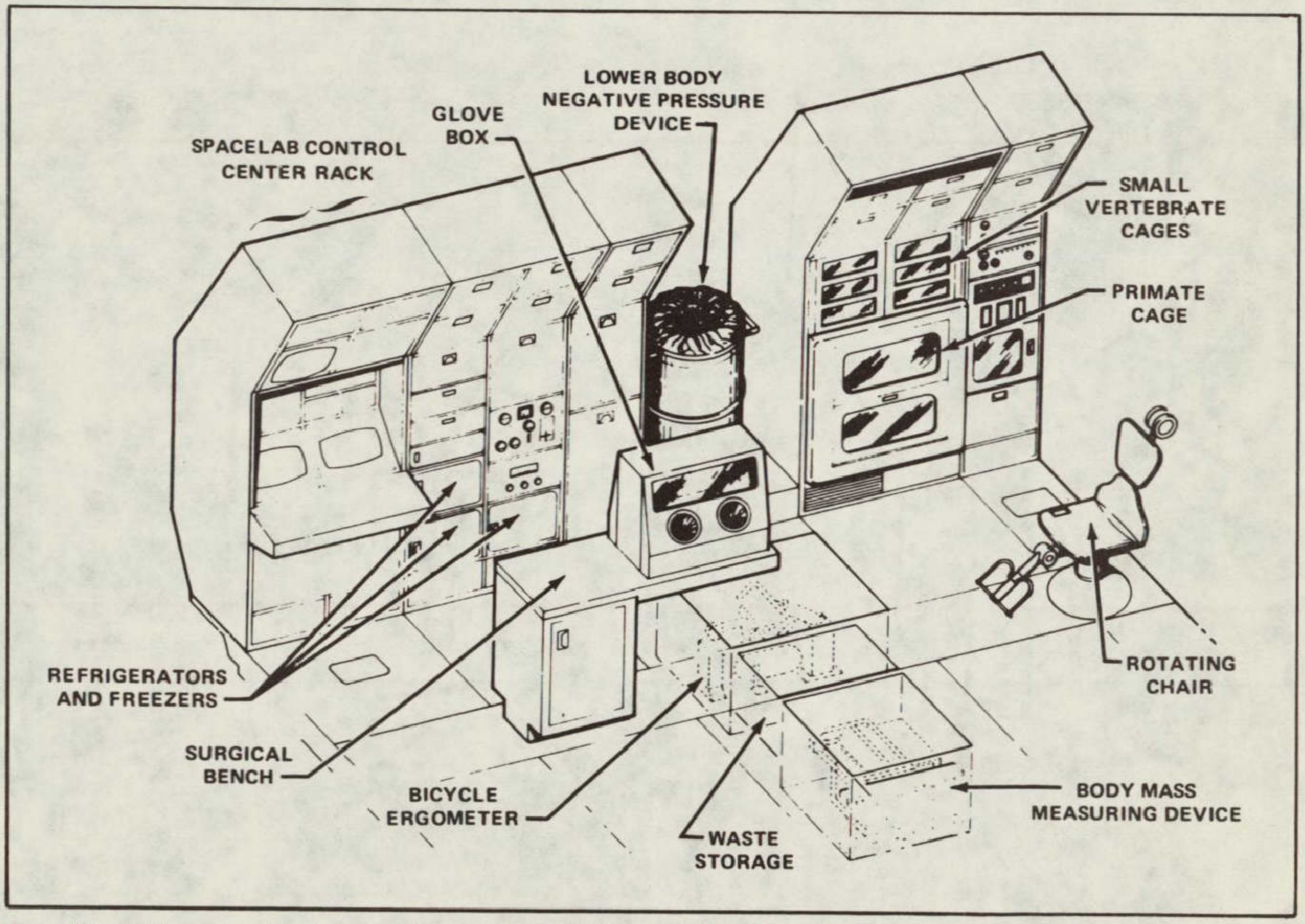
Initially, 7-day missions are scheduled with the Spacelab dedicated to life sciences experiments. Eventually, dedicated flights as long as 30 days are envisioned. The carrier will generally consist of the pressurized Spacelab module with racks and payload support equipment; pallets may or may not be used. The Spacelab will be outfitted with selected common operational research equipment (listed in the table) especially acquired to support the project. For a given flight, 10 to 20 life sciences experiments will be carefully selected and developed that can be operated by one or two onboard payload specialists. These specialists may be supported by other onboard crewmembers and may receive real-time and off-line support from ground-based scientists and engineers via air-to-ground data, television, and voice communications links to the POCC and to remote monitoring areas. Several dedicated life sciences Spacelab missions are currently planned.

Typical common operational research equipment

Function	Equipment
Blood sample	Freezer, clinical centrifuge, hematocrit reader, radiation detector
Urinanalysis	Total solids refractometer, pH meter, freezer, refrigerator
Cardiovascular function	Limb plethysmogram, cardiotachometer, phonocardiogram,oscilloscope, biomedical recorder
Small vertebrate physiology	Glove box, surgical table, mass measurement device, veterinary kit, small vertebrate holding facility
Primate monitoring	Telemetry receiver, biomedical recorder, oscilloscope, primate holding unit
Cell, tissue growth, morphogenesis	Microscope, still camera, colony chamber, biological specimen holding facility incubator
Vestibular function	Rotating chair, electrocardiograph, electroencephalograph, electromyograph, electro-oculograph, cardiotachometer, biomedical recorder

A representative life sciences laboratory layout is shown. This and other typical Spacelab configurations will support medical/biological/technological applications experiments on subjects of man, primates, small vertebrates, plants, cells, and tissues, and will provide null gravity research capability for advanced life support systems.

Other payload configurations will consist of carry-on laboratories and minilaboratories, which will be designed to fit either in the Orbiter mid deck or in the Spacelab. Carry-on laboratories will generally be designed to require a minimum of inflight crew time for operation or maintenance and will minimize inflight control and data transmission. Shared Spacelab missions (with minilaboratories) will be similar in all respects to the dedicated Spacelab missions except that the life sciences experiments will make up only a part of the payload. One or more racks will usually contain not only the necessary common operational research equipment and subsystems, but also the experiments they support.

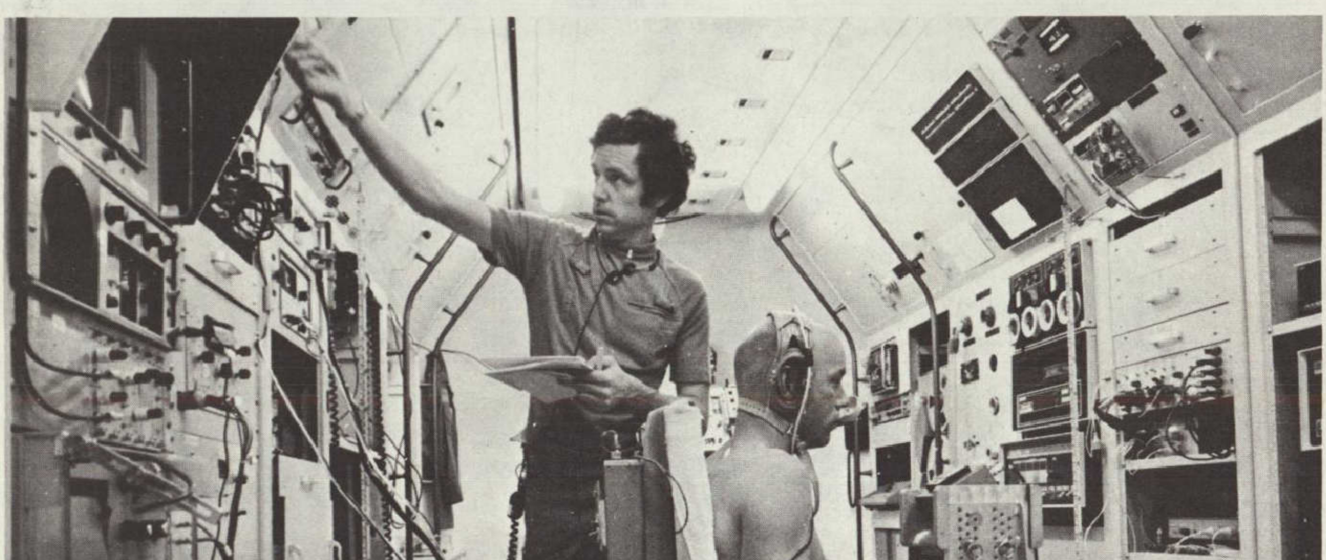


Typical layout for a Spacelab dedicated to life sciences, with possible locations of center aisle and starboard racks.

The development and handling sequence for life sciences experiments will involve the following.

- Issuing of announcements of opportunity on a periodic basis (enough for 2 or 3 years of missions) by the NASA Office of Space Science, submittal of the experiment proposal by the investigator, and selection by NASA.
- Assignment of the experiment to a NASA development center (Ames Research Center for those involving animals and JSC for those involving humans), experiment development by the principal investigator, and delivery of the experiment to the development center for verification/checkout.
- Mounting of experiments in flight racks, checkout, rack integration, integrated testing/training, research equipment integration, and POCC interfacing at JSC.
- Transfer of integrated experiments to KSC for higher level integration, checkout, preflight preparation, launch, and return.

The life sciences payloads project is in the formative stages. Data given here are intended to serve only as a guide to the prospective experimenter. Additional information is available from NASA Director for Life Sciences, Mail Code SB, National Aeronautics and Space Administration, Washington D.C. 20546.

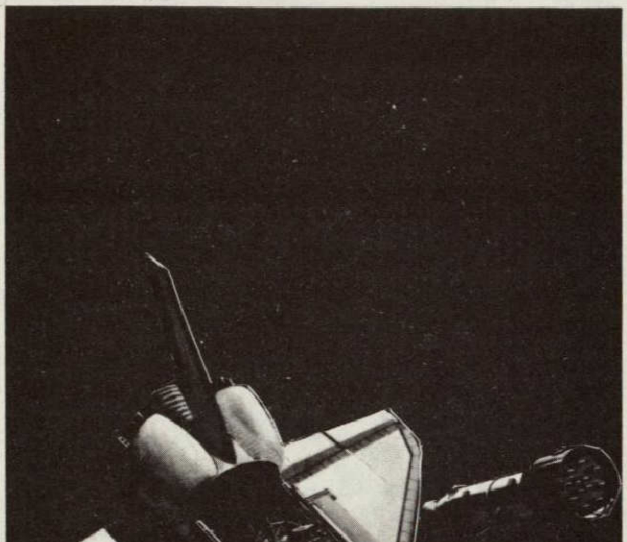


Training in a Spacelab life sciences mockup.

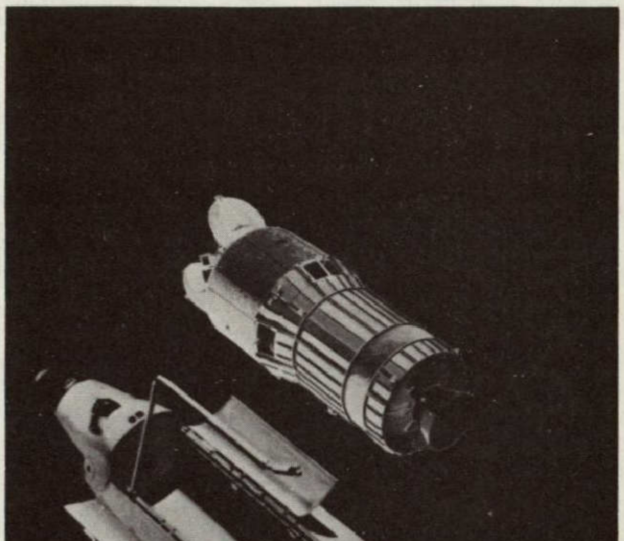
UPPER STAGES

The expendable upper stage is a reliable, simple, low-cost vehicle for spacecraft missions with altitudes, inclinations, and trajectories beyond the basic Shuttle capability. The upper stage systems consist of one or more solid-propellant propulsive stages, airborne support equipment, ground support equipment, software, and unique facilities.

Two upper stage systems are currently planned. A solid propellant spin-stabilized stage called the spinning solid upper stage (SSUS) is designed for Atlas-Centaur and Delta classes of missions. The solid propellant three-axis-stabilized interim upper stage (IUS) is intended for boosting single or multiple spacecraft to higher orbits and escape trajectories.



Spinning solid upper stage.



Interim upper stage.

Spinning solid upper stage

The SSUS, being planned by the NASA, relies upon an initially imparted delta-velocity and spin momentum for trajectory and stability control to boost a single spacecraft to a predetermined destination or apogee. The SSUS capability is comparable to current expendable launch vehicles.

The Shuttle Orbiter performs the initial pointing, spin up and release of the SSUS, similar to that performed by the first two stages of the Delta three-stage launch vehicle. The SSUS performs the function of the Delta third stage for transfer orbit injection. This approach will simplify the user's transition from expendable vehicles to the STS, with the added advantage of multiple spacecraft launches or shared launches with other payloads being possible. The result will be a significantly lower cost to the user per spacecraft launch.

The SSUS is designed to accommodate two primary classes of spacecraft: the Delta class, which requires 2000 to a maximum of 2400 pounds (900 to 1088 kilograms) to be put into geosynchronous transfer orbit, and the Atlas-Centaur class, which requires 4000 to a maximum of 4400

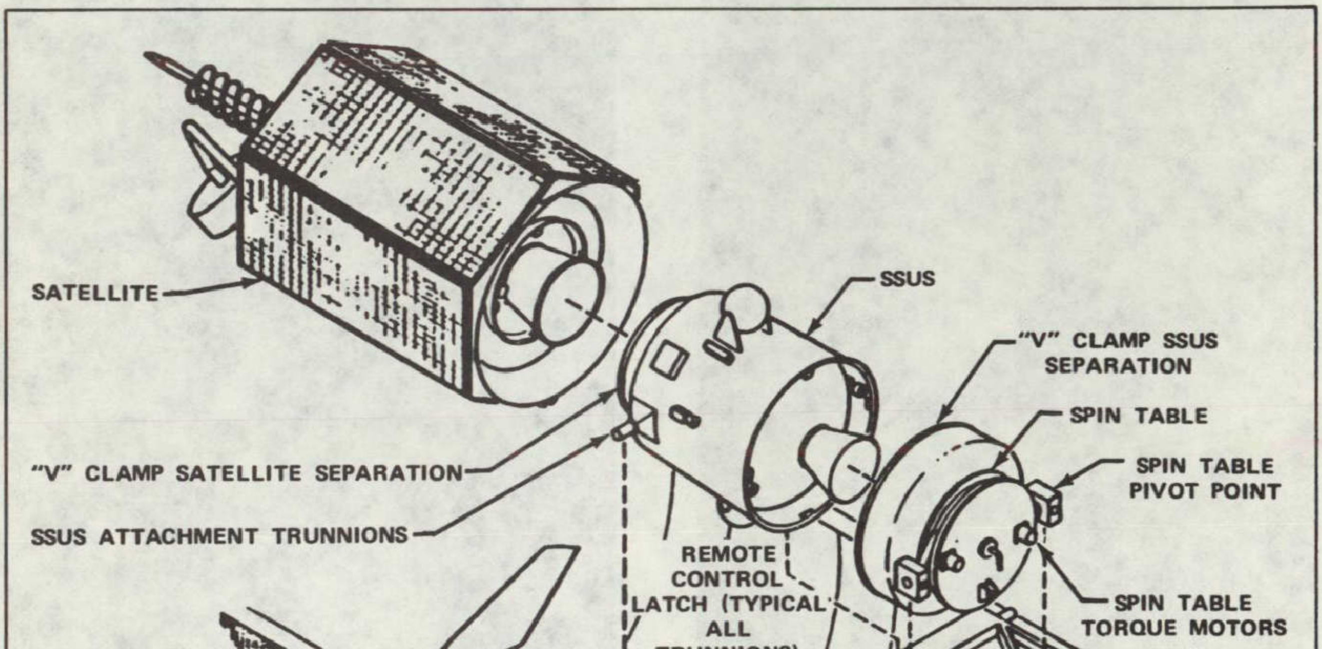
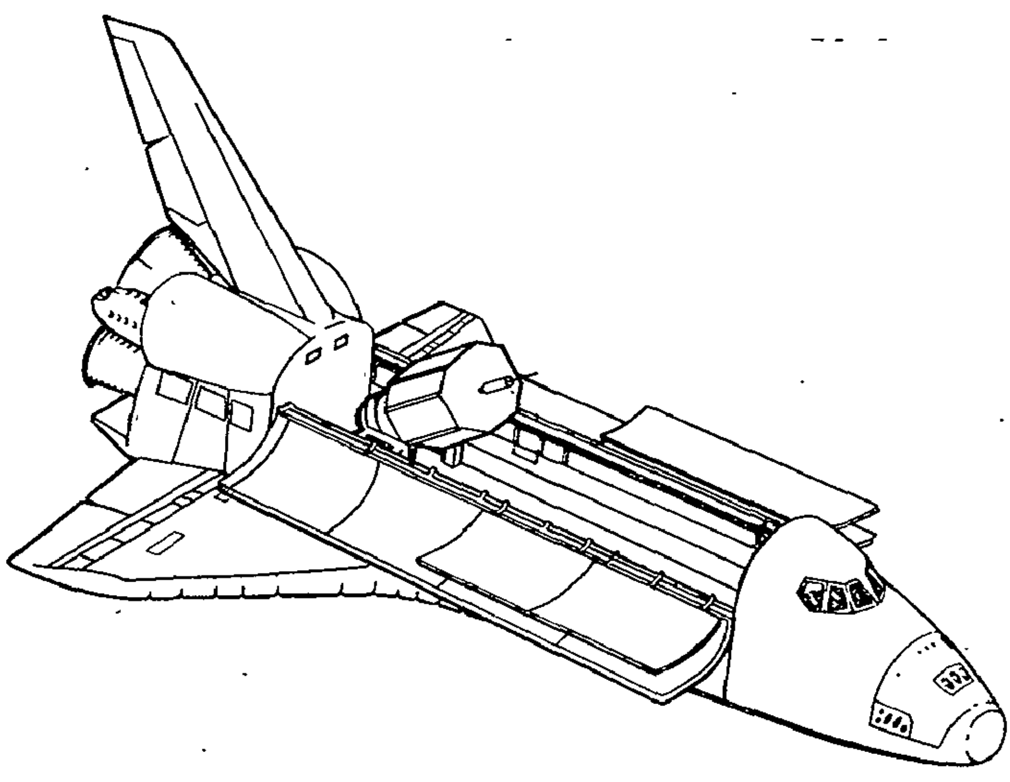


Diagram of SSUS structure in cargo bay.

pounds (1800 to 1996 kilograms) to be put into geosynchronous transfer orbit. It is expected that four Delta class (SSUS-D) or two Atlas-Centaur (SSUS-A) class stages with spacecraft can be carried on a single Shuttle flight. One or two SSUS/spacecraft may also share a flight with other Orbiter payloads.

For a nominal geosynchronous mission, the Shuttle Orbiter places the payload into a 160-nautical-mile (296-kilometer) circular orbit inclined at 28.5°. After checkout, the SSUS and spacecraft are spun up and deployed by the Orbiter. Initial stabilization position, attitude, and the perigee velocity vectors are obtained from the Orbiter. The spin-up procedures are initiated and controlled from the Orbiter aft flight deck. Spin capability of up to 100 rpm for the SSUS-D and 65 rpm for the SSUS-A is available from the airborne support equipment (ASE) spin-up mechanism. After the SSUS and spacecraft are released, the Orbiter maneuvers to a safe distance. The SSUS and Orbiter coast in the parking orbit for approximately 45 minutes until the appropriate crossing of the Equator. At this time, the SSUS motor fires and injects the SSUS/spacecraft into a 160- by 19 323-nautical-mile (296- by 35 786-kilometer) geosynchronous transfer orbit.

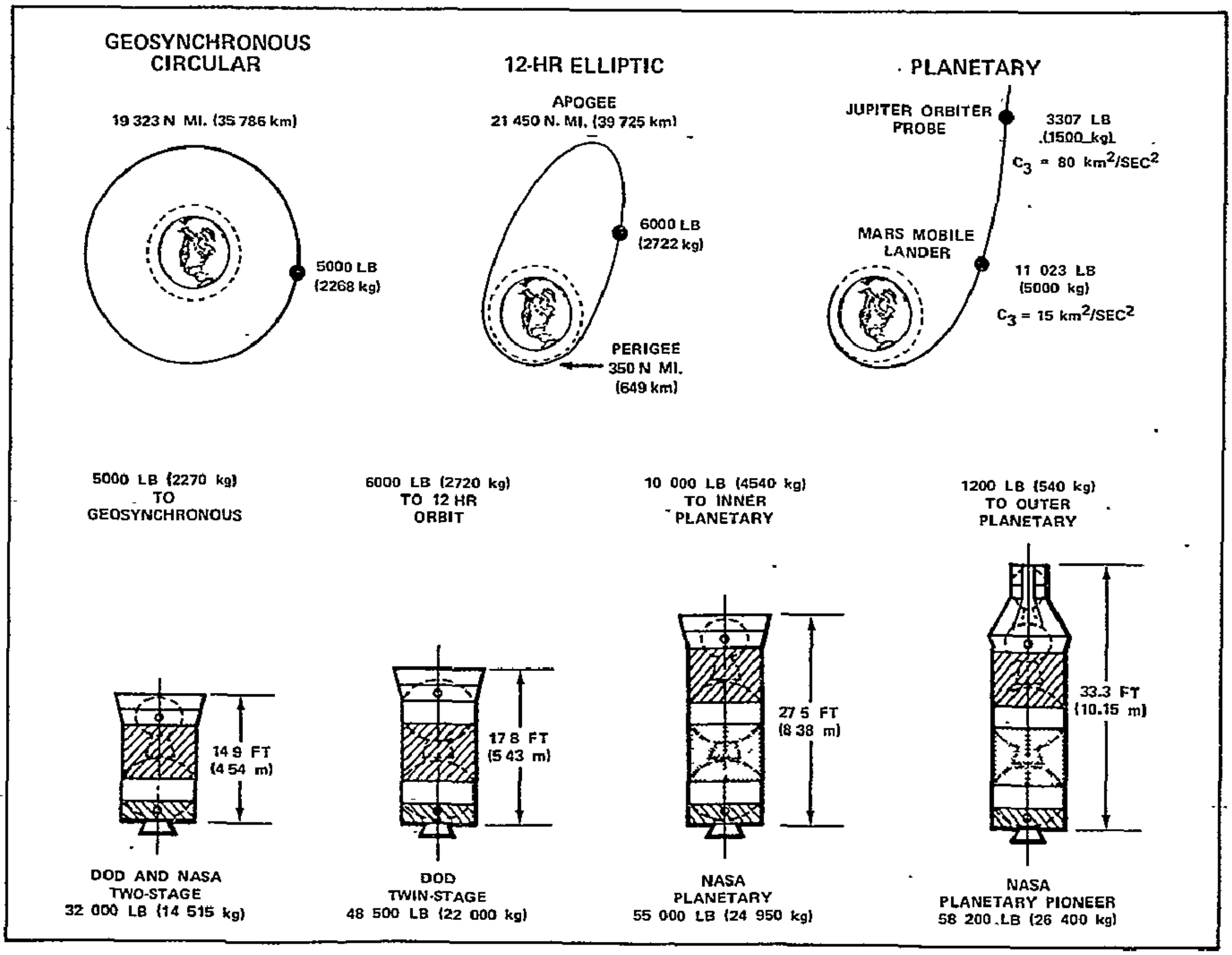


SSUS tilt/spin table mounted in the Orbiter cargo bay.

Interim upper stage

The IUS, under development by the Department of Defense (DOD), relies upon a three-axis stabilized propulsive and avionics system for trajectory and stability control to place larger class spacecraft or multiple spacecraft in Earth orbit, or to place planetary spacecraft on escape trajectories. The IUS has the potential for simple and standard operational and functional interfaces with the spacecraft, Orbiter, supporting facilities, and ground equipment for a wide range of missions. Spacecraft are cantilevered from the interface adapter and all services to and from the spacecraft are through the IUS. Deployment is by means of the remote manipulator system.

The IUS family consists of a basic two-stage vehicle with three- and four-stage configurations for the high-energy missions. The two-stage vehicle can accomplish all of the projected DOD and NASA Earth-orbital missions. The three-stage vehicle is formed by adding another large motor as a lower stage to the two-stage vehicle. The four-stage vehicle is formed by adding an existing motor to the three-stage vehicle. The three- and four-stage vehicles are required for the Earth escape missions.



Preliminary performance options of the IUS configurations. (Final performance data will be available late in 1977.)

LONG DURATION EXPOSURE FACILITY

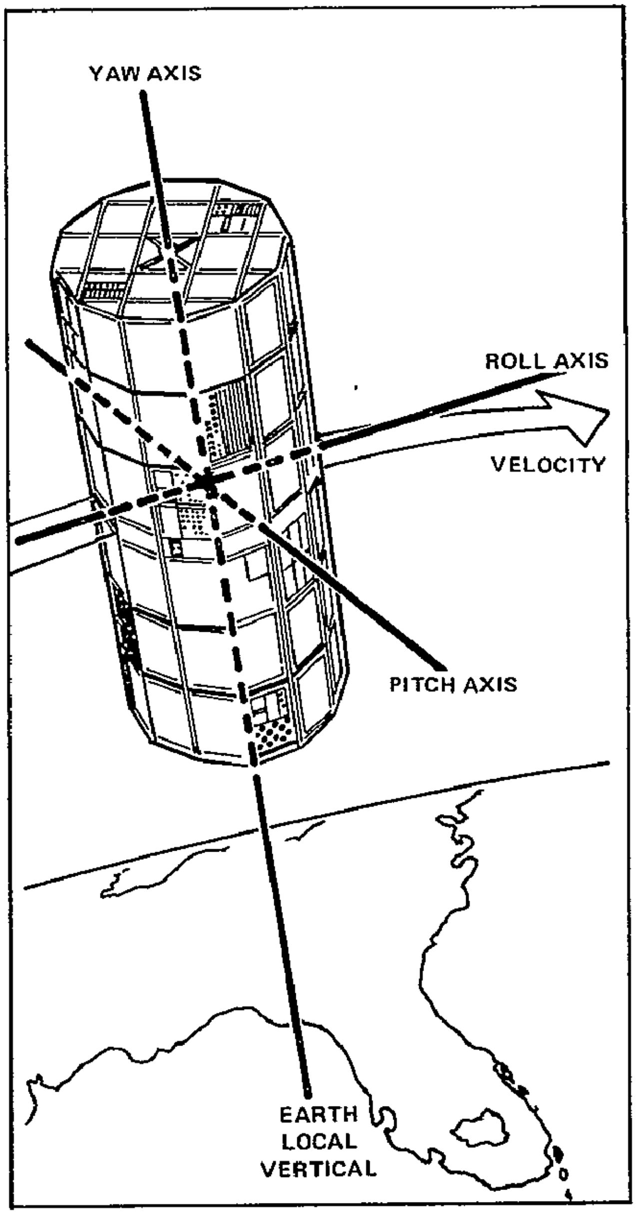
The Long Duration Exposure Facility (LDEF), being developed by the NASA Office of Aeronautics and Space Technology, is a reusable, unmanned gravity-gradient-stabilized, free-flying structure. It can accommodate many technology, science, and applications experiments, both passive and active, that require exposure to space. The LDEF provides an easy and economical means for conducting these experiments. Users are expected to include governments, universities, and industries in both the United States and other countries.

Though not considered an STS element, it is available to users from NASA and is delivered by the STS. The Space Shuttle Orbiter places the LDEF in Earth orbit, where it remains for 6 months or more until another Shuttle flight retrieves it and returns it to Earth. In orbit, the Orbiter remote manipulator system removes the LDEF from the cargo bay. The longitudinal axis of the LDEF is aligned with the local Earth vertical, other required orientations are established, and the angular velocities are brought within specified limits. The LDEF is then released into a circular orbit of approximately 300 nautical miles (556 kilometers) with an inclination to the equatorial plane between 28.5° and 57°. Gravity-gradient stabilization is used in combination with a viscous magnetic damper to null transients. Initially, the LDEF undergoes large periodic motions. Within 8 days, the steady-state point is within 2° of local Earth vertical and oscillations about the longitudinal axis are within 5°. The maximum acceleration level at release is 1×10^{-3}g and the maximum steady-state acceleration is 1×10^{-6}g. The orbital period ranges from 92.8 to 95.6 minutes. During the planned exposure the altitude decays about 20 nautical miles 37 kilometers).

After the Orbiter lands and the LDEF is removed from the cargo bay, the experiments are removed and returned to the experimenter.

For passive experiments, data measurements will be made in the laboratory before and after exposure to space conditions. Power, data storage, and other data-gathering systems may be necessary for active experiments. These must be provided by the experimenter as an integral part of the experiment assembly. Each experimenter will work cooperatively with the LDEF Project Office at the NASA Langley Research Center in establishing that the experiment is safe to fly and will not adversely affect other experiments on the LDEF.

The "natural" orbital environment (acceleration, ambient atmosphere, particle flux, magnetic field, and solar radiation) combines with the predicted



Orientation of LDEF in free flight.

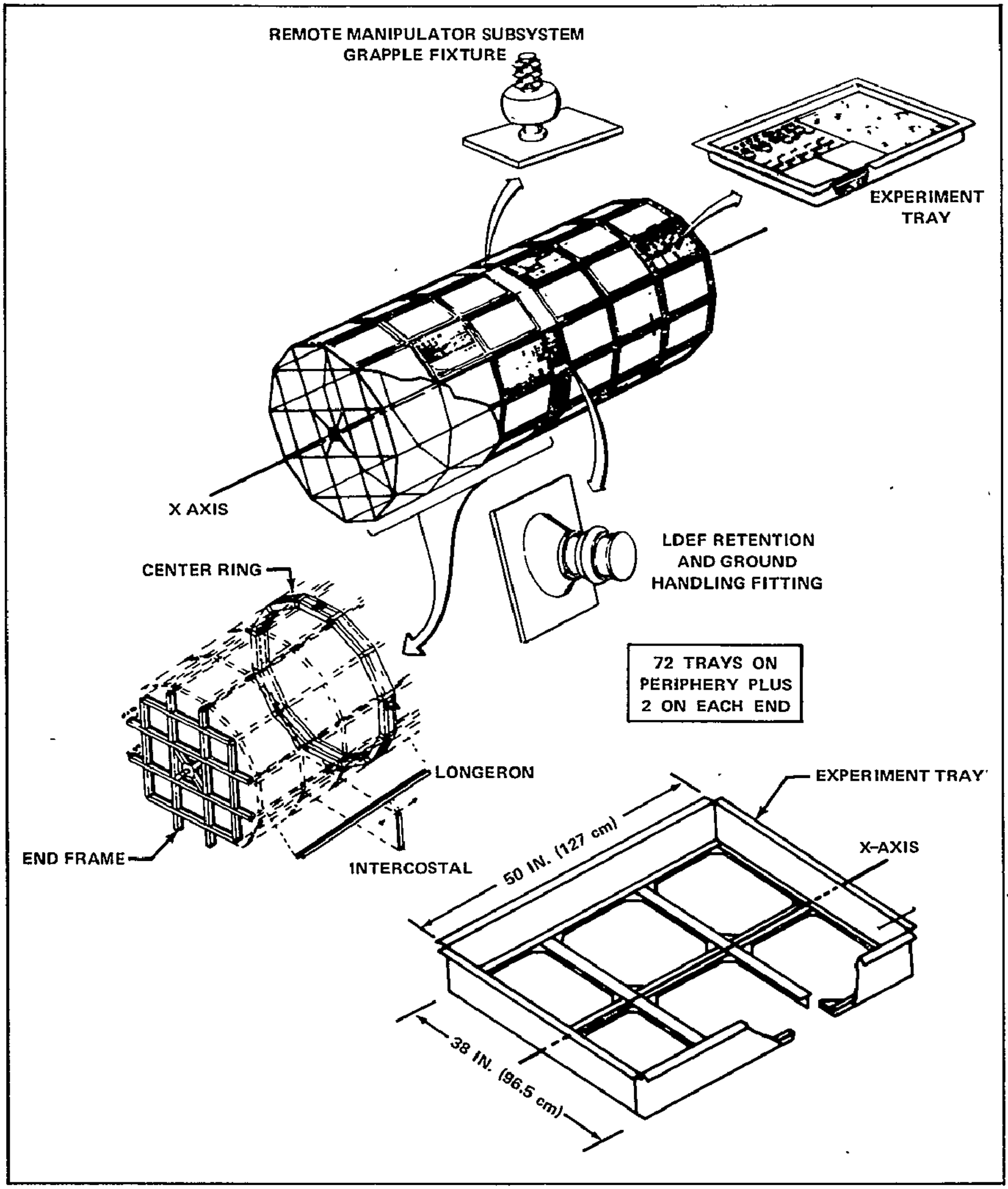
thermal environment shown in the table to establish the conditions under which an experiment must operate. Temperatures shown in the table could vary as much as ±27 °F (±15 K) as a result of variations in design and coatings or accuracy of the mathematical model. The overall environment will vary, depending on the exact orbit and the location of the experiment on the LDEF. In addition, an experiment environment can be modified by such design parameters as shielding, pressure-sealed containers, or special thermal coatings. (The data in the table are for experiments using typical surface coatings.) Any such modification will be the responsibility of the experimenter. However, the LDEF Project Office will provide consultation on applicable techniques and design approaches. After an experiment is selected for the LDEF, the LDEF Project Office will define the specific conditions available and work closely with each experimenter in choosing the best possible location for the experiment.

The LDEF is a 30-foot (9.14-meter) long structural framework as shown in the figure, with room for 72 experiment trays on the periphery and 2 trays on each end. The LDEF cross section is a 12-sided regular polygon of bolted aluminum I-beam construction with a diameter of 14 feet (4.27 meters). The primary framework consists of 7 ring frames and 12 longerons fabricated from aluminum extrusions. Trays containing experiments are mounted into the bays formed by the ring frames and longerons. Each tray is approximately 50 inches long and 38 inches wide (127 by 97 centimeters). Trays are 3, 6, or 12 inches deep (8, 15, or 30 centimeters). Trays are provided by NASA and individual experiments are bolted to the trays. Standard experiments are sized to fill a full tray or 1/6, 1/3, or 2/3 of a tray. The total mass allowable in a single tray is 175 pounds (79

Predicted thermal environment ranges
[57° inclination orbit]

Location	Minimum temperature, °F (K)	Maximum Temperature, °F (K)	Typical temperature differential per orbit, °F (K)
On LDEF structure			
Internal average	-22 (243)	95 (308)	--
Earth end (aluminum surface)	-13 (248)	104 (313)	9 (5)
Space end	-13 (248)	113 (318)	45 (25)
Typical experiment			
$\alpha = 0.3, \epsilon = 0.3$[a]			
Internal surfaces	-31 (238)	122 (323)	5 (3)
External surfaces	-40 (233)	167 (348)	--
$\alpha = 0.25, \epsilon = 0.17$			
Internal surfaces	-58 (323)	149 (338)	18 (10)
Thin external surfaces	-175 (158)	302 (423)	364 (200)
$\alpha = 0.3, \epsilon = 0.8$			
Internal surfaces	-53 (158)	86 (303)	11 (6)
External surfaces	-103 (198)	86 (303)	--

[a] α absorptivity, ϵ emissivity



Structural characteristics of LDEF and experiment trays.

kilograms). Experiment sizes are not necessarily limited to the dimensions of trays; heavier or larger experiments and different mounting locations or arrangements will be considered on an individual basis. However, no experiment can protrude beyond the planes defining the 12-sided polygon of the LDEF.

The LDEF Project Office has the overall responsibility for experiment integration. Experimenters will assemble their own flight experiments and, when using full trays, may also mount them in the trays. Experiments will be sent to Langley Research Center, where partial-tray experiments will be mounted and all trays will undergo flight acceptance testing. The LDEF Project Office also will provide for the correct placement of trays on the LDEF to obtain the desired exposure, field of view, etc., and will assure the mutual compatibility of all experiments. The trays will be sent to the John F. Kennedy Space Center (KSC) launch site, where they will be bolted onto the LDEF.

An experimenter may participate in launch site operations and verify flight readiness of the experiment, if required. The experimenter will also have an opportunity to view the experiment on its return from orbit, before it is removed from the LDEF at KSC.

The LDEF approach to low-cost space operations has been engineered and standardized with the STS operations. Therefore, the experimenter can devote his total energies to his experiment and let the LDEF Project Office take care of getting it into space.

Announcements of flight opportunities or announcements of flight periods issued regularly by the NASA Office of Aeronautics and Space Technology will aid in the experimenters' planning process and will provide greater detail on specific technical objectives. With this information, an experimenter can better identify experiment objectives, requirements, and schedules.

Because the LDEF can fly a wide variety of missions, the exposures available for experiments cannot be fully presented in a brief summary. Data given here are intended to serve only as a guide to the prospective experimenter. More detailed data are provided in the document, Long Duration Exposure Facility (LDEF) Guide for Experiment Accommodations, prepared by the LDEF Project Office. Additional information is available from the LDEF Experiments Manager, Mail Stop 158B, National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia 23665; telephone (804) 827-3704, FTS 928-3704.

Interface flow

STS OPERATIONS

↕

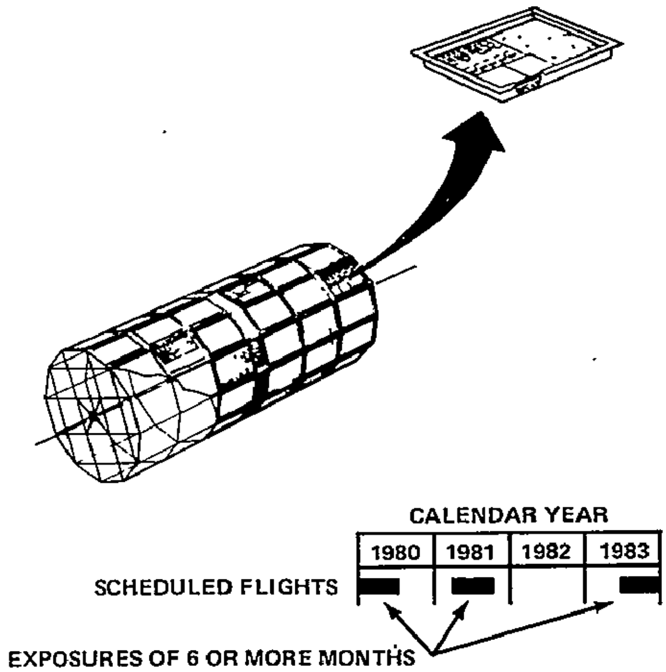
LANGLEY RESEARCH CENTER
LDEF PROJECT OFFICE

↕

PRINCIPAL INVESTIGATORS

REPRESENTING

- LANGLEY RESEARCH CENTER
- OTHER NASA CENTERS AND GOVERNMENT AGENCIES
- UNIVERSITIES
- INTERNATIONAL ORGANIZATIONS
- INDUSTRY



Responsibility	Phase						
	Initial program planning and approval	Mission and experiment planning	Operations integrated planning [a]T-2 years to T-16 weeks	Final flight planning, T-16 weeks to T=0	STS flight operations	LDEF flight operations	Postflight
Langley Research Center	Primary	Primary	Primary	Support	Support to POCC	Primary	Primary
STS operations	Provide User Handbook	Provide STS user references	Provide supporting documentation	Primary	Primary	None	None

[a]T = time from launch.

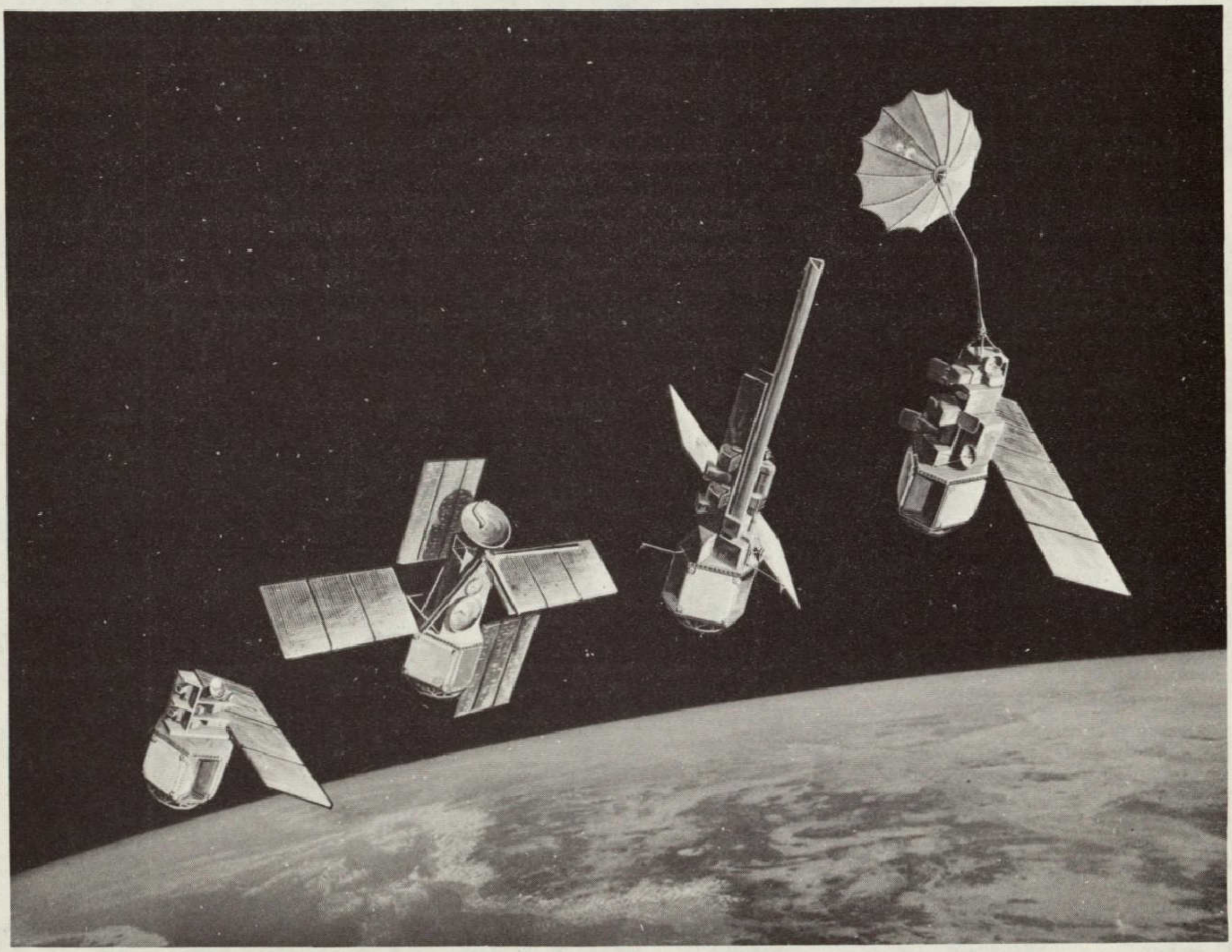
An example of a principal investigator's involvement in ongoing LDEF operations. The primary interface is shown, along with a flight schedule and the NASA centers' responsibilities.

MULTIMISSION MODULAR SPACECRAFT

The Multimission Modular Spacecraft (MMS) can be used in low Earth and geosynchronous orbits for a wide range of remote-sensing missions. Although not classified as an STS element, it is a planned NASA payload carrier fully compatible with the launch environments and other requirements of the Space Shuttle as well as with a variety of expendable launch vehicles (including the Delta 2910 and 3910 series).

The reusable MMS offers several significant advantages over the conventional uniquely integrated spacecraft. Within its standard range of capabilities, it can be adapted to many varied payload requirements, eliminating the need for costly and time-consuming design, development, production, and procurement activity.

The Multimission Modular Spacecraft with its payload can either be brought back from space or reserviced on orbit by the Space Shuttle, as desired by the user. This represents a major cost-saving capability unavailable with uniquely integrated spacecraft. In instances where on-orbit repair or refurbishment is not desired, the MMS can be retrieved by the Space Shuttle, returned to Earth for refurbishment or upgrading, and relaunched.



Typical Multimission Modular Spacecraft mission configurations.

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The flight support system that carries the MMS in the Orbiter cargo bay also provides the on-orbit reservicing capability. In addition, this flight support system is versatile enough to be adapted to other types of spacecraft.

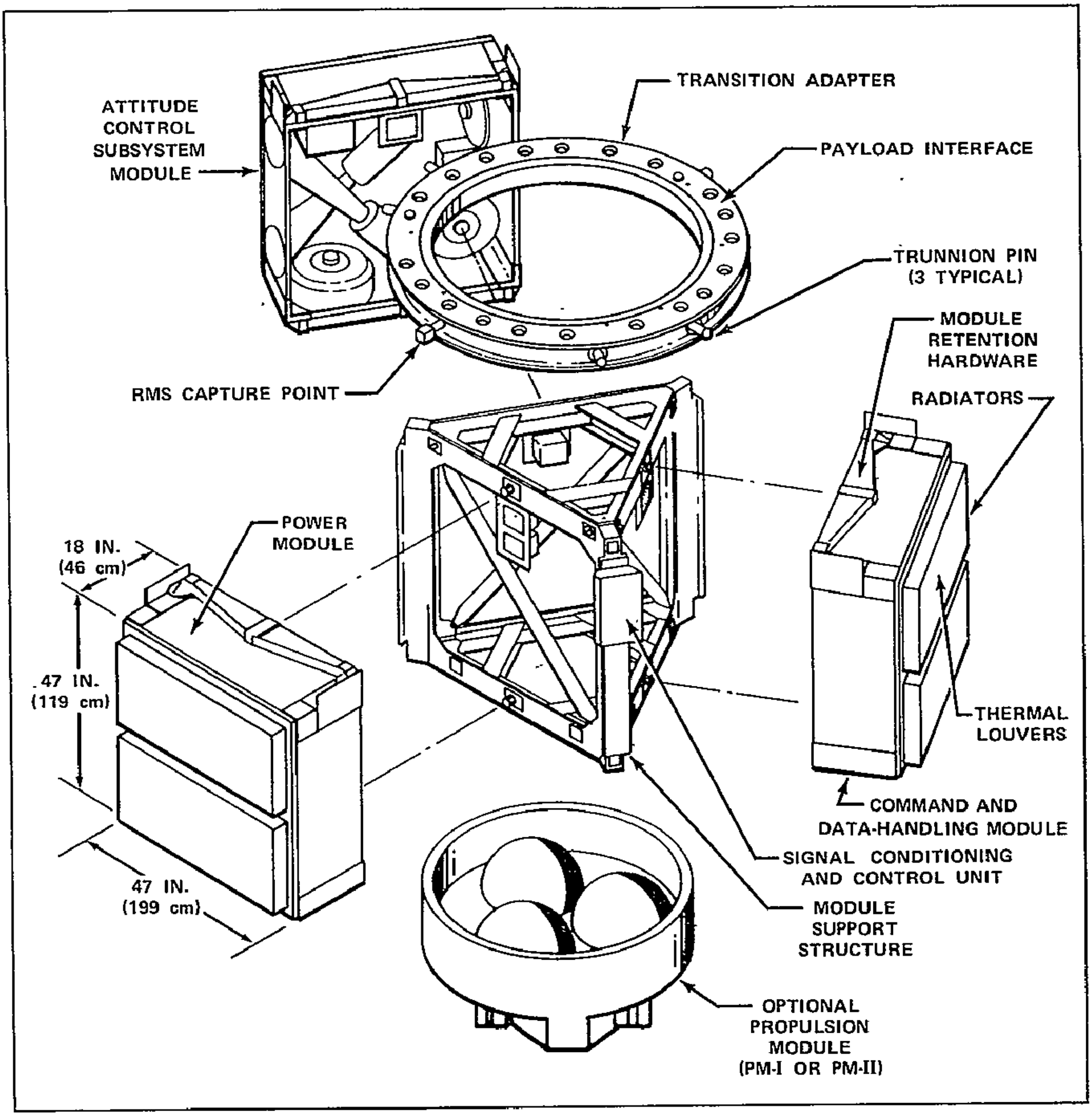
The program management responsibility for development of the MMS is within the NASA Office of Space Science. More detailed information on MMS capabilities and missions, as well as on the flight support system, is contained in the Multimission Modular Spacecraft Users' Guide prepared by the Goddard Space Flight Center, which is responsible for technical management of the MMS project. A copy of the guide or other information is available from the MMS Project Office, Code 408, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Md. 20771; telephone (301) 982-5913, FTS 982-5913.

MMS systems and capabilities

The basic MMS consists of two major structural subassemblies plus three major subsystem modules. The module support structure subassembly interfaces with the transition adapter subassembly, and is the central core structure of the MMS. It carries all structural loads imposed by, and all structural and functional interfaces with, the modules. In addition, when the MMS is launched on expendable vehicles, the module support structure carries all launch loads.

The transition adapter provides a standard payload interface to the MMS, provides the interface to the Space Shuttle Orbiter (through appropriate supporting hardware), and provides the capture point interface to the Shuttle remote manipulator system (RMS) for retrieval and on-orbit servicing or return to Earth.

The three major subsystem modules, each having a standard range of performance capabilities, provide communications and data handling, power, and attitude control services. Optional propulsion modules are available as required, and a variety of mission-specific subsystem elements can be added to tailor the capabilities of the MMS to the user's requirements. Examples would include a tape recorder in the command and data-handling module, or additional batteries in the power module. Additional features such as antenna systems and solar arrays, also considered mission-specific, must be supplied by the user.



Modular mechanical subsystem components of the MMS.

General MMS capabilities

Payload weight

For Shuttle launches, in excess of 10 000 pounds (4536 kilograms) limited by payload configuration

Orbital capability

Low-Earth, 270 to 864 nautical miles (500 to 1600 kilometers) (any inclination) and geosynchronous.

Life expectancy/redundancy

Minimum life expectancy of 2 years. The MMS is designed to have no single-point failure that would prevent resupply or retrieval by Shuttle

Subsystem performance capabilities

Communications and data handling subsystem	
Transponder	S-Band, STDN/TDRSS, transponder output power at antenna port 1.0, 2 5, 5.0 watts Prelaunch selectable
Command rates	2 kilobits/sec baseline, 125 to 1 kilobits/sec selectable
Telemetry rates	1, 2, 4, 8, 16, 32 or 64 kilobits/sec
Telemetry formats	2 selectable prior to launch, plus in-orbit programmable capability; all formats contain 692 data word maximum
Onboard computer	18 bits per word, 32 000 words of memory, baseline expandable to 64 000 words 5 microsecond add time
Payload accommodation	
Maximum remote interface units (RIU) and RIU expanders for experiments	27 units plus 3 expanders per RIU
Command capability per RIU	Eight 16-bit serial magnitude, 62 discrete/relay drivers
Telemetry capability per RIU or RIU expander	64 inputs All usable for analog/discrete bilevel, 16 usable for serial digital, 8 bits each
Attitude control subsystem	
Type	3-axis, zero momentum
Attitude reference (without payload sensor)	Stellar (inertial)
Pointing accuracy (one sigma)	
without payload sensor	<0.01°
with payload sensor (ideal)	<0 00001° (direct analog signal processing) <0.0001° (signal processing via computer)
Pointing stability (one sigma)	
Average rate	<0 000001 deg/sec
Jitter	
Without payload sensor	<0 0006° (20 min)
With payload sensor (ideal)	<0.000001° (direct analog signal processing) <0.00001° (signal processing via computer)
Slew rate	Based on spacecraft inertia
Power subsystem	
Regulation of load bus	+ 28 ± 7 V dc
Bus noise and ripple	1.5 V P-P (1 to 20 MHz) maximum
Load bus source inpedance	<0.1 ohm (dc to 1 kHz) <0 15 ohm (1 kHz to 20 kHz) <0.30 ohm (20 kHz to 100 kHz)
Typical load switching transients	± 2 V (50 millisec)
Fault mode transients	Down to 0 V or up to 40 V for 500 millisec
Batteries	Two 20-ampere-hour batteries as baseline and up to three 50 ampere-hour batteries maximum
Power capabilities	200 watts, average, 3000 watts, peak (allowable for 20 min, once per orbit, day or night)
Module temperature range	0 to 40° C (273 to 313 K)
Propulsion subsystem	
Propellant	Hydrazine (MIL-P-26536C, Amendment 1)
Propellant load	
PM - I	167 lb (75.75 kg)
PM - II	1060 lb (480.8 kg)
Pressurant	Gaseous nitrogen
Thrusters	12 at 0 2 lbf (0.9 N); 4 at 5 lbf (22.24 N)
System operating mode	3 to 1 blowdown
Design operating pressure	400 psia (2758 kN/m^2)
Design burst pressure	160 psia (11 032 kN/m^2)
Thermal control	Active and passive
Operating temperature range	10 to 60° C (283 to 333 K)

Flight support system

Both for transport to orbit and for servicing and retrieval, the MMS is supported in the Orbiter cargo bay, structurally and functionally, by the flight support system. This system, as currently designed, consists of four major subsystems: the retention cradle, the payload positioning platform, the module exchange mechanism, and the module magazine.

Each of the four major elements can be operated independently or they can be used collectively as a unified system, depending on the specific mission requirements.

During Shuttle launch and landing, the MMS is carried in the retention cradle, which provides mechanical interfaces to the MMS transition adapter (through which launch and landing loads are transmitted). The retention cradle may be the only element necessary for a launch or retrieval mission (if RMS or spring-ejection deployment is used).

If the mission requires erection out of the cargo bay, to a predetermined position relative to the Orbiter, the payload positioning platform is added to the retention cradle. For deployment, the MMS is erected by the platform to a vertical position. It is grappled by the remote manipulator system, released from the positioning platform, deployed by the RMS, and released. For retrieval, these operations are reversed. After the Shuttle establishes rendezvous and stationkeeping with a free-flying MMS, the RMS grapples the spacecraft and berths it onto the erected positioning platform. If the MMS is to be returned to Earth, it is lowered into the retention cradle.

In the case of a servicing mission, the payload positioning platform, module exchange mechanism, and module magazine are required. Replacement modules are carried into space in the module magazine. After the MMS is captured and berthed, the module exchange mechanism removes a new module from the magazine and exchanges it with the old module in the MMS. After the servicing operation is completed and systems are checked out, the MMS is again deployed by the RMS.

The baseline envelope requirement for the retention cradle is the support of two MMS in an over-and-under orientation. Other spacecraft configurations or a complement of mixed spacecraft can be accommodated by use of interface hardware that satisfies the unique spacecraft requirements on one side and adapts to standardized support system fittings on the other side.

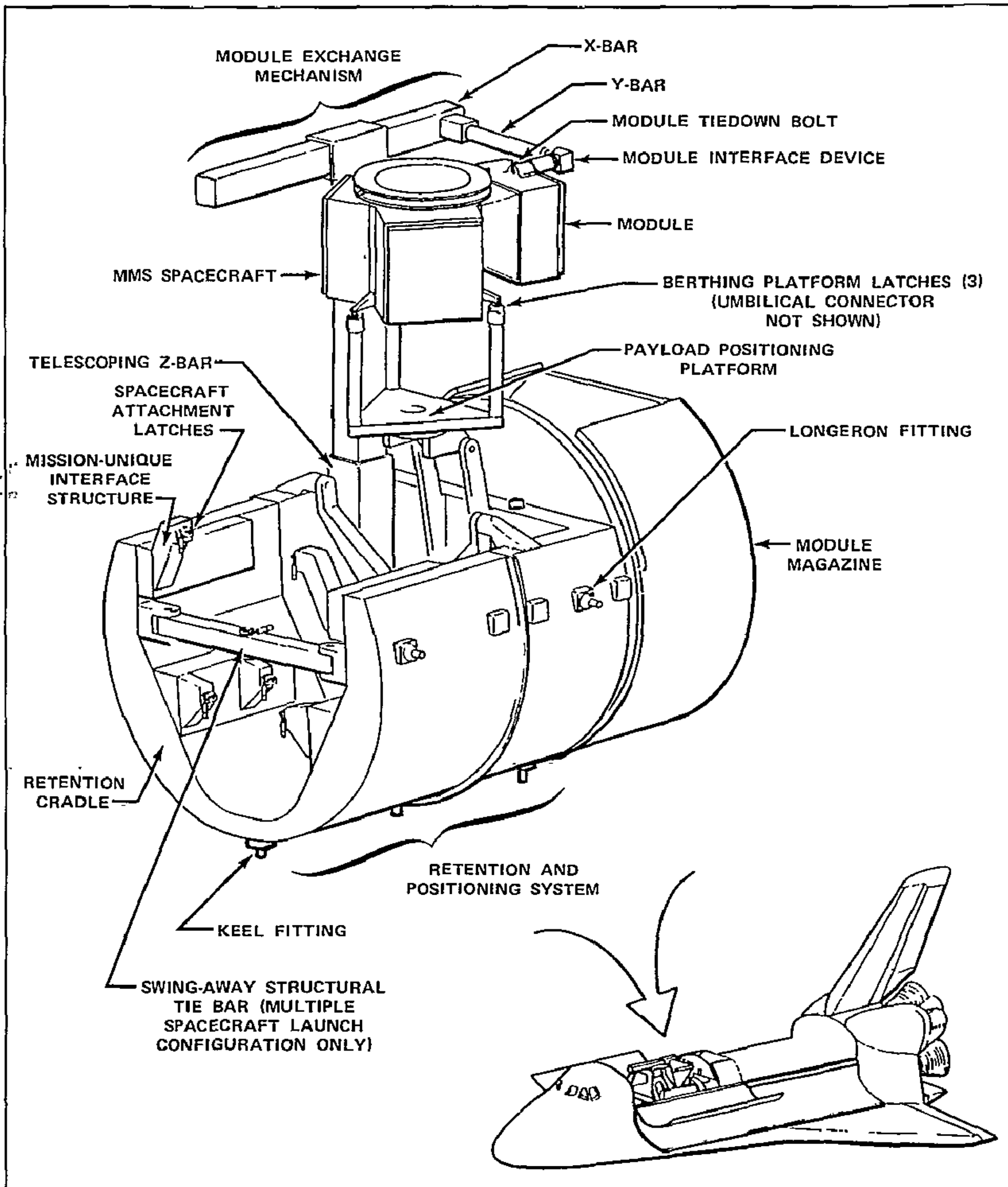
The basic retention-cradle core structure is designed to accommodate a single large spacecraft such as the MMS with a large payload; a small spacecraft piggyback with a satellite such as the Intelsat-5; two MMS; an MMS with two smaller spacecraft; or four smaller spacecraft.

The spacecraft is structurally attached with a set of three trunnions (mounted on the MMS transition adapter), each locked in place by a remotely operated latch mechanism. These latches and their supporting structure can be located forward and aft, up or down the side wall structure of the retention cradle. The ability to place these latches almost anywhere in the retention cradle is a key feature in providing payload accommodation versatility. In short, the retention cradle uses a pegboard approach.

The pegboard approach is also applied to the payload positioning platform. Depending upon the specific mission, the platforms can be hinged from almost any position in the cradle in order to achieve the desired swing trajectory and erection position.

In addition to positional versatility, the payload positioning platform can accommodate various payload adapters ranging from standoff posts and conventional conical structures to spin tables and spring separation systems.

For spacecraft missions requiring precision pointing before Orbiter separation, star trackers can be mounted to the platform. The Orbiter is oriented to the desired position as referenced by the platform tracker output data. This type platform pointing eliminates the thermoelastic and mechanical tolerance errors caused by transferring coordinates from the Orbiter inertial measurement unit to the launch platform.



Structural assemblies of the basic flight support system, mounted in the Orbiter cargo bay.

Management and procedures

Flight systems

3

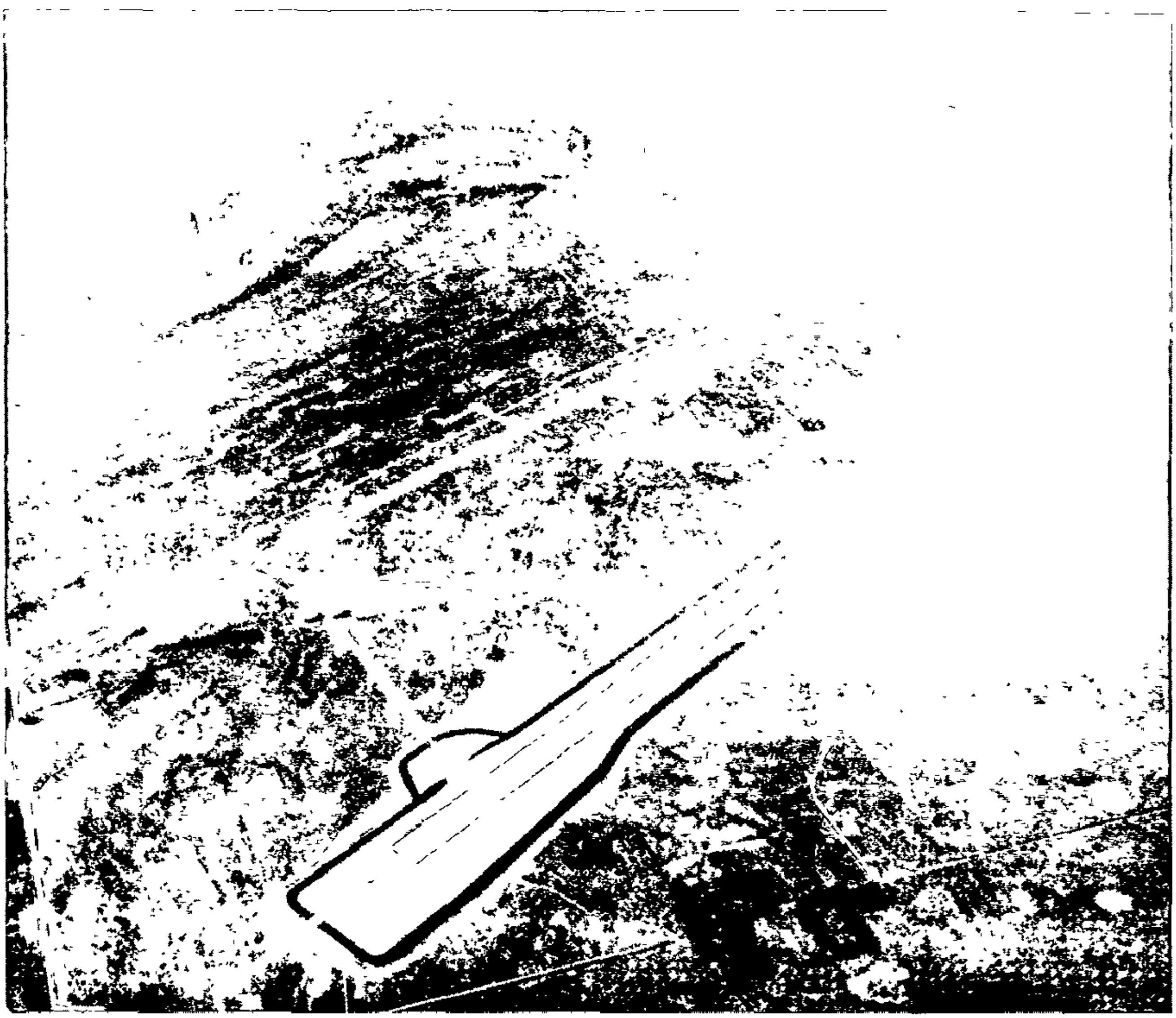
Launch and landing site operations

Flight operations

Appendixes

Launch and landing site operations

AN OVERVIEW



Orbiter landing strip at KSC, showing the Vehicle Assembly Building at the top right.

User payloads receive final checkout, cargo integration, interface verification, and launch preparation at the launch site.

Certain standard facilities and services are generally available and are allocated on the basis of user requirements. Any special facilities or services required for a specific payload must be provided or funded by the user.

This section is intended to provide the user with a general understanding of the scope of operations at the launch site. Facilities and ground flow at the John F. Kennedy Space Center (KSC), as well as those unique to Vandenberg Air Force Base (VAFB), are described.

The user's responsibilities in support of launch site operations are defined through standard interfaces and documentation sequences summarized here. The basic document is the KSC Launch Site Accommodations Handbook for STS Payloads (K-STSM-14.1). A launch site support manager

(LSSM) will be assigned early in the planning program and will be the primary interface with the user.

(Payloads scheduled for standard carriers — such as the Long Duration Exposure Facility — will be integrated into the carrier and its ground operations by the organization responsible for that carrier.)

A brief explanation of the overall STS ground flow at the outset will help users understand how their own payloads fit into the pattern. Operations involving payloads and standard STS elements are described more fully under separate headings.

The Shuttle ground operations at KSC begin when the Orbiter lands. Some payload time-critical items may be removed at this time; for all other payloads, services such as purging and ground power are initiated.

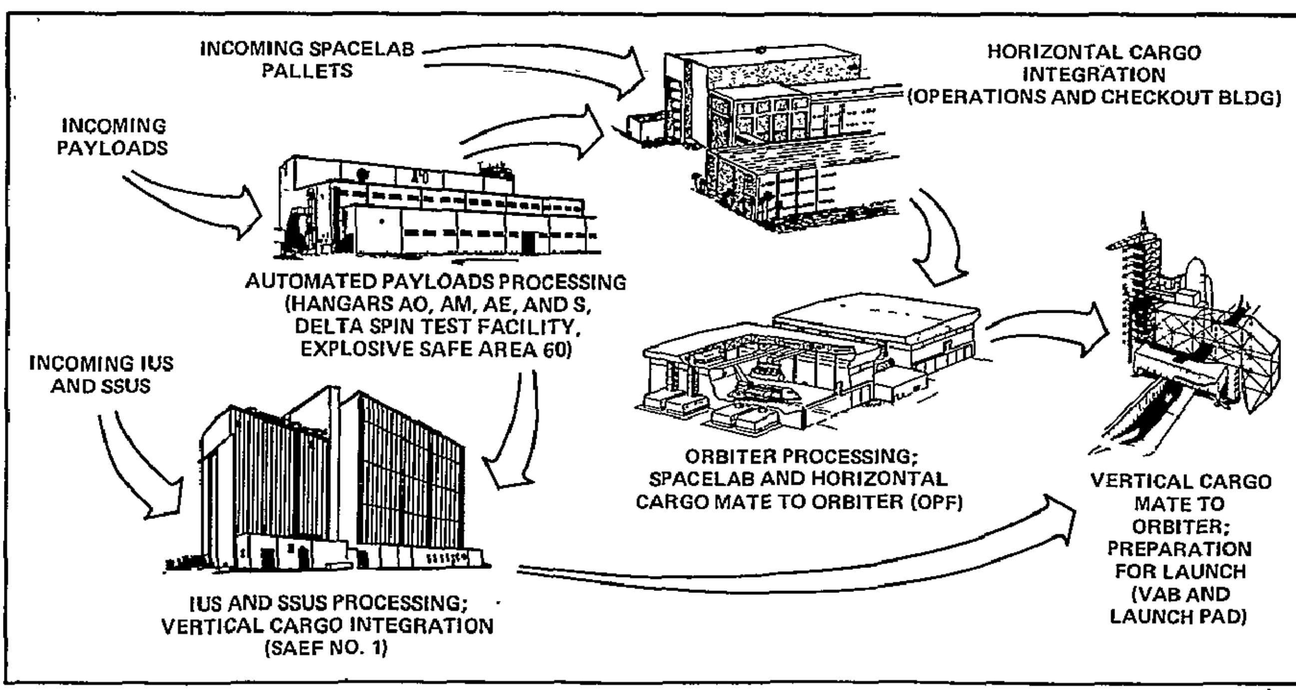
The Orbiter is then towed to the Orbiter Processing Facility (OPF), where most payloads are removed. Maintenance and checkout of the Orbiter for its next flight are done here, while certain subsystems may be removed and serviced elsewhere.

New or refurbished payloads, meanwhile, are being assembled and tested elsewhere at the launch site. Most payloads will be installed horizontally; they are brought to the OPF and put into the Orbiter at this time. The Spacelab, already integrated with its experiments, is installed in the OPF.

The Orbiter is towed to the Vehicle Assembly Building (VAB), where it is hoisted and rotated to a vertical position for mating to the external tank and solid rocket boosters. The Shuttle vehicle is then transferred to the launch pad on the mobile launch platform.

Those payloads that require vertical installation are brought to the launch pad (in an environmentally controlled canister) ready for installation and are put into the Orbiter by use of the payload changeout room (PCR). For example, an upper stage/spacecraft cargo is mounted in the Orbiter at this time.

After all necessary procedures and verifications are completed — involving both the Shuttle and the cargo — the countdown for launch begins.



Typical payload ground flow at the launch site.

KSC OPERATIONS

Payload transportation

Payloads can be transported to the launch site by any means acceptable to the user. The launch site is capable of receiving payloads shipped by air, overland, or water.

One method of overland shipment that has been acceptable to spacecraft programs is in a commercial air-ride van provided with environmental control. The payload is usually mounted on a platform and protected by a soft cover. It is estimated that this system could accommodate most spacecraft or as many as six Spacelab racks at one time. A typical example is illustrated later in this section.

In addition, a standard transportation method will be available to payload users for transporting payloads up to 14 feet 4 inches (4.37 meters) wide, 10 feet 10 inches (3.3 meters) tall, and 21 feet 10 inches (6.65 meters) long. This method would use containers mounted on commercial air-ride low-boy trailers. These maximum dimensions also provide for a 2-inch (5-centimeter) clearance all around. Power and environmental control is provided by a self-contained unit mounted on the trailer forward of the container. This system will accommodate the widest planned payload, which is a Spacelab pallet. A connected two-pallet train (with mounted elements not exceeding the overall height limit) can be transported if the overhang does not exceed 4 inches (10.2 centimeters) on one end and 28 inches (71.1 centimeters) on the other. A pallet with taller experiments must be turned on its side, so that the 9-foot 8-inch (2.95 meter) length of the pallet becomes the height. In this configuration – the same position as the pallet will be at the Shuttle launch – only one loaded pallet can be accommodated in a container. Pallet keel fittings are not disturbed by this rotation. To utilize this standard transportation system, the user must initiate the transportation cycle by submitting payload shipment requirements to the launch site. Containers will be delivered to the user's site on a negotiated schedule.

Payload processing

Before mating with STS

Processing of a payload at the launch site can usually be divided into two distinct phases: those activities performed before the payload is mated with an STS element and those activities involving one or more of the STS elements (Shuttle vehicle, Spacelab, upper stage).

The typical operations that must be performed to ready a payload for launch on a Shuttle vehicle will vary according to the complexity of the payload, the technical disciplines involved, and the level of testing already done before the payload arrives at the launch site.

Because of the 160-hour turnaround constraint for preparing Space Shuttle Orbiters for launch, integration of payloads with the Orbiter will be limited to mandatory tasks. A payload element should be delivered to the launch site in as near flight-ready condition as is practical. Typical prelaunch operations include receiving, assembling, checking out, servicing, and preparing for integration with other payload elements. Preparation and testing will not follow a fixed plan for all payloads.

The launch site activity plans must be established before arrival of a specific payload at the site to assure satisfactory completion of all flight-readiness preparations, including integration into a total cargo. The schedule will identify all major tests, all hazardous (systems) operations, interface verification, and all operations that require launch site services.

Individual payloads will be integrated into a single cargo before mating and checkout with the Orbiter. The integration testing of the total cargo will include a Shuttle interface verification test, using the cargo integration test equipment, before the mating of cargo and Orbiter. This test is critical to the overall operation because Shuttle on-line operations assume compatibility between the cargo and the Shuttle system.

Customized STS/payload time lines, negotiated through the LSSM, will be part of the launch site support plan for a particular payload.

Mating of payload with STS

Those operations required to prepare the Orbiter for payload installation are performed in parallel with the Orbiter systems checkout. These payload-related operations include installation of any payload accommodations modification kits assigned for the flight. Then payload/STS operations can begin.

Payload operations involving the Shuttle begin with the actual payload installation, either at the Orbiter Processing Facility or at the launch pad (using the payload changeout room).

Payloads installed horizontally are put into place in the OPF at this time. They are hoisted into the cargo bay and secured. Interfaces are connected and verified. Then an Orbiter integrated test is conducted to complete the verification of interfaces between the payload and Orbiter. This test includes validation of payload data via Orbiter data systems, if applicable.

After the cargo bay doors are closed, the payload environment will be maintained to the Vehicle Assembly Building and then to the launch pad. There will be a period of approximately 40 hours during Orbiter hoisting operations in the VAB when the environmental purge will be interrupted.

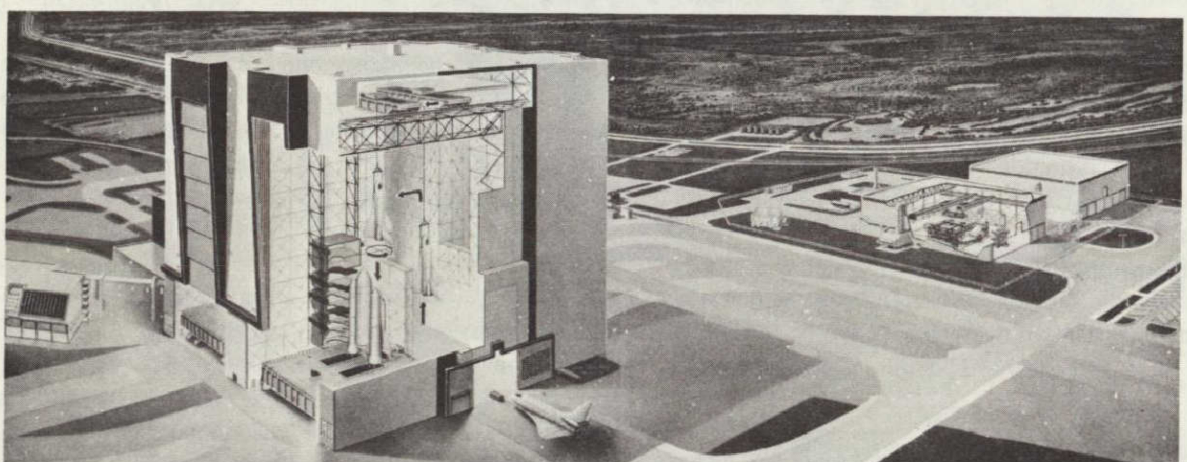
At the VAB, the Orbiter is hoisted to a vertical position, transferred to an integration cell, and lowered and mated to the external tank and solid rocket boosters. After the Orbiter aft umbilicals have been connected, a Shuttle interface test is conducted to verify vehicle/facility interface compatibility and readiness.

No payload activities will be done in the VAB except those required for stationkeeping; for example, monitoring of a potentially hazardous system. Electrical power will not be available for payloads from the Orbiter during tow to the VAB, Orbiter erection in the VAB, and transfer to the launch pad.

The integrated Shuttle vehicle is transferred to the launch pad on the mobile launch platform. The vehicle and platform are mated to the pad and the interfaces are verified.

Payloads that require vertical installation are moved to the launch pad in an environmentally controlled canister the same size as the Orbiter cargo bay. At this time, those payloads are installed in the Orbiter by the payload ground handling mechanism in the payload changeout room. Environmental control is maintained during the installation and the Orbiter-to-payload interfaces are verified.

A launch-readiness test verifies the integrity of the pad/Shuttle/payload system interfaces for launch. Hypergolic, fuel cell cryogenic, and pneumatic systems are serviced, and countdown preparations continue until 2 hours before launch. At that time the Shuttle cryogenic propellants are loaded, the flight crew boards, and final countdown is begun.



Vehicle Assembly Building with adjacent Orbiter Processing Facility.

Spacelab ground flow

The major user responsibility in the ground processing flow of Spacelab is for assuring that the payload elements function properly.

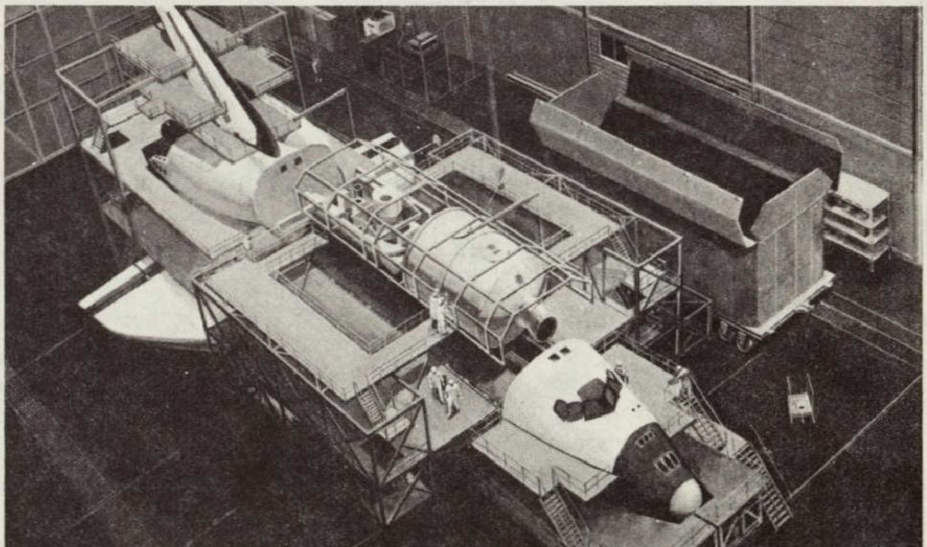
The Spacelab ground operations concept is mission independent and is applicable to all payloads. Experiment activities that occur before the experiment end-item is mated to the Spacelab support systems or simulators are not affected by these processing operations.

The user can design and develop an experiment and integrate it to the level at which a group of individual experiments are integrated into a complete Spacelab payload. Integration and checkout of experiment equipment with racks and pallet segments can be performed at the user's own facility or at some other site distant from the launch site. Experiments sponsored by ESA will use the European Integration Center for this type integration involving European payload elements (through the ESA office of Spacelab payload integration and coordination in Europe (SPICE)).

Racks and pallet segments ready for use will be shipped to the integration site, as will common payload support equipment according to individual mission requirements. Only that Spacelab ground-support equipment necessary to support handling and transport of the Spacelab elements will be sent to the remote sites.

Unique ground-support equipment and test and servicing equipment must be provided by the user. This type of equipment should be held to a minimum by making maximum use of Spacelab flight systems and ground-support equipment. Instrumentation system capabilities and sensors required to support ground test equipment must, if practical, be included in the flight experiment to minimize requirements for ground-support equipment. Ground-support equipment provided by the experimenter will be operated by the experimenter's personnel and will be scheduled and observed by the STS Spacelab processing team.

Access to the Spacelab exterior after it is installed in the Orbiter is through the cargo bay until the cargo bay doors are closed. While the Orbiter is still horizontal, limited internal access to the Spacelab pressurized module is available through the Orbiter cabin. At the pad/payload changeout room, where the Orbiter is in a vertical position, contingency access to both the interior and exterior is through the Orbiter cargo bay.



Spacelab being installed in Orbiter in the Orbiter Processing Facility.

Ground flow for upper stages

Initial preparation of the upper stages is accomplished separately from their payloads, which undergo concurrent operations in another building. The spacecraft are brought to the Spacecraft Assembly and Encapsulation Facility no. 1 (SAEF-1), where they are mated to their upper stages. Installation into the Orbiter cargo bay is normally done at the launch pad.

Interim upper stage

Buildup of the interim upper stage (IUS) begins with the first stage being placed in the assembly fixture. Next, the interstage assembly is connected to the first stage. The second stage is then installed. Proper alignment of the stages is verified and electrical interfaces are connected and verified. If the IUS is a three- or four-stage configuration, these stages are added in the same manner.

Following assembly of the IUS, airborne support equipment is connected and tests of subsystems and systems are performed to verify that the IUS and its airborne support equipment are functionally operational and that the IUS is in a proper status to receive its assigned spacecraft. These tests involve electrical and avionics, attitude control, and structural subsystems. Redundant circuits are individually verified where possible.

Systems and combined systems tests verify the overall functional compatibility of the IUS operating equipment. These tests include verification of proper guidance and control and other data processing software flow to the Orbiter interface points, particularly caution-and-warning-related items. Simulation equipment is used to provide end-to-end checks at incomplete interfaces involving ordnance items, the spacecraft and the Orbiter. IUS automatic checkout functions are performed and limited-scope flight simulation tests are anticipated. Once interfaces (mechanical and electrical connections) are mated and verified, they are maintained wherever possible.

After the IUS systems testing, the reaction control subsystem tanks are loaded with hydrazine. The system is pressurized to flight pressure and checked for leakage.

Preparations are then made for spacecraft mating operations. The spacecraft mounting adapter is installed, if it was not installed during buildup. The flight spacecraft and IUS cargo is assembled in a SAEF-1 stand where Orbiter interface compatibility (simulated) can be verified off-line and where ground handling capability is available for installation of the cargo into the payload canister.

The spacecraft is positioned on the SAEF-1 high bay floor and hoisted from its container/transporter support fixture, moved over the IUS spacecraft mounting adapter, and lowered into position. When in position, the spacecraft is bolted in place and interface connections are made. The IUS/spacecraft alignment is verified.

Two IUS vehicles being readied for the same flight are checked out and mated to their spacecraft sequentially.

The degree of testing required for any combination of IUS and spacecraft will depend upon the complexity of the particular spacecraft and its interface with the IUS. The simplest test mode will be with a spacecraft that has a mechanical interface only. Under this condition, the testing will satisfy spacecraft specific requirements separately. Ordinarily, there are IUS/spacecraft electrical interfaces that require verification and a requirement for IUS/spacecraft functional compatibility tests can be expected for many missions. The most severe checkout conditions exist when the configuration consists of two IUS vehicles in tandem; i.e., stacked one above the other ready for installation in a single Orbiter cargo bay. Under all conditions, testing and checkout shall provide a high degree of confidence (specified for individual missions) that the IUS/spacecraft is completely functional and that the combined vehicle will be compatible with the Orbiter.

After completion of IUS/spacecraft checkout, the payload canister, positioned vertically on its transporter, is moved into the SAEF-1 high bay area and positioned to receive the cargo. The cargo is transported to the launch pad in the canister in the vertical position. Electrical power, environmental control, and other services are provided.

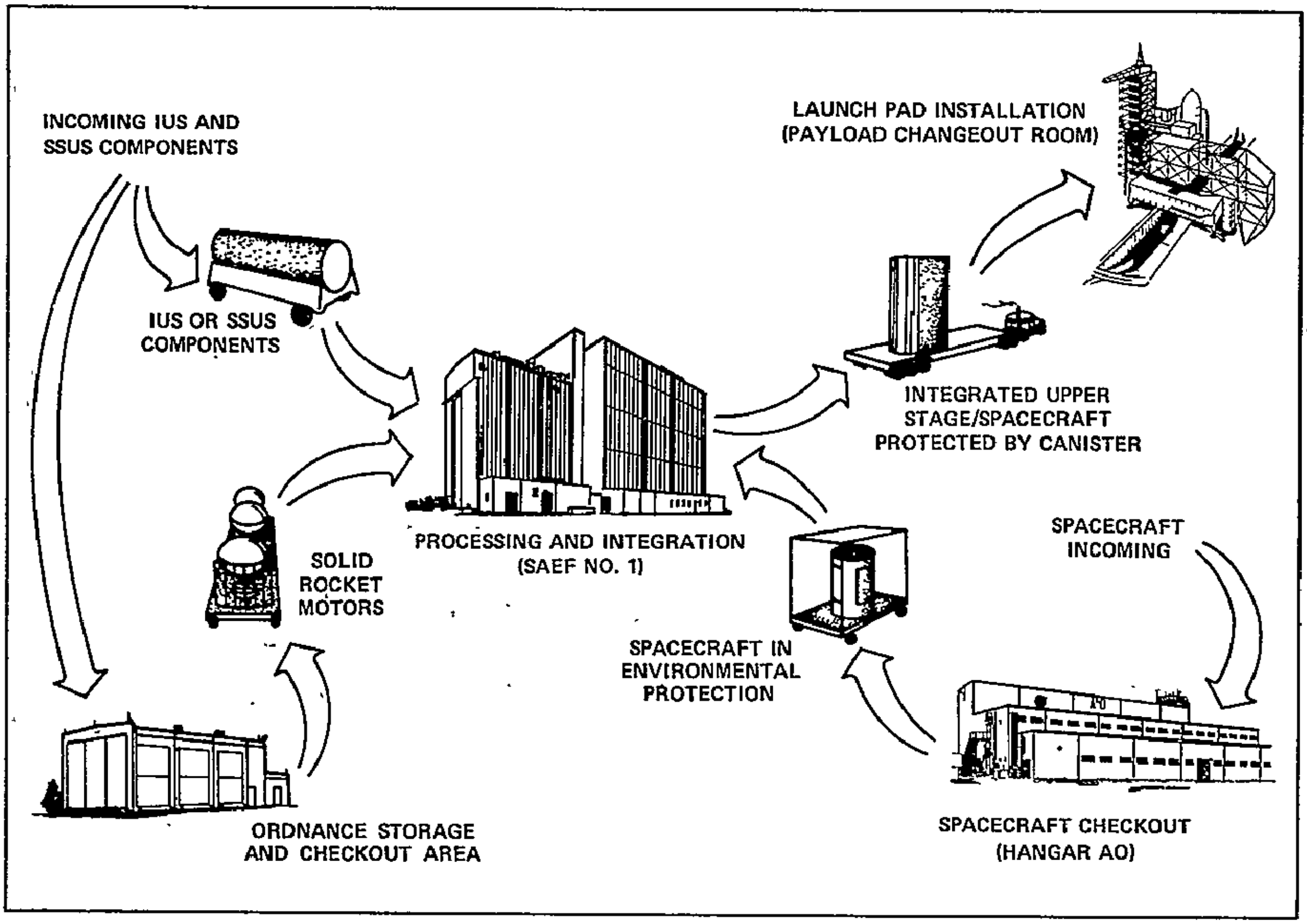
Spinning solid upper stage

The spinning solid upper stage (SSUS) missions depend heavily on successful spin table performance; therefore, thorough spin table testing is performed. Concurrently, SSUS solid rocket motor checkout and assembly is made in another area.

The SSUS assembly begins by securing the cradle/spin table to a workstand in the SAEF-1. The SSUS interstage structure and solid rocket motor are then mated to the cradle/spin table and alignment checks are made. Following assembly, subsystems and systems tests are made to verify proper SSUS operations.

The SSUS is now ready for mating of the payload, which has undergone its checkout in another area. The payload is brought to SAEF-1, positioned on the SSUS mating surface, and the attaching clamp is installed. Then, electrical interface verification checks between the payload and cradle are made. Mechanical interfaces are also verified to ensure compatibility with the Orbiter cargo bay and with other payloads if the flight involves multiple payloads.

The spacecraft/SSUS is installed in the payload canister and moved to the launch pad.



Typical ground operations, from arrival at KSC to launch, involving upper stages.

Upper stage launch pad operations

Operations at the launch pad are similar for both spacecraft/IUS and spacecraft/SSUS payloads. They are governed in sequence and time by established Shuttle turnaround activities.

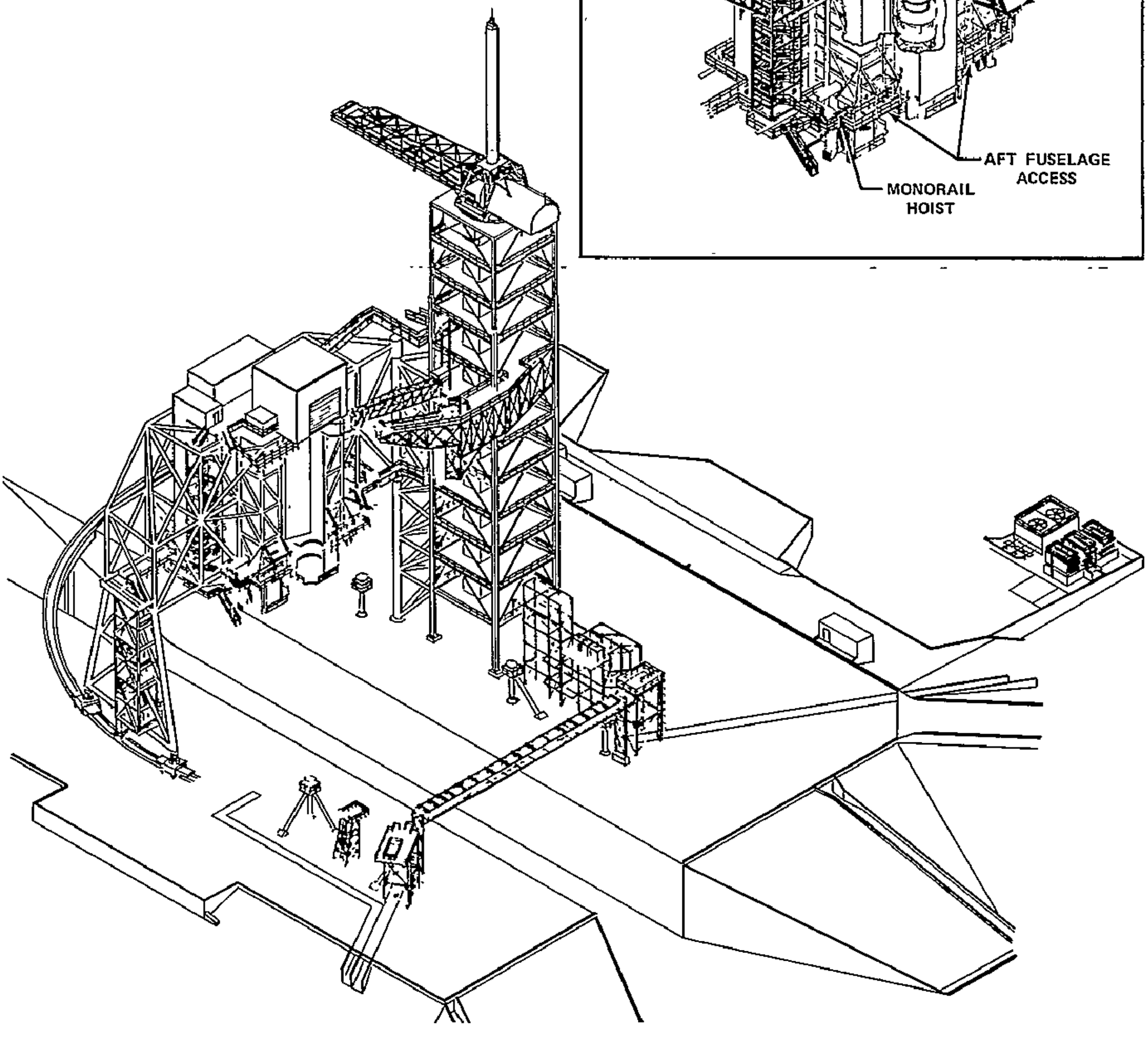
When the canister is vertical, it simulates the Orbiter position and its configuration in the cargo bay area. An inflatable seal at the canister/PCR interface permits continuous control of the PCR interior environment. The cargo is raised from the canister support points, removed from the canister, and translated into the PCR by moving the payload ground-handling mechanism along its overhead rail support to the rear of the PCR. The spacecraft/upper stage, and other payloads (if any), receive final preparations for installation into the Orbiter. The canister is lowered and removed. Finally, the PCR is extended to the Orbiter position. The upper stage requires little or no attention at this point.

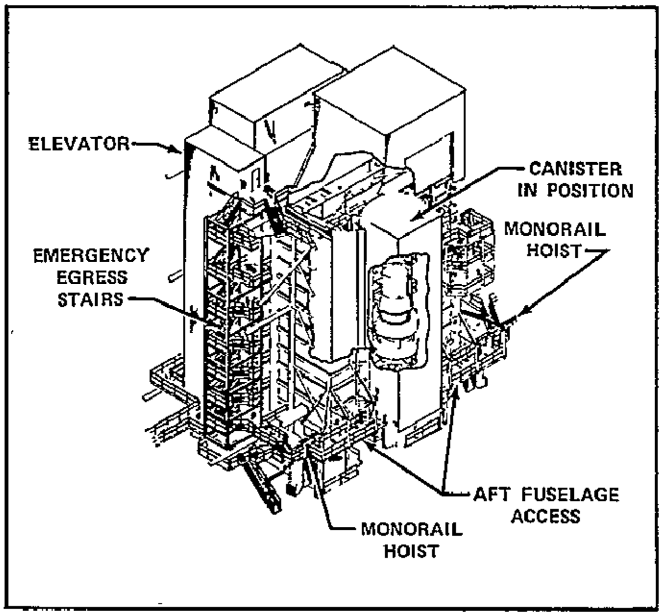
The canister and transporter are placed on a standby status in the event that they are required to support cargo/payload changeout operations.

At the allocated time the PCR structure is extended to make contact with the Orbiter. The PCR/Orbiter seal is inflated, the interstitial space between the PCR and Orbiter is purged and both sets of doors (PCR and Orbiter cargo bay) are opened. The payload ground-handling mechanism is moved toward the Orbiter to insert the spacecraft/upper stage into the cargo bay. The vertical and horizontal adjustment features of the mechanism are used to align the airborne support equipment trunnions to the Orbiter payload attachment points on the longeron bridge. The cargo is then lowered to the Orbiter retention (boltdown) hardware and fastened in place. Spacecraft/upper stage access equipment is placed into position as required.

The upper stage is mechanically and electrically connected to the Orbiter and all interfaces verified. Launch-readiness verification functions are performed and Orbiter/upper stage spacecraft integration, previously checked off-line with simulation equipment, is completed. Specific tests are conducted as required. Compatibility of the cargo with the Orbiter must be assured, at least for flight safety. No physical access to the upper stage or spacecraft is available during the countdown period.

A vertical-to-horizontal position change is required whenever it is necessary to install the cargo while the Orbiter is in the Orbiter Processing Facility (OPF). Because the SAEF-1 crane cannot lift the fully loaded payload canister, this translation procedure is performed in the VAB.





Payload changeout room in the position for payload transfer into the Orbiter. No Space Shuttle is on the launch pad so all structures can be seen. The inset shows a cutaway canister in the PCR.

Postflight handling

Normally, the payload will be returned to the primary landing site (the launch site). Shortly after landing, some payload time-critical items, if they are capable of being transported through the Orbiter cabin, may be removed. If any time-critical postlanding operation needs to be performed at the launch and landing site, it should be specified well in advance.

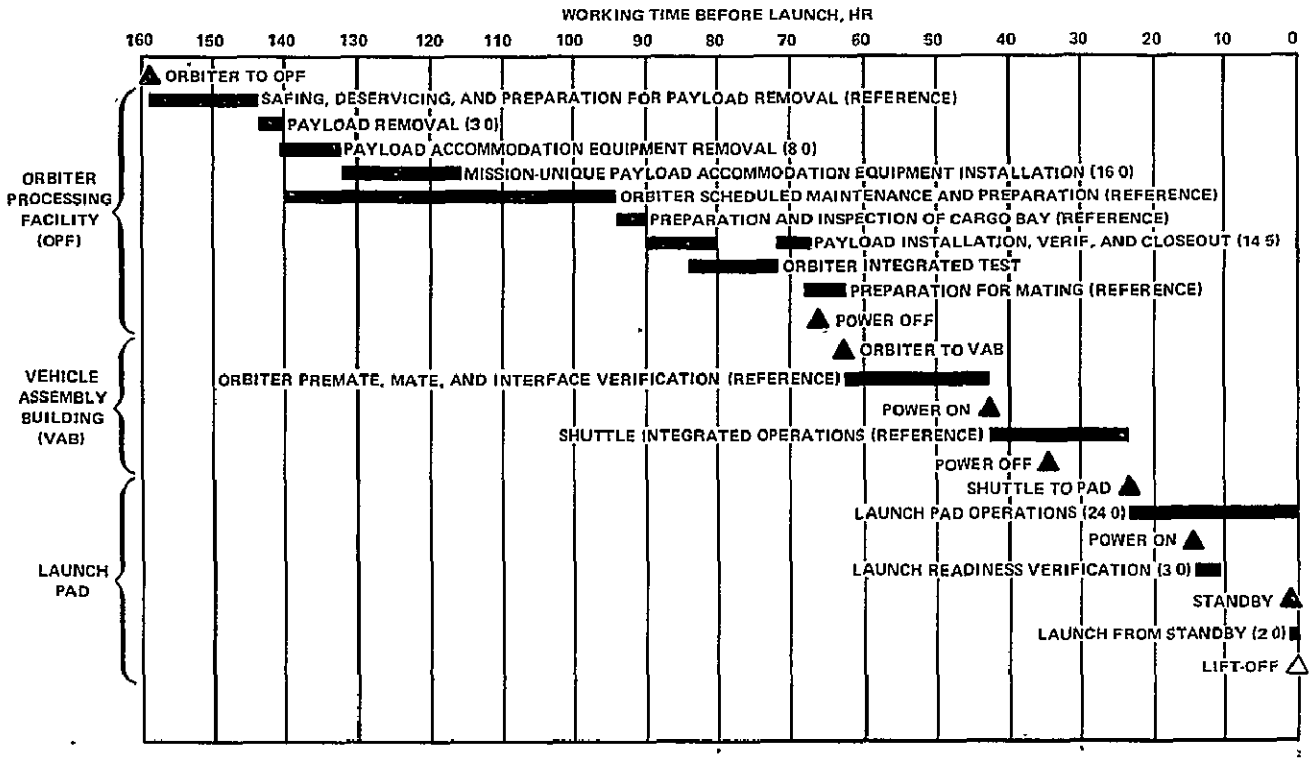
The Orbiter is taken to the OPF, where both the Orbiter and payload are rendered safe. Drain, vent, and purge operations are performed, if applicable. At this time, flights kits are removed or, if they are to remain aboard, checked. Flight modules (aft propulsion subsystem pods and forward reaction control subsystem module) that are removed are taken to the Hypergolic Maintenance Facility.

After preparatory payload tasks are completed, the returning payloads are removed — to be returned to the user, prepared for the next flight, or stored.

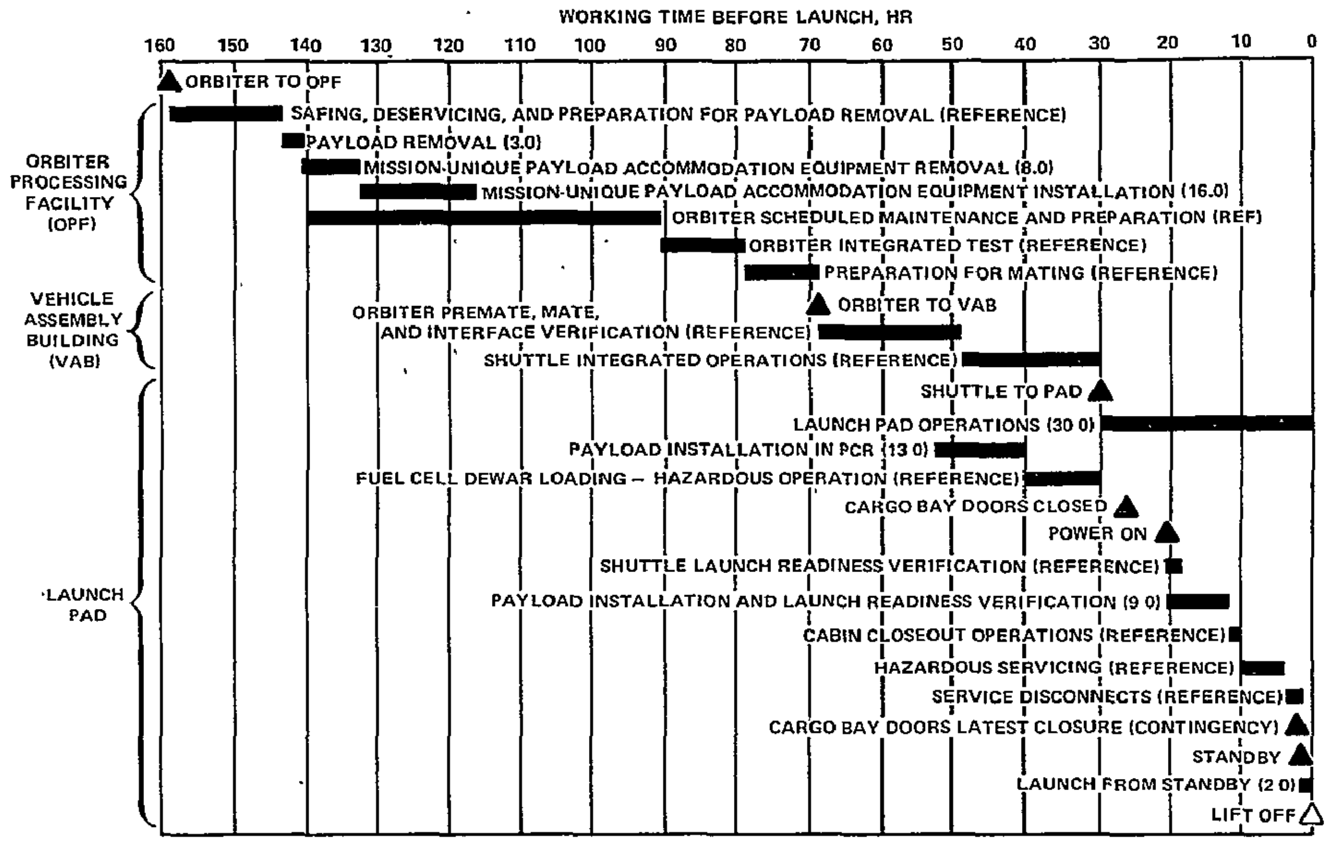
Then maintenance and checkout of the Orbiter begins to prepare it for prelaunch operations.

In the event of an Orbiter landing at the secondary site or a contingency landing site, the launch site will be responsible for coordinating the dispatch of resources required for payload removal operations. The secondary site will have basic support equipment available for the Orbiter and for payload removal. A contingency landing site will not have any special payload equipment available; only equipment for crew survival and Orbiter towing is planned to be immediately available. The launch site is responsible for coordinating all necessary resources if a contingency landing site is used.

After payloads are removed, in either instance, they must be prepared for transport by the user to either the launch site or a site selected by the users for normal postlanding or turnaround activities.



Typical processing schedule for payloads installed at the Orbiter Processing Facility. Allocated times shown are approximate only. The lines marked as reference indicate STS processing that does not involve the payload; they are shown to acquaint users with the overall ground flow.

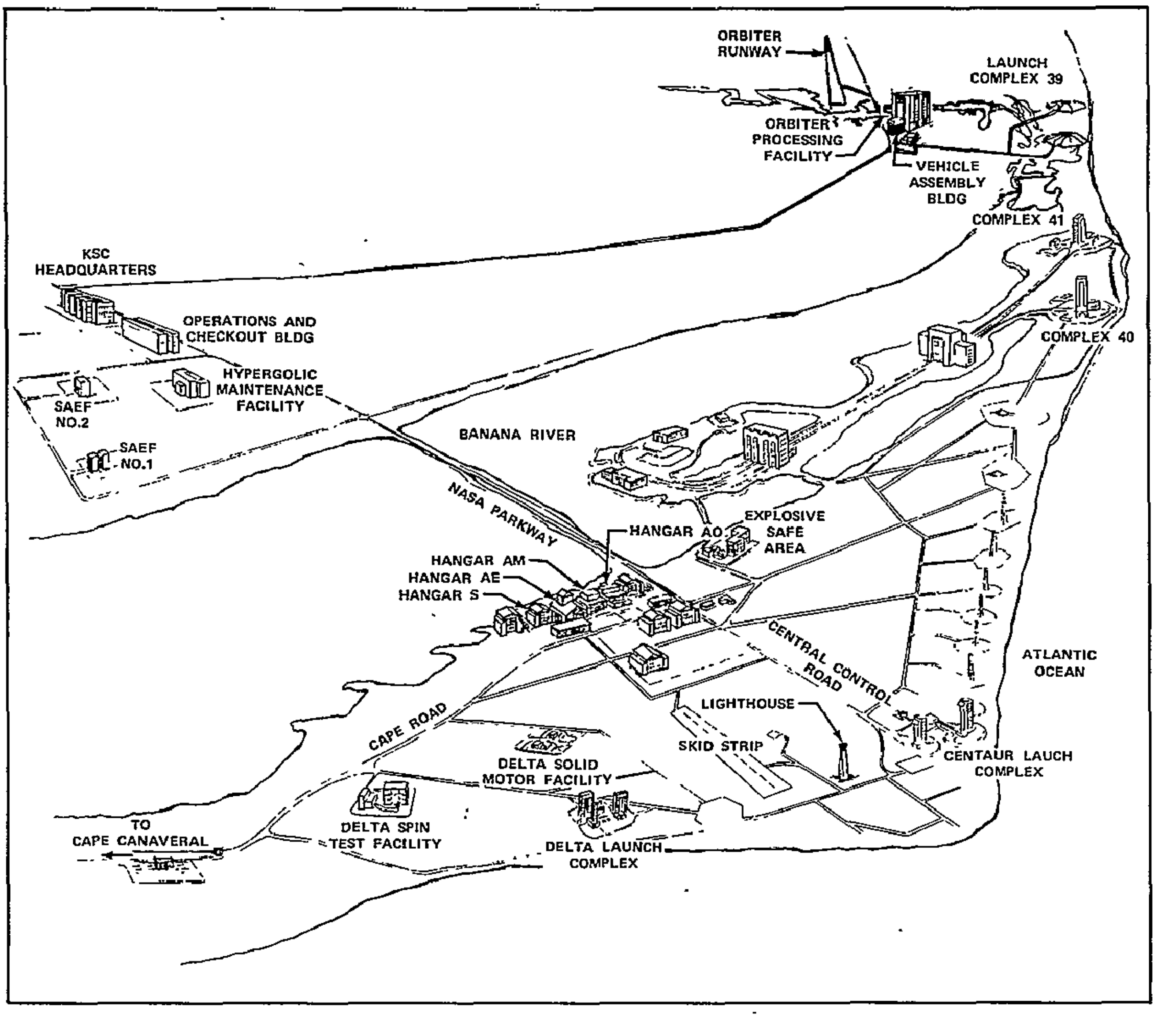


Approximate ground-processing times when payloads are installed at the launch pad. Those operations involving only the STS, without the payload, are also shown for reference.

Buildings and test areas

The payload assembly and test areas, launch complexes, and other specialized facilities will be used for payloads during prelaunch preparations. The user can obtain detailed information about the facilities required from the LSSM. The LSSM will ensure that appropriate facilities are assigned to meet individual needs.

Various specialized facilities are intended primarily for processing of payloads before they are mated to the STS. Others are primarily for processing STS elements (Orbiter, Spacelab, upper stages) or for payload integration and simulated Orbiter interface verification. Both categories are summarized in the tables on the following pages.



STS processing facilities

Facility	Location	Primary uses	Other uses
Operations and Checkout Bldg.	KSC industrial area	1. Spacelab refurbishment 2. Spacelab processing 3. Horizontal cargo integration	1. Special purpose laboratories 2. Office space
SAEF-1	KSC industrial area	1. Upper stage processing 2. Vertical cargo integration	
OPF	Launch complex 39 area	1. Orbiter refurbishment 2. Payload installation and interface verification	
VAB	Launch complex 39 area	1. Shuttle assembly	1. Office space
Launch pad	Launch complex 39 area	1. Shuttle launch 2. Payload installation and interface verification	

Payload processing facilities

Facility	Location	Primary uses	Other uses
Hangar S	Cape Kennedy Air Force Station	1. Spacecraft processing	1. Ground station area 2. Office space
Hangar AE	Cape Kennedy AF Station	1. Spacecraft processing	1. Ground station area 2. Office space
Hangar AM	Cape Kennedy AF Station	1. Spacecraft processing	1. Ground station area 2. Office space
Hangar AO	Cape Kennedy AF Station	1. Spacecraft processing	1. Ground station area 2. Office space
Explosive safe area 60A	Cape Kennedy AF Station	1. Spacecraft hazardous systems processing	
Propellant lab		1. Propellant fueling	1. Ordnance operations 2. Pressurization operations
Spacecraft Assembly Bldg.		1. Ordance operations	1. Propellant pressurization operations 2. Encapsulation activity
Delta Spin Test Bldg.	Cape Kennedy AF Station	1. Spacecraft hazardous systems processing	

Facility environments[a]

Location	Temperature, °F (K)	Humidity, %	Clean room, class[b]
Hangar S			
Clean rooms	72 ± 3 (295 ± 1.7)	45 ± 5	100 000
Systems test area	76 ± 3 (297.6 ± 1.7)	50 ± 5	
Hangar AO			
High bay	75 ± 2 (297 ± 1.1)	45 ± 5	100 000
Hangar AE			
Clean room	72 ± 3 (295 ± 1.7)	45 ± 5	10 000
Hangar AM			
High bay	75 ± 3 (297 ± 1.7)	45 ± 5	
Clean room	75 ± 5 (297 ± 3)	40 (max.)	10 000
Explosive safe area 60A			
Spacecraft Assembly Bldg	73 to 95 ± 3 (296 to 308 ± 1.7)	50 ± 5	100 000
Propellant lab	73 ± 3 (296 ± 1.7)	50 ± 5	100 000
Instrument lab	76 ± 3 (297.6 ± 1.7)	50 ± 5	
Delta Spin Test Bldg	75 ± 5 (297 ± 2.8)	50 ± 5	
Operations & Checkout Bldg	75 ± 3 (297 ± 1.7)	45 ± 5	100 000
SAEF-1			
Airlock and high bay	70 ± 5 (294 ± 2.8)	45 ± 5	5 000 (inlet)
SAEF-2			
Airlock, high and low bay	75 ± 3 (297 ± 1.7)	45 ± 5	100 000
VAB	Not controlled	Not controlled	Not controlled
Orbiter Processing Facility			
High bay	75 ± 3 (297 ± 1.7)	50 (max.)	100 000 (inlet)
Cargo bay enclosure	70 ± 5 (294 ± 2.8)	50 (max.)	5 000 (inlet)
Launch pad	Not controlled	Not controlled	Not controlled
Payload changeout room	70 ± 5 (294 ± 2.8)	30 to 50	5 000 (inlet)

[a]All figures represent design specifications; in some facilities, actual conditions could vary because of ambient conditions and the nature of the operations being conducted.

[b]Federal Standard 209B, April 24, 1974, Clean Room and Work Station Requirements for Controlled Environments.

Cargo support equipment

A variety of equipment is available at the launch site for processing payloads. The user should identify his needs to the LSSM as early as possible. Unique payload ground-support equipment must be provided by the user and should be identified, controlled, and funded by the user's organization or development agency. Interfaces to this equipment at the launch site should be planned with the LSSM.

Transportation equipment

The standard transportation equipment, summarized earlier in this section, is designed to protect the payload en route to the launch site. The payload is protected from contamination by a static-free clean bag, which encloses the payload before it is attached to an adapter assembly. The air is evacuated so the bag will cling to the payload surface.

The supporting adapters are attached to the payload at normal flight interfaces and to the containers in a universal mounting pattern. A special damping material between the adapter and the container platform shock-isolates the payload. These adapters will not impose g-loads to the payload structure greater than those imposed by the Orbiter. Three adapters are used: one end-mounted and two types of Spacelab pallet adapter (for horizontal and vertical transport).

Tiedowns, which interface with universal tiedown rings and commercial carrier tiedowns, are provided. A sling set is provided to be used with cranes or hydraulic hoists to handle the loaded containers and the self-contained environmental and power units. The same slings are used to rotate a pallet when it is to be transported horizontally.

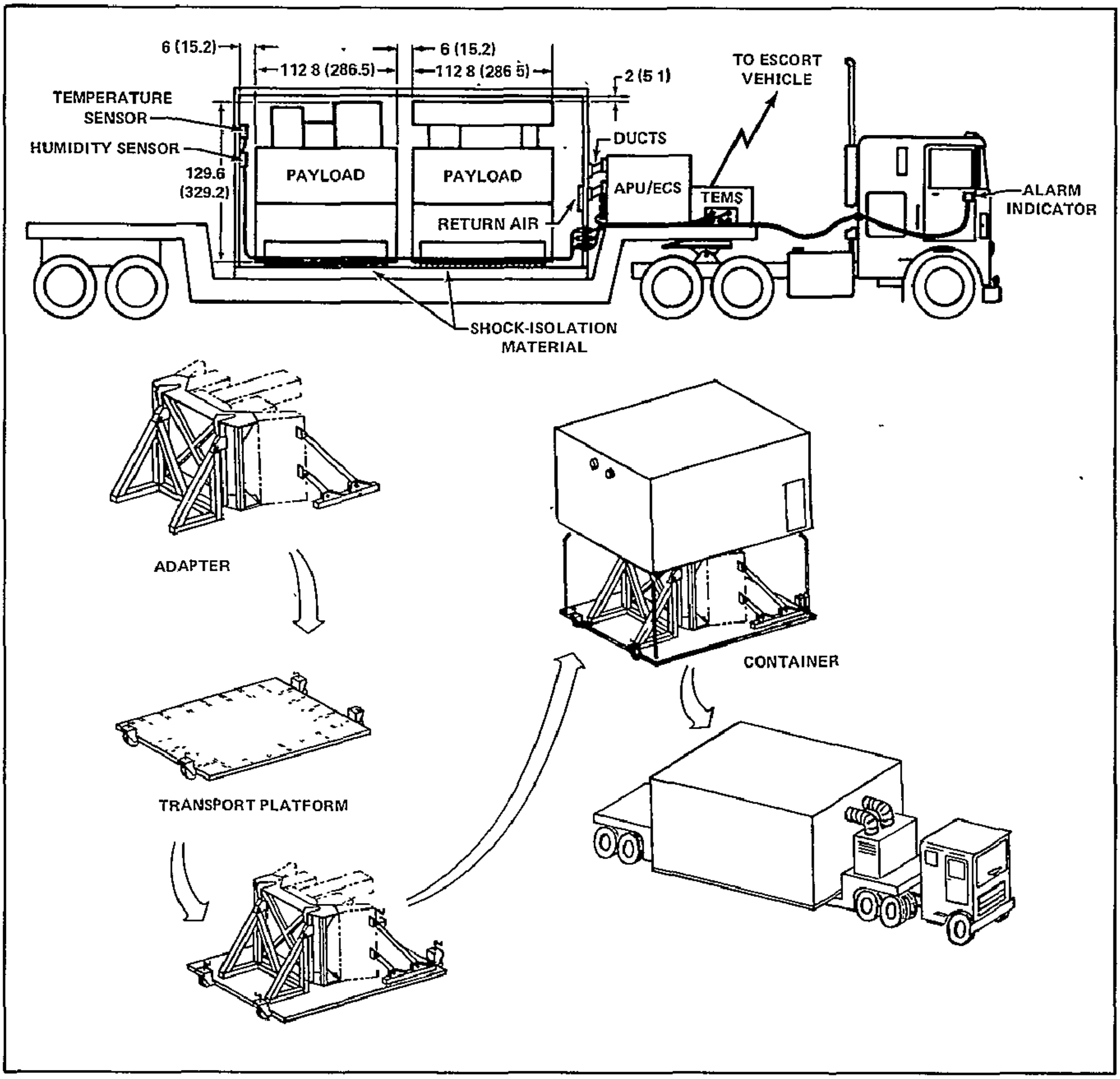
A transport environment monitoring system (TEMS) will be required to sense shock, vibration, temperature, humidity, and power levels of the payload. An alarm system in both the tractor cab and an escort vehicle would provide warning if any critical parameters are out of tolerance. In addition, engineering data on these same parameters would be continuously recorded to determine the acceptability of the payload shipment.

The base of the standard container is of steel construction and the floor is insulated with polyurethane. The insulated cover is 2 inches (5 centimeters) thick. The outside surfaces are sheet aluminum and the inside surfaces are fiberglass. An interface feedthrough panel provides payload services as required. Two sides have 3- by 4-foot (0.91- by 1.22-meter) access doors. Lights and reflectors on the outside meet Interstate Commerce Commission regulations for highway movement.

Payload/standard transportation system interfaces

Type and purpose	Interface
Mechanical or structural	
Structural mount	Payload adapter
Shock insolation	Payload adapter Carrier air-ride system
Electrical	Auxiliary power unit (28 V dc; 115 V ac, 50/60 Hz)
Environmental	
Temperature	Environmental control system
Relative humidity	Environmental control system
Cleanliness	Static-free bag
Protection	Hard container
Instrumentation and data recording	Accelerometers Thermometer Humidity sensor Power-level sensor Alarm system

The container has its own environmental control system (ECS), which requires 208 volts ac, three-phase 50/60 hertz to operate. The power is provided by the auxiliary power unit (APU) or from facility power sources. A positive-pressure filtered air purge is maintained to the container during transit. A battery is included that could supply power to the payload and operate the transport environment monitoring system for at least 4 hours if the generator were inoperable.



Elements of the standard transportation system and the type of commercial carrier used.

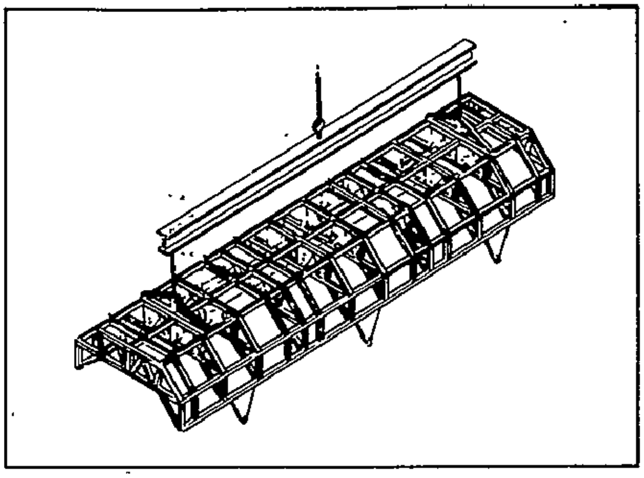
Payload-handling equipment

Those items in the basic hardware inventory for payload handling that will be needed by most users include payload canisters, canister transporters, and payload-handling fixtures (strongbacks).

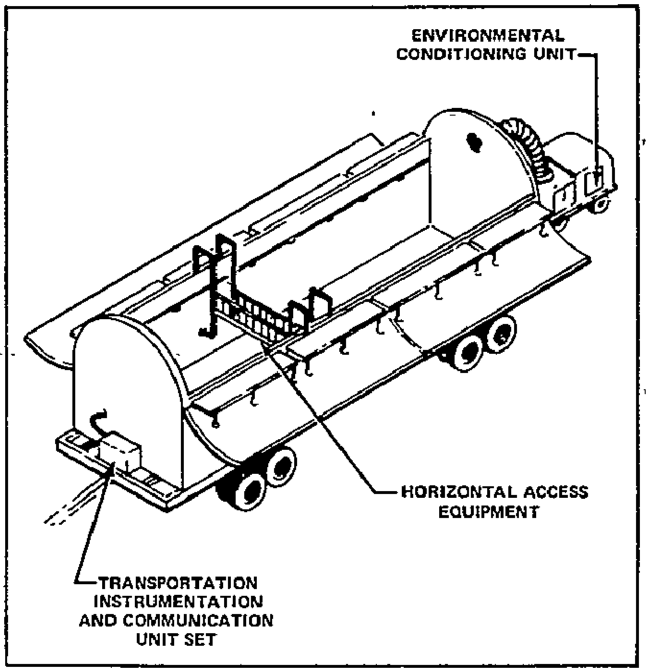
The strongback is a rigid-frame device consisting of beams, cables, attachment hook devices and rings. It is adjustable to accommodate varying lengths and shifting centers of gravity of payloads up to the maximum for an Orbiter payload. The strongback will interface with the payload so that it will not interfere with engagement and load transference to attachment/retention points. It will not induce any bending or twisting loads on any payload element.

The canister is equal in size and configuration to the Orbiter cargo bay, including similar doors on the top. In addition, one end is hinged to allow vertical payload installation. Service panels, tiedowns, and lift points are also part of the canister to allow rotation of the container. Special platforms for personnel access to the open canister can also be used. This equipment consists of a bridge-type structure that spans the canister and walkways along each side of it. The bridge can be raised or lowered; at maximum elevation it clears the payload envelope.

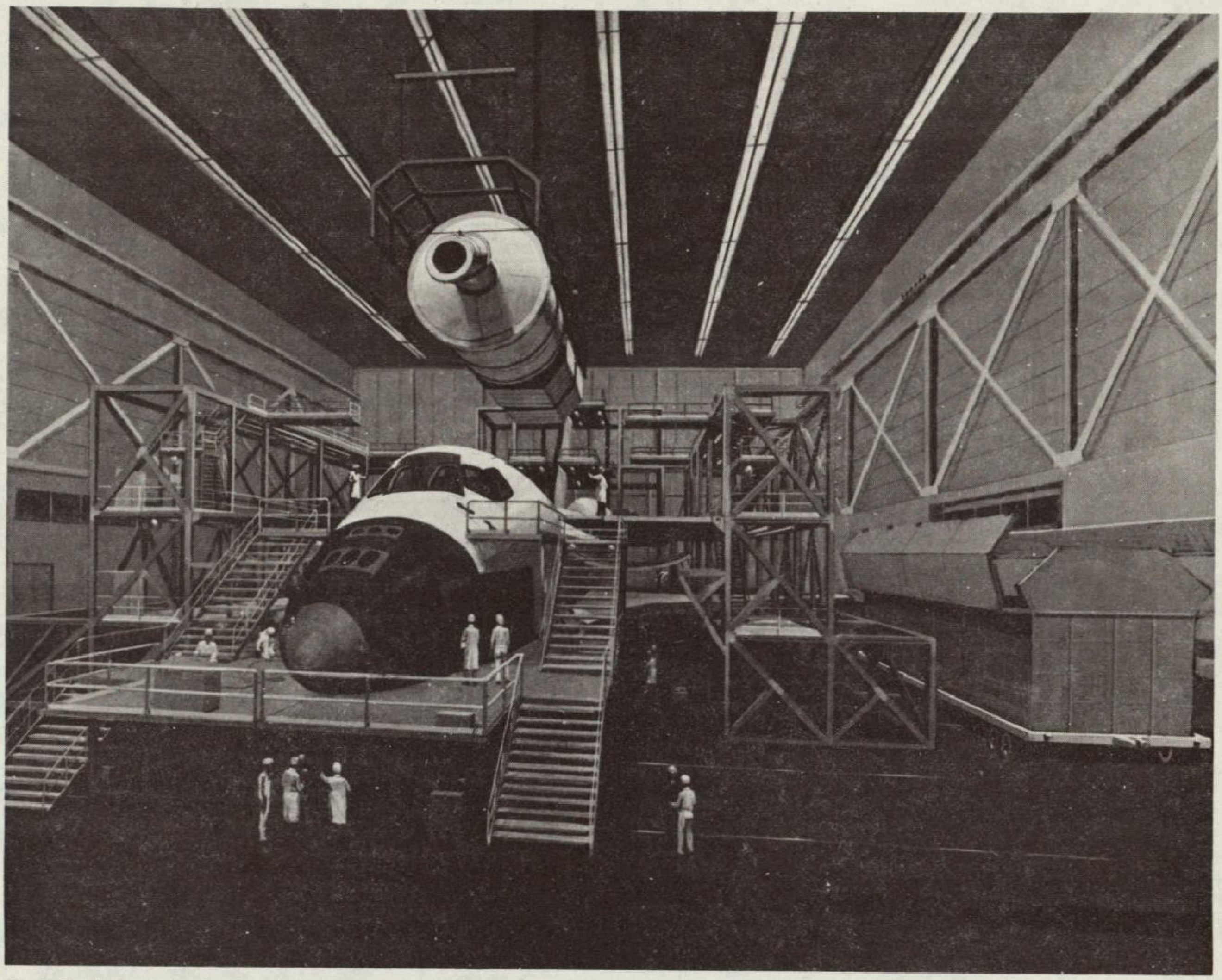
The transporter is capable of moving a fully loaded canister. Its suspension system helps to minimize shock and vibration.



Horizontal handling fixture (strongback) for payloads.



Payload canister shown mounted on its transporter.



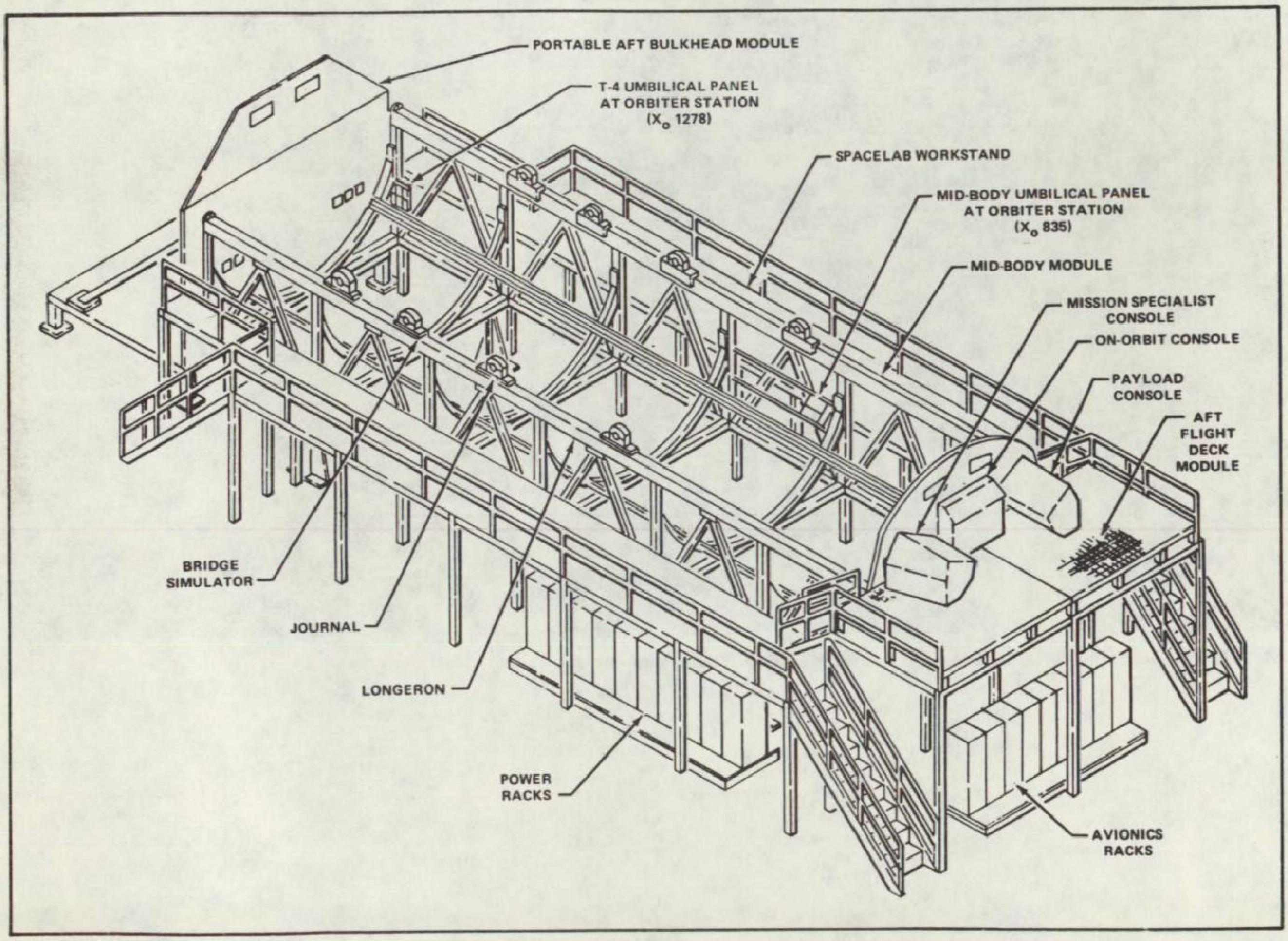
Strongback in use for horizontal installation of Spacelab. The empty canister is also clearly visible.

Cargo integration test equipment

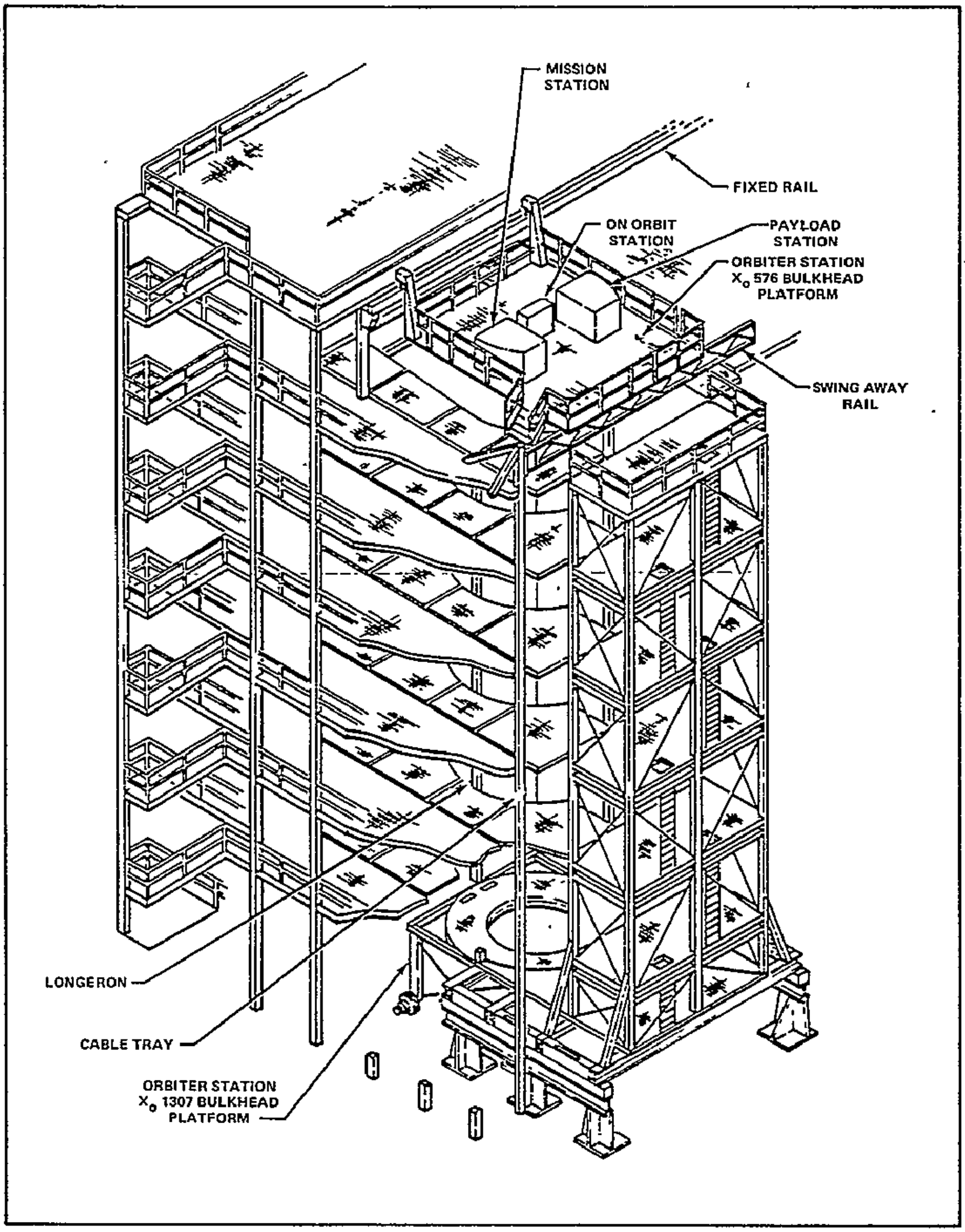
Cargo integration test equipment (CITE) has the capability to verify interfaces off-line, including payload-to-payload and cargo-to-Orbiter mechanical and functional interfaces.

The CITE in the Operations and Checkout Building can accommodate horizontally processed cargoes. Vertical processing is done by the CITE in SAEF-1.

Included in this equipment are structural assembly stands, mechanical clearance and fit gauges, electrical wiring, thermal-conditioning items, electronic test sets, and radiofrequency transmission equipment adapters. The CITE satisfies the STS requirement to perform final assembly and integrated testing of cargo before it is mated to the Shuttle. It may also be used to satisfy the payload interface verification requirements.



Layout of cargo integration test equipment for horizontal cargo.



Vertical cargoes can undergo interface verification in this CITE configuration.

Services

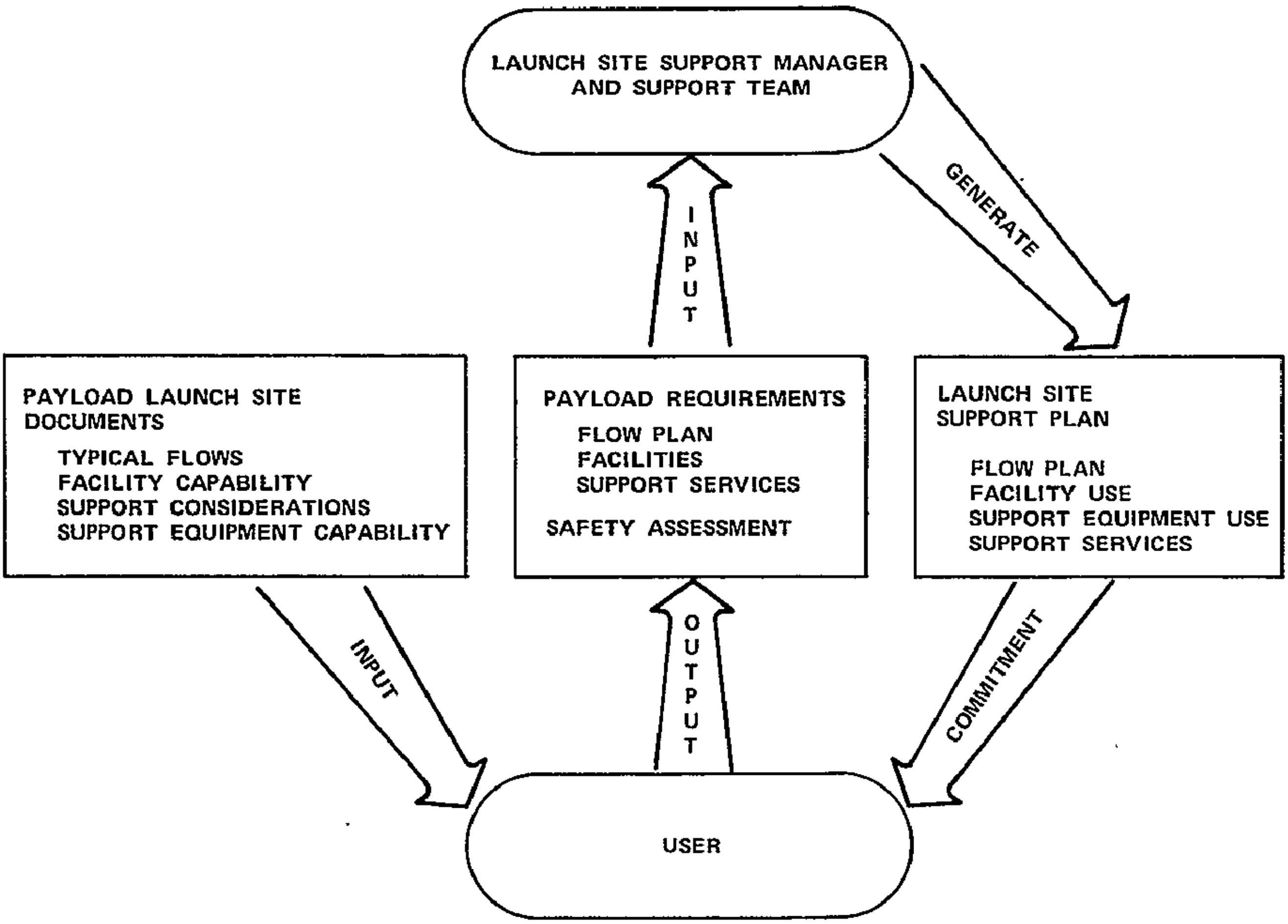
In addition to the equipment, both technical and administrative support services are available to fit the needs of users. Administrative support includes office space, communications and transportation facilities, equipment, and tools. Technical support for payload processing includes clean rooms, test equipment, propellants, ordnance testing and storage, chemical analysis, shops, and laboratories.

Complete technical services are available to satisfy legitimate requirements of users. However, these are not intended to supplement work that should have been performed in the user's home plant. If inactive support services — above those that are standard — must be reactivated for a user, negotiated cost and schedules must be considered.

Interfaces

Standard payload interfaces and services required at the launch site will be made available to all users but the users will retain primary responsibility for performance and off-line processing of their payloads. To fulfill this host concept, the launch site staff must schedule and integrate facilities, support equipment, services, and personnel.

Planning launch-site support for payloads will begin with initial contact between the user and the designated launch site support manager. The LSSM will be assigned early in the program and will become the user's "host." He will become acquainted with the user's organization and will work with that organization in defining launch site capabilities and planning launch-site operations. Initial emphasis will be on long-lead items, conditions that might affect payload design, and resolution of problems that pose potential difficulties. Any new capabilities required must be evaluated for cost and schedule effects. Even if payload processing requirements are incomplete, they should be submitted at the earliest possible date to allow ample time for evaluation, planning, and integration into the STS processing.



User's involvement in planning launch site operations with the LSSM for a specific payload.

Responsibilities

During planning, the user, using the KSC Launch Site Accommodations Handbook, has the responsibility to:

- Establish specific processing flow requirements
- Identify facility services required
- Identify payload-supplied support equipment required for use at the launch/landing site
- Identify activation/deactivation requirements associated with unique support equipment
- Ensure reliability and quality assurance during the off-line processing in support of payload readiness
- Prepare procedures for accomplishing processing before STS mating
- Input to and review integrated procedures for on-line testing with the STS
- Perform safety assessment
- Identify test support requirements for payload involvement in integrated operations
- Provide certification of payload readiness
- Identify proprietary information, if appropriate, or security designations according to applicable regulations
- Identify and budget for payload costs to be incurred at the launch site

The launch site organization will be responsible for providing assistance to the user in planning integration and checkout of the payload elements with the STS, planning and scheduling facility use and payload flow, assuring that all payload requirements are met, and conducting the launch operations. Users must provide sufficient documentation to define all requirements for their payloads at the launch site.

For complex payloads (particularly those requiring major construction of facilities at the launch site), planning should begin several years before the payload is scheduled to arrive at the launch site. Most payloads, however, will require significantly shorter lead times.

The user will retain prime responsibility for off-line operations involving only his hardware. Once integration with other payloads or STS hardware begins, the launch site will assume overall responsibility but will require detailed inputs and data review from the user. Users will retain performance responsibility for their payload and will remain involved through the entire on-line flow as well.

SAFETY CONSIDERATIONS

A safety program at the launch site is intended to protect personnel and the public from hazards, to prevent damage to property, to avoid accidental work interruptions, and to provide data with which to evaluate risks and loss factors. The launch site safety program is part of the overall STS safety program.

At KSC, the director of safety, reliability, quality assurance, and protective services is responsible for safety planning. Safety requirements at KSC include Department of Defense requirements. Those NASA operations in Air Force areas will be conducted in accordance with local Air Force safety regulations and within the framework of KSC safety standards. Safety surveillance will be coordinated with Air Force representatives.

The user is responsible for applying the provisions of the safety program by:

- Maintaining surveillance in assigned areas to detect and correct unsafe practices and conditions
- Coordinating with the safety operations office on all matters pertaining to accident prevention
- Submitting the required safety data
- Ensuring that employees have and use safety clothing and equipment during hazardous operations

A hazardous operation is one that could result in damage to property or injury to personnel because it involves one or more of the following.

1. Working area and environment: Any environment that deviates from normal atmosphere (in pressure, chemical composition, or temperature, for example, and including confinement within a closed spacecraft) or work in proximity to pressure vessels.

2. Explosive ordnance: Handling, transportation, installation, removal, closeout, or checkout of ordnance devices or an ordnance system.

3. Propellants: Loading, unloading or flow, hookup or disconnect, movement of loaded storage units, or opening contaminated systems involving solid, liquid, hypergolic, or cryogenic propellants.

4. Cryogenics: Loading, unloading, flow, hookup or disconnect, movement of loaded storage units, or repair of a system containing cryogenics.

5. Hoisting: Any operation involving lifting, loading, or transporting a large or heavy item.

6. Radiation: Any operation involving an ionizing radiation source or radiographic equipment or producing more than a specified level of radiofrequency radiation. Authorization at KSC for exposure to ionizing radiation is controlled centrally through the Radiation Safety Program. Rules are consistent with NASA, Energy Research and Development Administration, and State of Florida regulations.

7. Toxic/combustible/corrosive: Risks involved in the use of toxic, combustible, or corrosive liquids, gases, or solids, such as mercury, acids, or solvents.

8. Pressure: Operations involving the pressurization of systems or components in which the first pressurization of a vessel exceeds 25 percent of design burst; in which any pressurization of a vessel containing hazardous fluids exceeds 25 percent of design burst; in which any pressurization of a vessel exceeds 50 percent of design burst; or in which any pressurization of tubing, fittings, and other components exceeds 25 percent of design burst.

9. Electrical: Any operation involving risk because of the nature of the equipment involved.

10. Spacecraft: Personnel inside a spacecraft with hatch closed.

11. Other: Any operation not previously specified that could endanger people or hardware (as examples, use of other high-energy sources or work at heights).

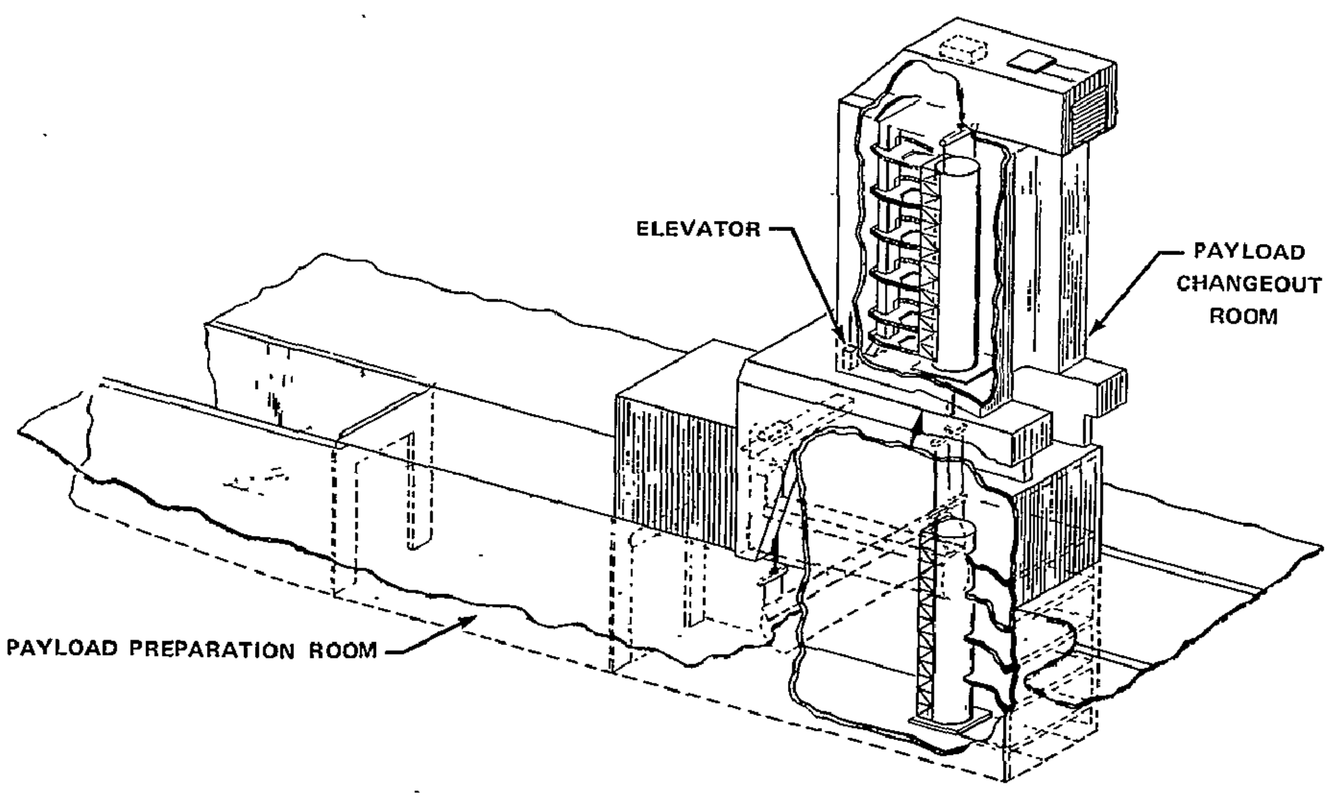
The safety operations office at KSC will review hazardous operating procedures. A variance from normal safety operations may be issued under certain circumstances.

VAFB OPERATIONS

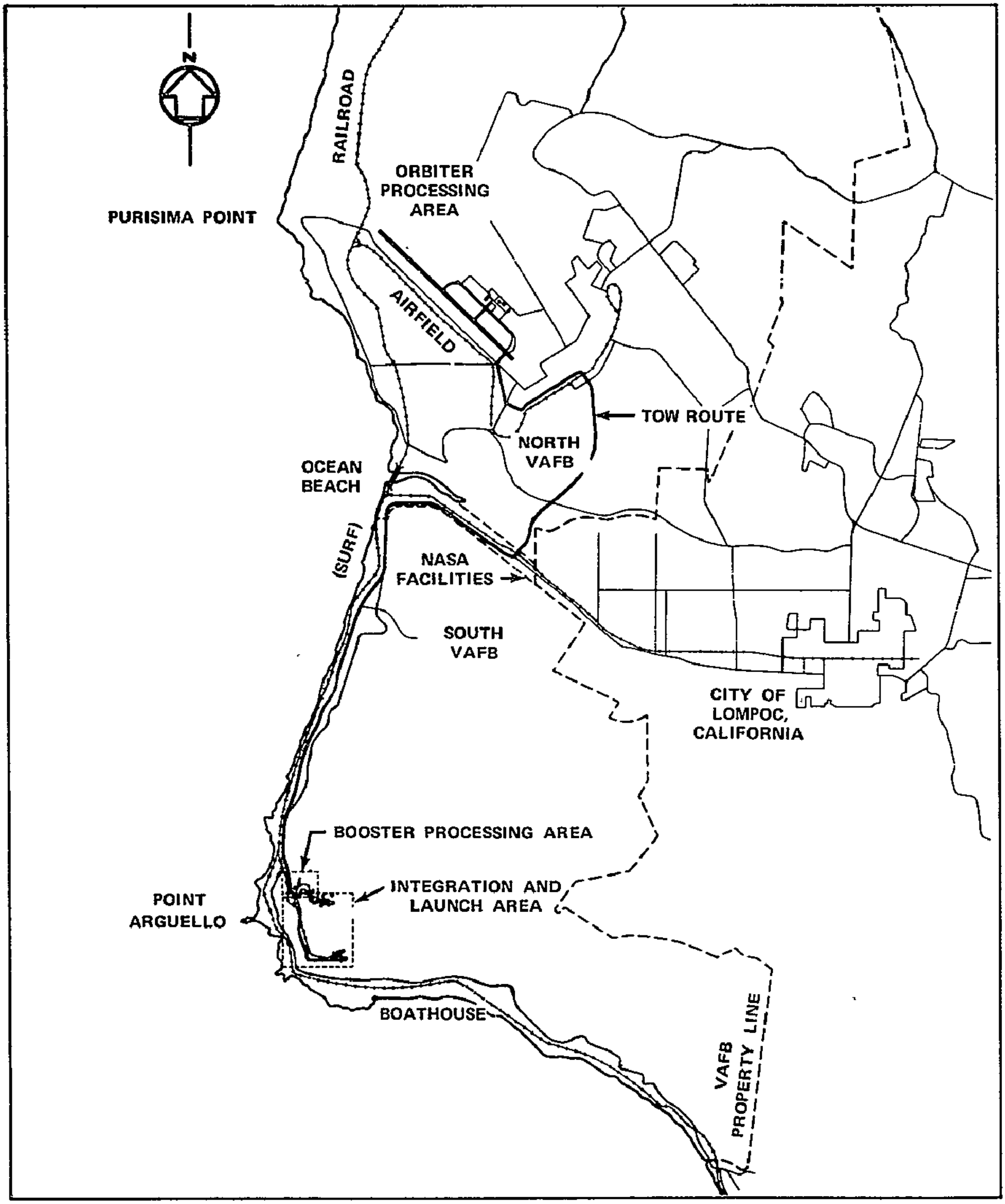
At Vandenberg Air Force Base, the Department of Defense (DOD) will be responsible for the general-purpose Shuttle equipment and facilities necessary to perform the ground, launch, and landing activities for all Space Shuttle operations. Initial operational capability at VAFB is planned for no earlier than December 1982. The NASA/KSC will be responsible for launch site support for all NASA and civilian payloads before they are mated with the Orbiter, while the U.S. Air Force at VAFB will be responsible for DOD payloads as well as for overall Shuttle facilities.

Payloads will be installed either at the Orbiter Maintenance and Checkout Facility (in a manner identical to the Orbiter Processing Facility) or at the launch pad by use of the payload preparation room/payload changeout room. The latter is DOD baseline. Vertical installations will differ slightly from those at KSC because the facilities differ. At VAFB, the payload may be delivered to the launch pad payload preparation room (located underground), where preparations for mating and checkout will be completed. The payload will then be transferred to the adjoining payload changeout room and installed on the Orbiter as it is at KSC. As at KSC, the payload will be completely checked out and ready for flight before its installation in the Orbiter. Actual mating, integration, and checkout of payloads will be the responsibility of DOD (with NASA participation when non-DOD payloads are involved).

After the Orbiter lands, safing and deservicing will be done in a special facility. Payloads will be removed at the Orbiter Maintenance and Checkout Facility. Shuttle operations at VAFB are more fully described in the VAFB Ground Operations Plan.



Payload preparation and payload changeout rooms at VAFB launch site.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RAILROAD
ORBITER PROCESSING AREA
PURISIMA POINT
AIRFIELD
TOW ROUTE
NORTH VAFB
OCEAN BEACH
(SURF)
NASA FACILITIES
SOUTH VAFB
CITY OF LOMPOC, CALIFORNIA
BOOSTER PROCESSING AREA
INTEGRATION AND LAUNCH AREA
POINT ARGUELLO
BOATHOUSE
VAFB PROPERTY LINE

Management and procedures

Flight systems

Launch and landing site operations

4

Flight operations

Appendixes

4-0

Flight operations

FLIGHT PLANNING

Flight planning is an ongoing process; it involves the specific user at the point when payloads mission-planning activities are integrated with the STS operations planning. The STS operations organization is responsible for all STS planning except payload-specific planning, which is done by the user.

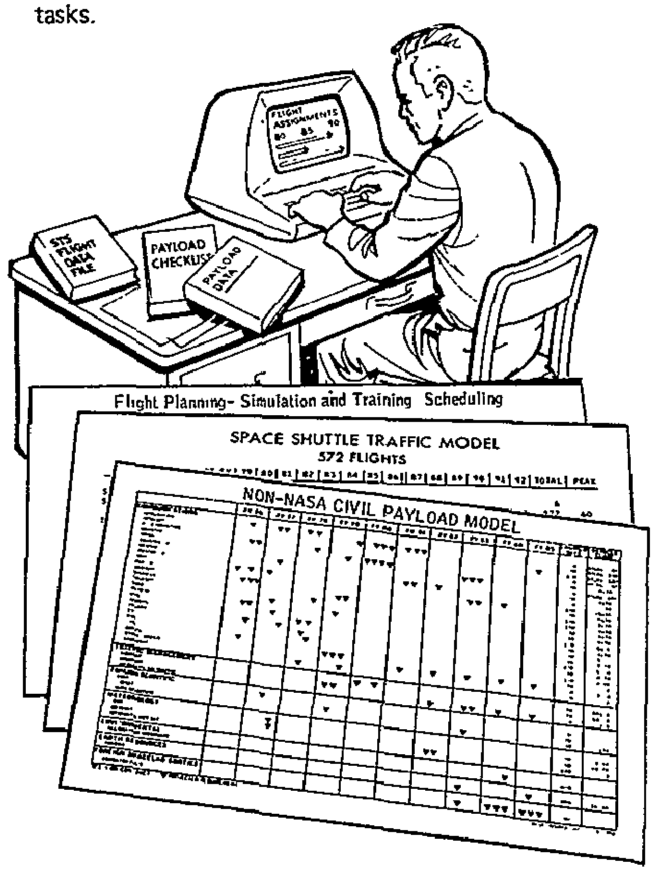
The payload mission plan is provided by the user and is necessary for integrating the payload planning and STS flight-planning activities. It is fundamental to the payload flight assignment, obtaining the STS flight profile design, and subsequent crew activity planning.

The time needed for the planning cycle is related to the complexity of a flight as well as to the number of times a given type of flight has already occurred. The basic objective for STS operations is to achieve a short (16 weeks) detailed planning cycle for simple or repeat-type flights. The first few times a new type of flight is planned, a longer planning cycle is required for developing standardized phases (which can then be used in planning later similar flights). Planning of standard flight types and flight phases has been underway for several years. Longer planning cycles of individual flights are also needed for those complex flights involving analysis and multidiscipline coordination.

Real-time revision of plans (such as consumables management, updates to procedures, or changes in crew activities) during a flight is a natural continuation of the preflight planning process.

The following five interdependent elements, all related to payloads flight planning, make up STS flight planning.

- Utilization planning – the analysis of approved (funded or committed) payloads with operational resources, leading to a set of firm flight schedules with cargo manifests
- Flight design – detailed trajectory, attitude, and pointing planning (among other parameters), which becomes part of the basic flight profile
- Crew activity planning – the analysis and development of required activities to be performed in flight, resulting in a set of crew activity procedures and time lines for each flight
- Operations planning – performing those tasks that must be done to ensure that vehicle systems and ground-based flight control operations support flight objectives
- Training preparation – those activities required to assure that the proper resources are available to train the flight crew and flight operations support personnel to perform their assigned tasks.



Utilization planning

Integration of approved missions into flight manifests and flight schedules is the responsibility of the STS operations organization. For this function, users must provide payload mission objectives, flight data requirements and constraints, and payload descriptions.

Selected support to proposed missions is provided to determine if they can be supported by established STS system capabilities. If additional capabilities would be required, these are identified (and, as applicable, cost estimates are made).

Approved missions are then integrated into flight manifests based on their priority and compatibility. For this to be done, payload requirements for STS payload interface, trajectory, time of launch, crew activities, training, STS systems support, and payload hardware integration must be provided or payloads must be analyzed to determine these requirements. This phase of standard planning requires close coordination between the user and all STS operations support elements and is managed in the same manner for all flights.

Payload planning includes mission planning and payload flight planning. The latter is conducted in parallel to the STS flight-planning process. A user can enter the STS planning cycle at almost any point within a 5-year time frame, depending upon the following payload variables.

- Suitability of the payload experiments to an existing standard carrier or free-flying system
- Interflight requirements related to payload mission objectives
- Payload design complexity, the lead time requirements from design concept to flight
- Characteristics of a payload that would permit its sharing a flight
- Data-flow/data-handling requirements and software interface
- Hardware integration requirements, including control/monitoring instrumentation (crew station), cargo bay installation (ground services), and flight kits
- Flight design requirements, including trajectory, consumables, attitude and pointing, and deployment or retrieval
- Flight crew activity requirements relative to payload operation

Flight design

The flight design activity encompasses trajectory, consumables, attitude and pointing, and deployment/retrieval planning. To minimize the requirement for unique and detailed planning and analysis, standardized flights will be used if they are consistent with the specified payload objectives. The standard planning approach, involves sets of orbital destinations (inclination, orbital altitude), flight phases (launch, on-orbit time line, deployment/retrieval sequences), maneuver sequences (rendezvous, orbital adjustments, deorbit), and crew activities blocks. Analysis of electrical, communications, and environmental needs at this stage will lead to such decisions as whether to include various flight kits on the flight.

Based on mission plans, which establish a set of requirements for a given flight, the flight profile design will be initiated.

The end result of the flight design phase is a detailed trajectory and, flight profile that includes such information as maneuver sequences, vehicle attitude and pointing, consumables time lines, communications coverage, and lighting data.

Modular software and standard flight phases will be used to assemble the flight trajectory from launch to landing. After evaluation and alterations of the flight trajectory have been made, a flight profile will be produced. It will be prepared approximately a year before launch for complex and new types of flights and will become the basis for all detailed planning activities. For routine repeat flights, no flight-specific documentation will be produced before the 16-week planning cycle begins.

Occasionally, a change in flight requirements, cargo manifest, or launch schedule may require modification of the flight profile.

During the period beginning about 16 weeks before the launch, detailed flight design data are generated to support any necessary simulation and training preparation activity, consumables loading parameters, and crew activity plans.

Crew activity planning

A time line plus the necessary procedures and crew reference data to accomplish a given flight are generated from crew activity planning.

During the utilization planning phase, crew activity planners support the analysis of mission compatibility and flight feasibility in relation to crew activities. The crew activity aspect of utilization planning will result in definition of the flight duration and crew size and identification of any new technique or procedure requirements.

Crew activity planners will also support payload crew activity planning. The users are responsible for performing the experiment planning, scheduling, and tradeoffs necessary to accomplish the payload flight requirements. The STS operations center is responsible for performing the STS planning and STS activity scheduling necessary to support payload activities and to maintain crew and vehicle safety.

About 1 year before launch, the payload/STS flight data requirements are baselined. This activity serves as a checkpoint to determine which length planning cycle is warranted and it establishes the following.

- STS procedures and reference data
- STS/payload interface procedures and reference data
- Payload procedures and reference data
- Time lines and crew activity plans

If new STS procedures are identified in the requirements for STS/payload interface procedures, the longer planning cycle is warranted, and development of these procedures will begin and will continue until approximately 32 weeks before launch.

The summary STS time line is developed, containing the crew activities for the STS flight phases (launch, rendezvous, entry, etc.), crew work/rest cycles, and crew personal and system maintenance periods. The summary STS time line, in combination with the flight profile, serves as a baseline for experiment planning and scheduling.

Payload procedures will be developed by payload crew activity planners, leading to a summary payload time line that is consistent with STS constraints and schedules and with the scientific activities necessary to accomplish the payload flight requirements. Some modifications to the STS activities may be needed to enhance or optimize the payload activities; the intent is to accommodate the payload flight requirements as completely as possible within the planning resources limits, while maintaining STS vehicle and crew safety limits.

The STS crew activity planners will combine the payload activities (which have been planned and scheduled by the payload crew activity planners) with the STS activities to create a single integrated summary crew activity plan. Those STS activities required to support the payload activities will also be scheduled. As a part of this integration process, a vehicle attitude time line will be developed.

During this time frame, an update to the flight profile is produced, if required, and detailed systems analyses are conducted. This is necessary because of the interrelationships among flight design, operations planning, and crew activity planning. As a result of this process, a preliminary integrated summary crew activity plan and a preliminary vehicle attitude time line will be developed.

These products are used to develop the payload planning details. The payload details consist of any required payload time line details that go beyond the basic activity definitions in the summary crew activity plan, or any payload data required for the execution of these activities. If modifications to the integrated summary crew activity plan are required, they will be coordinated with the STS crew activity planners.

About 12 weeks before launch (in either the long or the short planning cycle), the payload flight data file will be completed. At 8 weeks, the final STS flight data file will be produced by the STS planners. This is the material actually carried onboard and includes the crew activity plans, procedures, reference material, and test data needed by the crew for flight execution.

During this same time frame, the STS operations planners will produce the final issues of the command plan, flight rules, and network and logistics support plan. This will allow the crew and the STS flight control team (assigned 8 weeks before launch) to begin their flight-specific training and will serve as a basis for their preparations. Six weeks before launch, the user will provide the final payload flight data file and the final payload details. Any subsequent planning updates will be performed only as required.

The majority of STS procedures are standardized; changes required from flight to flight will be primarily a result of vehicle configuration changes. The STS/payload interface procedures, however, are candidates for standardization only for repeat payloads The scheduling of STS payload support activities depends on the payload activities themselves. For this reason, standardization in these areas is very difficult (without sacrificing flexibility in payload scheduling or accepting less than optimum results).

Operations planning

Operations planning includes that planning performed to ensure a smooth execution of the flight itself. The results of the analyses performed during the utilization planning and flight design phases are the primary inputs to the operations planning phase.

During this final phase, the flight documentation to be used during flight operations is evaluated and updated no later than 8 weeks before launch if the flight requirements demand modifications. The following documents are involved.

- Flight rules
- Console handbook
- Command plan
- Communication and data plan
- Systems schematics
- MCC/network support plan
- Logistics support plan
- Countdown test checkout procedures
- Systems command procedures handbook

Detailed systems and consumables analyses and budgets for the flight, using the reference trajectory as a basis, are also done in this final planning phase.

Training preparation

The training preparation task for a specific flight begins with the determination of training requirements. If new facilities are needed, they must be identified far enough in advance to allow funding and design work.

Once the training requirements have been identified, standardized training plans will be modified to fit the flight requirements, the training facilities will be scheduled, the simulation scripts written, and the actual training performed to support both flight crew and flight controller tasks.

All STS-related training, both for onboard and ground personnel, is the responsibility of JSC. All payload-related training is the responsibility of the user. Close coordination is, therefore, required to achieve a compatible and balanced training plan.

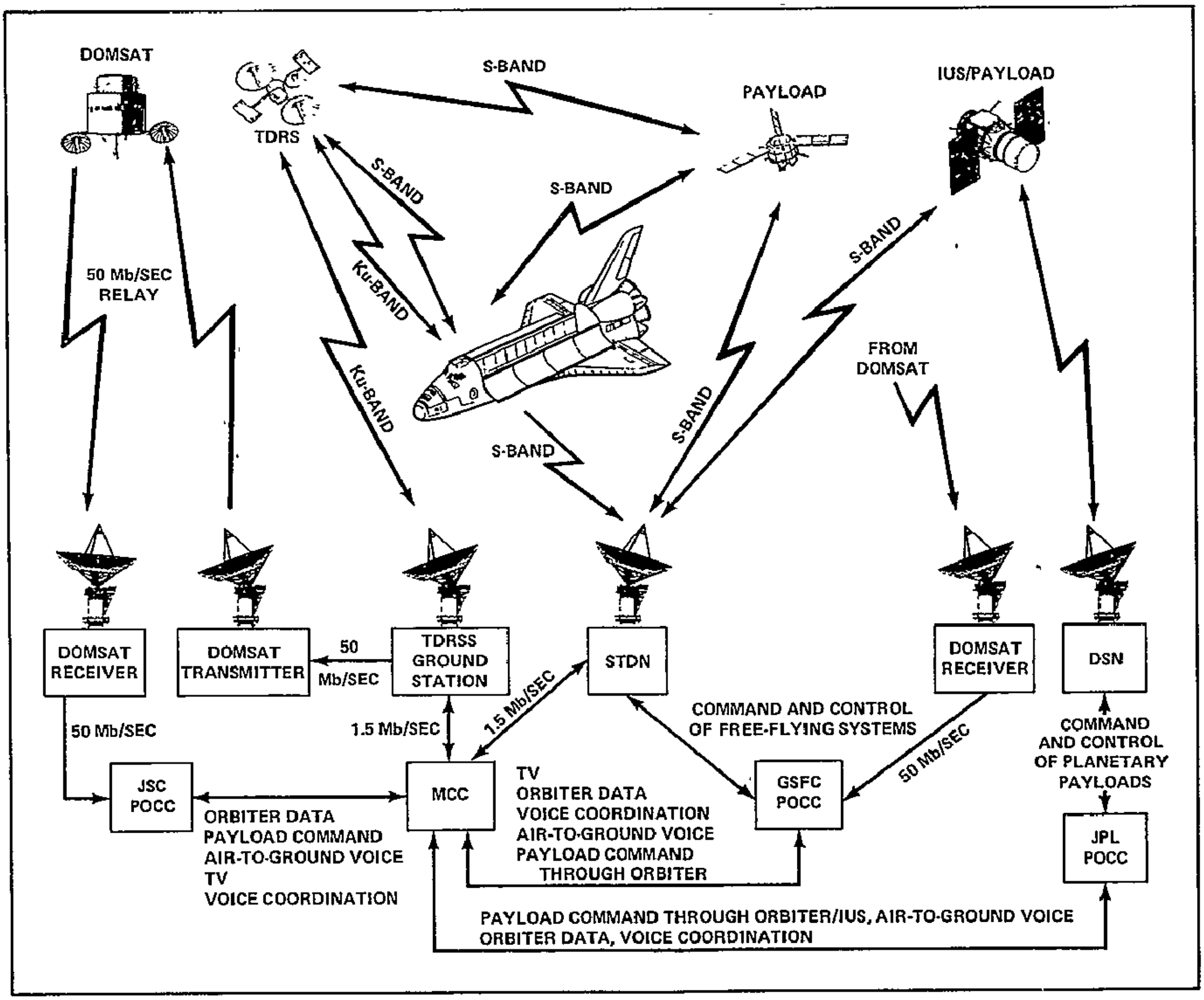
Additional information about schedules, requirements, and specific facilities is in the section entitled "Training and Simulations."

COMMUNICATIONS NETWORK

The network used by the Space Transportation System provides real-time communication links between the user on the ground and his payload — whether it is attached or detached — during most of the time on orbit. This communication, managed either through the Mission Control Center or network control, will originate in the Payload Operations Control Center.

The communication links provide capability for downlink telemetry data, uplink command data, two-way voice, downlink television, and uplink text and graphics.

The STS communications network is a combination of the Tracking and Data Relay Satellite system (TDRSS), consisting of two geosynchronous satellites and one ground station, and the space tracking and data network (STDN). The NASA communications network (NASCOM), which may be augmented by an interface with a domestic satellite (Domsat), links the tracking stations with the ground control centers. In addition, the deep space network (DSN) is used to support all interplanetary flights.



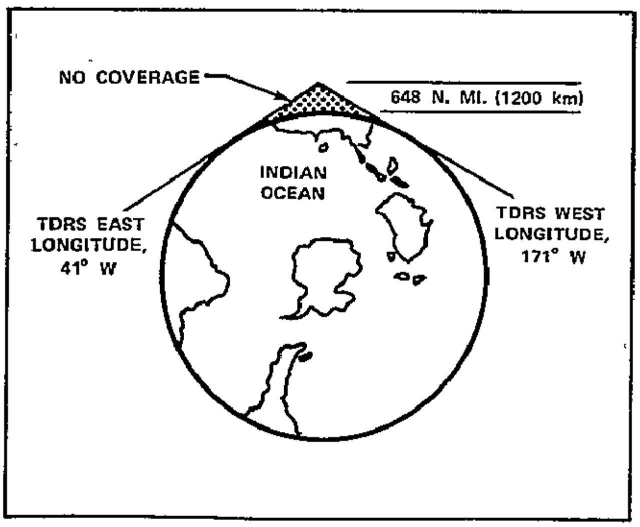
Tracking and Data Relay Satellite system

The TDRSS provides the principal coverage for all STS flights. It is used to support Orbiter attached payloads as well as free-flying systems and propulsive upper stages in low and medium Earth orbit. The nearly continuous monitoring capability helps reduce the probability of experiment failure, reduces the need for onboard data storage, and allows for in-flight modifications of experiments.

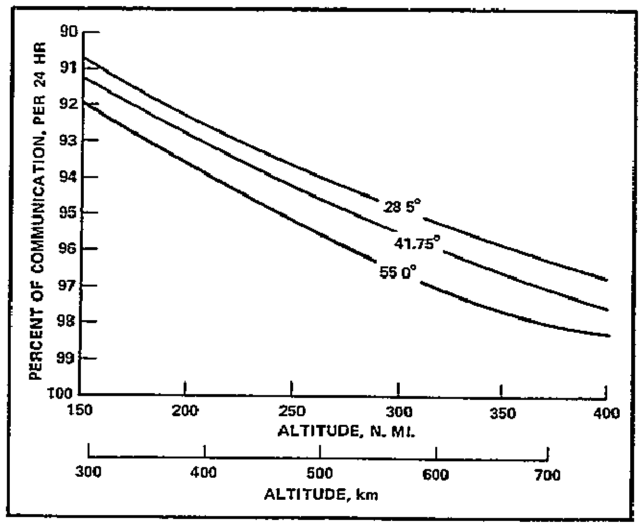
The system consists of two active communications relay satellites in geosynchronous orbits 130° apart and a single ground station at White Sands, New Mexico. The two satellites provide a minimum orbital communications coverage of approximately 85 percent for all spacecraft, even those at the lowest orbital altitude. Coverage increases with altitude, becoming approximately 98 percent at 600 nautical miles (1111 kilometers), the highest operating range of the Orbiter. User spacecraft at low altitudes and inclinations will pass through the zone of no coverage during every orbit and, therefore, receive the least coverage. Those at high altitudes and high inclinations will pass through the no-coverage zone only periodically; for example, a spacecraft at 540 nautical miles (1000 kilometers) and 99° will be in the zone only once per day or less. The limited coverage area is generally between 60° and 90° east longitude (central Asia, India, and the Indian Ocean).

Communications coverage by TDRSS may be further constrained as a result of antenna patterns during those payload operations that require specific Orbiter attitudes. For example, an Orbiter "heads down" position for Earth resources viewing could restrict coverage to as low as 30 percent of the time, depending on orbital inclination and Orbiter attitude position.

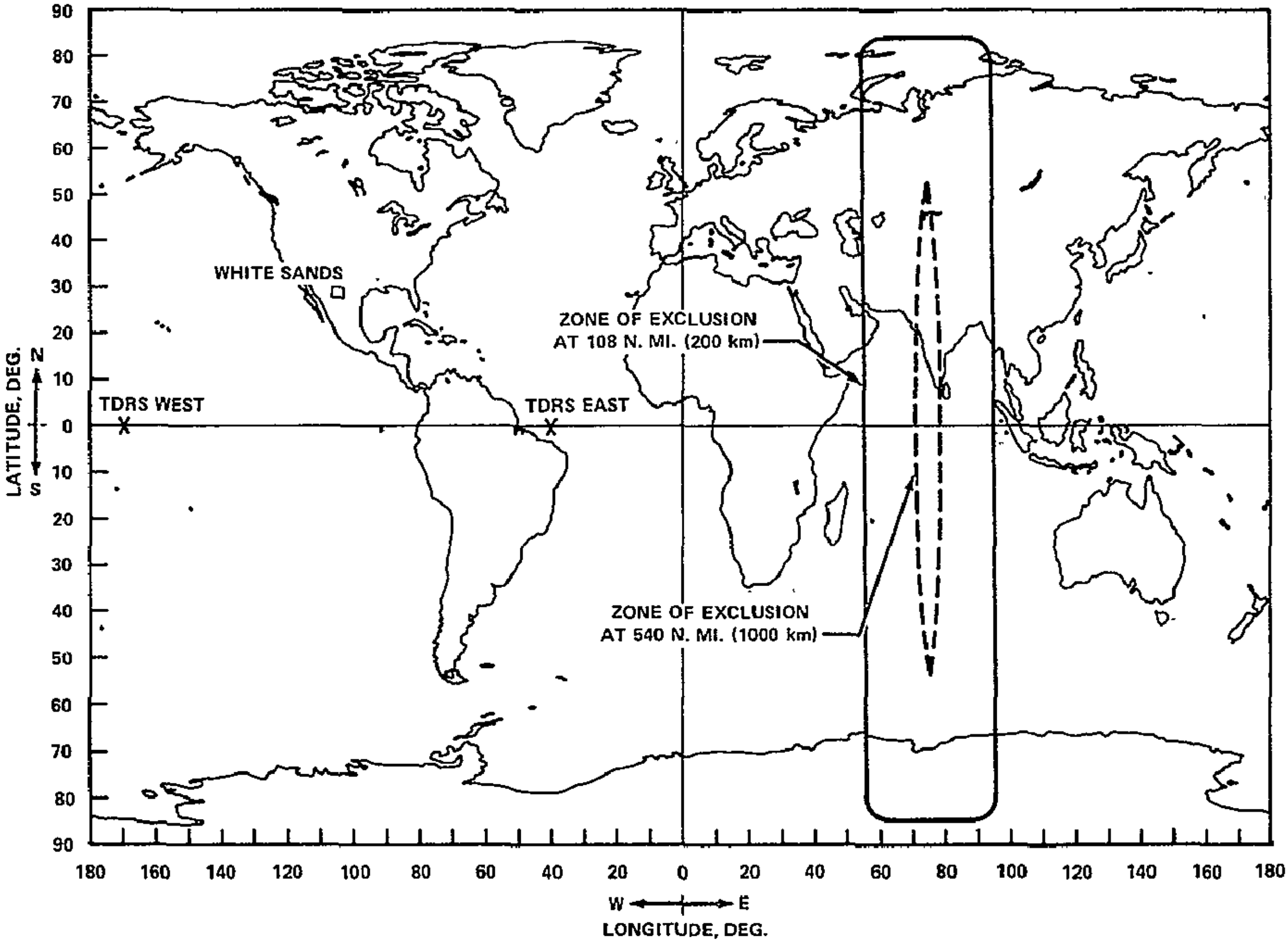
Details of TDRSS capabilities are provided in the TDRSS Users' Guide (GSFC STDN 101.2).



Two-satellite Tracking and Data Relay Satellite system showing area of no coverage.



Percent of TDRSS communication at various inclinations and altitudes.



Areas where the Orbiter is out of communication on the TDRSS network are shown for two altitudes.

Space tracking and data network

The space tracking and data network consists of several S-band stations scattered around the world for support of Orbiter launch and landing operations, as well as for propulsive upper stages and free-flying systems operating in high-Earth orbit.

Because the STDN can accommodate only the Orbiter S-band downlink, the data rate for payloads will be limited to less than 4.0 megahertz or 5.0 megabits/sec.

NASCOM and Domsat

The NASA communications network, managed by the Goddard Space Flight Center, forms the ground links between the tracking stations and both the Mission Control Center and the Payload Operations Control Centers.

Depending on the network design, the data will be handled in one of two ways. The TDRSS ground station may reroute the entire STS downlink stream (up to 50 megabits/sec) unchanged through a Domsat to a Domsat ground terminal at Johnson Space Center. Any agency in the continental United States having a Domsat terminal would also have access to the STS downlink.

In the other design (known as the selected throughput design), the TDRSS ground station may route selected portions of the STS downlink stream (up to about 1.5 megabits/sec) unchanged through a wideband circuit directly to the MCC.

Payload control

All commanding through the Orbiter to payloads will pass through or be initiated at the MCC. As much as 2 kilobits/sec of command data (various types, formats, and bit rates) can be transmitted to payloads through the Orbiter. The intent of the Shuttle command system (onboard and ground system) is to provide for maximum transparency to payload commands, while retaining adequate control for crew safety. Some specialized preflight planning with the user is necessary to achieve this goal. The following command system features and operations concepts are used.

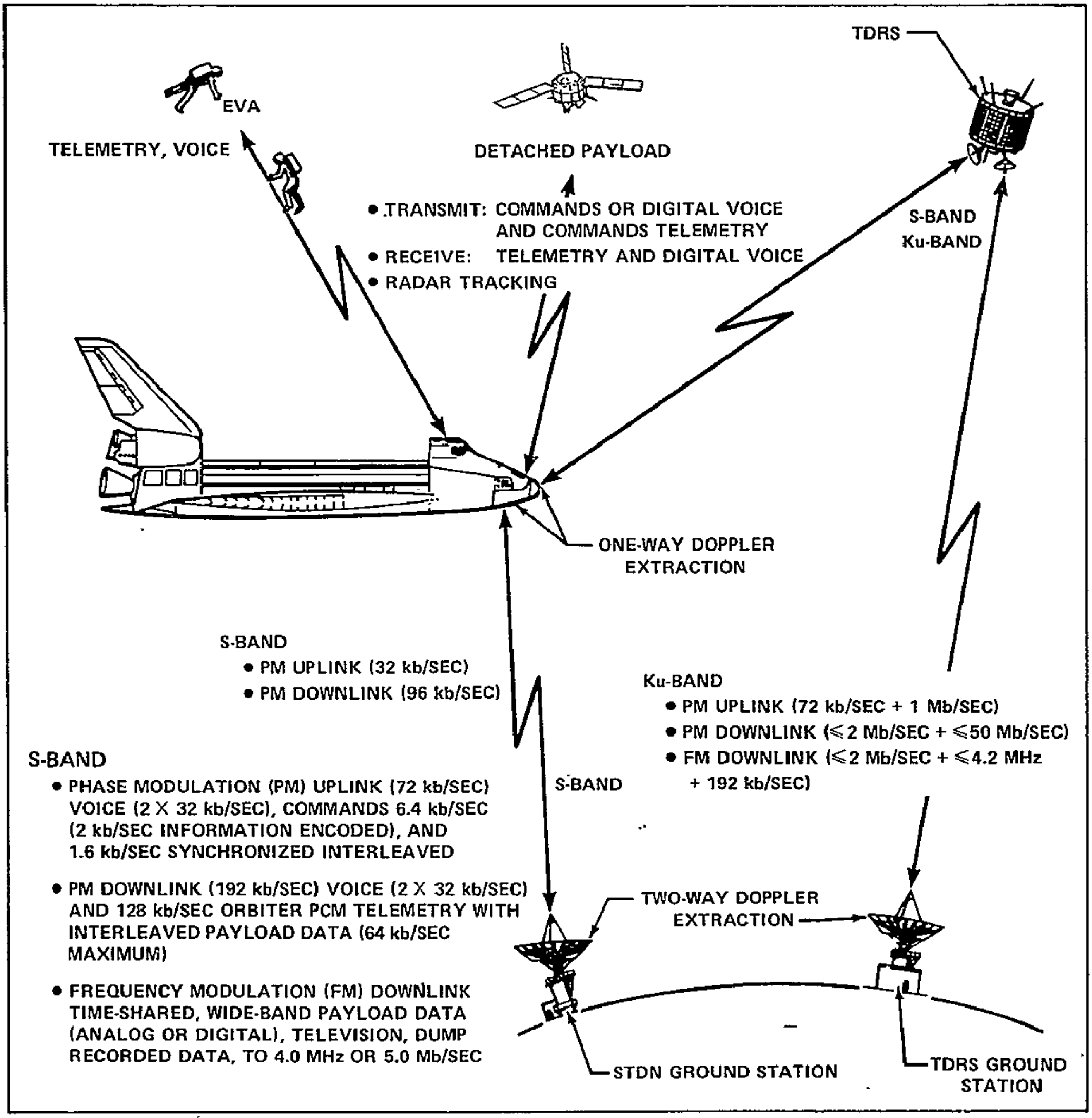
An STS/payload command plan will be developed and jointly agreed upon by JSC and the user, with particular attention given to the countdown, launch, insertion, and payload-activation sequences. To ensure Orbiter safety and to allow for interruption of normal, preplanned POCC command sequences during Orbiter contingencies, the MCC will maintain the capability to enable/disable POCC command output through the MCC.

A list of payload commands that constitute a hazard to the Orbiter (while the payload is attached to or near the Orbiter) will be identified jointly by JSC and the user during preflight planning. The user may add to the list any commands considered hazardous to the payload itself. This joint command list will be entered into the MCC command software (safed).

A definite handover time for detached payload operations will be established jointly by JSC and the user before the flight. The plan will define the point after which POCC commands will cease to pass through the MCC and will be initiated and routed independent of STS commands. In establishing the proper handover time, the primary consideration is to maintain Orbiter and crew safety after the handover of command responsibility.

Telemetry and data systems

When attached payloads are flown, up to 64 kilobits/sec of data can be transmitted (interleaved with the STS operations telemetry) to the ground. Selected portions of these data can also be displayed onboard to the crew. The payload data and voice transmission will automatically be recorded on the operations recorder whenever the proper data format and voice channels are selected. In addition, up to 50 megabits/sec of payload data (either in real time or recorded) can be transmitted to the ground via TDRSS.



Somewhat less capability exists for detached payloads telemetry through the Orbiter. Up to 16 kilobits/sec of payload data can be transmitted to the Orbiter, displayed to the crew, and transmitted (interleaved with the STS operations telemetry) to the ground. These data (and voice, if available) will also be recorded onboard whenever the proper data format and voice channels are selected. Up to 4 megabits/sec (or 4.5 megahertz) can be transmitted from the payload through the Orbiter to the ground via the "bent pipe" route. However, the crew would not have access to the data.

After crew- or ground-commanded checkout of a detached payload has been completed and after the Orbiter has executed a separation maneuver, the payload control function no longer involves the Orbiter. The POCC will then assume complete control of the detached free-flying payload and command/telemetry data will no longer be routed through the Orbiter or the MCC.

If a flight involves an upper stage/payload combination, the MCC will retain control through separation of the upper stage and its payload at a desired orbital position. However a payload may have its own radiofrequency telemetry interface with a network simultaneously with the upper stage telemetry downlink.

Voice and video links are also provided. The MCC will control all air-to-ground voice channels. The POCC will normally communicate with the crew for payload operations on the air-to-ground science operations channel (which is separate from the Orbiter operations channel). However, if the command/telemetry interface is low bit rate to and from the Orbiter, the POCC will share the same channel with the MCC. The MCC will continuously monitor usage of the air-to-ground science operations channel and will enable/inhibit POCC voice capability as required for crew safety and in-flight operations.

The crew controls voice recording, but the MCC, with crew coordination, controls recorder dumps (playbacks to the radiofrequency system for downlink of recorded information).

The source of video can be the cockpit television camera, one of the four cameras associated with the cargo bay and manipulators, or from an attached payload. Coordination of video use between the MCC and the POCC will require integrated flight planning.

Payload/Orbiter telemetry data

	Data link	Can be recorded onboard	Can be displayed onboard	Can be received by STDN	Can be received by TDRSS
Detached payload interfaces	Up to 16 kilobits/sec	Yes	Yes	Yes	Yes
	Bent pipe	No	No	No	Yes
Attached payload interfaces	Up to 64 kilobits/sec	Yes	Yes	Yes	Yes
	Up to 50 megabits/sec	No	No	No	Yes
	Up to 1.024 megabits/sec	No	Yes	Yes (dump)	Yes (dump)
	Up to 5 megabits/sec	No	No	Yes	Yes
	4.2 megahertz	No	Yes	Yes	Yes

MISSION CONTROL CENTER

During all on-orbit periods when a payload has an operational interface with the Space Transportation System, flight operations support will be provided jointly by the Mission Control Center (MCC) and by the Payload Operations Control Center (POCC) responsible for that payload. The MCC will provide total support for other phases of the flight – prelaunch, ascent, reentry, and landing.

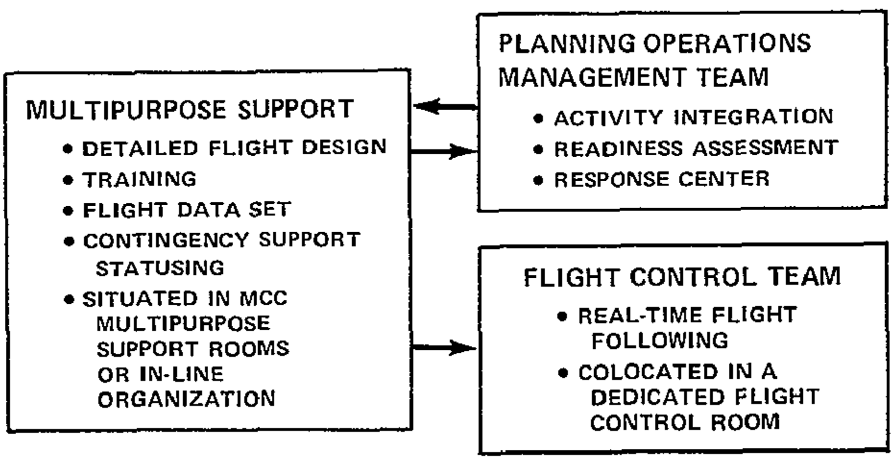
The MCC is located at the Lyndon B. Johnson Space Center (JSC), which has been designated as the STS operator for all NASA flights. Flight operations command and control facilities are located in the MCC.

For all flights, the MCC provides systems monitoring and contingency support for all STS elements, provides two-way communications interface with the crew and onboard systems, performs flight data collection to a central site, and provides a preflight and in-flight operational interface with the POCC to coordinate flight operations.

Specific types of payloads require some variations in the interface support provided by the MCC. The MCC operation has sufficient flexibility to accommodate all types of missions with varying degrees of user participation and STS services to payloads. The operations concepts are intended to provide economical and convenient services in response to user needs.

Three basic flight types involve (1) attached payloads, (2) deployment and retrieval in Earth orbit, and (3) use of upper stages to deliver payloads.

For flights involving attached payloads, the MCC provides these standard items: Spacelab systems monitoring, contingency support, and systems support for unattended operations; Spacelab software support for standard Spacelab services; interface systems support; and other items related to combined POCC and MCC tasks. The MCC also provides a ground team to develop whatever preflight documentation is required for a given flight, including the STS payload support plan, flight rules and constraints, troubleshooting plans and procedures, and command plans. The ground support role is flexible and able to operate with standardized Spacelab configurations and documentation sets.



Organization of the Mission Control Center.

Deployment and retrieval missions fall into two broad categories of MCC support: those requiring little or no checkout or special training of flight crews and operations support personnel and those that involve significant crew activities and systems interfaces between the Orbiter and the payload. For the limited-interface category, MCC support will follow a standardized plan that requires consideration only of trajectory and deployment end conditions. Variations in ground systems may relate only to command and telemetry format modifications and trajectory monitoring.

The MCC interface will be more extensive for those flights that require significant crew and systems interfaces. Real-time telemetry and voice and command system capabilities will be provided through STS operations interfaces. Payload systems expertise will be provided by the user. Payload telemetry processing at MCC will include only that payload data received in the operational data stream that are required to accomplish STS interface responsibilities.

For payloads involving use of standard propulsive upper stages (requiring trajectory placement that cannot be achieved by the Orbiter), MCC will be responsible for the systems monitoring, contingency support, and operational control of the upper stage. Telemetry data from the upper stage will be processed at MCC to support flight control, both while the upper stage is in the cargo bay and while it is operating deployed from the Orbiter. Payload data transmitted through the Orbiter or independently of the STS communication systems will also be made available at MCC if those data are required to support flight operations.

The STS operations organization within the MCC consists of three major elements or functions: a planning operations management team (POMT), multipurpose support groups, and small flight control teams.

The POMT serves primarily to perform a preflight (approximately 2 years to 16 weeks before launch) function, with management responsibility for the detailed development, planning, scheduling, and status of all STS flights. The POMT will provide assistance to the user in preparing requirements documentation for facilities, software, command, telemetry, flight requirements, and POCC interfaces.

The multipurpose support function includes the bulk of STS flight planning, procedures development, and systems expertise and manpower. The multipurpose support teams provide direct support for preflight planning and training activities and, during the flight, provide systems and trajectory statusing support to the flight control room on a routine and periodic basis.

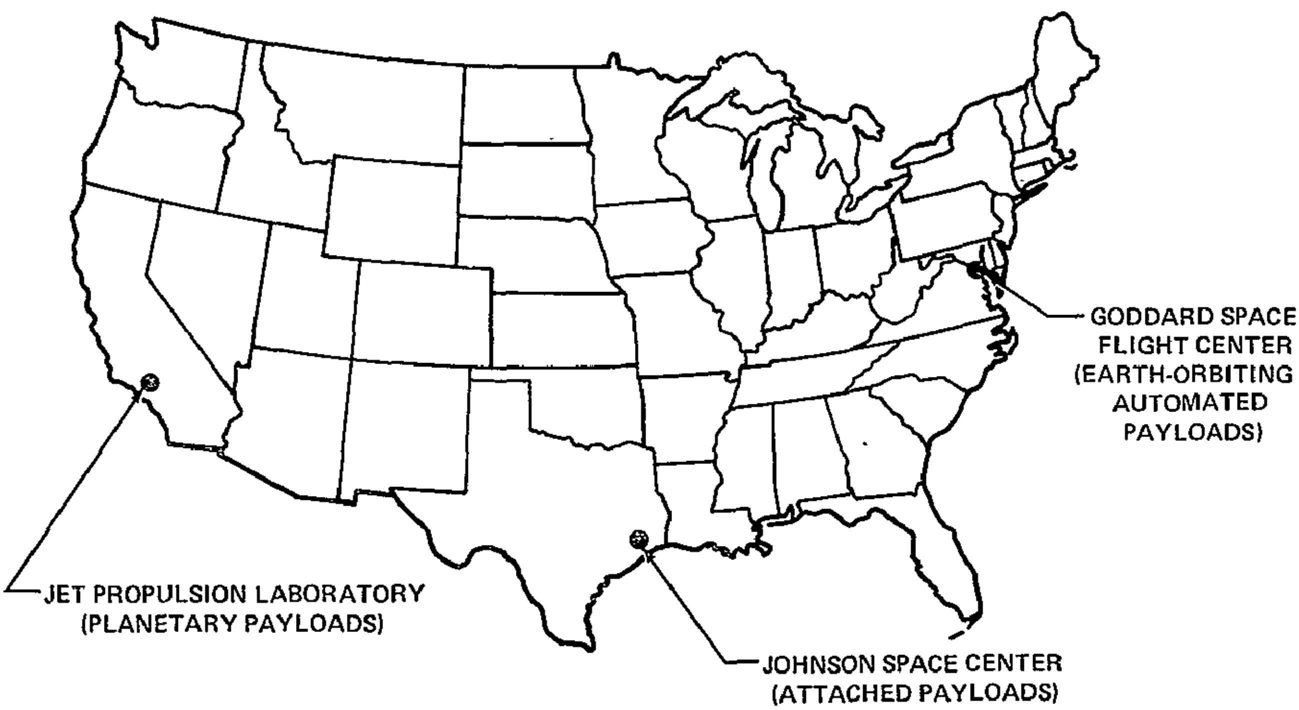
The flight control team is the only flight-dedicated element in the operations concept; these people are on duty 24 hours a day for the duration of each STS flight. They provide direct real-time flight support to the crew through flight monitoring and assistance during launch and entry, and by following the flight acitivities during the orbital phase. The real-time planning and execution of payload operations activities will be primarily the responsibility of the POCC.

PAYLOAD OPERATIONS CONTROL CENTER

Operating in conjunction with the JSC Mission Control Center are three Payload Operations Control Centers (POCC's), from which the STS user or experimenters can monitor and control their payloads.

The relationship between the MCC and each POCC is essentially the same. Each POCC has the computation and display capability necessary to provide data for operational control of payloads as well as the capabilities for payload communications and command.

Normally, only one POCC will be involved with a single flight. Attached payloads, including all Spacelab manned modules and/or pallets, are controlled from the POCC at JSC. Free-flying systems that are deployed, retrieved, or serviced in Earth orbit by the Orbiter are monitored by a POCC at the Goddard Space Flight Center (GSFC). Payloads with distant destinations, such as those exploring other planets, are controlled from the POCC at the Jet Propulsion Laboratory (JPL).



Locations of Payload Operations Control Centers.

Attached payloads

Flight operations activities for support of attached payloads are conducted from the POCC at JSC. This POCC provides the facilities and accommodations necessary to monitor and control the payload operations.

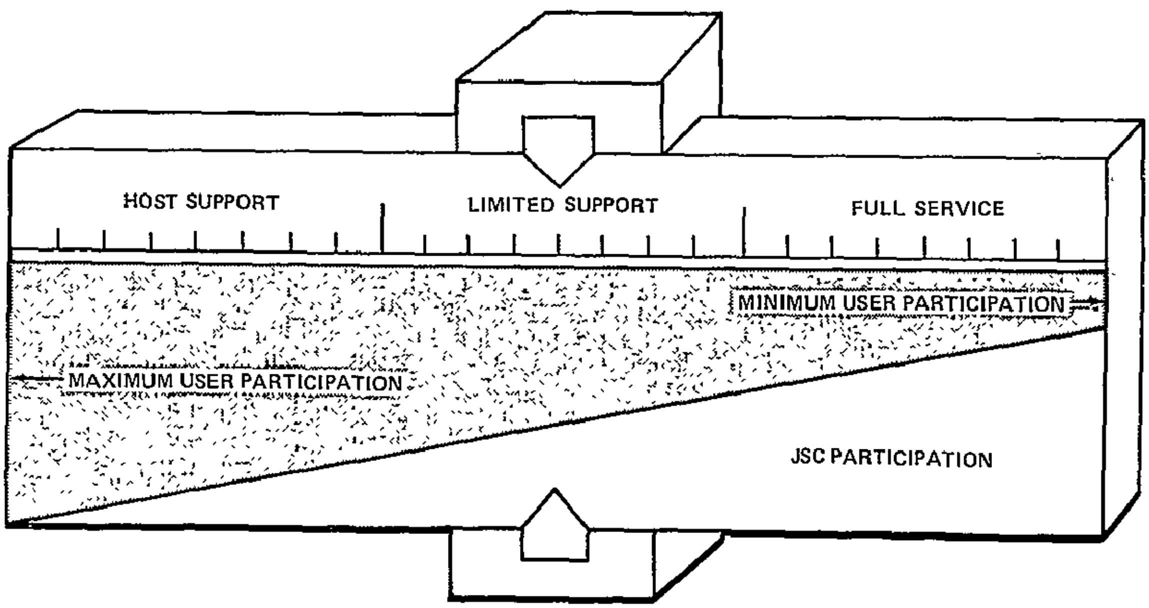
The user can select the level of support needed in the POCC for payload support. The three basic modes are as follows.

- Host — in this mode, the POCC provides host facilities with a standard complement of capability for data monitoring, payload commanding, and voice communications with the crew and the MCC. The user provides all the payload operations personnel necessary to support real-time crew activity planning, crew procedures changes, command and control, systems monitoring, science processing, and analysis. JSC will provide one liaison position to support POCC familiarization, because it is expected that a wide variety of users will be spending only a short time in the POCC and will be somewhat unfamiliar with the standard STS/MCC/POCC operations.
- Limited — in this mode, the user provides part of the payload support and NASA provides payload support in selected areas.
- Full service — in this mode, NASA provides all the required payload support to conduct the user's payload operations. However, as in the other modes, the user will be responsible for all science management support.

Generally, the same data that are available to the STS controllers within the Mission Control Center are also available to the user in the POCC. The POCC also provides similar capability to the MCC for command uplink and voice communications both with the onboard crew and with flight controllers in the MCC. The accompanying table provides a summary of the standard capabilities in the JSC POCC for data monitoring, command and control, accommodations, and services.

Interfaces between the POCC and the MCC are simplified somewhat by the fact that both are located in the same building (building 30 Mission Control Center complex at JSC). Payload operations for attached payloads require close coordination between the POCC and the MCC throughout the duration of a flight. No handoff is made, as it is to the other two POCC's when their spacecraft get out of range of the Orbiter.

The responsibility for managing and staffing the JSC POCC lies with the user; thus, the organizational structure is flexible and may vary somewhat from flight to flight. However, the user is expected to designate an individual within the POCC who has overall responsibility for all payload operations decisions.



Scale of support options from the POCC available to the user.

JSC POCC standard capabilities

Facility	• Consoles, desks, chairs, tables, recorders, telephones, headsets for voice monitoring, conference areas
Voice communications	• Voice loops (both internal and external to JSC) for coordinating STS/payload flight planning activities • Two-way voice communications with crew during flight • Voice transcripts and/or voice tapes of crew conversations
Command data (uplink)	• Commands can be initiated from an assigned console position in the POCC • Command histories can be retrieved from real-time processors and displayed on the console. Command histories may also be obtained from off-line processors (printouts or tapes)
Telemetry data (downlink)	• Real-time monitoring of the STS systems data (same capability as MCC controllers) • Real-time processing and display of payload command and control data • Real-time processing and display of science data contained in independent science downlinks • Near-real-time processing and display of science data contained in independent science downlinks

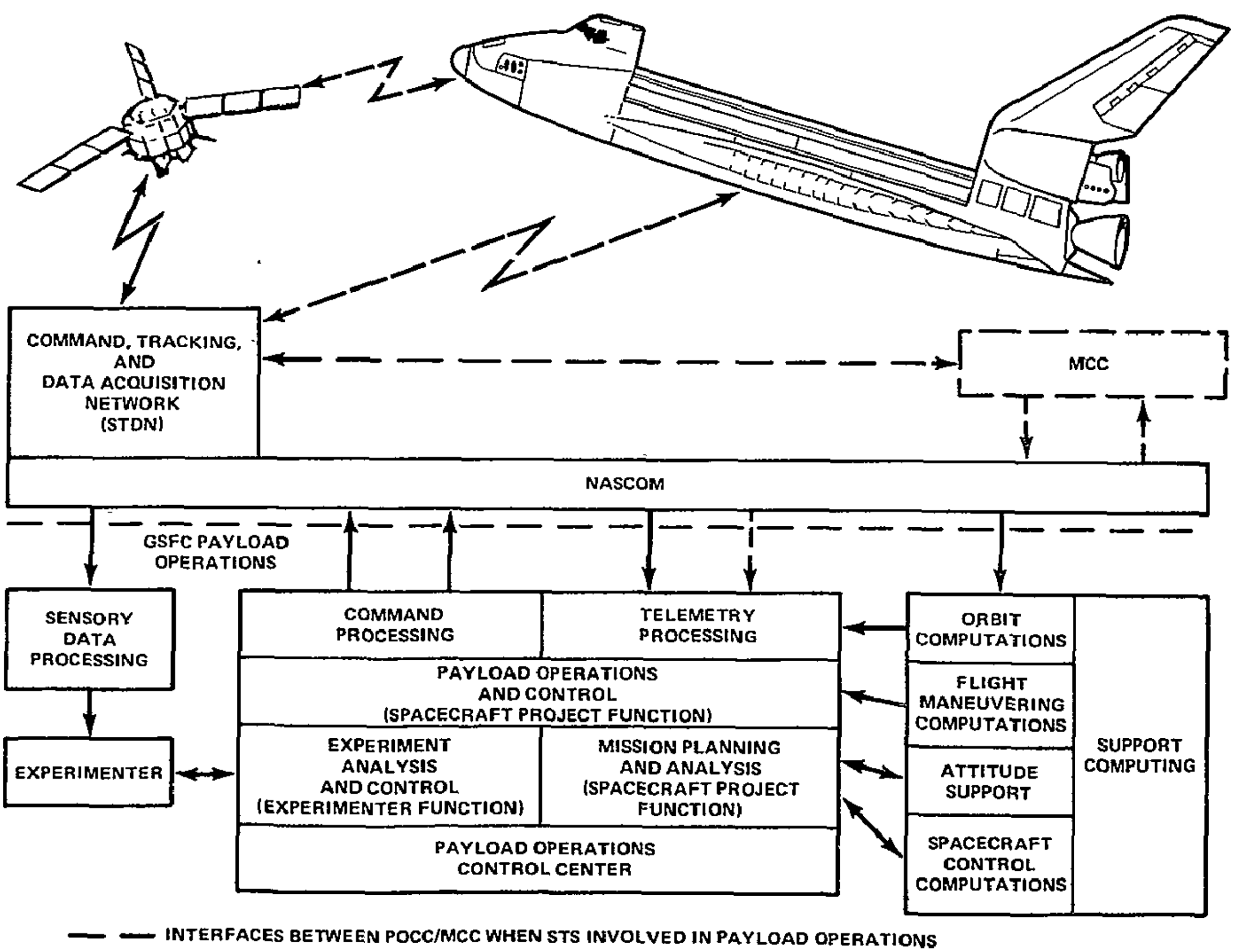
Data processing	• Standard unit conversion, limit sensing, and simple arithmetic computations • Analysis program support (the amount of support will be negotiated on a case-by-case basis)
Trajectory	• All ongoing trajectory and Orbiter attitude information will be made available to users as required • Orbit phase processing of trajectory will be performed as required to support payload operations
Output devices	• Digital television equipment displays • Strip chart recorders • Tabular reports • Standard computer-compatible tapes containing STS systems and trajectory data
Video downlink	• Can monitor in real time all STS-compatible video downlink • Video tapes available postflight
Natural environment support	• Worldwide meteorological data • Space environment data (reports on solar activities, energetic particles, artifical events, geomagnetic activity, auroral data, and ionospheric disturbances)

Free-flying automated payloads

Goddard Space Flight Center is equipped to conduct operations of NASA Earth-orbiting free-flying spacecraft. Eight to 10 individual POCC's exist, each of which has the capability to support flight operations of several spacecraft. Normally, an individual dedicated POCC will support a series of spacecraft or spacecraft in similar scientific disciplines. A Multisatellite Operations Control Center, which provides support for those spacecraft that do not require a dedicated POCC, can support 5 to 10 spacecraft, depending on extent of operational requirements.

The GSFC payload operations are functionally organized into three main areas: the project operations control center, which is the focal point for payload operations and control; the support computing functions, which include computations of orbit, attitude, flight maneuvers, and spacecraft control; and the sensory data processing, which provides preprocessed time-ordered data and processed image data to experimenters and organizational users. These functions and their relationships are illustrated.

A non-real-time computing capability exists for mission analyses, design of payload flightpath, and in-orbit flight data analysis and navigation computations.



Capability exists to simulate spacecraft characteristics, operational constraints, environmental parameters, and to generate data for checkout of the end-to-end data system and spacecraft responses to command activities. The simulation capability is normally mission-unique.

The standard POCC capabilities are quite similar to those described previously for the JSC POCC. The size and computational support will vary, depending on individual mission requirements.

The GSFC POCC normally provides the control facilities, computational capability, and software necessary to interface with the STDN, to process the free-flying spacecraft telemetry data, to generate the necessary data outputs and displays to support the spacecraft evaluation and operations, and to generate the necessary commands for spacecraft operation. The required operations personnel are also provided by GSFC.

The user normally provides the spacecraft operations team that works from a mission operations room. The individual experimenters and principal investigators either work within the POCC or have interfaces to the POCC. They are responsible for operation and evaluation of their own experiments. If required, data can be transmitted to an experimenter's home facilities, at the experimenter's expense.

Each POCC at GSFC will provide standard interfaces to the STS for times when operations are conducted with the spacecraft attached to the Orbiter or in its sphere of influence. These interfaces include command, telemetry, Orbiter attitude and orbit ephemeris, flight-planning data, voice capability to the Mission Control Center and the Orbiter, and video as required.

Support from a POCC at GSFC is arranged through the Office of Tracking and Data Acquisition at NASA Headquarters.

Planetary payloads

The POCC (also called the Mission Control and Computing Center) at the Jet Propulsion Laboratory is equipped to support planetary or lunar mission operations as well as some Earth-satellite operations managed by JPL. More than one mission can be supported simultaneously. The POCC includes two buildings (the Space Flight Operations Facility and part of the System Development Laboratory). The amount of actual area needed changes with the mission requirements.

An auxiliary powerhouse, computers, software, terminal and display equipment, communication equipment, operating personnel, and other miscellaneous items are part of the JPL POCC.

The functional systems include those for imaging, telemetry, operations and control, simulation, command, tracking, and data recording.

The figure shows the top-level data processing hardware configuration. In this illustration, two missions are being supported simultaneously. Mission 1 is receiving its data from the deep space network, while mission 2 (which could be either in a launch configuration test or a launch/on-orbit phase) is receiving data from the STS.

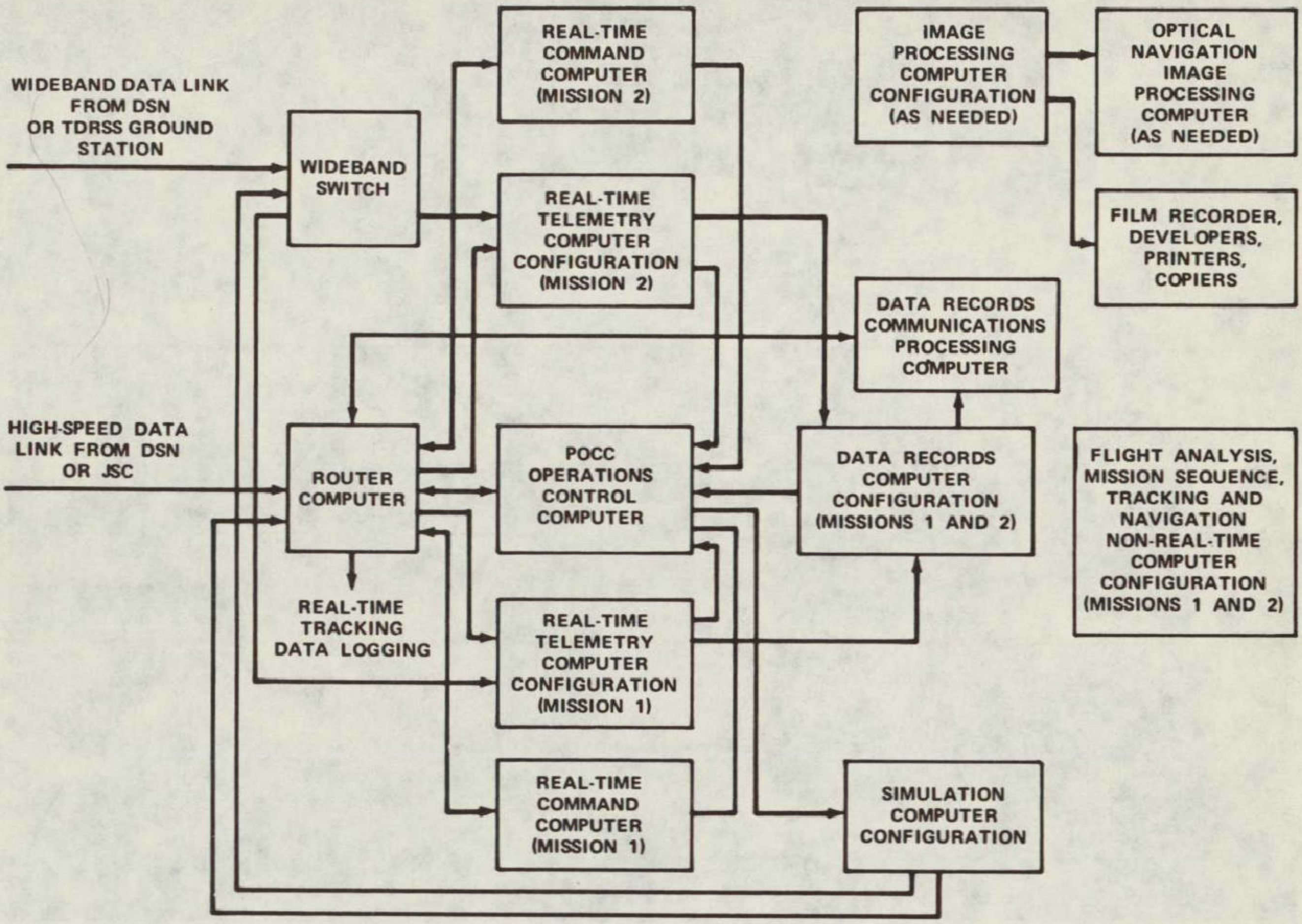
Two basic categories of computers and associated equipment are for real-time and non-real-time processing. For real-time processing, a decentralized approach, using dedicated computer configurations, is followed.

When the mission requires it, image processing to generate pictures and the processing of image data to obtain optical navigation parameters are done in dedicated computer configurations. These configurations may or may not be connected to the real-time data communication network. Neither function is required in the STS/POCC interface.

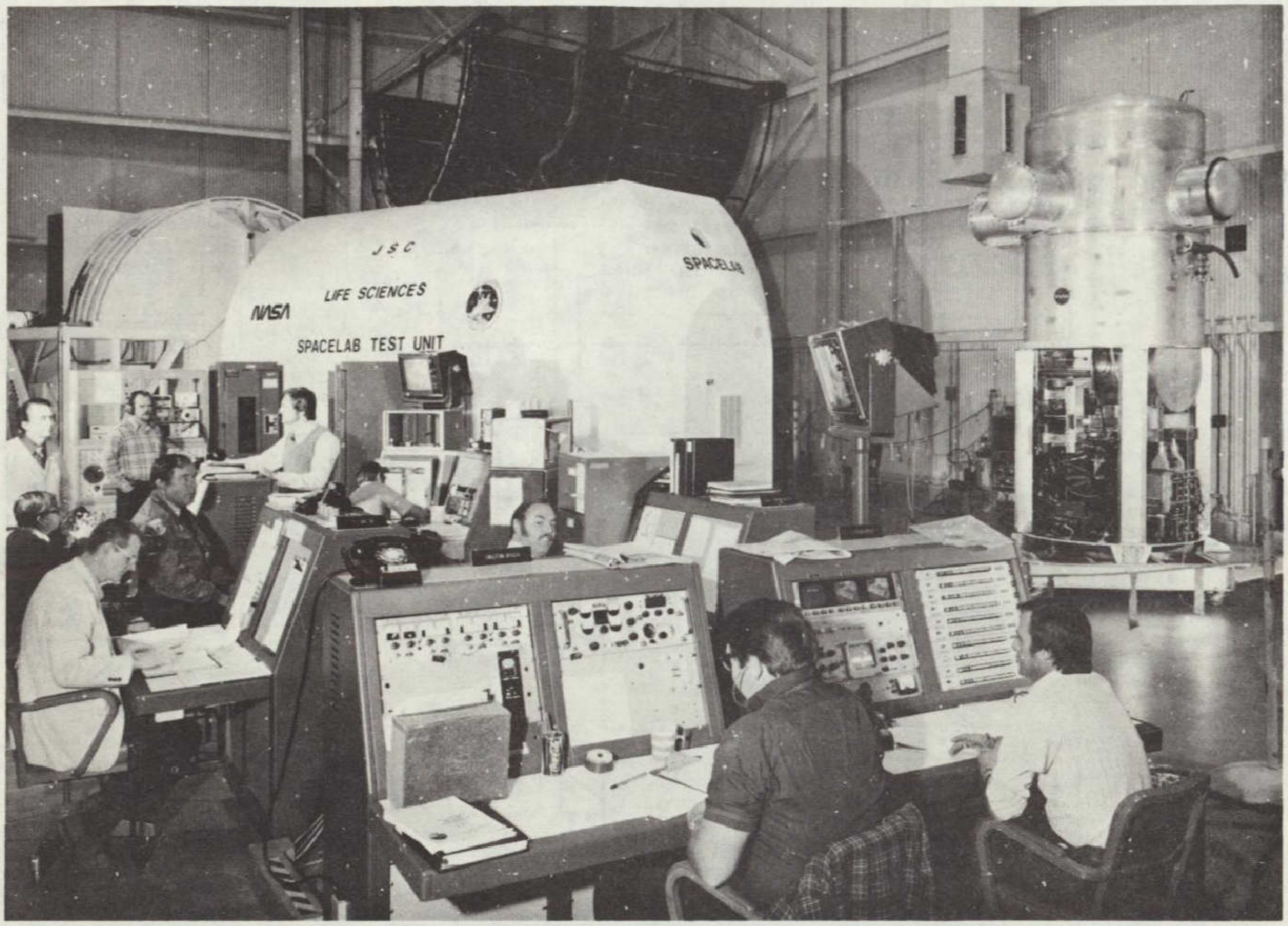
The non-real-time computing is shared by all missions in a large, centralized computer configuration, where all flight data analysis and navigation computation, mission sequencing necessary for mission control, and generation and validation of the final data records are performed. Some of the data record file preparation is done on minicomputers.

Simulation of the spacecraft and of other external data interfaces of the end-to-end data system are obtained through a computer-based simulation system dedicated to a mission.

Backup configurations are also provided.



Configuration of computers for handling multiple missions.



Life sciences simulation being conducted in a Spacelab simulator.

The STS operations provides all users with flight-qualified commanders, pilots, and mission specialists. In addition, the concept of noncareer crewmembers permits visting payload operators to fly as payload specialists. These payload specialists who augment the basic crew are selected by the user in accordance with appropriate NASA management instructions. These payload specialists, if they are provided by the user, are required to undergo the minimum STS training considered necessary for them to function efficiently as members of a flight crew.

In general, the STS crewmembers (commander, pilot, and mission specialist) are responsible for operation and management of all STS systems, including payload support systems that are attached either to the Orbiter or to standard payload carriers. The payload specialist is responsible for payload operations, management, and the attainment of payload objectives.

Crew duties

The following description of crew duties is summarized from Space Shuttle System Payload Accommodations (JSC-07700, Volume XIV).

The Orbiter crew consists of the commander and pilot. Additional crewmembers who may be required to conduct Orbiter and payload operations are a mission specialist and one or more payload specialists. A commander plus a pilot or pilot-qualified mission specialist are always required to operate and manage the Orbiter. Makeup of the rest of the crew depends on the mission requirements, complexity, and duration. Detailed responsibilities of the mission and payload specialists are tailored to meet the requirements of each individual flight.

The commander has ultimate responsibility for the safety of embarked personnel and has authority throughout the flight to deviate from the flight plan, procedures, and personnel assignments as necessary to preserve crew safety or vehicle integrity. The commander is also responsible for the overall execution of the flight plan in compliance with NASA policy, mission rules, and Mission Control Center directives.

During the payload operations phase of the flight, the commander will, within the described limitations connected with crew safety and vehicle integrity, be subject to the authority of the mission specialist in directing the allocation of the STS resources to the accomplishment of the combined payload objectives, including consumables allocation, systems operation, and flight plan modifications.

The pilot is second in command of the flight. The pilot assists the commander as required in the conduct of all phases of Orbiter flight. He or she has such authority and responsibilities as are delegated to him or her by the commander (for example, during two-shift orbital operations). The commander or the pilot will be available to perform specific payload operations if appropriate and at the discretion of the user.

The mission specialist is responsible for the coordination of overall payload/STS interaction and, during the payload operations phase, will direct the allocation of the STS and crew resources to the accomplishment of the combined payload objectives. The mission specialist is responsible to the user or users, when carrying out assigned scientific objectives, and will operate in compliance with mission rules and Payload Operations Control Center directives. When so designated by the user or users, the mission specialist will have the authority to resolve conflicts between payloads and to approve deviations from the flight plan such as may arise from payload equipment failures or other factors.

He or she may also operate experiments, consistent with responsibilities assigned before the flight and in agreement with the user. The mission specialist has prime responsibility for experiments to which no payload specialist is assigned, or will assist the payload specialist when appropriate, or both. During launch and recovery, the mission specialist is responsible for monitoring and controlling the payload to assure payload integrity and vehicle safety. He or she will also assist the commander and pilot during these phases as required.

The payload specialist is responsible for the operation and management of the experiments or other payload elements that are assigned to him or her, and for the achievement of their objectives. The payload specialist is responsive to the authority of the mission specialist and operates in compliance with mission rules and Payload Opera-

Flight crew complement

Crewmember	Payload carrier					
	Orbiter only	Spacelab module	Spacelab pallet	IUS or SSUS	Long Duration Exposure Facility	Multimission Modular Spacecraft
Commander	1	1	1	1	1	1
Pilot	1	1	1	1	1	1
Mission specialist	1	1	1	1	1	1
Payload specialist	0-1	1-4	0-3	0	0	TBD
Crew total	3-4	4-7	3-6	3	3	3

tions Control Center directives. He or she will be an expert in experiment design and operation, and onboard decisions about detailed experiment operations will be made by the payload specialist. When desired by users, a payload specialist may be designated to resolve conflicts between those users' payloads and to approve deviations from the flight plan such as may arise from payload equipment failures or other factors related to these payloads.

The payload specialist will be cross-trained as necessary to assist the mission specialist or other payload specialists in experiment operation, but may not be required to manage experiments outside his or her area of expertise. In some instances, the payload specialist may be responsible for all experiments onboard. He or she may operate those Orbiter and Spacelab payload support systems that are required for efficient experiment operation, such as an instrument pointing subsystem, command and data-management subsystem, and scientific airlocks. The payload specialist will be responsible for knowing how to operate certain Orbiter systems, such as hatches, food and hygiene systems and for proficiency in those normal and emergency procedures that are required for safe and efficient crew operations.

The responsibility for on-orbit management of Orbiter systems and attached payload support systems, as well as for extravehicular activity and payload manipulation with the remote manipulator system rests with the basic crew, because extensive training is required for safe and efficient operation of these systems. Assignment of these functions within the basic crew will vary to meet the requirements of each flight. In general, the commander and pilot will manage Orbiter systems and standard payload support systems, such as Spacelab and IUS systems; the mission specialist and/or payload specialists will manage payload support systems that are mission dependent and have an extensive interface with the payload, such as instrument pointing subsystems.

STS crew training

The STS crewmembers are available on orbit for user-defined functions approximately 8½ hours per crewmember per shift. In certain cases, it will be to the user's advantage to utilize an STS crewmember for the management or operation of the payload (experiment). Use of the mission specialist as the prime onboard payload manager/operator and use of the commander or pilot as payload operator will require special training. The extent of crew participation in payload functions is limited by the amount of preflight training time available.

Special payload or experiment training is highly dependent on how a specific user desires to involve the STS crewmember with the payload or experiment; therefore, it is best provided by the user instead of the STS operations. The explicit involvement will be defined during the payload-to-STS integration process. However, before this integration the user should consider the choice of training facilities.

Training facilities may be in the form of mockups, functional trainers, mathematical models compatible with various computer complexes, or complete payload (experiment) simulators. They may be designed to emphasize the payload's philosophy, operations, malfunctions, objectives, or requirements. They can be located either at JSC or at a site chosen by the user.

Several training facilities at JSC are capable of providing an interface to payloads or experiments and, therefore, can be used to provide flight crew training in payload operations.

Classrooms and individualized learning carrels, both equipped for audiovisual presentations, are available to the user at JSC.

The Orbiter one-g trainer (ORB 1-g) is a full-scale representation of the flight deck, mid deck and mid body. Payload interface attachment points are provided in the cargo bay. It will be used for flight crew training in habitability, extravehicular activity, ingress, egress, television, waste management, stowage, and routine housekeeping and maintenance.

The Orbiter neutral buoyancy trainer, designed to be used in a water immersion facility, is a full-scale representation of the crew cabin mid deck, airlock, and cargo bay doors. It also has attachment points in the cargo bay. This facility provides a simulated zero-g environment for training in EVA procedures.

The Shuttle mission simulator (SMS) provides full-fidelity forward and aft crew stations. The SMS is computer controlled with systems mathematical models, consistent with the flight dynamics, driving the crew station displays. It will be used to provide training on combined systems and flight team operations. It includes the capability to simulate payload support systems with mathematical models, remote manipulator system dynamic operations using computer-generated imagery, and Spacelab support systems by interfacing with the Spacelab simulator. The SMS is to be interfaced with the Mission Control Center for conducting crew/ground integrated simulations.

The remote manipulator system task trainer consists of an aft crew station mockup, a cargo bay mockup, and a mechanically operated arm. It will provide an environment for training on payload grappling (in the cargo bay), berthing, visual operations, cargo bay camera operations, and manipulator software operations. The user will provide helium-inflatable models to simulate the payload geometrically.

The Spacelab simulator (SLS) consists of a core and experiment segment interior with computer modeling of the Spacelab systems. It will be used for crew and ground team training on flight-independent systems and for some limited flight-dependent training. The SLS will also be used as a one-g trainer for crew accommodations; habitability, stowage, and safety methods. Growth of this trainer to incorporate experiment interfaces and experiment part task trainers is projected if required.

Several of the STS training facilities cannot be interfaced with payloads or experiments because they are intended to satisfy only STS operations requirements. However, the crew software training aid (CSTA), which provides training in Orbiter CRT display features, keyboard functions, and operational syntax for given functions, will be used for payload specialist training.

Payload specialist training

The training requirement for a payload specialist scheduled for an Orbiter-only flight is approximately 180 hours. A flight with Spacelab pallets requires 234 hours, and one with a Spacelab module requires 239 hours of training.

The tables and figure illustrate the typical training schedule and training types for a payload specialist. In the tables, no attempt has been made to break down the number of hours for each task, and the totals for each trainer are representative and intended to provide only a general idea of the training required. An X indicates that some time is required in the facility and a C indicates coordinated training with at least one STS crewmember present.

The 12-month schedule is typical, but for some payloads the user may want the candidate to be screened longer before the flight. This can be done.

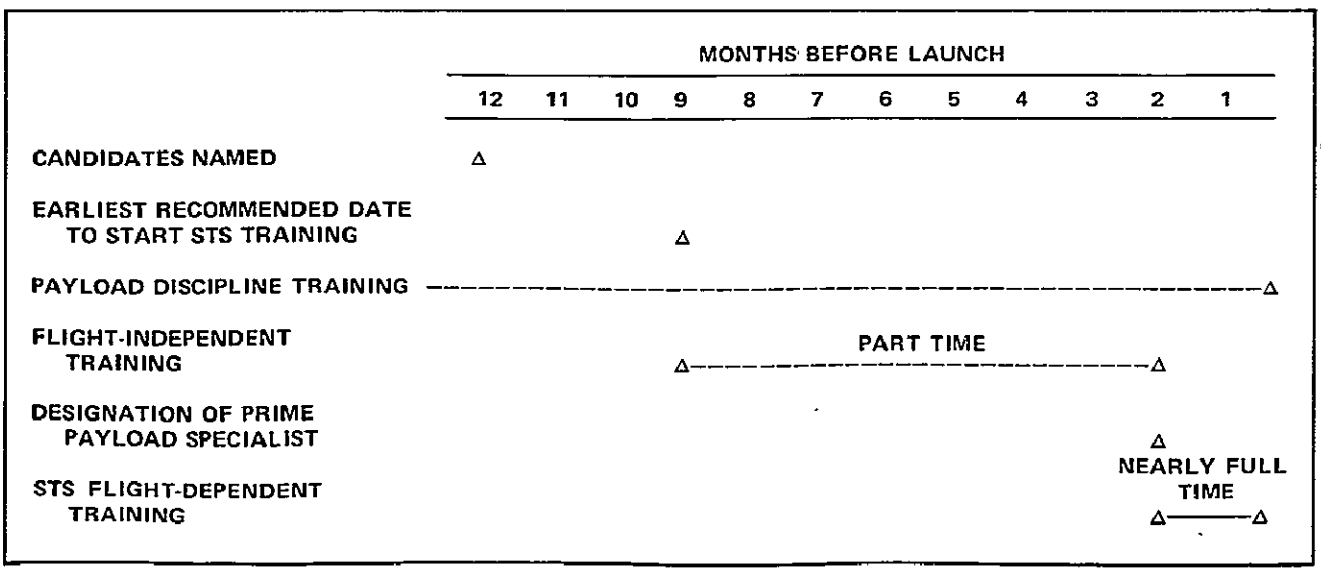
Two months of nearly full-time training approximates 320 hours available, half of which are spent in formalized classroom and trainer/simulator training. The remaining time of JSC residence can be allocated to STS/payload flight plan integration and reviews, flight/mission rules development and reviews, flight techniques meetings, and flight requirements implementation reviews. For some complex payloads (e.g., multidiscipline) the dedicated training may require more than 2 months.

Payload specialists who have flown before are required to take a proficiency examination and repeat any training deemed necessary.

Flight-independent training for the payload specialist involves those crew tasks necessary for any crewman to function effectively during flight. This totals approximately 124 hours.

Flight-dependent training can be divided into two types: payload discipline training and training necessary to support STS/payload integrated operations. The second is characterized by integrated simulations involving the entire flight crew and ground-based flight operations support teams. These simulations — in one or more of the JSC training facilities — will involve the appropriate POCC as necessary, and will practice accomplishment of various payload objectives to ensure a certain measure of mission success. Approximately 115 hours are devoted to this type of training.

Payload discipline training consists of the individual experiment training which includes use of user research facilities, experiment prototype or development hardware, and possibly experiment flight



Typical training schedule for a payload specialist.

hardware. There may be certain limitations to using flight and development hardware for training exercises. However, in general, the amount and type of payload training for the crew is the responsibility of the user, who should provide whatever training considered necessary. This training could occur within a time frame that would be compatible with the STS crew and payload specialist schedules and may start as early as 2 years before a flight.

Spacelab phases

Training type	Facility (SLS and SMS)
Activation and checkout	C
Orbital operations	C
Deactivation	C
Hours (approximate)	32

Spacelab systems

Training, type	Facility		Total
	Class	SLS	
Electrical power distribution subsystem	X		
Environmental control subsystem	X		
Common payload support equipment	X	X	
Command and data management subsystem	X	X	
Instrument pointing subsystem	X	X	
Hours (approximate)	8	13	21

Orbiter phases

Training type	Facility (classroom only)
Orbiter phase training: crew activity plan and data management	X
Onboard pointing coordination	X
Hours (approximate)	10

Orbiter systems

Training type	Facility			Total
	Class	CSTA	ORB 1-g	
Orbiter systems	X		X	
Guidance, navigation, and control/ software	X	X		
Ground-support network	X			
Hours (approximate)	15	4	4	23

Orbiter habitability

Training type	Facility				Total
	Class	ORB 1-g or SLS	Water tank	Launch pad	
Shuttle Program orientation	X				
STS systems overview	X				
Space-flight physiology	X				
Crew systems					
Ingress/egress	X	X		C	
Habitability	X	X			
Stowage	X	X			
Emergency/survival	X	X	C	C	
Medical	X	X			
Crew station activation/ deactivation	X	C			
Hours (approximate)	50	45	1	4	100

Spacelab habitability (module only)

Training type	Facility		Total
	Class	SLS	
Spacelab crew systems emergency/safety	X	X	
Hours (approximate)	2	3	5

Integrated crew/ground simulations

Training type	Facility		Total
	ORB 1-g	SMS or SLS	
Ascent		C	
Entry		C	
On-orbit operations	C	C	
Hours (approximate)	10[a]	48	48

[a]The Orbiter 1-g trainer is used in conjunction with the simulators for transfer; therefore this figure is part of the simulator total.

Ground team

The flight operations support team can be divided into an STS team and a POCC team. These teams and the flight crew must function together to accomplish the flight objectives. Each team has unique responsibilities that may require coordination with each other and with the flight crew. Training of each of these teams is conducted separately and culminates in the crew/ground integrated simulations. The STS support team will receive their training through the formal JSC training process. For the POCC support team, no STS training other than the necessary integrated simulations is required. Further POCC support team training requirements are included in the users' guide for each POCC.

Management and procedures

Flight systems

Launch and landing site operations

Flight operations

Appendixes

A-0-a

Appendixes

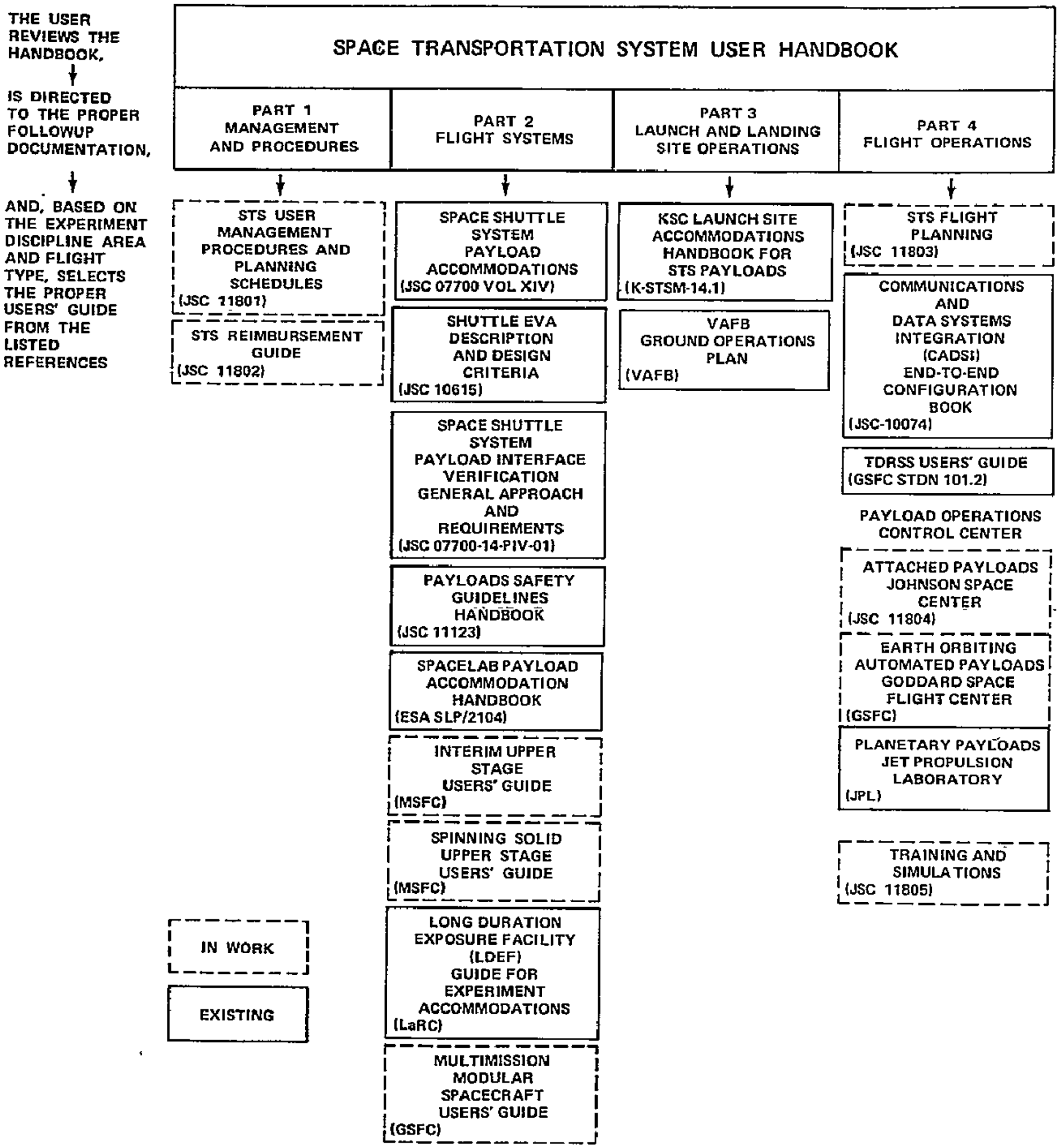
A-0-a

APPENDIX A

References

User-oriented documents

Selected STS references have been prepared to assist users in obtaining additional information. These publications represent a condensation of many documents, are designed to readily assist the user, and support the major parts of the Space Transportation System User Handbook. They are listed below according to the parts of this handbook to which they refer.



References

References cited throughout this handbook are listed here with their sources. They are organized in the same order as the handbook and listed under the part to which they are most pertinent. Users requiring any of these references should make their requests on company or government letterhead to the organization listed for each document. Some documents are still being prepared and have various completion dates during 1977. All requests will be filled as soon as the documents are available.

Part 1

STS User Management Procedures and Planning Schedules (JSC-11801)
STS Reimbursement Guide (JSC-11802)

Lyndon B. Johnson Space Center
Mail Code JM 61
National Aeronautics and Space Administration
Houston, Texas 77058

Part 2

Space Shuttle System Payload Accommodations (JSC-07700 vol. XIV)
Shuttle EVA Description and Design Criteria (JSC-10615)
Payloads Safety Guidelines Handbook (JSC-11123)
Space Shuttle System Payload Interface Verification General Approach and Requirements (JSC-07700-14-PIV-01)

Lyndon B. Johnson Space Center
Mail Code JM 61
National Aeronautics and Space Administration
Houston, Texas 77058

Spacelab Payload Accommodation Handbook (ESA SLP/2104)

George C. Marshall Space Flight Center
Mail Code NA 01
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

or

European Space Agency
8-10, Rue Mario Nikis
75738 Paris Cedex 15
France

Interim Upper Stage Users' Guide
Spinning Solid Upper Stage Users' Guide

George C. Marshall Space Flight Center
Mail Code PF 02
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

Long Duration Exposure Facility (LDEF) Guide for Experiment Accommodations

Langley Research Center
Mail Stop 158
National Aeronautics and Space Administration
Hampton, Virginia 23665

Multimission Modular Spacecraft Users' Guide

Goddard Space Flight Center
Mail Code 408
National Aeronautics and Space Administration
Greenbelt, Maryland 20771

Part 3

KSC Launch Site Accommodations Handbook for STS Payloads (K-STSM-14.1)

John F. Kennedy Space Center
Mail Code SP-PAY
National Aeronautics and Space Administration
Kennedy Space Center, Florida 32899

VAFB Ground Operations Plan

Space and Missile Systems Organization
U.S. Air Force Systems Command
Los Angeles Air Force Station
Attn: Code LVO
Box 92960, Worldway Postal Center
Los Angeles, California 90009

Part 4

STS Flight Planning (JSC-11803)

Communications and Data Systems Integration (CADSI) End-to-End Configuration Book (JSC-10074)

Lyndon B. Johnson Space Center
Mail Code JM 61
National Aeronautics and Space Administration
Houston, Texas 77058

TDRSS Users' Guide (GSFC STDN 101.2)

Goddard Space Flight Center
Mail Code 864.2
National Aeronautics and Space Administration
Greenbelt, Maryland 20771

Payload Operations Control Center for Attached Payloads (JSC-11804)

Lyndon B. Johnson Space Center
Mail Code JM 61
National Aeronautics and Space Administration
Houston, Texas 77058

Payload Operations Control Center for Earth-Orbiting Automated Payloads

Goddard Space Flight Center
Mail Code 513
National Aeronautics and Space Administration
Greenbelt, Maryland 20771

Payload Operations Control Center for Planetary Payloads

Jet Propulsion Laboratory
Mail Code 180-402
4800 Oak Grove Drive
Pasadena, California 91103

Training and Simulations (JSC-11805)

Lyndon B. Johnson Space Center
Mail Code JM 61
National Aeronautics and Space Administration
Houston, Texas 77058

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Office of Planning and Program Integration
Mail Code O
National Aeronautics and Space Administration
Washington, D.C. 20546