Space Platform Accommodations

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Several studies have been conducted over the past few years aimed at understanding the benefits of space platforms. From the payload viewpoint, these have been of a generic nature. This paper presents some results of an in-depth analysis of five space platform design reference missions that were composed of realistic, well-defined instrument complements representing several science and applications disciplines. The missions were chosen to stress various space platform subsystems and therefore were not optimized for scientific compatibility. Despite this lack of optimization, it was found that the objectives of a wide variety of disciplines can be satisfactorily accommodated, and a considerable amount of operational flexibility is available to the payloads due to the large degree of payload autonomy provided on most missions.

Introduction

FOR several years, NASA has been conducting studies to define a space station that would support operations of multiple, interchangeable payloads. Manned, unmanned, and concepts that would evolve from unmanned to manned have been considered. All concepts would be tended by the Space Shuttle. At present, no concept has been chosen for production of flight hardware, although the space platform concept, on which this paper is based, could begin production if it were approved.

This paper summarizes the results of a study undertaken to determine how various science and applications payloads could be accommodated on the space platform. Because the detailed designs developed for NASA by contractors are sensitive data under the A-109 procurement regulations, the initial study used a reference space platform design that approximated, but was not identical to, the contractors' designs. This study is reported in this paper.[1] A follow-on study used the contractors' detailed designs. As was expected, the details of the methods for accommodating the payloads changed somewhat, but the overall conclusions of the study did not change.

Payload Complement

In contrast to most previous studies, which considered large numbers of potential payloads and only considered the resource envelopes, this study was limited to a relatively small number of payloads, but considered the accommodations in detail. The payloads used and the grouping of payloads into platform missions were specified by NASA Headquarters. Because a detailed accommodations analysis was desired, the payloads are composed largely of existing instruments, or instruments that were well into development for Spacelab or other flight programs. An effort was made to include instruments from as many disciplines, and with as wide a range of requirements, as possible.

Since the space platform supports multiple payloads, the payloads were grouped into five design reference missions (DRMs). The composition of the DRMs was chosen to stress various space platform systems to drive out any hidden problems. They were not chosen to optimize space platform usage, scientific compatibility, or information return. In that sense, this study is a worst-case analysis.

The payloads which were used for this study are shown in Fig. 1 and described in Table 1. Electrical power and data requirements range from very low to very high [synthetic aperture radar (SAR), advanced materials experiment assembly (MEA)]. Thermal control requirements range from none (passive control) to high heat load combined with low, narrow temperature range requirements [electrophoresis operations in space (EOS)]. Attitude control requirements range from extremely low disturbance limits (MEA) through very high pointing accuracy and stability [solar optical telescope (SOT), Shuttle infrared telescope facility (SIRTF)]. Viewing requirements include none, Earth, anti-Earth, sun, terrestrial magnetic field orientation, and celestial. Some viewing payloads simply look in a fixed direction [spectra of cosmic ray nuclei (SCRN), (SOT)]; others continually switch from target to target (SIRTF). Several payloads deploy on orbit into much larger volumes than they occupy in the Space Shuttle [very long baseline interferometry (VLBI), (SIRTF, SOT, SAR)].

Space Platform Concept

The space platform reference concept that we used for this study is illustrated in Fig. 2. This concept is not identical to either of the two designs currently being considered but does approximate both well enough to support a valid accommodations analysis. The most significant features of this concept, from a payload standpoint, are described below.

Physical Accommodations

Three active berthing ports are provided for payload attachment plus one inactive parking port. The parking port is intended to facilitate payload changeout. The active ports provide physical attachment for payloads, interfaces to the power, signal and active thermal control subsystems, and limited payload orientation through rotation and hinge mechanisms. All berthing ports are located at the aft end of the platform. One port is on the X axis, two are on the $\pm Y$ axis, and the parking port is on the Z axis. Each active port is on a collapsible standoff, 3 m from the body of the platform.

The solar arrays extend perpendicular to the X-Z plane and are capable of rotating around the Y axis to track the sun. The

Submitted Oct. 4, 1982; presented as Paper 82-1814 at the AIAA/DGLR/AAS/BIS Space Systems Conference, Washington, D.C., Oct. 18-20, 1982; revision received April 22, 1983.

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arrays are 8.7 m wide by 42 m tip to tip. The solar array rotation axis is 8.1 m from the *Y*-port rotation axes.

The thermal radiator is 4.9 by 16.3 m located in the *X-Z* plane. This is fixed in position during operation on orbit.

Each active port incorporates a rotation and hinge mechanism. The hinge allows the attachment plane to be positioned either perpendicular or parallel to the port rotation axis. Rotation allows the port orientation to be set at discrete 90-deg intervals. This concept does not incorporate continuous port rotation.

Electrical Power

The platform provides 12.5 kW of continuous total power to the payloads at 30 and/or 120 V dc regulated. Each active port is capable of handling the total electrical power capability. Off-nominal attitudes in which the solar arrays are not perpendicular to the sun line will reduce the power capability.

Command and Data Handling

The platform communication system is capable of utilizing the full Tracking and Data Relay Satellite System (TDRSS) Ku- and S-band capability. Direct-access connections from each port to the Ku-band communications system allow payloads to use this capability. We have assumed, however, that the TDRSS Ku-band single-access channels would be shared with other spacecraft and consequently would only be available for 20 min per orbit. An S-band TDRSS multiple-access channel was assumed to be continuously available except during the times of TDRSS blockage by the Earth (about 5% blockage on a daily average). Payload access to the S-band capabilities is by means of a data bus through the platform data system.

The platform data system uses Spacelab-type hardware for the high-rate section [high-rate multiplexer (HRM), high-data-rate recorder (HDRR)], which imposes some additional constraints. The HRM has 16 input channels, each limited to

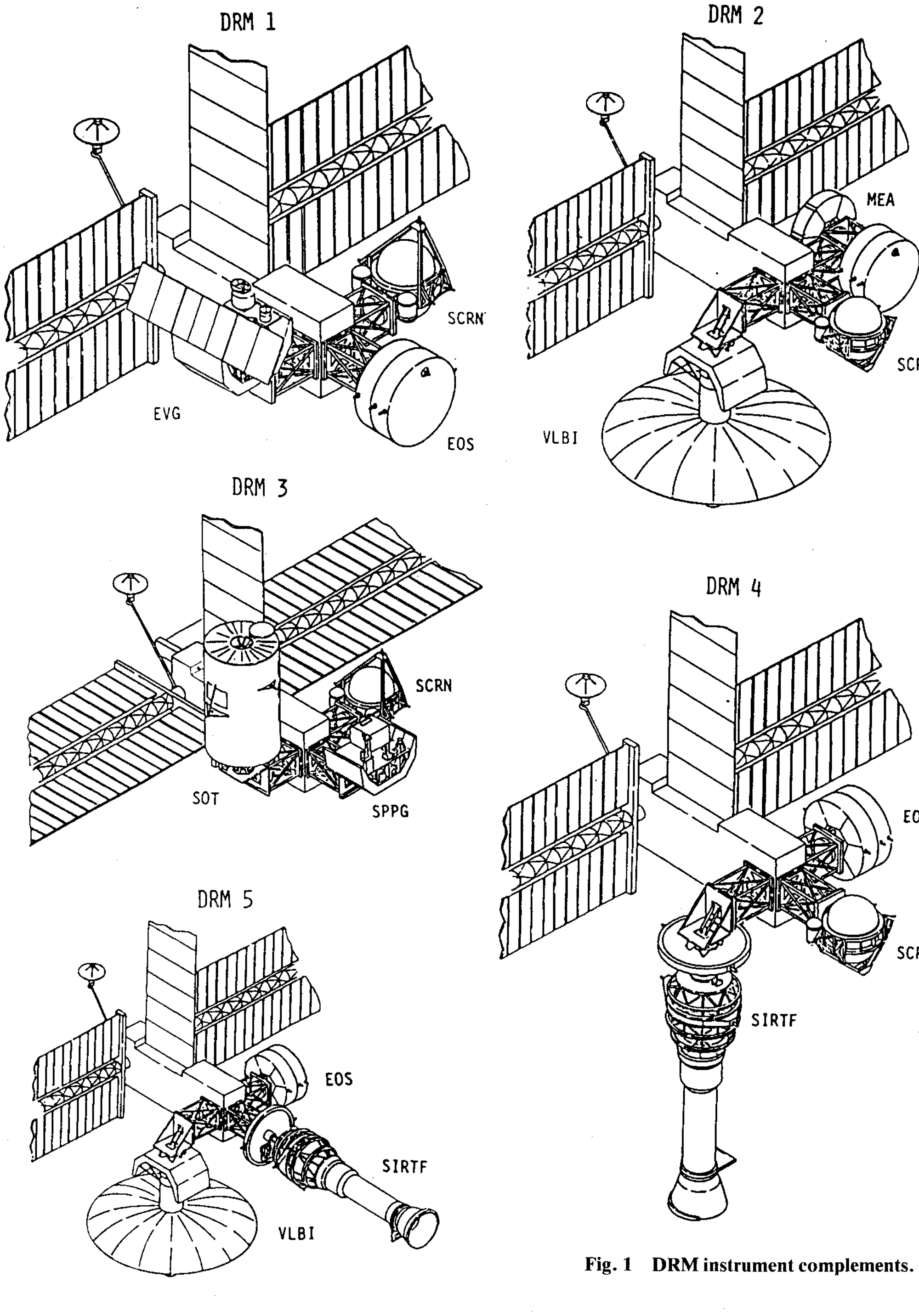


Fig. 1 DRM instrument complements.

16 Mbps, with the total HRM output limited to 48 Mbps. The HDRR is limited to a maximum of 32 Mbps.

Active Thermal Control

Thermal control is provided to payloads through a heat exchanger that has fluid lines to each payload port. The payload is responsible for pumping fluid through its side of the heat exchanger. The thermal control system is capable of dissipating the entire (12.5-kW) power output of the platform at payload fluid temperatures of 0 to 3°C. Off-nominal attitudes which allow the sun to shine on the radiator result in a rapid degradation of heat rejection capability.

Attitude Control

Contamination-free control moment gyros are used for attitude control with magnetic torquers to dump secular momentum buildup. A thruster type, replaceable reboost module is used intermittently for altitude maintenance.

Platform attitude control, at the navigation base, is 10-arc·sec pointing accuracy and stability. At the payloads, this degrades to 0.5-deg accuracy and 3-arc·min stability due to alignment tolerances and flexure between the navigation base and the payload. Any one payload can achieve the full platform attitude control capability by providing its own attitude sensor to drive the platform attitude control system. A payload that includes a pointing system can, of course, achieve the full capability of the pointing system (typically 1-acr·sec pointing accuracy and stability). Full illumination of the solar arrays coupled with no illumination of the thermal radiator requires the *Y* axis to be perpendicular to the sun line (*Y*-PSL).

Stable platform flight attitudes are those for which the *X* axis is either perpendicular to the orbit plane (*X*-POP) or in the orbit plane. In particular, the *X*-POP *Y*-PSL, *Z*-POP *Y*-PSL, and *Z*-LV *Y*-POP (*Z*-axis local vertical, *Y*-POP or airplane attitude) can be held indefinitely. Other attitudes are possible, but the time before saturation of the CMGs was not defined.

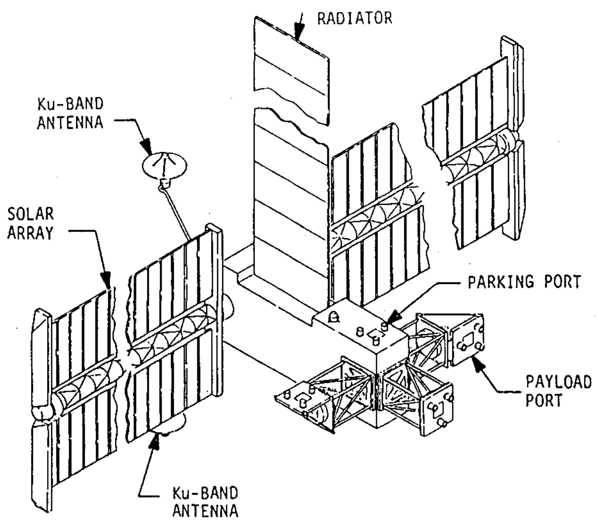
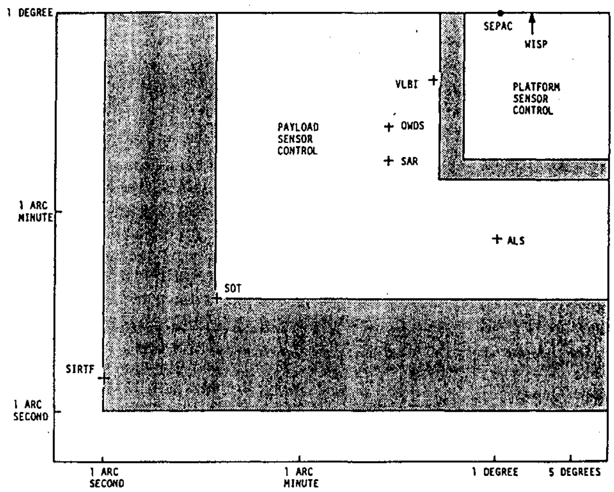


Fig. 2 12.5-kW space platform reference concept.

Payload Requirements

Table 2 and Fig. 3 summarize the instrument requirements for platform services. The platform provides electrical, communications, and thermal control resources to the payloads but performs only those control and monitoring functions that cannot be performed by the individual payloads. These are primarily functions that relate to the health and safety of the platform. The payloads are



- SIRTF REQUIRES A FINE POINTER FOR POINTING ACCURACY/STABILITY REASONS
- PAYLOADS FOR SOT, VLBI, SAR, ALS, AND OWDS REQUIRE A PAYLOAD-PROVIDED SENSOR

Fig. 3 Instrument pointing requirements vs platform pointing capability.

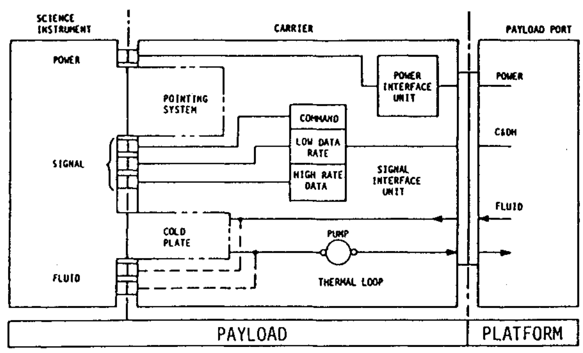


Fig. 4 Instrument/platform interfaces.

Table 1 DRM science instruments/facilities

Research area	Characteristic	Instruments/facilities
Space plasma physics	Magnetic field pointing	Space experiments with particle accelerators (SEPAC) Wave injection in space (WISP)
Materials science	Low-*g*	Electrophoresis operations in space (EOS) Advanced materials experiment assembly (MEA)
Earth observation	Earth/limb pointing	Ocean wave directional spectrometer (OWDS) Advanced limb sounder (ALS) Land observing radar (synthetic aperture radar—SAR)
Astronomy	Full sky pointing	Shuttle infrared telescope facility (SIRTF) Very long baseline interferometry (VLBI)
High-energy astrophysics	Anti-Earth pointing	Elemental composition and energy spectra of cosmic ray nuclei (SCRN)
Solar physics	Solar pointing	Solar optical telescope (SOT)

Table 2 Accommodation requirements for DRM science instruments/facilities

Acronym	Launch mass, kg	Volume (equivalent pallets)	Power, kW average/peak	Data rates, kbps SCI./STAT.	Heat rejection (No. of cold plates)	Special requirement
ALS [b]	72	1/10	0.17/0.19	8/TBD	[a]	Nadir orientation, limb viewing
OWDS [b]	250	1/4	0.20/0.23	20/1	...	Nadir pointing
SAR [b]	590	1/2	6.0/6.0	120,000/1	[c]	Antenna mounted parallel to velocity vector
SCRN	2826[c]	1-1/3	0.33/0.39	102.4/10	[a]	Anti-Earth pointing
EOS	4536[c]	1	3.5/TBD	1/0.001	Freon loop	Low-g, 0-5 deg limit on inlet coolant temperature
MEA	2215[c]	1/2	5/TBD	0.6-6/TBD	Freon loop	Low-g (10^{-5} g)
VLBI	342	1	0.2/0.5	4000/12000/1	...	Celestial pointing (15 arc·min)
SOT	3512	3	1.08/1.60	3000/40[d]	...	Solar pointing (30 arc·sec)
SEPAC [b]	665	1/3	1.0/1.5	512+TV[e]/0.5	[e]	Magnetic field pointing (1 deg)
WISP [b]	780	1/2	1.1/7.6	4096/32	[d] + Hx	Magnetic field pointing (2 deg)
SIRTF	6355	4	0.2/0.2	4000/TBD	...	Celestial pointing (1 arc·sec)

[a] Numbers reflect instruments/facilities configured for a 6-month flight duration.
[b] Indicates grouping into same payload as specified by NASA.
[c] Includes carrier.
[d] Includes allocation for slow-scan TV.
[e] TV includes requirement for wideband analog channel.

Table 3 Characteristics of DRM carrier adapter and interface hardware

Item	Mass, kg	Operating power, W
Standard adapter and interface package (SAIP)	254	400
Adapter with interface connectors	120 (est.)	NA
Signal interface unit	10	25
Power interface unit with inverter capability	40	50
Thermal control package	63	325
Power and signal cabling	7	NA
Subsystem cold plate and support structure	14	NA
Additional standard hardware		
Experiment cold plates with plumbing and support structure	22	NA

Table 4 DRM pointing system package

Hardware units	Mass, kg	Power average/peak, W
Basic pointing system	338	370/1540
Mechanical assembly	208	
Control electronics	111	
Payload electronics assembly	11	
Sensor package	8	
Additional equipment	44	
Cold plates (2) and support structure	44	
Generic pointing system	382	370/1540

responsible for their own carrier structure, power branching, switching and instrument protection, command and data handling, thermal control, and fine pointing.

Most payloads will require additional integration equipment, in addition to the instruments themselves, to match the platform interfaces. A schematic diagram of these interfaces is shown in Fig. 4. Estimates (based on existing hardware) of the characteristics of this integration equipment are given in Tables 3 and 4. Interface requirements for each payload were analyzed and the appropriate integration hardware was added to the payload. The payload requirements thus defined were used for the DRM accommodations analysis.

On-Orbit Operations

Individual payloads are grouped into five DRMs, which are listed in Table 5. Power use, high- and low-rate data transmission and storage, TDRSS Kuband downlink scheduling, flight attitude, port assignment, and viewing constraints were considered in the accommodations analysis.

View-Related Considerations

Flight attitude and port assignment are related to the viewing characteristics of the payload. Figure 5 shows hemispherical, fish-eye-type views of the platform, in three viewing directions, as seen by a payload on a Y port. The $-Z$ direction view is similar to the $+Z$ view without the radiator extending toward the center. In the $+X$ direction, the view is determined primarily by the payload on the X port.

Because this platform concept only includes discrete positioning of port rotation, flight attitudes and port assignments are determined almost entirely by the payloads' targets. Earth-viewing payloads are restricted to operation in Earth-oriented attitudes, such as Z-LV. The simple airplane attitude (Z-LV Y-POP) can have serious power and heat rejection problems. The severity of these problems depends on the orientation of the orbit with respect to the sun. These problems can be partially alleviated by mission planning and timelining. They are eliminated by providing continuous port rotation, since it is then possible to use either inertial attitudes (X-POP Y-PSL) or dynamic, Earth reference attitudes (X-LV Y-PSL) for Earth viewing. It is likely that a space platform, as implemented, would include continuous port rotation. Other instruments besides Earth viewers benefit from a local vertical attitude. Cosmic ray instruments, which prefer to scan a wide swath of sky, and cryogenically cooled telescopes, which want to avoid the heat load of looking at the Earth, are two examples.

Celestial viewing instruments generally prefer an inertial attitude since their targets are stationary in inertial space. Again, continuous port rotation allows them to use the local vertical attitudes. The ideal configuration for solar viewing instruments is mounted on a *Y* port flying a *Y*-PSL attitude with continuous port rotation, since the port rotation alone can track the sun.

Resource-Related Considerations

In general, analysis of resource use requires operation timelines for the payloads. For many cases, a simple consideration of which instruments could be operating simultaneously suffices to show that there is no power problem.

Heat rejection also usually parallels the power analysis. Because the heat rejection capability is comparable to the power generation capacity, problems only occur for those payloads with unusually low- or narrow-temperature range requirements and potentially for life science payloads that generate metabolic heat. EOS is an example of stringent temperature range requirements. No example has yet been analyzed for which metabolic heat is a major consideration.

Data handling has required the most detailed analysis because continuous real-time transmission is not available for high-rate data. The recorders needed for data storage during the noncontact periods limit both total data rate and data volume. Somewhat less stringent limits are also imposed by the high-rate multiplexer. We should point out here that although the quantitative details of these constraints are determined by the platform design, the existence of the constraints is due to the lack of full-time TDRSS Ku-band access.

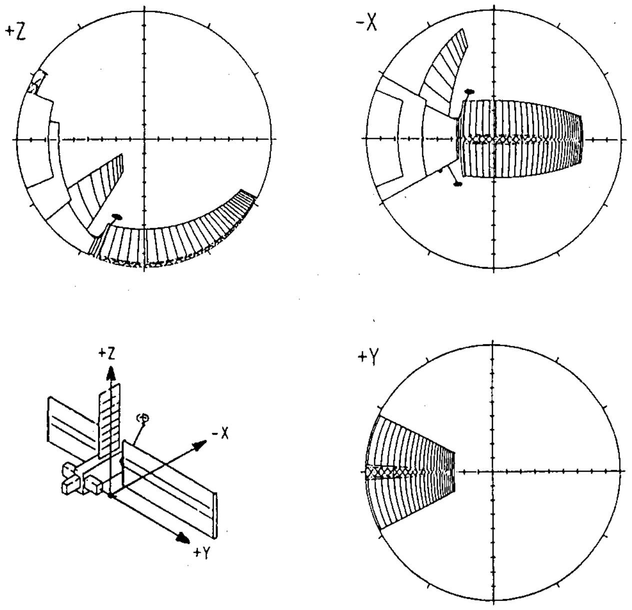


Fig. 5 *Y* **port view field for space platform reference concept.**

Contamination

An important consideration for many payloads is contamination. The platform itself is very clean since it is unmanned and uses propulsive thrusters only for attitude maintenance. Some payloads, however, produce contamination that should be considered in mission planning.

Venting of infrared active gases (such as H_2O, CO_2, Ar, Ne) by payloads such as EOS and some cosmic ray detectors can be a major source of interference to infrared viewing payloads such as SIRTF and some Earth-viewing instruments. A similar problem exists in the ultraviolet for SOT. The increase in ambient density and pressure due to gaseous contamination is also a source of interference for some plasma physics investigations. All optical instruments are, of course, sensitive to deposition of particles or condensable gases. Leakage from the life support systems of life sciences payloads is a potentially serious source of contamination for sensitive payloads. Electromagnetic interference is also a potentially serious problem for high-powered payloads and sensitive receivers.

STS Transportation

The Space Transportation System (STS) Shuttle Orbiter is used for all space platform servicing, including initial delivery of the platform to orbit, delivery and retrieval of payloads,

Table 5 Design reference missions

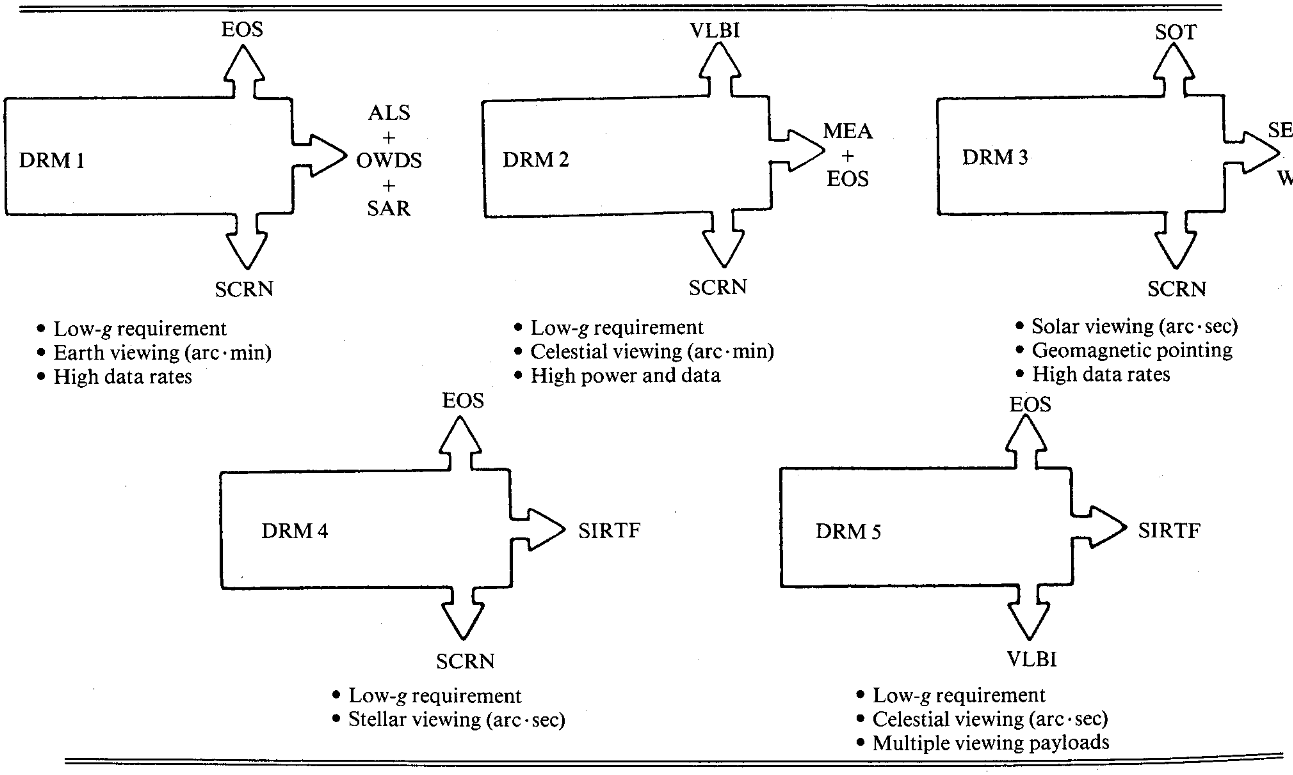


Table 6 Platform mission scenario

Mission	1	2[a]	3	4[a]	5	6	7
Launch date	7/1/87	1/1/88	7/1/88	1/1/89	7/1/89	1/1/90	7/1/90
Port A	OSS-3 (EVG)	SEPAC/WISP	SOT (direct mount)	SIRTF (pointed mount)	Solar terres. obs' try (SEPAC/ WISP)[b]	SOT (direct mount)	SIRTF[a] (pointed mount)
Port B	EOS	EOS[b] (resupply only)	Advanced imaging radar (EVG)	MPS (MEA)	Advanced imaging radar (EVG)[b]	MPS (MEA)[b]	Life sciences research facility (EOS + MEA)[b]
Port C	CRN	CRN (Same payload as Mission 1. No service or resupply)	LAMAR OSS-2 upgrade (CRN new)	TRIC	VLBI	LIDAR (CRN new)	TRIC[b]

[a]These missions were selected for total STS operations analysis. [b]Reflight payloads. Note: Parentheses indicate substitution of payloads of equivalent integration complexity to provide better interface definition for this study.

Table 7 Flight manifests Shuttle load factor based on 0.75 of Shuttle payload length or mass capacity

Mission No.	Flight No.	Flight complements	Length margin,[b] m	Mass margin,[c] kg	SLF	Remarks
1	1 Up	EVG, EOS, SCRN, RBM	1.72	228	1	
	1 Down	Residuals	13.57	6900	0.7	Can be shared
2	1 Up	SEPAC/WISP, EOS resupply,[a] RBM	8.79	5200	0.95	
	1 Down	EVG, EOS resupply, RBM	7.37	2795	1	
3	1 Up	SOT, SCRN	3.13	7633	1	
	1 Down	SEPAC/WISP, SCRN	7.9	4027	0.96	
	2 Up	EVG, RBM[a]	8.97	7903	0.75	Can be shared
	2 Down	EOS (production + resupply module)	10.10	2254	1	
4	1 Up	SIRTF	[illegible]	[illegible]	1	
	1 Down	SIRTF's forward frame, SOT	6.50	4809	0.89	Can be shared
	2 Up	MEA, TRIC, RBM[a]	5.04	2116	1	
	2 Down	EVG, SCRN, RBM	6.68	769	1	
5	1 Up	RBM[a]	13.42	10557	0.56	Can be shared
	1 Down	MEA, TRIC, RBM	6.68	−2041	1	Overloaded
	2 Up	SIRTF's forward frame, SEPAC/WISP,[a] EVG,[a] VLBI	4.04	4796	1	
	2 Down	SIRTF	0.85	2313	1	
6	1 Up	SOT, MEA[a]	3.13	6427	1	
	1 Down	SEPAC/WISP, VLBI	8.95	4647	0.91	
	2 Up	SCRN, RBM[a]	9.49	7139	0.81	Can be shared
	2 Down	EVG, RBM	8.97	4840	0.89	Can be shared
7	1 Up	SIRTF[a]	1.00	5219	1	
	1 Down	SOT, MEA	5.79	2870	1	
	2 Up	EOS[a] (production + resupply module) + T docking adapter + MEA,[a] TRIC, RBM[a]	1.99	−5169	1	Overloaded
	2 Down	SCRN, RBM	9.49	3282	1	

[a]Reflight payloads. [b]Length margin based upon maximum length—18.2 m. [c]Mass margin for up missions, estimates capacity—18,184 kg for 400-km circular orbit altitude at 57 deg with integral OMS kit. For down missions, estimated capacity—14,515 kg.

and servicing of the platform and payloads on orbit. Initial delivery of the platform requires one Shuttle flight with a Spacelab pallet-sized payload carried on the same flight. The platform then remains on orbit and only payloads are carried on subsequent flights.

On orbit, the Shuttle docks to the space platform by means of a docking arm, which is part of the platform. The docking arm allows the platform to be oriented in various positions over the Shuttle payload bay. Payloads are exchanged between the Orbiter and platform using the Orbiter's remote manipulator system (RMS). The platform parking port provides a temporary holding position for payloads while the exchange is taking place.

A scenario of seven platform missions was provided to use in analyzing the logistics of implementation of platform missions. Several payloads in this scenario had not been included in the accommodations analysis, so we substituted payloads of equivalent integration complexity. Table 6 lists the scenario as given and as modified.

On the basis of this scenario, a Shuttle manifest was developed that took into account the flight support equipment needed for the Orbiter, platform, and payloads. The Orbiter mass limit for ascent was taken as 18,184 kg for a 400-km altitude, 57-deg inclination platform orbit. The return mass limit is 14,515 kg. The manifest developed is shown in Table 7.

The most obvious feature of this manifest is that two Shuttle flights are needed to change out all three payloads on most missions. Many of these flights do not utilize the full Orbiter capability. This emphasizes the fact that the Shuttle is an integral part of platform utilization. Careful mission planning is needed to efficiently use both the STS and the platform.

The basic consideration for STS utilization in platform mission planning is that the Shuttle returns with a different payload than it delivers. This requires that the necessary flight support equipment for both ascent and descent be in the Shuttle round trip. Any payload equipment (such as launch cradles) left in the Shuttle severely constrains the other half of the flight.

Efficient platform utilization implies that the same number of payloads are carried up in the Shuttle as are carried down on the return. The size and mass of payloads vary over a wide range, so mission planning must consider a sequence of missions rather than each mission independently.

Payloads that need an active interface (power or signal) with the Orbiter during delivery or retrieval create a requirement for an interface unit that can be remotely connected and disconnected and that does not constrain Shuttle manifesting (i.e., can be stored outside the Orbiter payload bay dynamic envelope). This unit does not currently exist.

Results

This study has shown that the requirements of a wide range of science and applications disciplines can be satisfied by the space platform, and a large degree of autonomy can be provided to the payloads. Mission planning, which considers payload design, STS transportation, and platform utilization, all with consideration of preceding and following missions, is necessary for efficient use of both the STS and the platform.

Payload autonomy results from the resource richness of the space platform. This provides a great deal of flexibility for payload operations. Several factors can reduce this autonomy, but most of them can be minimized by proper planning. A small set of basic flight attitudes can satisfy most payload requirements. Most payloads also can operate in more than one attitude, but any payload that requires a unique attitude can create operational constraints. Large pointed or deployable payloads can impinge on others' field of view or create a collision hazard, which requires coordination of operations with the platform. Total payload autonomy cannot be achieved in data handling unless the TDRSS Ku-band single-access link is available full time. The severity of this constraint on high-data-rate or volume users depends on the flexibility of scheduling TDRSS access times. This does not appear to be a serious constraint for the missions analyzed.

The major advantages of a platform to the payloads are 1) extended time on orbit compared with the Space Shuttle, 2) elimination of the need to provide resource subsystems on the payload, 3) increased resources, and 4) decreased disturbances (accelerations and contamination) compared with the Shuttle.

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