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# Mixed Mode Missions

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# MIXED MODE MISSIONS
## (Designing Payloads to Match Flight Opportunities)

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ABSTRACT

Shuttle missions have typically been viewed as being devoted to a single mission mode, i.e., delivery of free flyer, Spacelab, etc. Full utilization of the STS capabilities as a platform for space research dictates a flexible strategy towards payload integration and mission design. Simple interfaces, single disciplines and large design and resource margins point the way towards lower payload integration and operation costs. Payloads for early missions, e.g., OSTA-1, OSS-1 and MEA are used as illustrations. The implication of this approach on NASA's future plans, as well as potentially new STS operational concepts, are discussed.

INTRODUCTION

The Space Transportation System (STS) when conceived was envisioned as a system primarily for conducting the following types of missions: space station logistics, placement and retrieval of satellites, on-orbit servicing of satellites, delivery of propulsion stages and short duration orbital missions. Figure 1 represents the initial mission characteristics that were derived for the Space Shuttle (now known as the STS) in the 1968-1969 timeframe. These types of missions were then used to project the flight requirements and develop traffic models. During the ensuing years of the development of the Space Transportation System, this same utilization concept has been predominately used by mission planners and payload developers. Spacelab missions, as we know them today, evolved from the short duration orbital missions in the right-hand column of Figure 1.

As the date approaches when the first scientific payload will fly (on the second flight of the STS), payloads are in various stages of development. This first generation of payloads is primarily of two types: free flying satellites and those that remain attached to the Orbiter to conduct their mission. These two mission types are being melded into a mixed mission mode that is becoming a major concept of STS utilization that was not envisioned by the early STS planners. The majority of instruments that will fly on the STS in an attached mode will be assigned to dedicated Spacelab missions, e.g., Spacelabs 1, 2, 3, 4, etc. However, there are a number of instruments that are more suitable for accommodation on non-dedicated missions.

MINOR MISSION CONCEPT

The pattern for accommodating instruments on less than dedicated Spacelab missions had its beginnings in the solicitation of experiments for the Orbital Flight Test Program. Complements of instruments were assembled into payloads that required very little in the way of resources and could be operated within some overriding Shuttle operational constraints.

As a result of the solicitation, one payload, OSTA-1, was assembled for compatibility within the OFT test objectives, i.e., payload bay pointed to Earth to achieve a benign thermal environment. Another payload, OSS-1, was assembled for compatibility with the OFT test objectives of establishing the upper thermal boundaries of the payload bay environment through solar orientation for the payload bay alternated by a deep space orientation.

A third type of payload in the minor mission category is an outgrowth of the use of sounding rockets to support the materials processing program. This payload, the Materials Experiment Assembly (MEA), will transition the sounding rocket program to the Shuttle. The MEA is primarily self-contained and presents a simple interface to the Orbiter for integration and operations.

Other payloads similar to OSTA-1, OSS-1 and MEA are being developed for accommodation on STS flights that have as their primary purpose the delivery of free flying spacecraft. Our experience has dictated the following guidelines for developing these payloads: (a) keep the STS interfaces simple, (b) emphasize single disciplines, and (c) maintain large design and resource margins. Adherence to these guidelines for payload development and the employment of a mixed mode delivery should lead to a more efficient utilization of the STS and substantially lower payload integration and operation costs.

## EARLY MISSION EXAMPLES (OSTA-1, OSS-1, MEA)

The payloads for OSTA-1, OSS-1 and MEA are unique in terms of their mission objectives, design parameters, and method of integration. Each mission will be discussed in terms of its design and mission parameters and integration concept in order to illustrate the utility of the guidelines previously identified.

### OSTA-1

As previously stated, the experiments selected for the OSTA-1 payload were chosen to be compatible with STS test objectives that required the payload bay pointed towards the Earth for an extensive period of time. The OSTA-1 payload carrier, an engineering model of the Spacelab pallet developed by the European Space Agency (ESA), was available to provide the required structural support in the payload bay. Electrical power, thermal conditioning, data, and a command and control capability were added to make the engineering model pallet a more versatile and functional system.

The OSTA-1 payload consists of the following experiments:

Shuttle Imaging Radar-A (SIR-A) - This experiment has been adapted for use as a geological mapping tool and uses some elements from the synthetic aperture radar flown on Seasat.

Shuttle Multispectral Infrared Radiometer - This is an early experiment aimed at determining rock types through measurement of infrared reflectance spectra and will provide measurements for geological classification.

Measurement of Air Pollution from Space - This experiment will provide data to evaluate the relative amounts of natural and man-made carbon monoxide in the atmosphere.

Ocean Color Experiment - This experiment will evaluate a passive ocean color sensing technique for mapping chlorophyll producing phytoplankton in the open ocean.

Night/Day Optical Survey of Thunderstorm Lightning - This experiment will evaluate the use of photo-optical techniques for satellite detection and spectra of cloud to cloud lightning.

Feature Identification and Location Experiment - This experiment will demonstrate advanced techniques for identifying, spectrally classifying, locating and tracking surface features or clouds.

The OSTA-1 pallet-mounted instruments are shown in Figure 2. It should be noted that the SIR-A Antenna is 30 feet in length (one half the payload bay length) and extends some 10 feet over both ends of the pallet. Normally, this would be a very undesirable feature since it would effectively occupy so much of the payload bay. However, the flexibility to install the OSTA-1 payload near the center of the payload bay is not a problem for STS flight number two.

Subsequent flights of this experiment will include a foldable antenna. Integration and checkout of OSTA-1 has been completed and it is ready for integration into the Orbiter for launching.

Management of the OSTA-1 mission is the responsibility of the Johnson Space Center. Integration and checkout was accomplished at the Kennedy Space Center with Rockwell International as the integration contractor.

## OSS-1

As in the case of OSTA-1, the experiments for the OSS-1 payload were also chosen from the broad experiment solicitation for the OFT missions. Experiments were selected that would measure the Orbiter environment and its effect on scientific investigations by studying electromagnetic interference, contamination and plasma interaction. Additional experiments were also selected that were scientifically suited to the particular solar orientation of the Shuttle. One life science experiment was included that is accommodated inside the Orbiter cabin.

A Spacelab engineering model pallet provided by ESA serves as the payload carrier. Capabilities for power, cooling, command and data were developed around a set of flight quality avionics from the International Ultraviolet Explorer (IUE) and incorporated into the payload design as a part of the integration and mission development process.

Figure 3 illustrates the IUE avionics adapted for the OSS-1 mission. The primary function of the avionics is to collect the up to 20 kilobits of digital data and 63 $KH_z$ of analog data generated by the OSS-1 science instruments and process it for storage on the tape recorders. A limited amount of "quick look" data will be provided to the ground via the Orbiter S-Band communication link.

The OSS-1 pallet carries three instruments that will evaluate specific aspects of the Orbiter environment. These experiments are:

Plasma Diagnostics Package (PDP) which will measure the electromagnetic background of the vehicle and perturbations on the ambient field produced by the Orbiter. The PDP will also be used to demonstrate the capability of the Orbiter Remote Manipulator System when it is moved about the cargo bay to scan the electromagnetic background in that area.

Vehicle Charging Potential - This experiment will examine the electrical charging characteristics of the Orbiter as a precursor to active experiments using electron beams on later missions.

Shuttle/Spacelab Induced Atmosphere Experiment will assess the optical background that may be present due to particulate scattering of sunlight.

In addition, the OSS-1 payload includes two Solar Physics experiments and one Technology demonstration experiment. These experiments are:

Solar Flare X-ray Polarimeter which will measure the degree of polarization of x-rays emitted during solar flare activity.

Solar Ultraviolet Spectral Irradiance - The first accurate measurement from space of the Sun's ultraviolet radiation will be determined by this experiment. The absorption of this radiation by the outer reaches of the atmosphere plays an important role in influencing conditions at lower levels that affect our lives.

### Technology

Thermal Canister Experiment will evaluate the application of recent development in heat pipe technology to space instrumentation. The demonstration of this technology is important to instrument designers for follow-on Spacelab missions.

The OSS-1 pallet mounted experiments are shown in Figure 4. A secondary structure is required to accommodate the variety of instruments and supporting hardware.

OSS-1 is providing NASA with first-hand integration experience. In December 1979 a Spacelab engineering model pallet was shipped to GSFC, the Center having mission management responsibility. The integration, test and checkout of the OSS-1 instruments and the Spacelab pallet is being conducted at GSFC by NASA personnel. Upon completion, the pallet with instruments installed, will be shipped to KSC where it will be integrated into the STS.

## MEA

The MEA, having evolved from the use of sounding rockets to support the materials processing program, is largely a self-contained payload. MEA is essentially a large rectangular box. It contains four experiment assembly containers each of which can conduct separate materials processing experiments. Electrical power is provided by batteries and heat is rejected by a self-contained radiator system. A low-g accelerometer and a data management system are also integral parts of the MEA.

The "self-contained" nature of MEA and the Materials Processing Program's plans for repeat flights were driving factors in establishing the carrier design requirements. The requirements resulted in a carrier design that maximizes the potential locations (and therefore flight opportunities) in the Orbiter payload bay while maintaining minimum physical and functional interfaces with the Orbiter. An additional design requirement on the carrier was the need to provide MEA with the elevation in the payload bay that would permit the radiator to reject the heat generated during operation of the experiments.

Figure 5 shows the MEA (which weighs approximately 2200 lbs. with experiments on board), installed on its support structure, mounted in the Orbiter payload bay.

The support structure occupies approximately three feet of payload bay length. Its versatility is further illustrated by structural/mechanical design criteria which accounts for changes in the environment induced by the Orbiter or MEA. The support structure can be installed in the payload bay at 28 different locations, giving it a high probability of being "mixed" with a broad range of other payloads.

The first flight of MEA will contain experiments in three assembly containers. Experiments will be conducted in the acoustic levitator system, an isothermal furnace, and a general purpose gradient furnace.

Management of the MEA mission is the responsibility of the Marshall Space Flight Center. MSFC, having responsibility for OSTA's materials processing program, is also responsible for development of the MEA and the MEA experiments.

## CONCLUSION AND SUMMARY

The integration and operation of MEA, OSTA-1, and OSS-1 require consideration of a broad range of complex interfaces. It may not be practical to think in terms of payloads which only have discrete interfaces. However, the integration activities associated with each interface are quantifiable and can serve as a useful guide in the mission management decision making process.

Figure 6 illustrates the relative integration and operation costs for missions having interfaces with varying degrees of complexity. From the examples previously discussed, the MEA, by virtue of its "self-contained" design, is considered to be representative of a payload which would fall on the least complex, least cost portion of the curve. OSTA-1 and OSS-1 have more complex interfaces with the STS and, therefore, correspondingly greater integration and operation costs.

Spacelab is dependent upon the Shuttle Orbiter for its electrical power, thermal conditioning, communication, and life support systems. This closely coupled nature of these two systems adds an additional dimension of complexity for experiments. Consequently, dedicated Spacelab missions represent an extreme, in complexity, for the model represented in Figure 6.

The experience developed with early missions such as OSTA-1, OSS-1, and MEA have led to additional plans for similar missions. Figure 7 represents the NASA mission model for "Minor Mission" payloads for mixed mode STS flights. The model builds to four or five "minor missions" per year in 1984 which is the equivalent of a single dedicated Spacelab mission. These early years include the traditional payload types, similar to MEA, OSS-1, and OSTA-1 which have already been approved for development or planning. However, as the payload activity increases, a number of new payload types are anticipated. Typical of these are the Experiments of Opportunity (EOP) and experiments designed for accommodation in the Orbiter mid-deck lockers.

# SPACE SHUTTLE MISSION CHARACTERISTICS

| ORBITAL CHARACTERISTICS | SPACE STATION/ BASE LOGISTICS SUPPORT* | PLACEMENT AND RETRIEVAL OF SATELLITES | DELIVERY OF PROPULSIVE STAGES & PAYLOAD | DELIVERY OF PROPELLANTS | SATELLITE SERVICE & MAINTENANCE | SHORT DURATION ORB. MISSION |
|---|---|---|---|---|---|---|
| ALTITUDE (N. MI.) | 200 - 300 | 100 - 800 | 100 - 200 | 200 - 300 | 100 - 800 | 100 - 300 |
| INCLINATION (DEG.) | 28.5 - 90 | 28.5 - SUN SYN. | 28.5 - 55 | 28.5 - 55 | 28.5 - SUN SYN. | 28.5 - 90 |
| ON-ORBIT $\Delta$ V (1000 FPS) | 1 - 2 | 1 - 5 | 1 - 1.5 | 1 - 2 | 1 - 5 | 1 - 2 |
| MISSION DURATION (DAYS) | 7 | 7 | 7 | 7 | 7 - 15 | 7 - 30 |
| CREW | 2 | 2 | 2 | 2 | 2 | 2 |
| PASSENGERS (MIN.) | ROTATE 50 MEN/QTR | 2 | 2 | 2 | 4 | 10 |
| ASCENT DISCRETIONARY PAYLOAD | | | | | | |
| WEIGHT (1000 LBS.) | **70/QTR | 10 - 50 | 25 - 50 | 50 | 5 - 15 | 25 - 50 |
| VOLUME (1000 FT.$^3$) | | 5 - 10 | 10 | 10 | 5 - 10 | 4 - 6 |
| CRITICAL DIMEN. DIA. (FT.) | 10 - 15 | 15 | 15 | 15 | 15 | 15 |
| RETURN DISCRETIONARY PAYLOAD | | | | | | |
| WEIGHT (100 LBS.) | **45/QTR | 10 - 50 | — | — | 15 | 50 |
| VOLUME (1000 FT.$^3$) | — | 5 - 10 | — | — | 5 - 10 | 4 - 6 |

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Figure 1

# OSTA-1

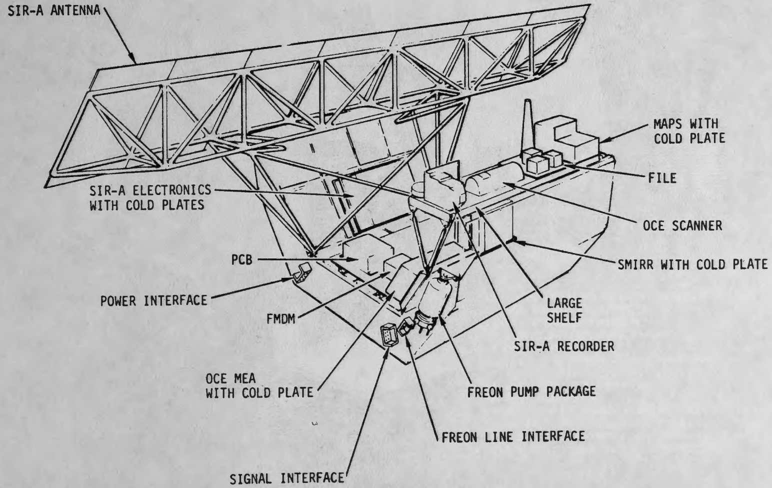


Figure 2

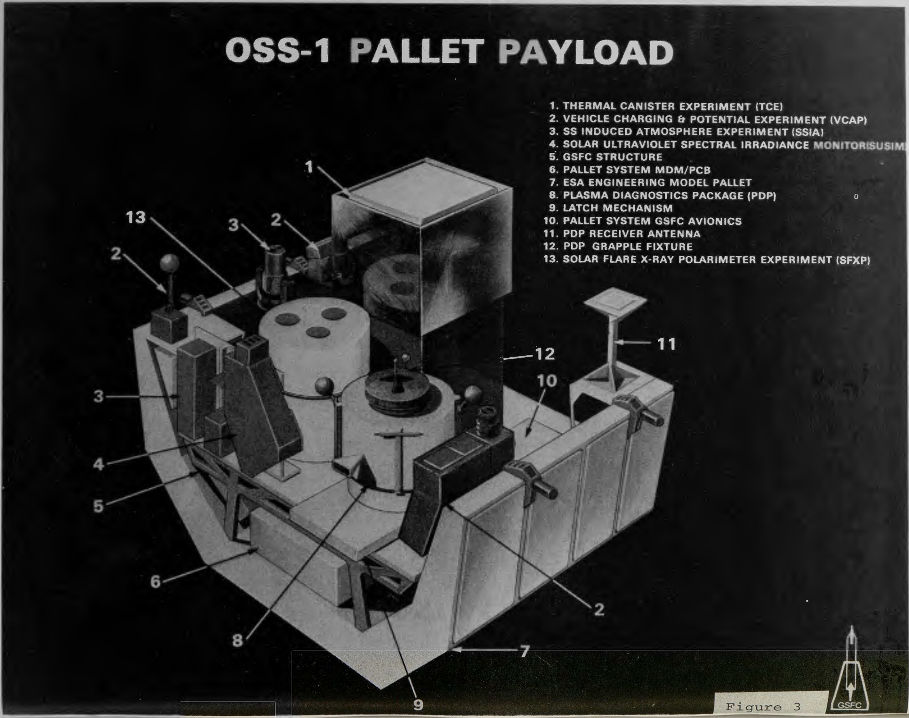
OSS-1 PALLET PAYLOAD
1. THERMAL CANISTER EXPERIMENT (TCE)
2. VEHICLE CHARGING & POTENTIAL EXPERIMENT (VCAP)
3. SS INDUCED ATMOSPHERE EXPERIMENT (SSIA)
4. SOLAR ULTRAVIOLET SPECTRAL IRRADIANCE MONITOR(SUSIM
5. GSFC STRUCTURE
6. PALLET SYSTEM MDM/PCB
7. ESA ENGINEERING MODEL PALLET
8. PLASMA DIAGNOSTICS PACKAGE (PDP)
9. LATCH MECHANISM
10. PALLET SYSTEM GSFC AVIONICS
11. PDP RECEIVER ANTENNA
12. PDP GRAPPLE FIXTURE
13. SOLAR FLARE X-RAY POLARIMETER EXPERIMENT (SFXP)
GSFC

Figure 3

# OSS-1 AVIONICS

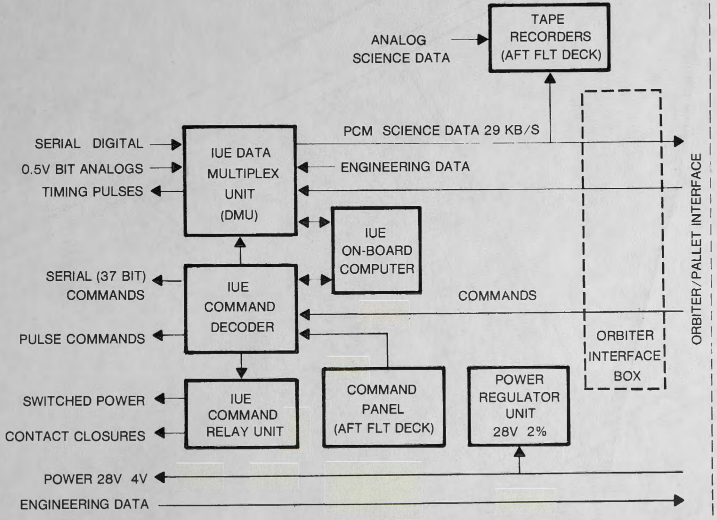


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Figure 4

# MATERIALS EXPERIMENT ASSEMBLY (MEA)

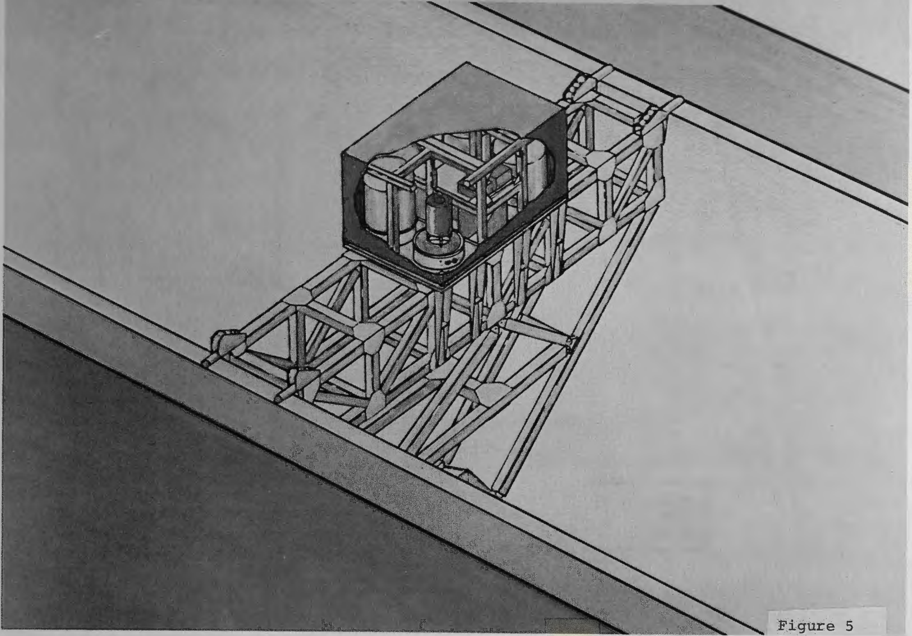

Figure 5

# MISSION MANAGEMENT COSTS AND INTERFACE COMPLEXITY

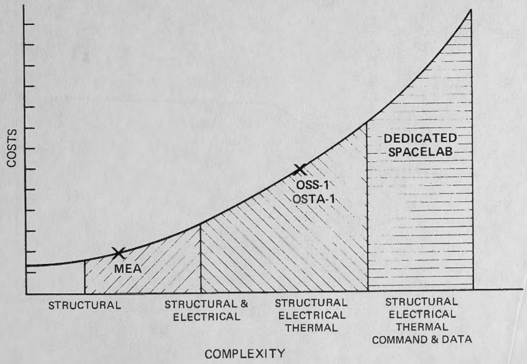


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Figure 6

# AGENCY MODEL
## MINOR MISSIONS

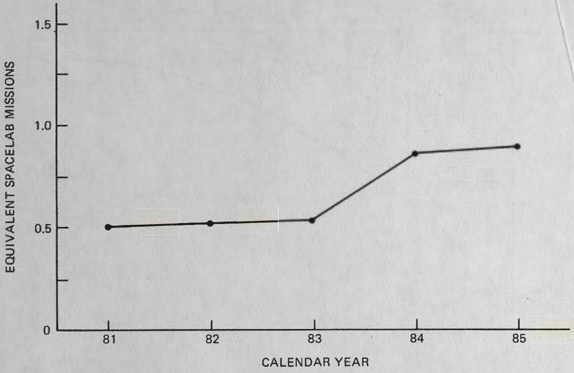


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Figure 7