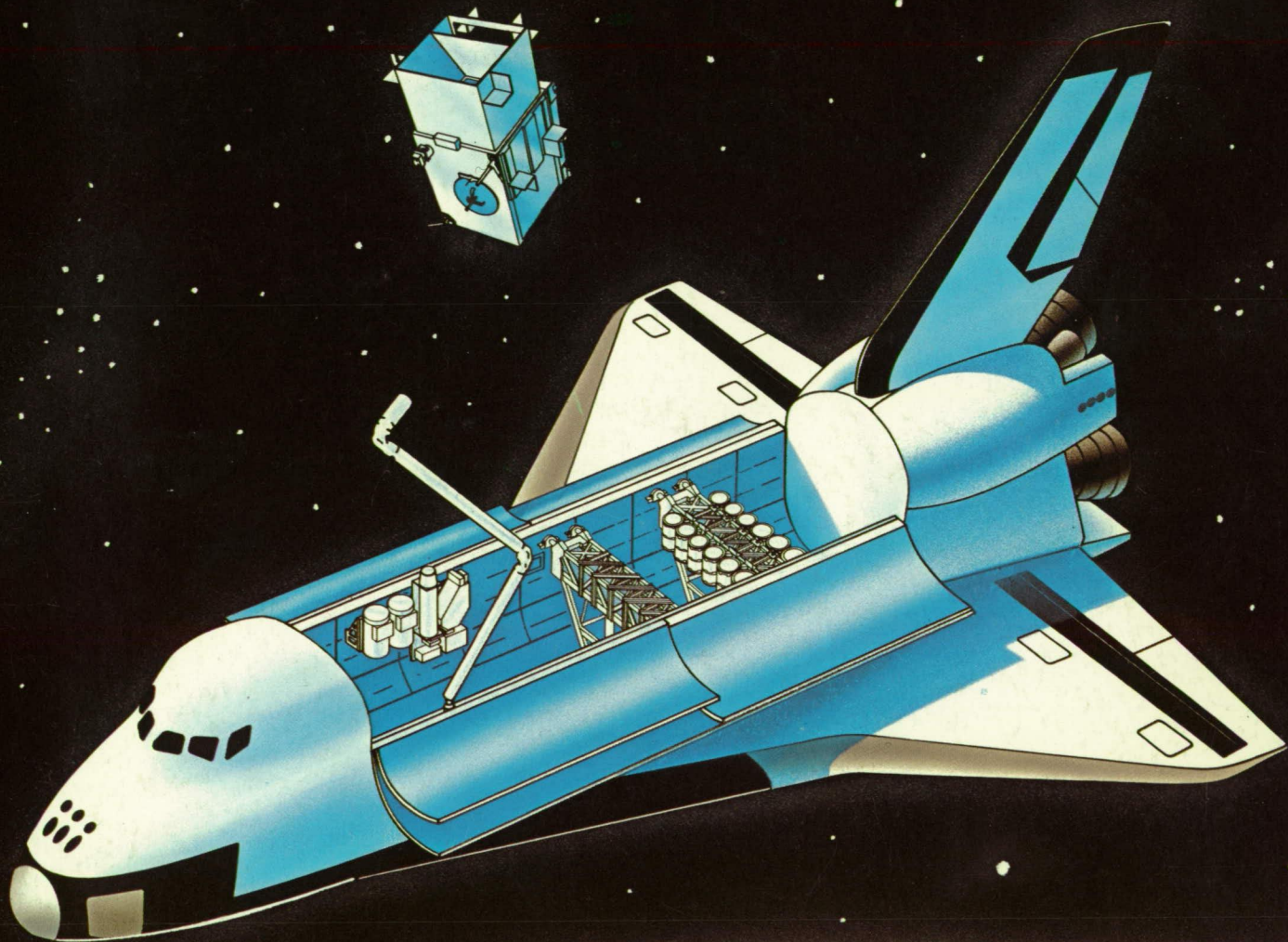


Attached Shuttle Payload Carriers

Versatile and Affordable Access to Space



(NASA-TM-103395) ATTACHED SHUTTLE PAYLOAD
CARRIERS: VERSATILE AND AFFORDABLE ACCESS TO
SPACE (NASA) 20 p CSCL 22B

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NASA

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

INTRODUCTION

What are the Attached Shuttle Payload Carriers?

The Shuttle has been primarily designed to be a versatile vehicle for placing a variety of scientific and technological equipment in space including very large payloads such as the Space Telescope and the large pressurized Spacelab module. However, since many large payloads do not fill the Shuttle bay, the space and weight margins remaining after the major payloads have been accommodated often can be made available to small payloads. The Goddard Space Flight Center (GSFC) has designed standardized mounting structures and other support systems, collectively called Attached Shuttle Payload (ASP) carriers, to make this additional space available to researchers at a relatively modest cost. Other carrier systems for Attached Shuttle Payloads are operated by other NASA centers.

A major feature of the ASP carriers is their ease of use in the world of the Space Shuttle. ASP carriers attempt to minimize the payload interaction with Space Transportation System (STS) operations whenever possible. Where this is not possible, the STS services used are not extensive. As a result, the interfaces between the carriers and the STS are simplified. With this near-autonomy, the requirements for supporting documentation are considerably lessened and payload costs correspondingly reduced.

In the pages that follow, the ASP carrier systems and their capabilities will be discussed in detail. The range of available capabilities assures that an experimenter can select the simplest, most cost-effective carrier that is compatible with his or her experimental objectives. Examples of payloads which use ASP basic hardware in non-standard ways are also described.

What are the Research Opportunities with the Attached Shuttle Payload Carriers?

The ASP carriers are appropriate for a large range of users. High school students, as well as some of the most experienced space scientists, have flown experiments in Get Away Special canisters. In others cases, the Hitchhiker-G or Spartan ASP carriers may best suit an individual's needs. Some advantages of the carriers for the researcher follow.

The ASP carriers offer an opportunity for educational institutions to become involved in space science research without having to devote years of effort to a single major project. For the simplest payloads, which make few demands on the STS, the time from experiment delivery to

Attached Shuttle Payload Carriers



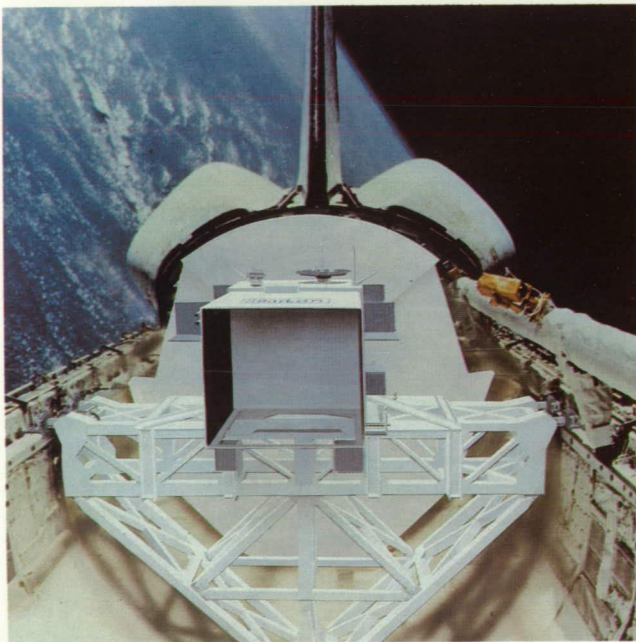
GAS canisters in the Shuttle bay, STS-7 mission.

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Camden and Woodrow Wilson High School students (Camden, N.J.) with GAS payload sponsored by RCA. The payload explored the colony behavior of ants in a weightless environment.



Artist's conception of SPARTAN and associated mounting structure in the Shuttle bay.

flight can be just a few months. For example, an experiment could be carried out from conception to conclusion in the time normally devoted to a thesis project. The flight costs are sufficiently modest that one or more reflights can be included either in the original plan or in subsequent requests which result from information gained during the first flight. For more complex experiments, a teacher can involve several students in major aspects of the experiment in much the same way as students have been involved in the past with major rocket experiments. In contrast to one sounding rocket flight, many hours of observations can be obtained from a single Shuttle flight - often enough to supply a faculty member and several graduate students with sufficient data to analyze for an extended period.

Industry may find an ASP carrier a convenient and cost-effective way to test components or techniques. Major STS or satellite payloads often contain components that first must be qualified for use in space. Ground testing and analysis is effective in many cases, but in others, direct exposure to the space environment may be the only method of verifying that a component or technique is acceptable for long-duration operations on expensive free-flying spacecraft.

Industrial processes can benefit from the near-zero gravity environment of space to produce materials that cannot be commercially produced on earth. The ASP carriers provide an economic means of evaluating and refining such processes before making long-range commitments for volume production on a more expensive payload.

What Kinds of Carriers are Available?

Three kinds of Attached Shuttle Payload carrier systems have been developed by the GSFC. The simplest is the Small Self-Contained Payload or Get Away Special (GAS). This carrier is an aluminum canister which provides complete containment for the experiment, making safety assurance comparatively simple. These payloads are assigned to Shuttle flights on a space-available basis. GAS has been a popular system and has had wide acceptance.

Accommodation for more demanding Attached Shuttle Payloads based on GAS hardware, but requiring more Shuttle resources has also been developed. The supporting equipment has been grouped into a system of equipment called "Hitchhiker-G." This carrier can mount experiments too large for a GAS canister but too small to make efficient use of a Spacelab pallet. The primary features that distinguish this carrier from the GAS carrier are access to Shuttle power and avionics and interactive control of the experiment from the ground.

Finally, the Shuttle provides an opportunity to fly and recover short-lived free-flying satellites. A carrier for pointed experiments has been developed from systems used on pointed sounding rockets. Known as Spartan, this carrier supports payloads which may be thought of as long-lived sounding rocket experiments with flight times of tens of hours rather than a few minutes. Like a rocket payload, each must be completely self-contained. The longer duration flight increases cost over a comparable rocket experiment, but the cost per minute of data is much lower.

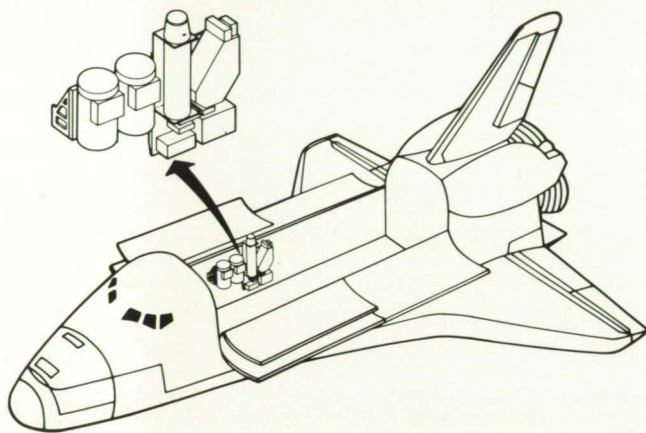
Table 1 provides a comparison of the three GSFC Attached Shuttle Payload options.

Can I Choose the Orbital Parameters or Shuttle Pointing?

The orbital characteristics of the Shuttle are selected to meet the needs of the prime Shuttle payload. Payloads such as Spartan are considered primary. Gas and Hitchhiker-G are payloads of opportunity and have little or no priority in determining STS flight activities. However, if you have special requirements for a particular orbital altitude or inclination, or time of year, NASA will attempt to assign your instrument to a compatible flight. Such constraints will reduce your flight opportunities and you may wait longer for a flight. The most frequently available orbit will be circular, at an altitude of 160 nautical miles (nmi) and an

Table 1
Characteristics of Standard GSFC Attached Shuttle Payload Carriers

	GAS	HITCHHIKER-G	SPARTAN
Telemetry	None	Real-time downlink of serial data at up to 1.4 Mbps	None
Pointing	None - timing of payload operations can be coordinated with major payload pointing requirements. The more specific requirements the more you limit your opportunities.	Shuttle bay pointing possible	± 3 arc-min. stellar; $\pm 10-20$ arc-sec. solar
Payload Size	19.75 inches radius; 28.25 inches or 14.13 inches high	Dependent on CG	Size of SPARTAN carrier is mission dependent. Dimensions of SPARTAN 1 are 31.89 x 31.89 x 22.05 ins. For SPARTANS 2 and 3, static envelop radial limits of 85.83" across the bay and 51.18" along the bay
Payload Weight	200 lbs., 100 lbs., or 60 lbs.	Currently the Hitchhiker-G is restricted to payloads weighing less than 750 pounds, with a choice of several modes of accommodations depending on size and weight	500 lbs. (for experiment)
Last Access Before Launch	2-3 months	2 months	1 month
First Access After Landing	2 weeks	2-3 weeks	1 week
Mission Specialist Participation	Operate two toggle switches and power on-off switch	Limited	Pre-release checkout, go-no go status check, pre-release orbiter and payload orientation, release, recapture
Frequency of Launch Opportunity	Approximately 50 per year, 29 have flown as of October 1984	Currently one every six months	2/year building to 11 by 1990
Testing Requirements	Safety	Safety	Safety
Lead Time	11-13 months before launch	Six months from initiation to flight	Instrument dependent, with a minimum of nine months
Documentation	Drawings, electrical and mechanical schematics, chemical and biological balance equations, heat flow diagrams, assembly and handling procedures, safety hazard reports	Documentation requirements currently under development	Interface definition and safety packages
Mission Duration	Shuttle flight duration or limited by battery supply	Shuttle flight duration	≤ 40 hours
Power	Battery supply (Customer Supplied)	Available through the Shuttle. A single payload has a maximum 500 w available, the total payloads have 1400 w available	Battery Supply (GSFC Supplied)
Uplink or Downlink	None	An asynchronous downlink channel at 1200 baud. An asynchronous uplink at 1200 baud. Medium rate downlink channel of 16 Kbps to 1.4 Mbps	None
Remote Control Possibilities	None	A Hitchhiker-G customer may send a limited number of bilevel and serial commands to the payload	Preprogrammed (microcomputer)



Hitchhiker-G in a typical flight configuration.

inclination of 28.5° (due east from the Kennedy Space Center). This orbit has a period of about 90 minutes of which 36 minutes are in the earth's shadow.

The amount of activity which the Shuttle crew will devote to your payload depends on the demands of the prime payload. Participation by the crew is limited for any of these small Attached Shuttle Payloads. Normally, orientation of the Orbiter will be dictated by the major payloads. However, some Shuttle orientation for small payloads may be possible. Of course, Spartan pointing is independent of the Shuttle orientation once Spartan has been released.

Is the Paperwork Extensive?

The ASP program is designed to minimize the required STS documentation. The most complex documentation requirement will be to detail all aspects of the experiment which might have an impact on its compatibility with other payloads, or on the safety of the Shuttle and its crew. The ASP experiments must meet the same safety standards and reviews as all other Shuttle payloads. However, the ASP project has developed standard interfaces and generic documentation to minimize the requirements on the user. A detailed description of one's experiment including both its objective and its design will be required at a scheduled time in the program. For Spartan, an interface agreement between the Principal Investigators (PIs) and the GSFC is also required. GSFC philosophy is to reduce formal documentation and to emphasize informal discussions throughout the experiment development.

What Help Will I Get from GSFC?

The amount of help provided to you by GSFC depends on the selected carrier system and the complexity of your experiment. GSFC will provide the mounting hardware and some components, as well as interface drawings and mounting equipment. GSFC will also provide integration, flight support, and liaison with Shuttle activities. At extra cost, GSFC will provide optional equipment capabilities, and analysis. In particular, GSFC will assist the experimenter who has special problems and provide information on suitable, commercially available components.

How Do I Get On One of These Carriers?

If you believe that you would like to fly a GSFC Attached Shuttle Payload, you should contact one of the individuals listed at the end of this brochure for informal discussions. This will provide you with detailed information about the carrier you wish to use and alert you to any obvious complications. If you require NASA funding, either for your experiment development or for NASA services, you must arrange for funding through the appropriate offices at NASA Headquarters. All funding will be based on a competitive review of the funding requests received not only for similar flights, but also for other Shuttle payloads.

For all reimbursable missions (Department of Defense and commercial), after it has been established through GSFC that a GSFC ASP carrier is appropriate, a flight must be booked through the NASA Headquarters Customer Services Division, Code MC. Spartan is not yet available for commercial purposes.

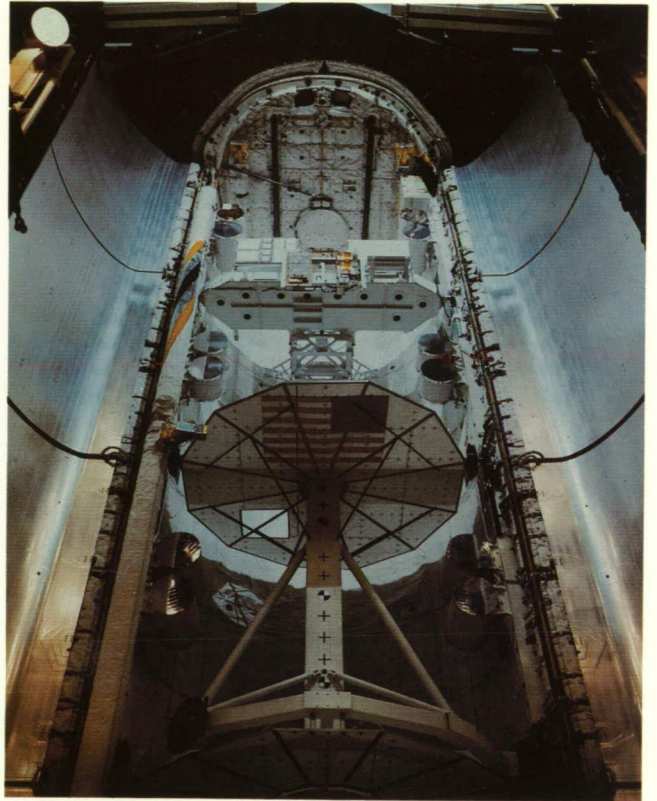
For NASA-sponsored payloads, the sponsoring discipline office at NASA Headquarters will make the proper arrangement. For cooperative international missions, you must go through the International Affairs Office at NASA Headquarters.

GET AWAY SPECIAL (GAS)

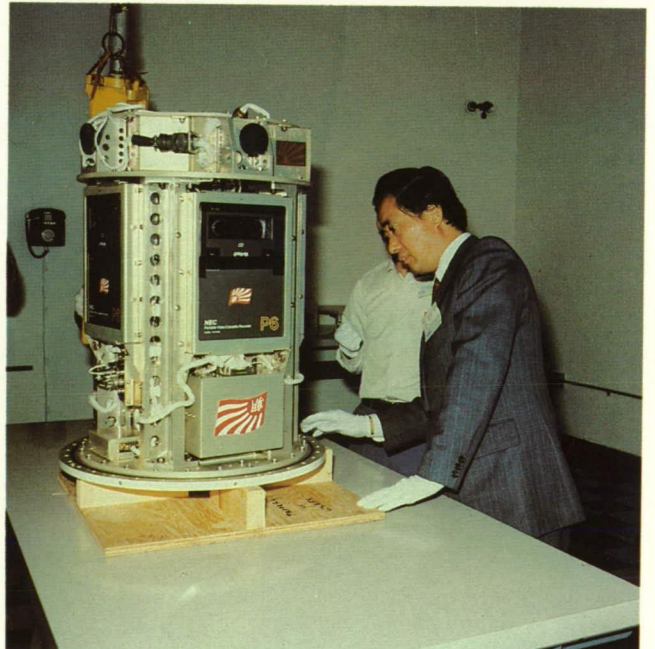
Why Choose GAS?

The advantage of a GAS payload is that it is the simplest experiment configuration which can be conducted in the Shuttle cargo bay. These experiments are small and self-contained. It is easy and comparatively inexpensive to get a flight opportunity for a GAS experiment. Providing that your experiment can meet the volume, safety, and self-sufficiency constraints, a scientific or technological development, or test experiment will be accepted on a first-come, first-served basis. At present about 50 experiments are planned for each year. A 60-pound experiment can fly in a 2-1/2 cubic foot canister for as little as \$3,000; the largest, heaviest GAS experiment with no optional extras costs only \$10,000 for launch and support services. The fact that the experiment is contained within a strong canister simplifies the design and requires minimal documentation.

Normally, an experiment using the GAS carrier is installed in the GAS canister about two months before launch, although attempts are being made to reduce this time to about one month. The experiment is not removed until about two weeks after landing. Thus, an experiment requiring live specimens or requiring rapid access may be impractical unless special precautions are taken.

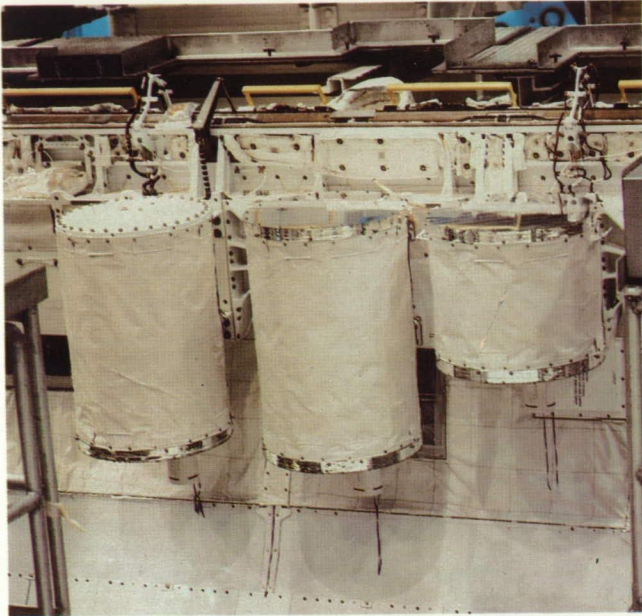


GAS canisters in the Shuttle bay, STS-8 mission.

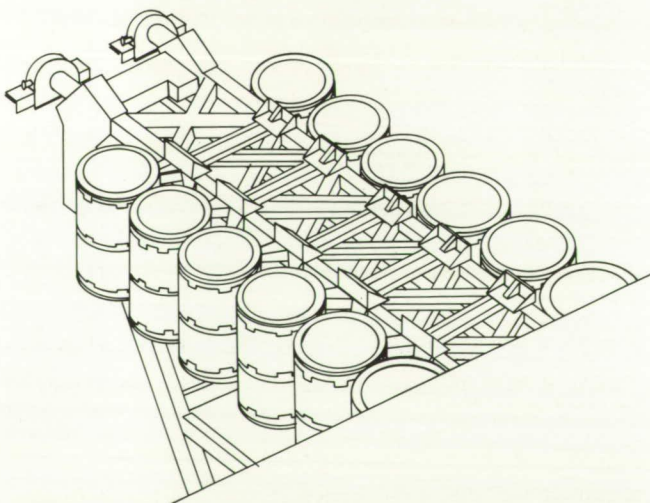


GAS payloads sponsored by the Asahi Shimbun Company demonstrating snow crystal growth in a weightless environment. The experiment used water from Mt. Fujiyama.

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The full complement of GAS experiments which flew on the STS-6 mission. Two of the experiments were housed in the large volume (5 cubic feet) GAS canisters, while the third was housed in the smaller volume (2¹/₂ cubic feet) GAS canister.



Detail of the GAS bridge which holds 5-12 GAS canisters. The GAS bridge is presently available to support missions.

What Kind of Experiments are Appropriate for GAS?

The simplicity of GAS experiments and their short lead times make them particularly well suited for educational experiences. Educational institutions are using GAS as a means of providing their science and engineering students with hands-on space experience. Some canisters are even being used by high school students with a strong interest in science and engineering.

In addition to its educational applications, GAS carriers have been particularly effective for materials science experiments. Small quantities of materials can be processed in automated systems with photographic recording of the experiment progress. Among the many experiments of this nature are several which have investigated various aspects of soldering in the space environment – investigations which will facilitate on-orbit repair of major spacecraft. A number of biological experiments have also been flown or are scheduled, with primary emphasis on the effects of very low gravity, but with concern also about the effects of cosmic rays or other aspects of the space environment. A seed company flew 25 pounds of various vegetable, herb, and flower seeds in small packages. Some packages were left open to expose the seeds to the space environment in various ways – perhaps the first step in space agriculture. The use of the GAS carrier also includes the study of how common devices work, in ways which cannot be studied in an earth-bound laboratory. For example, a manufacturer of high efficiency arc lamps used GAS to observe the behavior of the lamp arc without the disturbances of gravitational convection forces, thus taking advantage of low-cost research to design even more efficient lamps.

What Does a GAS Canister Look Like?

The GAS canister is a closed cylinder which can carry up to 200 pounds. The inner diameter of the canister is 19.75 inches and 28.25 inches in height. A less expensive flight opportunity with the same diameter, but 14.13 inches in height can carry up to 60 or 100 pounds. The GAS canister can either be purged with dry nitrogen and sealed, sealed with another environment, or opened to the Shuttle environment through a filter. There is no telemetry. The only Shuttle support other than transportation are three addressable function switches operated by the Shuttle crew. The experiment's equipment support structure is attached to the canister by screws to a top cover plate. The sides and bottom of the canister are insulated; the top may or may

not be insulated, as the experimenter wishes. For controlling payload functions, three latching relays can be operated by the Shuttle crew using the Autonomous Payload Controller (APC). If APC use is required, the GAS experiments will operate for 2-3 fewer days than the total mission.

Normally the canisters are mounted to the side of the Orbiter bay. Recently, a GAS bridge which spans the Shuttle bay has been developed. This bridge will hold from 5 to 12 GAS canisters and will be flown at the first possible opportunity.

What are My Responsibilities?

Once you have determined that a GAS payload is appropriate for your needs, you must make a GAS payload reservation through NASA Headquarters, Code MC, which requires a non-refundable \$500 earnest deposit. When this earnest money is accepted by NASA, an agreement is reached regarding the earliest acceptable launch date for your GAS payload. Table 2 lists a typical schedule of technical activities for a GAS experiment. Experiments with unusual safety problems, particular flight requirements, or other complications, will take longer. Reflights or simple experiments can be processed more quickly. Although a new experiment will be placed on a waiting list, a flight opportunity may arise earlier if the experiment is complete and ready for delivery ahead of schedule. One experiment was flown less than four months from its initiation.

Can the GAS Configuration Be Modified?

Within the constraints of size, shape, weight, and self support, engineers at the GSFC are working to increase GAS capabilities as customers request. For example, one experimenter assisted NASA in developing a door in the top of the canister, which can be opened in orbit and this configuration is now being made available to others. For this configuration, the experiment will be mounted to a ring with a hole 15-3/8 inches in diameter instead of on a solid plate. The opened canister can be closed by an optical window if desired. For another experimenter, a small antenna has been mounted on top of the canister for transmission of amateur radio signals. In this mode, frequency and power constraints must be met not only to comply with FCC rules, but also to avoid interference with the Shuttle avionics and other payloads. In addition, GSFC is now developing the ability to eject non-recoverable GAS payloads. Any deviations from the basic capabilities will be at extra cost.

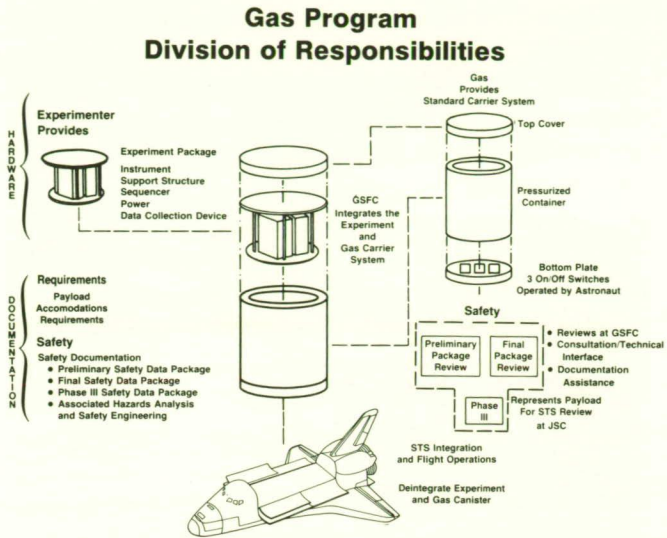
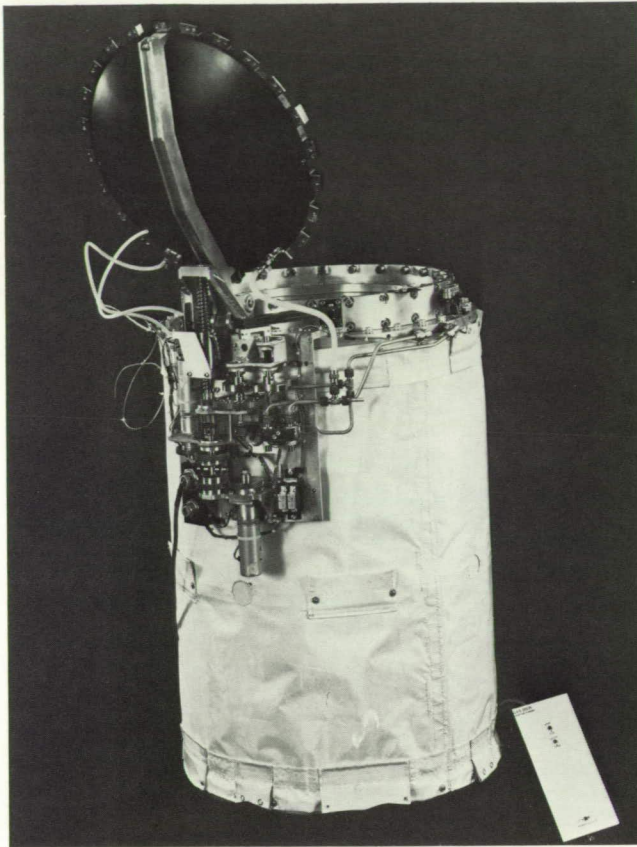


Table 2
Typical Schedule of Technical Activities for Get Away Special:
Nominal Timeline

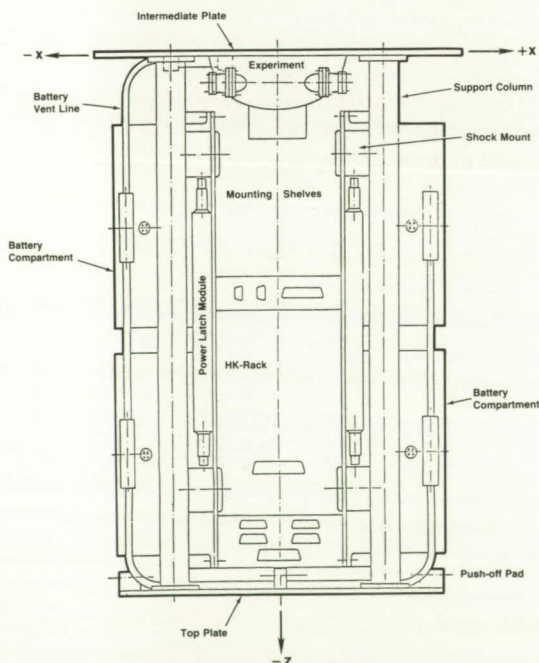
Standard Services	Date to be Completed
Customer completes payload accommodations requirements document and sends it to GSFC	Launch-13 months
Customer sends preliminary safety data to GSFC	Launch-10 months
GSFC completes preliminary safety data to data review	Launch-8 months
Customer sends final safety data to GSFC	Launch-7 months
GSFC sends shipping end plate to customer	Launch-7 months
GSFC completes final safety data review	Launch-6 months
Customer sends Phase III safety data to GSFC	Launch-5 months
Customer sends closed assemblies for preship inspection to GSFC	Launch-4 months
GSFC sends closed assemblies back to customer	Launch-3 ¹ / ₂ months
Payload safety certification acceptance by STS safety panel	Launch-3 months
Payload and customer arrive at launch site	Launch-63 days
Customer and GSFC install payload in container	Launch-60 days
Launch	Launch
Customer and GSFC remove payload from container	Launch + 2 weeks
Customer returns loaned hardware to GSFC	Launch + 1 month
GSFC sends post flight data to customer	Launch + 2 months



GAS canister showing motorized door assembly in the open position.

Can You Give Me A More Detailed Example of a GAS Experiment?

Many future materials science experiments plan to use halogen lamps to heat materials in space. As yet, it is uncertain whether these lamps will perform as predicted during extended periods of microgravity. An experiment to test extended operation (60 hours) is planned. It includes a gold-plated ellipsoidal half-shell mirror machined out of aluminum. A 55 watt halogen lamp will be inserted so that its filament is at the focus of the mirror. The lamp will radiate either directly or by the mirror to an intermediate plate, bolted directly to the mounting plate, which is used for heat dissipation. A thermostatic switch near the experiment on this plate guards against thermal runaway through the Payload Power Contactor (PPC) malfunction controller. The lamp base will be cooled by two heat pipes to the intermediate plate which are also protected by thermostatic switches. The shell containing the lamp will be evacuated during ascent and repressurized during descent. In orbit, a lamp voltage control will slowly raise the voltage to a predetermined level. Gas pressure in the lamp will rise to between 200 and 255 psi, and the temperature of the tube will range between 250° and 350° C. Power will be provided by four battery boxes of a type previously flown, with redundant vent ports. The payload is self-contained and does not require any Shuttle services such as power, thermal control, or computers.



Detail of halogen lamp experiment.

HITCHHIKER-G

Why Choose Hitchhiker-G?

The primary advantage of Hitchhiker-G compared to other Attached Shuttle Payload carriers is that experiments using this system have access to a substantial portion of the Shuttle avionics system. Payloads up to 750 pounds can share, with up to five other Hitchhiker-G payloads, 1.4 kW of power and 8 Kbps or 1.4 Mbps (shared) telemetry. Thus payloads which require interactive control and monitoring from the ground can be accommodated. As with other Attached Shuttle Payloads, documentation has been minimized and it is possible to progress from initiation to launch in as little as six months. Access to the payload is possible up to one month before launch and one week after landing.

What Kinds of Experiments Are Appropriate for Hitchhiker-G?

Science or engineering investigations whose requirements do not place heavy demands on Shuttle operations are candidates for Hitchhiker-G. Small experiments which need real-time interaction are also appropriate. For example, an experiment to photograph thunderstorm activity might be turned on as the Shuttle flies in an appropriate attitude over an area identified from ground-based observations to be experiencing such activity. Parameters in a crystallization experiment might be changed as the progress of crystallization is noted.

What Does Hitchhiker-G Look Like?

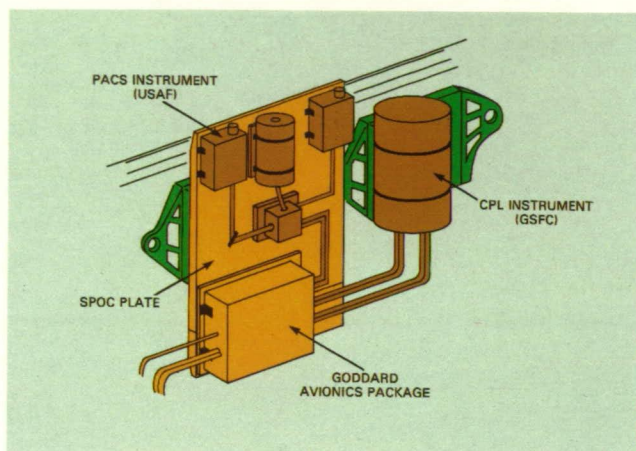
Hitchhiker-G has three different versions of a mounting system. The version selected depends on the size and weight of the equipment. The possibilities for Hitchhiker-G are:

- **GAS Canister** – up to two flight units of the standard GAS canister can be flown providing for a payload weighing up to 170 lbs. Either the closed or motorized opening door version can be used.
- **Plate Mounting** – flight hardware of up to 250 lbs can be accommodated on a vertical plate (Z-axis) mounted at the Orbiter sill level. A second plate may also be used to accommodate up to 500 additional pounds of hardware.
- **Direct Mounting** – up to 750 lbs can be accommodated by mounting the flight unit directly to an Orbiter beam.
- **Combination Mounting** – subject to approval by the Hitchhiker-G management, certain combinations of the three mounting configurations above may be used.

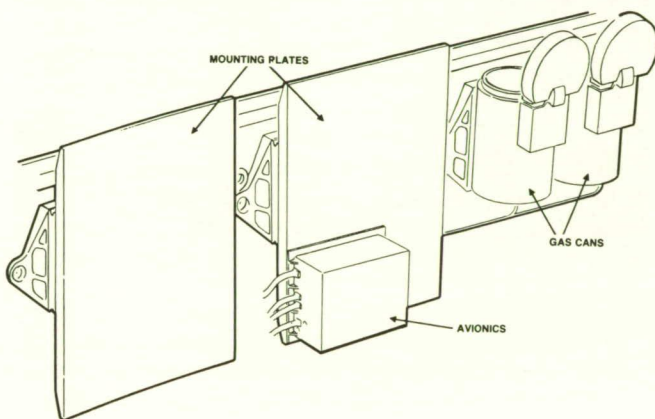
What Capabilities will GSFC Provide?

As with other Attached Shuttle Payloads, GSFC will work with you to provide a reasonable amount of help and advice. However, the main capability available to Hitchhiker-G payloads is access to substantial Shuttle avionics. This will allow you to operate and interact with your instrument in real-time using ground support equipment at GSFC. Attitude positioning will be constrained by the needs of the prime Shuttle users.

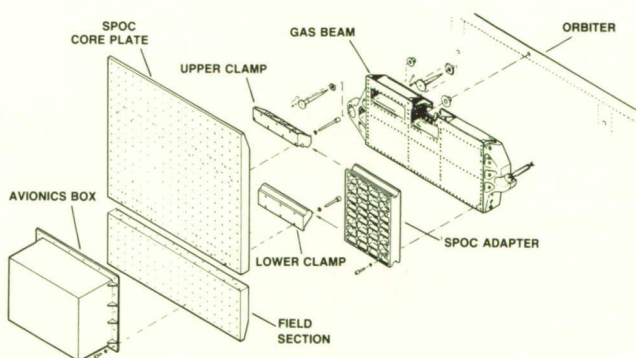
The basic Hitchhiker-G operations philosophy is that downlinked experiment data will be provided to the GSFC Payload Operations Control Center (POCC) for recording, engineering evaluation, and quick-look analysis. Real-time data and command connections can be made directly



Typical utilization of a Hitchhiker-G mounting plate and GAS beam. This configuration will be flown in the first Hitchhiker-G Mission.



Re-usable mounting hardware used in Hitchhiker-G. The hardware shown will accommodate a GAS canister, plate mount and direct mount configurations.



Exploded view of the HITCHHIKER-G structural assembly.

Table 3

Typical Schedule of Technical Activities for Hitchhiker-G:
Nominal Timeline

Standard Services	Date to be Completed
Payload Select/Manifest	Launch-6 months*
Mission Analysis Begins	Launch-6 months
PIP Appendix to Johnson Space Center	Launch-5 ¹ / ₂ months
Phase I Safety	Launch-4 months
Flight Planning Annex	Launch-3 ¹ / ₂ months
User Payload Delivery	Launch-3 ¹ / ₂ months
Integration/Testing Begins	Launch-3 ¹ / ₄ months
Mission Analysis Completed	Launch-3 months
Deliver to Orbiter	Launch-2 ¹ / ₄ months
Final Safety	Launch-2 months
Orbiter Processing Begins	Launch-2 months
Orbiter Processing Completed	At Launch
Launch	Launch
Deintegration/Instruments Returned to Customer	1 week after mission complete
Data Tapes Delivered to Customer	Launch + 1 ¹ / ₂ months

*8 months prior to this period; Candidate payloads are identified, user requirements documentation is made available and a compatibility analysis of candidate payloads is performed.

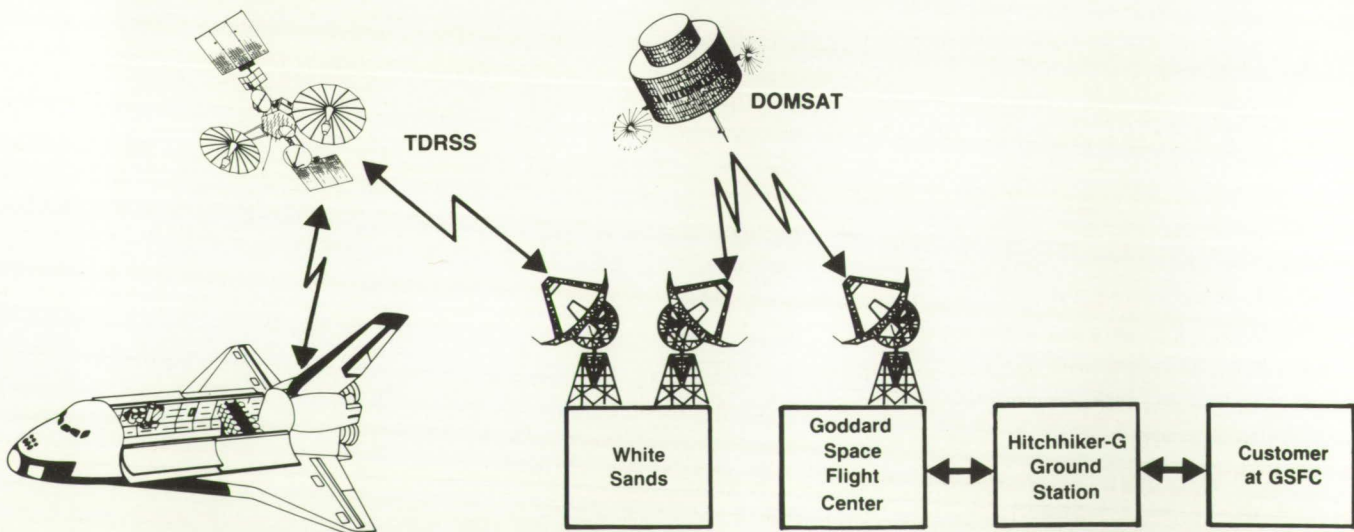
to a customer's ground equipment. In addition, displays of Orbiter attitude and other useful data will be provided along with access to downlinked voice communications. Primary experiment control will be via the standard Orbiter command uplink, augmented by limited crew involvement from the Aft Flight Deck (AFD). The AFD commands will be issued by the crew using a hand controller.

There are two potential classes of Hitchhiker-G flights – standby and scheduled. Standby flights are used as filler payloads to increase the Shuttle load factor. They will, in general, be completed within a period of six months from the time a payload is chosen from the waiting list. This type of flight will normally require minimal crew involvement and training. The system for performing standby missions has been approved. A typical program milestone schedule is shown in Table 3.

A scheduled flight generally will be planned at least 12 months in advance. The extra time will permit planning pointing requirements, timelining, crew involvement, etc. A plan for performing scheduled Hitchhiker-G missions is now under development with Shuttle payload integration personnel at Johnson Space Center.

Are Any Enhancements Planned?

Specific enhancements are not planned for Hitchhiker-G, but NASA will work with each experimenter to use the versatility of the Hitchhiker-G system to best meet the needs of the experimenter.



The Hitchhiker-G System allows real-time interaction between a customer at a GSFC ground station and his experiment.

How Often Will Hitchhiker-G Fly?

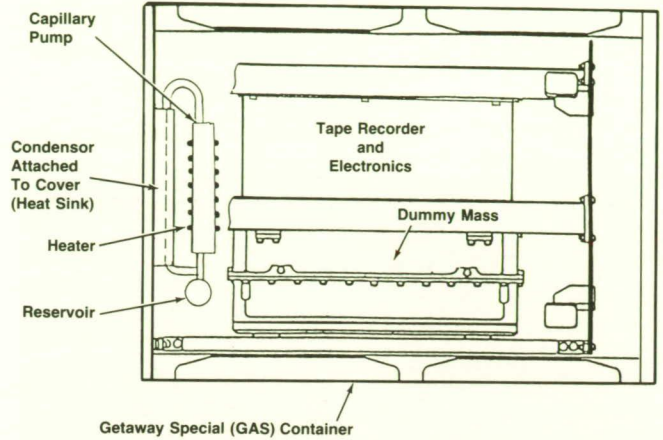
Flights are assigned on a space – available basis; however, NASA is planning at least one flight every six months. As Shuttle flights become more frequent, Hitchhiker-G opportunities will also increase. Of course, experiments requiring special orbits or special pointing may have to wait longer for a ride.

Can You Give Me an Example of an Experiment Which is Appropriate for Hitchhiker-G?

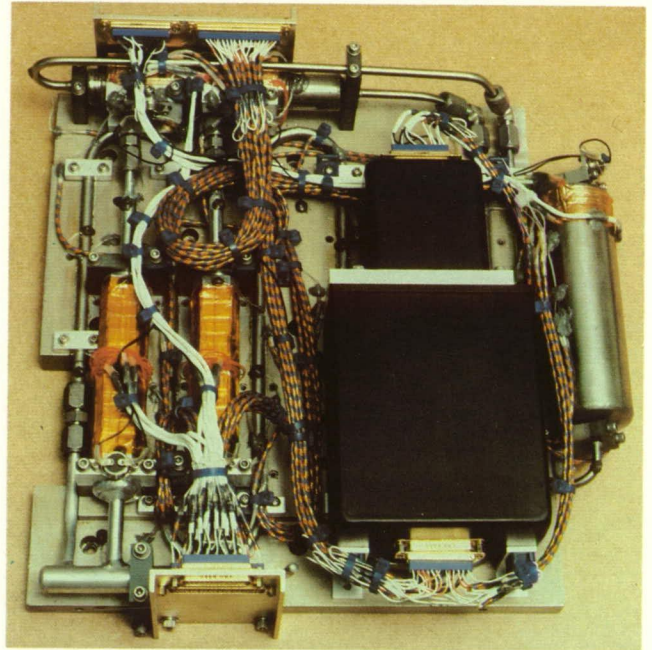
Most scientific instruments operate satisfactorily only within a narrow range of temperatures. Some must dissipate substantial amounts of heat. This temperature control requires thermal systems which have high density heat acquisition and transport capability. One such system under development at the GSFC is the Capillary Pumped Loop (CPL) which transfers heat from a series of evaporators to condensers through a liquid pumped by capillary forces. Since these pumps rely solely on the small pressure developed by the capillary, they are very sensitive to the effects of gravity. Therefore, it is impossible to test them satisfactorily on the ground.

The first test of this heat pump system was done as a GAS experiment. However, power limitations for GAS limited the fluids which could be tested. Therefore, a decision was made to transfer the experiment to the Hitchhiker-G system. The experiment will be mounted in a GAS canister and mounted to a GAS beam structure, but the additional Shuttle power available (1400 watts) permits the use of higher performing working fluid such as ammonia. Flying on the Hitchhiker-G also permits greater flexibility using ground commands and downlink data for experiment operations.

The experiment consists of a pair of capillary pumps each containing a wick of porous material. The pumps are fed liquid by a reservoir which holds sufficient fluid (ammonia) to saturate the wicks. Liquid drawn from a reservoir is evaporated into vapor at each pump site through the use of heaters. The vapor is transported to an aluminum block located under the GAS cover, which acts as a condenser. The condenser liquid is then returned to the reservoir to complete the transport loop. By selectively cycling the heaters, the pumps can be reactivated several times during the mission. It is also possible to test the effect of drying out the reservoir, and the behavior of the wick can be evaluated separately from that of the remainder of the system. By activating a single evaporator with the



Operating elements of the Capillary Pump Priming Experiment in a GAS canister.



External view of Capillary Pump Priming Experiment before enclosure in a GAS canister.

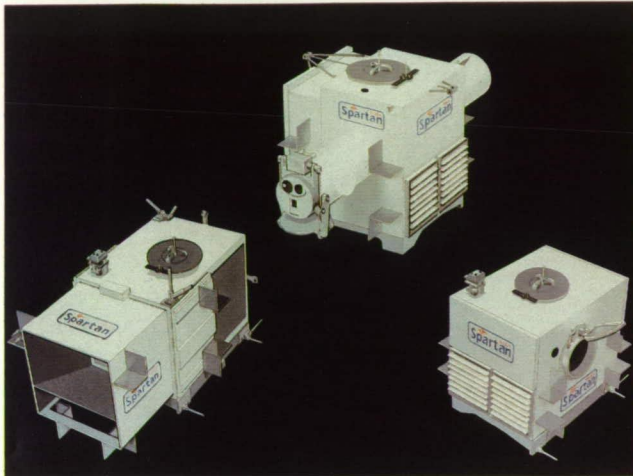
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second pump acting as a condenser, heat sharing can be demonstrated. The experiment will contain a tape recorder for data collection and Hitchhiker-G interface electronics for data transmittal and command functions.

SPARTAN

Why Choose Spartan?

Spartan is for those scientists who enjoy the ease of flying sounding rocket payloads which are pointed at celestial objects, but are hampered by the short time at altitude. Spartan applies to Shuttle payloads the management approach and the components of the pointed sounding rocket program to achieve 36 hours of observing time for "rocket payloads." Although carried to altitude by the Shuttle, Spartan is released and operates as an independent mini-satellite for up to 40 hours. It is then recaptured by the Shuttle for return to earth. As in the rocket program, NASA provides a standard carrier and support equipment to meet your needs and helps you integrate your experiment into the mission.



Artist's conception showing the configuration of (from left to right) of SPARTAN 1, 2, and 3.

What Kind of Experiments are Appropriate for Spartan?

Any experiment which requires fairly good celestial pointing and observation time of tens of hours is appropriate for Spartan. Spartan uses Attitude Control Systems (ACS) developed for astronomical sounding rocket experiments. A microprocessor is added to handle the greater maneuvering flexibility required for longer missions. There are no RF links with Spartan. The first four Spartan missions will carry instruments derived from those flown on sounding rockets. In the future, it should be possible to accommodate fields and particles experiments on Spartan.

Does a Spartan Payload Look Like a Rocket Payload?

Although instruments that have previously flown on sounding rockets may be obvious candidates for Spartan missions, the use of the Shuttle allows for flexibility in shapes and sizes. A long telescope, which would fit along the vertical axis of a rocket, can be mounted horizontally across the Shuttle bay on the Spartan service module which is a more cubic structure. The constraint is that the entire Spartan must fit within the static envelope of the cargo bay 86 inches in radius from the center of the support bridge with a height of less than 56 inches. Typically a 17-inch diameter telescope tube would reach 120 inches in length.

Spartan is affixed to a bridge across the cargo bay called the Spartan Flight Support Structure. A release/engage mechanism is the interface between the Spartan service module and this structure. The service module contains the ACS electronics, batteries, tape recorder, etc. The attitude sensors are usually mounted on the optical reference surface within the instrument, to allow fine alignment.

After the Shuttle has released its prime payloads, a crew member will activate and check out the Spartan, employing the same APC used to operate the GAS equipment. The Orbiter Remote Manipulator System then orients the Spartan in the appropriate position for the actual release. The payload will be released and then the ACS is activated. The Shuttle moves away before the Spartan starts its sun and stars acquisition sequence. It is then ready to follow its preloaded pointing and operation sequence. About two hours before scheduled recapture, the Spartan is rotated to the capture orientation and the equipment is powered down to a keep-alive status. Cold gas is used to accomplish rotation maneuvers; Spartan has no capability to perform translational maneuvers.

What Are My Responsibilities?

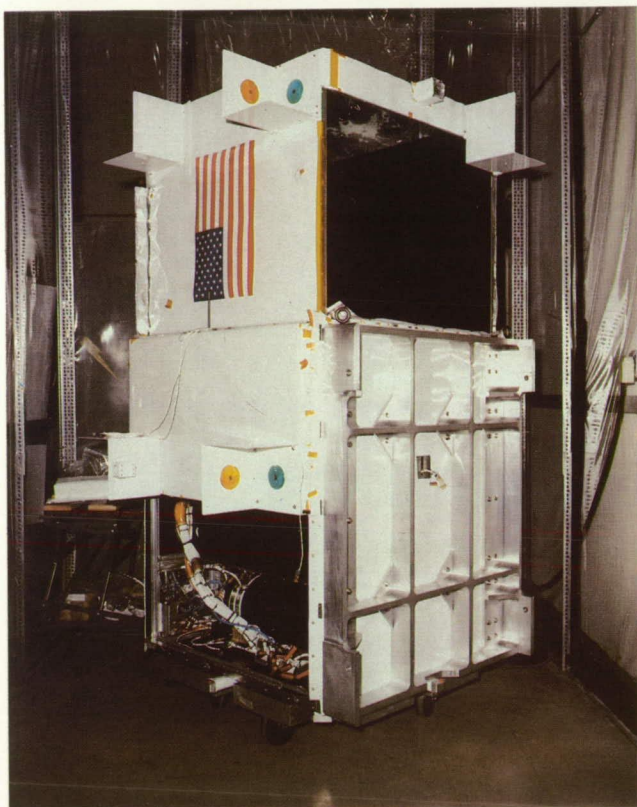
You will be responsible for all aspects of your instrument, including the following:

- Science instrument development
- Experiment system testing (functional and environmental)
- Experiment thermal analysis, design, and control
- Experiment mechanical design and analysis (fracture control)
- Safety data, analysis, and verification
- Materials lists and verification
- Critical alignments and related analyses, procedures, and special test equipment
- Electrical and mechanical aerospace ground equipment peculiar to the experiment
- Science data reduction and reporting
- Support and monitoring of instrument system performance at all levels of integration and operations activities at the GSFC and the launch site
- The cost and weight of all non-standard items provided by NASA.

Table 4
Typical Schedule of Technical Activities for a SPARTAN Reflight Mission:
Nominal Timeline

Standard Services	Date to be Completed
Payload initiation conference	Launch-18 months
Hardware inventory to support mission refurbishment	Launch-18 months
Carrier Subsystem mission analysis	Launch-12 months
Carrier Subsystem mission-peculiar mods developed	Launch-8 months
Carrier available from previous flight	Launch-8 months
Payload Integration Plan (PIP), PIP annexes and interface control document reviewed/ revised	Launch-6 months
Incorporate mission peculiar mods	Launch-4 ¹ / ₂ months
Refurbish carrier	Launch-4 ¹ / ₂ months
Integration/test SPARTAN carrier & flight instrument	Launch-3 ¹ / ₂ months
Acceptance test on integrated SPARTAN carrier/instrument complete	Launch-2 ¹ / ₂ months
Inspect/refurbish SPARTAN flight support structure	Launch-2 ¹ / ₂ months
Integrated SPARTAN mission FRR/PSR	Launch-2 months
Flight preparations begun	Launch-2 months
Launch	Launch
Instrument and data returned to PI	Launch +2 months

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SPARTAN 1 prepared for launch prior to leaving the GSFC.

Although documentation will normally be limited to safety documentation and an interface control document, you will work closely with GSFC throughout the program. Each Spartan payload will be assigned a dedicated mission manager and engineering team. A typical program milestone schedule is shown in Table 4.

What Capabilities Will GSFC Provide?

For the Spartan carrier, GSFC will be responsible for the following items:

- Carrier
- Safety management, including fracture control
- STS documentation, coordination, and analysis
- Integration and system testing (functional, environmental)
- Structural interface to experiment,
- Basic thermal control system
- Data formatting and recording
- Mission planning and analysis
- Electrical and mechanical aerospace ground equipment for carrier and Special Payload Division-provided systems.

For the most part, the capabilities provided for Spartan are very similar to those provided for pointed sounding rockets. If the attitude control sensors are carefully aligned with the instrument, Spartan can be pointed within 3 arc minutes for stellar pointing and 10-20 arc seconds for solar pointing. Peak to peak jitter is less than 10 arc seconds at 0.05-0.2 Hz. Batteries will be 28 v silver zinc batteries; up to 8 kWh will be provided to the experimenter at up to 10 amps. A 10^{10} bit, 14 track tape recorder will be supplied; up to about 5×10^8 bits of storage are available to the experimenter on this recorder. Thermal control is provided at $\pm 25^\circ\text{C}$. GSFC can provide the thermal control system for your instrument, but the design is your responsibility. They will also provide such payload unique items as motorized doors, stress analysis, an extra tape recorder, or other systems as optional services.

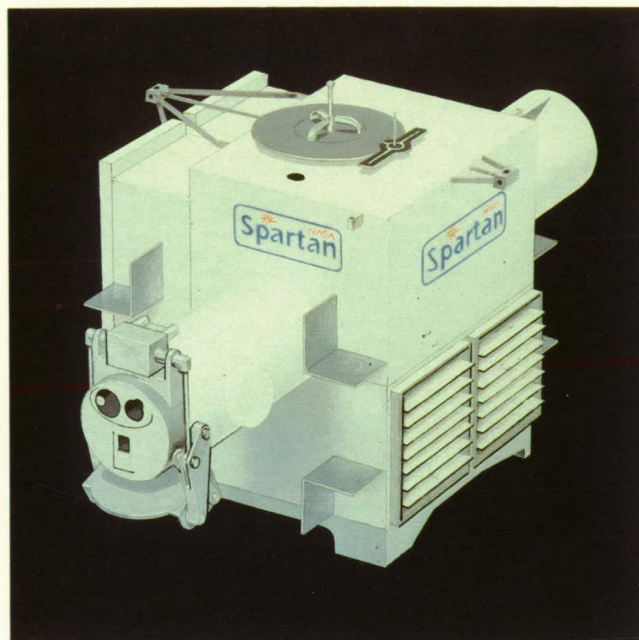
What are the Planned Enhancements for Spartan?

The GSFC is looking at a number of ways to enhance the capability of Spartan. These enhancements will be phased with successive Spartan flights. With Spartan 4, there will be an improved valve controller to reduce jitter from 10 second peak-to-peak to 1 second peak-to-peak. The additional enhancements to Spartan 6 include: improved attitude sensors to achieve better accuracy (sun sensors, gyros, tracking), increased payload capability, multiple payloads capability, increased data rates, and increased power capability. Candidate enhancements for future carriers include solar panels, a momentum exchange system, and the possibility of man-in-the-loop and RF uplink and downlink capability.

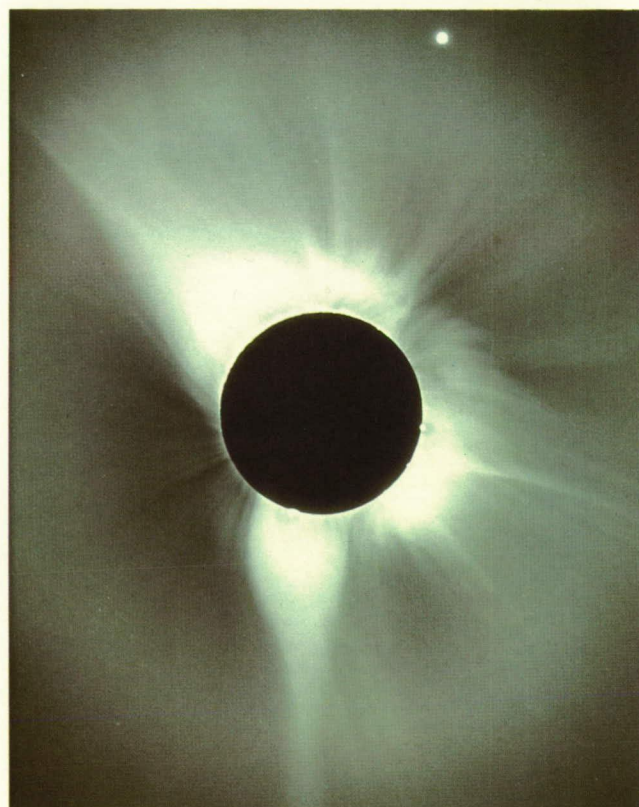
Can You Give Me an Example of a Payload Which is Appropriate for Spartan?

An ultraviolet coronal spectrometer from the Smithsonian Astrophysical Observatory and a white light coronagraph from the High Altitude Observatory have flown together several times on sounding rockets. They are now scheduled to fly on the first flight of Spartan 2. Together, these instruments will provide most of the information which theorists need to better understand the solar wind. The coronagraph takes pictures of the complete corona every few minutes. The brightness at each point is a measure of the electron density at each location in the corona, thus mapping the structure of the corona. The spectrograph provides measures of the velocity of the wind and the proton temperature. Most of the emission observed from the corona in the resonance line of hydrogen results from the scattering of the chromospheric line by the few neutral hydrogen atoms present in the corona. The higher the outward velocity of these hydrogen atoms, the less light they will be able to scatter and the weaker the emission will be. The width of the scattered emission is a measure of the temperature of the ions and atoms in this region. However, this scattered emission is weak because of the low density of neutral atoms in this hot, tenuous region so that it takes up to an hour for a measurement. During a rocket flight, it is only possible to measure this scattering at a few locations along a single solar radius. On Spartan, the spectrograph will scan a radius and then shift in angle to scan another radius until a picture has been built up of the entire corona.

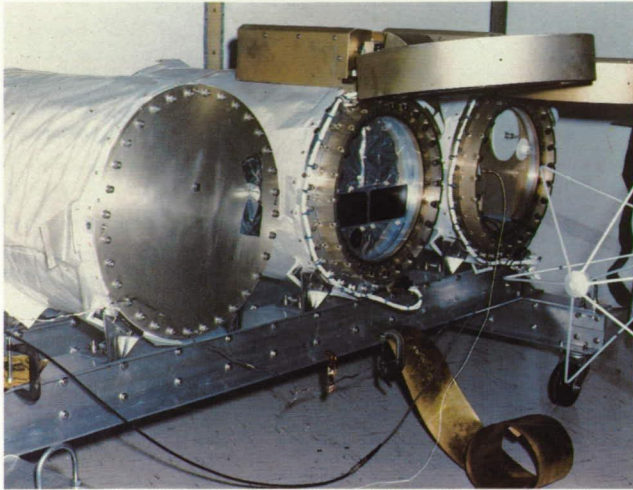
The two instruments share a common tube which is mounted horizontally in the Spartan carrier. The roll angle for the initial observations on the sun may be selected by



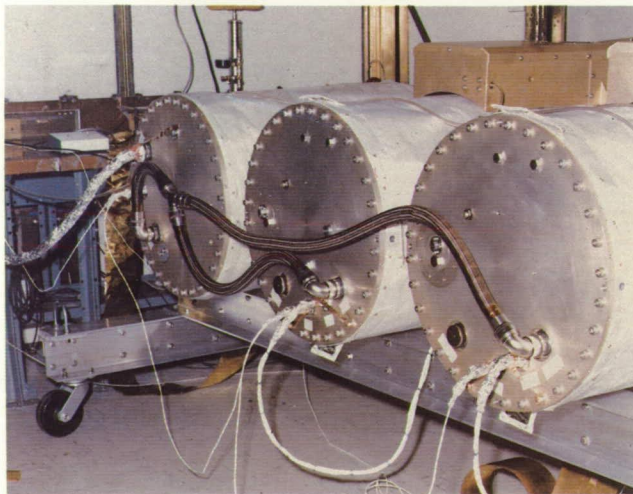
Artist's conception of the SPARTAN 2 mission showing the long cylindrical rocket instruments mounted horizontally on the carrier.



SPARTAN 2 will study the Solar Corona, the impressive outer atmosphere of the Sun. Credit: Naval Research Laboratory.



UVX configuration showing the GSFC avionics package on the left. The GAS canister with experiment elements can be seen in the center and right canisters with opening lids.



View of UVX configuration showing arrangement of interconnections between elements.

the experimenters relatively close to launch so that the most interesting features can be selected for study. Accurate roll-angle information is obtained from post-flight reduction of data from a star field camera.

SPECIAL ATTACHED SHUTTLE PAYLOADS

Although NASA considers the three payload carriers described here as standard systems, GSFC has been flexible in trying to meet the demands of individual customers by combining hardware from various systems to extend capabilities. Since these variations tend to be costly, they are limited to high priority experiments that demand such capabilities. Two such experiments which have been approved are described in this section. Both the Ultra-Violet Experiment (UVX) and the Shuttle High Energy Astrophysics Laboratory (SHEAL) missions experiments use standard equipment in a non standard way.

Is There a Special Experiment Based on the GAS Cans?

The UVX is designed to measure the galactic and extragalactic contribution to the diffuse background which is observed in the ultraviolet. It will also attempt to detect ultraviolet radiation resulting from either solar phosphorescence or chemical reactions of gases released from the Shuttle. The Johns Hopkins University will fly two spectrometers for observations in the 1300-1800 A and the 1700-3200 A regions. The University of California at Berkeley will fly two spectrometers for the 350 A to 1300 A wavelength region.

The two payloads are very similar and must observe the same regions of the sky. Moreover, since the background may vary with time, it is important to have simultaneous measurements in the ultraviolet and the extreme ultraviolet. Each experiment fits comfortably in a GAS canister with a motorized door. Each has a solar sensor to close its own internal door and/or remove high voltage from the detector if the sun gets too near the aperture and each has an aspect camera to determine the exact pointing of the instrument after the data are recovered. Since the experiments operate almost identically in their basic functions, they can use the same avionics support and the same commands.

Located in a third, closed canister is a Goddard Avionics Package (GAP) consisting of batteries, a tape recorder, a data formatting system, and special purpose electronics. Commanding of the experiments is done through the APC.

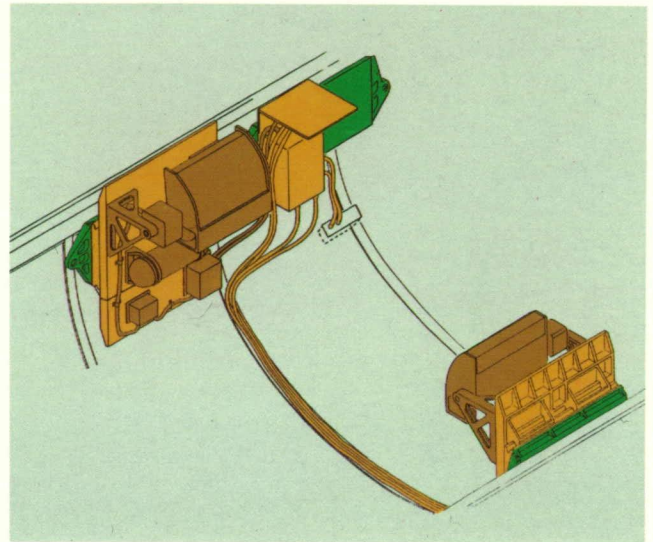
Since three GAS canisters are used, nine commands are available from the APC, most of which are sent to the two experiments simultaneously.

Using the APC, payload power and the canister heaters are turned on within 12 hours after launch for thermal control. At least 12 hours after launch, the motorized doors are opened to permit outgassing for a minimum period of 12 hours. The instruments are then prepared for observation less than one hour before the observation sequence is to start. This sequence is initiated by the crew maneuvering the Orbiter -Z axis to the celestial target attitude. The data taking is initiated by the APC at least two minutes after local sunset and ends at least two minutes before local sunrise, also by APC command. The doors are closed between observations. After the last observation, the APC is used to shut down all payload power including the heaters. All data are stored on the tape recorder. There is no telemetry capability.

Are Experiments Under Consideration Which Require More Resources Than the Standard Attached Shuttle Payloads?

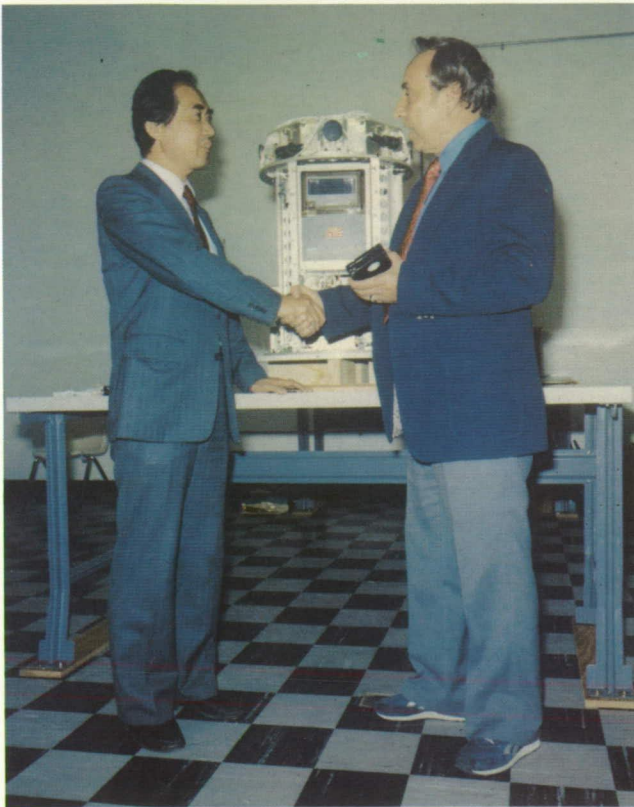
Yes. The SHEAL mission, which will measure soft X-rays from an extensive portion of the sky, is planned for a 1986 mission. Interstellar space appears to be pervaded by a very tenuous gas (about 3,000 atoms per cubic meter) at a temperature near a million degrees Kelvin. Moreover, our solar system seems to be embedded in such a region. A gas of this temperature and density emits many lines in the soft X-ray region which can be used to determine its physical characteristics more accurately. Variations in elemental abundances can also be derived from measurements of the strengths of these emission lines.

Crystals of lead stearate (PbSt) will be mounted on a curved panel which is so shaped that Bragg reflection directs all incoming radiation of a single wavelength to the same position in the focal plane. In this plane, a one-dimensional position sensitive detector is mounted. Although the entire spectral region (44 - 84 A) is covered simultaneously, each wavelength comes from a different direction. Therefore, to get full spectral coverage for a single region of the sky, the crystal panel must be rotated slowly about an axis perpendicular to the dispersion. A ten-degree collimator limits the instantaneous angular coverage of each detector element. The covering on the detector is very thin to transmit the soft X-rays being observed. Thus, the filler gas tends to leak during the observation and must be continuously resupplied. The crystals, collimator, detector, gas supply, and electronics are mounted on a vertical plate.



SHEAL configuration for 1986 mission.

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The GSFC team eagerly awaits the opportunity to provide you with support necessary for an exciting, successful experience with its Attached Shuttle Payload Program.

For the first flight, two plates, one on each side of the Shuttle, will be used. Later, two additional modules will be flown with crystals chosen for shorter wavelengths. Two modules, each mounted on separate plates, will be placed on opposite sides of the Shuttle bay.

Shuttle resources which will be used at each plate include 4 bilevel commands, three thermistors, uplink for both real-time and stored commands, 200 Kbps Ku-band downlink, 12 Kbps PCM telemetry, a time signal, and approximately 160W of power (maximum). Aside from normal monitoring, the real-time telemetry and command capability serves two important special purposes. It is imperative to stow the crystal plate during the daylight portion of the orbit since the crystals are rapidly destroyed by ultraviolet light. Even the light reflected from earth would destroy the crystals. Since the orbit characteristics will not be known accurately before launch, the time tagged commands for stowage and un-stowage must be sent after the Shuttle is in orbit. As the gas leaks from the detector, the detailed composition changes. Eventually, the detector must be flushed and refilled. The time to do this refilling must be determined by examining the characteristics of the data.

Obviously, this experiment must observe the sky during darkness. The plan is for it to fly on a mission which can orient the payload bay to within a few degrees of the zenith at orbital midnight. It may fly with other experiments which require celestial pointing.

CONCLUSION

Attached Shuttle Payloads will make access to space comparatively easy for potential experimenters ranging in background from high school students to the most sophisticated and experienced space scientists. GSFC has designed three basic carriers to provide standard interfaces with the Space Transportation System to make these interfaces both simpler and cheaper. Each of these carriers offers some flexibility in its accommodations to meet the needs of individual experimenters. Research which cannot be specifically adapted to one of these carriers, yet meets the ASP requirements, may sometimes be accommodated by judicious selection of ASP hardware. Because of the additional planning and documentation required, such flights will be more expensive and will take longer to schedule than those using the basic carriers. The GSFC philosophy is to keep its interaction with the experimenter on an informal basis, thus minimizing extensive paperwork.

WHO DO I CONTACT?

The Attached Shuttle Payload Program offers you a chance for innovative research in space. If you would like to become involved with this program, call or write to one of the people listed below. You may discover an exciting opportunity.

Mr. Sterling Smith
Project Manager
Attached Shuttle Payload Program
NASA/GSFC, Code 420
Greenbelt, MD 20771
(301) 344-7387

Mr. Donald Miller
Deputy Project Manager
Attached Shuttle Payload Program
NASA/GSFC, Code 420
Greenbelt, MD 20771
(301) 344-7387

For specific information about individual programs, the following people should be contacted:

GAS

Mr. James Barrowman
GAS Mission Manager
NASA/GSFC, Code 420
Greenbelt, MD 20771
(301) 344-4968

Mr. Alan Ladwig
GAS Program Manager
NASA Headquarters, Code MCN
Washington, DC 20546
(202) 453-2556

HITCHHIKER-G

Mr. Ted Goldsmith
Hitchhiker Mission Manager
NASA/GSFC, Code 730
Greenbelt, MD 20771
(301) 344-8799

Mr. Edward James
Hitchhiker Program Manager
NASA Headquarters, Code MLD
Washington, DC 20546
(202) 453-1151

DoD and commercial (for manifesting only):

Mr. Alan Ladwig
Manager of Secondary Payloads
NASA Headquarters, Code MCN
Washington, D.C 20546
(202) 453-2556

SPARTAN

Mr. Robert Weaver
Associate Division Chief
NASA/GSFC, Code 740
Greenbelt, MD 20771
(301) 344-8921

Mr. John Glaab
Spartan Program Manager
NASA Headquarters, Code EZ
Washington, DC 20546
(202) 453-1467