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Experiments of Opportunity Payloads Revisited

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ABSTRACT
A paper entitled "Development of an Experiment of Opportunity Test Payload for the Space Transportation system" was presented at the 17th Space Congress in 1980. Over the next 5 years and through the gauntlets of budget crunches, technical snags, administrative reorganizations, and changes in name, the basic concept survived and matured into the Spartan program. Spartan 1 was launched aboard STS 51G in June 1985. The final design and operating concepts are discussed, along with results of its first flight.

INTRODUCTION
As an evolutionary enhancement to its successful Sounding Rocket program, NASA has fostered the development of the Spartan program as one means to take advantage of Space Shuttle as a tool for conducting exoatmospheric science research. Key features of the Spartan Program which distinguish it from other NASA science programs are the fact that it is organized and intended to be conducted on a repetitive basis-i.e., experiments are changed, but support equipment remains invariant from mission to mission. Several Spartan missions per year (each with different science) are planned, as the inventory of reusable support equipment grows.

Cost of Spartan missions is viewed as being on the low end of the budget spectrum when compared with single purpose science missions typical in NASA. Risk of failure is, however, higher since redundancy is used less to keep costs low. By design, Spartan presents fairly simple interfaces to the STS, another factor which sets it apart from other programs. The method chosen by NASA to realize its goals of extending Sounding Rocket technology (both science and support systems) into the shuttle era was to develop "small" carriers which would be deployed from the Shuttle, operate autonomously for a period of time gathering science data, then be retrieved on the same mission and returned to Earth. Engineers in what was then the Sounding Rocket Division at the Goddard Space Flight Center began efforts in earnest on BOP in the late 1970s, and the transition to the era of the Shuttle was signalled by the consolidation of remaining Sounding Rocket activities at the Wallops Flight Facility and the reorganization of the Goddard Sounding Rocket Division into the Special Payloads Division in 1982.

GENERAL CHARACTERISTICS
Spartan has been designed to be as independent of the STS as possible; hence there are no RF links—all data is stored in a tape recorder aboard Spartan. Orbiter interfaces are minimized to the essential mechanical ones for mounting and support, operation of the mechanisms to release and manipulate Spartan, and a simple two wire communication link from the aft flight deck normally used by Get Away Special Payloads for on-off and predeploy status checks. Tracking of the Orbiter and Spartan while deployed is provided by the NASA C-band Tracking Network. These simple interfaces make manifesting Spartan into any mission with available space/weight capacity relatively straightforward and thus Spartan is capable of taking advantage of manifesting opportunities created by delays in other shuttle payloads. There are generally no special orbit requirements for the astronomy-type payloads that form the core of the Spartan Program because science target selection and pointing timelines can be adjusted 6-9 months prior to flight to compensate for any chosen orbit.

Figure 1 shows an artist's concept of Spartan 1 with external parts identified.

Data Storage and Handling
All data is stored onboard the Spartan Carrier to eliminate the need for expensive and elaborate Payload Operation Control Centers (POCC) and the like. Interface problems attendant with these systems are also eliminated.

Digital and analog data from all sources on Spartan—experiment, ACS, battery and
temperature monitors, etc. are received and encoded into a single serial data stream by the micro PCM data handling system, which has been used for a number of years on Sounding Rockets. The data is then stored on magnetic tape in a MARS 1400 tape recorder (shown in Figure 2), making recovery of the free-flying Spartan an absolute necessity. The recorder offers the following features:

- Multiple tracks (14)
- Switchable tape speeds (1.5 to 60ips)
- $10^{10}$ bit storage capacity

The data storage and handling system (PFCS) is mounted to a plate approximately 25x41 in. which weighs 125 lbs., as shown in figure 3.

Attitude Control System

The attitude of Spartan is under the control of an electronic system (125 lbs., 25x41 in.) shown in Figure 3. Performance goals for the attitude control system, which relies on an accurate three-axis deploy attitude from the Shuttle (+/- 8-10 deg.), solar-stellar initialization, and periodic (once per orbit for Spartan 1) stellar updates are as follows:

- Accuracy +; 3 arc minutes (3 axes) prior to gyro free drift period
- Limit cycle + 5 arc seconds at .05-0.2Hz. repetition rate
- Drift rate (gyro) 0.1 deg/hr.

It was planned that the Spartan 1 gas storage vessels would provide enough control gas for about 40 hours of science data collection, although the maneuver timeline was only guessed at during the design stage. The actual Spartan 1 flight required more maneuvers and consequently ACS gas availability limited the planned science observations to 27 hours. The attitude sensors used by Spartan are:

- Tuned Restraint Integrating Gyros (TRIG), Teledyne SDG-4
- Startracker, Ball Aerospace CT201
- Solar sensors (various types), Lockheed Missiles and Space Company

Analog signal processing and control loops are configured with digital logic via a ruggedized version of the Z80 STD bus microcomputer. Pointing programs and timelines are stored in the computer memory in such a manner that mission duration is limited only by consumables (power and control gas) and STS operational considerations. The attitude sensors and control loops, and a digital sequencer were taken from the Sounding Rocket program, and provided the foundation for Spartan ACS design.

The ACS pneumatic thruster system uses expulsion of cold gas through nozzles connected in opposing pairs to produce a force couple for control authority. Argon was used as the control gas because it is chemically inert and provides relatively high specific impulse compared to other inert gases. The ACS electronics generates on-off signals to the control valves, which open/close and cause Spartan to rotate, etc. The gas is stored in two 1631 cu. in. storage vessels made from an aluminum sleeve wrapped with Kevlar. Other components (valves, regulators, etc.) were taken from the Sounding Rocket Program. It was only necessary to change some elastomers to meet STS material requirements. The pneumatics assembly shown in Figure 4. is 42 in. by 42 in., and weighs 175 lbs., including 42 lbs. of Argon gas stored at 3000 psi.

Power

The power system again draws upon the Sounding Rocket experience by utilizing silver-zinc primary cells which are of the same type as those still in use aboard sounding rockets. They provide high charge to weight density and are considered safe for use on the shuttle. Spartan 1 had a total power capacity in excess of 20 Kwh.

Structure

The rectangular frame of Spartan 1 (Figure 5) was fabricated from linear aluminum extrusions reinforced by machined corner fittings inside the extrusions and welded together at the corners, and by aluminum honeycomb panels attached with screws. The ACS and data systems are mounted to solid aluminum plates which also serve as thermal radiators when exposed to space by motorized doors, while the ACS pneumatics is mounted to a large honeycomb panel. Each subsystem can be independently removed for service if necessary. The 6 ft. 3 in. long sunshade is constructed of aluminum honeycomb and riveted sheet aluminum. A large motor driven door also also made from lightweight honeycomb uncovers the experiment upon command from the ACS. The completed Spartan 1 is shown in Figure 6. It weighed 2222 lbs. at deployment.

Spartan 1 was mounted on the Spartan Flight
Support System (SPSS) off line and then installed in the Orbiter payload bay in the OPF, as shown in Figure 7 and 8. The SPSS is a version of the Teledyne-Brown Mission Peculiar Support Structure (MPESS) which has flown on several Shuttle flights for various payloads. Four trunnions provide Orbiter sill attachment and carry Z and X loads, while a single keel fitting takes Y loads.

Spartan 1 was separated from the MPESS for deployment by the REM system, built by the Marshall Space Flight Center. The two halves of the REM are the REM adaptor, which stays with the Spartan, and the REM base, which remains on the SFSS. Figure 9 shows the two REM halves. A motor/gear box assembly in the REM base operates a crank mechanism which engages the REM adaptor after the RMS operator has placed it in its "ready-to-latch" position on the REM base, and pulls the two round and square pins into engagement with making holes in the REM base. These four pins provide the primary load path.

Since recovery was crucial to obtaining data, two alternates were implemented with the STS to improve recovery chances in the event of certain problems. Foot restraints were added to the SFSS so two crewmen could stand atop the SFSS, and reach up and grab Spartan and place it in the "ready-to-latch" position on the REM in the event of an RMS failure. There were also plans for an alternate tie-down of Spartan in the event of a REM failure to latch.

The mechanical system was extensively inspected and tested. The welds were subjected to dye-penetrant and x-ray inspection and the structure underwent extensive fracture analysis. A modal survey was performed on an engineering model, and this data was used to help model structural acceptance level vibration specifications for ACS, data system, and experiment components. The engineering model frame with dummy subsystem masses also underwent a load test in the GSFC centrifuge.

Thermal

The spacecraft thermal control area was a new one to the designers of Spartan 1, since thermal control is not generally a critical factor in a short Sounding Rocket flight. Fortunately, the science thermal requirement was not severe, and all other subsystems were designed to operate over a rather broad 0-50 deg. C range, so the thermal problem was not too complex. Analysis showed that the majority of the heat would be generated on the ACS and data system assemblies, so the back side of each 25x41 inch aluminum plate was coated with silverized Teflon, and thus became a radiator. Thermostatically controlled motorized doors exposed the radiators when cooling was required (see Figure 1). All internal components are black, to facilitate radiative transfer inside Spartan. Multiple layered insulation was used to cover the entire craft. It was made of alternate layers of Mylar and Teflon netting, with a Kapton outer layer which was painted with white Chemglaze.

Science Experiment

The scientific objective of the Spartan 1 mission was to study the structure of two prominent cosmic x-ray sources, the Perseus cluster of galaxies and the center of our own galaxy, the Milky Way. When galaxies formed in the early universe, they arose not as isolated entities, but in clusters, some containing several thousand galaxies. Using x-ray instruments astronomers have discovered that clusters are filled with a tenuous, very hot (approx. 100 million degrees) gas, and a detailed study of its thermodynamic and spatial distribution should provide information valuable in our attempts to discover how clusters formed and evolved. The Perseus cluster was chosen for the Spartan 1 mission because it is relatively near (approx. 100 Mpc.) and because it is a strong x-ray source. The center of the Milky Way, a region a few hundreds of parsecs in extent, is of special interest to astronomers. The density of stars is very high, and there appears to be a massive central nucleus which may be a black hole, feeding off the material produced by tidal disruption of stars in its strong gravitational field. The region is known to contain numerous faint x-ray sources, but there have been few opportunities to resolve them with spaceborne instruments. Spartan 1 gave astronomers an opportunity to survey the region over a broader range than was possible using the "Einstein" observatory spacecraft, the only other extensive survey to date.

The Spartan 1 science experiment was provided by the U.S. Naval Research Laboratory (NRL), Washington, D.C. under a NASA grant. The NRL x-ray detectors are shown in figures 10 and 11. They comprise two large P10 gas filled proportional counters, sensitive to x-ray wavelengths between 1 and 15 angstroms.
Mechanical collimators mounted atop the detectors give each one a thin slit field of view, 3 degrees long by 5 arc minutes wide. The assembly measures about 3 ft. by 3 ft., and has an x-ray aperture with a net collecting area of 1200 cm². The figure also shows the 35mm aspect cameras, used to photograph the star field during the observations, and hence to verify ACS fine pointing.

TEST

A fairly routine test sequence was planned and carried out for Spartan 1, complicated somewhat by the fact that it was not launched aboard STS 41F in late August, 1984, even though it was at KSC and ready to go. Spartan went through a period of electro-mechanical integration which culminated in an all up "40 hour" test, which was a total mission simulation from predeployment checks through regrapple. Astronauts participated in this test and used it to develop and verify flight procedures for checking status and starting the Spartan operating sequence with the Getaway Special Autonomous Payload Controller.

Once the "40 hour" test was successfully completed, Spartan was subjected to EMI/RFI tests, acoustic noise, mass property measurement, and another "40 hour" test during thermal-vacuum exposure. A third "40 hour" test was performed at room ambient after return from environmental test. It was also necessary to repeat thermal-vac testing immediately prior to shipment to KSC, due to problems experienced during the first one.

Field testing was limited to brief functionals since Spartan 1 was shipped in nearly "ready to fly" condition.

When STS 41D failed to ignite properly on June 26, missions were reshuffled and Spartan was finally assigned to STS 51G. During the period between 41D and 51G, the ACS was returned to GSFC for reprogramming and gyro compensation, and the science experiment was returned to NRL for additional testing. The sunshade was also lengthened by an additional 39 inches due to the proximity of one of the science targets to the sun. Alignment checks and an abbreviated "40 hour" test were conducted at KSC in the spring of 1985 prior to launch, and then it was loaded into Orbiter Discovery.

OPERATION AND FLIGHT RESULTS

Summary

Spartan 1 was launched aboard STS 51G June 17, 1985, deployed June 20, and retrieved June 22. The total deploy-to-retrieve time interval was 45.5 hours. All Crew-related activities-status checks, pre-deploy commands to set day of deploy-specific maneuvers to compensate for Solar motion, release, regrapple, etc. were nominal and performed with no problems. All systems performed exactly as planned during the period of time Spartan 1 was free-flying with one exception, namely the ACS control gas was depleted prior to completion of the pointing timeline.

Data and Power System

All data system components performed as planned. Data was successfully recorded and retrieved from the tape with zero errors. Power consumption was nominal for the actual mission duration, as deduced from remaining battery capacity.

Attitude Control System

Performance of the ACS was nominal, and all planned trackable targets-stellar and solar-were acquired. Deployment accuracy (which was of great concern) was closer than 2 degrees. Spartan control authority was enabled a few seconds before release to minimize the effects of any tipoff rates that might be imparted by the RMS during release. Tipoff rates at RMS release were very low, but difficult to measure accurately due to the Spartan rate gyro scale factor. An analysis of control jet actuations showed that the tipoff rates caused by RMS release were less than 0.17 deg/sec, well within the capabilities of Spartan to control. Figures 12 and 13 show Spartan in the Orbiter prior to deployment, and shortly after deployment, respectively.

Deploy occurred at the proper mission time near orbit sunrise and all subsequent events occurred based on time elapsed from deployment. Immediately after deployment, Spartan 1 performed a 45 degree maneuver at 1 deg/sec about the grapple fixture (and return) as a signal to the Shuttle crew that Spartan systems were operating properly. It was necessary to wait one orbit (limit cycle on gyros) between deploy and solar
acquisition to allow the Orbiter to depart from the vicinity of Spartan so its Solar reflections would not bias the Spartan Solar attitude sensors. Solar acquisition occurred near noon of the second orbit day as planned and the Sun was acquired within 20 seconds after acquisition was enabled. Immediately following Solar acquisition a small correction maneuver was made to correct for solar ecliptic motion. The magnitude of the maneuver depended upon the actual day of deploy, and was set by the astronauts from the aft flight deck, using the APC hand controller prior to deployment.

During the next orbital night period, the startracker was energized and the search for the guide star Vega was begun by performing a 1/2 deg/sec maneuver to sweep the startracker through the sky. Vega was chosen as the guide star partly because of the paucity of trackable stars in its vicinity, which minimized the number of "intercepts" expected. An intercept would occur if a star were to be acquired while searching for Vega, but star magnitude discrimination software was designed to reject all stars except Vega. In actuality, there were no intercepts and Vega was acquired after about 11 deg of rotation, about what was expected. Next the ACS maneuvered 23.8 degrees to Deneb to enable the ACS electronics to correct angular errors about the startracker line of sight. The startracker and the science experiment were co-aligned to each other prior to flight. At this point the solar-stellar acquisition cycle was completed and the experiment line of sight and rotational errors were less than 3 arc minutes.

After completing attitude initialization the ACS performed a preset sequence of maneuvers, slow scans (16-24 arc min/min) across the science targets, and stellar updates to compensate for gyro drift. Control gas availability and usage budgeting dictated a science observing routine of 27 hours, with the remaining 18 hours to be spent in a gyro-controlled attitude hold awaiting pickup. All ACS activities and events during free flight took place exactly as planned, with the exception of early termination of the Spartan pointing timeline due to depletion of ACS control gas, which is discussed later in this paper. Absolute pointing accuracy in three axes was measured once each orbit by using startracker information obtained while updating on Altair and Deneb, and from the film aspect cameras carried as part of the science experiment. Both camera and startracker information yielded results near the ± 3 arc min. accuracy goal in all 3 axes prior to the start of a period of gyro control. Additionally, gyro drift was found to be 1.73 arc min/hr. and 3.53 arc min/hr. in pitch and yaw and 11.13 arc min/hr. in roll. The roll data implies a systematic drift or maneuver error which has not been identified to date. Limit cycle performance was nominal, but the repetition rate was near 0.2 Hz., a bit higher than expected.

Since recovery of Spartan 1 was of top priority, a simple Minimum Reserve Shutdown (MRS) was implemented to insure that there would be sufficient consumables (battery power and ACS control gas) to keep Spartan stable enough to permit pickup by the Shuttle crew at the appointed time, or even a couple orbits late if necessary. If and when battery voltage or gas pressure dropped below preset values, all systems aboard Spartan except certain timing functions would be shut down, and it would drift uncontrolled. At a time prior to the specified regrabble time, only the ACS would be turned back on to stabilize Spartan in a random attitude, and thus use the remaining control gas and/or battery power to keep it stable enough so it could be regrabbed and stowed in the cargo bay.

The inclusion of the RMS concept in Spartan 1 proved to be a wise one since it was triggered into MRS mode 17.5 hrs. after deploy by low gas pressure. At 40.5 hrs after deploy, the ACS was again turned on by timer and it stabilized Spartan 1 for retrieval, using the control gas remaining in the tanks. The Orbiter rendezvoused with Spartan at the appointed time and it was successfully grappled and stowed back in the cargo bay. Figure 14 shows Spartan 1 a few moments after regrabbing.

Analysis of the flight data tape showed a full gas charge at the beginning of the mission; hence there was no leakage of gas since its last fill during payload processing. This leads to the conclusion that gas was used at higher rates than planned. There were found to be three basic areas in which gas usage was higher than expected:

1. Slight variations in mass properties from those used to set controller parameters caused the control loops to perform less efficiently with respect to gas usage.

2. A detail of the control logic dealing
with the sequence of capturing to null causes a second "fine" step capture to occur at the end of each maneuver. This second fine capture was not considered in the budgeting process.

(3) The presence of electronic noise on the rate signal produced by the gyros caused high control valve duty cycles (extra valve activity) during the coast phase of each maneuver.

Since 32 minutes of each 92 minutes science orbit was spent maneuvering Spartan, the extra valve activity during maneuvers was devastating to the gas budget. In fact, 70% of the excess gas usage is attributable to factor (3). If factor (3) had not been present Spartan still would have gone into MRS due to (1) and (2), but not until the completion of all science observation orbits (27 hours after deploy).

Analysis of the electronics design after flight, along with 3-axis air bearing tests, identified the cause of the controller noise to be a combination of high rate signal gains (necessary for control purposes), and inadequate rate signal low pass filtering. Pass bands were lowered and upon retest on the air bearing, valve activity was significantly reduced during maneuver coasts. Subsequent ACS electronics have undergone low pass filter modifications to eliminate the problem in future Spartans.

Structures

There was no structural damage evident and all mechanisms including the REM performed as expected.

Thermal

The thermal performance of Spartan 1 was generally better than the predictions of the thermal math model because of the conservative design approach which was used.

There were no temperature monitors available while Spartan 1 was in the Orbiter bay, but the mission time at which Orbiter-powered Spartan heaters were switched on by internal thermostats indicated that Spartan cooled more slowly, by a factor of 1.8, then predicted by the math model. This fact leads to the conclusion that the thermal isolation of the REM adaptor was adequate, a point about which there was some concern prior to launch.

It was found that the thermal coupling between the two coldplates (ACS and data system) was better than the prediction, and that the coldplates never got hot enough prior to MRS shutdown at 17.5 hours to cause the thermal doors to operate to expose their radiating surfaces. A corollary to this is that the interior of the payload remained warmer than expected since the heat generated on the coldplates was rapidly transmitted throughout the structure. The main structure showed no orbit-to-orbit temperature fluctuations, while sunshade temperatures clearly oscillated in sync with the orbital period.

Science Experiment

During the mission and after ACS initialization on Vega, a preset observing sequence was repeated each orbit. The detector was pointed at the Perseus cluster 26.7 minutes, and then at the galactic center for 14.8 minutes. The remainder of the 90 minute orbit was spent updating the gyros on stars Altair and Deneb, and waiting for the science targets to become visible in the sky. Each science observation consisted of several slow scans across each source at specific rates which varied between 16 and 23 arc min/min. The direction of the scans was changed each orbit in such a manner that uniform coverage in scan azimuth was achieved during the mission. This is illustrated in Figure 15, which shows the locations on the sky of the eight scans of the galactic center which were completed prior to MRS. Departures from symmetry in Figure 15 reflect the pointing errors made by the ACS in acquiring the target under gyro control. The largest miss on the galactic center was 7 arc min, and the average is 3.4 arc min, well within the accuracy requirements of the science instrument.

The long axis of the collimator slit field of view (3 degrees long) was oriented perpendicular to the scan direction. The motion of the slit along the scan path caused the detector to respond to changes in the x-ray structure of source; however, what was obtained was a one-dimensional projection of this structure onto the scan path because variations along the long axis of the slit were not measured. Nevertheless, two dimensional information about the structure of the source was obtained because the scan direction was systematically varied over the course of the mission. The observations of this instrument have much in common with medical x-ray diagnostics using computer
assisted tomography (CAT scanning).

Figures 16 and 17 show some typical plots of x-ray count rate as a function of time, obtained from the flight data. Figure 16 represents one scan across the Perseus cluster (2 degree total at 16 arc min/min.), generating a relatively smoothly varying signal subject to statistical fluctuations of the x-ray photon counting) reaching a maximum at the center of the cluster. In Figure 17 on the other hand, several non-statistical variations in the x-ray count rate are evident, representing transits of individual galactic center sources through the collimator field.

The Spartan 1 data analysis has progressed to the point where x-ray maps may be synthesized using the data from all the scans. Figure 18 shows a map of the galactic center region, revealing six x-ray sources which did not appear on earlier maps. Although further analysis is needed to confirm this, it does appear that many of the sources in this region are transient in nature. The dashed line is the plane of the spiral disc of our Milky Way galaxy. The very center of the galaxy lies on this line, close to the pair of sources in the center of the field. The galactic center lies to the right of the lower source in the pair. These galactic center sources revealed by Spartan 1 are the subject of ongoing studies which are attempting to relate them to structure revealed already in infra-red and radio observations. X-ray maps of the Perseus cluster have been synthesized also from the flight data. They are being compared with theoretical models of the origin and distribution of hot gas in clusters.

THE SPARTAN PROGRAM

The idea central to the development of the Spartan Program as an outgrowth of the Sounding Rocket Program is aimed at providing low cost science opportunities. Spartan program costs were (and will be) kept relatively low by:

- Simplified interfaces - The necessary mechanical interfaces (Trunnions, keel and the RMS/grapple fixture interface) had been defined and used on previous missions, so no new ground was uncovered in their use. The GAS hand controller was originally developed by the Special Payloads Division and used on numerous flights, and the REM electrical interface was designed by MSFC to be compatible with the active payload retention system already designed and implemented in the Orbiter.

- Generic documentation - was not developed for the Spartan program but documentation (at all levels at GSFC, JSC, and KSC) can be used over after mission specific modification. Generic documents will eventually result after a few Spartan missions.

- Hardware reuse - The use of existing (Sounding Rocket) hardware, tape recorder, gyros and electronics, startracker, sun sensors, ACS programmer, POM data system undoubtedly forced some design and implementation compromises, but it also put boundaries on the initial design, and permitted a cost effective final system design to emerge. Future Spartans will include enhancements that might have been included on Spartan 1 but would have undoubtedly increased its cost and jeopardized its development schedule.

- Risk acceptance - Although it is difficult to quantitize, the minimal use of redundancy in design to enhance system simplicity (and keep costs down) was accepted by management as a reasonable risk of failure to achieve the science goals. The limited duration mission (45 hours as opposed to months) provided the opportunity to test system performance several times from start to finish, giving assurances that, given the opportunity, all systems were capable of functioning together for the duration. In the area of safety there is, of course, no compromise, and Spartan payloads meet all safety requirements.

It was originally planned that no Orbiter resources would be used, and that Spartan would be deployed at a random attitude at any time; however, thermal and ACS considerations forced modifications in these areas. Power for heaters in the REM and Spartan was taken from a spare 28VDC buss in the Orbiter system, and the hardware interface was worked out with no problems and without a lot of fanfare. It was found that ACS design could not be practically implemented unless Spartan was deployed in a specific attitude and at a specific time. No major problems cropped up during the implementation of the ACS deployment requirements. It appears that limited use of Shuttle resources is feasible.
NASA is currently pursuing a path toward a "stable" of Spartans, capable of supporting astrophysics investigations at the rate of four per year by 1988. Each Spartan would use the same basic support structure/subsystem design, with only the science experiment to be changed from mission to mission.

As a result of the Spartan 1 pathfinding experience the Goddard Special Payloads Division designed a second generation carrier system to support the continuing Spartan program. The first flight of this new carrier system was slated to observe Halley's Comet and was aboard the ill-fated STS 51L when it went down.

The next Spartan flight was scheduled for STS-71C prior to the 51L disaster, and work is proceeding at GSFC towards its completion to meet that date. Figures 19 and 20 illustrate the second generation module design, with the next two science payloads, a 10 ft. long x 17 in. diameter solar telescope, and a 22 in. dia. spectrographic camera for galactic astronomy. These payloads will weigh about 2700-2800 lbs. when deployed. The second generation carrier utilizes a non-welded aluminum structure held together with threaded fasteners. Heat-actuated louvers are used in place of the Spartan 1 motorized thermal doors. The ACS and data (PFCS) systems are the same as developed for Spartan 1, while the power capacity is slightly expanded. The lower portion, or service module, remains the same from mission including science experiment is intended to be uniquely configured for each mission.

The capabilities of Spartan will grow with experience, and such growth will lead to enhancements such as RF links to the Orbiter for commands, "smarter" ACS software and hardware, and better attitude sensors. This growth will be much the same as the growth of sounding rocket technology as the engineers responsible for it gained knowledge and experience through their repetitive involvement.
Figure 1
Artists concept of Spartan 1 showing major external parts and dimensions.

Figure 2
MARS 1400 tape recorder with cover removed.

Figure 3
Spartan 1 data storage and handling system during test. The large box in the lower left hand corner houses the MARS 1400 tape recorder.
Figure 4
ACS pneumatic thruster system during vibration testing. Nozzles can be seen protruding from right and left sides.

Figure 5
Spartan 1 structural framework. The large open rectangular area is for the ACS plate, while the experiment occupies the upper volume.

Figure 6
Spartan 1 at KSC prior to Orbiter installation. The thermal door is in its "closed" position over the data system coldplate.
Figure 7
Ready to fly Spartan 1 mounted atop the MPSS, as it is hoisted into the Orbiter.

Figure 8
Shortly after installation in the Orbiter.

Figure 9
REM Mechanism used to separate Spartan from its mounting in the Orbiter. The long rods and grooved fittings are for visual guidance only.
Figure 10
X-ray detectors viewed from the rear. Between the detectors is the startracker (center) and the TRIG gyro package (right).

Figure 11
Front view looking into the mechanical collimators through which the proportional counters view the sky. The startracker and two aspect cameras are mounted between the detectors.

Figure 12
Prior to deploy, the RMS is coupled to the Spartan grapple fixture before the REM is actuated.
Figure 13
Spartan 1 a few moments after deploy. The shadow of the Shuttle RMS can be seen on Spartan. The Orbiter vertical stabilizer is in the top of the photo.

Figure 14
A few moments after regrapple.

Figure 15
The projection on the sky of the eight scans across the galactic center made during the Spartan 1 mission. An ideal scan would pass through the aiming point identified by the cross.
Figure 16
X-ray count rates during typical scans across the Perseus cluster of galaxies.

Figure 17
X-ray count rates during typical scans across the galactic center.

Figure 18
An x-ray map of the galactic center, constructed using data obtained during the eight scans traced in Figure 15.
Figure 19
Spartan 201 configuration with Solar Telescope.
Figure 20
Spartan 202 configuration with Galactic Astronomy experiment.