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JUN 30 1992

TO: Distribution

FROM: S/Associate Administrator for Space Science and Applications

SUBJECT: Mission Operations Report (MOR) for the Solar, Anomalous, and Magnetosphere Particle Explorer (SAMPEX)

The MOR for SAMPEX is enclosed for your information.

The first of NASA's Small Explorer missions, SAMPEX, will investigate energetic particles arriving at the Earth from space during declining solar activity. These particles include anomalous cosmic rays, galactic cosmic rays, solar energetic particles, and precipitating, relativistic, magnetosphere electrons. While SAMPEX will be 20 times more sensitive to galactic cosmic rays and solar energetic particles than any previous instruments, the most significant, new information will come from the investigation of anomalous cosmic rays.

The SAMPEX mission was designed and built by NASA engineers at the Goddard Space Flight Center in just 3 years following the selection of the mission. SAMPEX will carry scientific instruments from the University of Maryland, California Institute of Technology, the Aerospace Corporation, and the Max Planck Institute for Extraterrestrial Physics in Germany. The spacecraft includes the first use of the Small Explorer Data System which uses advanced computer technology and computer memory in place of a tape recorder to store engineering and scientific data.

L. A. Fisk

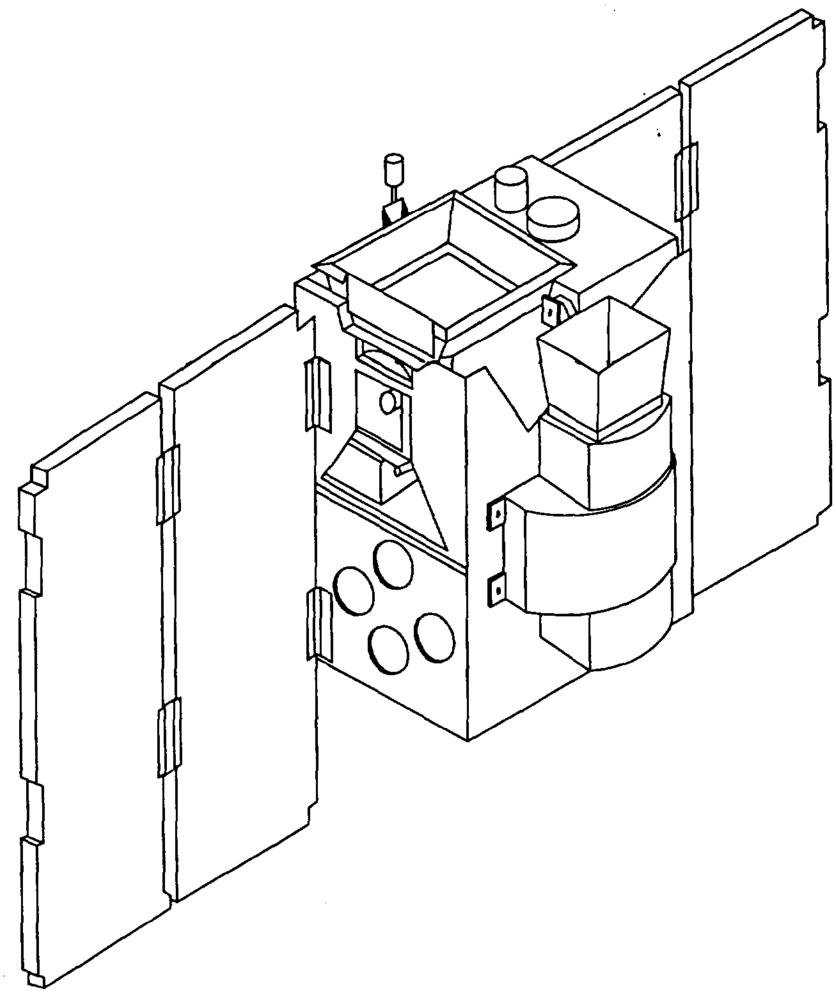
Enclosure

National Aeronautics and Space Administration

Mission Operation Report

OFFICE OF SPACE SCIENCE AND APPLICATIONS

REPORT NO. S-864-92-01



SOLAR, ANOMALOUS, AND MAGNETOSPHERIC PARTICLE EXPLORER (SAMPEX)

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FOREWORD

MISSION OPERATIONS REPORTS are published for use by NASA senior management, as required by NASA Headquarters Management Instruction HQMI 8610.1C, effective November 26, 1991. The purpose of these reports is to provide a documentation system that represents an internal discipline to establish critical discriminators selected in advance to measure mission accomplishment, provide a formal written assessment of mission accomplishment, and provide an accountability of technical achievement.

Prelaunch reports are prepared and issued for each flight project just prior to launch. Following launch, updating (Post Launch) reports are issued to provide mission status and progress in meeting mission objectives.

Primary distribution of these reports is intended for personnel having program/project management responsibilities.

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GENERAL

SAMPEX MISSION OVERVIEW

The Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX), designed and built by NASA with participation from Germany, will carry four high-resolution detectors to study anomalous cosmic rays, galactic cosmic rays, solar energetic particles, and precipitating relativistic magnetospheric electrons during three years of declining solar activity. SAMPEX will be launched on a Scout expendable launch vehicle from the Western Test Range (WTR) in June 1992, into a 550 x 675 km, 82° orbit. NASA's Goddard Space Flight Center (GSFC) built the spacecraft and will be responsible for tracking and data acquisition. Primary science data processing will be performed at the University of Maryland.

Cosmic rays, energetic particles that reach the Earth from space, were first discovered in the early part of this century. Their sources are known to include the Sun (solar energetic particles) and distant supernovae (galactic cosmic rays), and are also thought to include interstellar matter that enters the solar system (anomalous cosmic rays). Besides electrons, cosmic rays above the atmosphere consist mainly of ionized atoms of chemical elements, particularly hydrogen (about 90% of the total), helium (about 10%), and heavier elements (about 1%). The relative abundance of different elements and their isotopes in cosmic radiation reveals the chemical and nuclear history of the source of atoms, how atoms were first ionized and accelerated, how they acquired speeds close to the speed of light, and what happened to them before they reached the Earth. Cosmic rays are tangible evidence of the stellar processes and interstellar regions in which they were born and through which they travelled on their journey to Earth.

From its polar orbit, SAMPEX will intercept cosmic rays before they can enter and interact with the atmosphere. The Earth's magnetic field, however, serves as a filter for these incoming charged particles. At the equator, where the field lines are parallel to the Earth's surface, only the most energetic particles (e.g., galactic cosmic rays with energies exceeding ~15 GeV) can penetrate the magnetosphere. At higher latitudes, the magnetic field lines bend toward the Earth, allowing lower energy particles into the region where SAMPEX will be operating. At the magnetic poles, where the field lines are vertical, virtually all particles can reach the atmosphere. This is the so-called "latitude effect."

The parameter that determines whether a particle will be deflected by the Earth's magnetic field, or will be able to penetrate it, is the particle's "rigidity." Rigidity is proportional to the particle momentum (mass times velocity) per unit charge; particles with greater momentum or lower net charge have greater rigidity for penetrating a magnetic field. In the presence of a magnetic field, a charged particle will tend to move in a spiral path along the magnetic field lines. The lower the rigidity of the particle, the tighter the spiral. Consequently, low-energy, low-rigidity particles from outside the magnetosphere cannot reach the Earth directly, except near the magnetic poles; sufficiently energetic particles, whose trajectories are more "rigid," will not be deflected enough to avoid the Earth. The minimum rigidity required for a charged particle to penetrate the barrier produced by the Earth's magnetic field at a particular location is called the "geomagnetic cutoff." The lower-rigidity "trapped" magnetospheric populations, such as in the Van Allen radiation belts, must originate inside the magnetosphere or penetrate it indirectly by complex processes.

SAMPEX is designed to study cosmic rays and solar energetic particles over a wide range of energies, charge states, and masses. These particles are samples of material from a variety of sources, including the interstellar medium, Galactic and distant stellar phenomena, and the Sun. Analysis of these particles offers a unique opportunity to examine the chemical and nuclear composition of those sources.

Anomalous Cosmic Rays

SAMPEX will contribute significantly to the study of "anomalous" cosmic rays. This component of cosmic radiation is anomalous in a number of ways, including charge state, energy profile, chemical and nuclear composition, and, presumably, origin. Their chief components are six elements (helium, carbon, nitrogen, oxygen, neon, and argon) whose energy spectra show anomalously large increases in flux during periods of low solar activity, as compared to galactic cosmic ray background levels. They are believed to originate as neutral interstellar matter that has drifted into the solar system, where they are singly ionized by solar ultraviolet radiation or by charge exchange with particles in the solar wind. This is in contrast to galactic cosmic rays, which are most likely ionized and accelerated by the shock waves from distant explosive stellar events (e.g. supernovae), and reach the atmosphere having had some or even all of their electrons stripped on their journey through the galaxy.

Galactic Cosmic Rays

In addition to anomalous cosmic rays, SAMPEX will study galactic cosmic rays. Their nuclear composition indicates a different history from that of our solar system. SAMPEX will determine several crucial isotope ratios to test theories of the evolution of chemical composition of our galaxy since the universe began.

The Sun and Solar Energetic Particles

There is currently little direct knowledge of the heavier elements and their isotopic abundances in the Sun. Because the Sun accelerates vast quantities of matter, including heavy nuclei, during periods of solar activity, SAMPEX will be in an excellent position to study solar composition, particularly the acceleration sites where impulsive ^{3}He-rich flares originate. Comparing the abundances of helium isotopes ^{3}He and ^{4}He and abundances and charge states of elements up to nickel will provide insight into the physical processes that trigger these flares.

It has been shown that, for a limited energy range, the charge-to-mass ratio of the ions at coronal shock acceleration sites is the principal organizing factor for the energy and composition of the solar energetic particles that result. It must be determined whether this relationship extends to ratios outside the established range of energies and charge states.

Finally, measuring the average charge state of solar energetic particles will help to determine the temperature of the acceleration site.

Relativistic Magnetospheric Electrons

Besides cosmic rays, SAMPEX will investigate precipitating relativistic (i.e., moving near the speed of light) magnetospheric electrons. The principal objective of this study is to verify and quantify a possible connection between these electrons and ozone depletion. These electrons appear in the magnetosphere in intense bursts lasting a few days which occur most frequently and intensely near the minimum of solar activity and their energy range indicates that they originate in the solar system. They are of interest because some stratospheric and mesospheric models link these electrons to the production of certain nitrogen and hydrogen compounds, which in turn react with ozone (O_3), converting it to common molecular oxygen (O_2).

Charge State Determination

The SAMPEX instruments combine several types of measurements to determine the charge state of cosmic rays. While SAMPEX will add much to what is known about solar energetic particles and galactic cosmic rays, it will contribute substantially to the study of anomalous cosmic rays with literally every particle measured, since so little has been learned about them to date. Determination of the charge state of anomalous cosmic rays, believed to be singly ionized, will confirm or refute the prevailing theory of their origin.

Measurement of the charge of a high-energy ion can only be done indirectly, since solid-state detectors must be used, and their operation strips the electrons from the ions, destroying all information about their original ionization state. The SAMPEX orbit was selected in order to take advantage of the Earth's magnetic field in several ways, which together will allow ionic charge to be inferred.

SAMPEX AND THE SMALL EXPLORER PROGRAM

SAMPEX is the first mission in the Small Explorer Program. The objectives of the Small Explorer Program are to:

- Conduct scientifically important investigations in astrophysics and space physics that can be carried out on small satellites launched by small, expendable launch vehicles. This is at the low end of the spectrum of cost for scientific investigations in space.
- Quickly implement each mission, launching missions in three years from the start of detailed design.
- Launch approximately one mission per year.
- Select missions whose scope is such that a single Principal Investigator can have responsibility for the mission.

The scientific disciplines served by the Small Explorer Program are:

- Radio, submillimeter, infrared, visible, ultraviolet, x-ray, and gamma-ray astronomy, and relativity
- Ionospheric, magnetospheric, and heliospheric physics, solar physics, and cosmic ray physics
- Thermospheric and mesospheric science

The Small Explorer program is training NASA engineers and managers. The design, development, and integration of the SAMPEX mission included the development of an entirely new spacecraft data system that includes solid-state computer memory to store science data (the Small Explorer Data System) and the fully-implemented use of a new data transmission standard (the Consultative Committee for Space Data Systems standard for packetized data). It was also necessary to assemble a management and technical team at GSFC that could complete the task in the limited time available. The lessons learned and technologies developed for the SAMPEX mission will be applied to future Small Explorers, including the Fast Auroral Snapshot Explorer (FAST) and the Submillimeter Wavelength Astronomy Satellite (SWAS), scheduled for launch in 1994 and 1995. Elements of the SAMPEX project, specifically portions of the Small Explorer Data System, are being considered for larger missions.

SAMPEX was selected as the first Small Explorer in April of 1989, and held its first major design review, the Spacecraft Concept Review, in June of that year. It is a significant accomplishment of the program that scarcely three years later, in June of 1992, SAMPEX will be launched from Vandenburg Air Force Base.

SAMPEX MISSION OBJECTIVES

The objectives of the Solar, Anomalous, and Magnetospheric Particle Explorer Mission are to:

1. Determine conclusively whether anomalous cosmic rays are singly charged, and measure their isotopic composition.

2. Measure precipitating magnetospheric relativistic electron fluxes, determining their intensity and latitude and local time dependence, for a range of solar activity levels in the declining phase of solar activity.

3. Measure elemental and isotopic abundances and charge states of energetic solar flare particles in large and small solar events, including events rich in ^{3}He.

4. Measure galactic cosmic ray elemental abundances up to iron, and isotopic abundances for C, N, O, Ne, Mg, Si, S, Ar, Fe and Ni.

These objectives will be accomplished by:

1. For anomalous cosmic rays: Measuring the flux of anomalous oxygen in the critical zone of the geomagnetic field where oxygen atoms can penetrate only if they are singly charged. This could be done within a year if solar activity (which suppresses anomalous cosmic rays at solar maximum) is low. However, if the decline of solar activity follows the pattern of recent solar cycles, the measurement may take two to three years. Expecting that anomalous cosmic rays are singly ionized, indicating a source outside but close to the heliosphere, it is a goal of SAMPEX to determine their isotopic composition, particularly $^{20}Ne/^{22}Ne$ which varies by source and is indicative of the nuclear history of the source. The mission goal is to determine the ratio of ^{20}Ne to ^{22}Ne in the anomalous cosmic rays to at least 20% accuracy.

2. For magnetospheric electrons: Measuring the absolute fluxes of precipitating 1 to 30 MeV electrons over the polar orbit at all local times. Because these are burst events and come in a variety of sizes, this objective requires one year of operation of the PET instrument. For the goal of determining variability over the solar cycle, three years will be necessary. Ideally, the instrument should be operated through the onset of the next solar cycle. A mission goal is to provide an accurate characterization of these energetic electron fluxes to verify models of their effect on ozone depletion in the middle atmosphere.

3. For solar energetic particles: Obtaining composition, spectrum and average charge state measurements on at least 6 large solar energetic particle events with

an iron fluence of greater than 200 $(cm^2\text{-ster})^{-1}$ above 20 MeV/nucleon. The objective will be completed by obtaining composition, spectrum and charge state measurements on 50 ^3He-rich events with sufficient flux allowing 10% accuracy of iron/oxygen ratio. Although these events occur sporadically, this should be accomplished within two years. The mission goal is to observe 10 to 15 large solar particle events and over 100 ^3He-rich solar events.

4. For galactic cosmic rays: Measuring of the isotopic composition of elements Li (Z=3) to Ni (Z=28) in the range from about 10 MeV /nucleon to several hundred MeV nucleon. The objective is to obtain 20% accuracy in the $^{54}Fe/^{56}Fe$ abundance ratio, which is twice as accurate as previous measurements of this ratio. It is expected to achieve this in two years, if solar activity declines as expected. The mission goal is to measure $^{54}Fe/^{56}Fe$ to 10% accuracy, and to improve existing measurements of all galactic cosmic ray isotopic ratios from lithium to nickel by a factor of five.

L. A. Fisk
L. A. Fisk, Associate Administrator for
Space Science and Applications

Date: 6/18/92

George P. Newton
George P. Newton
Acting Director, Astrophysics Division

Date: 6/17/92

J. David Bohlin [for]
George L. Withbroe
Director, Space Physics Division

Date: 6/17/92

David A. Gilman
David A. Gilman, Program Manager

Date: 6/12/92

W. Vernon Jones
W. Vernon Jones, Program Scientist

Date: 6/8/92

MISSION DESCRIPTION

The basic mission characteristics for SAMPEX are listed in Table 1. SAMPEX will travel in a 550 x 675 km, 82° inclination orbit. This is required for several reasons. In low polar orbits, the Earth's magnetic field can be used to determine the charge state of incoming particles, which is critical to the investigations that SAMPEX is conducting. Also, low energy cosmic rays can only be observed in polar or near-polar orbit.

SAMPEX
Solar, Anomalous, and Magnetospheric Particle Explorer

- Principal Investigator: Dr. Glenn Mason, University of Maryland
- Instruments:
  - LEICA- Low Energy Ion Composition Analyzer: University of Maryland
  - HILT- Heavy Ion Large Telescope: Max Planck Institute for Extraterrestrial Physics, Garching, Germany
  - MAST/PET- Mass Spectrometer Telescope/Proton-Electron Telescope: California Institute of Technology
  - DPU- Data Processing Unit: Aerospace Corporation.
- Launch/Site: June 1992 / Western Test Range
- Vehicle: Scout 215C
- Spacecraft: GSFC / Momentum-biased / 1st Small Explorer
- Lifetime: 3 Year Goal
- Orbit: 550x675 km - 82° Inclination

	Weight (kgs)	Power (W)	Telemetry (kbps)
LEICA -	7.4	4.6	1.3
HILT (including isobutane)-	32.1	5.6	0.8
MAST/PET	8.8	5.3	1.7
Total Instrument:	**48.3**	**15.5**	
Total Mission:	**157.3**	**79.0**	

Table 1: MISSION DESCRIPTION

SAMPEX will point away from the Earth and operate in a survey mode, continually collecting incoming particles. Over the course of the mission, however, different types of particles will reach the spacecraft. At the beginning of the mission, shortly after the peak in the solar cycle, the particles collected will come predominantly from the Sun. As solar activity decreases, the composition of the incoming particles will shift, and particles from non-solar sources will reach the spacecraft. At this point, studies of anomalous cosmic rays, galactic cosmic rays, and precipitating magnetospheric electrons can be conducted.

Several innovative technologies and methods have been used in the SAMPEX program. The Small Explorer Data System (SEDS) is an advanced computer developed wholly by the Small Explorer program but which will be used on other missions. Also, SAMPEX will be the first spacecraft to use fully the new Consultative Committee for Space Data Systems (CCSDS) data transfer protocol. The use of this new international standard will allow large amounts of software developed for SAMPEX to be used on other missions.

Science and housekeeping data will be downloaded from the spacecraft twice a day during eight to ten minute passes over the NASA Wallops Island Tracking Station. Housekeeping data will be transmitted during two additional passes each day over Deep Space Network stations (Goldstone, Canberra, or Madrid). Raw telemetry will be transmitted to the Payload Operations Control Center and Packet Processor at GSFC. Within two days, this data will be delivered to the Principal Investigator at the University of Maryland, who will process the data, produce Prime Data Sets, and distribute these Prime Data Sets to the Co-Investigator institutions: Aerospace Corporation, Max Planck Institute for Extraterrestrial Physics, California Institute of Technology, GSFC, and NASA Langley Research Center.

MISSION SEQUENCE

SAMPEX will be launched from the Western Test Range at Vandenberg Air Force Base, California, on a Scout expendable launch vehicle.

LAUNCH VEHICLE

The SAMPEX spacecraft will be launched on a standard four-stage Scout, which is shown in Figure 1. The Scout is a solid-propellant booster system. LTV Corporation is the prime contractor to NASA for the entire launch vehicle system.

The Scout is equipped with a preprogrammed guidance system, which controls the trajectory and commands the separation of each expended stage in a timed sequence. The payload is protected from the high temperatures of aerodynamic heating during the early portion of the ascent stage by a two-piece heatshield, which is ejected just prior to third-stage ignition.

The yaw and roll axes of the spacecraft are maintained at the launch reference, while the pitch axis is programmed through a preselected angle corresponding to the desired vehicle trajectory. A yaw torquing capability is incorporated that allows programming of the yaw axis in contingency situations.

A proportional control system in the base of the first stage features a combination of aerodynamic tip control surfaces, operated by hydraulic servo actuators, and jet vanes. This system controls the vehicle throughout the entire first-stage period.

Second and third stage control systems also maintain the yaw and roll axes at the launch reference, but generate the control force differently. In these two stages, the control forces are produced by hydrogen peroxide reaction motors which are operated as an "on-off" system. The unguided fourth stage is spin stabilized prior to separation from the third stage.

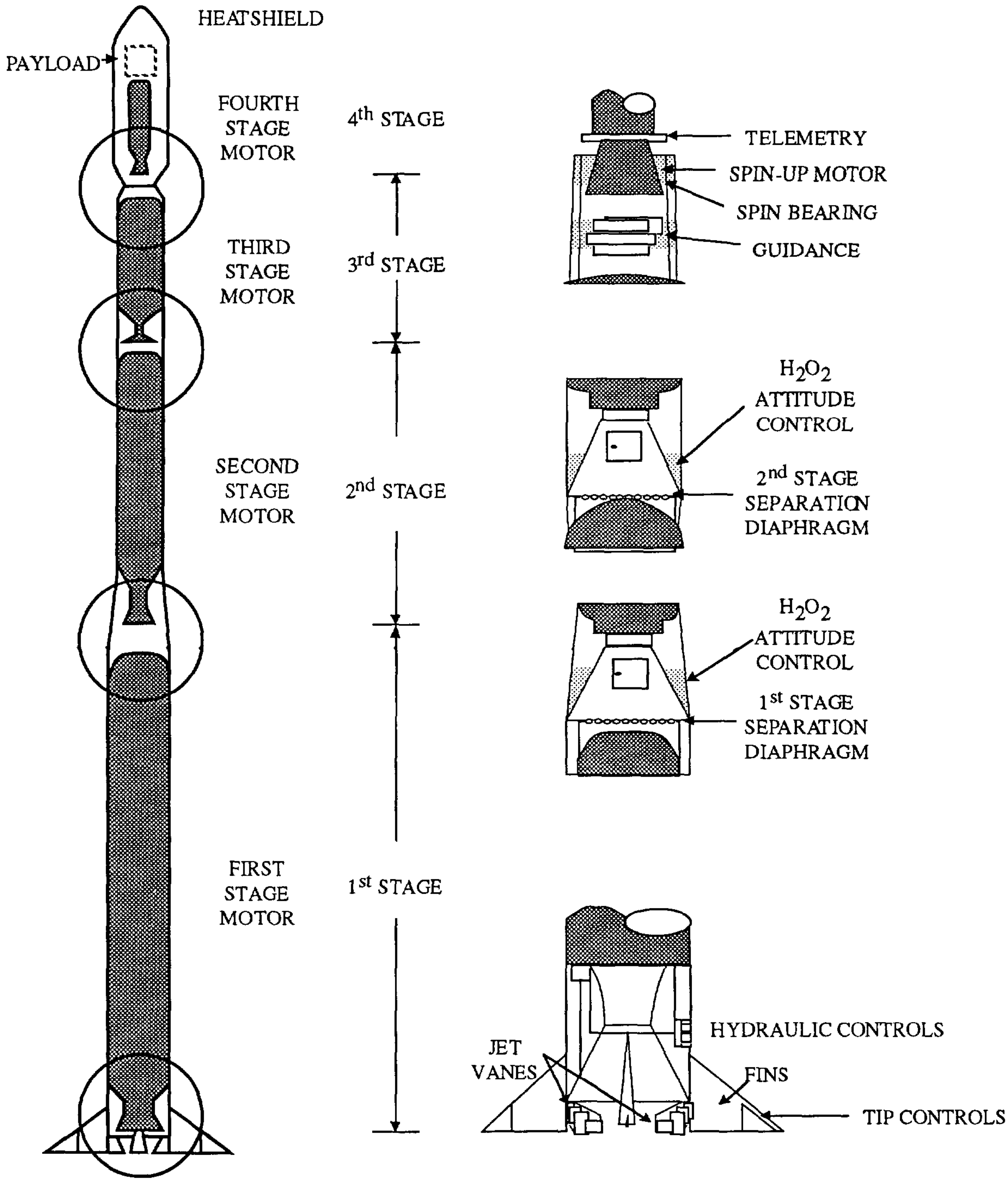


Figure 1: SCOUT MAJOR ASSEMBLIES

MAJOR MISSION EVENTS

Launch Sequence

The SAMPEX launch window opens at 7:22 a.m. PDT (10:22 EDT) and closes at 7:41 a.m. PDT (10:41 EDT) Launching inside this window assures that the spacecraft will be in full Sun during early orbit, which will assure adequate electrical power.

The launch pad will be Spacecraft Launch Complex 5 at the WTR at Vandenburg Air Force Base. The spacecraft is planned to reach a 550 km x 675 km, 82° inclination orbit.

The protective heatshield will be jettisoned when the vehicle leaves the sensible atmosphere after second stage burnout, approximately 2 minutes and 20 seconds after launch (see Table 2). The third stage will burn for approximately 48 seconds, followed by a 6 minute and 44 second coast period. Prior to third stage separation, the vehicle will be spin-stabilized. The unguided fourth stage will inject the spacecraft into its final orbit.

Event No.	Event Description	Mission Elapsed Time (MET) (hrs:min:sec)
1.	Launch	00:00:00
2.	First Stage Burnout	00:01:24
3.	Second Stage Ignition/First Stage Separation	00:01:28
4.	Second Stage Burnout	00:02:09
5.	Heatshield Separation	00:02:20
6.	Third Stage Ignition/Second Stage Separation	00:02:22
7.	Third Stage Burnout	00:03:10
8.	Coast (6 minutes and 44 seconds)	
9.	Spinup	00:09:46
10.	Third Stage Separation	00:09:54
11.	Fourth Stage Ignition	00:09:59
12.	Fourth Stage Burnout	00:10:32
13.	Coast (1 minute and 04 seconds)	
14.	Spacecraft Separation	00:11:36
15.	Spacecraft Despin and Solar Array Deployment	00:14:56
16.	Madrid DSN Station Contact on Third Orbit (Spacecraft Turn-on)	4:10:00
17.	Madrid DSN Station Contact on Fourth Orbit (Back-up Spacecraft Turn-on)	5:48:00
Note:	METs are approximate	

Table 2: LAUNCH EVENT SEQUENCE

Separation and Deployment

The spacecraft will separate from the fourth stage approximately fifteen minutes after launch. After release from the fourth stage, weighted cables ("yo-yos") will be extended and released to despin the spacecraft. The yo-yo release will reduce the spacecraft rotational velocity to less than 3 rpm. The solar arrays will then deploy and lock, and the spacecraft will acquire the Sun.

Acquisition, Initialization, and Checkout

The Deep Space Network (DSN) Station in Madrid will make the first contact with the spacecraft during the third orbit after launch. If contact is not established, a second attempt will be made during the fourth orbit. After first contact, it is critical that the controllers check to make sure that solar arrays have deployed, that the Attitude Control System (ACS) is operating, that the Sun has been acquired, and that the batteries are charging. NORAD will track the spacecraft prior to the Madrid DSN contact. This orbit data will be transmitted to the Madrid DSN station.

During the first day, the Recorder/Packetizer/Processor (RPP), part of the Small Explorer Data System (SEDS), will be initialized and the ACS control mode checkout will take place. This includes transmitting all stored data to verify Sun-point mode operation. Spacecraft checkout will continue through the second day with an adjustment to the spacecraft clock and loading of a new orbit vector. Within the first ten days after launch, instruments checkout should be complete, and all instrument covers should be open.

Normal Science Operations

Normal operations are expected to begin approximately two weeks after launch. SAMPEX is an autonomous spacecraft, and should require few commands or maneuvers.

In three years, the isobutane supply for HILT should be completely exhausted, at which time HILT will be turned off. MAST/PET and LEICA will continue to collect important data as long as they are able to operate.

SPACECRAFT DESCRIPTION

The SAMPEX spacecraft mechanical layout is shown in Figure 2. The spacecraft was built at GSFC by Engineering Directorate personnel, with support from the Office of Flight Assurance and the Mission Operations and Data Systems Directorate, and has virtually no redundancy. It attaches to the Scout launch vehicle by the Scout Adapter Section shown at the base of the spacecraft. The spacecraft weighs 157 kg, excluding the Scout hardware, which weighs 4 kg. The Scout launch vehicle has a total lifting capability of approximately 169 kg to the desired orbit.

The SAMPEX mechanical subsystem carries all the SAMPEX instruments and subsystem components and yet fits within the Scout small heat shield. The mechanical system

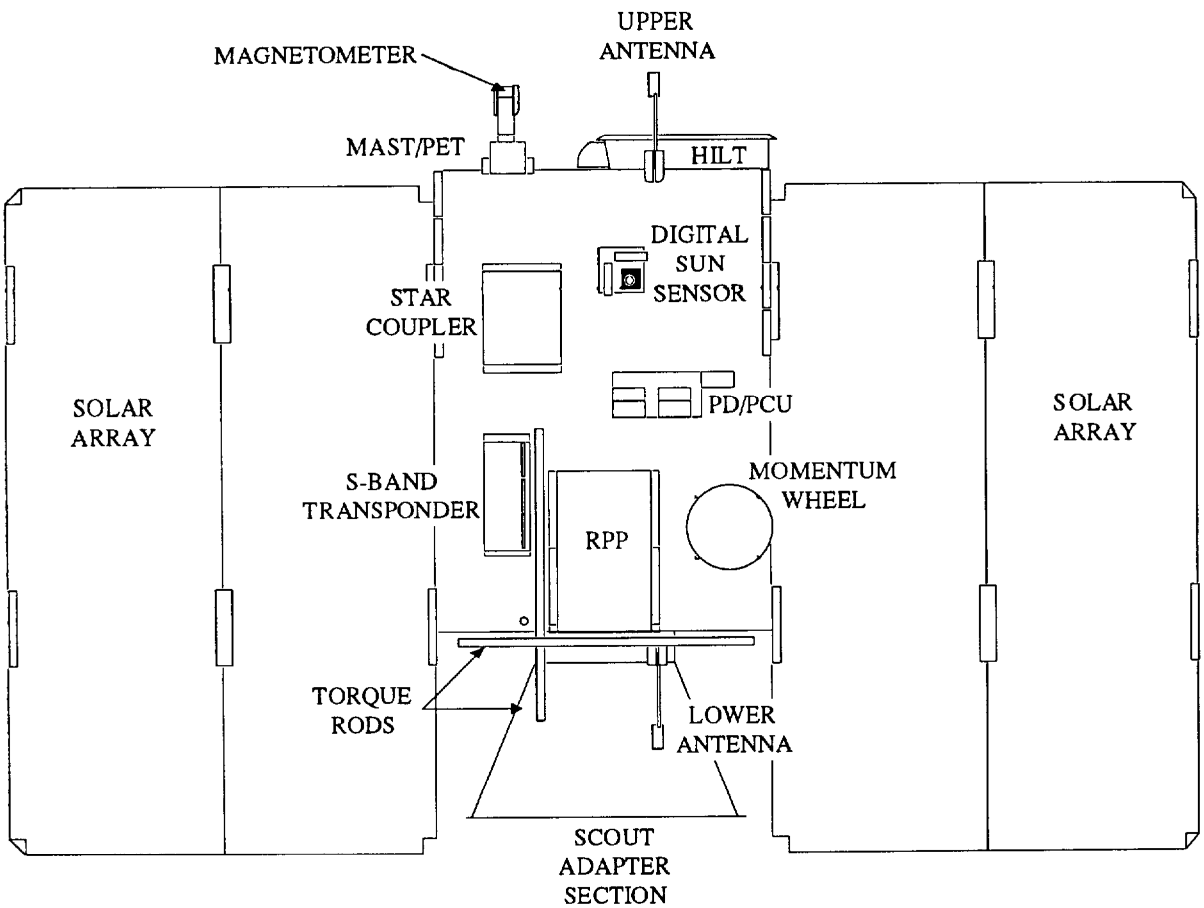


Figure 2: MECHANICAL LAYOUT

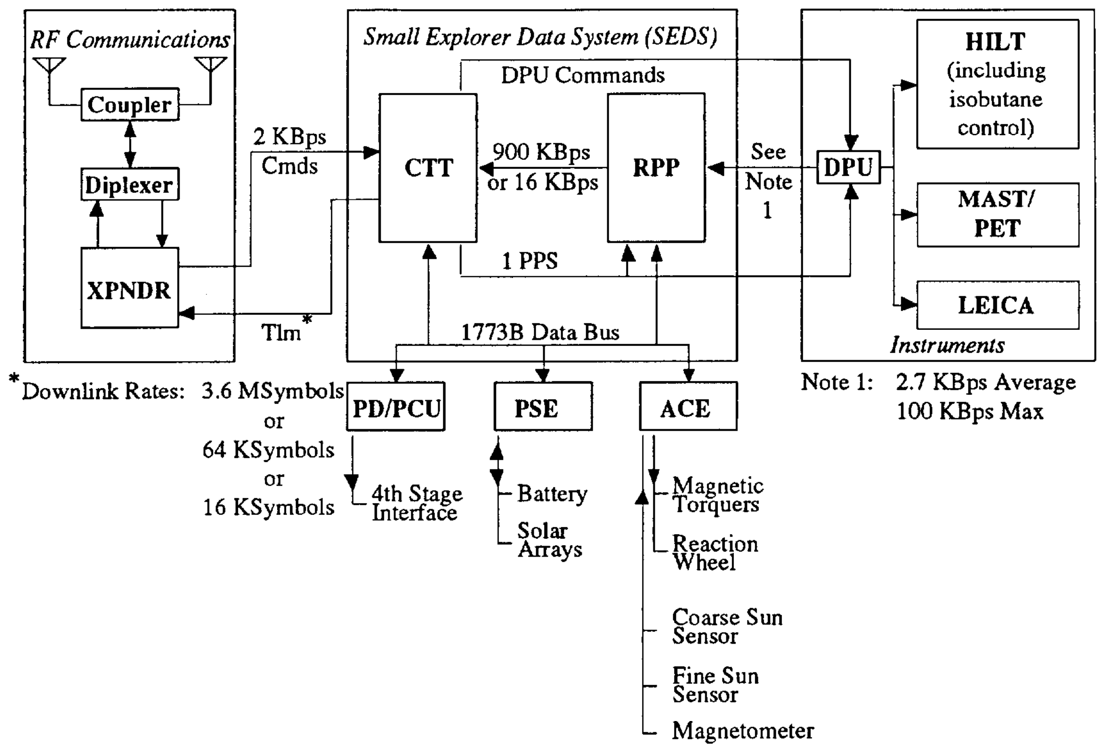
consists of the primary structure, the instrument support structure, the isobutane tank for the HILT instrument, the deployable solar arrays, and the yo-yo despin mechanism. The isobutane tank holds 7.1 kg of liquid isobutane (maximum expected pressure of 100 psi) needed for the HILT instrument. The tank is mounted in the center of the structure by trunnions on the top and bottom of the tank.

The Attitude Control System (ACS) is a solar-pointed/momentum-biased system, using a momentum wheel to keep the solar arrays pointed toward the sun while keeping the instrument viewing axis pointed toward the zenith over the poles. The spacecraft orientation is determined using one fine Sun sensor, five coarse Sun sensors, and one magnetometer. Three, orthogonal torque rods supplement the momentum wheel in controlling the attitude of the spacecraft.

The ACS is designed to maintain the spacecraft pitch axis within 5 degrees of the Sun at all times. During science operations, the experiment-view axis must approach the local vertical in the polar regions. This axis must also be greater than 45 degrees from the spacecraft velocity vector during science operations to protect the instruments from orbital debris and micrometeoroid damage.

The Small Explorer Data System (SEDS), developed entirely through the Small Explorer project at GSFC, is a new, flight-qualified computer that operates the spacecraft autonomously. It provides primary command and control of experiments and spacecraft subsystems, interfaces with the spacecraft communications system, and, with the ACS, controls the spacecraft attitude. SEDS collects and stores data from the subsystems and instruments, processes it, and sends it to the ground using the CCSDS packet telemetry standard. The data system uses solid-state memory to store spacecraft data when the spacecraft is out of contact with the ground. Figure 3 shows the functional relationship between SEDS and the rest of the spacecraft.

The antenna system is composed of two quadrifilar helixes, two 90-degree hybrid junctions, and a power divider. An S-Band transponder operating in full duplex mode receives up-linked commands, transmits telemetry data, and supports doppler tracking by NASA ground stations.



XPNDR	Transponder	MAST/PET	Mass Spectrometer Telescope/Proton-Electron Telescope
CTT	Command/Telemetry Terminal	LEICA	Low Energy Ion Composition Analyzer
RPP	Recorder/Packetizer/ Processor	DPU	Data Processing Unit
PD/PCU	Power Distribution/Pyro Control Unit	ACE	Attitude Control Electronics
PSE	Power System Electronics		
HILT	Heavy Ion Large Telescope		

Figure 3: FUNCTIONAL DIAGRAM

INSTRUMENTS

The United States, through GSFC, is providing three of the instruments: LEICA, PET, and MAST. Germany, through the Max Planck Institute for Extraterrestrial Physics, is providing all of the HILT instrument except for the analog electronics, which are being provided by NASA through the Aerospace Corporation. Each of the four instruments is designed to detect cosmic rays or energetic solar and magnetospheric particles over a specific energy range. The instrument layout is shown in Figure 4.

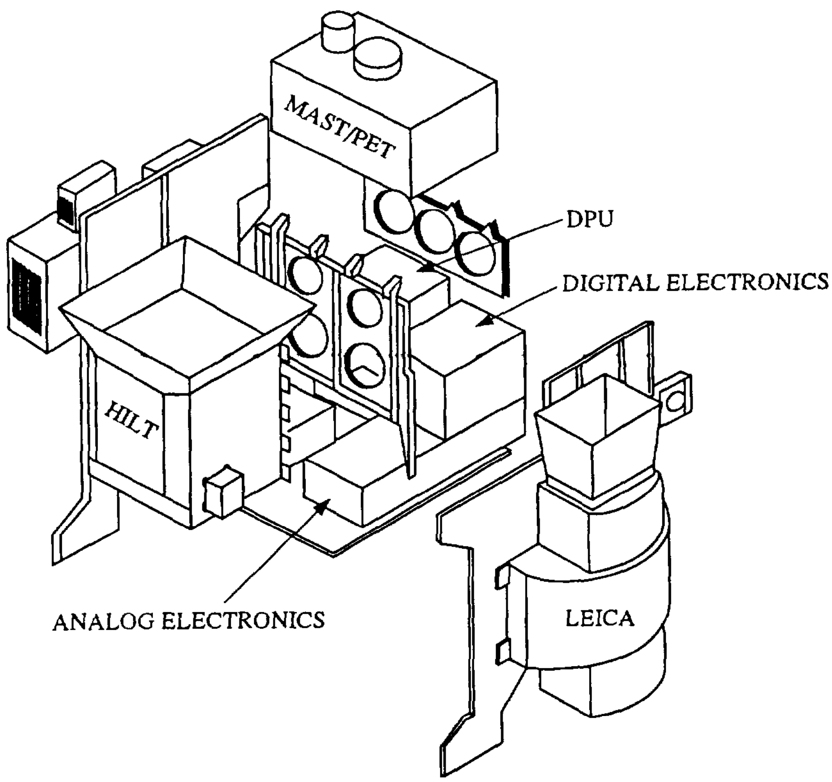


Figure 4: INSTRUMENT LAYOUT

LOW ENERGY ION COMPOSITION ANALYZER (LEICA)

LEICA, built by the University of Maryland, is designed to perform high-resolution mass spectroscopy on ion fluxes from sources of low-energy particles such as moderately large solar flares, ^{3}He-rich solar flares, and interplanetary shock events. Exploratory measurements of ultra-heavy species (heavier than nickel) will also be performed in a more limited energy range. A description of the particles measured by LEICA, as well as those measured by the other instruments, is listed in Table 3. A schematic cross-section of the LEICA telescope is shown in Figure 5.

	LEICA	HILT	MAST	PET
Energy range for:				
electrons	--	--	--	0.4-30 MeV
H	0.76-6.1 MeV	--	--	18-250 MeV
He	0.45-6.1 MeV/ nuc	4.3-38 MeV/ nuc	7-20 MeV/ nuc	18-350 MeV/ nuc
C	0.44-11.4 MeV/ nuc	7.2-160 MeV/ nuc	14-210 MeV/ nuc	--
O	0.43-9.0 MeV/ nuc	8.3-220 MeV/ nuc	16-240 MeV/ nuc	--
Ne	0.39-7.4	9.1-250 MeV/ nuc	18-270 MeV/ nuc	--
Si	0.33-5.5 MeV/ nuc	9.6-180 MeV/ nuc	21-330 MeV/ nuc	--
Fe	0.21-3.1 MeV/ nuc	11.0-90 MeV/ nuc	27-450 MeV/ nuc	--
Charge range for elements	1-28	2-28	2-28	1-2
Charge range for isotopes	2-16	2	2-28	1-2
Geometry factor (cm^2 sr)	0.8	60	7-14	0.3-1.6
Field of View	24^o x 20^o	82^o x 82^o	101^o (cone)	58^o (cone)
Mass (kg)	7.4	22.8	8.8	(incl. with MAST)
Power (W)	4.9	5.6	5.3	(incl. with MAST)
Telemetry (kbps)	1.3	0.8	1.7	(incl. with MAST)

Table 3: SCIENTIFIC INSTRUMENTS

LEICA is virtually identical to the solar energetic particles composition instrument developed at the University of Maryland for flight on a Space Shuttle Get-Away-Special (GAS) mission in 1988/1989.

LEICA is a mass spectrometer that identifies ion mass and energy by simultaneously measuring the velocity and residual energy of particles that enter the telescope and stop in one of the array of four silicon solid state detectors in the telescope. The measured energy and the velocity are combined to yield the mass of the ion, and the energy per nucleon, inside the telescope. The ion incident energy is obtained after correcting for the energy loss in the entrance foils.

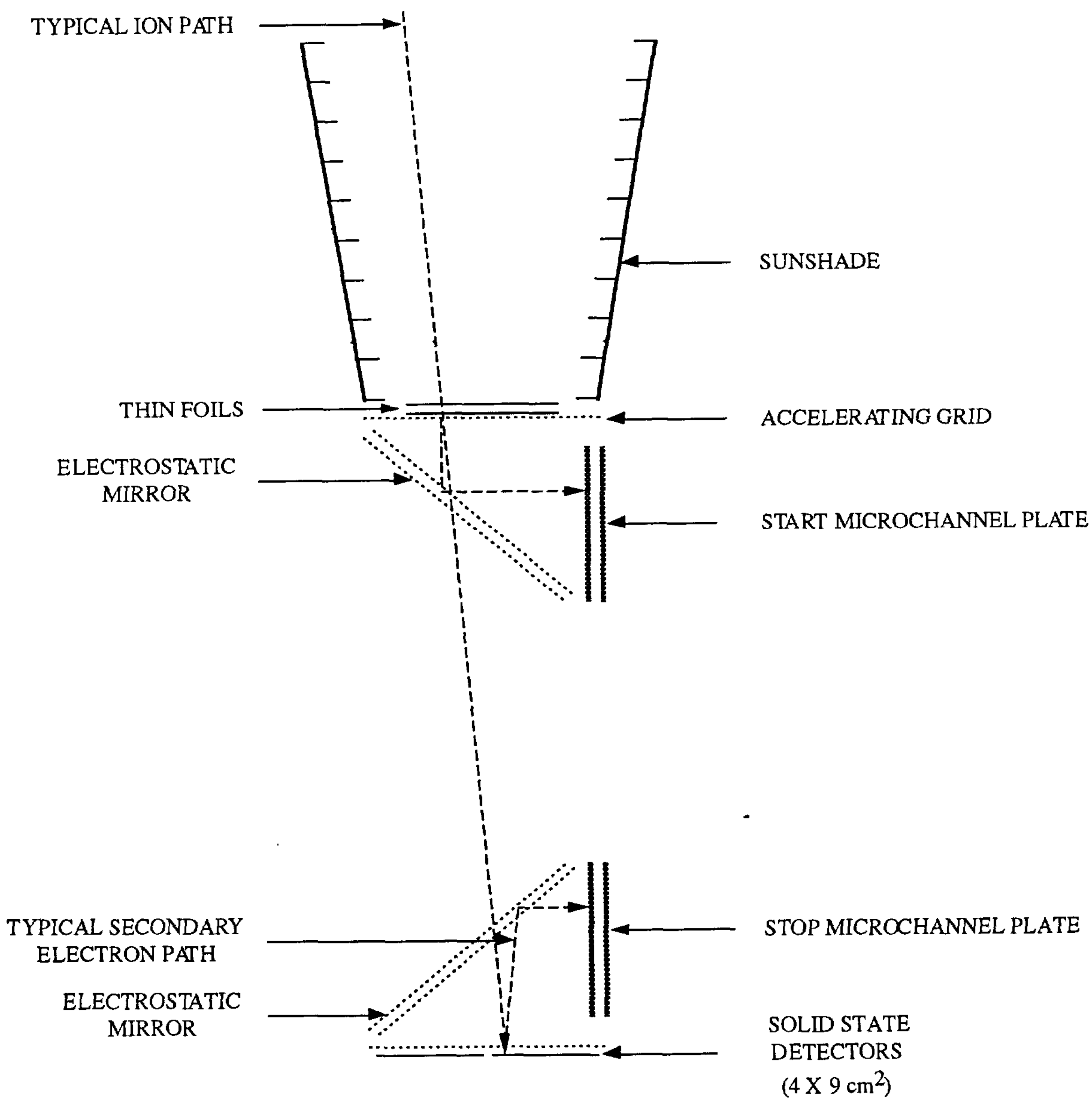
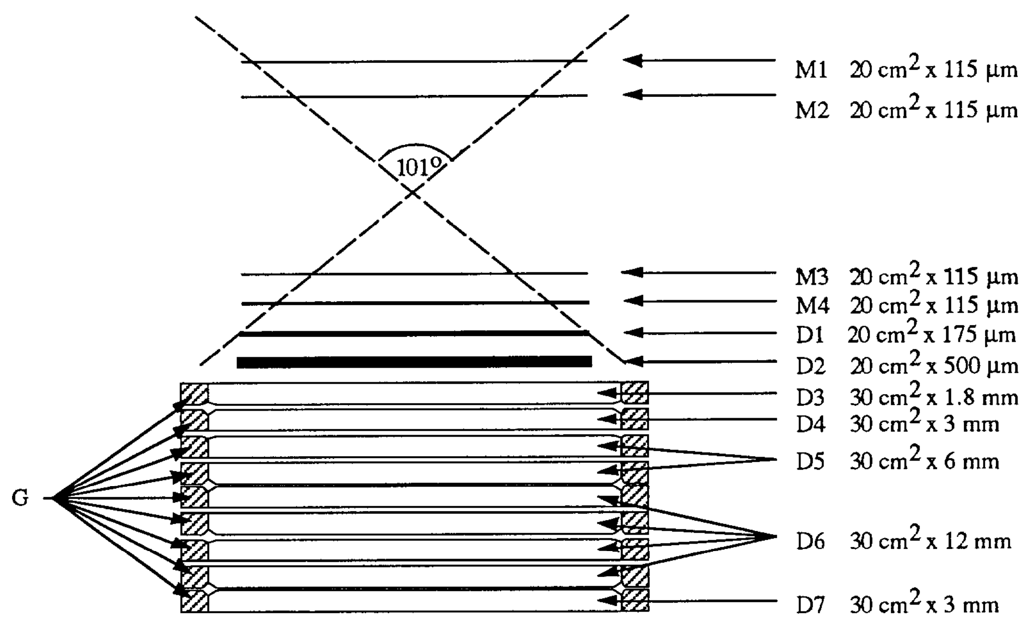


Figure 5: LOW ENERGY ION COMPOSITION ANALYZER (LEICA)

THE MASS SPECTROMETER TELESCOPE (MAST)

MAST, developed by the California Institute of Technology, will measure the isotopic composition with a mass resolution better than 0.3 atomic mass units. MAST uses position-sensitive detectors, combined with an all solid-state telescope optimized for isotope resolution. The geometry factor of MAST will be ~20 times greater than its largest predecessor, allowing statistically significant studies of rare isotopes. This combination of features makes MAST especially suitable for isotopic analysis of solar energetic particles, anomalous cosmic rays, and galactic cosmic rays.

MAST consists of a combination of surface-barrier and lithium-drifted solid state detectors, as shown in Figure 6. The first four detectors, M1 through M4, define the entrance acceptance aperture and determine the particle trajectories, allowing accurate corrections



D1,D2	Surface Barrier Detectors
D3-D7	Lithium-Drifted Detectors
M1-M4	One-Dimensional Position-Sensitive Detectors
G	Integral Guard Rings

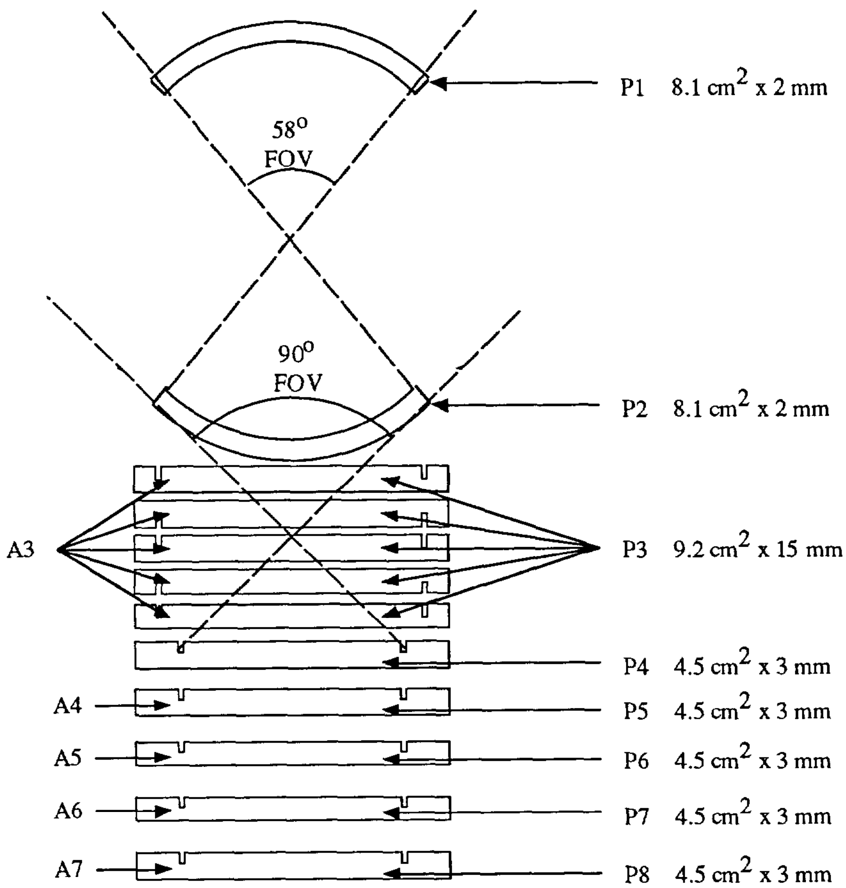
Figure 6: MASS SPECTROMETER TELESCOPE (MAST)

to be made for the pathlength variation with angle and detector response non-uniformities. MAST can determine isotopes of particles that pass through D1 and are stopped in detectors D2 and D6.

Isotope identification in MAST is accomplished by the energy loss vs. energy technique, using the energy lost in the last detector triggered as the energy, and the outputs of the previous detectors as redundant measurements of energy loss.

PROTON ELECTRON TELESCOPE (PET)

The PET instrument, also developed by the California Institute of Technology, will complement MAST by measuring the energy spectra and relative composition of protons and helium nuclei of solar, magnetospheric, interplanetary, and galactic origins, and the energy spectra of solar flare and precipitating electrons. Energy measurements of protons will also help determine the geomagnetic cutoff, an parameter that will be used to analyze the particles detected by the other instruments.



P1,P2	Spherical Aperture Detectors
P3-P8	Flat Detectors
A3-A7	Integral Guard Rings

Figure 7: PROTON-ELECTRON TELESCOPE (PET)

HEAVY ION LARGE TELESCOPE (HILT)

The HILT sensor, provided by the Max Planck Institute for Extraterrestrial Physics with analog electronics provided by the Aerospace Corporation, will measure heavy ions from helium to iron in the energy range from 4.3 to 250 MeV/nucleon (29,000 to 184,000 km/s). This range corresponds to medium-energy solar energetic particles, and is the range of maximum intensity for anomalous cosmic rays. HILT, together with LEICA and MAST/PET, will thus achieve a comprehensive measurement of the entire solar and anomalous particle population.

HILT will have a geometric factor approximately 20 times greater than any similar instrument previously flown. HILT also measures the particle trajectories. With the information of particle energy, mass, and direction, in combination with the spacecraft position in the low altitude polar orbit, it will be possible for the first time to infer the ionic charge of ions in the energy range measured by HILT.

A schematic diagram of HILT is shown in Figure 8. The sensor consists of a 3-element ion drift chamber with a thin multilayer entrance window (80 μm of aluminum, total) followed by an array of 16 solid state detectors and a CsI scintillation counter, which is viewed by 4 light-sensitive diodes. The entrance foil serves as part of the gas enclosure and assures, in combination with a bumper shield, a long lifetime against damage by micrometeoroids.

The ion drift chamber-proportional counter system operates with isobutane at a pressure of 1.5 psi (at 20°C). The gas supply consists of 7.1 kg of liquid isobutane, sufficient for a mission lifetime of 3 years, stored in a tank at a maximum pressure of 100 psi.

DATA PROCESSING UNIT

The Data Processing Unit is responsible for overall control of the science payload and serves as the interface between the science instruments and the spacecraft. Also, the isobutane supply is regulated by the Data Processing Unit .

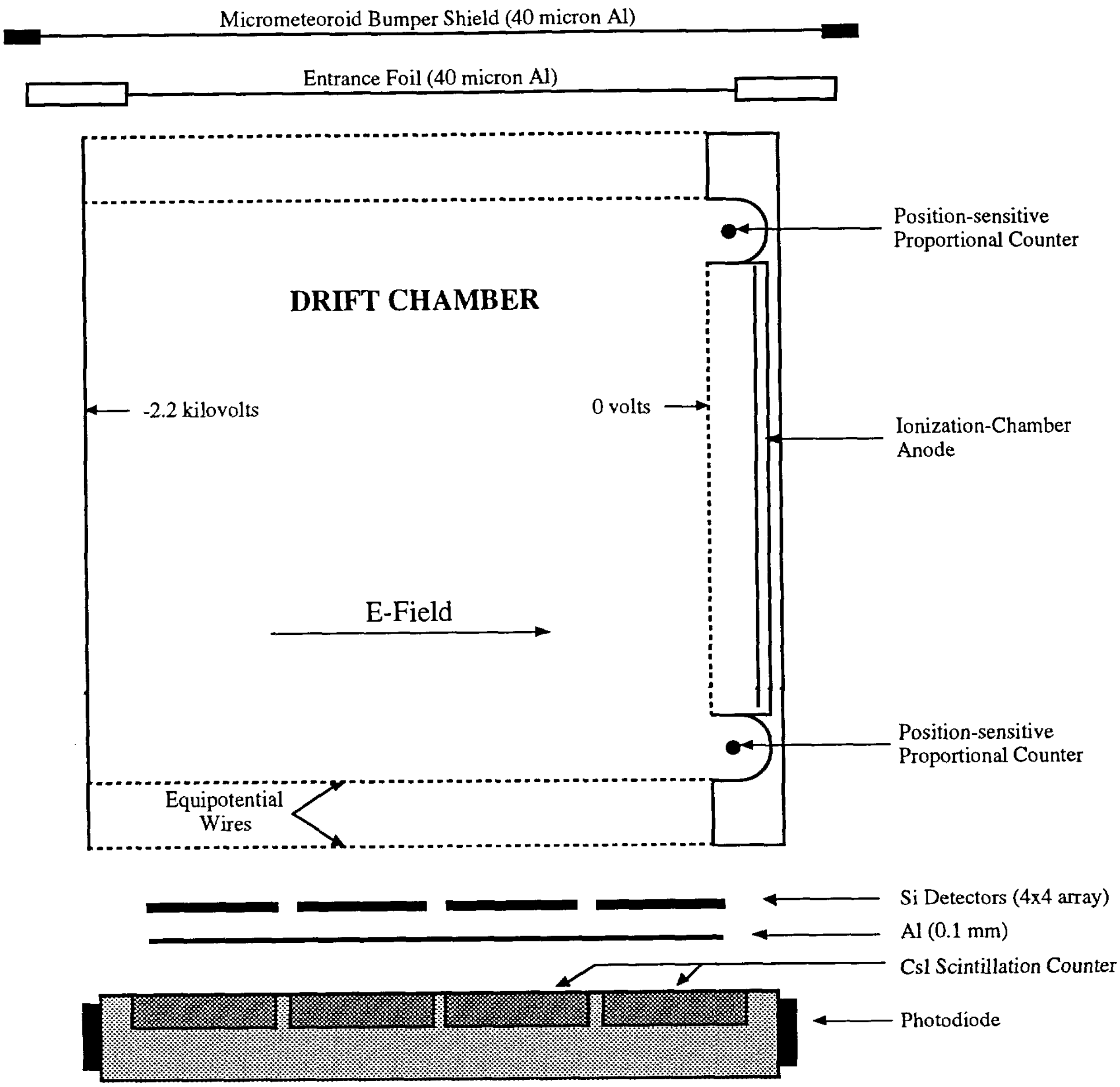


Figure 8: HEAVY ION LARGE TELESCOPE (HILT)

MISSION SUPPORT

TRACKING AND DATA ACQUISITION

Spacecraft tracking and download of housekeeping data is scheduled for approximately four passes each day, two at Wallops Island Tracking Station (WPS) and two passes at Deep Space Network (DSN) stations. Each pass lasts eight to ten minutes.

Science data will be transmitted only during passes at WPS. During normal science operations, data will be gathered from the instruments, and stored in solid-state memory. During each WPS pass, science and housekeeping data will be downloaded at 900 kbps.

FLIGHT DYNAMICS SUPPORT

The spacecraft will independently calculate its orbit and attitude and transmit this data in the telemetry stream. However, the Mission Operations and Data Systems Directorate of GSFC will provide regular orbit and attitude verification support. Predicted orbital elements will be uplinked to the spacecraft.

SPACECRAFT OPERATIONS SUPPORT

The data flow for the SAMPEX mission is show in Figure 9. The science payload aboard the spacecraft is controlled by the DPU, which collects science data and delivers it to the SEDS for storage. This raw telemetry will be transmitted to the Packet Processor (PACOR) in NASA Communication (NASCOM) blocks. PACOR will record all incoming data during real-time contacts with the spacecraft or by playback from the ground station.

DATA ANALYSIS

All SAMPEX data will be in the standard packetized format developed by the Consultative Committee for Space Data Systems. NASA is responsible for delivering the instrument data, attitude data, and orbit ephemeris data to the Principal Investigator within two days of its receipt at GSFC. The Principal Investigator will put the science data in the proper time order, remove overlapping information, and merge the data with attitude information, ephemeris data, and the magnetic field model to produce a prime data set. Each week, and within two weeks of its arrival at the University of Maryland, the Principal Investigator will distribute the prime data set to the Co-Investigator institutions: Aerospace Corporation, Max Planck Institute for Extraterrestrial Physics, California Institute of Technology, GSFC, and NASA Langley Research Center.

Each Co-Investigator will process the data from his instrument to make a Reduced Data Set, consisting of data in easily interpretable physical units. The science team will use the Reduced and Prime Data Sets for their scientific investigations and will report the results of their investigations in scientific literature. A copy of the Reduced Data Set will be submitted to the National Space Science Data Center (NSSDC); delivery of the reduced data set for the first year of flight will be made within two years of launch.

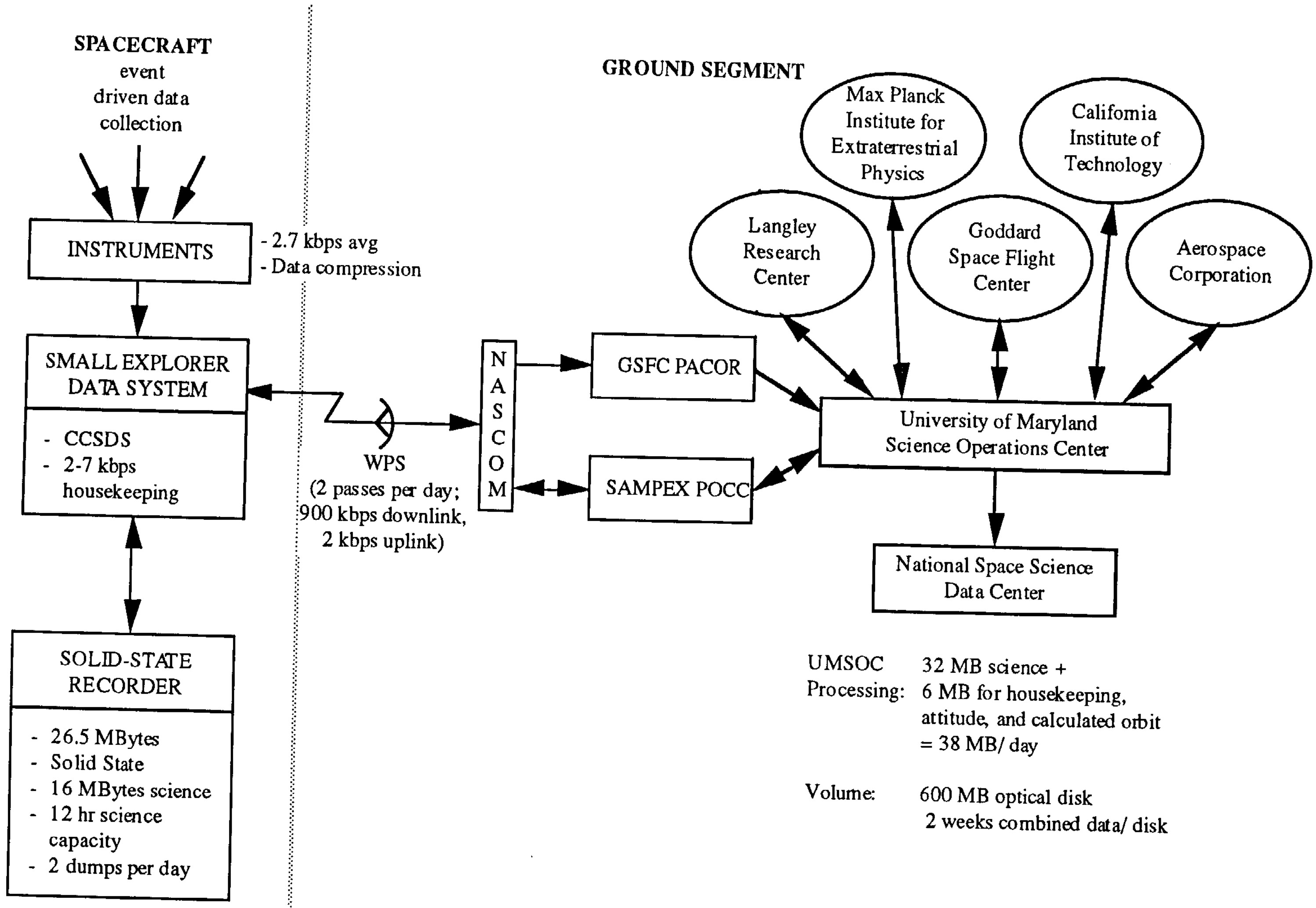


Figure 9: SAMPEX OPERATIONAL DATA FLOW

MISSION MANAGEMENT

The Office of Space Science and Applications (OSSA), NASA Headquarters, is responsible for the overall direction and evaluation of the SAMPEX Program. The OSSA Associate Administrator has assigned program responsibility to the Director of the Astrophysics Division. GSFC has been assigned Project Management responsibility and GSFC performed this project as an in-house activity. GSFC also has overall tracking and data acquisition responsibility The LTV Corporation is the prime contractor to the Orbital Launch Services Project at GSFC for the Scout launch vehicle and is responsible for the launch vehicle system.

The responsible personnel within these organizations are:

TITLE	NAME	ORGANIZATION
Associate Administrator for Space Science and Applications	L. A. Fisk	NASA Headquarters
Program Director (Acting)	G. P. Newton	NASA Headquarters
Program Manager	D. A. Gilman	NASA Headquarters
Program Scientist	W. V. Jones	NASA Headquarters
Associate Administrator for Space Operations	C. T. Force	NASA Headquarters
Principal Investigator	G. Mason	University of Maryland
Center Director, Goddard Space Flight Center	J. M. Klineberg	GSFC
Director of Engineering	T. E. Huber	GSFC
Chief, Special Payloads Division	R. Weaver	GSFC
Project Manager	O. Figueroa	GSFC
Mission Manager	G. Colon	GSFC
Project Scientist	D. Baker	GSFC
Deputy Project Manager	W. Nagel	GSFC
Project Support Manager	J. Byrd	GSFC
Systems Manager	J. Watzin	GSFC
Verification Manager	P. Mule	GSFC
Mission Operations Manager	J. Catena	GSFC

Instrument Manager	R. Aleman	GSFC
Spacecraft Integration and Test Manager	R. Patschke	GSFC
Small Expendable Launch Vehicle Mission Integration Manager	L. Mataosky	GSFC
Launch Operations Coordinator	D. W. Gates, Jr	Bendix Field Engineering Corporation
Director, Space Sciences	S. S. Holt	GSFC
Director of Mission Operations and Data Systems	D. L. Fahnestock	GSFC
Director of Flight Projects	V. J. Weyers	GSFC

Table 4: MISSION MANAGEMENT

PROJECT COSTS

	Thousands of Dollars
SAMPEX Spacecraft, Instruments, and Science Operations Center	$26,716

ACRONYMS

amu	Atomic Mass Unit (1 amu=1 proton mass)
Ar	Argon
BFEC	Bendix Field Engineering Corporation
C	Carbon
C	Centigrade (Celsius)
CCSDS	Committee for Space Data Systems
C&DH	Command and Data Handling
CsI	Cesium Iodide
CTT	Command and Telemetry Terminal
DSN	Deep Space Network
eV	Electron Volts (energy unit)
Fe	Iron
^{54}Fe	Iron-54 (rare isotope with 26 protons, 28 neutron in nucleus)
^{56}Fe	Iron-56 (abundant isotope with 26 protons, 30 neutron in nucleus)
GeV	Giga (Billion) Electron Volts (energy unit)
GSFC	Goddard Space Flight Center
He	Helium
^{3}He	Helium-3 (rare isotope with 2 protons, 1 neutron in nucleus)
^{4}He	Helium-4 (abundant isotope with 2 protons, 2 neutrons in nucleus)
HILT	Heavy Ion Large Telescope
kbps	Kilobits per second
kg	Kilogram
km	Kilometer
LEICA	Low Energy Ion Composition Analyzer
μm	Micrometer (or micron = 10^{-6} meters)
MAST	Mass Spectrometer Telescope
MB	Megabytes
MBPS	Megabytes per Second
MeV	Million Electron Volts (energy unit)
MeV/nuc	Million Electron Volts per Nucleon
Mg	Magnesium
N	Nitrogen
NASCOM	NASA Communications
Ne	Neon

NSSDC	National Space Science Data Center
O	Atomic Oxygen
O_2	Common Molecular Oxygen
O_3	Ozone
OSSA	Office of Space Science and Applications
PACOR	Packet Processor
PD/PCU	Power Distribution/Pyro Control Unit
PET	Proton Electron Telescope
POCC	Payload Operations Control Center
PSE	Power System Electronics
RPP	Recorder/Processor/Packetizer
S	Sulphur
SAMPEX	Solar Anomalous and Magnetospheric Particle Explorer
S/C	Spacecraft
SEDS	Small Explorer Data System
Si	Silicon
sr	Steradian (unit of solid angle; 4π sr subtend all of 3-D space)
UMSOC	University of Maryland Science Operation Center
WPS	Wallops Island Tracking Station
WTR	Western Test Range