Sounding Rocket Program Handbook
(SRPH)

Suborbital Projects and Operations Directorate
Sounding Rockets ProgramOffice

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Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia 23337

Preface

This Handbook describes the capabilities of the program, the design and technology applications to be considered, and the process NASA has established to integrate the customer (principal investigator/program user/scientist/experimenter) into the sounding rocket mission team to ensure the highest probability of a successful project.

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SECTION 1: NASA Sounding Rocket Program

1.1 Introduction

This Handbook was written with the primary objective of assisting the Sounding Rocket Program’s customers in developing payloads that will reliably perform the requirements necessary to meet the scientific objectives of the mission. It also serves a guideline that defines the minimum requirements for an effective quality system (ISO 9001). Customers of the Program are also referred to within this document as: principal investigators, program users, scientists, and experimenters.

The NASA Sounding Rocket Program (NSRP) is a suborbital space flight program utilized primarily in support of space and earth sciences research activities sponsored by NASA. The NSRP also provides applicable support to other government agencies, as well as to international sounding rocket groups and scientists.

Since the program's beginning in 1959, there have been approximately 2,800 flight missions with an overall science mission success rate exceeding 86 percent and a launch vehicle success rate of over 95 percent. The program is a low-cost, quick-response effort that currently provides approximately 20 - 30 flight opportunities per year to space scientists involved in the disciplines of upper atmosphere, plasma physics, solar physics, planetary atmospheres, galactic astronomy, high energy astrophysics, and micro-gravity research. These rockets are launched from a variety of launch sites throughout the free world.

In mid 1980, the NSRP was consolidated at the Wallops Flight Facility of the Goddard Space Flight Center. The program has continued to grow in terms of average payload size/weight (presently approximately 800 pounds) and complexity. Flight systems described herein make today's rocket payloads remarkably sophisticated spacecraft that are being flown to altitudes approaching 1800 kilometers.

The customers served by the NSRP consist primarily of university and government research groups; however, some research activities involve the commercial sector. The program has yielded numerous important scientific findings and research papers and has provided a developmental proving ground for satellite instruments. Many new scientists have also received training and developmental experience through graduate study programs offered by participating educational institutions.

Systems and services provided to customers of the NSRP encompass the complete spectrum of support. This includes mission management, payload design and development, launch vehicles, recovery systems, attitude control systems, payload testing and evaluation, analytical studies, launch range operations/coordination, tracking, and data acquisition and data processing. The customer is required to provide the scientific instruments/detectors for the payload and a comprehensive description of the support requested from NASA. They are also required to provide objective criteria that will used to determine the success or failure of the mission after all operations are completed.

The NSRP is conducted in compliance with ISO 9001 but without the formal and expensive reliability and quality assurance employed in the larger and more costly orbital and deep space programs. This informal approach, combined with the extensive use of surplus military rocket motors, is instrumental in enabling the program to complete approximately 20 - 30 missions per year, within the available resources, while maintaining an overall success rate of 85 to 90 percent.

This Handbook includes some of NASA's philosophy to provide a better understanding of the thinking behind the current approach towards implementation of the program: from design, through launch operations, to investigation of anomalies and failures. The customer is the essential source of information on how well the NSRP is working. Policy practices and procedures can change with time, as new ideas prove better suited to current activities. Effective communications between the NASA project support team and the customer are vital to the success of an individual sounding rocket mission and the overall program. Project meetings, reviews, and the required post flight assessment of mission results by the customer are all feedback mechanisms which provide observations, comments and constructive criticism for problem solving and programmatic improvements. This first hand feedback and customer interaction will result in this important program, which has successfully served the scientific community for approximately 40 years, being constantly improved while continuing into the future.

1.2 NASA Organizational Responsibilities

NASA HQ Management Role

NASA Headquarters program management responsibility for the Sounding Rocket Program is assigned to the Research Program Management Division (Code SR) of the Office of Space Science and Applications (OSSA) (Code S). The Code SR Director chairs the Suborbital Program Review Board whose membership is composed from the Earth Science and Applications, Astrophysics, Space Physics, and the Solar Systems Exploration disciplines. This board provides a forum for the review of the scope, balance and long term plans of the overall program and formulates recommendations to the Associate Administrator, Office of Space Science and Applications relative to overall program content, budgets and other programmatic issues. As a working element of the Suborbital Program Review Board, a Rocket Program Change Board comprised of the assigned Suborbital Program Manager from the SR and Scientific Discipline Chiefs from the four above identified disciplines deals with the scientific/technical assessment and feasibility of proposed missions, routine accommodation issues of flight approvals, specifications of annual fly-lists, priorities of approved missions and the review of program results. Program progress, problems, and significant issues and events are reviewed by the Associate Administrator, OSSA, as a part of the comprehensive monthly OSSA Program Review.

Program Management

The NASA Sounding Rocket Program at Goddard Space Flight Center (GSFC) falls under the Sounding Rockets Program Office (SRPO), Code 810, Suborbital Projects and Operations Directorate (SPOD), Code 800. The SRPO and SPOD are located at Wallops Flight Facility (WFF) Wallops Island, VA. Figure 1-1 is an organization chart of the SPOD. The program is implemented under the NASA Sounding Rocket Operations Contract (NSROC) which is administered by the SRPO. NASA retains overall management of the NSRP including certain programmatic elements such as mission selection, funding, international agreements, grant administration, oversight and approval of the ground and flight safety process, and ownership of program assets.

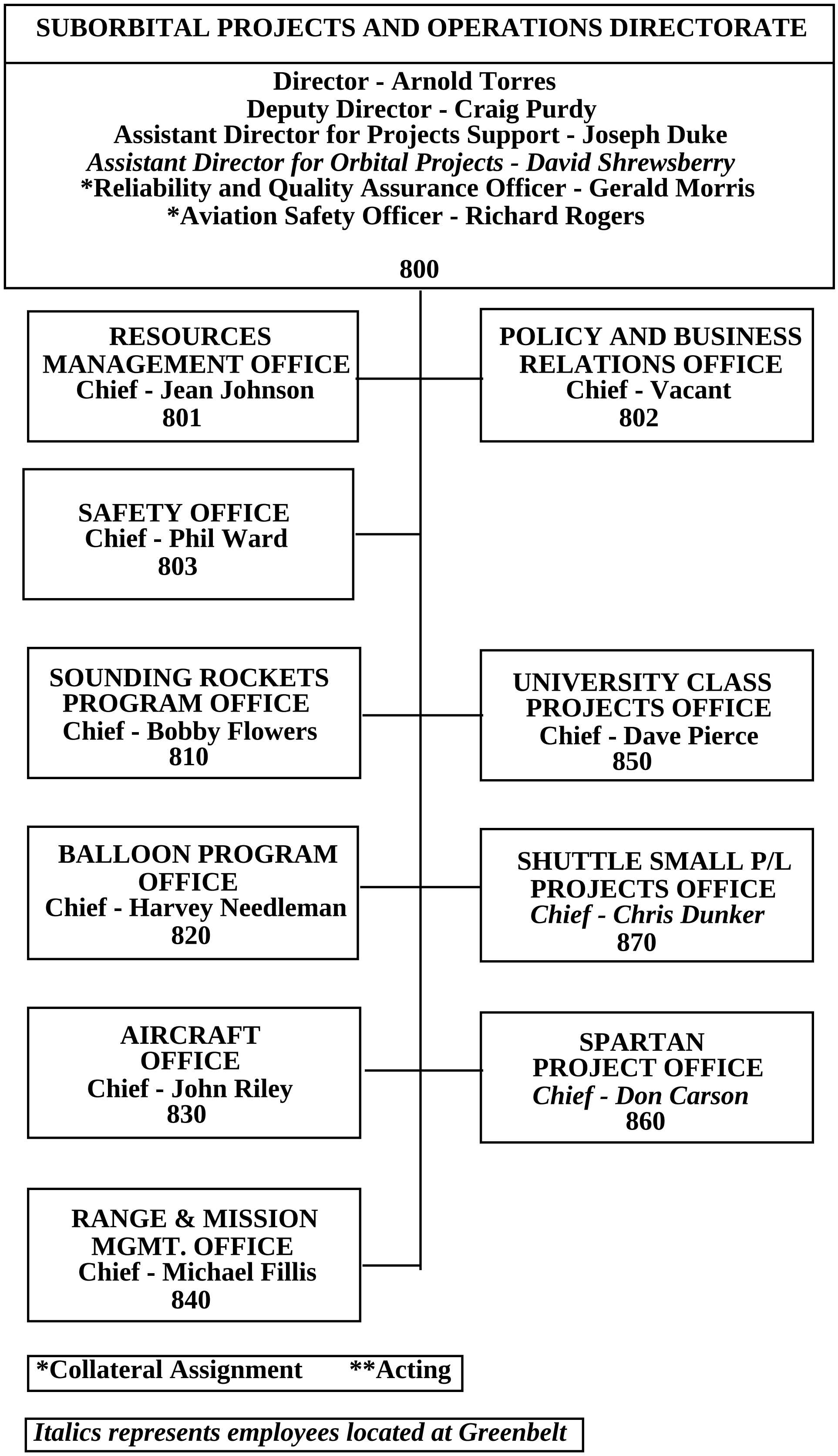


Figure 1-1. Suborbital Projects and Operations Directorate (Code 800)

Sounding Rocket Working Group

This group is appointed by the Director of Goddard Space Flight Center to provide counsel and a forum for exchange of information on sounding rocket systems, operational support, and developments in science as they affect the program. The NASA Sounding Rocket Project Scientist, Space and Earth Science Division, GSFC, chairs the Group. It consists of approximately 11 members from the principal scientific disciplines served by sounding rockets and from the technical and management support areas of importance to the NASA Sounding Rocket Program.

1.3 Sounding Rocket Program Customer's Role

General

Upon selection to participate in a flight, the customer becomes a member of the assigned Mission Team and is responsible for the preparation of the scientific experiment portion of the payload. The customer is responsible for defining the investigation being undertaken and for provision of the necessary scientific instrumentation. They also assist in establishing and conducting the operational program and are responsible for completing the timely processing and analysis of recovered data and publication of the results. The customer is expected to participate in a number of scientific and technical planning functions and formal reviews as described later in this document.

Philosophy

The customer's role is critical to the success of the mission. NASA procedures are designed to support the customer and facilitate the best possible scientific return from the mission. Information regarding past experiences with the reliability of specific components and techniques is made available. The assigned mission support team may recommend the use or avoidance of certain procedures and practices. However, the final decisions on the internal details of the scientific instrumentation are normally left to the customer. The capability of the scientific instrumentation to survive the flight environment is primarily determined by a series of environmental tests, which each payload is required to successfully complete during the testing and evaluation process. Determination of the ability of the scientific instrumentation to make the required measurements is normally made by the customer, since they are the authority on that subject.

Payload and Instrumentation

The customer is normally responsible for developing and providing scientific instrumentation and related support equipment that is not provided as part of the customary mission support functions as described under Section 1.4 - Sounding Rocket Project Support Elements. Customer provided scientific instrumentation must conform to various mechanical, thermal, and electrical interfaces; meet all required safety standards; and be capable of surviving the predicted conditions created by the flight environment. Scientific instrumentation and related support equipment may be built within the customer's own laboratories or by associated contractors. The customer has primary responsibility for ensuring that instrumentation they provide operates according to the required interface specifications and that adequate calibrations are made under predicted flight environmental conditions. To help ensure a safe operation, the customer is required to furnish the data specified in this Handbook in Section 8 - SAFETY and Appendix I - GSFC/WFF Safety Data Requirements.

1.4 Sounding Rocket Project Support Elements

Introduction

The NSROC contractor provides the programmatic, technical, and business management functions necessary to plan, organize, implement, control, track, report, and deliver the goods and services required for implementation of the NSRP. The NSROC contractor implements and reports their management functions to NASA through a comprehensive Integrated Management Plan (IMP) and an Integrated Reporting System (IRS). The IMP reflects the NSROC contractor's corporate approach to accomplish technical, safety, schedule, cost, and business objectives in an efficient and effective manner.

The NSROC contractor provides the individual mission management of all assigned sounding rocket missions including all planning and scheduling associated with individual mission requirements. Each mission is planned to meet science objectives and scheduled so that it does not interfere with the timely and cost efficient completion of other ongoing missions. An overall programmatic schedule is maintained in the IRS for all missions which reflects, as a minimum, the planned schedule for the following milestones: Mission Initiation Conference (MIC); Requirements Definition Meeting (RDM); fabrication; Design Review (DR); integration; testing; Mission Readiness Review (MRR); launch; post flight activities; and Mission Close-out Report (MCR).

The NSROC contractor provides services and supplies necessary for implementation of the individual missions and the overall program. As such, the contractor designs, fabricates, integrates, and performs flight qualification testing of sub-orbital payloads, provides launch vehicles, systems, and associated hardware, and provides various activities associated with subsequent mission launch operations.

Program Provided Support Elements

Customers of the Sounding Rocket Program are provided with a variety of support services. The assigned Mission Team is typically responsible for implementation of the mission utilizing their individual efforts and the additional extensive support capabilities provided by the Program.

A typical Mission Team is composed of the customer, or his representative and applicable support staff, and the various team members provided by the support elements at WFF. The Mission Team is typically composed of the following positions:

- Mission Manager
- Customer & Staff
- Mechanical Engineer
- Electrical Engineer
- Instrumentation Engineer
- ACS Engineer
- Performance & Analysis Engineer
- Mechanical Technician
- Electrical Technician
- ACS Technician
- Recovery System Technician
- Launch Vehicle Technician
- Data Manager
- Safety Representative

The general categories of effort necessary for implementation of a mission are as follows:

- Flight Mission Management
- Scientific Instrumentation (*provided by customer*)
- Payload Analysis, Design, & Development

- Launch Vehicle and Payload Support Systems
- Payload Fabrication
- Payload Assembly/Integration, Testing, & Evaluation
- Launch & Flight Support Operations
- Post Flight Data Processing and Analysis
- Ground & Flight Safety

A detailed discussion of how sounding rocket flight projects are conducted with respect to a typical mission is included in Section 2 of this Handbook. The following is a brief description, including organizational responsibility, of the individual support elements provided by the Program for the typical mission. In limited circumstances, NASA AETD personnel may perform some functions that are normally the responsibility of the NSROC contractor. This would generally occur only when there is a mission specific requirement for NASA personnel to participate, such as on NASA Student Launch missions (a NASA educational outreach endeavor) or new technology development activities.

Flight Mission Management

NSROC management is generally responsible for selecting a Mission Manager (MM) for each mission. The MM has comprehensive responsibilities throughout the mission life cycle and is the central point of contact for the customer. The MM's responsibilities include the following:

1. Assuming lead role responsibility for developing an approach (technical, schedule, and cost effective), in conjunction with the assigned mission team, for meeting mission requirements as defined by the customer. This activity generally occurs in the period between the MIC and the RDM as described in Section 2 of this Handbook.

2. Coordinating and establishing a mutually acceptable date for holding the RDM; conducting the RDM; and documenting the RDM, along with mission requirements, in the subsequent Requirements Definition Meeting Memorandum.

3. Working with the customer and the NSROC Mission Team in the design, development, fabrication, integration, testing, and flight qualification of the payload. The MM is responsible for coordinating, directing, and managing this effort, as well as establishing and maintaining the project schedule.

4. Directing and coordinating all Mission Team activities, including formal presentations at Design Reviews and Mission Readiness Reviews and documenting the Mission Team's responses to any action items resulting from these reviews.

5. Coordinating and directing all field operations including preparation of the launch vehicle and conducting launch operations. The MM is the focal point for all field activities and has final real time go/no-go authority for the mission, including launch vehicle status (concurrence for launch by range safety and the customer is required). The MM has no authority to override a customer or range safety decision to halt a launch, but may stop a launch when, in his opinion, a condition exists that jeopardizes the success of the flight.

6. Assessing the results of the launch to the extent possible and submitting required reports to the SRPO.

7. Coordinating and directing post flight operations necessary to complete all mission requirements.

<u>Payload Analysis, Design, & Development</u>
A graphic representation of the analysis, design, and development support for payloads, launch vehicles, and associated flight systems provided by the various organizational elements at WFF is presented in Figure 1-2.

The following activities are associated with the analysis, design, and development function and are generally provided by the NSROC contractor:

Electrical engineering support for payloads, launch vehicles, and associated flight systems includes electrical systems (power supplies, event timing, wiring harnesses, monitoring subsystems) and instrumentation systems (telemetry subsystems).

Mechanical engineering support for payloads, launch vehicles, and associated flight systems includes all payload mechanical subsystems (overall layout and design, external skins, internal structures, bulkheads, component layouts, special mechanisms) and pyrotechnic devices, e.g., pin-pullers, bolt-cutters and thrusters.

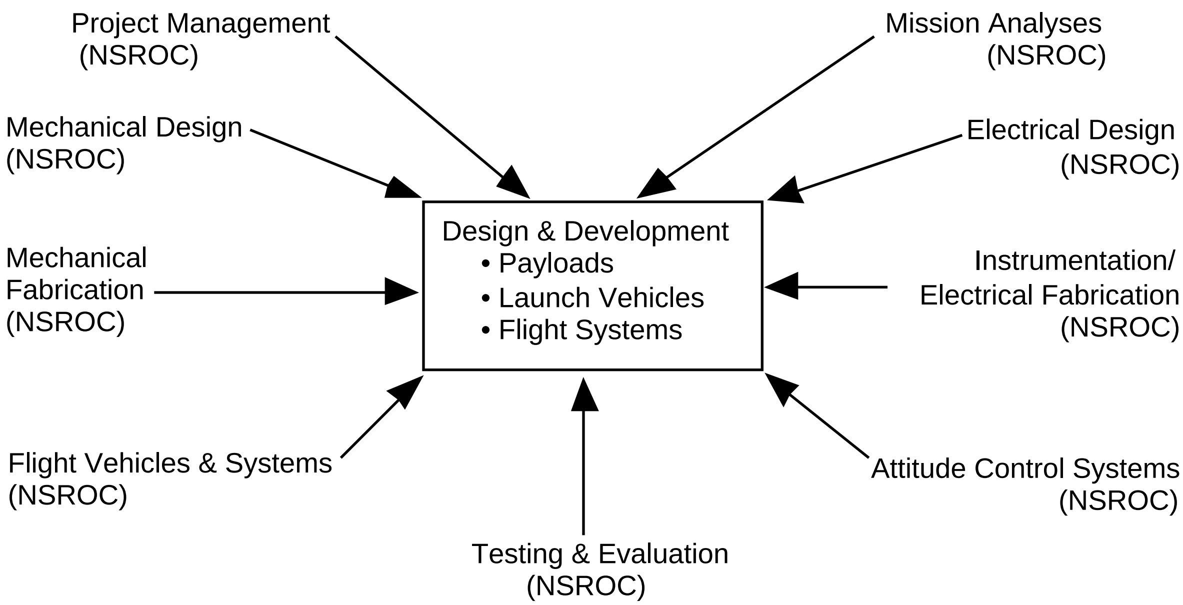


Figure 1-2. NSROC Sounding Rocket Analysis, Design, and Development

Mission analyses include launch vehicle performance and nominal flight trajectory analysis, flight trajectory dispersion, wind-compensation parameters, and impact aim point considerations. Also included is launch vehicle static and dynamic stability evaluation including aeroelastic effects, payload dynamics analyses, payload re-entry trajectory and recovery analyses, ascent and re-entry aerodynamic heating analyses, and other suborbital analyses. These activities are performed during the pre-flight and post-flight analyses for each mission.

Launch Vehicle and Payload Support Systems

Launch vehicle and payload support systems include rocket motors, pyrotechnics, and associated inert standard flight systems such as ejectable nose cones, payload/vehicle separation systems, upper stage ignition systems, and thrust termination systems. Activities associated with these systems include their inspection, modification, storage, shipment, assembly, launcher mating, umbilical rigging, and environmental control during launch operations. Other standard systems include payload recovery systems, special aerodynamic decelerators, payload attitude control and stabilization systems, and launch vehicle boost-guidance systems. These standard systems are provided by the NSROC contractor.

Payload Fabrication

Mechanical and electrical fabrication services are provided by the NSROC contractor. Electrical fabrication support includes specialized shops for electrical wiring assembly, printed circuit board fabrication, and electrical instrumentation development. The mechanical fabrication support includes the machine shop, welding shop, plastics and composite materials shop, sheet metal shop, and mechanical instrumentation shop.

Payload Assembly/Integration, Testing, & Evaluation

The progression of development of a mission leads from the fabrication of flight hardware to its assembly, along with the customer provided instrumentation and standard support systems, into a fully integrated payload. The payload then proceeds through the testing and evaluation process. This involves various engineering and technical support personnel, including the customer who has the technical knowledge of, and responsibility for, his instrumentation. This function is performed by the entire Mission Team, along with laboratory support personnel who operate the various facilities involved in the processes. Facilities utilized include payload assembly shops, telemetry ground stations, and those associated with the testing and qualification processes. These processes include physical properties determination; magnetic calibration; and vibration, shock, structural loads, spin-deployment, dynamic balancing, and vacuum testing. All of these services are generally provided to the customer by the NSROC contractor.

Launch and Flight Support Operations

A critical element of conducting the NASA Sounding Rocket Program involves performing launch operations from various locations worldwide. Several of these launch sites are existing, full-time launch ranges. Mobile sites can also be established at remote locations which satisfy particular science requirements, such as specific observations (solar eclipses, supernova) and operations in specific areas (auroral zones, equatorial zones, Southern Hemisphere).

The following are brief descriptions of the major applicable elements involved in supporting sounding rocket flight operations:

The SRPO utilizes an agreement with the NAVY at White Sands Missile Range to provide services for conducting launch operations from that location. The SRPO directs the NAVY to coordinate the provision of these services from the various service provider organizations and to support the specific requirements of each mission.

The SRPO utilizes a contract with the University of Alaska for the maintenance and operation of the Poker Flat Research Range. This mechanism provides support for launch operations conducted from this high latitude location. Additional support for tracking and data acquisition services is provided for through the NASA CSOC contract.

The SRPO also utilizes inter-governmental and international agreements necessary for the provision of launch operational support for mobile campaigns or from established foreign ranges such as Esrange, Sweden and Andoya, Norway.

The Range and Mission Management Office (RMMO), Code 840 is responsible for planning and directing the support necessary to meet the objectives of projects conducted on the WFF range and mobile campaigns. The implementation of mobile campaigns for sounding rockets involves the support of several organizational elements within SPOD, which is illustrated in Figure 1-3. Additional support may also be provided by the AETD.

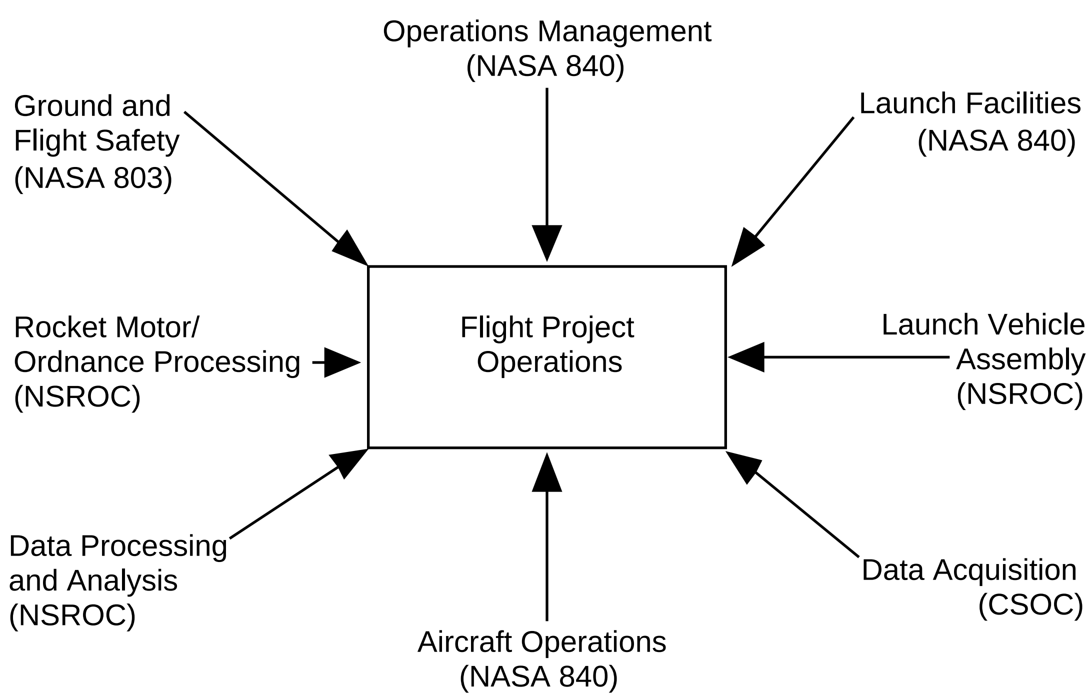


Figure 1-3. NASA Sounding Rocket Flight Project Operations

The RMMO schedules and directs flight test activities, provides test data packages to users, and coordinates range operations with various outside organizations for operations conducted from WFF and mobile campaigns. When conducting a mobile operation of sufficient magnitude, a "Campaign Manager" is usually assigned. This individual has overall responsibility for managing the campaign (which usually involves several separate sounding rocket flight missions) including interfacing with foreign government organizations, establishing the required launch support facilities, and coordinating launch operations.

Launch pads, launchers, blockhouse systems, controls, and consoles are provided by the range from which the operations are being conducted. Mechanical and electrical/electronic ground support equipment; flight support instrumentation such as search, tracking, and instrumentation radars; telemetry receiving and data recording stations; television and photographic tracking cameras; special purpose photo-optical equipment; surveillance and recovery operations aircraft; and facilities for payload preparation and check out are provided as part of the range services.

The NSROC contractor is generally responsible for conducting the actual launch operations as well as all functions relating to the preparation of the launch vehicle and payload leading up to that event.

Post-Flight Data Processing and Analysis

The NSROC contractor is generally responsible for providing post flight processing and analysis of raw scientific data recovered from sounding rocket missions. This data is provided to the customer in the format specified at the RDM. Section 10 has additional information on available data processing and analysis support and procedures for obtaining that support.

Ground and Flight Safety

All work performed in support of the SRP is done so in conformance with all WFF, GSFC, NASA, and other government regulations, requirements, and statutes. Ground and flight safety data requirements for sounding rocket vehicles and payloads are contained in the Range Safety Manual for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF), (RSM-93). This manual contains specific design requirements for flight systems and describes data that must be supplied to the Wallops Flight Facility Safety Office (Code 803) to obtain NASA safety approval for launch systems. Institutional safety requirements are contained in NHB 1700 (V1-B). The NSROC contractor is responsible for meeting these requirements as well as any additional safety requirements of any other domestic or foreign ranges utilized during implementation of the SRP. Further, the NSROC contractor is responsible for apprising itself of all changes and modifications to statutes, regulations, and procedures impacting ground and flight safety.

The NASA Safety Office is responsible for oversight and approval of all ground and flight safety processes. As such, the NASA Safety Office provides all necessary Safety Plans based on the data and analyses provided by the NSROC contractor. The NSROC contractor is contractually required to provide all data, analysis, and information necessary for the development of these, and any other, required plans. The NASA Safety Office plans and coordinates safety aspects of launch operations, establishes range clearance and range safety limitations, and reviews and approves assembly and pad procedures. The NSROC contractor is responsible for implementing all of the requirements of the Ground and Flight Safety Plans for NSROC supported missions.

For hazardous operations, the NSROC contractor is responsible for providing personnel whose primary responsibility is safety oversight. This person or persons, known as the Operational Safety Supervisor, interfaces directly with the NASA Safety Office oversight authority in resolving real-time safety concerns. The NSROC contractor is also responsible for implementing all general operation (crane operation, forklift operation, etc.), personnel safety (explosives and ordnance, pressure vessels and systems, chemical, radiation, etc.) and facilities (equipment calibration, maintenance of safety devices, access control, etc.) requirements.

A detailed discussion of sounding rocket safety considerations and policies is provided in Section 8 of this Handbook.

<u>Additional Information</u>

Section 11 - Wallops Flight Facility - has additional details on available NSRP support capabilities.

SECTION 2: The Sounding Rocket Flight Project

2.1 Introduction

This Section describes the process NASA uses in conducting a sounding rocket flight project (i.e. mission) using the management and support elements at Goddard Space Flight Center's Wallops Flight Facility (WFF) discussed in Section 1.4.

From the time a mission is approved by NASA Headquarters through completion, several meetings and reports supply the means by which NASA and the customer (i.e. program user/scientist/experimenter) maintain awareness of the progress towards meeting the schedule, problems encountered and corresponding corrective actions, and mission outcome.

Meetings at Wallops

Meetings generally held for each mission occur in the order shown:

- Mission Initiation Conference (MIC)
- Requirement Definition Meeting (RDM)
- Design Review (DR)
- Mission Readiness Review (MRR)

Additional meetings may also be held as follows:

- Status Reviews
- Pre-Integration Review (PIR)

These meetings represent milestones in the overall project schedule. Each is treated as an important event. The major events that occur in the life cycle of a typical sounding rocket mission are shown in Figure 2-1.

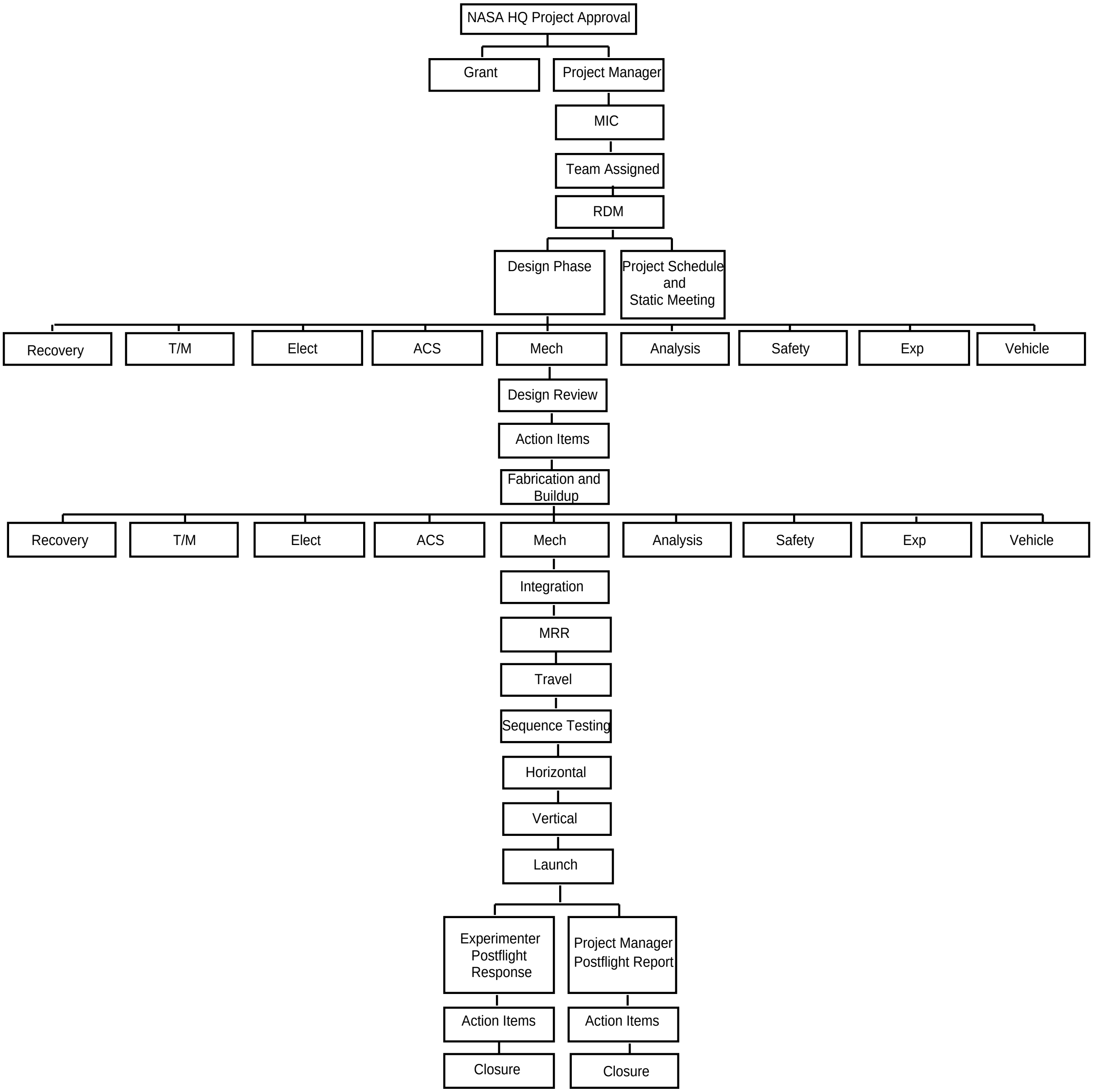


Figure 2-1. Typical Sounding Rocket Mission Flow Diagram

2.2 The Mission Initiation Conference

Purpose

Flight projects must be approved by the appropriate science discipline chief at NASA Headquarters. Once this approval has been obtained, a meeting is scheduled between the customer and WFF personnel. The purpose of this meeting is for the customer to present his requirements and specify the support necessary for the mission. This first meeting is called the Mission Initiation Conference (MIC). The customer is contacted by the SRPO to establish a mutually acceptable date for the MIC. Attendees include appropriate WFF supervisory and engineering personnel along with NSROC supervisory, engineering, and technical personnel. This first meeting is very important as it provides the basis from which all requirements for the mission are established. The meeting is chaired and documented by the SRPO.

Customer Data Package

The customer is required to present a detailed MIC data package. An outline of the information required is provided in Appendix A. A well conducted and documented MIC will result in a strong foundation on which to begin the mission.

Project Schedule

The customer should be prepared to answer many specific and detailed questions regarding the scheduling of project milestones. An outline of all important project milestones will be developed at the MIC. These include pre-integration events, integration, testing, all planned reviews, shipping, range approvals, and a field operations schedule.

Mechanical Devices and Structural Elements

The requirements for mechanical work will be discussed in as much detail as possible. Mechanical items of interest include deployable nose cones (standard or special), doors (access, deployable or retractable), extendible booms, antennas, sensors, and any unique structural items or payload skin requirements. Any temperature limitation or vacuum requirements should be discussed as well as any special mechanical devices/systems such as despin, air, land, and water recovery.

Flight Performance

All payload flight trajectory/timeline requirements such as apogee, altitude, or time-above-altitude should be reviewed. Customers should include requirements for payload dynamics, e.g., spin rate and/or coning limits. Some payload designs involve long, flexible booms while others may involve tethers and sub-payloads; dynamics requirements for this type of payload should be presented. The flight performance characteristics of NASA sounding rocket launch vehicles are presented in Section 3 and Appendix E. The best estimate of payload weight should be determined for the MIC, being careful not to eliminate any significant payload components. An appropriate launch vehicle to meet scientific requirements can generally be selected at the MIC.

Instrumentation

Experiment data requirements should be available at the MIC in sufficient detail to allow definition of the telemetry system for the payload. Experiment programming requirements, such as on-board timers, uplink commands, or special monitoring should be discussed. A detailed description of standard instrumentation systems is included in Section 5 of this Handbook.

Attitude Control

Attitude control and stabilization of space science payloads are key elements in most astrophysics and solar physics experiments. Attitude control requirements should be fully discussed at the MIC to allow a determination of the type of Attitude Control System (ACS) to be used. The nature of celestial targets should be defined and pointing accuracy and stability (jitter) should be specified. The various types and capabilities of sounding rocket attitude control systems are presented in Subsection 5.13, Appendix H, and Section 6.

Data Reduction

The customer can obtain assistance in data processing and analysis from WFF. Specific data reduction requirements should be discussed at the MIC. A description of WFF capabilities for data processing and analysis, and guidance on requesting support, is provided in Section 10.

Testing

Overall testing policies of the Sounding Rocket Program are detailed in Section 7. In general, all flight payloads must be tested in accordance with the testing specifications. Any special testing concerns or requirements should be discussed at the MIC.

Action Items

The responsibilities for all aspects of preparing a flight payload and conducting launch operations should be clearly established at the MIC. Action items and required suspense dates for each group at WFF supporting the Sounding Rocket Program will be established so the customer's objectives and requirements will be met on schedule.

2.3 The Requirements Definition Meeting

Within a period of 45 days after the MIC, the NSROC contractor initiates and conducts a Requirements Definition Meeting (RDM) which includes representatives from NASA and the customer. In the period between the MIC and RDM, the NSROC contractor develops mission concepts such as launch site, mission support requirements, payload complexity category, launch vehicle configuration, mission schedule (including fabrication, integration and testing, and post flight requirements schedules), target cost estimates, success criteria, recovery requirements, data product formats, and other pertinent mission defining elements. The results of this mission defining process are presented at the RDM. The RDM presents all information necessary to define and demonstrate the overall feasibility of the mission, and how the mission requirements can be achieved. The NSROC contractor documents the RDM in the Requirements Definition Meeting Memorandum (RDMM) which is provided to NASA within 5 days of the RDM. This serves as the contractor's task plan and documents mission technical requirements, the approach to satisfying those requirements, schedule, and cost information. NASA either concurs in the RDMM and issues a task to the NSROC contractor to support the mission, or provides action items to the contractor for resolution prior to issuance of the task.

2.4 The Design Review

General

A Design Review (DR) is held when a payload contains new equipment of a type that has not been flown before. A DR is also held if the payload is a new configuration that has not been flown before, even if the scientific instrumentation in whole or part is of existing design with previous flight history. The DR is generally waived if the payload is a direct refly of an existing payload.

Purpose

A DR may be requested by anyone who carries responsibility for the payload, e.g. the customer, NSROC contractor, or the SRPO. During the DR, the Mission Team formally and systematically presents all information necessary to demonstrate that the proposed design and mission approach can meet all mission and safety requirements. Complete descriptions of the proposed test plan for the complete payload and each system associated with the mission are included and presented. A listing of all procedures involving hazardous operations, safety-related issues, and assembly of the launch vehicle and payload is provided. Procedures of any type involving hazardous operations or safety-related issues, which have not been approved by NASA Safety, are required to be provided. Any new or revised procedures are provided. A preliminary Flight Requirements Plan (FRP), which outlines range support requirements; flight performance aspects; data product requirements; and field operations plans and schedules is required as part of the Design Review documentation. The mission schedule is updated, if necessary, and any changes since the RDM are justified and documented.

The objective of the review is to discuss all aspects of the design, to establish various design parameters, to define and elicit solutions to problems, and to make all with responsibility aware of the current design plans. NASA, NSROC, and customer representatives may attend the DR and assign action items as necessary.

The design of the payload should be generally complete in order for a DR to be held. If this is not appropriate because of schedule constraints, etc. the review should be held as soon as a sufficient design has been completed to allow a thorough review. The customer should be prepared to discuss all details of the scientific instrument design and interface with the support systems. A customer data package is required for handout at the review. The format and contents of this data package are provided in Appendix B. The customer's data package should be provided to the Chairman of the Design Review Panel approximately 48-hours prior to the scheduled meeting.

Design Review Panel

A Design Review Panel is established by the NSROC contractor and is composed of a Chairman and other experienced personnel who are not directly involved with the mission.

All members of the panel are NSROC personnel with representatives competent in each area of technical support being provided for the mission. This generally includes the following:

- Flight Performance
- Mechanical Systems
- Electrical Systems
- Instrumentation Systems
- Attitude Control and Boost Guidance Systems
- Recovery Systems
- Launch Vehicle Systems
- Ground and Flight Safety

Design Review Process

The general process for the DR is as follows:

1. The MM formally requests a DR in a memorandum to NSROC management; this memorandum will include an agenda for the review.

2. NSROC management formally announces the DR, specifying the subject flight mission, date, time, place, and Design Review Panel personnel assignments.

3. The Chairman of the Design Review Panel conducts the review. After completion of the meeting, the panel re-convenes to discuss the results, and formulate and document action items that are provided to the MM for disposition.

4. The NSROC contractor generates a Design Review Memorandum (DRM) which summarizes the meeting and documents all assigned action items. The DRM documents that the DR package and presentation demonstrated the proposed design and mission approach is capable of meeting the mission success criteria.

5. The MM is responsible for directing the Mission Team in responding to DR action items. This effort is formally documented with a memorandum to the Design Review Panel Chairman.

6. The Panel Chairman re-convenes the panel and reviews the responses to the action items. Any responses considered inadequate by the panel are reviewed by NSROC management with the MM, Panel Chairman, appropriate Mission Team member(s), panel members(s), and support area supervisor(s). All action items must be dispositioned (i.e. responded to by the Mission Team and approved by the Design Review Panel or NSROC management) prior to scheduling the Mission Readiness Review.

2.5 Mission Status Meeting

General

During the course of any sounding rocket flight mission, it may be necessary to have status meetings to review on-going project activities. A Mission Status Meeting is usually held when any event or condition changes, or threatens to change, the schedule or the planned conditions for the flight. While a status meeting may be desirable for a number of reasons, it becomes most important for flights with little or no flexibility in the launch date. This typically occurs on missions involving comets or eclipses, when the launch is scheduled from distant or foreign sites, or when more than one agency is involved.

When Held

The meeting is held as soon as possible once sufficient information is on hand. More than one Mission Status Meeting may be required when new developments and their impacts need to be discussed.

Who Requests the Meeting

The meeting may be requested by any individual involved with the mission including the customer.

Chairing the Meeting

The MM is responsible for conducting Mission Status Meetings and documenting the results.

Resolution
The problems/concerns discussed may not be resolved at the meeting but may be assigned to one or more individuals to resolve within a certain time limit. Such assignments are recorded in the minutes of the meeting as "Action Items".

2.6 Payload Fabrication and Pre-Integration Testing

New mechanical and electrical hardware is fabricated in the shop facilities at WFF. Payload specific hardware is fabricated and assembled at WFF, with the exception of standard flight systems such as ignition/despin/separation systems, attitude control/boost guidance systems, recovery systems, and nose cones. Mechanical hardware is assembled and fit-checked prior to integration with scientific instrumentation provided by the customer. Electrical and telemetry instrumentation wiring and components are assembled and tested prior to integration with the customer's electrical/data systems to facilitate a smooth, trouble-free integration effort. Special pre-integration design qualification tests are often performed for new separation/ejection/deployment mechanisms, vacuum doors, and other devices. These special tests are in addition to the total payload post-integration testing that must be successfully completed before flight.

2.7 Pre-Integration Review

General
The PIR, generally chaired by the MM, is held at the discretion of NSROC management. The purpose of the initial phase of this meeting is to review the Mission Team’s readiness to support payload integration activities prior to authorizing travel by the customer or his staff. This serves to insure that the customer is not inconvenienced in having to wait while WFF personnel complete preparation activities for support systems necessary for payload integration.

The second phase of this meeting is actually just a variation of the Mission Status Review meeting. It occurs when the customer arrives with his instrumentation at the payload integration site. The purpose is to coordinate the upcoming activities associated with payload integration, identify any outstanding issues early in the process, and develop approaches towards their resolution.

2.8 Payload Integration and Testing

General

Payload integration and testing is comprised of a pre-integration checkout, payload integration, acceptance testing, and final checkout. When the final checkout indicates that all the subsystems operate as planned and are mutually compatible, the payload can be shipped to the launch site with confidence that only minor adjustments or calibrations will be necessary in the field. Figure 2-2 shows the integration of a NASA Student Launch Program payload at WFF.

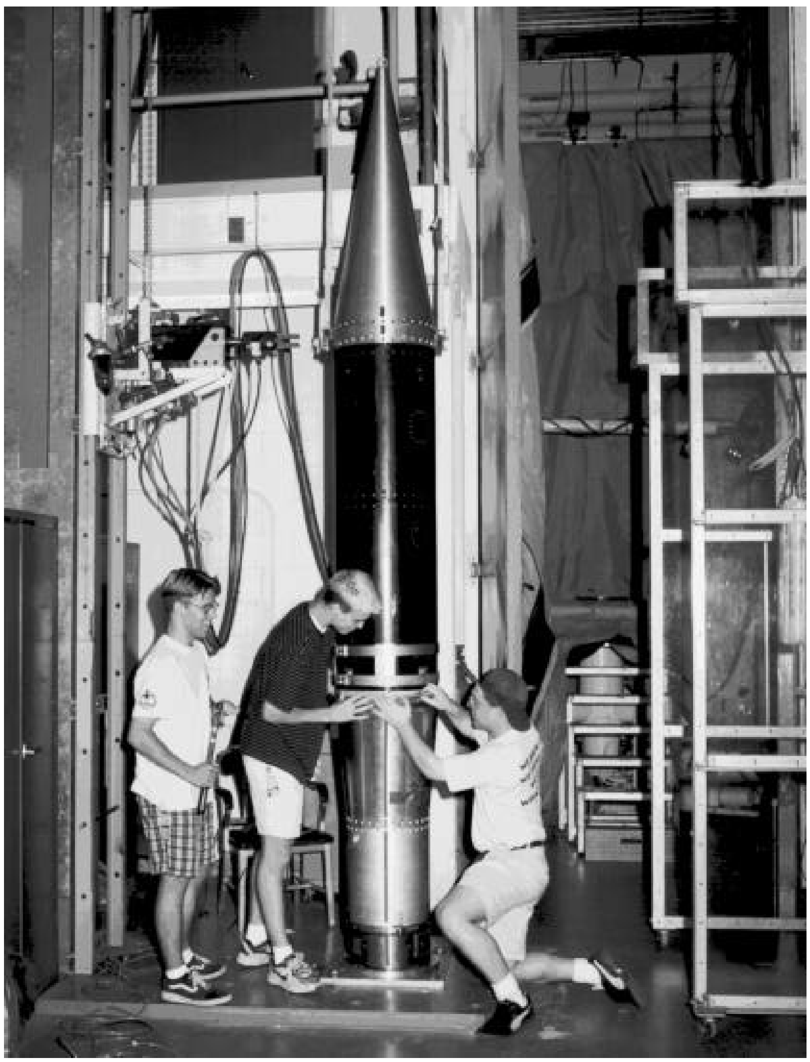


Figure 2-2 Payload Integration of “Student Launch Program” Payload at WFF

Integration and testing of new payloads (except as described below) is usually conducted at WFF. General information concerning the integration and testing laboratories at WFF is presented in Section 11 and Section 7 describes specific testing policies. Integration and testing of SPARCS payloads are performed at WSMR as these systems require special equipment that is resident only at that location. Section 6 provides a description of the facilities available for SPARCS payloads at WSMR.

Pre-Integration Checkout

Pre-integration checkout insures all parts and systems are available, have been assembled mechanically, and passed appropriate electrical functional test.

The pre-integration checkout criteria are determined by the customer and Mission Team. The MM insures that all appropriate pre-integration checks have been completed prior to scheduling payload integration activities. Pre-integration checkout activities for consideration in making this determination are listed below:

ACS

- Mechanical assembly completed
- Electrical/functional test completed
- Air Bearing test completed
- Vibration test completed

Mechanical

- Fit check
- Load-bend test completed (new structures)
- Deployment/separation tests completed (new systems)

Vehicle

- Recovery system checked
- Firing/despin module checked

Instrumentation

- Battery requirements established
- Telemetry checkout complete
- Sensors/transducers calibrated
- Tone ranging checked
- Timers verified
- Power-on checks completed
- Functional checks completed

Experiment (*by the PI*)

- Assembly completed

Calibration checks completed
Functional checkout completed

Payload Integration

Payload integration is the first-time assembly of all the parts and pieces into the launch configuration. All aspects of the design and operation are checked including mechanical fit and operation, telemetry and electrical systems operation, and systems compatibility. Pre-testing sequence tests are performed to insure the event-programming system functions properly.

Acceptance Testing

After successfully passing the payload integration checks, the assembled payload is taken to the Test and Evaluation (T & E) Laboratory where it is subjected to acceptance tests. Acceptance tests simulate some of the conditions the payload is likely to encounter in flight. Payload sub-systems that are required to operate in flight are functional during the acceptance tests. Every system must demonstrate the ability to survive flight conditions through completion of its intended function.

Waivers

When special conditions or circumstances occur which warrant an exception to standard testing policies, the customer may submit a written request for waiver to the MM. The reason for the request, possible results if failure should occur during flight, and any other pertinent details should be stated in this request. Although waivers are infrequently required, they may be granted by NSROC management after consultation with all involved parties.

Final Checkout

After the payload has completed acceptance testing, it receives the final checkout. The final checkout is essentially a duplicate of the payload integration checks described earlier. This process looks for workmanship defects or other anomalies that may have been revealed as a result of the acceptance testing process.

Integration and Test Scheduling

All integration and testing schedules are prepared and coordinated by the MM. The integration and test facilities at WFF are in demand by many flight projects. Use of these facilities is usually scheduled several weeks ahead of the requirement; however, requests for immediate services may sometimes be accommodated. The customer should coordinate with the MM with respect to scheduling these activities and any special requirements while at WFF. The MM will interface with the Integration and T&E Laboratory supervisors regarding integration and testing activities.

Mission Team members are responsible for documenting the integration activities and T&E results for presentation at the Mission Readiness Review (MRR). All problems encountered during integration and testing are thoroughly discussed at the MRR.

2.9 Mission Readiness Review

General

The Mission Readiness Review (MRR) is a formal review that is held after integration and testing have been completed. The purpose of the review is to determine if the mission is ready to proceed with launch operations with a high probability of meeting the mission success criteria. All action items identified in the DR must be dispositioned (i.e. responded to by the Mission Team and approved by the Design Review Panel or NSROC management) prior to scheduling a MRR.

The MRR generally follows the same basic process as the DR regarding formal project documentation. Information presented at the MRR should also demonstrate that all environmental testing and flight qualifications have been successfully completed; all required GSE and range support assets and services have been identified and scheduled in a detailed field operations plan; and that arrangements for the provision of all required GSE and range support assets and services have been completed. Problems encountered during integration and testing are reviewed, including the adequacy of any modifications or repairs. Information regarding procedures, similar to that presented at the DR, is provided. A final FRP, which includes the detailed field operations plan and schedule, is included in the MRR documentation. The mission schedule is updated and any changes in the design, test plan, procedures, or mission approach which have occurred since the DR are fully documented and justified.

The customer should be prepared to discuss all aspects of experiment hardware status, test results, and mission success criteria. A customer data package is required for the MRR. The format and content of this data package are provided in Appendix C. The data package from the customer should be delivered to the Chairman of the MRR approximately 48-hours prior to the scheduled meeting.

Mission Readiness Review Panel

The Mission Readiness Review Panel is established by NSROC management and is composed of a Chairman and other technically qualified personnel not directly involved with the flight project. This panel is similar in composition and function to the Design Review Panel.

Mission Readiness Action Items

Action items may result from the MRR process. It is highly desirable that these action items are dispositioned prior to shipping payload hardware, or travel of the Mission Team, to the field. NASA, NSROC, and customer representatives may attend the MRR and assign action items as necessary. One major difference between the DR and MRR action items is that if the MRR action items are not adequately addressed (i.e. to NASA's satisfaction) then NASA has the authority to halt launch operations until this requirement is met. As a final go/no go checkpoint, the SRPO issues written authorization to the NSROC contractor to proceed with launch operations after they are satisfied this requirement has been met.

Additional Review

If, at the MRR, it becomes evident that major rework of the payload is required a second MRR may be necessary.

2.10 Launch Operations

Following payload integration, testing, and completion of the MRR, the sounding rocket project proceeds to the final major phase - launch operations. Sounding rocket launch operations are conducted from various launch sites worldwide that vary from well-established launch ranges to barren temporary facilities outfitted with mobile equipment. A detailed discussion of launch operations at various domestic, foreign, and mobile launch sites is included in Section 9 and Appendix J. Section 11 has information regarding the range at WFF.

Flight Requirements Plan

Ninety days prior to arriving at the launch range, the NSROC contractor submits a Flight Requirements Plan (FRP) to the range detailing all support requirements the launch range must provide for launch and payload recovery operations. The launch range uses the FRP to plan and coordinate its support functions. The MM is responsible for ensuring that this document is accurate, complete, and timely. FRPs are used for launch operations at White Sands Missile Range, Poker Flat Research Range, and established foreign ranges.

Operations and Safety Directive

Support requirements for launches at WFF are documented in the Operations and Safety Directive (OSD). For launches at WFF, this Directive substitutes for the FRP. The OSD is prepared by the Range and Mission Management Office (Code 840).

Sounding rocket launch operations at temporary launch sites are generally conducted as a campaign, with several rockets being launched while the range is in operation. In this case, the Campaign Manager will prepare an OSD that serves as the definitive document for describing all launch vehicle systems, payloads, and launch support activities.

Operational Safety

All aspects of sounding rocket launch operations are considered in detail regarding personnel hazards and overall safety concerns. A detailed discussion of NASA Sounding Rocket safety policies and responsibilities is included in Section 8 of this Handbook. The MM will ensure that the Mission Team is in compliance with all applicable safety policies regarding both ground and flight safety during project launch operations.

2.11 Post-Launch Activities

Mission Results

Immediately following a launch, the MM is responsible for providing a preliminary assessment of the results. The customer should assess the science results and report the overall status to the MM as soon as possible. In some cases, the payload must be recovered and returned for analyses in order for final science results to be determined. In the case of a flight failure, all recovered hardware is impounded by the NSROC contractor for inspection by cognizant personnel in a failure investigation.

Immediately following a launch, the NSROC contractor issues a quick-look report. The quick-look report indicates apparent mission success or failure based on the best data available to the MM at that time.

Preliminary Post-Flight Report

Within a few days of a launch, the NSROC contractor submits a Preliminary Post-Flight Report to the SRPO. This report provides all available preliminary flight results data. Any problems encountered during flight are detailed for all vehicle and payload flight systems. The Preliminary Post-Flight Report also includes a chronology and discussion of any problems or anomalies encountered during launch operations. An outline of the Preliminary Post-Flight Report is included in Appendix D.

The customer is requested to provide a written response indicating the level of success, or failure, of the mission. This should also include any recommendations for improvements that the customer may suggest. NASA officially classifies the mission as a success or failure based on this input.

Post-Flight Conference

Most established launch ranges conduct a post-flight meeting to review mission results. This provides the opportunity for the customer to provide compliments or complaints concerning the field services provided. NSROC and range support personnel utilize this input towards implementation of future improvements in service.

Post-Flight Data

The customer’s data requirements should be documented in the RDMM. Any changes that occur in these requirements during the progress of the mission should be documented in the DRM or MRRM. The MM is responsible for insuring that all data requirements are satisfied. Special data processing and/or analysis support can be made available. A discussion of available data processing and analysis capabilities is provided in Section 10. A sounding rocket mission is not considered complete until all data requirements and post-flight reporting requirements have been satisfied.

2.12 Mission Success/Failure

NASA sounding rockets have maintained a historical 86 percent mission success rate. A successful flight is defined as one that meets the minimum success criteria. When the minimum success criteria for any given flight are not met, the flight is officially considered a failure. All sounding rocket flight failures are formally investigated to identify the cause(s) of the failure so that appropriate corrective action(s) can be taken. If the failure is caused by a problem with the scientific instrumentation or associated hardware provided by the customer, the customer is responsible for determining the cause(s) and taking corrective action(s) prior to re-flight. Technical assistance and consultation can be provided to the customer as necessary. Upon completion of the failure investigation, the customer is requested to provide the findings, conclusions, and corrective action(s) to NASA through the Chief, SRPO.

Failure Investigation Committee

If a failure or anomaly is caused by any of the supporting sub-systems provided by the SRP, the investigation will be conducted by the SRP, with external consultants as required. The NSROC contractor is responsible for identifying anomalies, failures, and systemic problems with flight vehicle systems, payload systems, GSE, and analytical methods they employ in support of the NSRP. All direct and contributing causes of all anomalies, failures, and systemic problems are investigated, resolved, and fully documented with corrective action being identified and implemented in a timely manner. NASA also reserves the right to observe and/or participate in contractor-staffed anomaly and failure investigations and to conduct independent investigations.

The Failure Investigation Committee is composed of individuals selected for their expertise in areas related to the failure. The customer or his representative may be requested to serve on a Failure Investigation Committee. The committee will, in some cases, issue preliminary findings and recommendations regarding pending missions that may be affected by similar problems. Launch operations for these missions may be postponed until a resolution of the problem has been achieved. A formal, final investigation report is issued as soon as possible following completion of the investigation.

In-Flight Anomalies

In some cases, problems occur during flight with payload sub-systems that result in abnormal payload operations but do not result in a mission failure. Likewise, the launch vehicle can exhibit abnormal performance characteristics, but still provides an adequate flight trajectory for satisfying the minimum requirements for scientific success. In these cases, the overall mission is termed a success, and the abnormal occurrences are considered an in-flight anomaly. Mission failures are always termed "major" occurrences that require formal investigation. Anomalies may be termed "major" or "minor", depending on the particular circumstances involved. For major anomalies (generally those which, should they recur, have the potential to jeopardies the success of future missions) an Anomaly Investigation Committee with the same charter and authority as a Failure Investigation Committee is appointed.

Failure/Anomaly Review Committee

A Failure/Anomaly Review Committee reviews the findings and recommendations of Failure and Anomaly Investigation Committees. Responsible senior individuals from each major technical support area are included on this committee. Each recommendation made by the Failure/Anomoly Investigation Committee is reviewed by the Failure/Anomaly Review Committee and assessed with respect to applicability to the problem and the overall programmatic impact of the recommendation. The Failure/Anomoly Review Committee makes the determination of weather or not to implement the recommendations presented by the Failure/Anomoly Investigation Committees.

All failures and major anomalies are input into the GSFC non-conformance reporting system with corrective action being implemented as required. Failure Investigation Reports are routinely provided to the customer of the associated mission and NASA Headquarters.

Section 3: Sounding Rocket Launch Vehicles and Their Performance Capabilities

3.1 Introduction

A family of standard sounding rocket launch vehicles is available in the NASA Sounding Rocket Program for use in conducting suborbital space science, upper atmosphere, and other special applications research. Some of the vehicles are commercially available; others have been developed by NASA for exclusive use in NASA programs. These vehicles are capable of accommodating a wide variety of payload configurations and providing an extensive performance envelope.

NASA Mission Designation System

NASA sounding rocket launch vehicles are identified by a numbering system. The first two digits of the flight mission number identify the type of launch vehicle used. The remaining three digits indicate the mission number for that particular launch vehicle type. The first and second letters following the digits identify the type of organization sponsoring the mission and the scientific discipline of the experiment, respectively. Table 3-1 lists the specific vehicle numbering system as well as the agency and experiment type. Table 3-1 also has an example Flight Mission Number.

3.2 NASA Sounding Rockets

There are currently thirteen operational support launch vehicles in the NASA Sounding Rocket Program. All NASA sounding rocket launch vehicles use solid propellant propulsion systems. Extensive use is made of 20 to 30-year-old military surplus motors in 10 of the systems. All vehicles are unguided except those which use the S-l9 Boost Guidance System. During flight, all launch vehicles are imparted with a spinning motion to reduce potential dispersion of the flight trajectory due to vehicle misalignments. Outline drawings for these fifteen vehicles and their NASA vehicle numbers are presented in Figure 3-1.

Table 3-1.
Sounding Rocket Vehicle, Agency, and Experiment Identification

NASA Vehicle Numbers:

12 - Special/Development Test Vehicles
15 - Super Arcas
21 - Black Brant V
27 - Nike-Black Brant V
29 - Terrier-Malemute
30 - Orion
31 - Nike-Orion
33 - Taurus Orion
35 - Black Brant X
36 - Black Brant IX (Terrier-Black Brant VC)
37 –Viper Dart
39 - Black Brant Xl
40 - Black Brant Xll
41 - Terrier Orion

Organization Sponsoring Mission (first letter):

G - Goddard Space Flight Center
W - Wallops Flight Facility
N - Other NASA centers
U - College or University
D - Department of Defense
A - Other U.S. Government Agency
C - Industrial Corporations
I - International

Experiment (second letter):

E - Plasma Physics
G - Galactic Astronomy
H - High Energy Astrophysics
L - Planetary Astronomy and Atmospheres
P - Special Projects
S - Solar Physics
T - Test and Support
U - Upper Atmosphere Research

Example of Mission Number

3 3	. 0 3 5 U E	U	E
Taurus-Orion	35th Assigned Mission	College or University	Plasma Physics

Performance Characteristics

Performance characteristics for apogee altitude and weight capability and flight time above 100 kilometers for NASA sounding rocket vehicles are included in Figure 3-2. This data is presented for a sea level launch using a launch elevation angle of 85 degrees. Appendix E has detailed descriptions and flight performance characteristics for these vehicles.

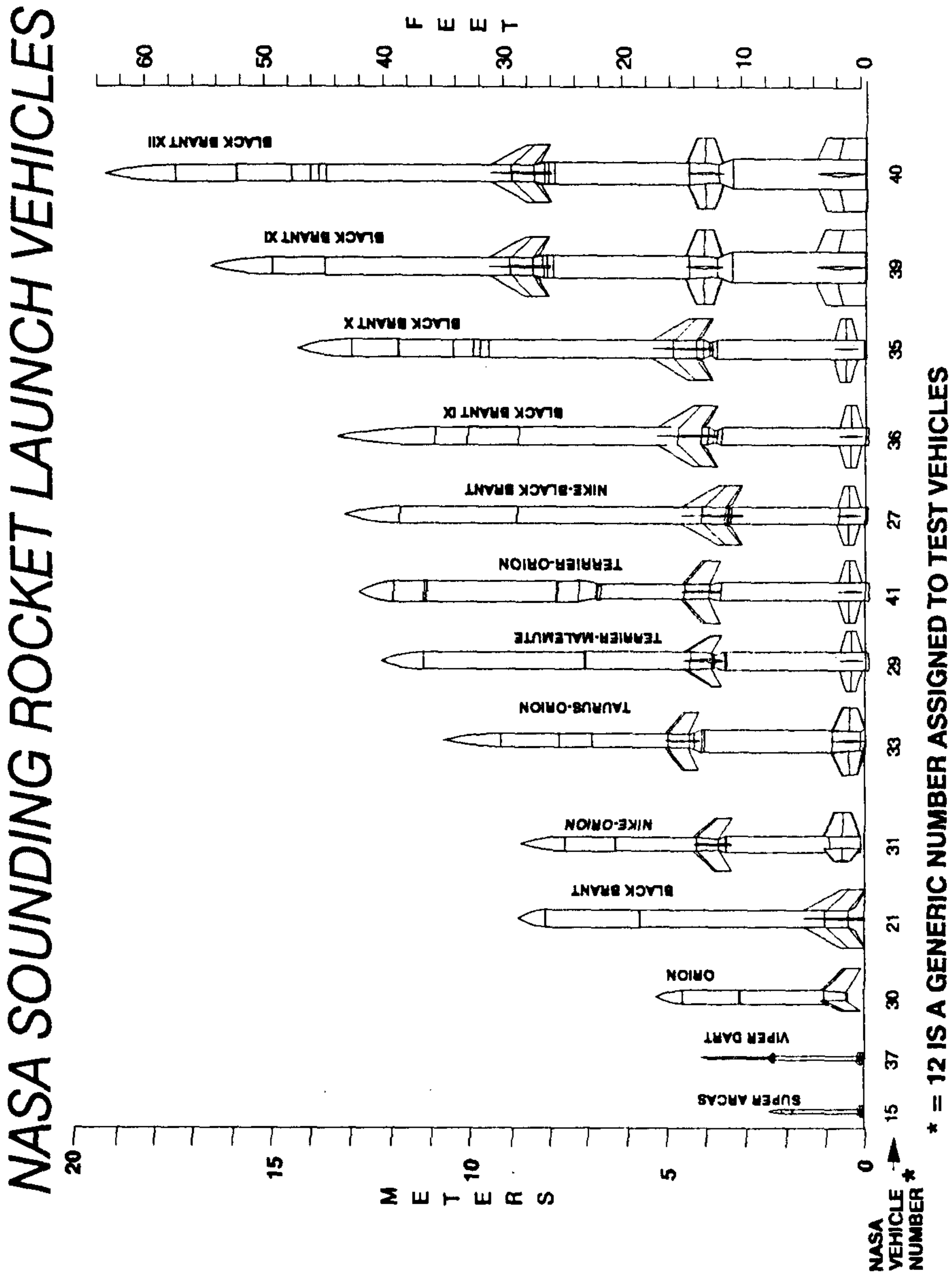


Figure 3-1. NASA Sounding Rocket Launch Vehicles

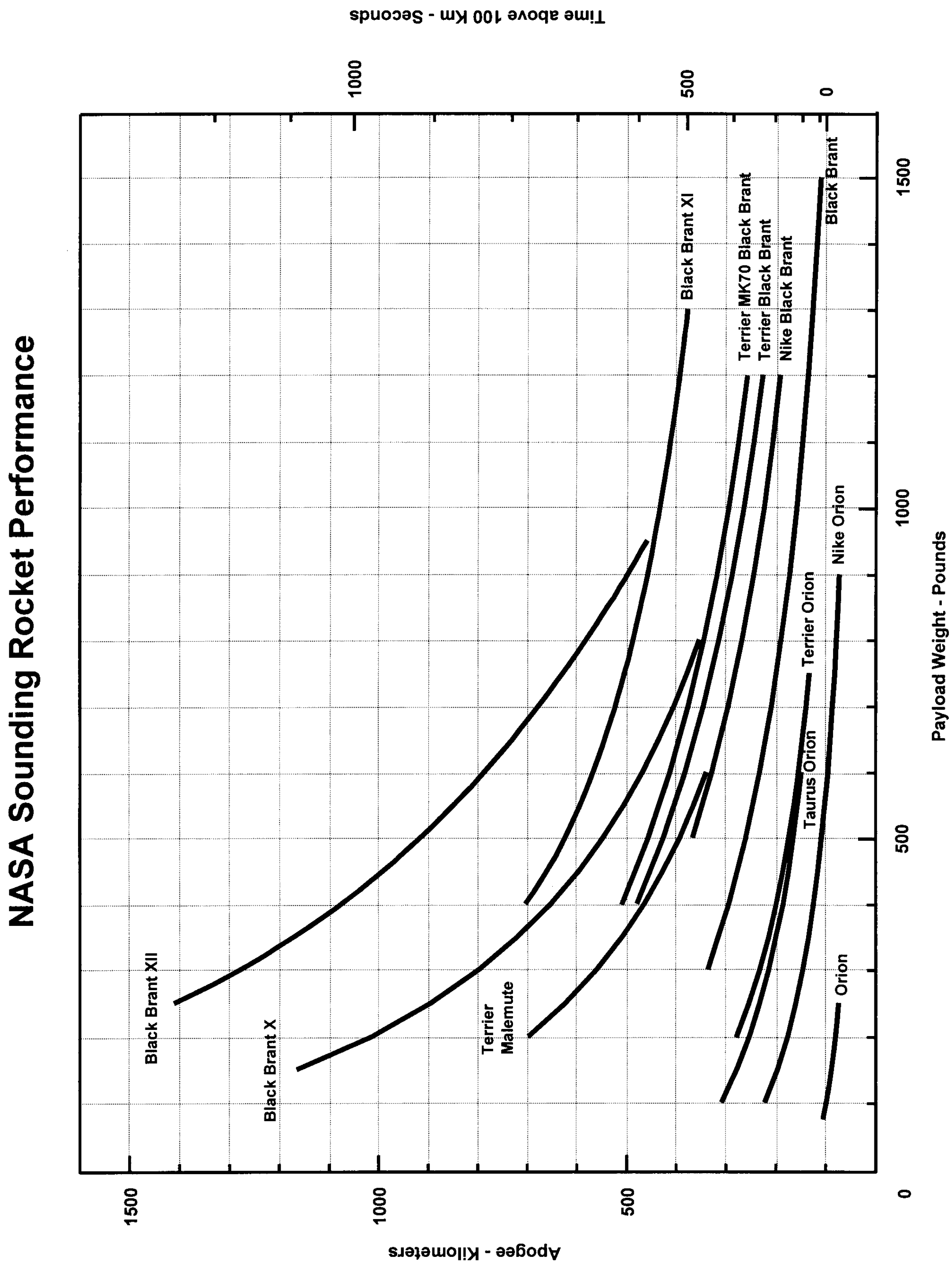


Figure 3-2. NASA Sounding Rocket Performance

3.3 S-19 Boost Guidance System

Purpose

The S-l9 Swedish (SAAB) developed Boost Guidance System, applicable to several sounding rockets, has unique capabilities. The main purpose of the S-l9 guidance system is to reduce impact dispersion and to acquire accurate trajectories. With this guidance system, it is possible to launch sounding rockets to higher altitudes and in higher winds while maintaining tolerable trajectory dispersion. Compared with an unguided rocket, a trajectory impact point dispersion reduction factor of 5-10 (depending on the detailed conditions) can be expected. The following launch vehicle systems currently use the S-l9 Boost Guidance System:

- Black Brant V
- Nike-Black Brant V
- Terrier-Black Brant V
- Black Brant X

Operation

The guidance system is a constant attitude control system. The vehicle pitch and yaw angles are detected by a gyro platform that produces corresponding output signals. These signals are processed in an auto-pilot and, after roll resolving, are used as servo command signals. There is no active roll control. Each servo turns a pair of canards, thus achieving vehicle aerodynamic control. The four canards are mounted pair-wise on two orthogonal shafts. Each pair of canards is deflected by a pneumatic servo that is supplied with nitrogen or air from a pressure vessel. The guidance system operates during the first 10 to 18 seconds of flight. Figure 3-3 is a photograph of the S-l9 Boost Guidance System.

Description

Major characteristics of the system are below:

Guidance Time

Lift-off to 10 - 18 seconds

Dispersion

Crossrange: <0.2 km/km apogee

Downrange: <0.25 km/km apogee

Example: Apogee 500 km gives <10 km crossrange and <12.5 km downrange dispersion.

Weight

Total 35 kg.

Dimensions

Length	0.4 m
Diameter:	0.438 m (17.26 inches)

Structure

One piece, magnesium casting 5mm skin thickness. Joints are male radial axial (RADAX) on the front and female RADAX on the rear. They are mounted as part of the payload.

Figure 3-3. S-19 Boost Guidance System

Section 4: Sounding Rocket Payload Design Considerations

4.1 Payload Design Activities

For new sounding rocket payloads, the most intense activity encountered by the Mission Team is the overall design of the payload. The Principal Investigator (PI) and his support staff will have to work very closely with the NSROC mission team. Mechanical and electrical design elements must be integrated with close attention to proper interfaces between all payload subsystems.

Sounding rocket payloads are designed to accommodate extremely diverse scientific objectives. As a result, individual payloads vary greatly in design characteristics and requirements. However, all payloads generally consist of most or all of the following subsystems that require coordination in the design phase:

- scientific instrumentation
- mechanical systems
- electrical systems
- event timing/programming
- pyrotechnic devices
- telemetry systems
- attitude control system
- recovery system

In addition to the above subsystems, the payload may also include sustainer ignition, separation, and despin systems. In general, however, these functions are provided by standard modules that are designed to interface with various standard sounding rocket launch vehicles.

Sounding rocket payloads must endure a relatively hostile flight environment during the rocket boost phase of flight. NASA has extensive experience in the flight environment and other factors which influence effective payload design. This Section describes many factors to be considered in payload design and construction to help ensure a reliable, safe, productive, and cost effective payload.

A well designed piece of equipment will pay dividends throughout its lifetime in reliable operation and ease of servicing and handling. However, the PI will normally have to make some tradeoffs in equipment design since many of the design factors are interdependent. It is axiomatic that a flight-proven design is likely to be more quickly available and more reliable than a new design. Always make sure there is no existing design that is adequate before a new design is undertaken with its inherent burdens of design qualification testing, debugging, and possible modifications.

4.2 Flight Environment

The environment for rocket payloads may prove hostile to the proper mechanical, electrical, and aerodynamic functioning of the payload. The controlled environment for payloads on earth abruptly changes at launch. Great variations in temperature, acceleration, atmospheric pressure, vibration, and other extreme conditions are encountered. The specific flight environment for any given flight demands consideration in the design and construction of successful payloads.

Mechanical Loads and Vibration

A major parameter to be considered in the design phase is the longitudinal and lateral loads imparted due to rocket motor thrust, steady state spin rates and abrupt changes in spin rate due to despin devices. Another major flight environment factor is the vibration induced by rocket motor burning. Longitudinal acceleration levels depend on the specific type of launch vehicle used. Unguided sounding rocket launch vehicles fly with a spinning motion to reduce the flight trajectory dispersion due to misalignments. Most vehicles do not exceed 6-7 cycles per second (cps); however, the Super Arcas vehicle spins at a maximum spin rate exceeding 20 cps. The effects of spin-induced loads should be considered when components are mounted off of the spin-axis. Load factors exceeding 30 g's can be experienced by components mounted near the payload external skin for large diameter designs. Most electronic devices utilize relatively small, lightweight circuit boards and components. When soldering is properly performed, and a conformal coating applied, problems due to mechanical loads are very infrequent.

The vibration environment depends on the type of launch vehicle and the mass and structural characteristics of the overall payload. Vibration testing is one of the key elements involved in qualifying a payload for flight; all payloads must pass flight acceptance vibration tests.

Vibration test specifications are a function of the type of launch vehicle used and are largely based on actual measured vibration levels during launch. Vibration transmission problems and generally thin sections can create excessive motion of sensitive electronic parts. Components supported by their leads are vulnerable to failure from vibration. Close spacing of components to each other or mechanical structures require rigid attachments to prevent abrasion and subsequent shorting. A detailed description of vibration testing policies and specifications is included in Section 7.

Thermal Considerations

Typically, sounding rocket launch vehicles reach very high speeds traveling through the earth's atmosphere. Surface heating at hypersonic speeds is significant due to the friction encountered flying through the air mass. In addition, atmospheric heating is encountered when a payload re-enters the atmosphere from space. Even though payload exterior skin surfaces experience relatively high temperature rises due to ascent aerodynamic heating, the temperature of internal components does not vary greatly over the course of a typical flight. This factor depends primarily on where and how components are mounted relative to the payload skin. Heating of electronic components due to operation over long time periods, e.g. during preflight check-out, can be more severe. While the payload temperature may remain fairly constant during flight, hot spots within the equipment may develop if the vacuum of high altitudes impedes the heat flow from components. Specially designed heat paths may be required to ensure overheating does not occur. Specific heating analyses can be performed as a part of the overall mission analysis for any given mission. Also, design personnel at WFF have accumulated data through experience and actual measurements regarding the thermal environment encountered during sounding rocket flight. If a particular component is sensitive to elevated temperatures, it may have to be insulated or isolated from heat sources.

Vacuum and Out-Gassing

When rocket payloads rapidly ascend in the atmosphere during launch, ambient atmospheric pressure drops quickly to essentially zero. Payloads are generally designed to vent internal air. Barometric switches are often utilized for switching functions in payload electrical subsystems. Some types of payload components may not tolerate low atmospheric pressures; if the experiment must be subjected to vacuum, be aware of good vacuum design practices. Avoid contamination crevices and lubrication problems. Many devices can withstand vacuum, but vacuum plus elevated temperature is much more difficult to survive.

The two most common undesirable effects of vacuum are reduced heat transmission and corona. Both of these problems are relatively easy to overcome if they are recognized early. Another design consideration which can degrade data is out-gassing. Check materials used for lacings, insulation, and tapes. WFF can advise on suitable materials and techniques to minimize out-gassing.

In many cases, some portions of payloads require hermetically sealed joints or doors to maintain sealed conditions either under pressure or vacuum. WFF has designed and developed numerous types of hardware for sealing purposes.

Aerodynamic Design Factors
Any design that involves any perturberance or change in the rocket skin shape should be evaluated for aerodynamic heating, drag, or stability problems that may result from these changes. A major element in overall mission analysis is the evaluation of launch vehicle stability (both static and dynamic). The payload configuration and structural bending characteristics must be adequate for acceptable flight parameters to be satisfied. Flightworthiness should be established during the initial design process; final mission analysis results are presented at the Mission Readiness Review.

4.3 Other Payload Design Considerations

Comments concerning some other factors which influence successful design practice include:

Accessibility
Accessibility is frequently overlooked. Reset devices, battery packs, film holders, lens covers, filling connections, and cable connections, should be located to facilitate replacement or removal.

Availability of Parts

Availability of parts may delay completion of the experiment. Never design around a part listed in a stock catalog or stock list without checking to see if it is in stock.

Long lead-time items should be identified and ordered early in the design processes. Order sufficient spares. Avoid designs based on any part which is inaccessible or for which there are a few of, if any, replacements.

Dynamic Balance

Designing a balanced payload may save balancing weights. A favorable center of gravity location can increase rocket stability as well as provide an acceptable re-entry body for recovery considerations.

Cost

The cost of each item should be examined, i.e., parts machined from solid stock versus formed, welded, or cast. Excessively close tolerances on dimensions should be avoided. Let experience and judgment be the guide in purchasing electronic components; although, reliability may not go hand-in-hand with cost, "bargain basement" parts should be avoided.

Redundancy

Redundancy is most desirable, it is usually not as easy to attain in mechanical equipment as in electrical circuitry, but it should always be considered. Redundancy may often be obtained by separate battery packs, multiple means for turn-on or turn-off, and other techniques.

Weight

Weight may be a very serious problem depending on the capability of the vehicle and altitude requirements. Determine as early as possible if there is a weight problem so measures can be taken to minimize it. Performance capabilities of NASA sounding rockets are covered in Section 3 and Appendix E. The weight of solder is usually not a consideration. Soldering performed according to NASA standards will insure that no useless solder is flown and will help maintain reliable electrical characteristics. Rigidity without great weight has been achieved occasionally by using the rocket skin as a support.

Testing

Make the experiment cost effective and efficient to test, calibrate, and debug by providing adjustments, test connections, and supports. Test points in electronic circuits should be standard practice.

Section 5: Payload Systems

5.1 Introduction

Payload systems support the experimental payload by providing for telemetry data acquisition, tracking, power, timing, protection, mechanical configuration, stability, and recovery. The effective design and integration of payload systems is one of the most important challenges to a successful mission. Figure 5-1 shows an excellent example of a complex payload system undergoing final checkout. This payload features an attitude control system, boom mounted sensors which deploy during flight, a recovery system, and data transmission features. The mission was a GSFC Space and Plasma Physics experiment.

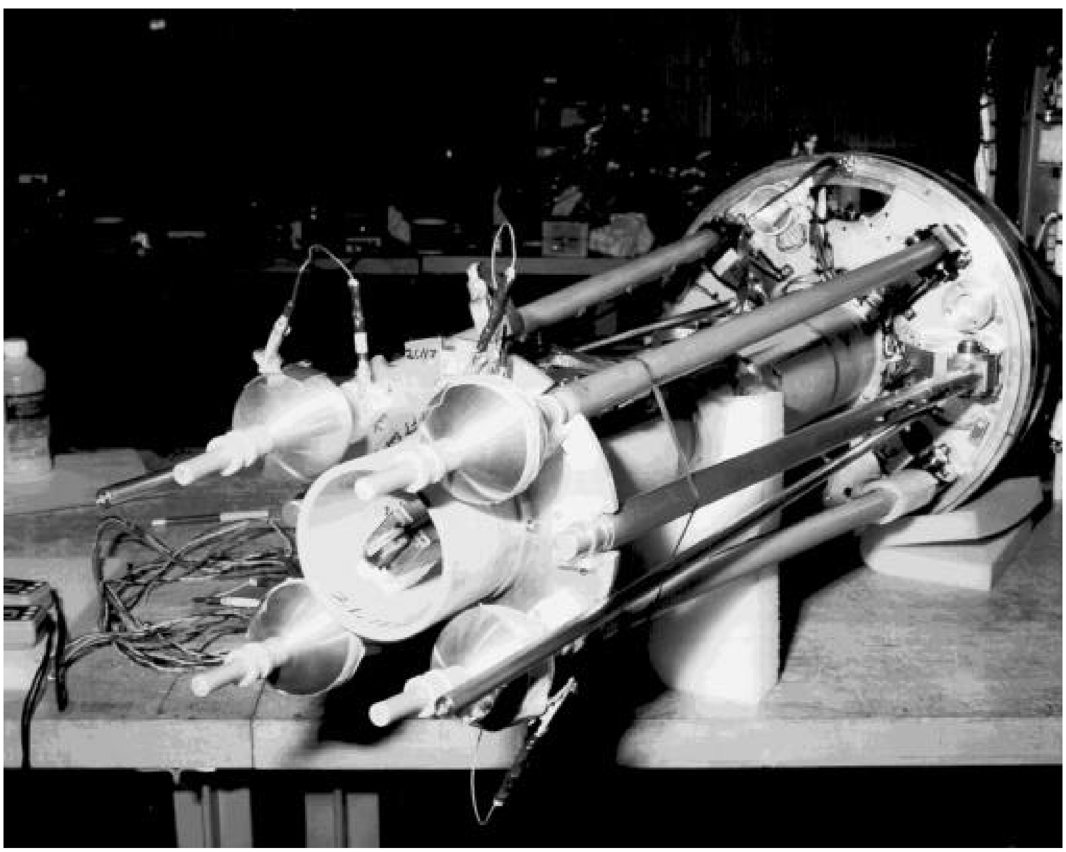


Figure 5-1. Payload for Plasma Physics Experiment Flown at WFF

This Section briefly describes payload system capabilities important to the successful experiment payload mission and sounding rocket program.

5.2 Telemetry Systems

General

Most data are obtained from sounding rockets by means of telemetry. The instrumentation system provided to the Principal Investigator (PI) takes many forms depending upon the complexity of the experiment, the configuration of the detectors, and the size of the rocket. In some cases, a separate instrumentation package is best; in other cases the instrumentation and detectors are fully integrated in the same housing(s). In either case, the instrumentation provides a means of formatting and transmitting the scientific and housekeeping data, provides control signals to the experiment, provides timing, and provides power if desired. Systems vary in complexity from a single link with no command or trajectory equipment to systems containing as many as eight down-links, command, and trajectory hardware. Almost all systems operate with S-Band (2200 to 2300 MHz) down-links although 1680 MHz is occasionally used for the down-links on some of the smaller rockets. Systems incorporating command uplinks use 568 MHz or 550 MHz for the uplink frequency.

Data Transmission Systems

Digital techniques are the predominant methods of transmitting data from a sounding rocket to the ground station; however, analog transmission is occasionally utilized in the NASA Sounding Rocket Program. Bi-phase or Non-return to Zero (NRZ) Pulse Code Modulation/Frequency Modulation (PCM/FM) and FM/FM are the two basic systems employed. PCM offers the advantage of many channels of accurate data readily convertible to processing. FM/FM offers the advantage of several channels of wide frequency response data that is required for measuring A.C. electric fields. When combined on the same payload the two systems complement each other and provide an excellent data collection system. Figure 5-2 shows a typical PCM encoder flown on sounding rockets. NOTE: With the advent of the WFF 93 PCM system very few FM/FM data systems are now flown. Occassionally a hybrid data system is flown where a single VCO output signal is mixed with PCM data and modulates a single downlink transmitter.

PCM/FM Systems

Three different types of PCM telemetry systems are currently used for NASA sounding rocket payload data requirements: the Vector MMP-900 System, the SPARCS WFF87 System and the WFF 93 System. Refer to Table 5-1 for a comparison of the characteristics of the three systems. Additional description and technical details are in Appendix F.

Table 5-1

PCM System Characteristics

	Bit Rate	Word Length	Frame Size	Parity	Output Code	Frames/ Subframe
WFF93	78 kb to 10 Mb	8 - 16	Up to 4k words	None	BiØL, M, S NRZL, M, S RNRZL Conv NRZM Conv NRZL	Limited to 4k
MMP 900 PCM	6.25, 12.5, 25, 50, 100, 200, 440, 800 kbit	8 9 10	2 to 256	Odd or None	BiØL, M, S NRZ-L, MS	2 to 32
SPARCS WFF87	12.5 kb to 800 kb BiØ up to 1.6Mb NRZ	8, 10, 12,	Up to 4k words	None	BiØL NRZS	Limited to 4k words

SPARCS Encoder System

The SPARCS system encoder, the WFF 87, incorporates more format flexibility and employs more modern components than the previously used ARC 75. Appendix F has technical details.

FM/FM Systems

In the FM/FM system several sub-carrier oscillators are multiplexed together and the composite signal is used to modulate an FM transmitter. Additional technical details are shown in Appendix F.

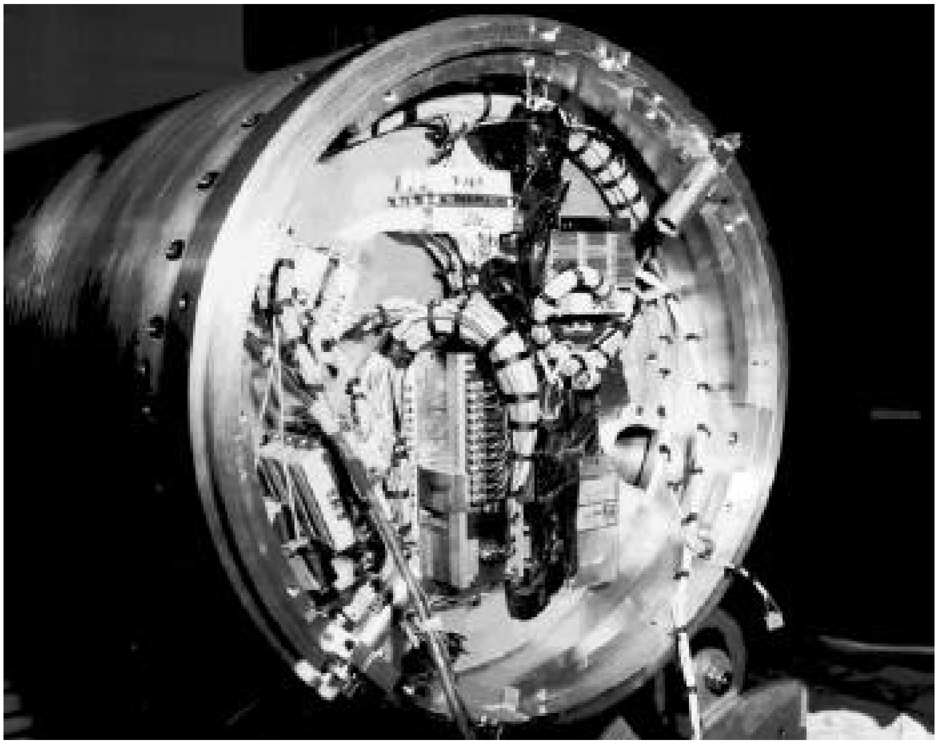


Figure 5-2. Typical WFF-93 PCM Encoder

PCM Versus FM

Whenever data are transmitted from one point to another, the question of whether to use an analog or a digital transmission system arises. In some cases the choice is clear, while in other cases, some study is necessary. Since FM is the most common analog technique used in telemetry it most often provides the standard of comparison for PCM.

No simple formula has been developed for comparing the two techniques because there are so many aspects to such a comparison. However, it is possible to contrast them in general terms. One of the most important points of comparison is the required accuracy of the system. If data accuracy is critical, (e.g. less than 1 percent error), a PCM is usually the choice.

Where large numbers of channels are involved, a PCM also has advantages, chiefly in size and weight. An airborne FM system of several hundred channels is quite bulky. However, an off-setting factor may be the frequency of the data to be handled. High frequency data channels require even higher sampling rates. In the extreme case, a few such channels could absorb the entire capacity of a PCM system which, in another arrangement, could handle many more low-speed or medium-speed channels. For example, to handle many channels of vibration data, an FM/FM system is likely to be the answer.

PCM has an advantage over FM when low power or a noisy transmission link results in a low signal-to-noise ratio. This comes about because the receiving equipment needs only to detect the presence or absence, not the height or shape, of a pulse.

5.3 Attitude Instrumentation Systems

General

Several types of attitude sensors are used to provide payload attitude information. These devices, used either singly or in combination, employ a variety of techniques discussed below.

Magnetometer

Depending upon the scientific requirement two axis and three axis magnetometers are used. This data, along with data from a solar/lunar or horizon sensor, is used to construct attitude. The magnetometers used are flux gate devices with +600 milligauss range of field and provide an accuracy of approximately 3 or 4 percent when calibrated in place in the payload. For applications where accuracy is a prime consideration, extreme care must be exercised in the placement of the unit to avoid stray fields generated within the payload.

Attitude Gyroscope

A gyroscope based inertially-referenced attitude sensor is available for experiments requiring coarse 3-axis payload attitude information (1-3 degrees in all axes). This attitude sensor, referred to as MIDAS, is manufactured and refurbished by Space Vector Corporation. The sensor is 7.5 inches in length by 5.25 inches in diameter and weighs approximately 8.3 pounds. The MIDAS unit consists of a pair of two-degree-of-freedom displacement gyros mounted on a roll-stable platform.

The spin axes of these gyros are arranged so that one of the gyros, the roll-yaw gyro, senses platform roll and is used to stabilize the platform by use of a servo motor. This roll-yaw gyro is also sensitive to vehicle yaw motion. The second gyro, the pitch gyro, senses vehicle pitch displacement. A photograph of the MIDAS attitude sensor is shown in Figure 5-3.

Solar/Lunar Sensors

The solar/lunar sensor is a device that detects the passage of the light source across slits on the face of the sensor as the rocket spins. Each revolution of the sensor results in a group of two pulses. As the aspect angle changes, the spaces between the pulses change. This device, used in conjunction with a time event module in a PCM system, provides an accurate and relatively easily reduced data set which when used in conjunction with magnetometer data can provide attitude information.

Horizon Sensor

Horizon sensors have been used which operate in the 5 micron region and the 15 micron region. These devices consist of a focusing lens, a filter, a thermal detector and associated electronics. Transitions of the horizon is automatically detected by the sensor which views out from the circumference of a spinning rocket. This information, combined with data from a magnetometer, provides a source of attitude information.

Television Cameras

Television cameras featuring low power consumption, compact size, and very high sensitivity are available for sensing star backgrounds. These intensified charge injection device cameras have a threshold sensitivity of 10^{-6} foot candles face-plate illumination and are compatible with standard broadcast monitors and recorders. These cameras operate from a 12 volt D.C. supply and require less than 10 watts of power. Volume is approximately 75 cubic inches and weight is less than 30 ounces. The output from these cameras is transmitted using a wide band TV transmitter.

Film Cameras

Thirty-five millimeter motor operated film cameras are provided for use in recording star backgrounds. These cameras are driven from a pulsed power supply programmed by payload timers or by special interfaces provided by the Principal Investigator (PI).

Figure 5-3. MIDAS Attitude Sensor

5.4 Transmitters

A variety of data transmitters are employed with a range of power from 600 milliwatt to 10 watt units. The transmitters are true FM units which are generally A.C. coupled. Transmitters used on a given project are sized to provide the necessary link margin while at the same time minimizing power requirements. These transmitters have frequency response up to 1.5 MHz and can be deviated +l MHz.

For wide band data or television transmission, special TV transmitters are used. These units have output power of 10 watts, frequency response to 20 MHz, and can be deviated ±6 MHz or ±12 MHz depending upon the unit used. Linearity is 2% maximum and total distortion is 2% maximum for ±7 MHz deviation.

5.5 Command Systems

Several different command systems are available depending upon the complexity of the command requirements, the launch location, and the other flight hardware configurations on the payload. All of these command systems require an up-link in the 400 MHz or 550 MHz range. Ground stations are equipped with capability ranging from one or two ON/OFF commands to the capability to point a sensor at various areas of the sun or some other target. Both tone and digital type systems are used. Command rates vary depending on the system used, from several seconds per command to several commands per second.

5.6 Telemetry Antennas

Several types of antennas are used depending upon the function to be performed, the payload and vehicle configuration, and the radiation pattern coverage required. For data transmission, a family of micro-strip antennas has been developed. These antennas, in 6-5/8, 9, 12, 14, 17, and 22 inch diameters, are configured in a variety of ways to allow installation beneath nose cones or other RF transparent skins and to provide varying degrees of thermal protection for different vehicle types. These wrap-around units require from 4 to 5-1/4 inches axially along the payload body. Some use is also made of micro-strip and strip-line antennas made by Ball Brothers and New Mexico State University, respectively. All of these data transmission antennas are linearly polarized and provide a basically omni-directional pattern with nulls at the very center of the nose and tail of the vehicle.

For command and trajectory (TRADAT) purposes, the most commonly used antenna types are quadraloops and spikes. These systems may consist of either two or four elements. Radiation coverage can be adjusted by the manner in which the elements are connected, and this is frequently done to provide maximally aft or maximally broadside patterns.

For radar transponder applications, two slotted blades or two Valentine units are normally used. These elements are mounted 180° apart and are fed from a two-way power divider. Special antennas such as cavity backed slots, bent wires, disc micro-strip, and rectangular micro-strip have been designed for unique applications in both the data acquisition and command areas.

5.7 Instrumentation and Experiment Power Supply

General

The electrical power for instrumentation and experiment electronics on sounding rockets is derived from batteries. The selection of the battery system type is based on a consideration of weight, size, capacity, and system power requirements. Although several types of battery systems are available, the ones used by WFF are silver zinc and nickel cadmium.

Silver Zinc Cells

Two different types of silver zinc cells are used in the NASA Sounding Rocket Program

1. High Rate Discharge Series This series of cells is designed for applications that require the total energy of the cell to be expended in one hour or less. The wet life (life after filling with electrolyte) of this series is approximately 10 to 20 charge /discharge cycles or 6 months, whichever comes first.

2. Manually Activated Primary Series This series of cells is designed for applications that require quick activation and high rate discharges. The wet life of this series is approximately 3 to 5 charge/discharge cycles, or 15 to 30 days, depending upon particular cell design

Nickel Cadmium

All of the nickel cadmium cells that are used in sounding rocket payloads are of the cylindrical sealed cell design. These cells incorporate a resealable safety pressure release vent and are virtually maintenance free.

Relative Advantages

The main advantage of the silver zinc system is that its energy density is approximately three to four times greater than that of the nickel cadmium system.

The advantages of the nickel cadmium battery system are:

1. Much less expensive
2. Not subject to electrolyte leakage
3. Can be mounted in any position
4. Longer life span and cycle life
5. Same battery that is used for environmental testing can be used for flight
6. Not sensitive to overcharge
7. Maintenance free

Both battery systems have a very successful flight history and are equal in reliability. However, the nickel cadmium system is normally the preferred system, primarily because of monetary considerations. Appendix G lists comparison and performance characteristics for various battery systems.

Voltage Output

The nominal system voltage output from the battery is 28V DC ±2V. PI's requiring voltages other than the nominal 28V DC are requested to provide their own power conditioning. The experiment's 28V can be supplied from the instrumentation batteries or from a separate 28V battery located in the instrumentation section. Some PI's prefer to supply their own battery. The PI should provide circuit protection to assure that other flight circuits are not affected by short circuits occurring in the experiment payload equipment.

Heaters

Externally powered battery heaters are installed on battery boxes in order to maintain battery temperatures above 60°F prior to launch. When this feature is adopted, careful design considerations should be employed to prevent over-heating.

Switching

In order to prevent power loss due to inadvertent relay transfer, all on-board power switching relays are backed up by first-motion lift-off switches or 5,000-foot altitude switches.

Pyrotechnic Power Supply

Power for payload pyrotechnic functions is normally supplied from a separate pyro battery. Voltage is made available to the pyro bus through 50,000-foot altitude switches. Squib monitor circuits provide telemetry with an indication of squib firings.

5.8 In-Flight Event Timing Systems

In-flight event timing is normally controlled by mechanical, electromechanical, or electronic timers including barometric switches.

Mechanical Timers

Mechanical timers consist of three basic components: "G" weight actuator, a spring wound timing mechanism, and an electrical switch system controlling external circuits, that are put into operation at the preset time. Units with three, four, six, or eight switches are available. Maximum time capacities range from 90 to 600 seconds.

The manufacturer's specified time accuracy is ±2% of the full time range of the timer; however, experience has shown that repeatability within ±3 seconds of the set time can be obtained.

Electromechanical Timers

Electromechanical timers consist of two basic components: 28v DC chronometrically-governed timing motor and an electrical switch assembly that controls external circuits. Units with either 9 or 13 switches are available. Event timers up to 720 seconds maximum can be obtained.

Electronic Timers

The timer uses CMOS logic circuitry for low power consumption and has a battery backup to keep the timing circuit active in case of a dropout on the payload power bus. Time-event decoding is done by programming EPROMs that enable a +28v DC sourcing output. There are 32 discrete outputs available. Each output can provide +28v DC into a minimum load impedance of 150 ohms. Events can be spaced as close as 100 milliseconds apart. A limited ability to provide random event programming also exists.

The timer can be started by either of two methods:

1. "G" or lift-off switch closure
2. Umbilical release at lift-off

A safe/arm latching circuit insures that the timer does not accidentally start when using the umbilical release method.

Barometric Switches

Barometric switches are used to hold off initiation of functions due to contact chatter during motor burning. Barometric switches operate at preset altitudes to activate or turn off various electronic functions such as internal power. Usually redundant switches are installed; however, they are sensitive to their location. Good design will place them in a location on the payload where they will not be adversely affected by aerodynamic air pressures.

5.9 Tracking Systems

Three types of tracking systems are used on NASA sounding rockets: radar transponders, Trajectory Data System (TRADAT), and GPS.

Radar Transponders

Radar transponders are used to enhance the tracking capabilities of radar. The transponder contains a receiver and a transmitter, both operate in the same frequency band as the tracking radar but are normally tuned to separate frequencies. This frequency separation is normally 75 MHz. The tracking radar interrogates the transponder by transmitting a pulse (or pulse pair depending upon the coding) at the proper frequency. Double pulse codes are normally set on an integer value between 3.0 and 12.0 microseconds. Upon receipt and detection of a valid interrogation (i.e., correct frequency and code) the transponder will transmit a reply pulse after a known fixed time delay (typically 2.5 microseconds).

The power output from a transponder ranges from 50 to 150 watts and provides a much stronger signal to the radar than is obtainable from the reflected skin return from the sounding rocket. The signal level received at the radar from a transponder decays at 6 dB/octave with range, whereas the skin return decays at 12 dB/octave, thereby providing as much as two orders of magnitude greater range tracking capability when using a transponder. The transponder requires an external antenna system. On sounding rockets this may consist of two slotted blade antennas mounted 180° apart on the skin which feed from a two-way power divider.

Transponders are used for several reasons:

1. To provide full trajectory tracking when the radars do not have skin tracking capability through the full trajectory.

2. To provide discrimination between vehicles which are in flight at the same time by means of frequency and/or coding.

3. To provide a higher probability of obtaining tracking data right off the launch pad.

4. To provide higher precision data than is available from skin track due to higher signal-to-noise ratio and a point source target.

TRADAT

The Trajectory Determination (TRADAT) system can provide trajectory information for any rocket, balloon, or airborne device that employs a ranging receiver and a telemetry receiver.

The TRADAT system was designed to be a lightweight, portable, relatively inexpensive means of providing trajectory data for vehicles which are launched at remote sites where radar sets are not readily available. The system uses range derived from a 16-bit PCM code which is transmitted through the vehicle in flight, and angles derived from a telemetry tracker to compute a trajectory.

The up-link signal, which is 3.9 kbit PCM, is transmitted to the flight vehicle on a 550 MHz carrier from a 28 watt or 200 watt FM transmitter. The signal may directly modulate the carrier or it may modulate a 70 kHz sub-carrier which in turn modulates the carrier. The signal is removed from the carrier in the airborne receiver and multiplexed with a telemetry down link.

In the ground TRADAT unit, range, angles, time, and status are multiplexed on a 1 kbit PCM link for recording along with other data parameters. Simultaneously, the data is processed to generate trajectory parameters which are printed for real time evaluation.

GPS

The WFF GPS Flight System is based on a 12 channel, L1 band, civilian code GPS receiver, wrap-around antenna, and preamplifier. Wrap-around antennas are available in 17.26” and 14” diameters. Time, position and velocity data, and timing signals are multiplexed and transmitted with the S-Band telemetry.

Ground support is provided by a lunchbox size computer which decommutates the S-Band video, and outputs a real-time differential solution and graphic display of payload position overlaying predicted path.

5.10 Mechanical Systems and Mechanisms

Nose Cones

Several types of nose cones are available for each of the different sounding rockets. Standard split nose cones with pyrotechnic ejection systems are available for 6-5/8, 9, 12, 14, and 17.26 inch diameter payloads.   One-piece aluminum nose cones are available for 6-5/8, 9, 14, and 17.26 inch diameter payloads. Fiberglass nose cones are available for 4-1/2, 6 and 6-5/8 inch diameter payloads. Stainless steel nose cones are available for 9, 12, 14, and 17.26 inch diameter payloads. Phenolic nose cones are available for 9 and 14 inch diameter payloads.

Nose cones of other materials or special shapes can be provided when necessary.

Structures and Skins

Structures and skins for the 6-5/8, 9, 14, 17.26, and 22 inch diameter payloads are usually custom made although some standard items may be used. A standard structure is available for the instrumentation section and is used where feasible.

Vacuum Doors

Electrically operated vacuum doors are available for 17.26 and 22 inch diameter payloads. These doors open an aperture of approximately 15 and 20 inches diameter respectively at either end of a payload structure. Vacuum doors are also available which open a rectangular aperture in the side of a 17.26 inch diameter payload. Vacuum doors may be operated to open above the atmosphere and close again before re-entry maintaining a vacuum tight seal during re-entry.

Deployment Mechanisms

Deployment mechanisms actuated by pyrotechnic or other means are available for doors, booms, shutters, etc.

Vacuum/Water Sealing

Payloads may be designed with sealed sections with appropriately sealed feed through devices to prevent entry or exit of gasses and liquids as required.

Miscellaneous Hardware

Standard battery boxes, pyrotechnics, and actuators are available at WFF.

Despin Systems

In many cases, payloads must operate without the residual spinning motion imparted by the launch vehicle. Also, in special cases, payloads must have very specific spin rates in order to accomplish scientific goals. Payload despin (to zero or to a pre-determined rate) can be accomplished by the use of mechanical yo-yo despin systems which release weights on fly-away cables which are wrapped around the payloads circumference and unwind when released. This technique is relatively simple and very reliable. The despin system can be utilized to despin both the launch vehicle final stage and payload prior to payload separation. Payloads can also be despun following separation from the vehicle. Roll control (roll-up or roll-down) can be provided by cold gas pneumatic systems. These systems are generally part of attitude control systems which are discussed in Section 5.13 and Appendix H.

5.11 Recovery Systems

Introduction

The primary use of recovery systems is to recover the payload so it can be refurbished and flown again. However, it is also necessary to recover some payloads to obtain scientific data, e.g., exposed film or atmospheric samples. Two types of payload recovery are used on sounding rockets:

• LAND
• WATER

Land

Four different parachutes are used for land recovery, their principal characteristics are listed below:

Type	Maximum Weight (Pounds)
24 Foot Flat Circular	300
28 Foot Flat Circular	750
36.2 Foot Cross	750
50.25 Foot Cross	1000
56.75 Foot Cross	1250
64.4 Foot Cross	1500
73 Foot Cross	2000

All of these parachutes are deployed in the 15,000 to 20,000 foot altitude region at a maximum dynamic pressure of 250 pounds per square foot.

Water

The water recovery system is rated for gross payload weights up to 500 pounds and it will float up to 225 pounds. At WFF, water recovery can be by boat, e.g., US Coast Guard or commercial source or by helicopter. Larger payloads must have floatation built into the payload.

Recovery Aids

Recovery aids assist in the location of the payload to facilitate recovery. The common recovery aids are:

- Flashing Strobe Light
- Homing Beacon Transmitter
- Smoke or Dye Marker
- Color Design of Canopy
- Reward Tags
- Sonar "Pingers"

5.12 High Altitude Decelerators

Standard Configurations

High altitude decelerator systems are used to slow a payload so that more time is available for an experiment to be conducted in a specific altitude region. The High Altitude Decelerator is designed to provide a highly stable, high drag area system to successfully deploy from a rocket at altitudes ranging from 40 to 100 kilometers. Of course, the higher you deploy a decelerator, the longer it will take to slow down. But typically, most systems reach equilibrium velocity in the altitude region of 60 kilometers. The characteristics of the four most reliable and frequently flown systems are listed below showing minimum dynamic pressure "Q" and maximum weight.

	"Q" (PSF)	MAXIMUM WEIGHT (Pounds)
16.6 Foot DGB*	0.0018	16
28 Foot DGB*	0.004	50
48 Foot DGB*	0.007	83
63.5 Foot Cross	0.0072	170

*Disc Gap Band

Special Purpose

High altitude decelerators are sometimes specially designed to meet specific scientific mission requirements. Spinning parachutes which use aerodynamic vanes along the canopy skirt or between shroud lines have been developed to provide a spinning sensor platform. This type parachute has been used for spin rates up to 2 cps, depending on descent velocity. Also, special radar-reflective decelerators have been developed for high-altitude wind sensors.

WFF can design special purpose systems to meet unique payload requirements. WFF has the facilities for the design, test, and operation of high altitude decelerators and integration with payload/sensor packages.

5.13 Attitude Control Systems

Overview

Attitude Control Systems (ACS) provide a stable pointed viewing platform for rocket experiments. Sounding rocket ACS has made possible the acquisition of large amounts of previously unobtainable scientific data at a relatively low cost. Since a large portion of a flight (typically five minutes or more after burn-out) is spent well above the atmosphere, scientific observations can be made without atmospheric distortion. Because atmospheric disturbance torques are low during the vacuum free-fall portion of the flight, the rocket can be pointed to any desired orientation and held there with relatively little force.

Typical payload objectives range from upper atmospheric studies, observations of the spectral distribution of the energy from stars, planets, and X-ray sources, and magnetic field studies.

ACS Selection

WFF selects the most appropriate flight system based on requirements of the experiment and availability of the system for individual launch vehicle and payload configurations. WFF has four flight-proven pointing systems for a variety of applications: Mark VI, Magnetic ACS , Space Vector System, and SPARCS.

A rate control system is available for applications requiring very low angular rates, e.g., microgravity research. Figure 5-5 shows the principal characteristics of the systems. The systems are described in more detail in Appendix H and, for SPARCS, in Section 6.

• Mark VI*	±2-5 Arcmin Non-Trackable Target
(Position/TRIG's)	On-Board Micro-Processor
	Drift Rate—10 Arcsec/Min
Magnetic—Referenced	Spinning Payloads Only (0.5-2.0 CPS)
(3-Axis Magnetometer)	System Will Align to Within 1-2° and
	Has Spin Rate Control Capability
• Space Vector	±3° Inertial Accuracy
(Position Gyros)	± 0.5° Track on Sun (Tracker)
	Drift Rate—5 Arcmin/Min

• LMSC/SPARCS*	Solar Pointing Only
(Solar Trackers/Mag)	High Accuracy (±30 Arcsec on Sun Center)
	Drift Rate—2 Arcsec/Min
Rate Control System	Maintains Low Rate (No Attitude)
(3-Axis Rate Gyro)	(0.2 °/Sec or Less – 3 Axes)
	(10^{-4} to 10^{-5} G's)

*Real-Time Ground Command Capability (±1-2 Arcsec)

Figure 5-5. Attitude Control/Stabilization System Capabilities

Section 6 - NASA Solar Fine-Pointed Rocket Payloads

6.1 The SPARCS Description

Introduction

In the mid-1960's, a rocket-borne solar research activity was initiated at NASA Ames Research Center. A contract was awarded to develop a unique, gyro-less solar pointing attitude control system for use on Aerobee sounding rockets. This system was referred to as the Solar Pointing Aerobee Rocket Control System (SPARCS). NASA responsibility for SPARCS was transferred from Ames Research Center to Goddard Space Flight Center in the mid-1970's. Since the Aerobee liquid-fueled rockets have been replaced by more efficient solid-fueled types, the SPARCS designation has been rephrased to Solar Pointing Attitude Rocket Control System. The support for solar-pointed sounding rocket payloads launched from White Sands Missile Range (WSMR) is not limited to the SPARCS, itself. A total payload support capability exists for payload integration and testing including airborne telemetry and electrical systems support. NASA sounding rocket activity at WSMR, including all SPARCS support, is coordinated through the NSROC contractor at WFF. Most of the payload support for SPARCS missions at WSMR is provided by the NSROC contractor, with the exception of launch operations that are supported by other organizations.

Using standardized flight proven components, SPARCS provides unique capabilities for solar experiments requiring fine pointing accuracy and stability when pointing at the sun or near vicinity. SPARCS payloads are generally configured to be flown on boosted Black Brant V launch vehicles. (See Appendix E) Solar pointing can be automatic to a specified position on the sun, or under the control of the Principal Investigator (PI) using a joystick and command up-link for three axis control. Data are received through telemetry, or on film when the payload is recovered. The SPARCS is a very reliable system and has been flown on over 160 missions with a success rate of over 93 percent.

SPARCS Program Elements

The SPARCS Program features the following elements, all maintained by NSROC at WSMR:

1. Solar Pointing Attitude Rocket Control System
2. Airborne Instrumentation (telemetry) System
3. Payload Integration and Test and Evaluation (T&E) facilities
4. Principal Investigator and program support facilities
5. Launch support

6.2 SPARCS Attitude Control System and Command Up-link

Description

The SPARCS control system is a highly accurate, low jitter, solar pointing system. In conjunction with the command up-link, the system is capable of pointing within arc seconds of a target on the sun. The SPARCS uses Coarse Sun Sensors (CSS) and a Miniature Acquisition Sun Sensor (MASS) to control the payload to within 2° of the sun (the sensors' fields of view overlap). The Fine Sun Sensor (FSS) or Lockheed Intermediate Sun Sensor (LISS) can control the payload from 10° to the selected target on the sun.

Targeting

The PI selects the target(s) on the sun before launch and SPARCS is remotely programmed during the last few minutes of the countdown. After the payload is pointed at the target, the PI may use the airborne command up-link to re-position the payload or change targets. The SPARCS will accept discrete push-button steps or the PI may use a joy-stick. A video image of the target or some method of indicating the pointing position relative to the target is required to provide this real-time control capability. Another option is the use of a pre-programmed scan pattern. The scan pattern may be started by an onboard timer function or by the command up-link.

Accuracy

The pointing jitter in pitch and yaw is sub-arc second, typically 0.20 to 0.5 arc seconds peak-to-peak. SPARCS uses a 2-axis magnetometer to control the roll position and can point the payload to +5° from a selected angle. A Rate Integrating Gyro (RIG) section can be added to the payload to reduce the drift in roll within 0.2° to 0 5° per hour.

Size/Weight

The SPARCS weight is 65 pounds which includes control gas and the command up-link hardware. The 17.26 inch diameter skin section can vary between 8.313 inches and 9.25 inches long.

Airborne Real-Time Command Uplink

The command receiver operates at 568 MHz with a minimum sensitivity of -101 dbm. Airborne signal level predictions at the command receiver are derived from slant range, payload antenna Radiation Distribution Pattern (RDP), and payload attitude and roll angle vs. the ground transmitter power, antenna gain and location. SPARCS command up-link can provide up to 15, single-throw double pole closures. The closures duration is controlled by software from momentary to latching. The commnds are sent by push button operation on the SPARCS Command Up-link Ground Unit (SCL/GU). It can also provide 3-axis offset commands, 1023 steps in pitch and yaw, to produce from 2 to 5 arc-seconds step. Roll can be commanded to any angle in 0.1° to 0.35 steps (dependent upon the ETA (h) angle, the angle between the solar vector and the earth's magnetic vector)

Automated SPARCS Command Up-link (ASCL)

The ASCL can provide 3-axis joystick control of airborne payloads. There is real-time analysis and data display of experiment information to provide the PI with the tools for critical decision making tasks during the flight. Pre-programmed absolute offsets can be set up to point at different targets during the launch. Table 6-1 lists SPARCS system specifications.

Table 6-1.
Solar Pointing Attitude Rocket Control System
(SPARCS) Specifications

PITCH/YAW PERFORMANCE:

Absolute Pointing Error is a function of the SUN sensor used (FSS or LISS) and the optical alignment.

PITCH/YAW JITTER amplitude (excludes external disturbances):
  1.0 arc-second p-p maximum.
  .2 to .3 arc-second p-p 90% pointing time.

PITCH/YAW DRIFT during the total fine pointing phase:
  Up to 7 maximum arc-seconds in each axis.

Table 6-1.
Solar Pointing Attitude Rocket Control System (SPARCS) Specifications (Continued)

ROLL PERFORMANCE:
ABSOLUTE pointing error:
±5 degrees maximum.

ROLL JITTER amplitude (excludes external disturbances):
0.1 degrees p-p maximum.
0.05 degrees p-p 90% pointing time.

ROLL DRIFT during the total fine pointing phase:
1.2 degrees total. Unless a RIG is used for control.

ROLL RIG (Rate Integrating Gyro) Specifications:
.25 degrees/hour maximum.

6.3 Instrumentation (Telemetry)

The SPARCS payloads use a standard airborne instrumentation telemetry system and specific standards for interface with the PI experiment. Pulse Code Modulation (PCM) encoders feed S-Band transmitters to send experiment and payload subsystem data to the ground.

The system presently uses a WFF 93 encoder that supports bit rates to 10 mb/sec and a WFF 87 encoder that supports bit rates from 12.5 kb/sec to 1.6 mb/sec bi-phase L or up to 1.5MB/sec NRZS. The systems have one or more S-Band transmitters, a TV S-Band transmitter for a video link, a Triplexer, a PSL stripline antenna band (2279.5 MHz, 2251.5 MHz, 2215.5 MHz) a radar beacon, command receiving decoder, and a set of four PSL 568 MHz quadraloop command up-link antennas.

The system furnishes battery power and timer functions to the experiment and to other subsystems on the rocket payload. The SPARCS instrumentation system currently uses 600 second electronic timers. Slower motors are available (time must be allowed to purchase and configure the timers) for longer timed functions. These timers provide 13 timed functions each; additional timers may be added for more functions.

Power is supplied by battery packs fabricated by PSL. These packs supply 28 v DC at 3.5 ampere hours. Higher currents can be supplied for a shorter time period; 9 amperes can be supplied from one of these packs for a nominal 18 minute period in flight (adequate for a 200 mile high flight). Voltage taps on the battery packs are available if required. Regulated voltages of 2.5 v DC and 5 0 v DC are available at up to 0.5 amperes.

6.4 SPARCS Payload Integration Facilities

The SPARCS payload integration facilities at WSMR have capabilities for payload and component vibration, dynamic balance, moment of inertia, center of gravity measurements, bend test, and magnetic calibration. Listed below is a brief description of the facilities and their capabilities.

Vibration Facility

Vertical height above shaker fixture to hook on bridgecrane in thrust axis = 189 inches
Vertical height above shaker fixture to ceiling in thrust axis = 232 inches
Vertical height above shaker fixture to hook on bridge crane in lateral axis = 203 inches
Vertical height above shaker fixture to ceiling in lateral axis = 246 inches

Table 6-2 shows the capabilities of the Vibration Facility.

Table 6-2
Vibration Facility Capabilities

SINE VIBRATION:

FORCE POUNDS in SINE LATERAL = 15,000 pounds			
	or 15,000/10g's	=	1500 pounds TOTAL
			- 346 pounds FIXED MASS
	LATERAL	=	1154 pounds PAYLOAD CAPABILITY
FORCE POUNDS in SINE THRUST = 15,000 pounds			
	or 15,000/10g's	=	1500 pounds TOTAL
			-136 pounds FIXED MASS
	THRUST	=	1364 pounds PAYLOAD CAPABILITY

Table 6-2
Vibration Facility Capabilities (Continued)

RANDOM VIBRATION:

FORCE POUNDS in RANDOM LATERAL = 12,000 pounds			
	or 12,000/12.7g's	=	944.9 pounds TOTAL
			- 346 pounds FIXED MASS
	LATERAL	=	598.9 pounds PAYLOAD CAPABILITY
FORCE POUNDS in SINE THRUST = 12,000 pounds			
	or 12,000/12.7g's	=	944.9 pounds TOTAL
			-136.0 pounds FIXED MASS
	THRUST	=	808.9 pounds PAYLOAD CAPABILITY

Dynamic Balance (on MRC Corporation Machine)

Total Weight capability is 2500 pounds.

Length of payload (Crane Hook Height): The crane hook height is 52 feet.

RADIUS 48 inches maximum (if fixtures are available).
Total indicated Runout is also performed on this machine.

Dynamic Balance to 3.5 ounce - inches squared for a small 25 pound payload to less than 1000 ounce - inches squared with a 1500 pound payload.

Moment of Inertia (on MRC Corporation Machine) Pitch/Yaw & Roll

Total Weight capability is 2500 pounds
Total Length is 240 inches
Overall Accuracy ±.3% of actual

Center of Gravity (on MRC Corporation Machine) Pitch/Yaw & Roll

Within 0.005 inches in Pitch, Yaw & Roll

Bend Test

1,000,000 Inch-Pound capability on Total Payload (dependent upon length)

Vacuum Systems

Turbo-Molecular Pump @ 1500 liters/minute and 1 x 10^{-6} or 10^{-7} torr (dependent upon payload outgassing)

Tower Retraction Mechanisms available

Helium Leak Test System available

Vacuum Tank with diffusion pumps capable of holding the complete experiment with capability to 1 x 10^{-6} or 10^{-7} torr (dependent upon payload outgassing)

Magnetic Calibration Facility

3-axis Station Magnetometer digital readout in milligauss

10 foot diameter Helmholtz coil with adjustable vector from zero to > one earth field in any axis.

Dark Room

Rotary light seal
Enlarger
Print washer
Temperature controlled water
Pressurized and filtered air to minimize potential dust problems

Facility (N-200) Cleanliness

The complete facility is air conditioned and pressurized to minimize dust entry

High bay measured equivalent to a CLASS 1000 specification:
- 5-50 Microns (6.5 particles per cubic foot)
- Larger than 50 Microns (0.5 particles per cubic foot)

Clean Tent is 8 feet wide by 19 feet long in the area with "Laminar flow" filtration; it is classified as a Class 1000 clean room.
- 5-50 Microns (3.1 particles per cubic foot)
- Larger than 50 Microns (0.7 particles per cubic foot)

Low bay is also pressurized, but the large door in the East wall can contaminate this area for extended periods after it has been opened to bring in experiments or supplies.

Targeting

Computer generated positions of the sun, stars, or planets for targeting is available.

Optics Capability

The following sources are available:

- 1/100 SUN (Incandescent), 32 arc minute with a 15 inch aperture.

- 50% SUN in lab from SUN TRACKER (dependent upon weather) with a 20 inch aperture. This device is servo driven and can be controlled from the sensor on the tracker or the sensor on the experiment to provide closed-loop operation. If a command link is installed in the payload, pitch/yaw closed-loop dynamic tests can be performed.

- 10 arc second STAR SOURCE (incandescent) with a 20-inch aperture and adjustable brightness.

Aperture Autocollimator - 16 inch with a one arc second resolution capability and various source patterns and intensities (incandescent). Co-alignment of mirrors, retro-reflections from telescope spectrometers and sensors on experiment payloads.

Granite Table - 5 feet x 8 feet flat to 100 x 106 inches and capable of being floated on bags for critical alignment techniques requiring low vibration for stability.

Hydrogen-Alpha Telescope - Direct view and photographs for evaluation and solar target locations.

Section 7: Testing Policies

7.1 Introduction

Policy

The SRPO and the NSROC relies on testing as a means to determine the adequacy of all parts of the payload to function properly throughout the flight. Periodic reviews of test levels are conducted to assure that test levels are based on the latest information and that "factors on factors" do not end up in unreasonable levels.

When required, requests can be made to reduce or even eliminate some tests. Justification can include:

- Concern that the tests are more severe than necessary
- Testing wears out the equipment
- Testing takes too much time that could be used for other purposes

Fatigue

Long experience indicates that wearing out equipment through repeated testing is not a problem. We do not test to failure, hence, we do not know where we are on the time-failure curve. Once a piece of equipment survives the design qualification test, repeated testing at the lower flight acceptance levels has never resulted in failure.

Principal Investigator Testing

PI's are encouraged to test their components to standards similar to those used at WFF prior to shipment to the integration site.

Scheduling

The Mission Manager arranges test schedules.

7.2 Payload Flight Acceptance Tests

It is preferred to perform flight acceptance testing on a completely assembled payload in the flight configuration. However, many factors can force modifications to this desirable method. The factors influencing exceptions are as follows:

1. The Attitude Control System (ACS) has its own test program. A "dummy" ACS is substituted for the flight unit and the flight unit is excluded for other standard tests with the payload, such as mass properties, spin balance, and vibration.

2. The parachute is not in place in the recovery system section, nor is it deployed.

3. Glass tubes, such as photo-multipliers, if purchased to acceptable specifications, and the PI accepts full responsibility for their proper operation in flight, may be omitted during vibration tests. If a tube failure in flight is attributed to a condition which testing would have revealed, the PI must present evidence of design change and acceptable operation after design qualification testing before re-flying.

4. Explosives purchased to acceptable specifications, are not included in payload vibration and other tests.

5. Pressurized vessels need not be vibration tested under operational pressures but are normally pressurized to levels that provide a minimum of 4:1 safety factor based on design burst pressure.

6. Testing reel-deployed booms may be impractical. When this type boom is used, the PI is responsible for furnishing units which have previously been tested and providing details of the test program used that will satisfy the test requirements for flight hardware.

7.3 Testing and Evaluation Activities

Tests Required

Relevant tests are based on the rocket type and the payload characteristics. Unless otherwise specified, all tests are performed at Goddard Space Flight Center's Wallops Flight Facility (WFF). SPARCS testing is performed at the White Sands Missile Range (WSMR). The test parameters along with the WFF organization most cognizant of the requirements are discussed below.

Deployment and Separation

All mechanically operated or deployed parts (such as nose cones, instruments, antennas, doors, and booms) must be tested in some practical manner to develop confidence that they will perform successfully in flight. Thermal and vacuum testing on mechanically deployed or separated parts are not required when it can be shown that no significant effect results from expected changes in temperature or pressure.

Load and Bend Tests

It is generally desirable to do a structural bend test and tip deflection measurement for all payloads. Exceptions are justified case by case.

Balance

Dynamic and static unbalance are routinely measured on all payloads. Correction weights are installed in most cases. Where installation of correction weights is not feasible, the resulting unbalance condition must be reviewed and approved. A complete explanation of balancing sounding rockets is available from the MM. Figure 7-1 shows a payload mounted on the static/dynamic balance test machine at WFF.

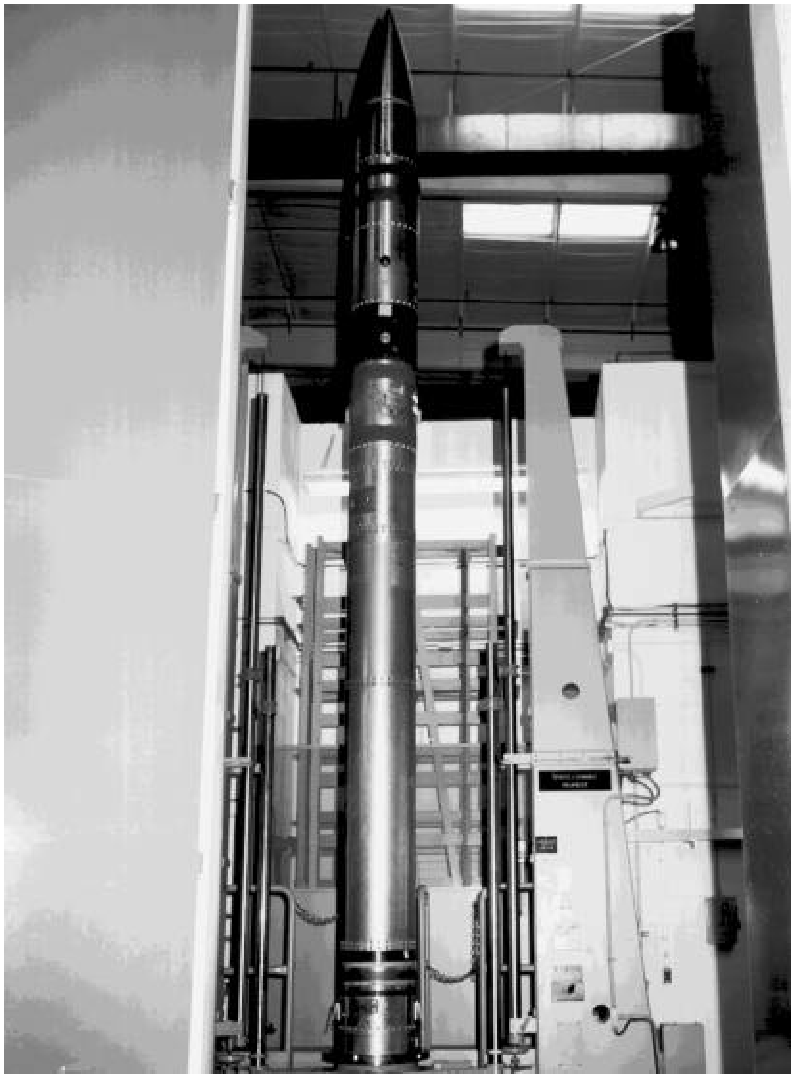


Figure 7-1. Static/Dynamic Balance Test Machine

Magnetic Calibration

When they are required, magnetic calibration tests are done - generally for all payloads with magnetometers except those in which the magnetometers are used as roll or yaw indicators. Exceptions require written authorization from the PI. Magnetometer testing is performed at either GSFC/Wallops or GSFC/Greenbelt locations. A magnetic calibration test facility exists at WFF.

Vibration

PI's are encouraged to test their components to appropriate vibration levels prior to shipment to the integration site. Components should be tested to the vibration test levels referenced below.

1. Previously unqualified and unflown components:
   a. Black Brant components: See Table 7-1.
   b. Undefined vehicle or other than Black Brant Vehicle: See Table 7-2

2. Previously qualified components and flight spares: See Table 7-3.

Components which have been previously flown successfully on similar type vehicles may be considered qualified and tested under Number 2, above.

All payloads must pass flight acceptance vibration tests. Vibration test specifications for entire sounding rocket payloads are included in Table 7-4.

For flight acceptance tests, previously flown payloads, or new payloads of the same design as those previously flown on the same vehicle type, only a three axis flight level random vibration will be done. New design and modified refly payloads are subjected to 3 axis flight sine and 3 axis flight random vibration.

Payloads modified after test or stored for more than three months after test may be required to undergo additional vibration testing.

Thermal-Vacuum

When out-gassing can degrade the performance of an experiment, a thermal-vacuum test will be required to prove the absence of contaminants. The test may be performed in several parts e.g., the nose cone might require a higher temperature for a longer period than the PI's equipment can tolerate. No fixed procedure for the thermal-vacuum test is specified. The only requirement is that the test must conclusively show that contamination will not impair the data to be gathered during flight. Expected temperatures during flight can be furnished. Each group will be responsible for determining whether thermal-vacuum tests are required on their hardware.

Table 7-1

Previously Unqualified and Unflown Black Brant General Component Qualification Specifications (Correspond to proto-flight payload levels)

Sinusoidal: Same in all three axes

Sweep rate 4 octaves/minute

5 - 24 Hz	5.9 inches per second (constant velocity)
24 - 110 Hz	2.3 G's
110 - 800 Hz	5.25 G's
800 - 2000 Hz	15 G's

Random: Same in all three axes, 10 seconds per axis

19.05 G's RMS overall

0.023 to 0.23 g2/Hz at 1.8 db per octave	20 to 1000 Hz
0.23 g2/Hz	1000 to 2000 Hz

Table 7-2

Previously Unqualified and Unflown Unidentified/Non-Black Brant General Component Design Qualification Specifications

Three Axis Sine - 4 octaves/minute sweep rate

7.3 IPS Constant Velocity - 5 to 89 Hertz
10.5G - 89 to 800 Hertz
15 G - 800 to 2000 Hertz

Three Axis Random - 20 seconds per axis

20.4 G RMS
0.115 G2/Hz. - 0.225 G2/Hz. 20-1000 Hz. @ 0.52 db/oct.
0.225 G2/Hz. 1000-2000 Hz.

Note: Levels are based on envelope of prototype levels for Black Brant, Nike-Tomahawk and Orion vehicles.

Table 7-3

General Spare and Previously Qualified Component Flight Qualification Specifications

Flight Spares receive 3 axis random vibration only.

10 Seconds per axis
13.6 G RMS
0.51 G2/Hz. - .1 G2/Hz. 20-1000 Hz. @ 0.52 db/oct.
0.1 G2/Hz. 1000-2000 Hz.

Note: Specifications envelope Black Brant and Nike-Tomahawk flight level random.

Table 7-4
Vibration Test Levels for New Design Payloads

	Vehicle Level One	Vehicle Level Two	Orion
Sine Sweep.			
Rate 4 Oct./Min.			
Thrust Axis	±3 in./sec. 10-144 Hz	±3.84 in./sec. 5-24 Hz	±4.87 in./sec. 10-50 Hz
	± 7 G 144-2,000 Hz	± 1.53 G 24-110 Hz	± 4.0 G 50-2,000 Hz
		±3.5 G 110-800 Hz	
		± 10.0 G 800-2,000 Hz	
Lateral Axis	± 3 in./sec. 10-35 Hz	Same as Thrust Axis	Same as Thrust Axis
	± 7 G 35-105 Hz		
	± 5 G 105-2,000 Hz		
Random:			
Duration	20 sec./Axis	10 sec./Axis	20 sec./Axis
Thrust Axis	10.0 G-RMS	12.7 G-RMS	6 G-RMS
	0.051 G^2/Hz	0.010-0.10 G^2/Hz	20-2,000 Hz
	20-2,000 Hz	20-1,000 Hz @1.8 db/Oct. 0.10 G2/Hz 1,000-2,000 Hz	0.018 G^2/Hz
Lateral Axes	7.6 G-RMS	Same as Thrust Axis	Same as Thrust Axis
	0.029 G^2/Hz		
	20-20,000 Hz		

Level One	Limiting Bending** Moment (inch/pounds)	Level Two	Limiting Bending** Moment (inch/pounds)
Nike-Orion	100,000	Black Brant V	300,000
Taurus-Orion	100,000	Black Brant Vlll	300,000
Terrier-Orion		Black Brant IX	300,000
		Black Brant X	300,000
Terrier-Malemute	200,000		

Note: Payload designs previously qualified to above levels receive only 3-axis random vibration as specified above.

* Limit model 1830 team table to 240,000 inch/pounds O.T.M.

** Input to payload during lateral sinusoidal vibration must be limited during the first bending mode to avoid exceeding the maximum bending moment at the base of the payload (via dual control accelerometer at C.G. of the payload, or device).

Vacuum

Experiments that utilize voltages above 200 volts must pass a corona check. This test is generally performed by the PI before bringing the equipment to WFF. Battery cases for voltages >100 should be pressurized and the cases should be resealed. When S-band equipment is used in vacuum, a RF corona check should be run in vacuum for 1/2 hour by monitoring spectrum and power output.

Mass Properties

The payload mass properties (weight, center of gravity, moments of inertia) will be determined before the Mission Readiness Review (MRR) by test or by calculation. Final measured properties are always determined during payload test and evaluation. Requirements for moments of inertia will be established. Requirements are necessary for determining trajectory suitability, ACS performance, and stability calculations.

Integration

Integration checks the sounding rocket payload as a system for the first time. Complete and successful system tests prior to the integration are required. Integration will not commence until all system testing has been completed. Figure 7-2 shows a MARK VI ACS neumatic can (SPS) section undergoing integration tests on the mass properties test unit at WFF.

Waivers

When special conditions necessitate a waiver or modification to stated policy, the PI may submit a written request to his Mission Manager. This should include the reason for the request, the possible results if failure should occur in flight, and other pertinent details.

Test Times

The following guide may be used for estimating the time required for the various tests:

Nose cones, deployments, and separation tests	1 - 3 days
Load and Bend Tests	1/2 - 1 day
Balance (check, balance and re-check)	1 - 3 days
Magnetic Calibration	1/2 - 1 day
Vibration	1/2 - 1 day

Thermal-Vacuum	1 - 2 days
Vacuum	1/2 - 1 day
Mass Properties	1/2 - 1-1/2 days
Integration	2 - 6 days

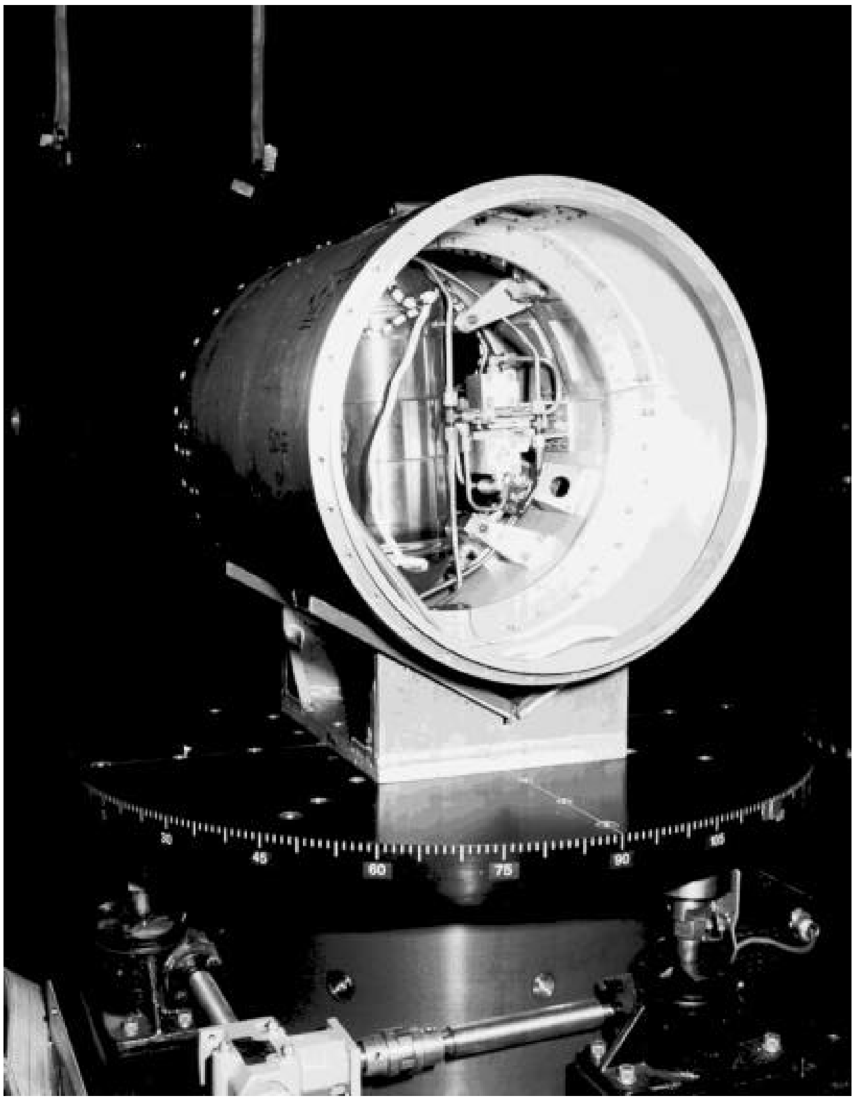


Figure 7-2. Integration Test for an MARK VI ASC

Section 8: Safety

8.1 NASA/GSFC/WFF Safety Policy and Responsibilities

Introduction

Safety is a paramount consideration in all successful sounding rocket missions. Safety requirements draw upon the unique and exhaustive experience of Goddard Space Flight Center's Wallops Flight Facility (WFF) with over 45 years of experience in sounding rocket operations, design, and technology. Safety is considered in all phases of sounding rocket mission planning, design, and engineering through the successful conclusion of a mission.

The policy and procedures discussed in this Section and the references apply to all mission activities conducted and managed by GSFC/WFF and to all NASA employees, contractor personnel, Principal Investigators (PI) and their support personnel. Missions conducted at other launch ranges (such as White Sands Missile Range) will comply with the local range requirements, including requirements that are more restrictive. However, policy and procedures described and referenced in this Section will be considered the minimum requirements for all personnel mentioned earlier in this paragraph.

Department of Defense personnel adhere to Department of Defense rules; however, they must also adhere to GSFC/WFF policy and guidelines while at WFF, when the rules are more restrictive.

This Section provides an overview of GSFC/WFF safety policy, organizational responsibilities, operational procedures, and flight and ground safety. PI's should discuss safety considerations with their Sounding Rocket Mission Manager (MM) and consult references for detailed design, engineering, operational and procedural guidance.

References

Two NASA/GSFC publications provide detailed safety policies and describe engineering and operational requirements.

1. NASA Goddard Space Flight Center Issuance Information Sheet, Range Safety Policies and Criteria for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF), GMI 1771.1, dated September 4, 1984.

2. Range Safety Manual for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF) RSM-93, dated June 23, 1993.

8.2 Policy and Responsibilities

Policy

GSFC/WFF will conduct all ground and flight operations with a degree of prudence appropriate for highly hazardous operations and in accordance with sound technology. In this manner, the possibility of injuring personnel, damaging property, or causing embarrassment to the United States will be minimized. To achieve this objective, three cardinal principles apply:

1. It is impossible to completely eliminate human error or system failures; therefore, safety planning and precautions are established to cope with the resulting hazard.

2. One preventive measure is insufficient for hazard control. Planning procedures or system requirements shall be established such that a combination of at least two extremely unlikely events must occur to cause an accident.

3. Safety is an integral function of each supervisor's responsibilities.

For any mission where these policies cannot be met, the risk will be analyzed and presented, recommending approval or disapproval, to the Director of Suborbital Projects and Operations (SPOD), Code 800, in a Risk Analysis Report described in Subsection 8.4 below.

Range Safety Organization

The Director of GSFC is responsible for safety at WFF. At WFF, the Director of SPOD, representing the Director of GSFC, has established a programmatic safety organization and designated safety responsibilities for other organizational elements. The references above describe the safety responsibilities for each organizational component. The Safety Office (Code 803) of SPOD is responsible for implementing the range safety policies, criteria, and operations at WFF. The Safety Office is the principal safety coordinator for GSFC/WFF sounding rocket missions performed at other ranges.

Mission Managers

The main point of contact for PI's for safety planning is your Mission Manager (MM). MM's will provide to the Safety Office, no later than 90 days prior to the scheduled launch date, the following data for all new or modified launch configurations:

1. Nominal flight trajectory data
2. Dispersion data
3. Vehicle physical characteristics
4. Rocket motor information
5. Vehicle structural limitations
6 Aerodynamic data
7. Wind compensation methods
8. Aeroelastic and flight loads analysis.

For standard vehicle configurations and payloads, nominal flight trajectory data, dispersion data, and wind compensation methods should be provided two months prior to the scheduled test date. The MM requires some data to be provided by the Principal Investigator, as explained below:

MM's review vehicles and payloads to assure criteria and range safety standards are met and refers all exceptions to the Safety Office (Code 803).

Approved safety procedures for vehicles and payloads meeting all range safety standards are published in the Operations and Safety Directive for all campaigns and WFF operations and in the Flight Requirements Plan for other ranges.

Principal Investigator

It is the responsibility of the PI's to acquaint themselves with the safety policies and criteria set forth in Range Safety Manual for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF) RSM-93, dated June 23, 1993.

PI's must design vehicle and payload systems to fully conform with the policies and criteria established by the GSFC/WFF. PI's must identify any vehicle or payload systems and/or operational requirements that cannot meet the GSFC/WFF and NASA safety policies and criteria.

PI's will provide data to the MM, either through conferences or formal documentation, for safety review. The data will include information on payload systems, description, and requirements of the project operations. PI's must also submit requests for any waivers from prescribed procedures before arriving at the GSFC/WFF. Appendix I details the data required in formal documentation. Appendix I is extracted from the Range Safety Manual for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF) RSM-93, dated June 23, 1993.

Mishaps

In the event of a mishap, NASA/GSFC/WFF will take reasonable and proper actions to limit or prevent injury to personnel and damage to or loss of equipment and property. Management and safety personnel will issue instructions through your MM for any investigation and reports required.

PI's will be required to provide information requested to fully understand the cause of the mishap and develop recommendations for any subsequent actions.

8.3 Ground Safety Plan

General

The ground safety goal of GSFC/WFF is to minimize the risks to personnel and property involved in the handling, preparation, and launch operations for launch vehicles and payloads.

A Ground Safety Plan will be prepared by the Safety Office, Code 803, prior to any launch operations conducted by GSFC/WFF at WFF or other ranges. This plan covers operating variables involving the storage and handling of explosives and propellants, vehicle and payload/experiment assembly, and pad preparations where other than normal procedures are used or operating conditions are particularly hazardous.

The Ground Safety Plan is based on information provided by the Principal Investigator (See Appendix I for details) the Mission Team, and Safety personnel.   NOTE: Ground safety data packages are provided for operations at established ranges: WSMR, Kiruna, Andoya. Ground Safety Plans are provided for operations at WFF, Poker Flat Research Range, and mobile campaigns.

Scope

The Ground Safety Plan will typically include information on the following:

1. List of all hazards associated with the mission.
2. Exposure limits for personnel working with hazardous material. The cardinal principle is to limit the exposure to the minimum number of personnel, to the minimum time, and to the minimum amount of hazardous materials, consistent with safe and efficient operations.
3. Operational restrictions to be observed by personnel during specific tests or operations.
4. Chemical Systems
5. Electro-explosive circuit requirements
6. Electrical storm criteria and restrictions on safe operations
7. RF restrictions on operations at specified RF levels
8. Personnel requirements for safety devices, clothing, and procedures
9. Radioactive sources safety requirements
10. Pressure vessel safety requirements
11. Security warning and control procedures
12. Operational control and procedures for all areas and material related to the mission

8.4 Flight Safety Plan

General

The flight safety goals are to contain the flight of all vehicles and to preclude an impact which might endanger human life, cause damage to property, or result in embarrassment to NASA or the U. S. Government. Although the risk of such an impact can never be completely eliminated, the flight should be carefully planned to minimize the risks involved while enhancing the probability for attaining the mission objectives.

The Flight Safety Plan is prepared by the Safety Office prior to any launch operation conducted at GSFC/WFF. This plan describes the quantitative and qualitative aspects of the proposed vehicle flight. For operations at other ranges, any special flight safety restrictions or requirements will be documented in the Flight Requirements Plan or other operations document.

The Flight Safety Plan is based on information provided by the Mission Team (See Appendix I for details) and information provided by WFF engineering, operational, and safety personnel. Details on flight safety criteria are found in Range Safety Manual for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF) RSM-93, dated June 23, 1993.

PI's are expected to determine their minimum requirements for launch and any requirements which are more stringent than those imposed by the Safety Office. The PI may be requested to participate in the planning for other safety related aspects of the mission.

Scope

The Flight Safety Plan will typically have information in the following areas.

1. Impact Criteria: All flights will be planned in accordance with impact agreements and conducted so that the planned impact or re-entry of any part of the launch vehicle over any land mass, sea, or airspace does not produce a casualty expectancy greater than 10^{-6} and an impact probability, on private property which might cause damage greater than 10^{-3} (PFRR) unless a Safety Analysis Report (See Subsection 8 5, below) is prepared and approved, or it can be proven that:

    a. The re-entering vehicle will be completely consumed by aerodynamic heating, or

    b. the momentum of solid pieces of the re-entering vehicles (such as balloons or parachutes) will be low enough to preclude injury or damage, or

    c. formal government or private agreements allow the use of the land mass for impact or re-entry

2. Overflight Criteria: Vehicle overflight of a populated area may only be planned when flight termination capability exists and one or more of the following criteria are met:

    a. The vehicle is in orbit

    b. The probability of a land impact and resultant CE due to an overflight failure does not violate established criteria

    c. Formal government or private agreements are established which allow the overflight.

    d. It is approved in a Safety Analysis Report.

3. Flight Termination Criteria: GSFC/WFF flight safety policy requires a flight termination system in every stage of a launch vehicle unless it is shown that the flight is inherently safe as

determined by probability estimates based on known system errors and qualifying conditions specified in safety regulations.

If a launch vehicle cannot meet the above set of conditions, a flight termination system must be employed whereby thrust may be terminated, stage ignition prevented or delayed, or other means employed to ensure that the impact and overflight criteria are not exceeded.

4. Flight Termination System Design Requirements: The design of a vehicle flight termination system must be submitted to the Safety Office (Code 803) for analysis and approval. The TTS design requirements are found in RCC 319-92 (commonality) or 127-1 ER/WR Range Safety requirements.

5. Flight Planning Criteria: Launch vehicle flight safety is usually associated with the containment of spent stages, hardware, and payload components within planned impact areas. Each flight is unique since the entire set of variables (vehicle aerodynamic/ballistic capabilities, azimuth and elevation angles, wind, air, and sea traffic, and proposed impact areas) are never duplicated. Therefore, vehicle design, reliability, performance, and error predictions for each flight case are analyzed by the Safety Office (Code 803) to ascertain the flight-worthiness of the launch vehicle.

6. Range Clearance Criteria for GSFC/WFF Launch Range: GSFC/WFF coordinates flight operations with the Federal Aviation Administration (FAA), the U. S. Navy, and other organizations, as required, to clear impact areas. The hazard areas for each rocket are defined and all flight safety criteria must be satisfied before a launch is allowed. No vehicles will be launched without prior clearance.

7. Operational Procedures: Criteria are specified for vehicles with and without flight termination provisions and include wind weighting, shipping, launch limitations, and prelaunch checks.

8.5 Safety Analysis Report

General

Safety Analysis Reports are prepared, when directed by GSFC/WFF, to document safety risks in reference to baseline safety requirements and criteria. These reports document a summary of hard hazard analysis and state the risks that may be incurred by a sounding rocket operation. Safety Analysis Reports are also the means for obtaining GSFC/WFF management approvals of waiver requests for exemptions from safety requirements.

Scope

A typical Safety Analysis Report has the following information:

1. Introduction and project description

2. Safety criteria

3. Specification of hazards, preventive measures, and risk assessment for:
   a. Ground safety
   b. Flight safety
   c. Environmental hazards

4. Details of all safety procedures

5. Formal specification, justification, and risks for any waiver requested for exception from safety requirement.

Section 9: Launch Operations

9.1 Introduction

Since its inception in the late 1950's, the NASA Sounding Rocket Program has conducted launch activities virtually throughout the free world. To exemplify the extent of these activities, a listing of NASA-supported sounding rocket launch sites which have been and are currently being used is included in Table 9-1.

Sounding rocket launch operations are currently being conducted at a number of United States and foreign locations. The facilities can vary from very comprehensive launch and payload preparation, launch, recovery, and data collection capabilities - such as those at Wallops Flight Facility and White Sands Missile Range - to austere sites equipped with mobile systems tailored to a specific campaign.

Many of the procedures are similar regardless of the launch location and support systems available. However, each range has some unique requirements. This Section highlights some of the procedures generally common to all fixed and mobile ranges.

Launch Ranges

Figure 9-1 shows the location of many of the United States and foreign ranges used for NASA sounding rocket flight operations. Mobile facilities deployed from Wallops Flight Facility (WFF) can augment the established facilities at any range as necessary. Details regarding the sounding rocket program support facilities, range operations, logistics, and visitor information at WFF are in Section 11. Descriptions of the other most frequently used fixed ranges, listed below, and their major features are in Appendix J.

1. U.S. Army White Sands Missile Range, Appendix J.l
2. Poker Flat Research Range, Appendix J.2
3. Andøya Rocket Range, Norway, Appendix J.3
4. Esrange, Sweden, Appendix J.4

Table 9-1

NASA Sounding Rocket Launch Locations

***Currently Used Sites**

*Andoya, Norway - Fixed Range (Full Facilities)
Antigua, U.K. - Mobile Range Site
Ascension Island, U.K. - Mobile Range Site
Barking Sands, HI - Fixed Range (Full Facilities)
Barter Island, AK - Mobile Range Site
Cape Parry, Canada - Mobile Range Site
Camp Tortuguera, Puerto Rico - Mobile Range Site
Chikuni, Canada - Mobile Range Site
Coronie, Suriname - Mobile Range Site
Eglin AFB, FL - Fixed Range (Full Facilities)
El Arenosillo, Spain - Fixed Range
Fort Churchill, Canada - Fixed Range (Decommissioned)
Fort Greely, AK - Mobile Range Site
Fort Sherman, Panama - Mobile Range Site
Fox Main, Canada - Mobile Range Site
Karachi, Pakistan - Fixed Range
Karikari, New Zealand - Mobile Range Site
Kerguelen Island, France - Mobile Range Site
Keweenaw, MI - Mobile Range Site
*Kiruna (Esrange), Sweden - Fixed Range (Full Facilities)
Kourou, French Guiana - Fixed Range (Full Facilities)
*Kwajalein, Marshall Is. - Fixed Range (Full Facilities)
Natal, Brazil - Fixed Range (Full Facilities)
Ny-Alsund,Svaldberg-Fixed Range
Point Barrow, AK - Fixed Range (Decommissioned)
Point Mugu, CA - Fixed Range (Full Facilities)
*Poker Flat Research Range, AK - Fixed Range (Full Fac.)
Primrose Lake, Canada - Mobile Range Site
Puerto Rico-Mobile Range Site
Punta Lobos, Peru - Mobile Range Site
Red Lake, Canada - Mobile Range Site
Resolute Bay, Canada - Mobile Range Site
San Marco, Kenya - Fixed Range
Sardinia, Italy - Mobile Range Site
Siple Station, Antarctica - Mobile Range Site
*Sondre Stromfjord, Greenland - Mobile Range Site
Thumba, India - Fixed Range
U.S.N S. Croatan - Shipboard Range (Decommissioned)
U.S.N S. Range Recoverer - Shipboard (Decommissioned)
*Wallops Island, VA - Fixed Range (Full Facilities)
Western Test Range, CA - Fixed Range (Full Facilities)
*White Sands Missile Range, NM - Fixed Range (Full Facilities)
*Woomera, Australia - Fixed Range (Partial Facilities)

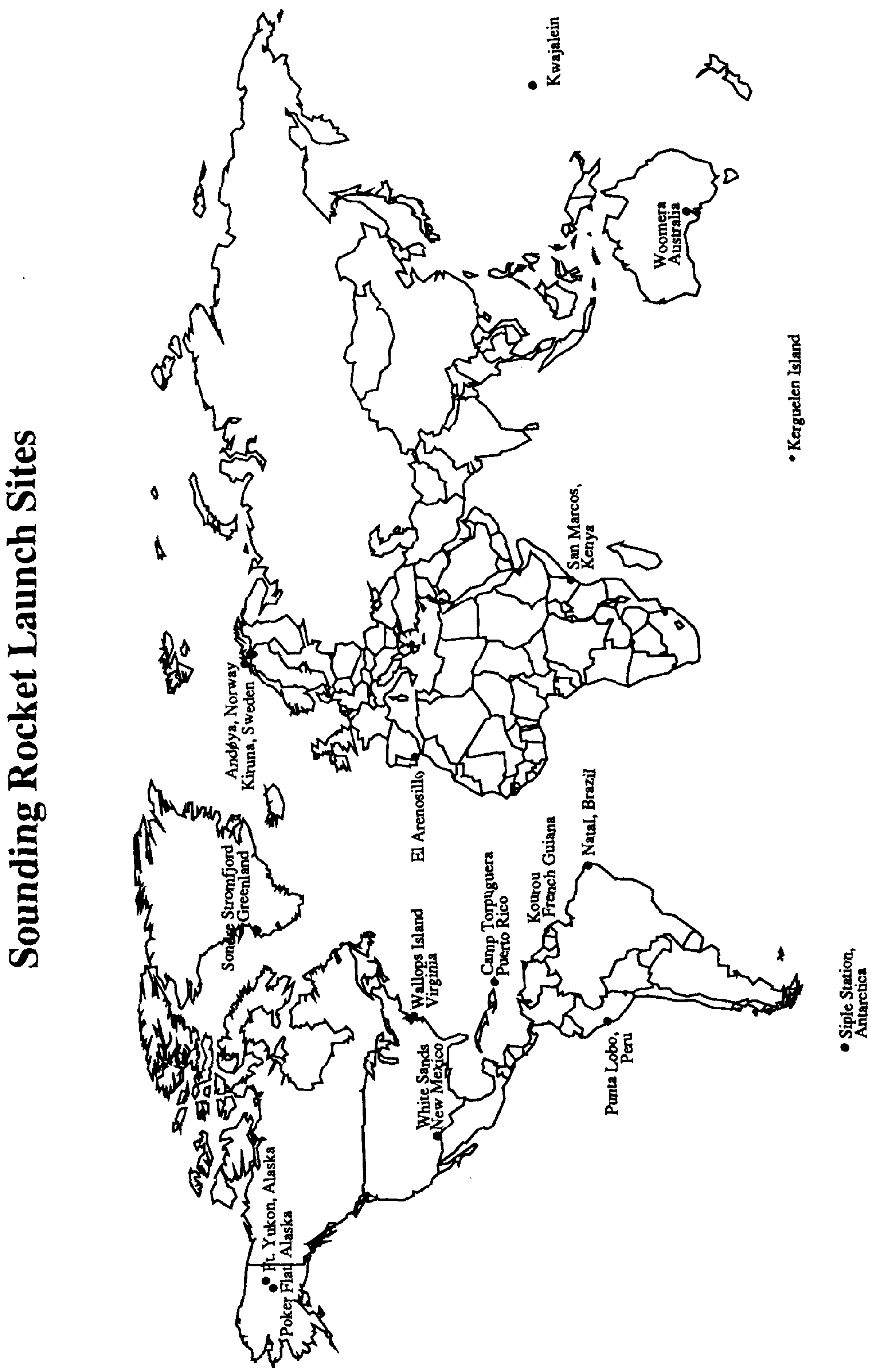


Figure 9-1. Sounding Rocket Launch Sites

Sounding Rocket Mission Manager

The principal point of contact for questions regarding procedures and requirements related to use of the various ranges is the sounding rocket Mission Manager (MM).

9.2 General Information on Launch Operations

Safety

Each range has unique safety considerations. All members of the mission team should be familiar with local procedures at the range. Be alert to signs and signals. Safety rules at foreign ranges along with NASA safety rules must be obeyed. Medical facilities may be minimal and an accident may end the participation in a campaign.

Rules To Remember

There are several rules to remember which are applicable to most ranges

1. Range Clearance: Range clearance requests must get to the range well before team and equipment arrival; the MM will coordinate clearance requests for all mission team members. Also, hand-carry a copy of the request to the range.

2. Foreign Nationals: Arrangements for clearance are made with the Mission Manager 60 days before arriving at a range. Paragraph 11.4 outlines the information to be provided to the Mission Manager.

3. Vehicle Pass: Most ranges require all vehicles to display a pass to allow entry. All private and rental vehicles will be processed according to local range procedures.

4. Alcoholic beverages: Some ranges have designated certain eating areas where alcoholic beverages are permitted. On all other range property, consumption of alcoholic beverages is usually forbidden.

5. Photography: Rules vary from range to range. Some ranges have very rigid restrictions on photography by other than designated personnel. Discuss your photography requirements with your Mission Manager and range personnel for the local ground rules.

Mission Manager

There may be questions about re-scheduling, range boundaries and buffer zones, flight termination, transportation, or other items. The field environment is conducive to many irritating occurrences and that is why certain procedures should be followed by all. The whole operation revolves around the PI. With so many people working in remote areas, it becomes most important to let others know operating plans. The Mission Manager should know where the Mission Team/Investigor's Team is staying and how each may be contacted. The Mission Manager should know what hours the Team will be on the range, any changes made the count-down, and any delays or problems encountered. The Mission Manager will make sure the message gets to the right people.

The Flight Requirements Plan

Several weeks before the PI arrives at the launch site, the NSROC prepares a Flight Requirements Plan or other operations directive and sends it to the range. This plan is discussed in Section 2. The Flight Requirements Plan (FRP) lists all of the supporting activities that the range must provide for the launch and recovery operations. Based on the FRP, the range can coordinate its functions. The FRP also includes data on the rocket and the experiment. At WFF, the Operations and Safety Test Directive substitutes for the FRP. For operations at mobile ranges, the Campaign Manager includes the same information in the Operations Document.

Test and Evaluation

In most instances, launch ranges do not have test and evaluation facilities. Therefore, these steps must be completed prior to shipment of the experiment and support equipment to the range. Typically payloads are integrated at WFF.

The Field Schedule

The field schedule is a document prepared by the Mission Manager and approved by NSROC. It lists every major operation. If any change has to be made to the schedule, the change should be made through the Mission Manager as promptly as possible.

The Preflight Conference

Very shortly after the arrival of the PI and WFF personnel at the range, the preflight conference is held. The PI and WFF personnel meet with range personnel to review the requirements and thoroughly discuss all aspects of the range support operations and coordination with the PI's activities. Any problems foreseen, either before or after launch, are resolved or become action items. The PI should present any required changes to the Flight Requirements Plan, especially for tracking.

Recovery

Recovery of payloads requires extensive prior planning. In the event of a failure, the recovered rocket (or parts) is considered property of NASA until inspection has been completed at the site and the Mission Manager decides that further disassembly or removal will not make an analysis of the failure more difficult.

Post-Flight Conference

Before leaving the field, a post-flight conference is held to present any compliments and complaints to range and NSROC personnel about the field services and make any suggestions to improve operations. Brief reports based on the information on hand are given regarding the success of the flight and review any anomalies that are known.

9.3 Foreign Ranges

The use of foreign ranges entails several additional responsibilities and procedures for the PI. Although the scientific and technical procedures for experiment preparation are similar to operations planned from U.S. ranges, regardless of launch location, the use of foreign ranges entails shipping, travel, communications, and living conditions which pose additional challenges to sounding rocket experiment success. The use of foreign ranges may well pose special considerations regarding the coordination of data acquisition sites and special provisions for communications. The SRPO is experienced in the use of foreign ranges and any special provisions which need to be made. Ranges at Andøya, Norway, and Esrange, Sweden, are discussed in Appendix J.3 and Appendix J.4 to give an idea of the types of facilities available. Figure 9-2 shows the range at Woomera, Australia - a fixed range with partial facilities. NASA operations at this range are augmented by mobile range systems provided by WFF.

Experimental Techniques

Some experimental techniques such as chemical releases, onboard radioactive sources, and explosive payloads, require additional coordination with the U.S. Department of State and foreign governments. Adequate time must be built into the schedule to allow for obtaining the necessary authorizations.

Figure 9-2. Range Support Operations in Woomera, Australia

Travel & Lodging

The Mission Manager can supply current information on available lodging and travel, including rates and distance from the site.   PIs are responsible for their travel and lodging arrangements.

Access

Access to foreign ranges is controlled by the foreign government or other institutions and their requirements must be adhered to. The Mission Manager can advise on proper procedures. Current passports and visas are mandatory when visiting foreign ranges.

Foreign Nationals

Access to foreign ranges by other foreign nationals is controlled by the host country.

Export Control

All Mission Managers shall ensure that transfers are consistent with the NASA Headquarters Program Office policies and include “export control milestones” in their program/project plans to ensure that export control matters are considered and resolved in advance of prospective shipping or transfer dates. In addition, all Mission Managers shall, in consultation with the CEA, ensure that international activities under their direction include:

a. Appropriate safeguards for commodities, technologies, and software exported or transferred pursuant to international agreements.

b. Provisions of necessary technical information to the CEA to permit a sound determination as to the need for validated export licenses or other documentation in specific activities, and for the completion of such documentation, where necessary;

c. Adequate lead time for the submission, processing, and receipt of validated export licenses, where necessary.

Postal Service

Usually a good postal service is available. The Mission Manager can provide the postal address of the foreign range.   Internet access is usually available at all ranges.

Shipping

Shipment of equipment from the United States to foreign ranges must be cleared through U. S. Customs also equipment shipped from foreign countries to the United States, e.g., WFF. Customs clearance when entering countries can be somewhat difficult and time consuming. Documentation must be correct, fully describe the shipment, and the shipment must be made well in advance of its need in a foreign country. The Mission Manager can provide information regarding shipping and should be kept fully informed of all shipments.

9.4 Mobile Range Operations

Introduction

Mobile range operations are conducted worldwide in locations dictated by the scientific experiment requirements. Mobile ranges that have been or currently being used by the NASA Sounding Rocket Program are listed in Table 9-1. WFF has the mobile sounding rocket support systems necessary to establish and support sounding rocket campaigns anywhere in the world. Table 9-2 lists the capabilities WFF can provide for the establishment and support of mobile ranges or to supplement capabilities at existing ranges.

Table 9-2 Mobile Range and Launch Facilities
C-band Radar
Telemetry Acquisition with Tracking Option
Data Acquisition and Recording Meteorological Payload Support
Power
Communications RF Wire Timing Launchers Optical Tracking and Recording Command/Destruct

The establishment and use of a mobile range entails a high degree of planning, coordination, and cooperation to ensure that the many tasks are accomplished to facilitate the scientific effort. Figure 9-3 shows an operation at the mobile range at Sondre Stromfjord, Greenland. This range and the range at Woomera, Australia, shown back in Figure 9-2, are examples of the adaptability of mobile operations in extreme conditions. While rainfall at each range is similar, the temperatures are very different; the Australian range is a hot desert and the Greenland range has arctic conditions. In spite of the differences, many requirements are similar. For example, environmental protective covers and other similar ground support equipment is required in both locations, and similar rockets are flown. Figure 9-4 shows a Black Brant IV astronomy payload being prepared for launch during the Supernova investigation in Woomera, Australia. Note the portable shelter to provide a controlled environment. This type shelter can be used worldwide.

Mobile Range Characteristics

Mobile ranges generally have some common characteristics that provide challenges to the efficient and effective planning required to conduct sounding rocket campaigns. Some of the more challenging conditions are:

Figure 9-3. Range Support Operations in Sondre Stromfjord, Greenland

1. Remote Locations: Mobile ranges are frequently located in remote foreign locations with limited habitability and sparse land, sea, or air communications. Transportation to and from the range, including customs clearance for equipment and personnel, becomes a major planning consideration. Living conditions are sometimes inconvenient or sparse. Adequate medical facilities may not be readily available. A medical emergency may mean a quick trip home.

2. Harsh Environment: Mobile ranges may be located in harsh environments which work against the proper functioning of equipment. Careful consideration of range environmental conditions during the planning, design, integration, and T & E phases is necessary.

3. Limited Technical Facilities: Frequently ranges have very limited or no technical facilities. Therefore, systems for the communications, launch preparation, launch, command and control, data collection, and recovery must be provided. Payloads must be ready to go when they reach the range because T & E facilities are non-existent.

4. Limited communications: Communication circuits on the range and to and from the range may be fewer than desired. This places additional burdens on communication planning so that minimum communications at least are available. Frequently campaigns at mobile ranges involve observers in other locations including other countries. Sparse communications may not allow the optimum communications between all participants in an experiment.

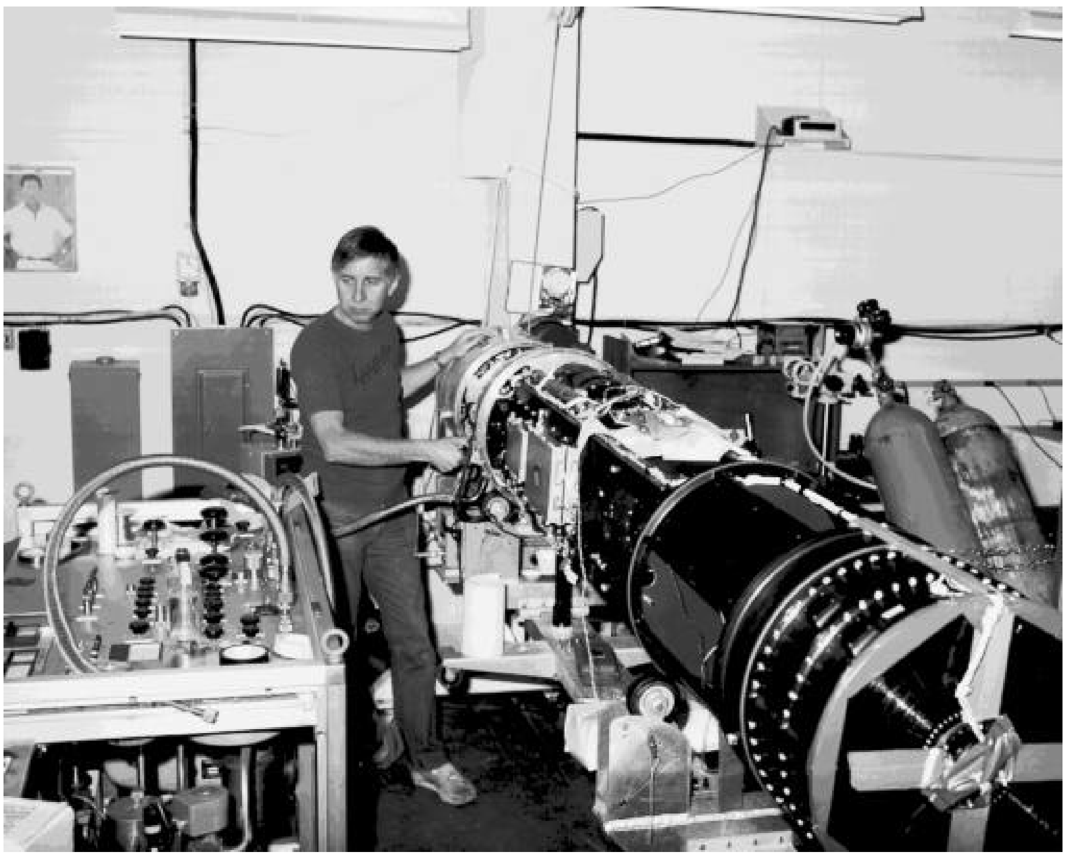


Figure 9-4. Black Brant IV payload in Woomera, Australia

Section 10: Data Processing and Analysis

10.1 Introduction

Extensive data processing and analysis systems and facilities are available at Goddard Space Flight Center's Wallops Flight Facility (WFF). These systems and facilities provide a wide range of support for sounding rocket planning, engineering, operations, data acquisition and analysis. This Section describes some of the specific support available and how a Principal Investigator (PI) obtains the support required for individual experiments.

10.2 WFF Data Processing and Analysis Systems and Facilities

General Purpose Computers

General purpose computer support is provided by GOULD/SELConcept/32 minicomputers organized into a Data Processing Installation (DPI). The three DPI systems most directly involved in sounding rocket projects are the Real-Time Computer System, Data Reduction Computer System, and the Engineering Computer System, discussed below.

Real-Time Computer System

The Real-Time Computer System (RTCS) is primarily a range safety tool used to accurately predict the impact point of any vehicle launched from WFF. The RTCS is part of a network of tracking radars and communications supporting control and data display facilities in the Range Control Center. This system is capable of transmitting separate command functions to the research vehicle. These can vary from stage firing of the vehicle to actuating command devices aboard the experimental payload. There have been many occasions when the PI has desired recovery of experimental equipment. The RTCS can direct recovery forces to the recovery point.

Many of the research vehicles launched from WFF have no guidance or destruct capability. This type of rocket must be launched in a manner to compensate for the forces acting on it which could cause it to deviate from a desired flight path. To aid range safety personnel in determining the compensation required, wind weighting is performed by the RTCS. Data from meteorological system sensors, chaff, and rawinsondes are used to obtain a profile of winds from ground level to an altitude of 129,000 feet and to compute the position of the launcher to compensate for the wind forces acting on the launched vehicle. In addition to providing range safety information, the RTCS can provide look angles (angles in elevation and azimuth that enable the radar or telemetry antenna to acquire the target) to any radar or telemetry installations which have compatible formats.

Data Reduction Computer System

The primary application of the Data Reduction Computer System (DRCS) is to perform flight radar data reduction operations. Data from other positional sources such as optics, telemetry, and special sensors can be incorporated. The DRCS also processes some telemetry data such as attitude data reduction from the Space Vector Corporation MIDAS platform gyros flown on many sounding rocket missions. The DRCS serves as a hot backup for the RTCS.

Engineering Computer System

The Engineering Computer System (ECS), is in direct support of sounding rocket programs. The ECS analytical tools and capabilities include:

1. Launch Vehicle Physical Properties
2. Aerodynamic Characteristics Determination
    - Subsonic, Supersonic, Hypersonic.
    - Linear, Non-linear
    - Launch Vehicles, Re-entry Bodies.
3. Flight Simulation (Endo-Exoatmospheric)
    - Launch Vehicle Performance (Flight Trajectory)
    - Launch Vehicle Stability (Static, Dynamic)
    - Launch Vehicle Guidance
    - Payload Dynamics, Attitude Control
    - Special Studies (Magnetic Field, Solar Eclipse Geometries)
4. Flight Loads & Structural Analysis
    - Launch Vehicle Vibrational Modes
    - Aeroelastic Effects
    - Vehicle/Payload Mechanical Design
5. Thermal Analyses (1,2, & 3-D Nodal Networks)
    - Aeroheating (Ascent and Re-entry)
    - Spacecraft Thermal Studies
    - Shuttle Bay Payload Thermal Analysis

Launch Status Review System

The Launch Status Review System, associated with the ECS, provides a capability for monitoring launch conditions during operations at White Sands Missile Range. Wind profile data, launcher settings, and simulated trajectories are transmitted to WFF in real time and captured in IBM PC/AT computers. Selected data are then sent to the ECS for display. For guided vehicles, wind profile data may be used as input to various flight simulations, the output of which is used to assess control system behavior and vehicle flight characteristics.

Special Purpose Computers

Many special purpose microcomputer and minicomputer installations support sounding rocket experiments and operations. The sounding rocket Mission Manager (MM) can advise on which ones may be the most helpful in correlation with the experiment.

Digital Telemetry Facility

The Digital Telemetry Facility is linked by cable to the telemetry receiving stations and readout stations. The purpose of the facility is to condition, synchronize, and process vehicle and payload performance serial PCM data; to digitize and process analog FM data, to format digital tapes, to display selected data or parameters in binary, decimal and engineering units, and to print out data in selected formats or provide data tapes for further reduction by the processing lab or the PI.

10.3 Obtaining Data Processing and Analysis Support

Arrangements for data processing and analysis support should be incorporated into pre-mission planning and coordinated with the Mission Manager.

Sounding Rocket Data Manager

The Sounding Rocket Data Manager (SRDM) is a data analyst assigned the responsibility for post-flight data reduction. The SRDM establishes requirements for data reduction of radar tracking data (including TM TRADAT) to position and velocity data and selected data reduction of WFF supplied instrumentation to engineering units and possible data solutions. An example is reduction of gyro data to an attitude solution. Subsequently, if required, the SRDM will oversee the actual data reduction.

The SRDM can coordinate the data reduction efforts associated with several sounding rocket campaigns. This coordination is extended to include scheduling the processing of telemetry data required to generate digital tapes and paper records from the flight analog tapes.

The SRDM is the PI's point of contact with the processing lab. Initial contact with the SRDM is arranged by the Mission Manager. After the initial contact, future data processing coordination is handled directly between the SRDM and the PI.

Flight Requirements Plan

The basic data processing and analysis requirements are provided by the PI in the Flight Requirements Plan, described in Section 2. The Flight Requirements Plan provides the processing lab with the background information needed prior to processing the data. It should describe the test and the expected results to be obtained. The test schedules and data requirements must be spelled out in advance to assist in planning the workload and manpower requirements. The PI submits the data requirements for the Flight Requirements Plan to the MM.

Information Required

The basic information needed for the Flight Requirements Plan includes:

1. Project identification including the job order number
2. Priorities, deadlines, and deliveries
3. Special processing needs, e.g., refraction calibration
4. Location and time of the experiment
5. Objectives of the experiment
6. General processing requirements, e.g., raw versus smoothed data, reference coordinates
7. Data dissemination requirements, e.g. hard copy reports, graphics, magnetic tape

The data sampling requirements must be clearly spelled out. These consist of timing intervals of the raw data as it is collected and the intervals to be processed. Other pertinent information may be needed depending upon the data requirements.

Instrumentation (Telemetry)

Real-time and post-flight data is normally requested through the Project Instrumentation Engineer. Real-time requirements for displays and paper charts are submitted to the Instrumentation Engineer who, in turn, prepares the necessary ground station support request. Basic RF link and airborne telemetry specifications are provided in the Flight Requirements Plan. The ground station support request forms, which vary with each launch site, are revised and submitted to the facility supervisor prior to the final launch countdown.

Actual flight events, established after quick-look review of real time data, frequently require changes to the post-flight data playback needs of the Mission Team. These changes are submitted, via the Instrumentation Engineer, to the ground station personnel. Playback operations are observed to evaluate completeness and accuracy of the data.

Non-Standard User Requirements

If the PI has the need for a technical capability that is not now available at WFF, two choices are available: (l) Either the PI can provide WFF with the computer programs to do the job, or (2) WFF can develop the capability. If WFF is to develop the capability, the PI should contact the SRDM and outline the requirements.

Positional Data Policy

In order to standardize the earth model between impact prediction and data reduction, the WGS84 Ellipsoid/North American Datum of 1983, is used for data products generated by the WFF Data Processing Installation. Wallops Internal Publication WFF-822.95-001 "Geodetic Coordinates Manual for NASA Goddard Space Flight Center, Wallops Flight Facility", January 1995, contains coordinate information on WFF and other sounding rocket and balloon facilities.

Data Dissemination

All data are disseminated through the Mission Manager. The data package produced for sounding rocket missions includes all tracking and telemetry data supporting the mission and processed to meet the requirements of the PI. A typical telemetry report to the PI is by digitized magnetic tape or CD ROM in the format shown in Appendix K.

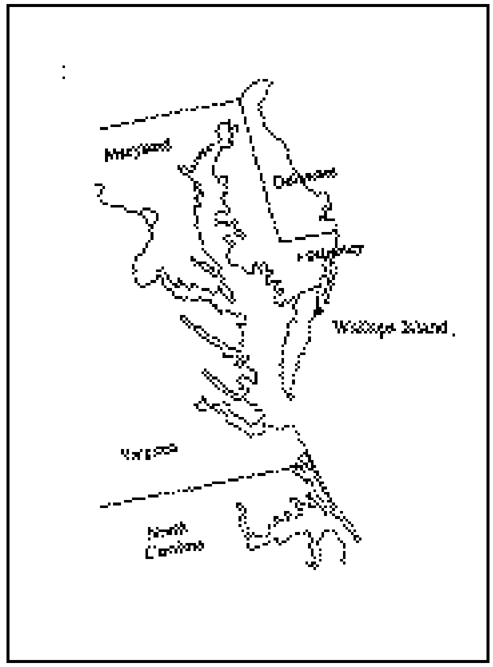
A typical positional data report is in the format shown in Appendix L.

Prior to dissemination, all material will have gone through a quality control review to determine that all data is of satisfactory quality and the request has been fulfilled.

Data Retention

Analog telemetry tapes are retained for five years. Digitized tapes are not retained. For positional data, original data paper records are retained for one year and all unedited /unsmoothed data measurements are retained for a period of four years. Tapes of processed positional data are retained indefinitely.

Section 11: Wallops Flight Facility



11.1 Introduction

Geography

Wallops Flight Facility (WFF) is located on Virginia's Eastern Shore approximately 40 miles southeast of Salisbury, Maryland. WFF consists of three separate sections of real estate: (l) The Main Base, (2) The Wallops Island Launching Site and (3) The Wallops Mainland.

1. Main Base The Main Base (Figure 11-1) houses the management and engineering offices supporting sounding rocket, balloon and aircraft projects. There are administrative offices, technical service support shops, a rocket inspection and storage area, an experimental research airport, laboratories, the main telemetry building, telemetry, radar, and communication facilities and a large computer complex. The Range Control Center to control range operations is based here. Several other U. S. Government agencies have tenant activities.

Figure 11-1. Wallops Main Base

2. Wallops Island Launching Site Wallops Island, named after John Wallop, a 17th century surveyor, is located on a barrier island off the coast of Virginia approximately seven miles southeast of the Main Base. Separated from the mainland by two miles of marsh and the Intercoastal Waterway, the Island (approximately six miles long and about one-half mile at its widest point) is connected with the Mainland by a causeway and bridge. Located on the Island are launch sites, assembly shops, blockhouses, dynamic balancing facilities, rocket storage buildings, and related facilities. The U. S. Navy has a major facility on the Island for training and development of personnel to support AEGIS operations with the Fleet. Figure 11-2 is a photo of Wallops Island looking north.

Figure 11-2. Wallops Island

3. Wallops Mainland Wallops Mainland, a half-mile strip of land at the opposite end of the causeway behind the Island, is the location for the long-range radars and communications transmitter facilities, and a Dobson Total Ozone Measurement Facility. Figure 11-3 is a photo of the Wallops Mainland.

Figure 11-3. Wallops Mainland

Geographic Location

WFF is located at 37.8° N 75.5° W. Detailed geodetic locations for all WFF facilities are found in the Wallops Internal Publication WFF-822-95-001 "Geodetic Coordinates Manual for NASA Goddard Space Flight Center, Wallops Flight Facility", January l995.

11.2 WFF Sounding Rocket Program Support Facilities

General

WFF has facilities for sounding rocket design, fabrication, mechanical test, telemetry, environmental test, assembly, launch, tracking, recovery, and acquisition and analysis of scientific information. Its facilities are used by scientists and engineers from the research centers of NASA, foreign and U. S. Government agencies, colleges and universities, and the world-wide scientific community.

Engineering Support

Engineering support includes analytical, feasibility, and design studies; payload, vehicle, and recovery system engineering; rocket and payload test and evaluation; and data analysis. Engineering and system design, development, and acquisition for data and communications systems, radar and optical systems, telemetry systems, and mechanical systems are performed by a highly qualified organization of engineers and technicians supported by laboratories, test, calibration, and data processing facilities.

Payload Integration Laboratory

The Payload Integration Laboratory includes facilities for complete payload build-up (mechanically and electrically) and checkout. The laboratory can support multiple payload processing simultaneously and includes telemetry ground stations and clean room facilities. Work areas are available for the Principal Investigator (PI) and staff to perform pre- and post-integration preparation and checks. The telemetry ground station is capable of supporting multiple links for all types of systems flown. Figure 11-4 shows a complex plasma physics payload undergoing integration in the Payload Integration Laboratory at WFF. An astrophysics payload is shown during integration in Figure11-5.

Environmental Testing Laboratory

Environmental testing of complete payloads, sub-assemblies and components is accomplished at WFF to verify their flight readiness when exposed to their intended flight environment. A detailed discussion of environmental testing policies and considerations is included in Section 7. Specialized facilities for environmental testing are available at WFF in the Environmental Testing Laboratory. This laboratory is adjacent to the Payload Integration Laboratory for convenience in payload handling and logistics. Various test equipment in the laboratory is briefly described below:

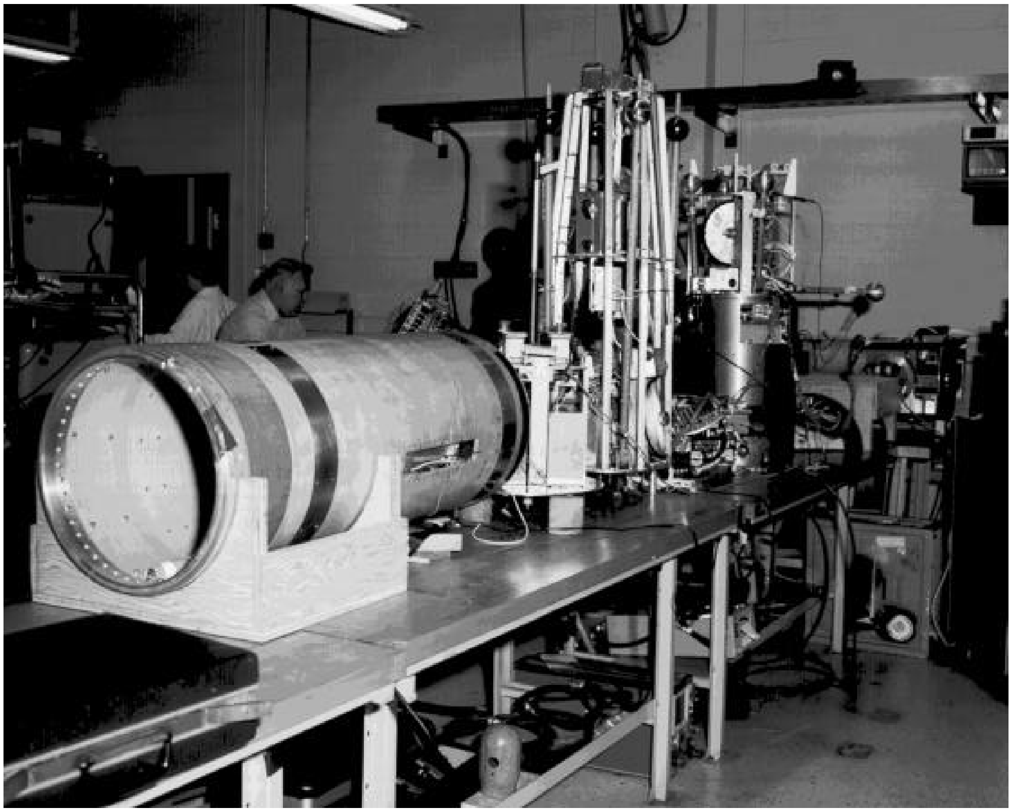


Figure 11-4. Plasma Physics Payload (36.0l5 UE) During Payload Integration

Figure 11-5. Astrophysics Payload During Payload Integration

1. Static Loads Facility: This facility is designed to produce static bending loads on rocket payloads mounted vertically. This facility will accommodate payloads up to 25 feet in length and 44 inches in diameter. Bend test force can be applied from one foot to 22 feet above the floor with up to 3500 pounds of force. Test results provide a measure of the overall structural characteristics of any given payload. Deflection data is used to evaluate the aeroelastic stability characteristics of launch vehicles during periods of high aerodynamic loading encountered in launch and to qualify the structural integrity of new payload designs.

2. Rotary Accelerator: The rotary accelerator provides radial acceleration for testing and calibrating payload components, hardware, and instrumentation. A rotating arm with the component attached is enclosed within a thick steel cylindrical shroud. Maximum size of the test article is a 24-inch cube. The angular velocity range is O to 326 rpm; which corresponds to an acceleration range of approximately O to 150 G. Typical examples of equipment tested are: payload subassemblies, solar sensors, battery packs, magnetometers, transmitters, and accelerometers.

3. Spin Test Facility: The spin test facility is primarily used for testing ejection and separation events that occur during rocket flight. With the test article mounted on the facility turntable (to simulate rocket flight spin-up) the doors, covers, or equipment are ejected on command and retrieved undamaged by a soft capture net. The spin facility is capable of following a programmed acceleration profile automatically or by manual control up to 36 rps.

   The size and weight limitations of test articles are:

Height:	3.35 m (11 feet)
Diameter:	92 cm (36 inches)
Weight:	500 pounds

4. Electromagnetic Shakers: Four electromagnetic shakers are currently available for simulation of the shock and vibration flight environment for entire payloads, or components of payloads. A Ling Electronics Model B395 is used for testing components during acceptance and special testing. Two Ling B335 units are used (one configured for thrust-axis and the other configured for lateral-axis) for testing payloads up to 22-inch diameter/1,500 pounds. A larger Ling B340 shaker is used for payloads up to 44-inch diameter/3,000 pounds and is convertible for both thrust and lateral axes testing. An astrophysics payload is shown

undergoing lateral-axis vibration testing on the B340 shaker in Figure 11-6. A detailed discussion of vibration testing policies and specifications is included in Section 7.

Figure 11-6. Astrophysics Payload (36.022) undergoing Lateral Vibration Testing

5. <u>Thermal Vacuum Chamber</u>: The vacuum chamber is a cylindrical, horizontal chamber with an inside diameter of 2.13 meters (7 feet), and a useable inside length of approximately 3.7 meters (12 feet). LN_2 is supplied from an 11,370 liter (3,000 gallon outside storage tank adjacent to the test area. A vacuum of 5×10^{-6} Torr (228,000 meters or 750,000 feet) can be achieved in approximately six hours at temperatures of -73°C (-100 F). The size limitation of test articles is approximately 91 cm (36 inches) in diameter by 3.7 meters (12 feet) long.

6. <u>Tenney Vacuum Chamber:</u> The Tenney 61 cm x 61 cm (24 in x 24 in) Thermal Space Simulation Chamber has the capability of reaching 3×10^{-8} torr at a temperature of –73° C (-100° F). The chamber employs a brine system that circulates around the outside walls of the chamber that will control the temperature of the chamber from -73° C (-100° F) to 125° C

(250° F). Temperature can be maintained within 1° C of set temperature. The systems uses a mechanical roughing pump with an LN_2 trap and an eight in cryogenic pump to evacuate the chamber. The chamber is capable of maintaining a vacuum level selected before or during a test cycle.

7. Tenney Space Jr. Temperature Vacuum Chamber: This 36 cm (14 in) diameter by 30 (12 in) deep, horizontal vacuum chamber is capable of reaching a vacuum as low as 7.5×10^{-8} torr (293,000 m [962,000 ft]) at –73° C (-100° F). This is accomplished within 10 hours with the use of a diffusion pump and an LN_2 trap. Inside dimensions of the chambers are 41 cm (16 in) width, 30 cm (12 in) height, 28 cm (11in) depth. However, test articles need to be somewhat smaller to accommodate instrumentation.

8. Portable Vacuum System: This portable system is a 91 cm (36 in) unit with a 10.1 cm (4 in) flange adaptable to a similar mating surface for the purpose of pumping a vacuum on any sealed container. Pumping is accomplished by a 5 cm (2 in) diffusion pump in conjunction with a roughing pump and a cold trap (LN_2, Freon or water). The vacuum capability is 10^{-7} torr or lower. There is no specific limitation as to the size of test chambers; however, the pumping capacity restricts the volume for high altitude simulation. Various other portable systems are available that employ cryosorption and cryogenic pumps.

9. Vacuum Leak Detector – Helium Mass Spectrometer: For leak detection, two models are available: a Varian Model 938-41 Leak Detector employs a diffusion pump and can detect leaks as small as 10^{-9} cc/sec. An Ulvac Model DLMS-531 employs a turbo pump and can detect leaks ata the rate of 3×10^{-10} cc/sec. There is no specific limitation as to the size or tyupe of items to be leak tested. Typical items tested include sealed payload units, pressure bottles and vacuum chambers.

10. Vacuum Bell Jar: The vacuum bell jar is a cylindrical vertical chamber measuring 45.7 cm (18 in) in diameter by 91.4 cm (36 in) high. The bell jar is equipped with a 0.14 m^3/min (5 cfm) mechanical pump, a 5.1 cm (2 in) diffusion pump and LN_2 trap. This system is used to test altitude switches and small components up to an altitude of 200,000 ft using a mechanical pump.

11. Tenney Jr. Temperature Chamber: This temperature chamber is capable of reaching a temperature of –73° (-100°F) to +177° C (+350° F) within ± 3° C (±1/2° F). Any

temperature in this range can be maintained automatically and indefinitely for soaking. A viewing port, recording and scanning equipment are available to monitor test articles.

12. Magnetic Test Facility: The magnetic test facility was designed to test sounding rocket and related space system payloads and to conduct air bearing tests of magnetic attitude control systems. Located in a non-ferrous facility in a relatively magnetically clean area, the three axis, 30-ft square Braunbek system will have the capability to null the earth's field and impose a new field in any direction with a resolution of approximately 10 navolesta and magnitude from 0 to 80,000 gamma. Running under computer control, many standards calibration routines will be fully automated.

13. Physical Properties Determination: Equipment is available at WFF which allows weight, mass center, and moments-of-inertia of entire payloads or components to be determined. Physical properties of all payloads are routinely measured during testing and are utilized for final mission analyses studies.

14. Static and Dynamic Balancing: Several balancing machines are available for static and dynamic balancing of entire payloads or components and payload/rocket motor combinations. Five machines are currently in use with weight capacities ranging from 300 pounds to 35,000 pounds.

Payload Construction

A fully equipped machine shop facility is available at WFF that is capable of fabricating sounding rocket payloads and launch vehicle components. An overview of the machine shop is included in Figure 11-7. There are facilities for the fabrication of electrical components such as circuit boards, cables, and custom interfaces between experiment components and standard sounding rocket components. Assembly of payload and system components, calibration, and integration of the experiment and sounding rocket vehicle is accomplished in WFF facilities.

Computer Support

Special purpose and general purpose computer systems at WFF perform preflight and flight mission analysis, data reduction, vehicle and payload analysis and support flight operations. Section 10: Data Processing and Analysis explains the available capabilities in more detail and outlines how PIs obtain support.

Figure 11-7 . Wallops Flight Facility Machine Shop – South View

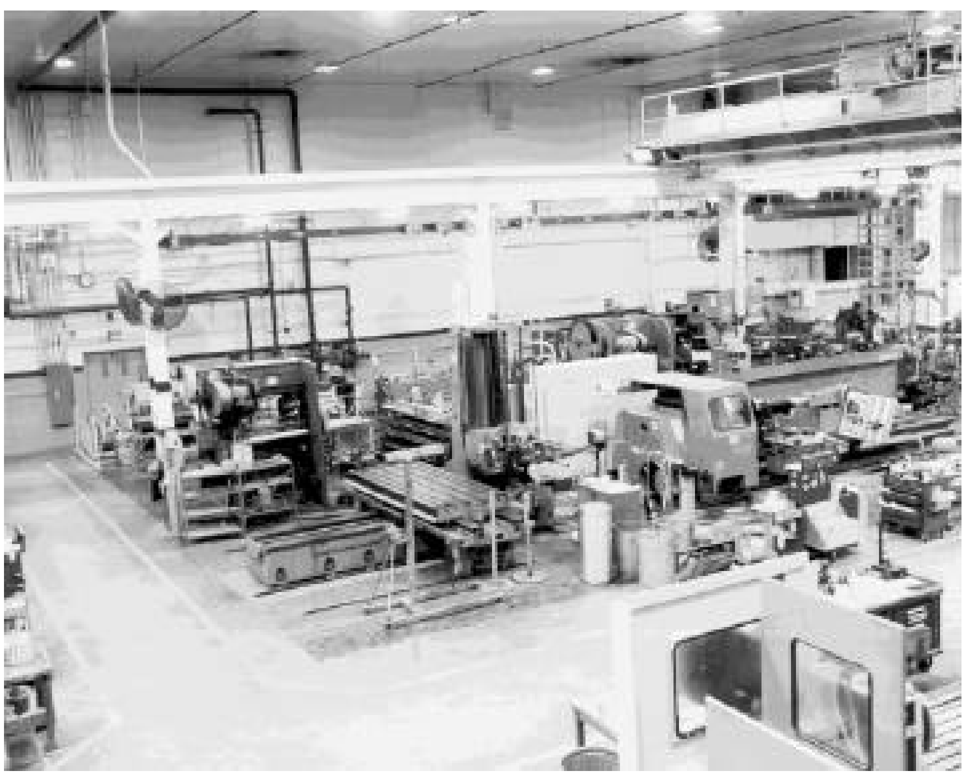


Figure 11-8 . Wallops Flight Facility Machine Shop – North View

Range Operations

WFF has a comprehensive, flexible complement of operational facilities providing a broad range of support for sounding rocket, balloon, and aircraft operations. These include:

1. Meteorologica1 Facilities: Wind data systems support launch operations. Fixed, balloon borne and optical sensors are available for coordinating experimental data with existing conditions. WFF is supported by NOAA data systems and a local forecasting office. An ionospheric sounding rocket station can provide detailed data on the ionospheric characteristics. A Dobson on Wallops Mainland can provide total ozone measurements. A lightning detection system displays lightning conditions over a wide area in the eastern United States.

2. Ground Tracking Facilities: Several mobile and fixed radars and related data reporting facilities support sounding rocket missions. The radars operate in the S, C, Ku, and X-bands.

3 Telemetry Facilities: Facilities support real time telemetry acquisition and data reduction and provide data for detailed analysis.

4. Launch Facilities: Launch facilities are located on Wallops Island. Facilities include pad, launcher, checkout, fire control and communications systems. Facilities can support all NASA sounding rockets. The range extends easterly over the Atlantic Ocean.

5. Recovery Facilities: A variety of payload recovery facilities are available. Water recovery operations are coordinated through the local U.S. Coast Guard in Chincoteague, Virginia. Homing systems, which can be included in the payload package, assist recovery.

6. Aircraft and Airfield: Mission and aircraft support is available by contacting the WFF Range & Mission Management Office (Code 840). This includes surveillance, transportation, optical and visual data acquisition, and telemetry support. There are three runways ranging in length from 4,000 to nearly 9,000 feet. Control Tower support is available. Procedures for use of the airfield are contained in GSFC/WFF Air Operations Manual.

7. Command, Control, and Communications: Launch operations are supported by an extensive network of command, control, and communications facilities. Several facilities support specific aspects of the operation such as radar plots and quick-look data acquisition; however, the focal point is the Range Control Center on the Main Base. Through this facility, launches, range safety, command/destruct functions, timing, and mission countdowns are controlled

through instantaneous communications with all involved activities. Limited quicklook data acquisition, graphic displays, and video views of launches are available.

8. Mobile Range Facility and Rocket Launching: Mobile range instrumentation vans support payload, meteorological, radar, control, telemetry, communications, power, and data functions. These facilities serve as mobile launching and tracking stations which can be set up as land based stations throughout the free-world or on board a large ship, such as an aircraft carrier, for experiments in international waters. Vehicle and payload handling and storage facilities are available. Also provided are a number of launchers, variable in both elevation and azimuth, which can safely handle multi-stage vehicles. All instrumentation vans are air-conditioned and are provided with communications, local intercom, precision timing, and data displays.

11.3 Facility Rules/Regulations/Logistics

Working Hours

The normal workday at WFF is 0800 to 1630, Monday through Friday. Note: a flexible work schedule arrangement allows employees to establish a schedule which they can start as early as 0600 or work as late as 1800. U.S. Government holidays are observed. Work at other times must be coordinated with the Mission Manager to ensure access to required facilities and the availability of necessary technical personnel.

Access

Access to the Main Base and the Island/Mainland complex is controlled by guarded gates, PI's should provide the Mission Manager with their identification, dates of visit, and vehicle identification prior to their arrival so that necessary passes can be obtained. The Main Base Receptionist is a necessary first stop to a WFF visit.

Housing

Two dormitories on the Main Base provide accommodations for NASA and other personnel on temporary duty at WFF. Use must be coordinated through the Mission Manager. Most range users make use of local motels and restaurant facilities.

Cafeteria

The Main Base Cafeteria is located in Building E-2. Breakfast (0700 to 0800) and lunch (1100 to 1300) are served. The Williamsburg Room may be reserved for special events including group evening meals.

Transportation On WFF

Transportation of sounding rocket components via truck can be arranged through the Mission Manager.

Express

United Parcel Service (UPS) and Federal Express perform delivery and pickup services at WFF daily.

Telephone

All long distance telephone calls by non-government personnel must be made through the WFF Operator by dialing "O" and shall be made collect or by credit card only. Federal Telecommunications System (FTS) service is available to U. S. Government users for official calls only. Access to the system is by dialing "8".

Smoking

Smoking is prohibited in all GSFC buildings.

Safety

Numerous safety restrictions are enforced at WFF. Obey control signals around high- energy emitters such as radar. Any safety question should be directed to the Mission Manager or specific facility personnel. Safety requirements for the design, development and operation of sounding rocket operations are further discussed in Section 8. Industrial safety procedures are typically enforced at GSFC facilities. Facility managers will advise on proper procedures for such things as safety shoes, hard hats, gloves, safety glasses, static dissipative clothing, and masks.

Precaution

PI's should notify the Mission Manager of the need for overnight operation of equipment or for the necessity of not turning on equipment during their absence. Never radiate from equipment without approval from the Mission Manager. It could be hazardous and wipe out someone else's test or day-to-day operational activities.

Shipping

Mailing Address: Name (NASA Code Number)
NASA
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia 23337

Freight Destination Address: Name (NASA Code Number)
NASA
Goddard Space Flight Center
Wallops Flight Facility
ATTN: Receiving, Building F-l9
Wallops Island, VA 23337

Motor Freight Truck Services

All cargo and freight is received at Building F-l9, except Class "A" and "B" explosives, and certain other hazardous material requiring advance notice of shipments.

Inbound shipments of Class "A" and "B" explosives, and other designated hazardous materials, will stop and park at the WFF Main Gate. Any shipment requiring delivering carrier's equipment to fly placards, and all shipments tendered as truckload, require RESHIP information in advance of delivery. Normal receiving hours are from 0800 to 1430 (for truckloads) and 0800 to 1600 (for partial loads), Monday through Friday, excluding holidays.

Air Freight Services

Air freight service to and from WFF is provided by Federal Express, Emery Worldwide, Bax Gloval, T.F. Boyle, Roadway Express and Roberts Express.

Chartered and private aircraft, both propeller and jet types, may land for business purposes at the WFF Airport, with prior approval clearance.

Packing

The PI is responsible for packing and unpacking the experiment and associated equipment. The Mission Manager can furnish additional information on packing criteria upon request.
Alcohol, explosives, corrosives, flammables and radioactive sources must be packaged separately. Radioactive sources require prior approval from the WFF Safety Office. Batteries must be packaged separately from electrolytes. Squibs are normally sent in separate containers. If squibs are included in a payload, the payload container must be marked to indicate squibs.

Material Handling Equipment

A variety of handling equipment is available. These include forklifts, overhead hoists, and dollies. All material handling equipment must be operated by WFF personnel. Any special equipment must be furnished by the PI.

Customs

Any international shipment should be routed through the Port of Baltimore. Notify your Mission Manager prior to shipment for coordination of U. S. Customs clearance.

11.4 Foreign Nationals

Foreign nationals who need to visit WFF or other launch facilities - particularly White Sands Missile Range - must provide information to the Mission Manager regarding their visit(s). The information should be received 60 days before a planned visit to allow for processing time and avoid delays in facility access and participation in the project.

The required information is listed below:

1. Project identification
2. Name in full, rank, title, position
3. Other names previously or currently used
4. Nationality
5. Previous or current dual nationalities
6. Date/place of birth
7. Purpose of visit and justification
8. Special qualifications of visitor
9. Present and prospective address in United States
10. Location(s), date, time and duration of proposed visit(s)
11. Sponsoring organization
12. Passport number; Visa number
13. Security clearance status, clearing agency, and degree
14. Status (i.e., foreign national or immigrant alien)

15 Height (inches)

16. Weight (pounds)
17. Color

18. Color eyes
19. Social Security Number as applicable
20. Emergency contact address and telephone number
21. Local or U.S. address while at WFF

11.5 Local Area Accommodations and Features

Accommodations

A variety of local accommodations are available within easy driving from WFF. Prices are generally moderate. Contact the Mission Manager for assistance with local accommodations.

Post Office

A U. S. Post Office is located on the Main Base. Address is Wallops Island, Virginia 23337.

Medical

In addition to WFF medical and emergency rescue capabilities, WFF maintains communications with local emergency rescue and medical organizations. Major medical and hospital facilities in the surrounding Virginia and Maryland counties include Shore Memorial Hospital in Nassawaddox, Virginia, and Peninsula Regional Medical Center in Salisbury, Maryland. Emergency rescue and ambulance support is available from surrounding communities.

Police and Fire Protection

WFF maintains communications with local police and fire fighting organizations. Police protection in the immediate area surrounding Wallops is provided by the Accomack County Sheriff's Office. They are assisted by Virginia State Police. Volunteer fire companies are located in the incorporated towns in Accomack County. They are equipped with modern fire trucks and other equipment to provide emergency first aid, rescue services, and fire fighting.

Transportation

U. S. Route 13 runs the length of the Delmarva Peninsula and connects with major routes along the Atlantic coastline from Maine to Florida. WFF, on the Eastern Shore of Virginia, is linked with the Norfolk-Hampton Roads area by the Chesapeake Bay Bridge Tunnel.

The nearest commercial airports are in Salisbury, Maryland, (40 miles north) and Norfolk, Virginia, (70 Miles south). Rental cars are available at these locations.

United Parcel Service, Federal Express, and various express services are available.

Visitors Center

A NASA Visitors Center and Gift Shop is located on Route 175 about one mile east from the WFF Main Base Gate. The Visitors Center includes a collection of spacecraft and flight articles as well as exhibits about America's Space Flight Program. Special movies and video presentations can be viewed and special events such as model rocket launches are scheduled. No admission is charged.

Emergency Numbers

Fire/Ambulance - Main Base	757-824-1333
Fire/Ambulance - Island	757-824-1333
First Aid/Health Unit	757-824-1266
Environmental Office	757-824-1103
Security	757-824-2536
Severe Weather Information/Facility Closing	757-824-2050

Appendix A
Principal Investigator's Data Package
For Mission Initiation Conference (MIC)

1. Description of scientific objectives and instrumentation.

2. History of the experiment including number of times the experiment or a similar one has flown, giving flight history and any modifications of previously flown payloads.

3. Outline diagram with station numbers including weights, center of gravity, moment of inertia data, deployable elements, doors, booms, nose cones, etc., if available.

4. Structures and Mechanisms

   a) Payload Structure
   b) Payload Housing
   c) Openings
   d) Doors
   e) Booms - Antennas
   f) Special Mechanisms

5. Outgassing requirements, magnetic material sensitivity, radio frequency interference susceptibility.

6. Time/Altitudes of all experiment related events.

7. Instrumentation – Telemetry

   a) Power Required
   b) Channels
   c) Transmitter(s)
   d) Antenna
   e) Commutator(s)
   f) Squib Circuits
   g) Monitors
   h) Aspect Sensors
   i) Magnetometers
   j) Accelerometer
   k) Radar Beacon
   l) Power

8. Vehicle

   a) Performance
   b) Minimum Altitude Required
   c) Coning Angle Acceptable
   d) Despin
   e) Special Systems
   f) Type Nose Cone
   g) Pointing Requirements

9. Flight qualification/operational status of experiment's subsystems, new flight items or deviation from previously qualified systems.

10. Restrictions, precautions, special requirements, limitations for environmental testing of integrated payload.

11. Range Support

   a) Telemetry Ground Station
   b) Tracking Requirements
   c) Special Ground Support Equipment

12. Launch Conditions

   a) Launch Range
   b) Time of Day
   c) Azimuth
   d) Launch Angle
   e) Window
   f) Special Conditions - Restraints

13. Unique or special range requirements including special checkout or support equipment. (Long lead time items)

14. Radioactive Sources - Payload/Calibration

15. List the minimum and comprehensive vehicle and payload systems and experiment performance and operational requirements which will be used to determine mission success or failure.

16. List of Contacts, Titles, Address, Telephone Numbers.

Appendix B
Principal Investigator's
Data Package For A Design Review

Vehicle No.___________

1. Brief description of experiment.

2. Block diagram and all pertinent schematics and detailed drawings.

3. Outline diagram including estimated weights, center of gravity, moments of inertia (best data available).

4. History of experiment including flights, problems and failures, number of times experiment or similar one has flown, giving flight number.

5. Specific criteria (times/altitudes, etc.) of all experiment related events.

6. Pointing requirements including:
   ACS
   Coning
   Spin
   Azimuth
   Elevation

7. Launch window requirements.

8. Comprehensive mission success criteria, include a statement of vehicle performance, i.e.___, lb. to ___KM apogee or, ___lb, above ___KM for ___seconds,

9. Minimum success criteria, include a statement of vehicle performance, i.e. , ___lb. to ___KM apogee or, ___lb above ___KM for seconds.

10. Support requirements including special considerations, i.e., real-time readouts, gases, environmental control.

11. Flight qualification/operational status of experiment's subsystems. Where there are any new flight items or deviations from previous qualified system, include all pertinent documentation.

12. Describe all redundant systems.

13. List history of items to be flown

14. Principal Investigator's go-no-go launch criteria (preliminary minimum success).

15. List experiment/instrumentation interface requirements including power, control/timing, data, power bus protection, etc.

Appendix C
Principal Investigator's Data Package
For A Mission Readiness Review

Vehicle No. __________

1. Description of experiment.

2. Block diagram and all pertinent schematics and detailed drawings.

3. Power requirements including short circuit protection and corona precautions.

4. Outline diagram including weights, center of gravity, moments of inertia data.

5. History of the experiment, flights, problems, failures.

6. Specific criteria (times/altitudes, etc.) of all experiment related events.

7. Pointing requirements including:
   - ACS
   - Coning
   - Spin
   - Azimuth
   - Elevation

8. Launch window requirements.

9. Comprehensive mission success criteria; include a statement of vehicle performance, i.e., ___lb. to ___KM apogee or, ___lb. above ___KM for ___seconds.

10. Final minimum success criteria; include a statement of vehicle performance, i.e., ___lb.to ___KM apogee or, ___lb. above ___KM for ___seconds.

11. Support requirements including special considerations, i.e., real time readouts, gases, environmental control.

12. Flight qualification/operational status of experiment's subsystems. Were there are any new flight items or deviations from a previous qualified system, include all pertinent information, documentation and test data.

13. Describe all redundant systems and list how they are tested.

14. Principal Investigator's master field check-off list with designated responsibilities.

15. Principal Investigator's Go-No-Go launch criteria.

16. List any special requirements in the event of a scrubbed mission.

17. List any post-flight requirements.

18. Provide a testing and integration malfunction log including corrective actions for the experiment system/subsystems.

19. List of all discrepancies still in the system to be corrected.

20. Summarize all suspect items in the experiment system/subsystem.

Appendix D
Preliminary Post-Flight Report Outline

TO: 810/Chief, Sounding Rockets Program Office

FROM: Project Manager

SUBJECT: Preliminary Post Flight Report on___________________________

Principal Investigator: ____

From: ____

Experiment: ____

____

Launch Range:____

Launch Date: ____

Launch Time: ____

Experiment Results: ____

____

Payload Weight: ____

Motor Temperature: ____

Flight Data:	Predicted	Actual
Peak Altitude (km)	_______	_______
Peak Time (Seconds)	_______	_______
Roll Rate (RPS) at Burnout	_______	_______
LOS	_______	_______
QE	_______	_______
Impact:		
Range (km)	_______	_______
Azimuth (deg true)	_______	_______
No Wind:		
Range km	_______	_______
Azimuth (deg true)	_______	_______

Ballistic Wind: _____________ fps at ____________________degrees true azimuth

Drogue Deployment (Actual): Time ____ Alt. _____km Velocity _____fps

Scrubs or Countdown Delays, if any: ____

____

____

Note anomalies with:

Experiment: ____

____

Timing Events/Instrumentation/Telemetry: ____

____

Control System: ____

____

Mechanical System: ____

____

Propulsion System: ____

____

Recovery System: Ground ____

____

Support System: ____

____

Prelaunch Problems:

When What

____

____

____

____

Action Items:

Item Discipline

____
____
____
____
____
____
____

____
(Signature)

Nonconformance Report Log

Flight Number________________

Item Number	**Date**	**Discrepancy**	**Remarks**	**Date Closed**

Appendix E
NASA Sounding Rocket Description and Flight Performance Characteristics

This appendix describes the various NASA sounding rocket launch vehicles and their performance.

E.1 Special Projects Launch Vehicles (12.XXX)

Special Projects refers to flight vehicles in a developmental status, vehicle systems that will be used only once, or systems presently in use by other organizations that will not be taken over for use at NASA. As an example, 12.039 WT and 12.040 WT were the engineering test flights of the Taurus-Nike-Tomahawk.

E.2 Super Arcas Launch Vehicle (15.XXX)

General

The Super Arcas vehicle system has been used since 1962 for carrying meteorological measuring devices as high as 100 kilometers. This system is also used to take other types of measurements in the same altitude region with little expense, and quick deployment, Atlantic Research Corporation manufactures the motor. Figure E-l shows the Super Arcas vehicle as it leaves the Arcas launcher. The white objects in the photograph are Styrofoam "sabots" (shoes) which guide the vehicle through the launcher.

Vehicle Performance

The Super Arcas rocket motor (Marc 60A2) has an average thrust level of 325 pounds and a total action time of 40.2 seconds. This motor, which weighs 83 pounds before launch, can boost a 10-pound payload to an altitude of 92 kilometers when launched from sea level at an effective launch angle of 86 degrees. An acceleration of 7g's and burnout roll rate of 25 revolutions per second are realized.

Payloads

The Super Arcas vehicle has successfully launched payloads ranging from 8 to 18 pounds. The payloads have an outside diameter of 4.5 inches and a typical payload length of 30 inches. These payloads usually consist of a tangent ogive nose cone housing the experiment mated to a parachute system assembly containing a high altitude, radar reflective decelerator. Payload separation is programmed by a delay train for 148 seconds after launch.

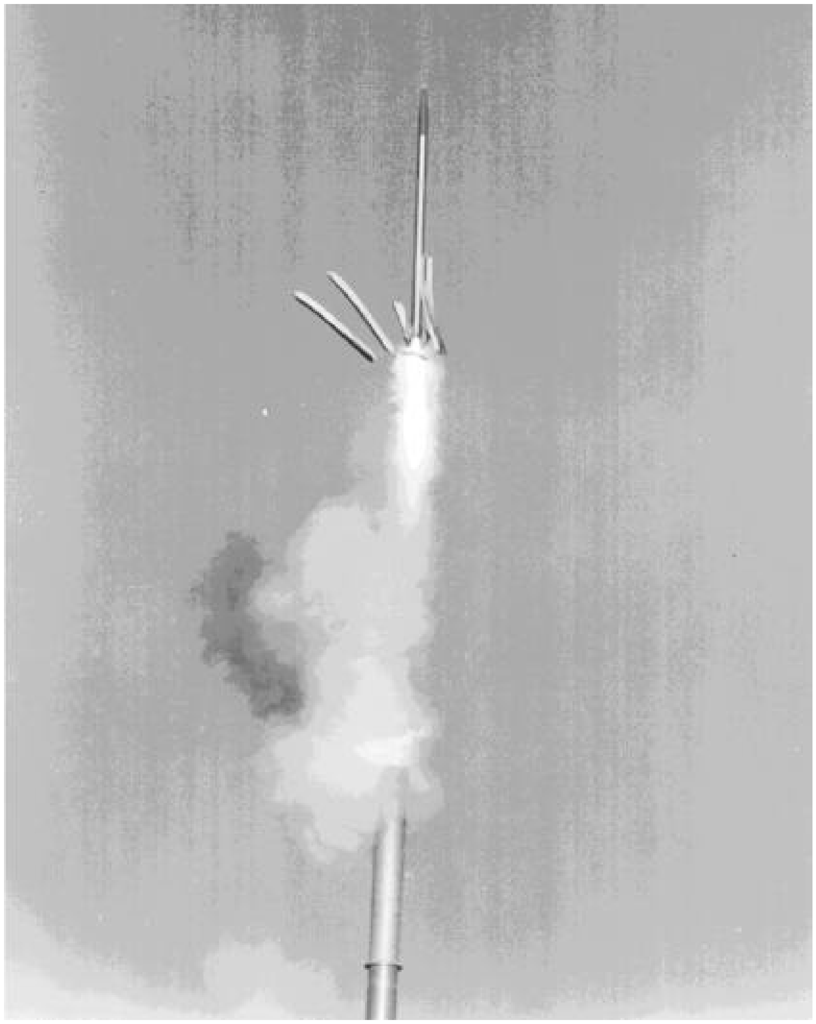


Figure E-1. Super Arcas Launch Vehicle

Decelerator

The primary purpose of the high altitude decelerator is to slow and stabilize payloads while making measurements in the mesosphere. It is also used for payload recovery, including air recovery. This rocket system also has an ejectable nose cone, and other special systems that can be incorporated into the payload design.

Performance Graph

Apogee altitude and range at various elevation angles and payload weights for the Super Arcas vehicle are presented in Figure E-2.

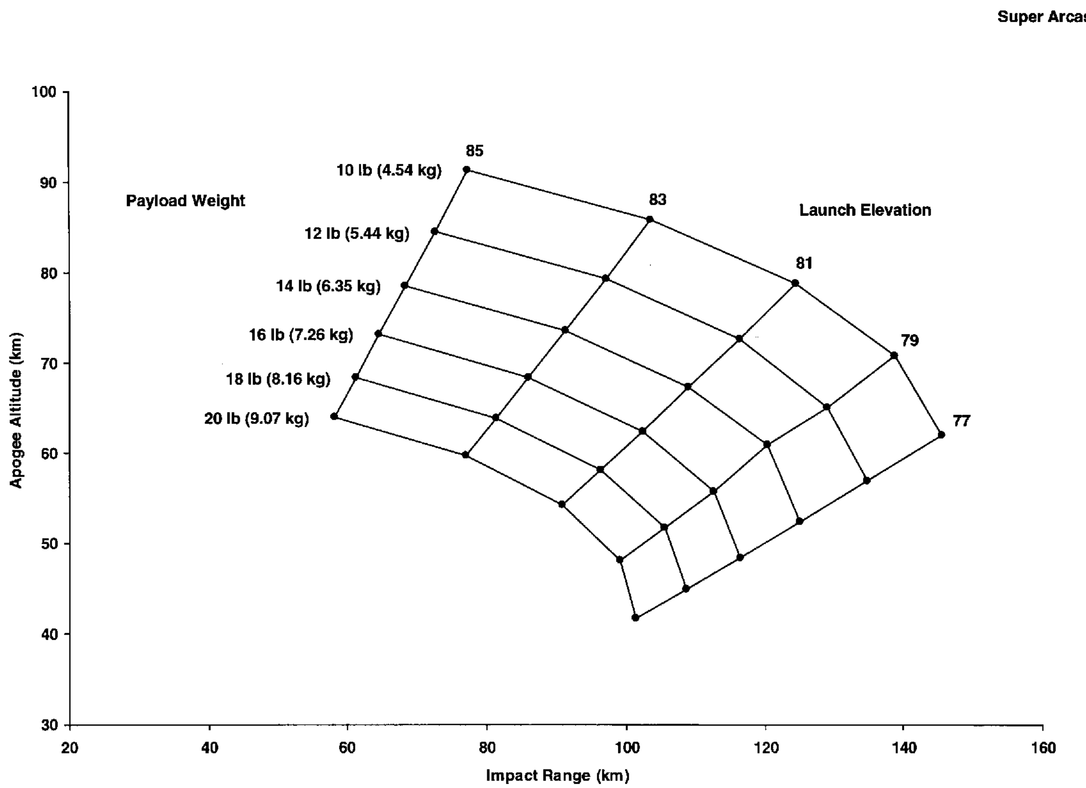


Figure E-2. Super Arcas Launch Vehicle Performance

E.3 Black Brant V Launch Vehicle (21.XXX)

General

The Black Brant V (BBV) is a single-stage solid propellant sounding rocket developed by Bristol Aerospace, Ltd. in Winnipeg, Canada. There is a 3-fin version (VB) and a 4-fin version (VC). Figure E-3 shows the Black Brant VB vehicle.

Vehicle Performance

The 26 KS 20,000 Black Brant V rocket motor produces an average thrust level of 17,025 pounds and an action time of 26.9 seconds. The primary diameter of the Black Brant V is 17.26 inches and it is 210 inches long. Loaded weight of the motor including hardware is 2,789 pounds which includes 2,198 pounds of propellant.

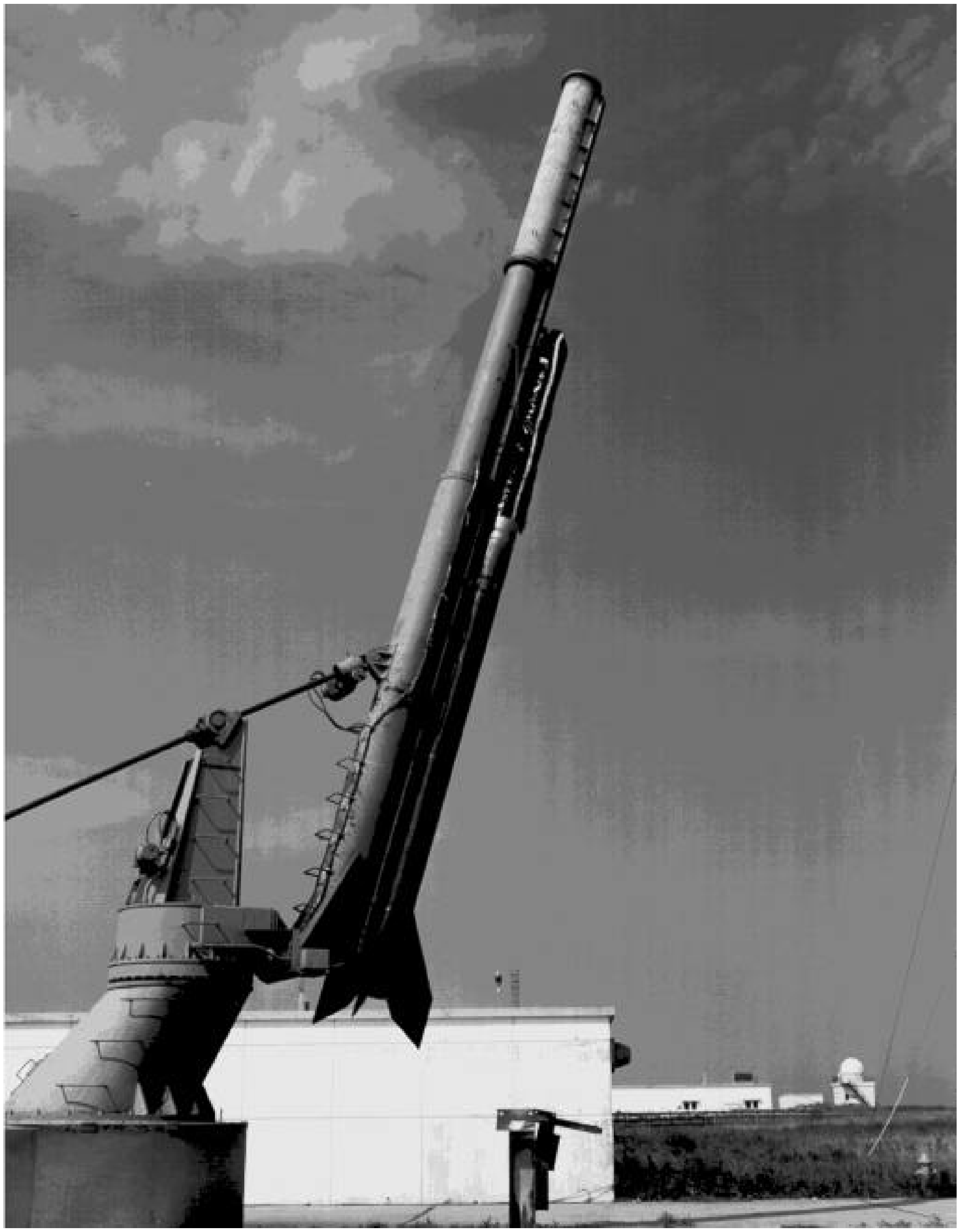


Figure E-3. Black Brant VB Launch Vehicle

Payloads

The standard payload configuration for the Black Brant V vehicle is 17.26 inches diameter with a 3:1 ogive nose cone shape. Payload length for the Black Brant V is limited to approximately 200 inches and weight is limited to approximately 1200 pounds. Because of the relatively high dynamic pressures, bulbous (larger than 17.26 inches diameter) payloads cannot be accommodated on the Black Brant V vehicle The SPARCS can be flown on this vehicle. See Section 6 for information regarding SPARCS.

Standard hardware systems that are available for Black Brant V motors include aft recovery systems for 750 lb. or 1000 lb. recovered weights. An Ogive Recovery System Assembly (ORSA) for the same weight ranges, payload separation systems (including a High Velocity Separation System) and despin systems are also available. These units are modular "stackable" such that a great deal of flexibility exists to meet experiment requirements.

Black Brant VB

The Black Brant VB provides slightly improved performance over the VC. The burnout roll rate for the Black Brant V is 4 cycles per second. Maximum longitudinal acceleration varies with payload weight; however, for a typical payload weight of 600 pounds, maximum thrust axis acceleration is approximately 12g's.

Performance Graph

Sea level launch performance capabilities are shown at various launch elevation angles and gross payload weights in Figure E-4 for the BBVC four fin version. Altitude vs. time profiles for various payloads weights launched from White Sands Missile Range, New Mexico, at high launch elevation angles are presented in Figure E-5 for the Black Brant VC.

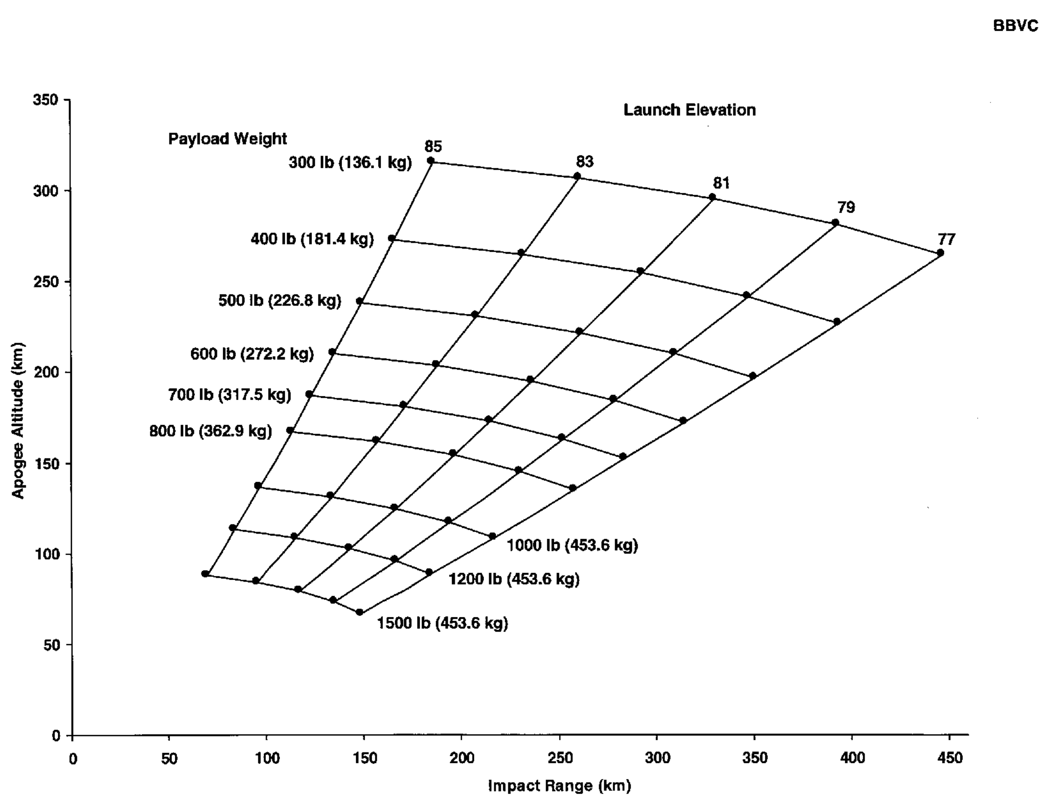


Figure E-4. Black Brant VC Launch Vehicle Performance

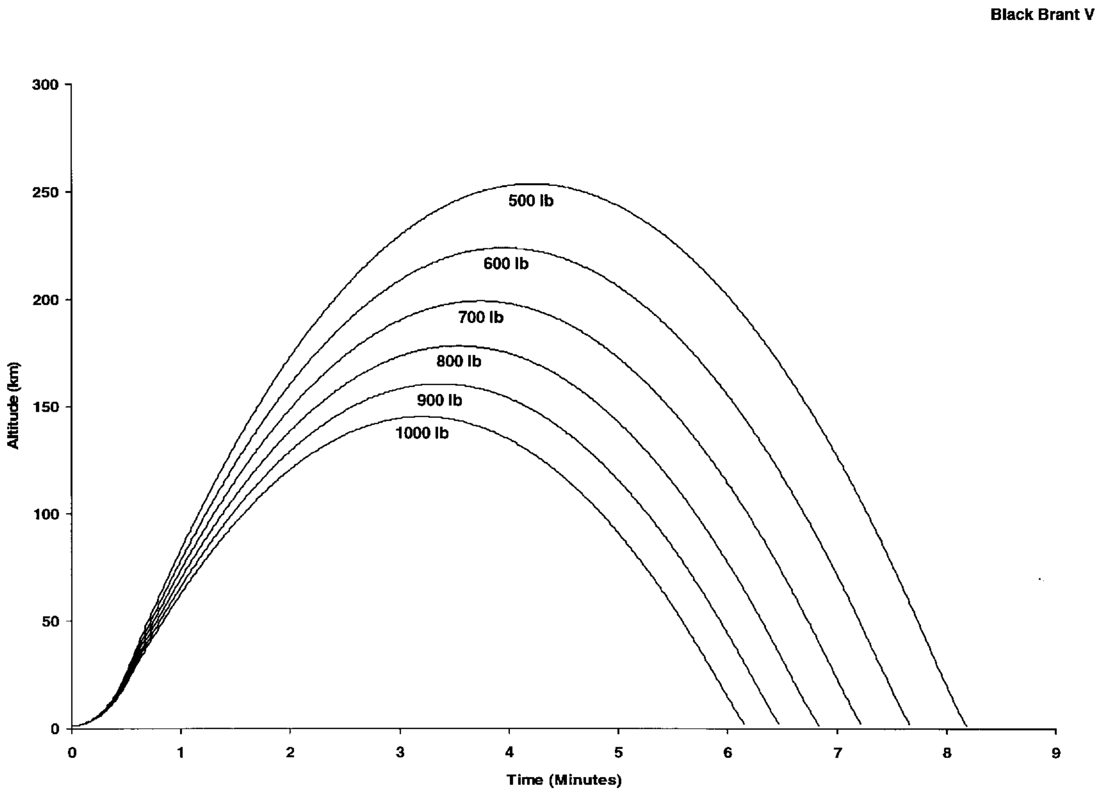


Figure E-5. Black Brant VB Altitude vs. Time Profiles for Launch at WSMR

E.4 Nike-Black Brant V B/C Launch Vehicle (27.XXX)

General

The performance capabilities of the Black Brant V vehicle can be enhanced by boosting it with a Nike booster. This configuration can be tower launched in three and four fin versions (VB and VC, respectively). The Nike M5-El booster is the same rocket motor used to boost the Tomahawk sustainer and can be configured with three or four fins, depending on Black Brant VB or VC application. The Nike and Black Brant V stages drag separate at Nike burnout and the Black Brant V ignites at 8.5 seconds flight time. The Black Brant V rocket motor is configured with the addition of an ignition module at the motor front end. Figure E-6 shows the Nike-Black Brant VC vehicle.

Figure E-6 Nike-Black Brant VC Launch Vehicle

Payloads

The payload configurations used with the Nike boosted Black Brant V are similar to, or even interchangeable with, those flown on the single stage BB V B/C version. The Nike boosted Black Brant V vehicle can also accommodate bulbous diameter payloads (up to 22 inches) for scientific instruments which require a larger diameter than the standard 17.26 inches The SPARCS can be flown on this vehicle. See Section 6 for additional information regarding SPARCS.

Standard hardware systems that are available for Nike-Black Brant V motors include aft recovery systems for 750 lb. or 1000 lb. recovered weights, an Ogive Recovery System Assembly (ORSA) for the same weight ranges, payload separation systems (including High Velocity Separation Systems) and despin systems. These units are modular 'stackable" providing a great deal of flexibility in meeting experiment requirements.

Performance Graph

Sea level launch flight trajectory parameters are shown at various launch elevation angles and gross payload weights in Figure E-7 for the Nike-Black Brant VC. Altitude-time profiles for various payload weights launched from White Sands Missile Range, New Mexico, are presented in Figure E-8 for the Nike-boosted Black Brant VB vehicle. Maximum thrust-axis acceleration is higher for the boosted Black Brant during booster burning with a value of approximately 20g's for a 600 pound gross payload weight.

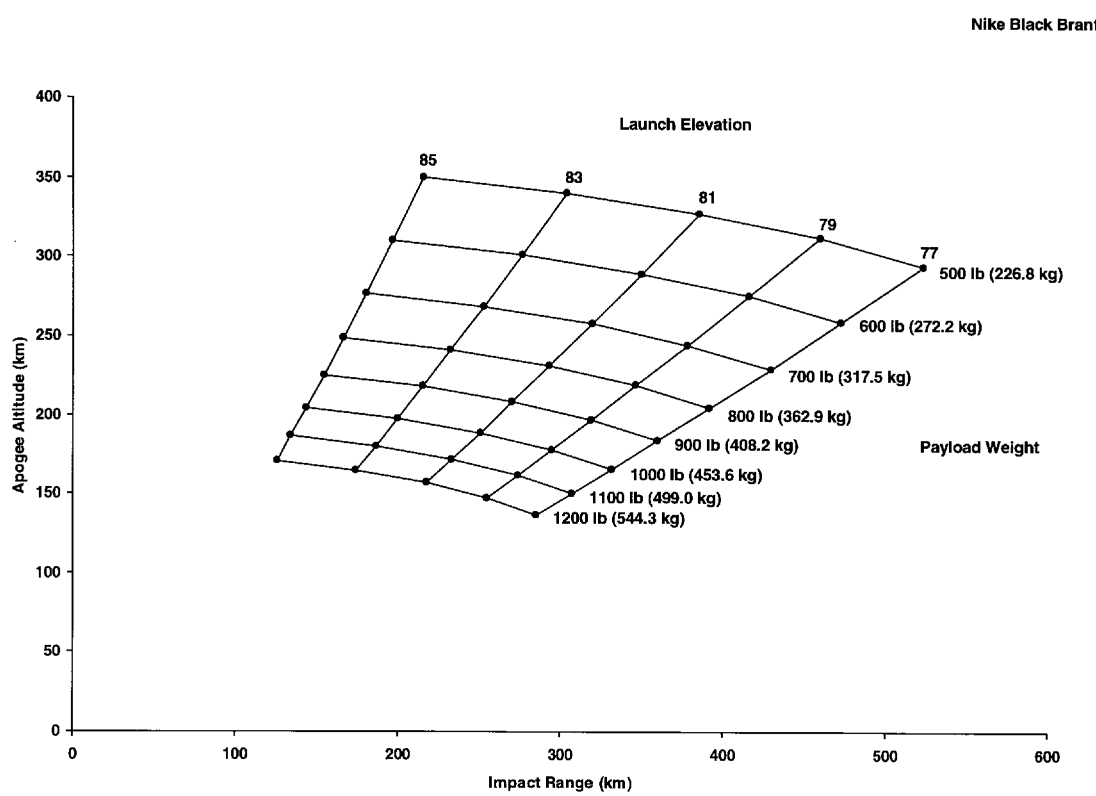


Figure E-7. Nike-Black Brant VC Launch Vehicle Performance

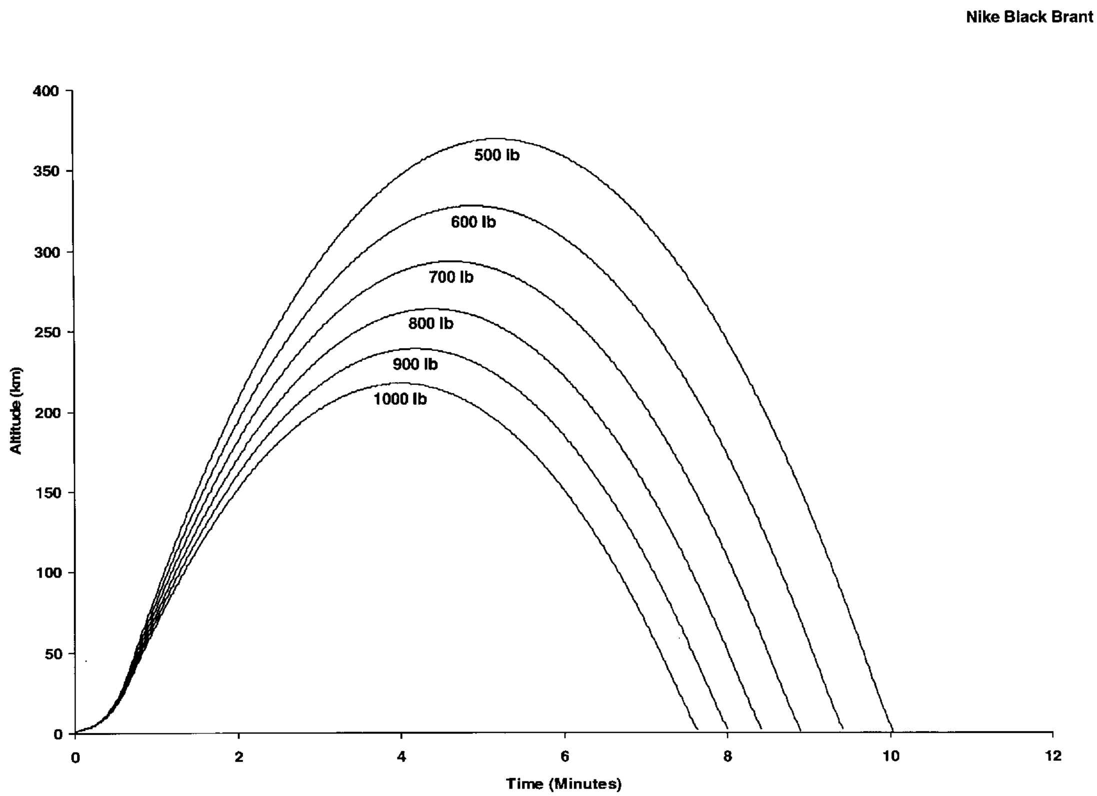


Figure E-8 Nike-Black Brant VB Altitude vs. Time Profiles for Launch at WSMR

E.5 Terrier-Malemute (29.XXX)

General

The Terrier-Malemute launch vehicle is a high performance two-stage vehicle used for payloads weighing less than 400 pounds. The first stage booster consists of a Terrier MK 12 Mod 1 rocket motor with four 340 square inch fin panels arranged in a cruciform configuration. The Terrier booster has an overall diameter of 18 inches. For a payload weight of 200 pounds, the longitudinal acceleration during the boost phase is 26g's. The second stage propulsion unit is a Thiokol Malemute TU-758 rocket motor which is designed especially for high altitude research rocket applications. The external diameter of the Malemute is 16 inches. Figure E-9 shows the Terrier-Malemute vehicle.

Vehicle Performance

The average thrust is 9,604 pounds. The maximum thrust level is approximately 14,200 pounds which results in a maximum longitudinal acceleration during second stage burning of 32g's for a

200 pound payload. Liftoff weight of the Terrier-Malemute launch vehicle, less payload, is approximately 3260 pounds. This vehicle is usually rail launched and can be accommodated at most established launch ranges.

Payload

The Terrier-Malemute vehicle is particularly suited for lower weight payloads; performance drops appreciably as payload weight increases. Bulbous diameter payloads can be accommodated on the Terrier-Malemute; however, the high dynamic pressures encountered by this vehicle result in high aerodynamic heating rates and high vehicle structural loads Thus, payload design characteristics must be carefully considered. This vehicle is generally used for relatively lightweight plasma physics payloads.

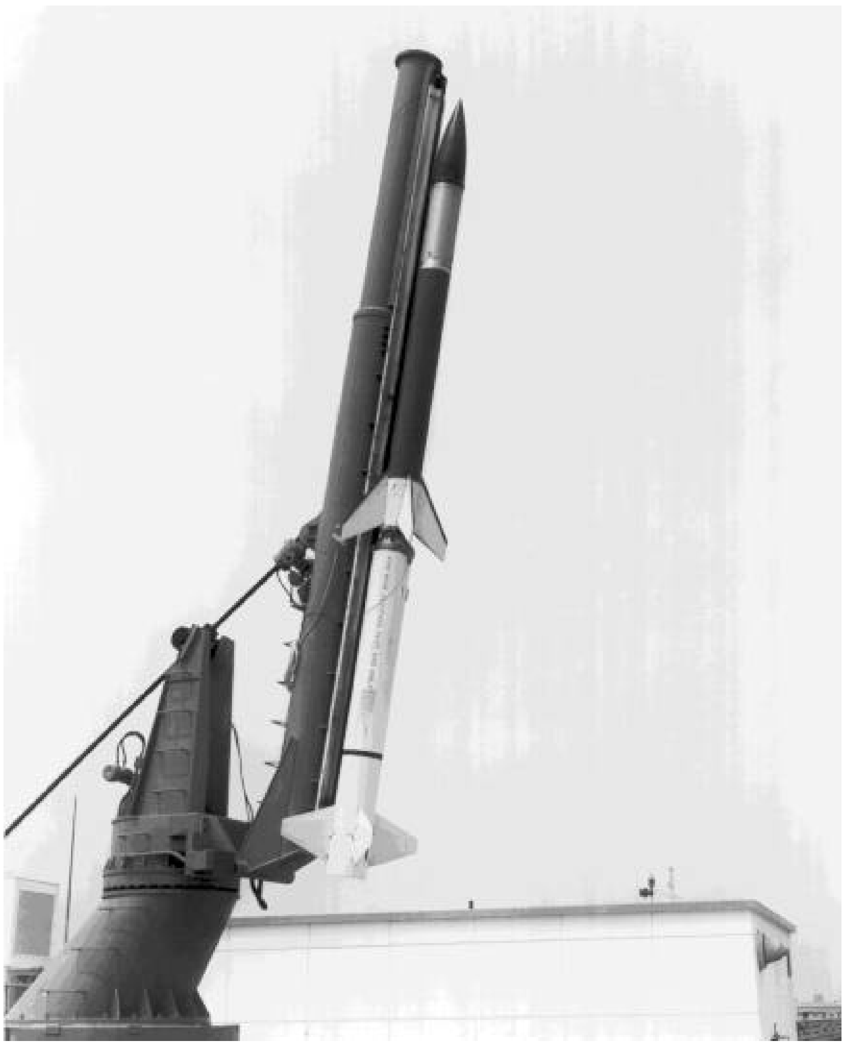


Figure E-9. Terrier-Malemute Vehicle

Performance Graph

Performance parameters of the Terrier-Malemute vehicle are shown in Figure E-10. The payload configuration for reference data is a 16-inch diameter with a 3:1 ogive nose shape.

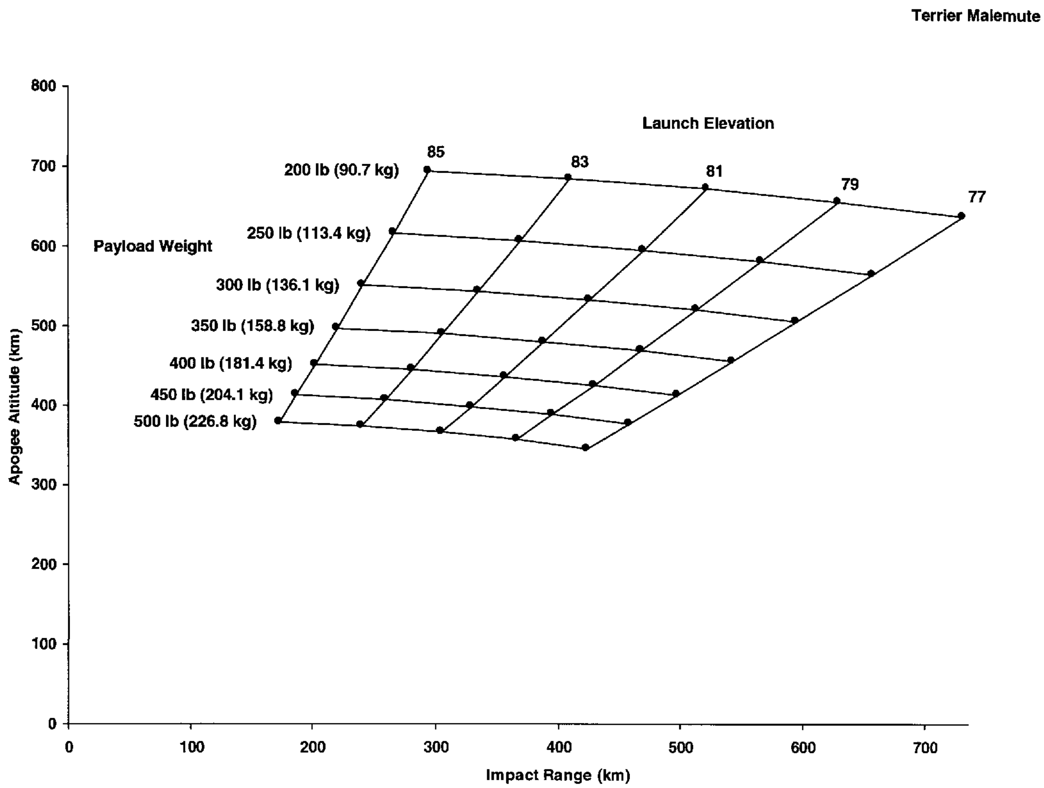


Figure E-10. Terrier-Malemute Launch Vehicle Performance

E.6 Orion Launch Vehicle (30.XXX)

General

The Orion is a single stage, unguided, fin stabilized rocket system which uses a surplus Army rocket motor having a dual phase propellant. Three fins on the aft end of the motor provide forces for rolling up the vehicle in flight for stability. Figure E-11 shows the Orion vehicle.

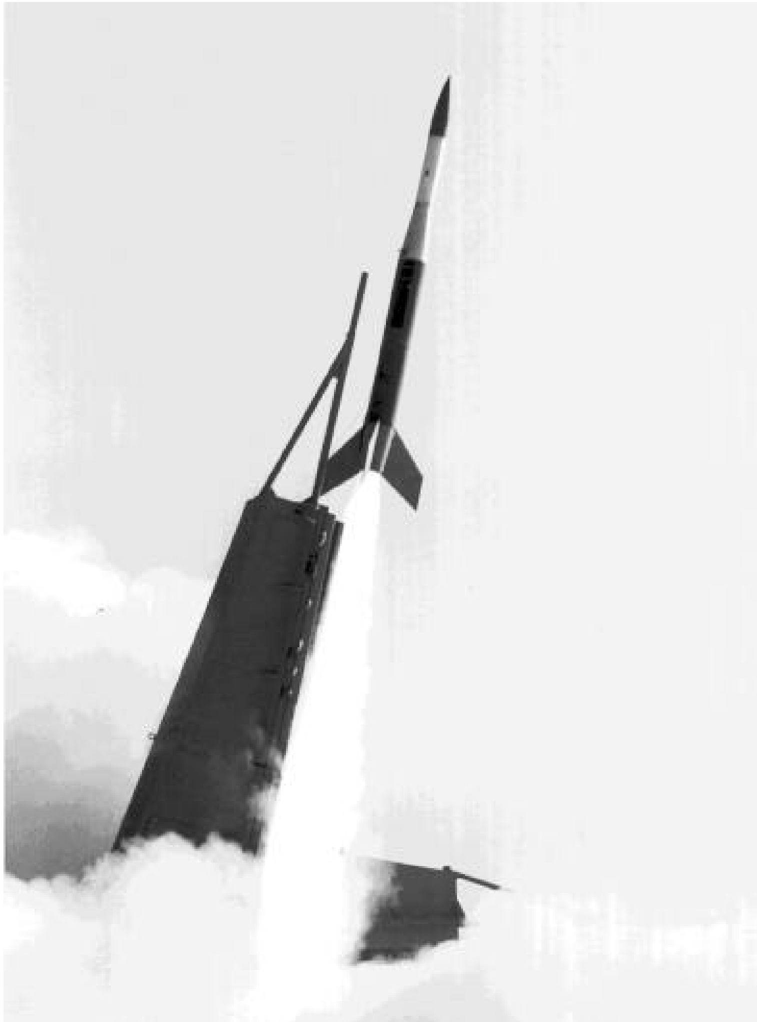


Figure E-11. Orion Launch Vehicle

Vehicle Performance

The Orion is 14 inches in diameter and 110 inches long. The Orion fins are nominally canted to provide a four revolutions per second spin rate at burnout. The rocket carries an 85 pound payload to 88 kilometers and a 150 pound pay- load to 71 kilometers when launched from sea level at an 85 degree launch angle.

Payloads

The standard payload for the Orion has a principal diameter of 14 inches and utilizes many nose cone shapes. The normal payload length varies from 72 to 100 inches although this is not the maximum envelope. Payload diameters as small as 4.5 inches are flown on the Orion and performance characteristics are most favorable for 85 to 150 pound payloads.

Standard hardware includes a separable clamshell nose cone and an Orion standard ignition system. Separation systems can be provided to separate the payload from the motor during ascent.

Performance Graph

The Orion launch vehicle apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure E-12.

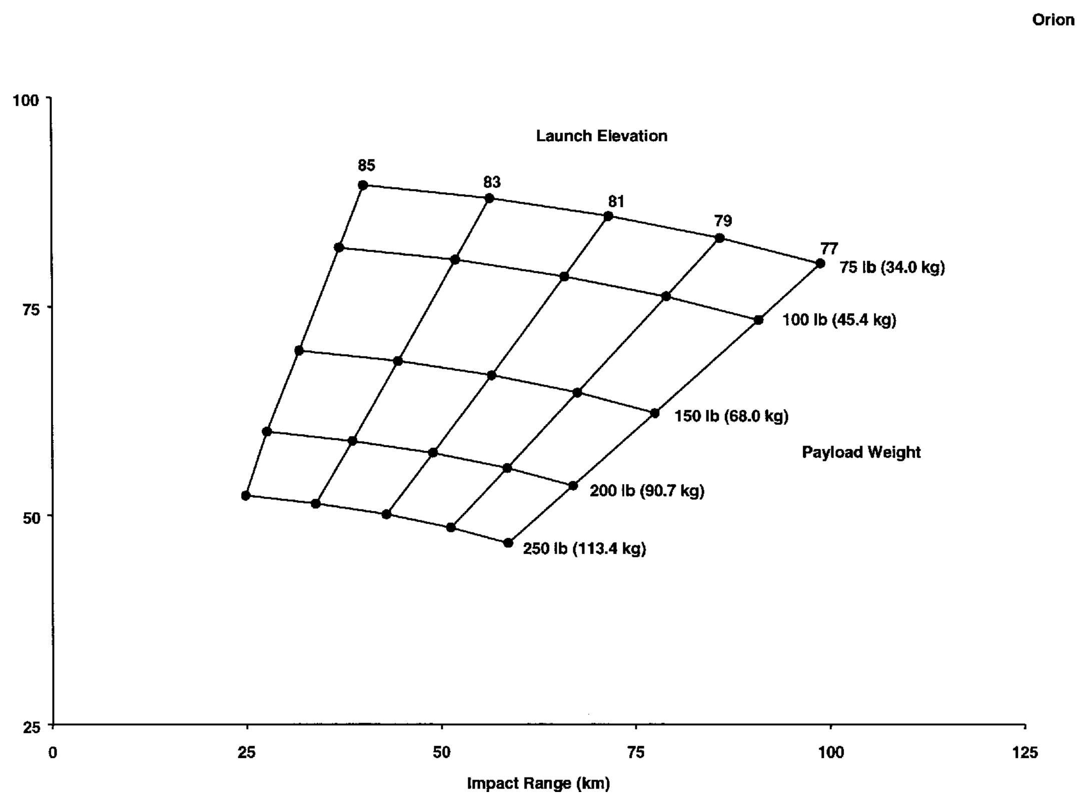


Figure E-12. Orion Launch Vehicle Performance

E.7 Nike-Orion Launch Vehicle (31.XXX)

General

The Nike-Orion is a two-stage, unguided, fin stabilized rocket system which utilizes a Nike M5-El (or M88) first stage booster and a surplus Army Orion rocket motor for the second stage propulsion. The Nike motor has three equally spaced unmodified Ajax fins, and the Orion motor has four fins on the aft end arranged in a cruciform configuration to provide stability. The first stage Nike booster has an action time of 3.2 seconds. The second stage ignites 9 seconds after liftoff and has an action time of 32 seconds. Figure E-13 shows the Nike-Orion vehicle.

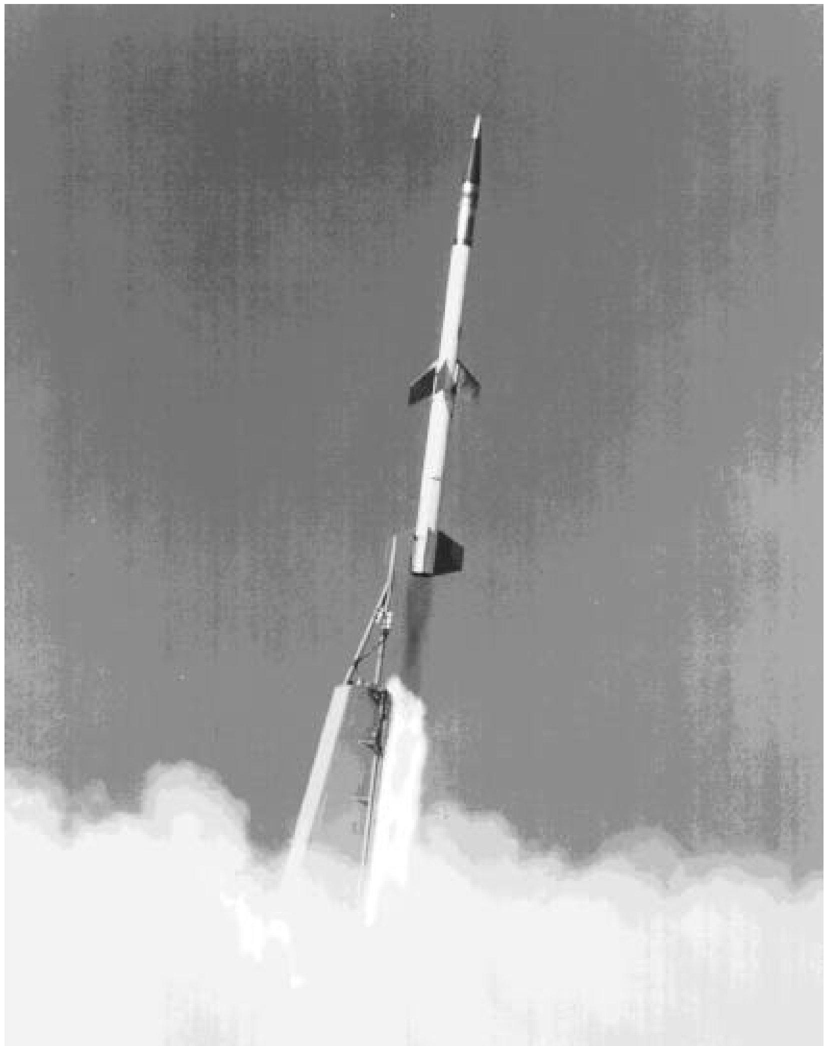


Figure E-13. Nike-Orion Launch Vehicle

Vehicle Performance

The average sea level thrust of the Nike rocket motor is 42,782 pounds. Overall specific impulse of the motor is 195 lbf-sec/lbm and the total impulse is 146,540 pound-seconds at sea level

The basic Nike motor is 136 inches long with a principal diameter of 16.5 inches. The interstage adapter is bolted to the front of the Nike and consists of a conical shaped adapter which slip-fits into the second stage nozzle, thus providing for drag separation at Nike burnout. Each Nike fin is 4.8 square feet in area. Normally, the fins are canted to provide a two revolutions per second spin rate at Nike burnout. Total weight of the booster system (with hardware) is 1321 pounds, including 755 pounds of propellant.

The Orion is 14 inches in diameter and 110 inches long. The Orion fins are normally canted to provide a four revolutions per second spin rate at burnout.

Payloads

The standard payload for the Nike-Orion has a principal diameter of 14 inches and utilizes various nose cone fineness ratios. The normal payload length varies from about 72 to 120 inches although this is not the maximum envelope. Payloads from 6 to 17.26 inch diameter are also flown on the Nike-Orion. Standard hardware includes a separable clamshell nose cone and an Orion Standard Ignition System. Separation systems can be provided to separate the payload from the motor during ascent.

Performance Graph

The rocket system will carry a 150 pound payload to 190 kilometers and a 450 pound payload to 90 kilometers when launched from sea level at an 85 degree launch angle. The Nike-Orion launch vehicle apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure E-l4.

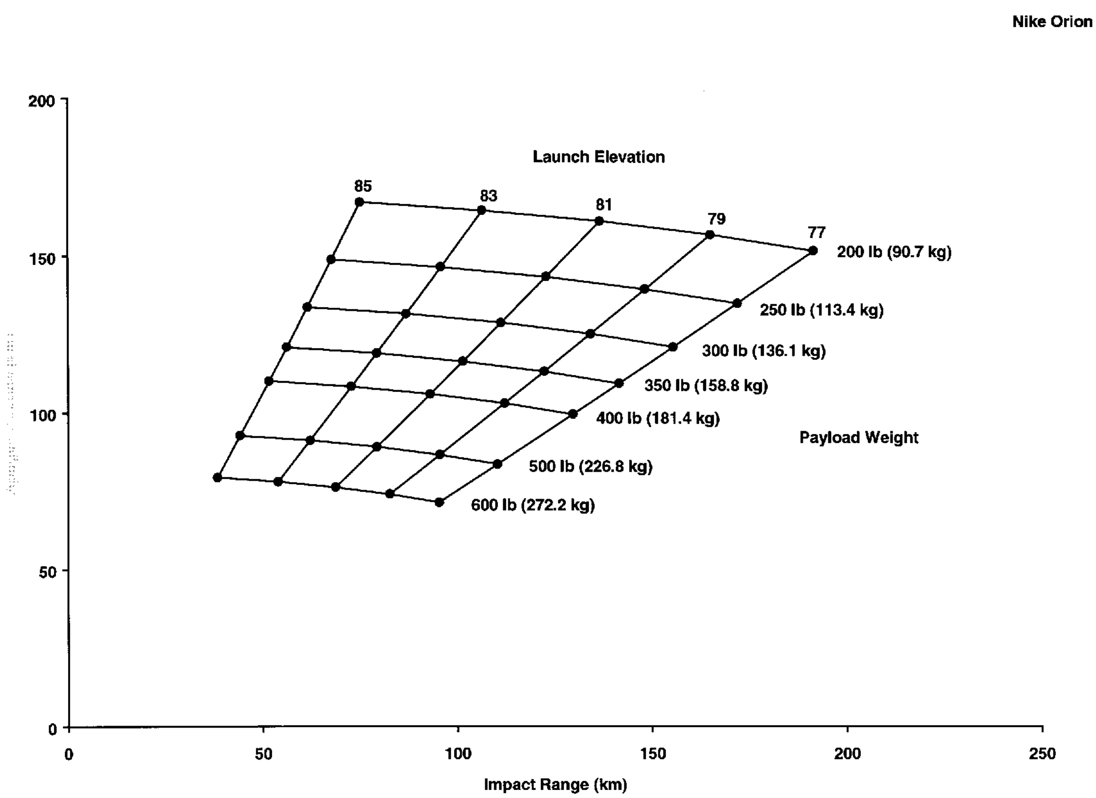


Figure E-14. Nike-Orion Launch Vehicle Performance

E.8 Taurus-Orion Launch Vehicle (33.XXX)

General

The Taurus-Orion is a two-stage, unguided, fin stabilized rocket system which utilizes a Taurus first stage booster and a surplus Army Orion rocket motor for the second stage propulsion. The Taurus motor has four equally spaced modified Ajax fins, and the Orion motor has four fins on the aft end arranged in a cruciform configuration to provide stability. Figure E-15 shows the Taurus-Orion vehicle.

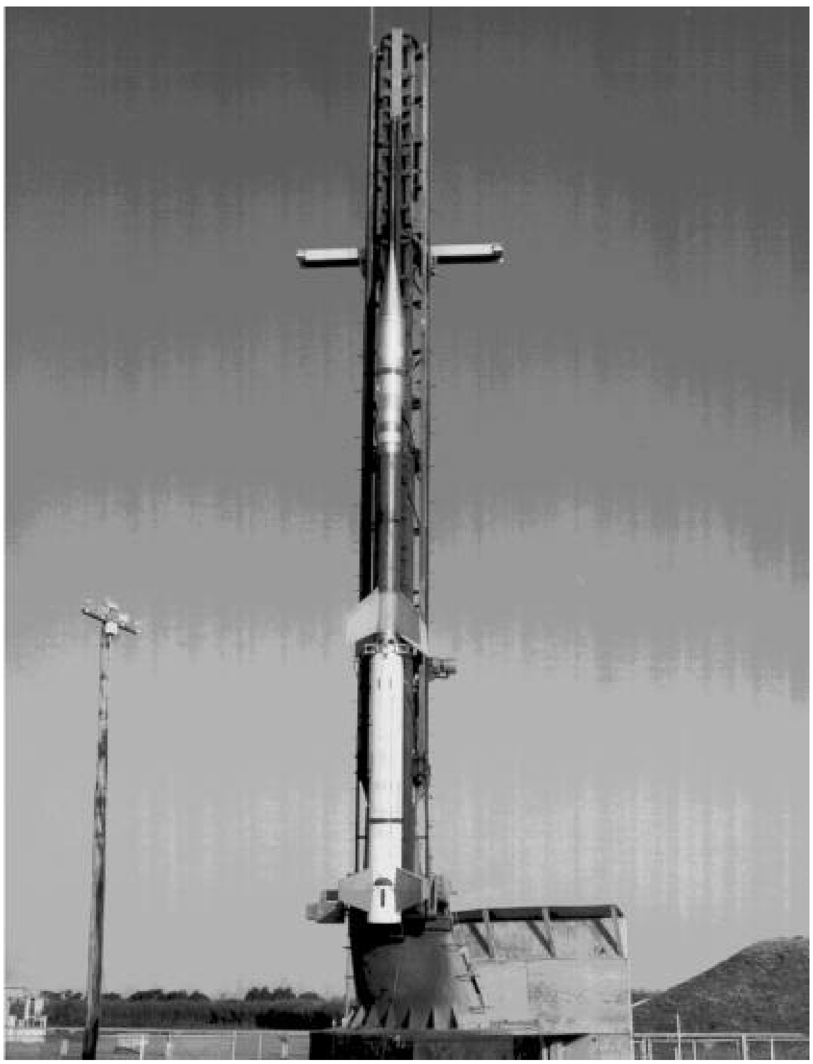


Figure E-15 Taurus-Orion Launch Vehicle

Vehicle Performance

The basic Taurus motor is 165 inches long with a principal diameter of 22.75 inches. The interstage adapter is bolted to the front of the Taurus and consists of a conical shaped adapter which slip-fits into the second stage nozzle, thus providing for drag separation at Taurus burnout. Each Taurus fin is 4.8 square feet in area. Normally, the fins are canted to provide a two revolutions per second spin rate at Taurus burnout. The weight of the booster system is 3005 pounds.

The Orion is 14 inches in diameter and 110 inches long. The Orion fins are normally canted to provide four revolutions per second spin rate at burnout.

Payloads

The standard payload for the Taurus-Orion has a principal diameter of 14 inches and utilizes various nose cone fineness ratios. The normal payload length varies from about 72 to 150 inches although this is not the maximum envelope. Payloads from 9 to 14 inches in diameter are also flown on the Taurus-Orion. The rocket system will carry a 150 pound payload to 260 kilometers and a 500 pound payload to 140 kilometers when launched from sea level at an 85 degree launch angle.

Standard hardware includes a separable clamshell nose cone and an Orion Standard Ignition System. A clamped interstage is available to provide better stability for vehicle configurations with very long payloads. Separation systems can be provided to separate the payload from the motor during ascent.

Performance Graph

The Taurus-Orion launch vehicle configuration and apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure E-16.

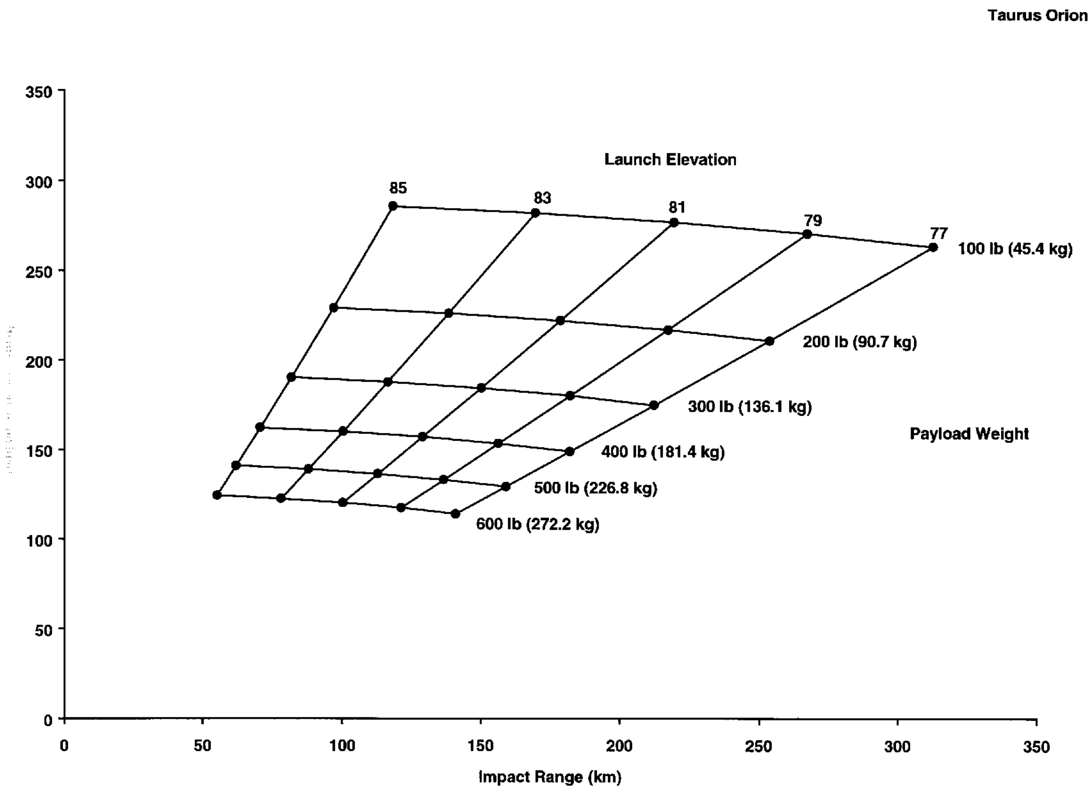


Figure E-16 Taurus-Orion Launch Vehicle Performance

E.9 Black Brant X Launch Vehicle (35.XXX)

General

The Black Brant X rocket system is a three-stage system; unique because the third stage motor is ignited once the vehicle system reaches exoatmospheric conditions. The motors and the finless third stage is the Nihka rocket motor, Figure E-17 shows the Black Brant X vehicle.

Vehicle Performance

The first stage booster consists of a Terrier MK 12 Mod 1 rocket motor with four 340 square inch fin panels arranged in a cruciform configuration. The Terrier booster has an overall diameter of 18 inches.

The 26 KS 20,000 Black Brant V rocket motor produces an average thrust level of 17,025 pounds with an action time of 26.9 seconds. The primary diameter of the Black Brant V is 17.26 inches and it is 210 inches long. Loaded weight of the motor including hardware is 2,789 pounds which includes 2,198 pounds of propellant.

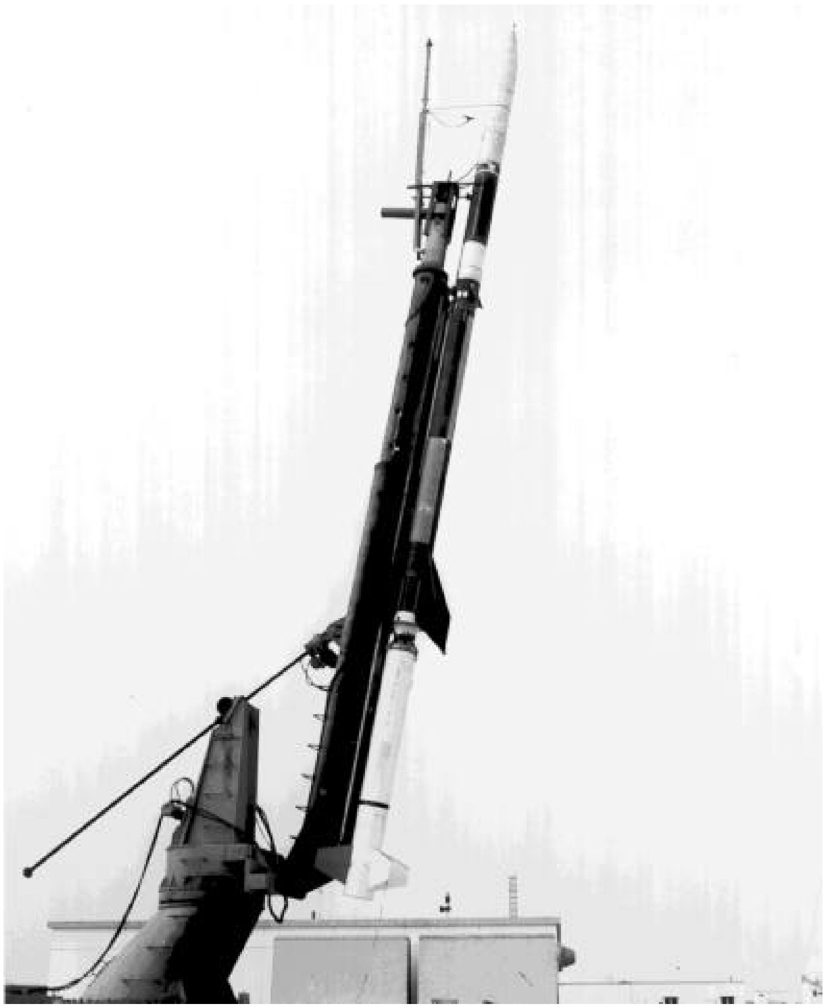


Figure E-17. Black Brant X Launch Vehicle

The Nihka rocket motor was developed specifically for the Black Brant X rocket system by Bristol Aerospace. The average thrust is 12,000 lbs. with a total impulse of 193,500 lb-sec. The primary diameter is 17.26 inches and the length is 76 inches. The Nihka motor weighs 894 lbs. including 756 lbs. of propellant.

Payload

The standard payload configuration for the Black Brant X vehicle is 17.26 inches in diameter with a 3:1 ogive nose shape. Payload length and weight limits for the Black Brant X are not defined as they are for the Black Brant V and specific limitations for this system are determined as the situation warrants.

Standard hardware systems that are available for Black Brant V motors include aft recovery systems, payload separation systems (including High Velocity Separation System) and despin systems. These units are modular "stackable" so that a great deal of flexibility exists in meeting experiment requirements.

Performance Graph

The Black Brant X launch vehicle configuration and apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure E-18.

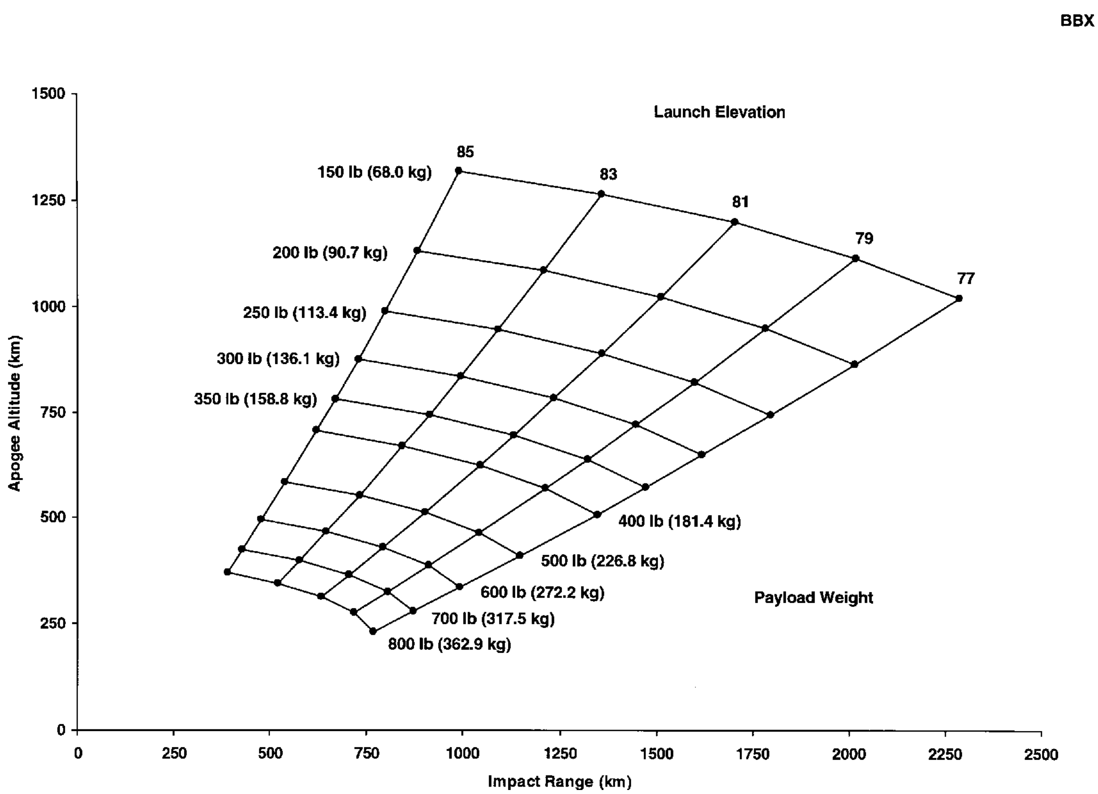


Figure E-18. Black Brant X Launch Vehicle Performance

E.10 Terrier-Black Brant VC Launch Vehicle (Black Brant IX, 36.XXX)

General

The Black Brant IX vehicle system (Figure E-19) is the fourth in the group of rocket systems using the 17.26 inch diameter Black Brant V rocket motor. This vehicle fulfills a weight to altitude requirement for the scientific community which is not met by other NASA vehicle systems.

Figure E-19. Terrier-Black Brant VC Launch Vehicle

Vehicle Performance

The first stage booster consists of either a Terrier MK 12 Mod 1 rocket motor or a Terrier MK 70 rocket motor, both of which are equipped with four 340 square inch fin panels arranged in a cruciform configuration. The Terrier booster has a diameter of 18 inches.

The 26 KS 20,000 Black Brant VC rocket motor produces an average thrust level of 17,005 pounds and an action time of 26.9 seconds. The primary diameter of the Black Brant VC is 17.26 inches and it is 210 inches long. Loaded weight of the motor including hardware is 2,789 pounds which includes 2,198 pounds of propellant.

Payload

The standard payload configuration for the Black Brant IX vehicle is 17.26 inches in diameter with a 3:1 ogive nose shape. Payload length and weight limits are not defined as they are for the Black Brant V and specific limitations will be determined as the situation warrants. The burnout roll rate for the second stage Black Brant is three to four cycles per second. The SPARCS can be flown on this vehicle. See Section 6 for additional information regarding SPARCS.

Standard hardware systems that are available for Black Brant V motors include aft recovery systems for 750 lb. or 1000 lb. recovered weights, Ogive Recovery System Assembly (ORSA) for the same weight ranges, payload separation systems (including High Velocity Separation System) and despin systems. These units are modular "stackable" such that a great deal of flexibility exists in meeting experiment requirements.

Performance Graph

The Black Brant IX (Terrier MK 12/Mod 0) launch vehicle apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure E-20.

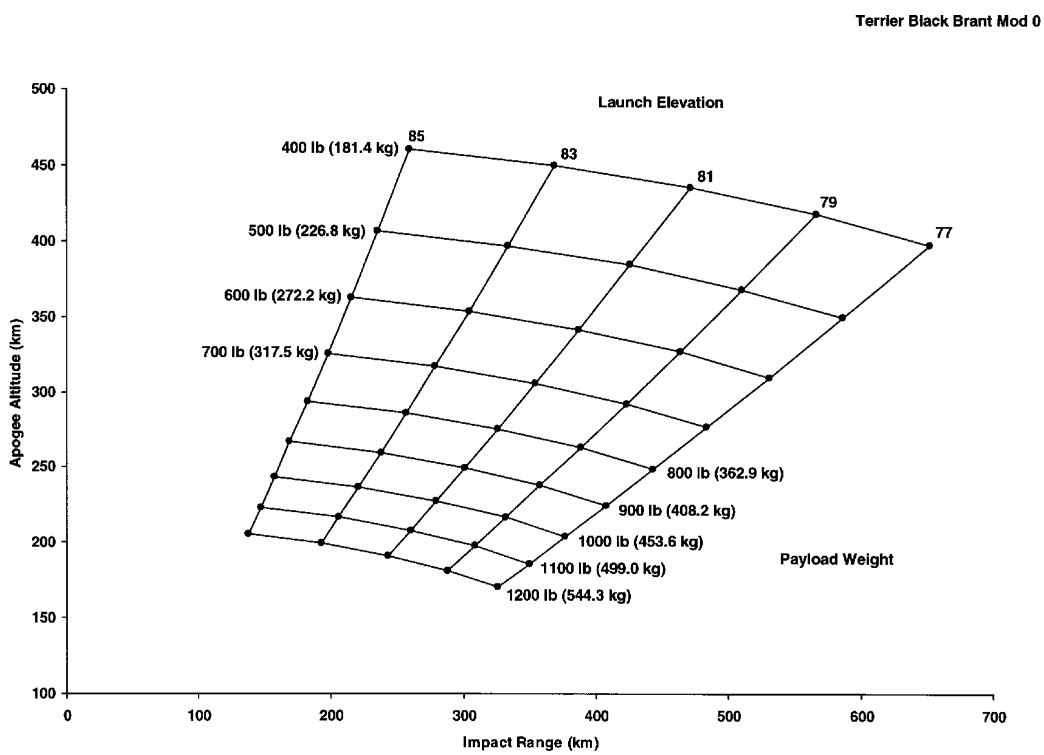


Figure E-20. Terrier-Black Brant VC (MK 12) Launch Vehicle Performance

Altitude vs., time profiles for various payload weights with the MK 12 configuration launched from White Sands Missile Range, New Mexico, at high launch elevation angles are presented in Figure E-21.

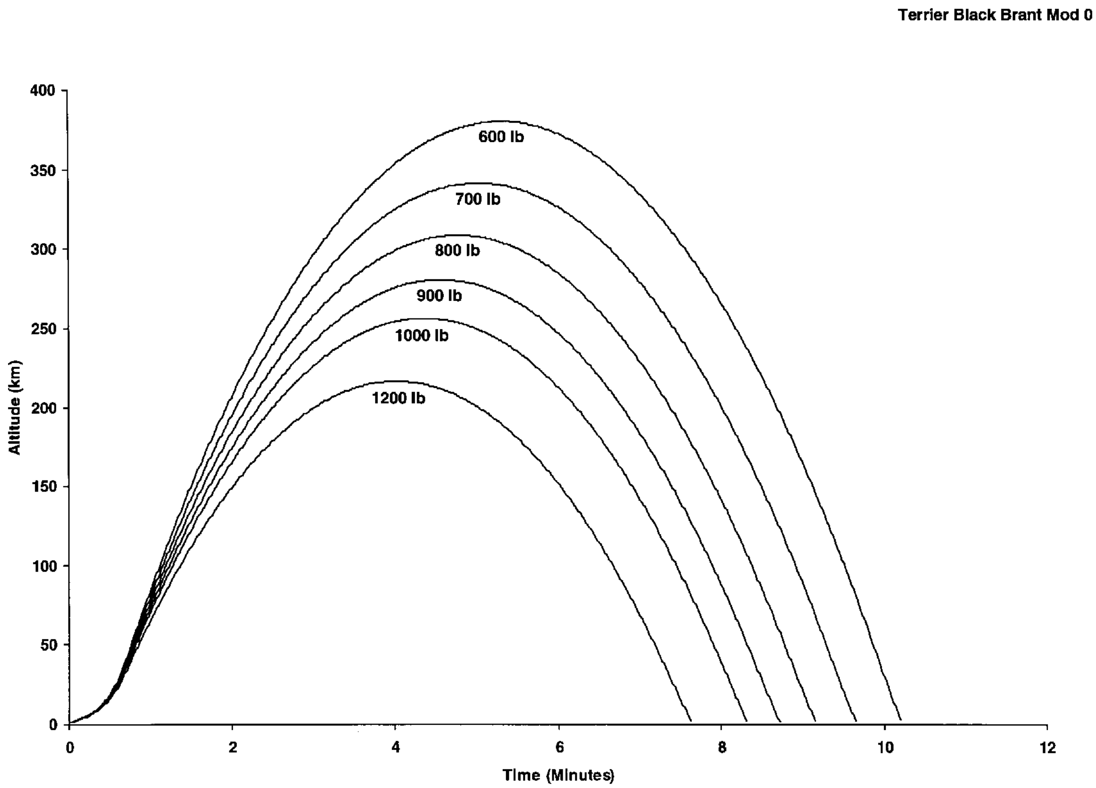


Figure E-21. Terrier-Black Brant VC (MK 12) Altitude vs. Time Profiles for WSMR Launch

The Black Brant IX (Terrier MK 70) launch vehicle apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure E-22. This is the Mod 2 Graph.

E.11 Viper Date Launch Vehicle (37.XXX)

Note:

At the time this handbook was being prepared for publication, the Viper 3A/10D Dart configuration had not completed the required developmental test round launch within the NASA Sounding Rocket Program. Additional information regarding this configuration, including performance curves, will be available upon the successful completion of this mission. The following is provided as a general overview of the proposed launch vehicle.

General

The Viper 3A/10D Dart is a two stage sounding rocket vehicle consisting of a solid propellant Viper 3A rocket motor as the first stage and a non-propulsive Dart containing the payload as the second stage. The Viper 3A motor has been flown successfully with the meteorological 12A Dart many times, but this configuration utilizes a 10D Dart. The 10D Dart is 2.125 inches in diameter whereas the 12A Dart has a diameter of 1.625 inches. The overall length of the 10D Dart is approximately 59 inches. As a result of the increased diameter, the 10D Dart has a significantly greater payload capacity than the existing 12A Dart. The performance of this configuration allows a 7.7 kilogram payload to be carried to approximately 98 kilometers. Motor burnout occurs at T+2.5 seconds at an altitude of approximately 2 kilometers and apogee is reached at approximately T+ 145 seconds. Acceleration loads for this configuration are in excess of 100 G's.

E.12 Black Brant XI Launch Vehicle (39.XXX)

General

The Black Brant XI rocket system is a three stage system used primarily to carry heavy payloads to high altitudes. Its development is a spin-off of the Black Brant XII development. See Appendix E.13. The first and second stages are the Mk 11 Mod 5 Talos rocket motor and the Taurus motor. The third stage is a modified Black Brant VC motor. The Black Brant nozzle is extended for exoatmospheric use and the tailcan has been changed to enclose the nozzle. The aft end of the tailcan has a restraining device to keep the Taurus and Black Brant connected during second stage coasting. This motor configuration makes up the first three stages of the Black Brant XII.

Vehicle Performance

The Talos motor is 132 inches long with a diameter of 31 inches. It is fitted with a conical adapter for mating to the second stage. Differential drag forces cause separation. Four fins are arranged at the aft end in a cruciform configuration and drive the vehicle to approximately one revolution per second burnout roll rate.

The Taurus motor is 165 inches long with a principal diameter of 22.75 inches. The motor has the interstage adapter bolted to the forward end, which is then clamped to the aft end of the Black Brant motor. Each Taurus fin is 4.8 square feet. Normally, the fins are canted to provide two revolutions per second spin rate at Taurus burnout. The weight of the booster system (with hardware) is 3005 pounds, including 1678 pounds of propellant.

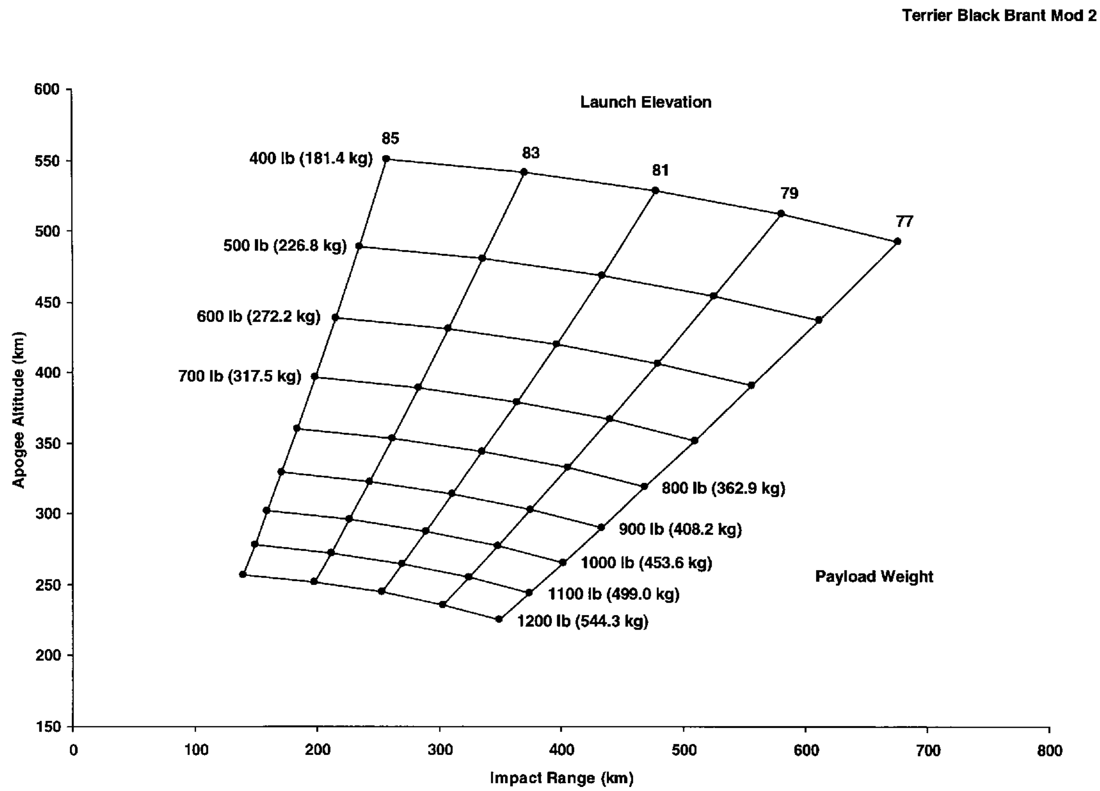


Figure E-22. Terrier-Black Brant VC (MK 70) Launch Vehicle Performance

The 26 KS 20,000 Black Brant V rocket motor has been modified for use as the third stage of the Black Brant XI. The nozzle cone has been extended as has the tailcan, and the diameter aft of the conical extension is 22.75 inches. The standard Black Brant V fin panels are used even though the tail assembly is different. The modified Black Brant V rocket motor produces an average sea level thrust of 17,025 pounds and an action time of 26.9 seconds. The primary diameter of the Black Brant V is 17.26 inches and is 223 inches in length. Loaded weight of the motor including hardware is 2,847 pounds which includes 2,198 pounds of propellant.

Payloads

The standard payload configuration for the Black Brant XI vehicle is 17.26 inches in diameter with a 3:1 ogive nose shape. Payload length and weight limits for the Black Brant XI are not defined as they are for the Black Brant V and specific limitations for this system will be determined as the situation warrants. For payload weights of 700 pounds, apogee altitudes of 500 km can be expected. A payload of 1200 pounds will reach 350 km. Both values use a launcher elevation angle of 85 degrees from a sea level launch location.

Standard hardware systems that are available for Black Brant V motors include aft recovery systems for 750 lb. or 1000 lb. recovered weights, Ogive Recovery System Assembly (ORSA) for the same weight ranges, payload separation systems including a High Velocity Separation System and despin systems. These units are "stackable" such that a great deal of flexibility exists in meeting experiment requirements.

Performance Graph

The Black Brant XI launch vehicle configuration and apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure E-23.

E.13 Black Brant XII Launch Vehicle (40.XXX)

General

The Black Brant XII rocket system is a four stage system used primarily to carry a variety of payloads to high altitudes. Its development is a spin-off of the Black Brant X development.

Vehicle Performance

The first and second stage are the Mk 11 Mod 5 Talos rocket motor and the Taurus motor. The third stage is a modified Black Brant VC motor. The Black Brant nozzle is extended for exoatmospheric use and the tailcan has been changed to enclose the nozzle. The aft end of the tailcan has a restraining device to keep the Taurus and Black Brant connected while coasting. The Talos motor is l32 inches long with a diameter of 31.1 inches. It is fitted with a conical adapter for mating to the second stage and differential drag forces cause separation. Four fins are arranged at the aft end in a cruciform configuration and drive the roll rate to approximately one revolution per second at burnout. Each fin is 6.9 square feet in area .

The Taurus motor is 165 inches long with a principal diameter of 22.75 inches. The motor has the interstage adapter bolted to the forward end, which is then clamped to the aft end of the Black Brant motor. Each Taurus fin is 4.8 square feet in area. Normally, the fins are canted to provide two revolutions per second spin rate at Taurus burnout. The weight of the booster system (with hardware) is 3005 pounds, including 1678 pounds of propellant.

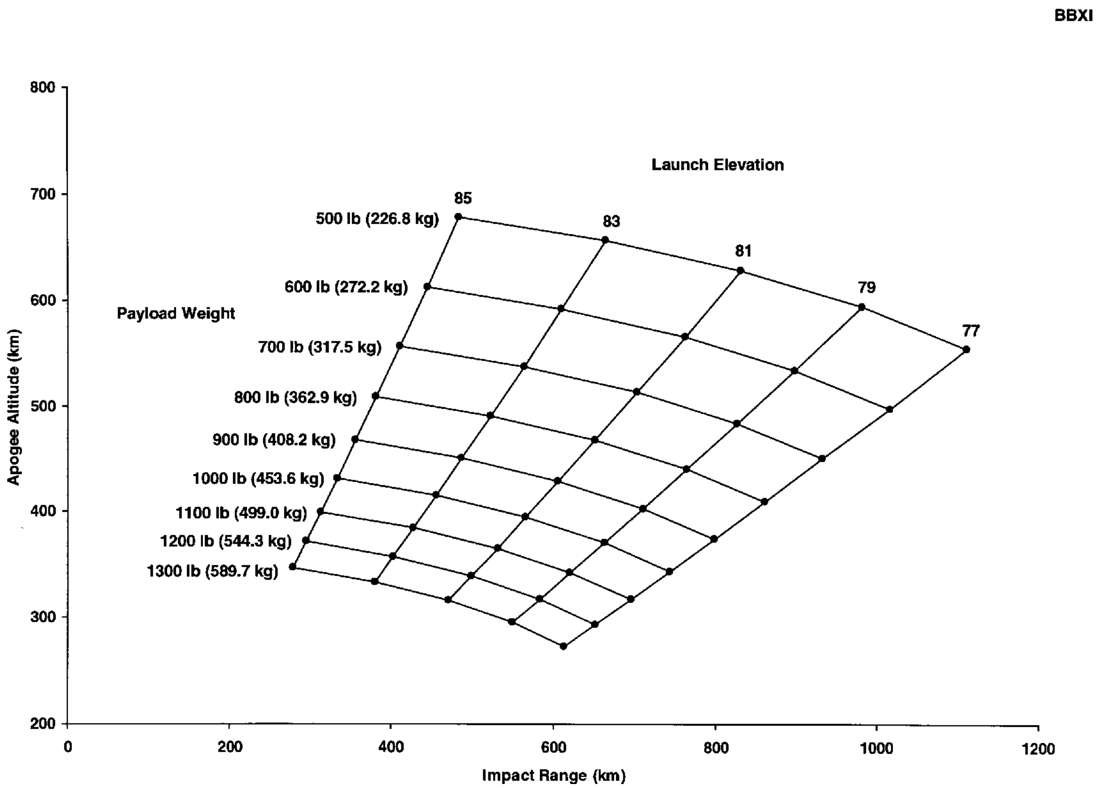


Figure E-23. Black Brant XI Launch Vehicle Predicted Performance

The 26 KS 20,000 Black Brant V rocket motor has been modified for use as the third stage of the Black Brant XII. The nozzle cone has been extended as has the tailcan, and the diameter at the aft end of the conical extension is 22 75 inches. The motor case wall is thicker which permits use with significantly higher thrust lower stages. The standard Black Brant V fin panels are used even though the tail assembly is different. The modified Black Brant V rocket motor produces an average thrust of 17,025 pounds with an action time of 26 9 seconds. The primary diameter of the Black Brant V is 17.26 inches and it is 223 inches long. Loaded weight of the motor is 2,847 pounds which includes 2,198 pounds of propellant.

The Nihka rocket motor, previously developed for the Black Brant X, is used on this vehicle system. The average thrust is 12,000 lb, with a total impulse of 195,500 lb-sec. The primary diameter is 17.26 inches and the length is 76 inches. The loaded motor weight of 894 lbs. which includes 756 lbs.of propellant .

Payloads

The standard payload configuration for the Black Brant XII vehicle is 17.26 inches in diameter with a 3:1 ogive nose shape. Payload length and weight limits for the Black Brant XII are not defined as they are for the Black Brant V and specific limitations for this system will be determined as the situation warrants. Because of relatively high dynamic pressures, bulbous (larger than 17.26 inches) diameter payloads are carefully considered before flight on the Black Brant XII. For payloads weighing as little as 300 pounds, 1500 km apogee altitudes can be reached. The 500 km altitude region is attainable with 1150 pound payloads from sea level, when the launcher elevation is 85 degrees.

Standard hardware systems that are available for Black Brant V motors include payload separation systems including a High Velocity Separation System and despin systems. These units are "stackable" such that a great deal of flexibility exists in meeting experiment requirements. It should be noted that because of the extreme range at even moderately high launch elevation angles, recovery of the payload may not be possible.

Performance Graph

The Black Brant XII launch vehicle configuration and apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure E-24.

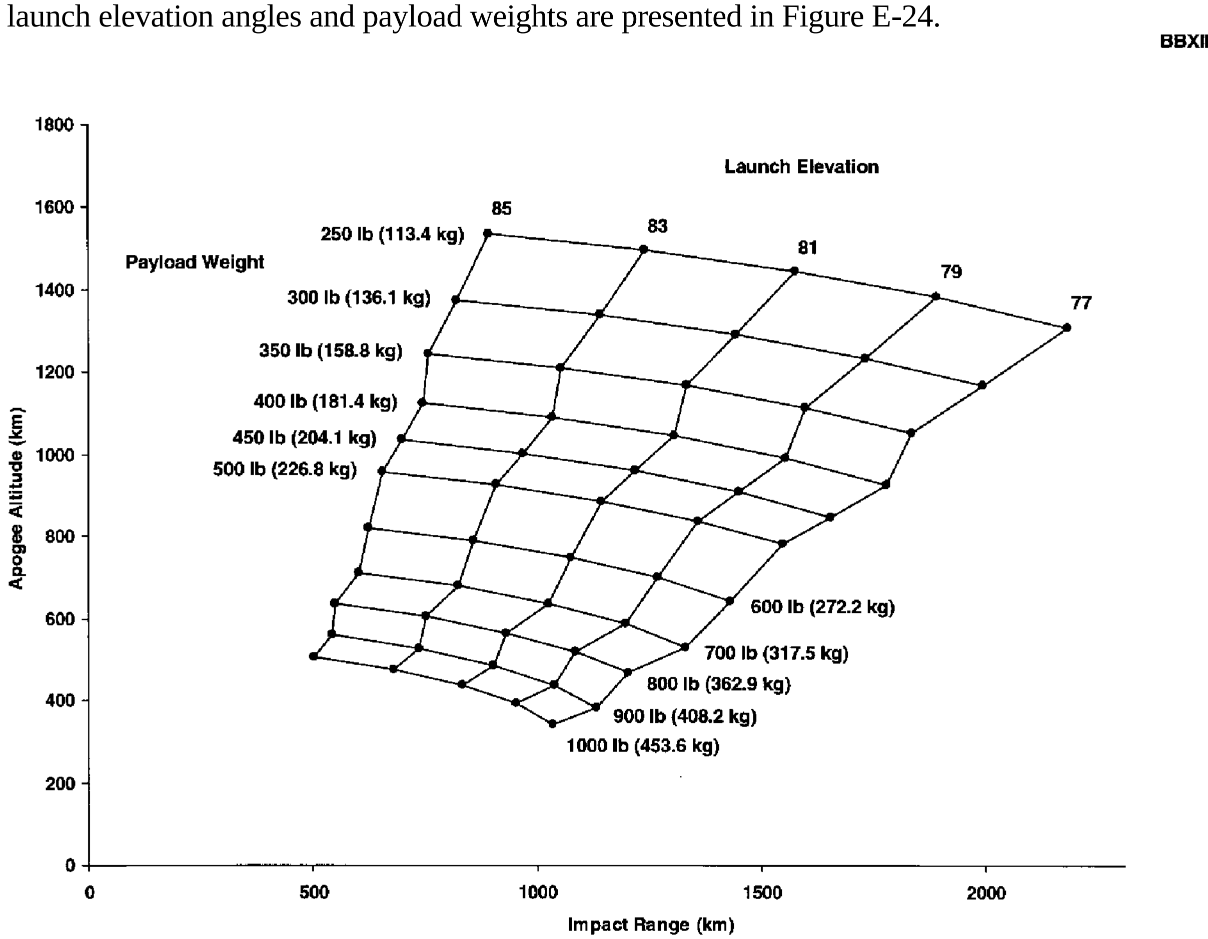


Figure E-24. Black Brant XII Launch Vehicle Predicted Performance

E.14 Terrier-Improved Orion (41.XXX)

General

The Terrier-Orion rocket system is a two stage spin stabilized rocket system which utilizes a Terrier MK 12 Mod 1 for the first stage and an Improved Orion motor for the second stage. The Terrier motor is 18 inches in diameter and is configured with 340 square inch fin panels arranged in a cruciform configuration. The Orion motor is 14 inches in diameter and 110 inches long. The vehicle is typically configured with spin motors and the total weight of this configuration, excluding the payload, is approximately 2,900 pounds.

Vehicle Performance

The Improved Orion motor has a bi-phase propellant system that results in thrust levels of approximately 19,000 pounds during the first four seconds of motor burn then trailing off to approximately 3,000 pounds until burnout around 25 seconds. The fins are generally configured to provide a burn out spin rate of four cycles per second. The Orion motor utilizes a clamp-released/load-bearing tail can to interface with the Terrier motor. This is a rail-launched configuration that can be supported at most fixed and mobile launch ranges.

Payloads

Payload configurations supported by this vehicle include 14 inch and bulbous 17.25 inch diameters. Payload weights ranging from 200 to 800 pounds can achieve altitudes of approximately 200 to 80 kilometers respectively.

Available support systems include the standard 14 inch Ignition Recovery Module Assembly (IRMA), ACS systems, and nose cones of various configurations. The complete cadre of 17.25 inch diameter support systems is available for use with the bulbous payloads. These include fixed and deployable nose cones; fine, course, rate control, and magnetic ACS systems; separation and despin systems; and forward and aft recovery systems.

Performance Graph

The Terrier-Improved Orion launch vehicle configuration and apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure E-25.

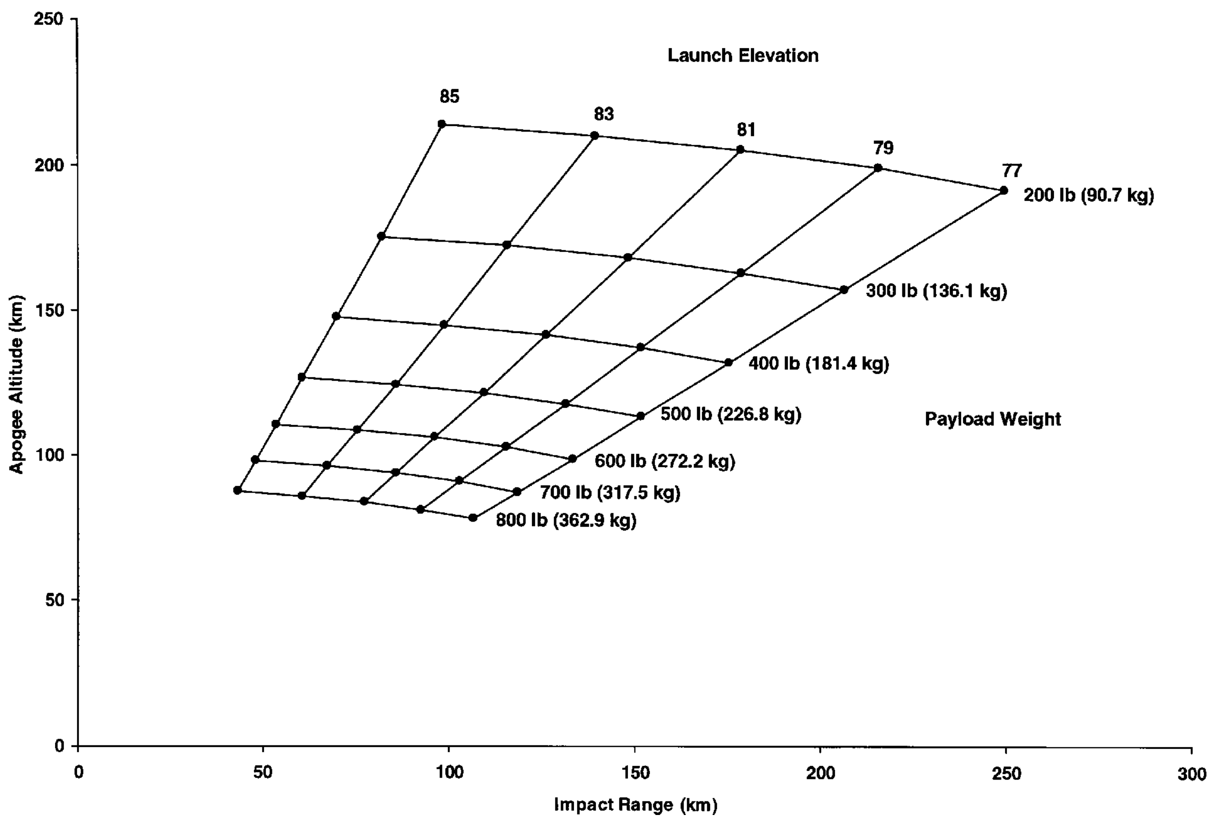


Figure E-25. Terrier-Improved Orion Launch Vehicle Predicted Performance

Appendix F
PCM/FM and FM/FM Telemetry Systems

F.1 Vector MMP-900 PCM System

The MMP-900 PCM system is a micro-miniature system with considerable flexibility. The data input forms accepted by the MMP-900 are analog, serial digital parallel digital, pulse count, and pulse time event data. The output format of the MMP-900 system has programmable flexibility. The matrix can be up to 200 x 32 words or reduced to 2 x 1. The user program, stored in a single EPROM, determines the output format. The selectable system parameters are bit rate, word length, parity, output code, and sample duration Refer to Table F-1 for individual module characteristics.

Table F-1
Individual PCM Module Characteristics
MMP-900 PCM System

Module	Description	Data Type	Number of Channels Possible
PX-984	Power Supply	N/A	N/A
TM-915D	Timer	N/A	N/A
PR-914	Processor	N/A	N/A
AD-906	Sample and Hold and Analog to Digital Converter	Analog	N/A
MP-901L	Analog Multiplexer	Analog	256
SD-924	Serial Digital Multiplexer	Serial Digital	32
PD-929	Parallel Digital Multiplexer	Parallel Digital	48
CM-922P	Counter Accumulator	Pulse Count	38
TA-923	Time Event Monitor with Alternating Resistors	Pulse Time-Event	2
TD-925	Time Event Monitor with Timing Buffers	Pulse Time-Event	4
FL-919A	Adjustable Quad Filters	N/A	N/A

NASA reference publication 1365, June 1995 entitled Pulse Code Modulation (PCM) Encoder Handbook for Aydin Vector MMP 900 Series System, fully describes the MMP-900 system. This publication is available from the Mission Manager.

F.2 SPARCS Encoder System

The SPARCS system encoder, the ARC 75, which has been used for a number of years on almost all astronomy rockets, has been re-designed to incorporate more format flexibility and to employ more modern components. Known as the WFF 87 Encoder, the unit is designed to be a general purpose, versatile, reconfigurable system for sounding rockets, balloons and other applications where system requirements are continually changing.

The standard unit will support bit rates from 12.5 kb/sec to 800 kb/sec Bi-phase L or up to 1.6 mb/sec NRZS. The format structure is configured by an interactive software program designed for the PC environment. The hardware is configured as a stack-up system with several data modules, which can be added as required. The system employs a vertical bus structure with power, address and data being passed through the bus EEPROMS are used as the nonvolatile program element, which permits the system to be reprogrammed in the field without disassembly of the hardware. HC logic and CMOS EPLD devices minimize power consumption. Inputs and outputs are LS and HC compatible. Present systems are temperature checked from -20 to +60 degrees C.

F.3 WFF93 Encoder System

This system is the newest available PCM encoder hardware used in support of the NASA Sounding Rocket Program. The WFF93 PCM encoder is a general purpose, versatile, re-configurable high rate PCM telemetry system for use where system requirements are subject to change. The format structure is configured by a software program designed for the PC environment. The hardware is configured as a stack up sytem with various data modules, which can be added as required. An EEPROM is used as the non-volatile program storage element, permitting the system to be reprogrammed to meet changing mission requirements without disassembly of the hardware. FCT logic and low power programmable logic devices minimize power consumption. Digital inputs and outputs are FCT/HC or RS422 compatible. Refer to Table F-2 for individual module characteristics.

Table F-2
Individual PCM Module Characteristics - WFF93 PCM System

Module	Description	Data Type	Number of Channels Possible
Power Supply	+28V input to +/-12 & +5 volt output power supply	N/A	N/A
Analog	Analog 0 to 5 volt input range, 10 bits/word maximum resolution	Analog, single ended	Addressing limit of 992 channels
Control Deck	System clock, timing, formatting, output code generation, and format programming control module	N/A	N/A
Serial	Serial digital single ended or differential input operation, 8 to 16 bits/word, parallel word enable timing signal available for each input	Serial Digital	Addressing limit of 124
Parallel	Parallel digital single ended input, 8 to 16 bits/word, parallel word enable timing signal available for each input	Parallel digital	Addressing limit of 62 channels
Asynchronous	Asynchronous RS232 or 422 inputs, 300 to 156K baud rates	Asynchronous	Addressing limit of 124 channels
Counter	Event counter differential input, 8 to 18 bits/word	Event counter	Addressing limit of 248 channels
Command	Accepts uplink command video and demodulates and synchronizes data. Outputs two independent asynchronous channels at rates from 1200 to 19.2K baud, plus parallel command data to uplink command decoder hardware	Uplink command FSK video	N/A
Time Event	Time event with single ended or differential inputs, buffered clock-minor frame-major frame-word clock outputs	Time Event	Addressing limit of 62 simple time event and 62 alternating register time event channels
Pre Modulation Filter	Selectable 1 of 8 premodulation filters with output amplitude adjustability	N/A	N/A
Top Plate	Top cover of assembled PCM stack	N/A	N/A

*NOTE: The number of words per major frame is limited to 4096 words maximum. A document entitled Pulse Code Modulation Encoder handbook for Physical Science laboratory/NMSU Model WFF93 System fully describes the WFF93 PCM System.

F.4 FM/FM Telemetry Systems

Two basic multiplex composites are most often used - these are the IRIG proportional bandwidth (PBW) and IRIG constant bandwidth (CBW) subcarriers multiplexes. The IRIG PBW is used where the data bandwidth requirements vary from channel to channel and precise time correlation is not a significant factor. CBW is used when a number of data channels require the same frequency response and time correlation between channels is important. Accuracy utilizing the subcarrier oscillator technique is generally in the range of 2%. Table F-3 lists the subcarriers generally used in the NASA Sounding Rocket Program.

Note: Support for FM/FM data systems has been drastically reduced recently and range users are recommended to check for availability of support hardware prior to TM system design.

Table F-3
Wallops Supported FM Subcarrier Channels

±7.5% IRIG PBW Channels			±30% IRIG PBW Channels			±15% IRIG PBW Channels		
Channel	Center Frequency (Hz)	Frequency Response (Hz)	Channel	Center Frequency (Hz)	Frequency Response (Hz)	Channel	Center Frequency (Hz)	Frequency Response (Hz)
1	400	6	A	22,000	660	EE	70,000	4,200
2	560	8	B	30,000	900	FF	93,000	5,580
3	730	11	C	40,000	1,200	GG	124,000	7,440
4	960	14	D	52,500	1,575	HH	165,000	9,900
5	1,300	20	E	70,000	2,100	II	225,000	13,500
6	1,700	25	F	93,000	2,790	JJ	300,000	18,000
7	2,300	35	G	124,000	3,720	KK	400,000	24,000
8	3,000	45	H	165,000	4,950	LL	560,000	33,600
9	3,900	59	I	225,000	6,750	CBW Channels - IRIG-E		
10	5,400	81	J	300,000	9,000			
11	7,350	110	K	400,000	12,000		512,000	3,200
12	10,500	160	L	560,000	16,800		640,000	3,200
13	14,500	220					768,000	3,200
14	22,000	330					896,000	3,200
15	30,000	450				CBW Channels - IRIG-E		
16	40,000	600						
17	52,500	790					320,000	1 ,600
18	70,000	1,050					384,000	1,600
19	93,500	1,395					448,000	1,600
20	124,000	1,860					512,000	1,600
21	165,000	2,475					576,000	1,600
22	225,000	3,375					640,000	1,600
23	300,000	4,500					704,000	1,600
24	400,000	6,000					768,000	1,600
25	560,000	8,400						

Appendix G
Comparison and Performance of Various Battery Systems

Table G-1

Comparison and Performance of Various Battery Systems

	Temp: 25°C			System Voltage (Nominal): 28V				
Cell Type	Silver Zinc	Silver Zinc	Silver Zinc	Ni-cad	Ni-cad	Ni-cad	Ni-cad	Ni-cad
Mod. No .	PMC1(2.5)	HR3DC-6	HR5DC-9	AF	"C"	"1/2D"	"D"	"F"
Manufacturer	-1 Yardney	Yardney	Yardney	GE	GE	GE	GE	GE
Electrical Characteristics Rated Capacity (AH):								
1 Hr. Rate	2.5	3	5	.750	1.8	2.2	4.0	6.2
Open Ckt. Voltage:								
Cell (volts)	1.86	1.86	1.86	1.3	1.3	1.3	1.3	1.3
System (volts)	37.2	37.2	37.2	31.2	31.2	31.2	31.2	31.2
VL (Average Plateau at C/1 Discharge):								
Cell (volts)	1.43	1.47	1.45	1.2	1.2	1.2	1.2	1.2
System (volts)	28.6	28.6	29.4	29	28.8	28.8	28.8	28.8
Operating Time to 27V Sys. Minm. (Min) at C/1 Discharge Rate	52	84	93	60	60	60	50	65
Shelf Life:								
Dry	5 yrs	5 yrs	5 yrs	N/A	N/A	N/A	N/A	N/A
Activated	30days	6mo	6mo	>10yrs	>10yrs	>10yrs	>10yrs	>10yrs
Cycles of Operation	3->5	10->20	10->20	>500	>500	>500	>500	>500
Physical Characteristics:								
Weight:								
Cell (ounces)	1.1	3.2	4.6	1.2	2.3	3.2	5.2	7.8
System (pounds)	1.375	4	5.75	1.8	3.45	4.8	7.8	11.7
Dimensions (inches):								
Height	2.02	2.86	2.91	1.98	1.86	1.45	2.34	3.48
Width	1.08	1.72	2.08					
Depth	0 54	059	079					
Diameter	—	—	—	0.7	1.06	1.33	1.33	1.33
Volume (inches3):								
Cell	1.18	2.9	4.78	0.76	1.64	2.0	3.25	4.83
System	23.6	58	95.6	18.28	39.4	48	78	116
Quantity Required for Nominal 28V System:	20	20	20	24	24	24	24	

Appendix H
Attitude Control Systems

H.1 Aerojet Mark VI

Description

The Aerojet Technical Systems Mark VI ACS is a multipurpose microcomputer controlled ACS for exoatmospheric control of sounding rocket payloads. A large repertoire of programmable features permits most missions the capability to be performed without hardware modifications. The Mark VI is especially well suited to a fine pointing mission that requires both inertial and optical sensors. The Mark VI uses a cold gas pneumatic system similar to that used in the STRAP Type ACS and is currently configured to interface with the 17.26 inch diameter family of Black Brant launch vehicles. A photograph of the MARK VI electronic and gyroscope travel package is shown in Figure H-1

Figure H-1. Aerojet Mark VI ACS

Capabilities

Maneuvers at rates between .005 and 10.0 degrees per second can be performed as either single axis maneuvers or simultaneous two axis maneuvers. Inertial gyro axes can be updated using an optical sensor. This is required for accurate pointing on untrackable targets. An extension of simultaneous two axes maneuvers and the use of two guide stars updates the third inertial axis. Any combination of up to 36 actions may be programmed at each of 255 program steps. An adaptive clock-timer and a real-time clock can be used interactively. Adaptive time resolution is 002 second and real-time resolution is 1 second. Pre-launch programming, control, and monitoring is performed by a desktop calculator and console which communicate with the flight system via a two-wire line.

The inertial reference is supplemented with a controller designed for fast maneuvering and stabilization so the time available to the experiment is maximized. Three-axes control is achieved using bi-level, cold gas reaction jets MARK VI ACS specifications are :

Accuracy – First Target	
With Roll-stabilized Platform	3.0 degrees
With Separate Flight control	1.0 degree
With Mark VI Flight Control	0 6 degree
With Stellar Update	2.0 arc min
With Star Pointer	1.0 arc min
Drift Rate On Target	
Standard	0.17 deg/hr
Limit Cycle	10 arc sec
Maneuver Accuracy	0.1%
Maneuver Rate	
Roll,Pitch,Yaw	10 deg/sec
Scan Rates	0.002 to 10 deg/sec
Programmable Intervals	255
Interval Size	O - 130 sec
Interval Resolution	0 002 sec
Interval Accuracy	0.01%

H.2 Magnetic ACS

Description

An attitude control system capable of pointing the roll principle axis of a spinning payload to within one degree of the magnetic field vector was developed by NASA in the early 1980's. Over the last few years, additional capabilities have been added to this system. The Magnetic ACS package consists of a pneumatic section with a high pressure gas vessel and the required solenoids, nozzles, pressure regulator, and monitoring transducers; and an electronics section which provides driving signals to the nozzle solenoids. A three axis magnetometer and a single axis rate gyro provide servo input signals. Signals from the magnetometer and rate gyro sensors are fed to the control circuits that generate commands for the jet thrusters. The spinning vehicle is processed by properly timed and phased gas jets to the desired attitude. The vehicle roll rate is also corrected by roll gas jets to the desired rate. Currently, the 17.26-inch diameter Magnetic ACS is not being flown, but it may return to the inventory in the future. The Magnetic ACS has been packaged in payload diameters as small as 9-inches.

Capabilities

The Magnetic ACS permits large angle acquisitions and alignment of the principal axis of a spinning payload relative to the earth's magnetic field. Angles of alignment from 0 degrees to 180 degrees are possible. Accuracy of alignment to within 2 degrees is possible for 180 degrees alignment and for 0 degree alignment. Roll rate control to an accuracy of ±0.1 rps is possible The system can be operated at roll rates from approximately 0.5 rps to 2.0 rps. The system can be configured to operate with a fixed dead band or a variable dead band for vehicle alignment to the magnetic field. With a fixed dead band, the system is enabled by the payload timers for a fixed time interval for both the initial alignment and for any updates. The ACS will then align to the limit of the fixed dead band. With a variable dead band, the payload timers provide a continuous "on" for the alignment maneuvers. The ACS will accomplish the initial alignment to the limit of the narrow dead band and then stop firing the nozzles. The ACS will then initiate an update whenever the limit of the wide deadband is exceeded. Again, the ACS will align to the limit of the narrow dead band. The system will operate to eliminate vehicle coning when it is enabled.

Operation

While the payload is on the launcher and powered up, the system is on and processing analog inputs from the magnetometer and the rate gyro. The generated commands are prevented from operating the nozzle solenoids in the absence of enable commands from the payload event timers. These enable commands control the solenoid driver inhibit circuits.

H.3 Space Vector System

Description

NASA utilizes several types of attitude control systems produced by the Space Vector Corporation for coarse pointing of sounding rocket payloads. These type systems have been used in the NASA Sounding Rocket Program since the mid - 1970's. The systems have varied in diameter from 9 inches to 17.26 inches, and all have utilized the MIDAS roll stabilized platform as the inertial reference. The MIDAS platform based control systems provides coarse pointing in the range of 1 to 3 degrees. See Section 5.3 for additional information. These systems are specifically configured for each mission, e.g., solar pointing types, both spinning and non-spinning, forward or side looking

Capabilities

The capabilities of the Space Vector Corporation ACS are:

1. System is capable of pointing the payload while spinning or non-spinning.
2. Inertial reference is established at the time the platform is uncaged on the launcher prior to lift-off and all maneuvers are referenced to that reference.
3. Upon ACS enable in flight, the payload is directly pointed to the first pointing requirement. All maneuvers are performed in a simultaneous two-axis maneuver (STAM) move.
4. Each consecutive maneuver is initiated by a payload command (usually a relay closure).
5. ACS pointing with platform can be overridden if a star tracker or sun sensor is used.
6. ACS dead band can be "opened up" when on a target to avoid nozzle firing during data gathering periods.
7. Pointing:
    - Multiple targets (±2°)
    - Scanning of payload in any of the axis at different rates
    - Spin-up of non-spinning payloads
    - Use of sun sensor (±.1°)
    - Pitch and Yaw axis can be offset in roll, using roll offset of the platform.

H.4 Rate Control System

Description

A sounding rocket payload free falling in space, with low angular body rates, provides a near zero-G environment. To efficiently utilize this time above the Earth's atmosphere, a positive means of controlling angular body rates must be provided for the payload. A three-axis cold-gas Rate Control System (RCS) has been developed by NASA which is used to minimize body rates for scientific and research applications requiring stabilization or low angular rates. After the sounding rocket exits the atmosphere, the payload separates and the RCS reduces the initial angular rates to low levels and maintains the low levels until the payload re-enters the atmosphere. Payloads can experience low-G environment below 10 for 300 seconds.

Zero-G does not mean the absence of the Earth's gravitational field, but the absence of a net acceleration force on one portion of the payload relative to other portions of the payload. To provide a very low acceleration field for an extended period of time, the following two conditions must be met:

1. Absence of a force gradient acting on the body
2. Absence of angular body rate

The first condition is met by a sounding rocket payload in free fall above the Earth's sensible atmosphere. The second condition is met by the proper operation of the RCS. Payload design must eliminate the possibility of extraneous forces that may be caused by mass expulsion or momentum exchange within the payload.

Capabilities

Experimental requirements for the G-level vary from a high of 10^{-3} G to a low of 10^{-5} G; in general the lower the better Low-G periods in excess of 5 minutes are desirable.

Operation

The Black Brant V rocket burns out at T + 32.4 seconds and at approximately T + 60 seconds, reaches an altitude of 250,000 feet where the dynamic pressure is low enough to begin payload deployments. The entire vehicle is despun by means of a yo-yo mechanism.

The payload then separates from the vehicle with a differential velocity of 10 ft/second and the valve-enable command permits the control thrusters to operate in response to rate gyro errors. High thrust levels permit removal of worst expected initial rates in less than 10 seconds. After achieving less than 0.12% in all axes, the thrust level is lowered by a factor of 15 to permit continued maintenance of low rates without causing high level G spikes if a control valve turns on to prevent a rate buildup.

In the absence of disturbing torques, further thruster activity will not occur after the initial rates are reduced below the 0.12% level. However, if a disturbance causes body rates to exceed 0.20°/second, a low-level thruster will turn on to counteract it. If the disturbance prevents the low thruster from reducing the rate in 5 seconds, the system will switch back to high thrust. The system again returns to low thrust after rates in all axes are reduced

The RCS can accept enable/disable commands from payload instrumentation by means of either an onboard timer or a ground control link. This feature permits deactivation of the RCS thrusters during critical periods in the experimental cycle. The RCS is self-contained in a 9-inch long, 17.26-inch diameter payload cylinder.

Appendix I

GSFC/WFF Safety Data Requirements

REFERENCE: The GSFC/WFF safety data requirements in this Appendix are extracted from Range Safety Manual for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF) RSM-93, dated June 23, 1993. The Principal Investigator is responsible for providing the data outlined in this Appendix. Vehicle Description Data is provided by WFF.

PAYLOAD DESCRIPTION DATA

1. Hazardous Materials

Pyrotechnic Details - Principal Investigators will provide the GSFC/WFF Mission Manager with six readily distinguishable copies of schematics and wiring diagrams of all pyrotechnic circuits and all other circuits physically or electrically related to pyrotechnics.

For each squib, the minimum sure-fire current, maximum no-fire current, recommended firing current, nominal resistance, and, if available, the RF characteristics must be shown. Provide a description of the power source, including output, battery life, and details on battery charging. Scale drawings must be supplied for any payloads having RF transmitters or beacons, showing the location of all pyrotechnic devices in relation to all transmitting antennas. The frequency, range, type of emission, type of radiating antenna, and radiated power (both peak and average) shall be shown for each transmitter or beacon. Schematics, drawings, operation descriptions of pyrotechnic check out and monitoring equipment, and any other auxiliary equipment will be supplied. The Range will be notified of changes as it is the responsibility of Principal Investigators to certify that all drawings are up-to-date.

Chemicals - The Principal Investigator will provide a description of all chemical systems, including toxicity and necessary precautions to be taken.

Pressure Vessels - The Principal Investigator will provide a description of any pressure vessels used in the payload, their technical characteristics, and details on design and test pressure.

Lithium Batteries - The Principal Investigator will provide necessary data as required by NASA Publication GHB 1710.5, "Lithium - Sulfur Dioxide Cell and Battery Safety "

2. Radioactive Materials

For all materials planned for use at the GSFC/WFF, which will involve exposure or possible exposure of personnel, application will be made by the GSFC/WFF to the Nuclear Regulatory Commission for a license granting the GSFC/WFF the authority to:

a. Handle, store, ship, and control sources in use at the GSFC/WFF.

b. Establish operational procedures and provide monitoring, dosimetry, and the required records.

c. Establish necessary emergency procedures in the event of malfunctions, explosions, or destruct actions.

d. Dispose of waste materials.

Permission may be granted by the GSFC/WFF for licensed Principal Investigators to possess and control small calibration or other small sources provided:

a. An operational procedure is submitted for storage, handling, shipment, etc.
b. Records are maintained for all radiation sources, etc.
c. Principal Investigators are responsible for the source as stated in the license

The following technical information on radioactive materials must be submitted:

a. Types and numbers of radioactive materials with their current curie content.
b. Size, shape, and general characteristics of the radioactive sources
c. Mission of each source
d. Radiation level versus distance from material.
e. Container description
f. Shipping and storage container and label description
g. Shipping date and method of shipment
h. Two copies of Nuclear Regulatory Commission's license details

i. Principal Investigator's personnel monitoring devices and methods of use (portable survey instruments, personnel dosimeters, film badges, procedures, etc.).

j. Location of radioactive source on research vehicle

k. Principal Investigator's representatives who shall have responsibility at the Range

l. A record of exposure of each individual who will be exposed at the range prior to operations at GSFC/WFF. This should include total exposure, last exposure date, etc.

m. A detailed breakdown of estimated time of source exposure during all build-up, test, and launch operations

n. Procedure for handling and use of external sources during all times exposed

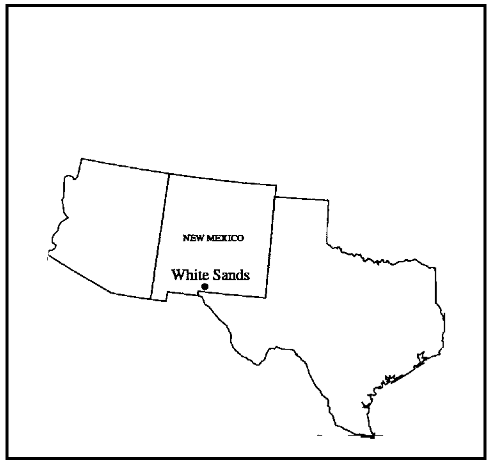
o. All calibration procedures involving the use of exposed radioactive sources

Appendix J
Sounding Rocket Launch Ranges

J.1 U.S. Army White Sands Missile Range

General

The White Sands Missile Range (WSMR) is the Department of Defense's largest overland National range. It is located in southern New Mexico (32.5° N 106.5° W) approximately 35 miles northeast of Las Cruces, New Mexico, and about 70 miles north northwest of El Paso, Texas. The climate is semi-arid with usually unlimited visibility, warm to hot temperatures, and low humidity. Occasionally snows occur in the area during the winter months thereby disrupting traffic and launch operations.



WSMR contains major test facilities, laboratories, launch and impact areas, extensive instrumentation and test equipment, and a very large ADP facility. There are several tenant activities at WSMR. The U. S. Naval Ordnance Missile Test Station sponsors the NASA sounding rocket launch activities. Figure J-l is a drawing of WSMR.

Mission Manager

The Mission Manger will initially coordinate the requirements with the WSMR sponsor. As activities progress, direct contact usually ensues with those technical counterparts involved, e.g., telemetry, ionosonde, and meteorology. The Mission Manager is the interface for launch operations.

Data Requirements

The range can provide extensive real time, quick-look and flight data. It is important to state detailed data requirements in sufficient time to be included in the Flight Requirements Plan which must arrive at the range at least 30 days prior to launch. See Section 2 for details on the preparation and processing of Flight Requirements Plan.

Data Request Forms

PI's using PCM telemetry and requiring computer-compatible data tapes, must complete the required "PCM Data Request" form, available from the Mission Manager to assure prompt processing of the data onto tapes.

Mass Properties

The determination of mass properties is usually performed prior to the horizontal test.

Payload Disassembly

Disassembly should be kept to a minimum following horizontal testing. If extensive disassembly is required, it may be wise to schedule a second horizontal test.

Operational Safety

Safety during launch operations at the pad is the responsibility of the WSMR Pad Supervisor. The launch pad is a very hazardous area and there are strict operational procedures for safety. The project team must adhere to the range safety procedures.

Industrial Safety

All project personnel are expected to comply with prudent industrial safety procedures. When appropriate, wear safety glasses, hard hats, reasonable clothing (steel toed shoes during activity where payloads/motors could cause grief if accidentally dropped), and special protective gear/devices when handling hazardous materials, e.g., liquid nitrogen, radioactive sources, and shaped charges. If not properly attired or qualified, leave the area.

Road Blocks

Frequently, road blocks are necessary on Highway 70 which runs through the range. Plan your arrival at the range around scheduled road blocks.

Traffic Regulations

Traffic regulations are strictly enforced. Use your seat belts. At White Sands a ticket is a Federal offense.

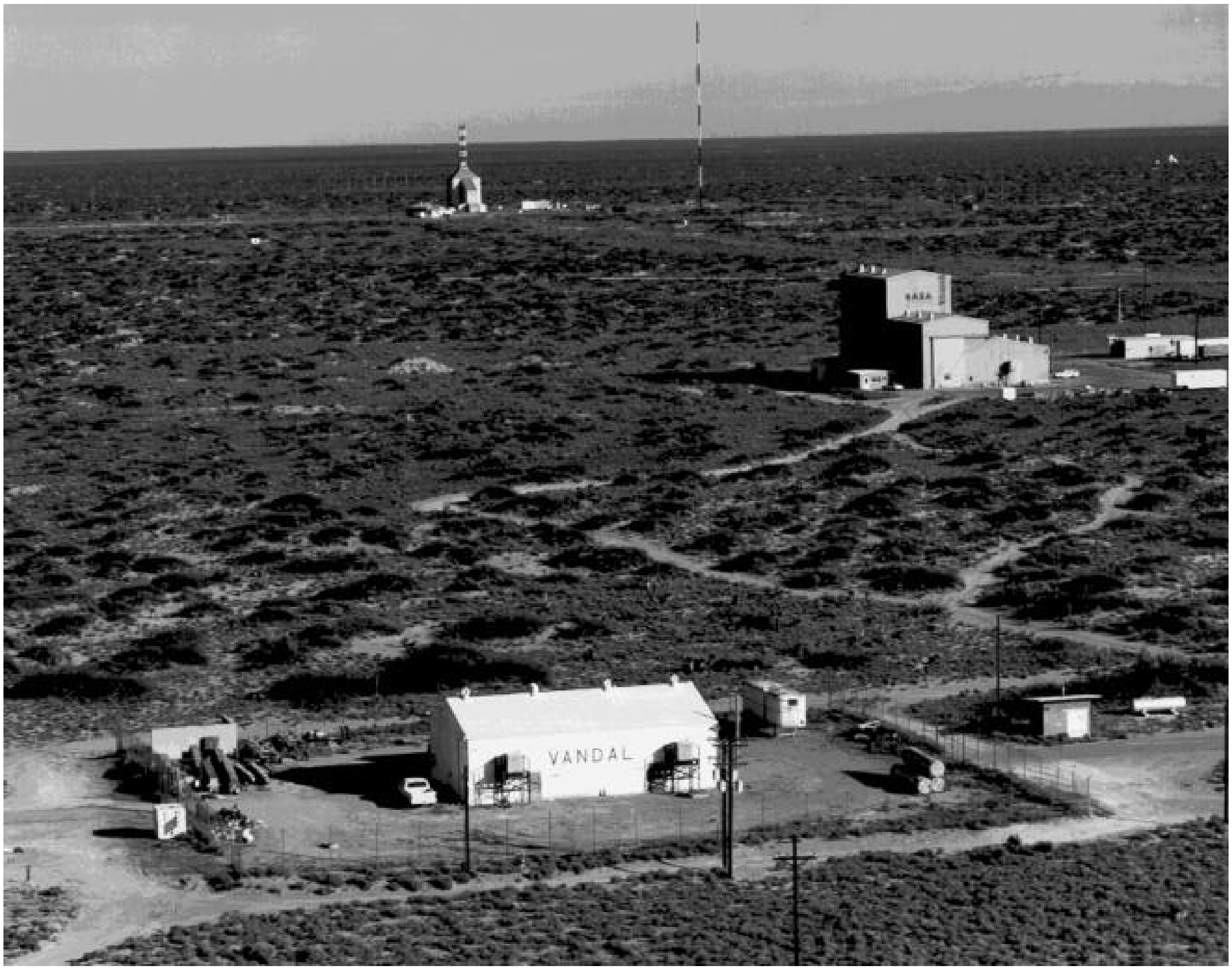


Figure J-1. White Sands Missile Range

Visit Requests

Visit requests for all personnel working (temporarily) or visiting the WSMR is required in advance. The PI's sponsoring organization is responsible for furnishing visitor information to the WSMR Security Office with an information copy to the U. S. Naval Ordnance Missile Test Station. If your payload requires radioactive sources for in-flight or preflight calibration, a pre-arrival written clearance must be obtained.

Foreign Nationals

Clearance for visits by foreign nationals to WSMR are arranged through the Mission Manager. Subsection 11.4 outlines the information required for approval of foreign national visits to WSMR. The Mission Manager should have this information at least 60 days prior to the scheduled visit. Foreign nationals are generally not permitted up-range. If their presence is required, check with the range for necessary clearances well ahead of time.

Photography

Photographs are prohibited in all areas except the rocket display located near the main entrance. The range can provide technical photos, e.g., your rocket, early stages of flight, recovered hardware. See your Mission Manager for details.

Test and Evaluation

A testing facility has been installed in Building N200. It is frequently used for test and evaluation of SPARCS related payloads. However, it is well suited for test and evaluation of other payloads. It has the capabilities for:

- Dynamic Balance
- Moment of Inertia and Center of Gravity Measurements
- Vibration Testing
- Magnetic Calibration
- Optical Alignment

There is a vacuum system, an optical bench, a photographic darkroom, a sun tracker and a Hydrogen - alpha telescope. The entire area, while not maintained to clean room standards, is maintained at positive pressure. Section 6 describes the facilities in more detail.

Shipping

The PI is responsible for shipping the experiment and associated support equipment to WSMR. This includes all costs. Air freight is the usual mode.

WSMR Contacts

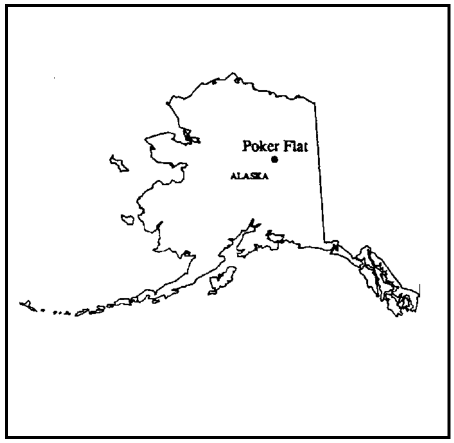
Below are listed some of the more important points of contact at WSMR:

Research Rocket Officer (NOMTS)	(505) 678-5502/1714
Head of the SPARCS Group Located at LC-35, Building N239	(505) 679-9716/9709
PSL Telemetry Group Located at LC-36	(505) 678-3998

J.2 Poker Flat Research Range

Introduction

The Poker Flat Research Range (PFRR) is located in the center of Alaska near Fairbanks, approximately 1-1/2° below the Arctic circle at 65.2°N 147.5°W.



The range is managed under contract by the Geophysical Institute, University of Alaska, Fairbanks, Alaska. Figure J-2 shows an aerial view of PFRR.

There are numerous range users; however, the major users are Department of Defense and NASA - both university and NASA Center sponsored. Questions regarding PFRR range capabilities, arrangements for use, procedures, travel, and accommodations should be addressed to the Mission Manager. Poker Flat has published a range users manual providing extensive information regarding the range. The manual includes a copy of the WFF Instrumentation Handbook "Poker Flat Research Range Systems", October 1998 (under revision), describing WFF designed and operated telemetry, timing, and radar systems at PFRR.

Figure J-2. Aerial View of PFRR

Capabilities

The major attributes of the range are:

- On United States real estate; high latitude site
- Land impact to 400 miles Ocean impact to 2800 miles
- S-band telemetry with trajectory option
- C-band transponder radar track
- Economical payload recovery
- Six major launch pads
- 22,000 pound launch capability
- 6,000 pound payload capability

Facilities

PFRR is situated at the 30 Mile Post on the Steese Highway, about 20 miles northeast of Fairbanks. Figure J-3 is a layout of the central complex. The complex, occupying about 7,000 acres, includes:

- Launch site, blockhouse, pads, communications, fire control, safety, and wind-weighting
- Payload and vehicle storage and assembly areas
- Clean room - 600 sq ft - Class 100
- An on range science site with geophysical monitoring and optical measurements
- Radar facilities

- Telemetry site
- Administrative and miscellaneous support facilities
- Down range science sites

Coordination

The operations at PFRR are cooperative ventures invariably involving several organizations. For example, WFF is responsible for managing, supporting, and operating a radar system, telemetry system, timing system and related equipment at PFRR while the University of Alaska employees manage and control launch operations. Therefore, it is important that all parties involved in a mission be fully informed on a timely basis on any action which could affect technical arrangements, operations, or scheduling.

Travel & Accommodations

Travel to Fairbanks is primarily by commercial air. Personnel using the range usually lodge in Fairbanks. Rental cars are available for travel to and from the range. Range users and visitors should coordinate their arrival in the Fairbanks area by contacting the Range Supervisor's office at (907) 474-7015 during work hours.

Shipping and Mail

Payloads are normally shipped to PFRR through Fairbanks via air freight. The Principal Investigator (PI) is responsible for arrangements and costs for experiment related equipment PFRR addresses are:

Freight Shipment:	Poker Flat Research Range 30 Mile Steese Highway Fairbanks, Alaska 99712
US Mail:	Poker Flat Research Range Geophysical Institute Fairbanks, Alaska 99775-0800

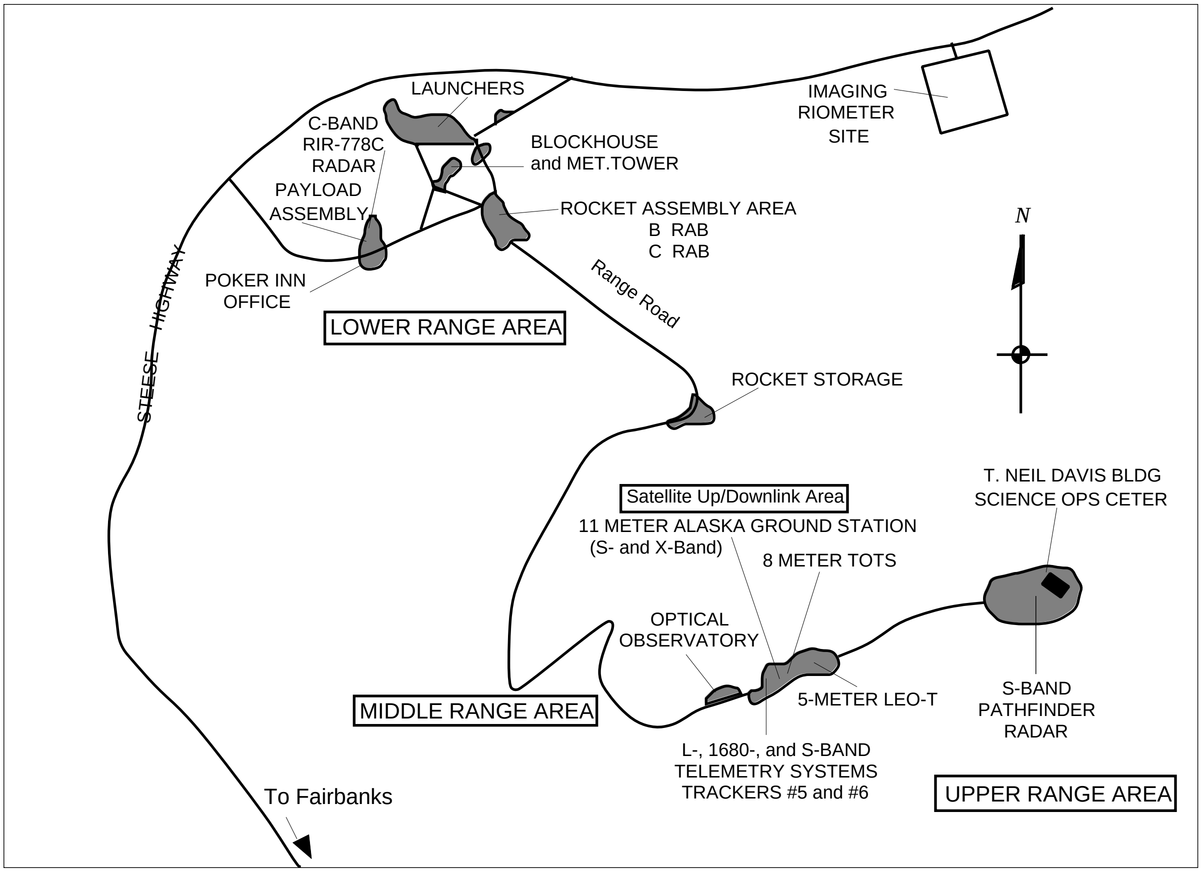


Figure J-3. PFRR Layout of Central Complex

Cold Weather

Most of the launch operations occur in mid-winter. Heated facilities are available to keep payloads warm up until launch. However conditions can be extreme and some special protective features may have to be designed into your payload. The Mission Manager can advise on any special requirements.

Environmental Clothing

PFRR does not provide environmental clothing to visitors. It will be necessary to have special clothing in mid-winter. The PI is responsible for providing appropriate cold weather clothing.

Driving Safety

The Steese Highway between Fairbanks and PFRR is infrequently traveled at night. Temperatures of -50°F and 50 knot winds produce a life threatening wind chill. Exposed skin can freeze in a matter of seconds. Take warm clothing. A breakdown at night in the wrong place can be fatal.

Photography

Photography is permitted anywhere on the range.

PFRR Contact

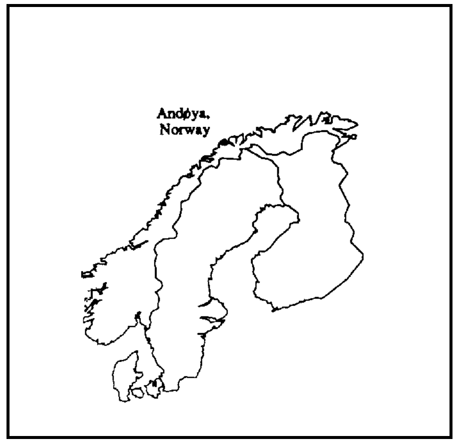
The primary point of contact at PFRR is:

____
Director
Poker Flat Research Range
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99775-7320

Commercial phone: (907) 474-7015
Fax: 907-474-5705

J.3 Andøya Rocket Range, Norway

General



Andøya Rocket Range is located in northern Norway. The range cooperates with European Space Agency (ESA) program and supports orbital satellite operations, sounding rocket and balloon operations.

Location

ANDØYA Rocket Range is located at geographic coordinates: 69°17' N 16°01' E

Trajectories and Impact Areas

The range offers a variety of possible trajectories and covers a large area both in latitude and longitude. This, together with the extensive system of ground observations, provides a great flexibility in selecting launch conditions and types of phenomena to be studied.

The impact areas in the Norwegian Sea set almost no practical limits to impact dispersion for rockets. Rockets have been launched to an apogee of approximately 800 kilometers, with impact of third stage at 900 kilometers.

Telemetry

Permanently installed telemetry systems operate in the P-band (216-260 MHz) and the S-band (2200-2300 MHz). Both systems are based on IRIG standards. All standard types of modulation used with sounding rocket telemetry can be handled

WFF Telemetry Radar Support

WFF can provide mobile telemetry and radar system support at Andøya to enhance the permanently installed capabilities or provide separate, unique capabilities. Section 2 and 9 discuss procedures for obtaining support to augment permanently installed capabilities. The requirements are coordinated through the Mission Manager.

Launch Pads and Launchers

There are eight launch pads in the launch area. The range has two universal launchers, two zero-length launchers for Nike rocket configurations, and one small rail launcher (overslung type). Pads are available for launchers provided by users. Figure J-4 is a photograph of the launch area.


Figure J-4. Launch Facilities at Andøya Rocket Range, Norway

Optical Site

An optical site, located 100 meters northeast of the control center, contains a laboratory and a room for recordings. The building also has an observation room with glass ceiling and walls, giving excellent conditions for overall watching of the aurora.

Tromsø Telemetry Site

The Tromsø telemetry station is located in northern Norway. The site primarily supports data acquisition. S- and L-band telemetry receiving and recording facilities are available. The station acts as a telemetry back-up facility for the Andøya Rocket Range during rocket launch campaigns. The Tromsø telemetry station's geographic coordinates are: 69°39' N, 18°56'E.

Other Sites

Other RF and optical data acquisition and launch support sites may be of assistance to individual experiments. Contact the Mission Manager for additional information.

Points Of Contact

Royal Norwegian Council for Scientific and Industrial Research (NTNF) Space Activity Division:

Gaustadelleen 30 D,
P.O. Box 309 - Bindern
OSLO 3, Norway

Telephone: 47-2-143590
Cable "Satellite"
Tel ex 0056-18174 space n
Telefax: (System 3M-9140) 47-2-143590 ext .123

Andøya Rocket Range:

Andøya Rocket Range
P.O. Box 54
N-8480 ANDENES, Norway

Telephone: 47-76-141644
Facsimile: 47-76-141857

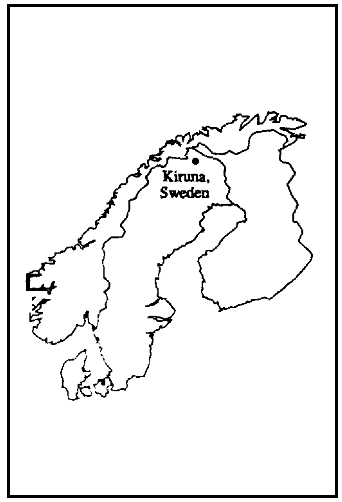
Tromsø Telemetry Station:

NTNF, Tromsø Telemetry Station
P.O. Box 387
N-9001 TROMSØ, Norway

J.4 Esrange, Sweden

General

Esrange is a space research range situated in northern Sweden above the Arctic Circle near Kiruna, Sweden. Esrange is located in the auroral zone, which makes it perfect for auroral studies and other high latitude phenomena. The base supports orbital satellites, sounding rocket, and balloon operations. The base is managed by the Swedish Space Corporation, which is a state-owned limited corporation under the Ministry of Industry.



The geographic coordinates for Kiruna are 68 0° N 21° E. A co-operative agreement exists between Esrange and the Norwegian sounding rocket range at Andøya, Norway.

Instrumentation

Esrange has modern instrumentation facilities to support the various rocket and balloon research activities. Special emphasis has been given to data display and quick look equipment to facilitate easy and quick data evaluation during countdown and flight. Timing and a variety of communications are available. Esrange has modern scientific equipment such as an ionospheric sounder, riometers, magnetometers, photometers, auroral TV systems, VLF receivers and sky cameras. Provisions are made for the PI's to install their own special equipment.

Other Support

Esrange is located close to the town of Kiruna, Sweden, with shops, hotels, and restaurants. There are daily jet flights to and from Stockholm.

Telemetry

Capabilities can be provided for IRIG standard FM/FM systems and PCM to a maximum bit rate of 1 Mbit/s. Two independent auto-tracking systems, and several wide band magnetic recorders, receivers, and antennas are available. Frequency bands are 134-150 MHz, 230-260 MHz and 400-402 MHz. Receiving equipment for S-band (1 65-2.4 GHz) is also available.

WFF Telemetry & Radar Support

WFF can design, build, and install telemetry and radar system support at Esrange to enhance the permanently installed capabilities or provide separate, unique capabilities. Section 2 and 9 discuss procedures for obtaining support to augment permanently installed capabilities. The requirements are coordinated through the Mission Manager.

Command/Destruct

Command and destruct capabilities are available to a range of 500 Km.

Trajectory Determination

C-band radar, tone ranging system, interferometers and telemetry tracking is available with real-time display.

Payload Preparation

There are two large rocket preparation halls (about 300 m^2 each) equipped with gantry cranes. The payload preparation area is divided into several laboratories. Clean room facilities are available.

Launchers

Six permanent launchers and support facilities including environmental controls and blockhouse make the launching of most types of sounding rockets possible. The range is equipped with launchers for many different rocket types, and ground instrumentation permits two simultaneous launchings, or launchings of several rockets in rapid succession. Examples of rocket launch capabilities are: Nike, Terrier and Taurus combinations, Black Brant, Skua, Petrel, and Skylark.

Observation Sites

Down range observations can be made from two different sites within the impact area north of the launch site. An extensive network of ground based scientific instrumentation has been established in northern Scandinavia. The Mission Manager can provide additional information on facilities available, planning, support requirements, and communications arrangements.

Payload Recovery

Recovery of payloads is a common requirement. About 50 percent of the rockets are equipped with recovery systems. Recovery missions are invariably successful. This is due to a number of factors: the open land impact areas, the fair climate, the tracking aids such as radar, auto-tracking TM antennas, interferometers, homing systems, and the excellent helicopter support from pilots well acquainted with this uninhabited region of Sweden. Use of the S-l9 Boost Guidance System is required for some vehicles. This system is discussed in Subsection 3.3.

Transportation

Virtually all transportation and travel is by air.

Points of Contact

Swedish Space Corporation:

Swedish Space Corporation
Tritonvagen 27
S-17154 Solna
Sweden

Tel:08/980200
Telex: 17128 Spaceco S

ESRANGE:

Swedish Space Corporation
Esrange
P. O. Box 802
S-981 28 Kiruna
Sweden

Tel: 46-980-72000
Facsimile: 46-980-12890

Cargo Address

All formalities regarding customs and shipment within Sweden will be taken care of by the Swedish Space Corporation. Shipments to Esrange should be addressed:

SWEDISH SPACE CORPORATION
ESRANGE
KIRUNA
SWEDEN

A pro forma invoice should be attached to the shipment stating contents and the price of the equipment enclosed. An extra copy of the invoice should be sent in advance to Esrange.

Appendix K
Wallops Flight Facility
Digital Telemetry System
(PDP11/60): Dites Tape Format

Format shown as dumped on PDP 11/60 Computer. Many computers will have the binary data with most significant byte (8-bits) last. M-2

The televent-ll data tapes consist of three different types of records. The first record is a header record that contains up to 80 ASCII characters. The second type of record is a data descriptor record. This record describes the data for each data stream recorded. The third type of record is the data record.

Header Record

There are as many header records as desired. These records are set up during the televent-ll setup processing. The format is:

WORD 1:	177776	-2 for DEC Fortran Compatibility
WORD 2:	NN	number of words in record
WORD 3:	000000	O to identify Header record
WORD 4:	B A	4 character stream ID
WORD 5:	D C	(note order of characters)
WORD 6:	N	Tape Number
WORD 7:	B A	ASC II TEST. Each character in a word is recorded most significant character last
thru		
WORD 46:	Z Y	“ “

Data Description Record

There are as many data description records as there are different streams recorded on the tape. There could be up to four different streams recorded on a tape. (The normal procedure is to record one stream on a tape.)

WORD 1:	177776	-2 for DEC Fortran Compatibility
WORD 2:	N	Number of words in record
WORD 3:	177775	-3 Identifier of description record
WORD 4:	BA	4 character Run ID from
WORD 5:	D C	Set up pf MAG-TAPE processing
WORD 6:	B A	4 Character Stream ID
WORD 7:	D C	(Generally the same as Run ID)
WORD 8:	N	Number of words per frame
WORD 9:	N	Number of frames per buffer
WORD 10:	N	Scaling factor (Normally =O)
WORD 11:	N	Number of frame Merge words
WORD 12:	N	Number of words/frame including merged words
WORD 13:	N	Number of preface words above 8
WORD 14:	N	Buffer Appendix Size

WORD 15:	N	INPUT Buffer Size (words)
WORD 16:	N	OUTPUT Buffer Size (words)
WORD 17:	N	Frames/Subframe Number 1
WORD 18:	N	Frames/Subframe Number 2
WORD 19:	N	Recording Mode (O=Word; l=Byte)
WORD 20:	020040	Two ASC II Blanks

Data Records

The data record is made up of a standard preface (8 words) and added preface (usually=2), the data, and an optional Appendix (usually=O). Data is recorded with time being merged at the end of each frame. That is, if three words of time are merged with the data, the time words will be at the end of each frame of data. (This is the usual recording made).

The data record format is:

WORD 1:	177776	-2 for DEC Fortran Compatibility
WORD 2:	NN	Buffer Size (words)
WORD 3:	N	Block number on tape
WORD 4:	B A	Stream ID
WORD 5:	D C	
WORD 6:	A P	A IS upper Byte=No. Appendix words; P=No. Preface Words
WORD 7:	L M	INPUT Buffer Size, last record (B15=1)
WORD 8:	S F	TFE Status and Frame No.
WORD 9:		Mag Tape write status
WORD 10:	00000	Zero not used
WORD 11:	thru N	Data and time

The TFE Status and Frame information in word eight is as follows:

BO thru B8	is Frame number of first search
B9	Sub com 2 Search on Last Buffer
B10	Sub com 1 Search on Last Buffer
B11	Frame Search on Last Buffer
B12	Multiple Search on one of below
B13	Subcom 2 Search Flag
B14	Subcom 1 Search Flag
B15	Frame Search Flag (most significant bit)

Time is merged at the end of each frame of data. The format of the time words, in the order in which they follow the data, is:

THE WORD NO. 3

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TENTHS OF SECONDS				HUNDREDTHS OF SECONDS				THOUSANDTHS OF SECONDS				DON'T CARE			

THE WORD NO. 2

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DC OA NR TE	TENS OF MINUTES			UNITS OF MINUTES				TENS OF SECONDS				UNITS OF SECONDS			

THE WORD NO. 3

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

100'S of Days	10's of Days	Units of Days	10's of Hours	Units of Hours

Appendix L

Radar Data Format

1.1.2155

PROGRAM NAME - POSDAT
FILE CODE - 4
MODE OF WRITING - FORMATTED
DISPOSITION - OUTPUT

Information is recorded in an ASCII character set at 800, 1600 or 6250 BPI. Each logical record is composed of 312 eight bit ASCII characters. One logical record is included in each physical record. The following is a definition of the parameters associated with each character position within the logical record.

CHARACTERS	PARAMETERS
1- 2	Year (1984 = 84)
3- 5	Day of Year (Jan 15 = 015)
6- 7	Epoch or launch time hours
8- 9	Epoch or launch time minutes
10- 11	Epoch or launch time seconds
12	Epoch or launch time tenths of seconds
13- 24	Elapsed time (seconds)
25- 36	Slant range from the tracker (meters)
37- 48	Azimuth from the tracker (degrees)
49- 60	Elevation from the tracker (degrees)
61- 72	Horizontal range from the launcher (meters)
73- 84	North-South range from the launcher (meters)
85- 96	East-West range from the launcher (meters)
97-108	Azimuth of vehicle from the launcher (degrees)
109-120	Altitude of vehicle (meters)
121-132	Latitude of sub-vehicle point (degrees)
133-144	Longitude of sub-vehicle point (degrees)
145-156	Earth relative velocity (meters/second)
157-168	East-West component of velocity (meters/second)
169-180	North-South component of velocity (meters/second)

181-192	Altitude component of velocity (meters/second)
193-204	Flight elevation angle (degrees)
205-216	Flight azimuth angle (degrees)
217-228	Slant range from look angle station (meters)
229-240	Azimuth from look angle station (degrees)
241-252	Elevation from look angle station (degrees)
253-312	Spare

Appendix M

Mission Manager and Support Sections

Approval for the Sounding Rocket Mission

1.0 SCOPE

This document provides the Mission Manager a method to assure that the Sounding Rocket Mission flows smoothly and procedures are followed.

2.0 MISSION MANAGER AND FLIGHT DATA:

Mission Manager: ______________________

Flight Number: ______________________

Date: ______________________

Experimenter: ______________________

2.1 Mission Team Members:

Attitude Control System: ______________________

Electrical System: ______________________

Electrical Technician: ______________________

Instrumentation System: ______________________

Mechanical System: ______________________

Mechanical Technician: ______________________

Mission Analysis: ______________________

Recovery/Igniter Housing: ______________________

Safety: ______________________

Vehicle: ______________________

S-19: ______________________

2.2 Mission Status Meetings

#1 ______________________

#2 ______________________

#3 ______________________

#4 ______________________

3.0 DESIGN REVIEW

Date Scheduled: ______________________

Team Members Notification: ______________________

3.1 Systems Design and Data Packages Complete

Attitude Control Systems: ______________________

Electrical Systems: ______________________

Instrumentation System: ______________________

Mechanical System: ______________________

Mission Analysis: ______________________

Recovery/Igniter Housing: ______________________

Safety: ______________________

Vehicle: ______________________

S-19: ______________________

3.2 Design Review Action Items

Complete: ______________________

4.0 PRE-INTEGRATION CHECKS (COMPLETE)

Attitude Control Systems: ______________________

Electrical Systems: ______________________

Instrumentation System: ______________________

Mechanical System: ______________________

Mission Analysis: ______________________

Recovery/Igniter Housing: ______________________

Safety: ______________________

Vehicle: ______________________

S-19: ______________________

Mission Manager ______________________

4.1 Pre-Integration Review

Date: ______________________

5.0 WITNESSES

All tests shall be witnessed by the Mission Manager, experimenter or his representative and by cognizant, responsible personnel from each support section. The witnesses shall report satisfactory completion of each integration step or shall initiate a non-conformance report beginning the first day of integration and continuing until after the post flight report is written.

Subsystem	**Responsible Engineer**
Experiment	______________________
ACS	______________________
Tracker - Sun Sensors	______________________
Command Link / SCS	______________________
Electrical System	______________________
Instrumentation	______________________

Mechanical System	______________________
S-19	______________________
Recovery/Igniter Housing	______________________
Mission Manager	______________________
Other	______________________

5.1 Integration Events

The integration shall include the following events (as required). The Mission Manager shall contact each responsible engineer upon completion of each event to determine performance. Satisfactory performance shall be indicated on the checklist by initial. Test data will be recorded by each subsystem engineer and maintained in the pertinent system logbook. All non-conformances will be recorded by the Mission Manager and must be cleared prior to installation. In the event wiring changes or corrections and/or reports are made to an electrical harness, all wiring in that harness will be thoroughly checked (for proper pin location and levels).

5.2 Range Meeting

A range meeting should be scheduled within the first two days after arriving at the range.

5.3 Subsystem Test

	Initial	**Date**	**Remarks**
Experiment			
ACS, RIG (if used)			
Tracker/Sensors			
Command Link/SCS			
Electrical System			
Instrumentation			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

5.4 Subsystem Mechanical Parameters

Transmit payload Balance & Gravimetrics data to the NSROC (Flight Performance).

______________________________ __________

Mission Manager Date

5.5 Connector Check

All subsystem interface connectors must be checked for proper voltage conditions. This test must be performed to the satisfaction of the cognizant engineers of the mating subsystems and the Mission Manager. It is mandatory that all pyrotechnic actuator connections be checked prior to payload assembly.

	Initial	Date	Remarks
Experiment			
ACS, RIG (if used)			
Tracker/Sensors			
Command Link/SCS			
Electrical System			
Instrumentation			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			

5.6 Mechanical Fit Check

Connector alignment and payload zero reference must be verified as the payload is assembled. Tracker/solar sensors must be mounted with reference to the control jets. All loose wiring and connectors must be secured during assembly. Sensor checks - i.e. field of view (FOV) for payload and sensor and orientation of axes. All procedures have been followed.

	Initial	Date	Remarks
Experiment			
ACS, RIG (if used)			
Tracker/Sun Sensors			
Command Link/SCS			
Electrical System			
Instrumentation			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

5.7 Payload Mechanical Parameters

Record payload weight and length.

Weight ____________________ Length ___________________

Mission Manager ____

Date

Remarks: ____

5.8 Power On Test

Power shall be applied to all sections of the payload to verify proper voltage levels and polarity.

	Initial	Date	Remarks
Experiment			
ACS, RIG (if used)			
Tracker/Sun Sensors			
Command Link/SCS			
Electrical System			
Instrumentation			
Mechanical System			

S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

5.9 No Fire Test

All timers will be run independently without pump down to verify:

1) squib circuits do not fire

2) altitude controlled or electrical circuits do not operate

	Initial	**Date**	**Remarks**
Instrumentation			
Mission Manager			

5.10 Pre-Environmental Integrated Test

The payload shall be subjected to a simulated flight sequence as a minimum from T-5 minutes to T +0 seconds. All mission essential equipment shall be operational. TM records shall be checked for interference from other payload equipment and noise. The sequence of events shall be verified, including all pyrotechnic functions and TM monitor.

5.10.1 Sequence Test

Timers shall be operated to verify both the proper sequence of events and proper timing. Sequence times shall be recorded in the instrumentation data log.

	Initial	**Date**	**Remarks**
Experiment			
ACS, RIG (if used)			
Tracker/Sun Sensors			

Command Link/SCS			
Electrical System			
Instrumentation			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

5.10.2 TM Test

TM channels shall be checked for proper operation: signal, polarity, gain, noise, and identifiable wave shapes.

	Initial	**Date**	**Remarks**
Experiment			
ACS, RIG (if used)			
Tracker/Sun Sensors			
Command Link/SCS			
Electrical System			
Instrumentation			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

5.11 Alignment Check (Pre-Environmental)

The proper alignment of the experiment and attitude sensors shall be verified.

	Initial	**Date**	**Remarks**
Experiment			
Sensors Rep.			
Mission Manager			

5.12 **Bend Test**

Perform Bend Test to prescribed procedures.

	Initial	**Date**	**Remarks**
Mechanical System			
Mission Manager			

5.13 **Mechanical Measurements**

A. TIR - Record

B. Spin Balance(refer to MASS Properties Test Procedure) record parameters on vehicle data sheet

C. Balance Weight Installation

D. Repeat Spin Balance

E. MOI - For Roll and P/Y - Record

F. Measure weights & C.G. for all up, control, & re-entry.

	Initial	**Date**	**Remarks**
Mechanical System			
Mission Manager			

5.14 **Vibration**

The entire payload shall be subjected to the pertinent vehicle vibration levels: (refer to vibration data). Any obvious damage or loose parts caused by vibration must be reported to the Mission Manager prior to post environmental power turn-on. The Mission Manager will make a final decision on continuation of tests based upon extent of damage. Disassembly may be required if loose components are suspected. In this case, all electrical connections should be maintained intact wherever possible.

	Initial	**Date**	**Remarks**
Experiment			
Electrical System			
Instrumentation			
ACS, RIG (if used)			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

5.15 Post Environmental Integrated Test

The payload shall be subjected to a simulated flight sequence as a minimum from T-5 minutes to T + 600 seconds. All mission essential equipment shall be operational. TM records as requested by cognizant personnel shall be checked for interference from other payload equipment and noise. The sequence of events shall be verified, including all pyrotechnic functions and TM monitors.

	Initial	**Date**	**Remarks**
Experiment			
ACS, RIG (if used)			
Command Link/SCS			
Electrical System			
Instrumentation			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

5.16 Alignment Check (Post-Environmental)

The proper alignment of the experiment and the attitude sensors shall be verified.

	Initial	Date	Remarks
Experiment			
Tracker/Sun Sensors			
Mission Manager			

5.17 Horizontal

The payload shall be subjected to a simulated flight sequence as a minimum from T-5 minutes to T + 600 seconds. All mission equipment shall be operational. Telemetry records shall be checked for interference from other payload equipment and noise. The sequence of events shall be verified, including all pyrotechnic functions and telemetry monitors.

	Initial	Date	Remarks
Experiment			
ACS, RIG (if used)			
Command Link/SCS			
Electrical System			
Instrumentation			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

5.17.1 Final Sensor Checks

Sensors checked for screw torque and sensor cleanliness.

	Initial	Date	Remarks
ACS Sensors			
Mission Manager			

5.18 End-To-End Test

The payload end to end test is performed to verify continuity, operation and phasing of SPARCS sensors with respect to the control jets. The sun sensors are cleaned and covers are tightened. This test is performed after final assembly prior to installation.

	Initial	Date	Remarks
ACS, RIG			
Command Link/SCS			
C/L Antenna Orientation			
Mission Manager			

5.19 Vertical

The payload shall be subjected to a simulated flight sequence as a minimum from T-5 minutes to T +0 seconds. All mission equipment shall be operational. Telemetry records shall be checked for interference from other payload equipment and noise. The sequence of events shall be verified.

	Initial	Date	Remarks
Experiment			
ACS, RIG (if used)			
Command Link/SCS			
Electrical System			

Instrumentation			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

5.20 <u>SPARCS Calculations & Calibrations Only</u>

Complete SPARCS calculations as specified on SPARCS Calculations & Calibration Sheet. This is to be done prior to day of launch (if possible).

	Initial	**Date**	**Remarks**
SPARCS ACS, RIG (if used)			
SPARCS Calculation Verification			
Command Link/SCS			
Targeting Verification			
SPARCS Targeting			
Mission Manager			

6.0 <u>INTEGRATION COMPLETE</u>

	Initial	**Date**	**Remarks**
Experiment			
ACS, RIG (if used)			
Tracker/Sun Sensors			
Command Link/SCS			
Electrical System			
Instrumentation			
Mechanical System			
S-19			
Recovery/Ign. Housing			
Mission Manager			
Other			

6.1 Flight Readiness Review (FRR)

Refer to FRR checklist and NonconformanceLog.

7.0 VEHICLE LOG

Rocket Motor Building and Staging Log Complete

______________________________ ________________
Mission Manager Date
Remarks: ____

8.0 VEHICLE LAUNCH COUNTDOWN

All subsystems will be checked during launch countdown. Subsystems not operational shall be reported to the Mission Manager.

______________________________ ________________
Mission Manager Date

Remarks: ____

9.0 RECOVERY

10.0 POST FLIGHT CONFERENCE