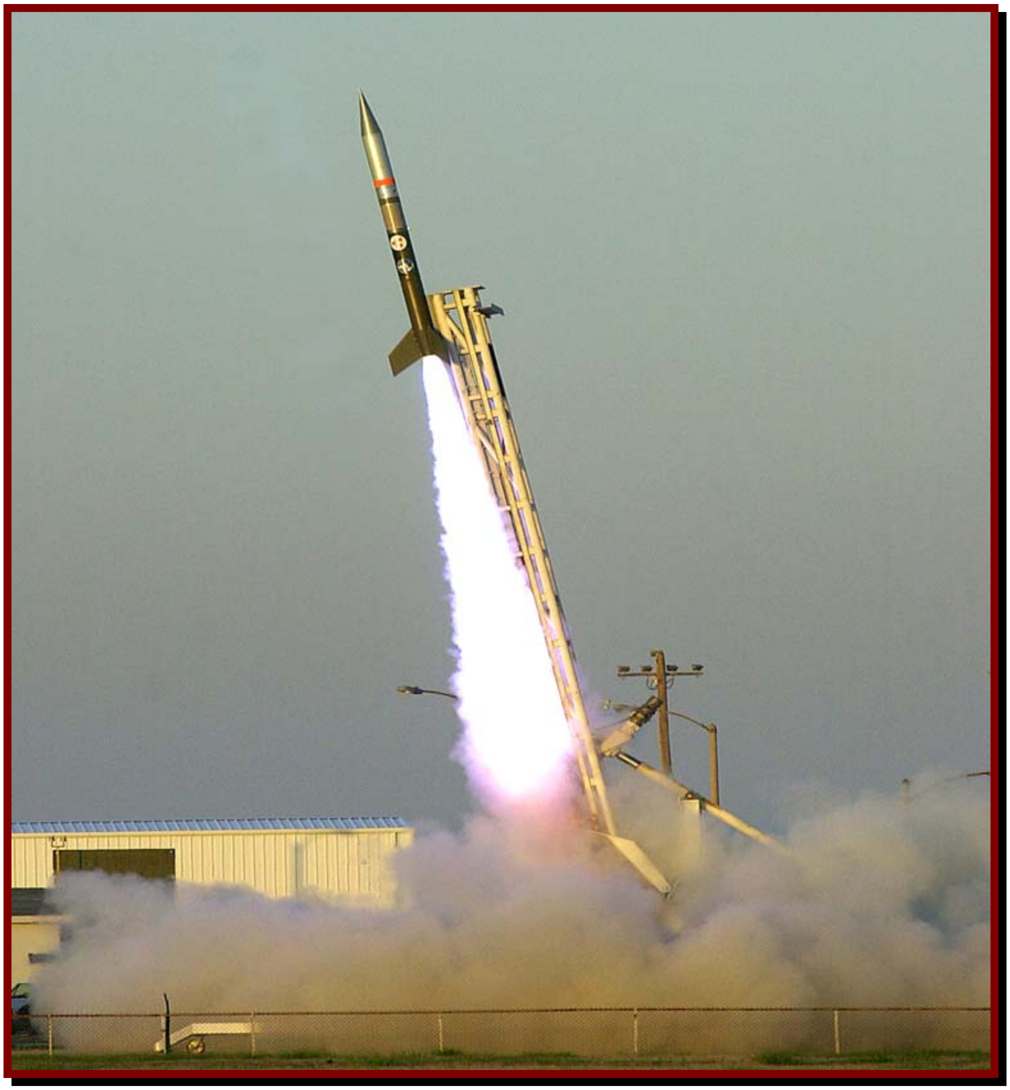
810-HB-SRP

SOUNDING ROCKET PROGRAM HANDBOOK

Suborbital and Special Orbital Projects Directorate

Sounding Rockets Program Office



National Aeronautics and Space Administration
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia 23337

July 2001

(Please check the NSROC website at www.nsroc.com to verify that this is the correct version to use.)

Preface

This Handbook describes the capabilities of the Sounding Rocket program, the design and technology applications used by that program, and the processes established to integrate the customer (principal investigator/program user/scientist/experimenter) into the mission team to ensure the highest probability of a successful project.

Neither the United States Government nor any person acting on the behalf of the Unites States Government assumes any liability resulting from the use of information contained in this document or warrants that the use will be free from privately owned rights.

The use of a company name does not imply approval or recommendation of the product to the exclusion of others that may also be suitable.

(Please check the NSROC website: WWW.NSROC.COM to verify that

this is the current version prior to use.)

SOUNDING ROCKET PROGRAM HANDBOOK

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

SECTION 1: The NASA Sounding Rocket Program (NSRP)

This Handbook was written to assist NSRP customers in developing payloads that meet the requirements necessary to achieve mission-specific, scientific objectives, and to serve as a guideline in defining NSRP quality standards and ISO 9001 requirements. For the purposes of this document, "Customers" shall include principal investigators, program users, scientists, and experimenters.

1.1 The Program: 1959 – the Present

The NSRP is a suborbital space flight program that primarily supports NASA-sponsored space and earth sciences research activities, other government agencies, and international sounding rocket groups and scientists. Since its inception in 1959, some 2800 missions have flown 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 20 - 30 flight opportunities per year to space scientists involved in 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, complexity, and range. NSRP flight systems are remarkably sophisticated spacecraft, capable of lofting 1000 pound payloads to 280 kilometers and 250 pound payloads to 1500 kilometers.

NSRP customers consist primarily of university and government research groups; however, some research activities involve the commercial sector. The program has contributed major scientific findings and research papers to the world of suborbital space science, validated satellite tracking and instrumentation, and served as a proving ground for space ship and space station components. Many new scientists have received training and developmental experience through NSRP internships and graduate study programs offered by participating educational institutions.

Systems and services provided to customers of the NSRP encompass the complete spectrum of support: 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.

Customers are required to provide the scientific instruments/detectors for the payload, a comprehensive description of the support requested from NASA, and 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, using available resident WFF and WSMR resources. The NSROC program is required to maintain an 85% success rate (complete mission, vehicle, payload and science) although the program goal is 100%.

Effective communications between the NASA project support team and the customer are vital to the success of individual sounding rocket missions and to the overall program. Project meetings, reviews, and the requisite post flight assessments of mission results by the customer are all feedback mechanisms which provide observation, comment and constructive criticism for problem solving and future programmatic improvements. The NASA approach to team-customer interaction is included in this Handbook to foster a better understanding of the thinking behind current Program procedures. From design and development of the payload through launch and data retrieval, the customer is the essential source of information on how well the NSRP is working.

1.2 NASA Organizational Responsibilities

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; board members include representatives from the Earth Science and Applications Division and the Astrophysics, Space Physics, and Solar Systems Exploration disciplines of the Office of Space Science. A discipline specialist from the microgravity community is also on the Board. 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 programmatic issues. As a working element of the Suborbital Program Review Board, a Rocket Program Change Board 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. The Rocket Program Change Board includes the assigned Suborbital

Program Manager from the SR and Scientific Discipline Chiefs from the previously identified disciplines. Program progress, problems, and significant issues and events are reviewed by the Associate Administrator, OSSA, as part of a comprehensive monthly OSSA Program Review.

1.2.1 Program Management

The NSRP at Goddard Space Flight Center (GSFC) falls under the Sounding Rockets Program Office (SRPO), Code 810, Suborbital and Special Orbital Projects Directorate (SSOPD), Code 800. The SRPO and SPOD are located at Wallops Flight Facility (WFF) Wallops Island, VA. 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.

1.2.2 Sounding Rocket Working Group (SRWG)

The SRWG 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, GSFC, chairs the Group which consists of 11 members from the principal scientific disciplines served by sounding rockets . The NASA SRPO reports to this Group in the areas of technical and management support.

1.3 Sounding Rocket Program Customer's Role

Once selected for flight participation, the customer becomes a member of the assigned Mission Team and is responsible for the preparation of the scientific experiment portion of the payload. Customers assist in establishing and conducting the operational program. Customers are responsible for defining the investigation, providing the necessary scientific instrumentation, completing timely processing and analysis of recovered data, and publishing the results. The customer is expected to participate in a number of scientific and technical planning functions and formal reviews described later in this document.

1.3.1 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. While the assigned mission support team may recommend the use or avoidance of certain procedures and practices, final decisions on the internal details of the scientific instrumentation are normally left to the customer. Each payload is required to successfully complete a series of environmental tests which measure, test and evaluate the ability of the scientific instrumentation to survive the flight environment. Determination of the ability of the scientific instrumentation to make the required measurements is normally made by the customer.

1.3.2 Payload and Instrumentation

Equipment provided as part of the Program's customary mission support functions is described in Section 1.4 – Sounding Rocket Project Support Elements. The customer is normally responsible for developing and providing all other scientific instrumentation and related support equipment. They are also responsible for ensuring that it conforms to all required mechanical, thermal, and electrical interface specifications; meets all required safety standards; and is capable of surviving the predicted flight environment. Scientific instrumentation and related support equipment may be built within the customer's own laboratories or by associated contractors. To help ensure a safe operation, the customer is required to furnish the data specified in Section 8 - Safety and Appendix J - GSFC/WFF Safety Data Requirements.

1.4 Sounding Rocket Project Support Elements

As the NSROC contractor, PRC 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. PRC implements and reports their management functions to NASA through a comprehensive Integrated Management Plan (IMP) and an Information Management Support System (IMSS). The IMP reflects PRC's corporate approach to accomplishing technical, safety, scheduling, cost, and business objectives in an efficient and effective manner. The IMSS provides online access to NSROC schedules, reports, documents, archival information and marketing activities.

PRC provides individual mission management for all assigned sounding rocket missions; this includes all planning and scheduling associated with individual mission requirements. Each mission is planned to meet science objectives and scheduled to avoid interference with the timely and cost efficient completion of other ongoing missions. The Mission Flylist Database is a programmatic schedule for all missions; it is maintained on the NSROC IMSS website, Mission Operations link. At minimum, the Mission Flylist reflects the planned schedule for the following milestones:

- Launch Date
- Launch Time
- Integration Site/Date
- Mission Initiation Conference (MIC)
- Requirements Definition Meeting (RDM)
- Critical Design Review (CDR)
- Mission Readiness Review (MRR)
- Mission Close-out Report (MCR).

PRC also 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 suborbital payloads, provides launch vehicles, systems, and associated hardware, and provides various activities associated with subsequent mission launch operations. The NSROC IMSS tracks each mission individually by Mission Number. All relevant information is updated and maintained on the Mission Operations/Current and Archived Missions links.

1.4.1 Program-Provided Support Services

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 extensive support capabilities provided by the Program.

A typical Mission Team is composed of the customer or his representative(s), applicable support staff, and additional team members provided by the support elements at WFF. A typical Mission Team includes the following positions:

- Mission Manager
- Customer & Staff
- Mechanical Engineer
- Electrical Engineer
- Instrumentation Engineer
- GNC (Boost Guidance, Navigation and Attitude Control) Engineer
- Performance Analysis Engineer

- Mechanical Technician
- Electrical Technician
- GNC Technician
- Recovery System Technician
- Launch Vehicle Technician
- Flight Safety Representative
- Ground Safety Representative

The general categories of effort necessary for implementation of a mission include:

- Flight Mission Management
- Scientific Instrumentation (*typically provided by the 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.

The following is a brief description, including organizational responsibility, of the individual support elements provided by the Program for the typical mission. 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.

1.4.1.1 Flight Mission Management

NSROC management is generally responsible for selecting a Mission Manager (MM) for each mission. The MM has comprehensive, team leader responsibilities throughout the mission lifecycle and serves as the central point of contact for the customer. MM responsibilities include:

1. Developing an approach (technical, schedule, and cost effective), in conjunction with the assigned mission team, for meeting the mission requirements 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, conducting, and documenting the RDM and all associated mission requirements in the subequent Requirements Definition Meeting Memorandum.

3. Working with the customer and the NSROC Mission Team to design, develop, fabricate, integrate, test and flight quality 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.

1.4.1.2 Payload Analysis, Design, & Development

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 (pin-pullers, bolt-cutters and thrusters).

GNC engineering support for payloads and associated flight systems includes all boost guidance systems, navigation systems and attitude control systems. Support includes requirement review, auxiliary attitude sensor selection, implementation of external interfaces to the payload, pneumatic system propellant selection and thruster locations.

Flight performance analyses include:

- Launch vehicle performance and nominal flight trajectory analysis
- Flight trajectory dispersion, wind-compensation parameters, and impact aim point considerations
- 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)
- Other suborbital analyses.

These activities are performed during the pre-flight and post-flight analyses for each mission.

1.4.1.3 Launch Vehicle and Payload Support Systems

Launch vehicle and payload support systems are provided by the NSROC contractor and 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.

1.4.1.4 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.

1.4.1.5 Payload Assembly/Integration, Testing, & Evaluation

The development of a mission progresses from the fabrication and assembly of flight hardware, through the addition of customer-provided instrumentation and standard support systems, to a fully integrated payload. The payload then proceeds through the testing and evaluation process which involves the entire Mission Team (engineering personnel, technical support personnel, and the customer who has the technical knowledge of, and responsibility for, his instrumentation) and the laboratory support personnel who operate the various facilities involved in the processes. These facilities 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.

1.4.1.6 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. Additional support may also be provided by the AETD.

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.

The range from which the operations are being conducted provides launch pads, launchers, blockhouse systems, controls, and consoles. 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 actual launch operations as well as all functions relating to the preparation of the launch vehicle and payload leading up to that event.

1.4.1.7 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.

1.4.1.8 Ground and Flight Safety

All work performed in support of the Sounding Rocket Program (SRP) is done 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-2002). 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 NPG 8715.3, NASA Safety Manual. The NSROC contractor is responsible for meeting these requirements as well as any additional safety requirements of 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 Operational Safety Supervisor(s) whose primary responsibility is safety oversight. This person or persons interfaces directly with the NASA Safety Office oversight authority in resolving real-time safety concerns.

- 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) requirements.

A detailed discussion of sounding rocket safety considerations and policies is provided in Section 8 of this Handbook; additional NSRP support capabilities are addressed in Section 2.

SECTION 2: The Sounding Rocket Flight Project

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

From mission approval by NASA Headquarters through launch to completion, required meetings and reports are the primary means by which NASA and the customer track a mission's progress in meeting the schedule, problems encountered and corresponding corrective actions, and mission outcome. Meetings generally held for each Mission include:

- **Mission Initiation Conference:** Initial review of a new NSROC project evaluates the probability of mission success, establishes science objectives and preliminary mission requirements for the Project Team. At this meeting, the PI Data Package (scientific objectives, instrumentation, engineering data, performance requirements, operational requirements and safety issues) will be analyzed and evaluated; and the preliminary schedule set..

- **Requirements Definition Meeting:** Establishes the project requirements baseline and reviews the preliminary payload stack to determine if proposed systems will provide the required functionality; validates the selected vehicle configuration and updates/refines project schedule.

- **Informal Mission Status Meetings:** Such meetings are held periodically during the course of a project to gauge progress, disseminate information, resolve issues, and maintain schedules.

- **Design Review**: The Detailed and Critical Design Reviews verify that the detailed design meets all requirements established at the RDM. All aspects of payload design are discussed and disseminated across all discxiplines. Design parameters are summarized, design problems are addressed and resolved, and, should they be required, new designs are verified as complete and ready for fabrication.

- **Pre-Integration Review**: The integration and testing process for integration of the payload and the flight vehicle is reviewed. At this meeting, the payload, vehicle elements, test plans/procedures, test equipment, facilities and personnel are thoroughly evaluated to ensure successful integration.

- **Pre-Shipment Review:** Verifies that the Integration and Testing process is complete and all shipping arrangements are in place. Range approvals, remote/mobile or foreign range logistics plans, license submittals, agreements for associated contractor range support, and field operations plan are also reviewed to ensure that every facet of the launch has been prepared, documented, approved and verified prior to the Mission Readiness Review.

- **Mission Readiness Review:** This final check answers the question: Are we ready to launch? Has every system - telemetry, electrical, mechanical, environmental, range safety - been checked and double checked to ensure a successful mission? Based on this input, consent for launching is provided.

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.

2.1 The Mission Initiation Conference (MIC)

Flight projects must be approved by the appropriate science discipline chief at NASA Headquarters. Once this approval has been obtained, the customer will be contacted by the SRPO to establish a mutually acceptable date for a MIC between the customer and WFF personnel. The purpose of this first meeting is for the customer to present a MIC Data Package which details his requirements and specifies the support necessary for the mission. (An outline of the information required in the MIC Data Package is provided in Appendix A.)

The MIC is chaired and documented by the SRPO. Attendees include the customer, appropriate WFF supervisory and engineering personnel and NSROC supervisory, engineering, and technical personnel. A well-conducted and documented MIC will result in a strong foundation on which to begin the mission. The MIC provides the basis from which all requirements for the mission are established. These include:

- **Project Schedule:** 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. The customer should be prepared to answer specific and detailed questions regarding the scheduling of these milestones

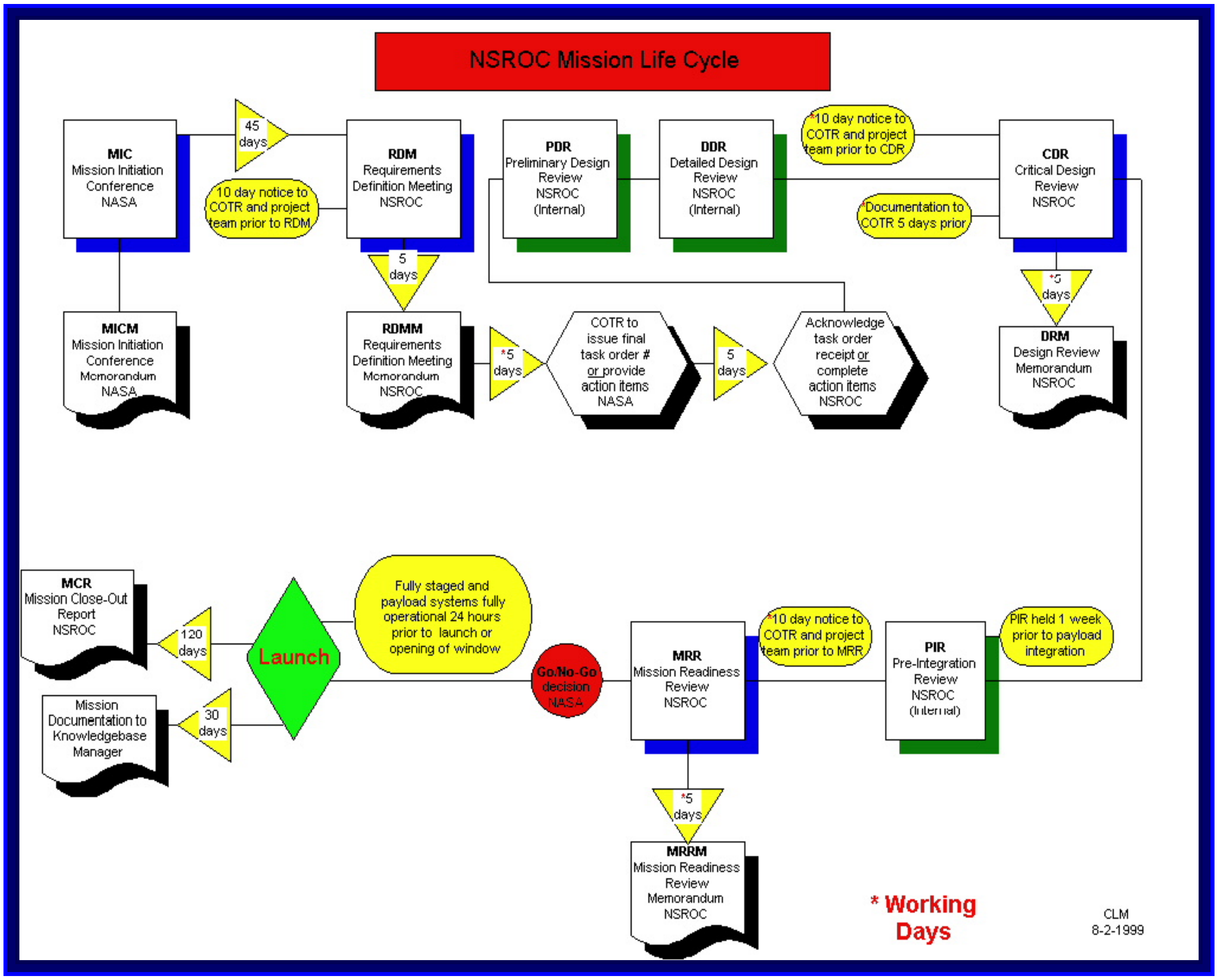


Figure 2-1. Typical Sounding Rocket Mission Life Cycle

- **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, vacuum requirements, or mechanical devices/systems (despin, air, land and water recovery) should also be discussed.

- **Flight Performance:** All payload flight trajectory/timeline requirements such as apogee, altitude, or time-above-altitude should be reviewed and requirements for payload dynamics (spin rate and/or coning limits) included. Some payload designs involve long, flexible booms while others involve tethers and sub-payloads; dynamics requirements for this type of payload should be presented.

The best estimate of payload weight should be determined for the MIC, being careful not to eliminate any significant payload components. The flight performance characteristics of NASA sounding rocket launch vehicles are presented in Section 3 and Appendix E. 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 (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 knowledge, control and stabilization of space science payloads are key elements in most science experiments. Attitude system requirements should be fully discussed to determine the type of Attitude Control System (ACS) required. The nature of celestial targets should be defined and any attitude maneuver sequences employed. Pointing accuracy and stability (jitter) should be specified. Known payload launch constraints are presented at the MIC. The types and capabilities of sounding rocket attitude control systems are presented in Subsection 5.12, Appendix I, and Section 6.

- **Navigation**: requirements frequently include detailed definitive knowledge of space/time during flight. Applicable requirements should be addressed in the MIC.

- **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:** SRP testing policies 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 to ensure that the customer's objectives and requirements will be met on schedule

2.2 The Requirements Definition Meeting (RDM)

Following the MIC, 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. Within a period of 45 days from the MIC, the results of this mission-defining process are presented at the second meeting in the Mission Life Cycle, the RDM. Initiated by the NSROC contractor, the RDM includes representatives from NASA and the customer. All information necessary to define and demonstrate the feasibility of the mission and how the mission requirements can be achieved will be presented at the RDM.

A Requirements Definition Meeting Memorandum (RDMM) is documented by the NSROC contractor and provided to NASA within 5 days of the RDM. It 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.

2.3 The Design Review (DR)

A 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 mission is a direct refly of an existing payload/vehicle configuration.

A DR may be requested by anyone who carries responsibility for the payload (the customer, NSROC contractor, or the SRPO). The objective of the DR is to discuss all aspects of the design, to establish design parameters, to define and elicit solutions to problems, and to make all with responsibility aware of the current design plans. The design of the payload should be completed in order for a DR to be held. If this is not possible because of schedule constraints, the review should be held as soon as a design has been completed that is sufficient to allow a thorough review. NASA, NSROC, and customer representatives may attend the DR and assign action items as necessary

- **Pre-DR Process**: Should a DR be required, the following process is used to request, initiate, conduct, document and respond to action items issuing from it:

    1) The MM schedules the Design Review and coordinates the Project Team preparedness.

    2) The NSROC Contractor establishes a Design Review Panel that reviews all aspects of the mission, vehicle, design, test plan and integration activities. The Panel consists of NSROC personnel who are not directly involved with the mission but who have established expertise in the areas of technical support required for mission success. These include: Flight Performance, Mechanical Systems, Electrical Systems, Instrumentation Systems, Guidance, Navigation and Control Systems, Recovery Systems, Launch Vehicle Systems, and Ground and Flight Safety (NASA personnel).

    3) The NSROC Mission Manager formally announces the DR, specifying the subject flight mission, date, time, and place.

    4) The Chairman of the Design Review Panel conducts the DR.

- **The Design Review Meeting:** 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. The customer should be prepared to discuss all details of the scientific instrument design and interface with the support systems.

    DR documentation includes:

    - Complete mission and vehicle design information including all subsystems on the payload and vehicle.
    - Complete descriptions of the proposed test plan for the complete payload and each system associated with the mission
    - A listing of all procedures involving hazardous operations, safety-related issues, and assembly of the launch vehicle and payload.
    - Procedures of any type involving hazardous operations or safety-related issues, which have not been approved by NASA Safety

- Any new or revised procedures

- A preliminary Flight Requirements Plan (FRP), which outlines requirements for range support, flight performance; data products, and field operations plans and schedules; the mission schedule is updated, if necessary, and any changes since the RDM are justified and documented.

- A Customer Data Package is required for handout at the review and should be provided to the Chairman of the Design Review Panel approximately 48-hours prior to the scheduled meeting. The format and contents of this data package are provided in Appendix B.

- **Post DR Process**

1) After completion of the meeting, the panel reconvenes to discuss the results, and formulate and document action items that are provided to the MM for disposition.

2) 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.

3) 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.

4) The Panel Chairman reconvenes 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).

5) All action items must be dispositioned (responded to by the Mission Team and approved by the Design Review Panel or NSROC management) prior to scheduling the Mission Readiness Review.

2.4 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.

Figure 2.4.1 The Very Complex Pfaff Payload Used Extended Booms to Investigate Sporadic E Events in the Ionosphere; Pfaff 21.126 Launched on 26 June 2001.

Figure 2.4-2 Mentored by NSROC Staff, UVA Students begin Electrical Wiring of the Laufer 30.046 payload for the University's "first ever" launch, 27 April 2001.

2.5 Pre-Integration Review (PIR)

A PIR by the project team (Mission Manager, subsystem disciplines and science) occurs prior to payload testing and integration. 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 a variation of the Mission Status Review meeting. It occurs when the customer arrives with his instrumentation at the payload integration site and is intended to coordinate the upcoming activities associated with payload integration, identify any outstanding issues early in the process, and develop approaches towards their resolution.

2.6 Payload Integration and Testing

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.

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

2.6.1 Pre-Integration Checkout:

Pre-Integration Checkout insures all parts and systems are available, have been assembled mechanically, and passed appropriate electrical functional test. The customer and Mission Team determine pre-integration checkout criteria; 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:

- **Attitude Control System (ACS):** Mechanical/electrical assembly completed
Air Bearing test completed
Vibration test completed
System Acceptance Test completed
Electrical/TM Functional test completed

- **Boost Guidance System (BGS):** Mechanical/electrical assembly completed
System Acceptance Test completed
Electrical/TM Functional 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

2.6.2 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.

2.6.3 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.

2.6.4 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.

2.6.5 Final Checkout:

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

2.6.6 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 where all problems encountered during integration and testing are thoroughly discussed.

2.7 Mission Readiness Review (MRR)

The MRR is a formal review to determine if the mission is ready to proceed with launch operations with a high probability of meeting mission success criteria. All action items identified in the DR must be dispositioned (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. A Mission Readiness Review Panel, composed of a Chairman and other technically qualified personnel not directly involved with the flight project, is established by NSROC Management. Information presented at the MRR must 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, including the adequacy of any modifications or repairs are reviewed. Information regarding procedures, similar to that presented at the DR, is provided; and 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; format and content of this data package are provided in Appendix C.

Should Action items result from the MRR process, it is highly desirable that they be 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 addressed to NASA's satisfaction, 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 the requirement in question has been met.

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

2.8 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. These 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.

2.8.1 Flight Requirements Plan (FRP):

Ninety days prior to arriving at the launch range, the NSROC contractor submits an 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. For launches at WFF, an Operations and Safety Directive is used in lieu of an FRP.

2.8.2 Operations and Safety Directive (OSD):

Support requirements for launches at WFF are documented in the OSD and 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.

2.8.3 Operational Safety:

All aspects of sounding rocket launch operations which impact or deal with personnel hazards and overall safety concerns are considered in detail. The MM is responsible for ensuring that the Mission Team is in full compliance with all applicable safety policies regarding ground and flight safety during project launch operations. NASA Sounding Rocket safety policies and responsibilities are discussed in Section 8 of this Handbook.

2.9 Post-Launch Activities

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 before 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. Post-Flight reports and conferences include:

2.9.1 The Quick Look Report:

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.

2.9.2 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 vehicle and payload systems problems encountered during flight

- 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.

2.9.3 Customer's Written Response:

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

2.9.4 Post Flight Conference:

Most established launch ranges conduct a post-flight meeting to review mission results. This conference gives the customer an opportunity to provide compliments or complaints concerning the field services provided; the input provides a "lessons learned" resource for future NSROC and range support service improvements.

2.9.5 Post Flight Data:

A sounding rocket mission is not considered complete until all data requirements and post-flight reporting requirements have been satisfied. 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.

2.10 Mission Success/Failure

NASA sounding rockets have maintained a historical success rate of 87 percent. 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 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.

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 anomalies, failures, and systemic problems are investigated, resolved, and fully documented with corrective action being identified and implemented in a timely manner. NASA reserves the right to observe and/or participate in contractor-staffed anomaly and failure investigations and to conduct independent investigations.

2.10.1 Anomaly Investigation Board (AIB):

An AIB 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 an AIB. The team 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.

2.10.2 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 provide 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 in-flight anomalies. In-flight anomalies that lead to a mission failure are always considered major occurrences that require formal investigation. For major anomalies (generally those which, should they recur, have the potential to jeopardize the success of future missions), an Anomaly Investigation Board is appointed.

2.10.3 AIB Action Item/Recommendation Implementation Team:

This Team consists of experienced individuals from each major technical support area. Its primary responsibilities are:

- Review of each recommendation made by the AIB
- Assessment of each recommendation with respect to applicability to the problem and overall programmatic impact.
- Determination as to whether or not the action items and/or recommendations of the Anomaly Investigation Board are implemented.

All mission failures are input into the GSFC non-conformance reporting system; corrective actions are implemented, as required. AIB reports are routinely provided to the customer of the associated mission and to NASA Headquarters.

2.11 The Mission Close-Out Report

This report fully documents the flight's success or failure and officially closes out the process.

SECTION 3: Sounding Rocket Launch Vehicles and Performance Capabilities

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.

3.1 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 3.1-1 lists the specific vehicle numbering system as well as the agency and experiment type. Table 3.1-1 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 thirteen vehicles and their NASA vehicle numbers are presented in Figure 3.2-1.

3.2.1 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 3.2.1-1. 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.

Table 3.1-1.
Sounding Rocket Vehicle, Agency, and Experiment Identification

NASA Vehicle Numbers		Type of Organization Sponsoring Mission	
(12)	Special /Development Test Vehicles	A	Government Agency other than D or N
(15)	Super Arcas	C	Industrial Corporation
(21)	Black Brant V	D	Department of Defense
(27)	Nike Black Brant	G	Goddard Space Flight Center
(29)	Terrier-Malemute	I	International
(30)	Orion	N	Other NASA Centers
(31)	Nike-Orion	U	College or University
(33)	Taurus Orion		
(35)	Black Brant X	**Type of Experiment**	
(36)	Black Brant IX (Terrier Black Brant VC)	E	Geospace Sciences
(37)	Viper Dart	G	UV/Optical Astrophysics
(39)	Black Brant XI	H	High Energy Astrophysics
(40)	Black Brant XII	L	Solar System Exploration
(41)	Terrier Orion	M	Microgravity Research
(42)	Terrier Lynx	O…	Student Outreach
		P	Special Projects
		S	Solar and Heliospheric Sciences
		T	Test and Support

Example of Mission Number: 33.035UE

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

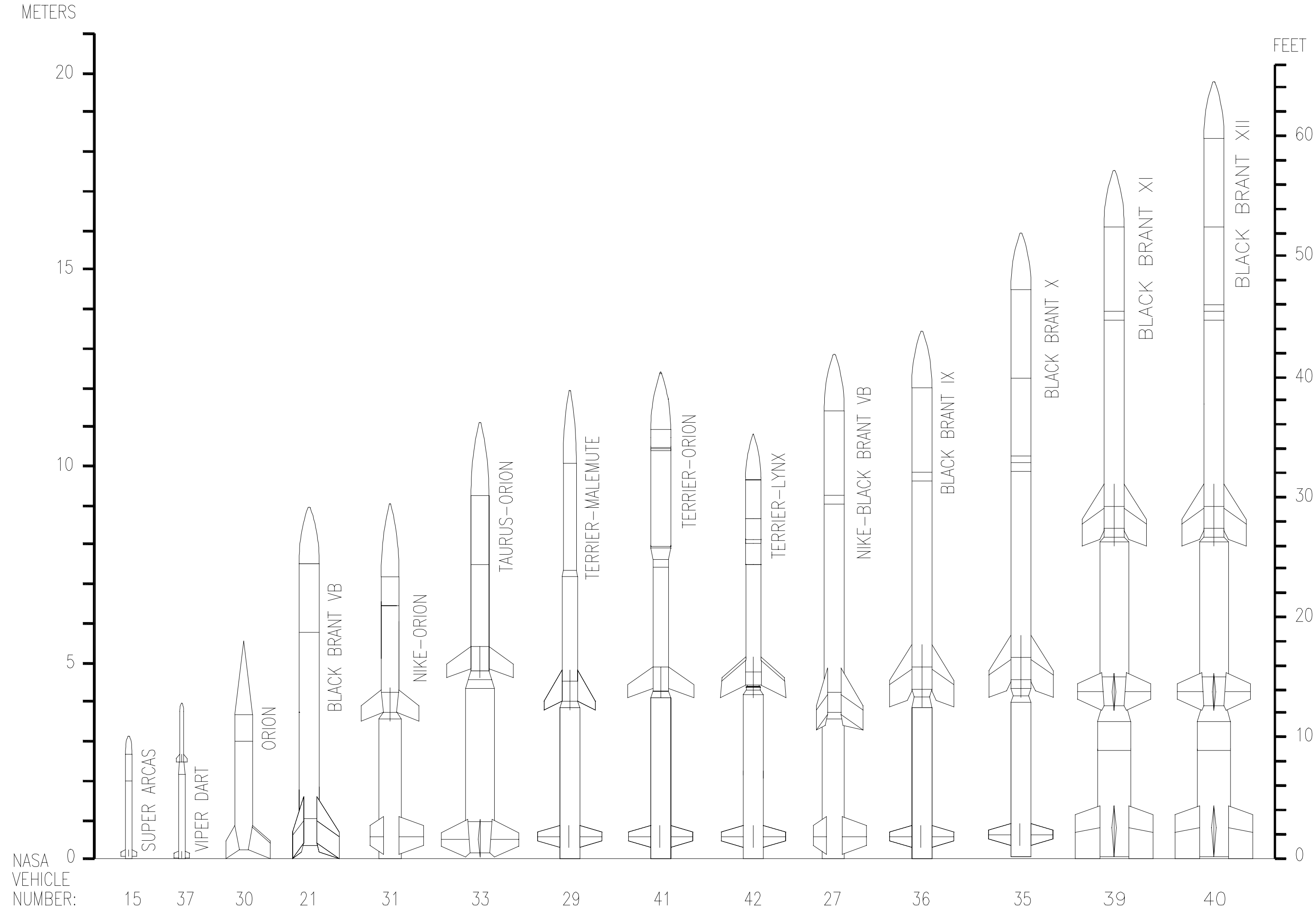


Figure 3.2-1 NASA Sounding Rocket Launch Vehicles

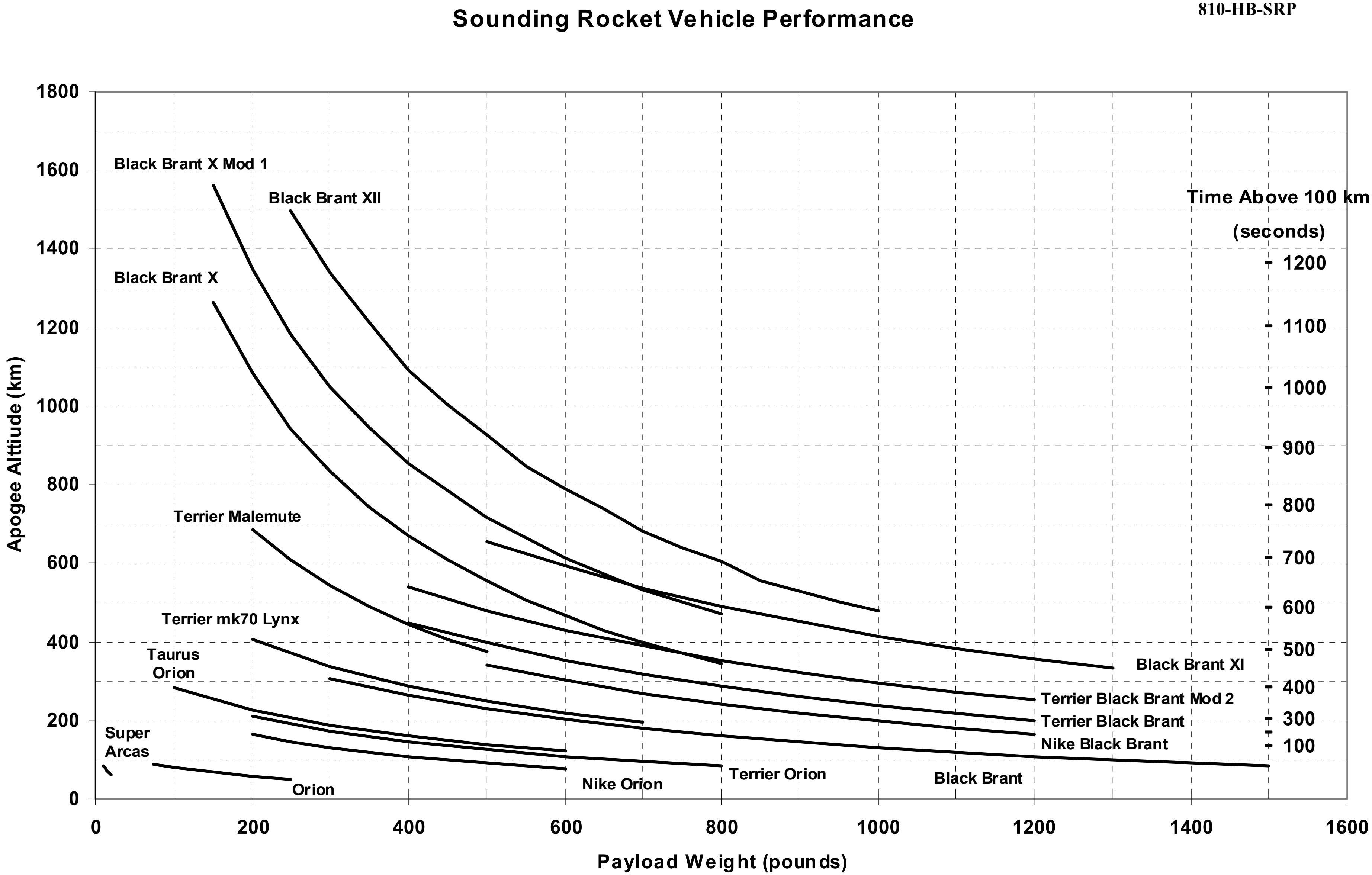


Figure 3.2.1.1 NASA Sounding Rocket Vehicle Performance

3.3 Boost Guidance Systems (BGS)

The Boost Guidance System is designed to reduce impact dispersion and to acquire accurate trajectories; the system is applicable to several sounding rockets. BGS unique capabilities make it 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.

Two Boost Guidance Systems are supported. Both the S-19 and DS-19 systems were developed by SAAB Ericsson Space. With the first flight of the DS-19 occurring in 1999. The DS-19 provides significantly better performance. Costs of both systems may be very comparable. Vehicle/payload configuration and BGS external interfaces are the major contributors to cost differences. These factors, as well as performance requirements, are considered at the time of BGS selection. Table 3.3.1 describes the Boost Guidance Systems currently used by NSROC.

Table 3.3.1 NSROC Boost Guidance Systems

	S-19 Boost Guidance System	DS-19 Boost Guidance System
Guidance Scheme	Guides to a specific attitude specified by the launch rail QE and AZ Canards decouple at t + 18 seconds.	Guides to a preprogrammed IIP and continually updates throughout the burn phase Canards decouple at t + 45 seconds
Dispersion Specifics	Impact dispersion (3s theoretical) Down Range = 7.5% of apogee Cross Range = 7.5% of apogee	Impact dispersion (3S theoretical) Down Range = 2% of apogee Cross Range = 1.2% of apogee
Onboard Sensor	MIDAS roll stabilized gyro platform (position gyros)	DMARS Inertial Measurement Unit (rate gyros, accels)

3.3.1 Operation of the S-19 Boost Guidance System

The S-19 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 in pairs 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. Figures 3.3.1-1a and 3.3.1-1b are photos of the S-l9 Boost Guidance System. Figure 3.3.1-1b on the following page is a photo of the DS-19 Boost Guidance System.

Figure 3.3.1-1a: S-19 Boost Guidance System

Figure 3.3.1-1b: S-19 Boost Guidance System

Figure 3.3.1-2 DS-19 Boost Guidance System

Section 4: Sounding Rocket Payload Design Considerations

The sounding rocket payload must achieve the scientific objectives of the customer while functioning within the mechanical, electrical and environmental parameters of a sounding rocket. Consequently, the Principal Investigator (PI) and his support staff must work closely with the NSROC mission team to ensure that all mechanical and electrical design elements are fully integrated and proper interfaces between all payload subsystems established.

4.1 Payload Design

Sounding rocket payloads are designed to accommodate extremely diverse scientific objectives. As a result, individual payloads vary greatly in design characteristics and requirements. However, most payloads generally consist 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
- Boost Guidance Systems

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 a variety of 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 <u>before</u> a new design is undertaken with its inherent burdens of design qualification testing, debugging, and possible modifications.

4.2 Flight Performance

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.

4.2.1 Mechanical Loads and Vibration

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 are major design condsiderations. 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 and the Viper Dart vehicles spin 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 caused by mechanical loads are very infrequent.

Another major flight environment factor is the vibration induced by rocket motor burning 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. 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.

4.2.2 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 while flying through the air mass; 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 (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; design personnel at WFF have accumulated significant historical data through experience and actual measurements of the thermal environment encountered during sounding rocket flights. If a particular component is sensitive to elevated temperatures, it may have to be insulated or isolated from heat sources.

4.2.3 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 most common undesirable effects of vacuum are reduced heat transmission and corona; both 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, 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.

4.2.4 Aerodynamic Design Factors

A design that involves any protuberance 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. Flight worthiness 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

Other factors which influence successful design practice include:

4.3.1 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.

4.3.2 Availability of Parts

If required parts are not "in stock," procurement delays may impact timely completion of the experiment. <u>Never</u> base a design on a part listed in a stock catalog or stock list; <u>always</u> ensure the parts you require are available. Long lead-time items and sufficient spares should be identified and ordered early in the design processes. Avoid designs based on parts that are inaccessible or parts with very limited replacement options.

4.3.3 Dynamic Balance

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

4.3.4 Cost

The cost of each item should be examined (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.

4.3.5 Redundancy

Redundancy is most desirable; although it is not usually as easy to attain in mechanical equipment as in electrical circuitry, 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.

4.3.6 Weight

Depending on the capability of the vehicle and altitude requirements, weight may be a very serious problem. 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 F.

4.3.7 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

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 is an example of a complex payload system undergoing final checkout. Designed for a GSFC Space and Plasma Physics experiment, this payload features an attitude control system, boom mounted sensors which deploy during flight, a recovery system, and data transmission features. Payload system capabilities are extremely important to the success of the overall mission.

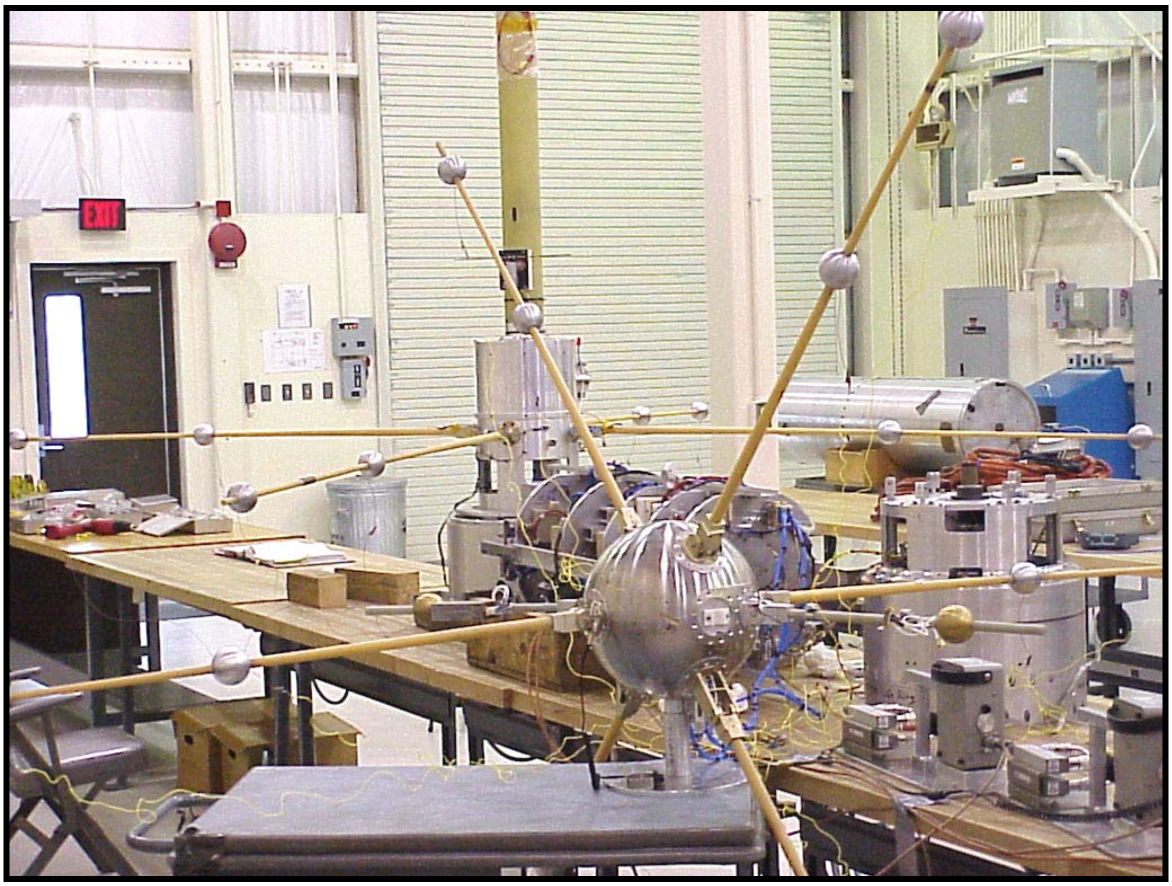


Figure 5-1. Pfaff Payload 21.126 with Booms Extended

5.1 Telemetry Systems

Telemetry is the primary means of obtaining data from sounding rockets. The instrumentation system provided to the Principal Investigator (PI) depends 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.

5.1.1 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 the wide frequency response data 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 5.1.1-1 shows a typical PCM encoder flown on sounding rockets. Note: Since the advent of the WFF 93 PCM system, very few FM/FM data systems are now flown. Occasionally a hybrid data system is flown; in this case, a single VCO output signal is mixed with PCM data to modulate a single downlink transmitter.

5.1.2 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. Table 5.1.2-1 compares the characteristics of these three systems. Additional descriptive and technical details are included in Appendix G.

Table 5.1.2-1: PCM System Characteristics

	Bit Rate	Word Length	Frame Size	Parity	Output Code	Frame/Subframe
WFF93	78kb to 10 Mb	8 - 10	Up to 4k words	None	BIOL, 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	BIOL, M, S NRX-L, MS	2 to 32

5.1.3 SPARCS (WFF87) Encoder System

The SPARCS system encoder, the WFF 87, is being replaced with the WFF 93 system. Appendix F has technical details of the WFF 93, seen below.

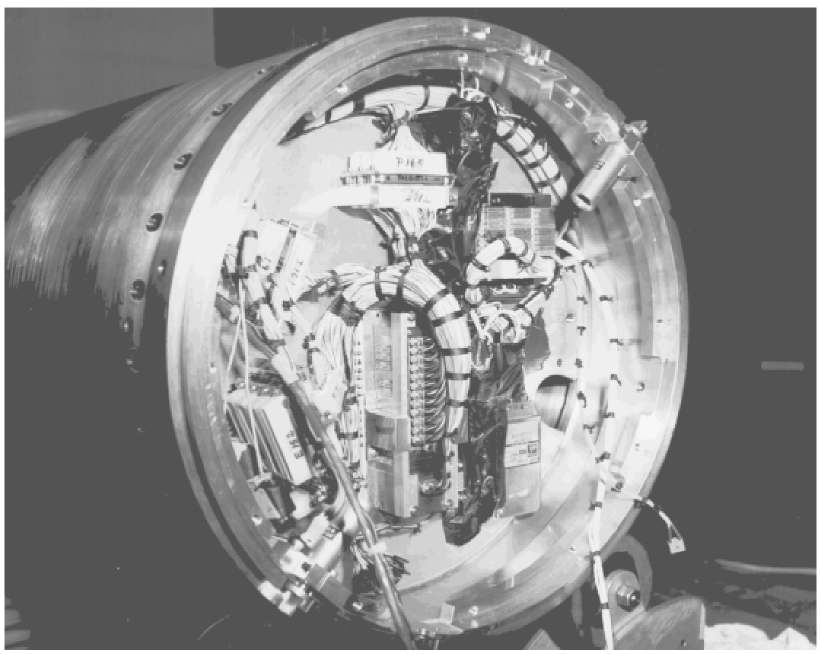


Figure 5.1.1-1. Typical WFF-93 PCM Encoder

5.1.4 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 G.

5.1.5 PCM vs. FM

The question of whether to use an analog or a digital transmission system arises when data must be transmitted from one point to another. In some cases the choice is clear, 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, (less than 1 percent error), a PCM is usually chosen.

A PCM also had advantages (chiefly, size and weight), when large numbers of channels are involved. 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.

5.2 Attitude Instrumentation Systems

Several types of attitude sensors are used to provide payload attitude information. Used either singly or in combination, they employ a variety of techniques:

5.2.1 Magnetometer

Depending upon the scientific requirement, two axis and three axis magnetometers are used. The magnetometers used are flux gate devices with a ±600 milligauss or 60,000 Gamma sensing range, providing an accuracy of approximately 3 or 4 percent when calibrated inside the payload. Magnetometers sense payload attitude relative to the earth's magnetic field and unless aligned perfectly with the field results in attitude knowledge of relative angular displacement from the local magnetic field line. This data, along with data from a solar/lunar or horizon sensor, is used to construct absolute payload attitude. For applications where accuracy is a prime consideration, extreme care must be exercised in the placement of the unit to avoid stray magnetic fields generated within the payload, and high static fields exhibited by magnetized ferrous material.

5.2.2 Attitude Gyroscope

The MIDAS, a gyroscope based, inertially-referenced attitude sensor is available for experiments requiring coarse 3-axis payload attitude information (1-3 degrees in all axes). Manufactured and refurbished by Space Vector Corporation, the MIDAS 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 stabilizes 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 5.2.2-1.

Figure 5.2.2-1. MIDAS Attitude Sensor

5.2.3 Solar/Lunar Sensors

The solar/lunar sensor 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 distance between the slits change which results in a change in time between the two pulses. The ratio of the times measured between the two subsequent pulses and the time for an entire payload revolution determines the payload solar/lunar aspect angle. Used in conjunction with a time event module in a PCM system, the solar/lunar sensor provides an accurate and easily reduced data set which, used in conjunction with magnetometer data, can provide absolute attitude information.

5.2.4 Horizon Sensor

Horizon sensors, which operate in the 15 micron region (Infra-Red), consist of a focusing lens, a filter, a thermal detector and associated electronics. The sensor is pointed to view out from the circumference of a spinning rocket and detects transitions of the horizon (sky to earth or earth to sky). This information, combined with data from a magnetometer, provides a source of payload attitude information.

5.2.5 Television Cameras

Television cameras featuring low power consumption, compact size, and very high sensitivity are available for sensing star backgrounds, in-flight events such as payload ejection's, and rocket motor performance. 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. Cameras used on Sounding Rocket payloads operate from a 12-volt D.C. supply and require less than 10 watts of power. Volume is typically 75 cubic inches or less for most TV cameras used and weight is less than 30 ounces. The output from these cameras is transmitted using a wide band TV transmitter.

5.2.6 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).

5.2.7 Rate Sensor

The Humphrey Rate Sensor is an example of the many rate sensors flown on several missions for relative attitude information after being ejected from the main payload body. Within a three inch cube, three single axis sensors are configured into a mutually orthogonal array which sense angular motion. Imagine each sensor being an axis of a three axis co-ordinate system (X, Y, Z).

As with most of our linear sensors, they are rate sensing devices. However, it can be safely assumed that anything measured along the sensing axis is equal to a vector component of that axis. The total vector then becomes a Pythagorean calculation (i.e. Square Root of Sum of the

Squares). Once the total vector magnitude is known, a simple trigonometry calculation can be made to calculate the off-axis angle of the phenomena being measured. A physical survey of the sensor's position in the payload establishes a frame of reference. The deck plates on which all the equipment is mounted are usually in the roll plane of the vehicle.

This device pumps a fluid using a solid state quartz crystal pump. The fluid is used to cool a hot film resistive wire which is part of a bridge circuit that is trying to remain at constant temperature. As angular moments (motion) is applied to various axis's of the payload (and, therefore the sensor), the flow of the fluid is deflected from its steady state path. The hot film element begins to warm up. The sensing outputs of the bridge circuit couple back to a driving circuit to reduce power to the bridge circuit to drop the temperature back down. The overall process is roughly linear and proportional to the amount of deflection or motion.

5.3 Transmitters

A variety of data transmitters are employed with a range of power from 500 milliwatt to 10 watt units. The transmitters are true FM units which are generally AC coupled. Transmitters used on a given project are sized to provide the necessary link margin while at the same time minimizing power requirements. Medium band transmitters have frequency responses up to 1.5 MHz and can be deviated +l MHz and can be used to transmit PCM data rates up to approximately 1.5 M bits per second.

For wide band data such as high frequency Baseband, high rate PCM, or television transmission, Wideband transmitters are used. Several different units are available that have output power of 2 to10 watts, frequency response of 6 MHz to 20 MHz, and can be deviated up to ±12 MHz.

5.4 Command Systems

Several different command systems are available; selection depends 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 568 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. System command rates vary from several seconds per command to several commands per second.

5.5 Telemetry Antennas

Several types of antennas can be used; selection is determined by 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 2, 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 pattern that is basically omni-directional, with nulls at the very center of the nose and tail of the vehicle.

For command purposes, the most commonly used antenna type is the quadraloop and consists of four individual 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 have recently been replaced with circular cavity backed helix antennas. 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-strips, and rectangular micro-strips have been designed for unique applications in both the data acquisition and command areas.

5.6 Instrumentation and Experiment Power Supply

The electrical power for instrumentation and experiment electronics on sounding rockets is derived from batteries. The selection of the battery system 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. Both battery systems have a very successful flight history and are equal in reliability. However, the nickel cadmium system is normally the preferred and most cost-effective system. Appendix G lists comparison and performance characteristics for various battery systems.

5.6.1 Silver Zinc Cells

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

- 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.

- 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

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.

5.6.2 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. Advantages of the nickel cadmium battery system are:

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

5.6.3 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.

> **Note:** The PI should provide circuit protection to assure that other flight circuits are not affected by short circuits occurring in the experiment payload equipment.

5.6.4 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.

5.6.5 Switching

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

5.6.6 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.

5.7 In-Flight Event Timing Systems

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

5.7.1 Mechanical Timers

Mechanical timers consist of three basic components:

- "G" weight actuator
- A spring wound timing mechanism
- 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.

5.7.2 Electromechanical Timers

These timers have been replaced with the electronic multi-function timers (MFT's).

5.7.3 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:

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

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

5.7.4 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 requires that the switches be placed in a location on the payload where they will not be adversely affected by aerodynamic air pressures

5.8 Tracking Systems

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

5.8.1 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 (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:

- To provide full trajectory tracking when the radars do not have skin tracking capability through the full trajectory
- To provide discrimination between vehicles which are in flight at the same time by means of frequency and/or coding
- To provide a higher probability of obtaining tracking data right off the launch pad
- To provide higher precision data than is available from skin track due to higher signal to nose ration and a point source target.

5.8.2 Global Positioning System (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 22, 17.26, and 14 inch diameters. Time, position and velocity data, and timing signals are multiplexed and transmitted with the payload 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. Received payload GPS data can be reformatted to provide a slaving source for accurate pointing of tracking RADAR's and telemetry tracking antennas.

Future missions may be able to take advantage of the accurate GPS position knowledge for in-flight determination of instrument on/off or deployment control. Altitude critical data collection or deployment systems can be controlled to accuracies of several hundred meters with GPS.

5.8.3 Magnetic Calibration Facility

The Magnetic Test Facility (MTF) was developed to support the magnetic testing capabilities for NASA at Wallops Island. The MTF consists of the computer, control software, power supplies, racks, computer desk, analog instrumentation chassis, reference magnetometer and relay box.

The coil system consists of a 30 foot "Square Braumbec" design to provide the facility with a 7 foot diameter homogeneous field.

The MTF software is designed to interactively operate the three axis magnetic coil system. The software provides the operator with the ability to control the magnetic coil system either manually or through standardized automated tests. Automated test modes include Zero Bias, Linearity, Cosine Law response, Axis Displacement, and Rotating Field. Other unique tests can be performed if required.

Three channels of analog data, typically corresponding to sensor X, Y, and Z outputs, can be digitized to 14 bit resolution and are sampled, averaged, and stored in computer files for each applied field. The stored data sets are text files which can be imported into spreadsheet software for easy data anaylsis. Payload RF data can also be sent to F-10 for data recording and display.

5.9 Mechanical Systems and Mechanisms

5.9.1 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.

5.9.2 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.

5.9.3 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.

5.9.4 Deployment Mechanisms

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

5.9.5 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.

5.9.6 Miscellaneous Hardware

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

5.9.7 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 I.

5.10 Recovery Systems

The primary use of recovery systems is to recover the payload so it can be refurbished and flown again; or to recover payloads to obtain scientific data (exposed film or atmospheric samples). Land and Water Payload recovery are used in conjunction with sounding rocket missions.

5.10.1 Land

Four different parachutes are used for land recovery, their principal characteristics are listed below in Table 5.10.1-1.

Table 5.10.1-1 Characteristics of Land Recovery Parachutes

Type	Maximum Weight (Pounds)
24 Foot Flat Circular	325
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

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.

5.10.2 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 (US Coast Guard or commercial source) or by helicopter. Larger payloads must have floatation built into the payload.

5.10.3 Recovery Aids

Recovery aids assist in the location of the payload to facilitate recovery. Commonly used recovery aids are:

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

5.11 High Altitude Decelerators

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. 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 in Table 5.11-1 which shows minimum dynamic pressure "Q" and maximum weight.

Table 5.11-1 Characteristics of High Altitude Decelerator Systems

	"Q" (PSF)	MAXIMUM WEIGHT
1.6 Foot Disc Gap Band (DGB)	0.0018	16 Pounds
28 Foot DGB	0.004	50 Pounds
48 Foot DGB	0.007	83 Pounds
63.5 Foot Cross	0.0072	170 Pounds

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.

5.12 Attitude Control Systems

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 to thirteen minutes) 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.

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 five flight-proven pointing systems for a variety of applications:

- Mark VI (Celestial Pointing)
- Magnetic ACS
- Inertial ACS
- SPARCS (Solar Pointing)
- Rate Control System.

A rate control system is available for applications requiring very low angular rates (microgravity research). Table 5.12-1 shows the principal characteristics of the systems. The systems are described in more detail in Appendix I and, for SPARCS, in Section 6.

Table 5.12-1 Attitude Control/Stabilization System Capabilities

Mark VI* (Position/TRIG's	±2-5 Arcmin Non-Trackable Target On-Board Micro-Processor Drift Rate—10 Arcsec/Min
Magnetic—Referenced (3-Axis Magnetometer)	Spinning Payloads Only (0.5-2.0 CPS) System Will Align to Within 1-2° and Has Spin Rate Control Capability
Space Vector (Position Gyros	±3° Inertial Accuracy ± 0.5° Track on Sun (Tracker) Drift Rate—5 Arcmin/Min
NSROC SPARCS* (Solar Trackers/Mag)	Solar Pointing Only High Accuracy (±30 Arcsec on Sun Center) Drift Rate—2 Arcsec/Min
Rate Control System (3-Axis Rate Gyro)	Maintains Low Rate (No Attitude) (0.2 °/Sec or Less – 3 Axes) (10^{-4} to 10^{-5} G's)
*Real-Time Ground Command Capability (±1-2 Arcsec)	

SECTION 6: The Solar Pointing Attitude Rocket Control System (SPARCS)

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 rocket 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.

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. SPARCS is a very reliable system and has been flown on over 160 missions with a success rate of over 93 percent.

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

- Solar Pointing Attitude Rocket Control System
- Airborne Instrumentation (telemetry) System
- Up-Link Command Airborne Electronics
- SPARCS Command System (SCS)
- Payload Integration and Test and Evaluation (T&E) facilities
- Principal Investigator and program support facilities
- Launch support.

6.1 SPARCS Attitude Control System and Command Up-link

The SPARCS control system is a highly accurate, low jitter, solar pointing system. In conjunction with the command up-link, it is capable of pointing within arc seconds of a target on the sun. The SPARCS uses Coarse Sun Sensors 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. In recent years, the new and improved digital SPARCS VII has replaced the successful analog SPARCS VI.

6.1.1 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. 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.

6.1.2 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.

6.1.3 Size/Weight

SPARCS VII has two versions, the 70X series and the 76X series both 17.26" in diameter. The 70X includes two sections, a 6" electronic section and a 15" pneumatic section (length could vary depending on control gas requirement). The 76X is 8.313" long section that includes both electronic and pneumatic system (sometimes an auxiliary tank is flown in another section). The 70X weight is 95.7 Lbs. without gas and the 76X weight is 56.4 Lbs without gas.

6.1.4 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 duration of the closures is controlled by software from momentary to latching. The commands are sent by push button operation on the SPARCS Command System (SCS) Ground Unit. It can also provide 3-axis offset commands, 2048 steps in pitch and yaw, to produce from 2 to 5 arc-seconds step. Roll can be commanded to any angle in 0.1° steps (dependent upon the ETA (h) angle, the angle between the solar vector and the earth's magnetic vector)

6.1.5 SPARCS Command Systems (SCS)

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 6.1.5-1 lists SPARCS system specifications.

Table 6.1.5-1: 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.
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
Roll:: Rig (Rate Integrating Gyro) Specs	.3 degrees/hour maximum

6.2 Instrumentation (Telemetry)

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.

6.3 The WSMR Payload Integration Facilities

The WSMR payload integration facilities have capabilities for payload and component vibration, dynamic balance, moment of inertia, center of gravity measurements, bend test, and magnetic calibration. These include:

6.3.1 The Vibration Facility

The Vibration Facility is in the Vehicle Assembly Building (VAB) at LC35 with practically no height limitations for sounding rocket payloads. Table 6.3.1-1 on the following page shows the capabilities of the Vibration Facility.

6.3.2 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.

Table 6.3.1-1
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

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

6.3.3 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

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

Within 0.005 inches in Pitch, Yaw & Roll

6.3.5 Bend Test

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

6.3.6 Vacuum Systems

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

6.3.7 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.

6.3.8 Dark Room

The Dark Room includes a rotary light seal, an enlarger, print washer, temperature-controlled water, and pressurized and filtered air to minimize potential dust problems.

6.3.9 Facility (N-200) Cleanliness

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

- High bay measured equivalent to a CLASS 10,000 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 10,000 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.

6.3.10 Targeting

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

6.3.11 Optics Capabilities:

- 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: Environmental Testing Policies

This section summarizes the Environmental Testing policies for NSROC. The content is largely an excerpt of the *NSROC Environmental Testing Manual* which can be read or downloaded from the NSROC Information Management Support System (IMSS), Engineering/Technical Documents link.

7.1 General Requirements

All tests, whether conducted on components or entire payloads, must be initiated by a Test Request. The individual responsible for the test must fill out a Test Request Form (available from NSROC Engineering) and submit it to the Testing and Evaluation Group.

7.1.1 Qualification Testing

New component designs are required to undergo design qualification testing. These tests expose items to environments that are more severe than those experienced throughout the mission. This ensures that the design is sound and that there is high confidence that failure will not occur during a mission. Components that undergo qualification testing are not used for actual flight.

7.1.2 Acceptance Testing

Previously qualified components and all fully assembled payloads (new or re-fly) must undergo acceptance testing, which exposes test items to the environments that mimic those experienced during a mission[1]. These tests are the final gauge for determining the launch worthiness of a component or payload.

7.1.3 Principal Investigator Testing

Principal Investigators are encouraged to test their components to standards similar to those included in this document prior to delivery to the integration site. If this is not possible, the NSROC facilities described hereafter can be utilized. It is recommended that Principal Investigators report to the Mission Manager any environmental testing completed prior to delivery. This information is required if the Principal Investigator requests a waiver for a test normally conducted by NSROC.

7.1.4 Test Plan

The Mechanical Engineer is responsible for developing a test plan for a particular payload and its related components. This entails 1) determining exactly which tests are required; 2) scheduling a time frame for testing with the Environmental Testing and Evaluation Group; and 3) generating test requests for each test. Some additional tests may be done by Telemetry Engineering or Power Engineering.

7.2 Testing Equipment and Capabilities

NSROC has two principal testing facilities. The main one is located at the NASA Wallops Flight Facility (WFF) in Wallops Island, VA, and the other is at White Sands Missile Range (WSMR) in White Sands, NM. Both facilities have the testing equipment necessary to perform the following functions:

- Mass properties measurements
- Static/dynamic balancing
- Vibration tests
- Bend tests
- Thermal and vacuum tests

In addition to these, WFF is also equipped with a spin deployment chamber and a centrifuge machine at the Main Base. A magnetic test facility and a second spin balance facilities are located on Wallops Island near the launch range.

7.2.1 Mass Properties Measurement Systems (WFF and WSMR)

The Environmental Testing and Evaluation Group at WFF is equipped with an Airdyne Mark 8 mass properties measurement system (Figure 7.2.1-1). This unit is used for measuring center of gravity (CG) locations and moments of inertia (MOI) on sounding rocket subsystems and payload stacks. Important technical data include:

- Maximum test article weight = 5,000 lb.
- Maximum CG height above the table = 120 in.
- CG and MOI measurement accuracy = 0.1%

The Mark 8 can also be used for static and dynamic balancing of sounding rocket payloads and/or subsystems that will not fit on the Gisholt machine discussed below. For example, it would be used on payloads that need to be balanced with booms deployed.

The NSROC facility at WSMR is equipped with an MRC model MKVII-12 mass properties measurement system. It has the following properties.

- Maximum test article weight = 2,500 lb.

- Maximum CG height above the table = 242 in.
- CG and MOI measurement accuracy = 0.1%

It is also used to perform all static and dynamic balancing of sounding rocket payloads at WSMR.

Figure 7.2.1-1 Airdyne Mark 8 Mass Properties Measurement System at WFF

7.2.2 Static and Dynamic Balancing Machine (WFF)

A Gisholt Rocket Balancing Machine is used to balance sounding rocket payloads at WFF (Figure 7.2.2-1). This machine's specifications are listed below.

- Max. payload weight = 1500 lb.
- Max. height of CG above table = 10 ft.
- Measurement accuracy = 2.0 oz. – in.^{2} at 225 rpm or more

Figure 7.2.2-1 Gisholt Rocket Balancing Machine at WFF

7.2.3 Shakers (WFF and WSMR)

There are four Ling Electronics shakers used for component and payload vibration tests at WFF (Figure 7.2.3-1) and two at WSMR. The following table summarizes some technical information on the shakers.

Table 7.2.3-1 NSROC Shaker Specifications

Shaker	B340	B335 (x2) WFF	B395 WFF	B335 (x2) WSMR
Rated Force Sine (lb.)	30,000	18,000	6,000	20,000
Rated Force Random (lb. rms)	30,000	18,000	5,750	16,000
Frequency Range (Hz)	5-2,000	5-3,000	5-3,000	5-3,000
Maximum Displacement Peak-Peak (in.)	1.0	1.0	1.0	1.0

The B340 can be rotated to mate with a TEAM Corp. model 482 sliding table so that it can be used for both thrust axis and lateral vibration tests. This table has the following specifications.

- Total travel = 2.5 in.
- Max. pitch moment capacity = 1,200 lb.-in.

One of the B335 units at WFF is connected to a TEAM Corp. model 1830 sliding table while the other is kept in the thrust axis position. This arrangement facilitates performing three-axis vibration tests in a timely manner, without having to rotate the shaker. Both B335 shakers at WSMR are also equipped with the TEAM 1830 table, which has the following specifications.

- Total travel = 1.5 in.
- Max. pitch moment capacity = 3,000 lb.-in.

The B395 is a smaller shaker mostly used for component level tests at WFF. Both the WFF and WSMR test facilities are equipped with 11 in. cube fixtures so that tests can be performed on small components in all three axes by mounting the test article in different orientations.

At the engineer's or Principal Investigator's request, sensors can be mounted on any part of the payload to monitor its response. WFF has 16 channel reliability and WSMR has 8 channel reliability

Figure 7.2.3-1 Ling Electronics B335 Thrust Axis Shaker at WFF

7.2.4 Vacuum Chambers (WFF and WSMR)

WFF has three sealed chambers capable of evacuating to approximately 10^{-6} torr. Two of these chambers are mainly used for performing corona checks on subsystems that utilize high voltage components (PV/T, Tenney Space Jr.). The third can be used as a thermal-vacuum chamber and as an ultra-clean environment for testing sensitive optics and other components that require contaminant-free surroundings (Tenney Space Simulation System). The table below summarizes technical data on these chambers. Chambers appear in Figure 7.2.4-1.

Table 7.2.4-1 WFF Vacuum and Thermal Vacuum Chamber Specifications

Manufacturer	PV/T Inc.	Tenney Space Simulation System	Tenney Space Jr.
Inside Dimensions (ft. dia. x ft. lg.)	7x12	2x2	1.2x1.0
Minimum Pressure (torr)	2×10^{-5}	3×10^{-8}	7.5×10^{-8}
Temperature Range (^{o}C)	N/A Heat lamps used if needed	-73 to +125	N/A
Pump Type	Diffusion	Cryogenic	Diffusion
Clean Environment?	No	Yes	No

The PV/T Chamber is also equipped with a mass spectrometer for outgassing analysis. In addition, WFF is equipped with several leak detectors and portable vacuum systems. Specifications for this equipment is available upon request.

Figure 7.2.4-1 PV/T Vacuum Chamber (left) and Tenney Space Simulation System Thermal Vacuum Chamber at WFF

WSMR has two sealed chambers capable of evacuating to approximately 10^{-6} torr. These chambers are also used for performing corona checks on subsystems that utilize high voltage components. Normally used with duel Welch 1397 oil sealed mechanical forepumps, fittings also allow the use of Cryo-trap equipped Turbo pumps. Other uses have been Nozzle flow separation tests into a vacuum. The table below summarizes technical data on these chambers. WSMR is capable of supporting the varied experimenter needs found in the field environment through unique system configurations, adapters and pumping setups.

Table 7.2.4-2 WSMR Vacuum and Thermal Vacuum Chamber Specifications

Manufacturer	NRL	PSL	Notes
Inside Dimensions (in.dia.x in.lg.)	20x36	31x51	Aluminum
Minimum Pressure (torr)	1×10^{-6}	1×10^{-6}	
Temperature Range (^{o}C)	N/A	N/A	
Pump Type	Turbo Model #3133C	Turbo Model #3133C	With Welch 1397 forepumps
Clean Environment?	Yes	Yes	With cold traps (LN2)

7.2.5 Bend Test Fixtures (WFF and WSMR)

Every sounding rocket payload is subjected to a bend test in order to determine the overall stiffness of the body. This information is used by the Flight Analysis Group to verify payload stability during flight. The bend test fixtures at WFF and WSMR consist of a base plate mounted to the concrete floor and a pneumatic (WFF) or motor driven (WSMR) linear actuator mounted to a steel I-beam pillar. The pistons are equipped with load cells, which are used to measure and control the applied load. The aft end of the payload is fastened to a base plate, and the actuator's position along the pillar can be adjusted to the proper height on the payload being tested. Land surveying equipment is used to accurately measure the tip deflection of the payload as the actuator applies lateral loads in both directions. Technical data for the systems is listed below.

Table 7.2.5-1 NSROC Bend Test Fixture Specifications

Facility	Maximum Load (actuator or load cell)	Maximum Actuator Height .	Accuracy of Deflection Readings
WFF	+/- 5,000 pounds	21 feet	0.05 inches
WSMR	+/- 1,150 poounds.	21 feet	0.05 I nches

Figure 7.2.5-1 Bend Test Fixture at WFF

7.2.6 Spin Deployment and Separation Equipment (WFF)

Payloads with deployable booms, nose cones, doors, etc. can be tested for proper operation using the spin deployment and separation chamber at WFF. The rotary table is capable of spinning a payload to a rate of 20 rps while withstanding an imbalance of up to 3000 ft-lb. 5 ft. above the table surface. The chamber is equipped with a heavy-duty Kevlar® tarp around the rotary table for catching deployed components. Also, there are video cameras mounted on the chamber walls for recording and timing the deployment events. Pyrotechnic release devices can be activated by connecting lead wires through a 20 channel slip ring that allows the table to rotate while maintaining electrical continuity.

Figure 7.2.6-1: Spin Deployment Chamber at WFF

The WFF test facility is also equipped with a portable spin table that is used for special deployment tests. These include inverted deployments, during which the spin table is suspended from the high bay bridge crane, and horizontal deployments.

7.2.7 Centrifuge Machine (WFF)

A Genisco Model 1068-2 centrifuge machine is used for component acceleration tests at WFF. It is capable of achieving up to 1000 g acceleration at a radius of 10.5 in. It has 8" of clearance between the 3' diameter rotary table and the cover.

Figure 7.2.7-1 Genisco Centrifuge Machine at WFF

7.2.8 Magnetic Test Facility (WFF)

This facility is used to conduct magnetic calibration of magnetometers on sounding rocket payloads and to perform functional tests on magnetic attitude control systems. When 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. Magnetometer testing can be performed at either GSFC/Wallops or, if necessary, at GSFC/Greenbelt. The testing equipment consists of a three axis, 30 ft. square Braunbek system which is capable of canceling the effects of the earth's magnetic field and then generating a test field in any direction. Technical data are listed below[5].

- Resolution = 10 nanotesla
- Field magnitude = 0 to 80,000 gamma.

The Magnetic Test Facility (MTF) was developed to support the magnetic testing capabilities for NASA at Wallops Island. The MTF consists of the computer, control software, power supplies, racks, computer desk, analog instrumentation chassis, reference magnetometer and relay box.

The coil system consists of a 30 foot "Square Braumbec" design to provide the facility with a 7 foot diameter homogeneous field.

The MTF software is designed to interactively operate the three axis magnetic coil system. The software provides the operator with the ability to control the magnetic coil system either manually or through standardized automated tests. Automated test modes include Zero Bias, Linearity, Cosine Law response, Axis Displacement, and Rotating Field. Other unique tests can be performed if required.

Three channels of analog data, typically corresponding to sensor X, Y, and Z outputs, can be digitized to 14 bit resolution and are sampled, averaged, and stored in computer files for each applied field. The stored data sets are text files which can be imported into spreadsheet software for easy data anaylsis. Payload RF data can also be sent to F-10 for data recording and display.

7.2.9 Spin Balance Facility (WFF, Wallops Island)

Although not directly under the responsibility of NSROC, this facility can be utilized if the need arises. There are two large Trebel Balancers in separate buildings (V-45, V-50), 800 ft. apart, which are controlled from a third building located between them (V-45). There are also three Gisholt Balacers (in V-45), which are similar to the one described in Section 7.2.2. The facility is also equipped with a vibration analyzer, which is used to detect and measure mechanical vibrations during balancing. Consult Tables 7.2.8-1 nd 7.2.8-2 for details about the equipment and control capabilities at the facility.

Table 7.2.8-1: Instrumentation Availiable at the Magnetic Test Facility

Item	Function	Specifications	Model
Proton Magnetometer	Calibration	Range: 20K-120K Gamma	GEM
		Resolution: 0.01 Gamma	System
		Accuracy: 0.2 Gamma	GSM-19
Triaxial Fluxgate	Test	Range: ±100K Gamma	EMDS
Magnetometer	Instrumentation	Resolution: 3 Gamma	SDM-313
		Orthogonality: 25 Arcmin	
Payload Magnetometer	Test	Range: ±100K Gamma	Bartington
	Instrumentation	Resolution: 3 Gamma	Mag-03MRN
		Orthogonality: 1 Degree	
Rotary Encoder	Alignment	Resolution: 20 Arcsec	BEI Corp.
Theodolites	Alignment	Resolution: 20 Arcsec	Dicarlo Theo020B
RF Horn Antenna	Data Receiving	Freq. Range: 1-18 GHz	Emco
		Gain: 7 dB	Model 3115
RF to Fiber-Optic	Data Conversion	Freq. Range: .1-5 GHz	Ortel
Transmitter		Watts: 6.4 mW	3450A-20

Table 7.2.8-2: Magnetic Test Facility Specifications

Physical Dimensions:	
Access Opening	8'8" H x 7'5" W
Static Field Environment:	
Magnitude (each axis)	±120K Gamma
Step Resolution	±3.7 Gamma
Stability	±10 Gamma/minute for first 5 minutes
	±3 Gamma/minute after 5 minutes
Homogeneity	0.02%, 7ft spherical diameter
Dynamic Field Environment:	
Magnitude	+60K Gamma
Frequency	10 Hz, Although 10 Hz to 100 Hz @ 1K Gamma has been performed
Turntable	4' Diameter
Coil Orthogonality	1.8 Arcmin, Calibrated on 9/27/96
Fields	Earth, 0-15 Volts DC, 0-25 Amps
	Test, (3-Axis) 50 Volts AC, ±8 Amps
	Gradient, 15 Volts DC, 6 Amps

7.3 Payload Testing

All payloads are required to undergo the following tests in order to be considered flight worthy:

- Static and dynamic balance
- Vibration (sine and/or random)
- Bending
- Mass properties measurement.

The results of these tests are presented at the Mission Readiness Review (MRR). Details of each type of test are discussed below.

7.3.1 Static and Dynamic Balance

The Mechanical Engineer must first determine which payload configuration(s) must be balanced (or measured for imbalance) in order to ensure mission success. The Mechanical Engineer must also provide the Test Technician(s) with the stations of the upper and lower balance planes for placement of balance weights. The payload launch configuration must then be measured for Tip Indicator Runout, which is the amount of lateral misalignment of the payload measured at the nose tip. The payload shall then be balanced such that the criteria in Table 7.3.1-1 are met. It is important to ensure that dynamic balancing is not performed at a spin rate equal to the payload's first natural frequency. This is done to avoid pitch-roll coupling, which can damage both the payload and the balancing equipment.

Table 7.3.1-1 Static and Dynamic Balance Specifications

Tip Indicator Runout (in.)	Static Imbalance (oz.-in.)	Dynamic Imbalance (oz.-in.^{2})
<0.25	<300	<20,000

These limits can be surpassed if the payload team, specifically the Performance Engineer, the Mechanical Engineer, and the Mission Manager agree that the vehicle can still be launched successfully. When applicable, the Mechanical Engineer must design the flight weights that act to transfer the effect of the test weights internally

7.3.2 Dynamic Spin Balance

The Performance and Analysis Engineer must calculate the maximum expected bending moment at the aft end of the payload (payload to motor interface) and predicted tip deflection under this load. The Performance and Analysis Engineer must then supply the Mechanical

Engineer with the lateral load necessary to achieve 125% of the bending moment or 50% of the rated capacity of the joints; whichever is greater. This load shall be applied near the forward end of the payload, usually at the first major joint.

It is important to bend the payload about more than one lateral axis, especially if the payload has multiple doors and/or large doors. After the tests are complete, the Mechanical Engineer must provide the Performance and Analysis Engineer with the maximum tip deflection of the payload during each bend test. These data will be used in the flight profile analysis and will be presented at the MRR.

Bend tests shall also be used to measure the compliance of non-standard joints or joints that have been modified significantly.

7.3.3 Mass Properties

Every payload must undergo mass properties measurements in both the launch and the control configurations and any other configurations that are critical during the mission; e.g. re-entry, booms in, booms deployed, etc. The following properties will be measured.

- Weight
- Center of Gravity
- Roll Moment of Inertia
- Pitch Moment of Inertia

The Mechanical Engineer must determine the angular orientation of the payload for the pitch MOI measurement in order to obtain the best representation of this value for the Guidance, Navigation and Control Group.

7.3.4 Vibration

The launch configuration of every payload must complete vibration testing in order to be considered acceptable for launch. Before any full level tests are conducted in each axis, a ½-g Sine Survey must be performed in order to determine payload natural frequencies. This information can be used to limit vibration input and protect payloads and testing equipment from excessive loads. The Mechanical Engineer must determine which vibration tests are required according to the flow charts in Figures 7.3.4-1 and 7.3.4-2. It is the responsibility of the Mechanical Engineer to provide the Environmental Testing Group with the vibration test levels for a particular payload according to Table 7.3.4-1. It is important to heed the footnote below Table 7.3.4-1 concerning payload bending during lateral vibration.

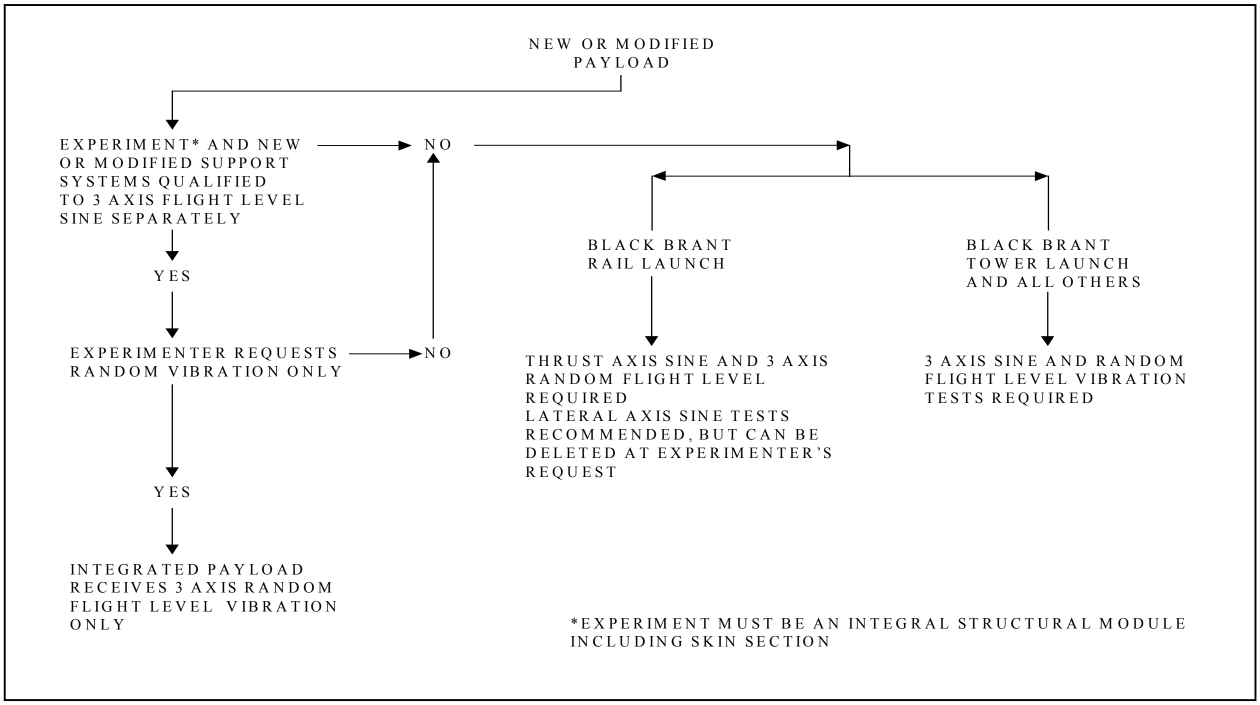


Figure 7.3.4-1 New or Modified Payload Vibration Testing Flow Chart

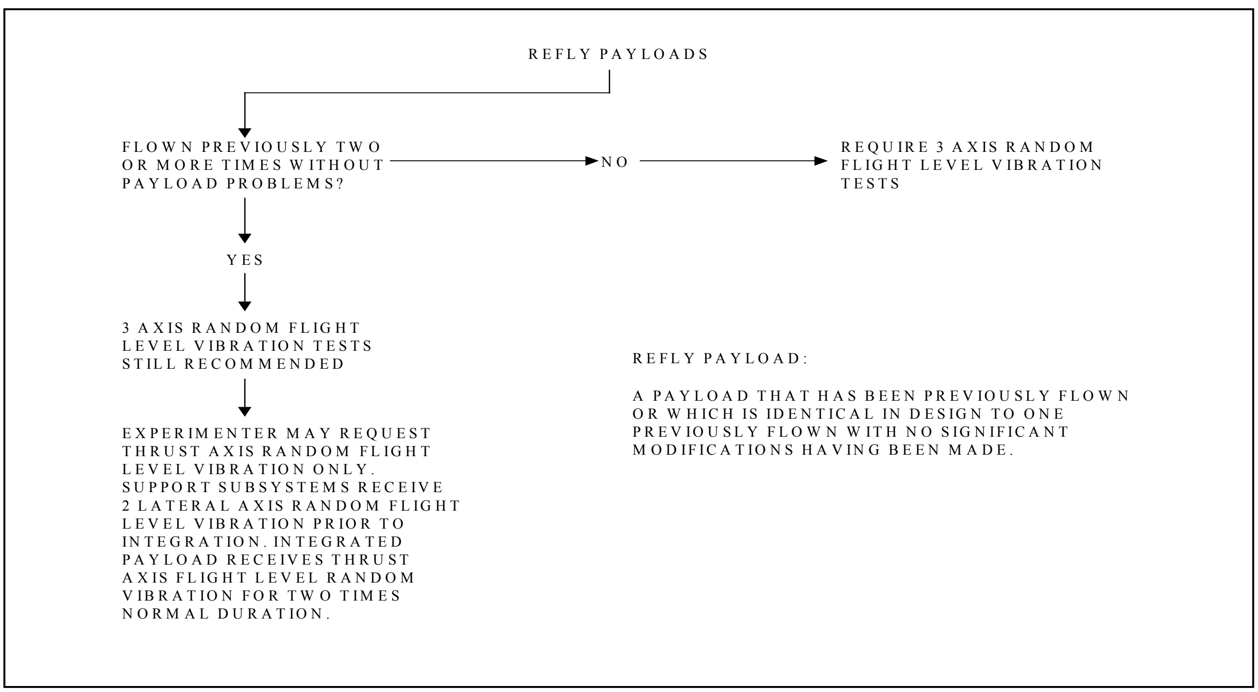


Figure 7.3.4-2 Refly Payload Vibration Testing Flow Chart

Table 7.3.4-1 Vibration Test Levels for New Payload Designs

	VEHICLE LEVEL ONE	VEHICLE LEVEL TWO	SINGLE STAGE ORION
SINE	Sweep Rate: 4 oct./min. Thrust Axis Profile: 3.0 in./s 10-144 Hz 7.0 g 144-2000Hz Lateral Axis Profile: 3.0 in./s 10-35 Hz 7.0 g 35-105 Hz 5.0 g 105-2000 Hz	Sweep Rate: 4 oct./min. Test Profile: 3.84 in./s 5-24 Hz 1.53 g 24-110 Hz 3.50 g 110-800 Hz 10.0 g 800-2000 Hz **SAME IN ALL AXES**	Sweep Rate: 4 oct./min. Test Profile: 4.87 in./s 10-50 Hz 4.0 g 50-2000 Hz **SAME IN ALL AXES**
RANDOM	Duration: 20 sec./axis Thrust Axis Spectrum: 10.0 grms 0.051 g^2/Hz 20-2000 Hz Lateral Axis Spectrum: 7.60 grms 0.029 g^2/Hz 20-2000 Hz	Duration: 10 sec./axis Spectrum: 12.7 grms 0.01 g^2/Hz 20 Hz 0.10 g^2/Hz 1000 Hz (on 1.8 db/oct. slope) 0.10 g^2/Hz 1000-2000 Hz SAME IN ALL AXES	Duration 20 sec./axis Spectrum: 6.0 grms 0.018 g^2/Hz 20-2000 Hz SAME IN ALL AXES
TEST INFO	**LEVEL 1** **VEHICLES** Nike-Orion Taurus-Orion Terrier-Orion Terrier-Malemute	**LEVEL 2** **VEHICLES** Black Brant V Black Brant VIII Black Brant IX Black Brant X Black Brant XI Black Brant XII	**LIMITED BENDING** **MOMENT** (in.-lb.) Orion 100,000 Malemute 200,000 Black Brant 300,000 Limit Model 1830 TEAM table to a max. of 240,000 in.-lb. overturn moment.

Note: Input to payload during lateral sinusoidal vibration must be limited during first bending mode via dual control accelerometer at CG of the payload. This is done to avoid exceeding the maximum bending moment at the base of the payload.

7.3.5 Waivers

In the event that a Principal Investigator wishes to exclude or modify one or more of the above payload tests, he or she must submit a request in writing to the Mission Manager. Another member of the mission team may submit the request on the Principal Investigator's behalf. The request shall include an explanation for the exclusion or modification and any other pertinent details. All requests must be reviewed and approved by the Mechanical Engineer, the Mission Manager, and by the NSROC Chief Engineer.

7.3.6 Test Times

The following guide may be used for estimating the time required for each test[3].

- Balance (check, balance and re-check) 1 – 3 days
- Vibration ½ - 1 day
- Bend Test ½ - 1 day
- Mass Properties ½ - 1½ days

7.4 Component Testing

A sounding rocket component is any self-contained functional unit comprised of two or more mechanical and/or electrical parts. This includes, but is not limited to, transmitters, batteries, receivers, gyroscopes, etc.[1,2]

In general, components that are new designs and/or that have never been launched before are required to undergo testing. The following is a list of typical tests that are conducted on sounding rocket components.

- Thermal Cycling
- Vacuum and Thermal Vacuum
- Vibration and Shock
- Acceleration
- Deployment and Separation
- Magnetic Calibration

SECTION 8: NASA/GSFC/WFF Safety Policy and Responsibilities

This Section provides an overview of GSFC/WFF safety policies, and associated organizational responsibilities, operational procedures, and flight and ground safety rules. Safety is a major consideration in all successful sounding rocket missions - from planning, design and engineering through launch, data recovery and mission close-out. Safety requirements draw upon the unique and exhaustive experience of the Goddard Space Flight Center's Wallops Flight Facility. As an experimental lab under the National Advisory Committee for Aeronautics, it's later role as a research flight facility, and in its current role as a GSFC facility, Wallops has 55 years of experience in sounding rocket operations, design, and technology.

The policies, procedures and references in this Section apply to all mission activities conducted and managed by GSFC/WFF and to all NASA employees, NSROC (NASA Sounding Rocket Operations Contract), contractor personnel, Principal Investigators (PI), and support personnel. Missions conducted at other launch ranges (such as WSMR) will comply with local range requirements, including requirements that are more restrictive; however, policies and procedures described and referenced in this Section will be considered the minimum requirements for all personnel. PIs should discuss safety considerations with their designated Sounding Rocket MM and consult references for detailed design, engineering, operational and procedural guidance.

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

NASA/GSFC/WFF and NSROC publications provide detailed safety policies to raise awareness of existing or potential hazards and provide appropriate control techniques:

- *Range Safety Manual* (RSM-2002) *for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF), dated 28 June 2002*. This manual can be accessed online at http://www.wff.nasa.gov/~code803/
- NASA Safety Standards such as NSS 1740.12 for Explosive Safety and NASA-STD-8719.9 for Lifting Devices Safety.
- NASA East/West Range Safety Requirements of EWR 127.
- NSROC Safety and Health Plan, NSROC Quality and Safety document, QS PUB 00001.

8.1 Safety Policy

Safety plays an integral role in NASA's quest to expand frontiers in aeronautics and space. As we move into the 21st century, we have designated safety and health as our highest priority. We will not compromise the safety and health of our people and property nor harm the environment. We are working to achieve zero mishaps in the NASA workplace, keeping in mind that every employee's safety and health, both on and off the job, is our concern.

The NASA Agency Safety Initiative (ASI) is aimed at strengthening NASA's capabilities so that safety permeates every aspect of NASA work. By fully implementing this initiative and incorporating safety and health principles and practices into NSROC’s daily decision making process, we will maintain our position of leadership in maintaining the safety and occupational health of our work force and the safety of the products and services we provide.

The ASI establishes the NASA safety hierarchy -the order we used to prioritize our safety efforts. The safety hierarchy is:

- **Safety for the public**; we absolutely must protect the public from harm.
- **Safety for astronauts and pilots**; they expose themselves to risk in high hazard flight regimes
- **Safety for employees**; we owe it to our employees to provide them with a safe and healthful workplace.
- **Safety for high value equipment**; we are stewards of the public's trust.

By focusing on the safety of NASA's mission and operations, we will improve quality and decrease cost and schedule

GSFC/WFF will conduct all ground and flight operations with a degree of prudence appropriate for highly hazardous operations and in accordance with sound technological principles. To achieve this objective, three cardinal principles apply:

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

- 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 in a Risk Analysis Report (See Section 8.4 below), with a recommendation for approval or disapproval, to the Director of Suborbital and Special Orbital Projects Directorate, Code, Code 800.

Again, safety is THE priority for sounding rocket operations. It is inherent in all policies and procedures and an integral part of the GSFC/WFF Quality Assurance and ISO 9001 programs. Responsibility for any given mission is shared by all parties involved.

8.2. The Range Safety Organization

The Director of GSFC is responsible for safety at WFF. The Director of SSOPD, who represents 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 of SSOPD (Code 803) 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.

8.2.1 Safety Responsibilities of the Mission Manager (MM)

The Mission Manager is the primary safety planning point of contact for Principal Investigators. The MM 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:

- Flight Requirements Plan
- Nominal flight trajectory data
- Dispersion data
- Vehicle physical characteristics
- Rocket motor information
- Vehicle structural limitations
- Aerodynamic data
- Wind compensation methods
- Aeroelastic and flight loads analysis
- All hazards associated with the launch operation.

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 reviews 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.

8.2.2 Safety Responsibilities of the Principal Investigator (PI)

It is the Principal Investigator's responsibility to become fully acquainted with the safety policies and criteria set forth in the *Range Safety Manual for GSFC/WFF* (RSM-2002) as well as the other safety materials cited in the introduction to this Section.

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

PIs will provide data to the MM, either through conferences or formal documentation, for safety review. The data will include information on payload systems, descriptions, and requirements of the project operations. PIs must also submit requests for any waivers from prescribed procedures before arriving at the GSFC/WFF. Appendix J details the data required in formal documentation. Appendix J is extracted from the Range Safety Manual for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF) RSM-2002, dated 28 June 2002.

In the event of a mishap, a NASA Mishap Report, Form 1627, will be initiated and forwarded to the WFF Safety Office, Code 803. The Safety Manager or the Operations Safety Supervisor 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 for any investigation and reports required through the MM.

PIs 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

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 J 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.

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

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

8.4 Flight Safety Plan

The flight safety goal of GSFC/WFF is to preclude an impact which might endanger human life, cause damage to property, or result in embarrassment to NASA or the U. S. Government. While some degree of risk exists for every mission, each flight must be carefully planned to minimize that risk while maximizing the probability of attaining mission objectives.

Prepared by the Safety Office prior to any launch operation conducted at GSFC/WFF, the Flight Safety 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 NASA/WFF and NSROC engineering, operations, and safety personnel. Details on flight safety criteria are found in the *Range Safety Manual for Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF)* RSM-2002, dated June 28, 2002.

PIs are expected to determine their minimum requirements for launch and any requirements that 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.

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

8.4.1. 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 landmass, sea, or airspace does not produce a casualty expectancy greater than 10^{-6}. Additionally, an impact probability on private property which might cause damage greater than 10^{-3} (in the case of Poker Flats Research Range (PFRR), must have a Safety Analysis Report (See Subsection 8.5, below) prepared and approved. It must be proven that any of the following conditions will result:

- The re-entering vehicle will be completely consumed by aerodynamic heating.
- The momentum of solid pieces of the re-entering vehicles (such as balloons or parachutes) will be low enough to preclude injury or damage.
- Formal government or private agreements allow the use of the landmass for impact or re-entry.

8.4.2 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:

- The vehicle is in orbit.
- The probability of a land impact and resultant CE due to an overflight failure does not violate established criteria.
- Formal government or private agreements are established which allow the overflight.
- It is approved in a Safety Analysis Report.

8.4.3 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. Inherent safety is 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.

8.4.4 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.

8.4.5 Flight Planning Criteria:

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

8.4.6 Range Clearance Criteria for GSFC/WFF Launch Range:

GSFC/WFF coordinates flight operations with the Federal Aviation Administration (FAA), the US. 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.

8.4.7 Operational Procedures:

Criteria are specified for vehicles with and without flight termination provisions and include wind weighting, shipping, launch limitations, and pre-launch checks.

8.5 Safety Analysis Report

When directed by GSFC/WFF, Safety Analysis Reports are prepared to document safety risks in reference to baseline safety requirements and criteria. These reports include a summary of hard hazard analysis and state the risks that may be incurred by a sounding rocket operation. Safety Analysis Reports are also used to obtain GSFC/WFF approvals of waiver requests for exemptions from safety requirements. A typical Safety Analysis Report includes:

- Introduction and project description
- Safety criteria
- Hazard specifications, preventive measures, and risk assessment for:
    - Ground safety
    - Flight safety
    - Environmental hazards
- Details of all safety procedures

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

SECTION 9: Launch Operations

Since its inception in the late 1950's, the NASA Sounding Rocket Program has conducted launch activities throughout the free world. 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 conducted at a number of United States and foreign locations. These facilities vary from very comprehensive launch and payload preparation, launch, recovery, and data collection sites like WFF and WSMR to more austere sites equipped with mobile systems that are tailored to a specific campaign. Although each range has some unique requirements, some commonality exists across all ranges. This Section highlights some of the procedures generally common to all fixed and mobile ranges.

9.1 Launch Ranges

Figure 9.1-1 identifies the locations of many US and foreign ranges used for NASA sounding rocket flight operations. Mobile facilities deployed from WFF can augment the established facilities at any range, as needed. Details regarding the sounding rocket program support facilities, range operations, logistics, and visitor information at WFF are in Section 11. Other frequently used fixed ranges are listed below and detailed in Appendix J:

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

> **Note:** 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).

Table 9-1: NASA Sounding Rocket Launch Locations

*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)
* Currently Used Sites	

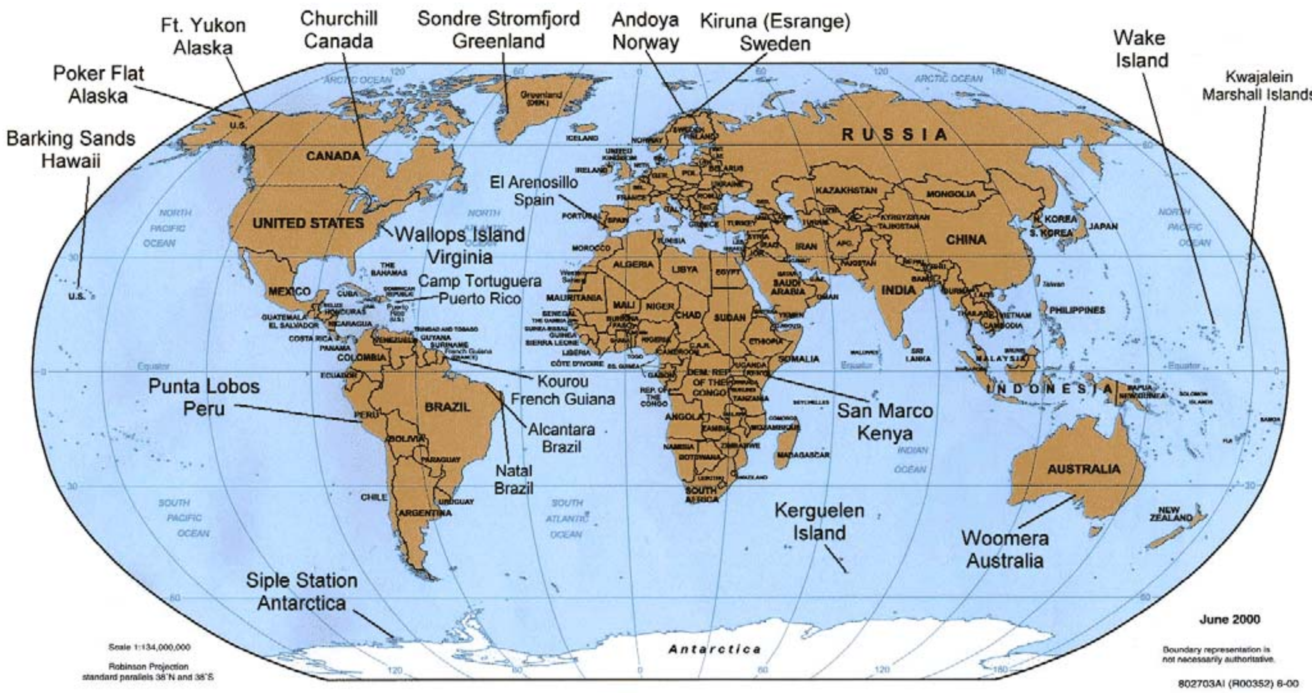


Figure 9.1-1. Sounding Rocket Launch Sites

9.2 Launch Operations

As always, safety is the priority for NASA operations. Each range has unique safety considerations and all members of the mission team must be familiar with local procedures and the governing protocols that regulate operations. Be alert to signs and signals. Medical facilities may be minimal; and an accident may end the participation in a campaign.

9.2.1 Rules To Remember

Rules applicable to most ranges include:

- Range Clearance: Range clearance requests must get to the range well before team and equipment arrival; the MM coordinates clearance requests for all mission team members. Always hand-carry a copy of the request to the range.
- Foreign Nationals: Arrangements for clearance are made with the Mission Manager 60 days before arriving at a range. Paragraph 11.3 outlines the information to be provided to the Mission Manager.
- 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.

- Alcoholic beverages: Some ranges have designated eating areas where alcoholic beverages are permitted; on all other range property, consumption of alcoholic beverages is usually forbidden.
- Photography: Some ranges have very rigid restrictions on photography by other than designated personnel, but rules vary from range to range. It is best to discuss your photography requirements with the Mission Manager and appropriate range personnel so that arrangements can be made to meet your requirements.

9.2.2 Role of the Mission Manager

The launch site is a place where fluctuation is almost inevitable and flexibility is a constant requirement. The Mission Team is focused on operations; the PI's Team is focused on science requirements and everyone is adjusting to the safety and operational rules governing the location. Communications across all areas is of paramount importance and the Mission Manager must be the primary point of contact for those communications. Questions about re-scheduling, range boundaries and buffer zones, flight termination, and transportation should be fielded through him; and the location of everyone participating in the launch should be known to him at all times. He should be constantly apprised of changes made, or delays and problems encountered. The Mission Manager will make sure that unresolved issues are addressed, procedures strictly adhered to, and the overall success of the mission ensured.

9.2.3 The Flight Requirements Plan

The NSROC MM prepares the *Flight Requirements Plan* (FRP) or operations directive (discussed in Section 2). The plan is sent to the range several weeks before the PI arrives at the range. The FRP includes data on the rocket and the experiment, and lists all of the supporting activities that the range must provide for launch and recovery operations. Based on the FRP, the range coordinates its functions. For operations at mobile ranges, the Campaign Manager includes the same information in the *Operations Document*.

9.2.4 Test and Evaluation

Most launch ranges do not have test and evaluation facilities. Therefore, it is imperative that T&E be completed prior to shipment of the experiment and support equipment to the range. Typically payloads are integrated at WFF.

9.2.5 The Field Schedule

Prepared by the Mission Manager and approved by NSROC, the field schedule lists every major operation. Any change to the Field Schedule should be made through the Mission Manager as promptly as possible.

9.2.6 The Preflight Conference

Shortly after arrival at the range site, the PI and WFF personnel meet with the range personnel in a Preflight Conference. Attendees review the requirements, thoroughly discuss all aspects of range support operations, and coordinate those operations with the PI's activities. Any problems anticipated before or after the launch are resolved or become action items. The PI should present any required changes to the FRP at this Conference.

9.2.7 Recovery

Payload recovery 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.

9.2.8 Post-Flight Conference

Before leaving the field, a Post-Flight Conference is held to present any compliments or complaints regarding field services to range and NSROC personnel. Suggestions for improved operations may also be presented at this time. Based on the information on hand, brief reports on the success of the flight are presented and any known anomalies are reviewed.

9.3 Foreign Ranges

The use of foreign ranges entails several additional responsibilities and procedures for the PI. Although the scientific and technical procedures are similar to those by U.S. ranges, the use of foreign ranges requires shipping, travel, communications, and housing arrangements which pose additional challenges. For example, special consideration regarding the coordination of data acquisition sites or special communications provisions may be required. The SRPO is experienced in the use of foreign ranges and any special provisions those ranges may require. Ranges at Andøya, Norway, and Esrange, Sweden, discussed in Appendix K.3 and Appendix K.4, provide an idea of the types of facilities available. Figure 9.3-1 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.

Figure 9.3-1. Range Facilities at Woomera, Australia

9.3.1 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.

9.3.2 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.

9.3.3 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.

9.3.4 Foreign Nationals

The host country controls access to foreign ranges by other foreign nationals.

9.3.5 Export Control

It is the Mission Manager's responsibility to ensure that transfers are consistent with NASA Headquarters Program Office policies. Export Control Milestones must be included 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:

- Appropriate safeguards for commodities, technologies, and software exported or transferred pursuant to international agreements.
- Provisions of necessary technical information to the CEA to facilitate sound determinations regarding validated export license requirements, activity-specific documentation, and the submission/completion of such documentation, where necessary;
- Adequate lead time for the submission, processing, and receipt of validated export licenses, where necessary.

9.3.6 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.

9.3.7 Shipping

Shipment of equipment from the U.S. to foreign ranges must be cleared through U. S. Customs as must equipment shipped from foreign countries to the U.S. Clearing Customs can be somewhat difficult and time consuming. Documentation must be correct and must fully describe the shipment; 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

Mobile range operations are conducted worldwide in locations dictated by the scientific experiment requirements. WFF and White Sands Missile Range (WSMR) Launch and Mobile Range Capabilities are included in Tables 9.4-1 and 9.4-2 on the following pages. WFF has the mobile support systems necessary to establish and support sounding rocket campaigns anywhere in the world. A military launch at WSMR is shown in Figure 9.4-1.

Table 9.4-1 WFF Launch Facilities

Launcher Name	Description	Boom Length	Rockets Launched
50 K Launcher	Rated as a 50K-pound maximum design load launcher with a movable environmental shelter	45'	All Sounding Rocket Program vehicles, except the Arcas*
Atlantic Research Corporation (ARC) Launcher	Rated as a 20K-pound maximum design load launcher with a movable environmental shelter.	38'	All Sounding Rocket Program vehicles except the Arcas*.
20 K Launcher	Rated as a 20K-pound maximum design load launcher with a movable environmental shelter.	37'	All Sounding Rocket Program vehicles except the Arcas*.
MRL Launcher	Rated as a 20K-pound maximum design load launcher with a movable environmental shelter.	37’	All Sounding Rocket Program vehicles except the Arcas*.
AML 4K Launcher	Rated as a 4K-pound maximum design load twin boom launcher	20’	Orion class Sounding Rocket Program vehicles
US Navy Vandal Launcher	Currently supports U.S. Navy VANDAL Program and is specifically designed for use by Vandals only.		
*Note: Viper Dart vehicle is launched from specialized rails that may be attached under the above listed launchers. The Arcas has a self-contained launcher assembly			

.

Figure 9.4-1: Military launches are often performed at WSMR

Table 9.4-2 WSMR Launch Facilities

Launcher	Shelter	A/I	Type	Length	Maximum Capacity	Current Capacity	Diameter	Rockets Launched	M
Trainable Tower L455	Yes 80 ft. tall at LC 36	I	4 Fin Tower Rail	160 ft. Flat Giude Rail	15K	15K	14 – 27"	BB, NBB, TSB	No
MRL L630	Yes 75 ft. long Movable at LC 36	A	NASA UH Rail	37 ft. NASA Standard Guide Rail	7.5K	7.5K	14 – 31:	BB, NBB, TBB, TO, NO, TUO	No
ATHENA L-738	Yes 100 ft. long Movable at LC 36	As	NASA UH Rail	48 ft. extrud Alum. Guide Rail	25K	16K	14 – 31"	VV, NBB, TBB, TO, NC, TUO	No
Aries L-536	Yes 50 ft. tall Movable at LC 36	I	Stool	44.4 ft. Clearance	54K		31 – 64":	M56.XM 100/M57	No
Thiokol 4.3K Dual	No at LC 35 & not installed	I	Rail UH	20 ft. NASA Standard	4K	4K	17"	Nike Tomahawk	Yes
Starbird L-763	No	I	NASA UH Rail	42 ft. NASA Standard Guide Rail	50K	16K	14 – 31"	Castor 1/M30	No
Aries L702	Yes 60 ft. tall	I	Stool	44.4 ft.	54K		31-54"	M56/XM 100/M47	No
Navy Movable	Yes Tent	I	NASA Standard UH	40 ft NASA Standard Guide Rail	10K	10K	14-31"		Yes
Standard HAD	No	I	NASA UH Rail	27 ft. NASA Standard Gide Rail	4K	4K	14 – 18"	Talos Terrier/TO	Yes
Nike M39	No	I	Rail Top Load	35 ft. NASA Std/Sandia	14K	14K	14-31"		Yes

A/I: Active/Inactive
Diameter: Diameter of rockets that can be luanched.
Capacity: Launcher capacity in pounds
Launchers that are not active can be activated within 30 – 60 days
Current Capacity: Reflects rail limitation
M: Movable

BB: Single Stage Black Brant
NBB: Nike Black Brant
TBB: Terrier Black Brant
TO: Terrier Orion
NO: Nike Orion
TUO: Taurus Orion

The selection and use of a mobile range entails a high degree of planning, coordination, and cooperation. Figure 9.4-2 shows an operation at the mobile range at Sondre Stromfjord, Greenland. This range and the range at Woomera, Australia (Figure 9.4-3), exemplify 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 9.4-2 Range Support Operations in Sondre Stromfjord, Greenland

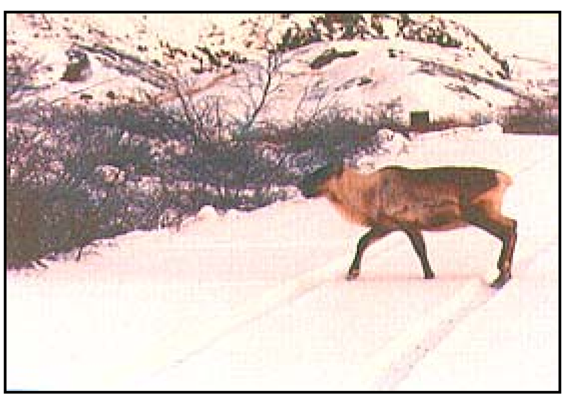


Figure 9.4-2a: Extreme Conditions: Sondre Stromfjord.

Figure 9.4-2b: Observations: Northern Lights at Sondre Stromfjord.

Figure 9.4-3 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.

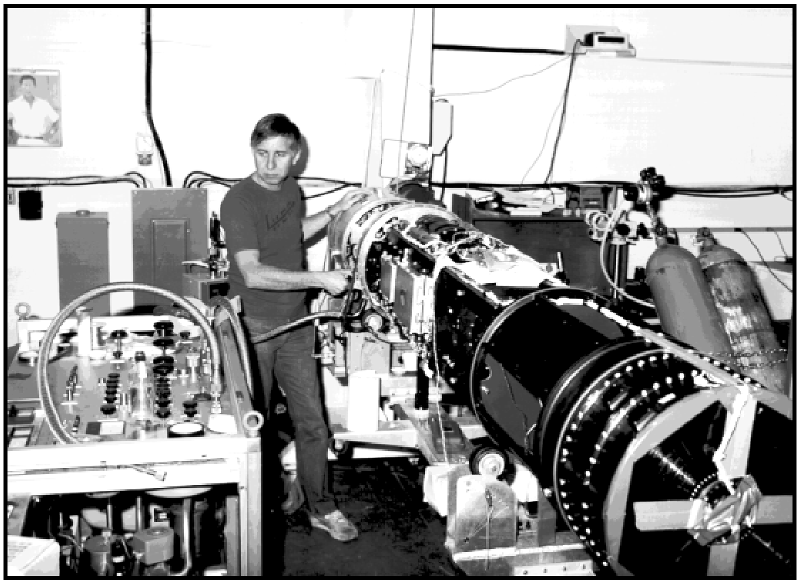


Figure 9.4-3 Black Brant IV Payload in Woomera, Australia

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:

9.4.1 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.

9.4.2 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.

9.4.3 Limited Technical Facilities:

Because ranges frequently have very limited or no technical facilities, systems for 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.

9.4.4 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 at least minimum communications requirements can be met. Campaigns at mobile ranges frequently involve observers in other locations or countries; sparse communications may prohibit optimum communications among all participants in an experiment.

SECTION 10: Data Processing and Analysis

WFF data processing and analysis systems and facilities provide a wide range of support for sounding rocket planning, engineering, operations, data acquisition and analysis. This Section describes those systems and the procedures by which PIs can obtain the support required for individual experiments.

10.1 Computer Systems

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:

10.1.1 Real-Time Computer System (RTCS)

Used primarily as a range safety tool, the RTCS is part of a network of tracking radars and communications supporting control and data display facilities in the Range Control Center. It accurately predicts the impact point of any vehicle launched from WFF and 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. In those instances when the PI requires recovery of experimental equipment, the RTCS directs 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 way that compensates or offsets the impact of any forces acting on it that 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.

10.1.2 Data Reduction Computer System (DRCS)

The primary application of the 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.

10.1.3 Engineering Computer System (ECS)

The ECS directly supports sounding rocket programs. ECS analytical tools and capabilities include:

- Launch Vehicle Physical Properties
- Aerodynamic Characteristics Determination
  - Subsonic, Supersonic, Hypersonic.
  - Linear, Non-linear
  - Launch Vehicles, Re-entry Bodies.
- 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)
- Flight Loads & Structural Analysis
  - Launch Vehicle Vibrational Modes
  - Aeroelastic Effects
  - Vehicle/Payload Mechanical Design
- Thermal Analyses (1,2, & 3-D Nodal Networks)
  - Aeroheating (Ascent and Re-entry)
  - Spacecraft Thermal Studies
  - Shuttle Bay Payload Thermal Analysis

10.1.4 Launch Status Review System (LSRS)

The LSRS, in association 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. Wind profile data may be used as input to various flight simulations for guided vehicles; the output is then used to assess control system behavior and vehicle flight characteristics.

10.1.5 Special Purpose Computers

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

10.1.6 Digital Telemetry Facility

The Digital Telemetry Facility is linked by cable to the telemetry receiving stations and readout stations. This Facility:

- Conditions, synchronizes, and processes vehicle and payload performance serial PCM data
- Digitizes and processes analog FM data
- Formats digital tapes
- Displays selected data or parameters in binary, decimal and engineering units
- Prints data in selected formats or provide data tapes for further reduction by the processing lab or the PI.

10.2 Obtaining Data Processing and Analysis Support

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

10.2.1 Flight Requirements Plan (FRP)

Basic data processing and analysis requirements are provided by the PI in the FRP which was described in Section 2. The FRP 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 defined in advance to assist in planning the workload and manpower requirements. The PI submits the data requirements for the FRP to the MM. Basic information needed for the FRP includes:

- Project identification including the job order number
- Priorities, deadlines, and deliveries
- Special processing needs (such as refraction calibration)
- Location and time of the experiment
- Objectives of the experiment
- General processing requirements (raw versus smoothed data, reference coordinates)
- Data dissemination requirements (hard copy reports, graphics, magnetic tape).

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

10.2.2 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 FRP. The ground station support request forms vary with each launch site and 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.

10.2.3 Non-Standard User Requirements

Should the PI require a technical capability not currently available at WFF, he/she can either provide WFF with the computer programs to do the job, or WFF can develop the capability. If WFF is to develop the capability, the PI should contact the SRDM and outline the requirements.

10.2.4 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.

10.2.5 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 L.

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.

10.2.6 Data Retention

Analog and/or Digital telemetry flight data tapes are retained by CSOC for five years. Telemetry data is currently digitized and stored on CD-ROM in PTP format (Appendix L) and will be retained by the NSROC EE group for five years. 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

Located on the Delmarva Peninsula approximately 80 miles northwest of Norfolk and 40 miles southeast of Salisbury, WFF sprawls over some 6000 acres of prime property on Virginia's scenic Eastern Shore. U.S. Route 13 runs the entire length of the Peninsula and connects with major routes along the Atlantic Coastline from Maine to Florida. WFF is linked with the Norfolk-Hampton Roads area by the Chesapeake Bay Bridge Tunnel.

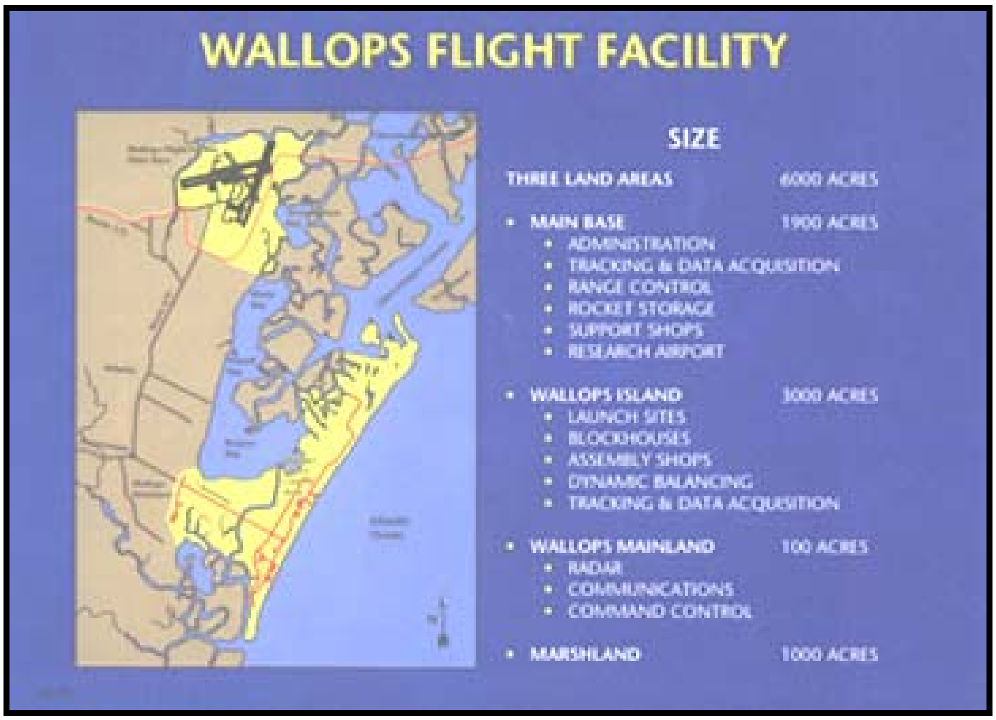


Figure 11-1: Wallops Flight Facility Map

WFF consists of three separate properties: the main base, the Wallops Island Launch Site and the Wallops mainland.

The Main Base (Figure 11-2) houses the management and engineering offices supporting NASA's sounding rocket, balloon and aircraft projects. This includes administrative offices, technical service support shops, rocket inspection and storage areas, an experimental research airport, laboratories, the main telemetry building, the Range Control Center, a large computer complex, and telemetry, radar, and communication facilities. The National Oceanographic and Atmospheric Agency, the U.S. Navy, the U.S. Coast Guard and the Virginia Commonwealth Space Flight Authority have tenant activities at WFF

Figure 11-2. Wallops Main Base

The Wallops Island Launch Site: Named after 17th Century surveyor John Wallop, Wallops is a barrier island (six miles long and one-half mile at its widest point), located two miles off the coast of Virginia, approximately seven miles southeast of the Main Base. A causeway and bridge permit easy access across the two miles of marsh and Intercoastal Waterway that separate it from the mainland.. Launch sites, assembly shops, blockhouses, dynamic balancing facilities, rocket storage buildings, and related facilities are resident on the Island. Training and development of support personnel for the Navy's AEGIS Command is conducted there as well. Figure 11-3 is a photo of Wallops Island looking north.

Figure 11-3. Wallops Island

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 11-4 is a photo of the Wallops Mainland.

Figure 11-4. Wallops Mainland

Geographically, 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.

11.1 WFF Sounding Rocket Program Support Facilities

The primary support functions for the NASA/WFF Sounding Rocket Program include sounding rocket design, fabrication, mechanical testing, telemetry, environmental testing, assembly, launch, tracking, recovery, and acquisition and analysis of scientific information; all have been thoroughly discussed in previous sections of this Handbook. The facilities which house those functions are used by scientists and engineers from the research centers of NASA, foreign and U. S. Government agencies, colleges and universities, and the worldwide scientific community. More specifically, these include:

11.1.1 Engineering Support Facilities

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.

11.1.2 Payload Integration Laboratory

The Payload Integration Laboratory includes facilities for complete (mechanical and electrical) payload build-up and checkout. The laboratory can support the processing of multiple payloads simultaneously and includes telemetry ground stations and clean room facilities. Work areas are available for the PI and staff to perform pre- and post-integration preparation and checks. The telemetry ground station is capable of supporting multiple links for all systems flown. Figure 11.1.2-1 shows a complex plasma physics payload undergoing integration in the Payload Integration Laboratory at WFF; integration of an astrophysics payload is shown in Figure11.1.2-2.

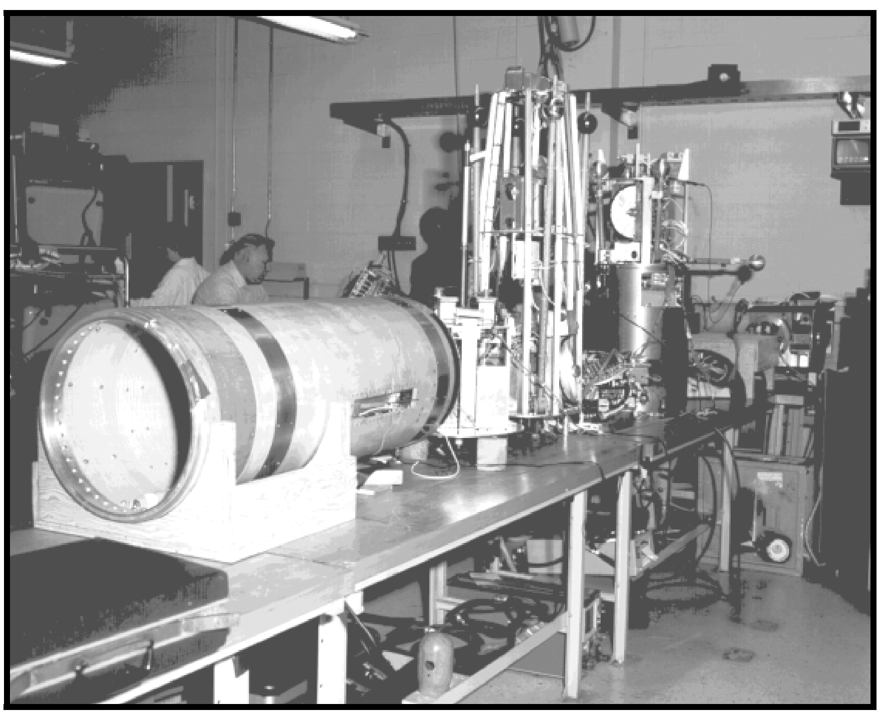


Figure 11.1.2-1 Plasma Physics Payload (36.0l5 UE) During Payload Integration

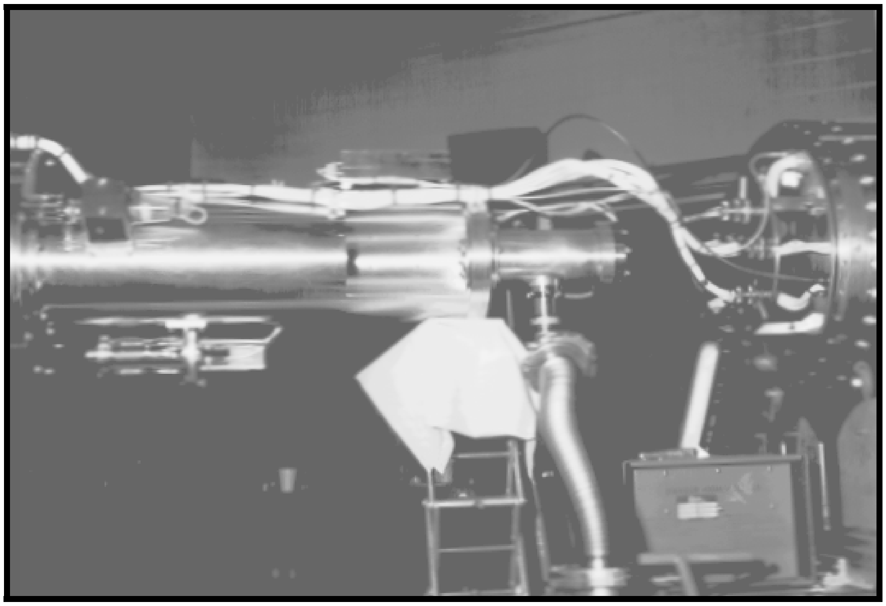


Figure 11.1.2-2. Astrophysics Payload During Payload Integration

11.1.3 Environmental Testing Laboratory

Environmental testing of completed payloads, sub-assemblies and components is accomplished at WFF Environmental Testing Laboratory where flight readiness is verified through exposure to intended flight environments. A detailed discussion of environmental testing policies and considerations is included in Section 7. This laboratory is adjacent to the Payload Integration Laboratory for convenience in payload handling and logistics. Test equipment includes:

- The Static Loads Facility is designed to produce static bending loads on rocket payloads mounted vertically. It 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 3500 pounds of force. Test results provide a measure of the overall structural characteristics of launch vehicles during periods of high aerodynamic loading encountered in launch and to qualify the structural integrity of new payload designs.

- 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.

- 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

- Four Electromagnetic Shakers are 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; 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 11.1.3-1. A discussion of vibration testing policies and specifications is included in Section 7.

Figure 11.1.3-1. Astrophysics Payload (36.022) undergoing Lateral Vibration Testing

- The Thermal 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.

- The Tenney Vacuum Chamber is a 61 cm x 61 cm (24 in x 24 in) Thermal Space Simulation Chamber with the capability of reaching 3×10^{-8} torr at a temperature of –73^o C (-100^o 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^o C (-100^o F) to 125^o C (250^o F). Temperature can be maintained within 1^o 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.

- Tenney Space Jr. Temperature Vacuum Chamber is a 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^o C (-100^o 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.

- The Portable Vacuum 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.

- 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.

- 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.

- The Tenney Jr. Temperature Chamber is capable of reaching a temperature of -73^o (-100^oF) to $+177^o$ C ($+350^o$ F) within $\pm$ 3^o C ($\pm 1/2^o$ 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.

- 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.

- Physical Properties Determination Equipment 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.

- Static and Dynamic 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.

11.1.4 Payload Construction

The WFF Mechanical and Electrical Fabrication Facility (See Figures 11.1.4-1 and 11.1.4-2 on the following page) is fully capable of fabricating sounding rocket payloads and launch vehicle components, including 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.

Figure 11.1.4-1: Wallops Flight Facility Machine Shop – Electrical Section

Figure 11.1.4-2: A Nose Cone is Streamlined in the Machine Shop

11.1.5 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.

11.1.6 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:

- 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. The Ionospheric Sounding Rocket Station provides detailed data on the ionospheric characteristics; the Dobson on the Wallops Mainland provides total ozone measurements; and a lightning detection system tracks lightning conditions over a wide area of the eastern United States.

- 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.

Figure 11.1.6-1: WFF Fixed Radar System

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

- 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.

- 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.

- Aircraft and Airfield 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 830-AOM-0001, *Aircraft Operations Manual* (AOM).

- An extensive network of Command, Control, and Communications Facilities support launch operations. Several facilities support specific aspects of the operation such as radar plots and quick-look data acquisition. The focal point, however, is the Range Control Center on the Main Base which controls launches, range safety, command/destruct functions, timing, and mission countdowns through instantaneous communications with all involved activities. Limited quicklook data acquisition, graphic displays, and video views of launches are available.

- 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. A number of launchers, variable in both elevation and azimuth, which can safely handle multi-stage vehicles are also available. All instrumentation vans are air-conditioned and are provided with communications, local intercom, precision timing, and data displays.

11.2 Working at Wallops – Rules, Regulations, and Logistics

Although the normal WFF workday is 0800 to 1630, Monday through Friday, the facility has a flexible work schedule that permits employees to start as early as 0600 or work as late as 1800. Work at other times must be coordinated with the MM to ensure access to required facilities and the availability of necessary technical personnel. All U.S. Government holidays are observed.

11.2.1 Access

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

11.2.2 Accommodations

Housing, cafeteria, mail and express delivery, and telephone service is available at WFF:

- **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. Many visitors prefer to use local motels and restaurants, available year round on neighboring Chnincoteague Island. The MM will be happy to assist with housing arrangements for either venue.

- **The Main Base Cafeteria** is located in Building E-2. Breakfast (0700 to 0900) and lunch (1100 to 1300) are served. The Williamsburg Room may be reserved for special events including group evening meals.

- **Mail and Delivery Services**: The WFF Post Office is located on Anderson Road, behind the Cafeteria and adjacent to the E-series administrative buildings. Express Delivery Services are provided by United Parcel Service (UPS) and Federal Express daily.

- **Transportation**: Once clearance is approved through the Main Base Receptionist, personal transportation is generally used on the Base. Transportation of sounding rocket components by truck is arranged by the MM. Packing, shipping/receiving and material handling of equipment and components is detailed in Section 11.2.4 below.

- **Telephone**: Collect and Credit Card long distance telephone services are available for non-government personnel through the WFF Operator by dialing "O". Federal Telecommunications System (FTS) service is available to U. S. Government users for official calls only. Access to the system is by dialing "9".

- **Airport**: Chartered and private aircraft, both propeller and jet types, may land for business purposes at the WFF Airport, with prior approval clearance. The nearest commercial airports are in Salisbury, Maryland, (40 miles north) and Norfolk, Virginia, (70 Miles south). Rental cars are available at these locations.

- **Medical:** In addition to the WFF clinic, 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 and the Virginia State Police. Volunteer fire companies are located in the incorporated towns in Accomack County. They are equipped with modern fire trucks, fire fighting equipment, ambulances and state certified volunteer staffs to provide emergency first aid, and rescue and fire fighting services.

- **The NASA/WFF Gift Shop** is located in Building E-2, adjacent to the Cafeteria.

- **The 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.

- Smoking is prohibited in all GSFC buildings.

11.2.3 WFF – Safety Rules and Regulations

Safety restrictions and industrial safety procedures are strictly enforced at WFF. Safety requirements for the design, development and operation of sounding rocket operations are discussed in detail in Section 8 of this Manual; the WFF Safety Manual is available on request or can be downloaded from the WFF website at http://www.wff.nasa.gov. Safety questions should be directed to the MM or specific facility personnel. Facility managers will advise on proper procedures for such things as safety shoes, hard hats, gloves, safety glasses, static dissipative clothing, and masks.

Note: Obey control signals around high- energy emitters such as radar.

Precaution

1

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.

The following address should be used for shipment to WFF; be sure to include the name and code number provided by the MM in Freight Destination Address.

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

Delivery services generally include:

- **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 the delivering carrier's equipment to fly placards, and all shipments tendered as truckload, require RESHIP information in advance of delivery.

  Normal receiving hours: 0800 to 1430 (for truckloads) and 0800 to 1600 (for partial loads), Monday through Friday, excluding holidays.

- **Air Freight Services** 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 MM 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**: Forklifts, overhead hoists, and dollies are available for use at WFF. 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 MM prior to shipment for coordination with US Customs clearance authorities.

11.3 Foreign Nationals

Foreign nationals who need to visit WFF or other launch facilities - particularly White Sands Missile Range - must provide information to the MM regarding their visit(s). The following 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:

- Project identification
- Name in full, rank, title, position
- Other names previously or currently used
- Nationality
- Previous or current dual nationalities
- Date/place of birth
- Purpose of visit and justification
- Special qualifications of visitor
- Present and prospective address in United States
- Location(s), date, time and duration of proposed visit(s)
- Sponsoring organization
- Passport number; Visa number
- Security clearance status, clearing agency, and degree
- Status (i.e., foreign national or immigrant alien)
- Height (inches)
- Weight (pounds)
- Color
- Color eyes
- Social Security Number as applicable
- Emergency contact address and telephone number
- Local or U.S. address while at WFF

APPENDICES

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

1. **Description** of scientific objectives and list of specific instruments.

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
    g) Hardware and Structures to be Fabricated at WFF.

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) Quantity and Bit Rate of RF Links
    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
m) Uplink

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: Clean Tent, Temp Constraints, Purge, etc.
d) Recovery

12. Launch Conditions

a) Launch Range
b) Time of Day
c) Azimuth
d) Launch Angle
e) Window
f) Special Conditions – Restraints – Go/No-go Criteria

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

14. **Radioactive Sources** - Payload/Calibration or Hazardous Materials

15. **List of Specific Minimum And Comprehensive Success Criteria**. If the flight is part of a launch series, criteria must be specified for each individual launch. Requirements should include such things as apogee, time above altitude, pointing, coning, roll rate, etc., as appropriate.

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

Appendix B: RDM Data Package

(This package is a follow-up to information initially provided by Mission Science in the MIC Questionnaire.)

Mission Science Contact: ____

NSROC designs (or modifies) science structures and support systems based on the physical properties, desired flight performance issues, power, event timing, pyrotechnic, signal handshaking, and channel monitoring/ sampling requirements of the desired science package (payload). The following information is requested from Mission Science for each payload (main, mother, daughter, etc.) proposed. A comprehensive data package containing all science information is requested before a complete design can be established.

Electrical Engineering

- List of Instruments to be flown
- Voltage and current requirements for each instrument
  - Instruments requiring power at lift-off or by timer function?
  - Current limiting protection provided in the instrument?
  - Are there power sharing issues?
- List of science booms (if any) and micro switch(s) monitor requirements
- Handshake signal requirements for each instrument (major frame, etc.)
- Matrix requirements
  - System word length (8--16 bits/word, analog data resolution up to 12 bit/word)
  - Symmetrical or non-symmetrical data sampling requirements
- Complete list of data channels required (All analog data channels must be conditioned to 0-5v)
  - Type of channel (serial, analog, counter, parallel, asynchronous, time-event) with label names (sciHV, sci15v, etc.)
  - Desired minimum sample rate (SPS) of each channel
  - .Stipulate if symmetrical sampling of the channel is required
  - Stipulate if contiguous sampling is required
  - For Serial:

    Stipulate multiplexing if used (typical design is one wire-one channel)

    Stipulate single ended or differential (reflect on pin-out)
  - For Counter:

    Stipulate single ended or differential (reflect on pin-out)

    Stipulate reset mode
  - For Parallel:

Stipulate pin for MSB on Parallel

Stipulate read, strobe

> ***NOTE:*** If not all channels have been defined allow for the maximum number of spare channels required, again with desired sample rates.

If the science package includes its own encoding or Baseband system, the following information is required.

- The encoder output must be adjustable for deviation setting
- Baseband requirements:

  System must have capability to interrupt the instrument output and send a calibrated tone to the transmitter. This tone should be a calibrated amplitude that will be used for receiver and recorder* calibration set-up. This calibration should be controlled from the GSE, through an umbilical line. It is recommended that the experimenter provide output amplitude adjustment capability designed for 75-Ohm load impedance and voltages of up to one volt RMS.

> ***NOTE***: A Data Tape model DTR-6, -8, or -16 recorder must be used for Baseband recording.

- Wire pin-out of each interface connector
  - Connector size, type, sex (experiment side, 15,25,37-cannon, hard-mounted/pigtail, etc.)
  - Power and ground requirements (pin 1-28v, pin2- pwr gnd, etc.)
  - PCM timing signals (major frame sync, word clock, etc) If in doubt as to what signals, narrow the list to the maximum signals needed and include all on the interface connector (after fully defined, use only what is needed on the science side of the connector). Stipulate if data line requires shielded cable, twisted pair, coax type, etc. (gnd which end?). All of this needs to be defined for each instrument.

- Flight Events list (all timer controlled science/experimenter events with turn-on requirements such as altitude or time)
- Altitude protected events
- ACS controlled or up-link command controlled requirements
- Special position determination requirements: GPS, Doppler, strobe lights

- GSE/Umbilical requirements
  - External Experiment Switching
  - External Experiment Monitoring
  - Special umbi requirements (Fiber Optic, RS232, etc)
  - Special launcher power requirements (3 phase 220 VAC)

- Miscellaneous –

  Any Special requirements such as an attitude gyro, solar aspect sensor, lunar aspect, magnetometer, or high resolution time tagging should be also be specified. Special testing/calibration such as magnetometer calibration, corona, etc. If the science package structure is to be furnished by WFF accurate dimensions of the instrument(s) in addition to the connector information will be required for hardware placement and wiring of the structure.

Guidance Navigation and Control

- Guidance desired?
- Attitude Control desired?
  - Stabilization: Two (payload spun) or Three Axis?
  - Attitude Requirements:
    - Pointing/rate requirements?
    - Jitter requirements?
    - Drift requirements?
  - Uplink Command required?
    - Instrument generated signal Interface to ACS required?
    - Maneuvering requirements?
  - Outgassing requirements?
  - Nozzle location or firing restraints?

- Post-flight attitude data required?

Mechanical Engineering

If Mission Science plans to provide a complete structure (structure, mounted instruments, and skin) the following is required.

- Mechanical Interface
- Mass Properties (Weight, CG, MOI)
- Special Testing

- Required Roll Rates (parameters for Boom deploy,etc.)
- Updated Drawing (includes openings-doors, etc.)
- Metal Finish required
- Shutter Door Required
- Crush Bumper
- Experiment pyrotechnics
- Magnetic Cleanliness

If NSROC will provide the structure and skin the following is required.

- All physical Characteristics
  - Instrument(s) size, dimensions, and Weight & CG, drawings w/ connector locations, clearance required for connectors, mounting hole patterns & sizes, (Boxes, Booms, etc.)
  - Desired location of instruments (accessibility/doors)
  - Out-gassing requirements
  - Experiment interfaces (umbilicals, nozzles, and access ports, etc.)
  - Acceptable science view characteristics
- Separation velocities
- Special Testing
- Required Roll Rates (parameters for Boom deploy,etc.)
- Metal Finish required
- Shutter Door Required
- Crush Bumper
- Experiment pyrotechnics
- Magnetic Cleanliness

If NSROC will provide the skin section only the following is required.

- Mass Properties of the hardware and structure (Wt. & CG
- Mechanical interface with skin section
- Experiment interfaces (umbilicals, nozzles, and access ports, etc.)
- Acceptable science view characteristics
- Separation velocities
- Special Testing

- Required Roll Rates (parameters for Boom deploy, etc.))
- Metal Finish required
- Shutter Door Required
- Crush Bumper
- Experiment pyrotechnics
- Magnetic Cleanliness
- Outgassing requirements.

Performance Analysis

- Trajectory Information
- Desired Altitude
- Desired Time above a given Altitude
- Apogee
- Dynamic issues?
- Time line issues?
- Impact range

Vehicle Systems

- Launch range
- Ground support requirements (payload handling)
- Thermal requirements on launcher
- Altitude
- Recovery required

The following information is required if Mission Science desires specific test or range facility support:

When will Science prefer to integrate? Where?

- What are the Hazardous Material requirements?
- Are there Thermal requirements on launcher?
- What are the Ground Support requirements (payload handling) during I & T & launch range?
  - Clean room environment for assembly / testing?
  - Purging gasses (Type of Gas, % Purity and amount required) for assembly / testing?
  - Cooling gasses (Type of Gas, % Purity and amount required) for assembly / testing?
  - Special Power Requirements (A.C. / D.C.) ?

- Special Environmental Testing Facilities required (Magnetometer Calibration, Vacuum testing of system(s) / components, boom / sensor deployment testing, etc.) ?
- Special GSE requirements?
- Special Payload Environmental Control Requirements (boxing of the payload for humidity and temperature control) during Pre-launch and Launch operations?
- Requirements for handling of Non-launched / Aborted Launch Mission flight hardware, hazardous materials?
- Computer / Communications Requirements?

Appendix C: 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 D

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 E: 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 F:

Descriptions & Flight Performance Characteristics for NASA Sounding Rockets and Special Projects Launch Vehicles

This appendix describes the various NASA sounding rocket launch vehicles and their performance. Special Projects Launch Vehicles are 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.

The following pages describe those vehicles currently used in the NASA Sounding Rocket Program at Wallops Flight Facility, Wallops Island, Virginia.

F.1 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 F.1-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.

Figure F.1-1: Super Arcas Launch Vehicle

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.

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 F.1-2.

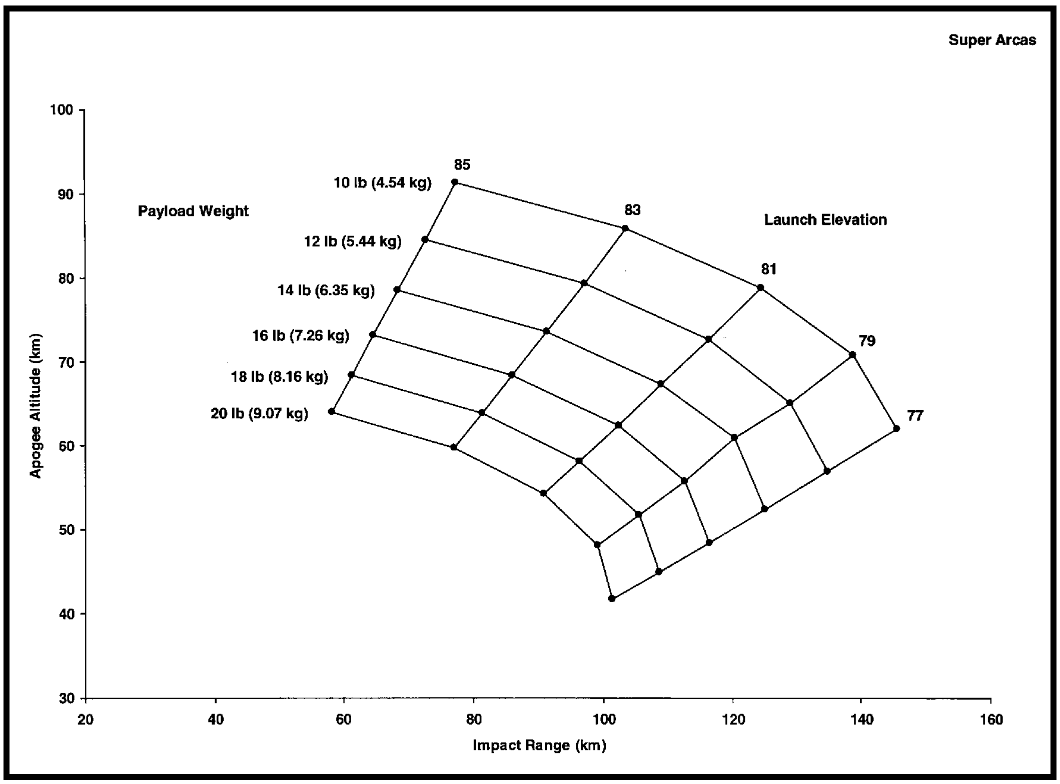


Figure F.1-2. Super Arcas Launch Vehicle Performance

F.2 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 F.2-1 shows the Black Brant VB vehicle.

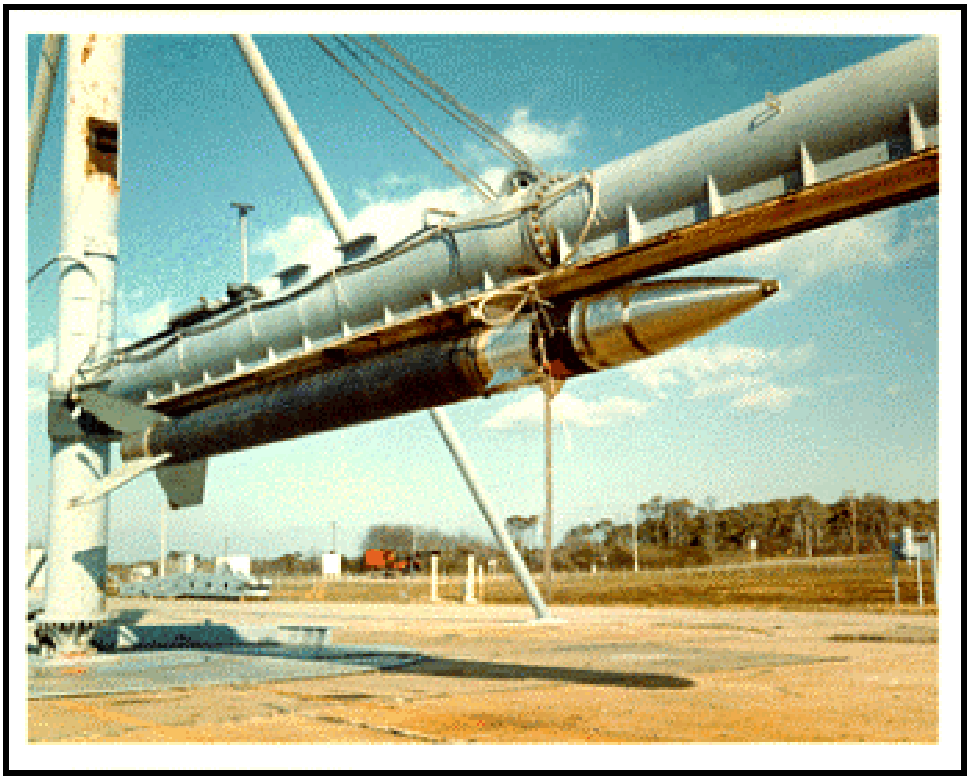


Figure F.2-1: Black Brant V Launch Vehicle

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.

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 F.2-2 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 F.2-3 for the Black Brant VC.

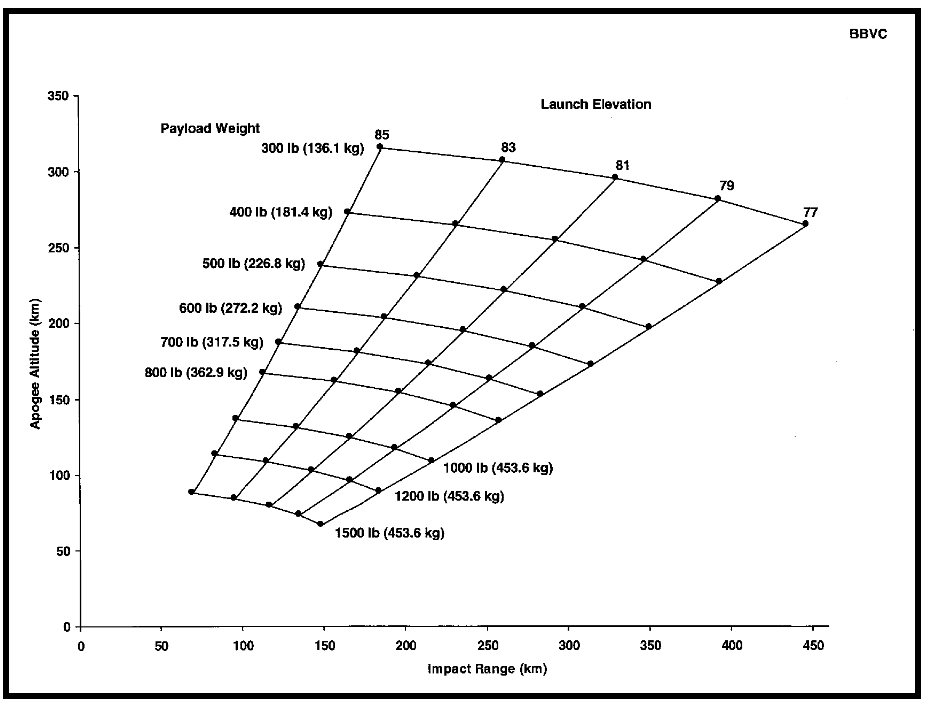


Figure F-2-2: Black Brant VC Launch Vehicle Performance

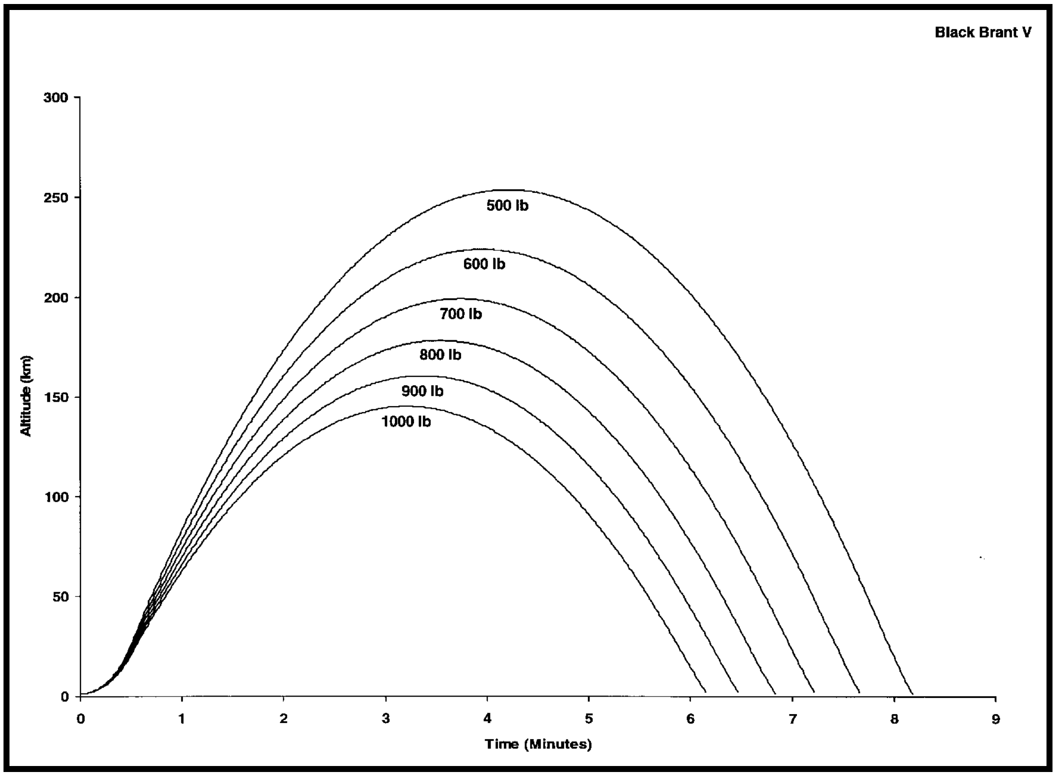


Figure F.2-3: Black Brant VB Altitude vs. Time Profiles for Launch at WSMR

F.3 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 F.3-1 shows the Nike-Black Brant VC vehicle.

Figure F.3-1: 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 F.3-2 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 F.4-3 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.

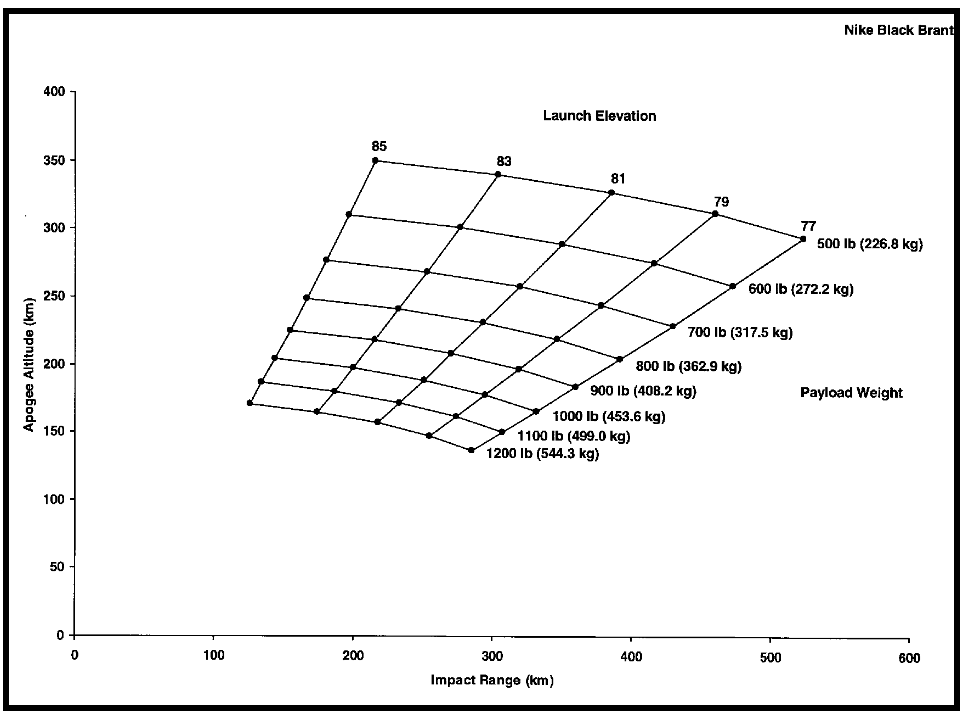


Figure F.3-2: Nike-Black Brant VC Launch Vehicle Performance

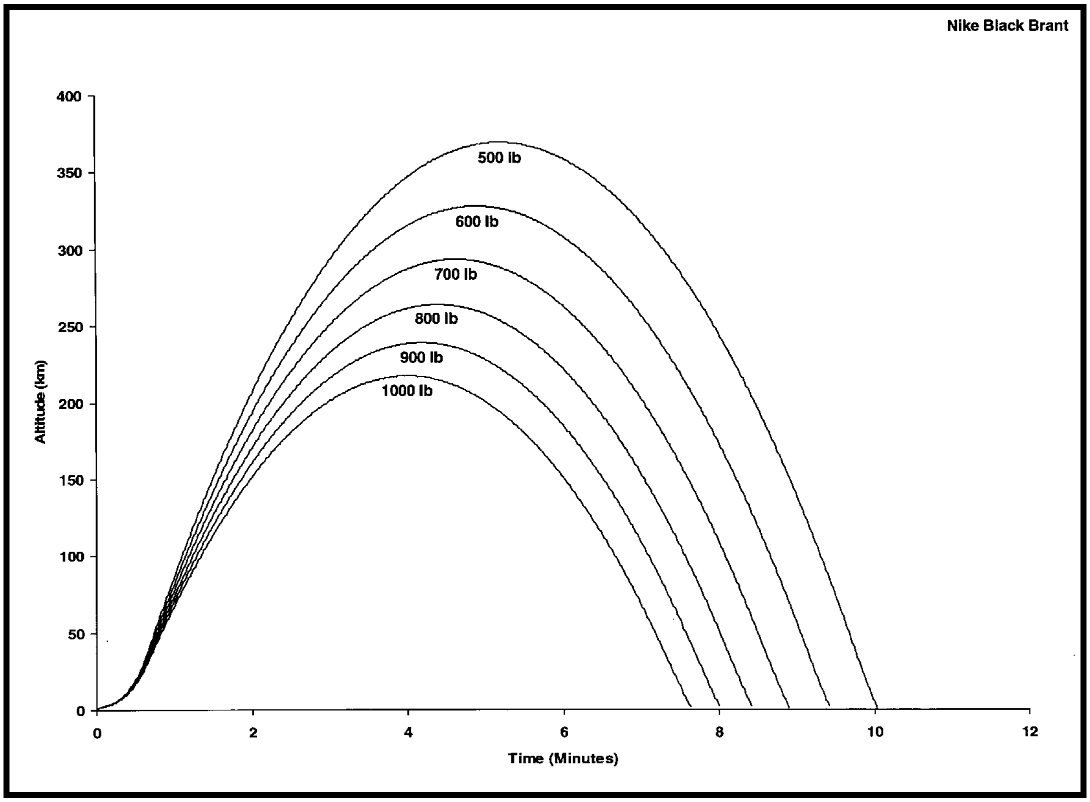


Figure F.3-3: Nike-Black Brant VB Altitude vs. Time Profiles for Launch at WSMR

F.4 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 F.4-1 shows the Terrier-Malemute vehicle.

Figure F.4-1: 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.

Performance Graph

Performance parameters of the Terrier-Malemute vehicle are shown in Figure F.4-2. The payload configuration for reference data is a 16-inch diameter with a 3:1 ogive nose shape.

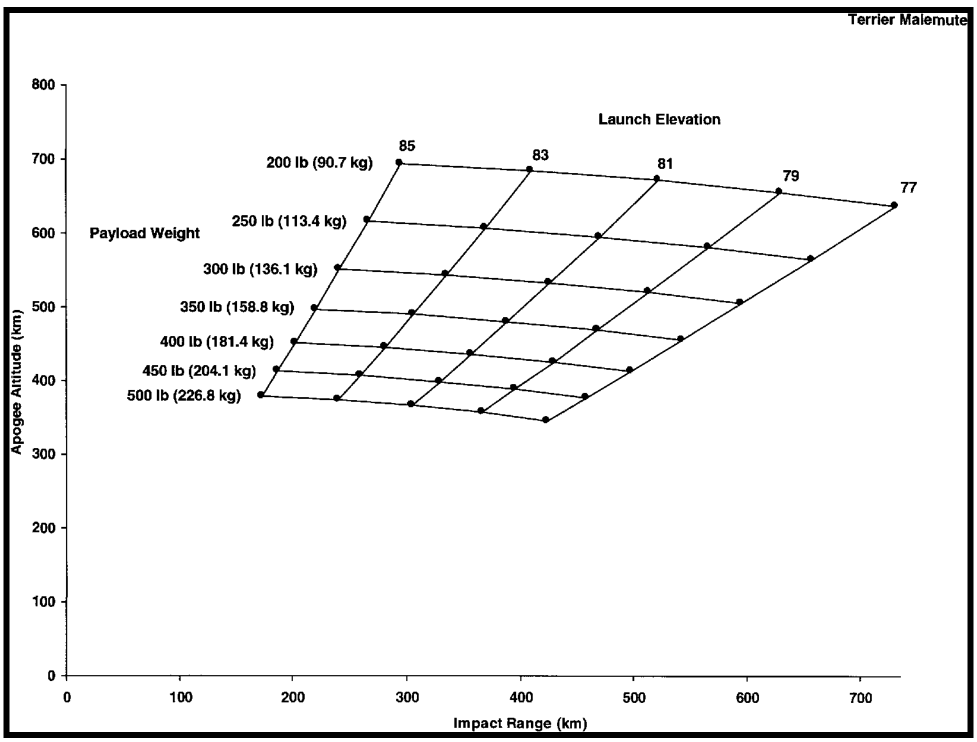


Figure F.4-2: Terrier-Malemute Launch Vehicle Performance

F.5 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 F.5-1 shows the Orion vehicle.

Figure F.5-1. Orion Launch Vehicle
(Photo by Scott Neville)

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 F.5-2.

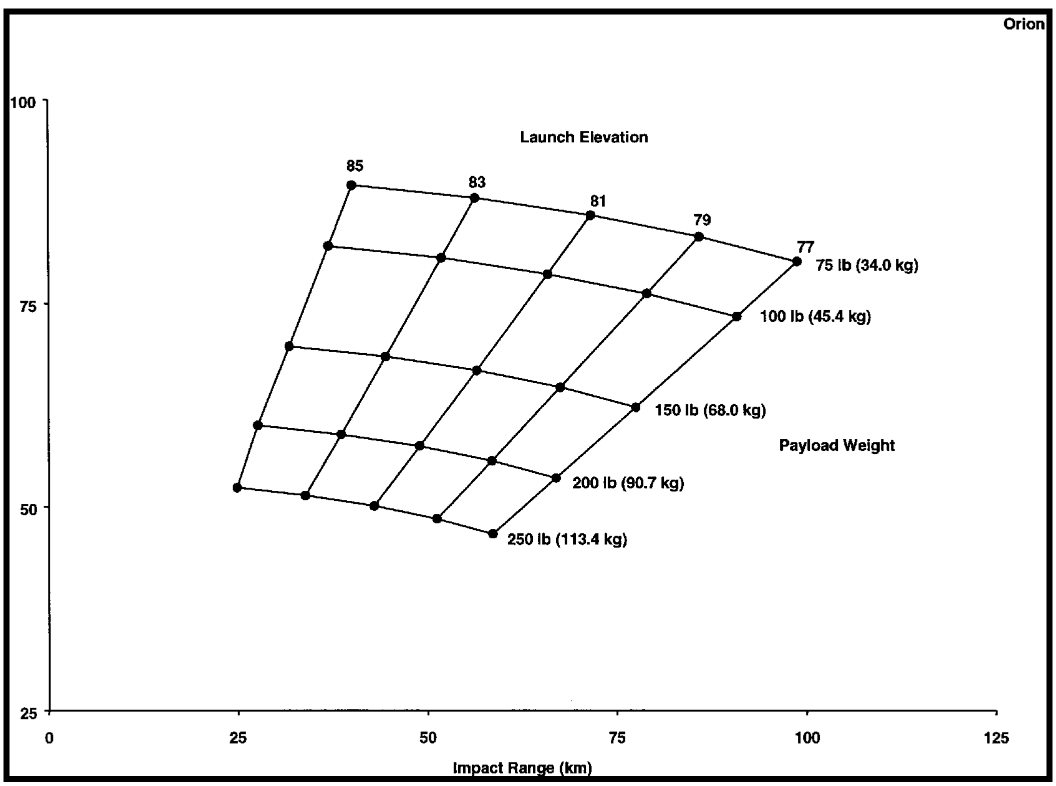


Figure F.5-2: Orion Launch Vehicle Performance

F.6 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 F.6-1 shows the Nike-Orion vehicle.

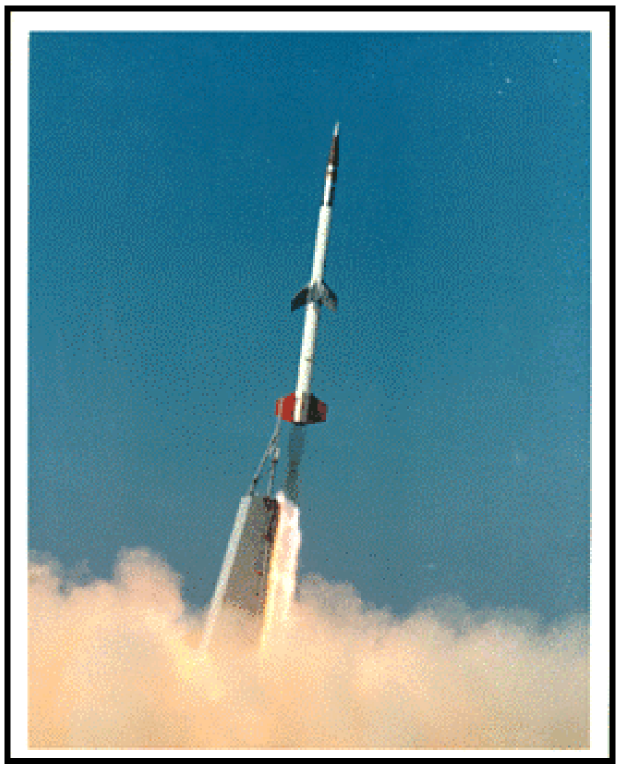


Figure F.6-1: Nike-Orion Launch Vehicle

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 F.6-2.

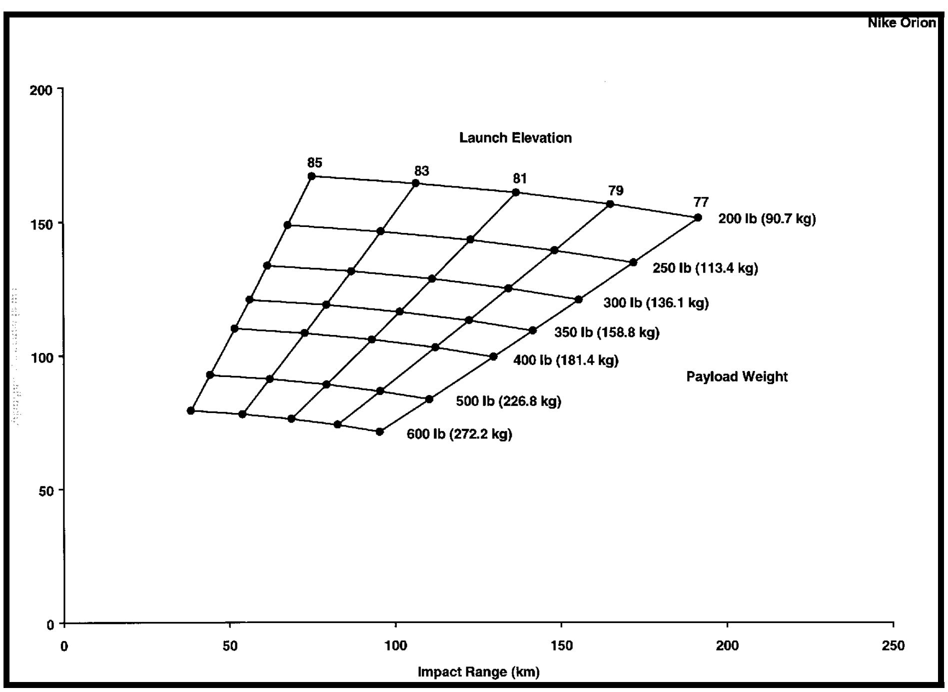


Figure F.6-2: Nike-Orion Launch Vehicle Performance

F.7 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 F.8-1 shows the Taurus-Orion vehicle.

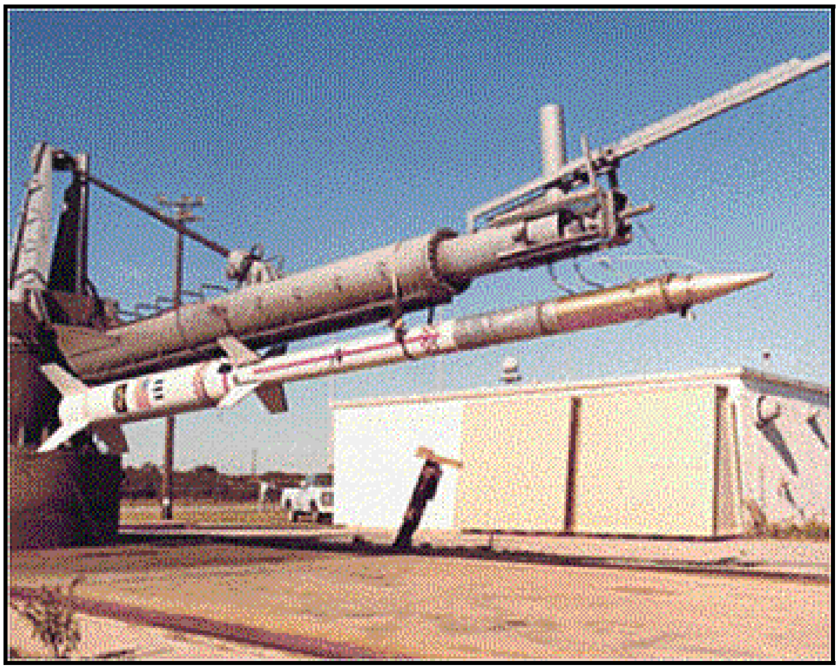


Figure F.7-1: Taurus-Orion Launch Vehicle

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 F.7-2.

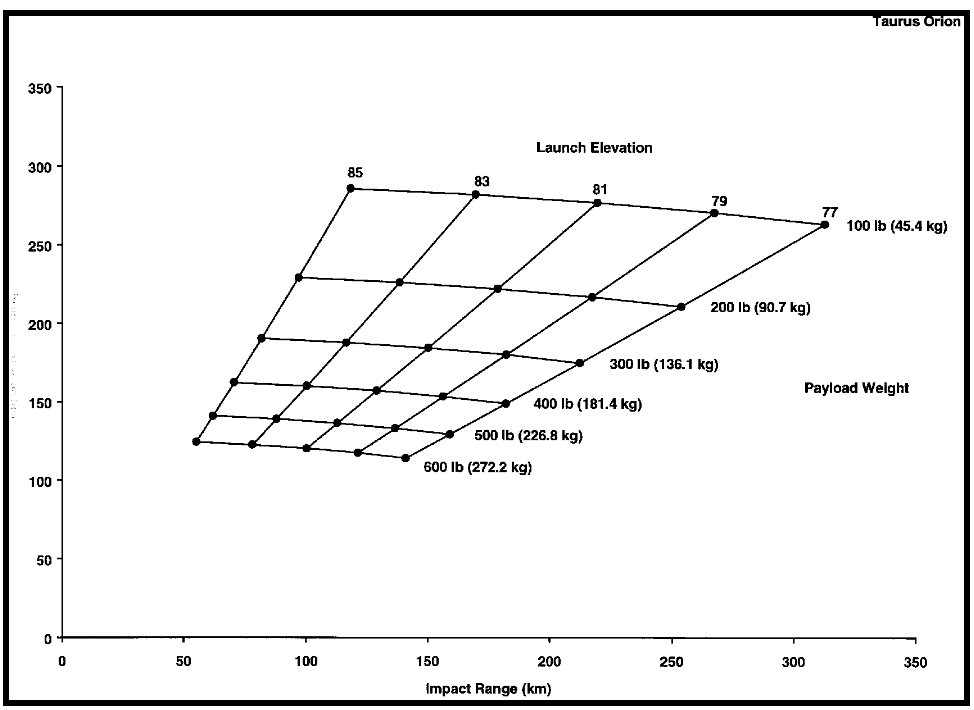


Figure F.7-2: Taurus-Orion Launch Vehicle Performance

F.8 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 F.8-1 shows the Black Brant X vehicle.

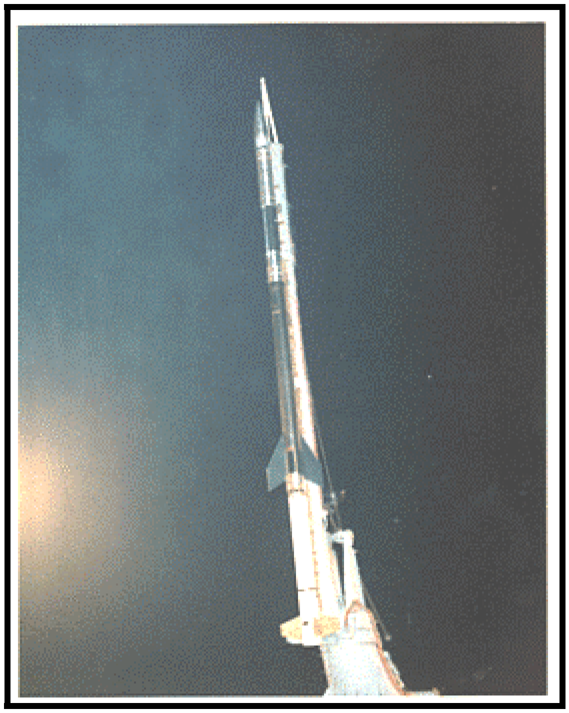


Figure F.8-1: Black Brant X Launch Vehicle

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. 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 F.8-2.

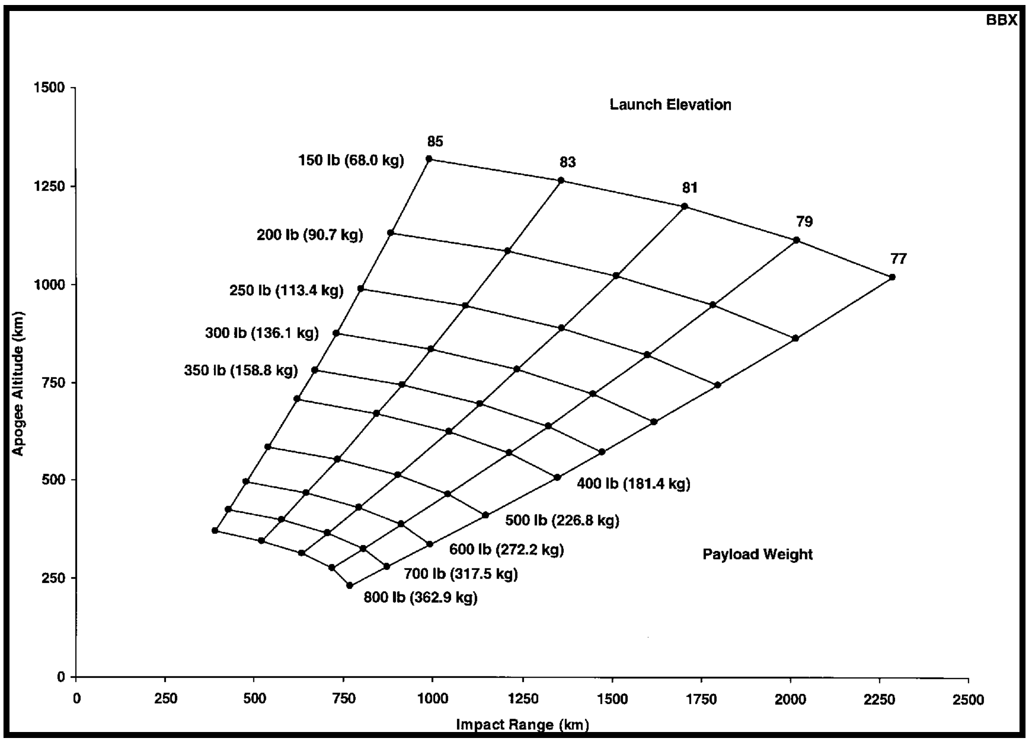


Figure F.8-2: Black Brant X Launch Vehicle Performance

F.9 Terrier-Black Brant VC Launch Vehicle (Black Brant IX, 36.XXX)

General

The Black Brant IX vehicle system (Figure F.9-1) 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.

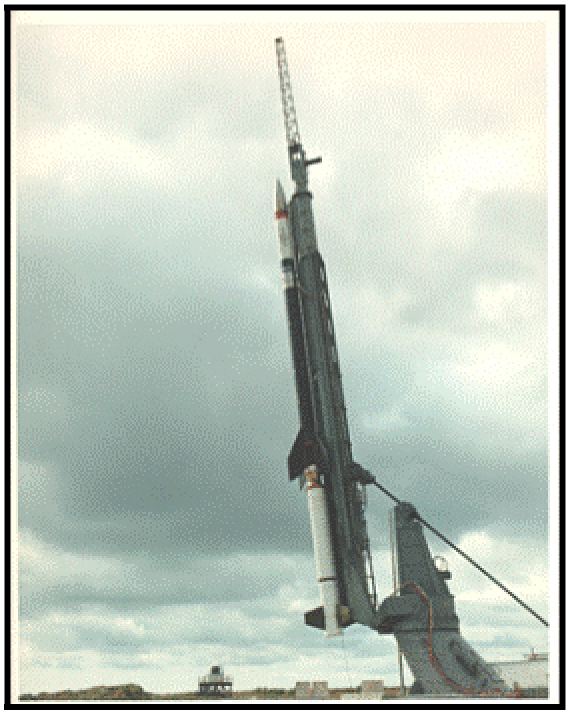


Figure F.9-1: Black Brant IX Launch Vehicle

There are three versions of the BBIX vehicle used. Each vehicle configuration is flight qualified and is available for mission selection:

- BBIX Mod 0: Terrier MK 12 – BBVC
- BBIX Mod 1: Terrier Mk 70 – BBVC
- BBIX Mod 2: Terrier Mk 7 – BBVC (with extended cone).

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., 1000 lb. or 1250 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

Performance Graphs showing the launch vehicle apogee altitude and impact range at various launch elevation angles and payload weights for the BB IX Mod 0, and the BBIX Mod 2 follow.

Mod 0:

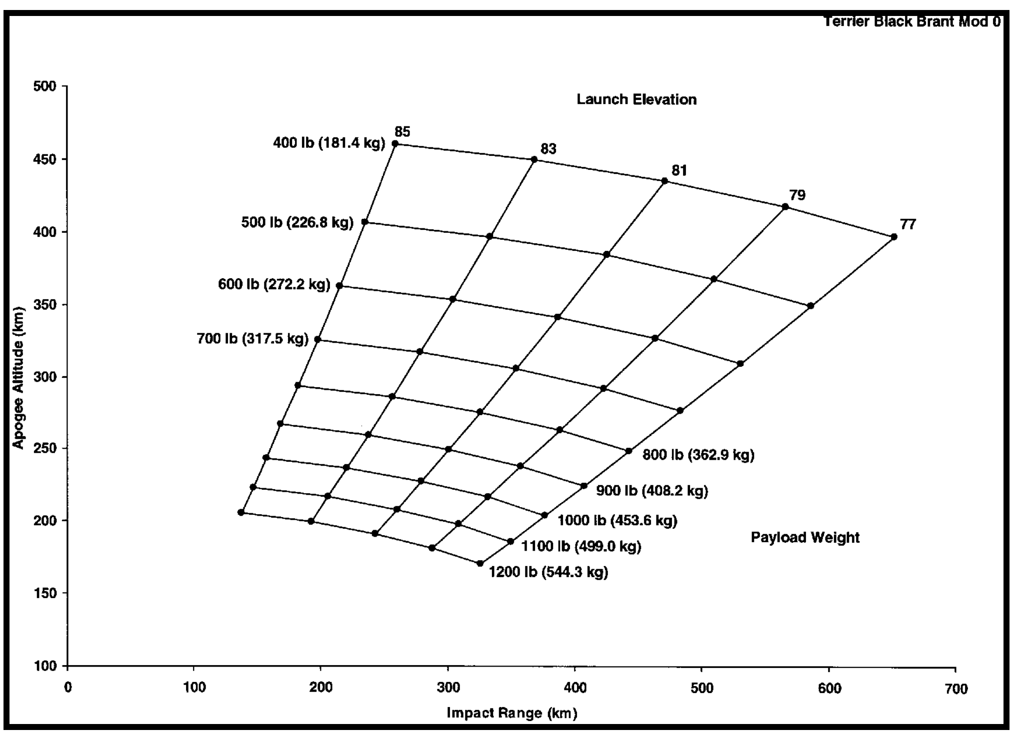


Figure F.9-2: Black Brant IX Mod 0 Launch Vehicle Performance

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 F.9-3.

MOD 0:

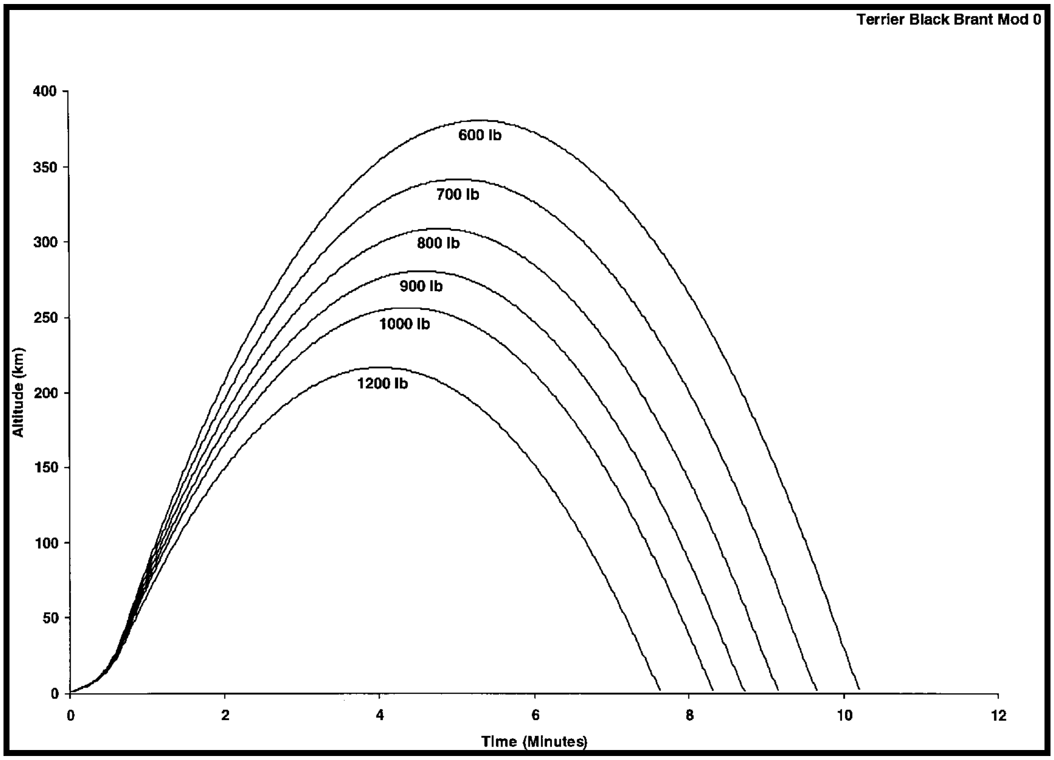


Figure F.9-3: Black Brant IX Mod 0 Altitude vs. Time Profiles for WSMR Launch

MOD 2

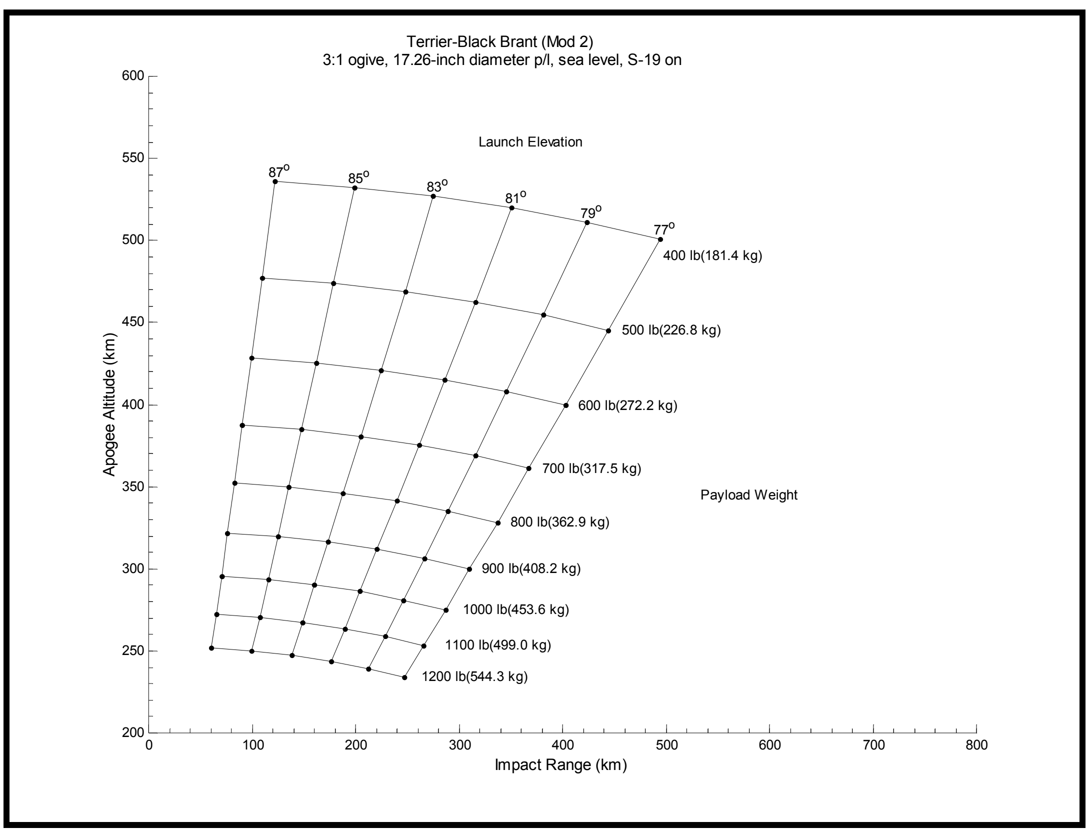


Figure F 9-4: Terrier Black Brant (Mod2) S-19 On

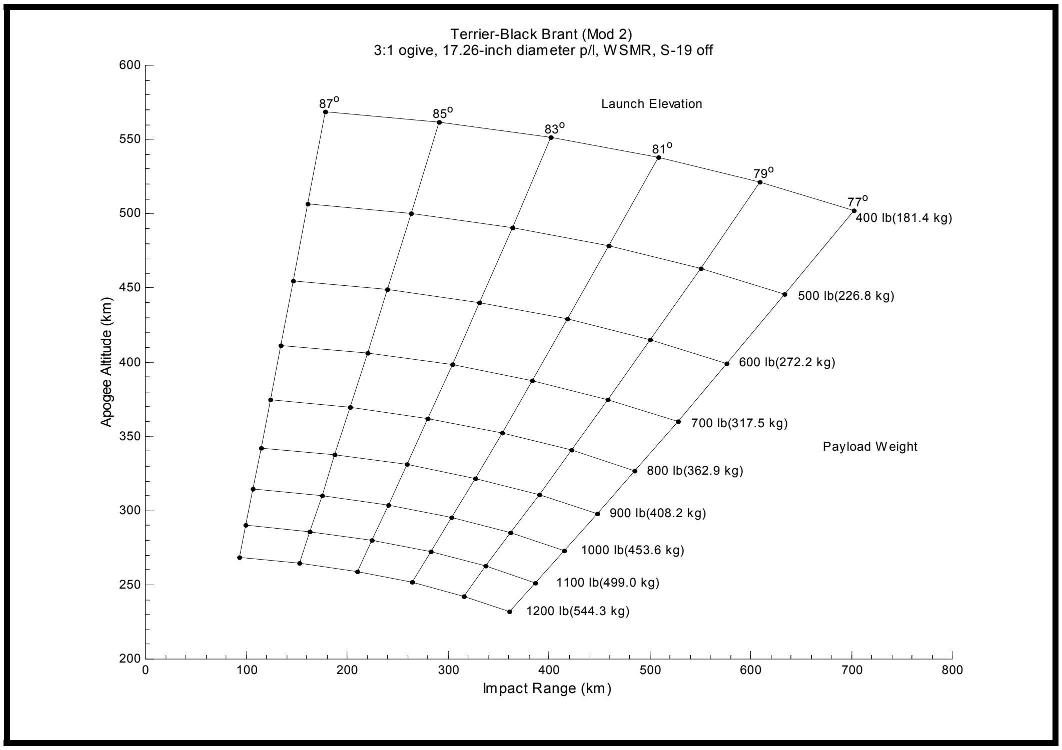


Figure F.9-5: Terrier Black Brant (Mod 2) WSMR, S-19 Off

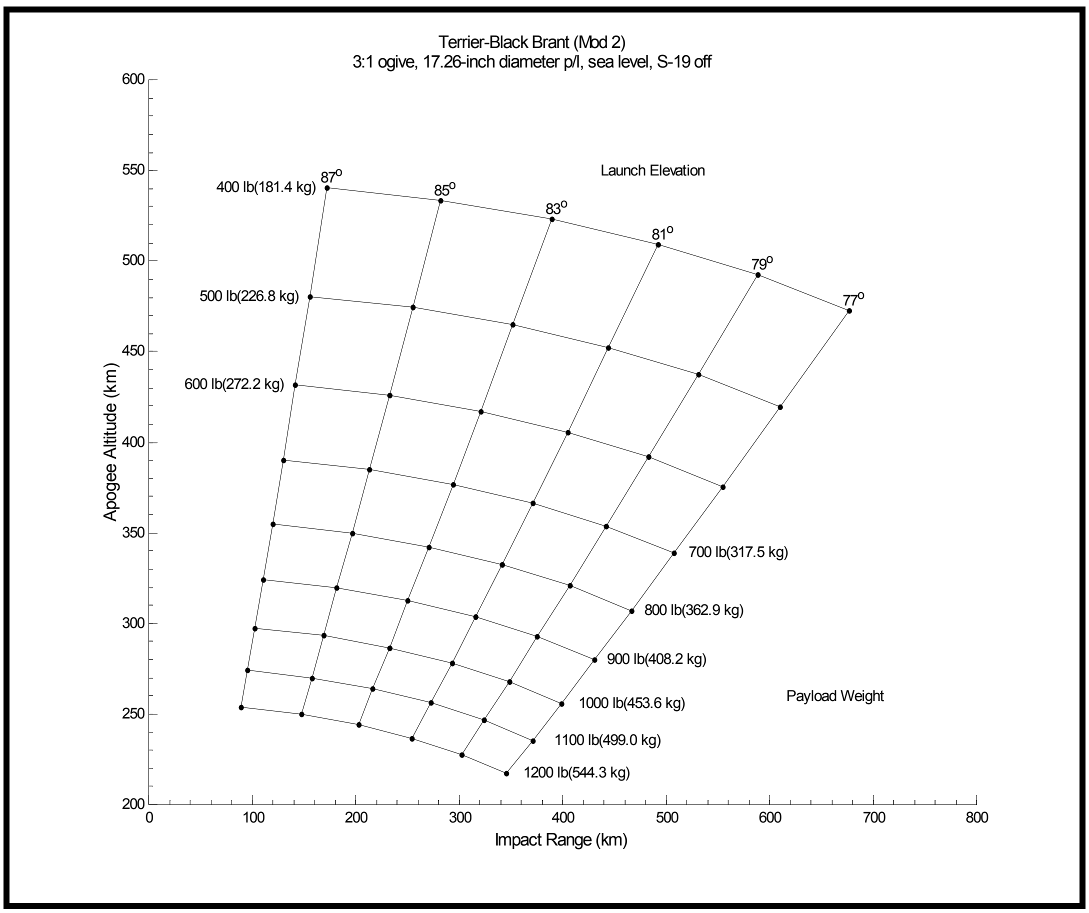


Figure F 9-6: Terrier Black Brant (Mod 2) Sea Level, S-19 Off

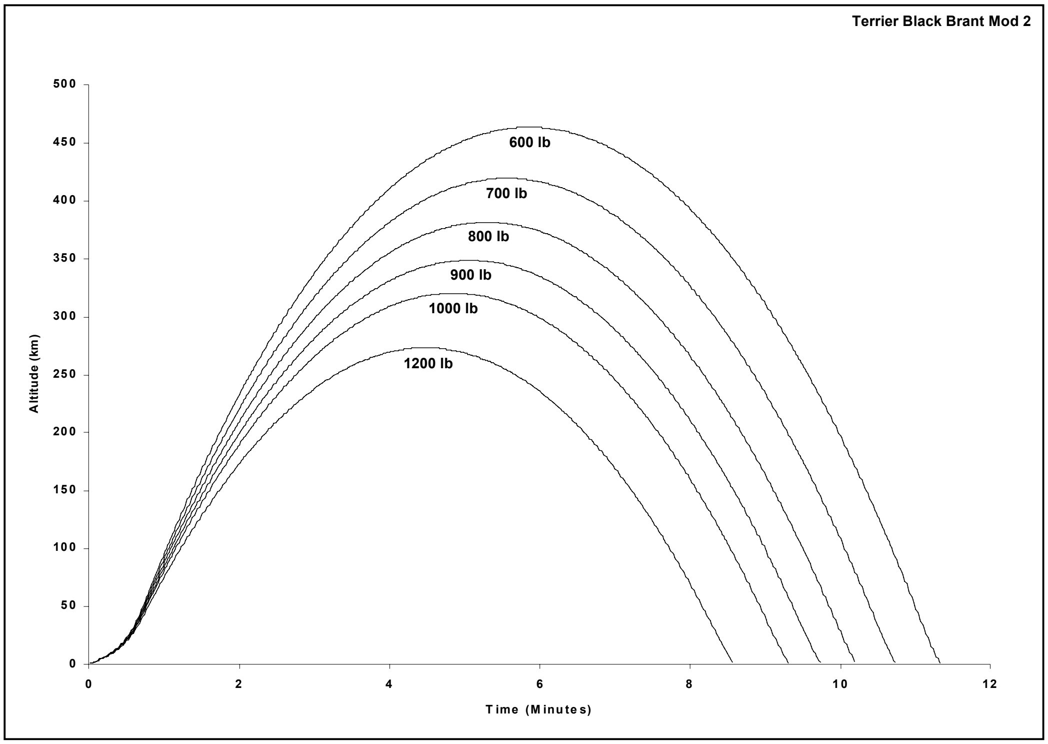


Figure F.9-7: Black Brant IX Mod 2 Altitude vs. Time Profile

F.10 Viper Dart Launch Vehicle (37.XXX)

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. Our Viper Dart configuration is an offshoot of the Viper IIA boosted PWN-10D vehicle frequently used as a meteorological vehicle to collect upper atmospheric data. The Viper Dart launches through a special helical launch rail and imparts a initial spin rate of ~6 Hz at launcher exit. The Dart achieves a maximum roll rate of ~20 Hz after separation from the Viper IIIA booster.

Figure F.10-1: Viper Dart Launch Vehicle

Vehicle Performance

The Viper Dart includes a commercially available Viper IIIA rocket motor to boost the Dart to collect the science data. The Viper IIIA motor is 4.5 inches in diameter and is 96 inches long. The Dart is 2.125 inches in diameter and is 59 inches in overall length.

The Viper motor burns out at ~2.7 seconds and the booster separates via differential drag. The high thrust and low vehicle weight produces rather high accelerations near burnout, in excess of 100 gs. The Viper motor contains 57.3 lbm of an elastomeric solid propellant.

Following separation from the Viper IIIA rocket motor, the non-propulsive Dart continues on its ballistic trajectory to apogee. The overall performance of the Viper Dart vehicle is highly dependant on the launcher's Quadrant Elevation (QE) and the Dart mass. A total dart weight of 19.5 lbm with a 83 deg. QE will produce a 93 km apogee.

Payloads

The current configuration for the Dart includes a device to quantify electron particles in the upper atmosphere. This configuration includes a separating nosetip.

The available payload bay inside the Dart includes a 2 inches diameter by 31 inches in length (97.4 in^3).

Performance Graph

The following Viper Dart Performance Graphs demonstrate the difference in performance when launched from Wallops Flight Facility (SFF) and White Sands Missile Range (WSMR). Differences are due to the variance in distance above sea level of the two launch facilities.

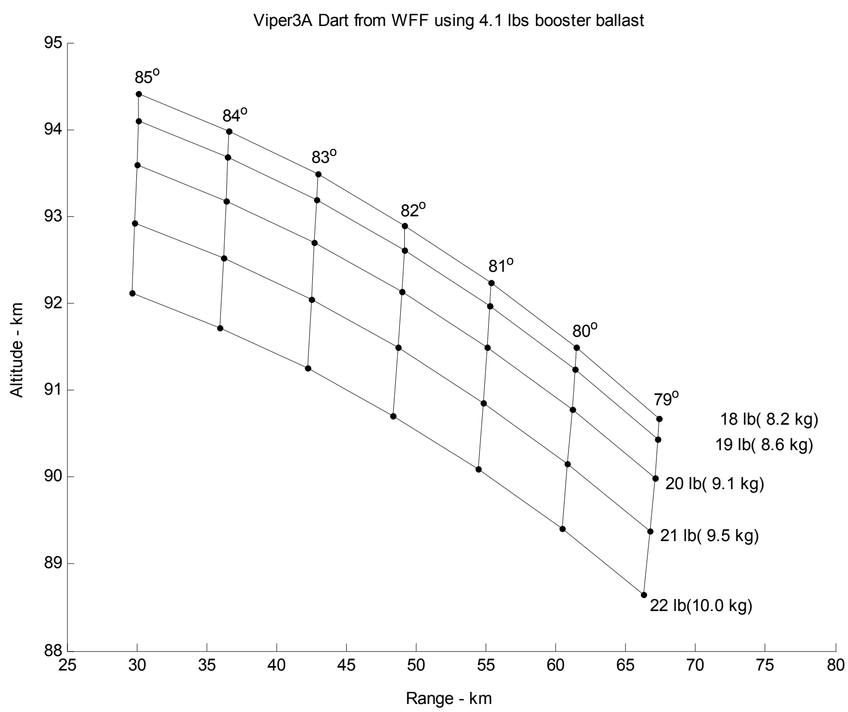


**Figure F.10-2 Viper Dart Using 4.1 Pound Booster Ballast
Wallops Flight Facility**

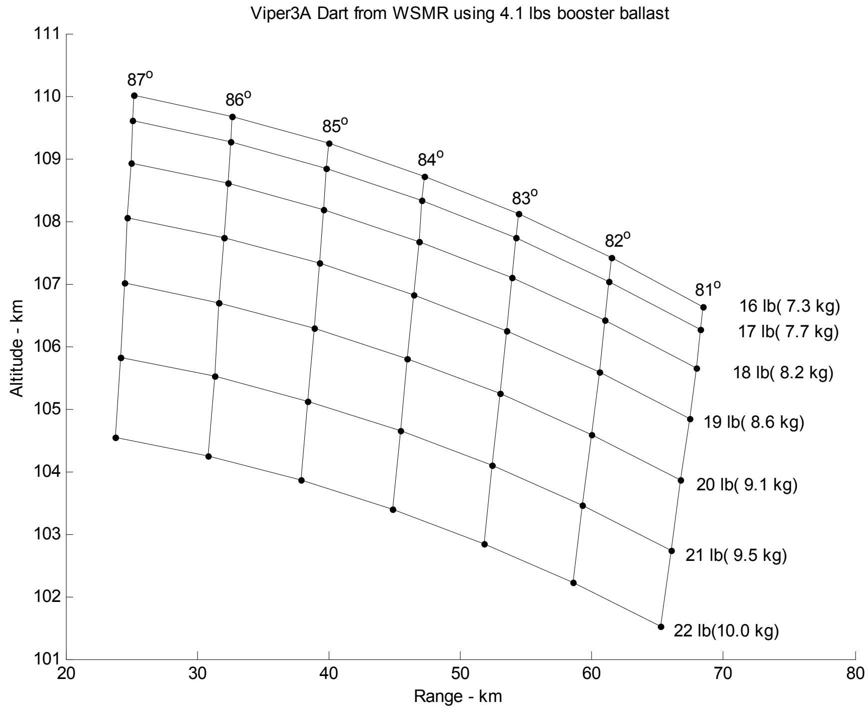


Figure F.10-3 Viper Dart using 4.1 Pound Booster Ballast (White Sands Missile Range)

F.11 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 F.12. 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.

Figure F.11-1: Black Brant XI Launch Vehicle

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.

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 F.11-2.

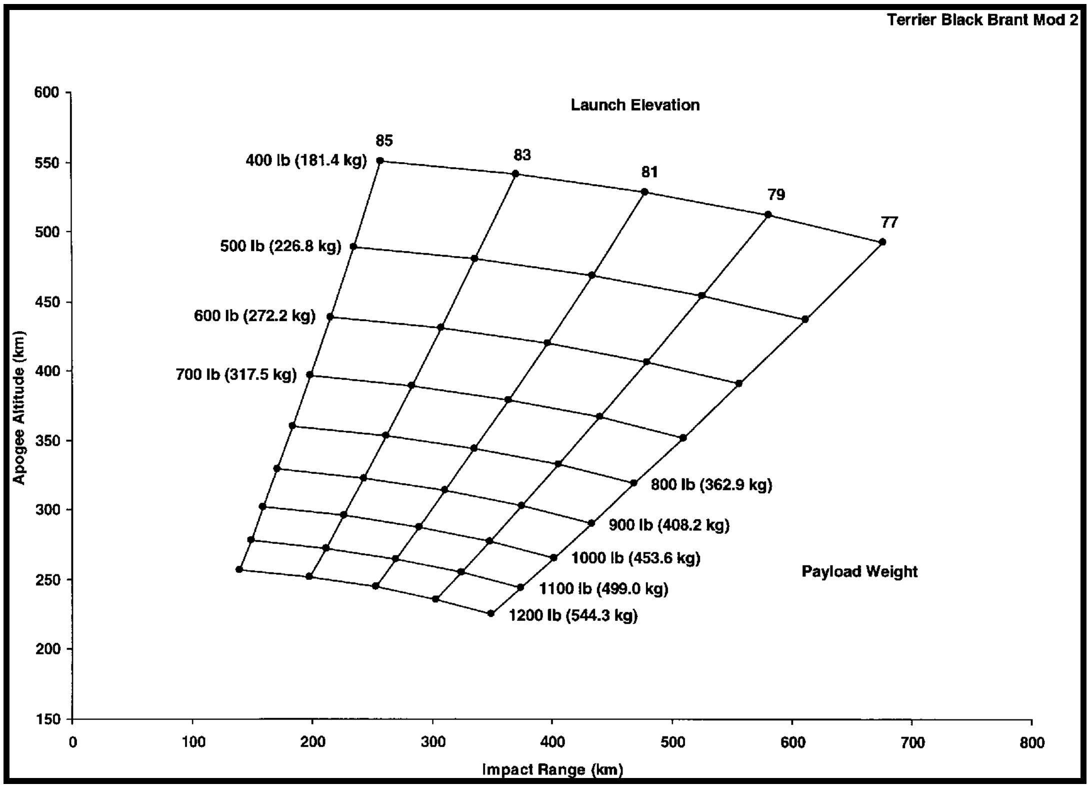


Figure F.11-2. Terrier-Black Brant VC (MK 70) Launch Vehicle Performance

F.12 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.

Figure F.12-1: Black Brant XII Launch Vehicle

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.

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 F.12-2.

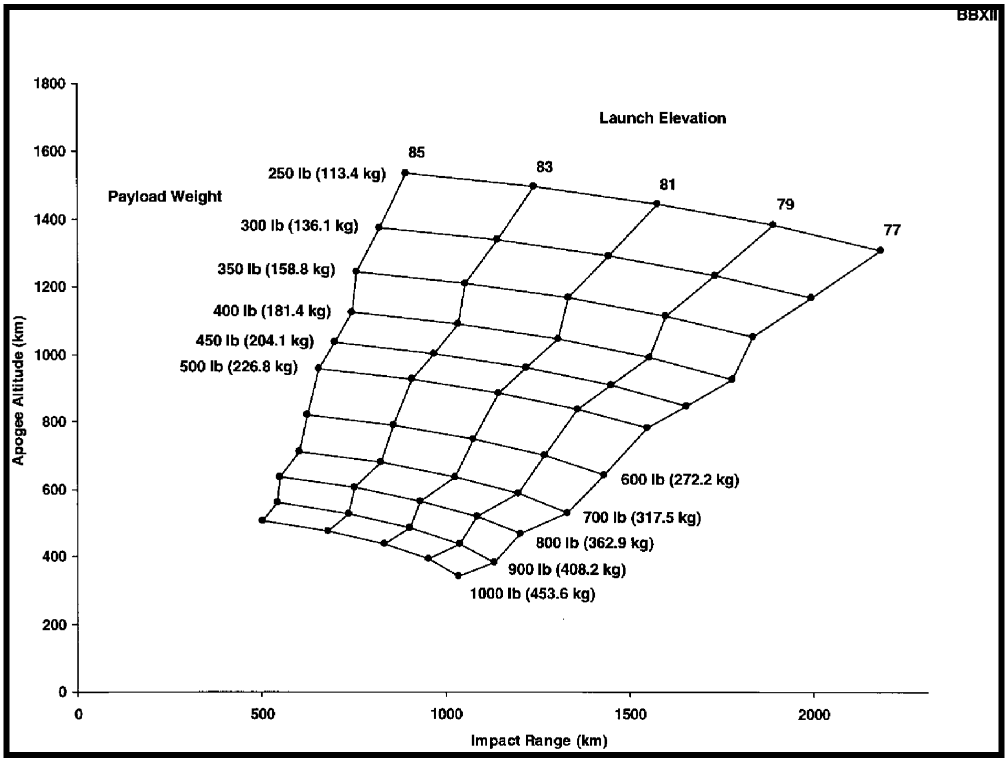


Figure F.12-2: Black Brant XII Launch Vehicle Predicted Performance

F.13 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.

Figure F.13-1: Terrier Improved Orion Launch Vehicle

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 F.13-2.

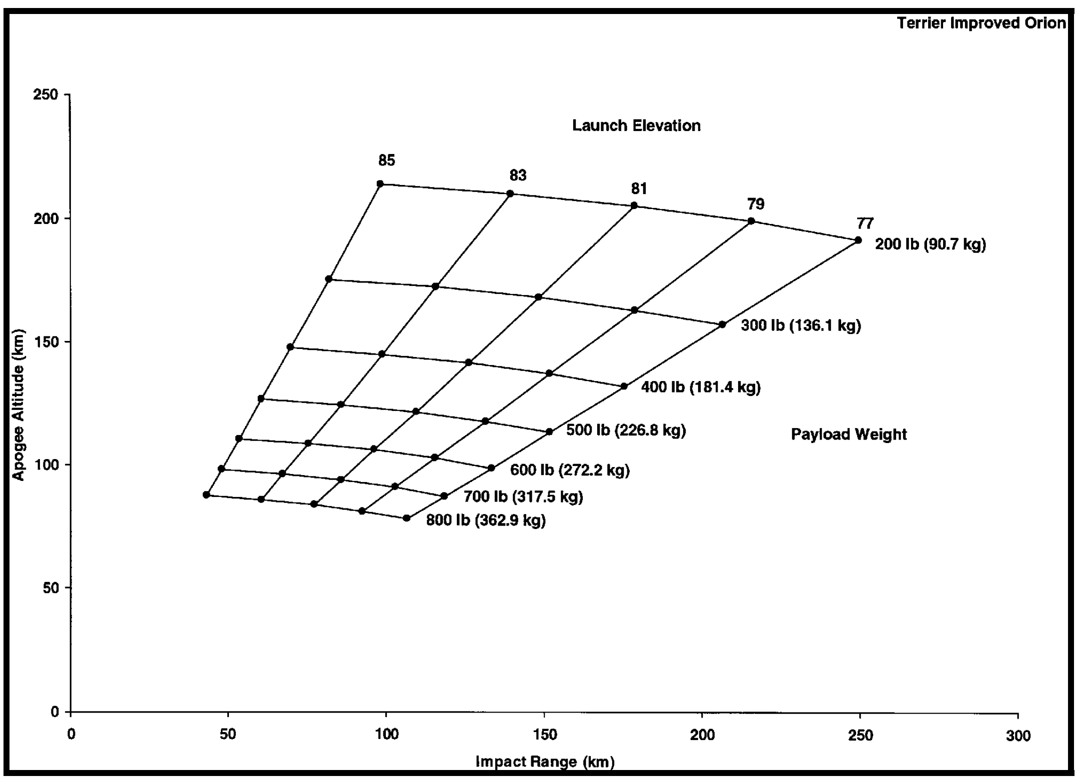


Figure F.13-2: Terrier-Improved Orion Launch Vehicle Predicted Performance

F.14 Terrier Lynx (42.XXX)

General

The Terrier Lynx is a two-stage, unguided, fin stabilized rocket system which utilizes a Terrier mk70 first stage booster and a Lynx rocket motor for the second stage propulsion. The Terrier mk70 motor has four equally spaced modified Ajax fins, and the Lynx motor has four modified Orion fins on the aft end arranged in a cruciform configuration to provide stability. Figure F.14-1 shows the Terrier Lynx vehicle.

Figure F.14-1 Terrier Lynx Launch Vehicle

Vehicle Performance

The basic Terrier mk70 motor is 155 inches long with a principal diameter of 18 inches. There is a 3 inch interstage adapter which allows for drag separation at Terrier burnout. Typically, the Terrier booster will utilize two spin motors to reduce dispersion and also serve as drag plates. Each Terrier fin is 4.6 square feet in area. Normally, the fins are canted to provide two revolutions per second spin rate at Terrier burnout. The weight of the Booster system is 2,288 pounds.

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

Payload

The standard payload for the Terrier mk70-Lynx has a principal diameter of 14 inches and utilizes a 3:1 ogive nose cone, although an 11 deg total angle cone can also be flown. The envelope of payload lengths that can be flown has not been established yet, however, it is expected to be similar to the boosted Orion family. The rocket system will carry a 250 pound payload to 378 kilometers and a 500 pound payload to 254 kilometers when launched from sea level at an 85 degree launch angle.

Standard hardware includes a 3:1 ogive nose cone and a capacitive discharge ignition system. Separation systems can be provided to separate the payload from the motor during ascent.

Performance Graph

The Terrier mk70-Lynx launch vehicle configuration and apogee altitude and impact range at various launch elevation angles and payload weights are presented in Figure F.14-2.

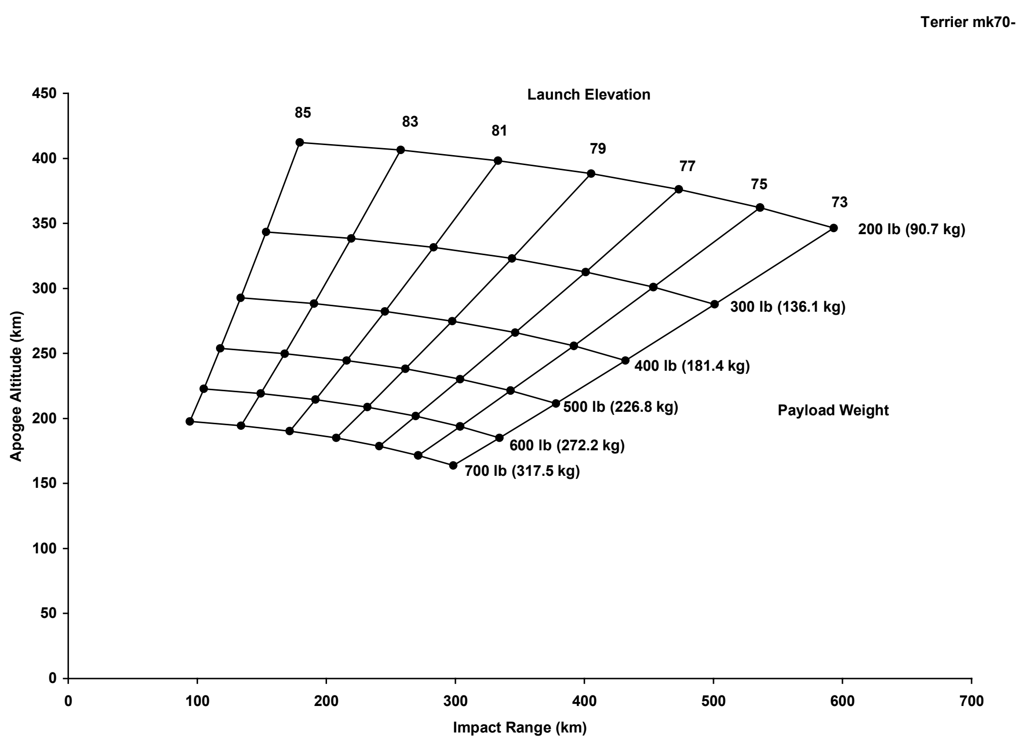


Figure F.14-2 Terrier Lynx Performance Graph

Appendix G: PCM/FM and FM/FM Telemetry Systems

G.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 G.1-1 for individual module characteristics.

Table G.1-1 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 Registers	Pulse Time-Event	2
TD-925	Time Event Monitor with Timing Buffers	Pulse Time-Event	4
FL-919A	Adjustable Quad Pre-Modulation 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.

G.2 SPARCS and the PSL WFF87 Encoder Systems

Both of these systems have been or soon will be replaced with the newer WFF93 encoder system.

G.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 system 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 G.3-1 for individual module characteristics.

Table G.3-1: Individual PCM Module Characteristics - WFF93 PCM System

Module	Description	Data Type	Number of Channels Possible (See *Note)
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, 32 channels per deck, 1 A/D converter per deck	Analog, single ended	Addressing limit of 992 channels
Analog	Analog 0 to 5 volt input range, 12 bits/word maximum resolution with readout capability in 2 words for systems with less than 8 bits/word, 8 channels per deck, 8 A/D converters per deck	Analog, single ended with – Signal Reference	Addressing limit of 248 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, serial word enable, inverted load, gated bit clock 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 single ended or differential input, 8 to 18 bits/word. Differential input count rates >10 MHz	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,	Uplink command FSK video	N/A

	plus parallel command data to uplink command decoder hardware		
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
TV Video Digitizer and Compressor	New capability which should be available by Fall, 2000. These modules digitize standard NTSC, RS-170 or SVHS TV video, compress the digitized data and are converted to MPEG-2 format, and multiplexed with payload PCM data to provide a single composite PCM output signal.	TV Video	Maximum unknown at this time.
Top Plate	Top cover of assembled PCM stack	N/A	N/A
Note 1: The maximum values are based on theoritical limits. (i.e. number of channels per module times 31, which is the module addressing limit) No one has ever attempted to fly the maximum. Current limitations in the power supply module may actually determine the maximum number of data modules that can be incorporated in a system.			
Note 2: 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.			

G.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 G.4-1 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. Flight hardware still exists though it is subject to being surplussed. Telemetry ground stations at Wallops Flight Facility, Va., White Sands Missile Range, N.M., and Poker Flat Research Range, Alaska have had the FM discriminators removed from their operational racks.

Table G.4-1: 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 H

Comparison and Performance

of

Various Battery Systems

Table H-1
Comparison and Performance of Various Battery Systems

	Temp: 25°C			System Voltage (Nominal): 28V				
Cell Type Mod. No . Manufacturer	**ilver Zin MC1(2.5 Yardne**	**ilver Zinc HR3DC-6 Yardney**	**Silver Zin HR5DC-9 Yardney**	**Ni-ca AF GE**	**Ni-cad "C" GE**	**Ni-cad "1/2D" GE**	**Ni-cad "D" GE**	**Ni-cad "F" 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	

Table H-2: Comparison and Performance of NiCad Battery Systems

Temp = 25C System Voltage Nominal = 28V							
Cell Type	**2/3 AF**	**A**	**C**	**Cs**	**D**	**F**	**M**
Manufacturer	**Sanyo**	**Panasonic**	**Gates**	**GE**	**GE**	**Sanyo**	**Sanyo**
Electrical Characteristics							
Rated Capacity (AH)	0.475	1.4	2.4	1.2	4.5	7	10
Open Circuit Voltage (Volts)							
Cell	1.35	1.35	1.35	1.35	1.35	1.35	1.35
24 Cell Pack	32.4	32.4	32.4	32.4	32.4	32.4	32.4
Average Plateau Voltage at C/1:							
Cell (Volts)	1.2	1.2	1.2	1.2	1.2	1.2	1.2
24 Cell Pack (Volts)	28.8	28.8	28.8	28.8	28.8	28.8	28.8
Operating time to 27V Min (min)	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Physical Characteristics of a Cell:							
Weight (oz)	0.65	1.2	2.3	1.7	2.7	6.8	14.1
Diameter (in)	0.67	0.67	1.01	0.88	1.28	1.28	1.66
Height (in)	1.11	1.94	1.88	1.67	2.3	3.5	3.5
Physical Characteristics of a Pack:							
Weight (lbs)	1.59	2.46	5.94	N/A	11	16.73	28.34
Length (in)	4.45	4.45	7.18	6.4	8.79	8.79	11.25
Height (in)	1.74	2.6	2.53	2.38	3.12	4.28	7.53
Width (in)	2.99	2.99	4.82	4.29	5.89	5.89	3.83

Appendix I: Attitude Control Systems

I.1 Attitude Control Systems (ACS) Overview

NSROC's ACS includes Coarse Control and Fine Control systems.

Coarse control systems feature:
- Inertial systems unsupported by fine sensors.
- Magnetometer systems that align the payload with the earth's magnetic field
- One to three-axis rate control systems.

Fine control systems include:
- **Sun Sensors:** . The current fine sun sensor is supported by a suite of coarse and intermediate sun sensors that allow acquisition and tracking without the need for an inertial platform

- **Star Trackers:** The current star tracker is a single tracker that must be supported by an inertial system capable of pointing it at a series of guide stars in order to acquire the star which is the specific target NSROC is currently developing an improved multi-star tracker.

I.2 NSROC Solar Pointing Attitude Rocket Control System (SPARCS VII)

Description

The SPARCS VII is a precise, three-axis solar pointing control system developed specifically for sounding rockets users. All SPARCS VII units are self contained; this includes control electronics, pneumatics, power and coarse, and intermediate and fine sun sensors. The attitude with respect to the roll axis is measured with magnetometers. The outputs of the sensors are direction cosines to the payload sun line and to the earth's magnetic field vector. This design is lighter in weight, cheaper, simpler and more reliable than systems that require the use of an inertial platform. SPARKS VII supports payloads that are designed to map the sun's temperature, measure X-ray intensity, observe solar features and capture other spectral data.

Capabilities

The SPARCS' enable signal is programmed to activate the SPARCS pneumatics system when the payload reaches an altitude in excess of 80 kilometers. SPARCS will normally acquire the sun and achieve stable fine pointing within 20 to 40 seconds after the pneumatics system is activated. The Timer setting for this event is determined by payload weight and vehicle flight trajectory data. The sun line and magnetic field enclosed angle (eta angle) should be less than 165 degrees to assure roll angle acquisition; and the launch window should be such that the sun is a minimum of 18 degrees above the horizon. The wobble angle of the sustainer and payload combination after burnout is nominally a half cone angle of 13 degrees or less.

Pointing control stability of less than 0.3 arc-seconds, peak to peak jitter, and solar acquisitions of less than 30 seconds after turn on have been recorded. SPARCS also provides a man in the loop system that permits the experimenter to point a SPARCS-controlled rocket while monitoring a video screen. The system is capable of pointing payloads to solar features which could not be clearly defined from ground observations.

Roll angle accuracy is 1.2 degrees; this is achieved with a calibrated magnetometer. For experimenters requiring roll stability to less than .3 degree per hour drift, a rate integrating gyro package (RIG) is available as an option. The RIG unit has demonstrated flight performance of less than 0.1 degree per hour drift.

<u>System Elements</u>

All SPARCS solar sensors use silicon photo voltaic cells as the detecting element. The cells are operated as a current source with current output proportional to illumination. This mode of operation significantly reduces the effects of temperature on the cell output. The output change with temperature is less than 1.5 percent from 10 to 70 deg C. Sun sensor characteristics are contained in the following table:

Table I.2-1 Sun Sensor Characteristics

SENSOR	LISS	MASS	CSS
Weight	16 0z	8 oz	2 OZ
Dimensions	1.4” X 1.4” X 3”	1.0” x 1.0” x 1.4”	0.5” dia
Accuracy	+/- 10 arcsec	+/- 0.5 deg	+/- 1.0 deg
Field of View	+/- 20 deg	+/- 35 deg	+/- 180 deg

The Lockheed Intermediate Sun Sensor (LISS) is a photoelectric fine sun sensor which provides precise pitch and yaw attitude information to the system in the fine control mode. The detector assembly is a quadrant array of four silicon N-on-P cells. Opposite cells are connected back to back to provide an error signal proportional to the difference in radiation falling on each cell A mode sensor. Each mode sensor has a circular field of view of 10.5 degrees and is used by the control system to switch acquisition modes.

The Miniature Acquisition Sun Sensor (MASS) is a restricted field of view (35 degree half cone) sensor used for coarse acquisition. The restricted field of view minimizes albedo effects; since the MASS and CSS signals are summed, solar energy is enhanced. The MASS is mounted on the front of the experiment and is aligned to the LISS electrical null.

The Coarse Sun Sensor (CSS) employs four sensors mounted with their normal lines along the transverse vehicle coordinate axes. Each sensor consists of two solar cells (the main cell and the bias cell) which are shaded by the pedestal construction to restrict the field of view. This ensures that the bias cell does not receive sun energy when the pointing axis is less than a 30 degree half cone angle from the sun. In this condition, the output of the bias cell is a function of the earth albedo. The output of the bias cell is first attenuated by 60% and then subtracted from the main cell output. The bias cell is attenuated to assure positive control for large initial solar pointing error when both cells see the sun.

The magnetometer in use on the SPARCS VII is a miniature, 3-axis Bartington Model MAG-03MS which utilizes the flux gate principle. Fluxgate sensing elements are mounted orthogonally at one end of the enclosure that contains the electronic circuitry; the connector is mounted at the opposite end of the enclosure. The sensors provide three high-precision analog outputs of 10 Volts full scale, proportional to the magnetic field along each axis. The relationship between the magnetic field and the analog output is very linear and the frequency response is flat from dc to at least 1 kHz with a bandwidth in excess of 3 kHz for the standard version. The low output impedance of the unit enables it to be operated over long cables and permits it to be interfaced to low impedance data acquisition systems.

Physical Parameters

The SPARCS VII unit consists of a pair of 17.26 inch diameter inserts for use with a standard Black-Brant rocket. One insert contains the electronics; the other contains the pneumatic control system. The size of the pneumatic section may vary depending on the size of the tank required. A hybrid version that uses just one section to house both pneumatics and electronics has also been developed.

The nominal SPARCS VII high pressure propellant vessel is an 880 cubic inch spherical composite tank manufactured by Brunswick. These tanks offer a proof pressure of 10150 psig, a working pressure of 5075 psig, and a man-rated pressure of 2537 psig.

Payload Interface

Absolute pointing with the Lockheed Intermediate Sun Sensor (LISS) is primarily a function of the alignment of the attitude sensor to the experiment (typically a few arc-seconds). The opportunity to stabilize the experiment and collect useful information on the sun lasts about 5 to 7 minutes, depending upon the weight of the payload and the type of rocket used. Instrumentation for the mapping of the sun's temperature, X-ray intensity, observation of solar features and other spectral data are among the many payloads commonly employed in these experiments.

The Lockheed Intermediate Sun sensor (LISS) contains a reference optical surface (ROS); the ROS is a polished aluminum surface that is an integral part of the main housing. The electrical null axis is aligned to the ROS, which is the reference for alignment to the experiment.

SPARCS provides a man in the loop system that permits the experimenter to point the SPARCS payload while monitoring a video screen.

Ground Support Equipment

The SPARCS VII GSE is a PC Laptop computer used to display the status of the system and to load flight parameters. The GSE includes an external power supply box with a built-in battery charger, an External/Internal switch, a voltmeter to monitor battery voltage and pressure transducers, and a current meter. SPARCS Attitude Control (SACSE) is a hardware-in-the-loop (HILTS) test platform that models a rigid free body (payload) with controlled thrusters, rate and attitude sensors. This system allows a rapid, inexpensive and comprehensive evaluation of ACS electronics, control equations, and flight parameters.

Operation

The SPARCS design is configured to provide rapid solar acquisition and the low pointing jitter required for scientific observation. This is accomplished by SPARCS' three basic modes of operation:

- **The Initial Coarse Mode** utilizes high control thrust and wide angle sun sensors for rapid solar acquisition from any initial attitude.

  Initial solar acquisition is performed using a set of four coarse solar sensors (CSS) mounted on the circumference of the SPARCS insert. These sensors provide a 360 degree field of view which allows solar acquisition from any initial position. Roll position is obtained using a magnetometer that senses payload orientation with respect to the earth's magnetic field. To assure rapid solar acquisition, a miniature acquisition sun sensor (MASS) mounted on the forward end of the payload is used in conjunction with the CSS. The MASS has a 70 degree field of view which reduces the pointing errors induced by solar reflection from the earth's surface (albedo). The narrow field of view shades a major portion of the sensor from the earth in the final pointing orientation.

The coarse mode is terminated when the mode sensor indicates a sun presence signal for period of approximately 4 seconds. The time delay avoids switching on false signals and assures that the vehicle rates are within limits for intermediate mode operation.

- **The Intermediate Mode** is initiated when the pointing error is reduced to less than 10 degrees from the solar disc. The narrow field of view of the fine pointing sensor is used in the intermediate and in the fine mode to eliminate the pointing error induced by solar reflection from the earth's surface (albedo).

  In the Intermediate mode of operation, the CSS, MASS and pitch gyro are disconnected and position control is derived from the FSS. Pitch and Yaw damping terms are obtained from the rate gyro. Roll control remains unchanged in the intermediate mode.

- **The Fine Mode** is the final phase; control thrust is reduced and electronic gains increased to provide the tight control loop required for precision pointing. The pneumatic system uses differential thrust to cancel out transient effects and provide fine control.

  The final pointing phase is performed using a precision sun sensor mounted on the forward end of the payload. This sensor has a 20 degree field of view that is completely shaded from the earth. Absolute pointing with the Lockheed Intermediate Sun Sensor (LISS) is primarily a function of the alignment of the attitude sensor to the experiment (typically a few arc-seconds). The opportunity to stabilize the experiment and collect useful information on the sun lasts about 5 to 7 minutes depending upon the weight of the payload and the type of rocket used.

Roll control remains essentially unchanged for all modes of operation. Minor gain changes are programmed to provide control stability in the various modes of operation as the pneumatic pressure changes. Damping in all modes is provided by a rate gyro. Roll position for SPARCS is derived by the use of magnetometers for roll attitude sensing.

SPARCS VII employs three pairs of electro-magnetically operated poppet valves for payload control. The valve command electronics provides a unique proportional thrust control system. This system, a Differential Pulse Width (DPW) modulator, results in an average control thrust which is proportional to error signal magnitude. The instantaneous thrust level during valve actuation is a function of supply pressure and gas and control nozzle characteristics; it is not altered by modulation. With the DPW technique used in fine mode, opposing valves are actuated to provide the precision control required for sub arc-second pointing. The coarse mode is operated in a standard bang-bang mode to save propellant.

After re-entering the atmosphere, the experiment and the SPARCS VII control system are recovered by parachute, refurbished and re-flown.

I.3 Space Vector Inertial ACS 16391

Description

The Space Vector Inertial ACS is an all in one, digital control system that can orient the payload with respect to an inertial reference. The controller is microprocessor-based resulting in maximum flexibility. The controller, pneumatic subsystem, battery, and platform are all located within a 19-inch skin section. An extra large pressure tank can be used, resulting in a 24-inch length. A dead-band can be programmed so the ACS doesn’t make corrections unless the error is greater than X degrees. This prevents data from being corrupted by abrupt changes in attitude or rates while allowing the system to maintain the desired alignment. The dead-band can be selectively reduced to improve alignment in non-critical phases of the flight.

System Elements

The ACS described here has been designed for and flown on a 17-inch diameter Black Brant payload.

- SVC MIDAS Roll Stabilized Platform as Inertial Reference.
- Digital Control Electronics using Motorola 68HC11 Microprocessor.
- Reaction Control Subsystem

MIDAS Roll Stabilized Platform

- A Euler Inertial Reference Platform for Attitude Control.
- Two Two-Degree-of-Freedom gyros mounted on a spin-stabilized frame.
- Outputs analog Pitch, Yaw and Roll angle data with respect to an uncaged reference frame.
- Includes an Optical Encoder on the Roll axis for incremental Roll data.
- Provides 360□ of freedom about the Pitch and Roll axes and □70□ about the Yaw axis.
- Principal error term is g-sensitive drift - <5□/hr/g each axis.

Digital Control Electronics

- Provides dynamic control and pointing of payload as well as mission timing.
- Obtains Euler angle data from MIDAS platform (and secondary sensors as required.)
- Consists of one circuit card within an enclosure with the following elements:
    1. Motorola 68HC11 Microprocessor with RAM, 32 Kbytes ROM, interrupt timers, and serial interfaces to GSE and to peripherals.
    2. Analog interface to sensors -- Eight 12-bit A-to-D converters (0.025% resolution.)
    3. Analog interface to telemetry -- sixteen 8-bit D-to-A converters (0.4% resolution.)
    4. PWM Nozzle Drivers -- provided pulse-width-modulated drive to RCS thrusters.
    5. Four discrete inputs -- primarily to provide synchronization with payload events.
    6. Four discrete outputs -- provides drive signals to external relays.

Reaction Control Subsystem

• Pressure Vessel	880 in^3 Kevlar-wound, 5000 psi	
Available Impulse – 680 lb-sec (Argon)		
• SVC Pressure Regulator		
• SVC Thrusters (three axes, 8 total)	Max	5 lbf
Nominal	3 lbf	
Range	3 lbf to .09 lbf (min bit)	
• Pressure transducer	0-7500 PSI.	
• Pull-away Pneumatic umbilical.		
• System Battery	24 cell, 28.8 VDC, 2 Ahr NiCad. Reserve capacity for approximately three missions using worst case temperatures.	

- Electrical Umbilical: 27 pin Deutsch or 25 pin Cannon D Pull-away.

<u>Physical Parameters</u>

Attitude Control System

• Weight	103 lbs (with Argon gas)
• Length	23.75 in (mated joint to mated joint)
• Diameter	17.26 in
• Transverse Moment of Inertial	1.5 SF^2
• Polar Moment of Inertial	0.9 SF^2

Typical Payload Parameters

• Weight		600 lbs
• Length		15 ft
• Diameter		17.26 in
• Spin rate		0.75 - 4 rps
• Transverse Moment of Inertial		600 sf^2
• Polar Moment of Inertial		13 sf^2
• Control Moment Arm	Pitch/Yaw	7 ft
	Roll	0.72 ft
• Angular Acceleration	Pitch/Yaw	10°/sec^2
	Roll	30°/sec^2

<u>Payload Interface</u>

Mechanical Interface

- Standard Black Brant Tension Joint – 32 ea 10-32 screws
- Male joint forward, female joint aft (screw heads point toward nose).
- Custom Joints at little or no additional cost.

Electrical Interface

- All electrical interfaces to the payload telemetry system and pull-away start signal are through one 37-pin Cannon connector mounted on the faceplate of the ACS electronics. Access to the connector when the payload is assembled is through a nearby door (at 90° payload).

- Electrical interface to external sensors is via separate sensor connector.
- Interface to command uplink equipment and/or relay control of payload subsystems may require special circuits external to the ACS controller. Support electronics have been developed to interface the ACS to various sensors including magnetometers, rate, inertial, solar, and optical sensors.

Ground Support Equipment

Pad Box

- Enclosed in a "battleship" terminal box and located at the launcher with a short umbilical run to the ACS.
- Pad Box and ACS communicate with the blockhouse ACS Terminal via 8-wire telephone cable at 4800 Baud. Runs greater than 2000 ft feasible.
- Pad Box includes provisions for external power, external/internal power transfer, platform cage/uncage control, and system battery charging. Remotely operates pneumatic boost pump (for pneumatic filling).

Figure I.3-1: Pad Box

ACS Terminal

- Minimum PC with special-purpose interface card and software.
- Controls both the Pad Box and the ACS

Boost Pump

- Provides remote fill of ACS pressure vessel (a normal range safety requirement.) Boosts 2000-psi supply tanks to 5000 psi required by the ACS.

- The Range normally supplies this equipment.

Operation

The mission is pre-programmed into a non-volatile memory. The controller is turned on, the TM verified. The final launcher settings are uploaded as offsets. The gyro is uncaged. The timer starts by a manual key press prior to t = 0. A break wire signals the ACS that the motor has separated and it is OK to start controlling. The ACS then executes the flight program. It can also perform a re-entry maneuver and spin the payload prior to re-entry.

I.4 Space Vector Magnetic ACS 16471-1

Description

The Space Vector Magnetic ACS is an all in one, digital control system that can orient the payload with respect to the earth's magnetic field. The controller is microprocessor-based, resulting in maximum flexibility. A typical mission will have a spinning payload aligned to the local magnetic field. The controller, pneumatic subsystem, battery, and rate sensor are all located within an 11½ inch skin section. The magnetometer used for control can be located anywhere on the payload. A dead-band can be programmed so the ACS doesn't make corrections unless the error is greater than X degrees. This prevents data from being corrupted by abrupt changes in attitude or rates while allowing the system to maintain the desired alignment. The dead-band can be selectively reduced to improve alignment during non-critical phases of the flight.

Figure I.4-1: Pneumatic subsystem, rate sensor, battery

System Elements

The Magnetic ACS described here has been designed for and flown on a 17- inch diameter Black Brant payload.

- Three-axis Flux Gate Magnetometer (usually part of the payload instrumentation).

- Single Axis Rate Sensor. (Duel for roll rate control)
- Digital Control Electronics using a Motorola 68HC11 Microprocessor.
- Reaction Control Subsystem

Magnetometer

- Delvco or similar – part of the payload instrumentation
- □ ̣̃mGaus range (□5 VDC or 0-5 VDC output).

Rate Sensor

- Systron-Donner QRS solid state rate sensor (□100 deg/sec)
- Resolution – 0.2 deg/sec (after digitizing).

Digital Control Electronics

- Provides dynamic control of payloads as well as mission timing.
- Obtains control information from the magnetometers and rate sensor and outputs resolved PWM valve commands to the reaction control subsystem.
- Auto-biases magnetometer and auto-aligns rate sensor.
- Outputs 16 channels of 0-5VDC telemetry data to an analog telemetry system.
- Built-in timer (started at or prior to launch) provides turn-on, gain scheduling and, if required, roll rate control.

Reaction Control Subsystem

• Pressure Vessel	145 in^3 Kevlar-wound, 4000 psi	
Available Impulse – 97 lb-sec (Argon)		
• SVC Pressure Regulator		
• SVC Thrusters (single axes, 2 total)	Max	5 lbf
Nominal	2.5 lbf	
• Pull-away		
• Pneumatic umbilical.		
• System Battery	24 cell, 28.8 VDC, 2 Ahr NiCad. Reserve capacity for approximately three missions using worst case temperatures.	

Electrical Umbilical: 27 pin Deutsch or 25 Cannon D Pull-away.

Physical Parameters

Magnetic Attitude Control System (MACS)

- Weight 50 lbs (with Argon gas)
- Length 9 in (mated joint to mated joint)
- Diameter 17.26 in

Typical Payload Parameters

•	Weight	□600 lbs
•	Length	15 ft
•	Diameter	17.26 in
•	Spin rate	0.75 - 4 rps
•	Transverse Moment of Inertial	600 sf^2
•	Polar Moment of Inertial	13 sf^2
•	Control Moment Arm Pitch/Yaw	7 ft
	Roll	0.72 ft
•	Angular Acceleration Pitch/Yaw	10□sec^2
	Roll	30□sec^2

Payload Interface

Mechanical Interface (Typical)

- Forward – Standard Black Brant Tension Joint
- Aft – V-band (mates to igniter housing).
- (Other arrangements feasible at little or no additional cost)

Electrical Interface

- All electrical interfaces to the payload telemetry system and pull-away start signal are through one 37-pin connector mounted on the faceplate of the ACS electronics.

Ground Support Equipment

Pad Box

- Enclosed in a "battleship" terminal box and located at the launcher with a short umbilical run to the MACS.

- Pad Box and ACS communicate with the blockhouse ACS Terminal via 8-wire telephone cable at 4800 Baud. Runs greater than 2000 ft feasible.

- Pad Box includes provisions for external power, external/internal power transfer, and system battery charging. Remotely operates pneumatic boost pump (for pneumatic filling).

Blockhouse Terminal

- Minimum PC or laptop computer plus RS232/LAN converter.
- Controls both the Pad Box and the MACS.

Boost Pump

- Provides remote fill of the RCS pressure vessel – a normal range safety requirement. Boosts 2000-psi supply tanks to 4-5000 psi required by the ACS.

Operation

Launch operations are fairly straightforward. The mission is pre-programmed into a non-volatile memory. The controller is turned on, the TM verified. The timer can either start by a manual key press prior to t = 0, or at lift-off by the pull of the umbilical. A break wire signals the ACS that the motor has separated and it is OK to start controlling. The ACS then executes the flight program. The system has a redundant timer backup for the control start function. The ACS can spin up the payload for re-entry as a timed event.

I.5 Space Vector Rate Control System P/N 16381-1

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 SVC 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 < .2 degrees per-second in all three axis and maintains the low levels until the payload re-enters the atmosphere. The RCS then spins up the Payload to help dissipate skin heating during re-entry. Payloads can experience environments of < 10 micro-Gs for 300 seconds or more.

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, two conditions must be met:

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

A sounding rocket payload in free fall above the Earth's sensible atmosphere meets the first condition. 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.

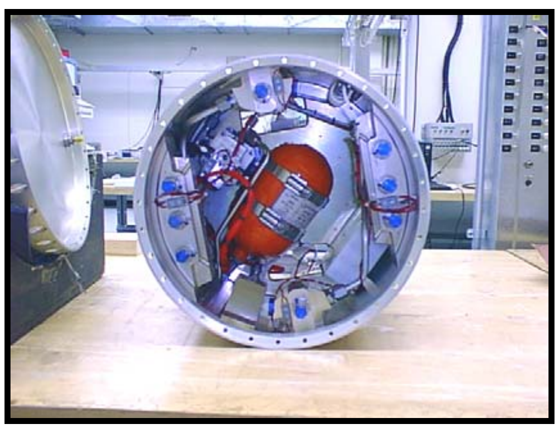


Figure I.5-1: Pneumatic Subsystem = Reservoir, Regulator, Valves And Transducer

<u>System Elements</u>

The RCS described here has been designed for and flown on a 17 inch diameter Black Brant Payload

- Three-axis Quartz Rate Sensor (QRS) Package.
- Digital Control Electronics using a Motorola 68HC11 Microprocessor.
- Reaction Control Subsystem.

<u>Three-axis Rate Sensor</u>

- Three Systron-Donner QRS solid state rate sensors (□ıdeg/sec)
- Resolution – 0.02 deg/sec (after digitizing).
- Mounted on a shock isolating plate to withstand recovery shocks.

Digital Control Electronics P/N 36251-21

- Provides dynamic control of payload as well as mission timing.
- Obtains rate information from the 3-axis rate sensors and outputs PWM valve commands to the reaction control subsystem.
- Outputs 16 channels of 0-5 VDC telemetry data to an analog telemetry system.
- Built-in timer (started at or prior to launch) provides event timing which include turn-on, high/low thrust control, gain scheduling and recovery spin-up.

Reaction Control Subsystem

• Pressure Vessel	145 in^3 Kevlar-wound, 4000 psi
Available Impulse – 97 lb-sec (Argon)	
• SVC Pressure Regulator	Two level, 5:1 range.
• SVC Thrusters (three axes, 8 total)	Max 5 lbf
Nominal	2 lbf / 0.4 lbf
Range 2 lbf to .04 lbf (min bit)	
Pressure Transducer	0-7500 PSI.
Pull-away Pneumatic umbilical.	
• System Battery	24 cell, 28.8 VDC, 2 AHR NiCad. Reserve capacity for approximately three missions using worst case temperatures.

Electrical Umbilical: 27 pin Deutsch or 25 pin Cannon D pull-away

<u>Physical Parameters</u>

Rate Control System

• Weight	52 lbs (with Argon gas)
• Length	9.5 in (mated joint to mated joint)

- Diameter 17.26 in

Typical Payload Parameters

- Weight □1000 lbs
- Length 15 ft
- Diameter 17.26 in
- Transverse Moment of Inertial 1000 sf^2
- Polar Moment of Inertial 13 sf^2
- Control Moment Arm Pitch/Yaw 7 ft

  Roll 0.72 ft
- Peak Angular Acceleration .26 – 2.3 ̃□sec^2 (two-level)

  Pitch/Yaw

  Roll 2 – 13 ̃□sec^2 (two-level)

Payload Interface

Mechanical Interface

- Forward and aft – standard Black Brant tension joint.

Electrical Interface

- All electrical interface to the payload telemetry system and pull-away start signal are through one 37-pin connector mounted on the face plate of the ACS electronics.

Ground Support Equipment

Pad Box

- Enclosed in a “battleship” terminal box and located at the launcher with a short umbilical run to the RCS.
- Pad Box and ACS communicate with the blockhouse RCS Terminal via 8-wire telephone cable at 4800 Baud. Runs greater than 2000 ft feasible.
- Pad Box includes provisions for external power, external/internal power transfer, and system battery charging. Remotely operates pneumatic boost pump (for pneumatic filling.)

Blockhouse Terminal

- Minimum PC or laptop computer plus RS232/LAN converter.

- Controls both the Pad Box and the RCS.

Boost Pump

- Provides remote fill of the RCS pressure vessel – a normal range safety requirement. Boosts 2000 psi supply tanks to 4000 psi required by the RCS.

Operation

Launch operations are fairly straightforward. The mission is pre-programmed into a non-volatile memory. The controller is turned on and the TM verified. The timer can either start by a manual key press prior to t = 0, Typical, or at lift-off by the pull of the umbilical. A break wire signals `the RCS that the motor has separated and it is OK to start controlling. The RCS then executes the flight program. The system has a redundant timer backup for the control start function. The RCS can spin up the payload for re-entry as a timed event.

I.6 Aerojet Mark VI Inertial ACS

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 I.6-1.

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.

Figure I.6-1. Aerojet Mark VI ACS

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, and Yaw	10 deg/sec

Scan Rates	0.002 to 10 deg/sec
Programmable Intervals	255
Interval Size	0 - 130 sec
Interval Resolution	0.002 sec
Interval Accuracy	0.01%

System Elements

1. **Power Supply** - Provides 12 different Voltage and Frequency combinations to all of the various components. It contains the switches that control the platform (power) and star tracker (power and high voltage). Uses high rate silver cells for batteries.
2. **Controller** – Utilizes a Motorola 6800 microprocessor clocked at 900kHz to achieve system flexibility. The controller is a modular design with 6 plug in boards for the digital section, 6 boards for the analog circuitry, and 3 fixed boards. It is the heart of the ACS in that it processes the signals from the tracker, TRIGs, Platform, and the GSE to generate the valve signals. The system is predominantly analog.
3. **Platform** – Manufactured by the Space Vector Corporation (SVC). Has full motion in both roll and pitch axes and +/- 85 degrees in yaw. It weighs 8 lbs. and draws from one to two amps of power, depending on servo load. It will operate at roll rates up to 720 degrees per minute. Maximum drift rate is one degree per minute when subjected to vibrations.
4. **TRIGs** (Tuned Restraint Inertial Gyro) Two two-axis sensors mounted orthogonally giving Pitch, Roll, Yaw, and Slave Pitch channels. Operates at 70 degrees C.
5. Two **removable reference mirrors** are mounted on a fixture to allow for fine calibration of the TRIGs.
6. **The Pneumatic system** is the Separable Pneumatic System (SPS) that is also used for the STRAP systems, with very minor changes.
7. A **Ball Brothers' Tracker** provides stellar updates. The tracker has an 8x8 degree Field Of View (FOV) and a Visual Magnitude Range of –3 to +4 degrees. The noise equivalent angle is 10 arcsec at a VMR of +3.
8. The deck plate and cabling make up the rest of the system.

Physical Parameters

The MarkVI has been adapted with extra gas tanks and a tri-level thrust, pitch and yaw, module. These add to the weight and size, but the basic system without gas is described below. Nitrogen, Argon, and Neon gases are available, depending on the amount of impulse needed.

Length (in.)	22.00
O.D. (in.)	17.26
Wt. (lbs.)	120.00
IRoll (Sl-Ft^2)	0.963
IPitch (Sl-Ft^2)	1.538
C.G. (in. from Fwd)	9.82

Payload Interface

The interface to the payload is by two electrical connections. The MarkVI requires a separation break-wire to signal that it should start controlling the payload. The Star Tracker signals must be routed through the payload, up to the ACS. The signals and pneumatic lines going to the ORSA mounted valves must be fed through the forward sections of the rocket.

Ground Support Equipment

The GSE consists of the launch console, portable computer, power supply, and cabling. The boost pump and its control console are used if 5k gas cylinders are not available.

Operation

The launcher position and launch time are entered into a software package. This program calculates the maneuver to the first target, checks the other maneuvers and uploads the program to the ACS flight computer. The countdown progresses, the platform is uncaged, and the rocket launches. The MARI platform maintains an inertial reference, within a few degrees, through the boost phase of the flight. At motor separation, the ACS begins to control the payload, using the MARI’s error signals. It reduces the roll until it is able to control the pitch and yaw, and then stabilizes the payload. This is referred to as capture. It then returns the payload to the same inertial attitude that it had on the launcher.

After arriving at the launcher attitude with rates that have settled out, the controller switches to the TRIGs. The ACS then points the star tracker at the first of two guide stars. This maneuver, and all others, are programmed in as steps and loaded before launch. It then switches to tracker mode. The pitch and yaw errors can be corrected when the tracker signals that the rocket is pointing at the first guide star. The ACS then moves the payload, using the TRIGs, toward the second guide star. The error measured at the second guide star is attributable to error in the roll channel. A portion of this information is then used to update the roll channel. All three channels have now been updated and the ACS is localized.

The ACS then goes to the science target. If the science target is trackable, it can be used as the second guide star. The uplink command system can direct the ACS to adjust the pointing, or move to a different target altogether. At a specific time into the mission, prior to re-entry, the ACS then begins to spin the payload. Spin-up is desired so the rocket can get heated evenly, preventing hot spots. Later, the rest of the gas is vented so the pressure vessel will be empty when the payload is recovered.

I.7 Aerojet Mark VID Inertial ACS

Description

The MarkVID is the newer addition to the MarkVI. It uses a Pentium class processor and is entirely digital. The added processor capability allows the ACS to maneuver directly to the first guide star, without stopping at launcher attitude. This requires less time to do the stellar updates. The TRIGs are from a different manufacturer, the power supply is much simpler and the entire system is lighter. The fundamental blocks are the same, but the details are vastly different. The processor has more I/O flexibility so some of the subsystems can be modified to be high speed serial. This reduces system complexity and noise. It has flown twice and seems to be a reliable and capable addition to the fleet. Performance in all aspects should be much improved over that of the MarkVI.

Capabilities

- **Performance**

  Pointing Accuracy

  2-3 Arcmin without uplink (depending on star tracker mount stability)

  0.1 Deg/Hr drift rate

Pointing Stability

- 1 Arcsec/sec jitter
- 1 Arcsec deadband

- **Functional**

Reduce detrimental flight time

- 40 degree/sec maneuver rates
- Maneuver directly to the first target after payload despin
- Simultaneous three-axis maneuver/ Inertial maneuvers

Support MarkVI and new control modes

- Despin
- Maneuvers
- Rate Control
- Integrated gyro rate plus derived rate
- Tracker
- Low drift gyro
- Low jitter
- Low drift gyro plus filtered tracker
- Special mode
- Future control modes such as Earth oriented tracking
- Support odd-axis and third axis updates and tracking
- Support analog command uplink
- Support serial command uplink

- **Interfaces**
  - Maintain compatibility with current MarkVI payload interfaces
    - NASA bi-level pneumatics
    - NASA telemetry
    - Space Vector Corp MARI platform
    - Ball Brothers star tracker
    - Analog interface to the telemetry system
    - Operate with existing launch facility landlines

Operate with new interfaces

Kearfott Conex1/S gyros interface

Tri-Level pneumatics (all axes)

Serial interface to command system

Asynchronous serial telemetry interface

System Elements

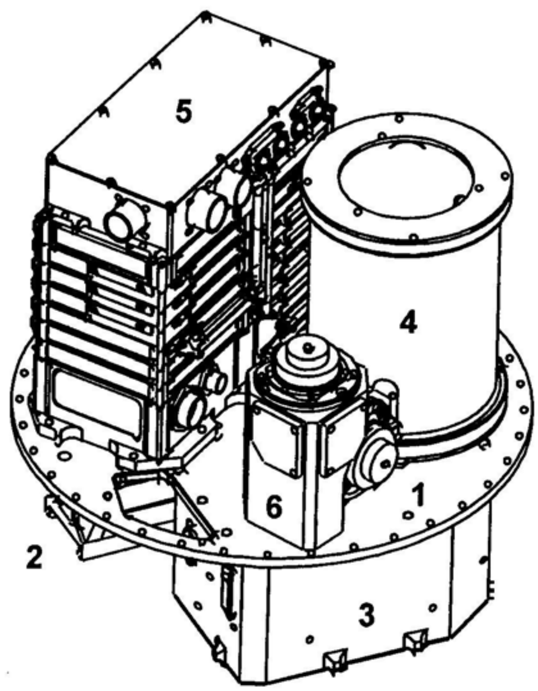


Figure I.7-1. System Elements

1. Base Plate
   - Similar to the MarkVI
2. Battery Rail
   - Mounted in a dedicated position to maintain compatibility with the MarkVI battery and roll mis-alignment measuring apparatus
3. Gyro Electronics Enclosure
   - Limited to five inches in height while increasing its strength
   - All circuit cards are fully supported
   - Provides a shield between the heater and interface boards
   - Simplified manufacture and assembly
   - Access covers for potentiometer adjustment

4. MARI Gyro
   - Same Pitch and Yaw orientation as the MarkVI
5. PC104 Stack Assembly
   - Repackaged to accommodate two columns of five PC104 board assemblies
   - Assembly includes: base assembly with power supply and backplane, PC104 modules, lid assembly with connector housing
   - Improved inter-module alignment
   - Reduced or eliminated entry of dirt and debris
   - Improved base design for additional mounting strength

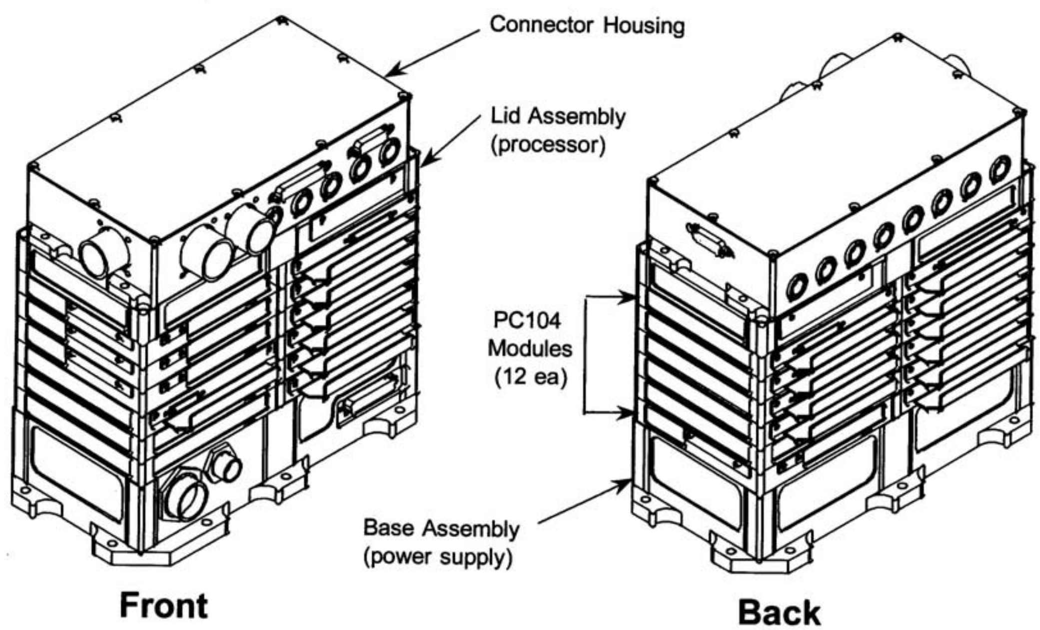


Figure I.7-2. PC104 Stack Assembly

6. Mirror / Gyro Mount
   - Combined gyro and mirror mount to eliminate alignment problems
   - Simplified roll-axis alignment to system base plate
   - Added adjustment mechanism for initial alignment
   - Redesigned to mount new Kearfott gyros

<u>Physical Parameters</u>

The MarkVID utilizes the same skin and pneumatics section as the MarkVI, so most of the physical parameters are the same. There is a small weight savings over the MarkVI bi-level system, and a six-pound savings over the MarkVI tri-level system. The dimensions are with the electronics installed in the skin, with no gas in the pressure vessel.

	Mark VI Bi-Level	Mark VI Tri-Level	Mark VID
Length	22.00 in	22.00 in	22.00 in
Diameter	17.26 in	17.26 in	17.26 in
Weight	120.00 lbs	125.25 lbs	119.25 lbs

Payload Interface

The interface to the payload is by two electrical connections. The MarkVID requires a separation break-wire to signal that it should start controlling the payload. The Star Tracker signals must be routed through the payload, up to the ACS. The signals and pneumatic lines going to the ORSA mounted valves must be fed through the forward sections of the rocket.

Ground Support Equipment

The GSE consists of the launch console, portable computer, power supply, and cabling. The boost pump and its control console are used if 5k gas cylinders are not available.

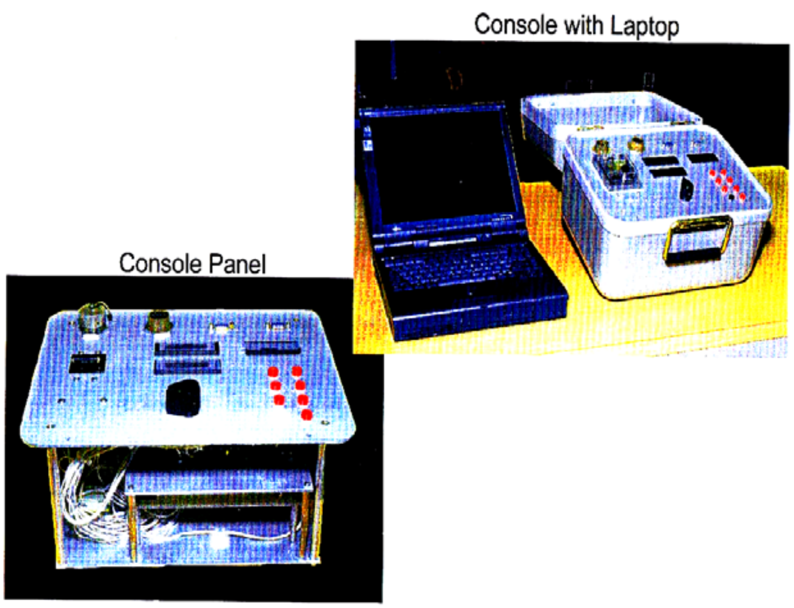


Figure I.7-3. Ground Support Equipment (GSE)

Operation

The fundamental operation for the MarkVI is as follows:

The launcher position and launch time are entered into a software package. This program calculates the maneuver to the first target, checks the other maneuvers and uploads the program to the ACS flight computer. The countdown progresses, the platform is uncaged, and the rocket launches. The MARI platform maintains an inertial reference, within a few degrees, through the boost phase of the flight. At motor separation, the ACS begins to control the payload, using the MARI's error signals. It reduces the roll until it is able to control the pitch and yaw, and then stabilizes the payload. This is referred to as capture. It then returns the payload to the same inertial attitude that it had on the launcher.

After arriving at the launcher attitude with rates that have settled out, the controller switches to the TRIGs. The ACS then points the star tracker at the first of two guide stars. This maneuver, and all others, are programmed in as steps and loaded before launch. It then switches to tracker mode. The pitch and yaw errors can be corrected when the tracker signals that the rocket is pointing at the first guide star. The ACS then moves the payload, using the TRIGs, toward the second guide star. The error measured at the second guide star is attributable to error in the roll channel. A portion of this information is then used to update the roll channel. All three channels have now been updated and the ACS is localized.

The ACS then goes to the science target. If the science target is trackable, it can be used as the second guide star. The uplink command system can direct the ACS to adjust the pointing, or move to a different target altogether. At a specific time into the mission, prior to re-entry, the ACS then begins to spin the payload. Spin-up is desired so the rocket can get heated evenly, preventing hot spots. Later, the rest of the gas is vented so the pressure vessel will be empty when the payload is recovered.

The implementation is similar for the MarkVID, with a few minor differences. The maximum maneuver rate is up to 40 degrees per second, from 10. The processor is smart enough to go directly from despin/ACS enable to the first guide star. These changes should increase time on target by reducing time spent maneuvering and acquiring the first guide star.

.

Appendix J: 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 2002. 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.

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 K: Sounding Rocket Launch Ranges

K.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 K.1-1 is a photo 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.

Figure K.1-1. White Sands Missile Range

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.

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 11.3 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

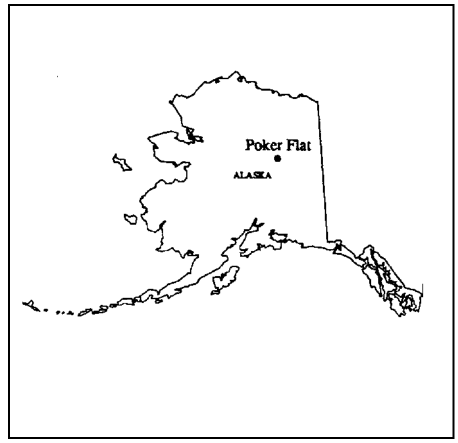
The PI is responsible for shipping the experiment and associated support equipment to WSMR. This includes all costs. Air freight is the usual mode.

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

K.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 K.2-1 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.

Figure K.2-1 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. 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

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:

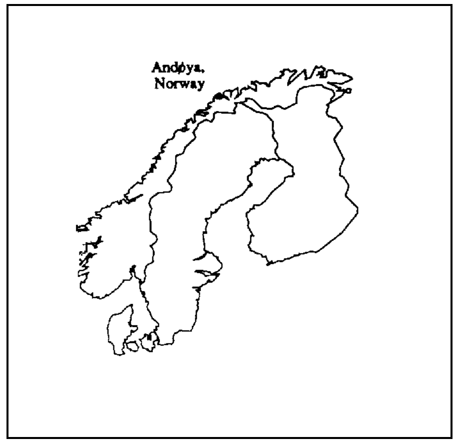
Director, Poker Flat Research Rang
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99775-7320

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

K.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 K.3-1 is a photograph of the launch area.

Figure K.3-1: 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:

Figure K.3-2: Launch at Andoya

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:

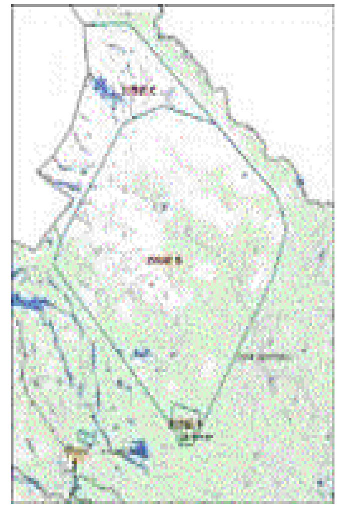
Andøya Rocket Range
P.O. Box 54
N-8480 ANDENES, Norway

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

Tromsø Telemetry Station:

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

K.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.

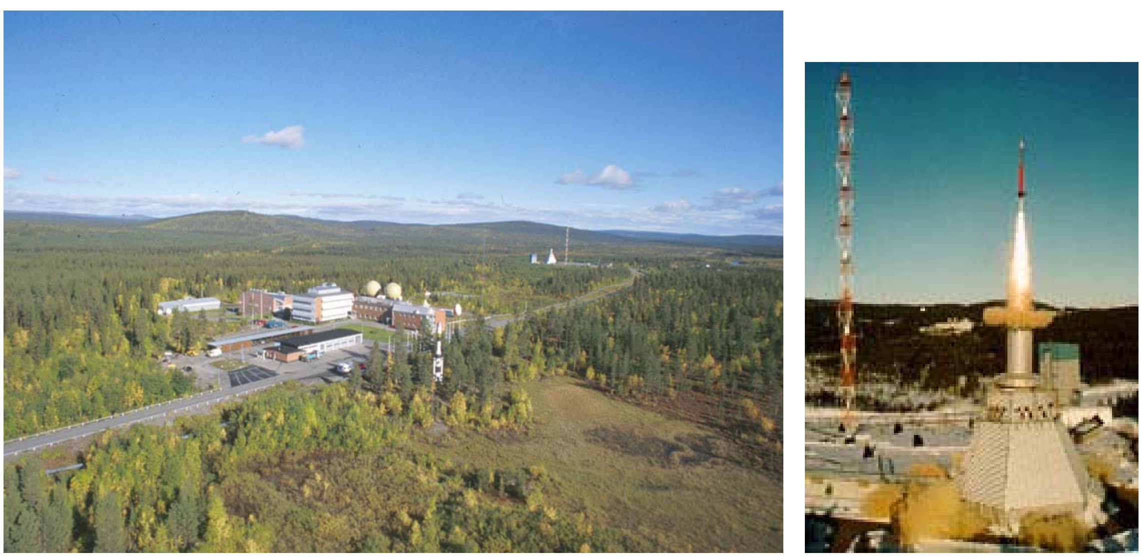


Figure K.4-1: Esrange Sweden Launch Area

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 L: Wallops Flight Facility Digital Telemetry System (PDP11/60): Dites Tape Format

The Dites tape format has now been replaced with the PTP (Programmable Telemetry Processor) CD-ROM format described below.

PTP CD-ROM Data Format

This document describes the CD-ROM data format generated by the "AVTEC SYSTEMS" Programmable Telemetry Processor for Windows NT (PTP NT).

The source of data will be telemetry data obtained from NSROC Sounding Rocket Missions. This Data Format is referred to as "PTP NT" format.

PTP PCM FORMAT

MUX (8 bytes)	Data Field (depends on Frame Length and Word Size)

Format Option #1: File Recorder Format with Record MUX Header enabled.

MUX (8 bytes)	PB-4 (6 bytes)	Data Field (depends on Frame Length and Word Size)

Format Option #2: File Recorder Format with Record Time Stamp enabled. (MUX header is automatically inserted).

MUX (8 bytes)	Appended Status (48 bytes)	Data Field (depends on Frame Length and Word Size)

Format Option #3: File Recorder Format with Record Status enabled. (MUX header is automatically inserted).

MUX (8 bytes)	**PB-4** (6 bytes)	Appended Status (48 bytes)	Data Field (depends on Frame Length and Word Size)

Format Option #4: File Recorder Format with Record Time Stamp and Record Status enabled. (MUX header is automatically inserted).

It is intended to only provide format option #2.

PTP MUX Header Format

Item	Field Name	Format & Size	Value
1	Header Synchronization	Unsigned integer (4 bytes)	30030330 hex
2	Source Module	Unsigned integer (1 byte)	Equal to the source module number minus 1. For example, if Module 3 sends a buffer to the file recorder, the Source Module field is equal to 2.
3	Header Types	Unsigned integer (1 byte)	Defines the other header types that follow the MUX Header. 0 = No additional headers 1 = PB-4 Time Code 2 = Serial Input Appended Status 3 = Both PB-4 and Appended Status
4	Next Header Offset	Unsigned integer (2 bytes)	Offset to the next MUX header in the file relative to the end of the current MUX header. Note that this is a Little Endian representation, the least significant byte precedes the most significant byte in the file. For example for 8 bit words and a PCM frame length of 128, the Next Header Offset appears in the file as 80 00 hex. (A 6 byte time stamp is normally after the header)
	Total Length	8 bytes	

NASA PB-4 Time Code Format

Item	Field Name	Format & Size	Value
1	Days of Year	Unsigned integer (11 bits)	Range 1 to 365
2	Milliseconds of Day	Unsigned integer (27 bits)	Range = 0 to 86399999
3	Microseconds of a Millisecond	Unsigned integer (10 bits)	Range = 0 to 999
	Total Length	6 bytes	

Note : "Days of Year" field uses only the least significant 9 bits of the 11 bit field.

PTP Data Field Format

Data field contains entire PCM minor frame including Frame synchronization pattern and any frame counters. PCM word sizes greater that 8 bits will be right justified in 2-byte words. The most significant byte will precede the least significant byte. If word lengths of 9 to 15 bits are used, the user will have to mask out the uppermost bits in the first word. (They will not be zeros.) The most significant bit (MSB) precedes the least significant bit (LSB) for each byte. The number of bytes per field is equal to the number of PCM words per minor frame if PCM word length is 8 bits. For PCM word lengths greater than 8 bits, the number of bytes per field is equal to 2 times the number of PCM words per minor frame.

Appendix M: 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 N: 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		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		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		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 SPARCS Calculations & Calibrations Only

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 INTEGRATION COMPLETE

	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

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
Baseline	July 2001	Initial Release
Revision 1	May 2003	1. Cover changed to reflect new Directorate Title 2. Verification Footer Added 3. Document Control # Added 4. RSM93 changed to RSM-2002 (Range Safety Manual) 5. NHB 1700 changed to NPG 8715.3 (NASA Safety Manual) 6. Air Operations Manual changed to 830-AOM-0001 Aircraft Operations Manual (AOM) 7. Dialing access changed from 8 to 9 8. Breakfast hours changed from 0800 to 0900 9. Reference to Lithium Batteries removed 10. Reference to WFF Instrumentation Handbook removed. 11. Change History Log added.

ACRONYM LIST	
ACS	Attitude Control System
AIB	Anomaly Investigation Board
ARC	Atlantic Research Corporation
ASI	Agency Safety Initiative
BB	Black Brant
BGS	Boost Guidance Systems
CBW	Constant Bandwidth
CDR	Critical Design Review
CEA	Center Export Administrator
CG	Center of Gravity
cps	cycles per second
CSS	Coarse Sun
DOD	Department of Defense
DPI	Data Processing Installation
DPW	Differential Pulse Width
DR	Design Review
DRCS	Data Reduction Computer System
DRM	Design Review Memorandum
ECS	Engineering Computer System
ESA	European Space Agency
FAA	Federal Aviation Administration
FM	Frequency Modulation
FOV	Field of View
FRP	Flight Requirements Plan
FSS	Fine Sun Sensor
FTS	Federal Telecommunications System
GNC	Guidance, Navigation and Control

GPS	Global Positioning System
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
IMSS	Information Management Support System
IMP	Integrated Management Plan
IRMA	Ignition Recovery Module Assembly
LISS	Lockheed Intermediate Sun Sensor
LSB	Least Significant Bit
LSRS	Launch Status Review System
MACS	Magnetic Attitude Control System
MASS	Miniature Acquisition Sun Sensor
MCR	Close-out Report
MFT	Multi-Function Timer
MIC	Mission Initiation Conference
MM	Mission Manager
MOI	Moments of Inertia
MRR	Mission Readiness Review
MSB	Most Significant Bit
MTF	Magnetic Test Facility
NRZ	Non-Return to Zeros
NSROC	NASA Sounding Rocket Operations Contract
NSRP	NASA Sounding Rocket Program
ORSA	Ogive Recovery System Assembly
OSD	Operations and Safety Directive
OSSA	Office of Space Science and Applicationss
PBW	Proportional Bandwidth
PCM	Pulse Code Modulation
PFRR	Poker Flat Research Range
PI	Principal Investigator

PIR	Pre-Integration Review
PTP	Programmable Telemetry Processor
PTP NT	Programmable Telemetry Processor for Windows NT
QE	Quadrant Elevation
QRS	Quartz Rate Sensor
RCS	Rate Control System
RDM	Requirements Definition Meeting
RDMM	Requirements Definition Meeting Memorandum
RDP	Radiation Distribution Pattern
RIG	Rate Integrating Gyro
RTCS	Real-Time Computer System
SACSE	SPARCS Attitude Control System
SCS	SPARCS Command System
SPARCS	Solar Pointing Attitude Rocket Control System
SPOD	Sub-orbital Projects and Operations
SRP	Sounding Rocket Program
SRPO	Sounding Rockets Program Office
SRWG	Sounding Rocket Working Group
SVC	Space Vector Corporation
T&E	Test and Evaluation
TM	Telemetry
TRADAT	Trajectory Data System
TRIG	Tuned Restraint Inertial Gyro
UPS	United Parcel Service
VAB	Vehicle Assembly Building
VCO	Voltage Controlled Oscillator
WFF	Wallops Flight Facility
WSMR	White Sands Missile Range