

FINAL REPORT
FEASIBILITY STUDY OF THE BOEING SMALL RESEARCH
MODULE (BSRM) CONCEPT
NAS 2-8526

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FOREWORD

This document is one of a series of four (4), describing the design, manufacture, and management of the Boeing Small Research Module (BSRM). The documents constitute the final report of Contract NAS2-8526, "Feasibility Study of a Small Research Module Concept," performed for the Advanced Space Projects Office of NASA-Ames Research Center.

The objective of the study was to define a low cost standardized spacecraft combining an existing spacecraft design with USAF Space Test Program (STP) management control and NASA aircraft program (ASSESS) instrument integration techniques. The results of the study, presented in this set of documents, includes a preliminary spacecraft design; plans for the management, development, manufacture, test and operation of the spacecraft; and rough order of magnitude (ROM) costs.

The four documents included in this final report are:

D180-18450-1	Executive Summary
D180-18450-2	BSRM Design Document
D180-18450-3	BSRM Program Definition
D180-18450-4	BSRM Program Costs

INTRODUCTION

This document describes the design, capabilities, and subsystem options for the Boeing Small Research Module (BSRM). Specific scientific missions are defined based on NASA-Ames Research Center requirements and the BSRM capability to support these missions is discussed. Launch vehicle integration requirements and spacecraft operational features are also presented.

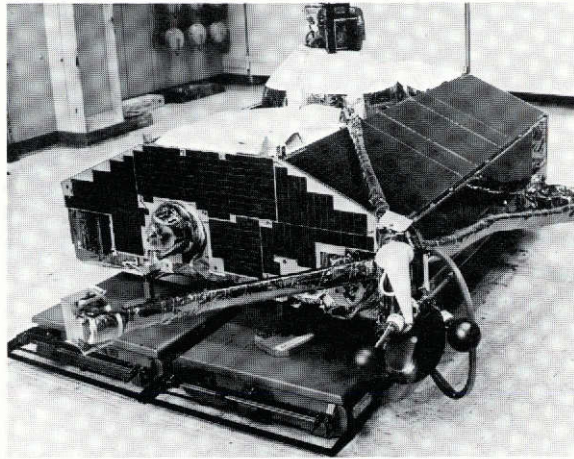
The BSRM program is a direct outgrowth of the successful S3 series of satellites fabricated by Boeing for the Air Force Space Test Program (STP) organization of SAMSO (Figure 1). All aspects of the BSRM program including the system integration design concepts, test program, AGE/GHE support and operational features have been proven on the S3 and other low cost Boeing spacecraft programs.

Three spacecraft were fabricated in the S3 program using standardized structure and subsystems for all three vehicles, successfully demonstrating the standardized, modular spacecraft concept. A total of 17 principal investigators supplied 35 experiments and 69 experimental packages which were successfully integrated into the three spacecraft.

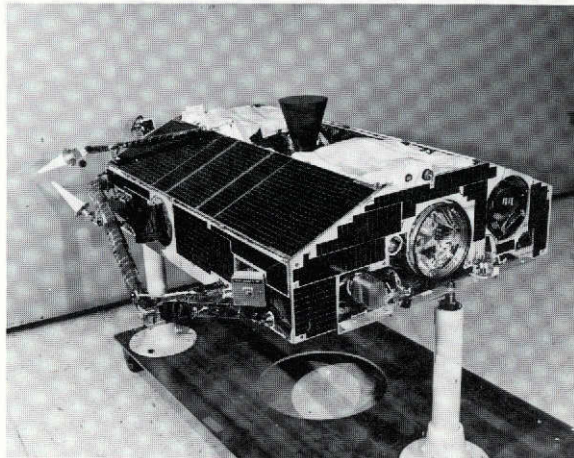
This document is one of a series constituting the Final Report for study contract NAS2-8526, Feasibility Study of a Small Research Module Concept. The total series of documents are as follows:

- D180-18450-1 Executive Summary
- D180-18450-2 BSRM Design Document
- D180-18450-3 BSRM Program Definition
- D180-18450-4 BSRM Program Costs

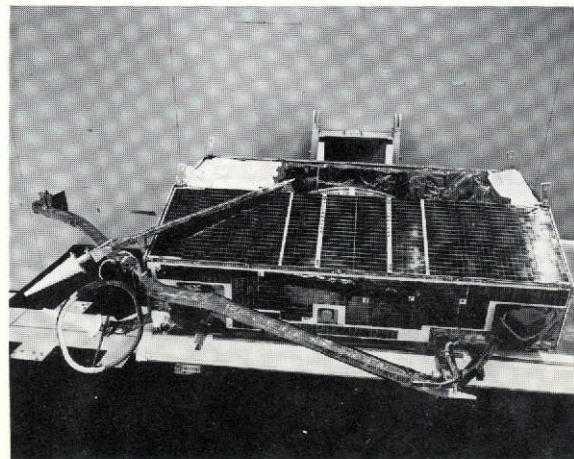
Small Secondary Satellites (S3)



S3-1



S3-2



S3-3

Figure 1. *BSRM Is Based on the Successful USAF S3 Program*

STUDY CONCLUSIONS

This study has demonstrated the adaptability of a Small Research Module to cost-effective earth orbital science. A baseline spacecraft design with a small number of subsystem options can readily accomplish a broad spectrum of scientific objectives at minimum cost. Boeing has demonstrated this concept on the successful USAF S3 program and has adapted S3 proven principles to the proposed BSRM program.

The wide variety of specific missions analyzed in this study do not impose requirements beyond the capability of the baseline BSRM and its defined set of options. Consideration of NASA-Ames program objectives has shown that the low-cost techniques successfully used by Boeing on USAF spacecraft programs for many years can be applied directly to NASA missions. These low-cost techniques have resulted in a demonstrated flight reliability of 96% (22/23 successful

launches). Program costs will be comparable to those previously demonstrated if the existing NASA-Ames approach to the BSRM program is maintained.

Consultation during this study with many Principal Investigators (PI) has shown their desire for working closely with the spacecraft integrator and BSRM standard interfaces. NASA-Ames' experience in the Airborne Sciences Program (ASSESS) and Boeing's experience on the S3 program affirms the advantages of full experimental involvement, standardized interfaces, and minimum documentation and control in conducting scientific research. For an efficient BSRM program, early coordination with experimenters and constant "cross-talk" throughout the program is essential. The precise definition, and subsequent freeze, of spacecraft subsystem interfaces and requirements is necessary to permit each PI to complete his experiment design cost-effectively and on schedule.

BASELINE DESIGN

The BSRM is a low-cost, highly reliable spacecraft based on the flight proven S3 satellite design. The extensive use of the S3 satellite subsystems ensures a cost-effective BSRM program. The baseline BSRM design is a spin-stabilized vehicle, configured to be launched on Scout as shown in Figure 2. Existing AGE, GHE, test facilities, software, procedures and other documentation are available to support BSRM. The Boeing-owned Mobile Test Lab will be used for automatic test and checkout, minimizing BSRM program costs.

The BSRM design offers the following advantages:

- Flight-proven subsystems and equipment, qualified for Scout, are used extensively to maximize reliability and reduce cost.
- Considerable mission flexibility is provided by a set of optional kits which accommodate a variety of experiment and mission requirements.
- Each BSRM experiment is located to achieve scientific objectives and to provide thermal control, mass balance, and proper spin inertia ratio within the gross weight limit.
- Compatibility with the STDN ground system is ensured through incorporation of qualified components and the necessary frequency changes in the S3 equipment.
- Software developed by Boeing for the S3 is readily adaptable to a wide variety of missions. The original programs will be modified to be compatible with NASA ground system computers.
- Proven EMI/EMC control techniques and methods are used to ensure system test and mission success.

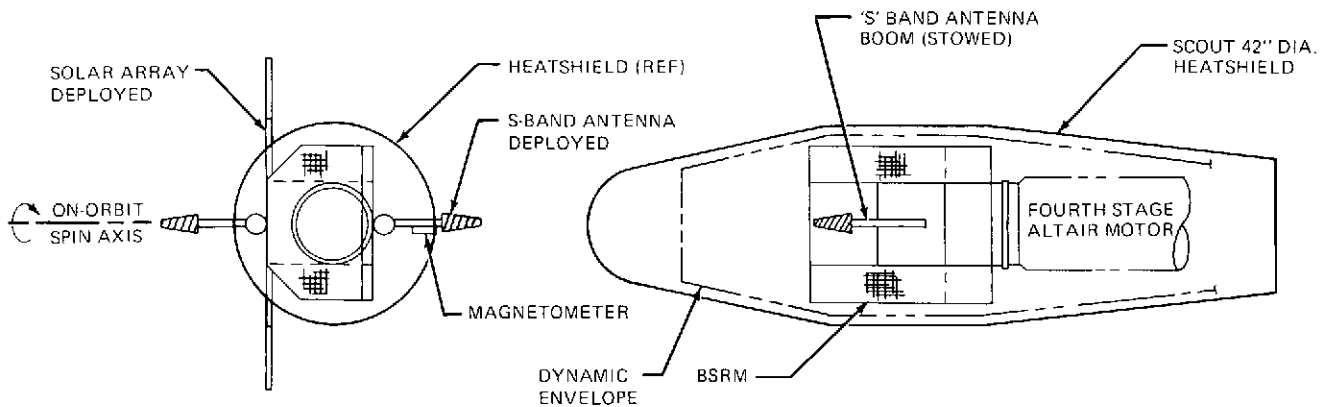


Figure 2. BSRM Meets All Scout Interface Requirements

Configuration: The baseline BSRM meets all Scout interface requirements. The spacecraft general arrangement features a minimum of deployments, up to ten cubic feet for experiments and considerable freedom in locating payloads to meet scientific requirements.

The BSRM structure is formed by longitudinal beams and transverse bulkheads of conventional aluminum construction with extruded and formed chord members and stiffened shear webs. The short, deep beams and bulkheads of the box provide a stiff, weight-efficient structure that meets the critical design objectives of minimum weight, commonality between BSRM configurations, and booster stiffness requirements.

The BSRM weights are summarized in Table 1. A contingency is provided for normal weight growth. The weights shown for the subsystems represent almost all actuals since the equipment is available and flight proven. The large proportion of actuals at this stage of the configuration development provides high confidence in the satellite weight and performance.

Electrical Power: The BSRM electrical power subsystem uses a deployed sun-pointing array and direct energy transfer subsystem. All components were flight-proven on the S3 satellite.

Spacecraft electrical power is provided by a true direct energy transfer (DET) system (Figure 3). Power from the solar array is transferred directly to the spacecraft bus which is controlled to 28 ± 4 VDC. There are no series voltage regulating elements between the solar array and the spacecraft bus, between the solar array and battery, nor between the battery and the bus. System efficiency is thus maximized reducing total subsystem weight.

The solar array consists of four deployable panels and one fixed panel, and is capable of producing an estimated 168 watts of electrical power at the end of a six month mission when oriented in a sun-pointed mode. Power during occulted periods is provided by a sealed ten ampere-hour nickel-cadmium battery. Battery charge/discharge history is monitored by an ampere-hour meter to automatically control battery charge levels and provide safeguards against excessively deep depths-of-discharge. Solar array voltage applied to the bus is controlled by shunting excess current through load resistors. The voltage limiter provides two-level control for full and trickle charging of the battery.

Critical battery temperatures are maintained through all mission phases by a flight-proven thermal louver facing deep space. Battery cells are fastened to a radiator plate directly under the louver to ensure close thermal coupling.

Table 1. The Weight of BSRM Is Low, Leaving a Substantial Payload Allowance

	LBS	KG
POWER SUBSYSTEM	41.30	18.77
*ATTITUDE & CONTROL DETERMINATION SUBSYSTEM	33.70	15.32
TT&C SUBSYSTEM	40.50	18.41
STRUCTURE	51.00	23.18
WIRING	19.00	8.64
THERMAL (LOUVERS, PAINT, BLANKETS, ETC.)	16.00	7.27
	<hr/>	<hr/>
	201.50	91.59
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GROWTH ALLOWANCE (15%) ON STRUCTURE, WIRING & THERMAL	12.90	5.87
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TOTAL WEIGHT + GROWTH ALLOWANCE =	214.40	97.46

*ADD 18.3 LBS (8.31 KG) FOR THREE-AXIS SPACECRAFT

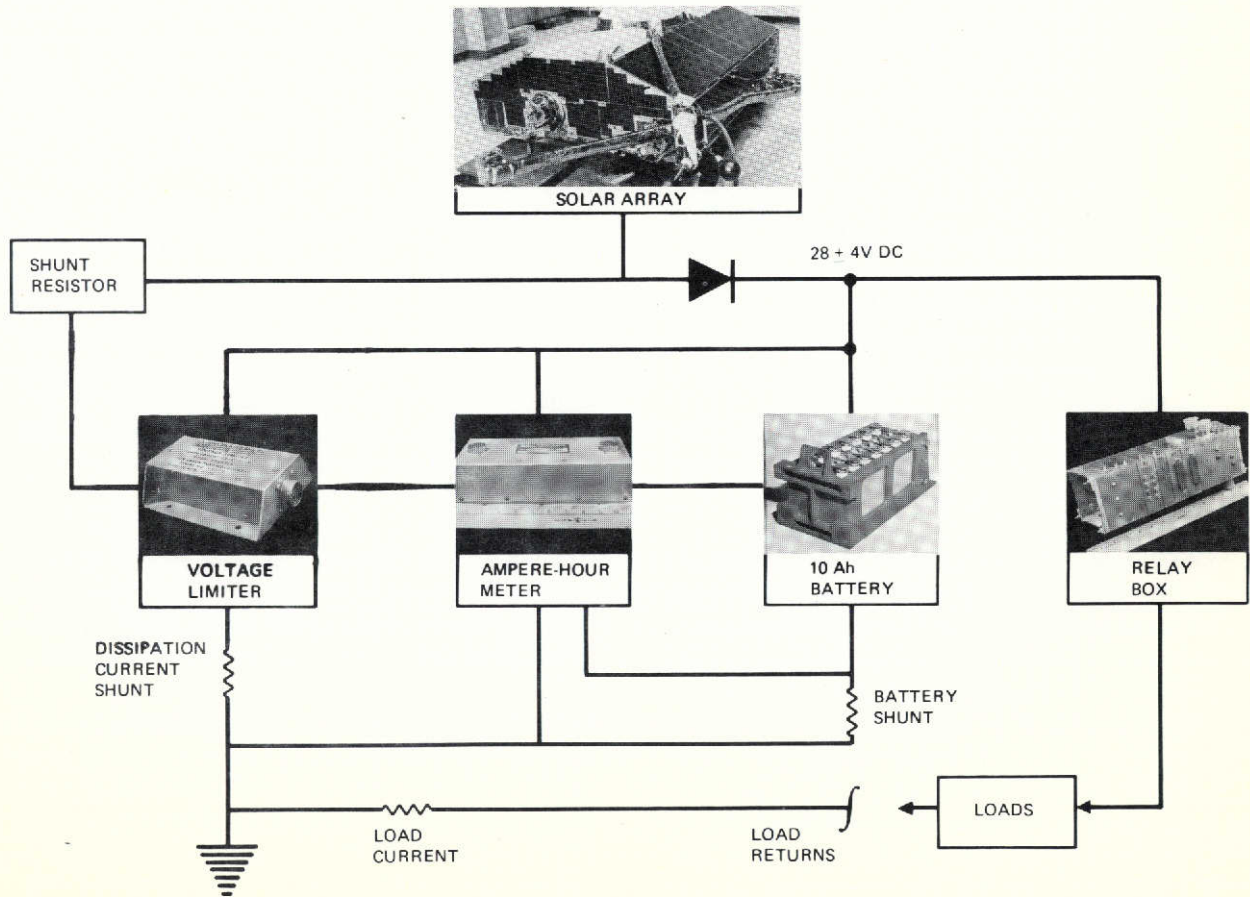


Figure 3. The BSRM Electrical Power Subsystem Is Identical to the Flight-Proven S3 Subsystem

Attitude Control and Determination: Attitude control and determination uses techniques and hardware developed for the USAF P72-1 and S3 satellites. The flight-proven system provides ground-closed control with low duty cycle, pointing accuracy of ± 1.0 degrees, determination accuracy of ± 0.5 degrees, and spin rate control of 0.5 rpm per hour.

The basic system components (Figure 4) consists of three electromagnets with associated electronics for switching and setting current levels, earth, sun and magnetic field sensors, and a passive fluid loop wobble damper. The precession coil which controls the spin axis orientation is mounted in the spacecraft parallel to the momentum vector. A second coil, lying in the plane of the spin, is used to control spin rate. All components are off-the-shelf and have been previously flown.

The angular momentum will drift under the action of environmental torques. Errors are determined by telemetering earth, sun and magnetometer sensor data to the ground where the spacecraft motion is reconstructed by a software program. Corrections are applied, on ground command, by modulating the current to a single electromagnet aligned with the momentum vector. The control is thus closed loop with the loop closed on the ground. This approach means slow response but provides considerable flexibility by permitting a choice to be made between various control and maneuver options. The slow response is not a liability since the stiffness imparted by the angular momentum ensures that the vehicle response will also be slow. An advantage of the method is the capability of discerning average and long term torque effects so that a torquing schedule can be devised both to correct current errors and compensate for expected future torques. Experience has shown that torque command updates may only be required as infrequently as once every two weeks.

Four modes of operation are possible with the spinning BSRM. These are the orbit normal, sun line, sun line normal, and inertial spin axis orientation modes.

Orbit Normal Mode. The vehicle spin axis is maintained perpendicular to the orbit plane. The primary attitude reference is the combination of earth sensor and sun sensor. Backup capability is provided by the three-axis magnetometer which can be used in conjunction with either the earth or the sun sensor.

Sun Line Mode. A two-axis sun sensor with its axis along the spin axis is used to keep the vehicle spinning about the sun line. This provides a good reference about two axes. The earth sensor will see the earth twice per orbit to provide a periodic correlation of position around the spin cycle.

Sun Line Normal Mode. The spin axis is maintained normal to the sun line and in the orbit plane in this mode. The sun sensor is oriented perpendicular to the spin axis, sees the sun once per revolution and provides one reference. The second is obtained twice per orbit from earth sensor data which will also provide information on position in the spin cycle.

Inertial Pointing Mode. Theoretically the spin axis can be oriented in any direction in inertial space. Practically, there are a number of constraints including power and thermal control which will restrict the range of possible orientations. From the control and determination point of view a basic difficulty is the lack of adequate references, which complicates both acquiring and holding the desired attitude. In most applications the earth and sun sensors can be positioned to provide periodic data; thus attitude corrections can be made if sufficient time is available. This time will be of the order of days. The most difficulty and least accuracy will be experienced in missions requiring frequent changes of inertial attitude.

Telemetry, Tracking and Command: The basic S3 concept has been retained to meet the BSRM requirements.

Figure 5 shows a schematic of the subsystem. Command reception and data transmission both use S-band to provide reliable communication out to 7000 km slant range (3400 km orbital altitude) using NASA's STDN. Both real-time and tape-recorded playback may be transmitted simultaneously assuring gapless data passes. The tape recorder has a storage capacity of 2×10^8 bits for 210 minutes of recording time at the 16 KBPS real-time data rate. Playback of one 95-minute orbit can be accomplished during a minimum pass time of 6.8 minutes. Standard PCM encoding of data is used throughout with eight bits per word for accuracies of better than one percent. Real-time and playback data modulate separate sub-carriers which are transmitted over a single, 8.5-watt transmitter.

Tracking is performed through ground station antenna azimuth and elevation data, plus slant range measurements transponded through the satellite. Slant range is measured by uplinking a ranging signal which is turned around and retransmitted (noncoherently) back to the ground station.

Commands are uplinked at a 1 KBPS rate and decoded to provide 128 discrete pulse outputs and up to 7 eight-bit digital words. An on-board timer, in conjunction with a relay matrix, generate delayed command functions for both satellite attitude control and experiment ON-OFF switching. Switching functions for up to six orbits can be set up in advance through ground control.

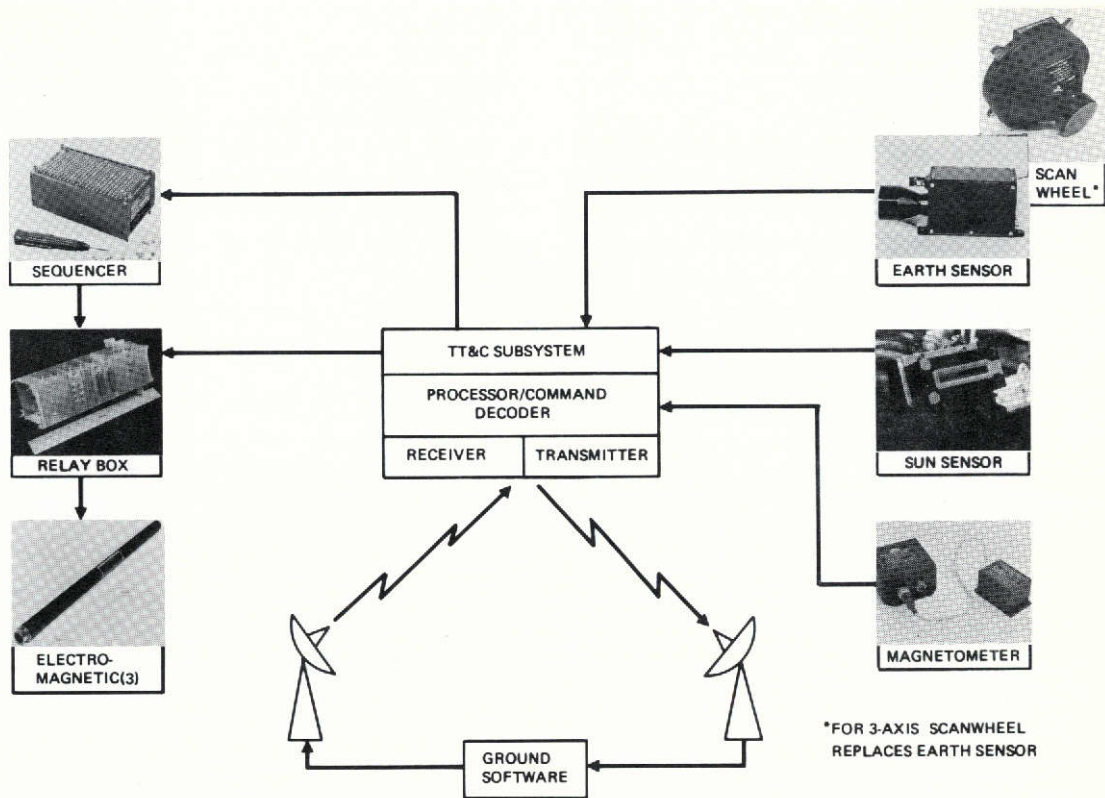


Figure 4. The BSRM Attitude Control and Determination AC&D) Subsystem Uses Flight-Proven Concepts and Off-the-Shelf Equipment

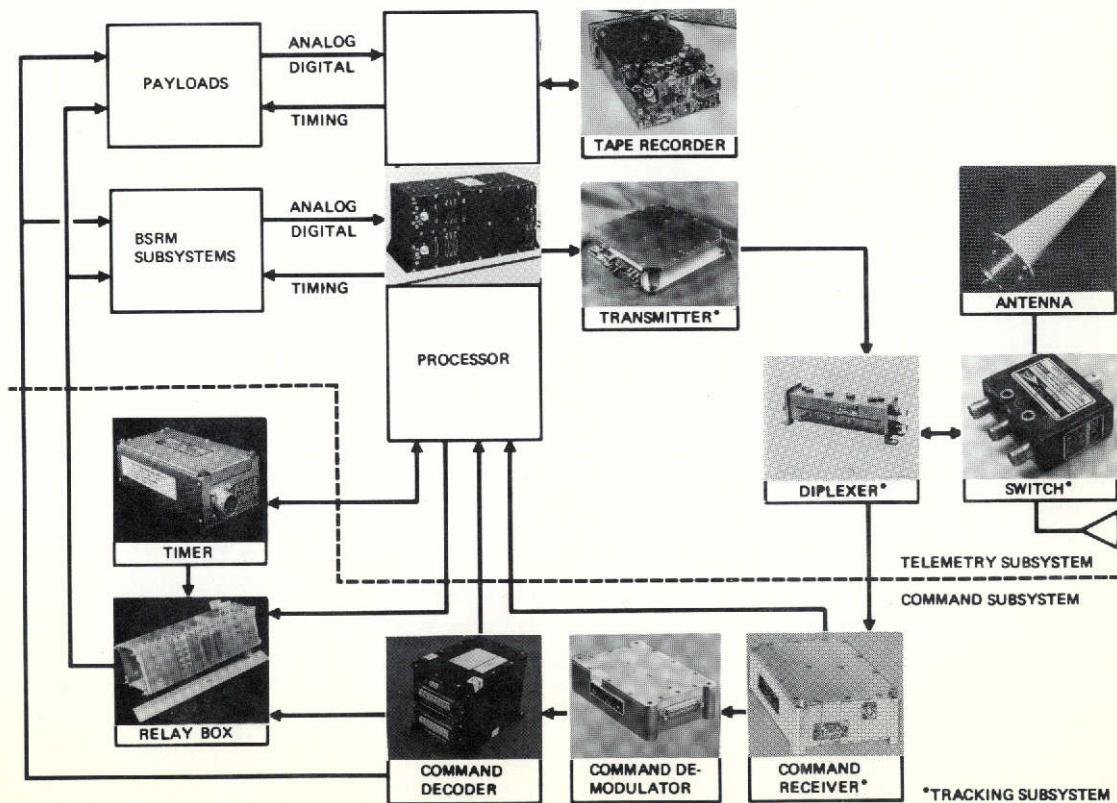


Figure 5. The Telemetry, Tracking and Command (TT&C) Subsystem Is Compatible With STDN and Uses Off-the-Shelf Components

With the exception of two switchable antennas, the TT&C subsystem uses single-thread components throughout.

Thermal Control: BSRM uses the same thermal control concept as the flight-proven S3 satellite.

The BSRM is isolated from the environment except by modulated radiation exchange through temperature controlled louvers. Open structure, emissive paint and equipment thermal mass are used to hold the BSRM interior to a $\pm 10^{\circ}\text{F}$ through all operating modes. All items proposed for the BSRM thermal control system are flight qualified and used on the current S3 design.

A thermal math model is used to design, analyze and predict the BSRM performance from launch through full orbital operations. The model will be correlated to thermal vacuum test results on the first BSRM vehicle to ensure accuracy of temperature predictions.

Software: Attitude determination and control is performed using BSRM sensor data processed by ground system software proven on the S3 program. Changes within existing sub-programs will be necessary to accommodate BSRM dynamics, sensor system outputs, different payload attitude determination requirements and to adapt to NASA facility interfaces.

Use of the existing software ensures:

- Low duty cycle at the Operations Control Center (OCC).
- Same technical specialists utilized on S3 to provide continuity.
- Minimal attitude determination software development.

The Small Satellite Attitude Control (SSAC) software, implemented at the Operations Control Center (OCC) determines vehicle attitude and computes all required satellite orientation and spin rate adjustment commands. Telemetry data of satellite attitude sensors, wheel speed (in the case of 3-axis systems) and control coil status is received at the network and relayed to the OCC. These data are then extracted, pre-edited to eliminate gross outliers and converted to engineering units. Ephemeris data from orbit determination and knowledge of vehicle attitude control system status is utilized to select commands for vehicle attitude and adjustment in conformance with operational requirements.

The Small Satellite Attitude Determination (SSAD) software is comprised of two elements. The major one, the Estimation Module (EM), is implemented at the OCC. The secondary one, the Output Module (OM), is used by the experimenter. The EM determines a time history of vehicle ephemeris and attitude. They are compacted and transmitted to the experimenter in data card form for input to the OM. The OM enables the experimenter to obtain the orbit state vector and the line-of-sight of his sensor(s) time-correlated to data observations.

Environments: The BSRM components are qualified for the Scout acoustic and random vibration levels. Scout accelerations are higher than most equipment qualification levels but this is considered a non-critical environment and requalification is not recommended.

The Scout boost trajectory is characterized by relatively high boost accelerations resulting from motor ignition transients and by relatively low acoustic levels because of its low first stage thrust. Most off-the-shelf equipment components are qualified to vibration levels well in excess of Scout requirements. Because acceleration is considered a low risk environment, it is not recommended that additional qualification be accomplished.

Equipment random vibration qualification test requirements derived for Scout are defined in Figure 6 and compared with levels specified for S3, Burner IIA, and STP P72-1. Qualification test levels were derived by adjusting response levels measured during S3 and P72-1 ground tests by the ratio of acoustic levels.

BSRM separation shock environments are similar to those encountered on previous Boeing developed upper stages and spacecraft and present a low technical risk. Qualification for shock by testing at the component level was not performed on past Boeing programs and is not recommended for the BSRM spacecraft.

AGE, GHE and Facilities: Existing electrical test equipment, handling and transportation equipment and facilities are available to support the BSRM program, and have been successfully used on similar spacecraft programs.

The BSRM will be produced, handled and tested using existing AGE and GHE developed for the S3 program. The AGE/GHE is conventional equipment necessary for satellite handling and test. The Boeing-owned Mobile Test Lab will be used on the BSRM program for automated test and checkout in-plant and at the launch site.

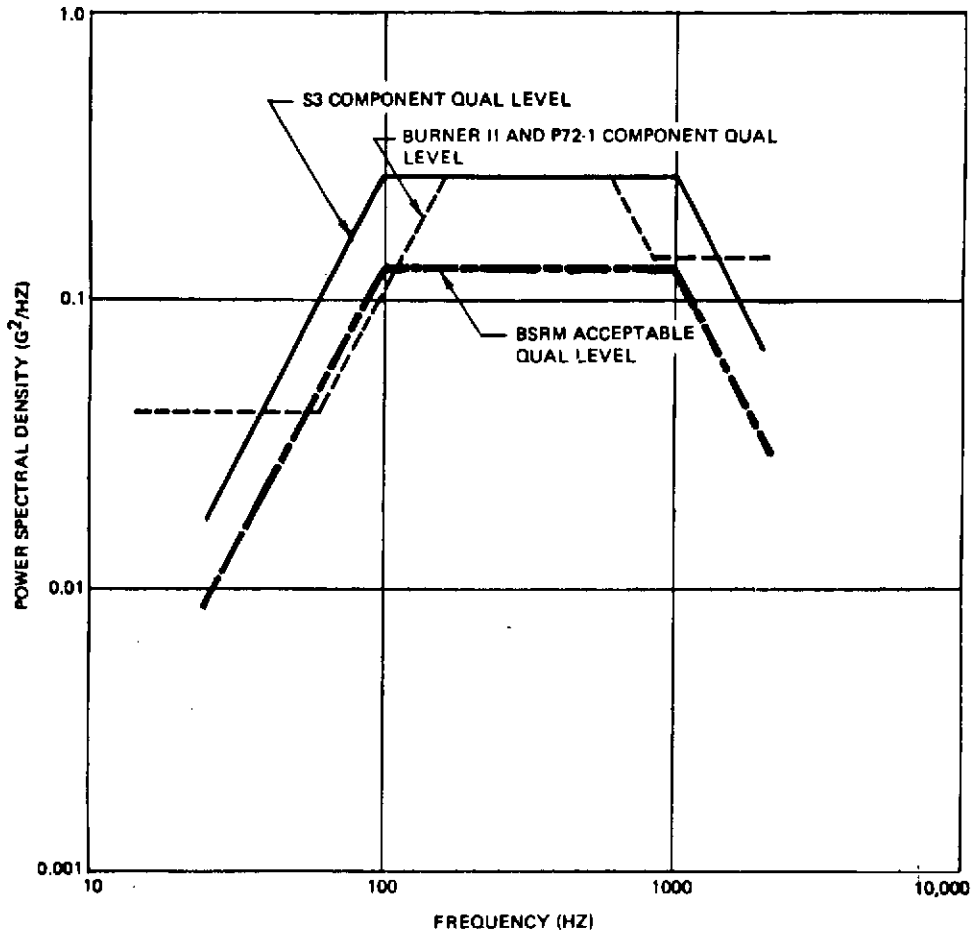


Figure 6. BSRM Components Are Qualified for Scout Random Vibration Levels

Electrical AGE. Functional testing of the BSRM spacecraft will be supported with AGE currently available. Testing with and without experiments installed will be accommodated. The equipment will be entirely portable, permitting support of testing at Boeing and any launch site. Significant electrical AGE includes the following:

- Control and Monitor Test Sets (CMTS) which performs satellite control, test monitoring and troubleshooting functions.
- Battery trickle charger which maintains the satellite flight batteries at a full state of charge until disconnected during the launch countdown.
- Break-In boxes provided for each type of satellite and satellite/experiment interface connector to support special tests and troubleshooting.
- Squib Simulator containing circuit breakers and indicator lights to simulate satellite squib loads and verify current supply capability of squib firing circuits.
- Antenna hoods are available for open loop command and telemetry communication between the BSRM and Mobile Test Lab.
- Sun and earth sensor stimulators and a "sun-gun" solar array stimulator are available.

An electrical simulator with operating procedures will be required from payload contractors for each experiment that interfaces with the satellite. The simulators will be used to check out the BSRM systems at the experiment interface prior to installation of slight experiments. The payload simulators will be required to duplicate experiment orbital electrical loads, indicate receipt of command, and provide termination of telemetry input circuits to the BSRM satellite.

Ground Handling Equipment. Existing GHE from the S3 program will be used to support the BSRM requirements. Minor modifications are required to some items to adapt to the Scout launch vehicle processing. Either vertical or horizontal installation on test fixtures can be accommodated. Significant GHE includes the following:

- Satellite container/transporter.
- Handling frame to lift and orient the satellite.
- Handling sling to permit lifting of the satellite and handling frame in any orientation.
- Solar panel containers.
- Battery storage/shipping container.

Each payload agency will provide any unique GHE with operating procedures to meet experiment requirements. The payload contractor will provide support for payload handling as required.

The BSRM with experiments installed will be shipped to the launch sites by air or truck (no rail). For truck transportation, a dedicated air-ride van will be used. No shock or vibration test equipment will be required as the existing transportation dolly has been tested on the S3 program to verify that transportation loads do not exceed flight loads.

Facilities. The BSRM program will be conducted at the Boeing Space Center in Kent, Washington. This facility complex was developed primarily to support space exploration programs and has ready access to the other Boeing facilities in the Seattle area and to highway, rail, water and air transportation systems.

All BSRM engineering, fabrication, assembly and testing will be accomplished at the Space Center. The program offices will be located in close relation to the fabrication and assembly of the spacecraft. Final assembly, integration, functional testing, magnetic, EMI, and spin balancing will be accomplished in the clean hi-bay area of the adjacent test building.

Farr clean benches and portable down-flow clean booths are available. In addition, other facilities such as a horizontal laminar flow clean room, pressure test facilities, tube cleaning facilities, specialized laboratories, and computers in other buildings at the Space Center will be utilized as required to support the BSRM.

Thermal-vacuum testing with solar simulation will be performed in Boeing Space Chamber A. Orbital sequences will be simulated and real time and recorded data transmitted to the Mobile Test Lab. All facilities for conducting this test are available for BSRM.

Subsystem Options: The baseline BSRM spacecraft is readily adaptable to a variety of earth orbit scientific missions with the incorporation of one or more optional subsystem kits. The options use flight proven equipment and thus retain the qualification status of the BSRM satellite.

The design approach of providing options in kits for incorporation into a baseline modular spacecraft design has been successfully demonstrated by Boeing on the USAF S3 program. The baseline BSRM subsystems will be designed to accept the options described below for any specific mission with an absolute minimum impact on the baseline spacecraft. Wiring changes, relay box module revisions and processor module changeouts are all that are required to install the options.

Three-Axis Stabilization. A three-axis attitude control system dynamically similar to the spinning satellite can be provided. Momentum bias is achieved by incorporating a scanwheel which combines the functions of an inertia wheel and horizon sensor. The third axis is controlled on-board by torquing the scanwheel. The scanwheel spin axis is oriented magnetically on ground command as in the spinning system. Spin rate control is no longer necessary but a second electro-magnet performs the analogous function of wheel desaturation. The following pointing accuracies are achievable with existing qualified equipment:

	<u>Hold</u>	<u>Determination</u>
Roll	±1.0 degrees	±0.25 degrees
Pitch	±0.5	±0.50
Yaw	±2.0	±0.50

The addition of the scanwheel and associated electronics for the 3-axis attitude control system add approximately 18.3 pounds (8.31 kg) to the BSRM subsystem weights. This includes allowances for secondary structural provisions to support the subsystem equipment.

Power Subsystem. An available DC/DC converter can be readily added to the power subsystem to provide a regulated (±2%) power bus for experiments if required. Flight experience on the Boeing S3 program has demonstrated that experimenters can accept the nominal 28 ± 4

VDC power regulation from the spacecraft bus without adverse affects by proper payload design. Weight is saved and spacecraft reliability enhanced if the DC/DC converter is not required.

Data Capability. Higher or lower data rates to meet specific experiment requirements can be provided by minor modifications to the on-board processor and substitution of other flight-proven tape recorders. The existing S3 processor can easily be modified by the change of a PC card to accept data rates from either of two Odetics tape recorders providing 6.4 KBPS or 32 KBPS to the TT&C subsystem. Spacecraft reliability is unaffected by the higher or lower data rates. Weight differences are less than one pound (.5 kg) for any option chosen.

Autonomous Attitude Control. A special purpose electronics package can be added to the attitude control and determination subsystem to considerably reduce the extent of ground control and ground station access time required to support the orbital operations of the BSRM. This concept has been flight proven on NASA-Goddard Space Flight Center spin-stabilized spacecraft and proposed for three-axis controlled vehicles. The baseline ground command control function would be retained as a backup capability. The addition of the on-board computer adds approximately 5 pounds (2.3 kg) to the BSRM subsystem weights and draws 4 to 5 watts of power.

The program costs of implementing this option, including design and procurement of the computer, development of the software and generation of the required test procedures would be offset by the ground control operational costs. Coordination with Goddard personnel indicates that total program costs could be lower with the autonomous on-board control, especially for long duration missions. If developed by Goddard, the three-axis technology could be readily adapted to the BSRM at a minimum non-recurring cost. Existing spin-stabilized autonomous control concepts are available to support BSRM.

Reliability: The reliability of the spin-stabilized BSRM is 0.88 for the six-month design life. The 3-axis stabilized spacecraft reliability is also 0.88 for a six-month mission and 0.78 for a one year design life.

Reliability analyses of the BSRM spacecraft have been performed using MIL-HDBK-217A failure rates and Boeing's test experience on the S3 program. The reliability prediction of the BSRM spacecraft is based on the simplicity of the space proven subsystem designs, 100% burn-in electronic equipment, ample life margins for life limited equipment and the high quality of electronic parts. Selective redundancy also contributes to the reliability in certain subsystems.

As the launch phase is of such short duration compared to the orbital phase of the BSRM missions, some of the equipment analyses have neglected the launch phase. Even considering the high environmental K factors for boost, the effects of launch on the six-month mission reliability is negligible for equipment qualified to the boost environment.

A summary of the BSRM reliability by subsystem is as follows:

	Stabilization		
	Spin	3-Axis	
Design Life	6 mos.	6 mos.	1 year
Power	0.9665	0.9665	0.9341
TT&C	0.9211	0.9212	0.8486
AC&D	0.9944	0.9942	0.9877
Mechanical	0.9982	0.9988	0.9988
Thermal	0.9998	0.9998	0.9996
Ordnance	0.9990	0.9999	0.9999

Power. This subsystem is identical for either the spin-stabilized or three-axis stabilized BSRM and nearly identical to the flight proven S3 satellite. There is no redundancy in the subsystem.

TT&C. Except for deployable antennas on the spin-stabilized BSRM, this subsystem is identical for all vehicles. There is no redundancy. Optional tape recorders for high and low bit rates have a small affect on the TT&C reliability analysis.

AC&D. For the spin stabilized BSRM, the attitude control subsystem has operating redundancy for the earth sensor by use of a magnetometer and a two-axis sun sensor. Additional partial redundancy exists as the subsystem can operate after failure of both the earth sensor and the sun sensor. The three-axis stabilized BSRM AC&D subsystem is similar to that of the spin stabilized spacecraft, with the exception that the earth sensor has been replaced by a scanwheel, and the redundant sun sensor is a more complex, two-axis unit. The subsystem also provides additional capability inasmuch as it can operate, in a degraded mode, with the magnetometer, after failure of both the scanwheel and the sun sensor. The scanwheel also has a considerable amount of internal redundancy.

Mechanical. The reliability of the satellite structure is assured through the establishment of positive safety margins in the structural analysis and by the successful completion of the test program. The reliability of all deployable items is identical and requires one actuation for success in each case. All pin-pullers have dual initiators. The satellite separation consists of a V-band with two release

clamps, either of which will release the satellite. The clamp is opened by two separation nuts each with a single ordnance cartridge. Four compression springs separate the satellite from the booster upon V-band release.

Thermal Control. This subsystem consists of passive coatings, insulation blankets, transmitter heat sink and flight proven louver assemblies. Adequate temperature control

can be maintained with two louver blades failed in the closed position. Each of three louver assemblies have four independently actuated blades, so the louver system is partially redundant.

Ordnance. This subsystem consists of spin motors, pin pullers and V-band clamp release all of which have redundant initiators.

BSRM INTEGRATION

System Integration. Boeing has established close working relationships with various government agencies, experimenters and launch vehicle contractors on numerous successful spacecraft programs. This experience will be applied to BSRM to ensure meeting experimenter and payload requirements.

Boeing will meet with experimenters to refine and update interface requirements and data at Technical Interface Working Group (TIWG) meetings. TIWG meetings will develop formal Interface Control Documents (ICDs) for each BSRM to be approved by all affected contractors. Proposed changes to the ICDs will be submitted by the originator to NASA and all affected contractors and agencies for evaluation of cost, schedule, and program impact and approved or rejected at the next TIWG meeting. Formal Interface Revision Notices (IRNs) will document all approved interface changes.

The requirements contained in the ICDs will be incorporated into the satellite documentation at all levels. Integration documentation will include:

- Block diagrams and schematics
- Component specifications
- Installation drawings
- Test plans and procedures
- Design analysis documents

Boeing will coordinate with each payload contractor and agency the detailed test requirements and procedures for integration and checkout of the experiment with the satellite system. Boeing will develop integrated test procedures including go/no-go criteria. Boeing will also provide facilities to support inplant payload personnel and test equipment.

Boeing will coordinate all operational, hardware and software interfaces of the BSRM including its payloads with the VAFB range and Range Safety offices, the STDN network and the launch vehicle. Figure 7 shows the overall BSRM program organization defining specific responsibilities for each subcontractor and government agency.

Interfaces with the VAFB range will be documented in the Program Requirements Document (PRD) prepared by the Test Wing using inputs supplied by the booster contractor and Boeing. Detailed coordination and scheduling of range operations will be accomplished at Launch Test Working Group (LTWG) meetings.

Interfaces with the NASA Space Tracking and Data Network will be documented in the Orbital Requirements Document (ORD) prepared by Boeing using inputs supplied by the experimenters. Detailed coordination and scheduling of STDN operations will be accomplished at Orbital Test Working Group (OTWG) meetings.

Interfaces with the booster and launch site will be defined in a payload/booster ICD prepared by the booster contractor. Detailed coordination of operations and schedules is accomplished at TIWG meetings.

System Test. The BSRM test program ensures a thoroughly tested and reliable spacecraft.

The test sequence, shown in Figure 8, features the following:

- The satellite subsystems are functionally complete and checked out, including simulated payload interfaces, prior to mating flight experiments.
- Complete subsystem tests assure proper operation under simulated flight conditions.
- Complete integration tests with all flight payloads installed verify end-to-end operation for maximum assurance of satisfactory operation in orbit.
- Use of the Boeing-owned Mobile Test Lab with telemetry ground station receiving and processing equipment accelerates the test schedule.
- Test procedures, techniques and software developed on existing spacecraft programs are available to support BSRM.

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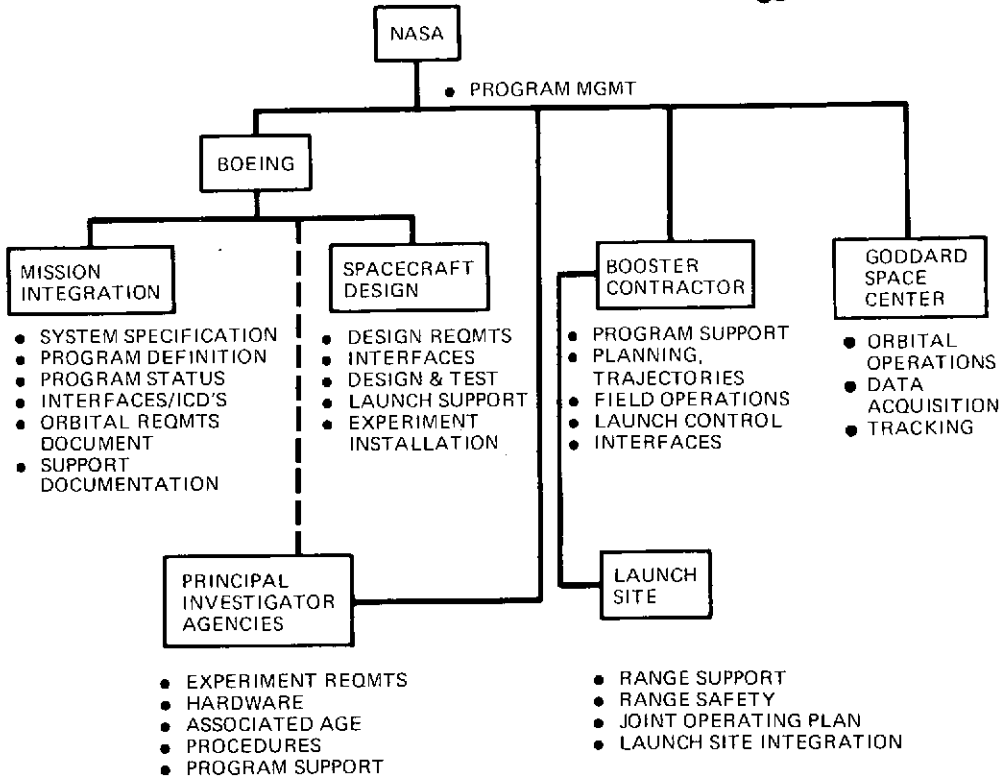
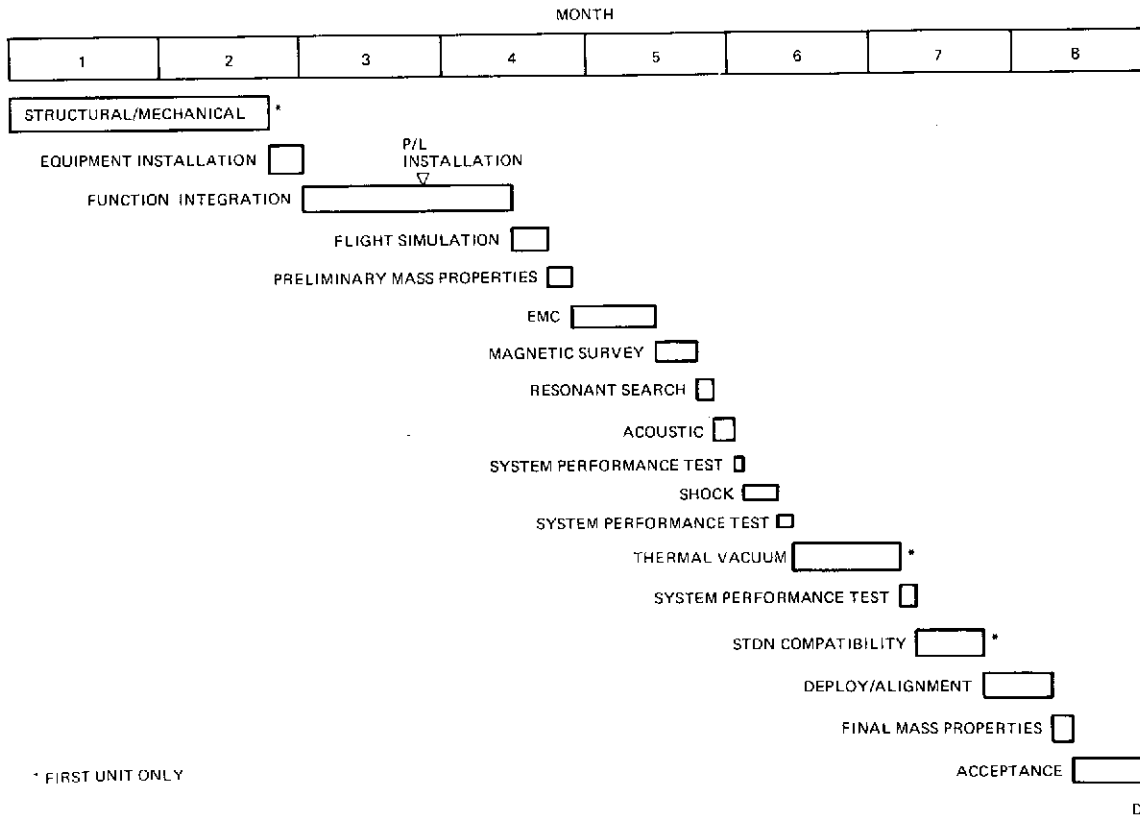


Figure 7. Boeing Has an Established and Experienced Organization to Provide BSRM Program Management



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Figure 8. The Thorough BSRM Test Program Emphasizes System Level Integration

The first BSRM will be subjected to structural tests to verify strength and stiffness. Starting with a complete satellite structure and wiring assembly, the satellite subsystems are then installed and integrated. After all satellite systems have been completely checked out with simulated payloads, and the telemetry system calibrated, the flight payloads are installed and connected. All payload command functions are initiated, and payload status and data channels (both real time and recorded) are transmitted to the Mobile Test Lab through the telemetry system. The payload data is processed for analysis by payload contractor personnel. The following tests are then conducted:

- Flight Simulation starting at satellite separation from the booster and ending when selected payload functions have been performed.
- Preliminary Mass Properties are determined to detect any gross differences from analyses.
- EMI/EMC Tests are conducted to verify EMC between all subsystems by demonstrating an electromagnetic interference (EMI) safety margin during all modes of system operation.
- Magnetic Survey is conducted.
- Mechanical and Acoustic Vibration at flight level environments.
- Deployment/Separation Shock Tests to verify functional characteristics and proper satellite operation after the shock events.
- Thermal Vacuum with solar simulation to verify first BSRM operation for nominal, worst cold and worst hot cases.
- Range Compatibility Testing at Scout launch site.
- Deployment/Alignment inspection.
- Weight and Balance to verify that design weight, balance, center of gravity, and inertia requirements are met.
- Acceptance Test to verify all performance objectives are satisfied prior to satellite delivery.

System Operation. BSRM boost and orbital operations use proven and versatile techniques to provide smooth data flow to the experimenters.

During separation from the launch vehicle, the BSRM timer is actuated to initiate deployment, spin-up, acquisition and stabilization events. Less than three hours after launch the BSRM will be in the orbital operations mode. Up to 48 hours are then required to process the spacecraft spin axis to the proper orientation.

During this period of time, ground commands are sent to the satellite to adjust the timer drive frequency and housekeeping functions are monitored to verify proper satellite operation. Ground commands are sent, at the completion of spin axis precession, to release pyro-operated covers and other payload deployment and enabling functions.

Orbital operation of experiments is accomplished by ground command and a pre-programmer timer/ground programmed relay matrix. Real time operation of an experiment is accomplished by first sending commands to enable the experiment(s) desired and then sending a command switching the experiment power bus from pre-programmed operation to the ON configuration.

Pre-programmed operation, using the timer, provides great flexibility in experiment operations. Timer output is programmed prior to each flight for twenty-one relay latching pulses per orbit. Each of the latching pulses may be used to either activate or deactivate the experiment bus during the orbit. Ground command is available to enable the use of the pulses.

Satellite ground operations are performed by the NASA Space Tracking and Data Network (STDN). This net provides ground command of the satellite and accumulation of experiment, housekeeping, attitude and ephemeris data. Satellite operations will be performed in accordance with the Orbital Requirements Document (ORD). Data transmitted from the satellite will be gathered by the remote tracking stations throughout the world. Real time data and commands will be transmitted to and from the satellite via land lines. Recorded data, transmitted from the satellite, is shipped from the remote tracking stations to the Goddard Space Flight Center.

Attitude and ephemeris are determined at Goddard. These data are then merged with the recorded experiment data, in a format compatible with the experimenters computer, to provide coordinated data.

EXPERIMENT REQUIREMENTS

The BSRM program features standardized spacecraft interfaces to which experimenters design their payloads. This approach reduces program costs and shortens schedules.

The following requirements are imposed on the payload design:

- The experiment shall be capable of withstanding boost accelerations of 16g axial combined with 4g lateral and 22g axial combined with 2g lateral.
- The experiment shall be capable of withstanding an overall level of 14.2 GRMS and the random vibration as defined in the ICD.
- The experiment shall be capable of continuous operation for one year or more in standby mode, with intermittent operation in normal operating mode exposed to space vacuum, with the experiment temperature in the range of +10°C to +35°C for non-deployed items.
- When packaged or otherwise prepared for shipment, the experiment shall be capable of withstanding or shall be protected for altitudes of 0 to 40,000 feet and temperatures of -45°F to +120°F with thermal gradients of 33°F per minute.

The experiment shall be subjected to a qualification test program consisting of the following as a minimum:

- Random Vibration 2 times G^2/Hz
- Acceleration 1.5 times maximum flight levels
- Thermal Vacuum Operate -5°C to +50°C (soak and cycle)
Survive -15°C to +60°C
- EMI Applicable sections of MIL-STD-461A

To demonstrate an electromagnetic compatibility margin of 6dB between the satellite equipment and the payloads, the electromagnetic generation and susceptibility characteristics of each payload package are to be provided by the experimenter.

The primary power return, signal return, and command return shall be isolated from the case and from each other by at least one megohm. Radio frequency coaxial returns may be grounded to the case.

All electrical/electronic equipment shall be installed and bonded in accordance with MIL-B-5087B. Bonding shall be accomplished by bare, clean metal-to-metal contact of all mating surfaces. Dissimilar metals shall be properly treated to avoid the long-term effects of galvanic action and corrosion. Mating surfaces shall be compatible with aluminum.

Each experiment package shall be tested for hard perm, soft perm, and active magnetic dipole moment along each of three orthogonal axes. Results of tests shall be submitted to Boeing in support of experiment-vehicle integration. The hard perm magnetic dipole moment shall be measured after first deperming the experiment package.

Connectors shall be non-magnetic and conducting to chassis. Cadmium plating is not permitted. Mating connectors shall be provided by the experimenter for Boeing to install on the spacecraft wire bundle.

Separate connectors shall be provided by the experimenters for EED firing circuits. The connectors shall have:

- Provisions for peripheral termination of shields
- Conducting back shells
- Construction such that, when being mated, the connector shell will mate before any of the conductors and will not break contact until all inner conductors have broken contact.

Single channel commands that perform alternating or sequential functions are undesirable because occasions arise that require retransmittal of commands to assure receipt. This leaves the disposition of the toggle command unknown and may upset the desired sequence.

Experiment processor interface characteristics and requirements of commands and the telemetry signals will be defined in the ICD.

In order to ensure dynamic stability of the spinning satellite, rigid booms shall have a lateral stiffness greater than $RPM/15$ Hz bending frequency. For booms with unsymmetrical mass distribution about their axis, torsional frequency shall be greater than $RPM/45$ Hz.

All experiment EEDs and circuitry shall comply with the requirements of SAMTECM 127-1 or AFTRM 127-1 and the 100 watt per square meter option of paragraph 3.3, Appendix A to AFMTGP 80-2 (issue of 1 Oct. 1963). EEDs shall be 1 watt, 1 ampere (1 ohm) no-fire and shall have been tested for RF and static sensitivity.

MISSION APPLICATIONS

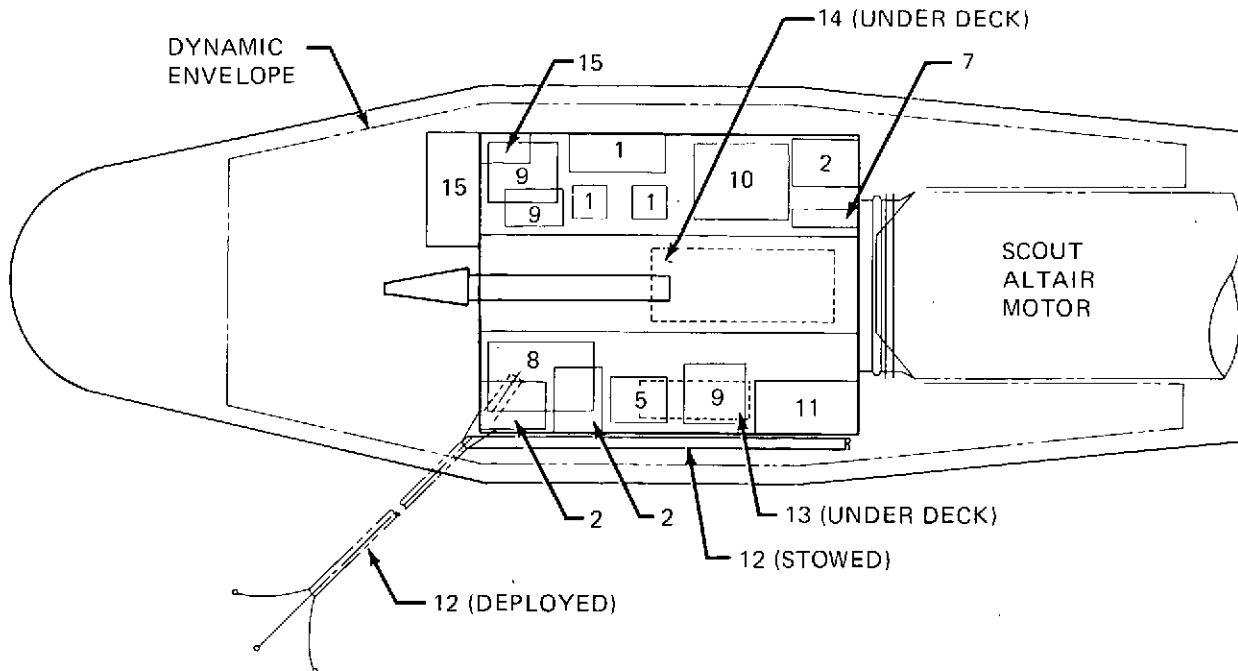
BSRM is capable of performing a significant number of scientific missions proposed for Scout-class, low-earth orbit satellites. A total of twelve missions were evaluated as to the capability of BSRM to meet their requirements. Preliminary analyses indicate all twelve can be accommodated with BSRM.

The scientific missions evaluated (Table 2) were proposed by various Principal Investigator (P.I.) groups in response to NASA-Headquarters Announcement of Opportunity for Scientific Definition of Scout Explorer-class Missions, A.O. #7, dated 15 July 1974. Two of the missions (Auroral and Aether Drift) were evaluated in-depth for this study. The other ten missions were studied using company-sponsored funds to determine the applicability of a standardized spacecraft.

Table 2. There Are a Significant Number of Scientific Mission for Which BSRM Can be Used

Mission	Orbit altitude	Inclination	Power	Data rate	Stabilization	Axis control	P/L weight	Special requirements
Auroral	250km perigee 800km apogee	Sun-synchronous	53.5w	16KBPS	Spinner	1°	48.6kg	Spin axis pointed at sun
Aether drift	550km circular	Terminator, sun-synchronous	31.5w	2KBPS	3-Axis geocentric	1°	28.5kg	12 Month life
X-ray telescope	500km circular	Equatorial	20	Low	3-Axis inertial	1°	82kg	
Gamma burst	500km circular	Equatorial	30	2KBPS	3-Axis geocentric	5°	82-91kg	
Soft x-ray	500km circular	Equatorial	20	400BPS	Spinner	1°	68kg	Spin axis pointed at sun
Extreme ultraviolet	350km circular	Equatorial	20	Low	Spinner		45kg	Spin axis pointed at sun
Ultraviolet	500km circular	Polar	<10	Low	3-Axis geocentric	1°	37kg	
Gamma burst	500km circular	Equatorial	25	16KBPS	3-Axis geocentric	1°	82-91kg	
Electrodynamics	300km perigee 3500km apogee	75°	20	FM/FM	Spinner		As much as possible	Spin axis perpendicular to orbit plane
Cosmic background radiation	1300km circular	Equatorial	30	45BPS	Spinner	1.5°	18.2kg	Spin axis pointed at sun
Solar telescope	350-500km circular	Equatorial	20-30	1.5KBPS	3-Axis		68kg	Solar pointing
Atmospheric anomaly	250km perigee 1050km apogee	15°	65 periodically	131KBPS real-time	Spinner		52kg	Spin axis perpendicular to orbit plane

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NOTES

- HOUSEKEEPING EQUIPMENT NOT SHOWN
- EXPERIMENT 4 (MAGNETOMETER) ON ANTENNA BOOM

Figure 9. The BSRM Baseline Readily Satisfies NASA-Ames Auroral Mission Requirements

Auroral Mission. This mission can be accomplished using BSRM. Figure 9 shows a simplified configuration of the BSRM with all experiments integrated into the spacecraft.

The primary purpose of NASA-Ames Research Center Auroral Mission is to produce a better understanding of the physical and chemical processes responsible for the production of auroras. A coordinated and complementary set of 11-13 experiments were chosen to be integrated into the BSRM. The missions stress the close correlation between remote-sensing optical instruments (ranging from 0.025 to 1.66 microns) and "in-situ" optical and particles-and-fields instruments (0.1 eV to 20 keV).

Weight, attitude control, power, and viewing requirements are satisfied with the baseline BSRM. It is necessary to use the high data rate TT&C subsystem to meet all data requirements. Deletion of two lower priority experiments reduces data requirements to where the baseline BSRM data system is satisfactory.

Aether Drift Mission. BSRM makes an ideal spacecraft to perform this mission. Figure 10 shows the two experiments mounted on the BSRM.

The Aether Drift Mission, proposed by U. of California Lawrence Radiation Laboratory, will detect and map the large-angular-scale anisotropies of the 3⁰ cosmic background microwave radiation. This would then allow the detection of the motion of the earth with respect to the distant matter of the universe, as well as our overall rotation of the universe. For purposes of this study the Solar Isotope Separation experiment, proposed by U. of Chicago, has also been included as part of the payload. This experiment would measure the isotopic and chemical composition and spectra of solar flare accelerated particles from hydrogen to iron.

The mission requires three-axis geocentric orientation which would be provided by the three-axis AC&D option kit. Pointing accuracy is adequate for the mission. Electrical power provided by the baseline BSRM is more than adequate for the mission; a reduced array size is even possible. Data requirements are low enough to utilize the low data option kit.

Other A.O. #7 Missions. Preliminary assessment of the mission requirements indicate that BSRM is suitable for all missions.

Boeing utilized company funds and data generated for this study (with the permission of NASA-Ames) to evaluate ten additional missions various P.I. groups proposed to NASA-Headquarters in response to A.O. #7. Table 2 tabulates the missions and their requirements. In most instances the payload is a single instrument requiring low

data rates; therefore the low data rate option kit would be utilized. The attitude control and determination subsystem would be either the baseline spinning system or the three-axis option kit. Although the evaluations of these missions were not as complete as Auroral and Aether Drift missions, it is felt that BSRM is capable of performing a multitude of scientific missions at minimal cost.

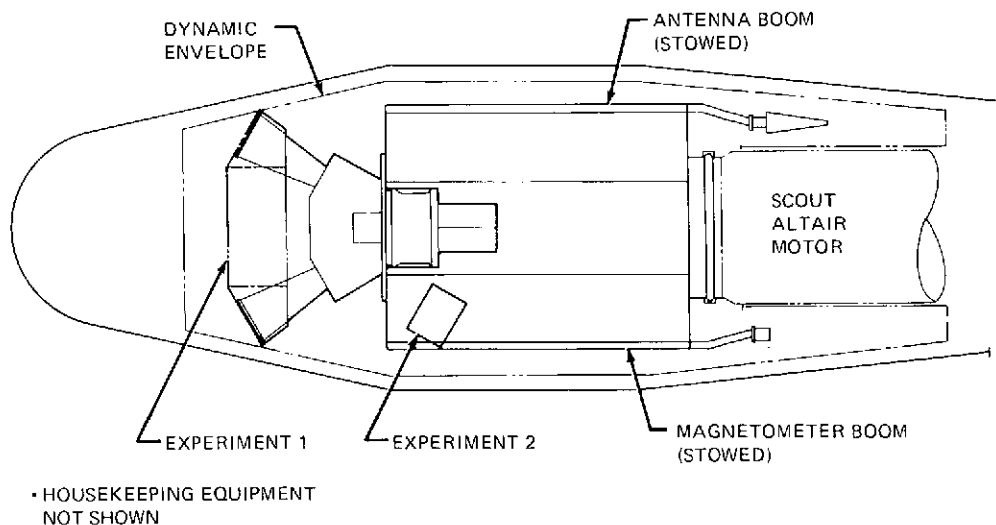


Figure 10. The Aether Drift Mission Can be Accomplished With Standardized Optional Kits Added to the BSRM Baseline

LAUNCH VEHICLE INTEGRATION

The BSRM is easily integrated with a variety of launch vehicles. The baseline BSRM design does not require any changes to the Scout booster and meets all Scout interface requirements. By retaining the existing S3 satellite general arrangement, the BSRM can readily be launched piggyback on the Delta or USAF classified Host Vehicle.

Scout. The BSRM design is compatible with the interface of the existing Scout F launch vehicle including the mechanical attachment, shroud dynamic envelope, separation technique and all operation features. There is no electrical interface with the Scout.

The first BSRM structure will be tested to verify flight qualification status. Modal survey and static loads tests will be conducted on the first flight structure with mass simulated components and payloads installed. A dummy Scout fourth stage or interface ring assembly will be used to perform a fit check and the structural tests.

Field processing of the BSRM with Scout is very similar to procedures successfully used by Boeing on numerous spacecraft missions on Thor and Atlas. All prepad operations will be performed at NASA Building 836 in south VAFB. The Boeing-owned Mobile Test Lab will be used at this facility for computer controlled testing prior to transfer to the launch site. Figure 11 summarizes the launch processing flow.

After receiving inspection in Building 836, the BSRM will be positioned inside a clean room, AGE will be connected and a functional test conducted. Spin motors will then be installed and ordnance connected. Thermal blankets will be closed out, and solar panels installed and electrically verified. The BSRM will be reinstalled in its shipping container and transported to the Scout launch complex for mating with the booster.

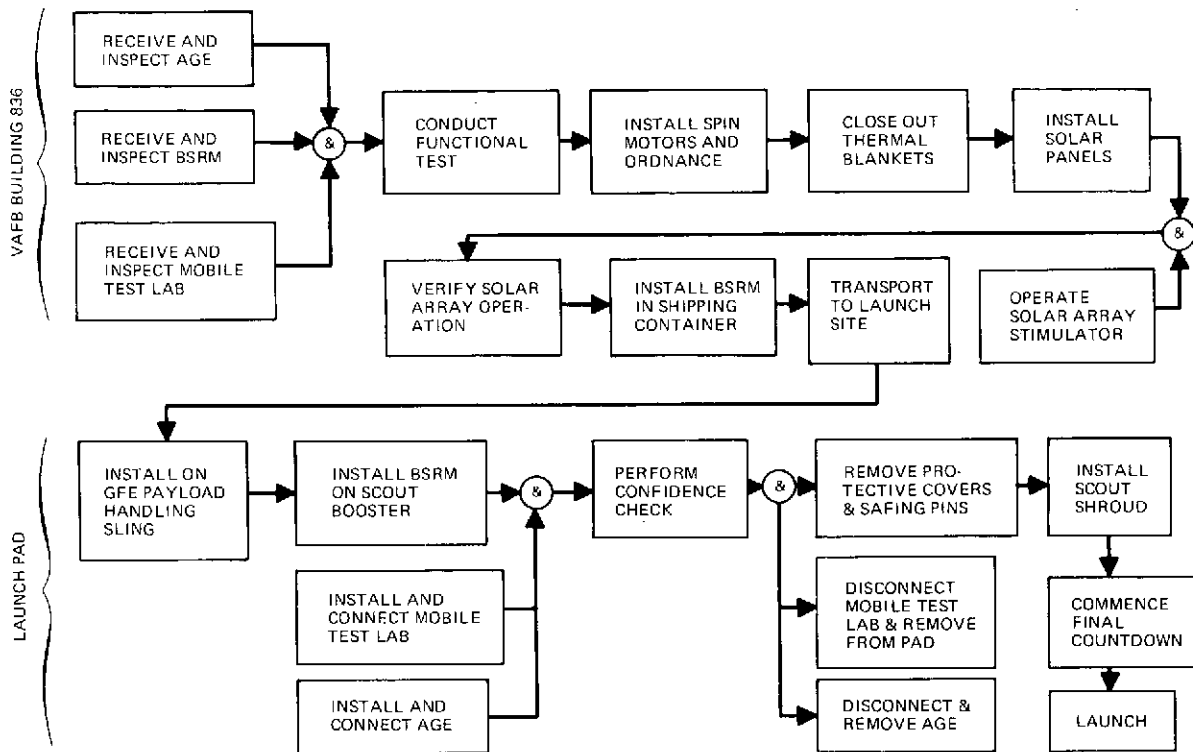


Figure 11. BSRM Launch Processing Is Simple and Compatible With Scout

At the launch complex the BSRM will be positioned inside the Scout moveable shelter and mated to the Scout fourth stage using the GFE Payload Handling Trailer. The V-Band will be torqued to the required specifications and the Mobile Test Lab will be connected to the satellite. A confidence test will be performed to verify no damage has occurred during the transportation and handling operations. This test will exercise the BSRM subsystems and experiments to the extent necessary to verify aliveness. Prior to Scout fairing installation, protective covers and safing pins will be removed and final inspections of the BSRM will be accomplished.

Delta. The BSRM can be launched either as the primary payload or piggyback on the Delta launch vehicle.

Figure 12 shows an approach for a two-stage Delta Configuration 2910 booster. The BSRM spacecraft are stowed around the primary payload. To maximize the primary payload envelope within the shroud dynamic envelope, the existing S3 general arrangement is used including the V-band attachment, ejection system and rocket motor installation flight proven on the recent S3-1 launch. Except for the slightly different shape, this version of the BSRM is identical to the subsystems, components and operational features discussed for the Scout launched BSRM.

The Delta launch is two-stages to a low earth parking orbit for this piggyback mode. A sequence is then initiated to jettison the BSRM spacecraft. Rocket motors in the BSRM then ignite to achieve the required BSRM orbit as successfully demonstrated by the S3 spacecraft. The Delta parking orbit can be elliptical and by proper selection of the jettison time, the BSRM can be put into a circular orbit. If a low circular parking orbit is used, an elliptical BSRM orbit is achieved. The Delta Configuration 2910 can launch a 1700 pound (772 kg) primary payload into a 200 n.mile (370 km) circular orbit from WTR with two piggyback BSRM. Greater capability is available for launches from ETR. Using solid rocket motors from the S3 program in the BSRM, the following orbits can be achieved from a 200 n.mile (370 km) circular parking orbit:

BSRM Motor	BSRM Final Orbit
TE-M-479	200 x 3200 n.miles (370 x 1750 km)
TE-M-516	200 x 1510 n.miles (370 x 800 km)
TE-M-521	200 x 6000 n.miles (370 x 3250 km)

Launching BSRM piggyback on the three-stage Delta Configuration 2914 was also considered in this study. Performance analyses showed this configuration cannot

achieve a meaningful primary payload mission with the existing TE-M-364-4 third stage since the BSRM spacecraft

has to be jettisoned from a parking orbit prior to third stage ignition.

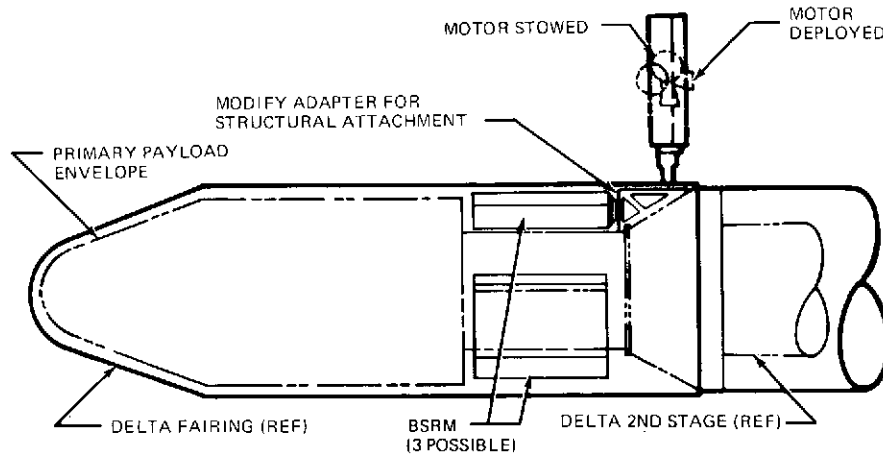


Figure 12. Low Cost Launches Can be achieved Piggyback on Delta

If a Delta Configuration 2913 launch vehicle is dedicated to the BSRM program, high energy and/or multi-satellite launches can be performed. Figure 13 shows a general arrangement of two BSRM spacecraft which can be inserted into a highly elliptical 100 x 16,000 n.mile (185 x 30,000 km) parking orbit. By properly selecting the jettison time and the BSRM solid rocket motor, a wide variety of final BSRM orbits can be achieved.

The synchronous payload capability of the three-stage Delta is 1540 pounds (699 kg) onto the transfer ellipse. After circularization and plane change by a BSRM apogee motor, approximately 700 pounds (318 kg) useful payload is available.

USAF Host Vehicle. Integration of the BSRM with the USAF Host Vehicle for piggyback launch has already been completed and verified by the successful launch of the S3-1 satellite.

The existing S3 general arrangement, ejection system and rocket motor installations would be retained for BSRM. All interfaces are proven and documentation, procedures, ICD's, etc., are available. This approach represents the minimum change to the S3 system for the BSRM program. Coordination between NASA Headquarters and DOD is necessary to obtain a commitment for such a piggyback launch.

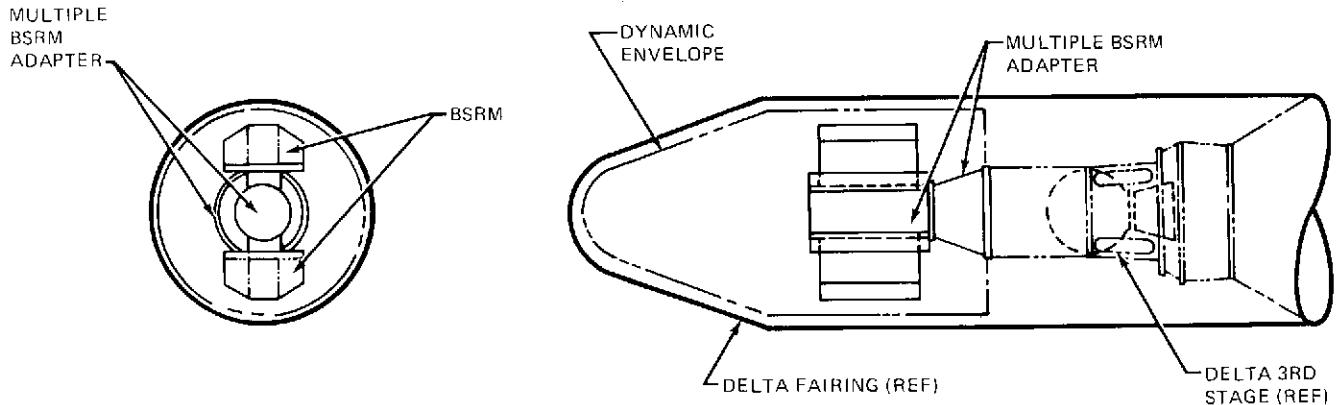


Figure 13. Considerable Mission Flexibility Is Achieved by Dedicated Delta Launches

PROGRAM DEFINITION

Preliminary plans defining the BSRM program have been completed consistent with the low cost approach utilized by Boeing on many successful USAF satellite missions. The use of existing plans, procedures, design and fabrication techniques, off-the-shelf equipment items, released design analyses, and other existing documentation will ensure implementing the BSRM program with a minimum of coordination resulting in a quick response schedule and low cost.

The documentation which can be used directly or with minor revision for BSRM includes the following:

- Numerous approved plans summarized below.
- Applicable CDRL submittals such as range safety documentation, qualification data, and design criteria.
- Applicable design analyses not affected by the experiment mix such as communication link analyses, EED analysis, and some subsystem analyses.
- Numerous procedures for operation of the Mobile Test Lab, subsystem demonstration tests, TM calibration, magnetic survey, and EMC/EMI acceptance.
- Software programs for attitude control and determination.
- Procurement specifications for off-the-shelf hardware.
- Complete data packages from suppliers for qualification verification, reliability, and performance for off-the-shelf hardware.

The plans summarized below will be reviewed, coordinated, and approved prior to initiation of a BSRM hardware contract. These plans would form the basis for conducting various aspects of the BSRM program. Major programmatic features of the spacecraft development, test and operation would thus be defined at go-ahead insuring high confidence in proposed costs, schedules and reliability.

Mission Integration Plan. Experiment and booster integration will be conducted using concepts and methodologies demonstrated on previous programs. A System Master Integrated Schedule will be prepared to identify and control major BSRM program milestones for each participating agency including experimenters.

Interface Working Group Meetings and Interface Control Documents will define and document all interface data and requirements. ICD's will be approved by all affected agencies, contractors and NASA-Ames.

Quality Assurance Plan. BSRM total program quality will be assured by the application of existing programs for the following:

- Reliability/Maintainability emphasizing an integrated plan during design, manufacture and test to achieve the desired reliability and maintainability potential.
- Parts Control and Standardization through the selection of specifications and standards in accordance with approved requirements. Screening and traceability will be imposed where deemed necessary.
- Supplier Selection and Control using a government approved source selection procedure with provisions for periodic audit, reporting and review of supplier progress.
- System Safety through analysis, design and procedures review and monitoring of operations to minimize all hazards to equipment and personnel. Range safety requirements will be met by submittal of the documentation necessary for each launch site.
- Quality Control using existing approved procedures to ensure all delivered equipment meets contract requirements that will not be degraded by human factors, procedures and testing. Material and processes control will be implemented in accordance with engineering instructions and established company policy.

EMC Control Plan. Interference control will be implemented through proper design and subsequently verified through analysis and test. Government specifications for EMC will be used including the establishment of an Electromagnetic Compatibility Control Board to govern all aspects of EMI/EMC.

Contamination Control Plan. The requirements, procedures and facilities to be used for contamination control will be consistent with experiment and mission requirements. A detailed plan will be developed for each BSRM defining the clean facilities, control procedures, inspection techniques and materials and processes suitable.

Manufacturing Plan. Fabrication and assembly of the BSRM will be accomplished using low cost tooling concepts, product control procedures and manufacturing techniques proven on previous successful spacecraft. The government approved Boeing Integrated Record System will schedule, direct and record all activities and their sequence.

Configuration Management Plan. Controls will be implemented to ensure compliance with a uniform system of

configuration definition, identification, control and accounting. The baseline configuration will be defined and changes controlled by formal Change Board procedures.

Data Management Plan. The existing Boeing data management system will identify data requirements, define data schedules, ensure technical content and provide data status visibility at periodic program reviews.

PROGRAM SCHEDULE

The BSRM spacecraft is similar in size and technical requirements to a number of satellites successfully integrated, tested and launched by Boeing on short schedules for the Air Force STP organization. A twenty-month schedule from go-ahead to launch is possible with the program groundrules defined in this study.

A preliminary Master Schedule is shown in Figure 14. The three-axis or spin stabilized versions can be developed within the same time span. Key features of the BSRM schedule are:

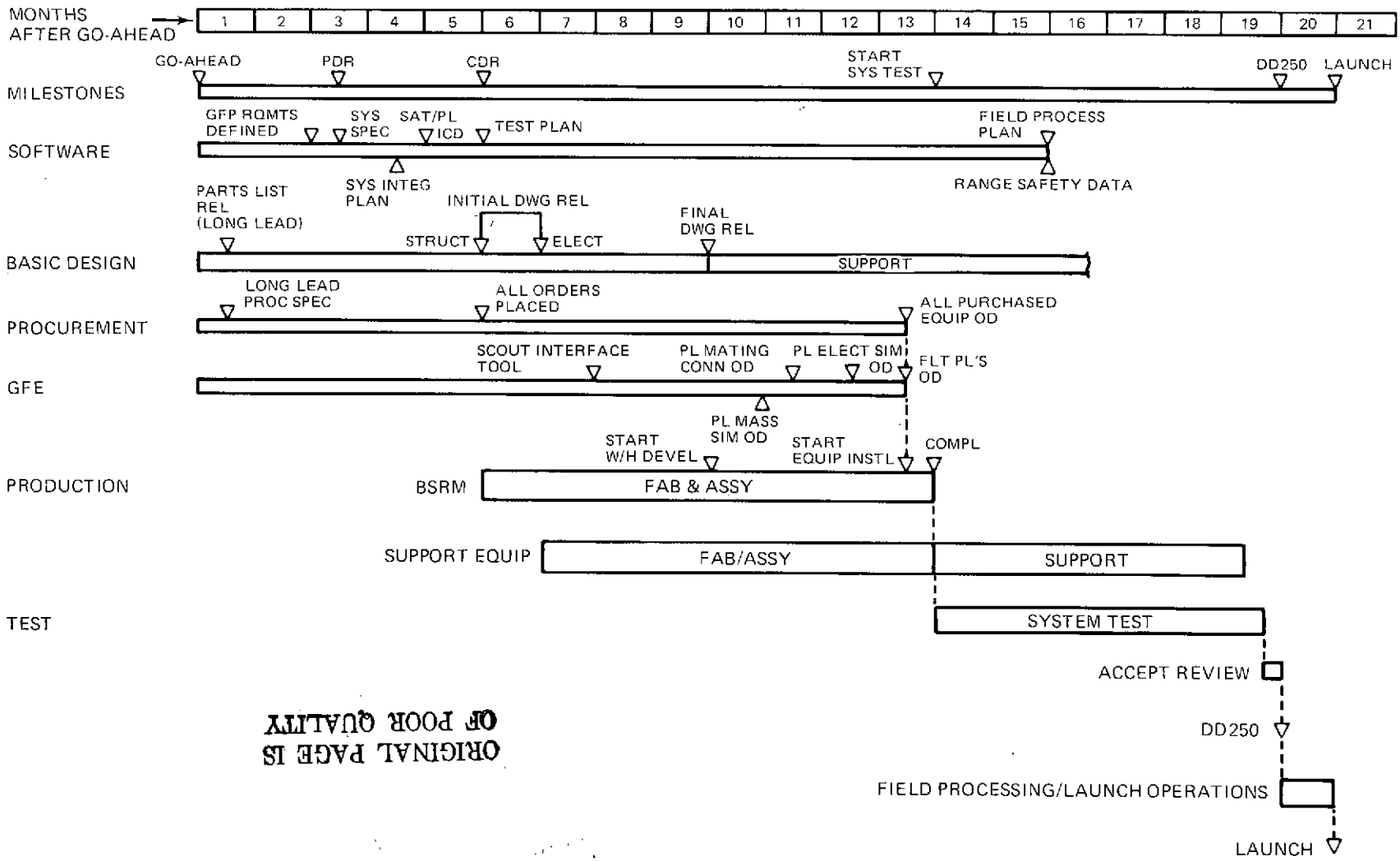
- Long lead procurement can be initiated within fifteen days of go-ahead, by release of specifications available from other programs. All BSRM components are flight qualified and no extensive procurement specification preparation is required.
- BSRM program plans will be prepared and approved by go-ahead to scope the schedule and total program costs.

- The Boeing-owned Mobile Test Lab with existing software will be used for automated testing inplant and at the launch site to reduce test and checkout schedules.

Delivery of each BSRM in a multiple unit buy will be made at seven month intervals to prevent conflict in the use of test AGE and GHE. Field processing personnel are the same individuals conducting factory testing and would not be available to support a factory BSRM during launch preparation of another vehicle.

The BSRM vehicles could be put into storage after DD250 instead of immediately going into launch processing. This approach was successfully demonstrated by Boeing on the S3 program. Condensed System Performance Tests will be conducted during the storage period at three month intervals. Acceptance test will be repeated at call-up prior to shipment to the launch site.

Extensive use of the subsystems, design concepts, program plans, software, and test procedures from previous STP programs ensures an efficient BSRM program schedule.



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Figure 14. The BSRM Schedule Is Very Similar to Previously Completed Small Satellite Programs