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Acronyms and Abbreviations

ACWP	Actual Cost of Work Performed
AXAF	Advanced X-Ray Astrophysics Facility
BASD	Ball Aerospace Systems Division
BATC	Ball Aerospace & Technologies Corp.
BCWP	Budgeted Cost of Work Performed
BPS	Ball Process Standards
C&DH	Configuration and Data Handling
C&DM	Configuration and Data Management
CCP	Contamination Control Plan
CDRL	Contract Data Requirements List
CDU	Command Decoder Unit
CIL	Critical Items List
CM	Configuration Management
COSTAR	Corrective Optics Space Telescope Axial Replacement
CRRES	Combined Release and Radiation Effects Satellite
CSCI	Computer Software Configuration Item
CSM	Command Storage Memory
CSU	Computer Software Unit
CVCM	Collected Volatile Condensable
DARPASAT	Defense Advanced Research Projects Agency Satellite
DM	Data Management
DSU	Data Storage Unit
DTU	Digital Telemetry Unit
ECP	Engineering Change Proposal
EEE	Electrical, Electronic, and Electromechanical
EMC	Electromagnetic Compatibility
EMI	Electromagnetic

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EO	Engineering Order
ERBS	Earth Radiation Budget Satellite
EVMS	Earned Value Measurement System
FMEA	Failure Modes and Effects Analysis
FQT	Formal Qualification Test
G&A	General & Administrative
GEVS	General Environmental Verification Specification
GFO	Geosat Follow-On
GHRS	Goddard High Resolution Spectrograph
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GTARG	Ground Track Targeting
I&T	Integration & Test
ICD	Interface Control Document
ICWG	Interface Control Working Group
IIRR	Instrument Integration Readiness Review
IMDC	Integrated Mission Design Center
IPT	Integrated Product Team
IRAS	Infrared Astronomical Satellite
LOP	Long-Term Orbit Propagator
LOSAT-X	SDIO Experiment Satellite
LV	Launch Vehicle
LVD	Launch Vehicle Development
MDR	Mission Design Review
MPM	MicroFrame Project Manager
MSPDP	Missile System Prelaunch Data Package
MSPSP	Missile System Prelaunch Safety Package
MTI	Multi-Spectral Thermal Image
NICMOS	Near-Infrared Camera Multi-Object Sensor

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NVR	Nonvolatile Residue
PAF	Payload Attach Fitting
PCC	Power Control Console
PDL	Program Design Language
PER	Pre-Environmental Review
PSR	Pre-Strip Review
QA	Quality Assurance
RFP	Request for Proposal
RGA	Residual Gas Analysis
RME	Radiation Mirror Experiment
RSA	Rapid Spacecraft Acquisition
RSS	Resource Scheduling System
SCC	Spacecraft Control Computer
SCCS	Software Change Control System
SCR	Software Change Request
SDR	Software Development Library
SDRL	Subcontractor Data Requirements List
SE	System Engineering
SEM	Software Engineering Manual
SEP	Support Electronics Package
SER	System Engineering Report
SOW	Statement of Work
SPS	Selected Process Specifications
SSR	Solid State Recorder
STIS	Space Telescope Imaging Spectrometer
STOC	Spacecraft Test Operations Console
TML	Total Mass Loss
TQCM	Thermal Quartz Crystal Microbalance
UV	Ultraviolet

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UVCS	Ultraviolet Chronograph Spectrometer
WBS	Work Breakdown Structure
WCS	Weapons Control System
WTR	Western Test Range

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1. Scope

This specification provides a concise and comprehensive description of Ball's management approach, tools, techniques, capabilities, and processes for the implementation activities listed below:

- Program Management
- System Engineering
- Contamination Control
- Mission Performance Verification
- Core System Integration and Test
- Observatory Integration and Test
- Storage, Transportation, and Handling
- Observatory Launch Site and Operations
- Operational Software Maintenance
- Operations Support and Transition
- Miscellaneous

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2. Reference Documents

The following documents are referenced in this specification.

Government Documents:

1. Rapid Spacecraft Procurement Request for Proposal (RFP 5-02816/001) Rapid Spacecraft Acquisition
2. Rapid Spacecraft Procurement Statement of Work, Section J Attachment A, Sept. 22, 1997.
3. ANSI/ISO/ASQC Q9001 - 1994 (IS09001)

Commercial Documents:

1. BATC ISO 9000 Compliance Plan, Volume IV of this proposal.

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3. Program Management

Ball will provide a dedicated and experienced program manager who will be responsible for successful implementation of the specific mission effort. He will lead the program management effort and provide the Government with reporting and real-time insight into the program status, including technical and programmatic performance for all activities performed under the delivery order. He will have full responsibility and authority for the management of the following SOW items:

1) CORE SYSTEM — Spacecraft development, implementation, test and delivery for instrument integration (also includes item 3 below)
2) MISSION SPECIFIC MODIFICATIONS — All core system or implementation modifications required to meet unique requirements necessary for a specific mission
3) OBSERVATORY SYSTEM — Instrument integration, environmental test, performance test, launch support and two years of on orbit operations
4) STANDARD SERVICES — Program and quality management, documentation, reviews, Government insight and audits, and system engineering
5) NON-STANDARD SERVICES — Both mission specific and non-mission specific analyses and studies as ordered by the contract

The RSA program will be managed using an Integrated Product Team (IPT) approach, departing from many traditional ways to achieve efficiency with an emphasis on "value-added" processes. The approach to decision-making is to delegate this responsibility to the lowest practical level to achieve cost-effectiveness and program efficiency. The IPT managers will be given full responsibility for technical, schedule, and cost performance of their mission element. They will use the management tools described later in this section to ensure their performance meets all schedule and cost constraints. Staffing and facilities support for all SOW areas will be provided as discussed in Section 3.9.

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All hardware and software products and services delivered by Ball under this contract will include accurate processing of the date and date-related data, providing compatibility prior to and including the year 2000 and beyond without human intervention. This date and date-related data bidirectional time capability is supported by Ball's recently implemented CostPoint system for all business accounting related data. All systems delivered under this contract will be compatible with the year 2000.

3.1 Non-Mission-Specific Delivery Order Management (Special Studies)

Ball has extensive experience and capabilities with the performance and management of special studies on two recent missions: Radarsat and Multi-Spectral Thermal Imager (MTI) Spacecraft. Special studies will be managed by the program manager and could be performed "fixed-price" as they were on the above contracts.

The program manager will have access to all the necessary technical and business staff resources to perform necessary mission-specific and non-mission-specific delivery orders. An example of the MTI special studies implementation form is provided in Section 13.

3.2 Scheduling and Program Control

The following set of existing tools will support managers in their monitoring and analysis of cost and schedule status. All of the tools have been tailored to satisfy the unique requirements of a cost and schedule constrained program.

3.2.1 Cost/Schedule Performance System

Ball will implement a system to collect costs and monitor schedule performance that is consistent with its current, commercial QuickBird program. This process will involve establishing meaningful and measurable cost and schedule baselines with each of the Cost Account Managers (CAM). Each CAM will participate in the monitoring and evaluation of their established performance metrics on a monthly basis. In addition to CAM involvement, reviews with the Program Manager and Ball's upper management will be of a regular nature to ensure

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that the overall health of the program is maintained. With the fixed price nature of the contract, cost reporting will be for internal use only.

3.2.2 Scheduling Development System

Project schedules were generated (utilizing the Microsoft Project scheduling tool) at the subsystem level (WBS level 3) during the proposal effort. They were constructed around major project milestone dates, for example, design reviews, and the launch readiness review. These schedules were iterated to identify critical paths, schedule slack and critical planning milestones, and to remove inconsistencies. The proposed baseline master schedule for the mission is provided in Section 3.10. The mission's master schedule will be used to monitor all project activities to ensure the project is progressing according to plan.

3.3 Quality Management

Ball Aerospace Systems Division's (BASD) currently implements a quality system that meets the intent of ANSI/ISO/ASQC Q9001-1994 (ISO9001) and complies with NHB5300.4(1B) and Mil-Q-9858A. Our tailorable and proven quality system has been successfully utilized over the past decades supporting successful design, procurement, manufacturing, and testing of highly complex and precision space flight hardware and software products. BASD's management has committed 1997 resources to restructure our operating system and implement a Quality Management System compliant with ISO 9001 (software included). This restructuring will provide a more user friendly and cost-efficient quality management system. BASD will pursue ISO 9001 third party registration in the third quarter of 1998.

Included as Volume 4 is a copy of the second draft of the BASD ISO 9001 *Quality System Manual*. The final version of this manual will be released by year end 1997 following the completion of the Quality Procedures for the 20 Elements of ISO 9001.

Because of the wide diversity of our business, BASD's implementation of ISO 9001 will permit individual program tailoring through the use of program unique Product Assurance Plans. Included in Section 13 is the RSA Product Assurance Plan for the Ball RS2000 Bus. This

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Product Assurance Plan contains our planned approach for implementing all elements of Product Assurance to be used on the RSA products. These Product Assurance elements include Design Assurance (Reliability); Electrical, Electronic, and Electromechanical (EEE) Parts; System Safety; Material & Processes; Configuration/Data Management (C/DM); Hardware Quality Assurance; and Software Quality Assurance.

3.4 Documentation Systems

See Attachment B to QuikSCAT Statement of Work.

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3.5 Reviews and Audits

Regularly scheduled programmatic and technical reviews provide a disciplined evaluation and control of all activities involved in the performance of any program. Program reviews will not only include those defined in section 3.5.2, but also various internal reviews held throughout the program in compliance with Ball policy. Internal reviews will be held to monitor cost, schedule, and performance status, as well as technical status to ensure all requirements are considered and implemented. Participants in internal reviews include key program personnel and other Ball managers and engineers selected for their expertise in the particular aspect of the program being reviewed. A Review Management Plan will be generated for each program as required by Ball policy.

Formal/informal Government audits will be supported as ordered through a separate task order.

3.5.1 Peer Reviews

Ball will use working level (peer) reviews to identify and resolve concerns before these issues reach the formal, high-level system reviews discussed in Section 3.5.2. Peer review participants include, but are not limited to, Ball functional departments and senior management, performance assurance, and systems engineering. The Government and its support contractors are invited to attend.

Peer reviews for the program will be conducted for hardware designs, major subsystems, and contamination control. The primary intent of the reviews is to ensure each element meets requirements prior to fabrication or implementation, and to convey information to team members.

A peer review will also be held for the software design. This review will verify all requirements are allocated, produced, and verified prior to integration into the system-level software. Internal reviews will be held throughout the software development process on a regular basis and provide inputs to the overall system approach, as well as verifying suitability of the software for the program.

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3.5.2 Formal Reviews

Ball will support all of the formal reviews as defined in SOW Paragraph 4.3.1.3.

3.5.3 Audits

Though no audits are planned, Ball will support any issued through a separate task order.

3.6 Government Insight

All contractor and subcontractor internal data, reviews, audits, meetings and other activities pertinent to the execution of a delivery order shall be open to the customer on an appointment basis. Timely notification will be provided to facilitate attendance to reviews and meetings.

3.7 Contract/Subcontract Management

3.7.1 Contract Management

BASD's contracts department is led by T.H. Lapotosky, director, Contracts & Government Compliance. Mr. Lapotosky reports to R.G. Bemis, vice president, Business Management. The contract managers are completely independent of the program in that they charge to a G&A account, report through a functional chain of command, and are trained to oversee compliance issues.

For QuikSCAT, Ball assigned the manager of the Civil Space Systems contracts department, Beth McGilvray. The Rapid Spacecraft Acquisition contract Number NAS5-97251 is handled by her department. She has been working with the program team from the marketing/business development phase and will continue through the proposal, fact finding, and negotiations process, so that when the delivery order is executed and administered, there is historical continuity and coherence. The independence is maintained yet the contract manager knows the customer and members of the IPT, understands the technology and programmatic objectives, and

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works closely with the team to ensure that the terms of the contract are met within the cost and schedule parameters.

3.7.2 Subcontract Management

The Quality Assurance program for BASD-procured articles ensures that all applicable contract, design, reliability, quality, and specification requirements are incorporated into the completed articles. These requirements are transmitted to suppliers and subcontractors by drawings, procurement specifications, purchase orders, and SOWS.

3.7.2.1 Selection of Procurement Sources

BASD's selection of procurement sources is based on an extensive evaluation program that allows selection of those suppliers who have demonstrated ability to furnish high quality material, or who have successfully demonstrated, by a quality survey, capability of supplying materials that meet all the applicable requirements. These evaluations are conducted by QA personnel who have the experience, training, and ability to evaluate quality systems. The "best value supplier" will be chosen. This determination will be made on the basis of cost, schedule, quality, and past history.

BASD maintains a supplier rating system, and evaluations of supplier performance data are made on a quarterly basis. A QA-approved supplier's list is provided to the procurement organization and appropriate QA personnel. Quality Assurance Directive (QAD 150) provides a list of qualified suppliers for 16 categories of outside manufacturing, processing, and inspection/testing. Subcontractors and vendors shall be approved by the quality engineer prior to placing purchase orders with them.

Training and/or technical assistance may be provided by BASD to ensure required quality if a supplier is otherwise acceptable.

When commercial or off-the-shelf items less than an agreed upon dollar value are procured, a survey will not be required. However, a tabulation of incoming results serves as a history for the supplier and is used as a basis for future RS2000 business with that supplier.

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3.7.2.2 Procurement

The procurement team consists of the purchasing officer, Product Assurance Manager (PAM), and responsible engineer. This group evaluates and consults on the supplier's acceptability and is responsible for management of the subcontract and subsequent testing and delivery of the hardware. Generally, contract award audits of the subcontractor will be done.

The subcontractor's system, including quality, management, and production will be used wherever possible. Ball-directed procedural changes and modifications to the subcontractor system will be minimized to the extent necessary to receive acceptable material. Copies of the subcontractor's PA plans are maintained at the subcontractor's facilities.

Vendor nonconformance control by Ball will begin at the start of end item test at the vendors. The supplier's quality organization shall be expected to handle other nonconformances per their written plan. Any end-item test failure requires notification of the PAM or subcontracts manager within 24 hours of occurrence. Notification can be by phone if previously agreed upon. Specification or contract nonconformances require BASD-approved waivers/deviations. The BASD PAM and the responsible engineer or systems engineer (if appropriate) shall have approval authority for waivers/deviations.

End-item acceptance testing shall be accomplished to BASD's approved test procedure(s). The BASD Quality department imposes the right to witness final acceptance tests.

Audits will be performed at the subcontractor's facility at least once during performance of the contract. These audits shall be conducted in a formal manner and will assess conformance to the supplier's written plans and examine hardware quality. The customer, with advance notification and agreement, may accompany BASD on these visits.

The PAM ensures that applicable quality requirements are imposed on suppliers and that hardware routing and inspection criteria coding are properly identified on procurement documents.

3.8 Risk Management

A comprehensive approach to risk management ensures the on-time launch of a technically compliant spacecraft. The production platform being proposed for QuikSCAT is the

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most significant aspect of the overall risk management on the program. This is due to the elimination of any major developmental risk and the corresponding schedule risk.

Our current program schedule for the QuikSCAT program is to have the spacecraft ready to launch in 12 months with one month of schedule reserve (see Paragraph 2.1.10). Ball is also planning to use some second shift work to support schedule critical operations and is willing to add additional shift work if required to meet schedule.

Potential risk areas are identified early and are managed throughout the program. The probability of the risk occurring and the consequences if the risk occurs is assessed for program impact. For risks rated medium to high, a risk reduction and control plan is developed, implemented, monitored, and reported throughout the program. Extensive use of 'What-If Analysis' allows an understanding of the ramifications if results aren't as expected. This aids in development of alternative approaches that have reduced risk and impact.

Ball has an excellent record of managing risks on commercial programs as well as on DOD and NASA projects. Some specific mitigation points applicable to QuikSCAT program areas are summarized below:

Programmatic

- The program schedules developed for the QuikSCAT program have reserve factored in at both the platform and the spacecraft level.
- Additional shift work can be added if required for schedule recovery in the event of severe problems.
- Establishment of a definite set of agreed to requirements prior to contract start and dedicated personnel assigned to understand and document instrument interfaces will ensure no misunderstandings about the scope of work, technical requirements, and instrument interfaces.
- Active involvement of key project personnel during the study phases to ensure full buy-in to all contractual commitments and facilitate a smooth transition to program start.
- Application of lessons learned from an experienced technical and management team that has participated in similar programs.

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- Quality Assurance, Production, Procurement, and Test are assigned to the program to assist and ensure the proper level of support and priority within the product areas providing the QuikSCAT hardware.
- The majority of subcontracted items are hand carried from the vendors under special arrangement with the airlines to minimize the risk of transit loss and damage.

Technical

- Production bus requiring little design activity as outlined in Paragraph 1.0.
- The bus proposed for the QuikSCAT mission has significant technical margins in all areas, minimizing the risks of any redesign activity. The excess margins also provide contingency for unanticipated on-orbit problems.
- A comprehensive set of Performance Specifications with ICDs is established for every component on the spacecraft to eliminate any misunderstandings about requirements and interfaces.
- An active parts obsolescence program is in place to identify in advance any electronic piece parts that are being phased out of production. This allows ample time to purchase parts being phased out or to redesign for alternate parts.
- Major technical issues of high accuracy, low noise pointing and high accuracy geolocation have been addressed on EarthWatch QuickBird platform.
- Internal research and development (IRAD) utilized ahead of schedule constrained programs to avoid technical development risks. For example the implementation of the Harris RHC-3001 processor on the MTI, EarthWatch, and other programs was initiated on IRAD. The design change to a larger propellant tank is an ongoing IRAD.

Production, Integration, and Test

- Extensive test program designed to find defects and problems prior to launch.
- Proof loading and validation of GSE prior to use with flight hardware.

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- Continuous trending of spacecraft parameters and test data to quickly find developing problems at the earliest possible stages of the test program.
- Comprehensive sparing philosophy including critical long-lead piece parts for in-house items and selection of in production subcontract items to allow more rapid replacement in event of a component failure during I&T.
- A 'look ahead' integration approach that includes fit checks, trial matings, and GSE debug to minimize the risk of delays from unanticipated problems.
- Flexible integration flow to permit and allow for 'workarounds' in the event a specific component is late. Engineering models are available for many critical components to assist with workarounds.
- Workarounds have been identified for the hydrazine tank and RF components, the two subcontracts yet to be placed. Thermal models for the propulsion subsystem, transmitters, and receivers will be built to support timely progress through thermal-vac testing if these components are not available in time.
- Ball maintains risk insurance that provides hazard protection for components, subsystems and systems against damage or loss during the performance of contracts. Additionally in transport insurance is also maintained.
- Full component tests, including environments, prior to spacecraft integration.
- Environmental testing done at system level providing significant schedule margins without increasing risk.
- Hardware design features are incorporated to reduce the probability of damage and subsequent delays during I&T including isolation circuitry, overtemp protection, uniquely keyed connectors to prevent mismates, and high margins of safety on all handling fixtures.
- Over $4 million of additional capital investments over the past 2 years to enable processing of multiple spacecraft and remote sensing instruments in parallel, eliminating the risk of special test equipment conflict and bottlenecks. Improvements also include upgrades to the clean room facilities.

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- Mission sequence testing and TT&C station compatibility testing is done to reduce risk of early mission operations. The hardware is put into flight configuration and run through the launch sequence and early orbit operations to ensure that it behaves as expected.

Launch and On-Orbit Performance

- A launch vehicle integration procedure and run through of launch site operations at the Ball facility are conducted to reduce the risk of unanticipated problems at the launch site where they are most difficult to correct.
- In the event of a launch delay, the spacecraft can be stored for a reasonable fee for an extended period with no major refurbishment required. The product team organization allows easy reassignment of personnel, which minimizes any storage costs to NASA, while keeping the critical skills readily available for a later launch date.
- An extremely robust safe mode system with multiple levels of protection and load shedding reduces risk of on-orbit loss due to operator errors, hardware failures, or software problems.
- On-orbit reprogrammability allows on-orbit updates to software should the need arise. A software test bench is maintained at Ball that utilizes a flight processor, flight command and telemetry unit, and a dynamic simulation of the spacecraft. This permits comprehensive software validation on representative hardware after launch and minimizes the risk associated with performing on-orbit uploads.

In summary, Ball's risk mitigation activities start before contact implementation and extend through the in orbit operations of the spacecraft. Through a series of active risk management activities and normal operating practices, Ball offers an extremely low risk approach to the QuikSCAT mission.

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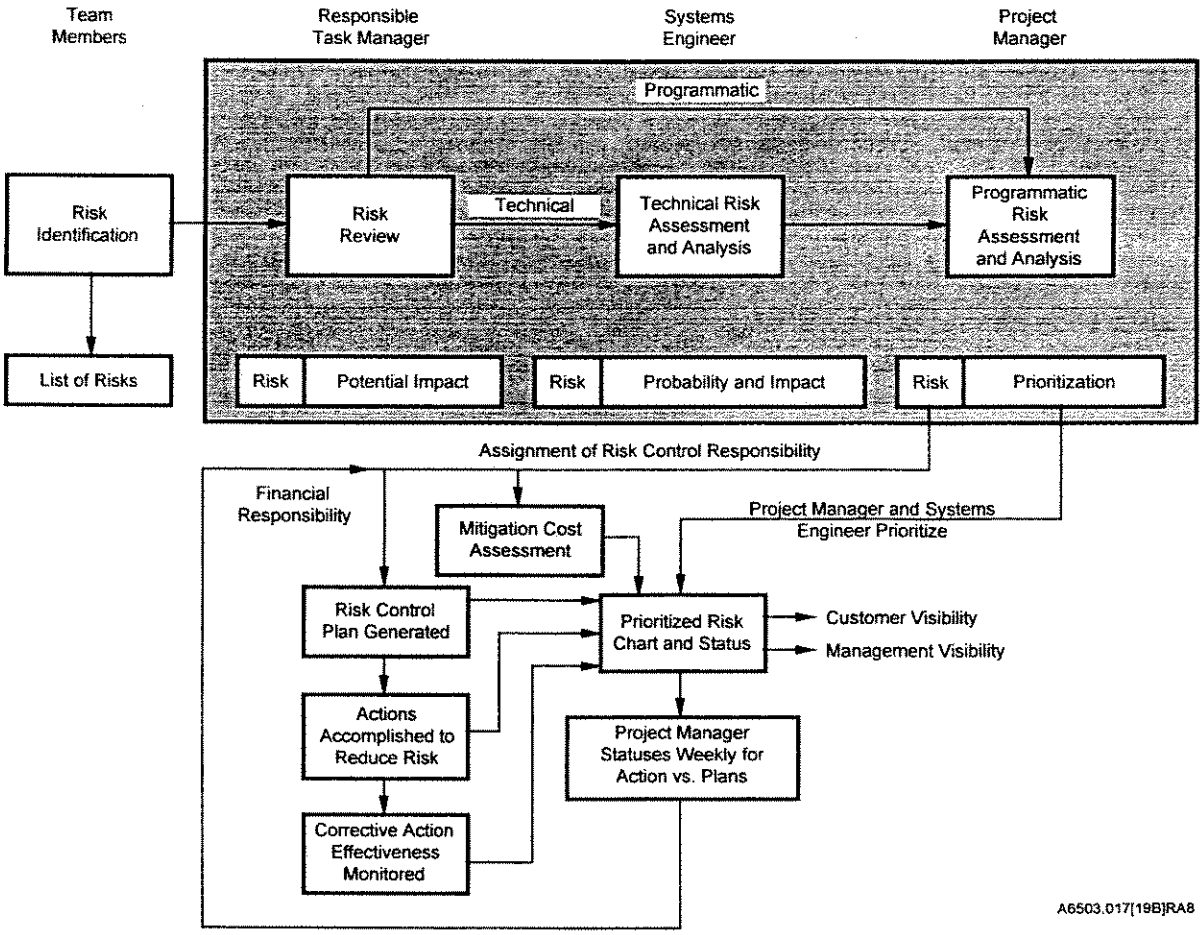
Process Flow



3.9 Resource Management (Staffing, Facilities, etc.)

3.9.1 Staffing

Ball is a program-focused organization. Line management, shown in **Figure 3-3**, is responsible for providing the program team with the people and resources necessary to efficiently execute the program. The program manager reports directly to Dave Taylor, Director of Commercial Space Operations, who is responsible for ensuring the program receives proper support from the line organizations.

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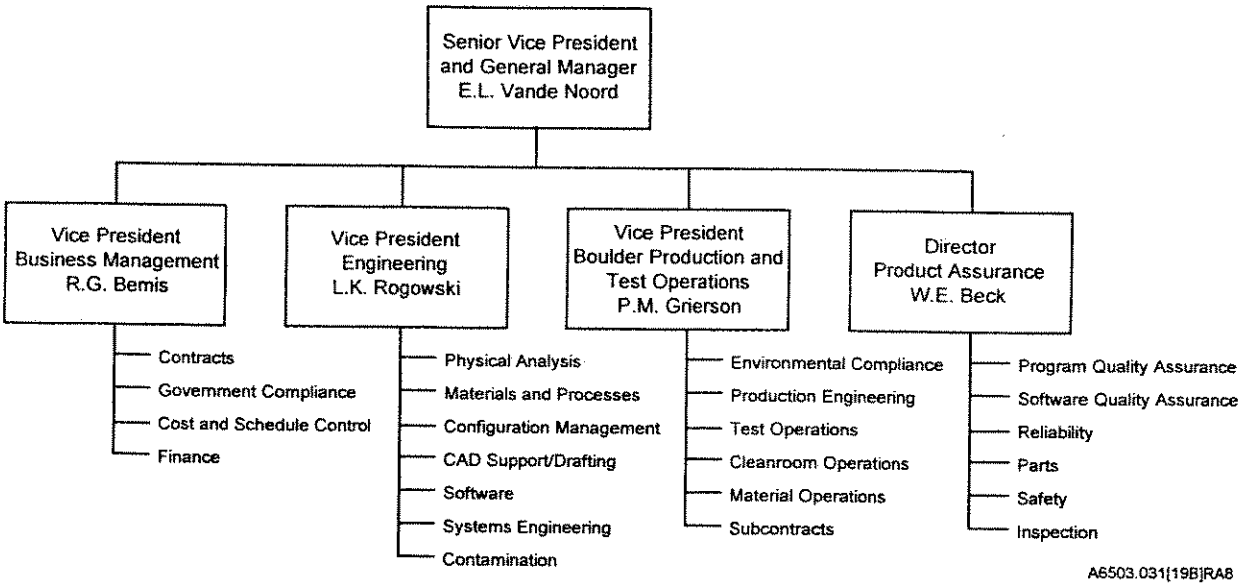

***Figure 3-3** Ball's line organizations will provide all needed support to the RSA program*

As discussed in Section 1.2.1 of Volume 1, Ball has a pool of 1,200 degreed personnel to address all task orders (mission unique or nonmission unique) written in support of the program.

3.9.2 Facilities

Ball owns extensive manufacturing, integration, and test facilities to provide space hardware. The facilities required for each program are scheduled immediately following the program's award. Ownership and scheduling control of facilities ensures we are able to maintain schedule and provides the program with flexibility. Section 1.2.2 of Volume I has a facilities/capabilities summary.

At the beginning of each project, production and test facility needs are identified using the Resource Scheduling System (RSS) for the duration of the project. This includes machine shop and support shop (metal finish, cleaning lab, etc.) hours, as well as, system test facilities (vibration, thermal, EMI/EMC, etc.) needs. The RSS is then used to identify near-term facility usage conflicts and to forecast long-term facility growth to meet the needs of all programs. Facility schedules are monitored daily by the facility resource managers, weekly by the projects, and on a monthly basis, long-term forecast are reviewed by senior managers. This system

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provides an effective planning tool that allows Ball to take full advantage of our assets while maximizing the return to our customers.

3.10 Implementation Schedule

A baseline implementation schedule is presented in Section 1. . All program reviews are shown as well as the key program phases. Key features of this schedule are:

- Spacecraft launch — 11.5 months after contract award
- Payload delivery — accommodates -6-month delivery of instrument
- Mission schedule — 11.5 months to launch

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Master Schedule

(See Section 1, Figure 20)

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4. System Engineering Role

A system engineering (SE) manager will be dedicated to the program for the entire contract duration. The SE will transition to project engineering functions after the MDR and will be a key contributor during verification. The system engineer reports to the program manager and is supported by specialists as required. In addition to the requirements flowdown process described below, the system engineer:

- Serves as the primary customer technical contact
- Develops and maintains bus Interface Control Documents (ICD) for the payload and ground segment
- Supports development of the launch vehicle ICD
- Performs risk identification and abatement
- Analyzes mission-specific issues that may affect system performance
- Serves as a catalyst to foster formal and informal communication throughout the program, including both internal and external meetings
- Monitors the entire design to ensure that performance margins are sufficient, yet not excessive
- Performs or supports system- or bus-level trade studies if required before MDR
- Manages specialty engineering disciplines

4.1 Requirements Analysis

During the period before MDR, the system engineering staff works with the customer technical team, possibly led by the Integrated Mission Design Center (IMDC), to establish the detailed requirements for the bus and its impact on the other elements of the system. Ball's SE effort will contribute to the goal of firming up the lowest risk overall mission implementation. In support of this, Ball will analyze the impact on the modified core system of variations to requirements that are suggested by the customer. These include issues such as: operation time histories, payload interfaces, testing schedules and procedures, orbit parameters, and ground station utilization.

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4.1.1 Requirements Flowdown

The requirements flowdown process is performed by system engineering and is done with a good understanding of the intent of requirements. These requirements are collected and flowed down to the subsystem-level allocation of requirements. SE, design, and test personnel ensure that requirements are verifiable by test, analysis, similarity, or inspection. Requirement allocation culminates in an "allocated baseline" at MDR. A verification matrix of the above requirements is included in CDRL-1, Mission Performance Verification Plan, which is provided as part of the mini-proposal. The verification matrix will be updated at MDR with freezing of the baseline.

4.2 Interface Definition and Maintenance

Ball applies the interface management approach to RS2000 that proved successful in managing internal and external interfaces on satellite programs such as ERBS, RME, CRRES, LOSAT-X, Radarsat, DARPASAT, and GFO.

Interfaces are identified, defined, and controlled by the system engineering part of Ball's team. Each interface is documented in a separate ICD. ICDs detail the interfacing functions and requirements, and Ball is accountable for their development and maintenance.

Section 5, Appendix A of the Performance Specification, and the Launch Vehicle and Ground Station ICDs from QuickBird or GFO will be modified, if necessary, during the baselining of the design before MDR. Preliminary ICDs for all the interfaces will be available 30 days prior to MDR, where they will be presented to the customer for final approval.

Integration of the observatory to the launch vehicle will be controlled by and maintained in the launch vehicle documents, written and controlled by the government. Ball will provide all needed supporting information in CDRL 4. Ball will also produce the Missile System Prelaunch Data Package defining integration and test procedures which conform to range safety. Launch site compatibility testing, interface hardware and software verification, final mating, and integrated checkout, which ensure spacecraft compatibility with the launch vehicle, are detailed in this document. During the processing cycle, launch site communication link verification with the spacecraft C&DH system and range safety testing will be performed. Each step of the

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integration to the launch vehicle is controlled by procedures and checklists to ensure configuration control. Ball and LV personnel will both participate in prelaunch, launch, and postlaunch activities to ensure a successful launch.

4.3 Reliability Analysis

Ball will update the existing analysis of the RS2000 reliability and report the results at the MDR, highlighting any potential reliability concerns. The analysis will be revised if design changes occur after this review. The performance of the reliability analyses is structured to: (1) ensure adequate safety margin between part stress ratings and the application and usage stress, and (2) provide the bus reliability prediction. It is assumed that no updates are required for the generic mission.

Ball will maintain an integrated and proactive reliability program throughout the contract period that is structured to ensure that performance and reliability objectives are achieved. Key elements of the program include continued application of the parts control program (described in paragraph 2.5 of the Product Assurance Plan), plus a structured set of analyses for new and modified designs (described in paragraphs 2.4.1 through 2.4.4 of the Product Assurance Plan), and a closed-loop failure reporting, analysis, and corrective action system (described in paragraph 2.4.5 of the Product Assurance Plan).

The following subsections identify the analyses being performed.

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4.3.1 Parts Stress Analysis

Part level electrical and thermal stress analysis will be performed only for new designs to verify that adequate operating margins are used. Where indicated by the analysis, corrective actions will be implemented or rationale for retention justified.

4.3.2 Worst-Case Circuit Analysis

Worst-case analysis for the RS2000 bus will be reported at the MDR. New worst-case analyses will only be performed on critical circuits in new or modified electronics to ensure that they will accomplish all functional requirements, within the performance margins, under the most unfavorable combination of realizable conditions. It is assumed that no new worst-case analysis is required for the generic mission.

4.4 Safety

A system safety program will be implemented to ensure the safety of personnel, flight equipment, facilities, and other equipment. The responsible engineer will coordinate the safety effort and will have responsibility for the following tasks:

- Preparing a System Safety Program Plan in compliance with EWR 127-1 requirements. The System Safety Program Plan will define safety program responsibilities and authority, program interfaces, safety milestones, safety tasks, and safety task outputs.
- Identifying applicable safety requirements by completion of a review of the spacecraft systems, GSE, and operations against EWR 127-1, OSHA standards, and other federal, state or local regulations
- Communicating safety requirements to the appropriate program personnel
- Performing analysis to identify hazards associated with flight equipment, GSE, and operations. Hazards analysis will identify hazard causes and assess the risk of mishap associated with each hazard. Hazards will be documented on hazard reports and tracked to resolution by elimination or control that achieves acceptable risk of mishap. Observatory hazards will be documented in the Payload Hazard Report.

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- Ensuring that appropriate controls are incorporated through design or procedures for each hazard
- Preparing program safety documentation including the Missile System Prelaunch Safety Package (MSPSP) required by EWR 127-1. The MSPSP will be developed and submitted in accordance with Item 13 of the CDRL.
- Coordinating safety program activities within the program and with external entities including the customer safety organization, payload organizations, the launch vehicle contractor, and the launch site safety organization.

Section 13.2 (Product Assurance Plan) has additional safety-related information.

4.5 Configuration & Data Management (C&DM)

C&DM is accomplished as an element of the program management function with appropriate support and interface with the Ball C&DM organization.

4.5.1 Data Management (DM)

Data is prepared by the project team for all program CDRLs and necessary operating information. Subcontractors support Ball in developing data and provide their own data, as defined in the subcontractor data requirements lists (SDRL), which are incorporated by Ball into the program data system.

The program configuration and data manager is responsible for managing the data system used for preparing and controlling technical and administrative documents. The data system and configuration management systems are performed jointly. Program data will result from the following efforts:

- Contract deliverable data per program CDRL
- Program data
- Supplier-generated data

The program CDRL defines the content and delivery schedule for all formal documents. The configuration and data manager prepares detailed schedules for each document and identifies the

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personnel responsible for preparing the data. A controlled file is maintained by the configuration and data manager for originals and extra copies. All issues are logged to identify current issue and approval status, when applicable. All changes to documents are clearly identified in the change log accompanying each document as well as the authority or reason for the change.

At the start of the program, the configuration and data manager identifies the various program disciplines, the categories of documents, and the numbering system to be used. The data accession list, lists each document and any revisions. The originals are filed by the configuration and data manager. Typical documents under this category are supplier's SOWs, engineering analyses, and test reports.

The Ball systems engineering report (SER) also falls into this category. The program will use the SER to document engineering studies, calculations, analyses, and other pertinent engineering information throughout the program. The SER is used to disseminate information internally and retains the information until such time that it is recorded in formal program documentation or no longer needed.

All supplier data requirements are detailed in a supplier data requirements list accompanying each SOW.

4.5.2 Configuration Management (CM)

Ball uses an efficient configuration management process during detailed design, fabrication, test, delivery, and operations. This process is based on CM approaches of MIL-T-31000, MIL-STD-100E, MIL-STD-490, MIL-STD-973, MIL-STD-498, and NASA Software Development Standards, with appropriate reviews and approvals.

Engineering changes will be classified as Class I or Class II and documented on engineering order (EO) forms. Class I changes are revision to baselined documents such as interface control drawings and will be controlled accordingly. Ball implements an engineering document release tracking system that schedules the need date for each document and tracks its progress toward that date to ensure engineering availability to support procurement, fabrication, and test schedules. Engineering changes are also tracked through this system to ensure timely release.

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As-designed configuration data is computer accessed by production and quality assurance (QA) to ensure the correct configurations are being fabricated, assembled, and tested. To support testing, a redline drawing control system will be implemented to document and control test procedure changes to correct problems identified during testing. The redlines must be officially incorporated and released before QA acceptance of the tested article. As-built vs. as-designed configurations are verified.

Subcontractor's CM systems are reviewed by Ball to ensure configuration control of procured components.

Software CM activities are controlled by the same program CM system. This system covers engineering, configuration management, QA, and test activities. Controls are implemented throughout the software lifecycle. The software development engineer controls the configuration prior to the release of the software. Subsequently the software configuration is controlled within the CM system.

4.6 Instrument and Mission Accommodations

4.6.1 Instrument Accommodations

To ensure instrument needs are met, Ball will assign an instrument accommodations engineer to the RS2000 program. In most cases, this person will have experience directly relevant to the mission's instrument. Since Ball realizes that it is the *instrument* that provides the data justifying the mission's expense, the instrument accommodations engineer will serve as a consistent advocate for the instrument developer's needs. This person will support development of the IICD, Spacecraft and Observatory I&T Plan, the Contamination/Cleanliness Control Plan, and External Interfaces Models and Analysis documents.

4.6.2 Mission Accommodations

For RSA, our main role will be to supply the spacecraft bus, integrate the instrument, test the observatory, and support the launch campaign. We will support the IMDC as the lead in allocating requirements among mission elements. As described in Section 1.1.3 of Volume 1,

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Ball has expertise in adapting RS2000 to various missions and, if desired, this expertise can support a separate task order.

Ball will work closely with NASA flight operations engineers to ensure that this interface is well understood. The system engineer will ensure that key interfaces are understood, with support from the communications subsystem and flight software lead engineers, and will lead development of a mission-specific Flight Operations Support Plan (CDRL 10) and Spacecraft Operations Description Manual (CDRL 8). Training will be led by a Ball mission operations specialist taking advantage of subsystem procedures used for compatibility and performance testing. For specific missions requiring more complex operations or interface modifications, this level of effort can be supplemented through a separate task order.

Ball will work closely with launch vehicle engineers from the LV supplier, NASA, and the launch site to ensure this interface is addressed adequately. The system engineer will ensure that key interfaces are agreed upon, with support from the mechanical, power, and propulsion lead engineers. Ball will prepare the LVD (CDRL 4), Observatory Launch Site Ops and Test Plan and Procedures (CDRL 11), MSPSP (CDRL 13), and Transportation and Handling Plan (CDRL 14) assuming a Titan II launch from WTR. Specific missions requiring more detailed planning or special considerations will require a special task order.

4.7 Mission Design and Analysis

The following mission-specific analyses are planned for RS2000, reflecting the idiosyncrasies of specific orbits, launch dates, launch vehicles, and ground station locations. Ball program personnel will include a number of multi-discipline engineers who can perform and document these analyses. The analyses we plan to perform are:

- **Radiation Environment** — Specific orbit conditions will be analyzed for radiation dose predictions and single-event upset environments. These analyses will be performed by an experienced analyst available through Ball's engineering directorate, using tools such as SHIELDOSE, MAG, ORB, and CREME. These analyses will be used to justify spot-shielding to protect particular components judged to be susceptible to radiation.

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- **Orbit Acquisition/Maintenance** — The mission's specific orbit and configuration will be used to generate predictions for nominal and worst-case ΔV and burn frequency. These analyses will be performed by program personnel supporting related activities, using tools such as GTARG and LOP. These analyses will be used to verify the propellant load for the selected operational altitude, and evaluate alternatives to ensure the availability of required fuel throughout the mission's specified duration.
- **Initialization Planning** — The details of how to transition from the as-launched state to a designated benign on-orbit state will be addressed based on launch vehicle, launch site, ground station locations, instrument constraints, and orbit conditions. An initialization timeline will be provided, including key inputs to the at-launch memory load to be used for detumble and autonomous sun acquisition. These analyses will be performed by program personnel supporting related activities.
- **Normal Operations Planning** — Data contact scenarios and optimization trades will be done in support of the mission design process including safe modes and power-down sequences.
- **Structural Analysis** — Finite-element structural model of the bus will be provided. This will be combined with a GFE model of the instrument to yield an observatory model. Structural analysis of the instrument and launch vehicle interfaces as defined in the ICDs
- **Thermal Analysis** — Analysis of the bus and observatory. A simplified GFE instrument model will be incorporated.
- **Ground System Compatibility Analysis** — Verification of telemetry protocols, data rates, and link budgets
- **Product Assurance Analyses** — See Section 4.3
- **Other** — All analyses will be performed as required to satisfy the Data Item Descriptions in Reference 2 for CDRL submittals.

Ball engineers will identify how these mission analyses impact component, subsystem, and flight software performance. If design modifications are desired by the customer, a special task order will accomplish the desired changes. Since Ball's historical niche has been for special-purpose spacecraft, the corporate culture means that project engineers will focus on how their

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hardware, software, or processes affect that particular mission. The requirements levied through the RFO, ICDs, and other sources will be subjected to classic flowdown to subsystems and components, and to the Mission Performance Verification Plan.

4.8 Failure Modes and Effects Analysis and Critical Items List

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5. Contamination Control and Materials and Processes Control

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5.1 Contamination

Ball has successfully developed and flown contamination-sensitive UV, IR, and visible space instruments and systems for four decades. The RS2000 Bus-specified contamination approach and methods will ensure that the cleanliness levels specified by the contamination budget are met starting with fabrication of the RS2000 Bus and carried through launch. These contamination requirements focus on designed-in contamination prevention with associated contamination detection capabilities.

Contamination controls also apply to GSE, special test equipment, tools, storage and shipping containers, environmental test facilities, and any hardware that comes into contact with, or is in the immediate vicinity of, the flight hardware, as applicable.

Implementation of these contamination controls will be the responsibility of the RS2000 Bus-assigned contamination control engineer. QA will verify that the contamination control processes are followed.

5.2 Materials and Processes

The M&P Control Plan describes the procedures for the selection and control of M&P to be used by BASD for the RS2000 Bus. The purpose of the M&P Control Plan is to augment the safety and success of the mission through proper selection and treatment of materials and processes for the fabrication of the RS2000 Bus. The RS2000 Bus program M&P engineer will implement the M&P tasks.

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6. Mission Performance Verification

Figure 6-1 illustrates the flowdown of verification requirements and associated analytical and test results with the original requirements. As test and analytical results become available, they will be associated with the originating verification requirements, ensuring that all requirements are met.

This system simplifies the flowdown of system requirements to lower level testing. This process allows early verification of system requirements thus reducing overall program risk. The Mission Performance Verification Plan (CDRL No. 1) detailing the I&T and on-orbit verification process will be submitted as part of the mini-proposal phase. However, the verification matrix included in this CDRL will only be final at MDR.

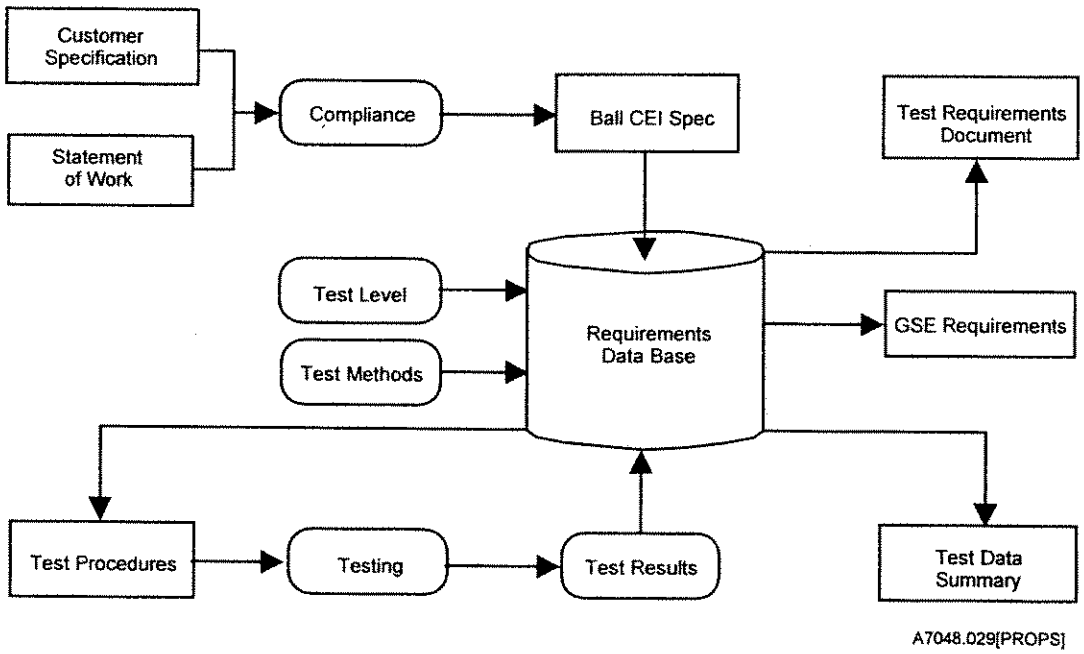

Figure 6-1 *Test Requirements Tracking and Reporting*

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6.1 Core System Integration and Test, Observatory Integration andTest

The matrix shown in **Figure 6-2** represents the verification matrix for the RS2000. A similar matrix for the Observatory details the requirements traceability. This matrix shows the methods (analysis, test, demonstration, and inspection), level (component, subsystem, bus, observatory), and location in the bus and observatory I&T flow that the requirements will be verified.

6.2 On-Orbit Verification

Ball will provide on-orbit verification per the checkout plan described in Sections 12.2 and 12.4. The checkout plan will be developed based on the mission-defined performance specifications, test requirements document, spacecraft operations manual, and the flight operations support plan. Results of the on-orbit performance tests will be compared to predicted values and test values and summarized in the 30-day on-orbit performance report.

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Figure 6-2. QuikSCAT Verification Matrix

Performance Specification Section	Analysis	Inspection	Test	Reference / Comment
1. SCOPE				Definition
2. APPLICABLE DOCUMENTS				Definition
3. QUIKSCAT SYSTEM PERFORMANCE CHARACTERISTICS				Definition
3.1 Observatory (or Mission) Level Performance				Header
3.1.1 Launch Vehicle Specifications				Titan II is the intended launch vehicle
3.1.1.1 Launch Vehicle Compatibility	X	X	X	Analysis and inspection as required per CDRL's 2 & 4. Testing as defined in QuickSCAT Test Plan.
3.1.1.2 Injection Orbit				Information Only
3.1.1.3 Injection Errors				Information Only
3.1.1.4 Payload Adapter		X		Definition, inspection of mating interfaces as defined in CDRL 4.
3.1.1.5 Launch Vehicle Separation	X		X	Analysis of spacecraft operation in response to the seperation signal. Testing of spacecraft system response as defined in QuickSCAT Test Plan
3.1.2 Orbit Compatibility/Constraints	X			Analysis per CDRL 2 Item G
3.1.3 Orbit Maintenance	X			Analysis per CDRL 2 Item G
3.1.4 Cleanliness Levels	X			
3.1.5 Design Lifetime	X			Analyses per CDRL 2 Items H,I
3.2 QuikSCAT System Performance				Header
3.2.1 Structural Characteristics				Header
3.2.1.1 Spacecraft Mass	X		X	Mass properties analysis, measurement
3.2.1.2 Structural Modes	X		X	Structural analyses per CDRL 2 Item B, Testing of spacecraft response as defined in QuickSCAT Test Plan
3.2.2 Electrical Scatterometer Power				Refer to section 4.2
3.2.3 Propulsion Performance				Refer to section 3.1.2
3.2.4 Attitude Control Performance				Header
3.2.4.1 Pointing Accuracy	X		X	Analysis per CDRL2 Item C, Testing of spacecraft response as defined in QuickSCAT Test Plan
3.2.4.2 Pointing Knowledge	X		X	Analysis per CDRL 2 Item C alignments as defined in QuickSCAT Test Plan.
3.2.4.3 Stability		X		By inspection of Analyses
3.2.4.4 Spacecraft Orientation	X			
3.2.4.5 Momentum Compensation	X			
3.2.4.6 Scatterometer Dynamic	X			

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Figure 6-2. QuikSCAT Verification Matrix

Performance Specification Section	Analysis	Inspection	Test	Reference / Comment
Disturbance				
3.2.4.7 Initial Sun Acquisition	X		X	Separation and LEOP analysis, Testing of spacecraft response as defined in QuickSCAT Test Plan
3.2.5 Command and Data Handling Performance				Header
3.2.5.1 On Board Computational Capacity			X	Software FQT
3.2.5.2 Autonomous Spacecraft Safing	X		X	Safe Mode description & analysis, Testing of spacecraft response as defined in QuickSCAT Test Plan
3.2.5.2.1 Scatterometer Anomalous Conditions			X	Testing of spacecraft response as defined in QuickSCAT Test Plan
3.2.5.2.2 Spacecraft Anomalous Conditions	X		X	Operational analysis, Testing of spacecraft response as defined in QuickSCAT Test Plan
3.2.5.3 Science Data Collection				Information Only
3.2.5.4 Data Storage Capacity	X			Data Storage Sizing Analysis
3.2.5.5 Data Storage Bit Error Rate		X		By inspection of RF Link Analysis
3.2.5.6 Spacecraft Time Synchronization	tbd		tbd	Design feature, details of analysis and test TBD
3.2.5.7 Equator Crossing Indication	tbd		tbd	Design feature, details of analysis and test TBD
3.2.6 Communications Performance				Header
3.2.6.1 Downlink Capabilities				Header
3.2.6.1.1 Downlink Format	tbd		tbd	Design feature, details of analysis and test TBD
3.2.6.1.2 Payload Downlink Period and Rate	X			Dowlink Operations Analysis
3.2.6.1.3 Downlink Channel Performance	X		X	Analysis per CDRL 5 Item G. Testing of spacecraft defined in QuickSCAT Test Plan
3.2.6.1.4 Downlink Bit Error Rate			X	Inspection of Link Margins
3.2.6.1.5 Downlink Bandwidth	X		X	Analysis per CDRL 5 Item G. Testing of spacecraft defined in QuickSCAT Test Plan
3.2.6.1.6 Ground Station Compatibility	X			Analysis per CDRL 5 Item G.
3.2.6.2 Uplink Capabilities				Header
3.2.6.2.1 Uplink Command Rate	X		X	Analysis per CDRL 2 Item F. Testing of spacecraft defined in QuickSCAT Test Plan
3.2.6.2.2 Uplink Channel Performance	X		X	Analysis CDRL 5 Item G. Testing of spacecraft defined in QuickSCAT Test Plan
3.2.7 Thermal Control	X	X	X	Analysis per CDRL 2 Item D, Testing of spacecraft defined in QuickSCAT Test Plan
3.3 Spacecraft Mechanical Alignment				Header
3.3.1 Alignment Errors Included in Pointing		X		By inspection of Analysis

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Figure 6-2. QuikSCAT Verification Matrix

Performance Specification Section	Analysis	Inspection	Test	Reference / Comment
3.3.2 Pre-Launch Alignment Measurement	X		X	Analysis per CDRL 2 Item C alignments as defined in QuickSCAT Test Plan.
3.3.3 Scatterometer Alignment Cube				Information only
3.4 System Verification				Header
3.4.1 Full-Up Spacecraft Operational Test			X	Reference SOW 4.3.5.2.1 and the QuickSCAT Test Plan
3.4.2 Environmental Verification	X		X	Thermal vacuum, vibration, pyro shock, fault protection and EMI/EMC are performed on the spacecraft per the QuickSCAT test plan. Acoustic compatibility is demonstrated by an observatory level acoustic test.
3.4.3 Spacecraft System Level Burn-In			X	Testing defined in QuickSCAT Test Plan
3.4.4 Launch Site Testing			X	Reference SOW 4.3.5.1 and the QuickSCAT Test Plan
4. SCATTEROMETER INSTRUMENT ACCOMMODATIONS				Header
4.1 Physical Requirements	X	X		Design feature supported by analysis.
4.1.1 Scatterometer Envelope	X	X		Design feature supported by analysis.
4.1.2 Scatterometer Mass Properties and Frequencies	X			Analysis per CDRL 2 Item B
4.1.3 Scatterometer Center of Gravity and Moment of Inertia	X	X	X	Itemized unit measurements supported by analysis. Measurement of X-Y CG is performed per the QuickSCAT Test Plan
4.1.4 Scatterometer Mechanical Constraints				Header
4.1.4.1 Mechanical Interface				Header
4.1.4.1.1 Standard Mounting Option				Definition
4.1.4.2 Interconnecting Cabling and Waveguide		X		Design feature
4.1.5 Scatterometer Thermal Interface	X		X	Analysis per CDRL 2 Item D, verified in spacecraft thermal balance
4.1.6 Field Of View Constraints		X		Design feature
4.1.7 Scatterometer Orientation Constraints	X			Analysis per CDRL 2 Item D. Design feature
4.2 Electrical Power and Signals/Data Interface		X		Design feature
4.2.1 D.C. Power	X		X	Analysis, Testing of spacecraft defined in QuickSCAT Test Plan
4.2.2 Power Availability	X		X	SC Power Budget analysis, Testing of spacecraft defined in QuickSCAT Test Plan
4.2.3 In-Rush Capability	X		X	Analysis, Testing of spacecraft defined in QuickSCAT Test Plan
4.2.4 Scatterometer Chassis	X	X	X	Analysis, Testing of spacecraft defined in

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Figure 6-2. QuikSCAT Verification Matrix

Performance Specification Section	Analysis	Inspection	Test	Reference / Comment
Grounding				QuickSCAT Test Plan
4.2.5 Scatterometer Pyro Interface		X	tbd	Design feature, testing TBD
4.2.6 Scatterometer Command Interface		X		Design feature
4.2.7 Scatterometer Data Interface				Header
4.2.7.1 Housekeeping Telemetry Data		X		Design feature
4.2.7.2 Science Data Interface	X	X	tbd	Analysis per CDRL 5 Item A. design feature, testing TBD
4.2.8 Scatterometer Control Interface		X		Design feature
4.2.9 Spacecraft Interface Cables		X		Design feature
4.3 Observatory Environmental Requirements				Header
4.3.1 Thermal Environment				Definition
4.3.2 EMI/EMC Environment	X		X	EMI/EMC analysis, Testing of spacecraft defined in QuickSCAT Test Plan
4.3.2.1 Spacecraft Radiated Susceptibility	X			EMI/EMC Compatability analysis
4.3.2.2 Spacecraft Radiated Emissions	X		X	EMI/EMC compatability analysis, Testing of spacecraft defined in QuickSCAT Test Plan
4.3.3 Radiation Tolerance				Header
4.3.3.1 Total Dose	X			Radiation analysis
4.3.3.2 Heavy Ions	X			Radiation analysis
4.3.3.3 Single Event Effect (SEE) Tolerance	X			SEE analysis
4.4 Operational Factors				Header
4.4.1 Science Data Distribution	X		X	Operational analysis confirmed in network test
4.4.2 Scatterometer Command Types			X	Testing of spacecraft defined in QuickSCAT Test Plan
4.4.3 Scatterometer Command Storage			X	Testing of spacecraft defined in QuickSCAT Test Plan
4.4.4 Ephemeris Predicts	X			Analysis per CDRL 5 Item J
4.4.5 Command Planning Timeline			X	To be verified in operations testing

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7. Core System Integration and Test

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8. Observatory Integration and Test

The instrument integration and system environmental and test flow is shown in **Figure 8-1.** Note accoustic testing is not shown in the flow, but will be performed as described in section 8.10.

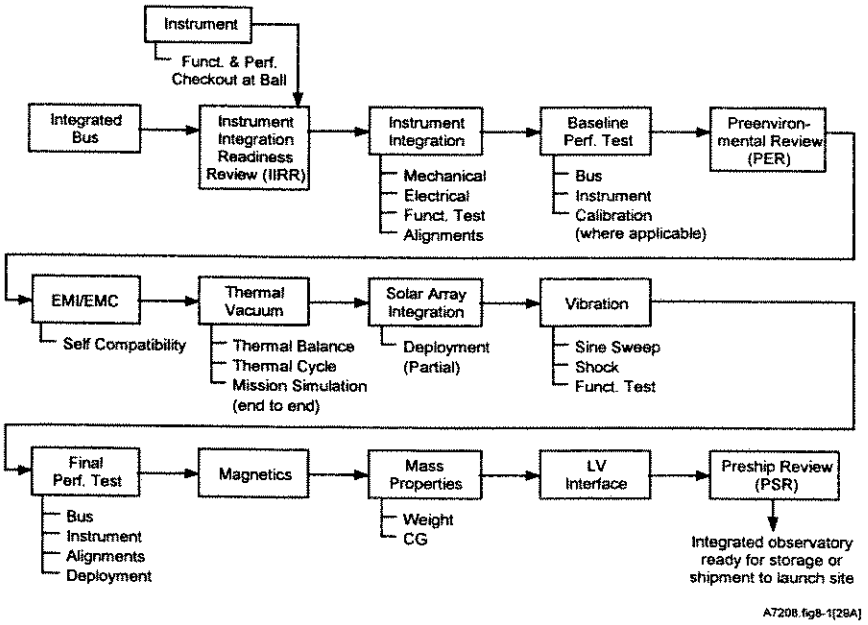

Figure 8-1 *Instrument Integration and System Test Flow (Typical)*

System test procedures are a mix of automated quick-look command and response tests and on-orbit simulations using mission operations procedures to run the satellite. This approach tests the observatory in its anticipated environments and operating modes to the maximum extent possible.

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At the conclusion of the baseline test on the observatory, a Pre-Environment Review (PER) will be conducted. This review will verify that the observatory has successfully completed all tests and is ready for environmental testing. Included in this review will be a discussion of all anomalies encountered and the resolution of any open issues. Detailed plans, expected results, and the review of test procedures for the individual environmental tests will be discussed.

Once the observatory has successfully completed the I&T sequence a Pre-Ship Review (PSR) will be held. This review will verify successful completion of environmental and final testing. Included in this review will be a discussion of all anomalies encountered and the resolution of any open issues. Shipping operations and launch site support plans will also be discussed by presenting a thorough analysis of the test results and satisfaction of the verification plan.

8.1 Instrument Integration

Prior to a components integration, the cognizant test engineer, system engineer, and instrument representatives will walk through the integration procedure using the applicable ICDs, interface schematics, and mechanical assembly drawings. This table-top conceptual integration finds potential problems or concerns and resolves them prior to the physical hardware integration. This task also familiarizes the integration and test engineers with the detailed integrated spacecraft design.

The use of paper integration and interface simulators ensures that the final physical integration will go smoothly. Electrical integration is performed via a detailed procedure which verifies electrical compatibility (power and ground isolation, continuity, and signal level) before connectors are mated.

8.1.1 Mechanical Integration

The use of mechanical instrument mock-ups, tooling plates, and the paper integration process ensure that the actual integration process will produce no surprises. Ball will coordinate with the instrument developer to review mechanical interfaces and develop a mechanical mock-up.

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8.1.2 Electrical Integration

The use of the bus and payload simulators and the paper integration process give us great confidence that the actual integration process will produce no surprises. Ball will coordinate with the instrument developer to review electrical interfaces during the development of the payload electrical simulator. This simulator is supplied to Ball as GFE.

8.1.3 Instrument Comprehensive Performance Test

Based on our extensive experience with testing of science instruments and existing on-site test facilities, Ball will work closely with the instrument developer. It is expected that the instrument supplier will provide performance test plans and procedures to be included in the observatory testing and provide personnel to support the testing.

8.2 EMI/EMC/ESD Test

EMC testing will be conducted to verify that the Observatory is compatible with itself, with its known environments, and its GSE as required by the performance specification. The tests will be designed to verify the following elements:

- Self-compatibility test such that Observatory EMI do not cause any self-degradation or loss of performance of any instrument or subsystem.
- Spacecraft grounding and electrical bonding comply with ESD control guidelines.

8.3 Optical Alignments Measurement

Optical alignment measurement will be done after the instrument is integrated into the bus.

8.4 Magnetic Survey

Ball approach to magnetic surveying is to impose strict design and test requirements on the individual components prior to integration. We also perform a system level interaction check of the completed spacecraft.

8.5 Attitude Control Subsystem Phasing

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8.6 Solar Array Integration

Ball plans to integrate the solar arrays after thermal testing and before vibration testing. This allows us to minimize the handling thus reducing the possibility of damage. During integration, solar array drive mechanical and electrical interfaces are verified, hold-down release mechanisms are verified, and the array themselves are installed and deployed. Acoustic testing with an integrated solar array is planned.

8.7 Flight Payload Attach Fitting Integration

The Flight Payload Attach Fitting (PAF) is integrated early in the integration activity to verify that the mechanical interfaces are compatible.

8.8 Mass Properties Measurements

Center of gravity measurements will take place to confirm the Observatory X-Y axis center of gravity.

8.9 Vibration Test

Ball will perform 3-axis vibration for characterization and quasi-static load testing. Vibration testing consists of 3-axis sinusoidal sweeps for characterization, and sine burst intended to expose the Observatory to expected launch environments. Survival through these environments is determined by health checks performed between axes and a test performed at the conclusion of

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vibration testing. Essential bus units are powered during the sine burst portion of the test. In addition, the observatory is instrumented with accelerometers, and low level sinusoidal sweeps are performed throughout the vibration test sequence so that structural integrity can be confirmed and empirical results can be correlated to analytical predictions.

8.10 Acoustic Test

Acoustics testing is performed to expose the Observatory to acoustic excitation expected during launch. The test is intended to excite those modes and structural elements normally not affected by mechanical vibration. Survival through this environment is determined by a functional test performed at the conclusion of acoustic testing.

8.11 Shock Test

Shock testing is performed to expose the observatory to the shock excitation that is developed by the pyrotechnic launch vehicle separation system. Survival through this environment is determined by a test performed at the conclusion of the test.

8.12 Solar Array Deployment

The solar arrays are deployed following exposure to the vibration environments. The test verifies that release mechanisms work and the arrays deploy properly. The deployment is gravity assisted or manually assisted due to the 1 g environment. Array second motion deployment is verified by a release and partial deployment.

8.13 Thermal Vacuum Test

The thermal vacuum test is performed to demonstrate the ability of the observatory to meet design requirements under vacuum conditions and temperature extremes that simulate those predicted on-orbit. The test will consist of two cycles to the hot and cold protoflight temperature limits. The test configuration we use during thermal testing places guard heaters within the view of all radiative surfaces and cooling the chamber shrouds to less than -150 °C. This allows us to

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trim the guard heater settings allowing us to put as many components as possible to the test temperature limits or simulate sun-induced gradients across the observatory. Once a hot or cold temperature plateau is reached, the observatory is allowed to "soak" or achieve steady-state conditions. At the conclusion of this dwell, tests are executed.

Proper operation and performance during all tests is required to be successful.

8.14 Thermal Balance Test

Ball will do thermal balance testing during thermal vacuum testing. The purpose of thermal balance testing is to compare empirical results to analytical predictions. Typically thermal models are adjusted to match the test conditions. Correlation between the measured data and predicted results are expected to be less than 5 °C.

8.15 Cleanliness, Control, and Monitoring

Contamination requirements are driven by the instrument requirements. Monitoring will be performed by the following methods as required by the CCP:

- Visual inspection
- Residual Gas Analysis (RGA) during vacuum testing
- TQCM measurements made during vacuum testing

In all cases, contamination limits established in the CCP will determine success criteria.

8.16 End-to-End Compatibility Test

The end-to-end test is designed to verify all communication links, both hardline and RF, between the observatory and the ground segment. The success criteria is the proper control of the spacecraft by the ground segment. The ground segment compatibility test van will be requested.

8.17 Performance Test

The performance test will be conducted in compliance with the test plan.8.18 Functional Test

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The functional test is a subset or quick version of the performance test. It is conducted throughout the system environmental test sequence in accordance with the test plan.

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9. Storage, Transportation, and Handling

9.1 Storage Approach

Ball's approach to storage of the Observatory consists of maintaining the hardware in a controlled environment until time of shipment.

9.1.1 Description of Storage Location

The location of this storage area is the clean room where the final baseline performance test was performed. This was assumed to be a class 100,000 clean room for the model instrument's needs. The clean room is a controlled access area that is dedicated to the project for its duration. As an alternative, the spacecraft shipping container may also be used for storage.

9.1.2 Storage Methods

The method for storage is ESD bagging and controlled access to hardware. Provision is made for dry nitrogen active purges of the instrument for contamination purposes.

9.1.3 Contamination Control

Contamination control is primarily accomplished by leaving the Observatory in the class 100,000 clean room or equivalent with the Observatory bagged. Additional levels of protection in the form of a continuous dry nitrogen purge is provided to prevent particulate contamination. The area is access limited to essential personnel.

9.1.4 Environmental Controls and Monitoring Equipment

All of Ball's clean rooms are equipped with temperature and humidity sensors. The Ball Clean room Facility staff are tasked with verifying the clean rooms' performance by airborne particulate counts on a weekly basis as part of Ball process standards. As part of this check a verification that temperature and humidity levels are within required limits as established by ESD process standards is performed.

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9.2 Transportation and Handling Approach

Transportation and handling of the observatory will be by proven methods and pre-approved procedures to control the activities. Ball is very conservative when it comes to transportation and handling activities and realizes the criticality of such operations. All equipment used to lift and support the hardware will be proofloaded on a yearly basis and inspected at each time of use. All operators of such equipment are certified and have practical experience in these types of operations.

A preliminary version of the Transportation and Handling Plan (CDRL No. 14) detailing methods, controls, equipment, and responsibilities will be submitted as part of the mini-proposal phase. This document will be updated during the initial phase of the program and resubmitted at the time of MDR.

9.2.1 Description of Shipping Container

The Observatory will sit horizontally and cantilevered in a Ball-owned shipping container. The container is fabricated from fiberglass and contains checkvalve filtered ports so that the container can breath. Provisions are also provided that allow for a active purge of the internal hardware. The payload envelope accommodations are shown in **Figure 9-1.**

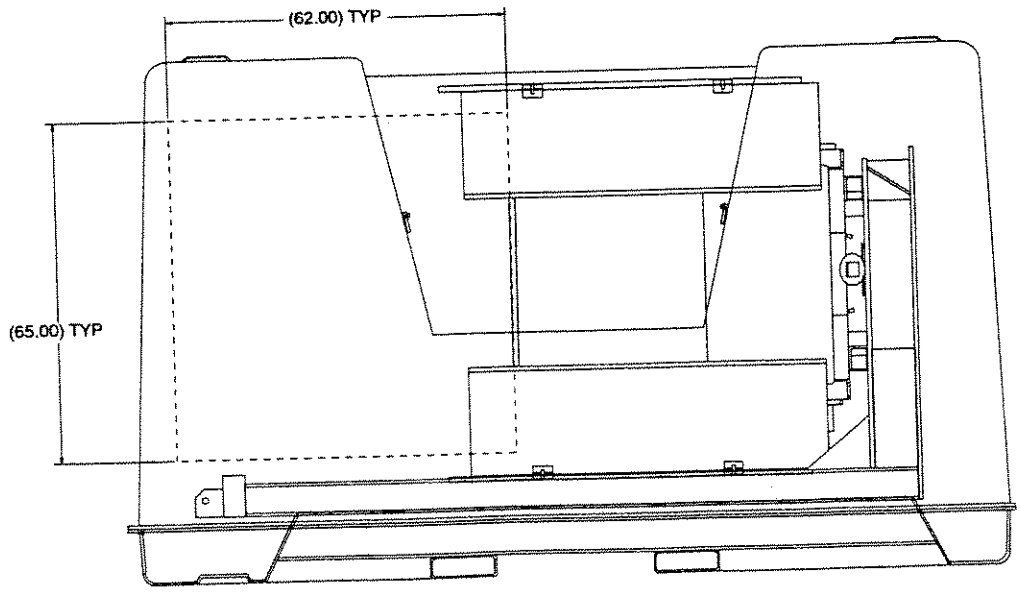

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Figure 9-1 Shipping Container Payload Accommodations

9.2.2 Methods of Transporting the Observatory

The in-plant transportation of the Observatory will take place on a support stand with four pneumatic wheels with lockable castors with the spacecraft in a vertical orientation. All lifting operations will take place using a Hydra-Set and certified overhead cranes located within Ball's test facilities. Lifting equipment used to connect the spacecraft to the crane will be certified. Ball has designed and built a fixture used to rotate the spacecraft from the vertical to horizontal orientation using an overhead crane in a controlled fashion. This method is very effective as it is both safe and can be accomplished in a short period of time.

The out-of-plant transportation will be via air-ride van or airplane in the Ball-owned shipping container.

9.2.3 Contamination Control

Contamination control during periods of transportation and handling consists of bagging the spacecraft and providing a dry nitrogen purge as needed. Access to the immediate area during transportation and handling exercises is limited to essential personnel and those individuals adhere to strict contamination requirements when working around the hardware.

9.2.4 Environmental Controls and Monitoring Equipment

Temperature, humidity, and 3-axis vibration sensors are mounted within the shipping container to monitor the environment that the Observatory experiences during shipment from the Ball facility to the launch site. A certified commercial air-ride van will be used to transport the Observatory and associated GSE. Pre-tested audible alarms will be mounted in the truck cabin and used to provide instant feedback of environmental conditions. During shipment to the launch site a support team from Ball will accompany the truck to manage the shipping activity and periodically monitor the shipping container sensors.

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9.2.5 Movement Between Facilities at the Launch Site

Movement between facilities at the launch site will be launch vehicle and processing facility dependent. The Observatory will be enclosed in either a launch vehicle payload can or encapsulated in the launch vehicle fairing and moved by specialized transports designed specifically for this task. This activity will be performed by the launch vehicle contractor.

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10. Observatory Launch Site and Operations

Ball's launch site processing approach, enabled by years of experience with several launch vehicles, takes less than 4 weeks and imposes no special requirements on the launch vehicle or launch range. The spacecraft arrives fully integrated, with no assembly required at the launch site.

We will use either the Integrated Processing Facility (Bldg 836) and the Hazardous Processing Facility (Bldg 1610) or the Astrotech Payload processing Facility for the observatory launch site checkout, spacecraft propellant loading, and encapsulation operations. After the spacecraft and support equipment are inspected, we will verify system functional performance with the bus electrical GSE. Propellant loading operations will be performed by the Ball team using the Ball propellant loading cart previously used on Radarsat and soon to be used on GFO and QuickBird spacecraft. Following encapsulation with the launch vehicle fairing, the observatory will be ready for transport and integration with the launch vehicle.

All operations will be accomplished using pre-approved processes and procedures. Ball will submit an observatory Launch Site Operations and Test Plan (CDRL 11) to provide a detailed overview of launch site processing and testing planned for the Observatory. Included in this plan will be activity timelines, facility needs, staffing plans, responsibilities, fueling methods, cleanliness requirements, and any other special needs for operations at the launch site. This plan will be the basis of agreement with the Western Range and it will define the needs for launch site test procedures. Preliminary observatory Launch Site Operations and Test Procedures (CDRL No. 12) will be submitted when required by the Launch Vehicle Contractor and Range Safety with the final submittal at the PSR. These procedures are written to provide a complete descriptionof all planned activities that are to be carried out at the launch site.

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10.1 Schedule

Figure 10-1 shows the planned spacecraft activities leading up to launch. It should be recognized that actual duration will be launch vehicle and observatory dependent.

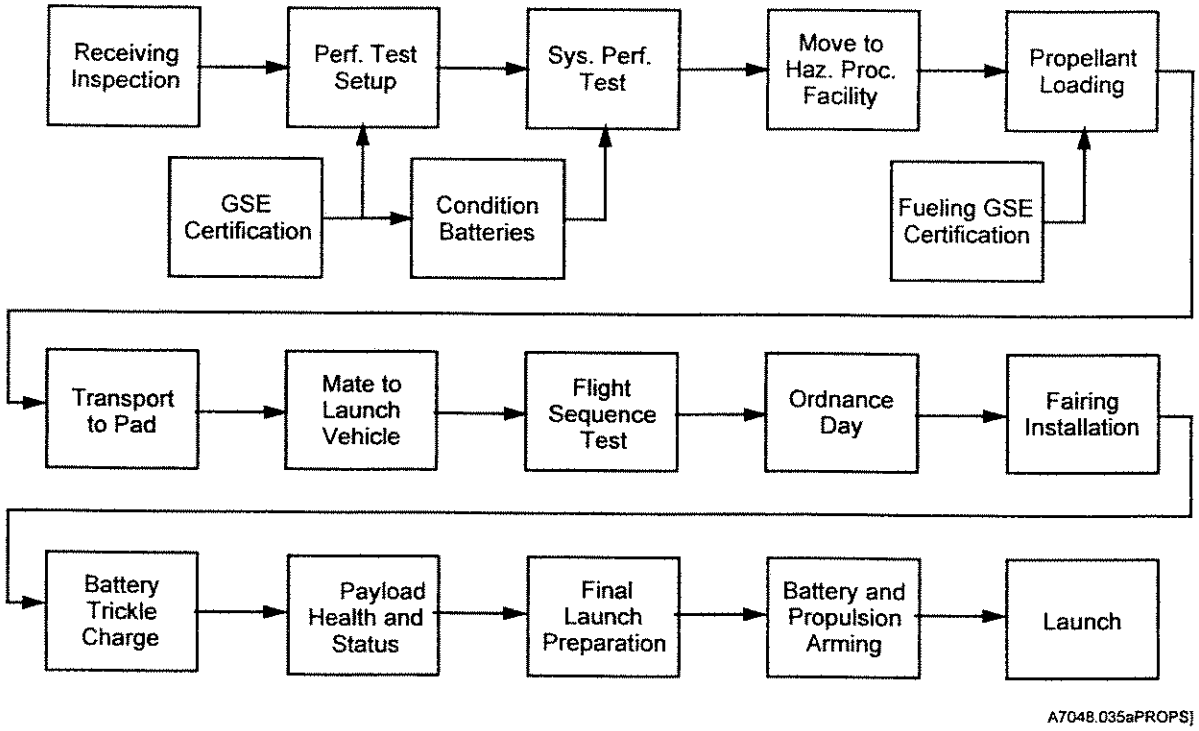

Figure 10-1 *Typical Launch Site Operations*

10.2 Government-furnished Facilities and Resources Needed

Ball will use the government facilities provided for payload integration at the Integrated Processing Facility (Bldg 836) and Hazardous Processing Facility (Bldg 1610). Flight and mock-up LV attach fittings are assumed as GFE.

10.3 Planned Fueling Methods

Fueling will be performed by a certified fuel loading team from Ball that has experience in spacecraft fueling operations. A Ball designed, certified and maintained propellant loading cart that has been used with previous spacecraft. The Ball propellant loading team will arrive at the launch site 1 week prior to the actual loading operation to begin activities associated with it. This starts with the checkout of all GSE, review of the hazardous procedures, and facility verification.

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Once the spacecraft is ready for fuel loading the highbay will be prepared for hazardous operations. Hydrazine will be delivered and SCAPE operations will commence on day 1. Day 1 consists of transferring the entire flight load of hydrazine from the 4BW hydrazine into the spacecraft's propulsion system. An intermediate pad pressure is applied to the gas side of the spacecraft tank and pressure is monitored to verify that there is no reaction of the hydrazine within the propulsion system. On day 2 the propulsion system is pressurized to the flight pressure and sealed. Fueling operations are accomplished in a totally closed loop sealed system, and no hydrazine vapors are released into the atmosphere. The fueling method has been developed over several fueling operations and keeping up to current industry methodology to provide maximum safety for both personnel and the hardware.

10.4 Cleaning and Cleanliness

Contamination control at the launch site will be similar to that used during the I&T activity at Ball. The control method is bagging of the hardware with a active purge with operations being conducted in a class 100,000 clean room.

10.5 Special Test Equipment

(b) (4)

10.6 Communications

Ball will conduct end-to-end testing to verify ground station compatibility prior to launch. The current spacecraft configuration requires an S-band RF link to support this test. Hardline interfaces will also be required between the PCC and STOC during pre-launch activities.

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