11. Operational Flight Software Maintenance

The Ball Software Engineering Manual (SEM) defines standards and practices that will be used throughout the software development process. These procedures serve as the guideline for the development process and documentation requirements. Software Quality Assurance ensures compliance with the SEM and the Software Development Plan.

11.1 Heritage

The core system flight software will be the QuickBird flight software, including Star Tracker Attitude Estimation, developed in the Ada programming language.

11.2 Software Development Process

(b) (4)

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(b) (4)

11.3 Documentation

The software documentation is produced during the course of the software development process. The documentation which will be produced for the core system includes:

- Software Development and Verification Plan
- CSCI software development folder containing:
  - CSCI requirements
  - CSCI review materials

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- CSCI integration test material
- CSCI integration test results
- FQT material
- FQT results

- CSC software development folder containing:
  - Structure charts
  - CSCI requirements allocated to the CSC
  - CSC structure charts
  - Timing and sizing estimates
  - CSC integration test material
  - CSC integration test results
  - CSC review materials
- CSU software development folder containing:
  - CSCI requirements allocated to the CSU
  - CSU structure charts
  - PDL
  - Source code listings
  - Code walkthrough results
  - CSU test materials
  - CSU test results

11.4 Rights

Source code will be provided with the delivered core system for the exclusive use on that spacecraft only. The flight software is Ball company proprietary and may not be distributed or used for any other purpose other than the delivered core system.

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11.5 Configuration Control

The Software Configuration Management Plan calls out the use of Software Change Control System (SCCS) for software configuration control. Following the software requirements review, requirements changes or additions are initiated by a Software Change Request (SCR). The requirement and other affected items (design information, source code, test material, etc.) are updated accordingly. The existence of an SCR for each requirement change facilitates record-keeping as to why a requirement was added or changed.

A source code Software Development Library (SDR) is maintained using the UNIX SCCS software configuration management tool. Computer Software Units (CSU) and all associated unit test material is placed under configuration management following completion of unit test. When a CSU is first placed under configuration management, it is assigned a revision number of 1.1. Subsequent changes to the module result in incrementing the revision number to 1.2, 1.3, etc. Following FQT, the revision number is changed to 2.1. If for any reason FQT is repeated, the leading digit of the revision number is incremented again.

After release of a unit to software configuration management, the following procedure is followed for changes as problems are found or requirements change: A SCR is filled out describing the problem of change. The unit(s) requiring change are "checked out" from the software development library (includes test procedures, drivers etc., if the unit test is affected). Changes are made and the unit test(s) rerun and modified if necessary. Modified units are then checked back in to the software development library and the SCR closed out.

11.6 Maintenance and Modifications

(b) (4)

(b) (4)

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12. Operations Support and Transition

Ball will provide the following services as part of the core system described in the previous volumes: On-orbit Check-out, mission operations support for two years, Anomaly Resolution Support, and Documentation that includes a flight operations plan, operations description manual, and command and telemetry description.

12.1 Flight Operations Training

Following spacecraft thermal-vac testing, Ball will provide subsystem and operations engineers for two training simulations and one dress rehearsal. Each training session and the dress rehearsal is expected to last 5 days. During these exercises Ball engineers will participate in the training simulations, provide analysis, answer questions, and evaluate the mission operations team readiness for launch and on-orbit operations.

12.2 Documentation

Ball will provide the following CDRLs and documentation as part of the Operations Support and Transition:

a) Spacecraft Operations Description Manual - This CDRL provides the recommended operating procedures and constraints needed to operate the core system during test and orbit. Included in this document are detailed descriptions of each subsystem, flight software functional descriptions, and contingency operations.

b) Telemetry and Command Requirements - This CDRL provides the command and telemetry reference source for the core system. Included in this document are complete descriptions of all applicable telemetry formats, command formats, and command and telemetry parameters.

c) Flight Operations Support Plan - This CDRL provides descriptions of operations support during test, launch, and on-orbit operations for the life of the mission. Included in this document are plans for anomaly identification, investigation and resolution, performance assessment, and resource allocation.

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d) End-To-End Test Plan - This document provides the test plan and procedures necessary to validate the ground control and data systems interface with the spacecraft. This test will be performed prior to launch to verify the proper operation of the spacecraft to the ground and re-verified on orbit.

e) Commissioning Plan - This document provides the test plan necessary to perform the core system on-orbit verification. Included in this document are specific procedures for performing each test and the expected results based on the mission performance specification.

12.3 Operations Transition Plan

12.4 On-Orbit Checkout

The combination of the initialization, initial acquisition, and deployment phase will provide much of the data required to do the on-orbit checkout. Through the collection of real-time data and analysis of SSR dump data, subsystem engineers will be able to determine if the bus subsystems are performing as expected. The intent is to verify each subsystem's performance in-orbit and ensure no problems have been induced during launch. The timeline for completing the on-orbit checkout phase for the spacecraft, including the orbit adjustment, could take as little as 10 days but is baselined for 30 days. Redundant units that are routinely used during on-orbit operations are fully validated. Redundant units that would pose a threat to the mission to configure are not validated until they are needed. Aliveness checks are performed on redundant units if it does not unnecessarily risk the spacecraft. The on-orbit checkout will be performed in a systematic fashion as defined in the commissioning plan described in Section 12.2.

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Each on-orbit test will include the following:

a) Test configuration

b) Performance parameters

c) On-orbit test acceptance criteria

d) On-orbit unit data acquisition period

e) On-orbit unit test anomalies and corrections

Successful completion of all on-orbit commissioning tests constitutes acceptance of the spacecraft. Following the on-orbit checkout a performance report will be prepared summarizing the on-orbit performance of the spacecraft bus compared to its predicted performance, issues affecting mission success, and operations team readiness for conducting the remainder of the mission.

The following sections give an overview of the on-orbit checkout by subsystem.

Telemetry, Tracking, and Command Subsystem

The C&DH subsystem on-orbit check-out will consist of the following validation tests:

a) Primary SCC operation

b) Solid State Recorder (SSR) record/playback operation

c) Loading and verification operation for CSM

d) Format verification for the DTU

e) Clock frequency and drift rate for the primary clock source

f) Command Decoder Unit (CDU) operation

g) DSU record/playback operation

h) Support Electronics Package (SEP) operation

RF Communications Subsystem

The RF Communication subsystem on-orbit checkout will consist of the following validation tests:

a) GPS data reception

b) Simultaneous SSR playback/real-time telemetry downlink

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c) Simultaneous uplink/downlink operations

d) Data rate verification for the DTU

e) Determination of link margins

Attitude Control & Determination Subsystem

Most of the components are functionally checked during separation and initialization. By the time initialization and deployment is complete, the operations team will be able to verify: SCC mode transitions, expected power levels, SCC is processing data from the selected star tracker, inertial reference unit, course sun sensors, attitude error correction, table load and dump operations, and actuator operations.

Planned unit on-orbit check-out includes:

a) SCC

b) Reaction wheels

c) Star trackers

d) Inertial reference unit

e) Coarse sun sensors

f) Magnetometers

g) Torque rods

h) Table loading and dumping for the primary SCC

i) Maneuvers and pointing

j) Flight software functionality

In addition there will be system performance monitoring during maneuvers and thruster burns to observe the attitude errors and the correction response to them.

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Electrical Power & Distribution Subsystem

The electrical power distribution subsystem on-orbit checkout will consist of the following validation tests:

a) Overall power subsystem analysis
b) Evaluation of operating currents and voltages
c) Battery
d) Power control unit
e) Solar array evaluation
f) Solar array segment switching operation

Propulsion Subsystem

The propulsion subsystem on-orbit checkout will consist of the following validation tests:

a) Thruster calibration burns
b) Initial orbit adjustment
c) Propellant and pressure monitoring

Thermal Subsystem

The thermal subsystem on-orbit checkout consists of the following validation tests:

a) Verification of heater set points
b) Heater operation
c) Comparison of actual vs. predicted temperatures

Payload Interfaces

Functional verification of all primary payload interfaces are part of the standard on-orbit checkout of the core system. Included in this checkout are:

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a) Verification of receipt of commands and downlinked telemetry

b) Verification of receipt of ascending node equator crossing

c) Verification of receipt of vehicle time code word

12.5 Anomaly Resolution and Support

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13. Miscellaneous

13.1 Special Studies Implementation Forms (Example)

Examples of forms used to implement special studies follow.

13.2 Product Assurance Plan

Ball's Product Assurance Plan is included as Attachment 1.

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Attachment 1

Product Assurance Plan

for the

RS2000Bus

Prepared for the

Rapid Spacecraft Procurement Request For Proposal 5-02816/001

Goddard Space Flight Center

Greenbelt, Maryland 20771

Prepared by

Ball Aerospace & Technologies Corp.

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1.0 INTRODUCTION

1.1 GENERAL

This Product Assurance (PA) Program Plan is based on the BASD Quickbird Bus PA program and contains the planned approach for implementing all elements of PA to be used on the RS2000 Bus program. BASD's Product Assurance ilities included in this PA Plan are Reliability (Design Assurance); Electrical, Electronic, and Electromechanical (EEE) Parts; System Safety; Hardware Quality Assurance (QA) and Software QA; Material & Processes; Configuration/Data Management (C/DM).

This plan incorporates all PA related requirements and defines the general policies, controls, procedures, and approaches to be followed in implementing all phases of the PA program. It ensures adherence to these requirements from design, procurement of material, through end-item shipment and launch of the RS2000 Bus.

This plan will be administered by the RS2000 Product Assurance Manager (PAM) who has direct access to higher management through the BASD Director of the Product Assurance (PA) organization.

1.2 PROCEDURES

BASD quality procedures/directives identify the normal methods used at BASD to implement quality operations and are modified by this RS2000 Product Assurance Plan. Applicable reference procedures are in **Table 1-1**, and at the end of subsequent paragraphs.

Table 1-1. Quality Procedures

DEPARTMENT POLICIES (QP 100 SERIES)

QP 101	Quality Assurance Responsibilities

DEPARTMENT POLICIES (QP 200 SERIES)

QP 201	Quality Procedure Revisions
QP 203	Inspection Stamps
QP 206	Quality Assurance Directive
QP 208	Quality Assurance Bulletin

QUALITY ENGINEERING (QP 300 SERIES)

QP 303	Design Review
QP 304	Configuration Change Control

NONCONFORMING MATERIALS (QP 500 SERIES)

QP 502	Corrective Action
QP 506	Nonconforming Material

INSPECTION (QP 600 SERIES)

QP 603	Clean Room & Clean Bench Monitoring
QP 609	Material Control
QP 610	Acceptance Testing Performed by Others for Receiving Inspection

QP 619	Limited-Life Materials
QP 623	Audit of Ball Process Standards
QP 629	Radiographic Inspection Procedure
QP 631	Printed Wiring Boards Inspection
QP 635	Machine Shop Critical Dimension Inspection System

QUALITY CONTROL (QP 700 SERIES)

QP 702	Acceptance Test Surveillance
QP 704	Calibration Surveillance
QP 706	Shipping - Project Material
QP 708	Certification Log Control

GOVERNMENT & CUSTOMER PROPERTY CONTROL (QP 800 SERIES)

QP 801	Receiving & Shipping of Government/Customer Furnished Property (GFP/CFP) and Government/Customer Furnished Equipment

FORMS PROCEDURES (QP 900 SERIES)

QP 908	Completion of Material(s) Discrepancy Report

These procedures will be available for review by authorized customer representatives.

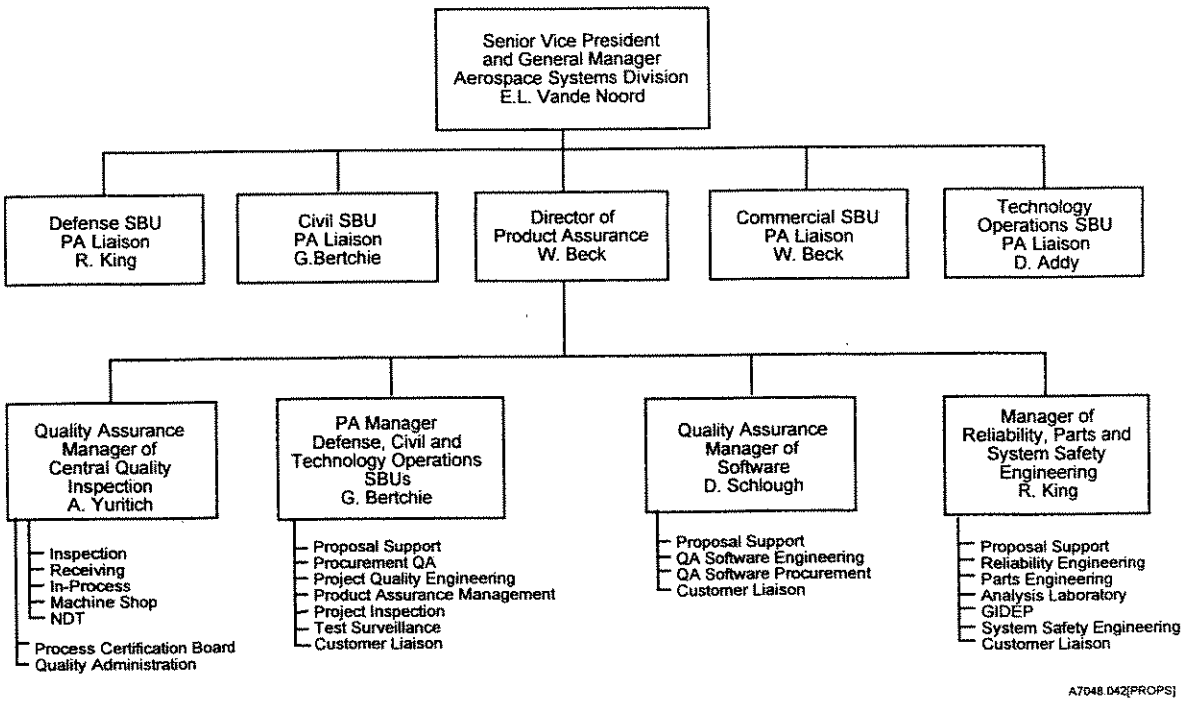
2.0 PRODUCT ASSURANCE MANAGEMENT

2.1 GENERAL

This tailored RS2000 Bus PA Plan is based on lessons learned from past successful space systems programs and the BASD Quickbird Bus that have included both space and ground equipment segments and small satellite programs. This PA Plan provides an approach that balances cost and risk throughout all RS2000 Bus program elements and phases. This plan establishes requirements that ensures mission objectives will be successfully achieved. It is structured to provide early recognition of potential or actual problems and to provide effective preventive and corrective action (QP 101).

2.2 ORGANIZATION

The BASD PA director is ultimately responsible for ensuring that all BASD PA programs are conducted in accordance with approved program plans. The PA director is accountable directly to the senior vice-president and general manager of BASD. The PA director, in turn, delegates responsibility through the PAM for directing and managing the individual PA plan for the program. Included is the organizational chart which identifies the PA reporting path.



The RS2000 Bus PAM, as primary interface with the customer Product Assurance representative, has direct authority over the PA team. The PAM major responsibilities are:

- Providing program/project product assurance management
- Implementing the approved plan through coordination with all PA disciplines
- Preparing quality work instructions (QP 301)
- Ensuring that quality requirements are met throughout all phases of production
- Participating in the design review (QP 303)
- Participating on change control board (CCB) (QP 304)

- Providing procurement control including source inspection
- Participating as a member of the subcontract management team
- Reviewing assembly fabrication and inspection planning

- • Planning for end-item assembly inspection, test surveillance, and documentation (QP 604)
- • Supporting significant program engineering and management meetings and reviews
- • Providing inputs to monthly status reports
- • Coordination and supporting customer audits
- • Directing and supervising the work of project assigned quality inspectors & engineers
- • Chairing the material review board (MRB)
- • Initiating quality procedure revisions, quality assurance directives, quality assurance bulletins, and quality assurance provisions (QP 201, QP 206, QP 208)
- • Managing the configuration control effort to assure timely, correct data entry, retrieval and distribution
- • Planning, assuring and documenting proper training
- • Auditing (in addition to the standard Ball audits) functional areas to determine conformance to plans
-

2.3 PLANNING AND WORK INSTRUCTIONS

The PA plan is the document in which the organized approach for ensuring compliance with contractual and company quality requirements are defined. Quality Work Instructions (QWI) are generated to implement the Quality Plan. The QWI provides program specific instructions and information in the following areas; Quality Engineering and Planning, Receiving Inspection, Subcontracts, In-Process Inspection and Test, Integration and Acceptance Test and Nonconforming Materials (QP301).

Operational directions for the manufacturing and inspection of production hardware are provided by production orders or production certification logs (Cert Logs) which constitute an objective

history of work and inspections accomplished according to drawings, standards, and specifications (QP604).

BASD uses internal workmanship standards which have been developed for aerospace applications and are compatible with industry standards, MIL-STD-2000 or NHB5300.4 series. These include Shop Standards (machine and mechanical assembly), Ball Process Standards (BPS), Ball Material Standards (BMS), and Production Support Procedures (PSP). In addition, program specific procedures detail any program unique processes or procedures.

Circuit boards with printed wiring traces will be compliant with the requirements of MIL-P-55110. Parts and assemblies susceptible to being damaged by electrostatic discharge (ESD) will be processed using controls specified by MIL-STD-1686 or Production Support Procedure (PSP) 120211.

2.4 RELIABILITY (DESIGN ASSURANCE)

The reliability effort is tailored to provide the most cost effective approach using proven analysis methodology. Risk areas will be addressed and resolved through a coordinated effort among program team members.

2.4.1 EEE Part Derating

Derating requirements are per GSFC PPL-21 will be used for parts not in MIL-STD-975. When no standard exists, responsible engineer judgment is used to extrapolate from best data available.. Effort will be made to resolve derating exceptions to minimize risk to the program, typically by changing the design or re-selecting parts. Information regarding non-compliances to be retained within the design will be available in the engineering notebooks.

2.4.2 Failure Mode Effects and Criticality Analysis (FMECA)

. The analysis will be performed at the component interface level, but will go to lower levels if needed to address critical issues. The analysis will address the following concern areas, as a minimum:

- • Verify that no failures will propagate across a component interface and cause loss of additional system functions
- • Verify that redundancy and back-up design features are not adversely affected by single failures
  - Identify any possible safety concerns and impacts on fault isolation provisions

. Analysis results will be documented in SER or equivalent format.

2.4.3 Worst Case Analysis

The space components will be reviewed by the system to identify mission critical circuits that have a degradation concern over the mission duration. Critical circuits are identified from a detailed review of the system, subsystem and component designs. A worst-case analysis will be implemented on these critical circuits Analysis exceptions will be documented in the engineering notebooks.

2.4.4 Limited-Life Analysis and Controls

Life margins will be established and analysis performed to identify limited-life. Analysis must prove capability for mission life including ground operations, plus margin. Control will be established for items with less than 2 x planned mission life. Analysis results will also be used as input to mechanical run-in requirements specified in the test specification. Analysis results will be documented in SER or equivalent format. or engineering notebooks

2.4.5 Failure Reporting and Analysis

Starting at box level testing, specification failures will be documented, analyzed and dispositioned via the Material Review Board system on non-conforming material control documentation [Material(s) Discrepancy Report (BR/4/067)]When contractually committed, at the start of system acceptance level testing formal failure reporting to the customer will occur in accordance with RP 309. Customer notification will occur within 1 working day and the customer is invited to participate. A failure is defined as the inability of the end-item assembly to perform within the limits of its specified test requirement or specification. Analysis will be performed and a Finalized Failure Report submitted to the customer no later than pre-shipment review. Open failure reports will be statused monthly in the progress report.

2.4.6 Previously Flown Component Analyses

Previously flown component analyses will be reviewed for consistency between the previous application and the customer application. Where the previous application is more rigorous, no further effort is required. When the customer applications are more stressful or the design has changed, all analyses will be reviewed to determine if they are compatible with the new application and updated as required. All analysis and documentation shall be contained in subsystem engineering notebooks which remain in the commercial program document control area.

2.4.7 Predicted Reliability

An initial apportionment/reliability estimate is included in the proposal.

2.4.8 Critical Items

A critical items list will be generated and maintained for the program. The following critical items are listed:

Item	Impact	Mitigation
Solar Array Drives	Loss of articulation for a single panel. Reduced power input to system	Dual windings with redundant drivers for each of the panels.
Thrusters	Loss of Fuel resulting in degraded or loss of mission	Dual seat thrusters. Two separate hydrazine circuits each can be isolated using latch valves. Latch valves normally closed
Propulsion lines, welds, fittings.	Loss of fuel resulting in degraded or loss of mission	Pressure testing and flight heritage.
Hydrazine Tank	Single Point Failure. Loss of propellant, and potential structural failures.	Burst Pressure margins of safety > 2.5. Flight Heritage.
Emergency Mode Controller	Single Point Failure. Loss of controlled spin under emergency condition.	Operation only required after a previous failure. Fully disableable.
Structure	Single Point Failure.	Structural analysis ensure sufficient design safety margins.
RF Switches	Single Point Failure. Loss of redundancy if stuck in one position. Loss of RF if stuck in between	High quality components with testing and fight heritage
RF Coupler	Single Point Failures. Loss of uplink or downlink.	Very simple design. Considered structural element.
Antennas	Single Point Failures. Loss of uplink or downlink.	Highly reliable. Qualification tested to launch loads. No deployments.

. Visibility on these items will be detailed and documented during negotiations.

2.5 EEE PARTS

This plan will provide the general guidelines for implementing Electrical, Electronic, and Electromechanical (EEE) parts for the program. It establishes an approach to maximize reliability while at the same time applying the lessons learned from previous Military and NASA programs. This plan applies only to the space segment hardware .

The RS2000 program philosophy will be to select suppliers with space proven experience and existing engineering, and then evaluate this experience/existing engineering in regards to the mission rather than to impose specific requirements as has been done in the past. This plan provides a "preferred approach" and is intended to identify those areas that need special attention based on BASD and Industry experience. It is not the intent to have subcontractors deviate from their existing policies, procedures, and formats but to make maximum usage of existing documentation and implementation techniques. Should there be a conflict between this "preferred approach" and in-house or subcontractors existing designs, the BASD Parts Engineer and Product Assurance Manager will evaluate the conflict, disposition it and document it as the responsible members of the Parts Control Board (PCB).

2.5.1 Parts Control

There are four key elements for parts control:

1. Part Selection - Start with a proven level of parts selection consistent with the mission. Part selection establishes a starting point for part screening and qualification and also provides a known reliability level.

2. Part History Evaluation (Reliability suspects) - All parts used in flight hardware will be evaluated to assure that they are not reliability suspect parts. This will assure that parts do not have a poor history. The evaluation will include Government and Industry Data Exchange Program (GIDEP), DPA and Failure history data.

3. Reliability Suspect Part Problem Mitigation - Parts that are considered "reliability suspects" as a result of the Part History Evaluation require some type of mitigation approach. Examples may include selective screening, Destructive Physical Analysis (DPA), life testing or limiting procurement to certain manufacturers. This information will be documented.

4. Radiation Evaluation - Radiation environments are unique to the mission orbit and will be re-assessed to assure that the environment previously used is equal to or worse than that expected for the current mission. Analysis results will be documented in SER or equivalent format.

2.5.1.1 Parts Control Board

An effective approach to maintaining these key elements is by utilization of a Parts Control Board (PCB). A PCB will be established and will consist of, as a minimum, the Parts Engineer and Product Assurance Manager. The responsibility of the PCB is to assure that each part has been evaluated to the guidelines herein and is not a reliability suspect part. Each component EEE parts list will have a column for approval status. This column will list whether a part is "883B or full manufacturer's equivalent" and if it is PCB approved. Approval will be noted by the initials of the Parts Engineer and the Product Assurance Manager. Technical rationale for use of non-"883B" parts will be on file and available for customer review if requested..

2.5.1.2 Standard Parts

Standard parts are defined as "883B or full manufacturer's equivalent". "883B" is defined as follows and is the baseline for preferred parts:

a) Microcircuits and Hybrids - Manufacturers' MIL-STD-883, paragraph 1.2.1 Compliant parts that are quality assurance level "B" or better.

b) Semiconductors - MIL-S-19500 quality assurance level JANTXV or better.

c) Passive Parts - Military Established Reliability level "R" or better.

This is not to suggest that other parts are unreliable, however it is a starting point for that hardware that is considered new design or for modifications to existing design.

2.5.1.2.1 Screening

All parts should meet the screening requirements of the nearest "883B" part as defined herein. Part evaluation will consider the application notes as noted in MIL-STD-975 in addition to the additional screening found in MIL-STD-975, Appendix B for a grade 2 part. These application notes usually reside at the beginning of each part type at the bottom of the page and at the bottom of the page for the specific part. Examples of foot notes include outgassing of connectors and low voltage applications for ceramic capacitors. All decisions relative to screening will be determined by the PCB. Additional screening decisions are based on extensive reviews of manufacturers screening. PIND and X-ray will be performed on all devices with metal seals. Screen will be performed to the nearest MIL STD 975 device criteria. Manufacturer's screening need not be repeated.

2.5.1.2.2 Qualification

All non-standard parts should use selected qualification tests specified in the nearest standard "883B" part specification. Selected tests should be based on the environment and the known tolerance of the part to that environment. These tests should be determined by evaluating the nearest "883B" parts qualification requirements with the environment for the specific application. If the parts have not been thermal shocked and they will see thermal shock during the mission then the part will be subjected to thermal shock. The same is true for vibration, etc. Life testing is the most valued test for supporting End-of-Life requirements. All decisions relative to qualification will be determined by the PCB.

2.5.1.3 Part History Evaluation

All parts will be evaluated to assure that they are not reliability suspect parts. The subcontractor or Ball Parts Engineer will perform a GIDEP search, evaluate the part for radiation performance and evaluate the part relative to previous usage i.e., failure, Destructive Physical Analysis (DPA) and history.

2.5.1.4 Reliability Suspect Part Problem Mitigation

If a part has been determined to be a Reliability Suspect part it must be subjected to compensating provisions to assure that the suspect issue has been resolved. Compensating provisions may include but not be limited to DPA, additional screening or selecting or denying a specific manufacture.

2.5.1.5 Destructive Physical Analysis (DPA)

DPA will be performed on each lot date code of active parts that do not meet the definition of "883B". DPA may be waived by the PCB when adequate data suggests it is not necessary. DPA may be considered as a compensating provision for any part that is a known reliability problem or has GIDEP Alerts or Problem Advisories written against it. In these cases the DPA should verify that the known problem does not exist in this lot of parts.

2.5.1.6 Parts Specifications

Parts procurement specifications will be generated only when existing documentation does not adequately define the items performance parameters or configuration. Screening specifications will be written to cover post procurement screening.

2.5.1.8 Subcontractor Parts Control

As previously mentioned, minimum parts requirements have been levied on subcontractors. To evaluate the subcontractors parts control approach and minimize reliability risks the responsible engineer will use the subcontractors parts list as a starting point. The list will be evaluated against the "883B" level as defined herein. Parts that appear to be a lesser reliability level or parts that are known to be reliability risks based on BASD or industry data will require additional evaluation. This may require the responsible engineer to contact the subcontractor and acquire the necessary information to support the use of the part.

2.5.1.8.1 Subcontractor Audits and Reviews

Subcontractor EEE Parts usage will be reviewed for compliance based on the guidelines specified herein. Audits will be determined by the PCB

2.5.1.9 Documentation

There are no formal documentation requirements for the program. Subcontractors will provide EEE parts lists during reviews. It is the responsibility of the Parts Engineer to properly document decisions relative to in-house and subcontractor parts usage. This documentation will

be informal however it will provide the necessary paper trail to insure a proper understanding of compliance.

2.5.1.10 EEE Parts Radiation Effects

All parts have been evaluated to assure compliance to the mission radiation requirements. Subcontractor parts lists have also been evaluated relative to the environment. Parts that were considered risk were identified to the responsible engineer with adequate information relative to the concern. The responsible engineer isresponsible for acquiring the necessary information to resolve the concern.

The evaluation criteria is basically a design margin of 3 or test the individual lot. There shall be no single event effects that cause permanent damage to a system or subsystem. Specific criteria based upon the particular orbit and operations will be developed for a compatibility check after contract award.

2.6 RECORDS AND DOCUMENTATION

BASD will use existing documents and forms for the identification of materials, inspection, fabrication, assembly and test operations. In addition, forms for the control and disposition of nonconforming materials will be used in accordance with the existing nonconforming product procedures. The following forms are applicable:

- BR-41 Failure Reporting
- BR/4/045 Material Identity Tag (MIT) for parts or assemblies being manufactured internally
- BR443-3.2 Commercial Production Record
- BR/4/067 Material(s) Discrepancy Report

- •BR-114 Corrective Action Request/Supplier Deficiency Notification
- •BR-122 Production Order (piece-parts)
- •BR/4/384 Source Inspection and Evaluation Report
- •BR 443 Production Certification Log (assemblies)
- •BR-447 Computerized MIT for procured parts, materials, processes and assemblies

Data is recorded on charts, graphs, and test data sheets that are included in approved procedures.

A MIT is attached to incoming material prior to admission into project (bonded) stores. Completed inspections are documented on CPRs and BR49s and are maintained in the cert log or receiving inspection.

Date coding of limited-life items is accomplished by the receiving inspector, with coding information being applied to the MIT, the material inspection record, and the next assembly inspection record (QP 619).

2.7 CORRECTIVE ACTION

Informal corrective action may be initiated by anyone aware of a problem. In general, these actions result from an assessment by the PAM. Formal actions initiated by the PAM will be documented in two ways:

- Nonconforming material documentation: Commercial Production Record (CPR), Production Order (PO), Action Item Lists (AIL) (BR443-4), and Material(s) Discrepancy Report (BR/4/067) as a result of material review activities
- Corrective Action Requests (BR-114)

The data that will be used to identify the corrective actions include the receiving inspection data, operator performance reports, corrective action reports and special presentations made by the material review board (QP 502).

2.8 QUALITY ASSURANCE AUDITS

BASD QA personnel perform defined and scheduled but unannounced audits of our Quality system by personnel not directly responsible for the function or program. Results of these audits are reported to the PA director. Auditors use an audit check list, state any deficiencies found, and outline recommendations for corrective action. The PA Director ensures follow-up and correction of causes leading to the deficiencies (QP 201, QP 308)

2.9 SOFTWARE QUALITY ASSURANCE

BASD's software development and assurance system is based on MIL-STD-498 and NASA Software Development Standards with appropriate reviews and approvals.

The RS2000 Bus flight software is based upon the flight software developed for the Advanced Spacecraft Design, IR&D and various BASD programs. Revisions to this software may be made to support the specific RS2000 Bus, and its Ground Support Equipment and Special Test Equipment requirements. The software development process will include the use of existing software, modified "reusable" software, and potentially the development of new software to support requirements.

BASD's operating approach is that software development engineering is responsible for the software development and software performance. This responsibility includes creating a Software Development Plan (SDP), implementing processes, and developing software products and testing these software products in accordance with that SDP. Software quality engineering participates in the software development life-cycle which includes audits of the software development and implementation, reviewing the planned approaches, and reviewing the SDP. Software quality engineering may call in additional expert help to conduct these processes.

Software quality engineering tasks include the following:

- •Evaluates software development activities and products for compliance with standards and requirements.
- •Evaluates flight software (reference Table 2-1)
- •Reviews the SDP to ensure that software will be adequately reviewed during development and that adequate Software Configuration Management (SCM) and QA activities are planned and conducted.
- •Provides ongoing, in-process reviews of technical documentation to identify deficiencies.

2.9.1 Documentation Approval

Project software documentation is reviewed and an audit of the software development folders is done by the SQE to ensure complete, correct and consistent documentation. These reviews and audits consists of the SDP, requirements, design, code and test information included in the Software Development Folders (SDFs) as well as the Software Project Notebook. Any documentation provided to the customer is also reviewed by the SQE. SQE ensures that BASD standards are adhered to and all necessary information is included in the documentation. Requirements traceability and design completeness are primary focuses of document review early in the program.

2.9.2 Review Participation

The SQE participates in formal and informal software reviews, as applicable. Primary review activities include ensuring software standards and conventions are being followed, action items are being assigned and tracked, requirements traceability is complete and ongoing, configuration

management principles are being followed, and problems related to the quality of the software are being addressed and resolved.

2.9.3 Test Support

The SQE audits software testing and monitors software acceptance testing.

Table 2-1. Flight Software Evaluation

Activity	SQE Evaluation
Determine Flight Software Requirements (Software Development Plan, CSCI Software Development Folder, Software Requirements Review) Develop Preliminary Flight Software Design (CSC Software Development Folders, Data Flow Diagrams, Software Mission Design Review) Develop Detailed Flight Software Design (CSC Software Development Folders, Software Detailed Design Reviews)	Review Software Requirements for completeness, consistency. Evaluate as to the ability to test these requirements. Evaluate CSCI SDF for completeness and consistency. Review preliminary and detailed design for adequacy of the design (meets all the requirements).
Code and Unit Test Flight Software (CSU Software Development Folders, Code Walk Throughs)	Monitor software development and participate in walk throughs.
Flight Software Integration and Hardware/Software Integration (CSC/CSCI Software Development Folders, Test Description Review, Test Readiness Review, Formal Qualification Test)	Monitor and evaluate testing to assure a disciplined testing methodology through evaluations of the testing process in terms of test sufficiency, adequacy and coverage, and certify test results. Evaluate results for completeness and consistency and ensure that all specified requirements have been verified.

2.10 CONTAMINATION CONTROL

2.10.1 Scope

This section describes the approach and methods of control that will be used by BASD for the RS2000 Bus to meet the cleanliness requirements and to meet the derived requirements for contamination control. The methods for controlling contamination will apply to the fabrication, integration, test, storage, shipping, RS2000 integration and test, and launch site operations. Implementation of these contamination controls will be the responsibility of the RS2000 Bus assigned contamination control engineer (CCE). This person will be assisted by other BASD Materials and Processes Engineering personnel and specialists from other departments as necessary.

2.10.2 Applicable Documents

The following documents of the current issue as of the date of this plan or of the issue shown form a part of the plan to the extent specified herein.

2.10.2.1 Government Documents

NASA RP-1124	Outgassing Data for Selecting Spacecraft Materials
FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
MIL-P-27401C	Propellant Pressurizing Agent, Nitrogen

2.10.2.1 Non-Government Documents

BASD Documents

BPS 3.54	Nitrogen, Gaseous, Controlled Purity
BPS 19.10	Contamination Sensitive Parts and Assemblies, Packaging, Identification and Storage of
BPS 21.04	Contamination Control, Clean Rooms and Clean Benches
BPS 27.20	Cleaning and Handling of Aerospace Hardware
BPS 27.43	Sampling Procedures for Particulates and Non-Volatile Residues (NVR)
BASD 33074	Method: Short Term Weight Loss and Condensed Contaminant Testing of Materials in a Thermal Vacuum Environment

Other Non-Government Documents

ASTM E595	Method of Test for Total Mass Loss and Collected Volatile Condensable Materials for Outgassing in a Vacuum Environment

2.10.3 Objectives

Objectives of the RS2000 Bus contamination control program are as follows:

- Maximum allowable contamination-induced degradation levels for contamination-sensitive surfaces
- Contaminant budgets and the budget allocations throughout the various phases of hardware processing
- Cleanliness requirements for the subcontracted hardware
- Cleaning procedures for components
- Contamination monitoring procedures to be used.
- Cleanliness controls sufficient to maintain the cleanliness of the cleaned components and assemblies within the contaminant budget allocations

2.10.4 Approach

For the RS2000 Bus contamination control program, the real requirements and controls were derived in a series of steps for the BASD Quickbird Bus as opposed to the application of a generic set of requirements. The prime requirement is to avoid exceeding the allowable performance degradation of the system.

The approach started with the establishment of this contamination control plan and a definition of each of the steps required to ensure that degradation levels are restricted to within their allowables. Those steps included: establishing the unique relationship between allowable degradation and allowable contaminant levels; setting the contaminant budgets; providing for the right cleaning methods, cleanliness controls, and monitoring methods; selecting appropriate low-outgassing and low-particulating materials; and implementing the results of the analyses and the selection of controls and monitoring methods by means of drawing notes or program-specific specifications, as necessary.

2.10.5 Baseline Plan

In general, the baseline plan is to select low outgassing and low particulating materials and to clean parts in two successive stages: (a) pre-clean prior to fit checks and other preliminary processing; and (b) precision clean and vacuum bake subassemblies prior to final assembly. Precision cleaning methods will be in accordance with BPS 27.20.

After precision cleaning, all operations will be under cleanliness control in clean rooms. When the RS2000 Bus is not being tested or work on, it will be covered using film material approved by the CCE. The baseline plan includes vacuum baking of conformal coated printed wiring assemblies (PWAs) and wire harnesses as subassemblies. The top assemblies will be vacuum baked with cleanliness monitoring appropriate to the RS2000 Bus' end-use.

2.10.5.1 Contamination Budget

Fixed points in the budget are as follows (contamination levels as defined in MIL-STD-1246):

RS2000 Bus External Surfaces	
Particulate	Visibly clean (Level 500) during ground operations. Level 1000 upon completion of acceptance testing and at launch site
Nonvolatile residue (NVR)	<1.0 mg/ft^2 (Level A)
RS2000 Bus Surfaces Near Instruments	
Particulate	Same as for specified instrument
NVR	<1.0 mg/ft^2 (Level A)

In order for the cleaning and controls to be sufficient, process controls are implemented at all stages of fabrication, integration and test. The effectiveness of these controls will be verified by measuring the contaminant quantities on witness mirrors; two per optic: one will be monitored at

end of integration and test and the other on a periodicbasis) all of which will have experienced the same environmental history as the hardware surfaces or sensor optics. If monitoring discloses significant over-budget contamination levels on sensitive surfaces, recovery measures appropriate to the conditions will be devised by the CCE and other specialists, and presented to the MRB for dispositioning.

2.10.5.2 Design Factors

(b) (4)

2.10.5.3 Materials Outgassing

Materials specified in the RS2000 Bus design will meet the minimum outgassing screening criteria provided by NASA RP-1124. Materials will exhibit total mass loss (TML) equal to or less than 1.0 percent, and volatile condensable material (VCM) equal to or less than 0.1 percent when tested in accordance with ASTM E595 or BASD 33074. Materials exceeding these test levels may be baked out (air or vacuum) in order to qualify, with approval of the CCE.

2.10.5.4 Vacuum Bake of Hardware

Flight components and assemblies will be vacuum baked at temperatures at least 20°C higher than the specified maximum survival temperature of 50°C. Baseline conditions are given below. Surface cleanliness will be inspected prior to vacuum baking or vacuum testing. BASD's

standard vacuum chamber operating protocols to prevent contamination and condensation on hardware will be implemented.

After precision cleaning and prior to final assembly, most components will be vacuum baked. The baseline vacuum bake conditions for most items will be 48 hours minimum at 80° to 85°C. The times and temperatures for specific components are as specified in engineering documentation notes. All wiring harnesses and connectors will be vacuum baked prior to installation into or connection to the RS2000 Bus. The baseline vacuum bake conditions for these items will be 96 hours minimum at 80° to 85°C. Prior to acceptance testing, selected critical assemblies will be vacuum baked, and their cleanliness and outgassing characteristics will be verified.

2.10.5.5 Vacuum Outgassing Certification

The RS2000 Bus will be subjected to thermal vacuum evaluation of outgassing rate in a chamber cleaned and monitored as described below. Chamber pressure will be equal to or less than 1×10^{-5} torr, and flight hardware will be maintained at 10°C above the maximum predicted on-orbit temperature. The chamber will be fitted with a temperature controlled quartz crystal microbalance (TQCM), with its field of view being as completely filled by the RS2000 Bus, as practical. The measured internal outgassing rate will be no greater than 4 Hz/hr when the TQCM is collecting at 10°C below the instrument's on-orbit coldest exposed temperature. In addition to the TQCM, the vacuum chamber will be equipped with a residual gas analyzer and witness plates. The locations of all sensors and witness plates will be carefully selected to measure and collect outgassing products from the RS2000 Bus. Thermal-cycling transitions and back filling with high-purity gaseous nitrogen will be controlled to ensure that condensation and molecular contamination will not occur. This will be accomplished by ensuring that the RS2000 Bus exhibits the warmest surfaces during transitions, with the last transition before return to ambient being from a hot soak.

2.10.5.6 Facility Types

Prior to final precision cleaning, flight hardware may be processed in a good housekeeping area. Following final precision cleaning, all flight hardware will be processed in controlled access clean rooms or clean benches equipped with high-efficiency-particulate-air (HEPA) filters. The clean rooms and movable downflow enclosures at openings of vacuum test chambers will be rated Class 100,000 or better in accordance with FED-STD-209. The clean benches will be rated Class 1,000 or better. Clean rooms, movable downflow enclosures, and clean benches will be controlled in accordance with provisions of BPS 21.04. This standard includes control of garments worn in all HEPA-filtered areas.

2.10.5.7 Monitoring of Vacuum Acceptance Test Facilities

a. Prior to use of facilities intended for vacuum testing of flight hardware, the facilities and accompanying ground support equipment and/or special test equipment will meet or exceed the cleanliness budget requirements for the hardware and will be baked and monitored for background contamination as follows:

   1. Bake the facility, including all test and monitoring equipment, at high vacuum and at a minimum of 30°C above the maximum intended test temperature of the hardware for a minimum of 72 hours. Include in the chamber are one or more NVR witness plates.

   2. Cool the facility to 45°C, and cool the TQCM to -20°C.

   3. Monitor the facility until the TQCM frequency shows an average change rate less than 1 Hz/hour for a minimum of 24 hours.

4. Collect two or more tape lift particle samples from chamber and test equipment surfaces as soon as the chamber is opened and collect NVR rinse samples from the witness plate and directly from accessible facility surfaces.
5. Test the NVR plates and tape samples to verify cleanliness of the facility.

Note: During vacuum test of flight hardware, the monitoring requirements are specified in notes in the engineering documentation.

2.10.5.8 Cleanliness at Delivery

Contaminant sampling directly on accessible flight hardware surfaces at the completion of acceptance testing will meet the following baseline cleanliness requirements: (a) the particle distributions will not exceed Level 1000 per MIL-STD-1246; (b) molecular contaminant quantities will be less than 1 mg/ft^2, Level A per MIL-STD-1246. The final requirements are specified in notes of the applicable engineering documentation.

2.10.5.9 Purge Requirements

The RS2000 Bus will be purged with gaseous nitrogen whenever instruments requiring nitrogen purge are installed. This requirement will apply while at BASD and during ground operations, including handling, transportation, and launch site activities. The nitrogen will meet the purity requirements of MIL-P-27401C, Type I, Grade B and will be certified to the requirements of BPS 3.54, Class 3, Grade B at point of delivery to the unit.

2.10.5.10 Packaging Materials

Following precision cleaning and following baking, parts and assemblies will be packaged in accordance with BPS 19.10, Type V, Class D, Grade 1 when they are outside of a cleanliness-controlled area.

2.10.5.11 Storage and Transportation

The RS2000 Bus will be shipped and stored in a sealed container that has been cleaned internally to visibly clean and that is compatible with Class 100,000 clean room operations. The container will be purged and pressurized during shipment with clean and filtered gaseous nitrogen.

2.10.6 Documentation

The establishment of contamination budgets, budget allocations, and cleanliness requirements are reported in a system engineering reports (SER). The requirements of this plan are implemented in notes on applicable engineering documentation.

2.11 MATERIALS AND PROCESSES CONTROL

2.11.1 Scope

This Materials & Processes Control Plan describes the procedures for the selection and control of materials and processes (M&P) to be used by BASD for the RS2000 Bus, beginning with hardware design. The purpose of this plan is to augment the safety and success of the mission through proper selection and treatment of materials used for construction of flight hardware.

2.11.2 Applicable Documents

The following documents of the current issue as of the date of this plan or of the issue shown form a part of the plan to the extent specified herein.

2.11.2.1 Government Documents

NASA CR-1871	Radiation Effects Design Handbook Section 5. The Radiations in Space and Their Interactions with Matter.

FED-STD-209	Clean Room and Work Station Requirements, Controlled Environments
MSFC-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking
MSFC-HDBK-527	Materials Selection List for Space Hardware Systems
MIL-P-55110	General Specification for Printed Wiring Boards
MIL-STD-889	Dissimilar Metals
MIL-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment
NHB5300.4(3A-2)	Requirements for Soldered Electrical Connections
MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
NASA RP-1124	Outgassing Data for Selecting Spacecraft Materials
X-900-93-03	Charged Particle Radiation Exposure of Geostationary Orbits (Barth and Stassinipoulos, 1993)
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program

2.11.2.2 Non-Government Documents

BASD Documents:

PSP 120211	Electrostatic Discharge (ESD) Control Procedure
33074	Method: Short Term Weight Loss and Condensed Contaminant Testing of Materials in a Thermal Vacuum Environment

Other Non-Government Documents:

ASTM E595-90	Total Mass Loss and Collectable Volatile Condensable Materials from Outgassing in a Vacuum Environment

2.11.3 Materials and Processes Control Requirements

This plan is the master planning and control document for implementation of the M&P control efforts.

2.11.3.1 Organization and Management

The M&P tasks defined herein will be implemented by the RS2000 Bus program M&P engineer. He/she will be assisted by other personnel of the M&P Engineering organization where specific experience in materials application or process development is required. The RS2000 Bus program PAM will provide overall management of the M&P discipline on the program.

2.11.3.2 General Requirements

Materials with successful space flight experience on programs, having materials requirements at least as restrictive as those for the BASD Quickbird Bus and the RS2000 Bus program, and which exhibit properties appropriate for the intended application, have been used in the design without further M&P review. New materials applications will be reviewed by the M&P engineer for determination of such factors as use, selection criteria, specification, and qualification in all other respects for the specific application. The PAM will review and approve the use of all new materials applications. Materials and processes used in subcontractor provided components will be subject to M&P engineer's approval for use in the design.

2.11.3.3 Selection Requirements

2.11.3.3.1 Program M&P Lists

Materials and processes have been selected from the sources listed in Section 2.11.2, as appropriate. New materials and processes will be approved by the PAM and M&P engineer. A materials and processes list will be prepared to list all approved M&P. Subcontractors of components will be required to list their M&P for BASD review. The materials and processes list will be available at RS2000

These processes are available for customer review with the exception of BASD's proprietary lubrication processes.

2.11.3.3.1.1 Conventional Applications

The approach to selection and control of materials and processes used in the RS2000 Bus are based on the BASD Quickbird Bus design. Past performance experience, available test data,

current test results, and appropriate materials and processes selection were used. Documents used by the M&P engineer for guiding material selections include MSFC-HDBK-527, MSFC-SPEC-522, MIL-STD-889, MIL-HDBK-5 and NASA RP-1124.

Processes with proven performance in space applications having requirements equal to or greater than those required will be used to the maximum extent possible.

2.11.3.3.1.2 Non-Conventional Applications

Materials lacking aerospace experience will not be used without documented verification based on similarity, analysis, testing, existing data, or a combination of these methods. Any new processes required will be qualified prior to their use. Data from these verification methods will be maintained and available for review. The analysis will be documented on SER, or equivalent format. BASD does not anticipate having to use materials lacking aerospace experience.

2.11.3.3.1.3 Special Concern Areas

The M&P engineer will pay particular attention to assuring proper control of certain materials, processes, and conditions which could present special problems. These areas include:

- Radiation Effects — The RS2000 Bus radiation environment in orbit is considered to be identical the radiation environment for the BASD Quickbird Bus. NASA CR-1871 and X-900-93-03 have been used as guides in analyzing potential material problems and guarding against material degradation. The M&P engineer will use inputs from radiation analytical specialists when evaluating material applications in locations where exposure to damaging levels is likely.

- Stress Corrosion Control — Metal alloys and heat treatments which result in high resistance to stress corrosion cracking will be used in tensile-load-carrying applications.

The selection criteria of MSFC-SPEC-522 is used for control of stress corrosion cracking. Metals that do not meet the high-resistance criteria are considered noncompliant and will require M&P approval if determined they need to be used. The determination of a noncompliant metal's qualification for a specific application will be based on similarity, analysis, testing, existing data, or a combination of these methods.

- Corrosion Control — Corrosion-resistant metals have been used throughout the BASD Quickbird Bus design and therefore the RS2000 Bus. If applications require use of other types of metals, proven measures will be instituted for the control and prevention of corrosion. MIL-STD-889 have been used to guide the selection of dissimilar metal couples where environmental conditions could lead to galvanic corrosion. In applications where dissimilar metal couples cannot be avoided, protection against galvanic corrosion have been implemented in accordance with MIL-STD-889. Zinc, cadmium, or electro-deposited tin will not be used as a corrosion-protective finish.

- Residual Stress Control — When necessary to minimize residual stresses in metallic structural parts, heat treatments such as annealing and stress relieving are specified on the engineering drawings. Residual stresses in nonmetallic parts, such as bonds and pottings, are controlled by appropriate design criteria and cure operations.

- Hydrogen Embrittlement — Appropriate provisions, such as air-baking, have been specified by engineering to guard against hydrogen embrittlement following certain metal treatments (e.g., acid etching, electroplating, heat treatment in a hydrogen environment).

- Lubrication — Lubricants and their processing are controlled by BASD documents (either company proprietary or non-proprietary, as appropriate) to avoid the cost impact of retraining or recertifying operators to unfamiliar processes. Dry-film lubricants are used in preference to wet lubricants where design considerations permit. But, in either case, lubricants selected are shown through analysis, test or previous flight experience to

be adequate for the operational life requirements. In addition, they have been selected to comply with the outgassing requirements specified in this PA Plan. Wet-lubricated bearings will be treated with barrier film to prevent creep, and molecular flow in vacuum will be retarded with labyrinth seals.

- Welding — Welds have been minimized in the structure. If welds are used, selection of the controlling documents are based on consideration of the weldments, including adjacent heat-affected zones, as they affect operational capability of the parts concerned.

- Composites — Parts fabricated from composite materials include printed wiring boards (PWBs), electrical insulators, ball-bearing separators, structures and spacers. PWBs will meet the requirements of MIL-P-55110E. Honeycomb sandwich panels will utilize vented cores. All will be controlled by military, other Government agency, industry, or BASD specifications, as appropriate.

- Metal Finishes — Metal finishes are controlled by military, other Government agency, or BASD specifications, as appropriate. Adhesion of paint, plating, and protective or thermal-control coatings will be verified by means of the quality assurance (QA) provisions of the respective process documents.

- Critical High-Strength Fasteners — Critical high-strength fastener applications will be reviewed from a fracture mechanics standpoint to the extent fracture mechanics is applicable. High-strength fasteners will be inspected to Quality Procedure No. 633.

- Soldering — Electrical and electronic assembly soldering will be verified in accordance with ANSI/IPC-A-610B, Class 3 (high performance electronic products), Acceptability of Electronic Assemblies.

- Electrostatic Discharge — Electrical, electronic, and electromechanical (EEE) parts will be protected from electrostatic discharge (ESD) in accordance with the requirements of MIL-STD-1686. This ESD protection will be implemented through Ball Production Support Procedure (PSP) 120211.

- Conformal Coating — All printed wiring assemblies (PWAs) will be conformal coated. The final cured coating will meet the outgassing requirements identified in the PA Plan. The heavier EEE parts on PWAs will be staked per engineering documentation.

- Bonding — Adhesive bonds will be prepared in accordance with BASD standards and specifications. Bonds with peak stresses greater than 250 psi will be verified by determining bond strength on appropriate witness specimens.

2.11.3.3.1.4 Metallic Materials

MIL-HDBK-5 has been used as a guideline for strength allowables and other properties of metals for highly stressed parts. Metals are controlled by military or other Government specifications.

2.11.3.3.1.5 Organic Materials

Organic materials, including adhesives, coatings, pottings, insulation materials, films, and elastomers, are controlled by BASD, military, other Government agency, or industry specifications, as applicable. Selection of such materials is governed by specific design requirements and, in general, by the outgassing limitations imposed by a total mass loss (TML) of equal to or less than 1.0 percent and a volatile condensable mass (VCM) of equal to or less than 0.1 percent when tested in accordance with ASTM E595 using BASD Test Procedure 33074. Guidance in selecting organics to meet these requirements will be provided by NASA RP-1124 and MSFC-HDBK-527. Organics that fail to meet the outgassing test requirements will be used only after coordination with the M & P engineer.

Processing of hardware using organics, such as bonding and coating, will be controlled by BASD and supplier documents to avoid the cost impact of retraining and recertifying operators in unfamiliar processes.

2.11.3.3.1.6 Considerations in Process Selection

The M&P engineer will pay particular attention to engineering selection and application of processes which may substantially change a material's properties.

All processes will be controlled by BASD, Government, or industry standards and specifications. Military specifications and BASD standards and specifications will be used whenever possible to avoid the cost impact of interchanging documents. Maximum use will be made of BASD's normal operating procedures, although, in certain cases, RS2000 Bus program-specific process documents may be required.

BASD documents for material and process control are prepared in accordance with MIL-STD-490 and have engineering release and revision control. They include as follows:

- Ball Material Standard (BMS)
- Ball Process Standard (BPS)
- Selected Material Specification (SMS)
- Selected Process Specification (SPS)
- Program Specific Documentation (SPxxx)

Process requirements will be flowed down to suppliers of hardware as defined in the applicable component specifications, together with the general requirements contained in this RS2000 Bus Product Assurance Plan.

2.11.3.3.1.7 Shelf-life Controlled Items

The QA and production functions will verify that limited-life ingredients and materials used in processes such as potting, bonding, and coating have not exceeded their shelf-life expiration dates. Outdated materials will be re-certified for use only upon satisfactory demonstration by means of appropriate tests that their critical properties, including outgassing, comply with functional requirements. Shelf-life duration limits are specified by the controlling specifications, and the specific expiration dates are based upon supplier identified lot date codes.

2.11.3.3.2 Materials Review

All M & P Lists will be reviewed by the PAM for the RS2000 Bus program.. Concern areas will be coordinated with the M&P engineer.

2.11.3.3.3 Material Procurement Specifications

Existing military, NASA, BASD, and subcontractor specifications will be used to the greatest possible extent. Supplier specifications and associated control numbers, in conjunction with source control drawings, may be used when the quality history is acceptable When a material's quality cannot be assured by this method, a procurement specification will be prepared. Such a specification will fully define the material's characteristics, environmental limits, and quality assurance provisions.

2.11.3.3.4 Procurement Documents Review

The PAM will coordinate procurement documents with the M&P engineer as necessary to ensure that M&P controls implement the applicable requirements.

2.11.3.3.5 Materials and Processes Qualification

Materials and processes used successfully on other spacecraft including the BASD Quickbird Bus with requirements that meet or exceed the customer requirements will be used without the need for further qualification testing. Any new materials or processes required will be reviewed by the M&P engineer to determine the extent of qualification testing required. Results of any testing will be documented and made available for review as necessary.

2.11.3.3.6 Subcontractor Controls and Reviews

The PAM, with the support of the M&P engineer, will ensure that the appropriate M&P requirements are specified in procurement documents. Subcontractor M&P usage will be reviewed for compliance with the RS2000 Bus program requirements by review of final M&P lists, as well as

on-site review during formal contract and design reviews. Quality assurance source inspections will verify hardware conformance with drawings and process requirements.

2.11.3.3.7 Incoming Inspection

Critical materials that cannot be adequately verified at receipt will be source inspected as determined by the M&P engineer or the PAM, or both.

2.11.3.3.8 Source Surveillance

Source inspections will be performed on critical and complex materials when material conformance cannot be verified at receipt.

2.11.3.3.9 Materials Traceability and Identification

All materials used in flight hardware will be traceable to the lot identified by the manufacturer through receiving records.

2.12 Prom Programming and Re-Identification

Programmed read only memorys (PROMs) and Field Programmable Gate Arrays (FPGAs) will be re-identified indicating their software revision level. The PROM program software will be verified to have been loaded correctly and the masters will be placed under configuration control.

2.13 Configuration and Data Management

2.13.1 Configuration Item Numbers (CI)

A single CI number will be used for the RS2000 Bus.

2.13.2 Engineering Drawing Numbers

Engineering drawing numbers shall be assigned by the Engineering Document Control Section as required by the BASD Drafting Manual. A log of these numbers as issued shall be maintained by project configuration.

2.13.3 End-Item Serialization

Serialization shall commence with serial number 0001 for the CI number.

2.13.4 Traceability and Lot Serialization

Critical parts and lots shall be serialized for traceability. All printed wiring assemblies are serialized as well as additional parts called out in the engineering documentation.

2.13.5 Hardware Identification Marking

Hardware is identified by part number, revision letter and serial number, if applicable. When space or contamination considerations preclude marking on the hardware, a separate label is prepared and bagged with the hardware. The MIT has the same information recorded on it.

2.13.6 Identification and Modification Plates

Each deliverable assembly shall have an identification plate and a modification plate or combination of same. The plate shall record, as a minimum, the part number, part name, revision, serial number, manufacturer and contract number. Modification plates will be used to show dates of modification, modification identification, and identity of the activity who performed the modification.

2.13.7 Configuration and Date Management Control

Configuration and Data Management (C&DM) is accomplished as an element of the RS2000 Bus Management function with appropriate support and interface with the BASD C&DM organization.

The configuration management system is based on the configuration management 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.

As a function of the Configuration Management for the RS2000 Bus program, C&D manager maintains drawing files, program documentation, SERs, revision control, print copying/distribution and configured article lists. Changes to engineering documentation are controlled through Engineering Orders (EOs) which are maintained in this configuration office. Test procedure control is under this same system. Redlines are only used for test procedures on the RS2000 Bus program. The redlines must be incorporated prior to QA acceptance.

As a function of the Data Management for the RS2000 Bus program, the C&D manager identifies the various program disciplines, categories of documents, and the numbering system. Data is prepared by the project team for all RS2000 Bus program CDRLs and necessary operating information. Subcontractors support BASD in developing data and provide their own data, as defined in the subcontractor data requirements lists (SDRLs), which are incorporated by Ball into the program data system.

The program configuration and data manager (C&DM) is responsible for managing the data system used for preparing and controlling technical and administrative documents.

2.13.7 Non-flight Drawing Control

Non-flight drawings are maintained in the same configuration as flight drawings.

3.0 FACILITIES AND STANDARDS

3.1 DRAWINGS, DOCUMENTATION, AND CHANGES

The BASD PA department participates in internal design reviews, formal design reviews, supplier design reviews, and technical document reviews, as appropriate. During these reviews, the PA representative determines whether the PA requirements contained in the drawings, specifications, and other technical documents are adequate and appropriate to control the cost-effective quality of the items purchased or produced throughout all phases of processing (QP 303).

3.2 MEASURING AND TEST EQUIPMENT CALIBRATION

BASD's metrology laboratory maintains a calibration system which meets the requirements of MIL-STD-45662A Calibration System Requirements. It is responsible for the calibration, repair, and maintenance of electrical, electronic, and electro-mechanical equipment; for control and calibration of all dimensional measuring equipment; and for maintaining adequate standards for this purpose. All standards are documented and traceable to U.S. National Standards or other nationally recognized standards.

A calibration label is attached to each unit of equipment showing the calibration technician's stamp, date calibrated, recalibration date, and instrument identity number. When test equipment arrives at the metrology laboratory for repair and/or calibration, an instrument repair/calibration card is completed listing the instrument identity number, the manufacturer, model, serial number, date of calibration, next calibration due date, etc.

Measurement and test equipment used by BASD for acceptance of product is calibrated and maintained at regularly scheduled intervals. An instrument classification list which identifies the specific classes of instruments along with their corresponding calibration intervals are reviewed annually. Individual instrument calibration intervals are adjusted accordingly. Equipment that cannot be transported to the laboratory is calibrated or serviced on-site by metrology personnel. Calibration due notices are distributed to equipment users two weeks prior to the expiration date. Various areas at BASD are designated for equipment requiring calibration. The metrology laboratory handles pickup and delivery from these areas (QP 704, D&P 7.09).

As a guideline, test instruments and equipment will have an accuracy equal to, or better than one-tenth the tolerance for the variable to be measured. The equipment data supplied by the manufacturer will be included in the measurement equipment selection process.

Tools, gauges, jigs, and fixtures used for acceptance inspection will be inspected and calibrated before use. These devices, when used repeatedly, are checked periodically to ensure continued accuracy.

4.0 CONTROL OF PURCHASES

4.1 GENERAL

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 statements of work

4.2 SELECTION OF PROCUREMENT SOURCES

BASD's selection of procurement sources is based on an extensive evaluation program which allows selection of those suppliers who have demonstrated their ability to furnish high quality material, or who have successfully demonstrated, by a quality survey, their 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 suppliers 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.

4.3 PROCUREMENT

The procurement team consists of the purchasing officer, PAM and responsible engineer. This group evaluates the supplier, consults on his 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 subcontractors PA plans are maintained at the subcontractors 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 non-conformances require BASD approved waivers/deviations. 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 be to assess the supplier's conformance to his written plans and to 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.

4.4 RECEIVING INSPECTION

Purchase orders route all articles intended for flight use to pre-dock inspection. Inspection is accomplished in accordance with planned quality work instructions (QWIs). Engineering drawings and specifications supplement the work instructions during actual inspection (QP 604, 606).

4.4.1 Receiving Inspection Instructions

All purchased items will be subject to the following inspections, in addition to the requirement stated in the QWIs, depending on the item type:

- Major items (source inspected)
  - Verify source inspection evaluation report is present
  - Visually examine for shipping damage
  - Issue MIT and route to stores
  - Maintain serial number identification
  - Log required information into the commercial program database

- Electrical piece-parts
  - Record manufacturer and manufacturer's lot/date code number
  - Visually inspect for damage
  - Issue MIT and route to stores
  - Additional screening, when necessary, will be done either at BASD or an approved independent test laboratory, per BASD Selected Item Drawing (SID) or Vendor Item Drawing (VID)
  - Enter required information into the commercial program database

- Raw materials
  - Identify by lot number (QP 602)
  - Issue MIT and route to stores.
  - Log required information into the commercial program database
  - Verify certificate of compliance and test data (as applicable).

- Support hardware
  - Identify by lot number
    - Issue MIT and route to stores
  - QP 633 for high strength, high grade mechanical fasteners
  - Log required information into the commercial program database

- Mechanical piece parts
  - Identify by lot number
  - Issue MIT and route to stores
  - Inspect per QWIs, Drawing and/or purchase order requirements
  - Verify certificate of compliance, as applicable
  - Log required information into the commercial program database

- Chemicals (bonding materials, epoxy, paint, etc.)(routed to receiving inspection)
  - Submit samples to the materials lab per Ball Material Standards
  - Determine expiration date of limited-life materials and identify on the MIT
  - Identify by lot number, issue MIT and route to stores
  - Log required information into the commercial program database

- Printed Wiring Boards
  - Inspect for shipping damage
  - Identify by lot number
  - Issue MIT and route to stores
  - Route coupons per QP 631, option 1 to the PAM
  - Log required information into the commercial program database

4.4.2 Nondestructive Testing

Nondestructive testing, such as radiographic (X-ray), will be performed per BASD screening requirements by experienced QA technicians. X-ray is a standard receiving inspection technique used at BASD as a tool in evaluating the acceptability of selected electronics piece-parts. BASD's X-ray technicians are certified in accordance with ASNT-TC-1A and MIL-STD-410 (QP 629).

4.4.3 Material Control and Traceability

BASD's existing material control system will provide material inventory control and traceability. Mechanized inventory control techniques will be applied through electronic data processing. The material control stores area is a controlled access area. Project controlled secure areas and cabinets may be used at production's discretion for specialized parts.

Piece parts, subassemblies, and assemblies are segregated by contract and stocked in part number sequence. The MIT provides traceability for the parts or materials. The purchase order number, part number, and other information are printed on the MIT when the items are received on the dock. The MIT stays with the part through receiving inspection and into stores. When the part is withdrawn for further processing or assembly, the MIT information is transferred to a production order or cert log for traceability (QP 609)

In addition to MIT number traceability, EEE parts will be logged into the RS2000 program database upon arrival at dock. The information will include mfgr. and lot/date code. Traceability, as related to electronic parts, means traceable to the printed wiring board where used but not to the circuit location where installed. Applicable GIDEP alerts will be addressed on a case by case basis.