DATA PROCESSING UNIT AND POWER SYSTEM FOR THE LANL REM INSTRUMENT PACKAGE

FINAL REPORT
Subcontract No. 1568K0013-9C
SwRI Project 15-5869

Submitted to:

Los Alamos National Laboratory
Space Sciences and Technology Division
Group SST-7, MS D466
Los Alamos, New Mexico

Submitted by:

Walter Lockhart
Southwest Research Institute
San Antonio, Texas

March 1994

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APPENDIX A

1.0 OBJECTIVE

The NEPSTP spacecraft needs highly reliable instrumentation to measure the nuclear reactor health and performance. These reactor measurements are essential for initial on-orbit phase operations and documentation of performance over time. Los Alamos National Laboratory (LANL), under the guidance of W. C. Feldman, principal investigator, has designed the Radiation Environment Monitoring (REM) package to meet these needs. The instrumentation package contains two neutron detectors, one gamma-ray detector, a data processing unit, and an instrument power system. The REM package is an integration of quick turn-around, state of the practice technology for detectors, data processors, and power systems. A significant portion of REM consists of subsystems with flight history.

Southwest Research Institute (SwRI) has been tasked by LANL to design support electronics, including the Data Processing Unit (DPU) and Power System for REM. Our goal for this project is to use technologies from current programs to speed up and simplify the design process. To meet these design goals, we use an open architecture VME bus for the DPU and derivatives of CASSINI power supplies for the instrument power system. To simplify integration and test activities, we incorporate a proven software development strategy and tool kits from outside vendors.

The objective of this report is to illustrate easily incorporated system level designs for the DPU, power system and ground support electronics (GSE) in support of the important NEPSTP program.

2.0 WORK PERFORMED

The DPU/electronics support package and GSE presented here for the REM meet the time frame and performance objectives sought for the NEPSTP spacecraft. Project development costs are reduced by using system components and software approaches from recent and ongoing programs. The use of an open architecture VME bus DPU speeds instrument design, integration and test activities.

Major Milestones completed during this phase of design activity include:

- VME Bus Data Processing Unit
- SC-7 RISC Processor
- High Efficiency/High Reliability Power System
- A Workable Software Development Plan
- Simple Ground Support Equipment
- Simple Command and Data Handling Strategy
- Recommendation of the NASA NHB 5300.4(1B) QA Program

3.0 REM PACKAGE OVERVIEW

As shown in Figure 3.0, the REM instrument package consists of two neutron sensors and one gamma-ray sensor. A central DPU provides command and data handling functions, low-voltage power to the instruments, and a spacecraft interface. High voltage power supplies are co-located with each instrument. Table 3.0 lists the subsystems and responsible institutions.

Figure 3.0 REM Package

QTY	SUBSYSTEM	RESPONSIBLE INSTITUTION
1	BOOM-MOUNTED NEUTRON DETECTOR	LANL
1	BODY-MOUNTED NEUTRON DETECTOR	LANL
1	BODY-MOUNTED GAMMA-RAY DETECTOR	LANL
1	VME FORM FACTOR DPU	SwRI
1	CENTRAL LOW VOLTAGE POWER SUPPLY (LVPS)	SwRI
3	DISTRIBUTED HIGH VOLTAGE POWER SUPPLY (HVPS)	SwRI
1	GROUND SUPPORT ELECTRONICS (GSE)	SwRI
1	FLIGHT SOFTWARE DEVELOPMENT	LANL/SwRI

Table 3.0 REM Subsystems

4.0 REM SUPPORT ELECTRONICS

Within the REM Package, support electronics are needed to provide the LANL neutron and gamma-ray sensors with power, command and data handling, and ground support. SwRI's role in this activity is to design a highly reliable support electronics system that simplifies test, integration, and on-orbit operations. The support electronics can be broken down into the following major functions:

- The DPU, including the CPU, instrument interfaces, and power management card.
- The high voltage power supplies,
- The central low voltage power supply

A breakdown of the support electronics is shown in Table 4.0.

QTY	SUBSYSTEM	LOCATION	DESCRIPTION
1	SC-1750A OR SC-7	DPU - VME CARD CAGE	VME FORM FACTOR, HIGH PERFORMANCE CPU WITH 1553B I/O
1	LVPS	DPU - VME CARD CAGE	CENTRAL LOW VOLTAGE POWER SUPPLY, +5V, +/-15V, -5.2V.
1	SC-VMEPM	DPU - VME CARD CAGE	VME FORM FACTOR POWER MANAGEMENT CARD, PROVIDES PROGRAMMING CONTROL TO HVPSs.
1	INSTRUMENT I/F	DPU - VME CARD CAGE	PROVIDES 2 SCALAR CHANNELS AND 4 ANALOG CHANNELS FOR INSTRUMENT DATA.
1	HVPS-1	BOOM-MOUNTED NEUTRON DETECTOR ELECTRONICS	HIGH VOLTAGE POWER SUPPLY FOR BOOM-MOUNTED NEUTRON DETECTOR, ~500VDC.
2	HVPS-2	BODY-MOUNTED NEUTRON AND GAMMA-RAY ELECTRONICS	PROGRAMMABLE HIGH VOLTAGE POWER SUPPLY FOR BODY-MOUNTED NEUTRON AND GAMMA-RAY DETECTORS, +1.5KV MAX.

Table 4.0 REM Support Electronics -- SwRI's Role for NEPSTP

We have completed a system level design of the REM Support Electronics and have formulated a software development plan for the flight computer and GSE. The following sections give a detailed description of our activities.

5.0 SUPPORT ELECTRONICS RECOMMENDATIONS

The following description is SwRI's recommendation for the REM Support Electronics.

5.1 Data Processing Unit (DPU)

The DPU is implemented with the Versa Module Eurocard (VME) bus standard and MIL-STD-1553B bus I/O. The DPU package consists of a standard, 5-slot, off-the-shelf VME card cage which is specially ruggedized and RFI shielded per SwRI specifications for space flight. It accommodates the 6U VME form factor CPU card, an instrument interface card, and a power supply monitor/interface card (SC-VMEPM). A dimensioned drawing of the VME card cage is shown in Figure 5.1a.

Figure 5.1a Ruggedized VME Card Cage

Power to the DPU will be provided by the LVPS (Low Voltage Power Supply). The LVPS is packaged within a separate compartment of the card cage. This is the central power source of regulated low voltage DC for the DPU and instruments.

A block diagram and interconnect drawing of the DPU is shown in Figures 5.1b and 5.1c.

Figure 5.1b DPU

Figure 5.1c REM Interconnect Diagram

The individual VME cards are described in the following sections.

5.1.1 High Performance CPU Card

In our original proposal for NEPSTP, we offered the SC-1750A as the central processing unit. Selection of this processor board was based on its recent flight history and improvements achieved through ongoing programs. However, vendor deliveries of 1750-based processors have been troublesome. We see reduced emphasis in the production and support of 1750-based processors. We are now recommending the SC-7 processor board. The SC-7 meets the same form, fit, and function of the SC-1750A, including dual redundant MIL-STD-1553B buses.

The SC-7 eclipses the performance of the SC-1750A by a wide margin. The SC-7 is based on the Texas Instruments TMS320C30 processor. With this RISC processor, the SC-7 offers a growth path for future developments. This would include software tools, hardware improvements, and instrumentation demands. As shown in Figure 5.1.1, key features of the SC-7 are:

- Texas Instruments TMS320C30 Processor
- 12 MIPS
- 24 MFLOPs
- Low Power - 6 Watts
- VME 6U Format
- VME Bus Master
- I/O Includes:
 - Dual Redundant MIL-STD-1553B Interface
 - Dual High-Speed Serial Interface
- On Board Memory Includes:
 - 1 MByte SRAM
 - 512 KByte EEPROM
 - 8 KByte PROM
- Selectable Clock Speeds
 - 6, 12, 24 MHz

Figure 5.1.1 SC-7 RISC Processor

5.1.2 Command and Data Handling

Data flow from the neutron and gamma-ray sensors is channeled through the Instrument Interface card. Control of the Instrument Interface is effected by uplink commands and/or stored command scripts within the CPU program memory. Instrument high voltage programming is controlled by the SC-VMEPM card. The SC-VMEPM provides individual programming voltages to each HVPS co-located with its respective instrument. All spacecraft communication is effected through the dual-redundant MIL-STD-1553 channels contained on the SC-7 card. In this way, the failure of any single channel will not affect the transfer of data to/from the spacecraft over this critical interface. See Figure 5.1.2.

Figure 5.1.2 REM Data Flow

5.1.3 Instrument Interface Card

The gamma ray and neutron instrument interfaces, along with VME bus interface circuitry, are placed on a single VME card. As shown in Figure 5.1.3, shielded differential analog interfaces are provided for the gamma ray and BOOM neutron sensors; Logic-level inputs to accumulator/registers are provided for the fast neutron sensors (LAND).

Figure 5.1.3 Instrument Interface Card

For data acquisition, the instruments operate in a comparable fashion. Instrument data acquisition is individually controlled by timers, which enable and disable data collection. Commandable timers, residing on the SC-7, provide gate-time intervals for data collection. At the beginning of each gated collection cycle, the card effects a general reset and configuration of all its registers, and then proceeds to enable the data transfer from each instrument. All data from the interface card is passed over the VME bus to the SC-7 for detailed processing and reduction. Memory arrays for each instrument are set aside in the SC-7 for spectrum accumulation and analysis. The desired results are then formatted for transmission over the MIL-STD-1553 bus to the spacecraft.

5.1.4 SC-VMEPM Power Monitoring/Control Card

The necessary control and analog monitoring electronics for the instrument power and housekeeping are contained on a single VME card. The SC-VMEPM block diagram is shown in Figure 5.1.4. Relays are used to control the application of +15 VDC to each instrument's high voltage supply. The on-card power supply control electronics also make use of SAFE and ENABLE logic signals, as well as Safe, Disarm, and Arm physical connector plugs.

Figure 5.1.4 SC-VMEPM Power Management Card

Each high voltage power supply is controlled by two logic lines called SAFE and ENABLE. The ENABLE line acts as an "ON/OFF" switch and is used to completely shut down the power supply. The SAFE line determines whether the power supply can be set to its maximum voltage, or only to a predetermined safe level (e.g. <10% of maximum value).

The output voltage levels are also controlled by Safe, Disarm, and Arm plugs which fit into a single connector located on the DPU. The logic is designed so the Safe connector will override any attempt from the microprocessor to set the power supplies to undesired voltages. Prior to flight or to laboratory tests in which high voltage (HV) is required to operate, the Safe connector is removed and the Arm connector is inserted. The SAFE plug, when installed, will jumper the SAFE logic line to signal ground (low state) and not jumper the ENABLE logic line to ground, so that the high voltage power supply can be turned on but its output confined to a pre-determined safe level regardless of DPU command. The Disarm plug, when installed, will jumper the enable line to signal ground, so that the high voltage output is disabled ($V_{out} = 0$ volts) regardless of DPU command. When the Arm plug is installed the jumpers to signal ground are removed, and the SAFE and ENABLE lines are controlled by the DPU.

Each HVPS generates an analog monitor signal whose magnitude corresponds with the actual output, and one temperature sensor is also provided. Analog data is received by an instrumentation amplifier on the SC-VMEPM card, and digitized to a precision of at least 8 bits. The input signal range is 0.0 to 5.0 volts for the analog signal monitors.

5.1.5 DPU Software Description

The data acquisition, analysis, compression, and transmission tasks are processed by the SC-7 RISC CPU. Spectrum analysis of data collected from the instruments is performed within allocated sections of memory on the SC-7. 256 by 24-bit arrays are used for the gamma ray and slow neutron instruments; Scalars with memory registers resident in the Instrument Interface Card are used to accumulate the fast neutron data.

Standard sets of control modes, data acquisition modes, data selection and compression, and calculations will be defined and implemented in the DPU. The sets are selectable via time tags or via commands from the spacecraft.

5.2 REM Software Development Environment

We recommend a high level approach to software development for REM. The REM software development environment incorporates commercial off-the-shelf products to support the definition, test, and validation of the instrument software systems. A REM software development station includes:

- Sparc Workstation
- ISI Software Development Environment
- Tartan Ada Cross-Compiler and Software Tools
- Commercial Quality REM DPU Testbed Unit

The REM software development environment will accelerate the REM software effort:

- Integrated Process From Requirements-->Design-->Test
- Direct Traceability Requirements-->Design-->S/W-->Test
- Rapid Response to Design Changes
- Automatic Code Generation
- Common Electronic Database for Design/Simulation
- Common Source of Design/Simulation Modules

The REM software development environment will allow integrated design and rapid prototyping of REM flight software. The REM DPU testbed unit can be used immediately, and a nonflight version (engineering model) may also be used directly with the development environment for testing of the software at real-time rates. Figure 5.2 shows the software development strategy.

Figure 5.2 REM Software Development

5.3 Software Development Hardware

The software development hardware consists of a software development workstation and a REM DPU Commercial Quality Testbed Unit.

5.3.1 Software Development Workstation

The hardware for a software development workstation will consist of the following units:

- Sparc Classic Workstation
- i486 PC with Software
- Laser Printer
- RS-422 converter for Sparc and PC
- Ethernet Card for Sparc and PC
- MIL-STD-1553B Interface for PC
- Computer Worktable
- Cabling

5.3.2 REM DPU (Commercial Quality) Testbed Unit

The REM DPU Testbed Unit will consist of the following components:

- Commercial VME Card Cage
- TMS320C30 development card
- MIL-STD-1553B Interface, VME based
- Cabling

The REM DPU Testbed Unit will be available immediately as a target testbed unit for initial software definition and testing.

5.4 REM Software Development Tools

5.4.1 ISI Software Development Tools

The recommended ISI Software Development Tools for the REM software development environment include:

- Advanced Simulation Package, Consisting of
 - MATRIXx/xMath
 - Control Design Module
 - System Identification Module
 - System Build with Interactive Animation Control Panels
 - CASE expansions module
 - Hyperbuild Module
- Autocode/Ada

The ISI software tools are commercial off-the-shelf tools that offer a unique solution for the design and development of software to support the definition, test, and validation of the REM software systems.

5.4.2 TARTAN, Inc. ADA Cross Compiler System

After the REM software has been designed, analyzed, and tested on the ISI Software Tool Set, the Tartan 320C30 Ada cross compiler can be used to target the software to the REM computer. (The Tartan Cross-Compiler can also be used independently of the ISI software tools.)

The Tartan Ada Compiler system consists of:

- Tartan Ada Compilation System
- Expanded Memory
- Adascope Simulator
- Assembler
- Profiler and Maintenance

ISI used the Tartan Ada software development system with great success on the MSTI program. It is very compatible with ISI's Autocode Ada.

5.4.3 Additional Third Party Support

The TMS320C30 processor on the SC-7 single board computer enjoys a wide selection of third party software development tools. These include real-time operating systems, software simulators, in circuit emulators, evaluation boards, and ANSI compatible C compilers. A partial listing of available tools and suppliers includes:

- Emulators
 - Texas Instruments - XDS500
 - Hewlett Packard
 - Electro
- Evaluation Boards
 - Texas Instruments - EVM Board
 - SwRI SC-7 EVM Board
- Software Simulator
 - Texas Instruments
- Operating Systems
 - SPOX Real Time O.S.
- C Compilers
 - Texas Instruments ANSI compatible C compiler with all support libraries and low level drivers

5.5 Instrument Power System

The Instrument Power System includes a central low voltage power supply (LVPS) housed within the DPU card cage that provides regulated and filtered dc voltages to the instruments and DPU. The high voltage programmable and stepping power supplies are co-located with the various instruments. HVPS control and monitoring functions are provided by the SC-VMEPM card in the DPU.

5.5.1 Low Voltage Power Supply

The low voltage power supply (block diagram, Figure 5.5.1) utilizes a Push-Pull Center Tap topology operating at 100 kHz. This approach is similar to the design used

in the ABE (Army Background Experiment) low voltage supply that was flown on the LACE satellite. The low voltage supply is the experiment interface to the NEPSTP spacecraft power system. It therefore includes an RFI filter and inrush current limiting functions for the subsystem.

Figure 5.5.1 Low Voltage Power Supply (LVPS)

The Pulse Width Modulator utilizes a CMOS controller chip and provides gate drive to two MOSFET power switches. Feedback from the +5 volt secondary is isolated, either by optical means if that can be made acceptable in the high radiation environment, or by use of a small transformer in a chopper circuit. Either approach will provide excellent output regulation since the error amplifier and reference are both at the secondary potential, and any errors induced by feedback components are divided by the loop gain.

Secondary rectifiers and filters are of conventional design, using fast recovery diodes and choke input LC filters. With the proposed instrument configuration, four outputs are expected to be required. These are: +5 vdc, -5.2 vdc, +15 vdc, and -15 vdc. The control loop is closed on the +5 volt output. No secondary regulators are expected to be necessary.

5.5.2 High Voltage Power Supplies (HVPS)

The Cassini MCP HVPS serves as a baseline and is extended and modified where necessary to meet the other instrument requirements. The CASSINI topology was selected because of the high efficiency and performance needed to bias the REM detectors. Figure 5.2.2 is a block diagram of the base circuit topology. The HVPS units are packaged with their respective instruments to minimize high voltage cabling and interconnect. Modified versions of

the Cassini IMS microchannel plate (MCP) bias supplies are used to provide detector bias in the gamma ray, fast neutron, and slow neutron instruments. These supplies have dual outputs with individual programming and control.

The gamma ray and LAND neutron instruments have similar bias supplies packaged with them. Each instrument contains a supply with a maximum output of +1.5 kv. The two identical supplies are derived from the CASSINI MCP supplies. They also utilize the fixed-frequency resonant topology, synchronized from the LVPS at 200 kHz for operation at 100 kHz. The programming input is a 0 to -10 volt analog signal derived from an eight bit D to A converter.

The boom-mounted neutron spectrometer requires a compact fixed high voltage supply to minimize package size and mass. This supply provides a fixed high voltage bias of approximately 500 volts with no provisions for programming or monitoring. This supply is also a derivative of the Cassini fixed frequency resonant MCP supply, but makes use of fewer multiplier stages.

Figure 5.5.2 High Voltage Power Supply (HVPS)

5.5.3 HVPS DPU Interface

Each programmable high voltage supply has a differential analog receiver input for analog control of the output voltage by the DPU. Accurately scaled analog monitors from each high voltage output are provided to the DPU. Logic inputs are provided to each high voltage supply for safe, enable, and range functions.

5.5.4 Power Supply Packaging

Each of the HVPS units is packaged within a separate housing and packetized with their respective instruments. Figure 5.5.4 shows package details.

Gamma & Neutron Instrument
HVPS Enclosure

Figure 5.5.4 HVPS Enclosure

5.6 Electromagnetic Compatibility

5.6.1 Design Considerations

The design approach to compliance with Electromagnetic Compatibility (EMC) requirements is similar to that successfully employed in preceding spacecraft power system designs. The requirements for conducted phenomena (emissions and susceptibility) are met by careful use of filtering. The main filtering components, common mode inductor, normal mode inductor, X-capacitors, Y-capacitors, and high frequency ferrite beads, are located as close to the spacecraft power interface as possible. A shielded enclosure for the filter, separate from the shielded electronics enclosure, is preferred. This arrangement filters the undesirable conducted ac components in both directions and isolates the spacecraft power line and experiment electronics from signals that might be coupled around the filter.

In addition to the main RFI filter at the spacecraft power interface, each power supply board in the system has its own input filter consisting of a common mode inductor and X-capacitors, with a normal mode inductor and more X-capacitors for each separate supply on the board. This extensive system of filters, in conjunction with careful power supply pc board layout, has been shown to be very effective in meeting the requirements of MIL-STD-461 in existing systems.

5.6.2 System Grounding Philosophy

The +28 volt spacecraft power bus is isolated from all secondary circuits and the chassis to prevent any primary power return current from flowing through the chassis to the spacecraft single point return. The secondary circuits are connected in common at a single point yet to be determined. Known sources of high frequency noise, notably the isolation (power) transformers in the various supplies will be bypassed as close to the noise source as possible to minimize the path length for the noise source return. This important grounding technique has worked well similar flight systems.

5.7 Mass and Power Estimate

QTY	SUBSYSTEM	MASS (GRAMS)	POWER (WATTS)	PACKAGE
1	SC-7	600	6	6U VME CARD
1	SC-VMEPM	480	1	6U VME CARD
1	INSTRUMENT I/F	480	1.2	6U VME CARD
1	VME CARD CAGE	6000*	7 (TERMINATION POWER)	5-SLOT VME CHASSIS
1	HVPS-1 HIGH VOLTAGE SUPPLY	100	0.1	4 X 4 INCHES
2	HVPS-2 HIGH VOLTAGE SUPPLY	500 EA. 1000 TOTAL	0.38 EA. 0.76 TOTAL	6.5 X 8.5 X 1.25 INCHES
1	LVPS DC TO DC CONVERTER	750	>75% EFFICIENT AT FULL LOAD	FITS WITHIN VME CHASSIS
		TOTAL =9410 GRAMS	TOTAL =21.4 WATTS**	

* VME Card Cage without vendor-supplied DC to DC converter.

** Does not include sensor electronics.

6.0 EXPERIMENT AND DPU GROUND SUPPORT EQUIPMENT

The Experiment Ground Support Equipment (EGSE) provides all interface, monitor, data, and control functions for the DPU. Figure 6.0 is a block diagram showing the relationship of the EGSE to the DPU and to the local data bus.

Figure 6.0 EGSE

The EGSE is based on a Sun SPARC Classic workstation and two general purpose PC i486 computers. The SUN workstation will be equipped with the following minimal hardware complement:

- 16 Mbyte memory
- Color Monitor
- 207 Mbyte internal SCSI-2 disk

Each PC system has the following minimum hardware components:

- 4 Mbyte RAM
- 80 Mbyte hard disk
- 1.2 Mbyte 5¼" floppy drive
- VGA display (1024 x 768) monitor
- Ethernet and MIL-STD-1553 interface cards

All interfaces to the DPU from the spacecraft utilize the MIL-STD-1553 bus. Communication between the workstation and PCs is via PC/NFS software and ethernet hardware. One PC monitors the 1553 bus for communication activity, and displays the real-time data in a meaningful format on its monitor. The other PC serves as a command and control center for the DPU and a laboratory 28 VDC power system; again, communication with the DPU occurs over the 1553 bus. Finally, the SUN workstation is used to archive all communications and data transfer activity, and to store command scripts and diagnostic sequences. The ethernet connection between the computers results in a simple and reliable system of file transfer and data exchange among themselves, and with the spacecraft Ground Support System (GSS).

The EGSE emulates all spacecraft functions and accompanies the DPU through spacecraft level testing. Via ethernet, it is also the sole interface between the DPU and the GSS. In order to assist and coordinate instrument subsystem level tests there is also a set of instrument level EGSEs (provided by LANL) that emulate the DPU function and its interface to the sensors.

7.0 PRODUCT ASSURANCE PLAN

As the core of the product assurance program, SwRI recommends a NASA NHB 5300.4(1B) QA program. This latter program is fully implemented at all appropriate levels of SwRI, and personnel work daily under its guidance. The complete Project Quality Plan (PQP) documenting the QA and inspection program is attached in Appendix A.

8.0 MANAGEMENT PLAN

For the REM Support Electronics, we plan to use a 6U VME 5-slot card cage for the DPU. Individual high voltage power supplies are used for the neutron and gamma instruments. The VME card cage will be populated with:

- SC-7 CPU Card
- SC-VMEPM Power Management Card
- Instrument Interface Card
- Low Voltage Power Supply

The SC-7 CPU design is complete. Most of the effort involved for the DPU will be for the SC-VMEPM and Instrument Interface Card. These card designs will require close interaction with LANL to define and specify their functions. The low voltage power supply is a spin-off from the LACE-ABE program. It will require significant efforts in repackaging to accommodate the flight-ruggedized VME card cage.

The REM neutron and gamma-ray sensors require high voltage to bias their detectors. SwRI will use spin-offs of high voltage designs from the CASSINI program to meet these requirements. Each power supply will be co-located with its respective instrument.

Flight software for the REM package will be developed using commercial design tools from ISI and Tartan Corp. Instrument operation modes, data formatting, and command structures will be investigated thoroughly. Joint consultations will be held with LANL and NEPSTP program managers to define a software requirements and test strategy.

Walter Lockhart will serve as Program Manager for the REM Support Electronics at SwRI. He will direct the design, fabrication, and test of the flight hardware and software. A work breakdown is given below.

Task 1	Detailed Design of the Instrument Interface Card
Task 2	Detailed Design of the SC-VMEPM Power Management Card
Task 3	Repackaging of the ABE Low Voltage Power Supply
Task 4	Design modifications to CASSINI High Voltage Power Supplies
Task 5	Design of the Ground Support Electronics
Task 6	Thermal analysis of the VME Card Cage and power supplies
Task 7	Parts selection for radiation environment
Task 8	Design software environment/testbed unit
Task 9	Develop and test flight software
Task 10	Procure parts, materials, and equipment
Task 11	Fabricate engineering model DPU (protoflight)
Task 12	Engineering level tests for DPU and Power System
Task 13	Fabricate flight hardware
Task 14	Integrate REM Package
Task 15	Perform full functional tests
Task 16	Perform shock and vibration tests
Task 17	Perform EMC tests
Task 18	Perform thermal cycle tests
Task 19	Perform burn-in tests
Task 20	Pre-delivery review
Task 21	Field support

We estimate this effort to cost \$1.1M and to be one calendar year in duration.

9.0 PEM INSTRUMENT DELTA

If the Plasma Environment Monitor Package is integrated with REM there would be some additional development effort required. The following work breakdown lists these additional tasks.

Task 22	Detailed design of TOF FIFO Buffer card
Task 23	Repackaging of LEF3D TDC electronics
Task 24	Fabrication of TDC and TOF FIFO Buffer electronics
Task 25	Fabrication of LEF3D HVPS
Task 26	Integration and Test of PEM in vacuum chamber
Task 27	LEF3D flight software modules
Task 28	Special handling of flight instrument

We estimate this additional effort to cost \$0.9M and to extend our original schedule by six months.

PROJECT QUALITY PLAN

for

SwRI Project 15-XXXX

Document No. PQP-94-15-XXXX

Revision 0

Change 0

**NUCLEAR ELECTRO PROPULSION SPACE TEST - PROGRAM
(NEPSTP)**

LOS ALAMOS NATIONAL LABORATORY (LANL)

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PROJECT QUALITY PLAN

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Document No. PQP-94-15-XXXX

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Project Manager

Date: _____

Project Quality Plan

PQP-94-15-XXXX

SwRI Project 15-XXXX

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i through iv	0/0	December 1993
1 through 38	0/0	December 1993

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CHAPTER 1: INTRODUCTION

1B100 GENERAL

This document describes the quality program to be used by Southwest Research Institute (SwRI) to accomplish the goal of a modified NHB5300.4(1B), *Quality Assurance Program Provisions for Aeronautical and Space System Contractors* quality system. This program is specifically applicable to the Data Processing Unit and Power System for the LANL REM instrument package. The format of the document is patterned after NASA NHB5300.4(1B) for ease of correlation.

1B101 RELATIONSHIP TO OTHER CONTRACT REQUIREMENTS

The requirements set forth in this plan are in addition to all other detail requirements contained in the Statement of Work or other parts of the contract. The Quality Assurance Program as defined by this plan shall effectively complement and support functions required by other contract requirements. This plan shall provide an effective quality assurance (QA) function for this project, with a minimum of duplication of effort. In the event of conflicts between the requirements of NHB5300.4(1B) and other contractual requirements, SwRI shall bring such conflicts to the attention of the Los Alamos National Laboratory (LANL).

1B102 ACTIONS AND PREROGATIVES OF THE LANL

The work and operations of SwRI and its suppliers as related to this contract shall be subject to evaluation, review, audit, survey, and inspection by the LANL or its representatives.

SwRI and its suppliers shall provide in a timely manner to LANL representatives any requested information, documents, records, samples, and materials that may be prepared, fabricated, or procured under the contract. SwRI and its suppliers will provide the use of inspection equipment, reasonable facilities, and assistance for the safety and convenience of the representatives in the performance of their duties.

1B103 QUALITY PROGRAM DOCUMENTS

The following documents, latest revision unless specified, are applicable to this plan. Any limitations of applicability are noted in the context of this document, the Product Assurance Plan, or in the contract itself.

1. NASA Documents

NHB5300.4(1B) Quality Program Provisions for Aeronautical and Space System Contractors

NHB5300.4(3A-2) Requirements for Soldered Electrical Connections

NHB5300.4(3G) Requirements for Interconnecting Cables, Harnesses, and Wiring

NHB5300.4(3H)	Requirements for Crimping and Wire Wrap
NHB5300.4(3J)	Requirements for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies
SP-R-0022A	General Specification - Vacuum Stability Requirements or Polymeric Materials for Spacecraft Applications
GSFC-PPL	GSFC Preferred Parts List
MSFC-SPEC-522B	Design Criteria for Controlling Stress Corrosion Cracking
NHB8060.1B	Flammability, Odor and Off Gassing Requirements and Test Procedures for Materials that Support Combustion

2. Military Documents

MIL-STD-275E	Printed Wiring for Electronic Equipment
MIL-STD-975H	NASA Standard Parts List for Flight and Mission Essential Ground Support Equipment.
MIL-STD-883C	Test Methods and Procedures for Microelectronics
MIL-STD-461A	Electromagnetic Emission and Susceptibility Requirements
MIL-STD-1541	Electromagnetic Compatibility Requirements for Space Systems
MIL-STD-45662A	Calibration System Requirements

MIL-STD-105E	Sampling Procedures and Tables for Inspection Attributes
MIL-STD-954	Standards. General Requirements for Electronic Equipment
MIL-STD-889	Dissimilar Metals
MIL-STD-973	Configuration Management
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-463	Definition and System of Units, Electromagnetic Interference Technology
MIL-P-55110D	General Specification for Printed Wiring Boards
DOD-STD-1686	Electrostatic Discharge Control Program
DOD-STD-2168	Defense System Software Quality Program

4. SwRI Documents

QAP-3-1	Quality Assurance Reviews and Planning for Proposals and Contracts
QAP-3-2	Project Quality Assurance Program
QAP-3-3	Quality Education and Training

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QAP-4-1	Design Control
OP-4-15-101	Division 15 Design Control
QAP-5-1	Document Control
OP-5-30-101	Document Control
OP-5-15-101	Document Control
QAP-5-2	Drawing Control
OP-5-15-201	Drawing Control

4. SwRI Documents (Cont'd)

QAP-6-1	Purchased Materials, Items and Services Control
OP-6-30-101	Approval of Suppliers
OP-6-30-201	Quality Assurance Purchase Requisition Review
OP-6-73-201	Purchase Order Processing
OP-6-15-201	Procurement Procedure
DOP-6-15-301	Identification Marking of Parts and Assemblies
OP-6-30-401	SwRI Source Inspection Activities
OP-6-30-501	Receiving Inspection of Materials, Equipment, Items, and Services
QAP-7-1	Initial Fabrication Planning
OP-7-15-201	Manufacturing Planning Sheet Procedure
QAP-7-2	Process Form Control
OP-7-30-101	Process Forms, Review and Use
QAP-8-1	Special Process Controls
DOP-8-15-112	Flatpack Component Lead Forming Procedure
DOP-8-15-113	Procedure for Use and Maintenance of Leister Hot Air Soldering/Desoldering Tool and Operation Certification
DOP-8-15-161	Solder Paste Control and Testing
DOP-8-15-162	Printed Wiring Assembly Fabrication Using Vapor Phase Reflow Soldering Process
DOP-8-15-163	Coplanarity Inspection of Formed Leads
DOP-8-15-164	Solder Pot Tinning of Component Leads
DOP-8-15-165	Rework of Surface Mounted Components
DOP-8-15-166	SMT Lead Alignment and Solder Inspection Criteria
DOP-8-15-167	Attachment of Raychem Compliant Leads to Leadless Ceramic Chip Carrier Packages
DOP-8-15-168	Rework and Repair of SMT Printed Wiring Boards
OP-8-15-301	Conformal Coating with Conathane EN-11
DOP-8-15-311	Staking Process for Electronic and Mechanical Parts
OP-8-15-312	Procedure for Mixing Conathane EN-11 to be Used as a Staking Compound
DOP-8-15-401	Soldered Assembly Cleaning Procedures
QAP-9-1	Test and Measuring Equipment Control

OP-9-30-103	Dimensional Measuring Equipment Calibration System
OP-9-30-104	Calibration System
OP-9-15-101	Calibration Control

4. SwRI Documents (Cont'd)

QAP-10-1	Inspection and Test Controls
OP-10-30-101	Control of Inspection Stamps
OP-10-30-102	Fabricated Parts Inspection
OP-10-30-103	Inspection Records
OP-10-30-201	Visual Inspection of Mechanical Assemblies
OP-10-30-202	Visual Inspection of Electrical/Electronic Assemblies
QAP-11-1	Records Control
QAP-12-1	Control of Nonconforming Materials, Items, and Equipment
OP-12-IW-101	Material Review Board
QAP-13-1	Forms Controls
QAP-14-1	Corrective Action to Prevent Recurrence
QAP-14-2	Quality Reporting and Analysis
QAP-15-1	Audit Control
OP-15-30-102	Audit Scheduling and Performance
QAP-15-2	Surveillance Control
QAP-16-1	Cleanliness, Handling, Storage, and Delivery
OP-16-15-101	Controlled Stores Procedure
DSS4	Fabrication Control Plan for the Department of Space Systems and Department of Space Sciences
OP-16-15-201	Clean Room Procedure
QAP-16-2	ESD Control Program
OP-16-15-301	ESD Control
QAP-17-1	Software Development Control
OP-17-15-101	Software Design, Development and Configuration Control
OP-17-30-101	Software Development Evaluation

CHAPTER 2: QUALITY PROGRAM MANAGEMENT AND PLANNING

1B200 GENERAL

The expressed purpose of this plan is to:

- Provide evidence to the contracting party that the quality aspects of the contract have been identified and that achievement is being accomplished and in an organized manner;
- Provide evidence that quality requirements are determined and satisfied in all phases of the contract;
- Provide evidence that quality aspects are fully included in all designs;
- Provide evidence that the designs are adequately monitored and are accurately incorporated into the fabricated article;
- Provide for the detection of actual or potential deficiencies, marginal quality, and trends or conditions which could result in unsatisfactory quality;
- Provide timely and effective remedial and preventive action; and
- Provide the objective evidence that inspection and testing is readily available to the contracting party or their designated representative.

1B201 ORGANIZATION

SwRI consists of a Board of Directors; President; Executive Vice President, Operations; Executive Vice President, Finance; and Vice Presidents of Operating Divisions (hereafter referred to as Divisions). Divisions are subdivided into Departments which are headed by Directors. Departments, in turn, are subdivided into Sections, which are headed by Section Managers. Projects sponsored by Clients are under the direction of Project Managers who plan, administer, and

exercise technical and fiscal control of projects. The Project Manager's position is a functional position which is abolished upon completion of a project. Standing committees are established in special technical management areas to assist Institute executive management in keeping abreast of current developments and to make recommendations on ways to enhance the technical and management program. An Institute organization chart is shown in Figure 1. This chart shows the management organization from the Board of Directors down to the Divisions.

Upon receipt of a contract, the responsible division establishes a project organization which is designed to carry out contractual requirements. The project organization is a functional group organized in accordance with Institute guidelines and is abolished upon completion of the project. The project organization usually consists of a Project Manager, professional staff members, technical support (technicians), clerical support, and Institute services. The Project Manager is selected from the managerial and professional staff based primarily on his experience in the technical area of contracts and his managerial capabilities. He reports to either a Section Manager, Department Director, Division Vice President, or Institute President, depending on the nature, size, and complexity of the program. The project organization coordinates with other Institute organizations, as required, to ensure satisfactory performance of the program. These services include, but are not limited to; contracts, accounting, purchasing, machine shop, and personnel safety.

The Department of Space Systems of the Instrumentation and Space Research Division (Figure 2) has the prime responsibility for the design, fabrication, testing, and qualification of the NEPSTP in accordance with the requirements stated in the contract, Statement of Work and any required supporting documentation.

The Project Manager is responsible to division management for the actions stated in the previous paragraph.

In the performance of the above requirements and to provide evidence of conformance, the project is responsible for the generation, retention, and storage of all design, fabrication, testing, and qualification documentation.

The project shall be responsible for the control of limited shelf-life articles. The project shall be responsible for use of properly trained and certified personnel on all special processes. The exact mechanism for the performance of all the responsibilities are described in detail in the Institute QA Procedures (QAP), Department/Division Operating Procedures (OP), and Work Instructions (WI).

The Institute QA Department has the prime responsibility for assuring compliance with all technical and quality requirements for the NEPSTP (see Figure 3).

Two groups of the Institute QA Department are directly responsible for the day-to-day operations of the QA program associated with this project. They are Project Quality Engineering and Project Quality Inspection.

The Manager of Project Quality Engineering shall assign a QA Engineer (QAE) to this project. Additional QAEs may be assigned when special skills are required to support the project.

The QAE assigned to the project is responsible for assisting the Project Manager in achieving all of the required quality requirements associated with the project. The QAE's prime responsibility is the constant assessment of conformance to requirements as set forth in the contract.

To that end, the QAE shall have overall responsibility for the quality aspects of the project. Among the QAE's duties and qualifications are:

- Review of purchase requests to assure that all of the requirements needed for the article(s) are correctly stated on the purchase requisition;
- Review of the Institute procedures and determine their acceptability as related to a project;
- Review of design documents, Environmental test requirements;
- A working knowledge of the contract, Statement of Work, any required specifications, and of the QAPs and OPs;
- Notification to the Manager of Project Quality Inspection as to the required qualifications and certifications needed by the various inspectors to support a project;
- Coordination with the LANL QA Representative regarding any and all production hold points; and
- Notification to the Manager of Project Quality Inspection regarding production hold point opportunities for LANL Quality Representative participation.

The Manager of Project Quality Engineering is responsible for the assignment of qualified and certified Inspectors. The Project Quality Inspection group is responsible for the coordination of inspections and testing with the LANL QA Representative, if and when required.

SwRI personnel controlling selected processes or operations shall be certified in accordance with an approved procedure.

The Contracts Department of the Institute has the responsibility for assisting QA in the performance of assuring compliance with contracted requirements. The Contracts Department is also responsible for assisting the Project Manager in meeting all of the fiscal and financial reporting requirements associated with a project. In addition, they are responsible for the tracking of all contract deliverable items and assisting the Project Manager in meeting additional special business clauses found in the Statement of Work or a contract.

The Purchasing Department of the Institute has the responsibility of purchasing items specified by a project, approved by QA, for the best price given, meeting the requirements stated in the purchase request.

1B202 TRAINING

The personnel engaged in the QA Program associated with a project shall have been qualified to perform their functions. The primary qualifications required are either formal training in the QA system or experience in the operation of a QA system.

Personnel who control selected processes or perform selected operations shall be certified in accordance with SwRI Procedure QAP-8-1. The records of the qualification of personnel shall be maintained by the organization performing the qualification.

1B203 QUALITY INFORMATION

The SwRI QA Program provides for the collection, processing, analysis, and recording of quality information. This quality information is gathered and recorded during all phases of the project. This information is analyzed on a monthly, quarterly, or annual basis.

The SwRI QA Program provides for the dissemination of the quality data to all concerned areas at the Institute, and when quality data affects suppliers or subcontractors data is supplied to organizations affected.

1B204 QUALITY STATUS REPORTING

After the commencement of the program, SwRI QA shall report the status of the quality program to LANL as specified in the contract. As a minimum, the report shall address any changes in the organization or key personnel changes. The report

shall address any significant program and parts status. The discussion shall describe the solution to these problems, plus any remedial and preventive actions that were taken, or that are proposed for this issue. The report shall describe SwRI's performance activities associated with the project for the period in question. The description shall, as a minimum, include the test and inspection activities, procurement activities, supplier selection if appropriate, surveys, audits, and documentation reviews. If appropriate, the report shall describe supplier performance.

1B205 QUALITY PROGRAM AUDITS

Audits of the project shall be performed in accordance with SwRI Procedures QAP-15-1, and OP-15-30-102. These procedures provide for scheduled and unscheduled audits of SwRI activities. They provide a minimum scope for the audit; however, the scope of the audit may be expanded. The subject of the audit ranges from the qualification and certification of personnel, the adequacy of the procedures and instructions, compliance with procedures and instructions, the adequacy of the technical documentation, and compliance with contract requirements.

The individuals performing the audit shall be independent of the project. A post-audit meeting shall be held to present findings and an audit report shall be generated. In the event of unsatisfactory findings, the audit team shall document these findings in the form of a Corrective Action Request (CAR). CARs will be processed, tracked, and reported in accordance with SwRI Procedure QAP-14-1.

1B206 QUALITY PROGRAM PLAN

This document constitutes the Quality Program Plan required by Section 1B206 of NHB5300.4(1B). The Quality Program described in this document is applicable to activities at SwRI which are performing tasks and operations in support of the SwRI contract with LANL. Applicable quality provisions of this plan shall be included in purchase orders and contracts to SwRI suppliers providing parts and materials and performing services in support of the SwRI contract with LANL.

CHAPTER 3: DESIGN AND DEVELOPMENT CONTROLS

1B300 TECHNICAL DOCUMENTS

All technical documents (i.e., specifications, procedures, drawings, and fabrication and planning documents) shall include, as applicable:

- Characteristics and design criteria necessary for procurement, fabrication, inspection, and test;
- The characteristic tolerances; and
- Identification in accordance with Section 1B400.

The Project Manager shall review the SOW and associated design requirement and fulfill contract requirements in accordance with QAP-4-1 and OP-4-15-101. Additional efforts will be made to meet any future contract requirements.

These technical documents and changes shall be reviewed by QA in a timely manner. These reviews shall ensure that necessary information has been included and that the requirements are clear and unambiguous. This review of technical documentation and any deficiencies shall be documented and reported. QA shall verify that deficiencies are corrected prior to document release.

1B301 QUALITY SUPPORT TO DESIGN REVIEW

QA may support and participate in the various design reviews associated with the project. QA shall participate in the review of the design to ensure that the design is producible, repeatable, can be inspected, and quality considerations are reflected

in the end-item. Participation may be by drawing, document, manufacturing planning sheet or similar document, review, and approvals.

1B302 CHANGE CONTROL

Change control shall be performed in accordance with SwRI Procedures QAP-5-1, QAP-5-2, OP-5-30-101, OP-5-15-101, and OP-5-15-201. The use of these procedures will ensure that all applicable documents are distributed to personnel performing activities in accordance with this plan, and that obsolete documents are removed from use.

CHAPTER 4: IDENTIFICATION AND DATA RETRIEVAL

1B400 IDENTIFICATION AND DATA RETRIEVAL

The project shall identify all parts, components, assemblies, sub-assemblies, or articles in accordance with OP-5-15-201. The use of this procedure will ensure a unique numbering system will be utilized for all of the various parts. This numbering system will provide a means for locating articles and materials.

1B401 IDENTIFICATION METHODS

Identification and traceability are established at the part and material levels and continue through the fabrication and assembly levels until completion of the deliverable items. Purchased parts will be identified by the manufacturer's part number and may be assigned a serial number upon receipt. Materials are normally identified by name and log number. Fabricated parts and minor subassemblies will be identified with an SwRI part number. Electronic subassemblies and assemblies will be identified by both part number and serial number.

1B402 DOCUMENTATION

Part numbers for SwRI designed parts and assemblies are controlled by a Document Control database. This process ensures unique drawing and part numbers are assigned. Unique serial numbers are assigned as part of fabrication planning.

1B403 IDENTIFICATION CONTROL

Detailed identification of material, part numbers, or serial numbers is governed by division procedures OP-5-15-201 and OP-5-15-101. The Document Control facility provides controlled access to drawings and documents and will issue document numbers and revisions. A closed-loop system of manufacturing, planning, and fabrication will be followed in accordance to OP-7-15-201. The Document Control facility will ensure that there is no duplication of identification numbers issued to material, parts, or documents for this project.

1B404 IDENTIFICATION LIST

The deliverable items or any end-item fabrication will have a top down indented parts list indicating part number, identification, nomenclature, procurement document, and reference designators. This list will undergo updating and revision with changes in the design.

1B405 RETRIEVAL OF RECORDS

Retrieval of records and document control will be in accordance with OP-5-15-101, and OP-5-15-201. The method of incorporating document changes and retrieval are made from the Document Control data base in accordance with OP-7-15-201.

CHAPTER 5: PROCUREMENT CONTROL

1B500 GENERAL

All purchases for this project shall be performed in accordance with SwRI Procedures QAP-6-1, OP-6-30-101, OP-6-30-201, OP-6-73-201, and OP-6-15-201. The use of these procedures will ensure that purchase orders are reviewed for technical and quality requirements and that these requirements are passed on to the suppliers.

1B501 SELECTION OF CONTRACTOR PROCUREMENT SOURCES

Where no supplier is cited, supplier selection shall be performed in accordance with SwRI Procedure OP-6-30-101. This procedure requires that the supplier quality system meets the requirements of this project. The suppliers of critical/complex items and services shall meet the following conditions: successfully complete a Supplier Questionnaire and successfully pass a site audit/survey. The Project Engineer and QA representative will jointly decide which items and services are critical/complex. Examples of critical/complex items and services include printed wiring board fabrication, parts screening services, and calibration services. The extent of source qualification will be dependent upon the item to be procured.

1B502 PROCUREMENT DOCUMENTS

Procurement documents shall be reviewed in accordance with SwRI Procedure OP-6-30-201. This shall ensure that the supplier has been selected in accordance with the requirements of Section 1B501, and that all applicable provisions and conditions are properly and accurately recorded on the purchase documents.

1B503 CONTRACTOR QUALITY ASSURANCE PERSONNEL AT SOURCE

Source inspections, where required, shall be performed in accordance with SwRI Procedure OP-6-30-401. Determination of when these inspections are required will be jointly made by project management and QA. Criteria shall include consideration of cost, complexity, test requirements, and special needs.

1B504 GOVERNMENT SOURCE INSPECTION

Government source inspection by a Government QA Representative is not required for this project.

1B505 RECEIVING INSPECTION SYSTEM

All end-item articles associated with this project received at SwRI shall be inspected in accordance with SwRI Procedure OP-6-30-501. This will ensure that compliance with procurement requirements has been met by the supplier. In addition, Institute QA shall perform inspection of hardware provided by co-investigators for workmanship and shipping damage.

1B506 RECEIVING RECORDS

Receiving records shall be generated and maintained in accordance with SwRI Procedures QAP-6-1 and OP-6-30-501. This will ensure that accurate records of the inspection are kept and maintained for later use, if required.

1B507 SUPPLIER RATING SYSTEM

A supplier rating shall be performed in accordance with SwRI Procedures QAP-6-1 and OP-6-30-101. This will ensure that the various suppliers supporting this project are providing consistent quality products.

1B508 POST-AWARD SURVEY OF SUPPLIERS

Surveys of suppliers and source inspections shall be performed, as appropriate, based upon the criticality of the item procured and the history of the supplier. These activities shall be controlled by Procedures QAP-6-1 and OP-6-30-401.

1B509 COORDINATION OF CONTRACTOR-SUPPLIER INSPECTIONS AND TESTS

Tests and inspections performed by the various SwRI contractors and suppliers shall be coordinated with SwRI to ensure the compatibility of the tests and inspections with the requirements and needs of the project. Project management and QA shall jointly be responsible for this coordination effort.

1B510 NONCONFORMANCE INFORMATION FEEDBACK

SwRI shall notify suppliers of significant nonconformances or trends in accordance with SwRI Procedure QAP-14-1. The use of this procedure ensures the use of a

closed-loop feedback system for the reporting and resolution of supplier nonconformance.

CHAPTER 6: FABRICATION CONTROLS

1B600 FABRICATION OPERATIONS

The fabrication processes and operations used to manufacture the articles associated with this project shall be accordance with SwRI Procedures QAP-7-1 and OP-7-30-101.

1B601 ARTICLE AND MATERIAL CONTROL

SwRI Procedure OP-6-30-501 shall be used for the release of accepted materials. Procedure QAP-16-1 shall be applicable for the storage and handling of accepted materials. SwRI Procedure OP-16-15-101 shall be used for the control of limited shelf-life items.

1B602 CLEANLINESS CONTROL

Fabrication, assembly, inspection and test areas shall be controlled in accordance with DSS4 and OP-16-15-201.

1B603 PROCESS CONTROLS

All processes which cannot be specified by drawing, and/or for which the quality cannot be assessed by inspection or test of the completed article, will be specified by Government, industry, or SwRI process specification.

The SwRI process specification shall be controlled in accordance with SwRI Procedures QAP-5-1, OP-5-15-101, and QAP-8-1. Specialized equipment required

for these processes shall be controlled in accordance with SwRI Procedures QAP-9-1 and OP-9-15-101.

Electrical/electronic parts storage and fabrication areas shall be controlled and operated in accordance with SwRI Procedures QAP-16-2 and OP-16-15-301.

1B604 WORKMANSHIP STANDARDS

SwRI does not plan to use any visual aids for workmanship criteria; however, illustrations and pictures of NHB5300.4 series and in Division Operating Procedures shall be used as guidelines for acceptable workmanship. For any future workmanship standards, SwRI will provide visual aids as required and documented procedures for APL approval.

As specified in the contract, Workmanship Standards NHB5300.4(3A-2), *Requirements for Soldered Electrical Connections*, and NHB5300.4(3J), *Requirements for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies*, shall be used.

For fabrication and assembly of printed wiring boards, surface mount technology (SMT) shall be used after process validation on qualification boards. In addition to OMNI workmanship standards, DOP-8-15-164, DOP-8-15-165, DOP-8-15-166, and DOP-8-15-168 would be used as guidelines for product assurance.

CHAPTER 7: INSPECTION AND TEST

1B700 GENERAL

Procured and fabricated articles and materials shall be inspected and tested to ensure conformance to contract, drawing, and specification requirements. Procured items shall be inspected in accordance with SwRI Procedure OP-6-30-501. Fabricated articles shall be inspected and/or tested during all processing, fabrication, assembly, and shipping phases as specified on the applicable manufacturing planning sheet. QA shall review and approve all manufacturing planning sheets in accordance with SwRI Procedure OP-7-30-101.

1B701 INSPECTION AND TEST PLANNING

In accordance with QAP-7-1, inspection and test planning will be implemented as part of fabrication planning and documented on Manufacturing Planning Sheets (MPSs). MPSs are prepared by the project and reviewed by QA in accordance with OP-7-15-201. Inspection and test points in the MPSs provide for the coordination and sequencing of inspection and testing at successive levels of assembly. Any specific hold points requested by LANL will be incorporated into the MPSs.

MPSs identify the applicable drawings, specifications, and process, fabrication and test procedures that are to be used during the various operations to be performed. Inspection and test procedures include requirements for inspection/test implementation, use of calibrated equipment, and accept/reject criteria as applicable.

1B702 TEST SPECIFICATIONS (END ITEM ACCEPTANCE TEST PLAN)

In addition, SwRI will generate an Acceptance Test Plan which shall include at a minimum:

- a) A brief technical description of the End Item.
- b) Performance requirements to be verified and whether verification is to be by inspection, test, analysis, or similarity.
- c) Tests to be performed.
- d) Sequence of test and time span required.
- e) Test facilities required, including ground support equipment (GSE).
- f) Environmental and other special conditions required.
- g) Acceptance and reject criteria.

Finally, the plan shall state the requirements for reporting test results and the disposition of the test article.

1B703 INSPECTION AND TEST PROCEDURES

Inspection and test procedures shall be prepared in accordance with SwRI Procedure QAP-10-1. In the absence of specific inspection and test procedures, the

inspections shall be performed in accordance with SwRI Procedure OP-10-30-102. When the inspection and test procedure requires the visual inspection of mechanical assemblies and has not stated a method for this inspection, these inspections will be performed in accordance with SwRI Procedure OP-10-30-201. When the inspection and test procedure requires a visual inspection of an electrical/electronic assembly and has not stated a method for this inspection, these inspections shall be performed in accordance with SwRI Procedure OP-10-30-202. Each End Item Acceptance Test Procedure that is developed for this project shall include the following as applicable:

- a) Identification of the End Item configuration to be tested.
- b) Performance parameters and operating characteristics.
- c) The nominal values and tolerances of performance parameters and operating characteristics to be measured.
- d) Measuring and test equipment to be used.
- e) Detailed operations to be performed by the test operator including operational checks and preliminary calibration of the test equipment.
- f) Conditions that must be maintained during testing including ambient or environmental conditions and precautions to be observed to prevent injury to personnel or damage to the articles or instruments involved.
- g) The current calibration status and due date for recalibration of test equipment (Class 1 required for deliverable hardware).

**1B704 END-ITEM INSPECTION AND TEST SPECIFICATIONS AND
PROCEDURES**

Separate end-item inspection and test specifications and procedures shall be developed by the project. These inspections and tests shall be conducted in a

manner, and under conditions, which simulate end-use and environments to the highest degree practical without damage to the end-item, and which still provide a valid measure of the overall quality of the end-item.

1B705 INSPECTION AND TEST PERFORMANCE

Inspections and tests shall be performed to verify compliance with specifications and procedures. These inspections and tests shall be performed on procured and fabricated articles prior to their installation into the next higher level of assembly. These inspections shall include a records review by QA Inspection, and test operations shall be traceable to the individual responsible for their accomplishment.

All inspections and tests shall be performed in accordance with applicable inspection and test procedures. If a malfunction occurs after the first power application to or mechanical operation of an assembled component, the incident will be reported by telephone to the LANL technical sponsor, as soon as they occur. Any malfunction or observed anomalies during tests shall be processed in accordance with QAP-12-1 and OP-12-IW-101.

The articles being inspected or tested shall be controlled using SwRI procedures and acceptable practices.

Equipment records shall be maintained and updated. The equipment records shall be kept for each subsystem and system as a means of documenting their continuous history. The records shall be maintained in chronological order to account for all fabrications, assemblies, inspections, and test operations, as well as ideal periods and movement. The entries shall be complete, self-explanatory, and signed.

Reinspection and retest after completion of approved rework or repair shall be annotated on respective Manufacturing Planning Sheets or on "as-run" test reports. QA shall perform reinspection and witness the retest as mandatory activities. Special criteria of re-test/reinspection shall be established in a pretest/prefabrication briefing prior to start of testing.

If and when required by the NEPSTP Project, SwRI will establish similarity of articles taking into consideration environmental conditions and will forward test data to APL for approval of the qualification of the articles.

Seven (7) calendar days before the consent to ship the hardware, SwRI shall generate an end-item data package. The final acceptance of the data package shall include the following items, as a minimum, as agreed by LANL and SwRI:

- Configuration Identification Summary,
- Copies of approved requests for deviations/waivers requiring LANL Contracting Office approval,
- As-built lists of each and every electronic part in the proto-flight unit,
- Lists of authorized tests or retests not completed in accordance with approved procedure,
- Handling constraints,
- Copies of Class I nonconformance documentation/MRB Actions,
- Summary of test data and results,
- Listing of critical and limited-life articles, and
- Total operating time/cycle records for each system and subsystem.

1B706 INSPECTION AND TEST RECORDS AND DATA

Inspection and test records and data shall be generated in accordance with SwRI Procedure QAP-10-1 and project procedures. The inspection and test records shall be maintained in accordance with SwRI Procedure QAP-11-1.

Equipment records shall be prepared, maintained and updated as required by the contract. The equipment record shall be kept for each subsystem and system as a means of documenting its continuous history. The records shall be maintained in chronological order to account for all fabrications, assemblies, inspection and test operations, as well as idle periods and movement. The entries shall be complete, self-explanatory and signed.

1B707 CONTRACTOR QUALITY ASSURANCE ACTIONS

Prior to testing, QA shall:

- Verify that applicable inspection and test documents are available;
- Ensure that requirements for selection and control of articles have been implemented and that test constraints have been resolved;
- Verify that articles undergoing test are identified;
- Verify the configuration of the articles;
- Verify that the configuration of Ground Support Equipment is consistent with the articles under test; and
- Verify that the test equipment is calibrated, and such calibration will be effective and sustained during the test period.

During the testing, QA shall:

- Ensure that the testing is accomplished in accordance with the test specifications and procedures;
- Ensure that accurate and complete recording of data and test results are performed;
- Document rework, repair, or modifications occurring during the test operations; and
- Document nonconformances and participate in their disposition.

After testing, QA shall:

- Ensure the proper disposition of the articles;
- Report any additional nonconformances and participate in their disposition;
- Ensure that remedial and preventive action has been accomplished relative to nonconformances; and
- Verify that test results and reports are accurate, complete, and traceable to the tested articles.

CHAPTER 8: NONCONFORMING ARTICLE AND MATERIAL CONTROL

1B800 NONCONFORMING ARTICLE AND MATERIAL CONTROL

SwRI shall operate a closed-loop nonconformance control system in accordance with SwRI Procedures QAP-12-1 and SwRI OP-12-IW-102. The system requires the documentation of each nonconformance, the accumulation of nonconformance data, and the reporting of the data.

1B801 NONCONFORMANCE DOCUMENTATION

The SwRI nonconformance system requires that each nonconformance report be issued a unique identification number to be used for tracking. The system also requires that the article found to be nonconforming be identified with its correct nomenclature, and a description of the nonconformance be provided. This description must include the required characteristic or criteria. The system requires that a cause or reason for the nonconformance be determined and provided, and the remedial action to be taken to rectify the situation identified. The system requires the disposition of the nonconforming article and that all parties to the nonconformance are identified.

1B802 REMEDIAL AND PREVENTIVE ACTION

Remedial and preventive actions shall be performed in accordance with SwRI Procedures QAP-12-1, QAP-14-1 and QAP-14-2.

1B803 INITIAL REVIEW DISPOSITION

The initial review and disposition of the nonconforming article or material shall be performed in accordance with SwRI Procedure QAP-12-1. The system provides for rework of articles, the scrapping of articles, the return of articles to the supplier upon receipt, and submittal of articles to a Material Review Board (MRB) for repair or use-as-is dispositions.

1B804 MATERIAL REVIEW BOARD

The membership, responsibilities, and authority of the MRB are specified in SwRI Procedure OP-12-IW-101. MRB membership shall, as a minimum, be comprised of an SwRI QA representative and a project engineering representative. The SwRI QA Representative shall act in the capacity of Chairman. MRB action, disposition, and review/approval of Class II nonconformances shall be accomplished through formal meetings or by routing documentation to the various members of the board. SwRI shall notify LANL of any Class I nonconformance and assist LANL as needed to resolve the nonconformance. Class I nonconformances are defined as those that affect form, fit, function, contract reliability constraints, safety, performance or weight of the end item.

**1B805 WRITTEN REQUEST FOR APPLIED PHYSICS LABORATORY
CONTRACTING OFFICER APPROVAL**

Class I MRB authority is not granted by LANL. Class I and Class II nonconformances shall be handled as discussed in 1B804.

1B806 SUPPLIER MATERIAL REVIEW BOARD

SwRI does not intend to delegate MRB responsibility to its suppliers.

CHAPTER 9: METROLOGY CONTROLS

1B900 GENERAL

SwRI will provide and maintain suitable inspection, measuring, test equipment of range, accuracy, and type necessary to ensure conformance of articles to contract requirements. When calibration is required, calibration and control will be in accordance with MIL-STD-45662A and SwRI Procedures OP-9-30-103, OP-9-30-104, and OP-9-15-101.

1B901 ACCEPTANCE

The use of the above-cited procedures, along with the rest of the SwRI QA Program, shall ensure that all measurement standards and equipment are inspected and/or tested to ensure conformance with the requirements. This process will also generate and maintain the required documentation.

1B902 EVALUATION

SwRI shall perform evaluation on all special measurement standards and equipment and maintain records of the evaluation. The items shall be evaluated under their intended operation conditions to verify that:

The standards and equipment measure the desired characteristic to the required accuracy and provide the desired indications or records when used in the intended measurement process;

The standards and equipment are compatible with the configuration of related hardware and environment; and

The operating instructions are correct and complete.

1B903 ARTICLE OR MATERIAL MEASUREMENT PROCESS

SwRI shall ensure that all random and systematic errors in any article or material measurement process shall not exceed 10 percent of the tolerance of the article or material characteristic being measured. In those situations where, for various reasons, this tolerance threshold cannot be maintained, SwRI shall request an exception on a case-by-case basis from LANL.

1B904 CALIBRATION MEASUREMENT PROCESSES

SwRI shall ensure that all random and systematic errors in any calibration measurement process shall not exceed 25 percent of the tolerance of the parameter being measured. In those situations where, for various reasons, this tolerance threshold cannot be maintained, SwRI shall request an exception on a case-by-case basis from LANL.

1B905 CALIBRATION CONTROLS

The SwRI procedure which controls calibration requires traceability of all standards to the National Institute of Standards and Technology. All calibrated standards and

equipment are so identified by the appropriate sticker as determined by the SwRI procedures. The label indicates the particular device that is calibrated, its calibration status and the date of its next calibration. This equipment is recalled and recalibrated at regular intervals.

SwRI Procedures OP-9-30-103, OP-9-30-104, and OP-9-15-101 require that calibration records be generated and maintained for each item that is processed through these facilities. The record identifies the article or item, its serial number and SwRI property number, its usable measurement range or operating range, the device accuracy, the date that the device entered the calibration system, the device source, the current group the device is assigned to, the calibration procedure to be used on the device, the device calibration cycle and the date for calibration recall. The record also contains the date of last calibration, the identity of the technician who performed the calibration and the date the next calibration is due. Finally, the calibration record contains a section that describes any repairs/remarks/and extent of calibration required. When a device is calibrated at another facility, the name of the calibration facility is required, as well as the above information.

1B906 ENVIRONMENTAL REQUIREMENTS

SwRI Procedures OP-9-30-103, OP-9-30-104, and OP-9-15-101 require that environmental conditions, as stated in the various calibration procedures, must be maintained in order to perform the required calibration.

1B907 REMEDIAL AND PREVENTATIVE ACTION

SwRI Procedures OP-9-30-103 and OP-9-30-104 require that remedial and preventive actions be taken on nonconforming standards and equipment, and on the articles and materials measured by the nonconforming standards or equipment. These remedial and preventive actions shall be taken in accordance with SwRI Procedure QAP-14-1.

CHAPTER 10: STAMP CONTROLS

1B1000 STAMP CONTROL SYSTEM

SwRI Procedure OP-10-30-101 provides for the issue, tracking, and control of SwRI inspection stamps. The procedure requires the generation of records that provide traceability to the individual to whom the stamp was issued, when the stamp was issued, and when and if it was lost or withdrawn from service. The procedure also delineates under what condition the stamp is to be used.

1B1001 STAMP RESTRICTION

SwRI Procedure OP-10-30-101 provides an example and a description of the official SwRI inspection stamp. The inspection stamp is not allowed to have the initial or symbol of another organization or party.

**CHAPTER 11: HANDLING, STORAGE, CONTAMINATION CONTROL,
PRESERVATION, MARKING, LABELLING, PACKAGING, PACKING AND
SHIPPING**

1B1100 HANDLING AND STORAGE

In the absence of project-created, program-specific handling and storage procedures in accordance with SwRI Procedure QAP-16-1, the project will use OP-16-15-101 for storage and OP-16-15-301 for ESD and handling. QAP-16-1 requires that the developed procedure take into consideration contract and product specification requirements, susceptibility to damage and deterioration, protective environment requirements, electrostatic discharge sensitivity and shelf-life limitations.

**1B1101 PRESERVATION, MARKING AND LABELLING, PACKAGING AND
PACKING**

This activity will be per TBD, "Instrument Safety, Operations, and Handling Document for the NEAR Program."

1B1102 SHIPPING

This activity will be per TBD, "Instrument Safety, Operations, and Handling Document for the NEPSTP."

CHAPTER 12: SAMPLING PLANS, STATISTICAL PLANNING AND ANALYSIS

1B1200 SAMPLING PLANS

With prior APL approval, sampling plans may be used when inspections or tests are destructive or when data, inherent characteristics or noncritical applications of a product permit a reduction in inspection or testing without jeopardizing quality, reliability or design intent. MIL-STD-105E will be used as a guide in establishing sampling requirements.

1B1201 STATISTICAL PLANNING AND ANALYSIS

The use of statistical planning and analysis is not planned for this project due to the limited number of items being fabricated.

CHAPTER 13: GOVERNMENT PROPERTY CONTROL

1B1300 GOVERNMENT PROPERTY CONTROL

Government property shall be controlled in accordance with the SwRI *Property Control, Equipment Inspection, and Maintenance Procedure for Government Property* Manual. Government property shall be inspected for evidence of acceptance by sponsor to the extent provided in the contract.

SOFTWARE QUALITY ASSURANCE

Southwest Research Institute (SwRI) currently has in place a Software Quality Assurance (SQA) plan. This program is intended to ensure that the software is designed, developed, and produced based on Sound Engineering principals. SwRI QA intends to use the program for reporting tracking discrepancies; the inspection and auditing of the design; development, production, and documentation cycles.

Software required for this contract will be developed and documented as defined in the LANL-approved Produce Assurance Plan.

Project Quality Plan

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