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18. PRESENTATION ON A SPACE ACCELERATION MEASUREMENT SYSTEM (SAMS)

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1.0 INTRODUCTION

A variety of Shuttle Orbiter experiments are currently under development as part of OSSA's Microgravity Sciences and Applications (MS&A) Program. These experiments generally require measuring and recording low gravity accelerations. Such measurements made to date have proven to be inadquate for certain microgravity experiments. As a result, Richard E. Halpern, Director of the MS&A Division at NASA Headquarters, requested that the Space Experiments Office of the NASA Lewis Research Center (LeRC) survey existing systems, establish general requirements, and formulate a plan for either procuring or developing a suitable acceleration measurement system. The survey was subsequently conducted, and it was found that no existing system met these requirements. It was therefore determined that LeRC should take the lead in developing such a system.

A preliminary set of technical specifications was then developed. Several references were consulted such as the Low Acceleration Characterization of Space Station Environment by Teledyne-Brown Engineering and the Feasibility Study for the Orbital Acceleration Research Experiment by KMS Fusion, Incorporated. In addition, a questionnaire was circulated in the microgravity science community to determine measurement requirements of potential users. In some cases, information was obtained from previous Shuttle experiments. The above inputs were used to develop a set of specifications. A plan to develop and qualify a Space Acceleration Measurement System (SAMS) meeting these specifications is presented herein.

2.0 PROJECT SUMMARY

The primary objective of the SAMS project is to provide an acceleration measurement system capable of serving a wide variety of space experiments. The design of the system being developed under this project takes into consideration requirements for MS&A experiments located in the middeck, in the orbiter bay, and in Spacelab. In addition to measuring, conditioning, and recording accelerations, the system will be capable of performing complex calculations and interactive control. The main components consist of a remote triaxial sensor head, a microprocessor-driven data acquisition system and an optical storage device. In operation, the triaxial sensor head produces output signals in response to acceleration inputs. These signals are preamplified, filtered and converted into digital data which is then transferred to optical memory. The system design is modular, facilitating both software and hardware upgrading as technology advances. The microprocessor chosen is code-compatible with the IBM PC-XT allowing maximum compatibility with the majority of experiments. The electronics package, utilizing CMOS technology, is on the STD-BUS modular interconnection system.

The project is managed and implemented "in-house" at Lewis with fabrication, drafting, engineering analysis and software development performed under contract, where appropriate. Support contractors will be used for the safety and integration documentation.

Two complete acceleration measurement flight systems will be built and tested under this project. The initial system is to be flown to acquire preliminary data in support of the JPL-managed Lambda Point Experiment. The initial system will be housed in a GAS can in the Shuttle bay with the sensor head located on an MPESS carrier. The second system will be built in a general purpose or baseline configuration and will be capable of supporting a wide variety of experiments. After the initial system has been flown, it will be retrofitted to the baseline configuration. Both these systems will then be made available to the space experiments community. In addition to the two flight units mentioned above, a complete set of spare parts, an engineering development system, and a breadboard system will also be provided.

The duration of this activity from initiation to completion is estimated to be 27 months with the first flight system scheduled for shipment in 20 months.

3.0 TECHNICAL PLAN

3.1 General Technical Approach

The Space Acceleration Measurement System (SAMS) will be comprised of a triaxial acceleration sensor head connected by an umbilical cable to an electronics package. The electronics package will be microprocessor-driven and will be designed to accommodate a wide variety of functions through the use of plug-in boards. The electronics package will be both modular and software-driven to facilitate future additions or modifications. The electronics package will be equipped to communicate with other electronics systems, e.g., other experiments, the Shuttle communications and control system. The data gathered from the sensors as well as ancillary data will be stored in an optical memory system. The SAMS will be equipped with its own power conditioning circuitry allowing operation from 28 VDC Shuttle power or self-contained batteries. The SAMS is designed to fit into a small volume, draw minimal power and operate over a wide temperature range so that it may be used in a wide variety of configurations. Figures 1 and 2 show the SAMS configured to fly in a middeck locker and a GAS can, respectively. Figure 3 shows alternate SAMS configurations.

3.2 Description of System

3.2.1 Hardware Description

The accelerometer sensor is a pendulous inertial type, employing a quartz flexure suspended proofmass, producing an acceleration output current independent of output load. The

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SPACE ACCELERATION MEASUREMENT SYSTEM

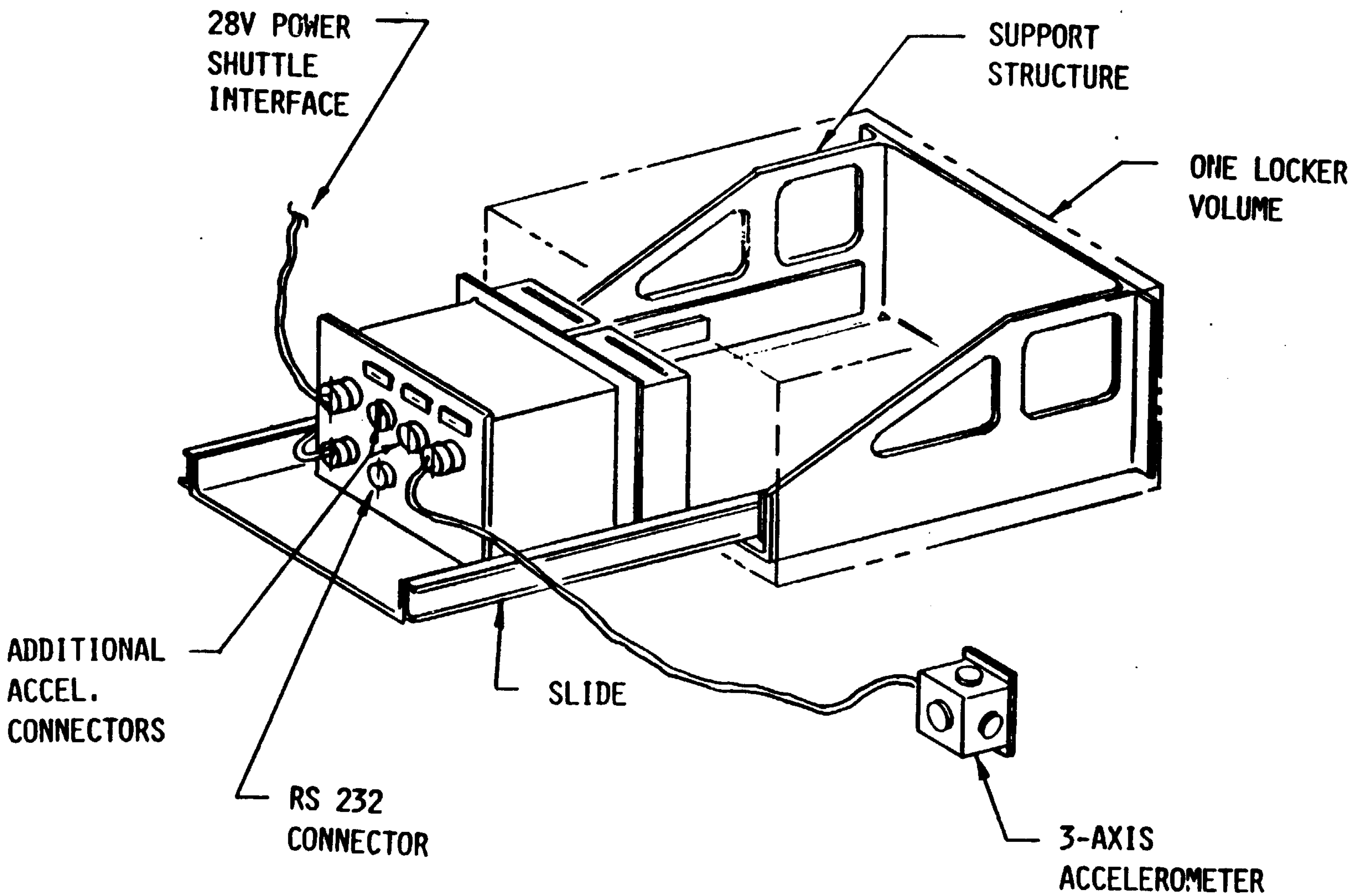


FIGURE 1

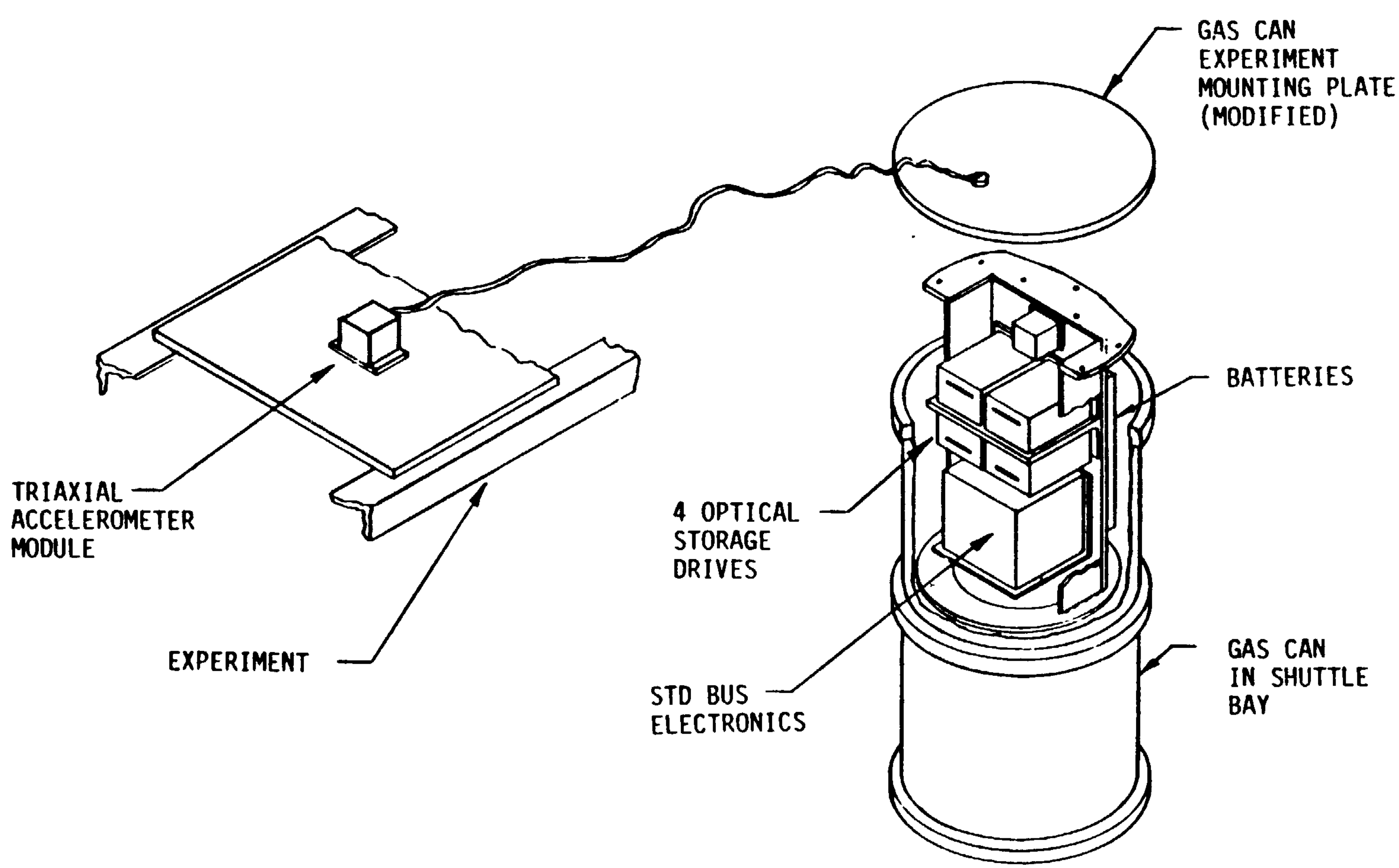
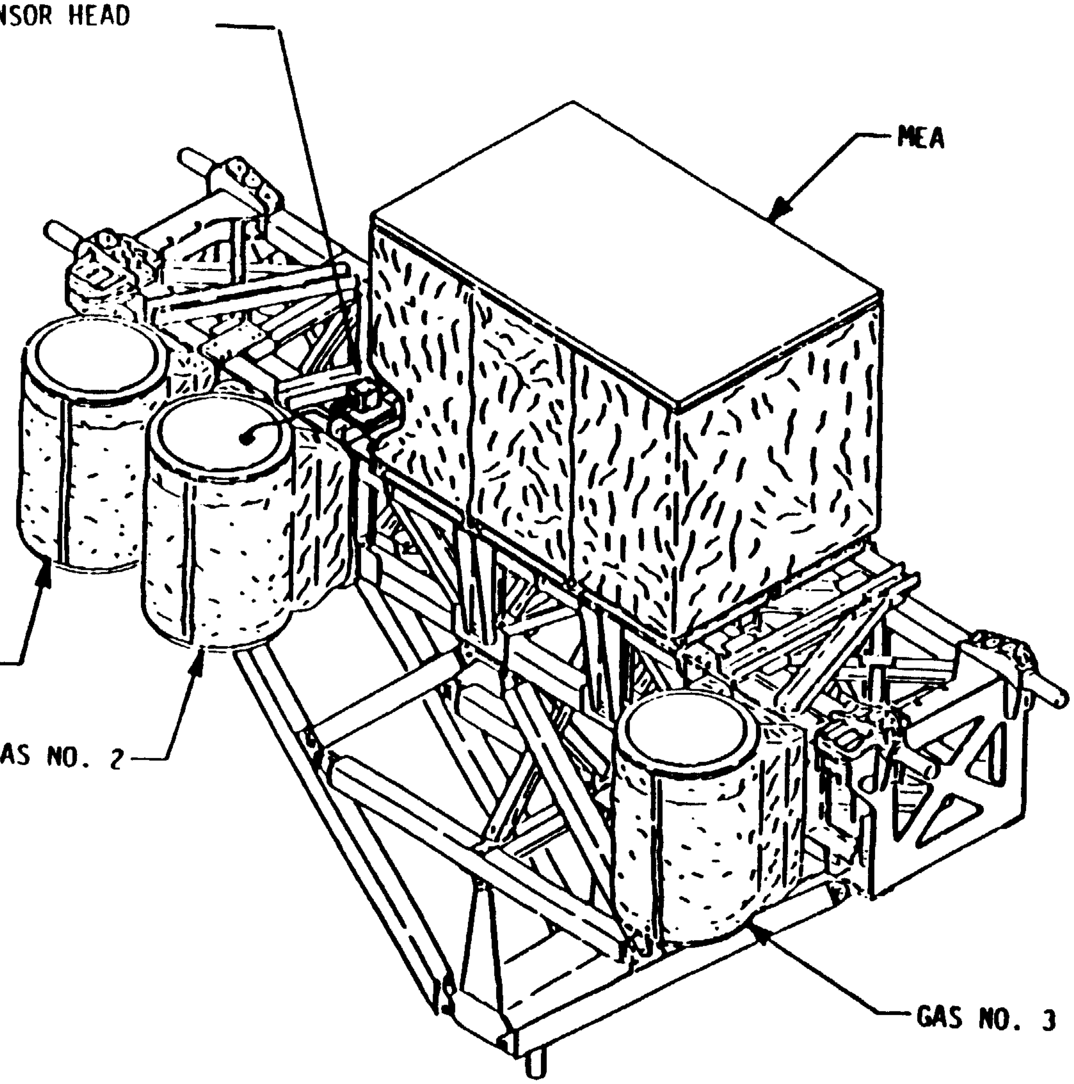


FIGURE 2 - SAMS-GAS CAN CONCEPT



MEA-1 PAYLOAD CONFIGURATION

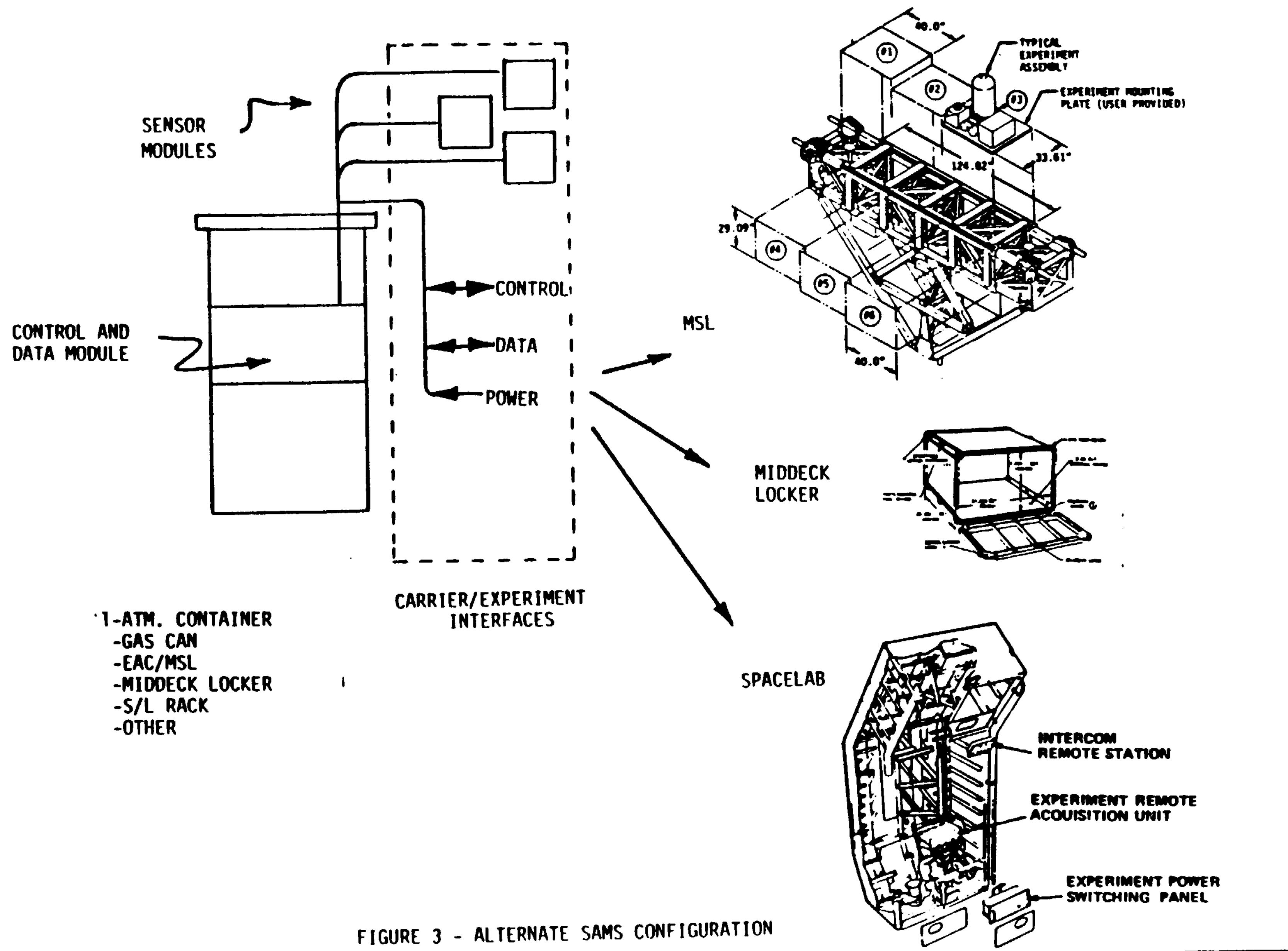


FIGURE 3 - ALTERNATE SAMS CONFIGURATION

Sundstrand Model QA-2000 high performance single axis-type sensor is to be used. Three such sensors will be mounted in a triaxial sensor head. The triaxial sensor head will also contain conditioning electronics. The sensor head will be separated from the electronics package by an umbilical cable. A range of cable lengths will be accommodated depending on experiment requirements. Each accelerometer will be equipped with a solid-state temperature sensor to enable correction of triaxial sensor output based on temperature.

The electronics package functional schematic is shown in figure 4. The design is based on the STD-BUS system. This industry standard interconnection system allows the utilization of modular electronic circuit boards incorporating a wide variety of functions. At present, at least 40 manufacturers provide products for the STD-BUS. Where possible, CMOS technology will be utilized to minimize power consumption and thermal dissipation.

A 16-bit Analog/Digital (A/D) converter card will be used to convert the accelerometer inputs as well as the temperature from each sensor.

An Input/Output (I/O) card will be used to provide bidirectional communications with the experiment.

The bytewide memory card will be used to temporarily hold data for transfer to the optical drives. This card can also be utilized to store firmware routines in ROM.

The central processor card will be equipped with the IBM PC-XT compatible 8088 Central Processing Unit (CPU). In addition, this card will be equipped with a math coprocessor, a real time clock, on-board monitor software, Read Only Memory (ROM) and capacity for 64K bytes of plug-in memory. The card will also have one RS-232 port. The RS-232 interface combined with the monitor will provide on-board checkout and verification capability through a dumb terminal.

The Small Computer Systems Interface (SCSI) card will be used to interface the optical drives to the STD-BUS.

The optical drive is the Model 5984 from OPTO-TECH, Incorporated. It uses Write Once Read Mostly (WORM) technology and occupies the same physical space as a standard 5.25" full-height floppy disk drive. It is possible to store 400 megabytes of formatted 8-bit data on two sides of the media. For unattended operation, only 200 megabytes are accessible. The system will accommodate up to four drives.

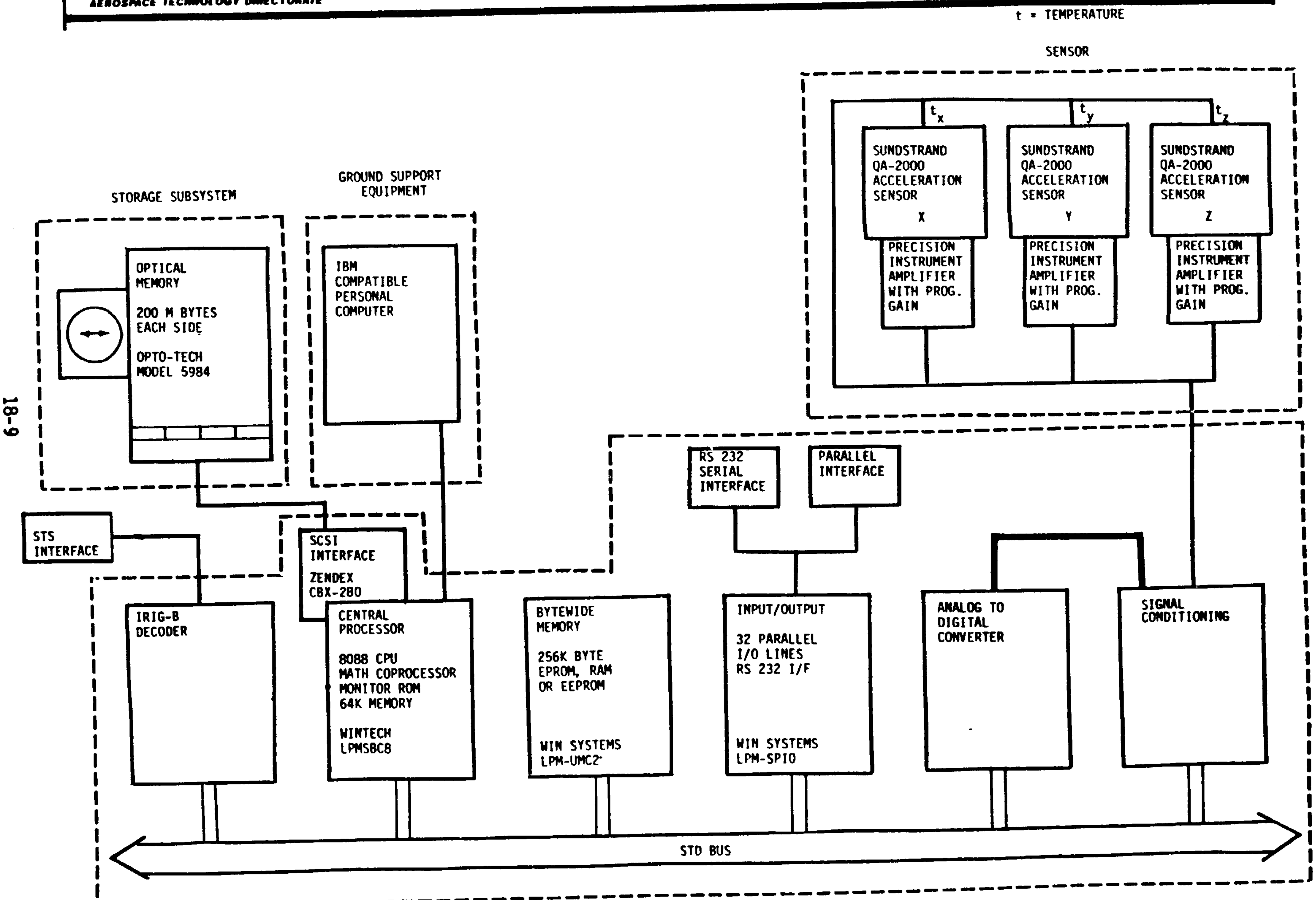


FIGURE 4 - FUNCTIONAL SCHEMATIC OF SPACE ACCELERATION MEASURMENT SYSTEM

The data transfer rate of the optical drive is 2.2 megabits/sec while the access time is 305 milliseconds (max). The mean time to failure of the drive is 20,000 hours. A ruggedized version of this drive is being developed by the Goddard Space Flight Center (GSFC). That activity will be followed closely to provide maximum benefit to the SAMS program.

Cards may be switched or added to this system to accommodate new requirements as they evolve.

Sufficient power conditioning electronics will be supplied with the package to allow the system to run from batteries or the Shuttle 28 Volt power bus.

3.2.2 Software

The software concept is shown in figure 5 and is based on the STD-DOS operating system. This DOS is IBM-capatible allowing the utilization of a wide variety of software written for the IBM-PC. This includes such things as utilities, interface drivers and high-level math routines. The three categories of application software which must be included as part of this measurement system are described below:

3.2.2.1 Input/Output

The input/output routines allow each component part of the system to communicate. All routines run on a microprocessor which is part of the STD-BUS CPU card. The memory card is used to store constants, temporary data, or systems software.

The accelerometers communicate with the STD-BUS through the analog to digital converter card. The software drivers in this case take temperature and acceleration data from each accelerometer sensor and transfer it to the optical memory.

The input/output card allows communication between the STD-BUS and devices external to the acceleration measurement system. The software drivers provide communications to experiments via parallel digital or serial (RS-232) ports. Typically, these interfaces would support the following functions: turn data gathering off and on; read data to or from experiment; flag an abnormal acceleration value; and time correlation.

The SCSI card couples the optical memory to the STD-BUS. The software drivers associated with this card provide read-write capability as well as formatting and error checking to the optical drive.

3.2.2.2 Utilities

Included among the software utilities are those that allow checkout, monitoring, and execution of developed software.

The SAMS is also equipped with a unique set of routines specifically oriented toward acceleration measurements. This includes tests of hardware such as accelerometers, A/D converters, optical drives and the serial/parallel interface.

3.2.2.3 System Software

The system software routines are defined as those which provide certain repetitive operations necessary to gather acceleration information and are as follows:

- Send and receive data over serial/parallel interface to external packages.

- Monitor peak value of acceleration and set a flag.

- Provide auto gain change for acceleration inputs based on acceleration levels or external commands.

- Read or write blocks of data from/to the optical drive.

- Provide moving window data acquisition based on either acceleration levels or external commands.

3.2.2.4 Calculations

This software provides the math routines which will utilize the math coprocessor. The math routines (1) convert accelerometer input from raw data to temperature compensated data via a polynomial calculation, and (2) digitally filter data based on certain input parameters.

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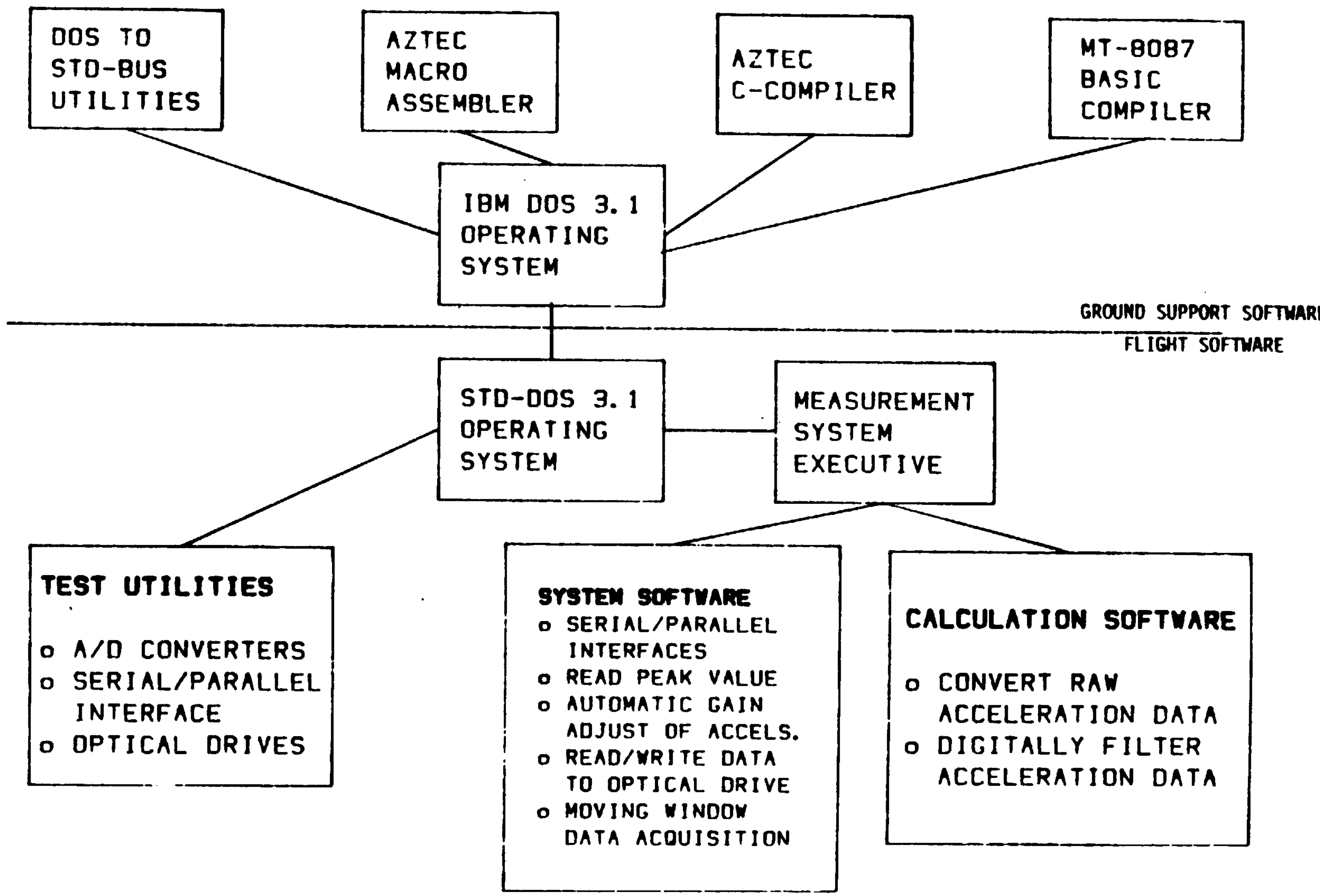

FIGURE 5 - SAMS SOFTWARE CONCEPT

3.3 System Specifications

The system specifications are defined below based on the flow of data from the sensor through to the optical recorder.

3.3.1 Acceleration Sensor

Pendulous inertial sensor employing a quartz flexure suspended proofmass, producing an acceleration output current independent of output load.

Internal temperature sensor mounted in each accelerometer to correct accelerometer output for bias, scale factor and alignment.

Sensor frequency response: 0-100 Hz +/- .2 %.

Sensor resolution and threshold: 1 micro-g.

Sensor absolute value: 10 micro-g +/- 1 micro-g

3.3.2 Sensor Package

Sensors integrated in a triaxial sensor head which includes dynamic over range prefiltering and amplification.

Sensor axes mutually orthogonal to within .0005" True Indicator Runout (TIR).

Amplifier computer-controlled with gains of 1,10,100,1000.

Sensor output standardized to +/- 1 G equal to +/- 10 volts output.

Range switching with the following ranges (16-bit word).

+/- 1 G to +/- 3 x 10^{-5} G's

+/- .1 G to +/- 3 x 10^{-6} G's

+/- .01 G to +/- 3 x 10^{-7} G's

+/- .001 G to +/- 3 x 10^{-8} G's

Triaxial sensor head operating temperature range: -55 to 95 deg. C

Triaxial sensor head separated from electronics package by a cable up to 20' in length.

3.3.3 STD-BUS Electronics Package

The electronics package is based on the STD-BUS system. The overall package will allow proper operation over a temperature range from -55 to 95 deg. C.

3.3.3.1 Signal Conditioning Board

Low pass filters configured for DC to 100 Hz.

Seventh order low pass anti-aliasing filter (-42 DB/octave).

Sensors placed into a test mode via computer control for calibration purposes.

Output controls sensor amplifier gain.

3.3.3.2 Analog to Digital Converter Card

Full 16-bit A/D conversion.

Sampling rates up to 500 samples per second, per channel.

X, Y, and Z axis inputs taken simultaneously.

3.3.3.3 Central Processor Board

IBM-XT compatible 8088 CPU chip.

8087 math coprocessor chip.

On board real time hardware clock.

Monitor ROM allowing communication via dumb terminal.

Socket space for 64K bytes of additional memory.

One RS-232 or RS-422 interface.

Programmable interrupt controller with 8 interrupts.

Direct addressing to 1 megabyte.

Precision power-on/brown out detect circuit.

iSBX module expansion connector.

iSBX to SCSI piggyback card (attaches to CPU card).

- Provides interface to the optical storage system.

3.3.3.4 Bytewide Memory Board

Stores up to 256K bytes of information.

Used for temporary storage of data.

Can be used for ROM or EPROM storage.

3.3.3.5 Input/Output Board

Allows communication with peripheral equipment.

32 lines of digital input/output (TTL or CMOS).

One RS-232 serial port.

3.3.4 Optical Recorder

Interfaced to STD-BUS system through SCSI interface.

SCSI interface supports up to four drives.

Recording capacity: 200 megabytes per drive without operator intervention.

Drive access time: 305 ms maximum.

Corrected bit error rate: 10^{-12}.

Mean time before failure: 20,000 hours.

Mechanically conforms to standard 5-1/4" full height floppy.

3.3.5 Recording Times

Assume one triaxial sensor head, three temperature inputs, time coding and assorted ancillary signals.

16 bits x 3 heads + 8 bits (all others) = 56 bits/sample

Sampling Rates	Freq. Resp.	Time to Fill 200 Megabytes (8 bits/byte)
500/sec	100 Hz	15.9 hrs
250/sec	50 Hz	31.7 hrs
50/sec	10 Hz	158.7 hrs (6 days, 14 hrs)
25/sec	5 Hz	317.4 hrs (13 days, 5 hrs)
5/sec	1 Hz	1587 hrs (66 days)

3.3.6 Power System

Sufficient power conditioning will be included in the package to allow the system to run from batteries or the Shuttle 28 volt DC power bus. DC to DC converters will be utilized to convert 28 volt power to +/- 15 volts, 12 volts, and 5 volts.

3.3.7 System Power Requirements

Triaxial accelerometer system	2 W
STD-BUS electronics package	10 W
Optical memory	15 W
	27 W
(Assumes DC to DC converter efficiency of 80%)	
TOTAL POWER REQUIRED	35 W*

* Does not include heating or cooling energy that may be required; thermal analysis to be performed to define requirements.

3.4 First Flight System Configuration

The first SAMS built is planned to be flown in the Shuttle bay in a GAS can (see figure 2). The system will be used to determine the response to low-level acceleration of the MSL-3/MPESS carrier containing the MEA and three GAS cans. The data gathered will be used to determine the isolation requirements for the Lambda Point Experiment managed by JPL. The data gathered should also be of interest to the space experiment community at large. In this configuration, the SAMS will be equipped with a battery pack to supply power to the electronics. Any additional power required to thermally stabilize the package will be supplied by the Shuttle 28 VDC power bus. External control of the SAMS will be accomplished through the use of the Autonomous Payload Control System (APCS). This will allow the astronauts to remotely control three latching relays located at the base of the GAS can. This system will provide the ability to power up, reset and time syncronize SAMS.

In this configuration, the triaxial sensor head will be mounted on top of the MPESS structure adjacent to the MEA as shown in figure 6. This location appears to be an optimum one for characterizing the MPESS structure. The sensor head will be insulated, heated and thermally isolated from the MPESS structure. This will insure that the sensors remain within a tolerable temperature range.

The general specifications outlined above in Section 3.3 apply to this configuration with the following exceptions:

Data will be recorded over a DC-100 Hz frequency range only.

All data will be stored as raw information.

No preprocessing or digital filtering of data will be employed.

Ten hours worth of data will be recorded.

Data will be taken in bursts ranging froom 10 to 20 minutes long.

Automatic range switching will be employed.

3 5 Baseline System Configuration

The baseline system configuration will conform to the general specifications given in Section 3.3 above. Two completely operational general purpose systems will be developed under this project. The initial system will be configured to meet the first flight requirements as specified in Section 3.4. After the initial system has been completed and in process, the second system will be assembled using the baseline configuration. Once the initial system has been returned from flight, it will be retrofitted such that both systems will be identical. The balance of the funding through 1991 will be used to adapt the SAMS to specific space experiments as requirements arise.

4 0 MANAGEMENT PLAN

The Space Acceleration Measurement System (SAMS) project will be managed by the Space Experiments Office (SEO) of the Aerospace Technology Directorate (ATD) of the Lewis Research Center. The organization charts for LeRC, the ATD, the SEO and the SAMS project are presented in figures 7 through 10, respectively. Other divisions at Lewis that will support the project include the R&QA Office, the Test Installations Division for testing and assembly, the Fabrication Support Division, and the Procurement Division.

Because the system being developed is a general purpose one designed to accommodate a wide-range of experiments, there will be no assigned principal investigator. However, since the initial system is to be used to take preliminary data for the Lambda Point Experiment, special consideration will be given to that project in developing the acceleration measurement system. The JPL-managed Lambda Point Experiment requires acceleration data as soon as possible to finalize experiment requirements.

The Marshall Space Flight Center will be responsible for payload integration with the MSL. LeRC will support the safety meetings and project integration documentation required by Marshall. MSFC will also supply the GAS can which attaches to the MSL and contains the SAMS hardware. Lewis will coordinate directly, but informally, with appropriate offices to insure that the system is readily adaptable to a variety of Shuttle Orbiter environments, viz., GAS cans, middeck, and Spacelab.

Progress will be reported in the MICS report submitted by LeRC SEO and Headquarters MSAD. Status will also be provided to Headquarters personnel during biweekly telecons.

5.0 PROCUREMENT APPROACH

The SAMS will be designed, fabricated, and assembled within LeRC. Engineering support will be supplied by an on-site support service contractor. Components, materials, and fabrication will be purchased through the normal Lewis purchase request system. Parts will be bought by the Procurement Division, and fabrication will be performed or contracted by the Fabrication Support Division of Lewis. Two systems will be developed for flight and one set of spares will be provided.

Accelerometer sensors and optical disk drives represent long lead-time items for this project.

6.0 PROJECT SCHEDULE

The project schedule is shown in figure 11. The project was initiated in March of 1986. The first unit is scheduled for delivery in 20 months (October of 1987), the time required to develop a general purpose system of sufficient capability to gather data for the Lambda Point Experiment. The second unit will be available in in June of 1988, 27 months after project start.

A PERT chart will be generated to assist the project manager with respect to hardware development, purchasing and fabrication. This chart will be updated periodically.

Dick Gates, Boeing: Can your system handle more than one sensor head as well as the Python?

Chase: It can support three sensor heads as it's configured. It is limited by the standard bus system to how many boards you can plug in. We have nine slots. The only other limitation will be the number of connectors you can get on the box that you're putting it into. We configured it so that there will be three connectors there allowing us to go to a total of three.

Bob Naumann, NASA/Marshall Space Flight Center: You said you completed a survey and found those other instruments inadequate. Yet I don't see anything terribly unique about this equipment. Can you tell me what this equipment does that others don't do.

Chase: We found that the instrumentation was either limited in the g-range, limited in frequency, and a little bit of this and a little bit of that, but nothing that would operate over the whole spectrum. Also, things like low power consumption, the ability to be able to go into one locker, mid-deck locker space, power, there are a number of considerations.

Naumann: What really worries me is that one of the biggest inadequacies is that we have not had a system that will integrate to get the background dc acceleration we know we're supposed to see. And you're saying that you had a hard time, I think you said it was a resolution of 1 Micro-g, with a 10-micro-g absolute accuracy. So if you're only working with 10 micro-g that's 10^{-5}, but that's the top end of the dc level we want to see. So that won't even sense the environment we hope to have on the Space Station.

Chase: That's true. That is dependent upon where you're going with the sensor technology. There's nothing magic about the Sundstrand. Those are the limitations attached to the Sundstrand. If you want to go to a Bell Model 11 that's a different story. If you want to pay the price penalty. That's something that the experimenter will have to determine. Again, there's nothing magic about the sensor, ...

it's the same as Byron's system. If you want to change the sensor, that's up to you.

Naumann: So the big problem there is in the noise at the low frequencies to the Sundstrand head, which you previously talked about, is that basically it?

Chase: Yes.