SUMMARY STATUS OF THE SPACE ACCELERATION MEASUREMENT SYSTEM (SAMS) - SEPTEMBER 1993

Richard DeLombard
NASA Lewis Research Center, Cleveland, Ohio.

ABSTRACT

The Space Acceleration Measurement System (SAMS) was developed to measure the microgravity acceleration environment to which NASA science payloads are exposed during microgravity science missions on the shuttle. Six flight units have been fabricated to date. The inaugural flight of a SAMS unit was on STS-40 in June 1991 as part of the First Spacelab Life Sciences mission. Since that time, SAMS has flown on six additional missions and gathered eighteen gigabytes of data representing sixty-eight days of microgravity environment. The SAMS units have been flown in the shuttle middeck and cargo bay, in the Spacelab module, and in the Spacehab module.

This paper summarizes the missions and experiments which SAMS has supported. The quantity of data and the utilization of the SAMS data is described.

Future activities are briefly described for the SAMS project and the Microgravity Measurement and Analysis Project (MMAP) to support science experiments and scientists with microgravity environment measurement and analysis.

Acronyms

ACAP	Acceleration Characterization and Analysis Project
BIMDA	Bio-Serve /ITA Materials Dispersion Apparatus
CD-ROM	Compact Disk Read Only Memory
CGF	Crystal Growth Furnace
EURECA	European Retrievable Carrier
FMPT	First Materials Processing Test
IML	International Microgravity Laboratory
KSC	NASA Kennedy Space Center
LeRC	NASA Lewis Research Center
LPE	Lambda Point Experiment
MEPHISTO	Matérial pour l'Etude des Phénoménes Intéressant la Solidification sur Terre et en Orbite
MMAP	Microgravity Measurement and Analysis Project
MPESS	Mission Peculiar Experiment Support Structure
MSAD	Microgravity Science and Applications Division
MSFC	NASA Marshall Space Flight Center
NASDA	National Space Development Agency of Japan
OARE	Orbital Acceleration Research Experiment
PCG	Protein Crystal Growth
PI	Principal Investigator
POCC	Payload Operations Control Center
SAMS	Space Acceleration Measurement System
SH	Spacehab
SL-J	Spacelab J
SLS	Spacelab Life Sciences
SMIDEX	Shuttle Middeck Experiment
SMSP	Shuttle-Mir Science Program
SSCE	Solid Surface Combustion Experiment
STDCE	Surface Tension Driven Convection Experiment
USML	United States Microgravity Laboratory
USMP	United State Microgravity Payload

1.0 BACKGROUND

1.1 Need for General Purpose Accelerometer

The mission of NASA's microgravity science program is to utilize the unique characteristics of the space environment, primarily the near absence of accelerations, to expand man's knowledge of physics, chemistry, materials and fluid sciences, and biotechnology; to understand the role of gravity in materials processing; and, where possible, to demonstrate the feasibility of space production of improved materials that have high technological, and possible commercial, utility.

Environmental factors (e.g., temperature, pressure, acceleration level) are typically measured during microgravity science missions to characterize the conditions to which the experiments are exposed. In the past, many science experiments, which were particularly sensitive to acceleration levels, had incorporated an accelerometer within the experiment package. The need for a general purpose acceleration measurement system arose from those numerous special purpose accelerometers. A general purpose system was desired which could be utilized as a standard to measure the microgravity environment for many diverse experiments in different locations on the Orbiter. Such a system should also be capable of multiple flights and configurations for the support of different experiments on successive missions.

The SAMS project was conceived in 1986 to develop such a general purpose instrument to measure low-levels of acceleration at experiment locations on the space shuttle Orbiter. The SAMS project was assigned to the NASA Lewis Research Center (LeRC) by the NASA Headquarters Office of Space Science and Applications, Microgravity Science and Applications Division (MSAD). The primary experiments to be supported are those funded by the MSAD, although other experiments are occasionally supported through arrangements with MSAD.

1.2 Development of SAMS Flight Units

Four general purpose "middeck-style" SAMS units were fabricated in-house at LeRC by 1990. This style of unit is capable of operation in the shuttle middeck, Spacelab module single and double racks, Spacelab module center aisle, and in the Spacehab module. The first unit was delivered to the NASA Kennedy Space Center (KSC) on March 26, 1990 for integration into the first Spacelab Life Sciences (SLS-1) mission (STS-40).

Two specialized "cargo bay-style" SAMS units were fabricated in-house at LeRC by late 1991. This style of unit is capable of operation in the shuttle cargo bay on a Mission Peculiar Experiment Support Structure (MPESS). These two units were delivered to KSC in April 1992 for integration into the first United State Microgravity Payload (USMP-1) mission (STS-52). These units were made expressly for the USMP-series of missions. These two styles of SAMS units are described in reference 1.

Each of the SAMS units may be connected to three remote triaxial sensor heads by umbilical cables. The response of each of these sensor heads may be individually set to one of six low-pass frequencies. This provides the capability to tailor the sensor head response to the needs of the science experiment being supported.

2.0 SAMS FLIGHT OPERATIONS AND RESULTS

The SAMS units have flown on seven shuttle science missions to date with a wide range of carriers and sensor head frequency responses. The accumulated data continues to provide insight into the microgravity environment experienced on-board the shuttle. The data continues to be used in the analysis of science data from a variety of experiments on the past missions. Efforts are also on-going in planning modifications to future missions for such areas as crew exercise methods and vehicle structural investigations. These are using past SAMS data as well as acquiring new data from the future flights.

2.1 Missions and Experiments

Table 3 lists the various missions which have included a SAMS unit along with the pertinent characteristics of the mission and the SAMS unit. These missions have ranged from missions with intensive science operations (e.g., USML-1) to missions involving satellite launches with a few science experiments on-board (e.g., STS-43). Typically, for primary microgravity science missions, the shuttle flies in a favorable attitude with a minimum number of attitude changes which may disturb the experiments. This results in a fairly "quiet" mission with relatively little disturbance to the microgravity environment. For other missions, the "quiet" microgravity environment may be maintained for a short period of time, but other segments of the missions may be subject to high levels of acceleration as other activities are conducted.

The main purpose of the SLS-1 mission was to study the mechanisms, magnitudes, and time courses of certain physiological changes that occur during space flight and to investigate the consequences of the body's adoption to microgravity and readjustment to 1-g [ref. 2]. The Solid Surface Combustion Experiment (SSCE) flew on this mission, one in a series of eight SSCE flights. The SAMS unit A measured the acceleration environment for the SSCE principal investigator (PI) and also to acquire data to enable a study of the transmission of accelerations through the Spacelab module structure. SLS-1 was launched on June 5, 1991 and operated for nine days with SAMS recording for 168 hours, resulting in 0.37 gigabytes of data.

The Protein Crystal Growth (PCG) and the Bio-Serve /ITA Materials Dispersion Apparatus (BIMDA) flew on the STS-43 mission along with a re-flight of SSCE and the SAMS unit E. The acceleration environment was measured on a locker door between PCG and BIMDA to support the PI's associated with those experiments. The acceleration environment was measured directly on the SSCE apparatus to support the PI associated with SSCE. A sensor head was also located on the crew exercise treadmill to measure the effects of this device on the microgravity environment. STS-43 was launched on August 2, 1991, and operated on-orbit for nine days with SAMS recording data for 186.5 hours, resulting in 2.70 gigabytes of data.

The first International Microgravity Laboratory (IML-1), the first United States Microgravity Laboratory (USML-1), and the Spacelab J (SL-J) missions were dedicated microgravity science missions. Each had a multitude of experiments which were operated during the course of the mission.

The IML-1 mission is the first in a series of shuttle flights dedicated to fundamental materials and life sciences research. As part of this series of missions, scientists from around the world have developed experiments that crew members completed inside the Spacelab module [ref. 3]. For IML-1, the primary experiments supported were those operated in the Fluid Experiment System (FES) and the Vapor Crystal Growth System (VCGS) apparatus. Sensor heads were also located near the Microgravity Vestibular Investigations rotating chair. The sensor heads were arranged to allow the vibrations generated by the chair to be compared with the vibration levels experienced in the rack. This data will contribute to the study of acceleration transfer through the vehicle structure. IML-1 was launched on January 22, 1992, and operated on-orbit for eight days with SAMS recording data for 162.5 hours, resulting in 4.63 gigabytes of data.

The USML-series of missions is one part of a science and technology program that will open NASA's next great era of discovery. This new era is certain to revolutionize the way we think about space and our world as dramatically as did the Apollo lunar missions. USML-1 flew in orbit for fourteen days, providing greater opportunities for research in materials science, fluid dynamics, biotechnology, and combustion science. In addition, the missions will also provide much of the experience in performing research in space and in the design of instruments needed for space station operations and the programs to follow in the 21st century [ref. 4].

For USML-1, the primary experiments supported by SAMS were the Surface Tension Driven Convection Experiment (STDCE), the Crystal Growth Furnace (CGF) and a multitude of experiments operated within the glovebox. USML-1 was launched on June 25, 1992 with SAMS recording data for 294 hours, resulting in 1.36 gigabytes of data.

Spacelab J was a joint venture between NASA and the National Space Development Agency of Japan (NASDA). Using the Spacelab module, forty-three experiments - thirty-four sponsored by NASDA and nine sponsored by NASA - were performed in the areas of microgravity materials and life sciences [ref. 5]. The SAMS sensor heads were mounted within the First Materials Processing Test (FMPT) equipment supplied by NASDA. There were multiple experiments operated within the FMPT equipment, both materials science and life science experiments. SL-J was launched on August 18, 1992, and operated on-orbit for twelve days with SAMS recording data for 169 hours, resulting in 2.44 gigabytes of data.

USMP-1 and the first Spacehab module (SH-1) missions were shared missions which included microgravity science experiments as well as other primary payloads.

Six days of STS-52 were flown in a "quiet" mode and attitude for the USMP-1 microgravity science to be conducted. The remainder of the mission was occupied with other activities, such as a satellite launch and experiments involving remote manipulator arm operations. The microgravity science experiments on USMP-1 were the Lambda Point Experiment (LPE) and the Matérial pour l'Etude des Phénoménes Intéressant la Solidification sur Terre et en Orbite (MEPHISTO). The MEPHISTO apparatus was supplied by the French Centre National d'Etudes Spatiales. During this mission, the SAMS units sent some data via shuttle downlink to the Payload Operations Control Center (POCC) at the NASA Marshall Space Flight Center (MSFC). The remainder of the data was recorded on optical disks. The downlinked data allowed near-real-time decisions to be made by the PI's based on the microgravity environment. USMP-1 was launched on October 22, 1992 and operated on-orbit for ten days with SAMS acquiring data for 228 hours, resulting in 2.97 gigabytes of data.

A major objective of the STS-57 mission was devoted to the capture and return to Earth of the European Retrievable Carrier (EURECA) which had been launched one year earlier. The maiden flight of the Spacehab module (SH-1) was the other primary payload on STS-57. There were a variety of commercial and NASA experiments carried inside the Spacehab module. One SAMS sensor head was mounted near the Environmental Control Life Support System Flight Experiment on the starboard side of the forward bulkhead. Another sensor head was mounted to the module structure in a similar fashion on the port side of that bulkhead. The third sensor head was mounted to the door of a stowage locker toward the center of that bulkhead. STS-57 was launched on June 21, 1992, and operated on-orbit for ten days with SAMS recording data for 162 hours, resulting in 3.38 gigabytes of data.

More detailed information on these missions and experiments may be obtained by consulting various reports and descriptive literature produced for each mission.

2.2 Carriers

The SAMS "middeck-style" units were originally designed to be mounted in the middeck of the shuttle by occupying one of the stowage locker locations. Many missions have included microgravity payloads in the middeck.

The Spacelab module was designed as a space laboratory to be installed in the cargo bay of the shuttle and accessed via a tunnel from the middeck. Typically, the module is mounted toward the rear of the cargo bay and envelops the vehicle center of mass while on-orbit. By design, the "middeck-style" SAMS unit can also be mounted in the Shuttle Middeck Experiment (SMIDEX) racks developed for the Spacelab module. Also, as part of the SAMS design, different components may be used to mount the SAMS unit to the center aisle floor of the Spacelab module.

The Spacehab module was expressly designed to accommodate experiments and lockers from the shuttle middeck. The "middeck-style" SAMS units mount directly in the module. The Spacehab module is mounted toward the forward end of the shuttle cargo bay and is also accessed via a tunnel from the middeck.

The MPESS carriers are truss structures designed to carry equipment in the shuttle cargo bay. The carriers attach to the Orbiter cargo bay sills and keel and may be mounted in nearly any location along the cargo bay. The MPESS carriers utilized by the USMP-series of missions incorporate subsystem equipment to supply power, thermal control and data services to the experiments.

2.3 Data Quantity

There are several different ways in which to describe the quantity of data acquired by SAMS on the various missions. One way is for the characterization of the shuttle microgravity environment. This environment has now been measured by a common instrument to an extent not accomplished before. The SAMS data allows comparison of environments for different missions as done in reference 6. This will also allow predictions to be made about the environment of future missions and will contribute toward the understanding of environments to be expected on space stations. To this end, SAMS has gathered data for an accumulated total of 68 days of on-orbit shuttle operations. This includes approximately 55 days of microgravity conditions.

Another way of describing the data quantity is the total time that the data represents. Since the three sensor heads are measuring different local environments, the total quantity of data acquired is significant for characterizing the local environment of various locations within the Spacelab module (for example). To this end, SAMS data represents 214 days of data from triaxial sensor heads.

Another way of describing the data quantity is the sheer quantity of data points measured during SAMS operations. This is indicative of the amount of data storage required to store the data or through which to search to find characteristics, trends, or other significant facets of the environment. To this end, SAMS data represents over four million samples of acceleration data. After data processing, this represents 17.9 gigabytes of acceleration data stored on computer disks.

For ease of access, the processed mission data has been put on compact disk read only memory (CD-ROM). This convenient form of data dissemination has been utilized for its de-facto standard across many computer platforms and the data capacity of each disk. There have been twenty-three CD-ROM's prepared at the present time for five of the first seven missions.

2.4 Utilization of Data

For the first six SAMS missions, the Acceleration Characterization and Analysis Project (ACAP) at MSFC has analyzed the mission data. Summary reports have been prepared by ACAP to assist users in understanding the vast amount of data. ACAP has also prepared special analyses on occasion for characterizing certain aspects of shuttle and experiment operations. Correlation of acceleration data with the results from the science experiments will lead to a better understanding of the science. This also leads to a better understanding of the microgravity environment requirements of the experiment. Some of the reports and papers prepared with SAMS data are listed in the bibliography. Examples of these analyses are given below.

SAMS data was utilized in near-real-time during the USMP-1 mission by the LPE and MEPHISTO experiment teams to ascertain the microgravity environment and the effect of it on their experiment operation and data.

The SAMS data from the USML-1 mission has been extensively reviewed by ACAP for the PI's associated with the CGF.

Correlation of the thruster firing data with the SAMS acceleration data and observed events on glovebox combustion flames has been accomplished.

SAMS data has been used to examine the signature vibration patterns of the Ku-band communications antenna, crew activity, satellite launches, remote manipulator system operations, experiment generated vibrations, and the Life Sciences Laboratory Equipment refrigerator/freezer.

Some of the SAMS data has been utilized to better understand the isolation of crew exercise equipment so that this necessary activity will have a minimal effect on the microgravity environment.

2.5 Carrier Characterization

An objective of the SAMS data acquisition program is to enable characterization of the various microgravity science experiment carriers and locations within the carriers. On the multiple missions with SAMS units on-board, the coverage of carriers by frequency response measurements are shown in table 2. Covering the ranges of frequency response for the various carriers will facilitate the prediction of environment for future experiments.

2.6 Supported Science

The various types of science that have been supported by the SAMS measurements are combustion, fluids, materials, fundamental, and life science disciplines. Some of the experiments have indicated a strong need for direct measurement of the acceleration environment within the experiment. In these cases, the SAMS sensor head has been mounted within or on the experiment apparatus. This enhances the correlation of the acceleration data with the science data. The various science experiments supported by SAMS are listed in table 3. Other science experiments on these missions utilize the SAMS data even though they do not have a sensor head directly mounted to the experiment.

3.0 FUTURE ACTIVITIES

3.1 Future Missions

The SAMS units will continue to support the future microgravity shuttle science missions, such as the USML, IML and USMP series of missions. The SAMS project is also participating in the Shuttle-Mir Science Program (SMSP) and will install a SAMS unit on the Mir space station in early 1994. Another type of SAMS unit is currently under development to support the science experiments to be flown on the international space station.

The future missions for SAMS are listed in table 4 with the current scheduled launch date and the primary science experiments being supported.

A standard SAMS unit is being modified, along with shipping containers, procedures, launch containers, etc., to facilitate the launch of SAMS on a Progress vehicle to the space station Mir. The SAMS sensor heads will be used to measure the acceleration environment in various locations throughout Mir and will support some of the experiments planned for the SMSP. It is expected that SAMS will remain operational on Mir for approximately fifteen months with the possibility that operations may continue for several years.

A new SAMS unit is under development that will take advantage of the services and opportunities presented by the international space station. This new SAMS unit will not require dedicated cables from the sensor heads to the SAMS unit and will have enhanced data processing capabilities. Master control of the SAMS unit and the sensor heads will be accomplished by the SAMS project. Control of sensor head and data processing characteristics will be accomplished by the PI's at their operations center in near-real-time. Display of SAMS data by downlink will be made at the PI's operations center.

3.2 Data Dissemination

In the very near future, the processed SAMS data will be available from a file server connected to the Internet. This will simplify both data access by the PI's and data dissemination by SAMS. Eventually, the summary reports prepared for each mission will be available in a multi-media format on the file server.

For SAMS on the international space station, some of the data will be available to PI's in near-real-time via downlink. The remainder of the data will be recorded for later downlink or return of storage media via shuttle re-supply missions. Processed data will then be available on CD-ROM and/or file server format.

3.3 OARE Operations

Under a different NASA project, the Orbital Acceleration Research Experiment (OARE) was designed and flown to measure the aerodynamic drag on the Orbiter vehicle during orbital flight. The sensors used in this accelerometer are more sensitive than the sensors used in SAMS and OARE was designed specifically to measure the very low frequency accelerations in the quasi-steady regime. This accelerometer has operated on STS-40 and STS-50. In early 1993, MSAD acquired the flight equipment and ground equipment infrastructure of the OARE project. The OARE will now be flown on the shuttle Columbia in concert with the SAMS units to support the science experiments. This data will continue to be useful for aerodynamic analyses for the Orbiter vehicle.

3.4 Microgravity Measurement And Analysis Project

A consolidation of the SAMS project and the ACAP project was initiated in mid-1993 resulting in the Microgravity Measurement and Analysis Project (MMAP) at LeRC. The MMAP will expand the roles of the previous projects to better serve the PI's needs for microgravity data, analysis and interpretation.

CONCLUDING REMARKS

Over a two year period, the SAMS instrument has acquired a vast amount of data which supports the efforts of a variety of activities. The SAMS data is being applied to the analysis of the microgravity science data for which the device was originally intended. The SAMS units will continue to be flown in support of future missions, carriers and experiments.

The SAMS data forms a vast amount of information from which analyses and studies may be performed, such as, prediction of future mission environments, recommended carriers, recommended shuttle attitudes, effects of vibration isolation systems, etc.

In the near future, comparisons may be made between the microgravity environment of the shuttle and the Mir space station. In the not-so-distant future, a similar comparison may be made between the international space station, Mir and the shuttle.

REFERENCES

1. R. DeLombard, B. D. Finley, and C. R. Baugher, "Development of and Flight Results From the Space Acceleration Measurement System (SAMS)," NASA TM 105652 (AIAA 92-0354), January 1992.

2. Spacelab Life Sciences 1, brochure number NP-120, NASA Lyndon B. Johnson Space Center.

3. First International Microgravity Laboratory, brochure, NASA Marshall Space Flight Center.

4. The First United States Microgravity Laboratory, brochure, NASA Marshall Space Flight Center.

5. Spacelab J, brochure, NASA Marshall Space Flight Center.

6. C. R. Baugher, G. L. Martin, R. DeLombard, "Low-Frequency Vibration Environment for Five Shuttle Missions," NASA TM 106059, also AIAA 93-0832, March 1993.

Bibliography

1. NASA TM 105301, November 1991, R. DeLombard and B. D. Finley (Sverdrup Technology, Inc.) "Space Acceleration Measurement System Description and Operations on the First Spacelab Life Sciences Mission".

2. NASA CP-10094, Richard DeLombard, "Science Objectives of the Early Space Acceleration Measurement System Missions", Prepared for the International Workshop on Vibration Isolation Technology for Microgravity Science Applications, NASA LeRC, April 23-25, 1991.

3. NASA TM 105261, William M. Foster II, "Thermal Verification Testing of Commercial Printed-Circuit Boards for Spaceflight", Prepared for the 1992 Annual Reliability and Maintainability Symposium sponsored by the Institute of Electrical and Electronics Engineers, Las Vegas, Nevada, January 21-23, 1992.

4. NASA TM 105300, January 1992, John E. Thomas, Rex B. Peters (Sundstrand Data Control, Inc.), Brian D. Finley (Sverdrup Technology, Inc.), "Space Acceleration Measurement System Triaxial Sensor Head Error Budget".

5. NASA TM 105652, AIAA 92-0354, January 6-9, 1992, R. DeLombard, B. D. Finley (Sverdrup Technology, Inc.) and C. R. Baugher (NASA MSFC), "Development of and Flight Results from the Space Acceleration Measurement System (SAMS)", Prepared for the 30th Aerospace Sciences Meeting and Exhibit sponsored by the American Institute of Aeronautics and Astronautics, Reno, Nevada, January 6-9, 1992.

6. NASA TM 105960, May 1993, Richard DeLombard, "Proposed Ground-Based Control of Accelerometer on Space Station Freedom", Prepared for the 39th International Instrumentation Symposium sponsored by the Instrument Society of America, Albuquerque, New Mexico, May 2-6, 1993.

7. AIAA 93-0832, January 1993, C. R. Baugher, G. L. Martin, R. DeLombard, "Review of Shuttle Vibration Environment", Prepared for the 31st Aerospace Sciences Meeting and Exhibit sponsored by the American Institute of Aeronautics and Astronautics, Reno, Nevada, January 11-14, 1993. Also NASA TM 106059, March 1993.

8. M. J. B. Rogers, C. R. Baugher, R. DeLombard, et. al. "Low Gravity Environment On-Board Columbia During STS-40", Prepared for the 31st Aerospace Sciences Meeting and Exhibit sponsored by the American Institute of Aeronautics and Astronautics, Reno, Nevada, January 11-14, 1993.

10. IAF-90-350, October 6-12, 1990, G. L. Martin, C. R. Baugher, R. DeLombard, "Vibration Environment: Acceleration Mapping Strategy and Microgravity Requirements for Spacelab and Space Station".

11. Project Report, 1992, C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "Early Summary Report of Mission Acceleration Measurements from STS-40".

12. Project Report, February 28, 1992, C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "Early Summary Report of Mission Acceleration Measurements from STS-43".

13. Project Report, June 1992 (draft),C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "Early Summary Report of Mission Acceleration Measurements from STS-42".

14. Project Report, March 31, 1993, C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "Summary Report of Mission Acceleration Measurements from STS-47".

15. Project Report, June 18, 1993, C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "STS-50 Summary Report of Mission Acceleration Measurements".

16. Project Report, August 2, 1993 (draft), C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "STS-52 Mission Acceleration Measurements Summary and Sensor Report".

17. Project Report, February 28, 1992, C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "Sensor Report for STS-40 & STS-43".

18. Project Report, May 28, 1993, C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "STS-42 Sensor Report".

19. Project Report, May 21, 1993 (draft), C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "STS-47 Sensor Report".

20. Project Report, May 11, 1993 (draft), C. R. Baugher and F. H. Henderson (Teledyne Brown Engineering); "STS-50 Sensor Report".

Table 1: Missions Supported by SAMS

Mission	Microgravity Payload Category	Microgravity Carrier	SAMS Unit	Frequency Responses
SLS-1	Primary	Spacelab module	A	5, 5, 5
STS-43	Secondary	Shuttle middeck	E	50, 50, 2.5
IML-1	Primary	Spacelab module	D	100, 100, 2.5
USML-1	Primary	Spacelab module	C	25, 5, 2.5
SL-J	Primary	Spacelab module	E	50, 50, 2.5
USMP-1	Primary	MPESS	F G	25, 10 100, 100
SH-1	Secondary	Spacehab module	A	100, 50, 5

Table 2: Frequency Coverage of Carriers by SAMS Measurements

	Sensor Head Frequency Response (Hertz)					
Carrier	2.5	5	10	25	50	100
Middeck	STS-43				STS-43	
Spacelab Module	IML-1, USML-1, SL-J	USML-1, SLS-1		USML-1	SL-J	IML-1
MPESS			USMP-1	USMP-1		USMP-1
Spacehab Module		SH-1			SH-1	SH-1

Table 3: Science Experiments Supported by SAMS

Science Category	Mission	Experiment
Combustion	SLS-1	Solid Surface Combustion Experiment
Fluids	IML-1	Fluid Experiment System
	USML-1	Glovebox experiments
	USML-1	Surface Tension Driven Convection Experiment
Materials	STS-43	Protein Crystal Growth
	STS-43	Bio-Serve /ITA Materials Dispersion Apparatus
	USML-1	Crystal Growth Furnace
	USML-1	Glovebox experiments
	SL-J	First Materials Processing Test - Material Science
	USMP-1	MEPHISTO
Fundamental	IML-1	Critical Point Facility
	USMP-1	Lambda Point Experiment
Life	SLS-1	Crew activity
	USML-1	Isolated crew exercise ergometer
	SL-J	First Materials Processing Test - Life Science
	SL-J	Frog Embryology Experiment
	SH-1	Environmental Control Life Support System Flight Experiment

Table 4: Future Microgravity Science Missions for SAMS

Mission	Launch Date	Experiments
SH-2	1/20/94	General carrier measurements
USMP-2	2/24/94	Advanced Automated Directional Solidification Furnace
		MEPHISTO
		Critical Fluid Light Scattering Experiment
		Isothermal Dendritic Growth Experiment
IML-2	6/23/94	Bubble Drop Particle Unit
		Critical Point Facility
		Electromagnetic Containerless Processing Facility
Shuttle - Mir Science Program	3/94	Carrier characterization
Middeck missions	2 per year	Various middeck microgravity experiments
USMP-3	10/95	Advanced Automated Directional Solidification Furnace
		MEPHISTO
		Gravity Probe - B
USML-2	9/95	Surface Tension Driven Convection Experiment
		Crystal Growth Furnace
		Glovebox experiments
		Mechanics of Granular Materials
International space station	6/97	Various station facility-class experiments, such as Space Station Furnace Facility, Combustion Module, Fluids Module

Discussion

Question: *How are the accelerometer heads configured ? Are they close to the cg ?*

Answer: It really varies by mission. On IML-1 they were fairly close. We had a sensor head toward the top of the rack and the base of the rack and out in the center aisle right in front of that rack. In SL-J the two Japanese experiments were on either side of the aisle, so we kind of had them opposite. On USML-I, I think they were fairly close to the CG but again across the center aisle around the Glovebox and surface tension and across the aisle on the CGF. You can look at the charts and see where those are, but I think, typically, they have been back toward the back of the module. Somewhat near the CG. We had three sensor heads in the Middeck. We were kind of spread out because PCG and BIMDA (Bio-Serve /ITA Materials Dispersion Apparatus), were at one side of the Middeck area and Solid Surface Combustion Experiment was at the other end and the treadmill was over in the floor in the middle. So it was kind of a distributed set of data there.