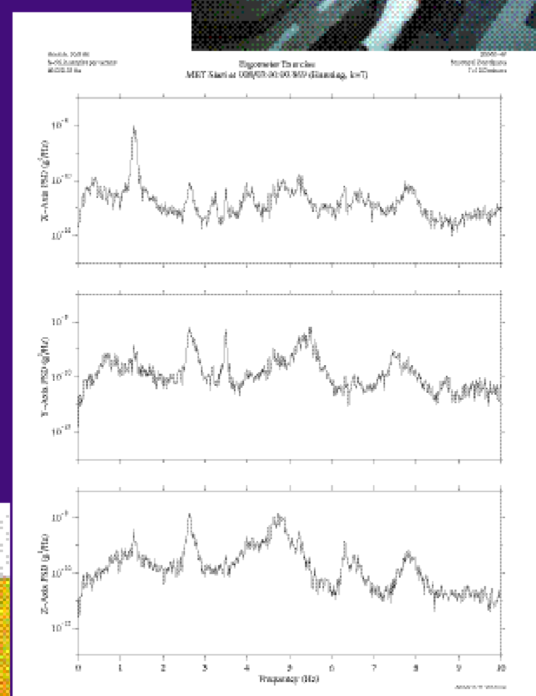
Glenn Research Center

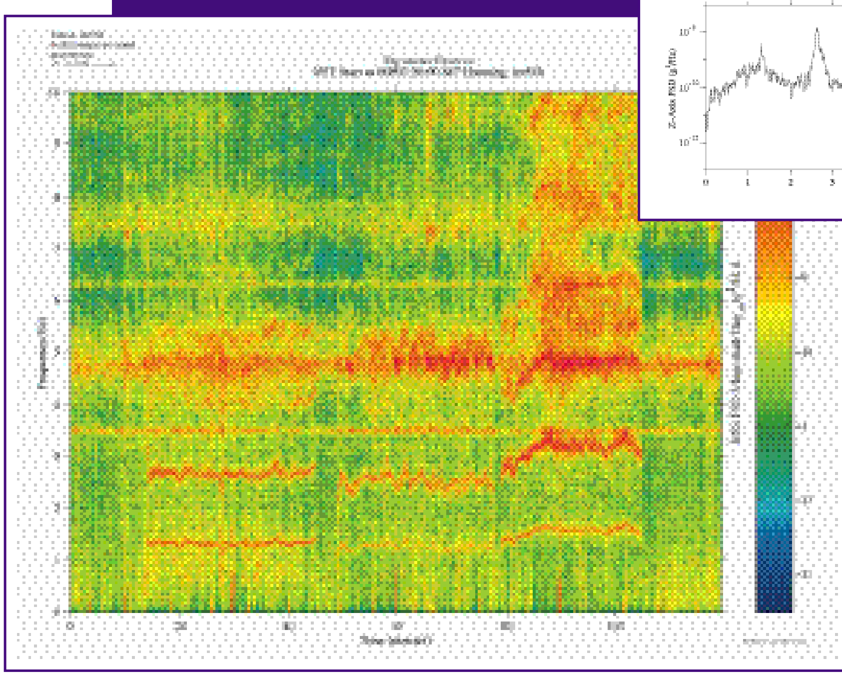
Microgravity Science Division

PIMS

Principal Investigator Microgravity Services

The Principal Investigator Microgravity Services project at the NASA Glenn Research Center supports NASA's Microgravity Research Program Principal Investigators by providing acceleration data processing, analysis, and interpretation for a variety of microgravity carriers including the International Space Station, the Space Shuttle, the Russian Mir Space Station, parabolic aircraft, sounding rockets, and drop towers. The PIMS project is funded by the NASA Headquarters Office of Life and Microgravity Sciences and Applications and is part of the NASA Glenn Research Center's Microgravity Measurement and Analysis Project which integrates the analysis and interpretation component of PIMS with the various NASA sponsored acceleration measurement systems.





Introduction

The Principal Investigator Microgravity Services (PIMS) project at the NASA Glenn Research Center supports NASA's Microgravity Research Program Principal Investigators (PIs) by providing acceleration data processing, analysis, and interpretation for a variety of microgravity carriers including the International Space Station (ISS), the Space Shuttle, the Russian Mir Space Station, parabolic aircraft, sounding rockets, and drop towers. The PIMS project is funded by the NASA Headquarters Office of Life and Microgravity Sciences and Applications (OLMSA) and is part of the NASA Glenn Research Center's Microgravity Measurement and Analysis Project (MMAP) which integrates the analysis and interpretation component of PIMS with the various NASA sponsored acceleration measurement systems.

Support of Microgravity Science Principal Investigators

The PIMS project supports Microgravity Research Program Office (MRPO) Principal Investigators in the science disciplines of biotechnology, combustion science, fluid physics, materials science, and fundamental physics. By providing support during experiment planning, performance, and evaluation of results, PIMS plays an active role throughout the experiment life cycle as shown in Figure 1.

Table 1. Reduced Gravity Platforms

Platform	Microgravity Duration
Drop Towers	< 5 seconds
Parabolic Aircraft	15-25 seconds
Sounding Rocket	500 seconds
Space Transportation System	10-16 days
Mir Space Station	Years
International Space Station	Years

Pre-Experiment Services

PIMS contributes to experiment teams through acceleration data analysis specific to the science under investigation. This effort is augmented by more general efforts aimed at educating microgravity Principal Investigators about the various reduced gravity experiment platforms' environments (Table 1) and about the accelerometer systems (Table 2) available to measure the environments of those platforms. This involvement with experiment teams during experiment planning stages results in the collection of acceleration data best suited for correlation with measured science data.

In general, a fundamental role of the PIMS project's acceleration data support efforts is to archive and disseminate acceleration data. The archival of acceleration data provides investigators the means to determine the environment under which their experiments were conducted. PIMS utilizes the archived data to support users interested in the microgravity acceleration environment by providing information about activities and acceleration sources. On numerous Space Transportation System (STS) missions and Mir, PIMS identified acceleration sources related to vehicle systems, experiment hardware, crew activity, and various other systems [1]. The result of this accumulated knowledge base is an improved understanding of the expected environment of the various reduced gravity platforms that is passed on to investigator teams during the experiment planning process.

Experiment Operations Services

In addition to providing the proper microgravity environment education during experiment planning, PIMS works with investigators to design acceleration data displays and analysis techniques best suited for understanding potential relationships between measured acceleration data and the science results. A number of plot options, displays, and analysis techniques [2] are currently available to Principal Investigators.

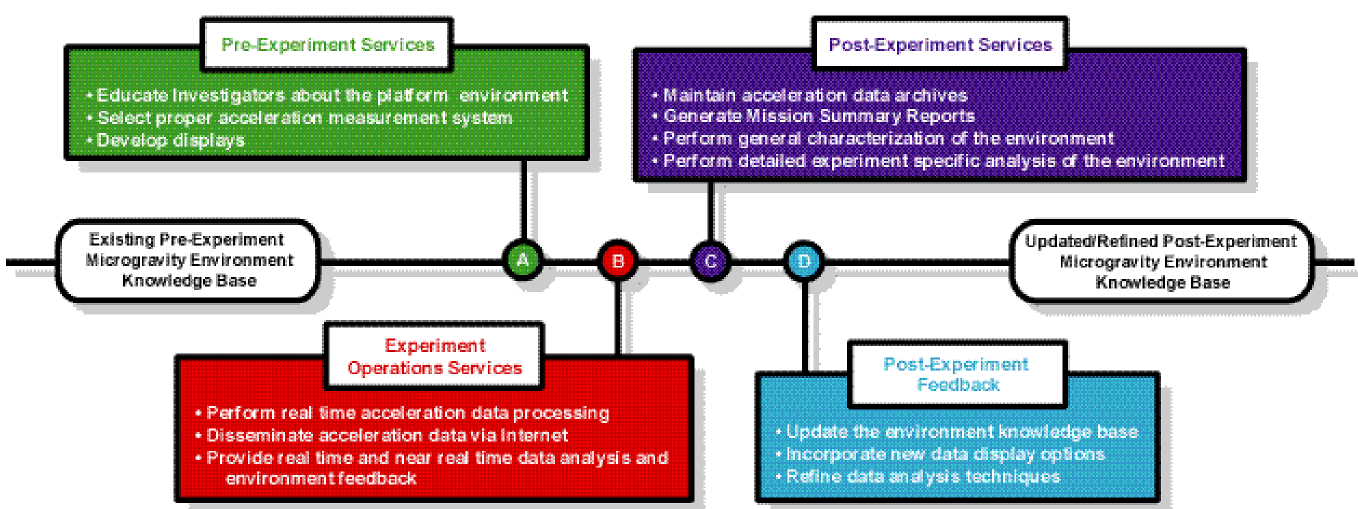


Figure 1. PIMS functions during experiment life cycle.

The STS is a reduced gravity platform which has been instrumented with several accelerometer systems and the resultant data have been analyzed and characterized. Several key points about PIMS operations during STS missions and post-mission analysis can be obtained from the PIMS STS paradigm. During STS microgravity missions, acceleration data were downlinked to PIMS ground support equipment where the data were processed, analyzed, and distributed to experiment teams. The distribution of the acceleration environment information was accomplished through the World Wide Web. The availability of the microgravity acceleration data in near real-time was employed by investigators as a tool for making decisions regarding when to initiate experiment operations and how to make adjustments from experiment run to experiment run to improve science results.

Post-Experiment Services and Feedback

After each STS microgravity mission, PIMS has provided the user community with a Mission Summary Report of the microgravity acceleration environment [3-5]. This standardized overview of the acceleration environment included a general environment summary and detailed analysis of any newly identified disturbance sources. Through such post-mission analysis and interpretation of acceleration data, the STS microgravity environment was further characterized, expanding the existing knowledge base. This knowledge base was subsequently passed on to future STS Principal Investigators during the experiment planning process, thereby continuing the cycle. PIMS has similar plans for the analysis and characterization of acceleration data recorded on-board the International Space Station (see ***International Space Station Operations*** section).

Table 2. Accelerometer Systems

Measurement System	Frequency Regime	Platforms Supported
SAMS	Vibratory/Transient	STS, Mir
OARE	Quasi-Steady	STS
SAMS-FF	Vibratory/Transient	STS, Sounding Rockets, KC-135
MMA	Vibratory/Transient	STS
MMA ASTRE	Quasi-Steady	STS
MAMS MESA	Quasi-Steady	ISS
MAMS HiRAP	Vibratory/Transient	ISS
SAMS-II	Vibratory/Transient	ISS

Microgravity Environment Components

The microgravity acceleration environment of orbiting spacecraft is dynamic in nature. When measuring and analyzing the total microgravity acceleration environment, it is useful to consider the environment as being comprised of quasi-steady, vibratory, and transient components. Figure 2 illustrates these components of the microgravity environment. The distinct characteristics of the quasi-steady and vibratory components have resulted in separate accelerometer systems for measuring each of these components. The quasi-steady component of the microgravity environment includes the influences of aerodynamic drag, vehicle rotation, and venting effects in the frequency band below 0.01 Hz. For this low-frequency regime, the utilization of rigid body assumptions allows accelerations measured at a single location to be mapped to alternate locations within the vehicle. On the other hand, the vibratory component of the microgravity environment is comprised of localized disturbances that produce vibrations that require measurement of the resultant accelerations as close as possible to the experiment hardware of interest. These vibratory disturbances are comprised of vehicle, crew, and experiment-related equipment disturbances in the frequency band above 0.01 Hz. Transient accelerations, which are limited in magnitude and energy content, may exist in the vibratory and the quasi-steady regimes. These are characterized as short, non-repetitive events caused by the vehicle, experiment equipment, and crew.

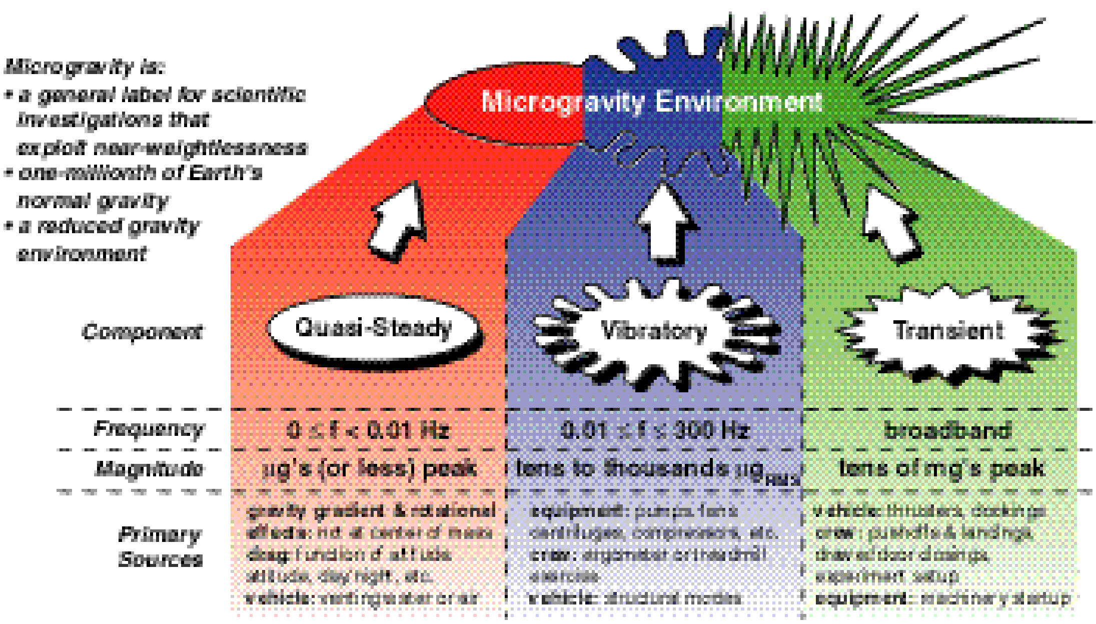


Figure 2. Summary of Microgravity Environment Components.

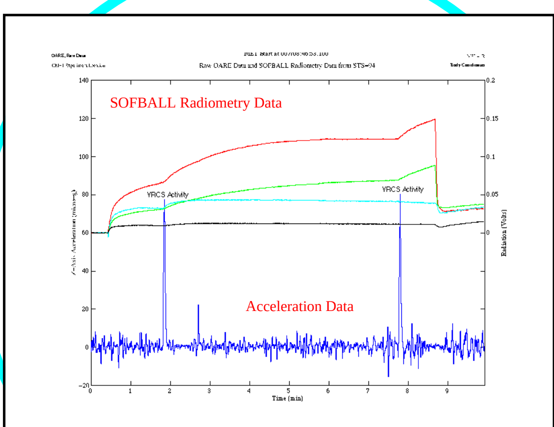
Principal Investigator Microgravity Services

PIMS has provided microgravity environment data processing and analysis for nineteen STS missions and over three years of Mir operations. Throughout this period, PIMS has sought to continually improve the services and products available to microgravity Principal Investigators. As a result of the unique requirements presented by the various microgravity science disciplines, a variety of methods for treating acceleration data have been developed. Table 3 describes the various time domain and frequency domain analysis techniques routinely employed by PIMS data analysts and the circumstances under which a particular technique might be invoked.

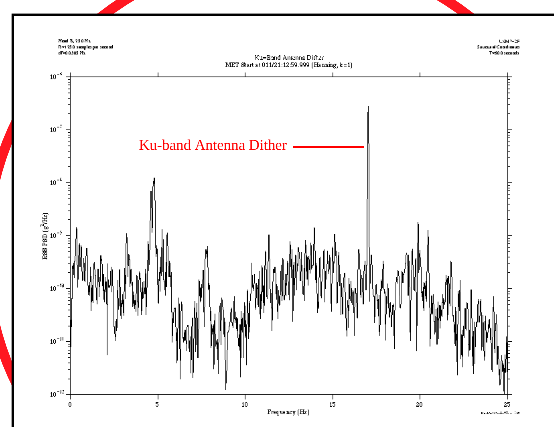
As stated in the introductory pages of this brochure, a main function of the PIMS project is aimed at educating Principal Investigators about the reduced gravity platforms on which their experiments are conducted and increasing their understanding of the tools available to them to best understand the relationship between their science results and the measured acceleration environment. One such tool utilized in the education process is the Accelerometer Data Analysis and Presentation Techniques (ADAPT) document [2] which contains detailed descriptions and examples of the analysis techniques cited in Table 3. Establishing for the Principal Investigator a better understanding of these analysis techniques increases the utility of the acceleration data provided to the Principal Investigator during a given experiment.

Table 3. Acceleration Data Analysis Technique

Display Format
Acceleration versus Time
Interval Min/Max Acceleration versus Time
Interval Average Acceleration versus Time
Interval RMS Acceleration versus Time
Trimmed Mean Filtered Acceleration versus Time
Quasi-Steady Mapped Acceleration versus Time
Quasi-Steady Three-Dimensional Histogram (QTH)
Power Spectral Density (PSD) versus Frequency
Spectrogram (PSD versus Frequency versus Time)
Cumulative RMS Acceleration versus Frequency
Frequency Band(s) RMS Acceleration versus Time
RMS Acceleration versus One-Third Frequency Bands
Principal Component Spectral Analysis (PCSA)



SOFBALL Radiometry Data Interaction with Acceleration Data from MSL-1 (STS-94).

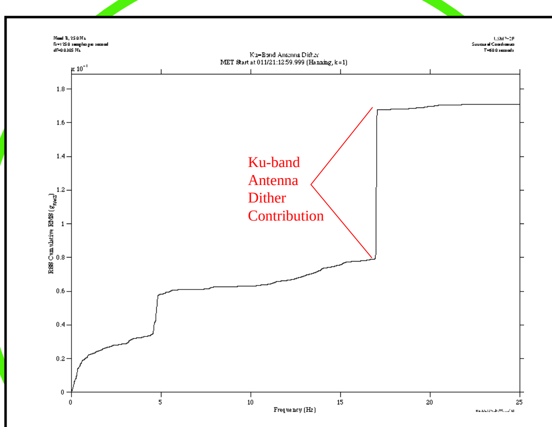


Ku-band Antenna Disturbance Signature from USMP-2 (STS-62).

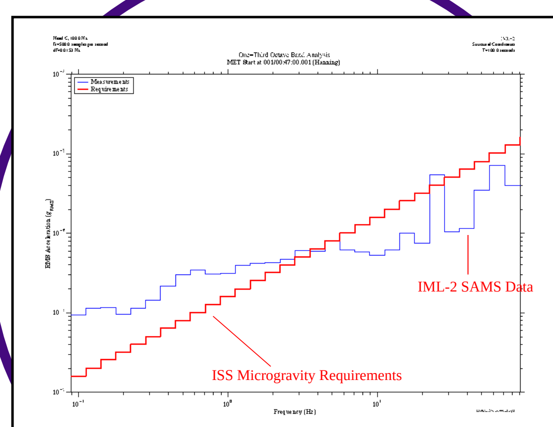
Regime(s)	Notes
Transient, Quasi-Steady, Vibratory	· **precise accounting of measured data with respect to time; best temporal resolution**
Vibratory, Quasi-Steady	· displays upper and lower bounds of peak-to-peak excursions of measured data · good display approximation for time histories on output devices with resolution insufficient to display all data in time frame of interest
Vibratory, Quasi-Steady	· provides a measure of net acceleration of duration greater than or equal to interval parameter
Vibratory	· provides a measure of peak amplitude
Quasi-Steady	· removes infrequent, large amplitude outlier data
Quasi-Steady	· use rigid body assumption and vehicle rates and angles to compute acceleration at any point in the vehicle
Quasi-Steady	· summarize acceleration magnitude and direction for a long period of time · indication of acceleration "center-of-time" via projections onto three orthogonal planes
Vibratory	· **displays distribution of power with respect to frequency**
Vibratory	· displays power spectral density variations with time · identify structure and boundaries in time and frequency
Vibratory	· **quantifies RMS contribution at and below a given frequency**
Vibratory	· quantify RMS contribution over selected frequency band(s) as a function of time
Vibratory	· **quantify RMS contribution over proportional frequency bands** · **compare measured data to ISS vibratory requirements**
Vibratory	· summarize magnitude and frequency excursions for key spectral contributors over a long period of time · results typically have finer frequency resolution and high PSD magnitude resolution relative to a spectrogram at the expense of poor temporal resolution

Another document representing a compilation of the PIMS knowledge base regarding microgravity acceleration data measurement is the Microgravity Environment Description Handbook (MEDH) [1]. This handbook summarizes the microgravity disturbance knowledge base accumulated by the PIMS project over the course of operations covering STS, Mir, and other reduced gravity platforms. The intent is to provide an overview of significant acceleration disturbances and their corresponding effect on the microgravity environment of various reduced gravity platforms. Each documented disturbance source is described on an individual page as shown in the section ***Microgravity Environment Description Handbook***. The majority of the MEDH illustrates disturbance sources from the STS and the Mir, but the environments of various sounding rockets and the KC-135 parabolic aircraft are included as well.

PIMS furthers the microgravity environment education process by conducting annual Microgravity Environment Interpretation Tutorials (MEIT) aimed at Principal Investigators and project scientists. In addition to covering topics described previously in the ADAPT and the MEDH, the tutorials address topics regarding available acceleration measurement systems and practical examples of the effects of the acceleration environment on experiments. PIMS also sponsors the Microgravity Measurement Group (MGMG) meetings to provide an international forum for the discussion of various aspects of microgravity acceleration research.

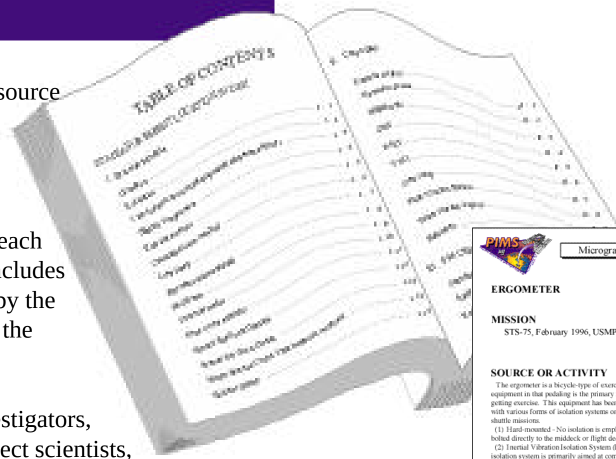


Quantifying Ku-band Antenna Disturbance from USMP-2 (STS-62).



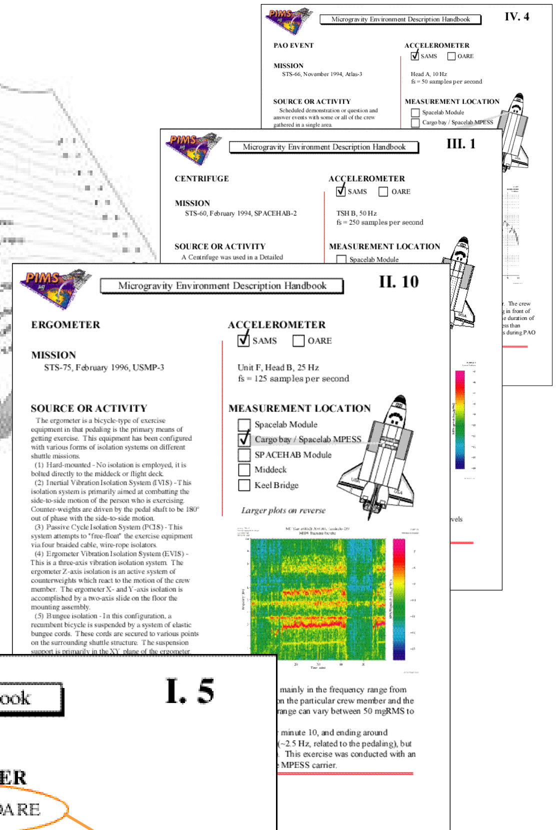
Comparison of Nominal IML-2 (STS-65) Environment vs. ISS Requirements Curve

Microgravity Environment Description Handbook



Each significant acceleration disturbance source is documented individually on a page containing one or more figures. These figures provide further insight into the disturbance under consideration, and are enlarged for clarity on the reverse side of each page. The front matter in the handbook includes cross references that list the disturbances by the vehicle, location of the measurement, and the characteristics of the disturbance.

The handbook is targeted at principal investigators, mission scientists, mission managers, project scientists, mission cadre, and hardware developers. Others interested in the disturbance sources that shape the microgravity environment of various platforms may find the handbook contents useful as well.



TITLE
Specifies the source or activity of the acceleration disturbance.

MISSION
Specifies the mission on which the disturbance was characterized.

SOURCE OR ACTIVITY
Provides background and operational characteristics of the disturbance.

ACCELEROMETER
Specifies the system used to make the acceleration measurements.

MEASUREMENT LOCATION
Specifies measurement location and vehicle configuration information.

EFFECT ON MICROGRAVITY ENVIRONMENT
Provides characterization of the disturbance in terms of source, magnitude, frequency, and/or duration.

Microgravity Environment Description Handbook — I. 5

Ku-BAND ANTENNA

MISSION
STS-65, July 1994, IML-2

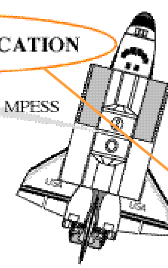
ACCELEROMETER
☑ SAMS ☐ OARE

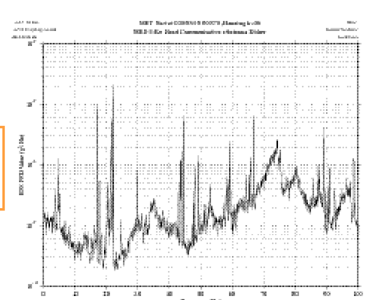
Head C, 100 Hz
fs = 500 samples per second

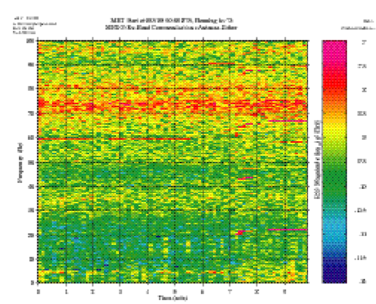
SOURCE OR ACTIVITY
The Ku-band antenna is located in the forward portion of the payload bay on the starboard side of the vehicle. On orbit, this antenna is deployed for communications between the orbiter and the Tracking Data Relay Satellite System (TDRSS). It is dithered at 17 Hz to prevent stiction of the gimbal mechanism to which it is mounted.

Larger plots on reverse

MEASUREMENT LOCATION
☑ Spacelab Module
☐ Cargo bay / Spacelab MPESS
☐ SPACEHAB Module
☐ Middeck
☐ Keel Bridge







EFFECT ON MICROGRAVITY ENVIRONMENT
Reaction torque forces at the base of the gimbal produce a distinct 17 Hz oscillatory disturbance which acts as a beacon signal within orbiter acceleration data owing to its intensity and nearly continuous operation. The intensity of this disturbance is variable, but root-mean-square acceleration levels resulting from this 17 Hz component are typically about 100 μg_{RMS}. Its second and third harmonics at 34 and 51 Hz are often quite prominent and the 85 Hz harmonic has also been seen.

For further information, contact PIMS Project Manager
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International Space Station Operations

The ISS microgravity acceleration environment consists of two regimes: the quasi-steady environment and the vibratory/transient environment; therefore, the measurement of the microgravity acceleration environment is best accomplished by two accelerometer systems. In the United States Laboratory Module, the measurement of these two regimes is accomplished by the Space Acceleration Measurement System-II (SAMS-II) and the Microgravity Acceleration Measurement System (MAMS). The vibratory/transient environment, consisting of vehicle, crew, and equipment disturbances and covering the frequency range 0.01 – 300 Hz, will be measured by the SAMS-II. Due to the localized nature of these vibrations, this frequency range requires measurement of the environment near the experiment hardware of interest. SAMS-II provides this distributed measurement system through the use of Remote Triaxial Sensor systems (RTS). An individual RTS consists of an Electronics Enclosure (EE) and two Sensor Enclosures (SE). A SAMS-II Control Unit housed in an International Subrack Interface Standard (ISIS) drawer collects data from all active EE's and prepares the data for downlink.

The MAMS will record the quasi-steady microgravity environment ($f < 0.01$ Hz), including the influences of aerodynamic drag, vehicle rotation, and venting effects. The MAMS unit will be located in the United States Laboratory Module in a double middeck locker enclosure. PIMS will utilize MAMS for its ability to sense the quasi-steady regime. The MAMS Miniature Electrostatic Accelerometer (MESA) sensor is a flight spare from the Orbital Acceleration Research Experiment (OARE) program that was used to characterize the quasi-steady acceleration environment of the Space Shuttle Columbia. Like the OARE data recorded during eleven STS missions, utilizing rigid body assumptions at these low frequencies will allow MAMS MESA data to be mapped to alternate locations within the ISS using ISS body rates and body angles data.

Due to the dynamic nature of the microgravity environment and its potential to influence sensitive experiments, the Principal Investigator Microgravity Services project has initiated a plan through which the data from these instruments will be distributed to researchers in a timely and meaningful fashion.

Beyond the obvious benefit of correlation between accelerations and the scientific phenomena being studied, such information is also useful for hardware developers who can gain qualitative and quantitative feedback about their facility acceleration output to the ISS. Further, a general characterization of the ISS microgravity environment will be obtained that affords scientists and hardware developers the pre-flight ability to anticipate the acceleration environment available for experimentation. Similar to STS operations, a handbook of acceleration disturbance sources for the ISS will be developed and maintained to provide a concise visualization of the ISS disturbance database.

PIMS ground support equipment located at the NASA Glenn Telescience Support Center will be capable of generating a standard suite of acceleration data displays, including the various time domain and frequency domain options described in Table 3. These data displays will be updated in real-time and will periodically update images available via the PIMS WWW page. The planned update rate is every two minutes. Future plans involve routing the measured ISS acceleration data directly to a PI's operations facilities.

To supplement the near real-time displays, planned information resources will also be provided throughout the tenure of the systems on the ISS. General characterizations of the environment as it evolves will be made available on a regular basis so that investigators are aware of the overall environment in which their experiments were conducted. Accelerometer data archives and automated data analysis servers will allow investigators the ability to request customized data analysis support. Additionally, a catalog of characterized disturbance sources will be available in the form of an ISS MEDH.

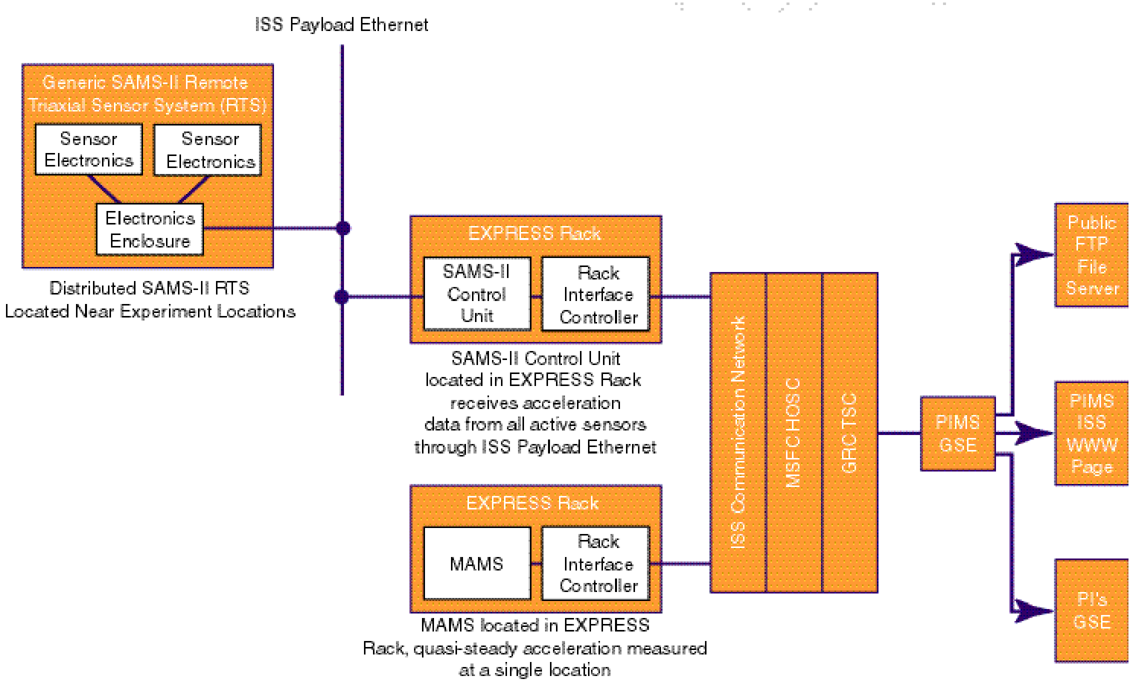

Figure 3. ISS Acceleration Data Flow.

PIMS Objectives

- Process, analyze, and interpret microgravity acceleration data for microgravity science Principal Investigators
- Distribute processed acceleration data in the form of acceleration data plots and acceleration data files
- Develop new and enhance existing data analysis techniques to better assist microgravity science Principal Investigators in their interpretation of their microgravity environment
- Develop near real-time data processing methods based on PI-defined requirements and the PIMS knowledge base
- Characterize the microgravity environment in a continuous effort to improve our understanding of the acceleration environment available for a variety of reduced gravity platforms
- Maintain an archive of recorded microgravity acceleration data from a variety of reduce gravity platforms and a variety of acceleration measurement systems
- Maintain the PIMS Microgravity Environment Description Handbook as a concise reference to the PIMS microgravity environment knowledge base
- Conduct astronaut briefings aimed at educating crew members about the microgravity environment
- Conduct annual MGMG meetings as an international forum
- Conduct annual Microgravity Environment Interpretation Tutorials aimed at educating microgravity science Principal Investigators about the microgravity environment for various reduced gravity platforms

World Wide Web Links

1. Microgravity Science Division at NASA Glenn Research Center
   http://microgravity.grc.nasa.gov
2. NASA Glenn Acceleration Measurement Program
   http://microgravity.grc.nasa.gov/MSD/MSD_htmls/accel_meas.html
   http://microgravity.grc.nasa.gov/MSD/MSD_htmls/mmap.html
3. Principal Investigator Microgravity Services Home Page
   http://microgravity.grc.nasa.gov/MSD/MSD_htmls/PIMS.html
4. Microgravity Environment Description Handbook
   http://www.grc.nasa.gov/WWW/MMAP/PIMS/HTMLS/Micro-descpt.html
5. Accelerometer Data Analysis and Presentation Techniques
   http:// www.grc.nasa.gov/WWW/MMAP/PIMS/HTMLS/adapt.html

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[2] Rogers, M. J. B., Hrovat, K., McPherson, K., Moskowitz, M., & Reckart, T. (1997) Accelerometer Data Analysis and Presentation Technique. NASA Technical Memorandum 113173.

[3] Moskowitz, M., Hrovat, K., Tschen, P., McPherson, K., Nati, M., & Reckart, T. (1998) Summary Report of Mission Acceleration Measurements for MSL-1. NASA Technical Memorandum 1998-206979.

[4] Rogers, M. J. B., Hrovat, K., McPherson, K., & Reckart, T. (1999) Summary Report of Mission Acceleration Measurements for STS-87. NASA Technical Memorandum 1999-208647.

[5] Hrovat, K. and McPherson, K. (1999) Summary Report of Mission Acceleration Measurements for STS-89. NASA Technical Memorandum 1999-209084.

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