IN-18

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Microgravity Environment Description Handbook

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National Aeronautics and
Space Administration

ABSTRACT

The Microgravity Measurement and Analysis Project (MMAP) at the NASA Lewis Research Center (LeRC) manages the Space Acceleration Measurement System (SAMS) and the Orbital Acceleration Research Experiment (OARE) instruments to measure the microgravity environment on orbiting space laboratories. These laboratories include the Spacelab payloads on the shuttle, the SPACEHAB module on the shuttle, the middeck area of the shuttle, and Russia's Mir space station. Experiments are performed in these laboratories to investigate scientific principles in the near-absence of gravity.

The microgravity environment desired for most experiments would have zero acceleration across all frequency bands or a true weightless condition. This is not possible due to the nature of spaceflight where there are numerous factors which introduce accelerations to the environment.

This handbook presents an overview of the major microgravity environment disturbances of these laboratories. These disturbances are characterized by their source (where known), their magnitude, frequency and duration, and their effect on the microgravity environment. Each disturbance is characterized on a single page for ease in understanding the effect of a particular disturbance. The handbook also contains a brief description of each laboratory.

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Appendices

Abbreviations and Acronyms

3DMA	Three-dimensional Microgravity Accelerometer
a	acceleration magnitude
APU	auxiliary power unit
ATCS	Active Thermal Control System
BDPU	Bubble, Drop and Particle Unit
CG	Center of Gravity
DLR	German Aerospace Research Establishment (German acronym)
DMT	Decreed Moscow Time (ddd/hh:mm:ss)
DSO	Detailed Supplementary Objective
DTO	Development Test Objective
EEPROM	electrically eraseable programmable read only memory
EORF	Enhanced Orbiter Refrigerator/Freezer
EVIS	Ergometer Vibration Isolation System
FCS	Flight Control System
FES	Flash Evaporator System
f_c	Cutoff frequency (Hz)
f_N	Nyquist frequency (Hz)
f_s	Sampling rate (samples per second)
g_o	Earth's gravity acceleration level at sea-level (9.81 m/s^2)
GBX	glovebox
GMT	Greenwich Mean Time (day/hour:minute:second)
Hz	Hertz
ILRD	interlimb resistance device
IML	International Microgravity Laboratory
IVIS	Inertial Vibration Isolation System
JSC	NASA Johnson Space Center
KSC	NASA Kennedy Space Center
LeRC	NASA Lewis Research Center
LV / LH	Local Vertical / Local Horizontal
LMS	Life and Microgravity Spacelab
LSLE R/F	Life Sciences Laboratory Equipment Refrigerator/Freezer
MEPHISTO	Materials for the Study of Interesting Phenomena of Solidification on Earth and in Orbit
µg	microgravity (1/1,000,000 of g_o)
MET	Mission Elapsed Time (day/hour:minute:second)
mg	milligravity (1/1000 of g_o)
MMA	Microgravity Measurement Assembly
MMAP	Microgravity Measurement and Analysis Project
MMD	Microgravity Measuring Device
MPESS	Mission Peculiar Equipment Support Structure
MSAD	Microgravity Science and Applications Division
MSD	Microgravity Science Division

NASA	National Aeronautics and Space Administration
NIZEMI	Slow Rotating Centrifuge Microscope (German acronym)
OARE	Orbital Acceleration Research Experiment
OAST	Office of Aeronautics and Space Technology
OMS	Orbital Maneuvering System
PAO	Public Affairs Office
PCIS	Passive Cycle Isolation System
PIMS	Principal Investigator Microgravity Services
POCC	Payload Operations Control Center
PRCS	primary reaction control system
PSD	power spectral density
QSAM	Quasi-steady Acceleration Measurement experiment
RCS	reaction control system
RMS	root-mean-square
rpm	revolutions per minute
RSS	root-sum-of-squares
SAMS	Space Acceleration Measurement System
SIMO Dump	simultaneous supply water and waste water dump
SOR/F	Sterling Orbiter Refrigerator/Freezer
STS	Space Transportation System
TDRSS	Tracking and Data Relay Satellite System
TEMPUS	electromagnetic containerless proccessing facility (German acronym)
TSH	triaxial sensor head
TSS	Tethered Satellite System
μg	microgravity (1/1,000,000 of g_0)
USML	United States Microgravity Laboratory
USMP	United States Microgravity Payload
VRCS	vernier reaction control system
VV	velocity vector
$X_{h,A}, Y_{h,A}, Z_{h,A}$	SAMS TSH A axes
$X_{h,B}, Y_{h,B}, Z_{h,B}$	SAMS TSH B axes
$X_{h,C}, Y_{h,C}, Z_{h,C}$	SAMS TSH C axes
X_O, Y_O, Z_O	Orbiter structural coordinate system axes
X_b, Y_b, Z_b	Orbiter body coordinate system axes
X_B, Y_B, Z_B	Coordinate notation for the Mir Base Block axes

1.0 Introduction

Fluid physics, materials science, combustion science, low temperature microgravity physics, biotechnology and life sciences experiments are conducted on the NASA Space Shuttle Orbiters and on Russia's Mir Space Station to take advantage of the reduced gravity environment resulting from the continuous free fall state of low earth orbit. Accelerometer systems are flown with these experiments to record the microgravity environment to which the experiments were exposed. This microgravity environment is a complex combination of accelerations and vibrations generated by orbital mechanics, vehicle subsystems, flight attitude, vehicle maneuvers, experiment equipment, and the crew.

Two common accelerometer systems flown to support experiments are the Space Acceleration Measurement System (SAMS) and the Orbital Acceleration Research Experiment (OARE). These accelerometer systems are managed by the Microgravity Measurements and Analysis Project (MMAP) within the Microgravity Science Division (MSD) at NASA Lewis Research Center (LeRC). These accelerometer systems are flown in support of science experiments sponsored by the Microgravity Science and Applications Division (MSAD) of the NASA Headquarters Office of Life and Microgravity Science and Applications. Other accelerometer systems are occasionally flown in support of these and other science experiments.

The Principal Investigator Microgravity Services (PIMS) project in the MMAP supports principal investigators of microgravity science experiments as they evaluate the effects of varying acceleration levels on their experiments.

1.1 Purpose

This handbook was prepared by PIMS to facilitate the interpretation of the microgravity environment of the various vehicles and carrier combinations which are commonly used for microgravity science experiments. The intended users are principal investigators, mission scientists, mission managers, project scientists, and the staff associated with the aforementioned personnel.

This handbook contains examples of microgravity environment disturbances which have been observed from many missions, several vehicles and several experiment carriers. These disturbances are first categorized by the source of the disturbance. Cross references are included that list the disturbances by the vehicle, the location of the measurement, and the characteristics of the disturbance.

1.2 Additional Information

There may be times that a user needs information on a particular type of disturbance which has not been included here. Please send a description of such disturbances to the PIMS project for consideration. This handbook has been designed to be updated in the future with additional descriptions as they are developed by PIMS. To obtain a copy or to "register" for updates, please send an appropriate request to the following address.

Duc Truong, PIMS Project Manager
Mail Stop 500-216
NASA Lewis Research Center
21000 Brookpark Road
Cleveland OH 44135

Correspondence may also be made by telephone, fax or e-mail.
Office number: 216-433-8394
Fax number: 216-433-8660
e-mail: pims@lerc.nasa.gov

Additional information for the missions supported by the SAMS and OARE accelerometers is available in PIMS mission summary reports published as NASA Technical Memorandum reports. A list of such reports is included in Appendix B. A copy of such a report may be obtained by contacting the PIMS Project Manager. A World Wide Web site is also maintained by the PIMS project. Descriptions of the environment, some mission summary reports, and links to SAMS, OARE & MMAP sites are included at this URL:

http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

1.3 Access to description sheets

Each disturbance to the microgravity environment has characteristics of magnitude, duration, and frequency content. These characteristics are affected by the location of the source, the structural dynamics of the vehicle, and the measurement location.

Since most users limit their quest to their carrier or location, the disturbances contained in this handbook have been categorized at the first level by the location where the measurement was made. Cross reference tables are provided which categorize the disturbances by disturbance source, vehicle, frequency, and magnitude.

The user must be aware that the categories are not mutually exclusive and that they do overlap one another. A particular disturbance may be found in many cross reference tables and table headings.

1.4 Description of laboratories

Orbiter Middeck

The Orbiter middeck provides crew accommodations and contains three avionics equipment bays. Modular stowage lockers are used to store the flight crew's personal gear, mission-required equipment, and experiments. There are 42 identical lockers, which are 11 X 18 X 21 inches. An experiment is either designed to fit inside a locker or replace one or more lockers. Individual microgravity science experiments are flown on a space-available basis in the Orbiter middeck. Few support services are available and, in general, mission parameters are not established by experiments in the middeck.

Additional information about the Orbiter middeck may be obtained from [1].

Spacelab Module

The Spacelab pressurized module, or laboratory, is a pressurized container connected to the Orbiter middeck by a tunnel. Inside the module are experiment racks in which most of the experiment hardware is installed. The mission crew members may operate the experiments in a shirt-sleeve, laboratory environment. The Spacelab module is used as a primary payload on dedicated microgravity science missions to operate a multitude of microgravity science experiments. The mission parameters, such as Orbiter attitude and crew timeline, may be optimized for microgravity science operations.

Additional information about the Spacelab module may be obtained from [2].

Spacelab MPESS

The Spacelab Mission Peculiar Equipment Support Structure (MPESS) is a truss structure with support subsystems which mounts in the cargo bay of the Orbiter. The support subsystems supply services, such as electrical power, data communications, and thermal conditioning, to the experiments mounted on the MPESS. The experiments are operated remotely primarily by commands from a science operations center or, in some cases, by remote crew interaction. These carriers have typically been used as partial Orbiter payloads with the mission parameters for microgravity science operations being established for only part of the mission.

SPACEHAB Module

The SPACEHAB, Inc. developed the SPACEHAB module to function as a shirt-sleeve environment laboratory similar to the Spacelab module and the Orbiter middeck and flight decks. The SPACEHAB Double Module is one of a fleet of modules the company owns and operates. The modules fit into the payload bay of Space Shuttles, providing laboratory and logistics resupply services to NASA, other international space agencies, industry, and academia on a lease basis. SPACEHAB is the first company to commercially develop, own and operate habitable modules that provide laboratory research facilities and logistics resupply services aboard the U.S. Space Shuttle system, supporting people living and working in space. [3]

Additional information about the SPACEHAB module may be obtained from [4].

Mir Space Station

Russia's Mir space station is a set of six interconnected modules forming an operational space station that can be permanently staffed by two or three crew members. The crew work in a shirt-sleeve environment operating experiments and performing housekeeping tasks. This complex is particularly appropriate for long duration experiments or for multiple operations of the same experiment.

Additional information about the Mir space station may be obtained from [5,6].

1.5 Orbiter coordinate system

The Orbiters have two basic orthogonal coordinate systems which are used to specify locations, positions and orientations within the orbiter: the body coordinate system, and the structural coordinate system. These are shown in Figures 1 and 2, respectively.

The body coordinate system (Figure 1) has an origin at the orbiter's center of gravity (CG). It is oriented such that the direction from tail to nose is $+X_b$, the direction from port to starboard is $+Y_b$, and the direction extending from the payload bay to the Orbiter belly is $+Z_b$. Typically, this is the system used to specify navigational directions and orientations such as for Local Vertical/Local Horizontal (LVLH) attitudes.

The structural coordinate system (Figure 2) has an origin at the tip of the external tank. It is oriented such that the direction from nose to tail is $+X_0$, the direction from port to starboard is $+Y_0$, and the direction upward out of the payload bay is $+Z_0$. Typically, this is the system used to specify the locations of equipment within the orbiter.

1.6 Spectral Analysis: Cutoff versus Nyquist Frequency

All data acquired by SAMS has been processed using a lowpass filter prior to digitization. This is an anti-aliasing filter with a roll-off of -140 dB per decade. Typically, the data sampling rate is 5 times the filter cutoff frequency. This results in oversampling, so that frequency information above the filter cutoff can be examined. However, the magnitudes of higher frequency disturbances (i.e. above the filter cutoff) have been attenuated.

The highest valid frequency present in the digitized data is called the Nyquist frequency, and is denoted f_N. Mathematically, this frequency is equal to one half of the sampling rate (f_s). The filter cutoff frequency is specified alongside the sensor head letter, such as "TSH C, 25 Hz" in the data plots of this handbook. In this example, sensor head C utilized a 25 Hz cutoff frequency. In order to obtain the Nyquist frequency for the head, the sampling rate (f_s) must be divided by two. For example, a sampling rate of 125 samples per second results in f_N=62.5 Hz.

Spectrograms and PSDs are often shown containing information to the Nyquist frequency. The user is cautioned that the magnitude of data above the filter cutoff frequency has been attenuated.

Even when imaged to the cutoff frequency, spectrogram plots are only a qualitative tool. Accurate determination of g_{RMS} levels can only be made by an integration of a PSD, and cannot be performed using the PSD magnitudes (colors) shown on a spectrogram plot.

1.7 Signal Aliasing

Signal aliasing is a phenomena caused during the analog-to-digital signal conversion process and occurs when there are signals present above the Nyquist frequency (denoted f_N). The Nyquist frequency is equal to one half of the sampling rate of the analog-to-digital converter. For example, for data sampled at 125 samples per second, the Nyquist frequency is 62.5 Hz. Although the SAMS unit utilizes a -140 dB per decade lowpass cutoff filter, signals which are high magnitude (or particularly close to the sensor head) may not be fully attenuated above the Nyquist frequency. When this occurs, these higher frequency signals appear to “fold-over” the Nyquist frequency, and appear as lower frequency signals in the data, that is, they are aliased. However, these lower-frequency signals do not really exist, and have no effect on experiments which may be sensitive to frequencies in these lower regions.

1.8 Accelerometer Polarity

The sign convention used for OARE is such that a forward thrust of the Orbiter is recorded as a negative X_b acceleration. This is consistent with a frame of reference fixed to the Orbiter.

The sign convention used for SAMS is such that a forward thrust of the Orbiter is recorded as a negative X_0 acceleration. This is consistent with a frame of reference fixed to a fixed inertial point in space.

For a detailed discussion of these two reference frames, including their origins, see [7].

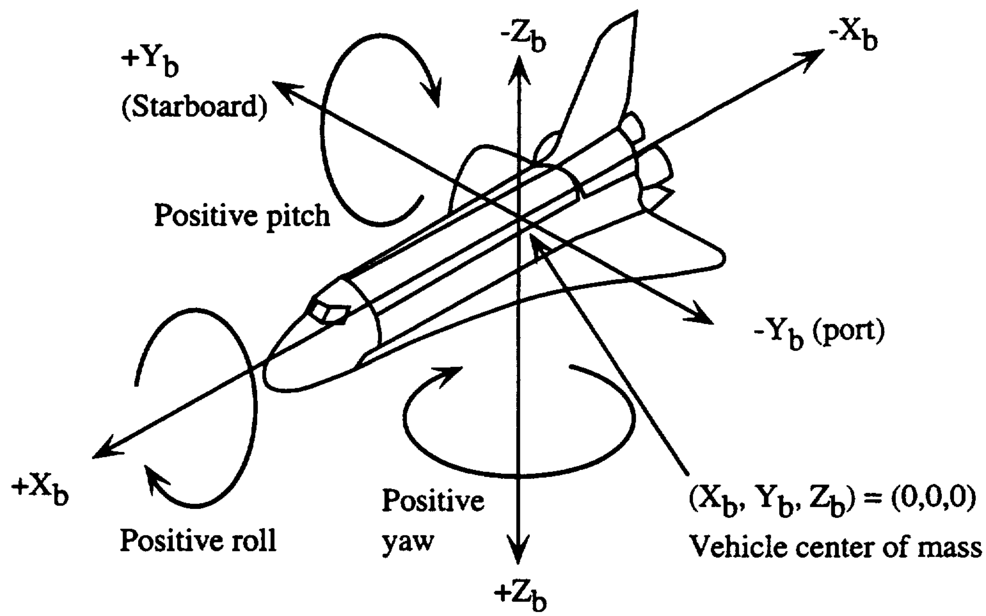


Figure 1. Orbiter body coordinate system

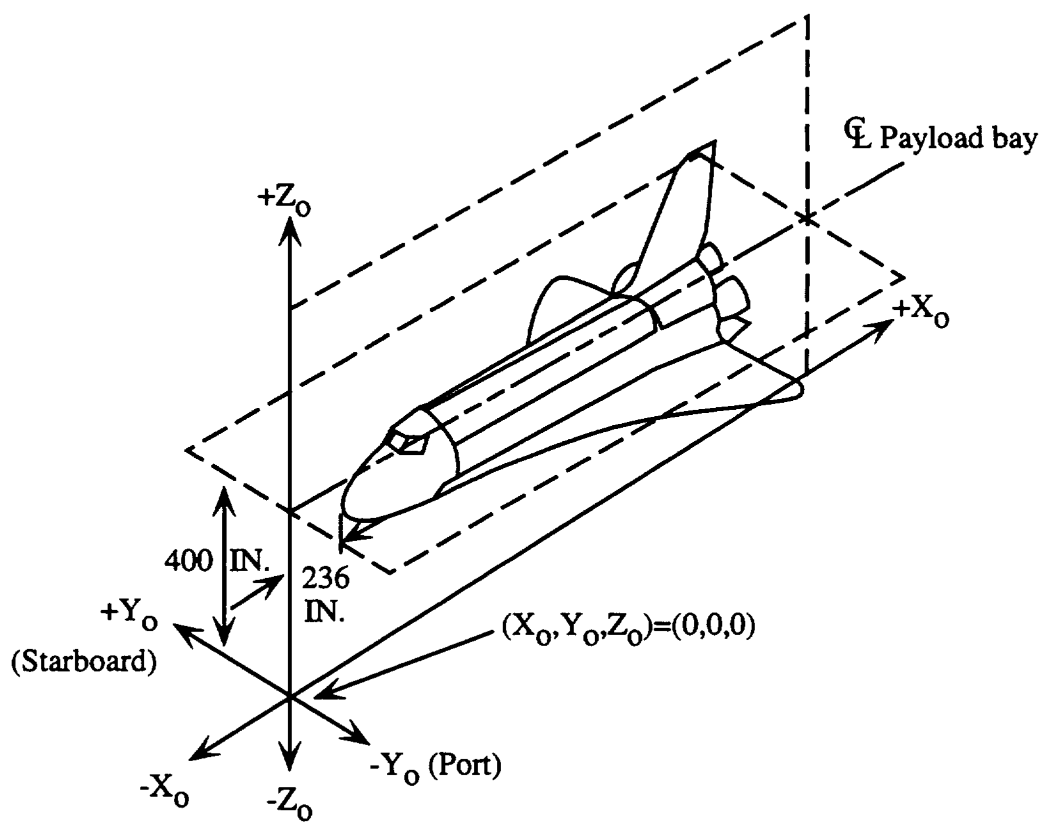


Figure 2. Orbiter structural coordinate system

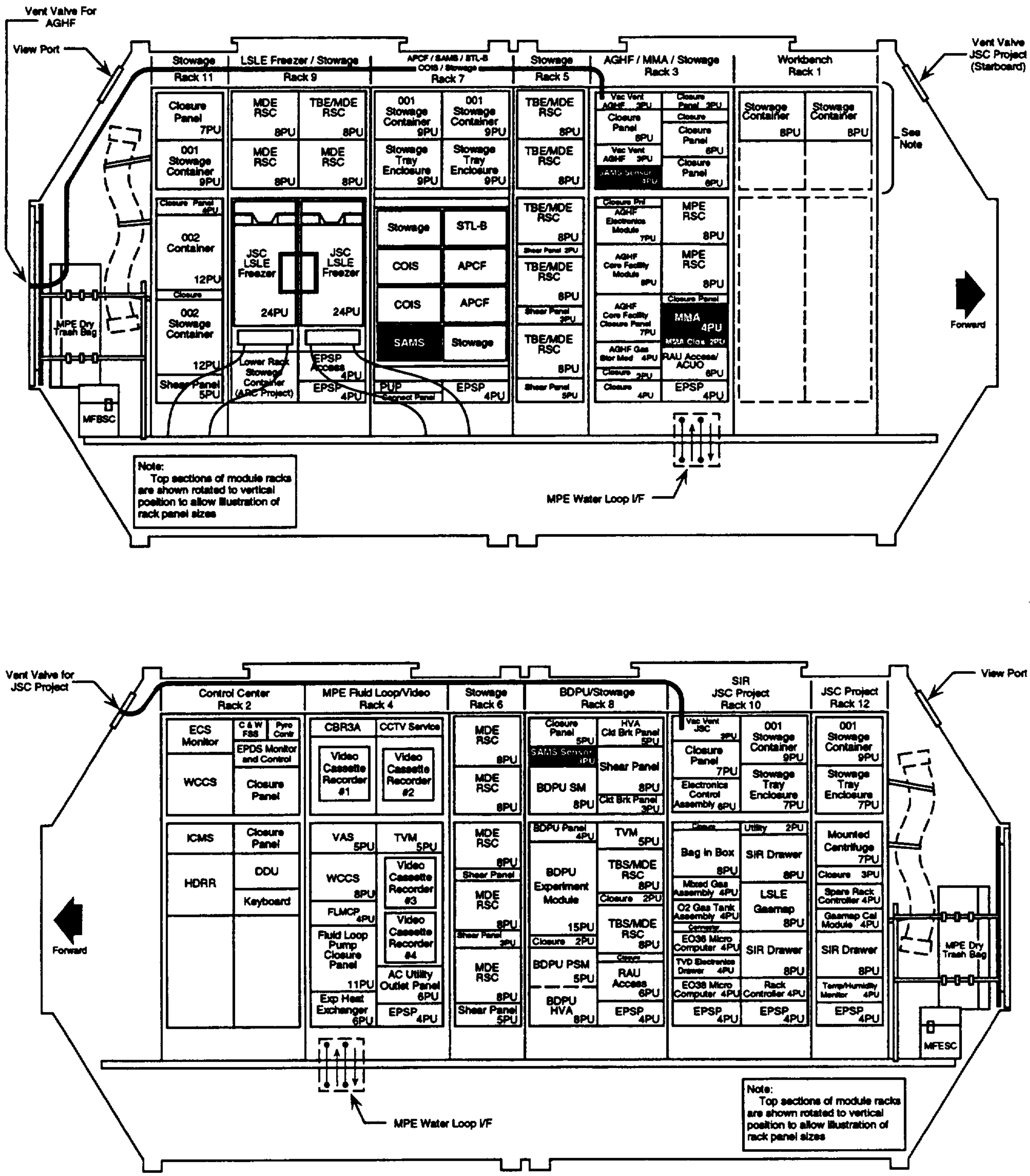


Figure 3. Typical Spacelab Rack Layout

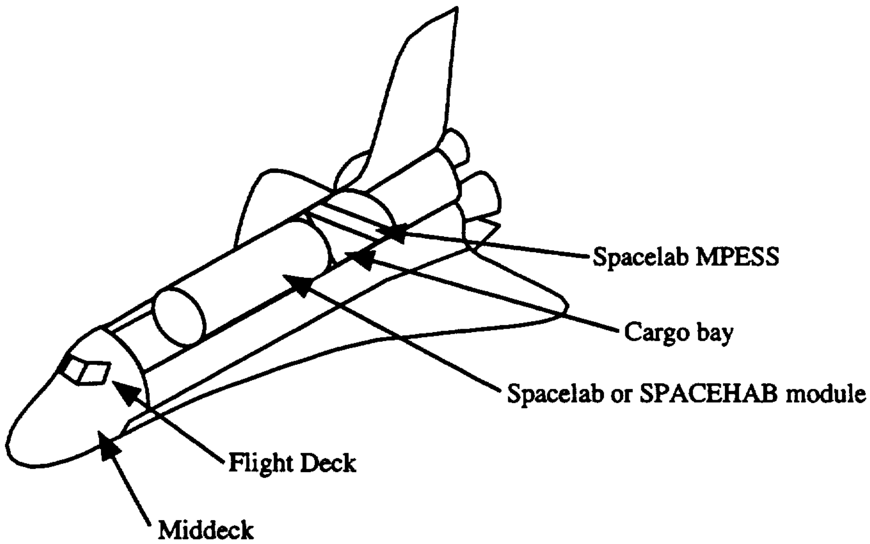


Figure 4. Microgravity Experiment Locations on the Orbiter

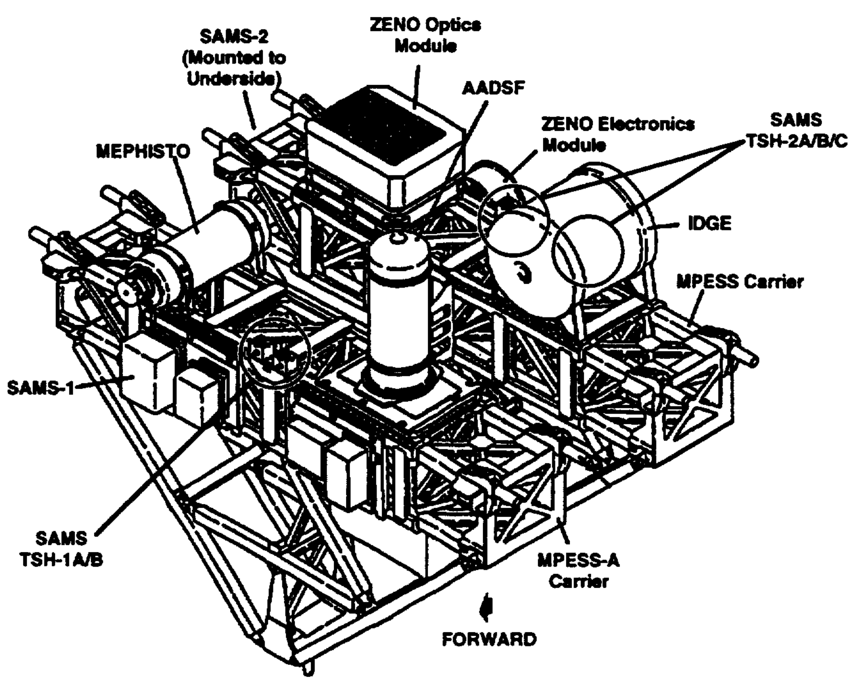


Figure 5. Typical Spacelab MPESS with experiments

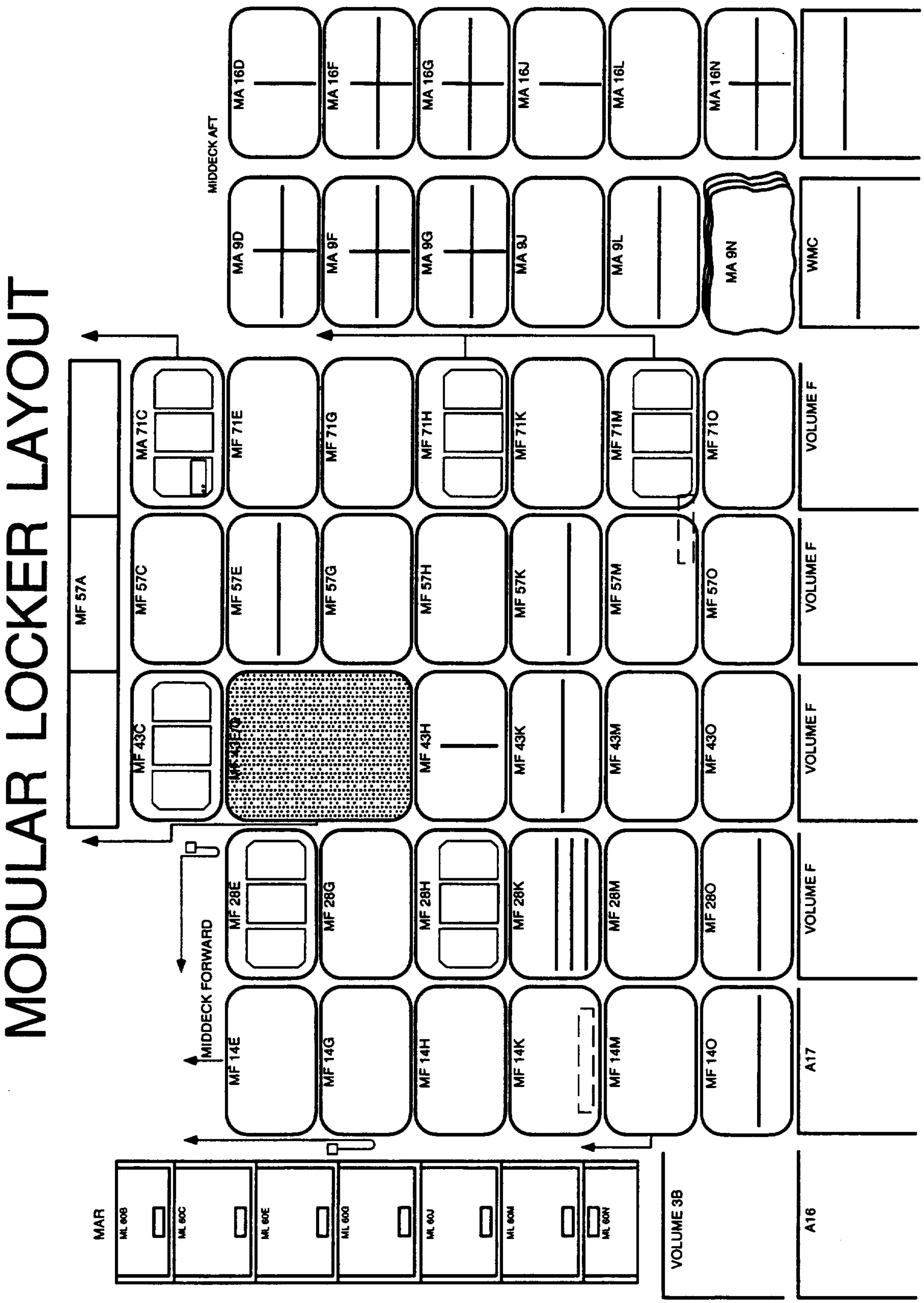


Figure 6. Typical Middeck Locker Layout

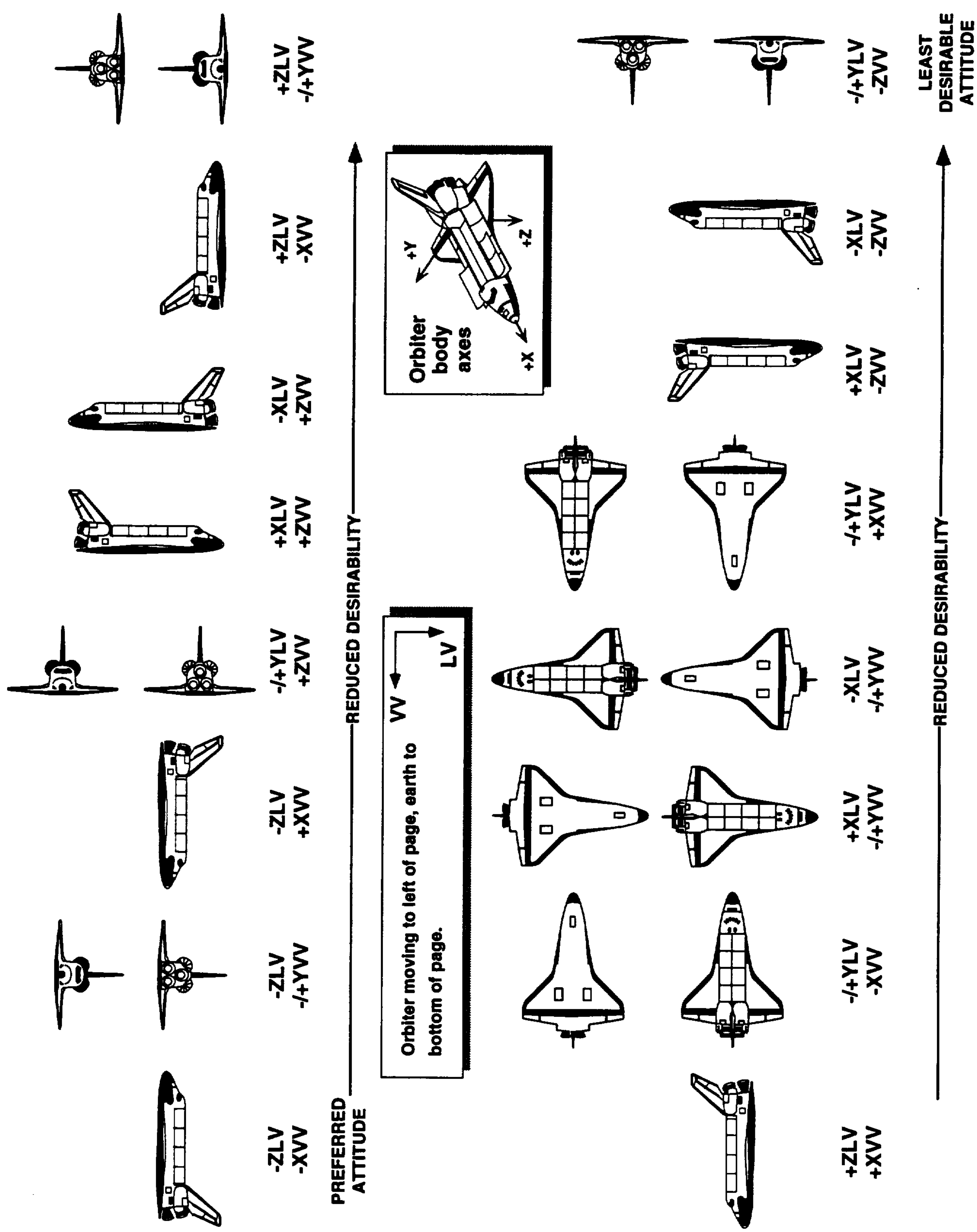
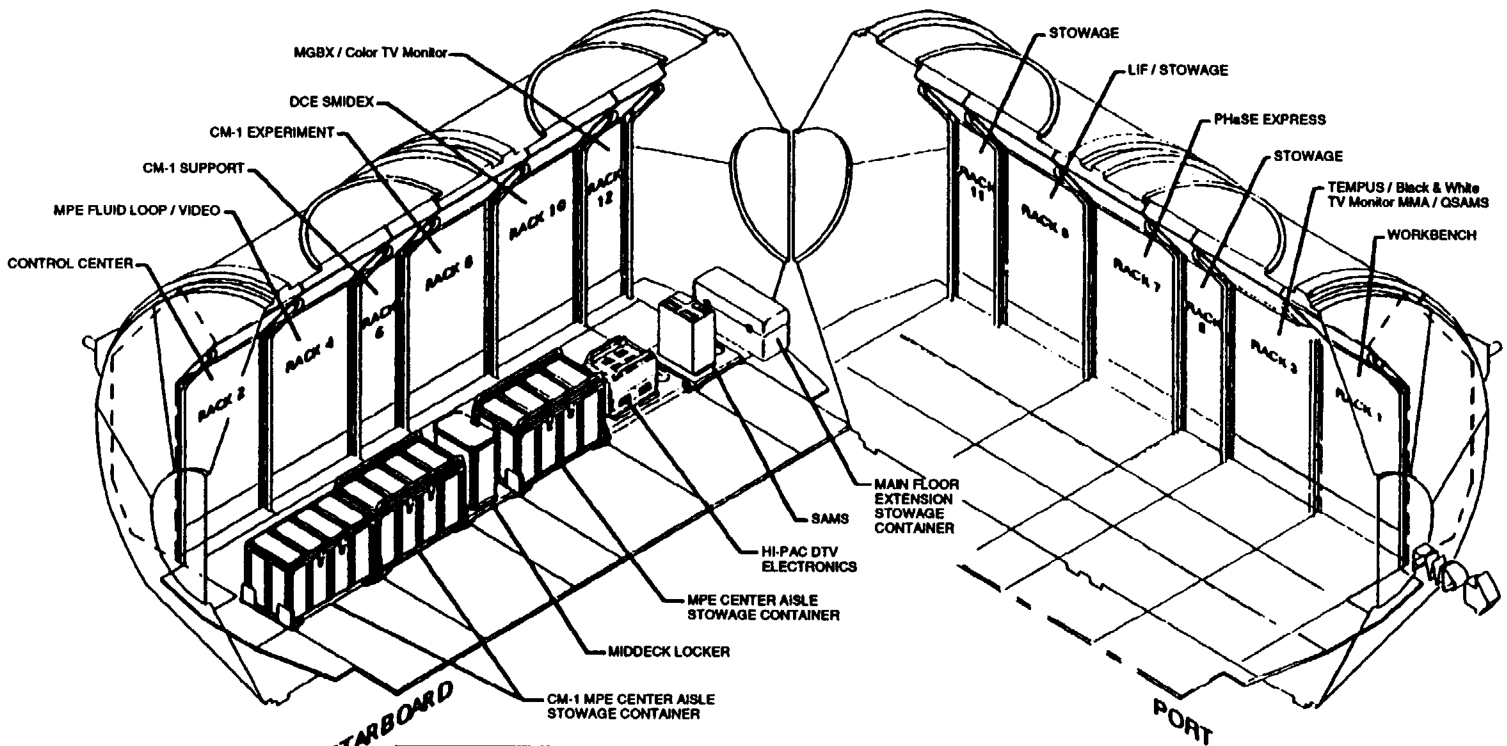


Figure 7. Earth-Oriented Orbiter Attitudes

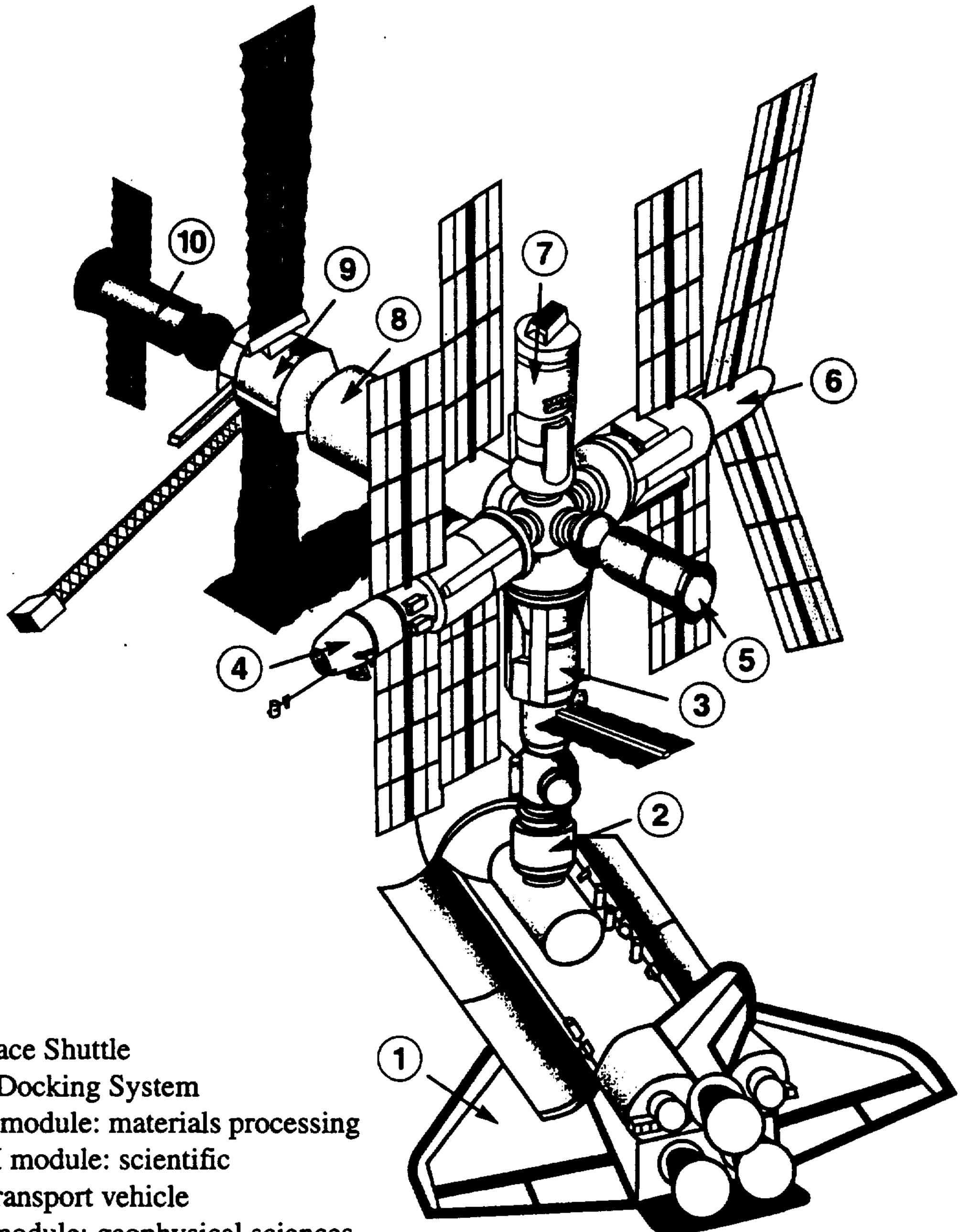


LEGEND

CM-1	- Combustion Module
DCE	- Droplet Combustion Experiment
PHaSE	- Physics of Hard Spheres
SAMS	- Space Acceleration Measurement System
EXPRESS	- EXpedite the PRocessing of Experiments to the Space Station
OARE	- Orbital Acceleration Research Experiment
MGBX	- Middeck Glovebox
PCG-STES	- Protein Crystal Growth-Single Locker Thermal Enclosure System
QSAM	- Quasi-Steady Acceleration Measurement
TEMPUS	- Electromagnetic Containerless Procesing Facility
MMA	- Microgravity Measurement Assembly
LIF	- Large Isothermal Furnace

MSL-1 MODULE EQUIPMENT OVERVIEW

Figure 8. Typical Spacelab module configuration



1) U.S. Space Shuttle
2) Orbital Docking System
3) Kristall module: materials processing
4) Kvant II module: scientific
5) Soyuz transport vehicle
6) Spektr module: geophysical sciences
7) Priroda module: Earth remote sensing
8) Core module: habitation, power. life support
9) Kvant module: astrophysics
10) Progress vehicle

Figure 9. Typical Mir configuration with docked Orbiter

1.10 References

1). http://www.ksc.nasa.gov/shuttle/technology/sts-newsref/stsover-prep.html#stsover-mpaccom

2). http://www.ksc.nasa.gov/shuttle/technology/sts-newsref/spacelab.html#spacelab

3). http://www.spacehab.com/press/news2.html

4). http://www.spacehab.com

5). http://www.osf.hq.nasa.gov/mir/

6). http://liftoff.msfc.nasa.gov/rsa/mir.html

7). DeLombard, R., Compendium of Information for Interpreting the Microgravity Environment of the Orbiter Spacecraft, NASA Technical Memorandum 107032, August 1996.

2.0 MEASUREMENT LOCATION INDEX

This index is based on where the measurements were made. The page numbers below are given by the handbook section number and the page number within that section.

I. Spacelab Module

II. Cargo Bay / Spacelab MPESS

III. SPACEHAB Module

IV. Middeck

V. Keel Bridge (low frequency measurements)

VI. Mir Space Station

VII. Other Locations

3.0 CROSS REFERENCE LISTS

3.1 DISTURBANCE SOURCE CROSS REFERENCE

Disturbances are caused by various classes of equipment and actions. The page numbers below are given by the handbook section number and the page number within that section.

I. Vehicle Subsystem Disturbances

II. Vehicle Attitude and Maneuver Disturbances

III. Experiment Disturbances

IV. Crew Induced Activities

3.2 VEHICLE CROSS REFERENCE

Disturbances peculiar to a vehicle are referenced here. The page numbers below are given by the handbook section number and the page number within that section.

3.3 PRIMARY FREQUENCY CROSS REFERENCE

The primary frequency of a disturbance is used to classify disturbances in this table. The user must be aware, however, that many disturbances do not produce an effect entirely at a single frequency. There are often harmonics of the primary frequency, secondary frequency effects and broad spectrum effects from disturbances.

The page numbers below are given by the handbook section number and the page number within that section.

I. Quasi-steady (f < 0.01 Hz)

II. 0.01 < f < 5 Hz

III. 5 < f < 10 Hz

IV. 10 < f < 25 Hz

V. 25 < f < 50 Hz

VI. 50 < f < 100 Hz

VII. f > 100 Hz

VIII. Transient

3.4 ACCELERATION MAGNITUDE CROSS REFERENCE

The acceleration magnitude of a disturbance has been used to classify these disturbances in this table. The user must be aware, though that many disturbances do not produce an effect entirely at a single magnitude at every occurrence. The purpose here is to categorize the disturbances according to their rough order of magnitude. The page numbers below are given by the handbook section number and the page number within that section.

I. a < 10 μg

II. a < 100 μg

III. a < 500 μg

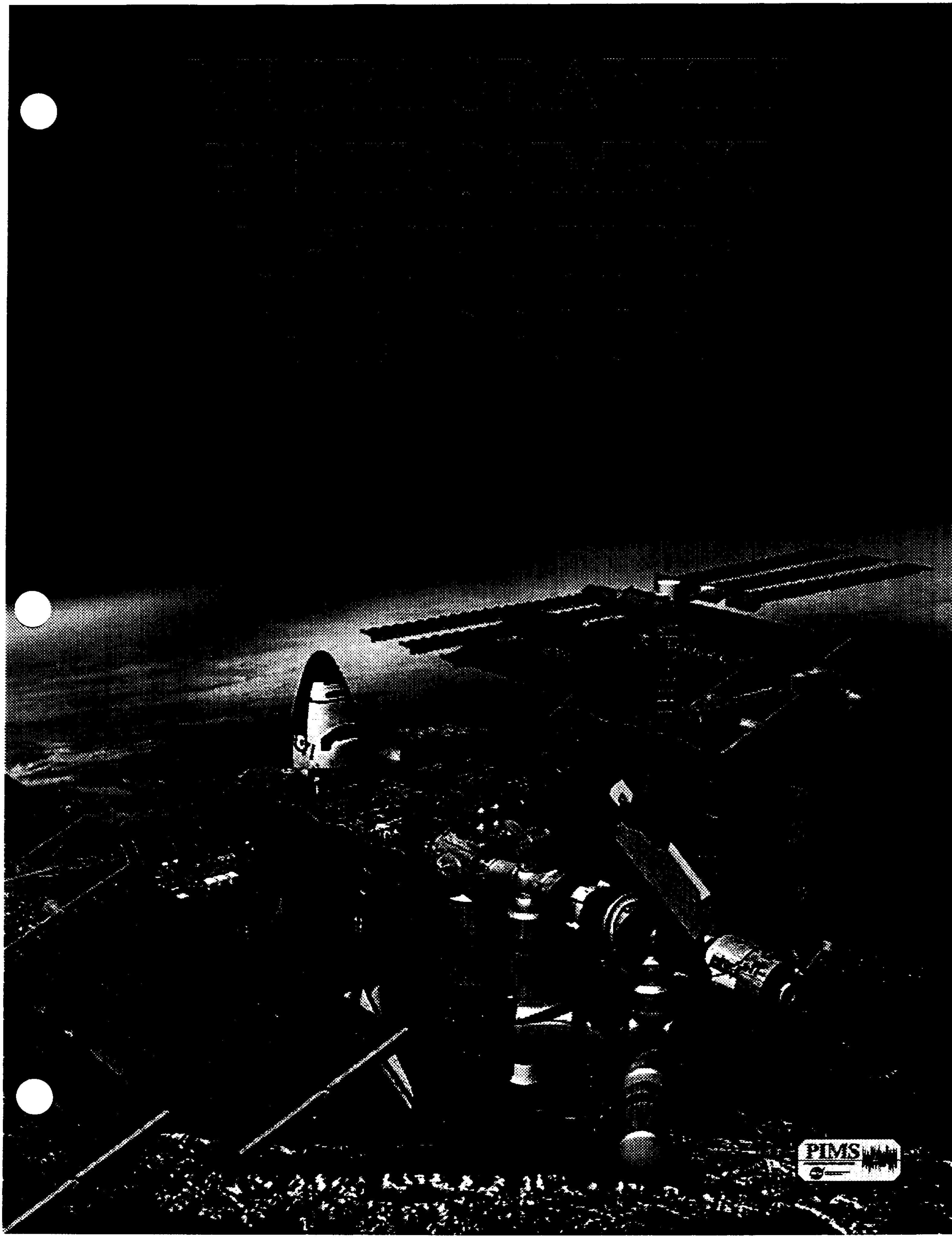
IV. a < 1000 μg

V. a > 1000 μg

3.5 NO DISCERNIBLE EFFECTS

Some activities and actions on a vehicle are not sufficient to cause a noticeable perturbation to the microgravity environment. These are included in this handbook to show that there should not be much concern for the effects these actions have on the microgravity environment

Events analyzed and shown to not have discernible effects are cargo bay camera motion and cargo bay door closing motions.


PIMS

SECTION I

Disturbances Measured in the Spacelab Module

GLOVEBOX

MISSION

STS-73, October 1995, USML-2

SOURCE OR ACTIVITY

The glovebox was flown in Rack 12 of the Spacelab module during the USML-2 mission. The glovebox allowed crew members to handle, transfer, and manipulate experiment hardware in ways that are not possible in the open Spacelab environment.

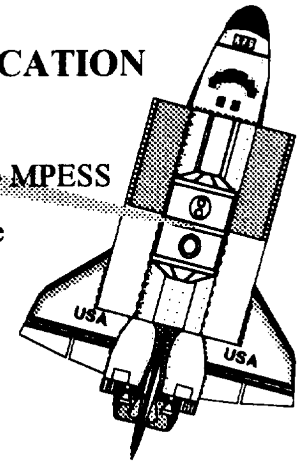
ACCELEROMETER

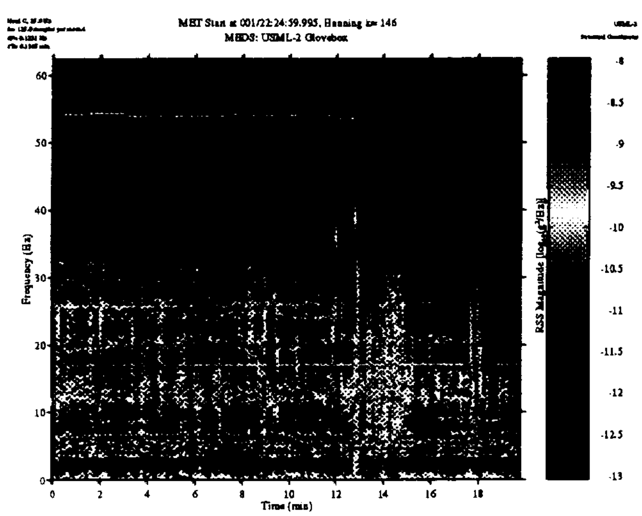
- [x] SAMS
- [ ] OARE

TSH C, 25 Hz
fs = 125 samples per second

MEASUREMENT LOCATION

- [x] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge





Larger plot on reverse

EFFECT ON MICROGRAVITY ENVIRONMENT

The glovebox fans contribute to the microgravity environment, as seen in the first portion of the above plot. As the fans were switched-off, the signals at approximately 13, 20, 39, 48, 51, 53, 58, and 61 Hz are seen to cease.

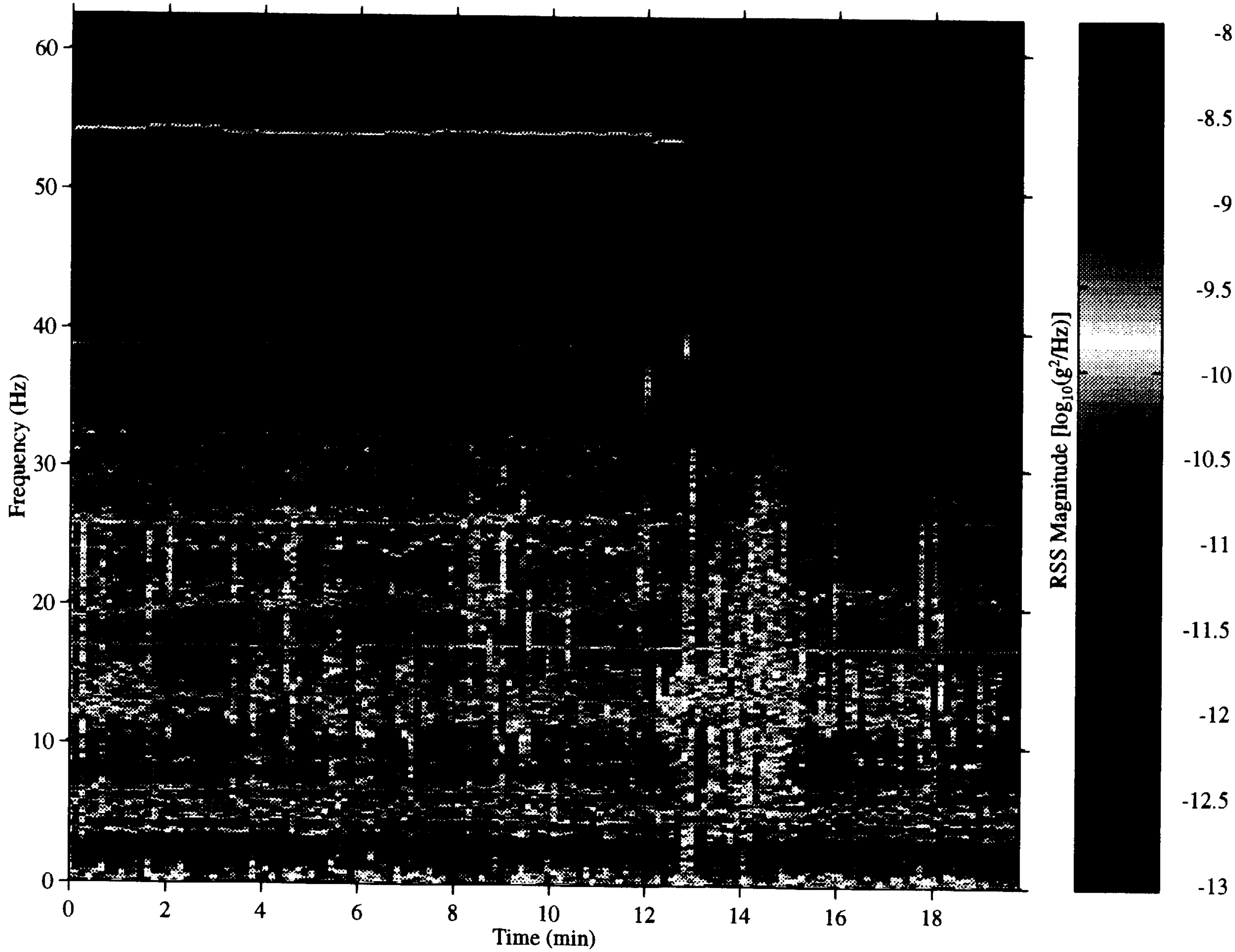
For further information, contact Duc Truong
NASA Lewis Research Center, Cleveland, Ohio.
e-mail: pims@lerc.nasa.gov.

Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

Head C, 25.0 Hz
fs= 125.0 samples per second
dF= 0.1221 Hz
dT= 0.1365 min

MET Start at 001/22:24:59.995, Hanning k= 146
MEDS: USML-2 Glovebox

USML-2
Structural Coordinates



MATLAB: 24-Feb-97, 01:12 pm

HYDRAULIC SYSTEM

MISSION

STS-65, July 1994, IML-2

SOURCE OR ACTIVITY

There are three independent hydraulic systems that are used for operation of actuators to control aero surfaces, main engine gimbals and valves, landing gear, and nose gear steering. On orbit, the hydraulic system's fluids are circulated periodically by electric motor-driven circulation pumps in order to absorb heat from a heat exchanger and distribute it to all areas of the system.

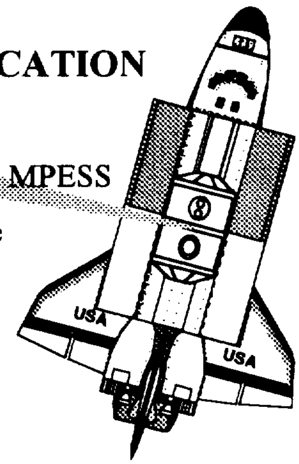
ACCELEROMETER

- [x] SAMS
- [ ] OARE

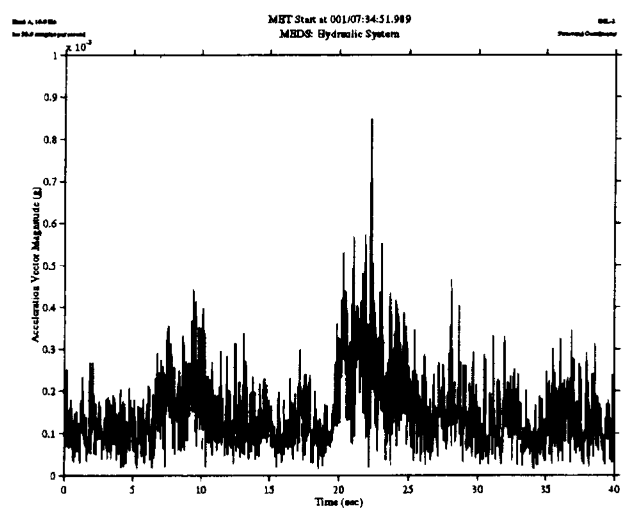
Head A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

- [x] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge



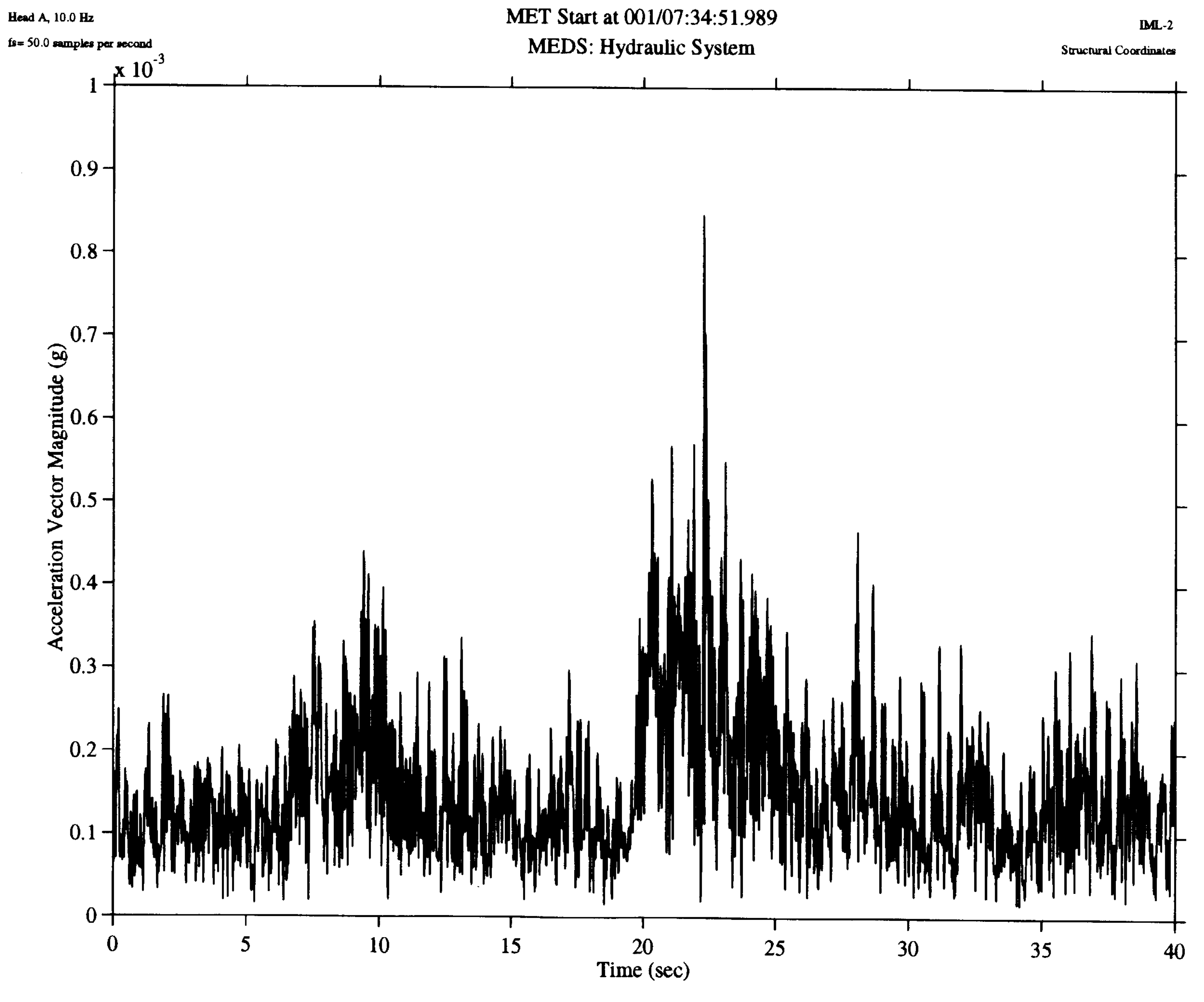
Larger plot on reverse



EFFECT ON MICROGRAVITY ENVIRONMENT

When these pumps are activated, a transient acceleration on the order of 1 mg can be produced. These pumps operate at 10,000 rpm (166.7 Hz) and normally run for several minutes at distinct times throughout a mission. The only noticeable impact, however, has been the transient at turn on.

For further information, contact Duc Truong
NASA Lewis Research Center, Cleveland, Ohio.
e-mail: pims@lerc.nasa.gov.
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


Head A, 10.0 Hz
fs= 50.0 samples per second
MET Start at 001/07:34:51.989
MEDS: Hydraulic System
IML-2
Structural Coordinates
x 10^-3
Acceleration Vector Magnitude (g)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
35
40
Time (sec)

REFRIGERATOR / FREEZER (LSLE)

MISSION

STS-65, July 1994, IML-2

SOURCE OR ACTIVITY

The Life Science Laboratory Equipment refrigerator/freezer was used during IML-2 to preserve perishable samples for postflight analysis. This refrigerator/freezer has a motor driven compressor which cycles on and off to maintain the temperature.

Larger plot on reverse

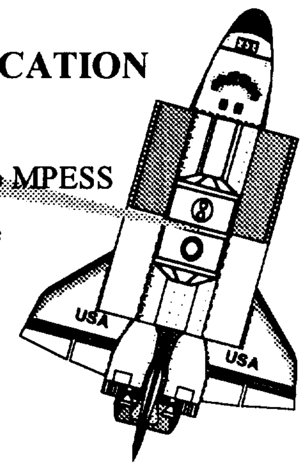
ACCELEROMETER

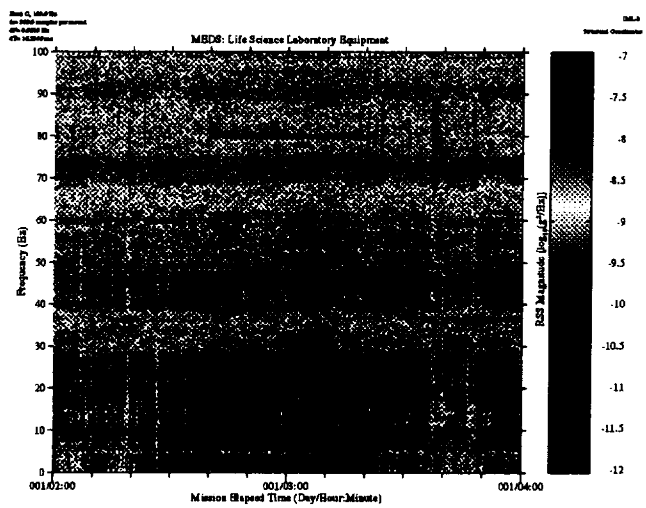
☑ SAMS ☐ OARE

Head C, 100 Hz
fs = 500 samples per second

MEASUREMENT LOCATION

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





EFFECT ON MICROGRAVITY ENVIRONMENT

Cycling of its compressor produced an intermittent oscillatory disturbance with a fundamental frequency around 22 Hz and with second, third, and fourth harmonics visible below the filter cutoff frequency. The LSLE operated for the duration of the mission with a duty cycle ranging from 9 to 13 minutes on and 16 to 25 minutes off. Root-mean-square acceleration levels resulting from this 22 Hz component are typically about 400 μg_{RMS}. This refrigerator/freezer was also operated on STS-42, STS-47, and STS-78.

For further information, contact Duc Truong
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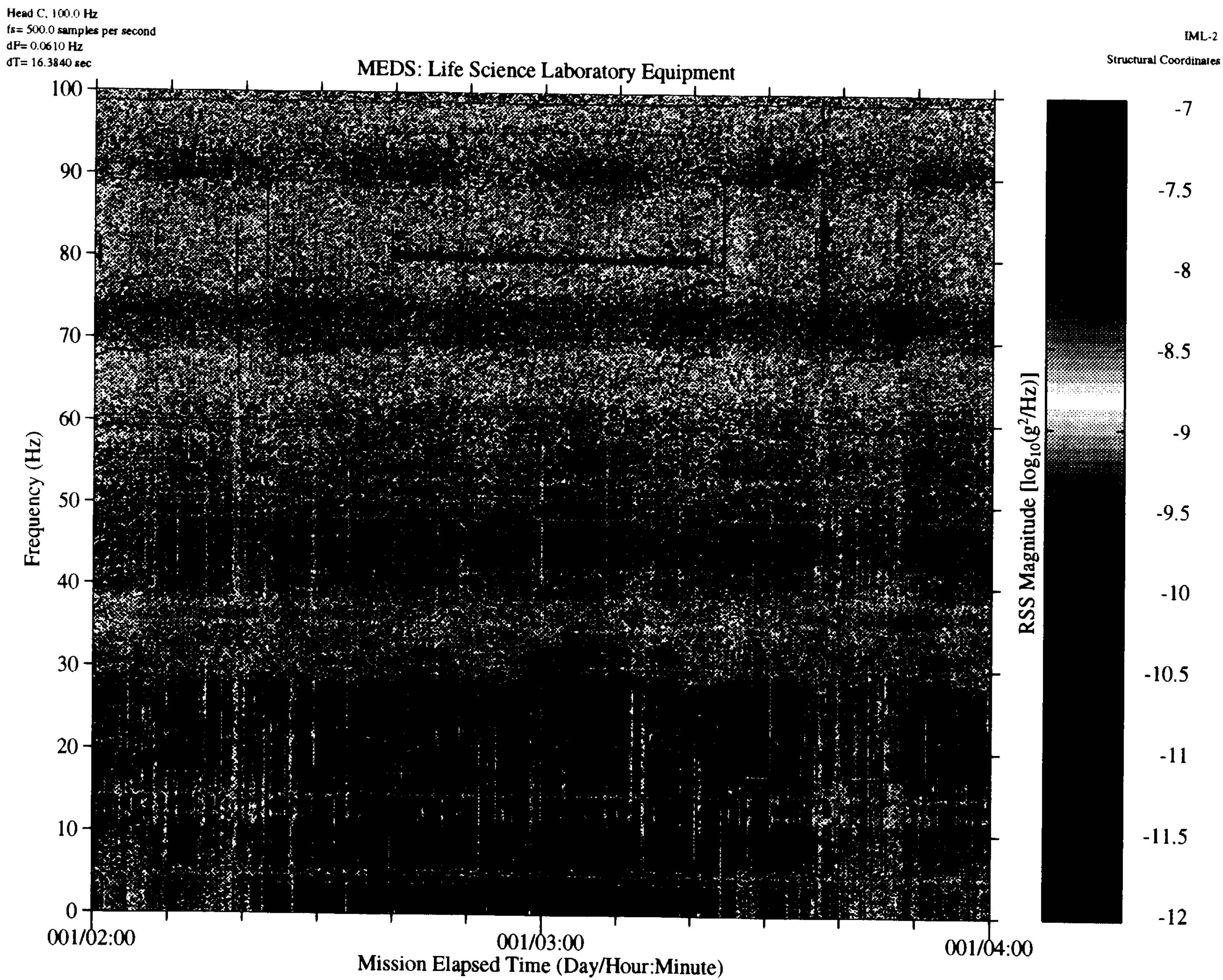
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



Head C, 100.0 Hz
fs= 500.0 samples per second
dF= 0.0610 Hz
dT= 16.3840 sec
MEDS: Life Science Laboratory Equipment
IML-2
Structural Coordinates
Frequency (Hz)
100
90
80
70
60
50
40
30
20
10
0
001/02:00
001/03:00
001/04:00
Mission Elapsed Time (Day/Hour:Minute)
RSS Magnitude [$\log_{10}(g^2/Hz)$]
-7
-7.5
-8
-8.5
-9
-9.5
-10
-10.5
-11
-11.5
-12

TEMPUS

MISSION
STS-65, July 1994, IML-2

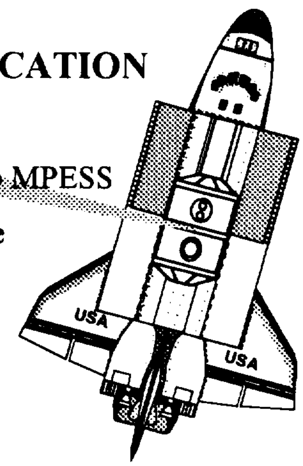
SOURCE OR ACTIVITY
During IML-2, TEMPUS enabled investigators to study various thermodynamic and kinetic properties of different samples without contamination from container walls. For each run, a spherical sample is levitated by an electromagnetic coil, melted, and then cooled. The TEMPUS facility utilized a water pump with a nominal rotational rate of 4800 rpm (80 Hz).

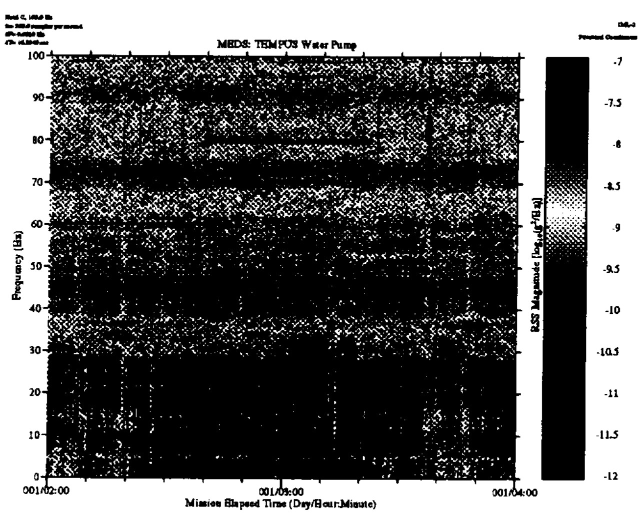
Larger plots on reverse

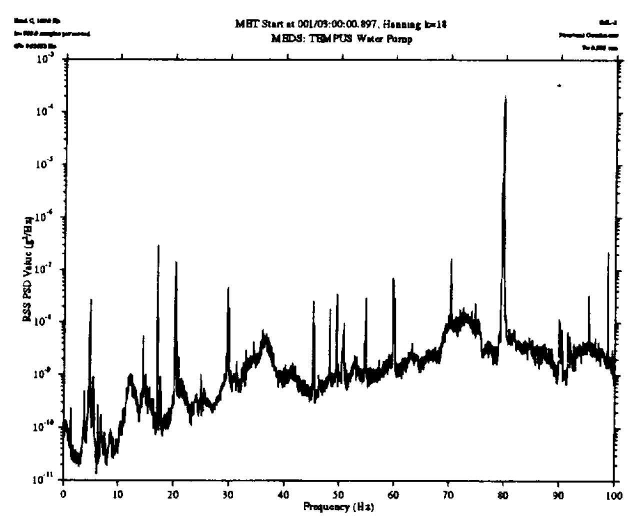
ACCELEROMETER
- [x] SAMS
- [ ] OARE

Head C, 100 Hz
fs = 500 samples per second

MEASUREMENT LOCATION
- [x] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge







EFFECT ON MICROGRAVITY ENVIRONMENT
When this pump was operating (duration times ranging from 10 minutes to over 7 hours), it caused a substantial disturbance around 80 Hz with a magnitude of 4 to 5 mg_{RMS}.

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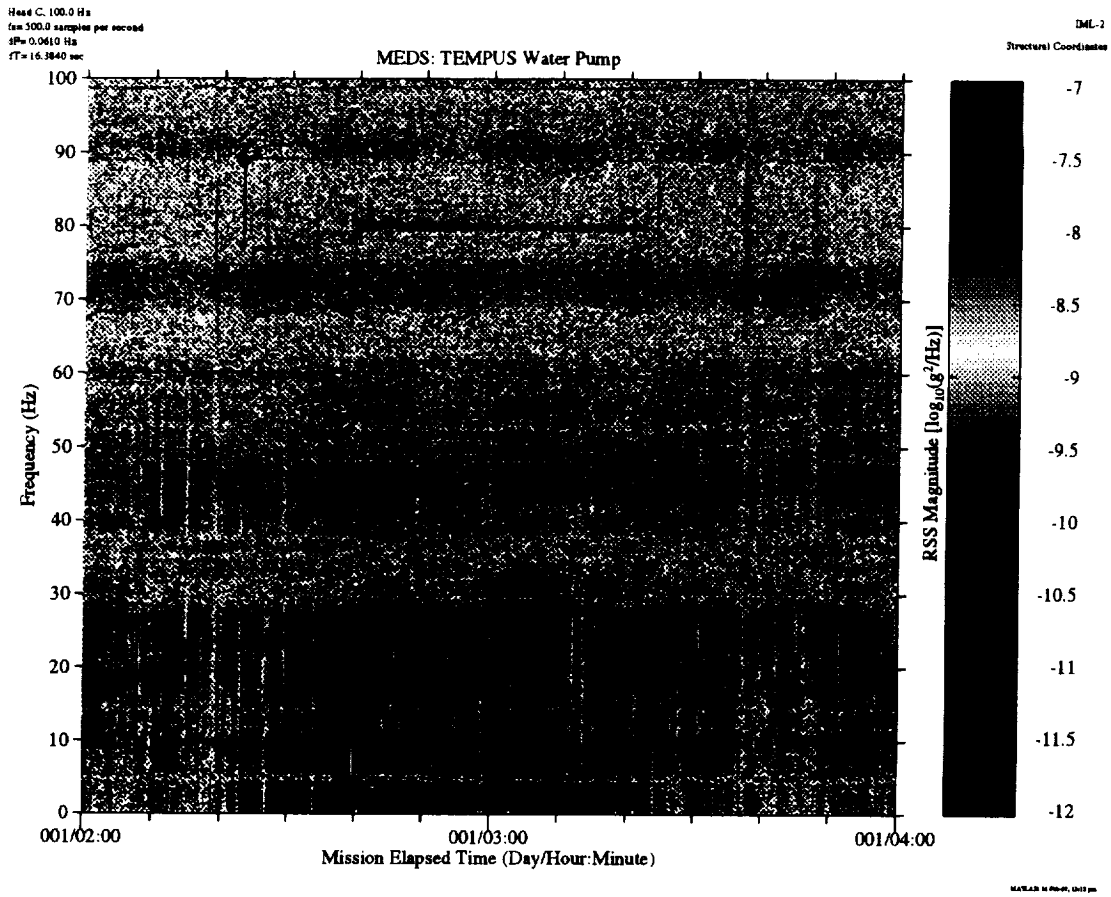
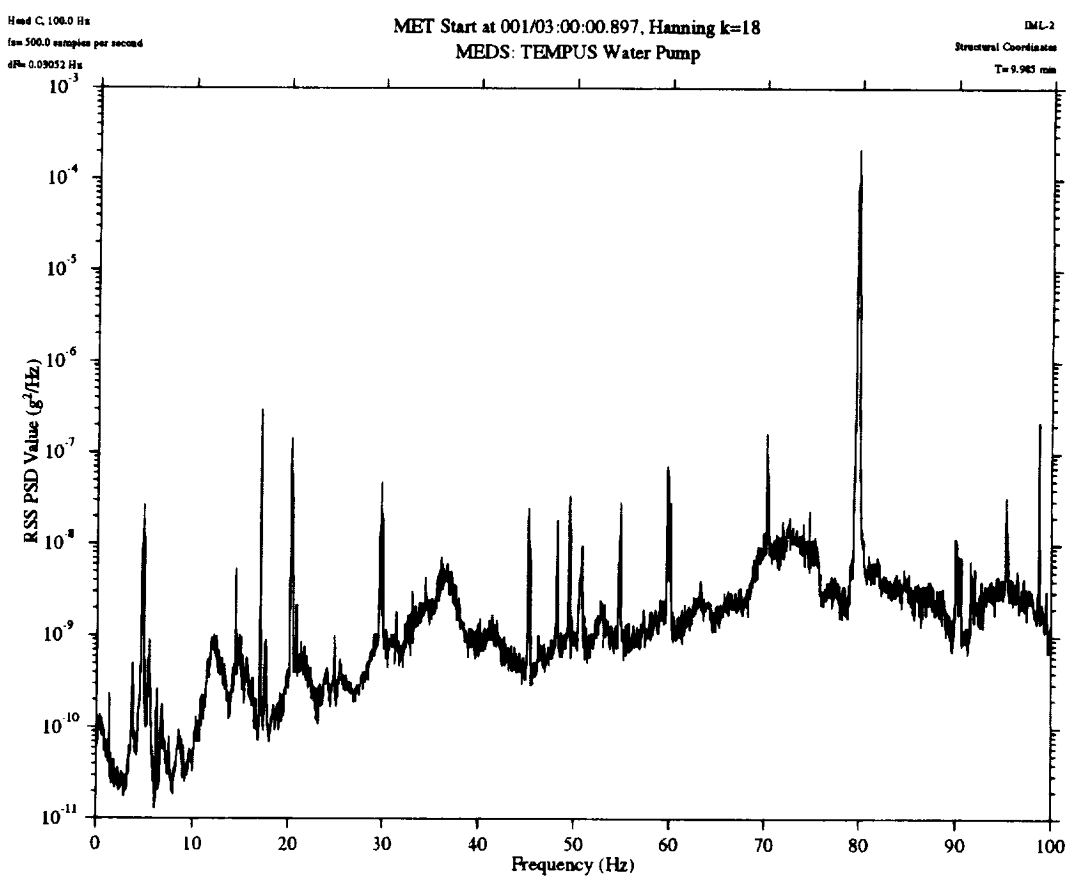
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



Head C, 100.0 Hz
fs= 500.0 samples per second
df= 0.0610 Hz
dT= 16.3840 sec
MEDS: TEMPUS Water Pump
IML-2
Structural Coordinates
Frequency (Hz)
RSS Magnitude [$\log_{10}(g^2/Hz)$]
Mission Elapsed Time (Day/Hour:Minute)
001/02:00
001/03:00
001/04:00



Head C, 100.0 Hz
fs= 500.0 samples per second
df= 0.03052 Hz
MET Start at 001/03:00:00.897, Hanning k=18
MEDS: TEMPUS Water Pump
IML-2
Structural Coordinates
T= 9.985 min
RSS PSD Value (g^2/Hz)
Frequency (Hz)

Ku-BAND ANTENNA

MISSION

STS-65, July 1994, IML-2

ACCELEROMETER

- [x] SAMS
- [ ] OARE

Head C, 100 Hz
fs = 500 samples per second

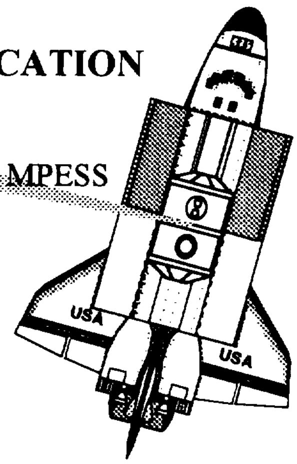
SOURCE OR ACTIVITY

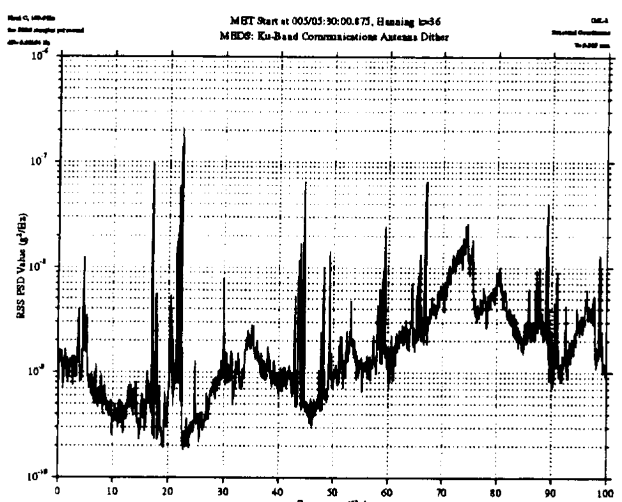
The Ku-band antenna is located in the forward portion of the payload bay on the starboard side of the vehicle. On orbit, this antenna is deployed for communications between the orbiter and the Tracking Data Relay Satellite System (TDRSS). It is dithered at 17 Hz to prevent stiction of the gimbal mechanism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

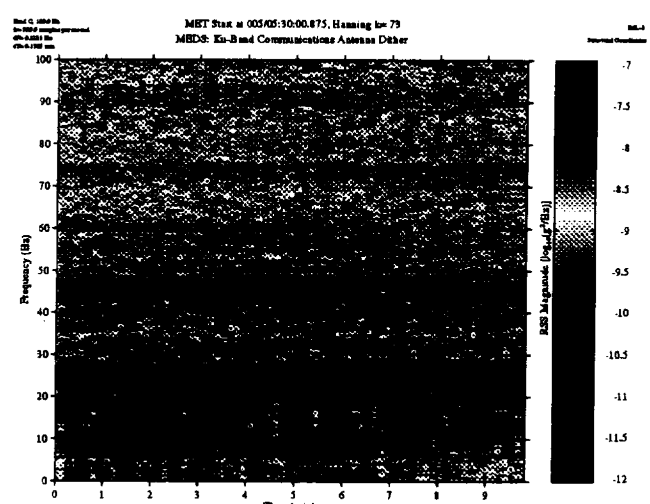
Larger plots on reverse

MEASUREMENT LOCATION

- [x] 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.

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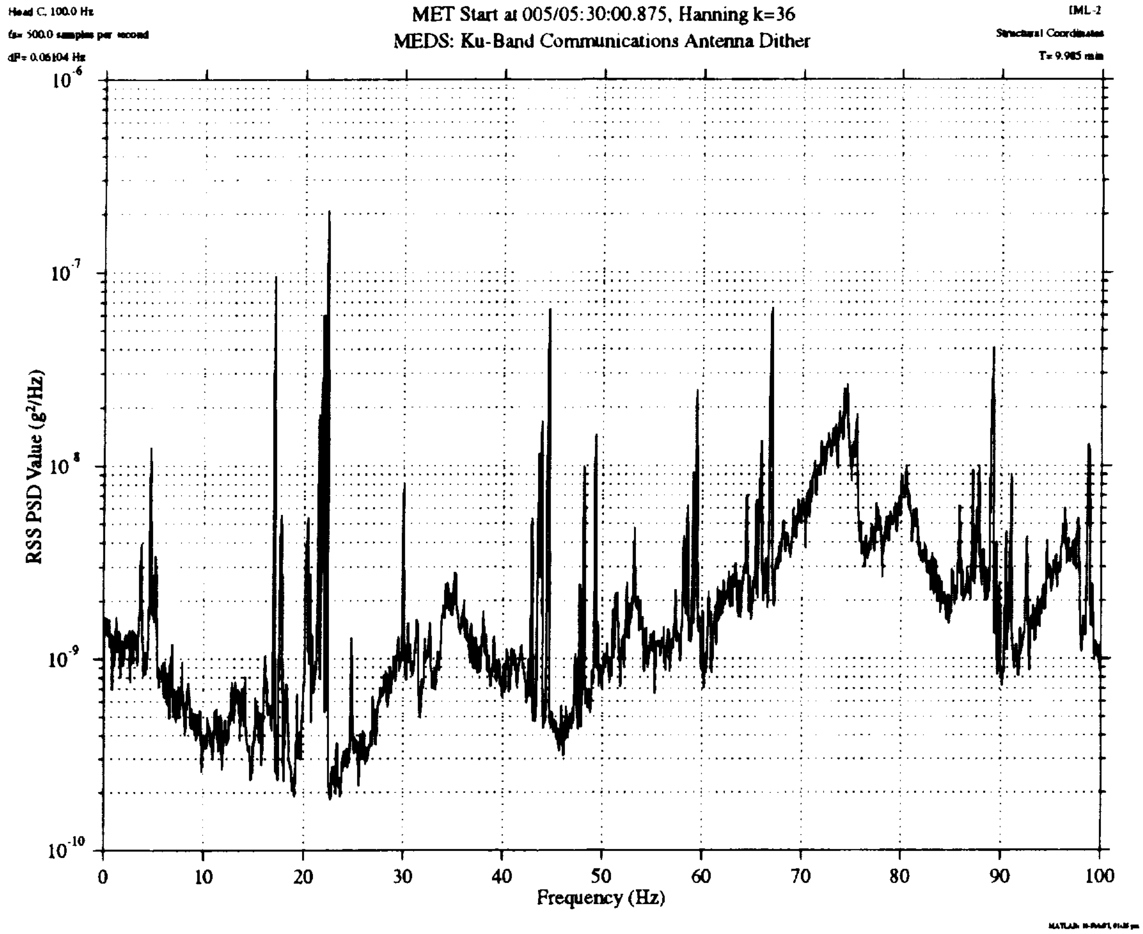
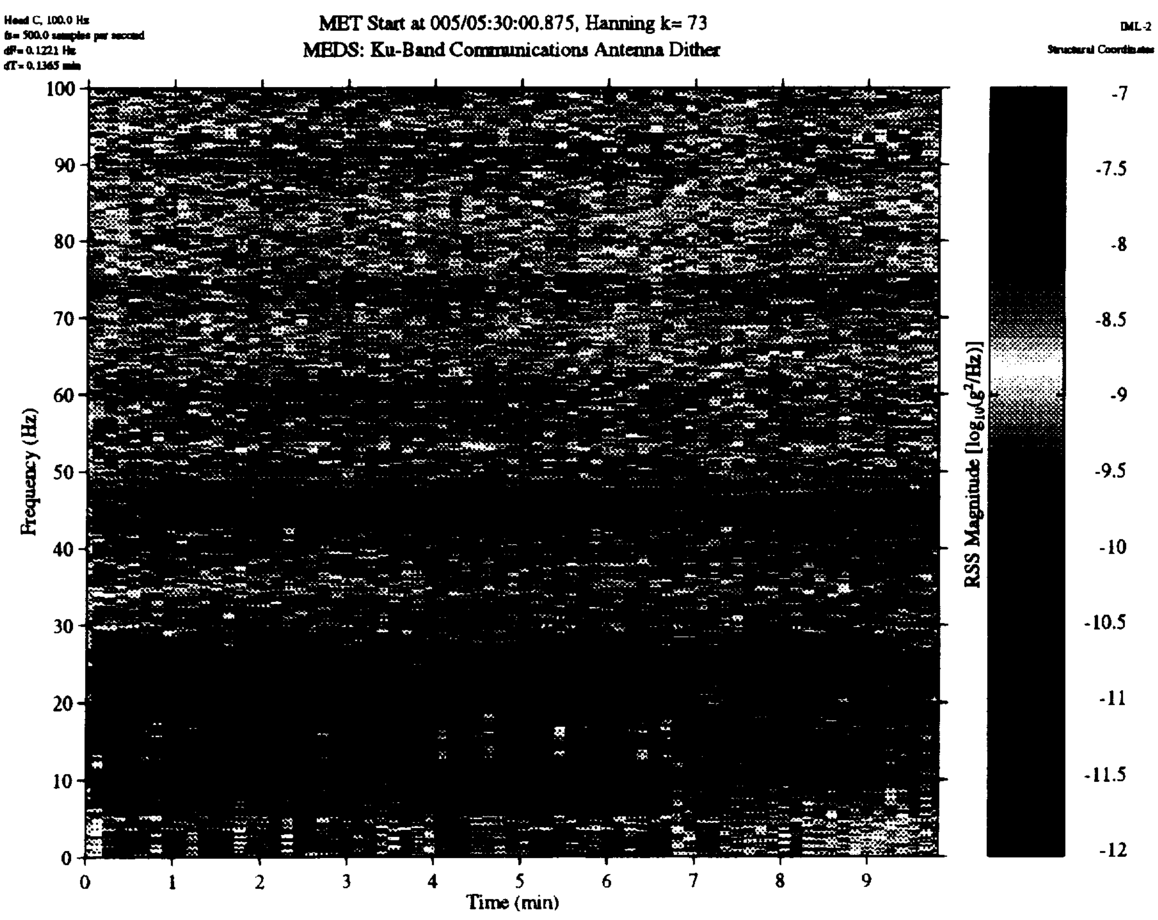


Head C, 100.0 Hz
fs= 500.0 samples per second
dF= 0.06104 Hz
MET Start at 005/05:30:00.875, Hanning k=36
MEDS: Ku-Band Communications Antenna Dither
IML-2
Structural Coordinates
T= 9.985 min
RSS PSD Value (g^2/Hz)
Frequency (Hz)



Head C, 100.0 Hz
fs= 500.0 samples per second
dF= 0.1221 Hz
dT= 0.1365 min
MET Start at 005/05:30:00.875, Hanning k= 73
MEDS: Ku-Band Communications Antenna Dither
IML-2
Structural Coordinates
Frequency (Hz)
Time (min)
RSS Magnitude [$\log_{10}(g^2$/Hz)]

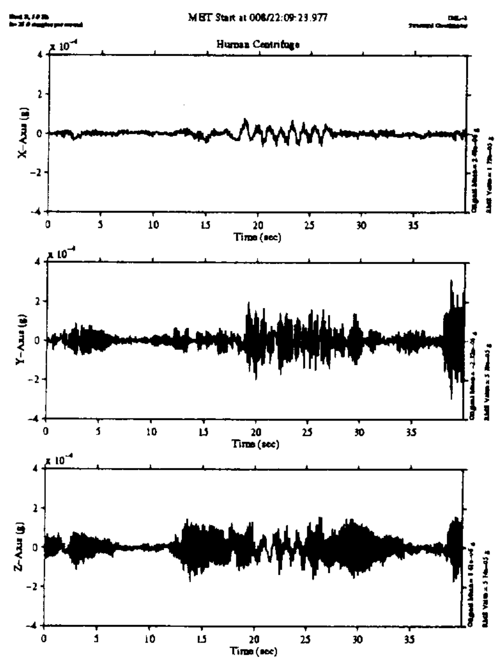
CENTRIFUGE *(crew member)*

MISSION

STS-65, July 1994, IML-2

SOURCE OR ACTIVITY

Experiment operations required a crew member to mix liquid experiment components. In live video downlink of this activity, the crew member was observed to be swinging the sample bag around, making full circles with his arm.



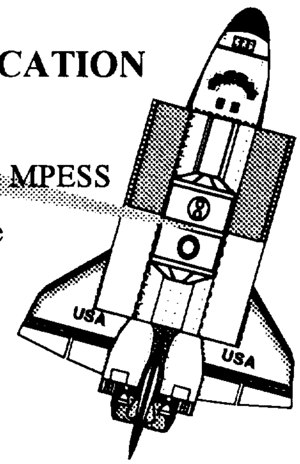
ACCELEROMETER

- [x] SAMS
- [ ] OARE

Head B, 5 Hz
fs = 25 samples per second

MEASUREMENT LOCATION

- [x] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge



Larger plot on reverse

EFFECT ON MICROGRAVITY ENVIRONMENT

The swinging frequency of the crew member's arm (about 8 cycles in 10 seconds) and his alignment imparted a 0.8 Hz disturbance mainly on the X_0 and Z_0 axes where peak-to-peak acceleration levels reached approximately 100 μg.

For further information, contact Duc Truong
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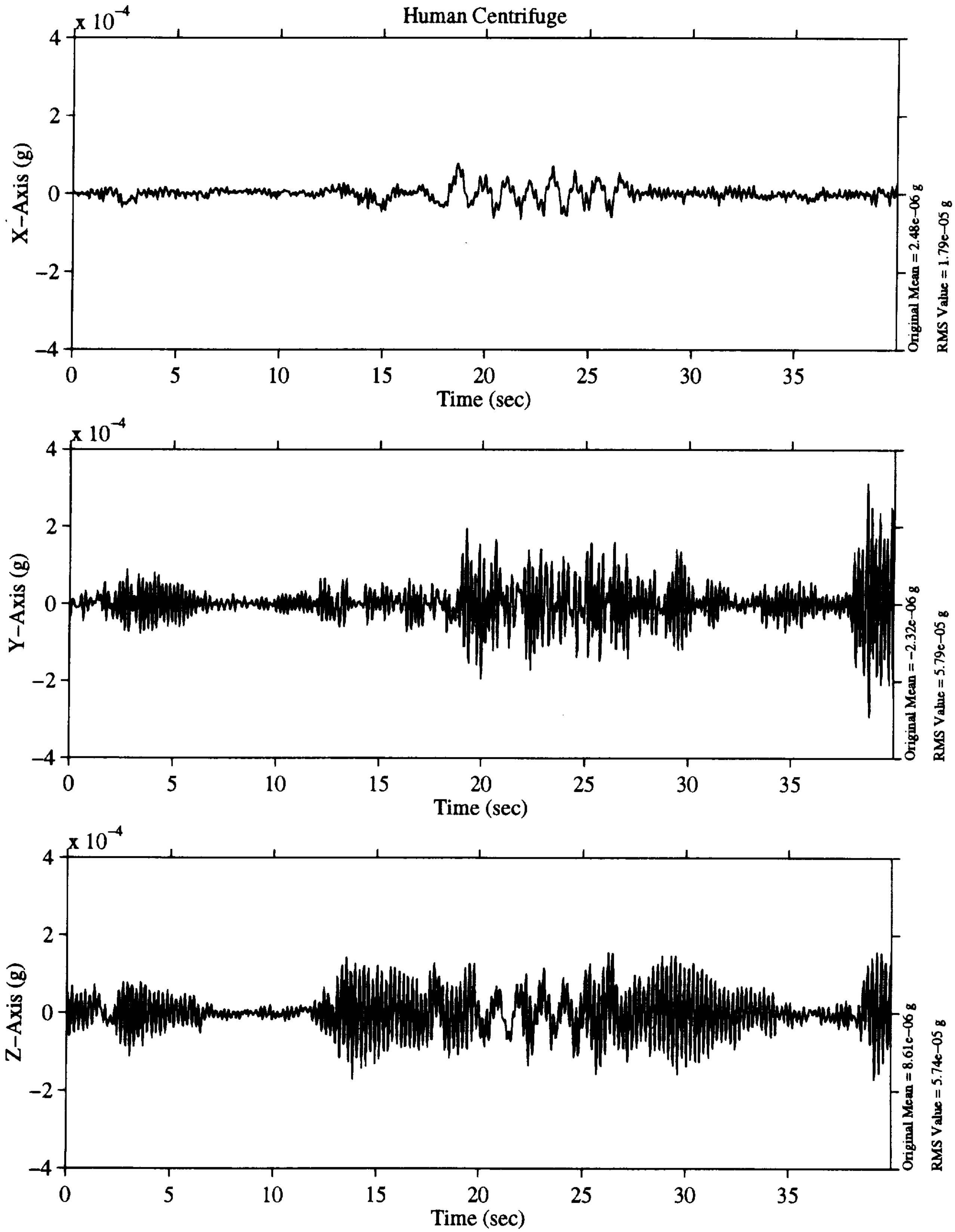
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

Head B, 5.0 Hz
fs= 25.0 samples per second

MET Start at 008/22:09:23.977

IML-2
Structural Coordinates



MATLAB: 13-Sep-96, 10:10 am

CREW SLEEP

MISSION

STS-78, June 1996, LMS

SOURCE OR ACTIVITY

On single shift missions, the microgravity environment becomes quiet during crew sleep. During these periods, crew induced disturbances, as well as disturbances from equipment requiring crew interaction are minimized. The lower activity level also leads to a diminished excitement of the vehicle structural modes.

Notice the characteristic transition to sleep shown in this spectrogram. Around MET 001/11:20, there is a diminished activity level (notice the quieting of the microgravity environment under 10 Hz, particularly at the structural resonance frequencies). Then at MET 001/13:20, there is a further quieting of the environment, lasting until MET 001/17:20, with a subsequent increase again at MET 001/19:00. This 2-step quieting is characteristic of sleep periods, apparently showing a gradual change in activity during pre-sleep and post-sleep periods.

Larger plot on reverse

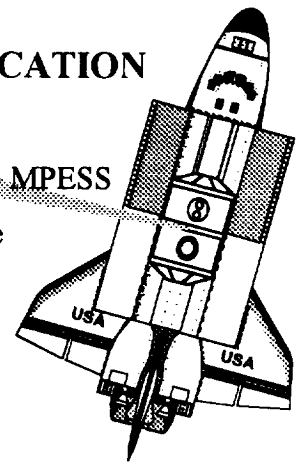
ACCELEROMETER

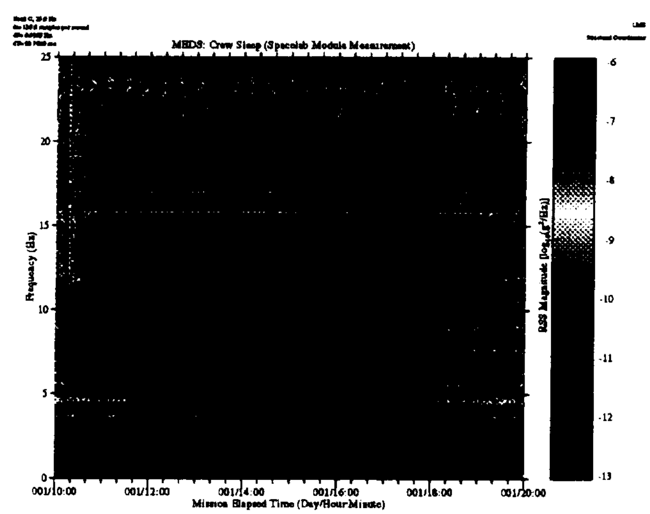
- [x] SAMS
- [ ] OARE

Head C, 25 Hz
fs = 125 samples per second

MEASUREMENT LOCATION

- [x] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge





EFFECT ON MICROGRAVITY ENVIRONMENT

Sleep during a single shift mission such as LMS results in acceleration levels in the 1 to 4 Hz range below about 3 μg_{RMS}. Vehicle structural modes, the Ku-band antenna, and refrigerator/freezer are the primary disturbance sources during crew sleep. Due to signal aliasing, this plot shows apparent frequencies in the 2-4 Hz region, aligned with the LSLE R/F operations. These aliases are a data artifact, and not indicative of the true microgravity environment. See Section 1 for more information on signal aliasing.

For further information, contact Duc Truong
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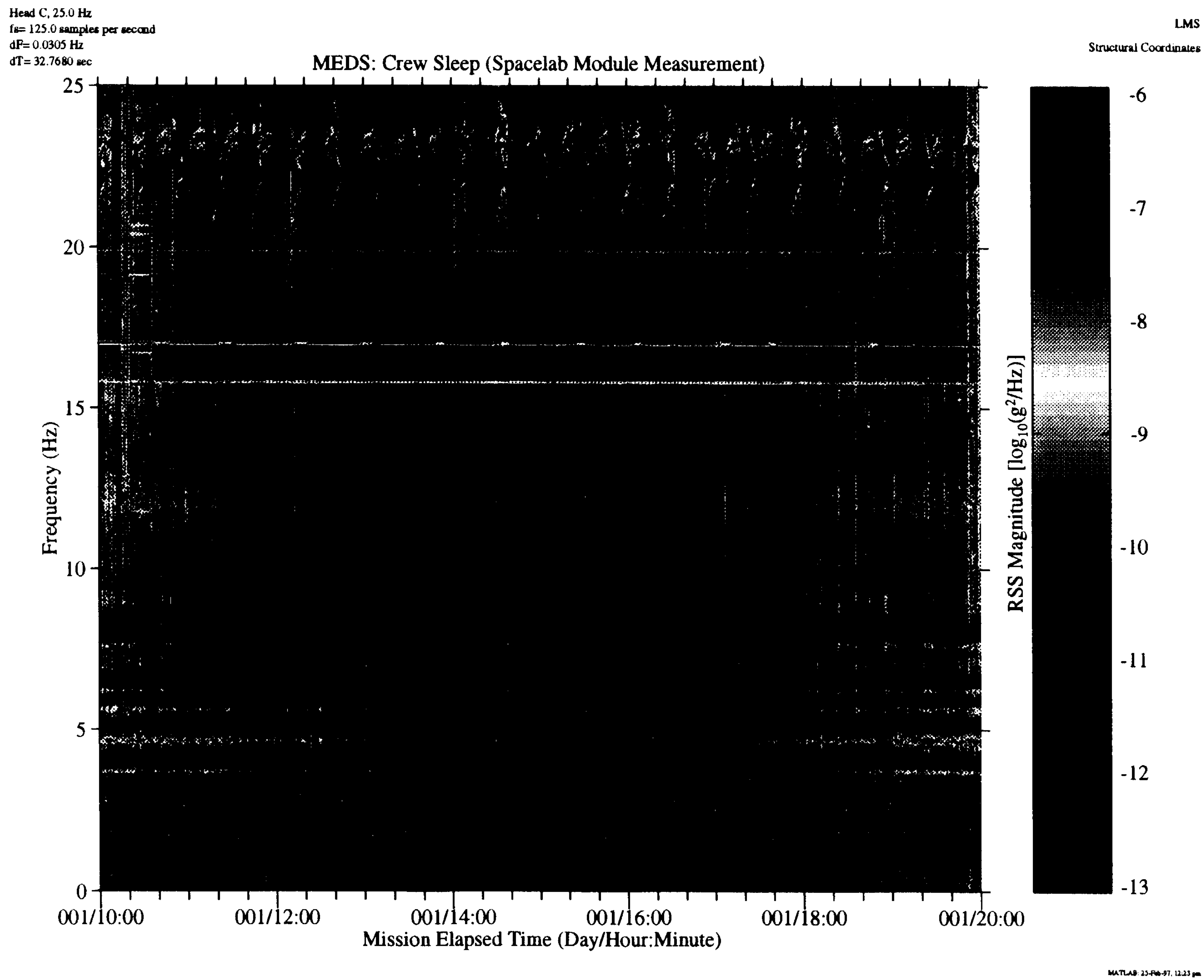

Head C, 25.0 Hz
fs= 125.0 samples per second
dF= 0.0305 Hz
dT= 32.7680 sec
MEDS: Crew Sleep (Spacelab Module Measurement)
LMS
Structural Coordinates
Frequency (Hz)
25
20
15
10
5
0
001/10:00
001/12:00
001/14:00
001/16:00
001/18:00
001/20:00
Mission Elapsed Time (Day/Hour:Minute)
RSS Magnitude [$\log_{10}(g^2/Hz)$]
-6
-7
-8
-9
-10
-11
-12
-13
MATLAB: 25-Feb-97, 12:23 pm

ERGOMETER *(crew exercise)*

MISSION

STS-65, July 1994, IML-2

SOURCE OR ACTIVITY

The ergometer is a bicycle-type of exercise equipment in that pedaling is the primary means of getting exercise. This equipment has been configured with various forms of isolation systems on different shuttle missions.

(1) Hard-mounted - No isolation is employed, it is bolted directly to the middeck or flight deck.

(2) Inertial Vibration Isolation System (IVIS) - This isolation system is primarily aimed at combatting the side-to-side motion of the person who is exercising. Counter-weights are driven by the pedal shaft to be 180° out of phase with the side-to-side motion.

(3) Passive Cycle Isolation System (PCIS) - This system attempts to "free-float" the exercise equipment via four braided cable, wire-rope isolators.

(4) Ergometer Vibration Isolation System (EVIS) - This is a three-axis vibration isolation system. The ergometer Z-axis isolation is an active system of counterweights which react to the motion of the crew member. The ergometer X- and Y-axis isolation is accomplished by a two-axis slide on the floor of the mounting assembly.

(5) Bungee isolation- In this configuration, a recumbent bicycle is suspended by a system of elastic bungee cords. These cords are secured to various points on the surrounding shuttle structure. The suspension support is primarily in the XY plane of the ergometer.

Larger plot on reverse

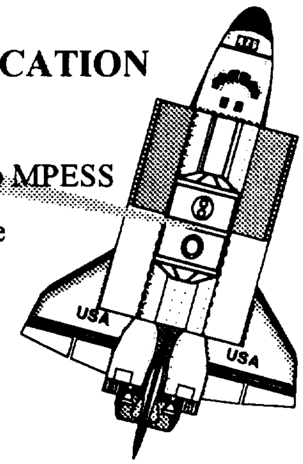
ACCELEROMETER

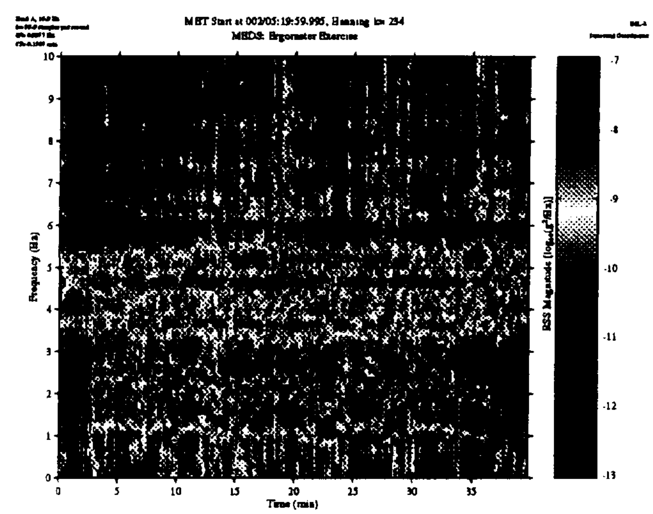
☑ SAMS ☐ OARE

Head A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

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





EFFECT ON MICROGRAVITY ENVIRONMENT

The effects of exercising on the microgravity environment are seen mainly in the frequency range from about 1 Hz to 4 Hz and last for the duration of the exercise. Depending on the particular crew member and the vibration isolation used, typical acceleration levels in this frequency range can vary between 50 μg_{RMS} to about 1 mg_{RMS}.

For further information, contact Duc Truong
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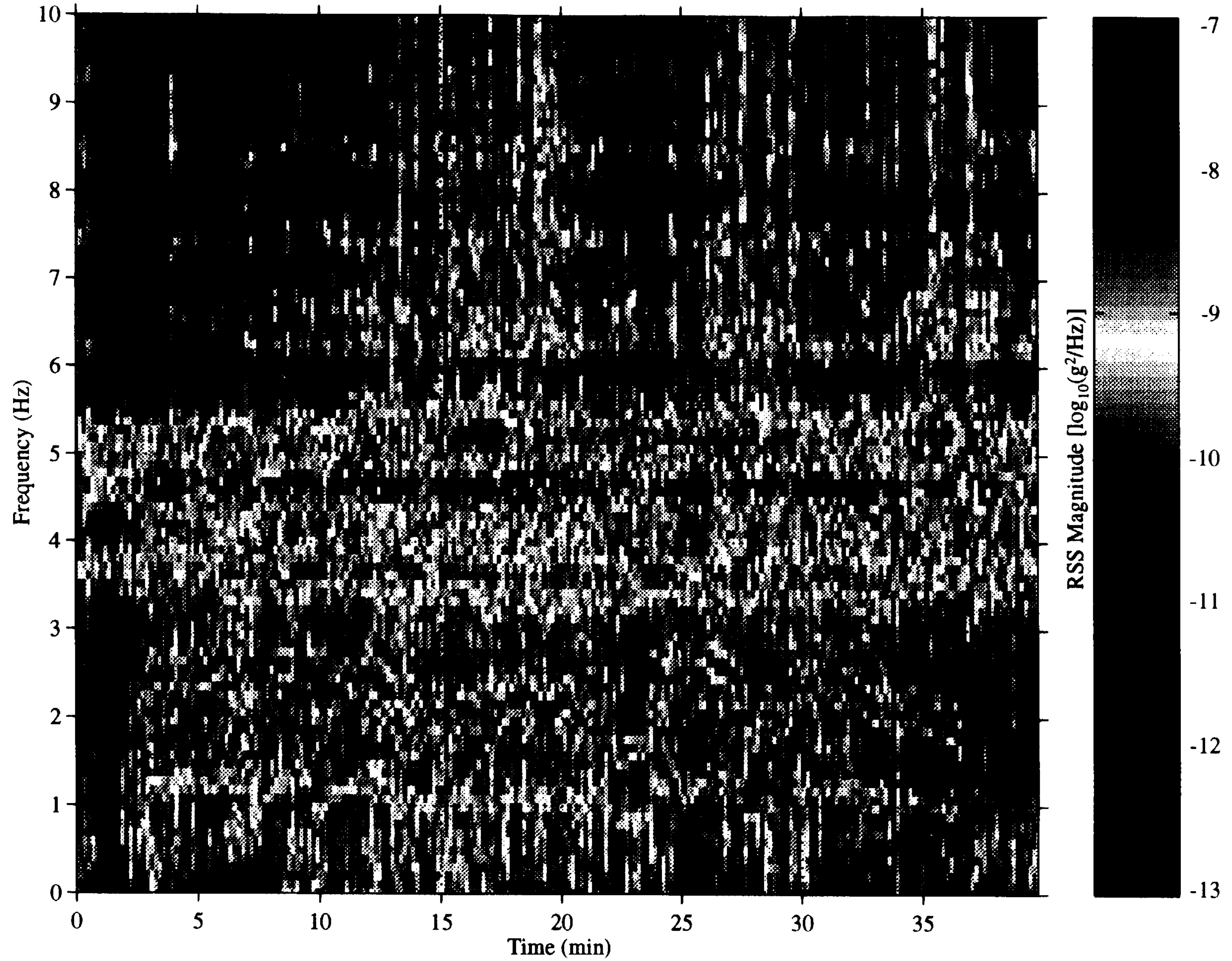
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

Head A, 10.0 Hz
fs= 50.0 samples per second
dF= 0.0977 Hz
dT= 0.1707 min

MET Start at 002/05:19:59.995, Hanning k= 234
MEDS: Ergometer Exercise

IML-2
Structural Coordinates



MATLAB 24-Feb-97, 12:49 pm

PAO EVENT

MISSION

STS-65, July 1994, IML-2

SOURCE OR ACTIVITY

Scheduled demonstration or question and answer events with some or all of the crew gathered in a single area.

Larger plots on reverse

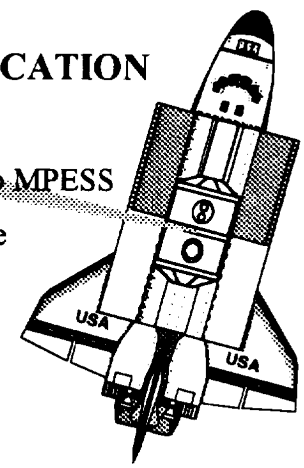
ACCELEROMETER

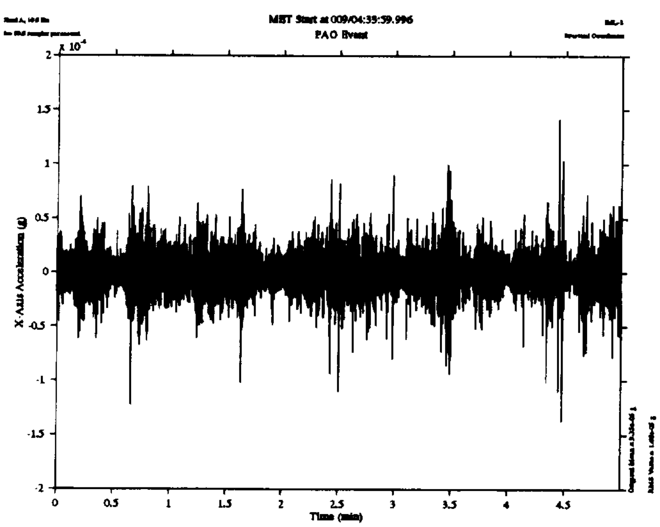
☑ SAMS ☐ OARE

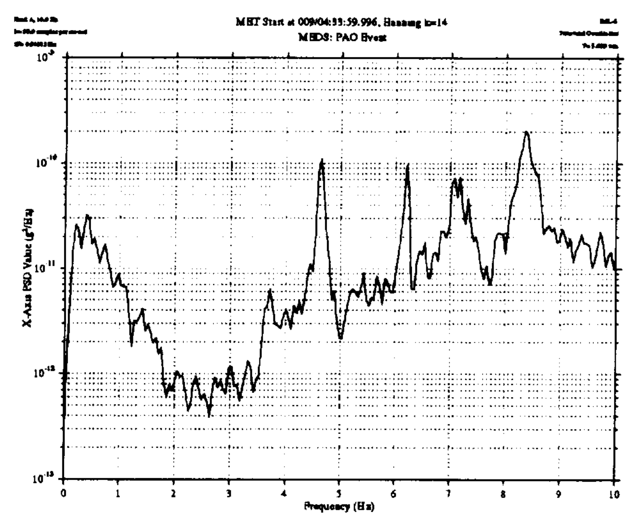
Head A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

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







EFFECT ON MICROGRAVITY ENVIRONMENT

It is common that when PAO events take place, the microgravity environment becomes quieter. The crew is typically not moving about or impacting the spacecraft structure, they are usually free-floating in front of a camera. Also, experiment operations involving crew interaction are not being conducted for the duration of the PAO event. This tends to reduce the overall acceleration background level below 10 Hz to less than 50 μg_{RMS}. Vehicle structural modes and the Ku-band antenna are the primary disturbance sources during PAO events.

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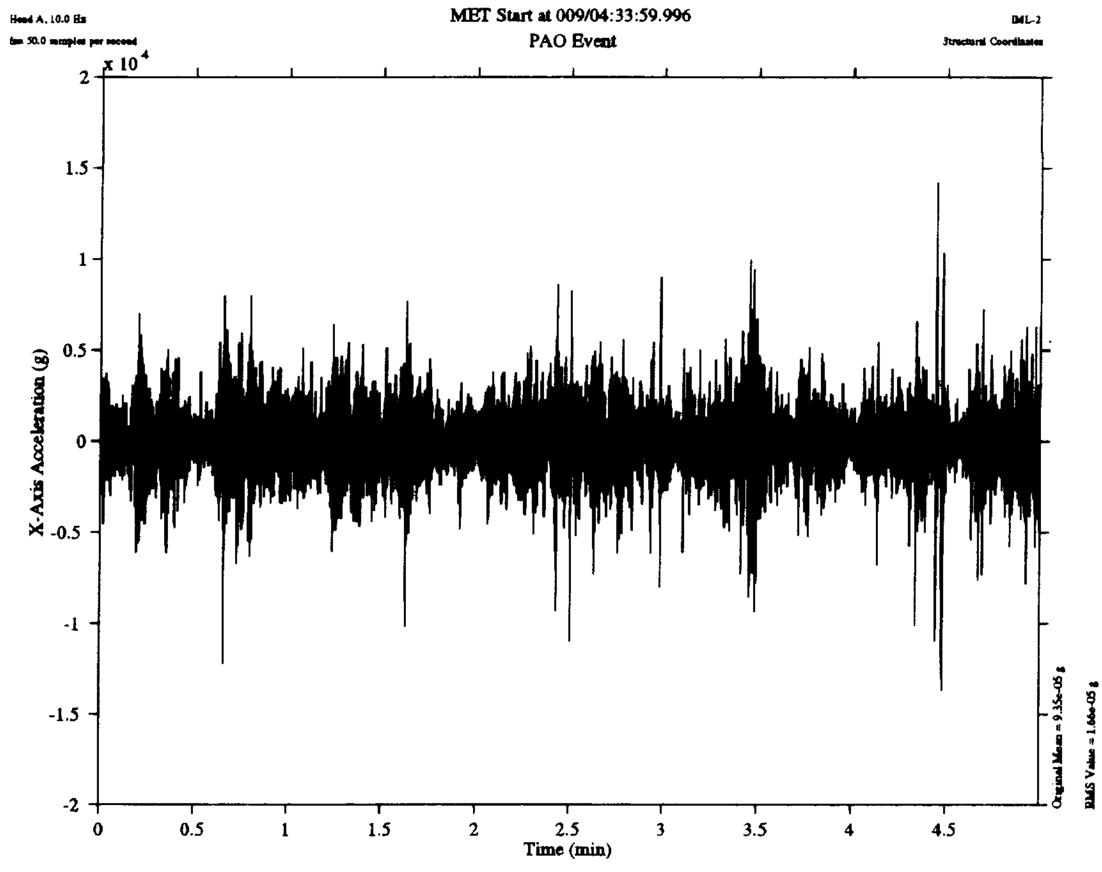
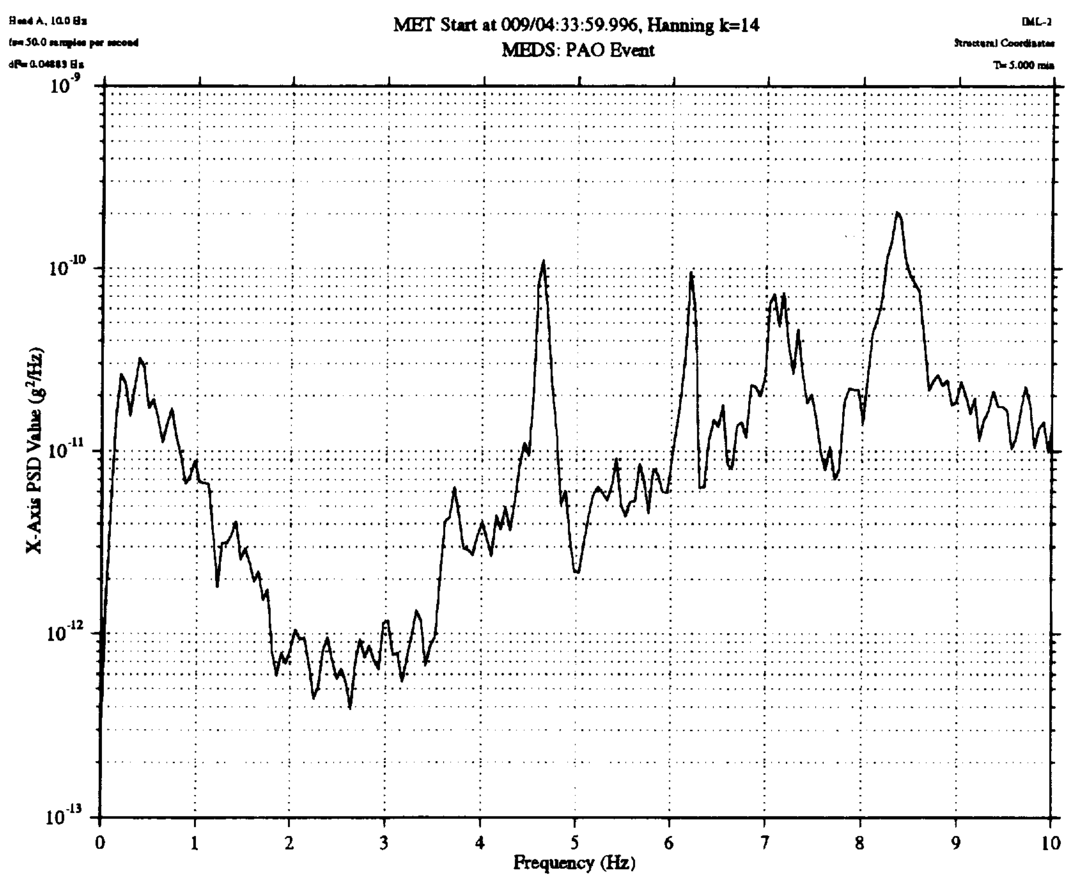
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



Head A, 10.0 Hz
fs= 50.0 samples per second
MET Start at 009/04:33:59.996
PAO Event
IML-2
Structural Coordinates
X-Axis Acceleration (g)
Time (min)
Original Mean = 9.35e-05 g
RMS Value = 1.66e-05 g

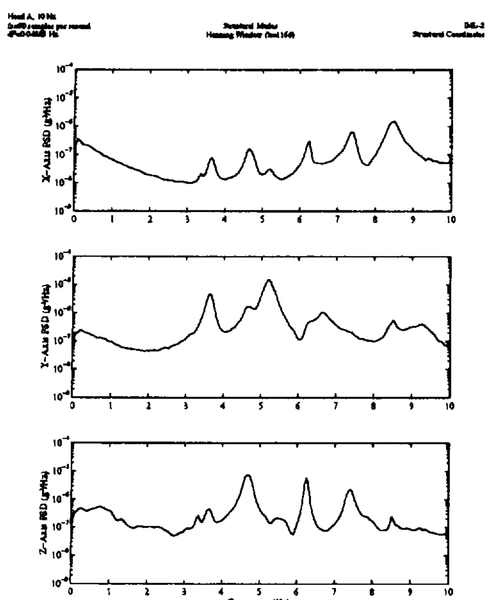


Head A, 10.0 Hz
fs= 50.0 samples per second
df= 0.04883 Hz
MET Start at 009/04:33:59.996, Hanning k=14
MEDS: PAO Event
IML-2
Structural Coordinates
T= 5.000 min
X-Axis PSD Value (g²/Hz)
Frequency (Hz)

STRUCTURAL MODES

MISSION
STS-65, July 1994, IML-2

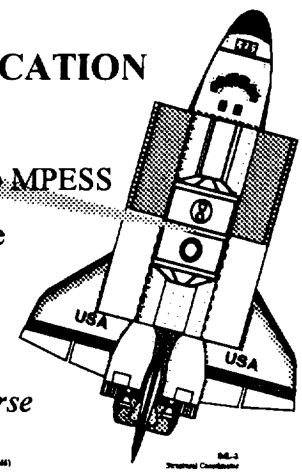
SOURCE OR ACTIVITY
Any structure, including the Orbiter, has natural frequencies characteristic of its underlying construction. These depend on many factors such as mass distribution, materials used in its fabrication, construction method, and so on.



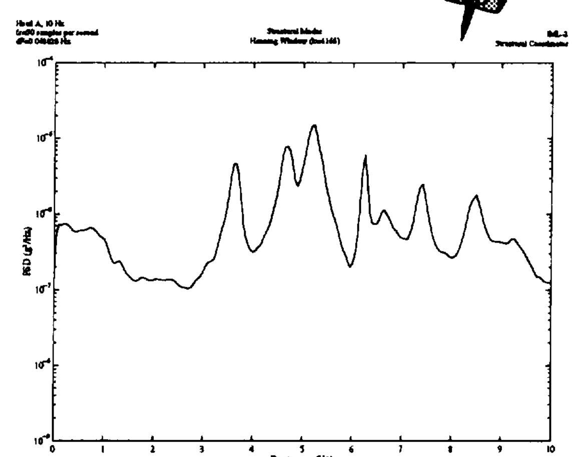
ACCELEROMETER
☑ SAMS ☐ OARE

Head A, 10 Hz
fs = 50 samples per second

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



Larger plots on reverse



EFFECT ON MICROGRAVITY ENVIRONMENT
Nominally, the spectrum below about 10 Hz is dominated by the structural modes of the Orbiter. As shown in the single axis plot, the shuttle has significant structural modes at about 3.6, 4.7, 5.2, 6.2, 7.4, and 8.5 Hz for the Spacelab module mounted in the cargo bay. Transient and oscillatory disturbances will excite these modes. Most notable is the response to thruster firings and crew exercise. As seen in the 3-axis plot, the structural modes at 3.6 and 5.2 Hz are aligned primarily with the Orbiter structural Y_o-axis, while the 4.7 Hz mode is felt strongest on the Orbiter structural Z_o-axis. The modes at 6.2 and 7.4 Hz have components in the Orbiter structural XZ-plane, while the 8.5 Hz mode is most pronounced on the X_o-Axis. Some of the Orbiter natural frequencies have been identified. For example, the 3.6 Hz mode corresponds to fuselage torsion wing and fin bending. The 5.2 Hz mode corresponds to fuselage first normal bending and the 7.4 Hz mode corresponds to fuselage first lateral bending. Structural modes associated with the payload bay doors and radiators are discussed on separate pages of this handbook.œÀ

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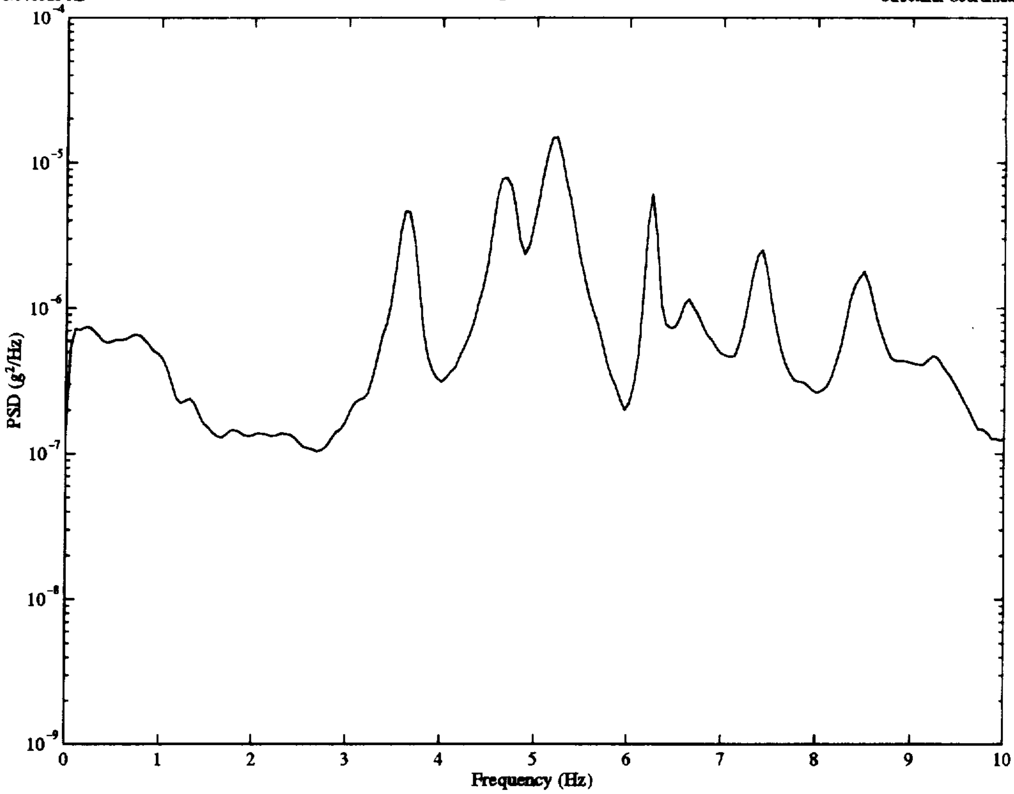
Head A, 10 Hz
fs=50 samples per second
dF=0.048828 Hz

Structural Modes
Hanning Window (k=1166)

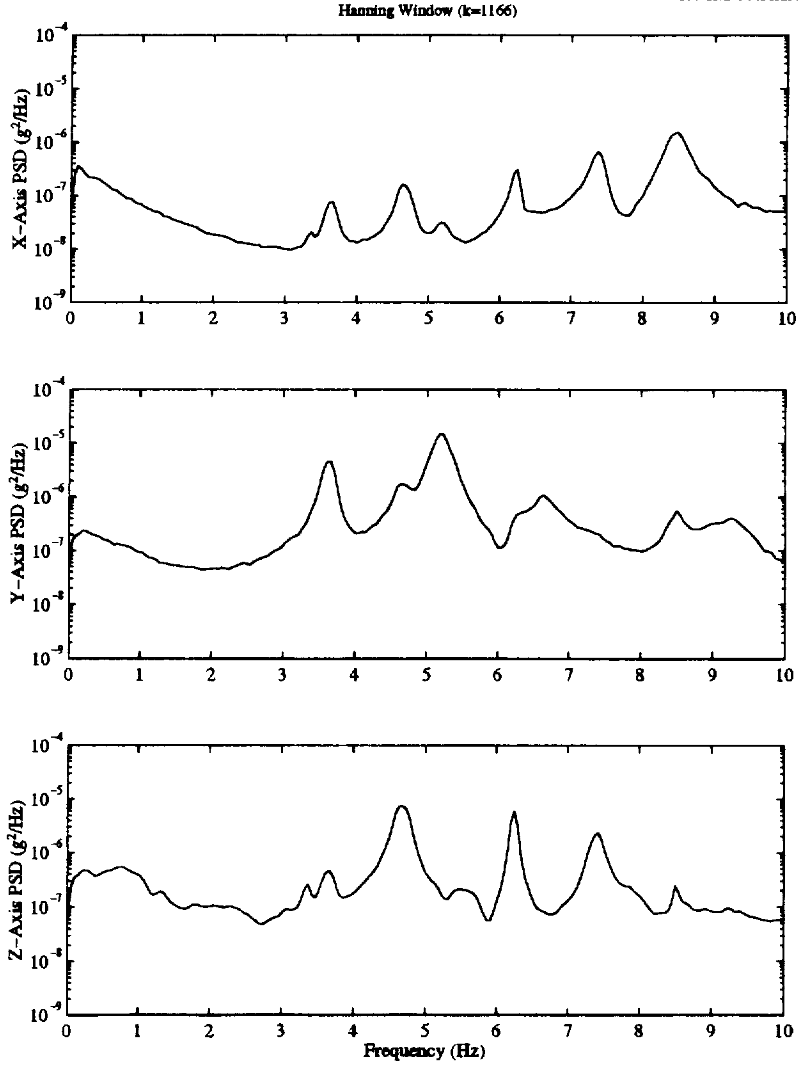
IML-2
Structural Coordinates



Head A, 10 Hz
fs=50 samples per second
dF=0.04883 Hz

Structural Modes
Hanning Window (k=1166)

IML-2
Structural Coordinates



ROWER *(crew exercise)*

MISSION

STS-42, January 1992, IML-1

SOURCE OR ACTIVITY

The rower is hard-mounted to the Orbiter middeck. There is an interface frame which allows the rower to be installed in place of any seat. Crews have also performed some resistive type exercises (bicep curls, squats, etc.) which they have adapted to meet the machine's operating characteristics.

Larger plots on reverse

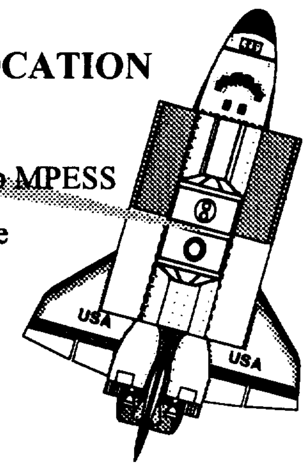
ACCELEROMETER

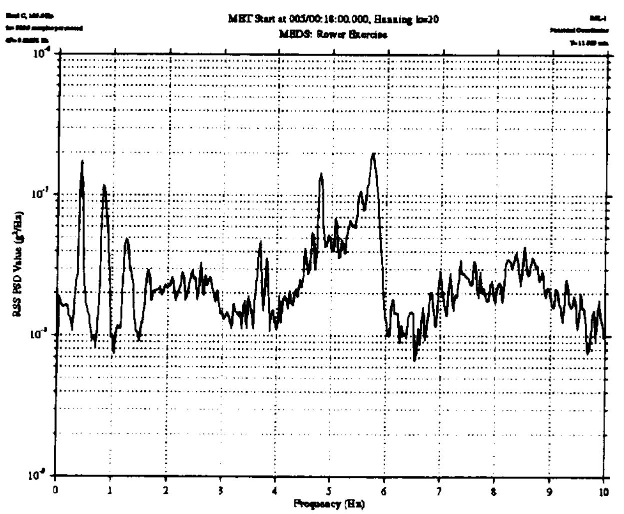
- [x] SAMS
- [ ] OARE

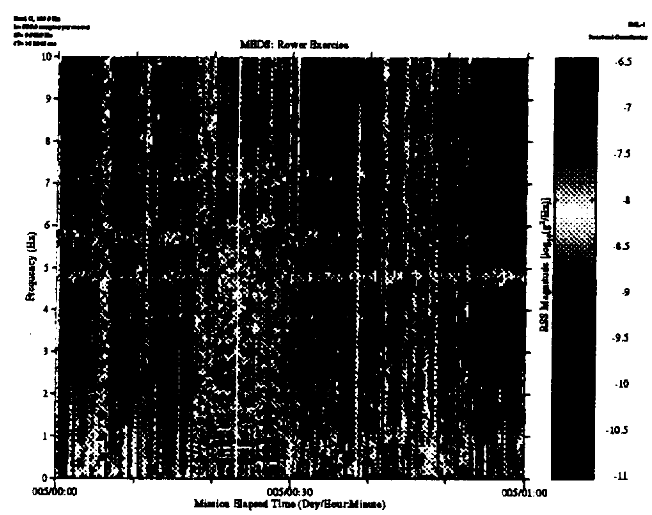
Head C, 100 Hz
fs = 500 samples per second

MEASUREMENT LOCATION

- [x] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge





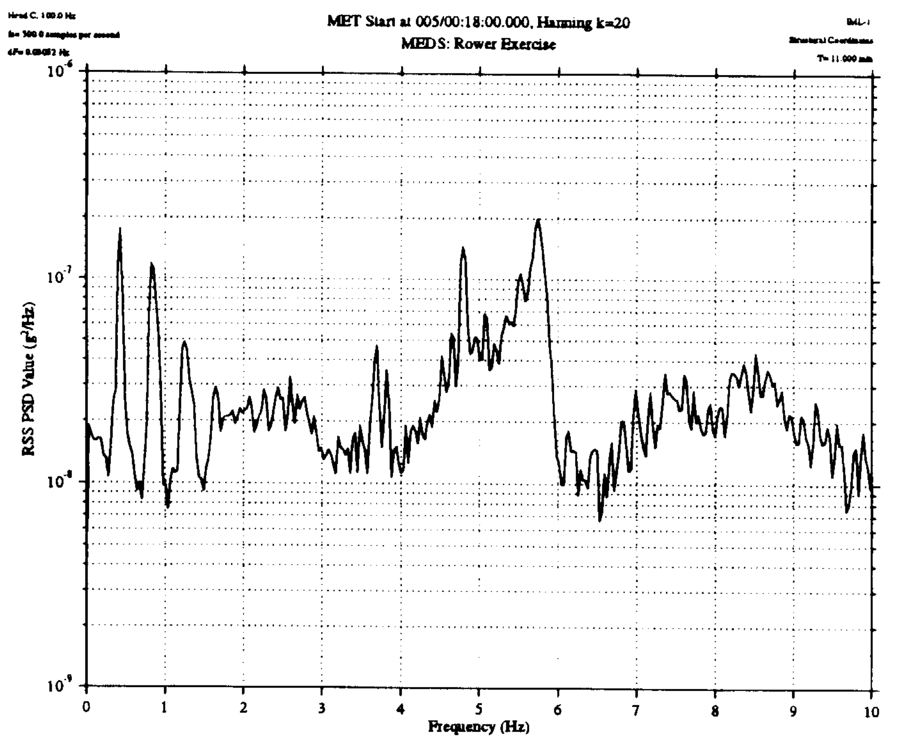


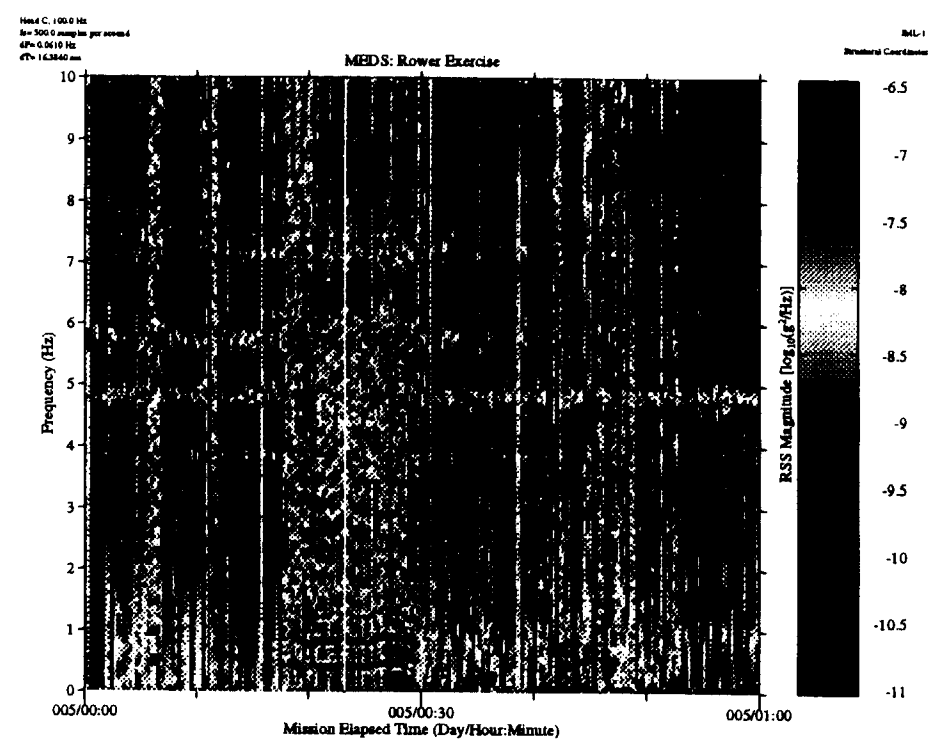
EFFECT ON MICROGRAVITY ENVIRONMENT

The rower exercise causes both fundamental and harmonic disturbances to the microgravity environment. In this spectrogram, the exercise begins at approximately MET 005/00:18, and ends at approximately MET 005/00:30. Variations in frequency with respect to time are characteristics of exercise in which the astronaut can change the pace of the exercise as they are working.

The table on the reverse side gives a select summary of the μg_{RMS} levels associated with rower exercise.

For further information, contact Duc Truong
NASA Lewis Research Center, Cleveland, Ohio. Telephone: 216-433-8394. Facsimile: 216-433-8660
e-mail: pims@lerc.nasa.gov. URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/





Frequency Bands			
f_{lower} (Hz)	f_{middle} (Hz)	f_{upper} (Hz)	Acceleration level (μg_{RMS})
0.35	0.45	0.55	116.4
0.75	0.85	0.95	114.8
1.16	1.23	1.30	62.7
1.30	1.35	1.40	52.4
1.52	1.59	1.65	51.5
1.65	1.68	1.70	27.9
1.70	1.76	1.82	49.6
2.5	2.80	3.1	147.0

PAYLOAD BAY DOORS OPENING MOTION

MISSION

STS-73, October 1995, USML-2

ACCELEROMETER

- [x] SAMS
- [ ] OARE

Head C, 25 Hz
fs = 125 samples per second

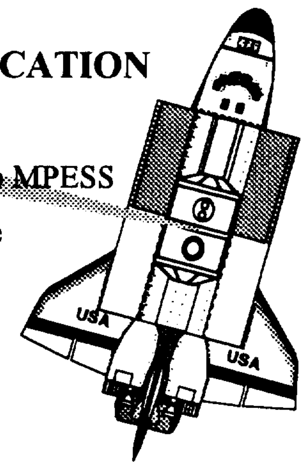
SOURCE OR ACTIVITY

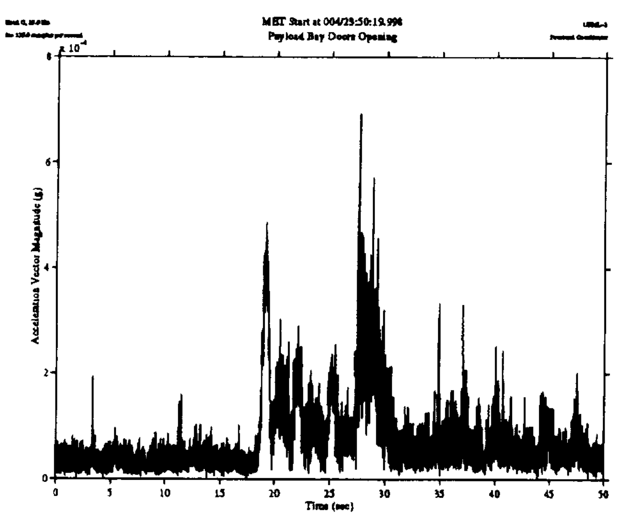
The payload bay doors consist of left- and right-hand doors hinged at each side of the mid fuselage and latched mechanically at the forward and aft fuselage and at the split top centerline. Each door actuation system provides the mechanism to drive its door to open, intermediate, or closed positions. Each mechanism consists of an electromechanical power drive unit and 6 rotary gear actuators.

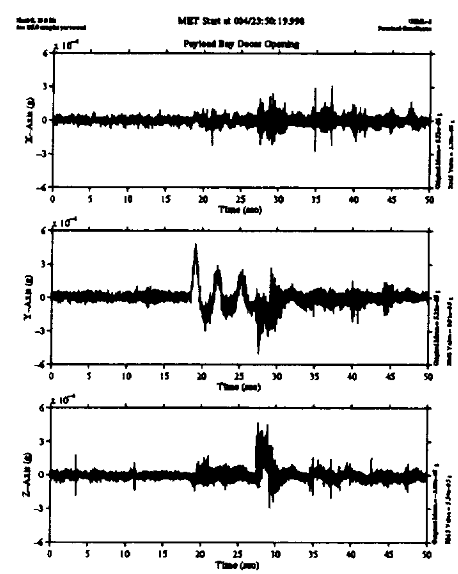
Larger plots on reverse

MEASUREMENT LOCATION

- [x] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB module
- [ ] Middeck
- [ ] Keel Bridge







EFFECT ON MICROGRAVITY ENVIRONMENT

The impact of moving the payload bay doors to a more open position is seen most clearly on the Y_O and Z_O axes. The peak acceleration vector magnitude during door motion can approach 1 mg and this motion has been seen to excite the 0.4 Hz payload bay door structural mode.

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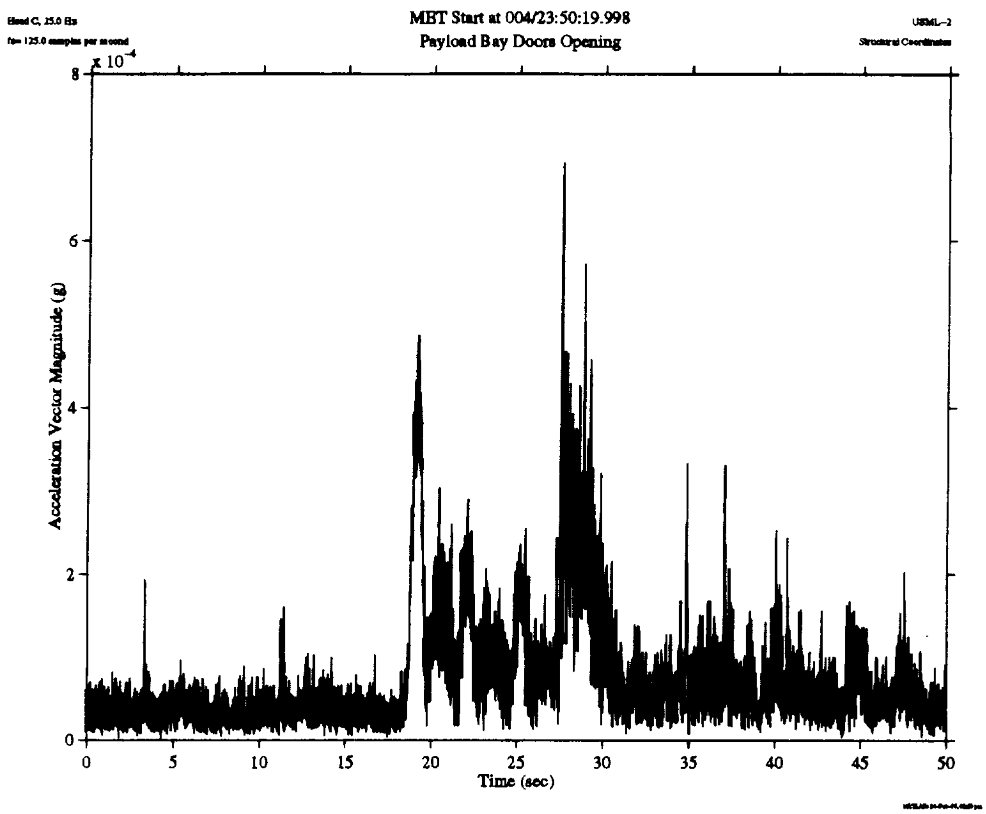
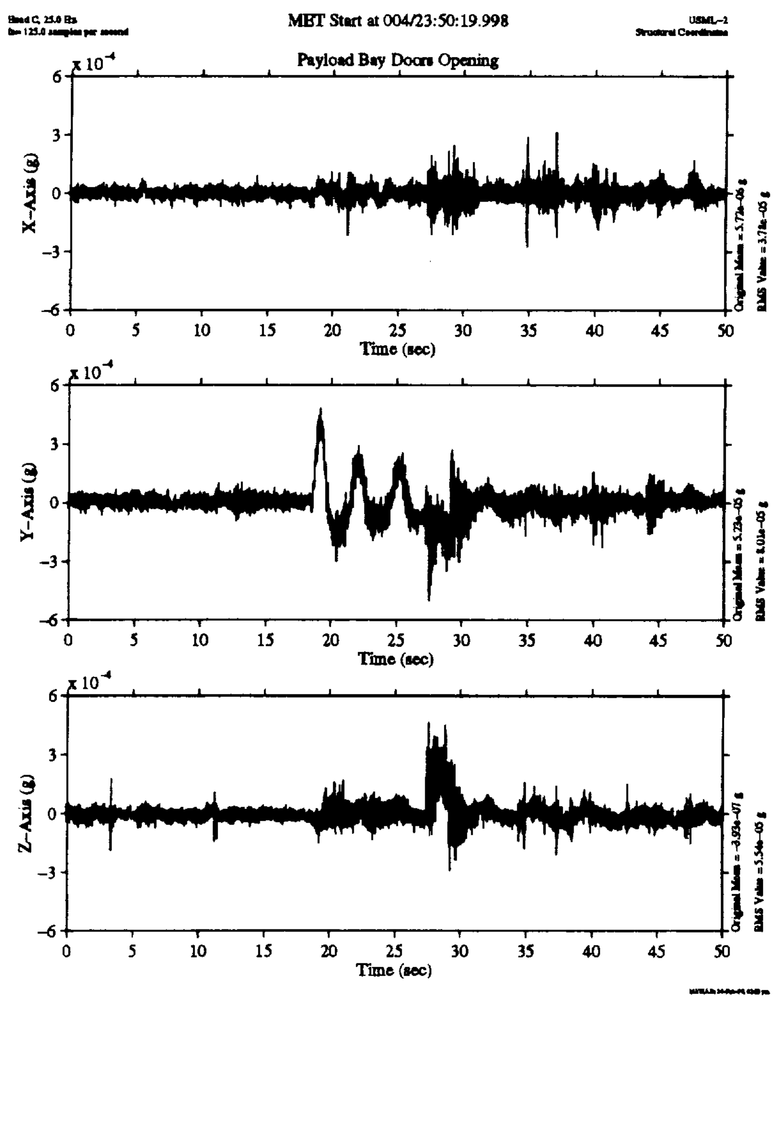

MBT Start at 004/23:50:19.998
Payload Bay Doors Opening
USML-2
x 10^-4
Acceleration Vector Magnitude (g)
Time (sec)


MBT Start at 004/23:50:19.998
USML-2
Payload Bay Doors Opening
x 10^-4
X-Axis (g)
Y-Axis (g)
Z-Axis (g)
Time (sec)

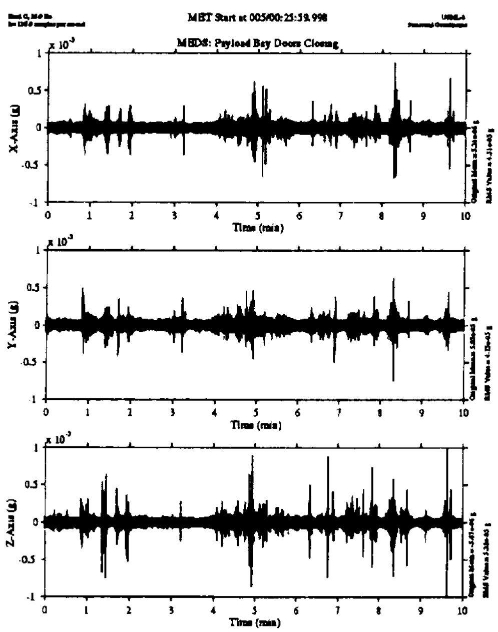
PAYLOAD BAY DOORS CLOSING MOTION

MISSION

STS-73, October 1995, USML-2

SOURCE OR ACTIVITY

The payload bay doors consist of left- and right-hand doors hinged at each side of the mid fuselage and latched mechanically at the forward and aft fuselage and at the split top centerline. Each door actuation system provides the mechanism to drive its door to open, intermediate, or closed positions. Each mechanism consists of an electromechanical power drive unit and 6 rotary gear actuators.



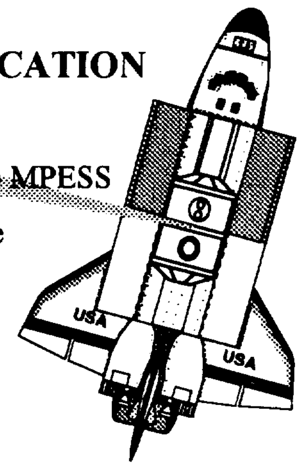
ACCELEROMETER

☑ SAMS ☐ OARE

Head C, 25 Hz
fs = 125 samples per second

MEASUREMENT LOCATION

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



Larger plot on reverse

EFFECT ON MICROGRAVITY ENVIRONMENT

No obvious impact for the partial closing of the payload bay doors has been identified in the SAMS data.

For further information, contact Duc Truong
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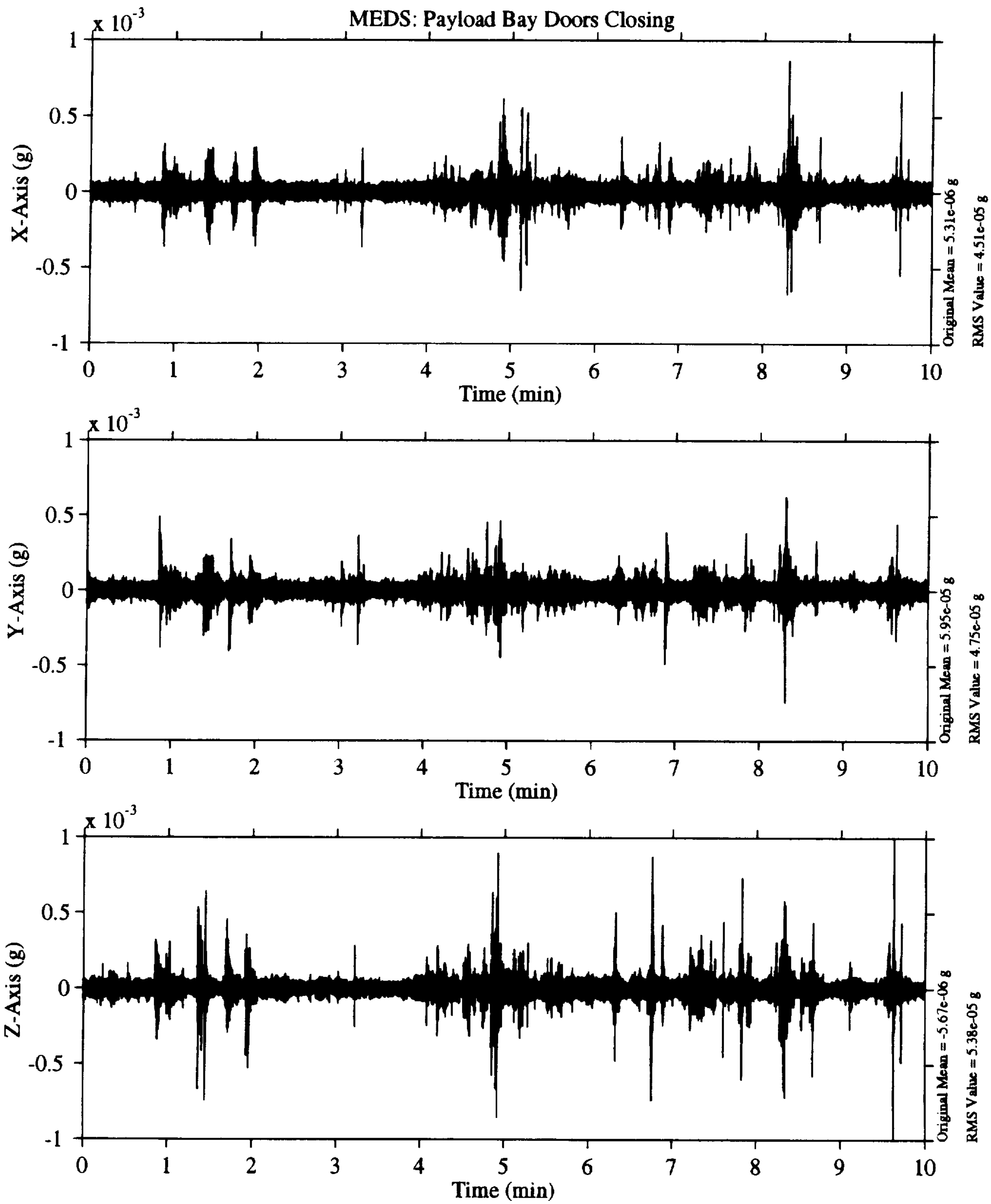
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

Head C, 25.0 Hz
fs= 125.0 samples per second

MET Start at 005/00:25:59.998

USML-2
Structural Coordinates



MATLAB: 4-Mar-97, 08:14 am

VERNIER REACTION CONTROL SYSTEM *(Reboost Maneuver)*

MISSION

STS-78, June 1996, LMS

ACCELEROMETER

☑ SAMS ☐ OARE

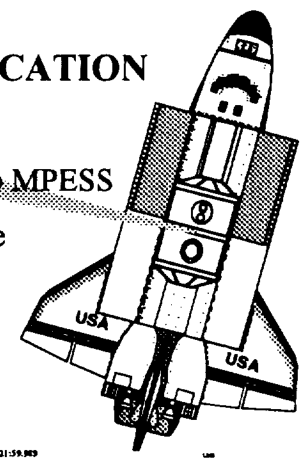
Head A, 10 Hz
fs = 50 samples per second

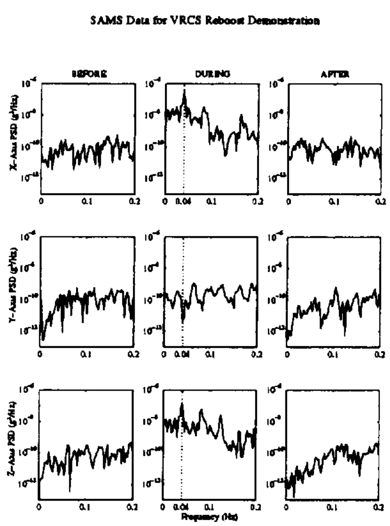
SOURCE OR ACTIVITY

During LMS, a detailed test objective called the Vernier Reaction Control System Reboost Demonstration was performed to demonstrate reboost capability for the Hubble Space Telescope on the STS-82 mission.

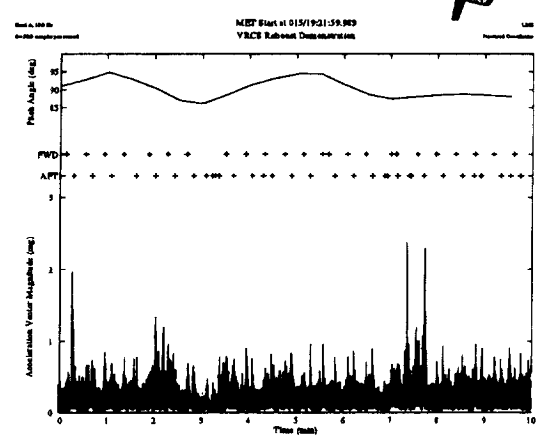
MEASUREMENT LOCATION

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





Larger plots on reverse



EFFECT ON MICROGRAVITY ENVIRONMENT

During this test, the Orbiter was in a -XLV/-ZVV attitude while two pairs of VRCS jets (F5L/F5R and L5D/R5D) were alternately fired in a precise pattern to slightly raise the Orbiter's altitude. This pattern can be seen in the figure on the right where the forward (FWD) and AFT vernier jet firings are indicated by the top and bottom rows of "+" markers, respectively. As a result, the Orbiter was boosted to a higher altitude as is suggested by the pitch angle data plotted at the top of the figure on the right. The acceleration vector magnitude during this test did not exceed 2.5 mg, and was nominally below about 1 mg, not much above the background acceleration environment. The power spectral density plots of the figure on the left show the acceleration spectra below 0.2 Hz from three different time frames for all three Orbiter structural axes, X_O, Y_O, and Z_O, from top to bottom. The left-most column of plots corresponds to a time frame just before the VRCS reboost. Plots in the center column were computed from accelerations measured during the test and the right-most column of plots corresponds to a time frame which occurred not long after completion of the test. Comparison of the "during" spectrum to both the "before" and "after" spectra reveals that the VRCS reboost excited the low frequency acceleration environment (below about 0.1 - 0.2 Hz) primarily on the X_O and Z_O axes. Most notably, the excitation produced an increased magnitude around 0.04 Hz.

For further information, contact Duc Truong
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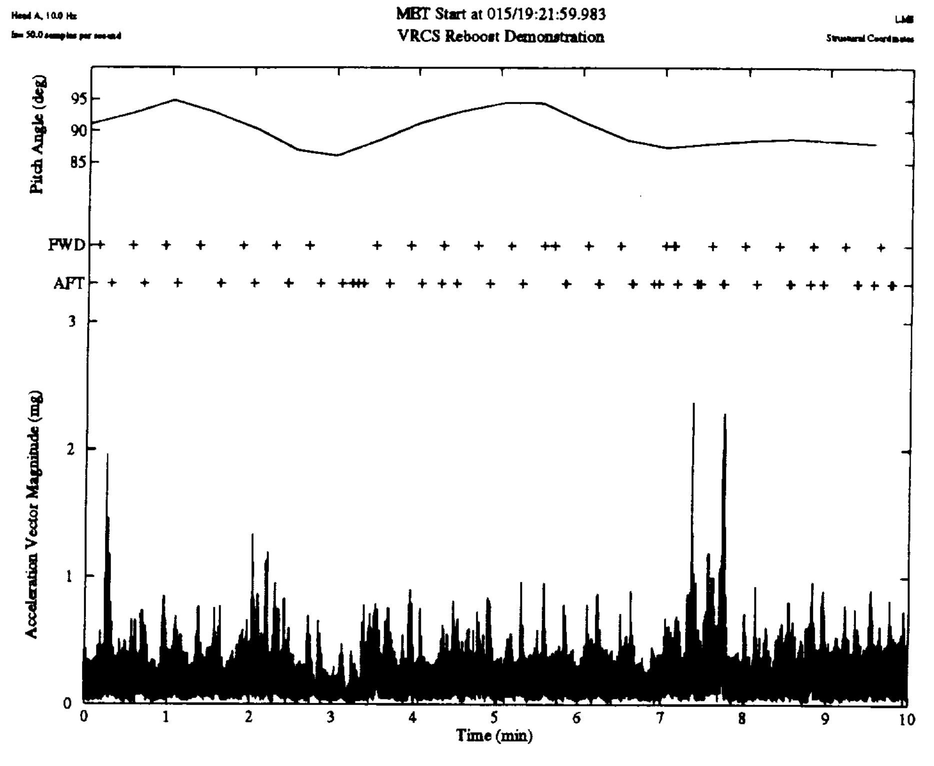
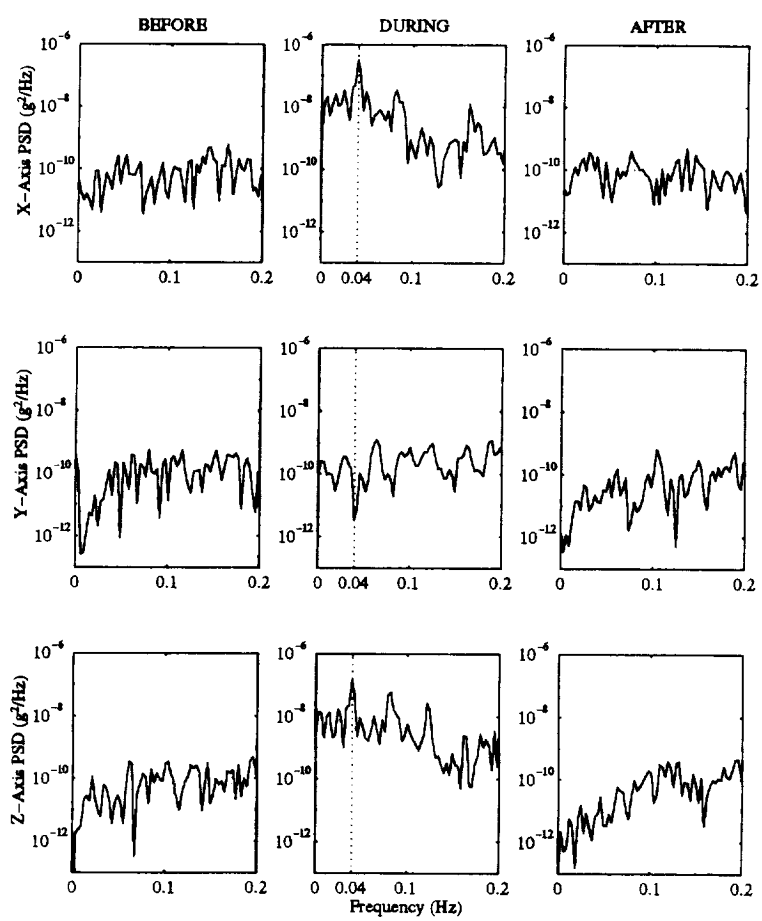
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



SAMS Data for VRCS Reboost Demonstration



RADIATOR DEPLOY

MISSION

STS-78, June 1996, LMS

SOURCE OR ACTIVITY

Radiator panels attached to the forward payload doors are part of the Active Thermal Control System which provides orbiter heat rejection during a mission. Depending on particular mission requirements, these radiator panels may be deployed at different angles and may be reoriented during the mission. In order to deploy each radiator, six motor driven latches must first be unlocked, and then the radiators are moved by a motor with a torque-tube-lever arrangement.

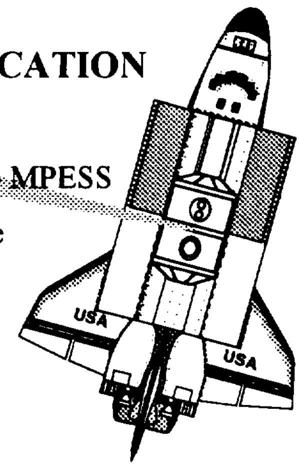
ACCELEROMETER

- [x] SAMS
- [ ] OARE

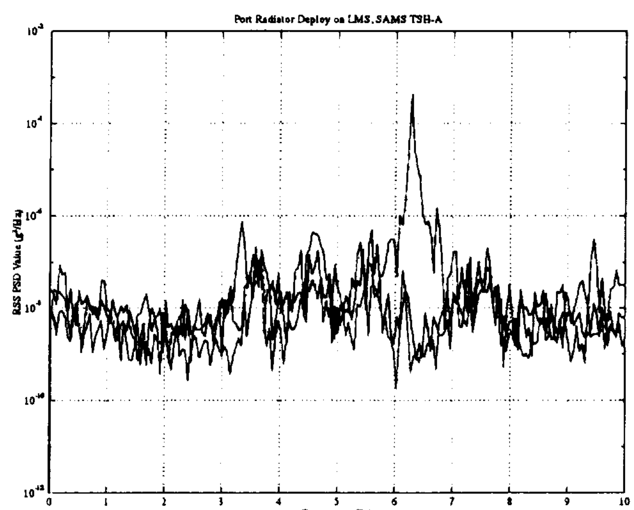
TSH A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

- [x] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge



Larger plot on reverse



EFFECT ON MICROGRAVITY ENVIRONMENT

When these doors are moved, transient disturbances are imparted on the orbiter structure by means of six motor-driven latches. These transients can reach magnitudes of 0.3 mg.

The above figure shows 3 overlapping PSDs, plotted for 25 second periods before deploy, during deploy, and after deploy of the port radiator. The during deploy period shows the presence of 6.30 Hz and 9.47 Hz peaks. After the deploy is completed, there is a 3.37 Hz peak present in the data.

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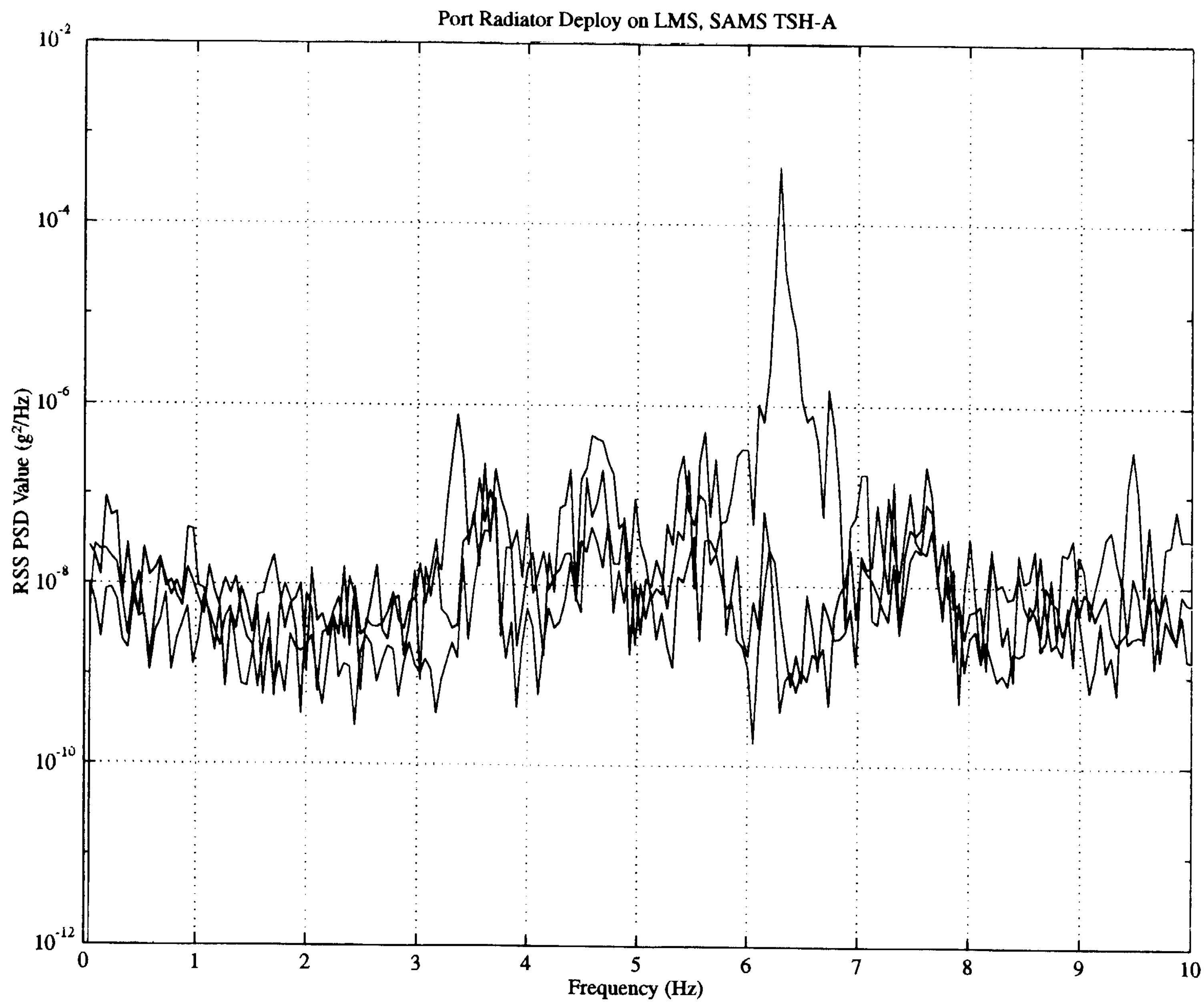
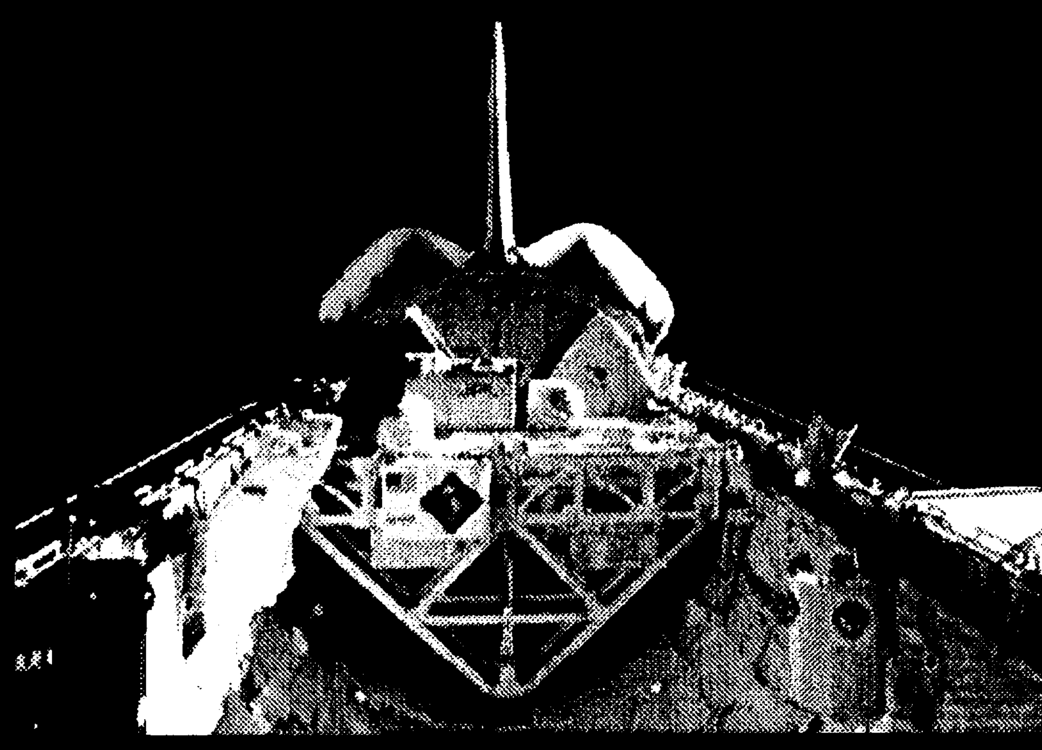
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



Port Radiator Deploy on LMS, SAMS TSH-A
RSS PSD Value (g^2/Hz)
Frequency (Hz)
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
0
1
2
3
4
5
6
7
8
9
10

SECTION II

Disturbances Measured in the Cargo Bay / MPESS Spacelab



RADIATOR DEPLOY

MISSION

STS-62, March 1994, USMP-2

SOURCE OR ACTIVITY

Radiator panels attached to the forward payload doors are part of the Active Thermal Control System which provides orbiter heat rejection during a mission. Depending on particular mission requirements, these radiator panels may be deployed at different angles and may be reoriented during the mission.

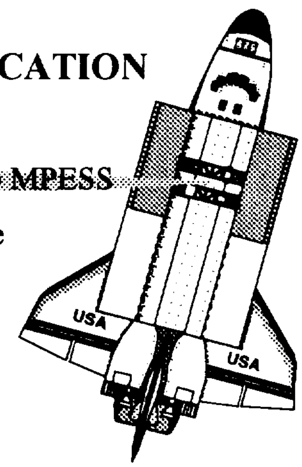
ACCELEROMETER

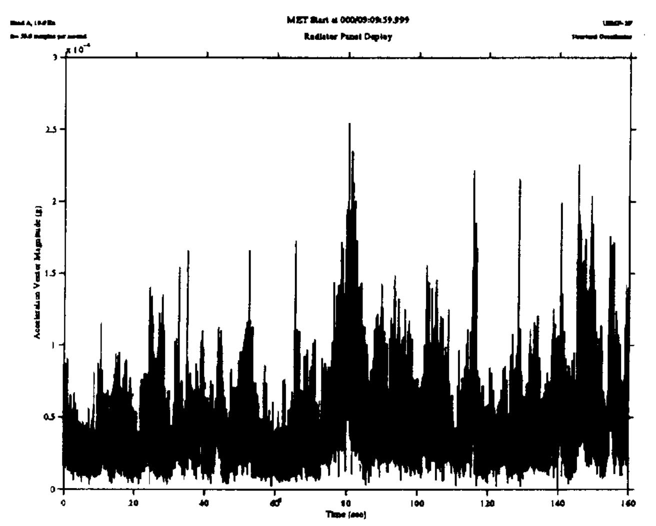
- [x] SAMS
- [ ] OARE

Unit F, TSH A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [x] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge





Larger plot on reverse

EFFECT ON MICROGRAVITY ENVIRONMENT

When these doors are moved, transient disturbances are imparted on the orbiter structure by means of six motor-driven latches. These transients can reach magnitudes of 0.3 mg.

For further information, contact Duc Truong
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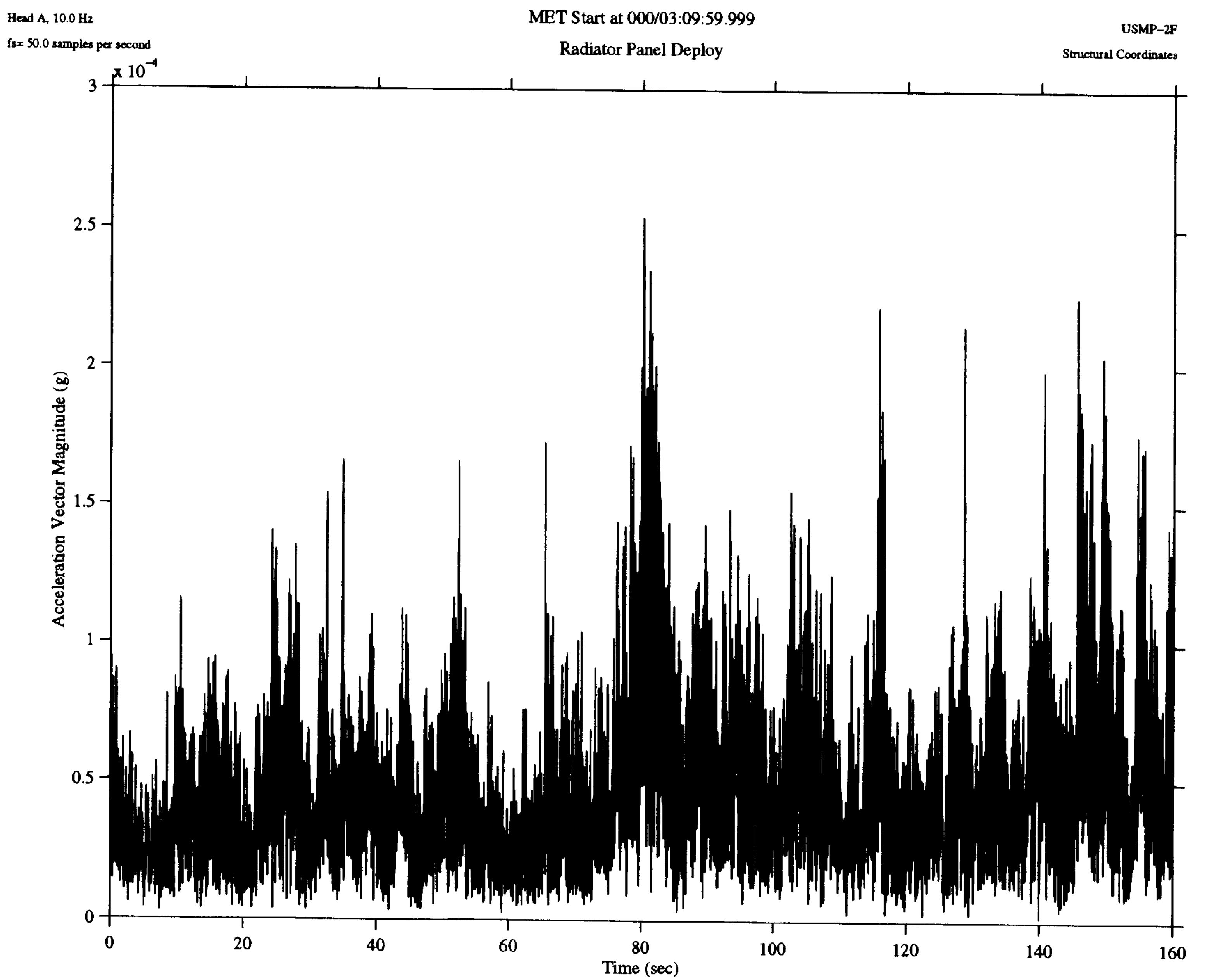
e-mail: pims@lerc.nasa.gov.
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


Head A, 10.0 Hz
fs= 50.0 samples per second
MET Start at 000/03:09:59.999
Radiator Panel Deploy
USMP-2F
Structural Coordinates
x 10^-4
3
2.5
2
1.5
1
0.5
0
Acceleration Vector Magnitude (g)
0
20
40
60
80
100
120
140
160
Time (sec)

Ku-BAND ANTENNA

ACCELEROMETER

☑ SAMS ☐ OARE

Unit F, Head B, 25 Hz
fs = 125 samples per second

MISSION

STS-62, March 1994, USMP-2

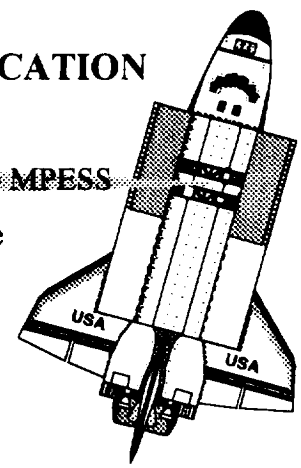
SOURCE OR ACTIVITY

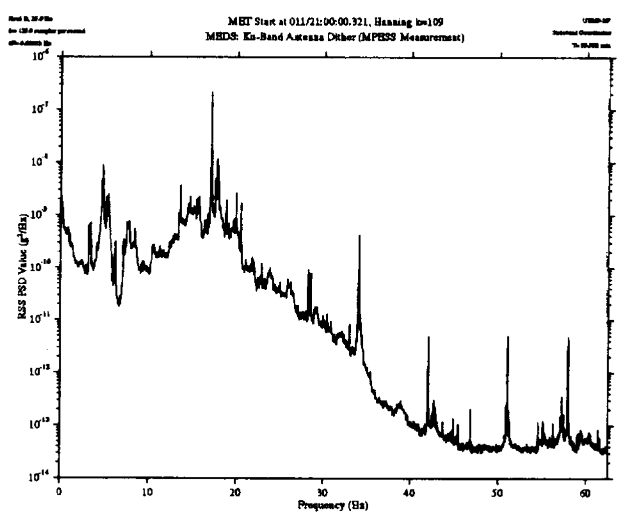
The Ku-band antenna is located in the forward portion of the payload bay on the starboard side of the vehicle. On orbit, this antenna is deployed for communications between the orbiter and the Tracking Data Relay Satellite System (TDRSS). It is dithered at 17 Hz to prevent stiction of the gimbal mechanism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

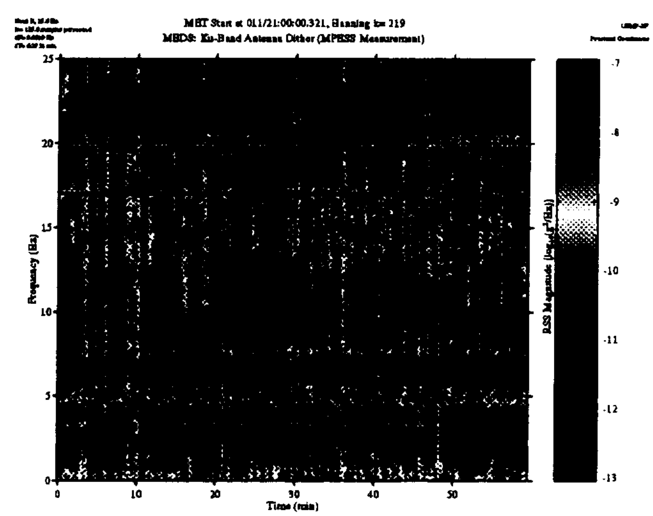
Larger plots on reverse

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 85 Hz has been seen on the other carriers, using higher frequency sensor heads.

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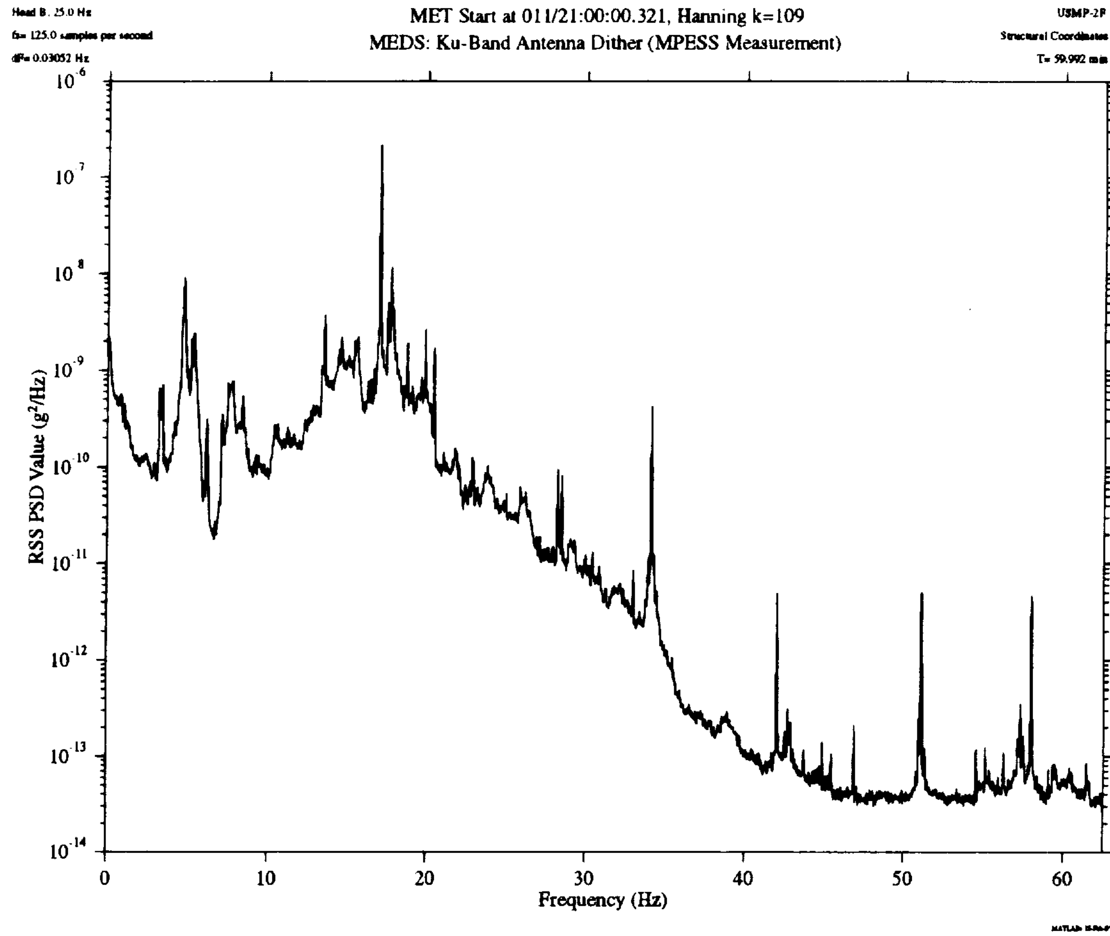
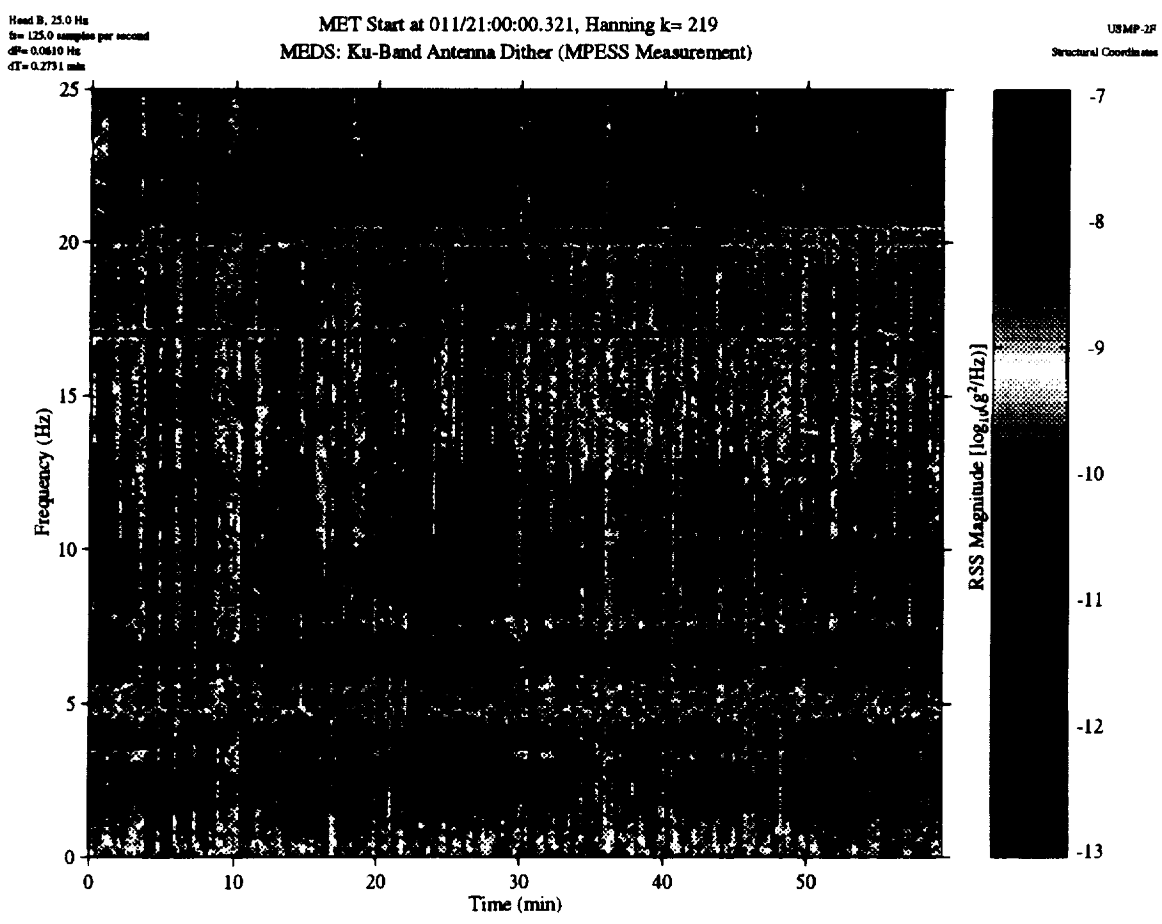
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



Head B, 25.0 Hz
fs= 125.0 samples per second
dF= 0.03052 Hz
MET Start at 011/21:00:00.321, Hanning k=109
MEDS: Ku-Band Antenna Dither (MPESS Measurement)
USMP-2F
Structural Coordinates
T= 59.992 min
RSS PSD Value (g²/Hz)
Frequency (Hz)



Head B, 25.0 Hz
fs= 125.0 samples per second
dF= 0.0610 Hz
dT= 0.2731 min
MET Start at 011/21:00:00.321, Hanning k= 219
MEDS: Ku-Band Antenna Dither (MPESS Measurement)
USMP-2F
Structural Coordinates
Frequency (Hz)
Time (min)
RSS Magnitude [log10(g²/Hz)]

MEPHISTO

MISSION
STS-62, March 1994, USMP-2

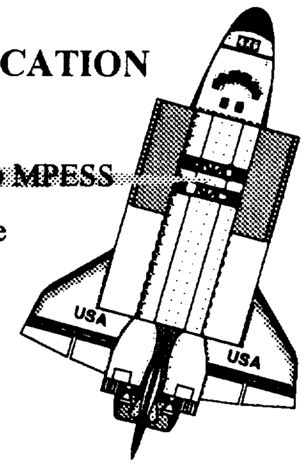
SOURCE OR ACTIVITY
A valve was closed on the Materials for the Study of Interesting Phenomena of Solidification on Earth and in Orbit (MEPHISTO) furnace experiment. This valve was latched during experiment operation to observe the effect of the vibration on the furnace sample.

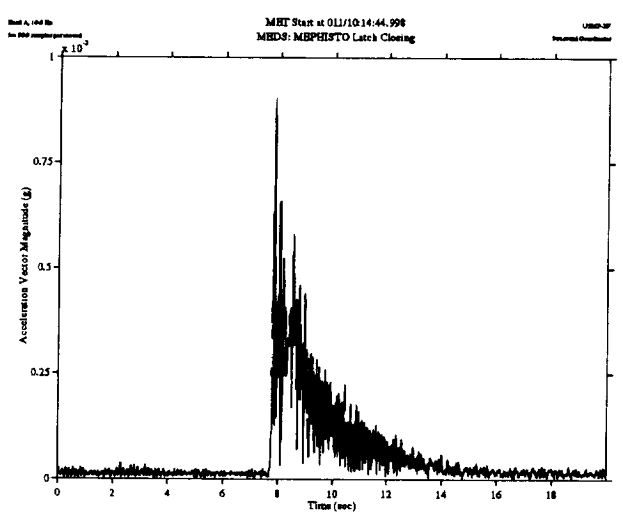
Larger plots on reverse

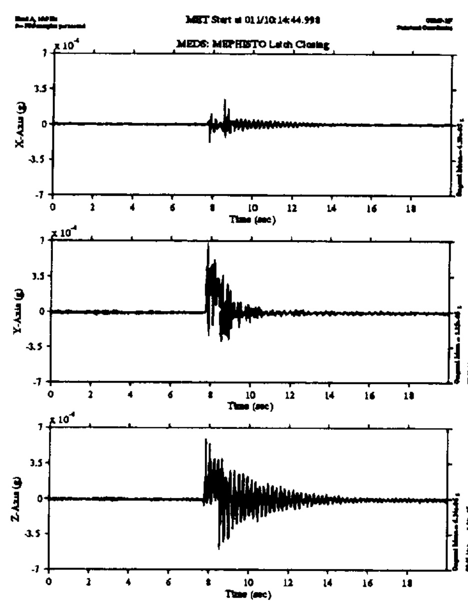
ACCELEROMETER
- [x] SAMS
- [ ] OARE

Unit F, Head A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION
- [ ] Spacelab Module
- [x] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge







EFFECT ON MICROGRAVITY ENVIRONMENT
Closure of a valve used in the experimental apparatus was noticeable in the acceleration data. The effect was a transient disturbance reaching about 1 mg, which excited a resonant damped ringing at 4.8 Hz evident primarily in the Z_0-axis.

For further information, contact Duc Truong
NASA Lewis Research Center, Cleveland, Ohio.
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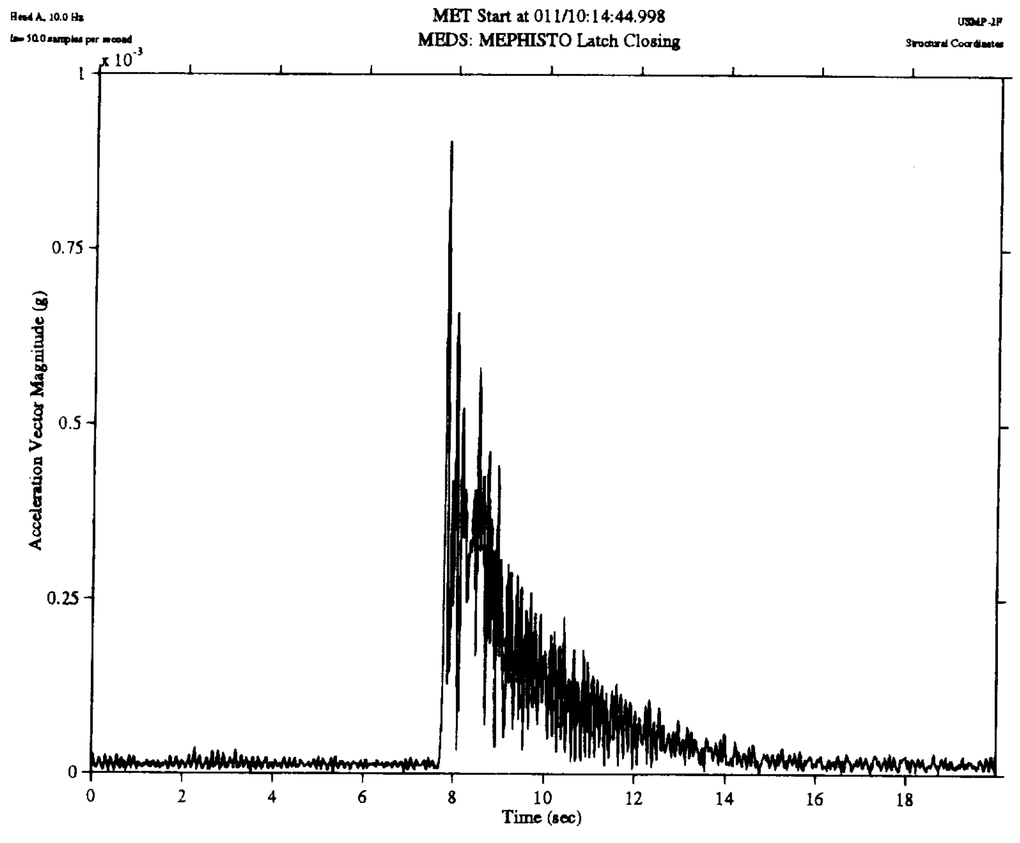
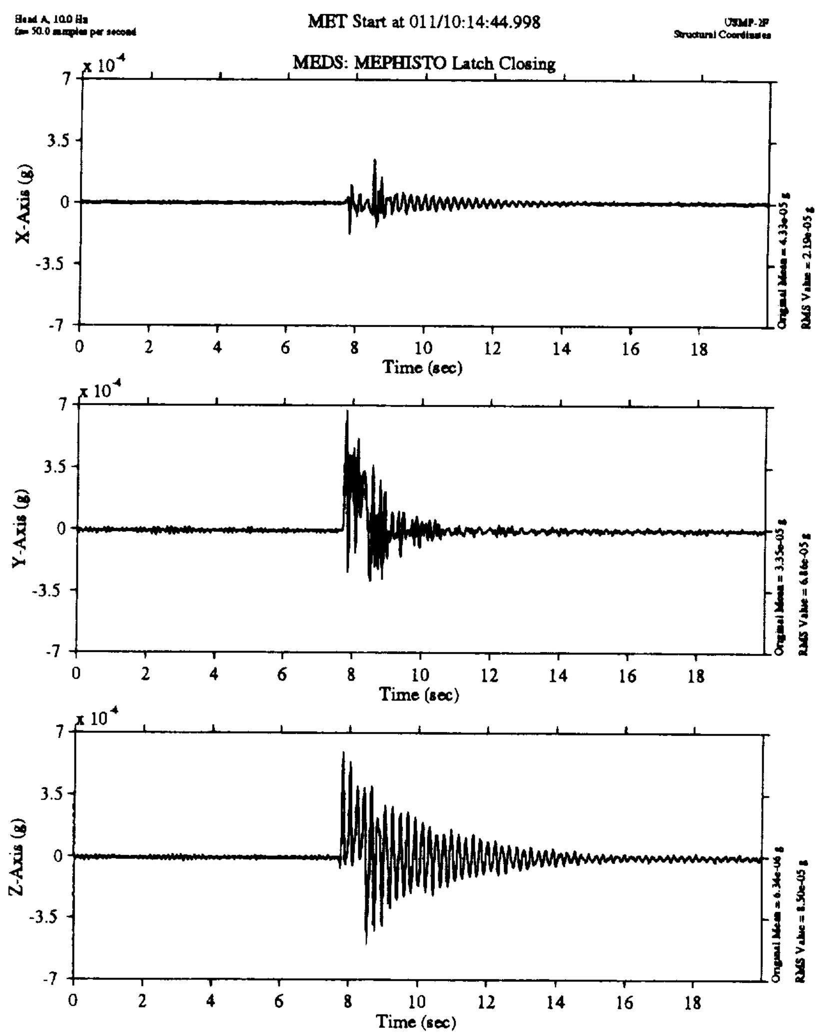
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


Head A, 10.0 Hz
fs= 50.0 samples per second
MET Start at 011/10:14:44.998
MEDS: MEPHISTO Latch Closing
USMP-2F
Structural Coordinates
x 10^-3
Acceleration Vector Magnitude (g)
Time (sec)


Head A, 10.0 Hz
fs= 50.0 samples per second
MET Start at 011/10:14:44.998
USMP-2F
Structural Coordinates
MEDS: MEPHISTO Latch Closing
x 10^-4
X-Axis (g)
Time (sec)
Original Mean = 4.33e-05 g
RMS Value = 2.19e-05 g
Y-Axis (g)
Original Mean = 3.35e-05 g
RMS Value = 6.86e-05 g
Z-Axis (g)
Original Mean = 6.34e-06 g
RMS Value = 8.50e-05 g

ORBITAL MANEUVERING SYSTEM

MISSION

STS-62, March 1994, USMP-2

SOURCE OR ACTIVITY

The OMS is used to place the vehicle in orbit, for major velocity changes and to slow the Orbiter for reentry.

Larger plots on reverse

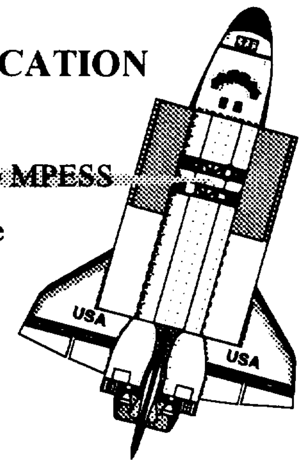
ACCELEROMETER

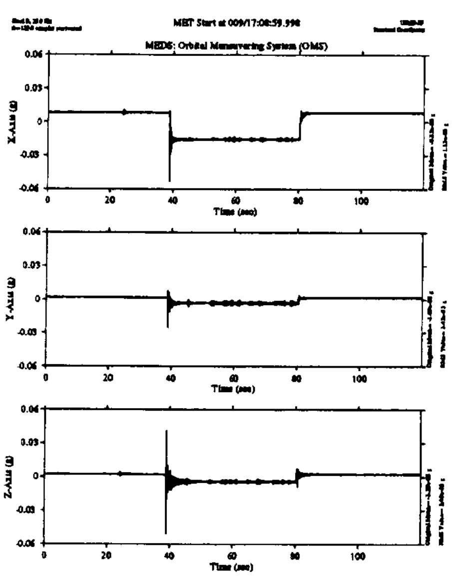
- [x] SAMS
- [ ] OARE

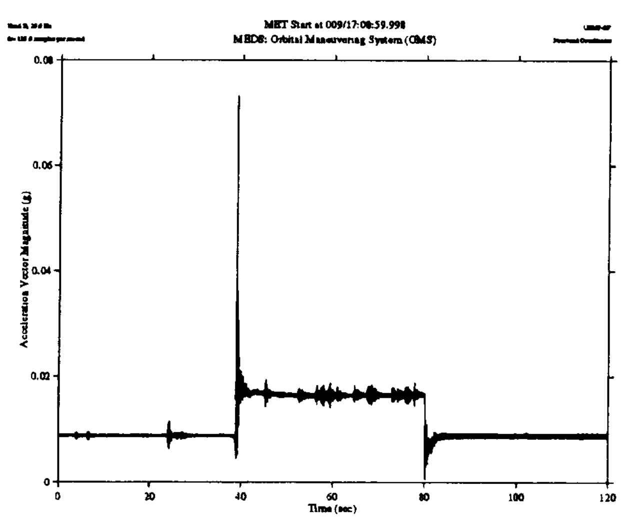
Unit F, Head B, 25 Hz
fs = 125 samples per second

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [x] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge







EFFECT ON MICROGRAVITY ENVIRONMENT

When the OMS engines are fired, initial transients in excess of 50 mg have been observed and net accelerations on the order of 20 mg lasting for as long as 40 seconds occur primarily in the -X_O direction. Due to the alignment of the engines, the accelerations occur primarily in the X_O axis.

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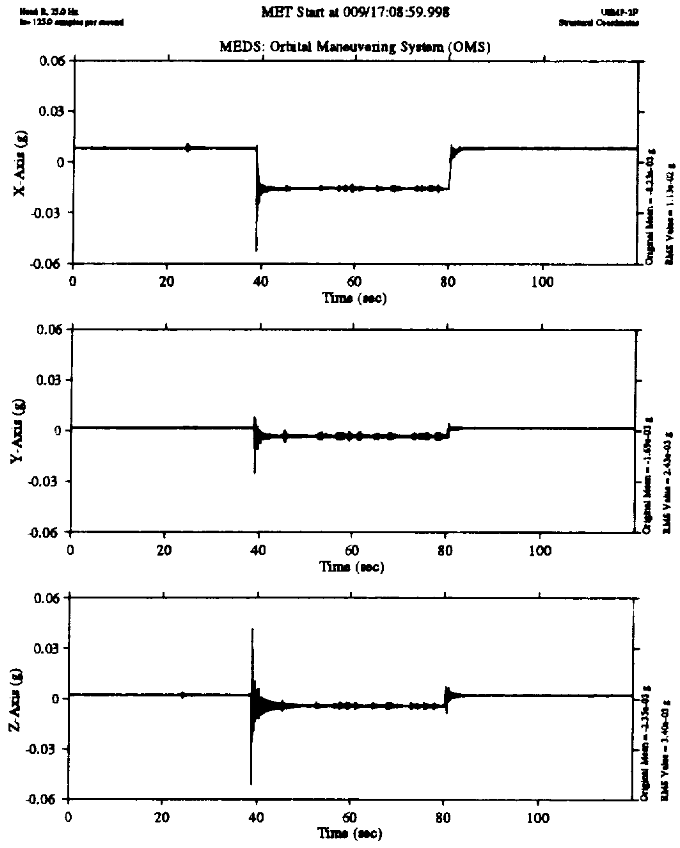
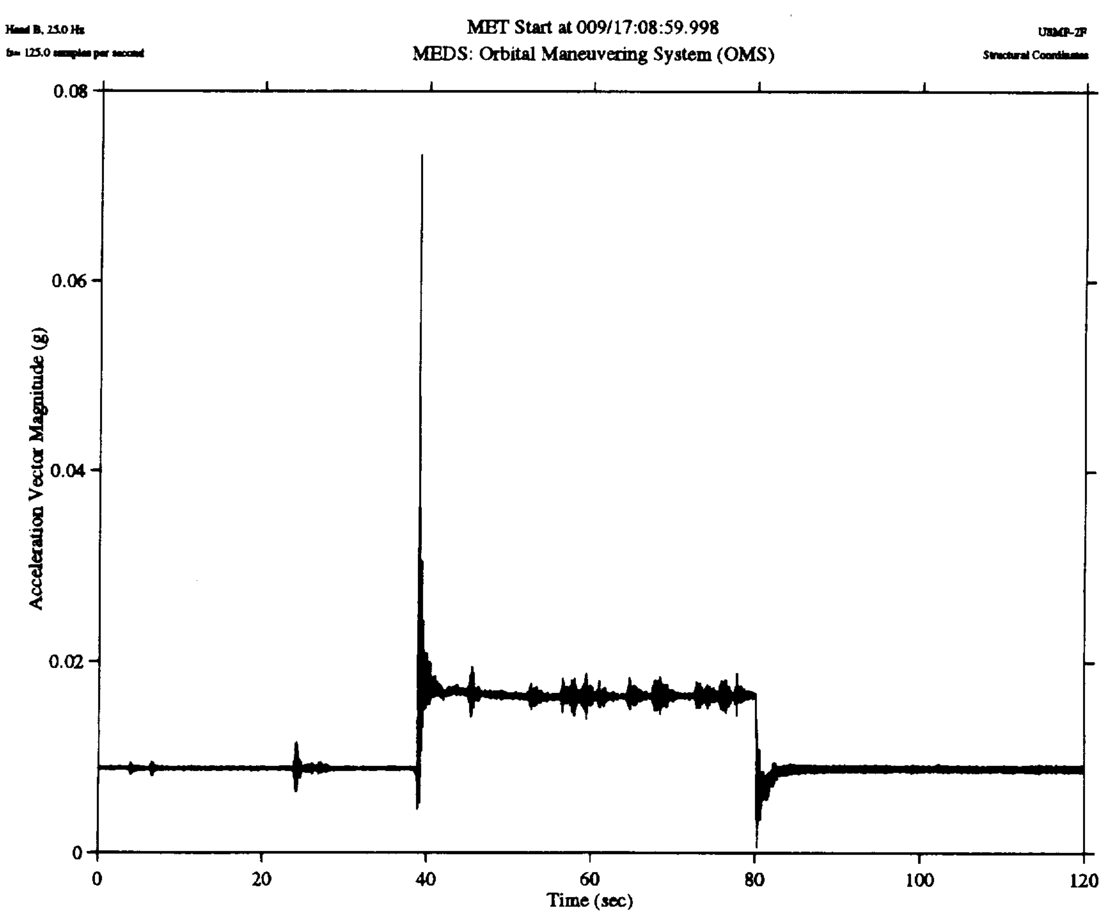


MET Start at 009/17:08:59.998
MEDS: Orbital Maneuvering System (OMS)
X-Axis (g)
Y-Axis (g)
Z-Axis (g)
Time (sec)
0.06
0.03
0
-0.03
-0.06
0
20
40
60
80
100



Head B, 25.0 Hz
fs= 125.0 samples per second
MET Start at 009/17:08:59.998
MEDS: Orbital Maneuvering System (OMS)
USMP-2F
Structural Coordinates
Acceleration Vector Magnitude (g)
0.08
0.06
0.04
0.02
0
0
20
40
60
80
100
120
Time (sec)

PRIMARY REACTION CONTROL SYSTEM

MISSION

STS-62, March 1994, USMP-2

SOURCE OR ACTIVITY

There are 38 Primary Reaction Control System (PRCS) thrusters located on the Orbiter. These are used on orbit to provide attitude pitch, yaw and roll maneuvers as well as translational maneuvers.

Larger plots on reverse

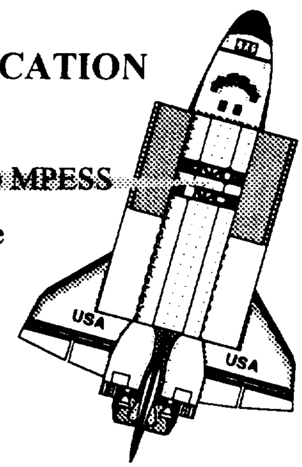
ACCELEROMETER

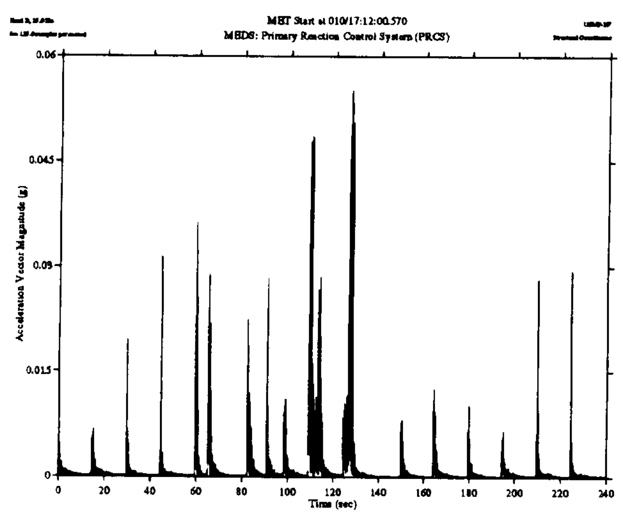
- [x] SAMS
- [ ] OARE

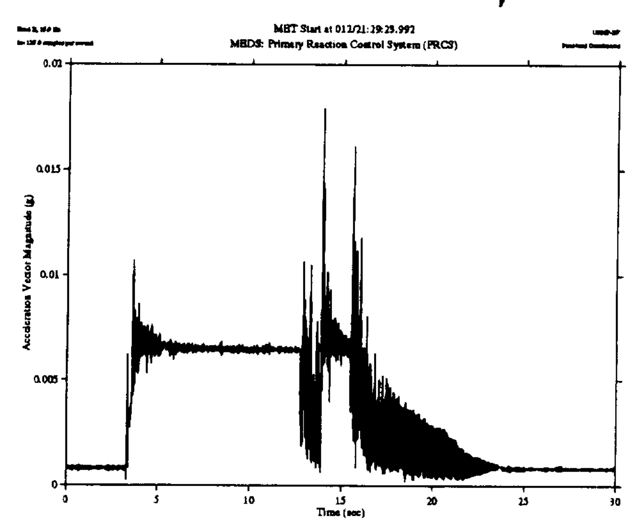
Unit F, Head B, 25 Hz
fs = 125 samples per second

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [x] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge







EFFECT ON MICROGRAVITY ENVIRONMENT

The impulsive nature of PRCS thruster firings produce relatively high acceleration levels ranging from 6 mg to about 55 mg for typical durations between tens of milliseconds and seconds. These impulsive events also typically excite orbiter structural modes at 3.5, 4.7, and 5.1 Hz. These structural excitations lead to the "ringing" behavior after the event as seen from 15 - 25 seconds in the plot on the right.

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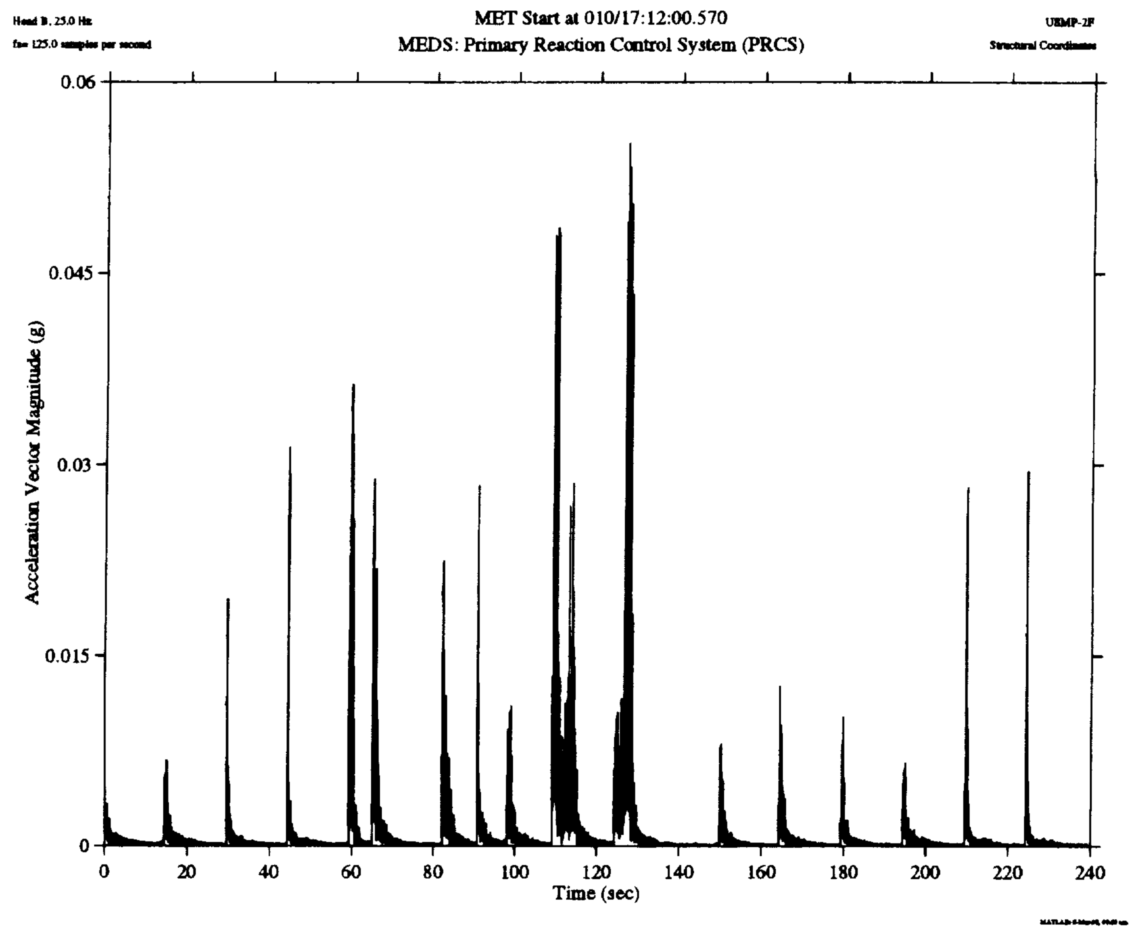
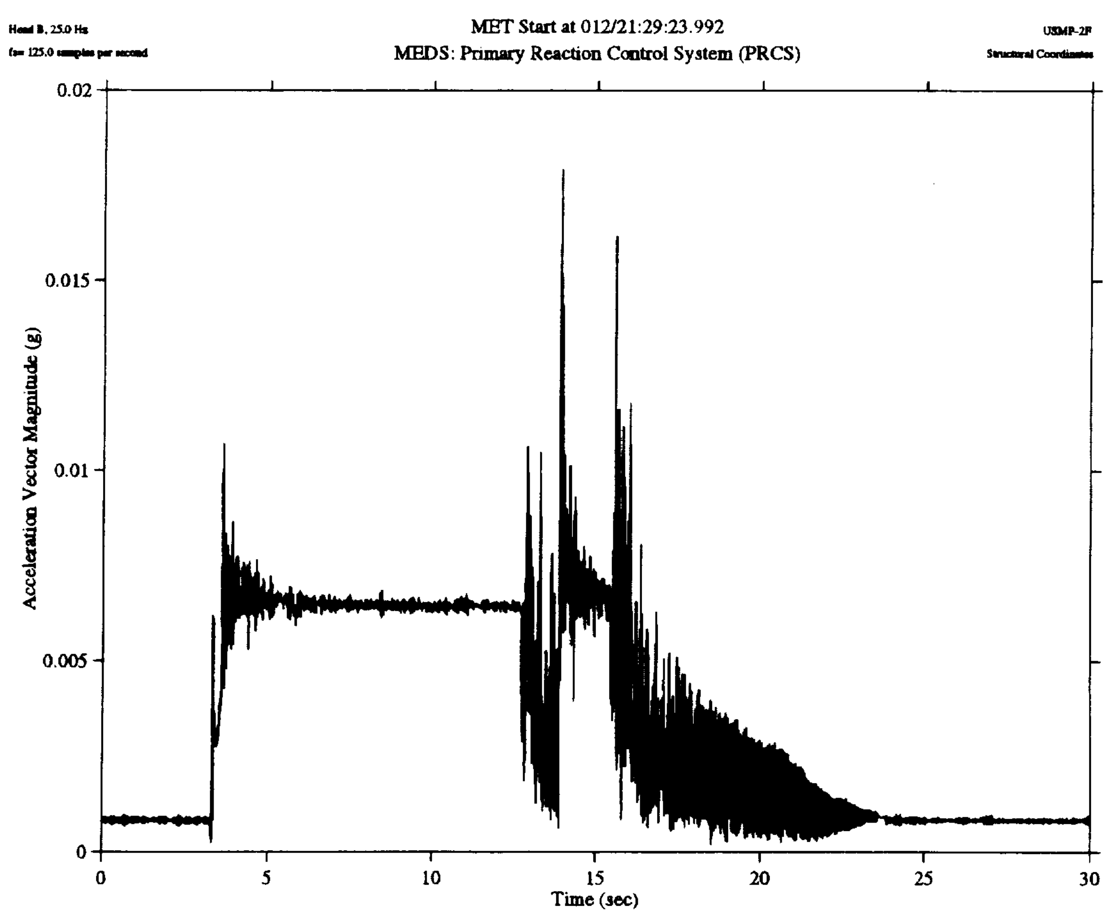

Head B, 25.0 Hz
fs= 125.0 samples per second
MET Start at 010/17:12:00.570
MEDS: Primary Reaction Control System (PRCS)
USMP-2F
Structural Coordinates
Acceleration Vector Magnitude (g)
Time (sec)
0
0.015
0.03
0.045
0.06
0
20
40
60
80
100
120
140
160
180
200
220
240


Head B, 25.0 Hz
fs= 125.0 samples per second
MET Start at 012/21:29:23.992
MEDS: Primary Reaction Control System (PRCS)
USMP-2F
Structural Coordinates
Acceleration Vector Magnitude (g)
Time (sec)
0
0.005
0.01
0.015
0.02
0
5
10
15
20
25
30

VERNIER REACTION CONTROL SYSTEM

MISSION

STS-75, February 1996, USMP-3

ACCELEROMETER

- [x] SAMS
- [ ] OARE

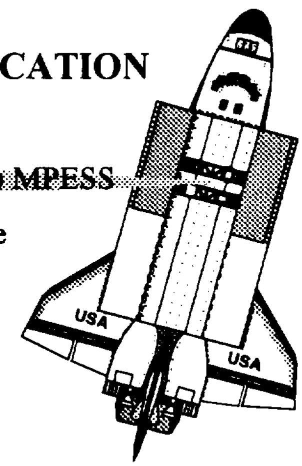
Unit F, Head B, 25 Hz
fs = 125 samples per second

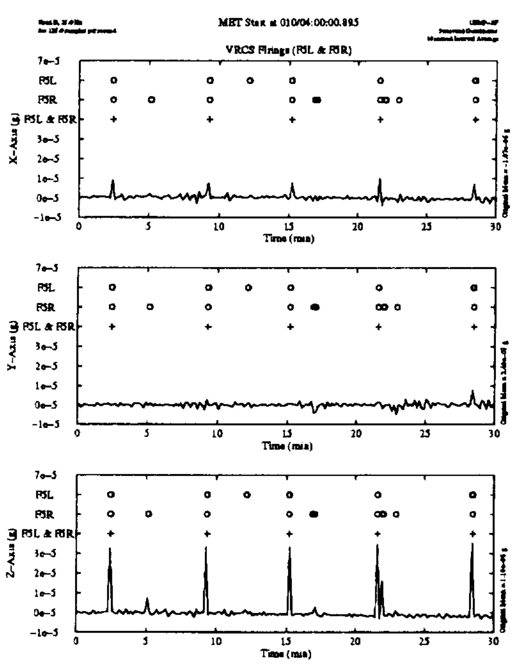
SOURCE OR ACTIVITY

There are six Vernier Reaction Control System (VRCS) thrusters used for fine adjustment of vehicle attitude. Two VRCS thrusters (F5R, F5L) are located in the nose of the orbiter, while four other VRCS thrusters (R5R, R5D, L5L, L5D) are located in the tail.

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [x] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge





Larger plot on reverse

EFFECT ON MICROGRAVITY ENVIRONMENT

The effects of VRCS thruster firings are not as noticeable as PRCS firings. Typical peak acceleration levels range from 0.3 mg to 0.7 mg. In the above figure, individual firings of the F5R and F5L jets are indicated by "o" symbols, while combined (simultaneous) firings are denoted by a "+". Notice the tendency for increased acceleration impulses in the Z_0-axis during these simultaneous firings.

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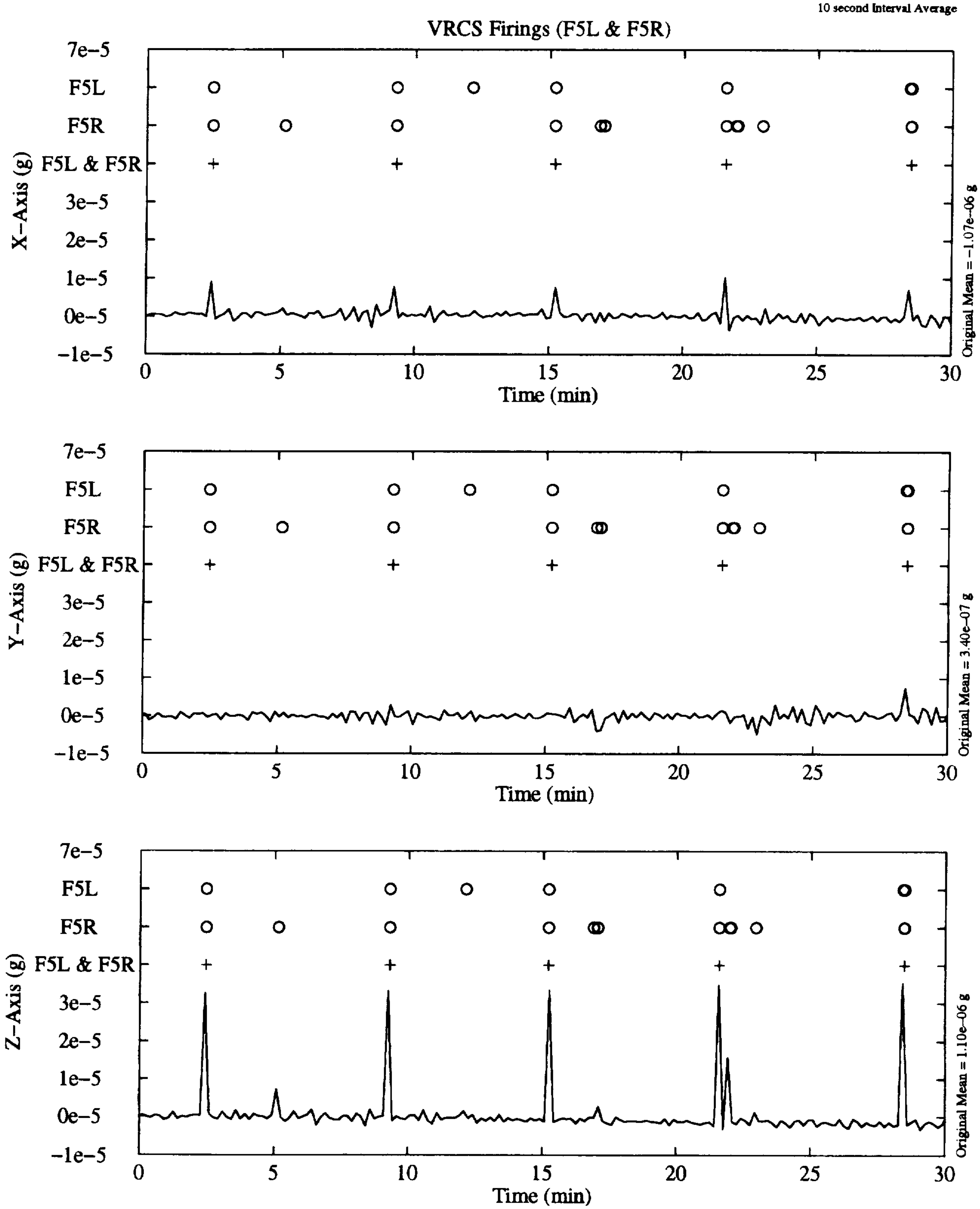
Head B, 25.0 Hz
fs= 125.0 samples per second

MET Start at 010/04:00:00.895

USMP-3F
Structural Coordinates
10 second Interval Average



MATLAB: 28-Aug-96, 8:16 am

CREW SLEEP

MISSION

STS-62, March 1994, USMP-2

SOURCE OR ACTIVITY

On single shift missions, the microgravity environment becomes quiet during crew sleep.

Larger plots on reverse

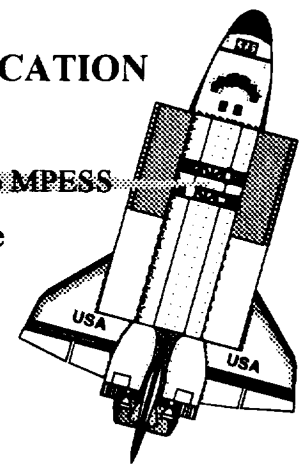
ACCELEROMETER

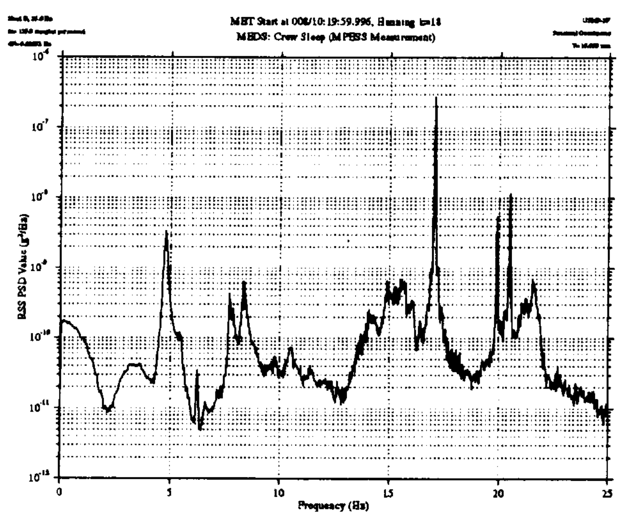
- [x] SAMS
- [ ] OARE

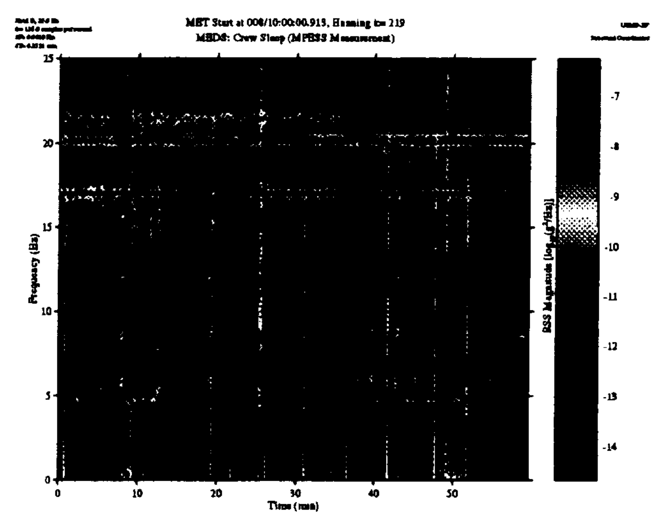
Unit F, Head B, 25 Hz
fs = 125 samples per second

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [x] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge







EFFECT ON MICROGRAVITY ENVIRONMENT

Crew sleep times during a single shift mission such as USMP-2 result in acceleration levels in the 1 to 4 Hz range below about 10 μg_{RMS}. Vehicle structural modes and the Ku-band antenna are the primary disturbance sources during crew sleep. VRCS firings continue to affect the environment, as evident by the broad-band (vertical yellow-green) disturbances in the color spectrogram plot.

For further information, contact Duc Truong
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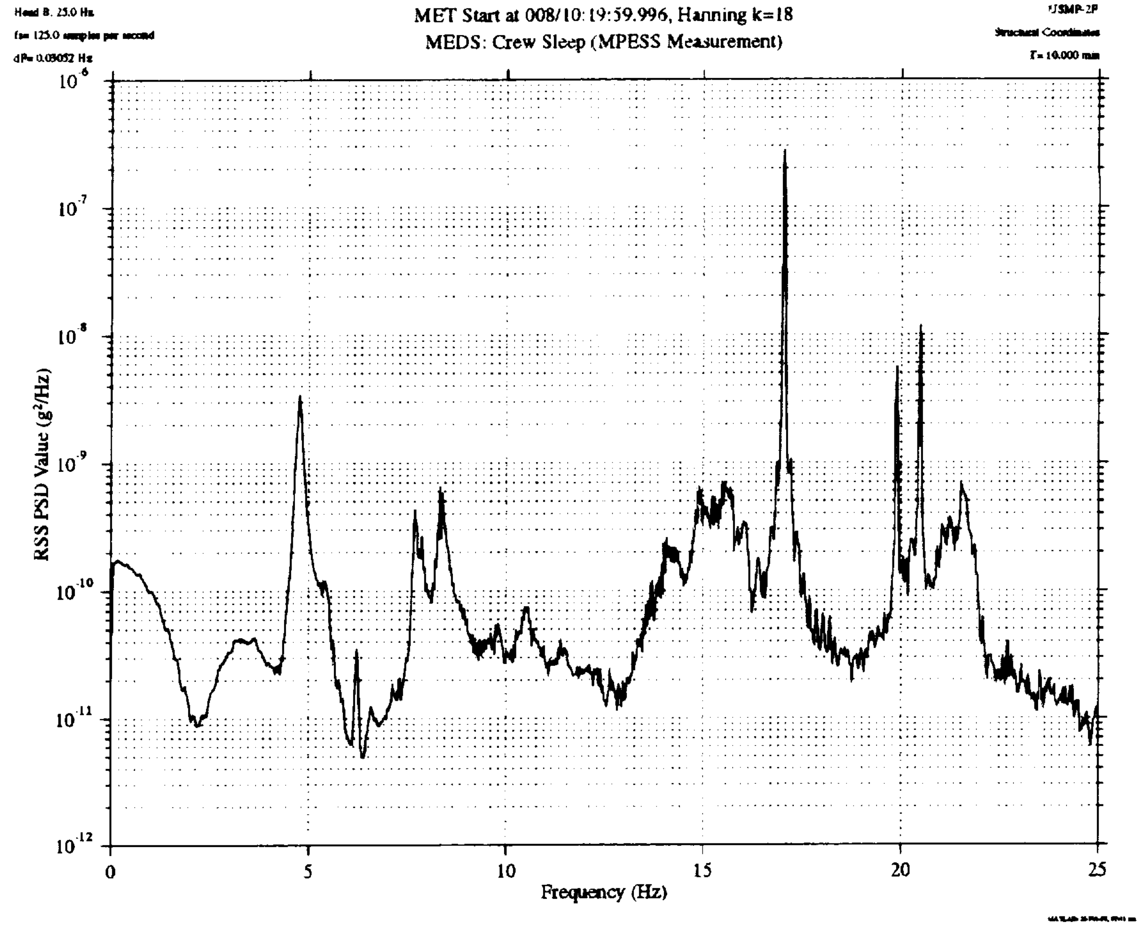
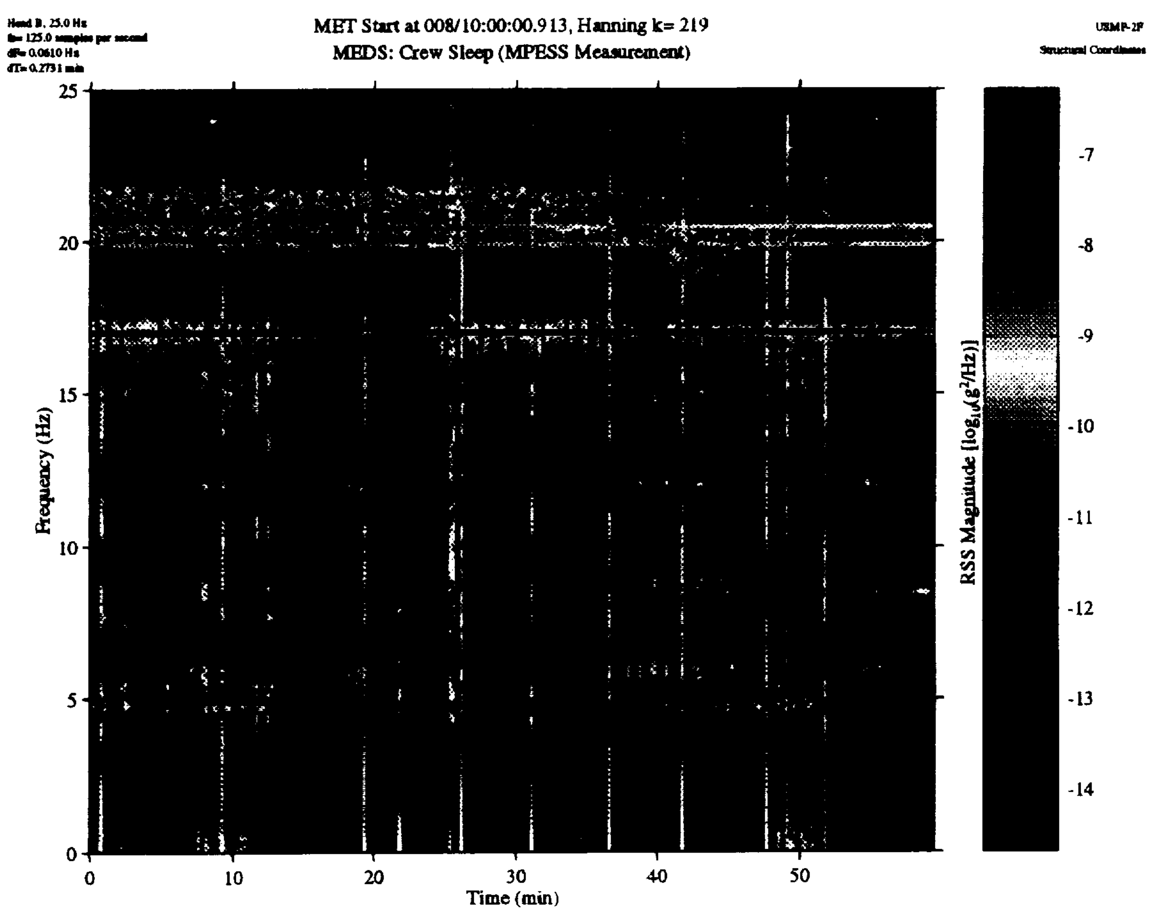
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



Head B, 25.0 Hz
fs= 125.0 samples per second
dF= 0.03052 Hz
MET Start at 008/10:19:59.996, Hanning k=18
MEDS: Crew Sleep (MPESS Measurement)
USMP-2F
Structural Coordinates
T= 10.000 min
RSS PSD Value (g^2/Hz)
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
0
5
10
15
20
25
Frequency (Hz)



Head B, 25.0 Hz
fs= 125.0 samples per second
dF= 0.0610 Hz
dT= 0.2731 min
MET Start at 008/10:00:00.913, Hanning k= 219
MEDS: Crew Sleep (MPESS Measurement)
USMP-2F
Structural Coordinates
Frequency (Hz)
25
20
15
10
5
0
Time (min)
0
10
20
30
40
50
RSS Magnitude [$\log_{10}(g^2/Hz)$]
-7
-8
-9
-10
-11
-12
-13
-14

FLIGHT CONTROL SYSTEM

MISSION

STS-75, February 1996, USMP-3

SOURCE OR ACTIVITY

Approximately one day before scheduled re-entry, a two-part checkout procedure is performed to verify operations of the Orbiter Flight Control System (FCS). The first part of this checkout uses one of the three auxiliary power units (APUs) to circulate hydraulic fluid in order to move the rudder, elevons, and ailerons of the Orbiter. As an APU is activated, exhaust gas is vented in the $+Z_O$ direction. The result of this venting is similar in nature to a VRCS jet firing, ranging from nearly 0 to 30 pounds of force. The exhaust does not vent as a steady stream, but cycles at approximately 1 to 1.5 Hz.

Larger plot on reverse

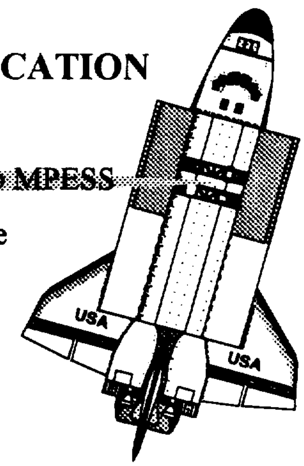
ACCELEROMETER

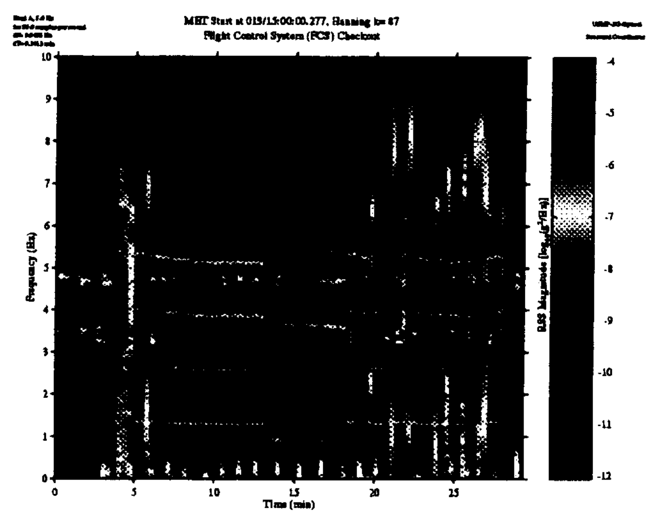
- [x] SAMS
- [ ] OARE

Unit G, Head A, 5 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [x] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge





EFFECT ON MICROGRAVITY ENVIRONMENT

The figure above shows a SAMS Unit G TSH A spectrogram showing the extent of the first part of the FCS checkout. The activation of APU1 is identified at about 3 minutes into the plot by a sudden change in acceleration characteristics. Of particular note is the appearance of a 1.3 Hz signal and several upper harmonics. These signals remain in the data throughout the checkout period, with slight shifts in the frequencies about 13 and 18 minutes into the plot. Broadband excitation of the microgravity environment about four minutes into the plot appear to be correlated with changes in APU1 turbine activity, as are the shorter excitations between 20 and 27 minutes into the plot.

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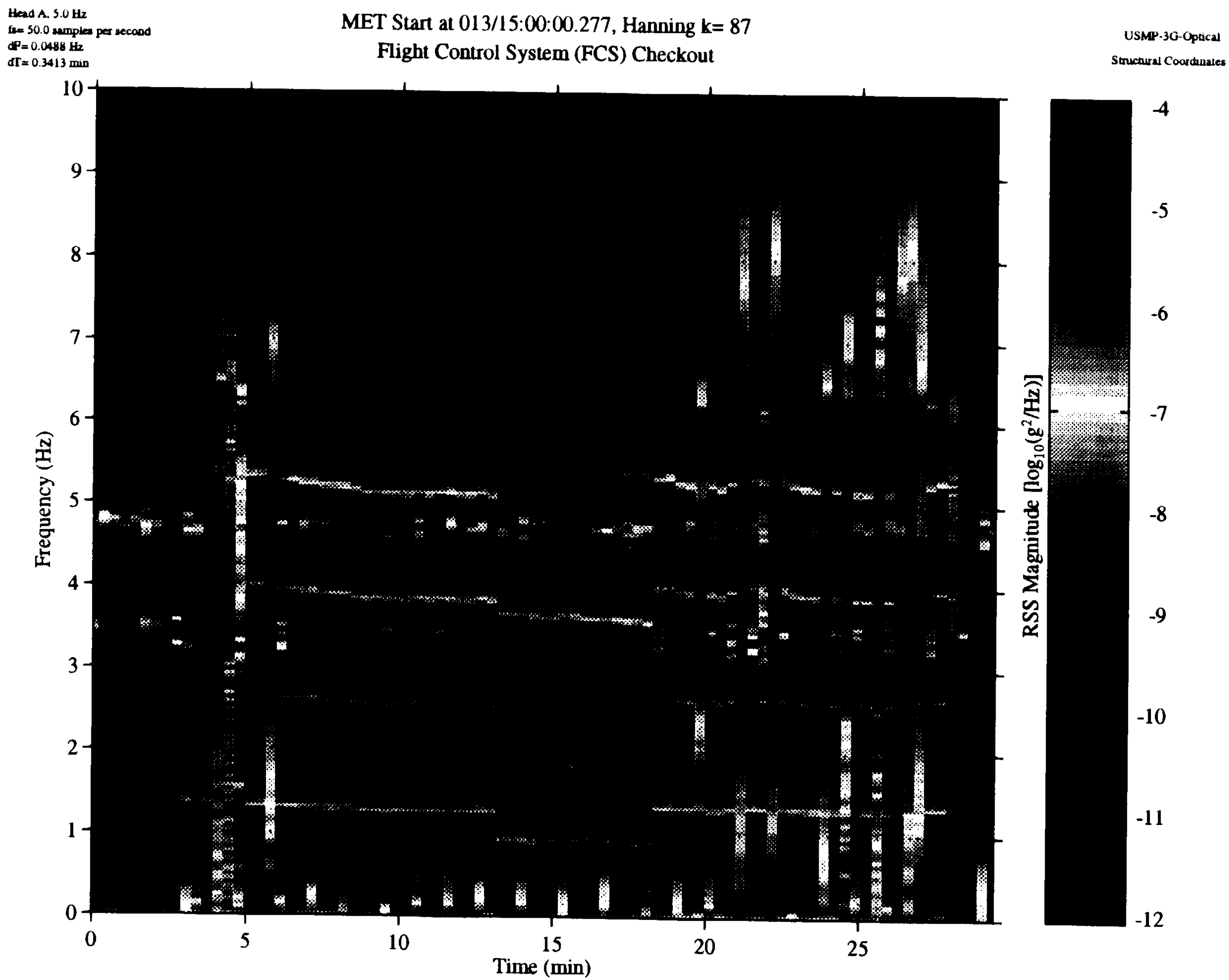


Head A, 5.0 Hz
fs= 50.0 samples per second
dF= 0.0488 Hz
dT= 0.3413 min
MET Start at 013/15:00:00.277, Hanning k= 87
Flight Control System (FCS) Checkout
USMP-3G-Optical
Structural Coordinates
Frequency (Hz)
Time (min)
RSS Magnitude [$\log_{10}(g^2/Hz)$]

TETHER SATELLITE SYSTEM DEPLOY

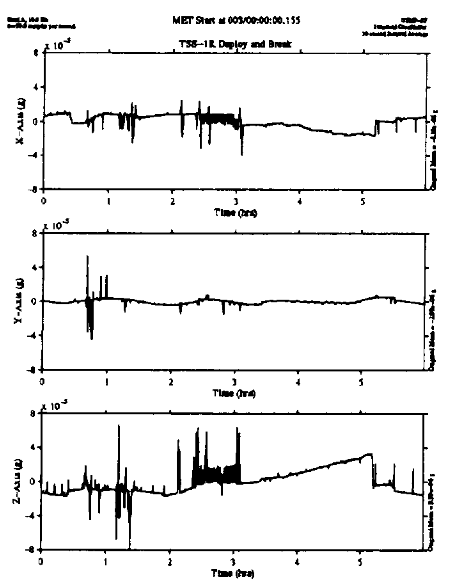
MISSION

STS-75, February 1996, USMP-3

SOURCE OR ACTIVITY

The deploy operation of the Tether Satellite System (TSS) deployed the experiment approximately 12.8 miles (20.7 km) overhead of the orbiter Columbia.

Larger plots on reverse



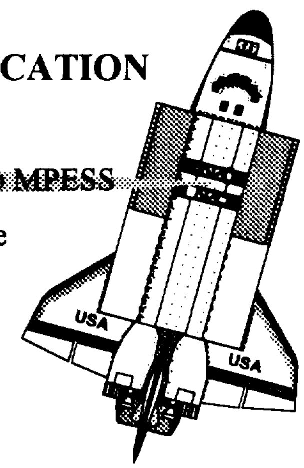
ACCELEROMETER

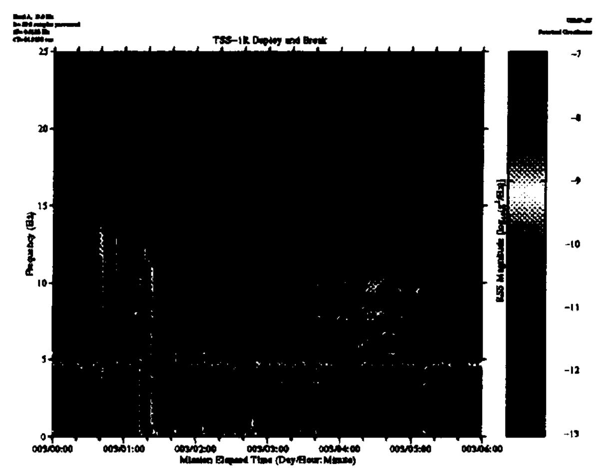
- [x] SAMS
- [ ] OARE

Unit F, Head A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [x] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge





EFFECT ON MICROGRAVITY ENVIRONMENT

The deploy of the satellite and tether caused two primary effects in the microgravity environment. The first effect is illustrated by the variable frequency disturbances in the spectrogram between 5 and 20 Hz. These disturbances were caused by the various pulleys used in the cable deployment mechanism.

The other effect is the gradually increasing quasi-steady levels primarily seen in the Z_O-axis. These changing levels are due to the gradual motion of the vehicle (Orbiter and TSS) center of mass location from within the Orbiter cargo bay to a position between the Orbiter and TSS. Gravity gradient and centripetal accelerations were then introduced into the SAMS measurements. At a separation distance of 20 km, the quasi-steady acceleration level was increased by about 50 mg.

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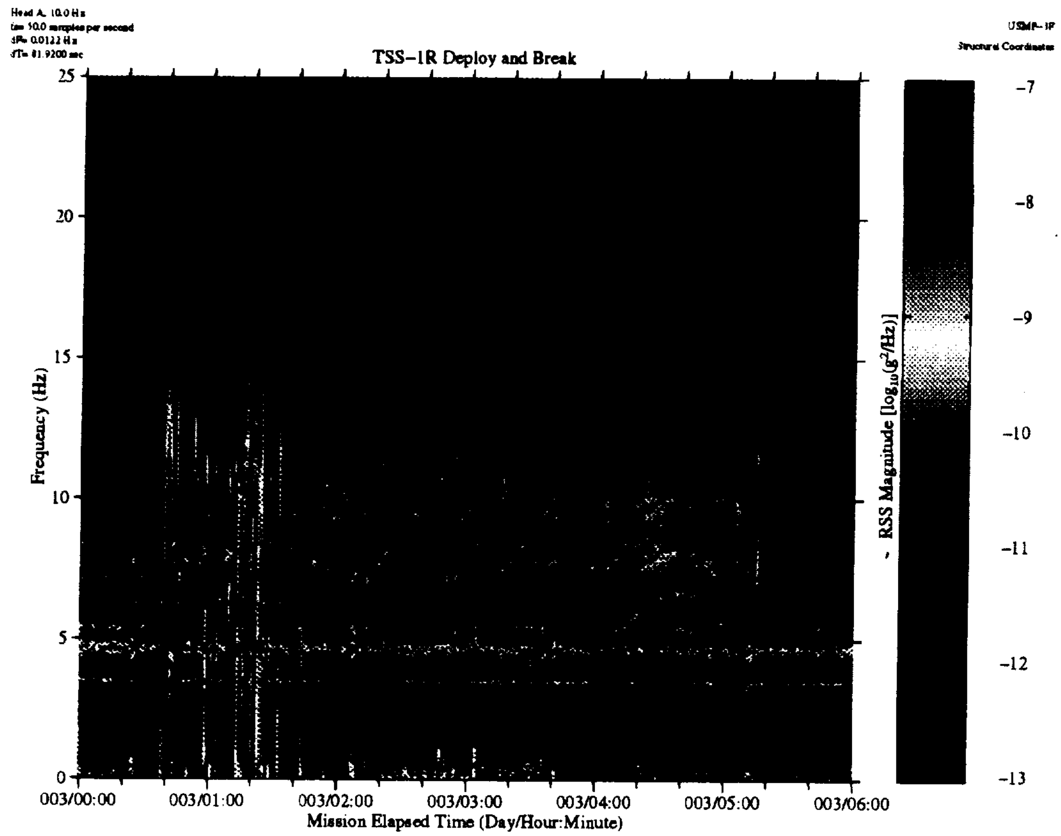
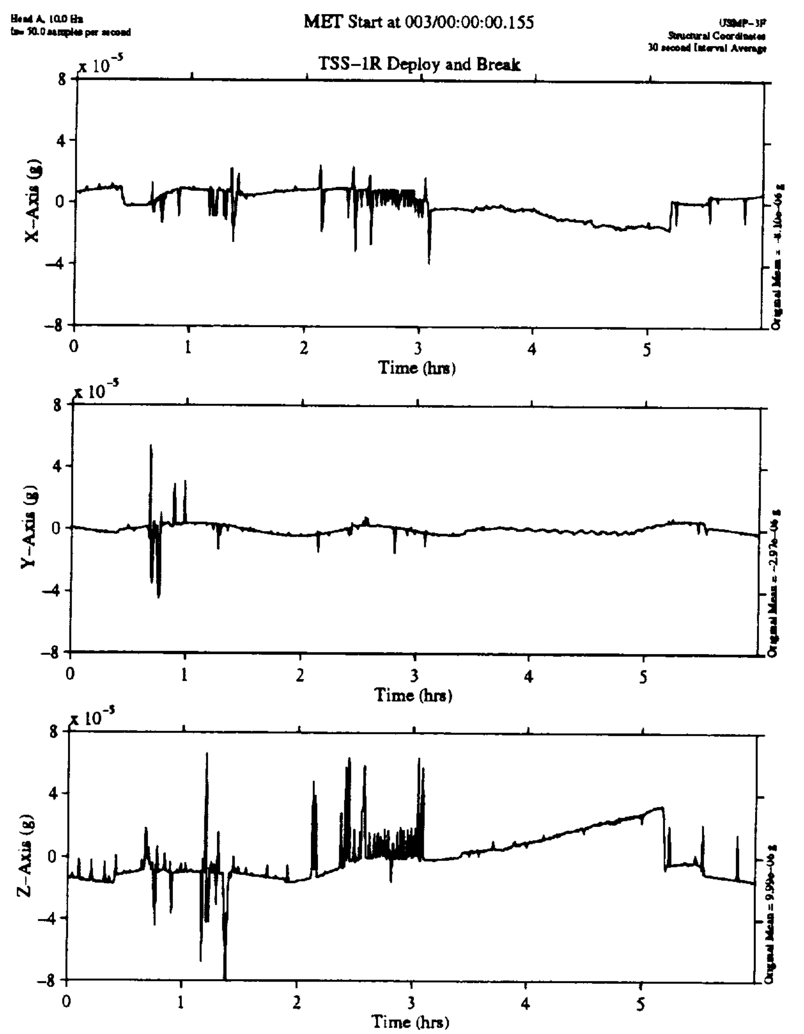


Head A, 10.0 Hz
fs= 50.0 samples per second
df= 0.0122 Hz
dT= 81.9200 sec
USMP-3F
Structural Coordinates
TSS-1R Deploy and Break
Frequency (Hz)
RSS Magnitude [log10(g²/Hz)]
Mission Elapsed Time (Day/Hour:Minute)
003/00:00
003/01:00
003/02:00
003/03:00
003/04:00
003/05:00
003/06:00



Head A, 10.0 Hz
fs= 50.0 samples per second
MET Start at 003/00:00:00.155
USMP-3F
Structural Coordinates
30 second Interval Average
TSS-1R Deploy and Break
x 10^-5
X-Axis (g)
Y-Axis (g)
Z-Axis (g)
Time (hrs)

ERGOMETER *(crew exercise)*

MISSION

STS-75, February 1996, USMP-3

SOURCE OR ACTIVITY

The ergometer is a bicycle-type of exercise equipment in that pedaling is the primary means of getting exercise. This equipment has been configured with various forms of isolation systems on different shuttle missions.

(1) Hard-mounted - No isolation is employed, it is bolted directly to the middeck or flight deck.

(2) Inertial Vibration Isolation System (IVIS) - This isolation system is primarily aimed at combatting the side-to-side motion of the person who is exercising. Counter-weights are driven by the pedal shaft to be 180° out of phase with the side-to-side motion.

(3) Passive Cycle Isolation System (PCIS) - This system attempts to "free-float" the exercise equipment via four braided cable, wire-rope isolators.

(4) Ergometer Vibration Isolation System (EVIS) - This is a three-axis vibration isolation system. The ergometer Z-axis isolation is an active system of counterweights which react to the motion of the crew member. The ergometer X- and Y-axis isolation is accomplished by a two-axis slide on the floor the mounting assembly.

(5) Bungee isolation - In this configuration, a recumbent bicycle is suspended by a system of elastic bungee cords. These cords are secured to various points on the surrounding shuttle structure. The suspension support is primarily in the XY plane of the ergometer.

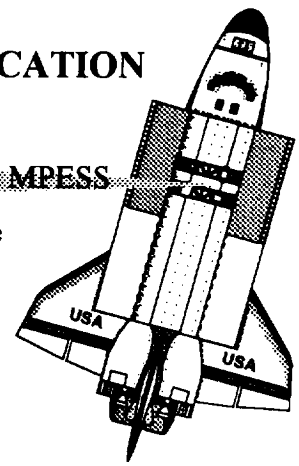
ACCELEROMETER

☑ SAMS ☐ OARE

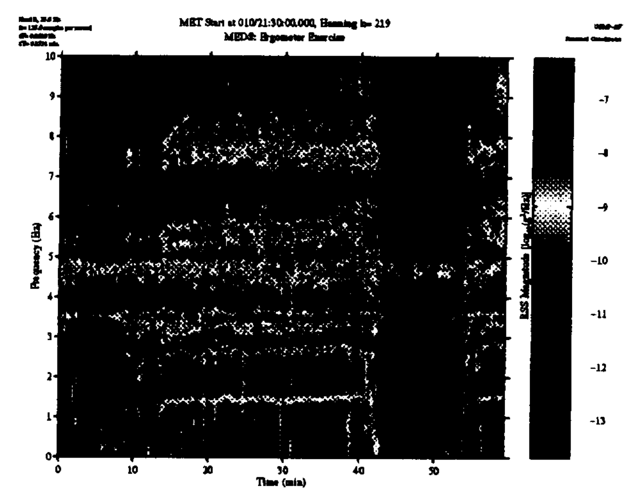
Unit F, Head B, 25 Hz
fs = 125 samples per second

MEASUREMENT LOCATION

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



Larger plot on reverse



EFFECT ON MICROGRAVITY ENVIRONMENT

The effects of exercising on the microgravity environment are seen mainly in the frequency range from about 1 to 4 Hz and last for the duration of the exercise. Depending on the particular crew member and the vibration isolation used, typical acceleration levels in this frequency range can vary between 50 μg_{RMS} to about 1 mg_{RMS}.

The exercise period may be seen in this plot beginning shortly after minute 10, and ending around minute 40. This plot not only shows the primary exercise frequency (~2.5 Hz, related to the pedaling), but also shows the sub-frequency (~1.25 Hz, related to shoulder rocking). This exercise was conducted with an ergometer in the crew cabin, while the SAMS unit was located on the MPESS carrier.

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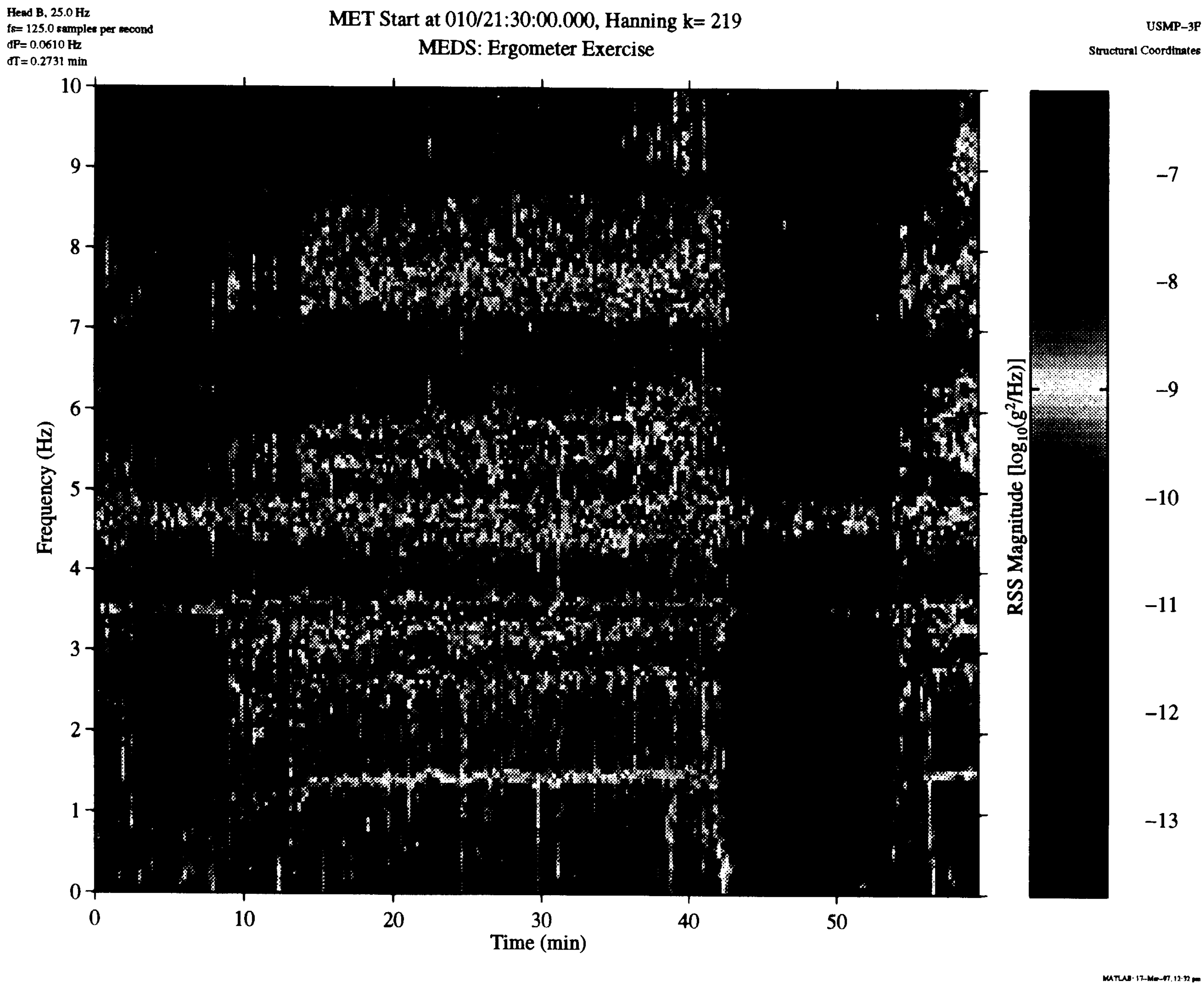
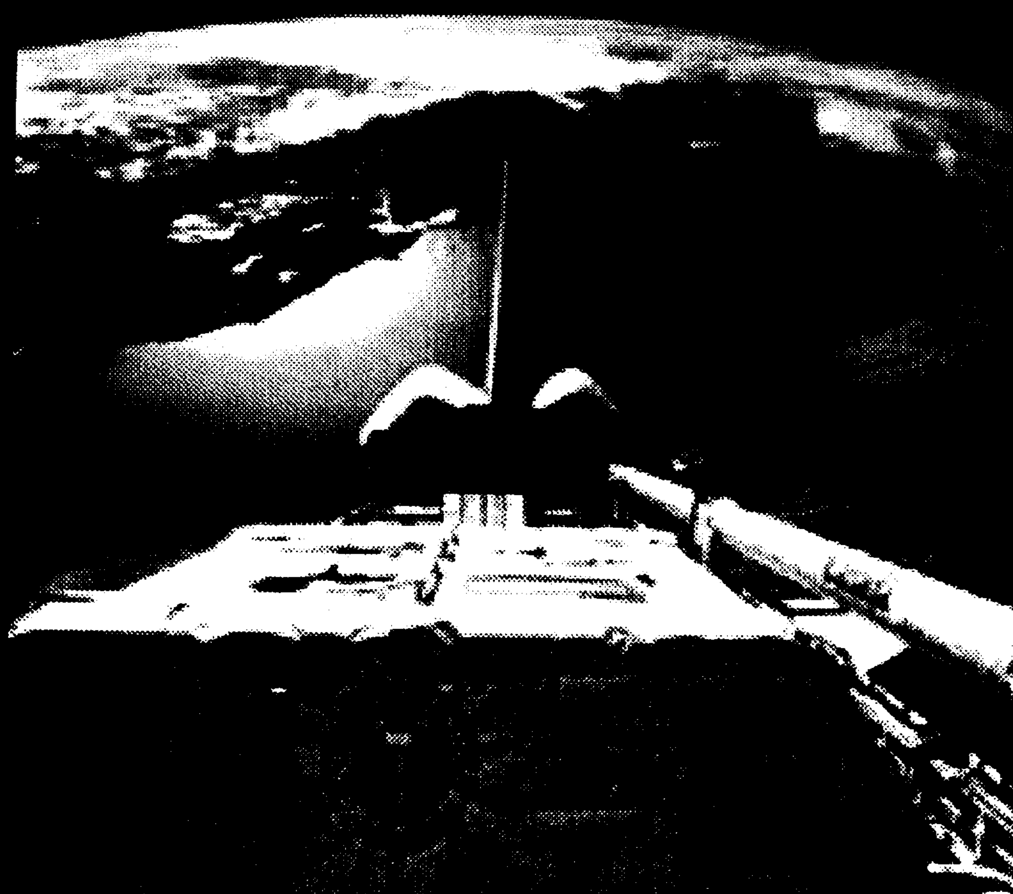


Head B, 25.0 Hz
fs= 125.0 samples per second
dF= 0.0610 Hz
dT= 0.2731 min
MET Start at 010/21:30:00.000, Hanning k= 219
MEDS: Ergometer Exercise
USMP-3P
Structural Coordinates
Frequency (Hz)
Time (min)
RSS Magnitude [$\log_{10}(g^2/Hz)$]
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
−7
−8
−9
−10
−11
−12
−13
MATLAB 17-Mar-97, 12:32 pm

SECTION III

Disturbances Measured in the SPACEHAB Module



CENTRIFUGE

MISSION

STS-60, February 1994, SPACEHAB-2

SOURCE OR ACTIVITY

A centrifuge was used in a Detailed Supplementary Objective (DSO-202) conducted during SPACEHAB-2. This was a joint U.S./Russian metabolic investigation into the effects of microgravity on body fluids.

Larger plots on reverse

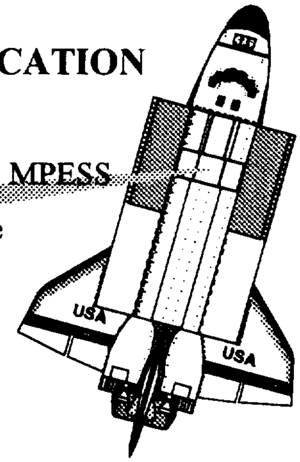
ACCELEROMETER

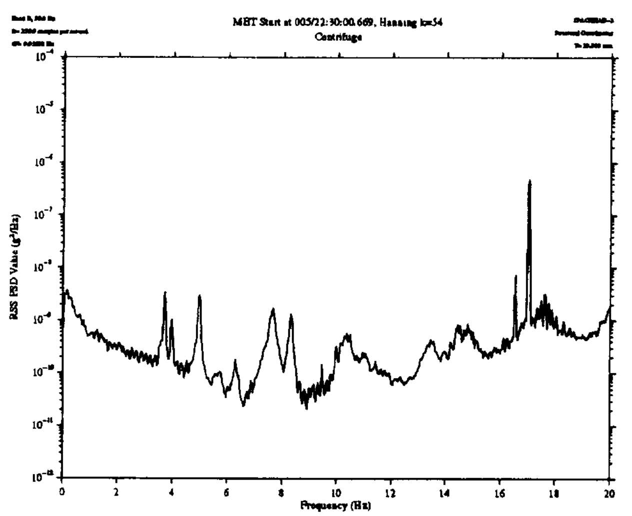
☑ SAMS ☐ OARE

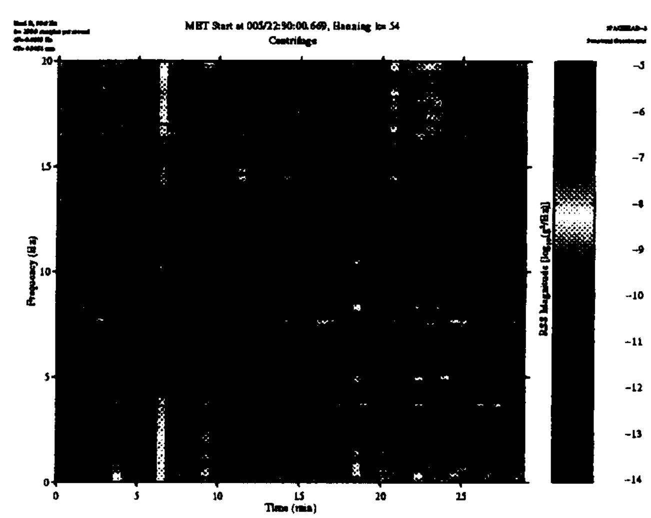
TSH B, 50 Hz
fs = 250 samples per second

MEASUREMENT LOCATION

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







EFFECT ON MICROGRAVITY ENVIRONMENT

During centrifuge operation, a strong, tightly controlled, 16.5 Hz disturbance with acceleration levels around 14 μg_{RMS} was evident in all three structural axes.

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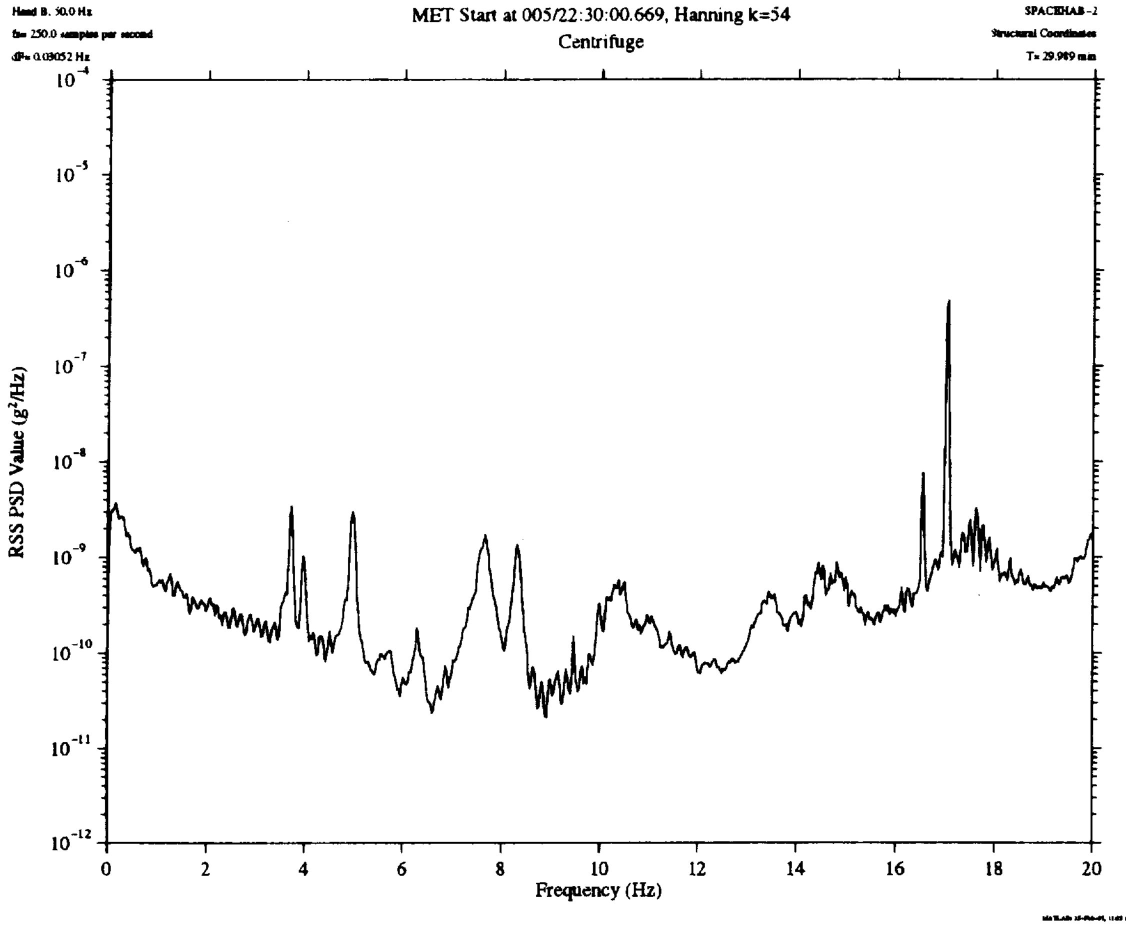
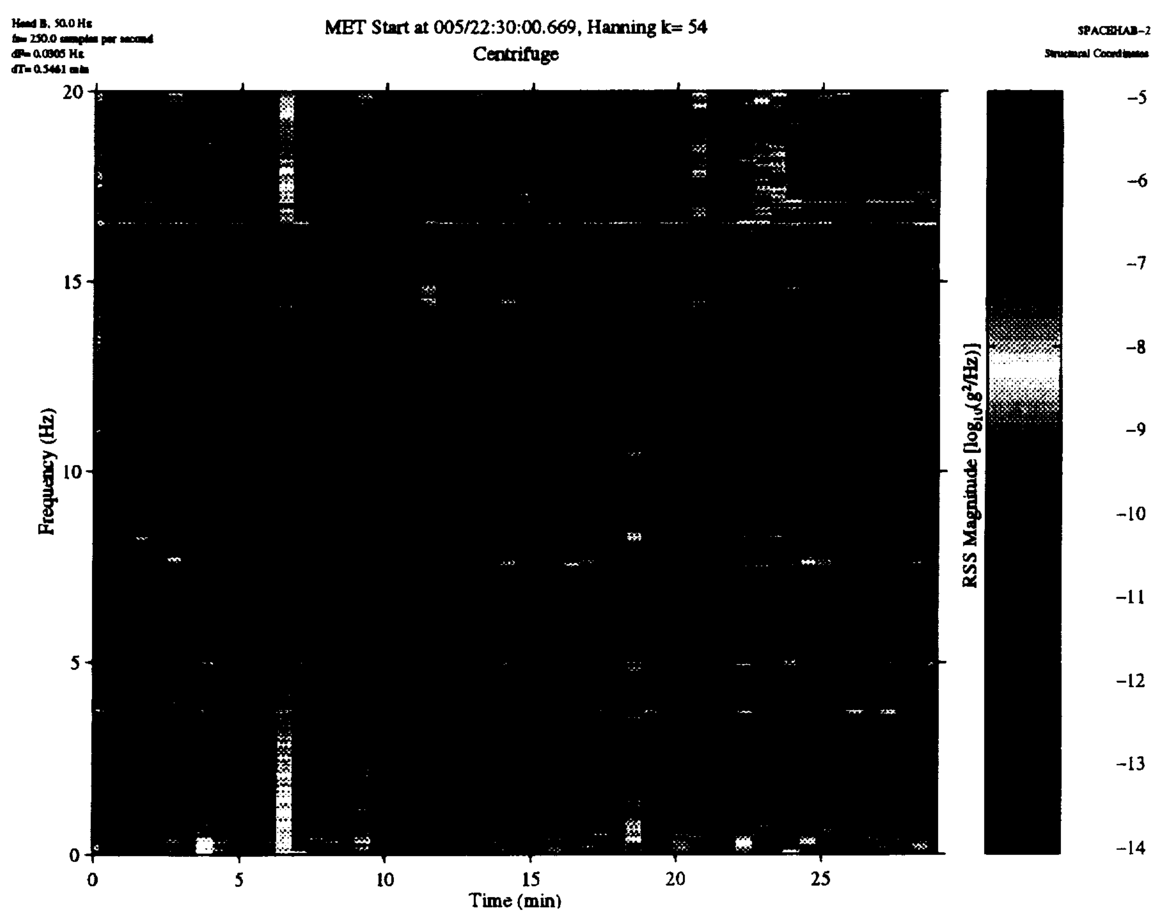

Head B, 50.0 Hz
fs= 250.0 samples per second
dF= 0.03052 Hz
MET Start at 005/22:30:00.669, Hanning k=54
Centrifuge
SPACEHAB-2
Structural Coordinates
T= 29.989 min
RSS PSD Value (g²/Hz)
Frequency (Hz)


Head B, 50.0 Hz
fs= 250.0 samples per second
dF= 0.0305 Hz
dT= 0.5461 min
MET Start at 005/22:30:00.669, Hanning k= 54
Centrifuge
SPACEHAB-2
Structural Coordinates
Frequency (Hz)
Time (min)
RSS Magnitude [log₁₀(g²/Hz)]

REFRIGERATOR/FREEZER (SOR/F)

MISSION

STS-60, February 1994, SPACEHAB-2

SOURCE OR ACTIVITY

The Stirling Orbiter Refrigerator/Freezer (SOR/F) was used on SPACEHAB-2. The refrigerator has a compressor which contains a piston driven by a linear motor.

Larger plots on reverse

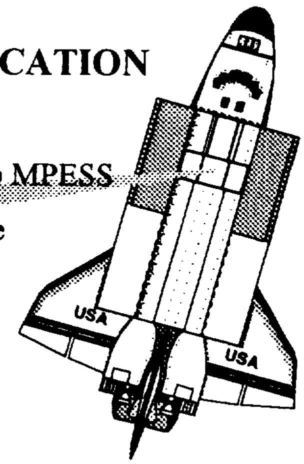
ACCELEROMETER

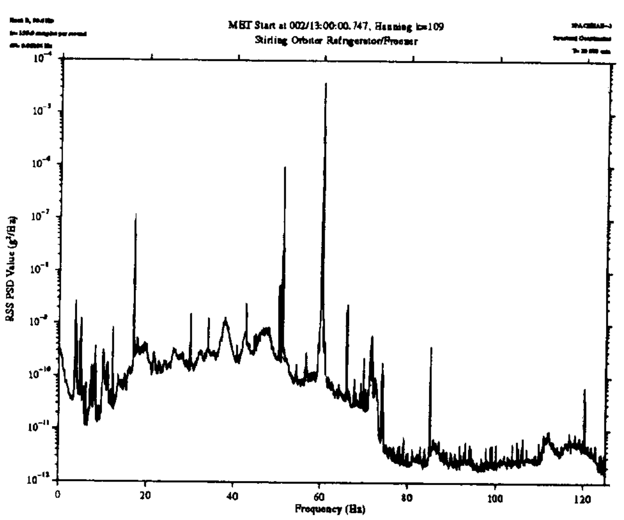
☑ SAMS ☐ OARE

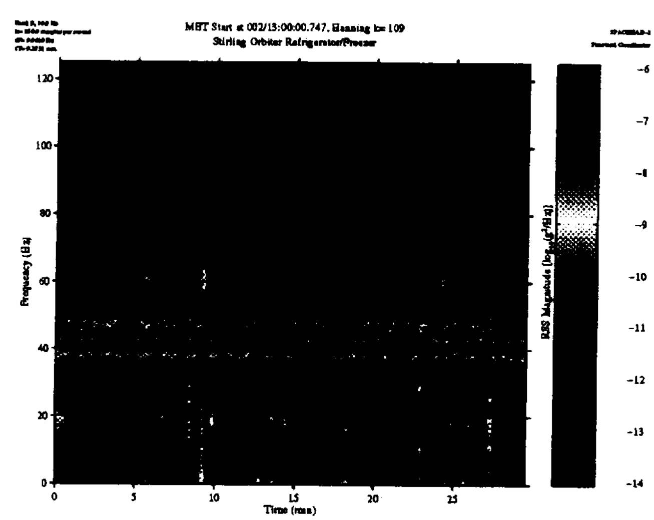
Head B, 50 Hz
fs = 250 samples per second

MEASUREMENT LOCATION

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







EFFECT ON MICROGRAVITY ENVIRONMENT

The dominant source of vibrations in this cryocooler is its compressor which contains a piston driven by a linear motor. Operation of the compressor during SPACEHAB-2 produced an intense oscillatory disturbance around 60 Hz and its second harmonic (120 Hz). This pump was the dominant oscillatory disturbance during its operation. It has been seen to produce accelerations in the 59.9 - 60.3 Hz region in excess of 2000 μg_{RMS}.

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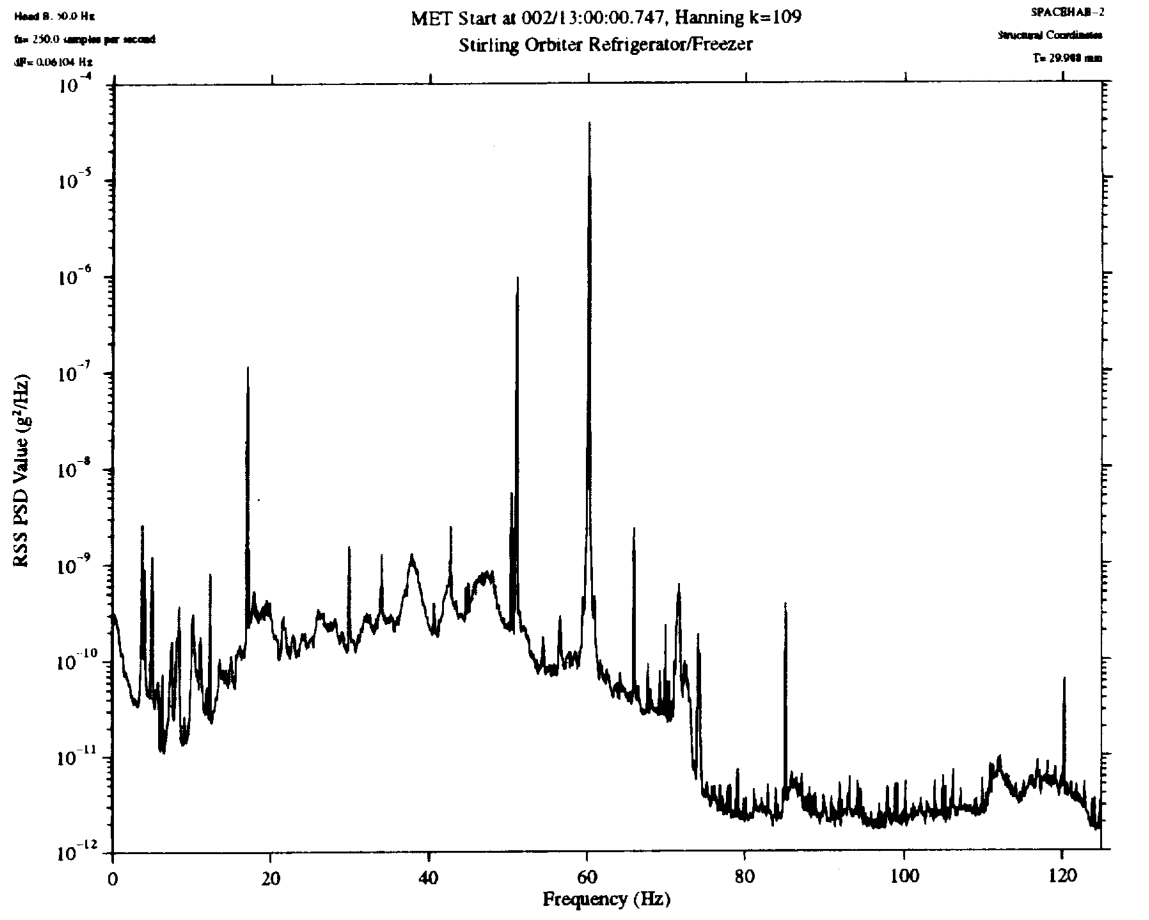
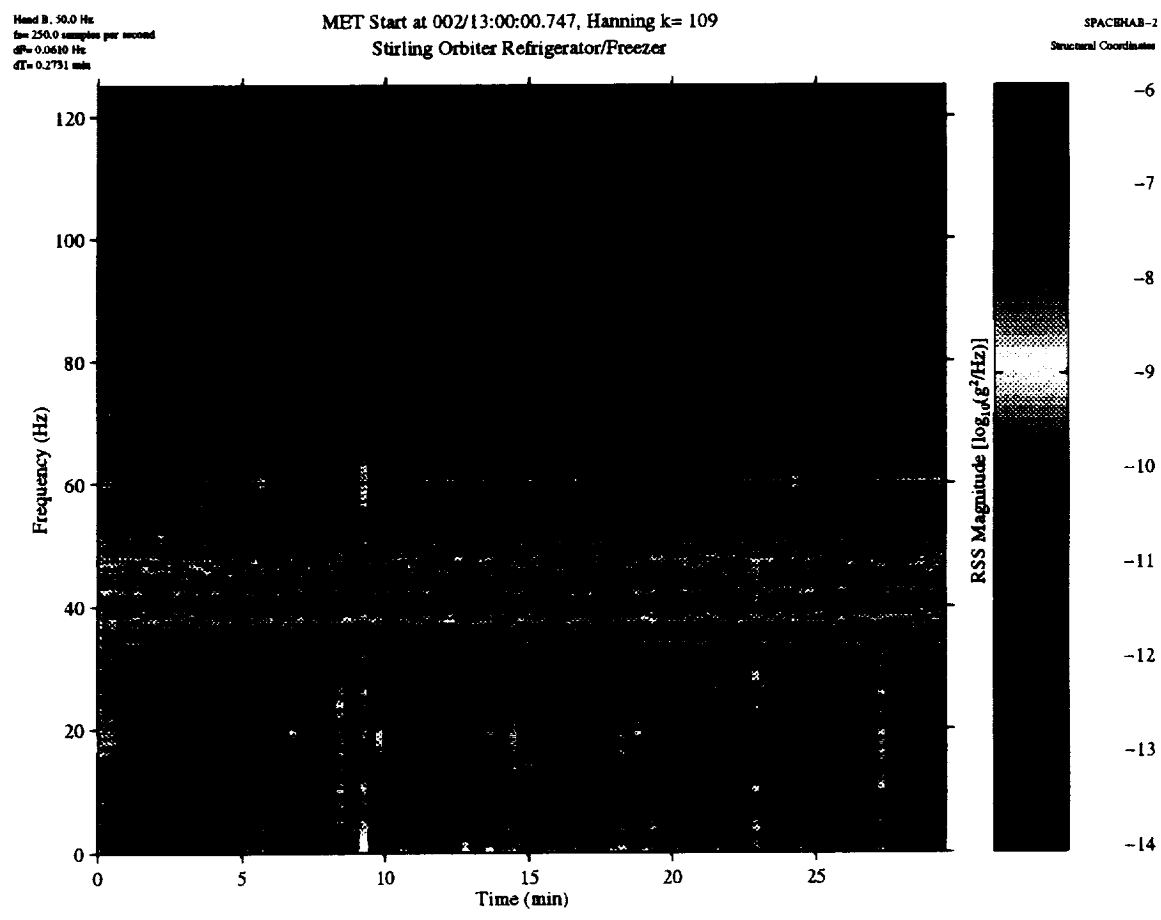


Head B, 50.0 Hz
fs= 250.0 samples per second
dF= 0.06104 Hz
MET Start at 002/13:00:00.747, Hanning k=109
Stirling Orbiter Refrigerator/Freezer
SPACEHAB-2
Structural Coordinates
T= 29.988 min
RSS PSD Value (g²/Hz)
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
0
20
40
60
80
100
120
Frequency (Hz)



Head B, 50.0 Hz
fs= 250.0 samples per second
dF= 0.0610 Hz
dT= 0.2731 min
MET Start at 002/13:00:00.747, Hanning k= 109
Stirling Orbiter Refrigerator/Freezer
SPACEHAB-2
Structural Coordinates
Frequency (Hz)
120
100
80
60
40
20
0
0
5
10
15
20
25
Time (min)
RSS Magnitude [log10(g²/Hz)]
-6
-7
-8
-9
-10
-11
-12
-13
-14

Ku-BAND ANTENNA

MISSION

STS-60, February 1994, SPACEHAB-2

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

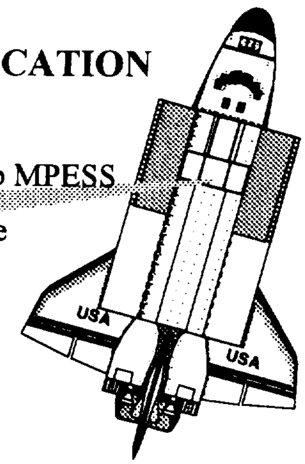
ACCELEROMETER

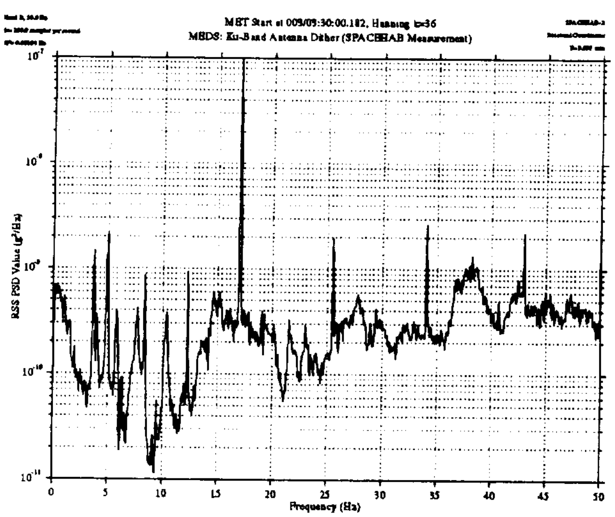
- [x] SAMS
- [ ] OARE

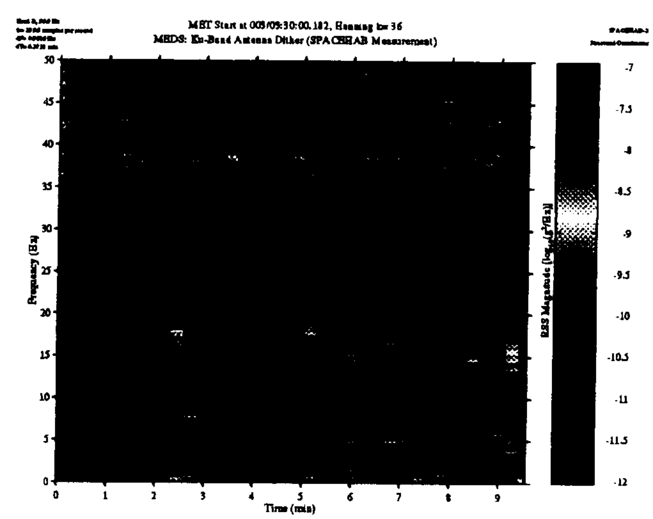
Head B, 50 Hz
fs = 250 samples per second

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [x] 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 85 Hz has been seen.

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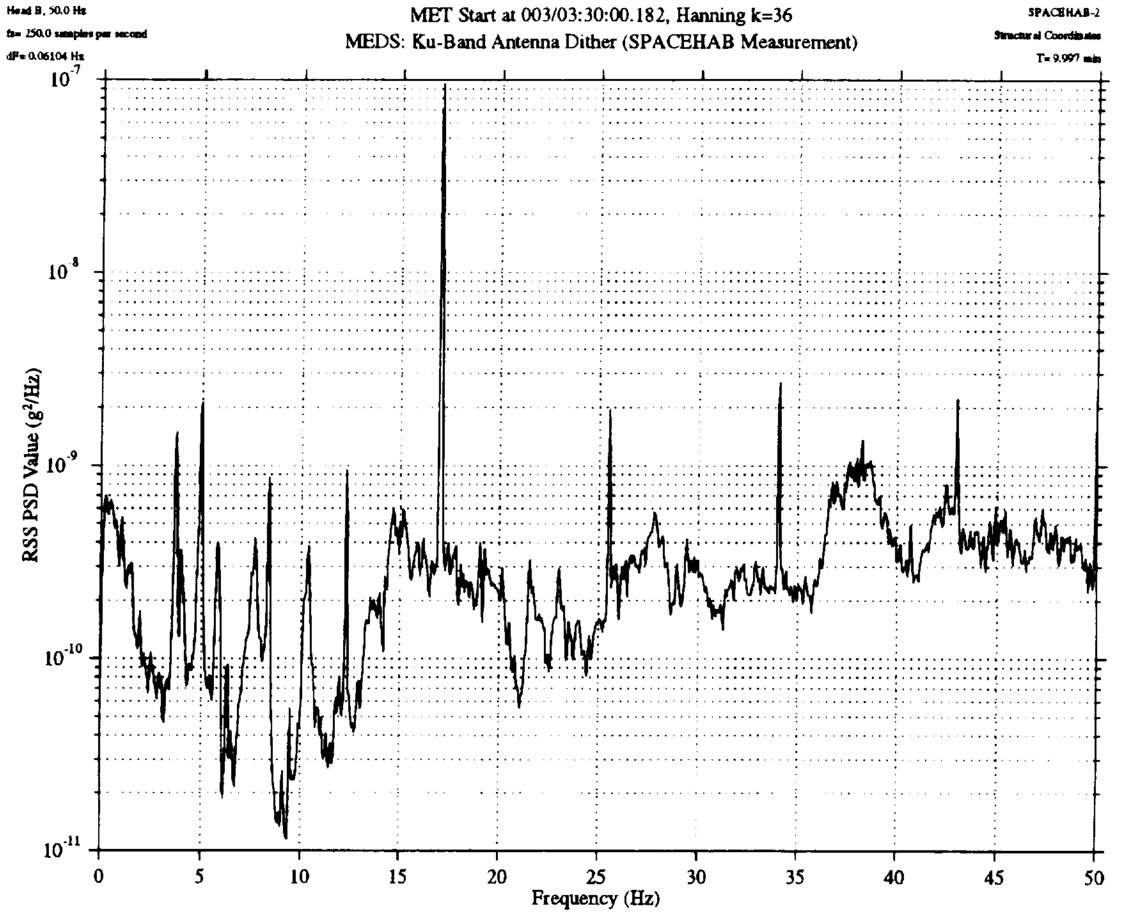
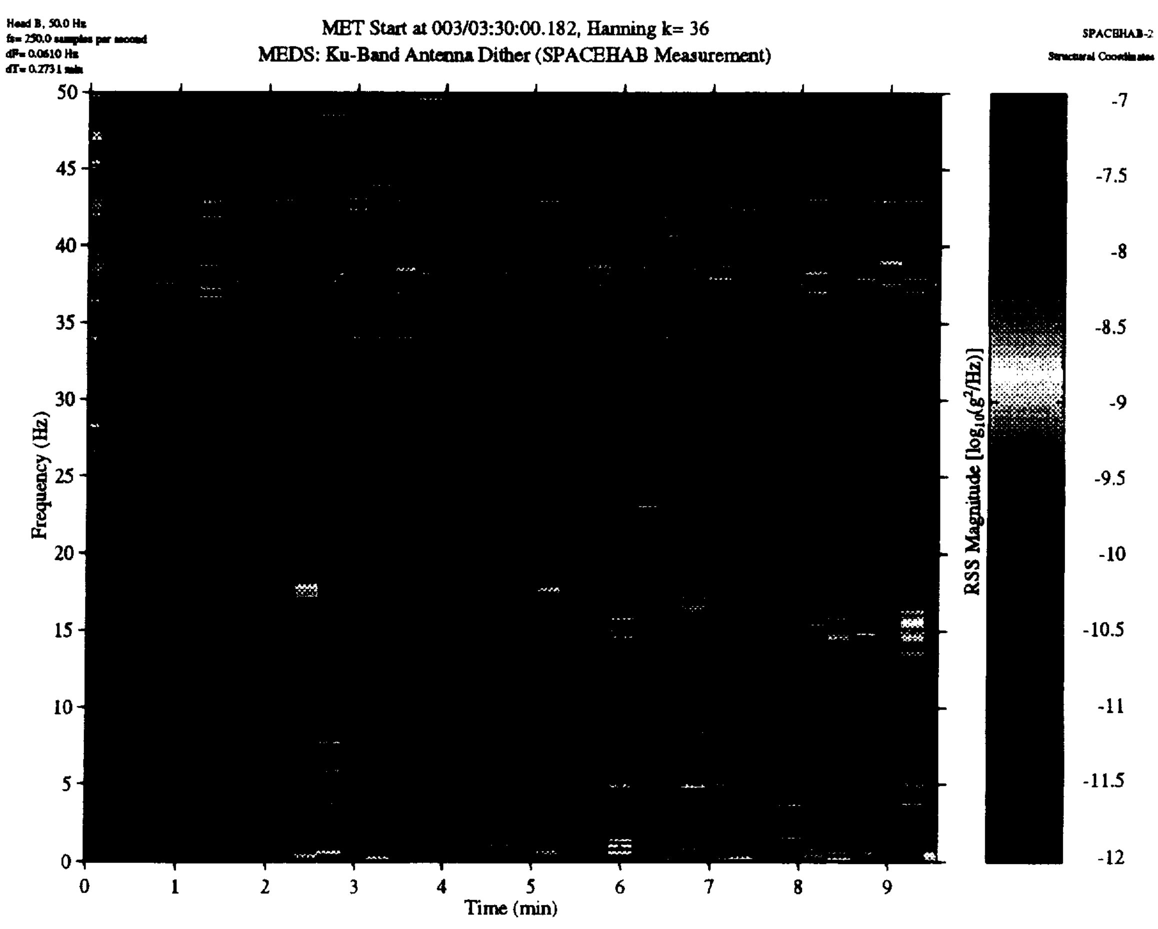
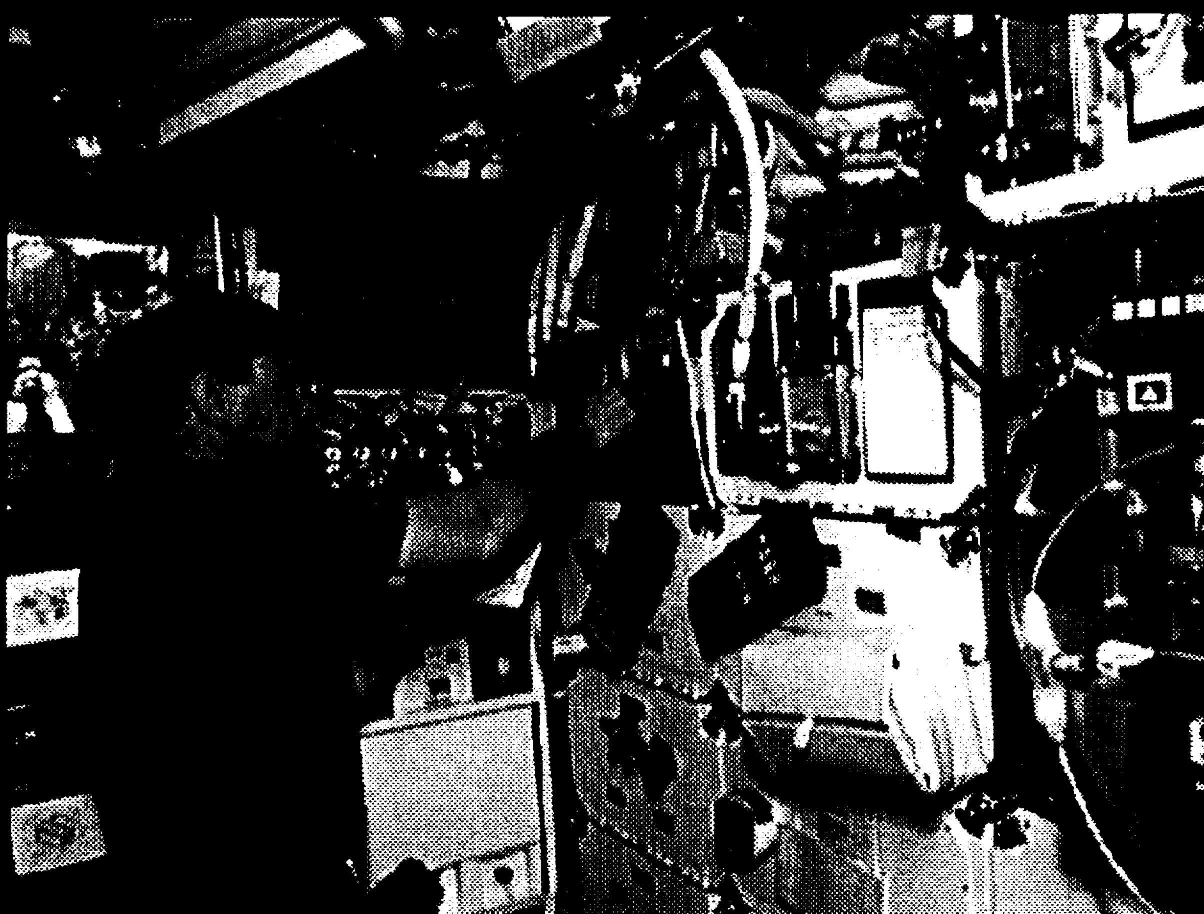

Head B, 50.0 Hz
fs= 250.0 samples per second
dF= 0.06104 Hz
MET Start at 003/03:30:00.182, Hanning k=36
MEDS: Ku-Band Antenna Dither (SPACEHAB Measurement)
SPACEHAB-2
Structural Coordinates
T= 9.997 min
RSS PSD Value (g²/Hz)
Frequency (Hz)


Head B, 50.0 Hz
fs= 250.0 samples per second
dF= 0.0610 Hz
dT= 0.2731 min
MET Start at 003/03:30:00.182, Hanning k= 36
MEDS: Ku-Band Antenna Dither (SPACEHAB Measurement)
SPACEHAB-2
Structural Coordinates
Frequency (Hz)
Time (min)
RSS Magnitude [log10(g²/Hz)]

SECTION IV

Disturbances Measured in the Middeck



CREW SLEEP

MISSION

STS-43, August 1991

SOURCE OR ACTIVITY

On single shift missions, the microgravity environment becomes quiet during crew sleep.

Larger plots on reverse

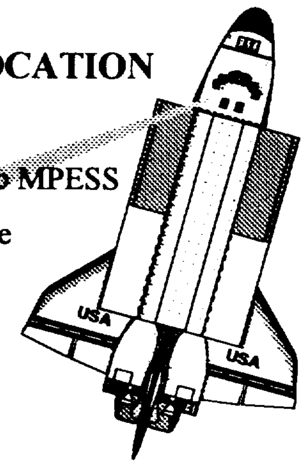
ACCELEROMETER

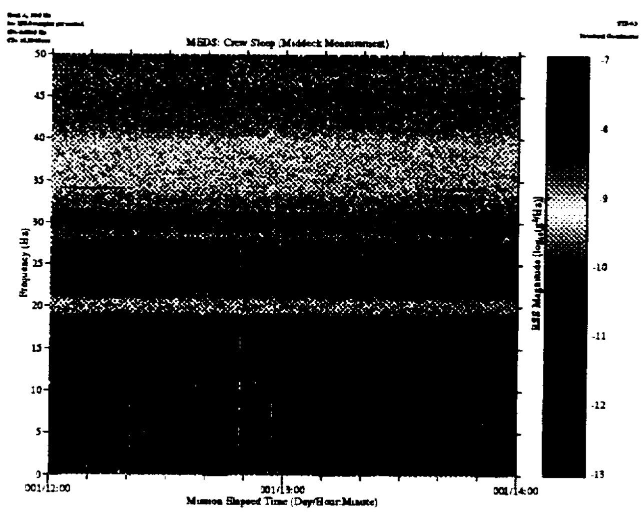
☑ SAMS ☐ OARE

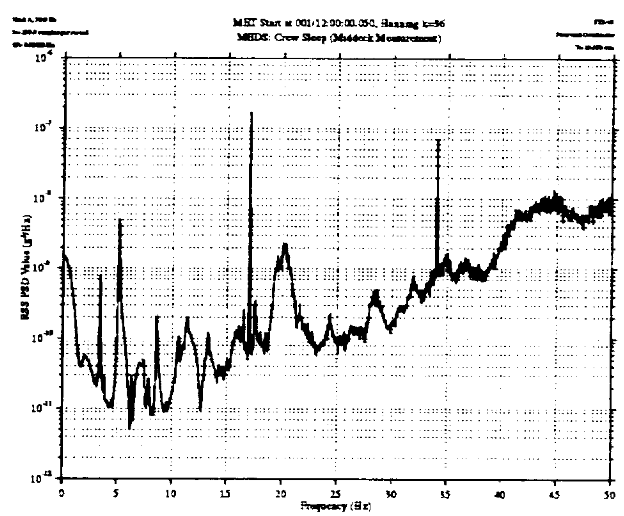
Head A, 50 Hz
fs = 250 samples per second

MEASUREMENT LOCATION

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







EFFECT ON MICROGRAVITY ENVIRONMENT

Sleep during a single shift mission such as STS-43 results in acceleration levels in the 1 to 4 Hz range below about 20 μg_{RMS}. Vehicle structural modes and the Ku-band antenna are the primary disturbance sources during crew sleep.

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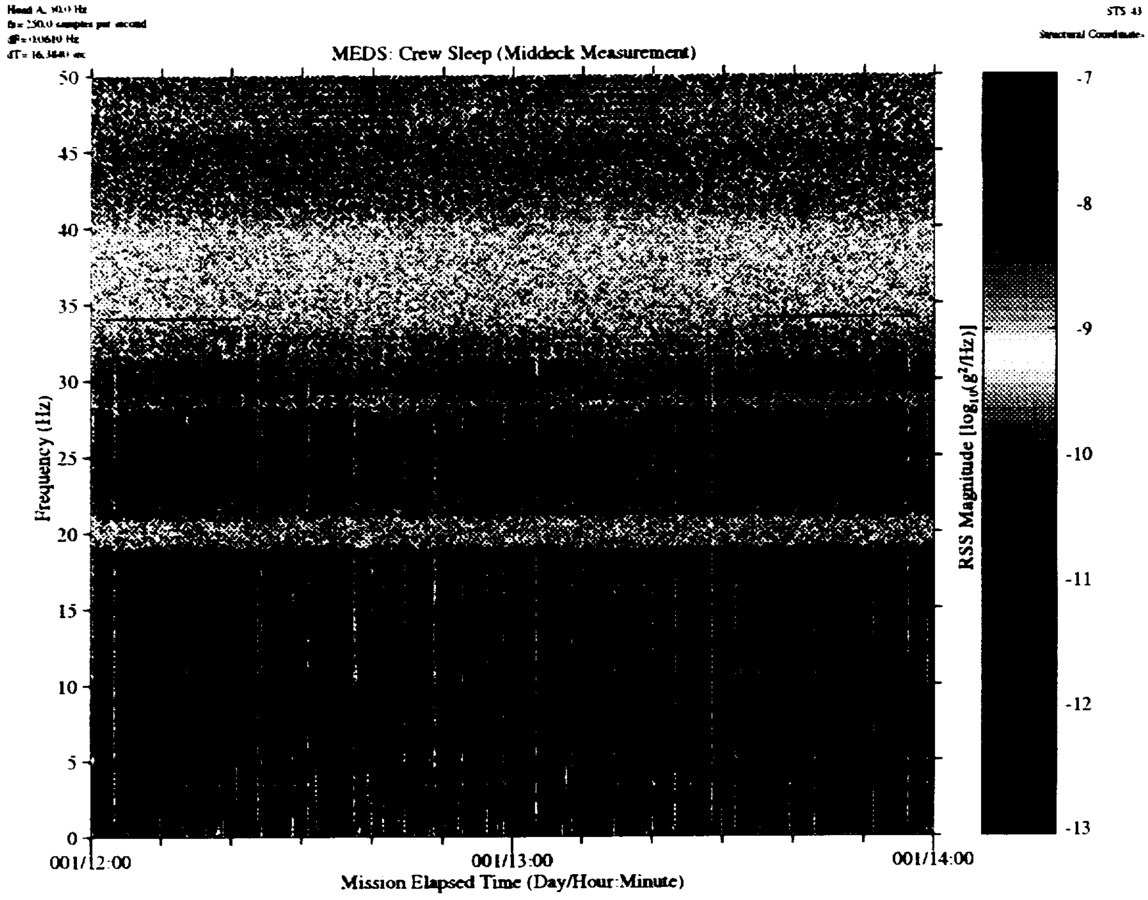
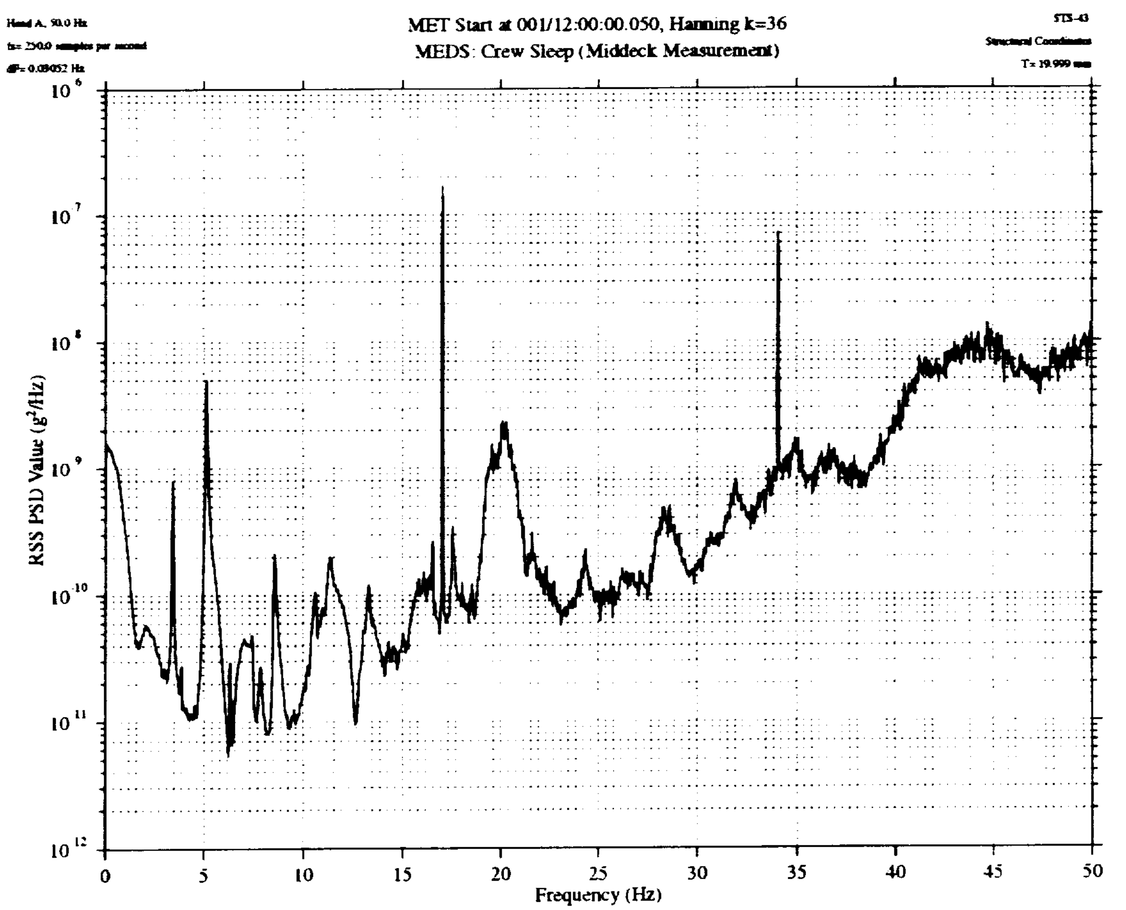


STS 43
MEDS: Crew Sleep (Middeck Measurement)
Frequency (Hz)
Mission Elapsed Time (Day/Hour:Minute)
001/12:00
001/13:00
001/14:00
RSS Magnitude [log10(g²/Hz)]



MET Start at 001/12:00:00.050, Hanning k=36
MEDS: Crew Sleep (Middeck Measurement)
STS-43
RSS PSD Value (g²/Hz)
Frequency (Hz)

ERGOMETER *(crew exercise)*

MISSION

STS-66, November 1994, ATLAS-3

SOURCE OR ACTIVITY

The ergometer is a bicycle-type of exercise equipment in that pedaling is the primary means of getting exercise. This equipment has been configured with various forms of isolation systems on different shuttle missions.

(1) Hard-mounted - No isolation is employed, it is bolted directly to the vehicle.

(2) Inertial Vibration Isolation System (IVIS) - This isolation system is primarily aimed at combatting the side-to-side motion of the person who is exercising. Counter-weights are driven by the pedal shaft to be 180° out of phase with the side-to-side motion.

(3) Passive Cycle Isolation System (PCIS) - This system attempts to "free-float" the exercise equipment via four braided-cable wire-rope isolators.

(4) Ergometer Vibration Isolation System (EVIS) - This is a three-axis vibration isolation system. The ergometer Z-axis isolation is an active system of counterweights which react to the motion of the crew member. The ergometer X- and Y-axis isolation is accomplished by a two-axis slide on the floor of the mounting assembly.

(5) Bungee isolation - In this configuration, a recumbent bicycle is suspended by a system of elastic bungee cords. These cords are secured to various points on the surrounding shuttle structure. The suspension support is primarily in the XY plane of the ergometer.

Larger plot on reverse

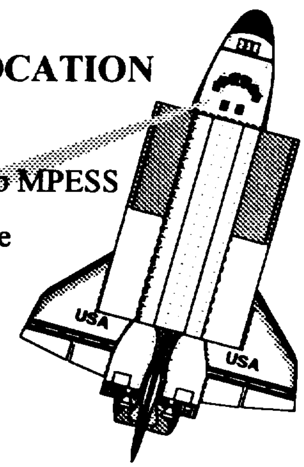
ACCELEROMETER

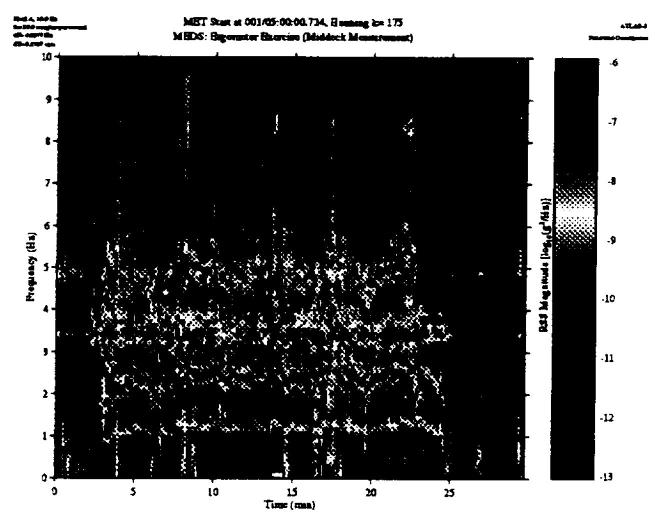
☑ SAMS ☐ OARE

Head A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

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





EFFECT ON MICROGRAVITY ENVIRONMENT

The effects of exercising on the microgravity environment are seen mainly in the frequency range from about 1 to 4 Hz and last for the duration of the exercise. Depending on the particular crew member and the vibration isolation used, typical acceleration levels in this frequency range can vary between 50 μg_{RMS} to about 1 mg_{RMS}.

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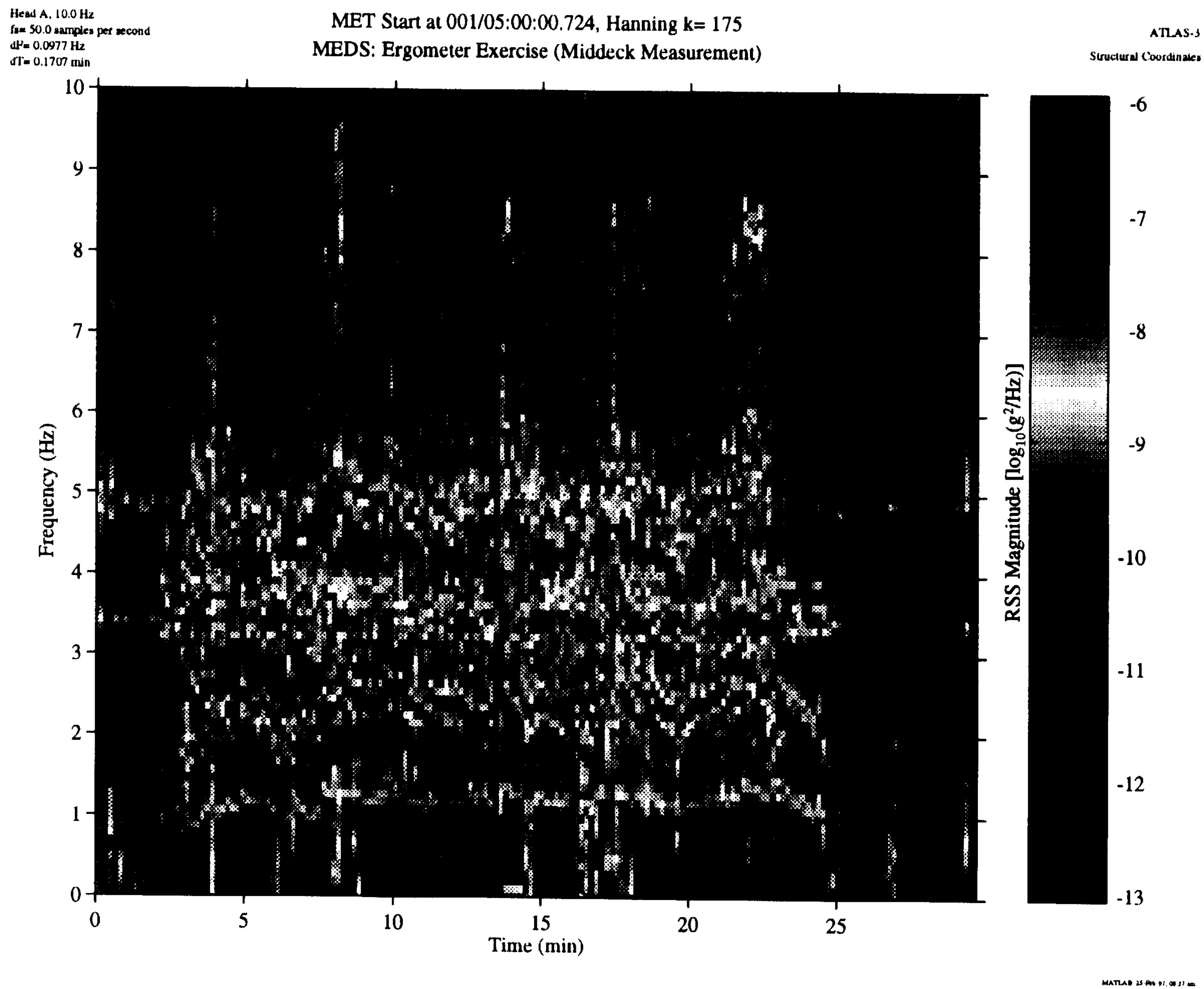

Head A, 10.0 Hz
fs= 50.0 samples per second
dF= 0.0977 Hz
dT= 0.1707 min
MET Start at 001/05:00:00.724, Hanning k= 175
MEDS: Ergometer Exercise (Middeck Measurement)
ATLAS-3
Structural Coordinates
Frequency (Hz)
Time (min)
RSS Magnitude [log10(g^2/Hz)]
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
-6
-7
-8
-9
-10
-11
-12
-13

INTERLIMB RESISTANCE DEVICE

(crew exercise)

MISSION

STS-66, November 1994, ATLAS-3

SOURCE OR ACTIVITY

This device consists of bungee tethers used to suspend a low-mass harness in the middeck. The ILRD provides variable resistance exercise by working one limb against another.

Larger plot on reverse

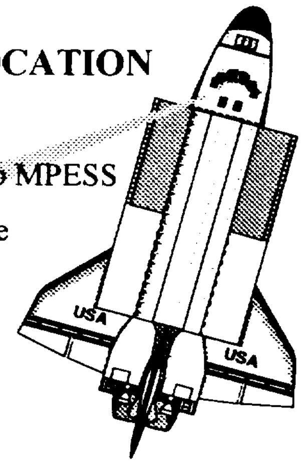
ACCELEROMETER

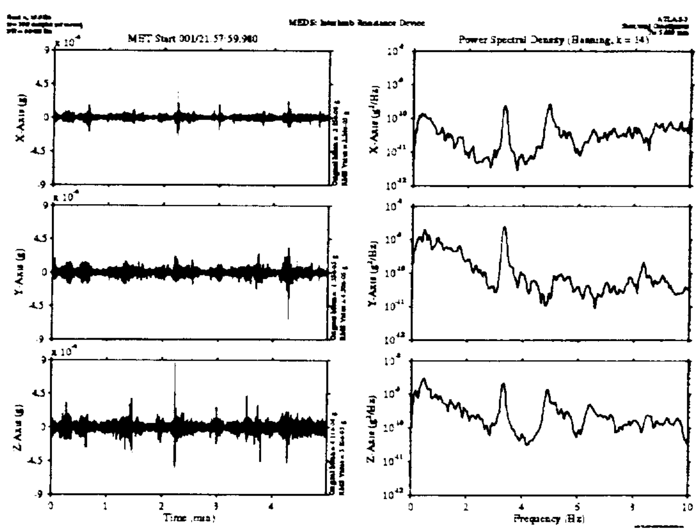
- [x] SAMS
- [ ] OARE

Head A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [x] Middeck
- [ ] Keel Bridge





EFFECT ON MICROGRAVITY ENVIRONMENT

This non-aerobic form of exercise has much less of an impact on the environment than does the ergometer, or treadmill equipment. Typical levels for this activity are less than 30 μg_{RMS}.

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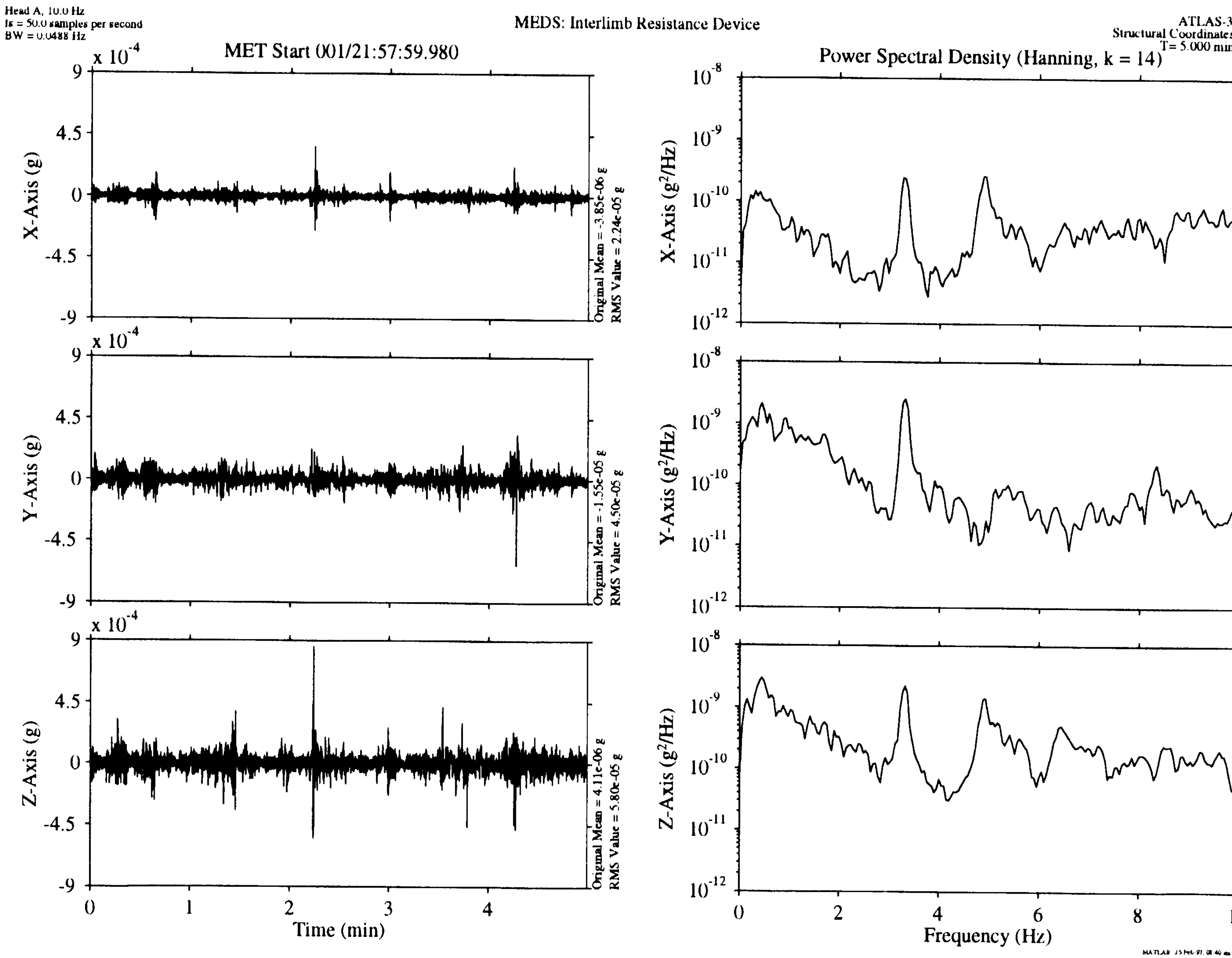
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


Head A, 10.0 Hz
fs = 50.0 samples per second
BW = 0.0488 Hz
MEDS: Interlimb Resistance Device
ATLAS-3
Structural Coordinates
T= 5.000 min
MET Start 001/21:57:59.980
Power Spectral Density (Hanning, k = 14)
x 10^-4
X-Axis (g)
Y-Axis (g)
Z-Axis (g)
Original Mean = -3.85e-06 g
RMS Value = 2.24e-05 g
Original Mean = -1.55e-05 g
RMS Value = 4.50e-05 g
Original Mean = 4.11e-06 g
RMS Value = 5.80e-05 g
X-Axis (g²/Hz)
Y-Axis (g²/Hz)
Z-Axis (g²/Hz)
Time (min)
Frequency (Hz)

PAO EVENT

MISSION

STS-66, November 1994, ATLAS-3

SOURCE OR ACTIVITY

Scheduled demonstration or question and answer events with some or all of the crew gathered in a single area.

Larger plots on reverse

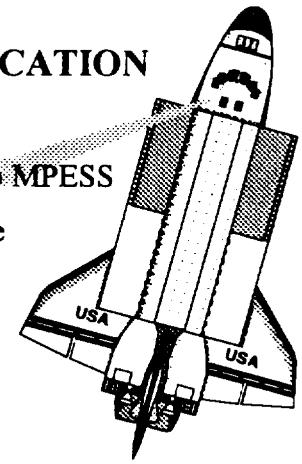
ACCELEROMETER

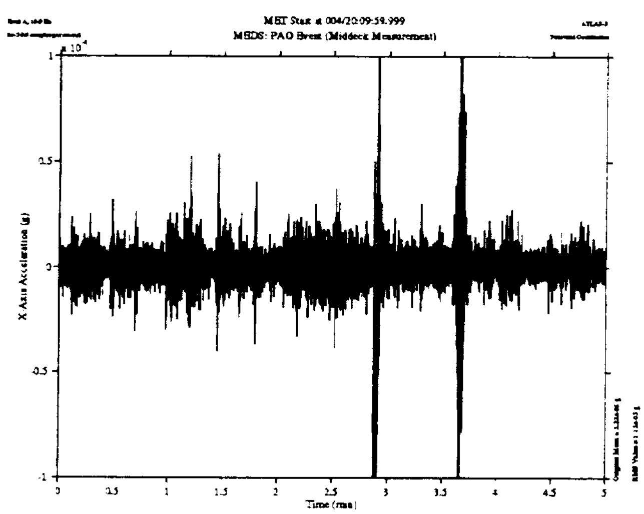
☑ SAMS ☐ OARE

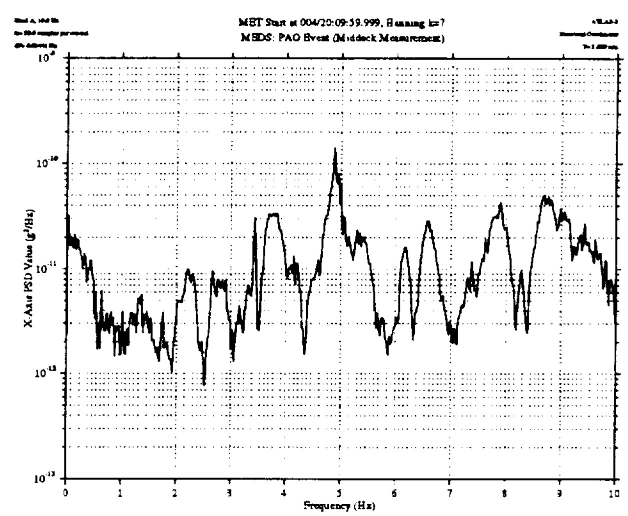
Head A, 10 Hz
fs = 50 samples per second

MEASUREMENT LOCATION

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







EFFECT ON MICROGRAVITY ENVIRONMENT

It is common that when PAO events take place, the microgravity environment becomes quieter. The crew is typically not moving about or impacting the spacecraft structure, they are usually free-floating in front of a camera. Also, experiment operations involving crew interaction are not being conducted for the duration of the PAO event. This tends to reduce the overall acceleration background level below 10 Hz to less than 50 μg_{RMS}. Vehicle structural modes and the Ku-band antenna are the primary disturbance sources during PAO events.

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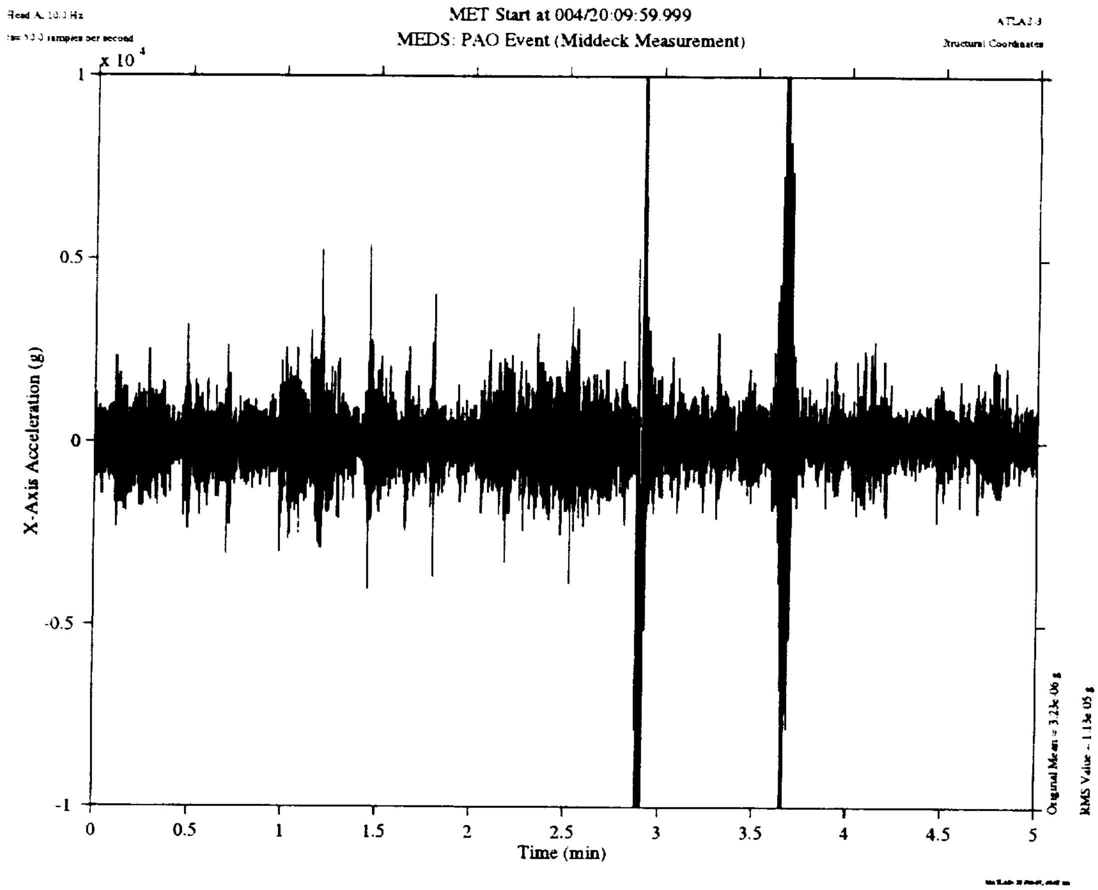
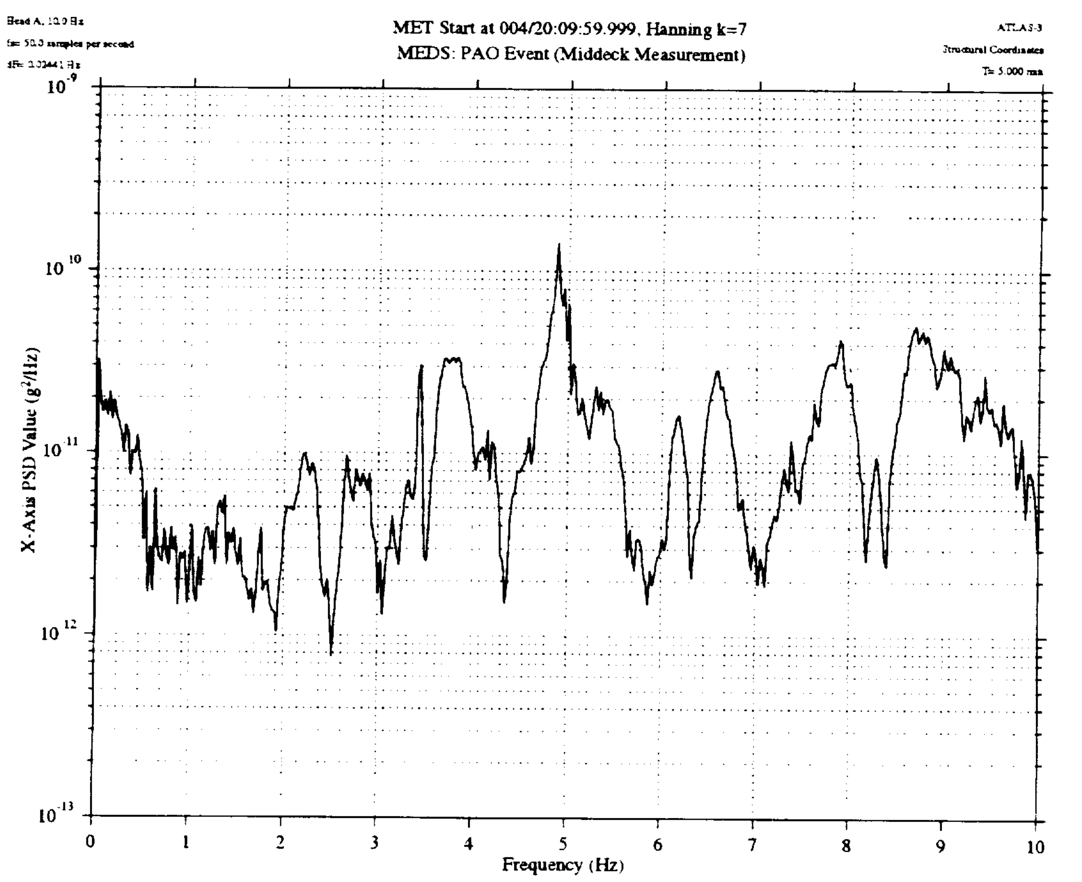
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


MET Start at 004/20:09:59.999
MEDS: PAO Event (Middeck Measurement)
ATLAS-3
Structural Coordinates
x 10^-4
X-Axis Acceleration (g)
Time (min)
Original Mean = 3.23e-06 g
RMS Value = 1.13e-05 g


MET Start at 004/20:09:59.999, Hanning k=7
MEDS: PAO Event (Middeck Measurement)
ATLAS-3
Structural Coordinates
fs= 50.0 samples per second
T= 5.000 min
X-Axis PSD Value (g²/Hz)
Frequency (Hz)

TREADMILL *(crew exercise)*

MISSION

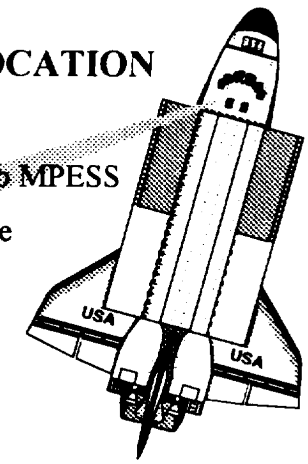
STS-43, August 1991

ACCELEROMETER

☑ SAMS ☐ OARE

Head A, 50 Hz
fs = 250 samples per second

MEASUREMENT LOCATION

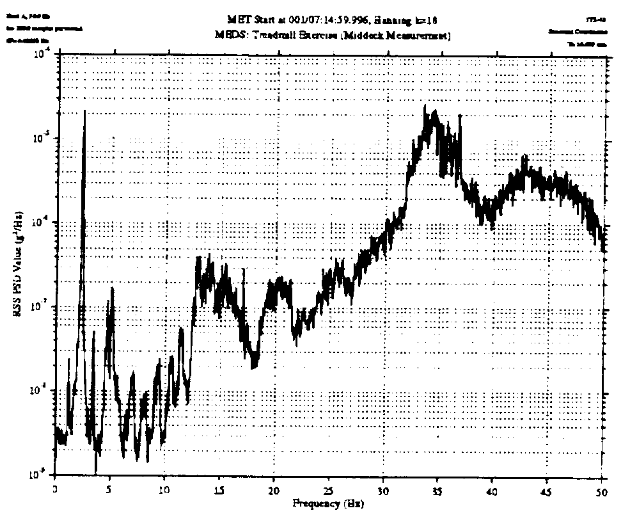


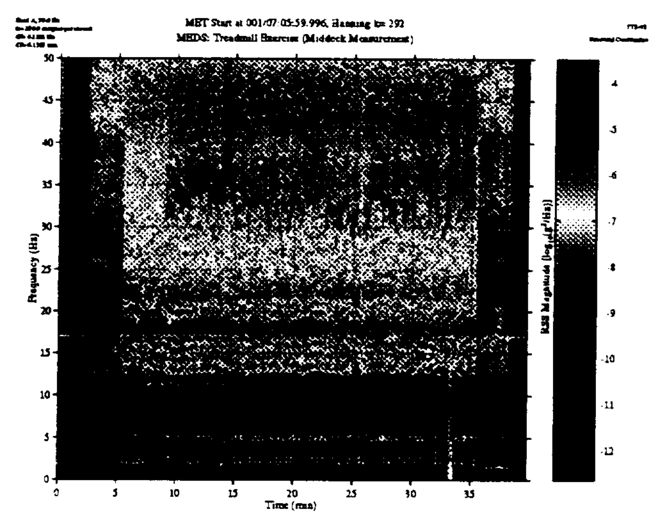
☐ Spacelab Module
☐ Cargo bay / Spacelab MPESS
☐ SPACEHAB Module
☑ Middeck
☐ Keel Bridge

SOURCE OR ACTIVITY

This piece of exercise equipment is hard-mounted to the orbiter middeck. Exercise comes mainly from walking/jogging/running on this passive rotary treadmill. The primary disturbance (2-2.5 Hz) is created by the footfall frequency. This frequency is generally constant throughout the exercise period, with the exception of the warm-up and cool-down at the beginning and end of the exercise.

Larger plots on reverse





EFFECT ON MICROGRAVITY ENVIRONMENT

The 2 - 2.5 Hz band was excited by 1,500 μg_{RMS}. This measurement was made by a sensor head on a locker door approximately 6 feet away from the treadmill.

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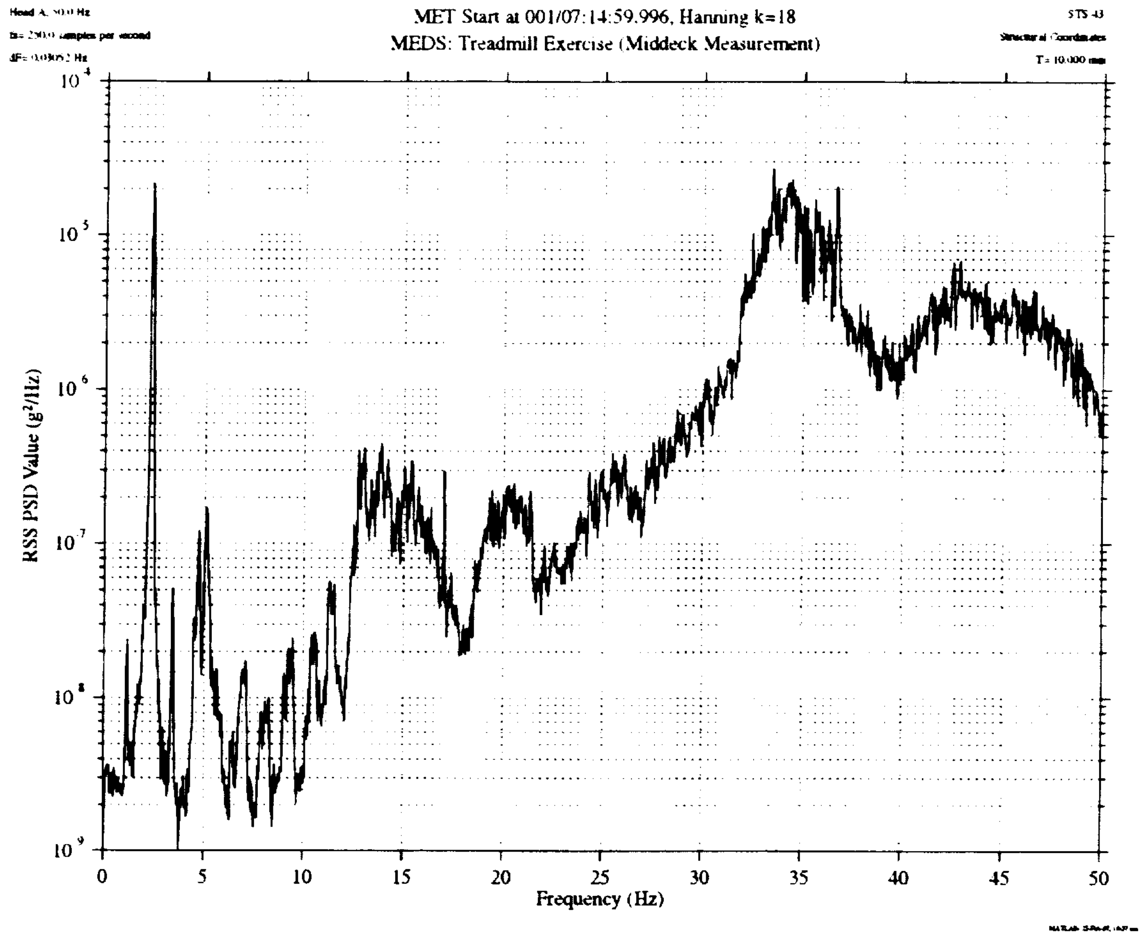
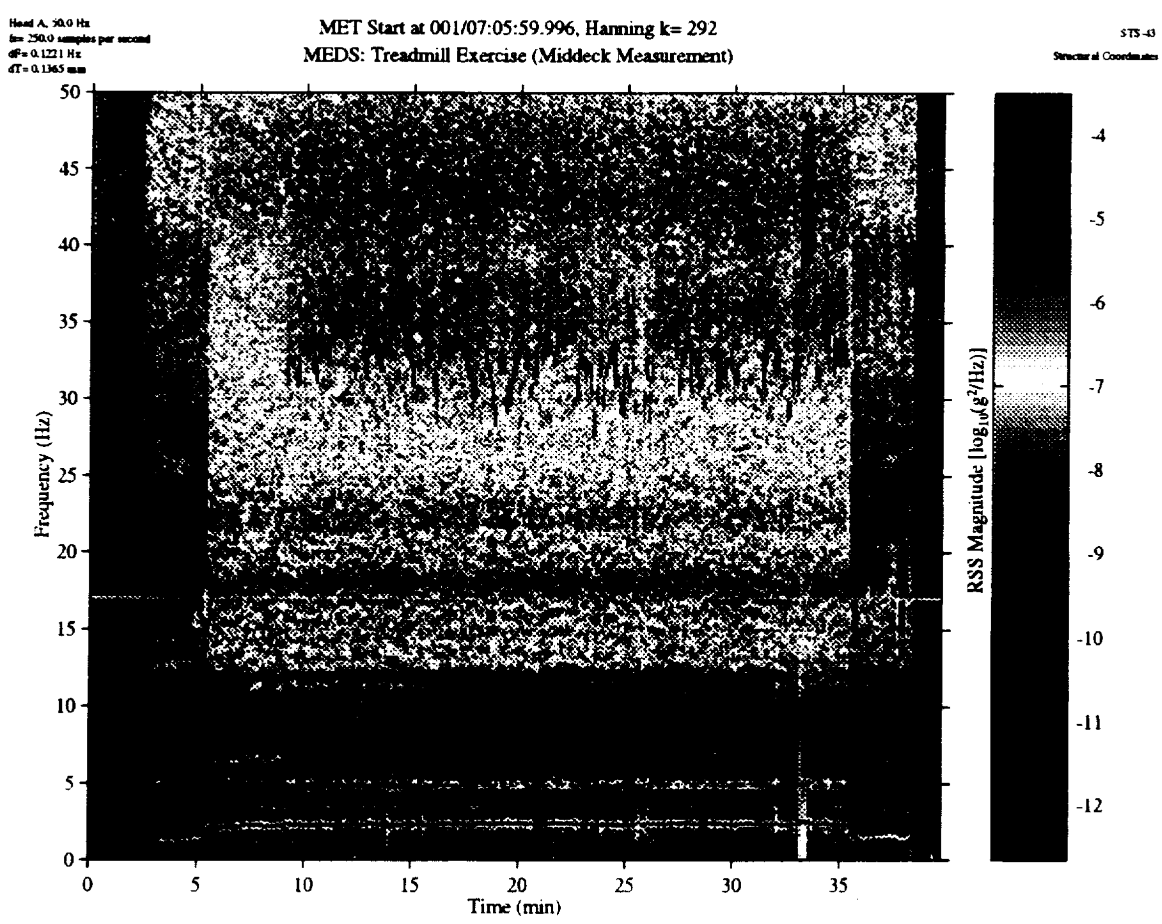
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



Head A, 50.0 Hz
fs= 250.0 samples per second
dF= 0.03052 Hz
MET Start at 001/07:14:59.996, Hanning k=18
MEDS: Treadmill Exercise (Middeck Measurement)
STS-43
Structural Coordinates
T= 10.000 min
RSS PSD Value (g²/Hz)
Frequency (Hz)



Head A, 50.0 Hz
fs= 250.0 samples per second
dF= 0.1221 Hz
dT= 0.1365 min
MET Start at 001/07:05:59.996, Hanning k= 292
MEDS: Treadmill Exercise (Middeck Measurement)
STS-43
Structural Coordinates
Frequency (Hz)
Time (min)
RSS Magnitude [log10(g²/Hz)]

Ku-BAND ANTENNA

MISSION
STS-43, August 1991

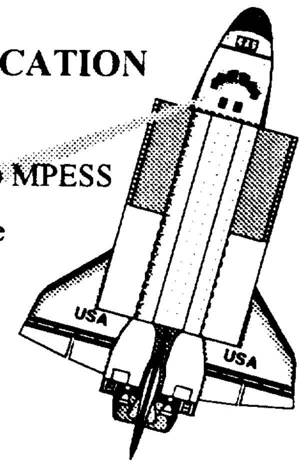
SOURCE OR ACTIVITY
The Ku-band antenna is located in the forward portion of the payload bay on the starboard side of the vehicle. On orbit, this antenna is deployed for communications between the orbiter and the Tracking Data Relay Satellite System (TDRSS). It is dithered at 17 Hz to prevent stiction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

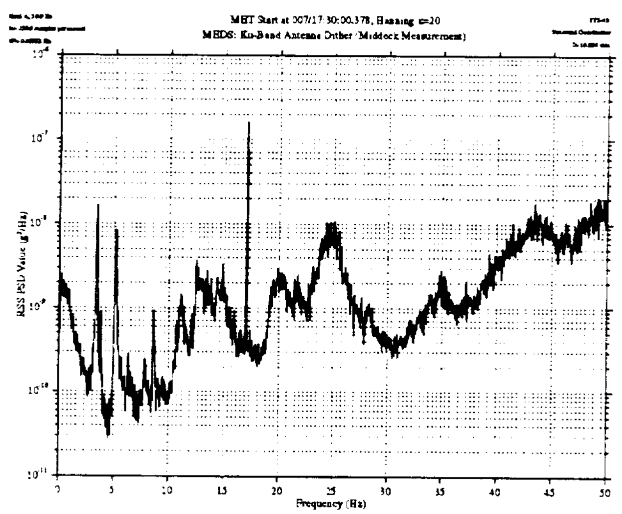
Larger plots on reverse

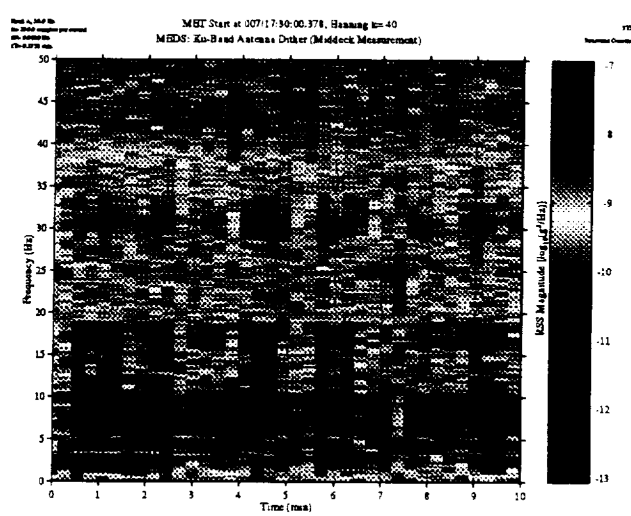
ACCELEROMETER
☑ SAMS ☐ OARE

Head A, 50 Hz
fs = 250 samples per second

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

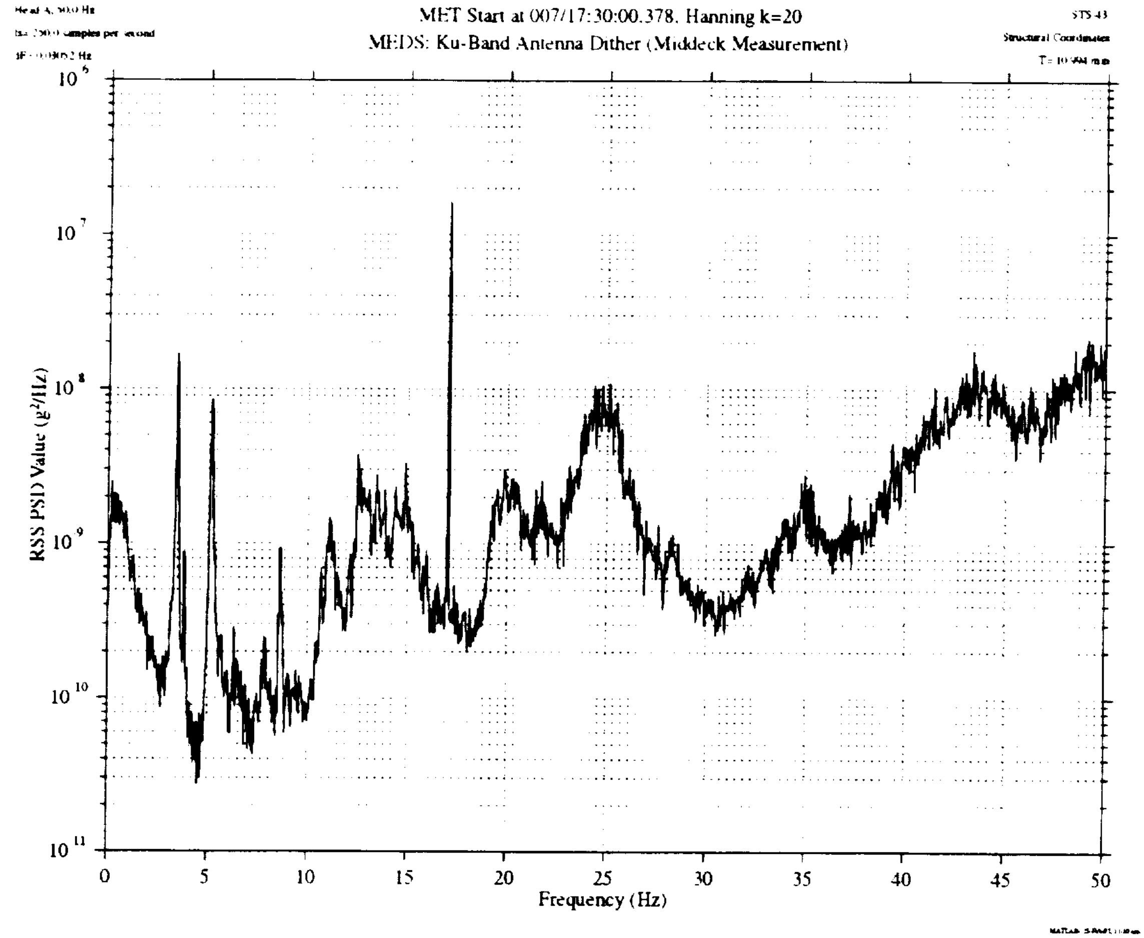


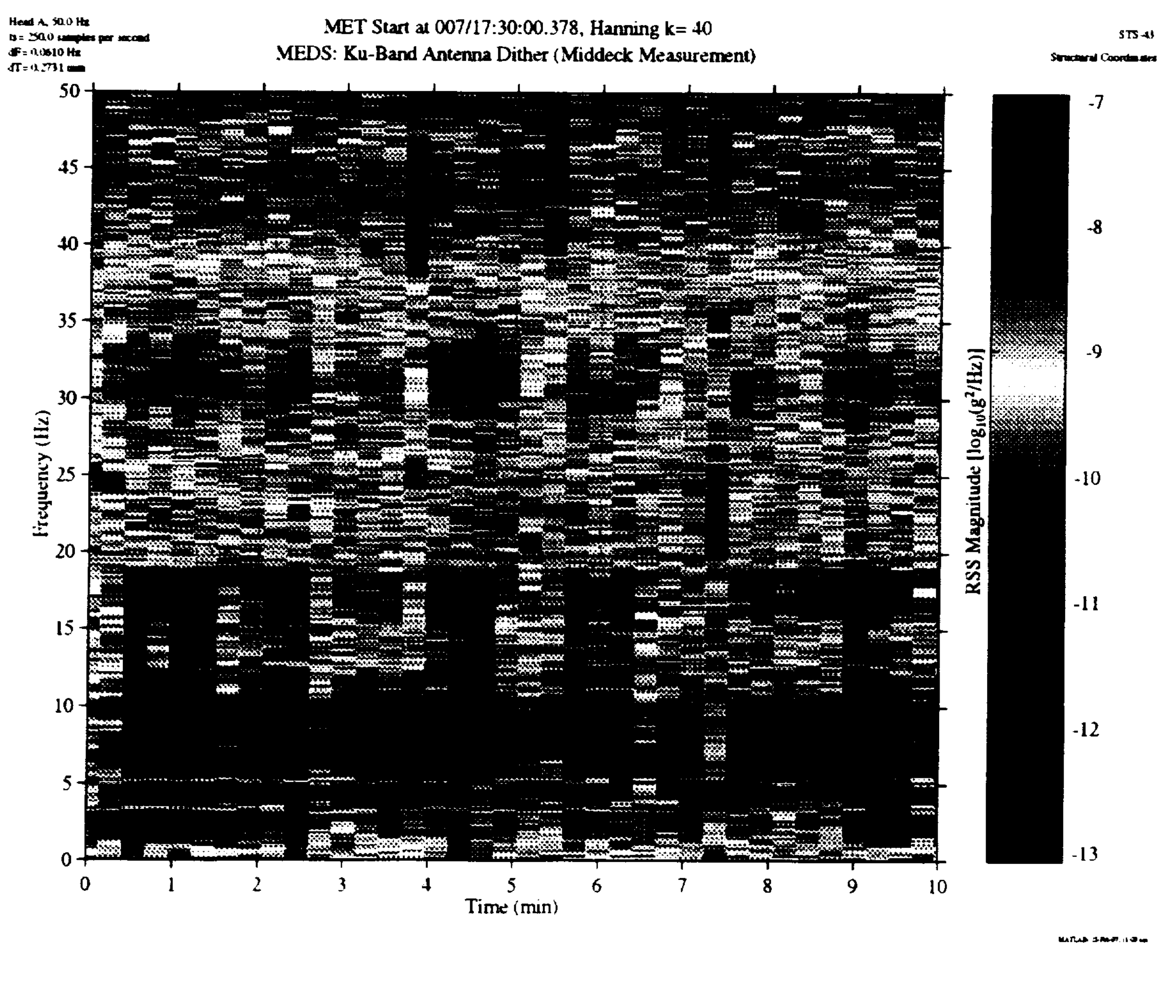




EFFECT ON MICROGRAVITY ENVIRONMENT
Reaction torque forces at the base of the gimbal produce a distinct 17 Hz oscillatory disturbance which acts as a beacon signal within orbiter acceleration data owing to its intensity and nearly continuous operation. The intensity of this disturbance is variable, but 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.

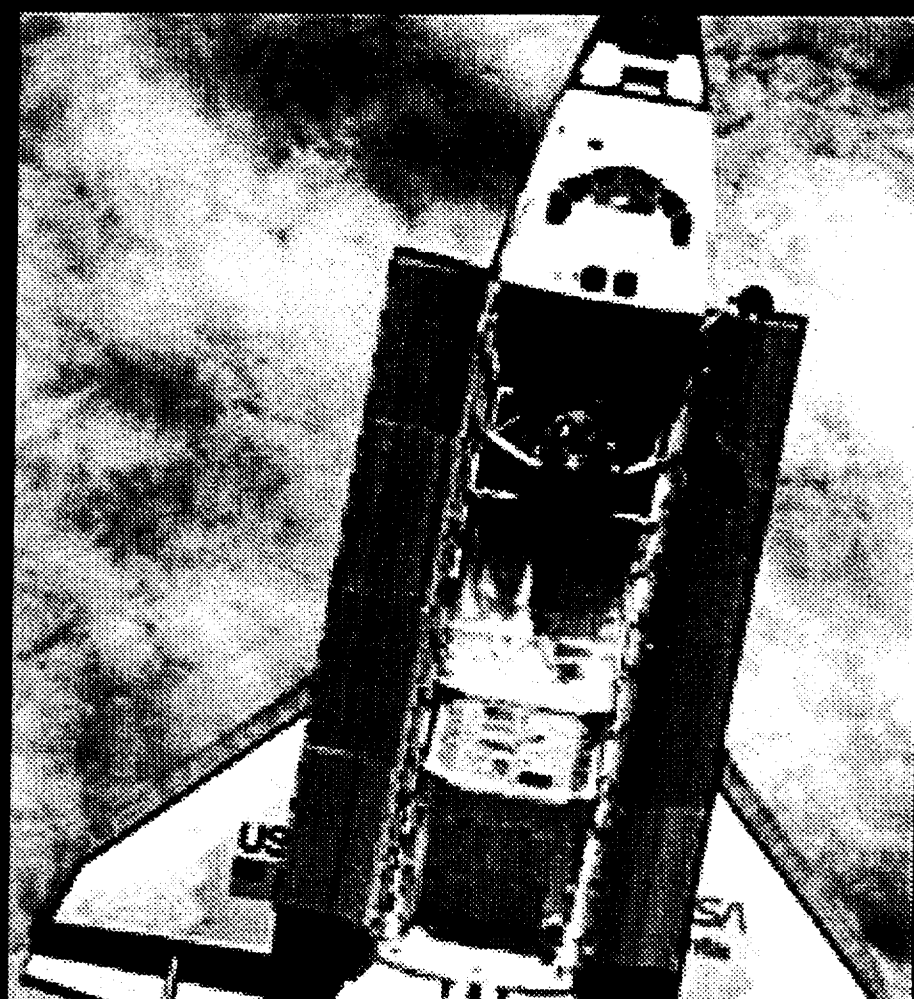
For further information, contact Duc Truong
NASA Lewis Research Center, Cleveland, Ohio.
e-mail: pims@lerc.nasa.gov.
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


Head A, 50.0 Hz
fs= 250.0 samples per second
dF= 0.0305 2 Hz
MET Start at 007/17:30:00.378, Hanning k=20
MEDS: Ku-Band Antenna Dither (Middeck Measurement)
STS-43
Structural Coordinates
T= 10.994 min
RSS PSD Value (g²/Hz)
10^6
10^7
10^8
10^9
10^10
10^11
0
5
10
15
20
25
30
35
40
45
50
Frequency (Hz)


Head A, 50.0 Hz
fs = 250.0 samples per second
dF= 0.0610 Hz
dT= 0.2731 min
MET Start at 007/17:30:00.378, Hanning k= 40
MEDS: Ku-Band Antenna Dither (Middeck Measurement)
STS-43
Structural Coordinates
Frequency (Hz)
50
45
40
35
30
25
20
15
10
5
0
Time (min)
1
2
3
4
5
6
7
8
9
10
RSS Magnitude [log10(g²/Hz)]
-7
-8
-9
-10
-11
-12
-13

SECTION V

Disturbances Measured in the Keel Bridge



ATMOSPHERIC DRAG -
Circular orbit

MISSION
STS-62, March 1994, USMP-2

SOURCE OR ACTIVITY
Atmospheric drag accelerations are caused by the Orbiter vehicle passing through the rarefied atmosphere at the orbital altitudes. The amount of drag is primarily determined by the Orbiter frontal area, which is dependent on the attitude of the Orbiter relative to its direction of flight. This area is a minimum when the Orbiter is oriented nose or tail forward and is a maximum when the Orbiter belly or cargo bay is forward.

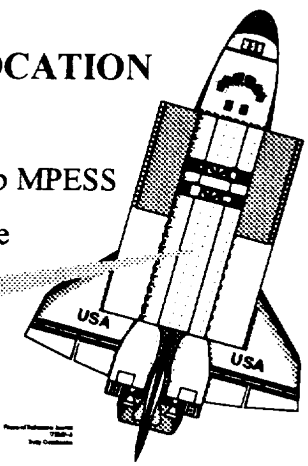
The atmospheric density is not constant around the Earth, thus causing a variable amount of drag as the Orbiter traverses its orbital trajectory. For an orbital trajectory of nearly constant altitude, the major variation in density is due to solar heating of the atmosphere on the light side of the Earth and radiative cooling on the dark side.

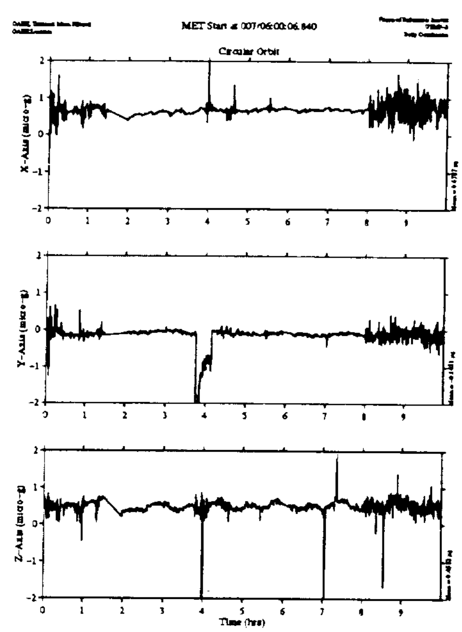
Larger plot on reverse

ACCELEROMETER
☐ SAMS ☑ OARE

Frequency Range: 1×10^{-5} - 0.1 Hz
fs = 10 samples per second

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





EFFECT ON MICROGRAVITY ENVIRONMENT
The effects of the atmospheric drag on the microgravity environment are seen in the quasi-steady frequency regime as a constant acceleration vector with a variable component. The variable component has a frequency based on the orbital period of the vehicle (approximately 90 minutes).

The figure shows the acceleration levels measured while the Orbiter was oriented with its $-Z_b$-axis in the direction of travel (i.e., with the cargo bay forward). The major component of the drag acceleration is in the Z_b-axis. The variable acceleration due to the atmospheric density variations is seen in the Z_b-axis with a period of about 90 minutes.

For further information, contact Duc Truong
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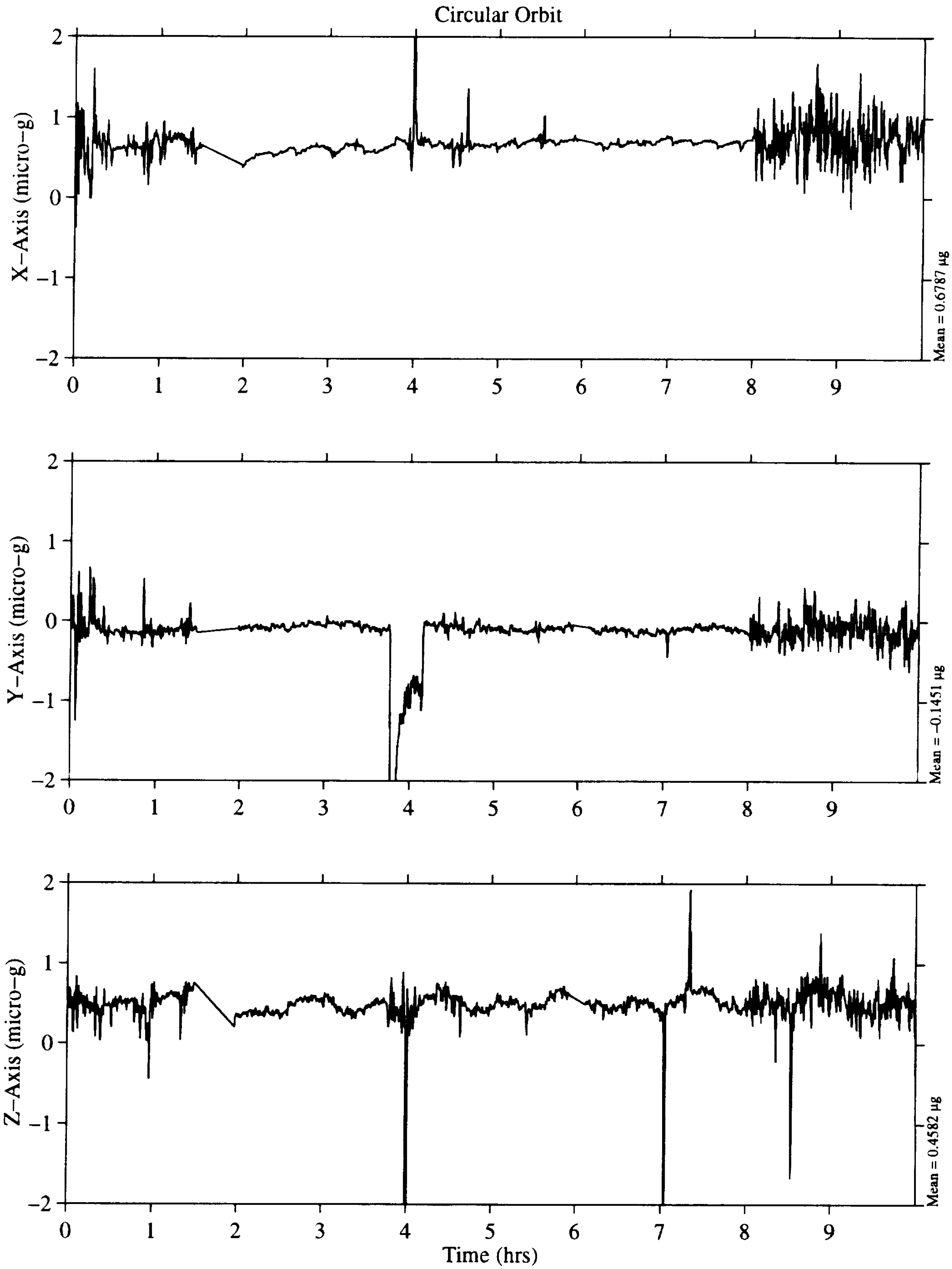
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

OARE, Trimmed Mean Filtered
OARE Location

MET Start at 007/06:00:06.840

Frame of Reference: Inertial
USMP-2
Body Coordinates



MATLAB: 30-Aug-96, 9:47 am

ATMOSPHERIC DRAG -

Solar inertial attitude

MISSION

STS-73, October 1995, USML-2

SOURCE OR ACTIVITY

Atmospheric drag accelerations are caused by the Orbiter vehicle passing through the rarefied atmosphere at the orbital altitudes. The amount of drag is primarily determined by the Orbiter frontal area, which is dependent on the attitude of the Orbiter relative to its direction of flight. This area is a minimum when the Orbiter is oriented nose or tail forward and is a maximum when the Orbiter belly or cargo bay is forward.

A solar inertial attitude orients the Orbiter attitude relative to the sun, as opposed to an Earth-oriented attitude. The solar inertial attitude then results in a variable frontal area during its orbital period, thus causing a variable atmospheric drag acceleration.

The atmospheric density is not constant around the Earth, thus causing a variable amount of drag as the Orbiter traverses its orbital trajectory. For an orbital trajectory of nearly constant altitude, the major variation in density is due to solar heating of the atmosphere on the light side of the Earth and radiative cooling on the dark side.

Larger plot on reverse

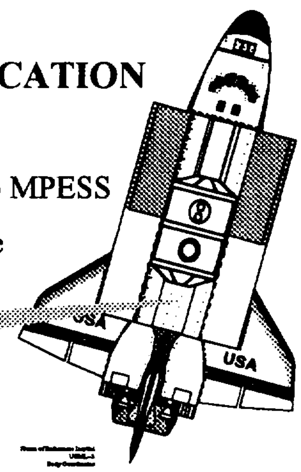
ACCELEROMETER

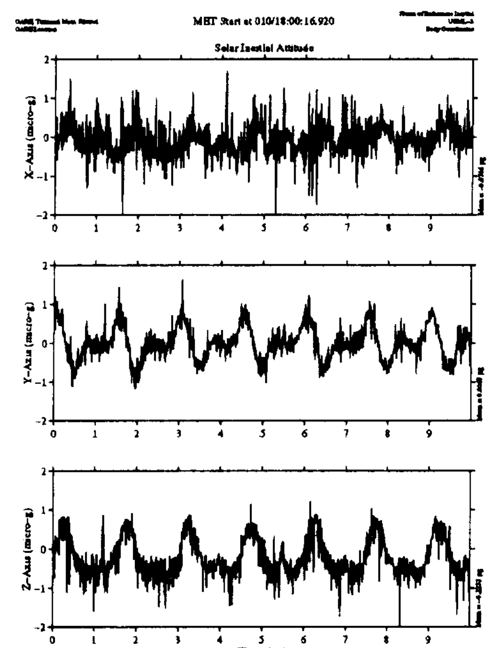
☐ SAMS ☑ OARE

Frequency Range: 1×10^{-5} - 0.1 Hz
fs = 10 samples per second

MEASUREMENT LOCATION

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





EFFECT ON MICROGRAVITY ENVIRONMENT

The effects of the atmospheric drag on the microgravity environment are seen in the quasi-steady frequency regime as a constant acceleration vector with a variable component. The variable component has a frequency based on the orbital period of the vehicle (approximately 90 minutes).

The figure shows the acceleration levels measured while the Orbiter was oriented in a solar inertial attitude. The major variation in the acceleration levels are due to the large variation in frontal area as the Orbiter tumbles relative to the Earth and the atmosphere.

For further information, contact Duc Truong
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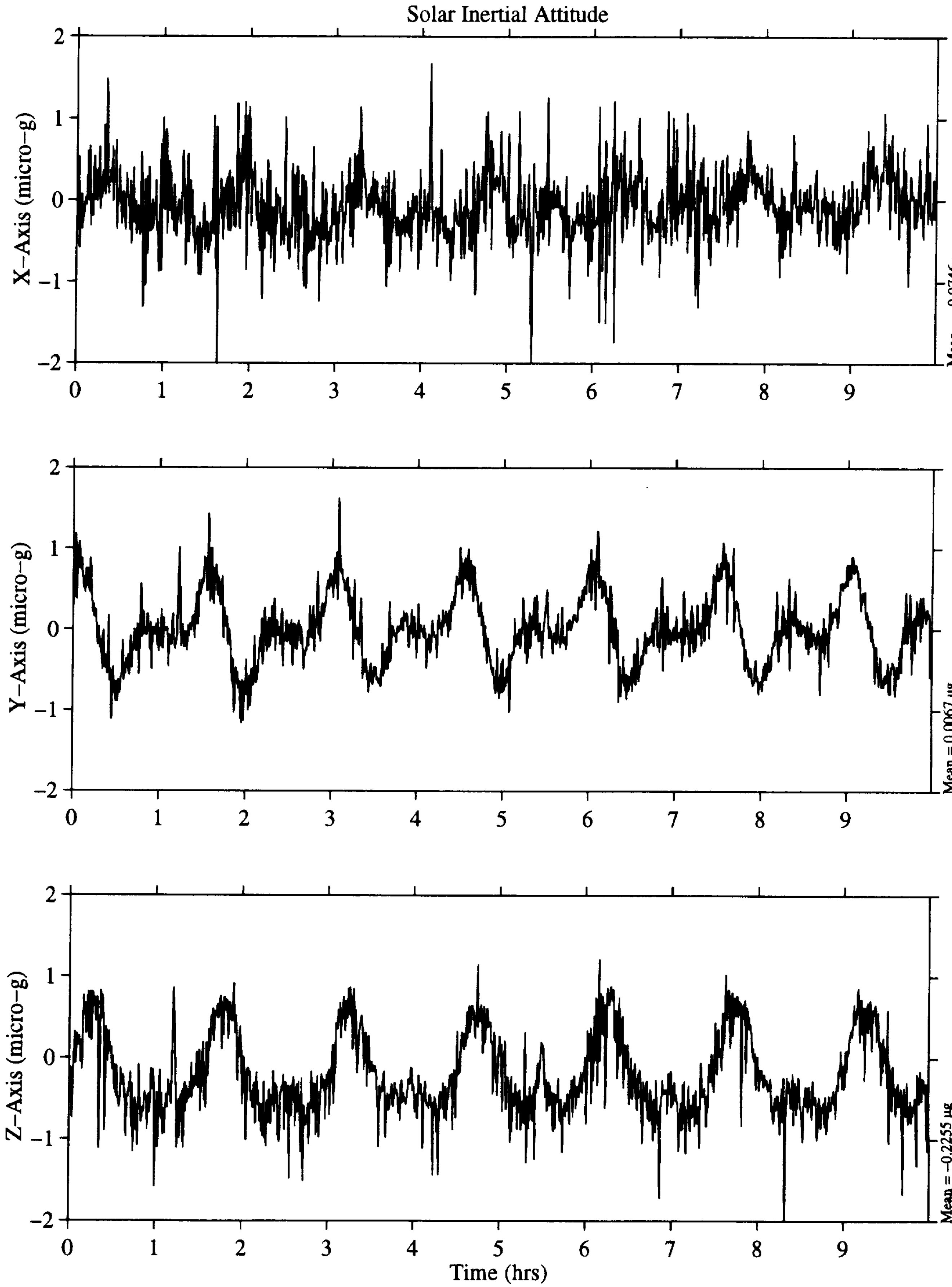
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



MATLAB: 30-Aug-96, 9:55 am

ATMOSPHERIC DRAG -
Elliptical orbit

MISSION
STS-62, March 1994, USMP-2

ACCELEROMETER

☐ SAMS ☑ OARE

Frequency Range: 1 x 10^{-5} - 0.1 Hz
fs = 10 samples per second

SOURCE OR ACTIVITY

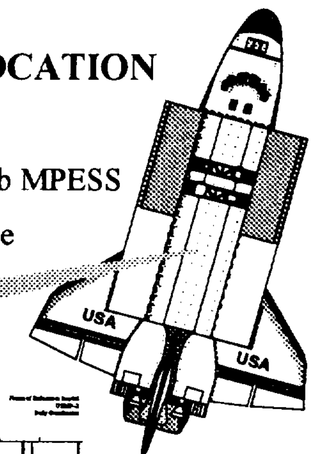
Atmospheric drag accelerations are caused by the Orbiter vehicle passing through the rarefied atmosphere at the orbital altitudes. The amount of drag is primarily determined by the Orbiter frontal area, which is dependent on the attitude of the Orbiter relative to its direction of flight. This area is a minimum when the Orbiter is oriented nose or tail forward and is a maximum when the Orbiter belly or cargo bay is forward.

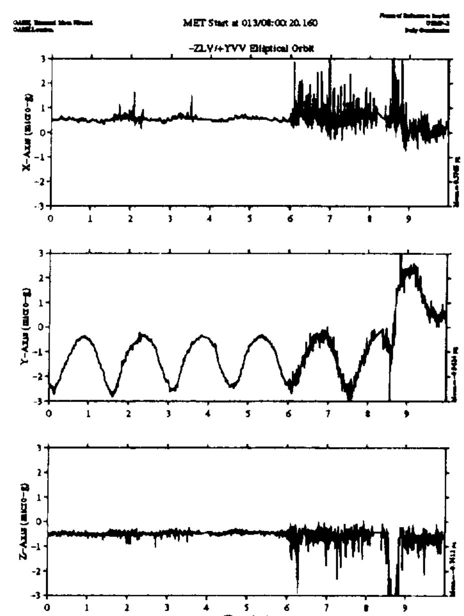
The atmospheric density gradually decreases with altitude above the Earth. When the Orbiter has an orbit which is not at a constant altitude, the density variation causes a variable amount of drag acceleration as the Orbiter traverses its orbital trajectory.

The atmospheric density is not constant around the Earth, thus causing a variable amount of drag as the Orbiter traverses its orbital trajectory. For an orbital trajectory of nearly constant altitude, the major variation in density is due to solar heating of the atmosphere on the light side of the Earth and radiative cooling on the dark side.

MEASUREMENT LOCATION

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





Larger plot on reverse

EFFECT ON MICROGRAVITY ENVIRONMENT

The effects of the atmospheric drag on the microgravity environment are seen in the quasi-steady frequency regime as a constant acceleration vector with a variable component. The variable component has a frequency based on the orbital period of the vehicle (approximately 90 minutes).

The figure shows the acceleration levels measured while the Orbiter was in an elliptical orbit of 138 nautical miles (perigee) and 105 nautical miles (apogee). The attitude was such that the Orbiter $+Y_b$-axis was oriented in the direction of flight so the drag variation is seen primary in the Y_b-axis data. The peak-to-peak acceleration variation (about 3 μg) is approximately ten times the variation experienced due to atmospheric density variations in a circular orbit.)

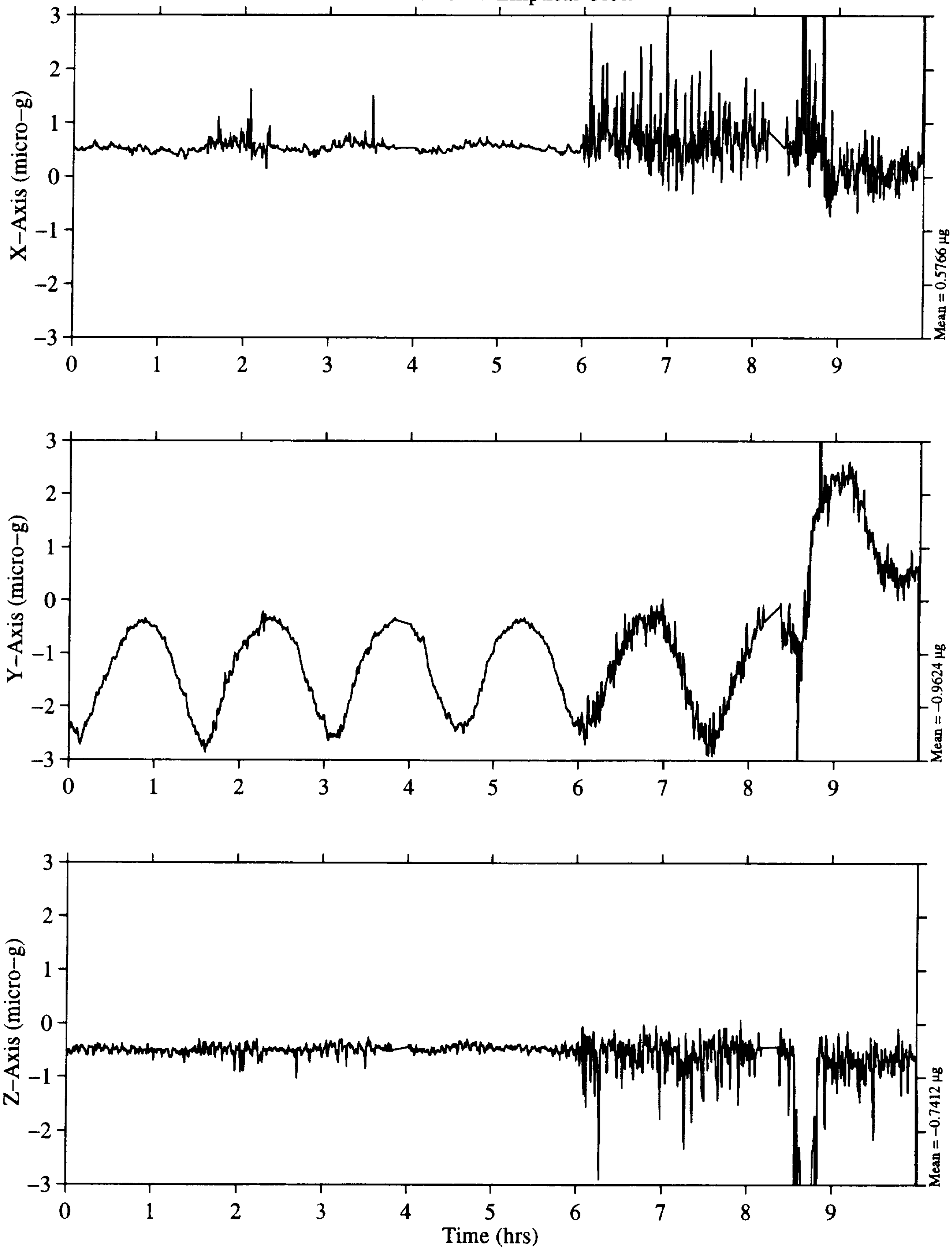
For further information, contact Duc Truong
NASA Lewis Research Center, Cleveland, Ohio. Telephone: 216-433-8394. Facsimile: 216-433-8660
e-mail: pims@lerc.nasa.gov. URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

OARE, Trimmed Mean Filtered
OARE Location

MET Start at 013/08:00:20.160

Frame of Reference: Inertial
USMP-2
Body Coordinates

-ZLV/+YVV Elliptical Orbit



MATLAB: 30-Aug-96, 9:52 am

FLASH EVAPORATION SYSTEM

MISSION

STS-78, June 1996, LMS

SOURCE OR ACTIVITY

On-orbit heat rejection is provided by radiator panels; however, during orbital operations the combination of heat load and spacecraft attitude may exceed the capacity of the radiator panels. Further heat rejection is provided on-orbit by the flash evaporator system (FES). FES operations provide heat rejection by vaporizing excess water as it contacts a core filled with hot Freon® The resulting vapor is vented out two opposing nozzles on the aft portion of the Orbiter.

Larger plot on reverse

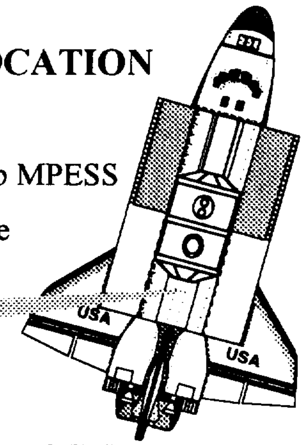
ACCELEROMETER

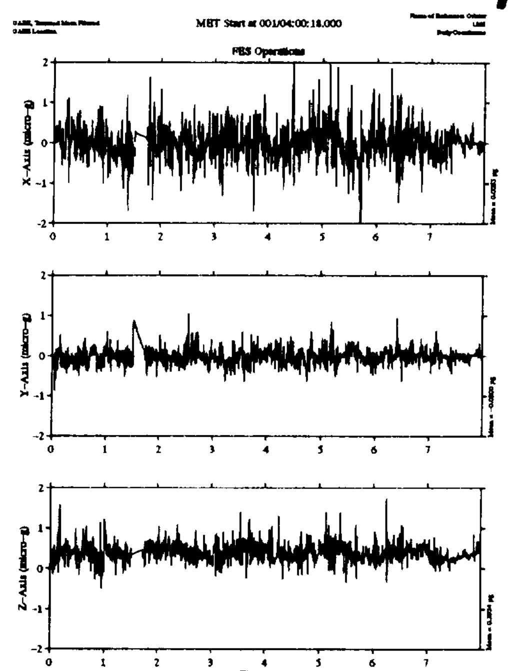
- [ ] SAMS
- [x] OARE

Frequency Range: 1×10^{-5} - 0.1 Hz
fs = 10 samples per seconds

MEASUREMENT LOCATION

- [ ] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [x] Keel Bridge





EFFECT ON MICROGRAVITY ENVIRONMENT

The FES was designed to provide a balanced vapor expulsion in the $+Y_b$-and $-Y_b$-axes. The resultant effect is typically less than 0.5 μg in any axis.

For further information, contact Duc Truong
NASA Lewis Research Center, Cleveland, Ohio.
e-mail: pims@lerc.nasa.gov
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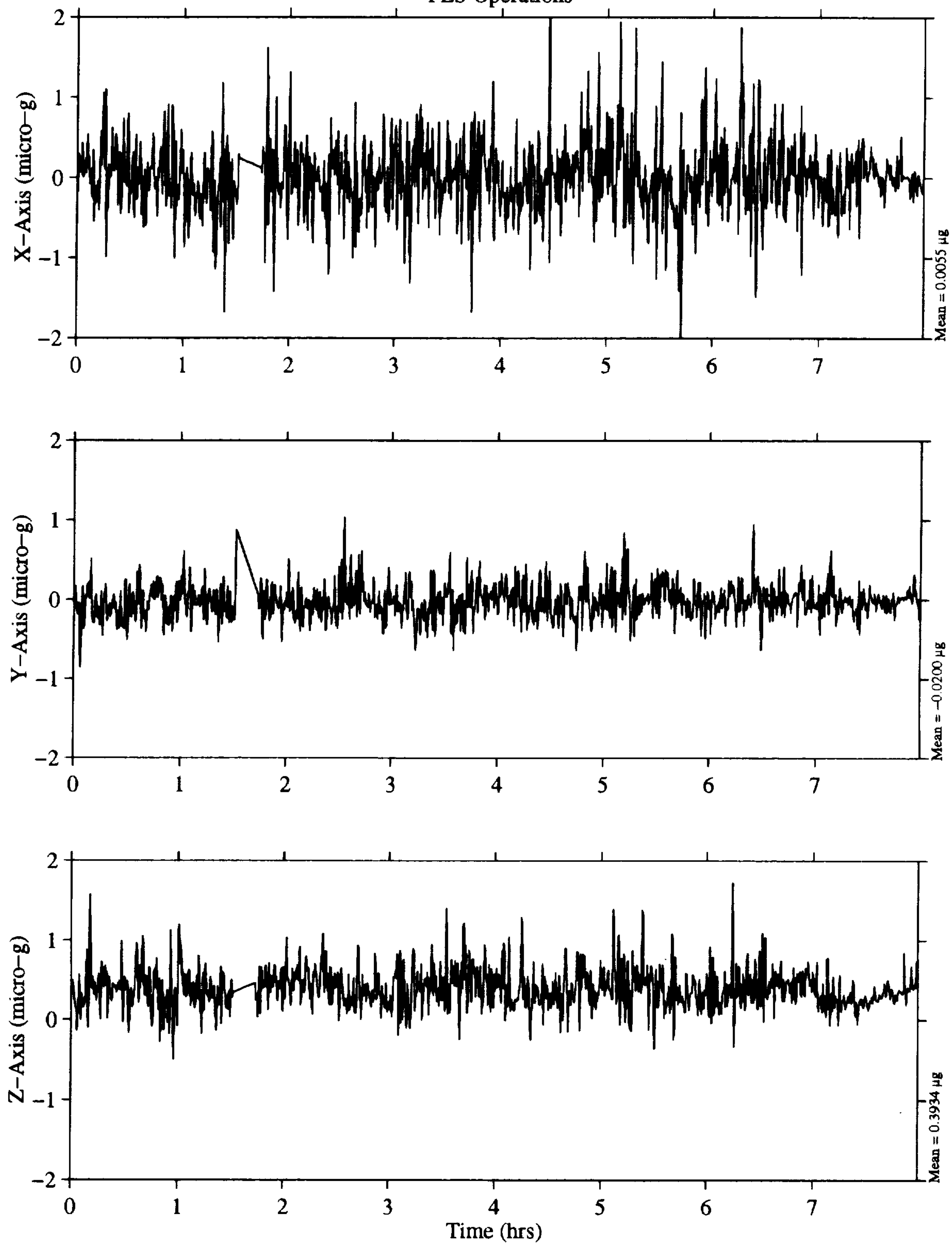
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

OARE, Trimmed Mean Filtered
OARE Location

MET Start at 001/04:00:18.000

Frame of Reference: Orbiter
LMS
Body Coordinates

FES Operations



MATLAB: 14-Apr-97, 04:24 pm

MISSION LOW-FREQUENCY ENVIRONMENT
(Two crew shift - Spacelab Module)

MISSION
STS-65, July 1994, IML-2

SOURCE OR ACTIVITY
The low-frequency or quasi-steady microgravity environment is a complex combination of many factors such as atmospheric drag, vehicle attitude, centripetal accelerations, gravity gradient acceleration, crew activity, vehicle venting, location within the vehicle, etc. Many of these factors will change during a mission and, therefore, so will the microgravity environment.

As explained elsewhere in this handbook, the atmospheric drag varies during each orbit. Periodically throughout a mission, gases and waste liquids are vented from the Orbiter which produce quasi-steady accelerations due to reaction forces. The requirements for some missions result in a crew split into two working shifts to maintain around-the-clock operations.

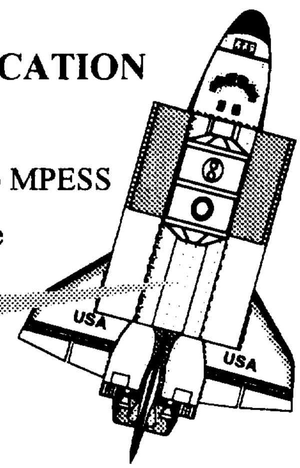
The STS-65 mission was devoted to one primary payload, the IML-2. The Orbiter utilized several attitudes to maintain microgravity conditions as required by the IML-2 experiments.

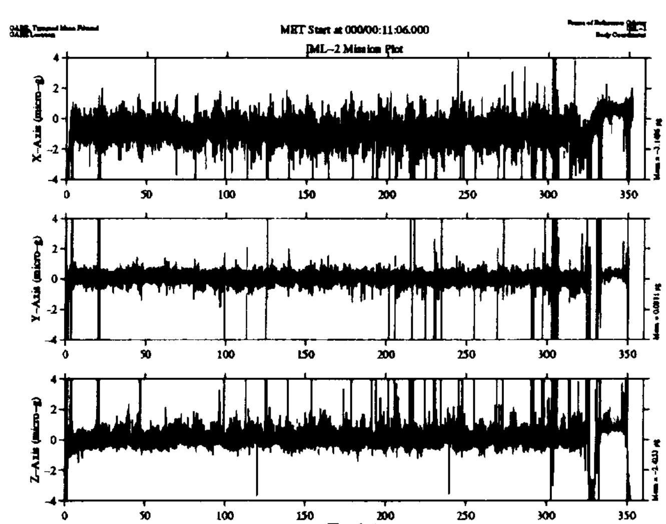
Larger plot on reverse

ACCELEROMETER
☐ SAMS ☑ OARE

Frequency Range: 1×10^{-5} - 0.1 Hz
fs = 10 samples per second

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





EFFECT ON MICROGRAVITY ENVIRONMENT
The low-frequency microgravity environment for the mission is shown in the figure. The major events affecting this environment for the mission are identified in the figure on the reverse side. For a detailed look at these activities, consult the pertinent pages in this handbook. Due to the two crew shifts and the nearly constant attitude, the levels are fairly consistent throughout the mission. This is in contrast with single-shift crew missions.

For further information, contact Duc Truong
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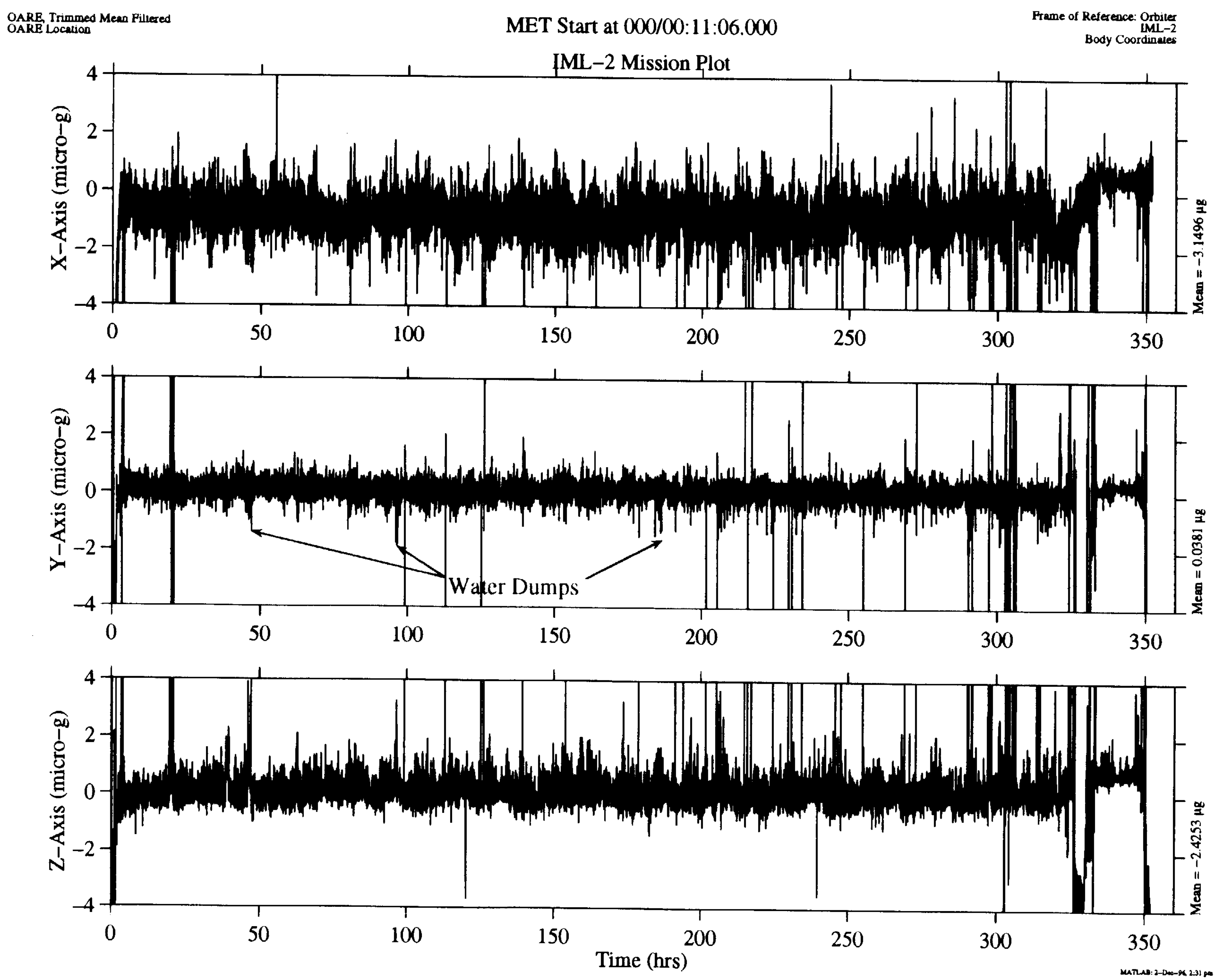
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


OARE, Trimmed Mean Filtered
OARE Location
MET Start at 000/00:11:06.000
IML-2 Mission Plot
Frame of Reference: Orbiter
IML-2
Body Coordinates
X-Axis (micro-g)
Mean = -3.1496 μg
Y-Axis (micro-g)
Water Dumps
Mean = 0.0381 μg
Z-Axis (micro-g)
Mean = -2.4253 μg
Time (hrs)

MISSION LOW-FREQUENCY ENVIRONMENT
(Two crew shift - Spacelab Module)

MISSION
STS-73, October 1995, USML-2

SOURCE OR ACTIVITY
The low-frequency or quasi-steady microgravity environment is a complex combination of many factors such as atmospheric drag, vehicle attitude, centripetal accelerations, gravity gradient acceleration, crew activity, vehicle venting, location within the vehicle, etc. Many of these factors will change during a mission and, therefore, so will the microgravity environment.

As explained elsewhere in this handbook, the atmospheric drag varies during each orbit. Periodically throughout a mission, gases and waste liquids are vented from the Orbiter which produce quasi-steady accelerations due to reaction forces. The requirements for some missions result in a crew split into two working shifts to maintain around-the-clock operations.

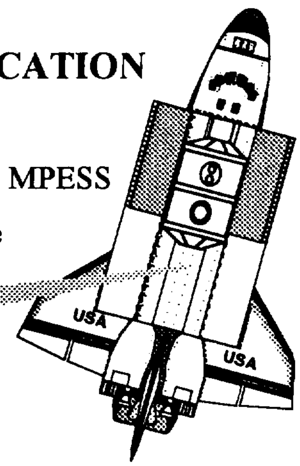
The STS-73 mission was devoted to one primary payload, the USML-2. The Orbiter utilized several attitudes to maintain microgravity conditions as required by the USML-2 experiments.

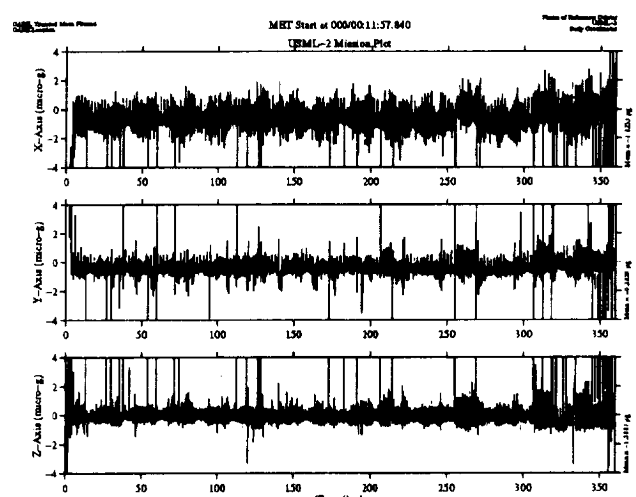
Larger plot on reverse

ACCELEROMETER
☐ SAMS ☑ OARE

Frequency Range: 1 x 10^{-5} - 0.1 Hz
fs = 10 samples per second

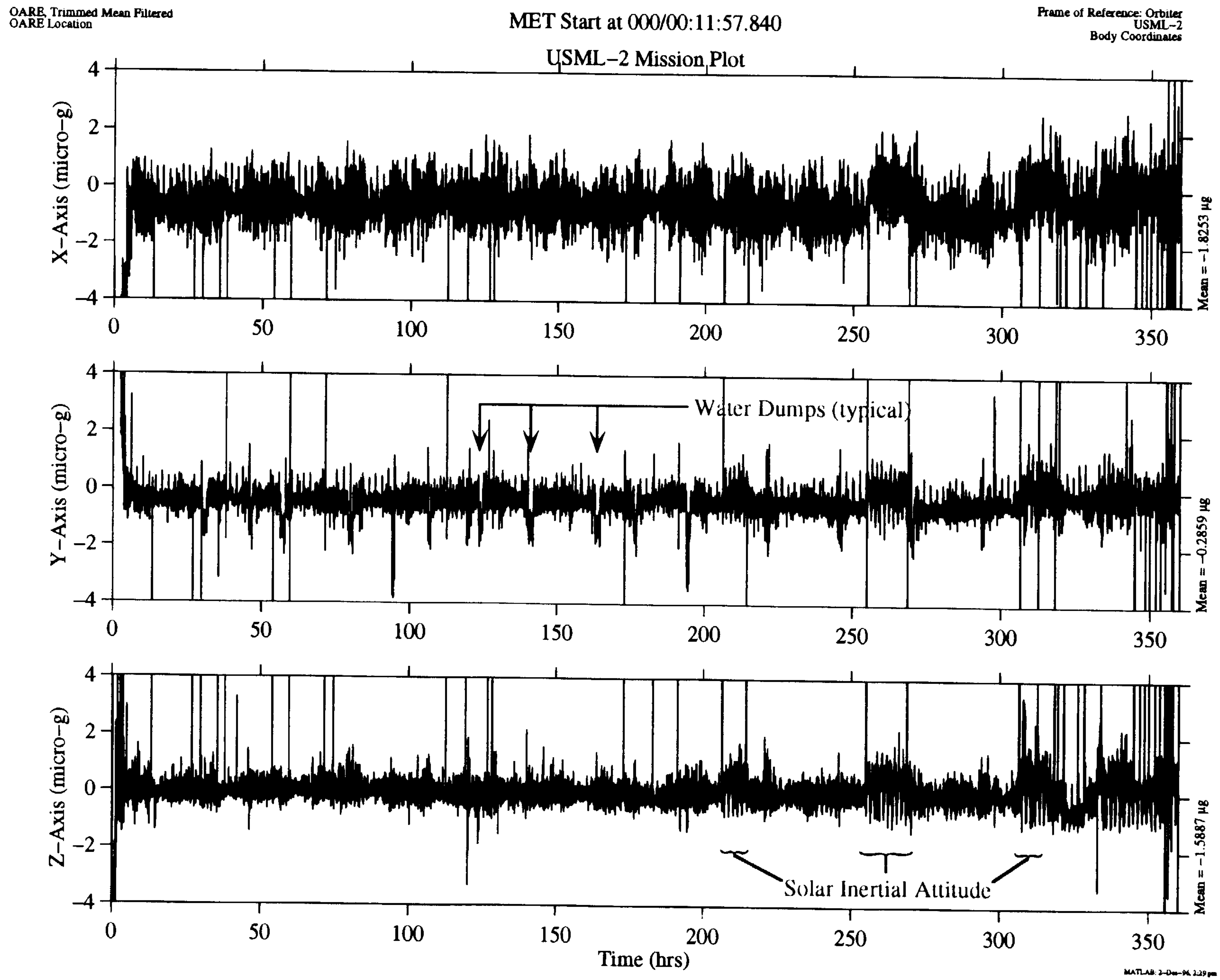
MEASUREMENT LOCATION
☐ Spacelab Module
☐ Cargo bay / Spacelab MPESS
☐ SPACEHAB Module
☐ Middeck
☑ Keel Bridge





EFFECT ON MICROGRAVITY ENVIRONMENT
The low-frequency microgravity environment for the mission is shown in the figure. The major events affecting this environment for the mission are identified in the figure on the reverse side. These events include water dumps and attitude changes. For a detailed look at these activities, consult the pertinent pages in this handbook.

For further information, contact Duc Truong
NASA Lewis Research Center, Cleveland, Ohio.
e-mail: pims@lerc.nasa.gov.
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


OARE, Trimmed Mean Filtered
OARE Location
MET Start at 000/00:11:57.840
Frame of Reference: Orbiter
USML-2
Body Coordinates
USML-2 Mission Plot
X-Axis (micro-g)
Mean = -1.8253 μg
Y-Axis (micro-g)
Water Dumps (typical)
Mean = -0.2859 μg
Z-Axis (micro-g)
Solar Inertial Attitude
Mean = -1.5887 μg
Time (hrs)
4
2
0
-2
-4
0
50
100
150
200
250
300
350

MISSION LOW-FREQUENCY ENVIRONMENT

(One crew shift - Spacelab MPESS)

MISSION

STS-62, March 1994, USMP-2

SOURCE OR ACTIVITY

The low-frequency or quasi-steady microgravity environment is a complex combination of many factors such as atmospheric drag, vehicle attitude, centripetal accelerations, gravity gradient acceleration, crew activity, vehicle venting, location within the vehicle, etc. Many of these factors will change during a mission and, therefore, so will the microgravity environment.

As explained elsewhere in this handbook, the atmospheric drag varies during each orbit. Periodically throughout a mission, gases and waste liquids are vented from the Orbiter which produce quasi-steady accelerations due to reaction forces. The requirements for some missions result in a crew which works in one shift.

The STS-62 mission was devoted to two primary payloads: the USMP-2 and the OAST-2. The USMP-2 payload operated with higher priority from MET 000/10:00 until 009/16:45 and the Orbiter utilized several attitudes to maintain microgravity conditions. The OAST-2 payload operated with the higher priority from MET 009/16:45 until 013/00:00 and the Orbiter operated in many different attitudes and elliptical orbits. This was a very dynamic acceleration environment compared with the USMP-2 operations, as can be seen in the figure.

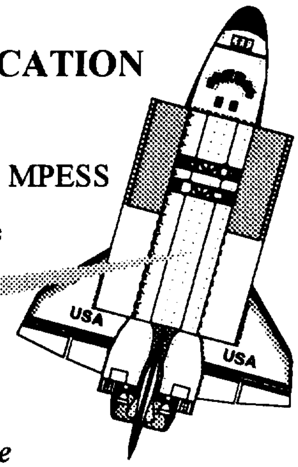
ACCELEROMETER

☐ SAMS ☑ OARE

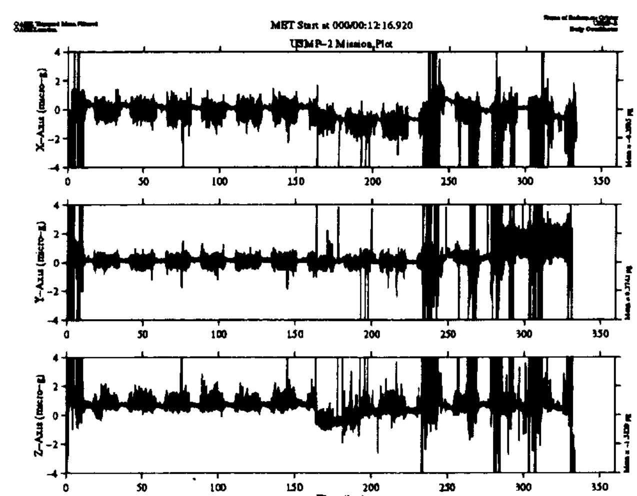
Frequency Range: 1×10^{-5} - 0.1 Hz
fs = 10 samples per second

MEASUREMENT LOCATION

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



Larger plot on reverse



EFFECT ON MICROGRAVITY ENVIRONMENT

The low-frequency microgravity environment for the mission is shown in the figure. The major events affecting this environment for the mission are identified in the figure on the reverse side. These events include PRCS thruster firings, attitude changes, crew active time, crew sleep time, and elliptical orbit. For a detailed look at these activities, consult the pertinent pages in this handbook.

For further information, contact Duc Truong
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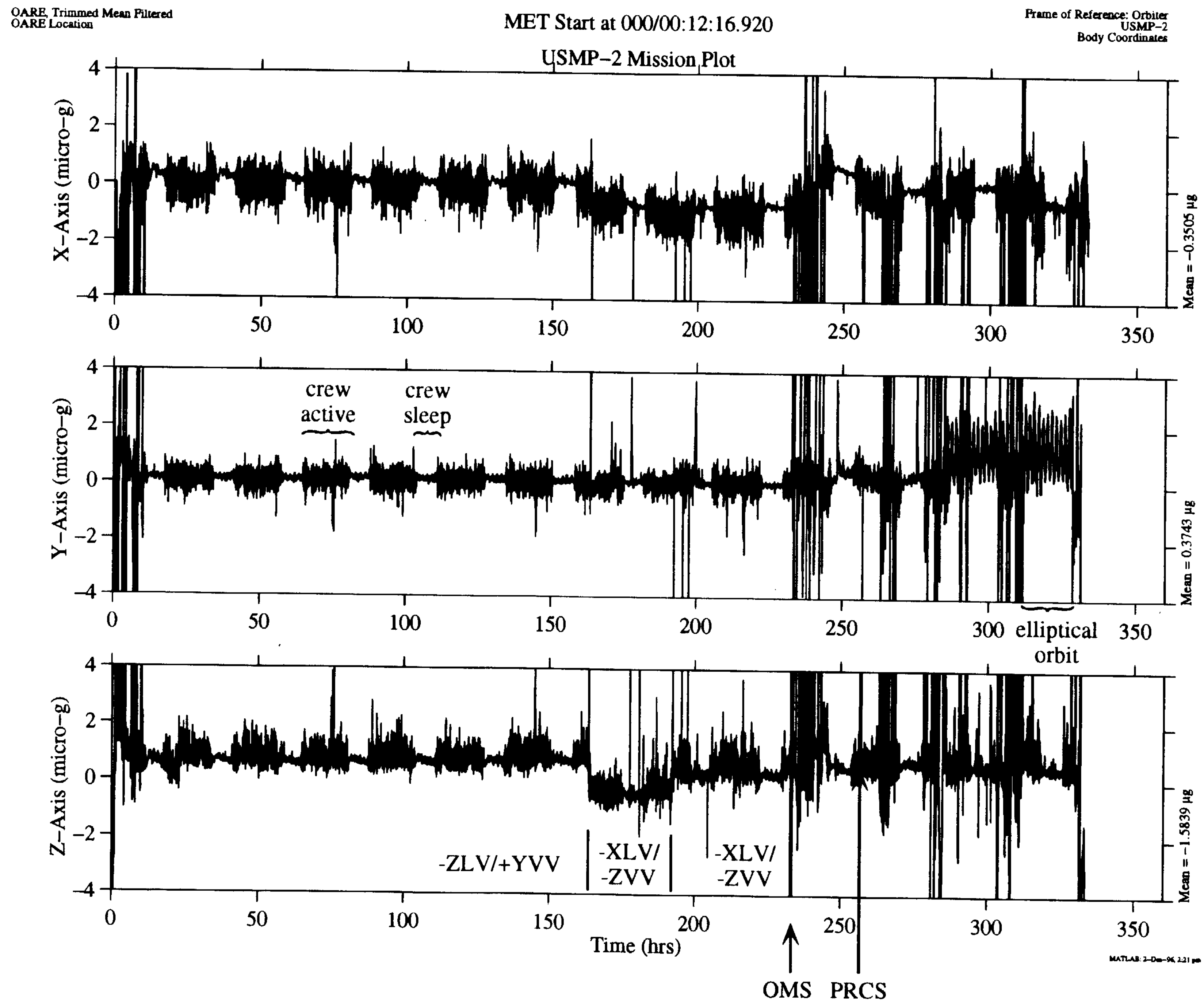
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


OARE, Trimmed Mean Filtered
OARE Location
MET Start at 000/00:12:16.920
USMP-2 Mission Plot
Frame of Reference: Orbiter
USMP-2
Body Coordinates
X-Axis (micro-g)
Mean = -0.3505 μg
Y-Axis (micro-g)
crew active
crew sleep
elliptical orbit
Mean = 0.3743 μg
Z-Axis (micro-g)
-ZLV/+YVV
-XLV/
-ZVV
-XLV/
-ZVV
Mean = -1.5839 μg
Time (hrs)
OMS
PRCS

MISSION LOW-FREQUENCY ENVIRONMENT

(Two crew shift - Spacelab MPESS)

MISSION

STS-75, February 1996, USMP-3

SOURCE OR ACTIVITY

The low-frequency or quasi-steady microgravity environment is a complex combination of many factors such as atmospheric drag, vehicle attitude, centripetal accelerations, gravity gradient acceleration, crew activity, vehicle venting, location within the vehicle, etc. Many of these factors will change during a mission and, therefore, so will the microgravity environment.

As explained elsewhere in this handbook, the atmospheric drag varies during each orbit. Periodically throughout a mission, gases and waste liquids are vented from the Orbiter which produce quasi-steady accelerations due to reaction forces. The requirements for some missions result in a crew split into two (and sometimes three) working shifts to maintain around-the-clock operations.

The STS-75 mission was devoted to two primary payloads: the reflight of the Tether Satellite System (TSS-1R) and the USMP-3. The TSS-1R payload operated with higher priority from MET 000/00:00 until 005/00:15 while the Orbiter operated in several different attitudes and deployed the tether satellite system. The USMP-3 payload operated with the higher priority from MET 005/00:15 until 013/14:00, and the Orbiter utilized several attitudes to maintain microgravity conditions as required by the USMP-3 experiments. The TSS-1R payload operation was a very dynamic acceleration environment compared with the USMP-3 operations, as can be seen in the figure.

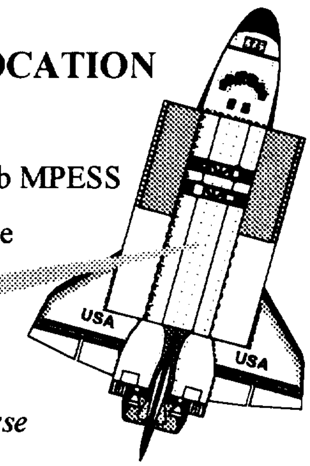
ACCELEROMETER

☐ SAMS ☑ OARE

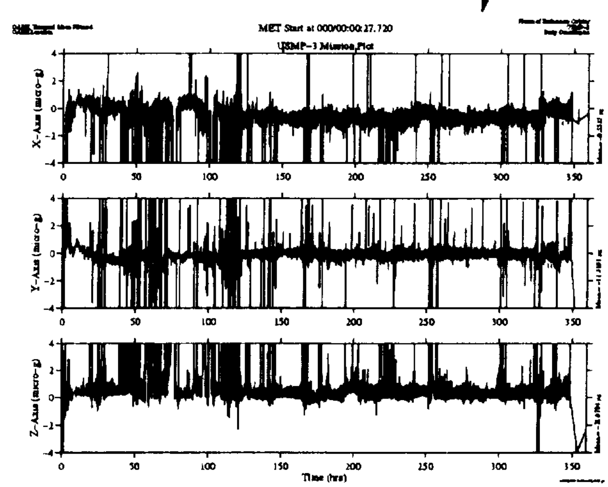
Frequency Range: 1×10^{-5} - 0.1 Hz
fs = 10 samples per second

MEASUREMENT LOCATION

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



Larger plot on reverse



EFFECT ON MICROGRAVITY ENVIRONMENT

The low-frequency microgravity environment for the mission is shown in the figure. The major events affecting this environment for the mission are identified in the figure on the reverse side. These events include water dumps, attitude changes, tether satellite deployment and PRCS thrusters. For a detailed look at these activities, consult the pertinent pages in this handbook.

For further information, contact Duc Truong
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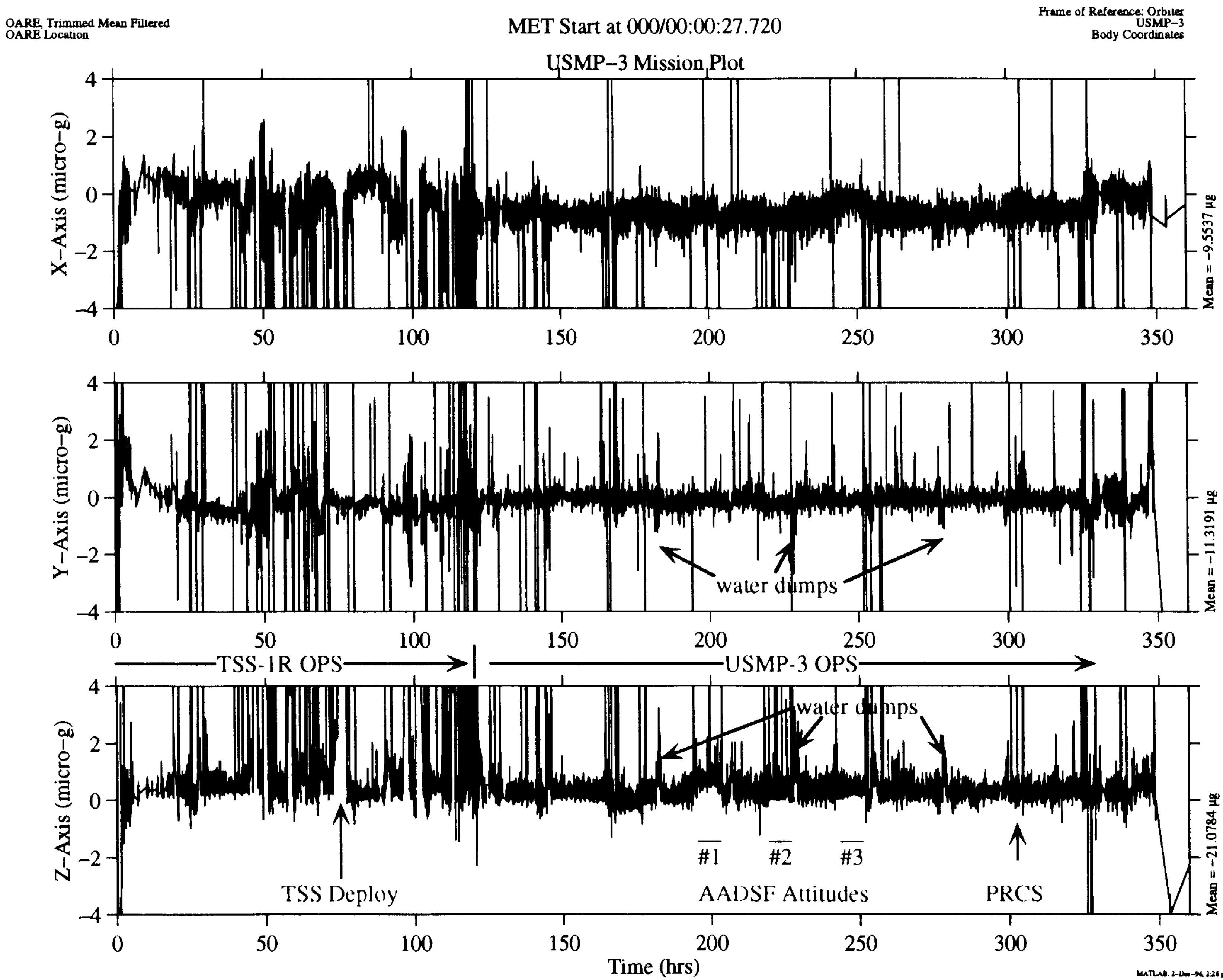
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


OARE, Trimmed Mean Filtered
OARE Location
MET Start at 000/00:00:27.720
Frame of Reference: Orbiter
USMP-3
Body Coordinates
USMP-3 Mission Plot
X-Axis (micro-g)
Mean = -9.5537 μg
Y-Axis (micro-g)
Mean = -11.3191 μg
water dumps
TSS-1R OPS
USMP-3 OPS
Z-Axis (micro-g)
Mean = -21.0784 μg
water dumps
TSS Deploy
#1
#2
#3
AADSF Attitudes
PRCS
Time (hrs)

MISSION LOW-FREQUENCY ENVIRONMENT

MISSION
STS-78, June 1996, LMS

SOURCE OR ACTIVITY
The low-frequency or quasi-steady microgravity environment is a complex combination of many factors such as atmospheric drag, vehicle attitude, centripetal accelerations, gravity gradient acceleration, crew activity, vehicle venting, location within the vehicle, etc. Many of these factors will change during a mission and, therefore, so will the microgravity environment.

As explained elsewhere in this handbook, the atmospheric drag varies during each orbit. Periodically throughout a mission, gases and waste liquids are vented from the Orbiter which produce quasi-steady accelerations due to reaction forces. The requirements for some missions result in a crew split into two (and sometimes three) working shifts to maintain around-the-clock operations.

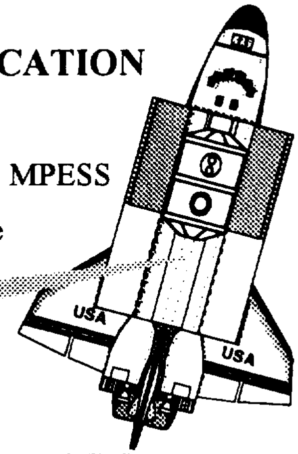
The STS-78 mission was devoted to one primary payload, the LMS. The Orbiter utilized several attitudes to maintain microgravity conditions as required by the LMS experiments.

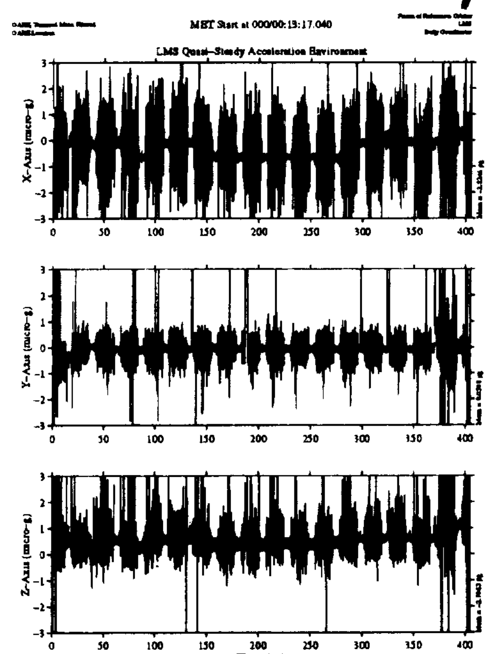
Larger plot on reverse

ACCELEROMETER
☐ SAMS ☑ OARE

Frequency Range: 1×10^{-5} - 0.1 Hz
fs = 10 samples per second

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





EFFECT ON MICROGRAVITY ENVIRONMENT
The low-frequency microgravity environment for the mission is shown in the figure. The major events affecting this environment for the mission are identified in the figure on the reverse side. These events include crew activities and attitude changes. For a detailed look at these activities, consult the pertinent pages in this handbook.

For further information, contact Duc Truong
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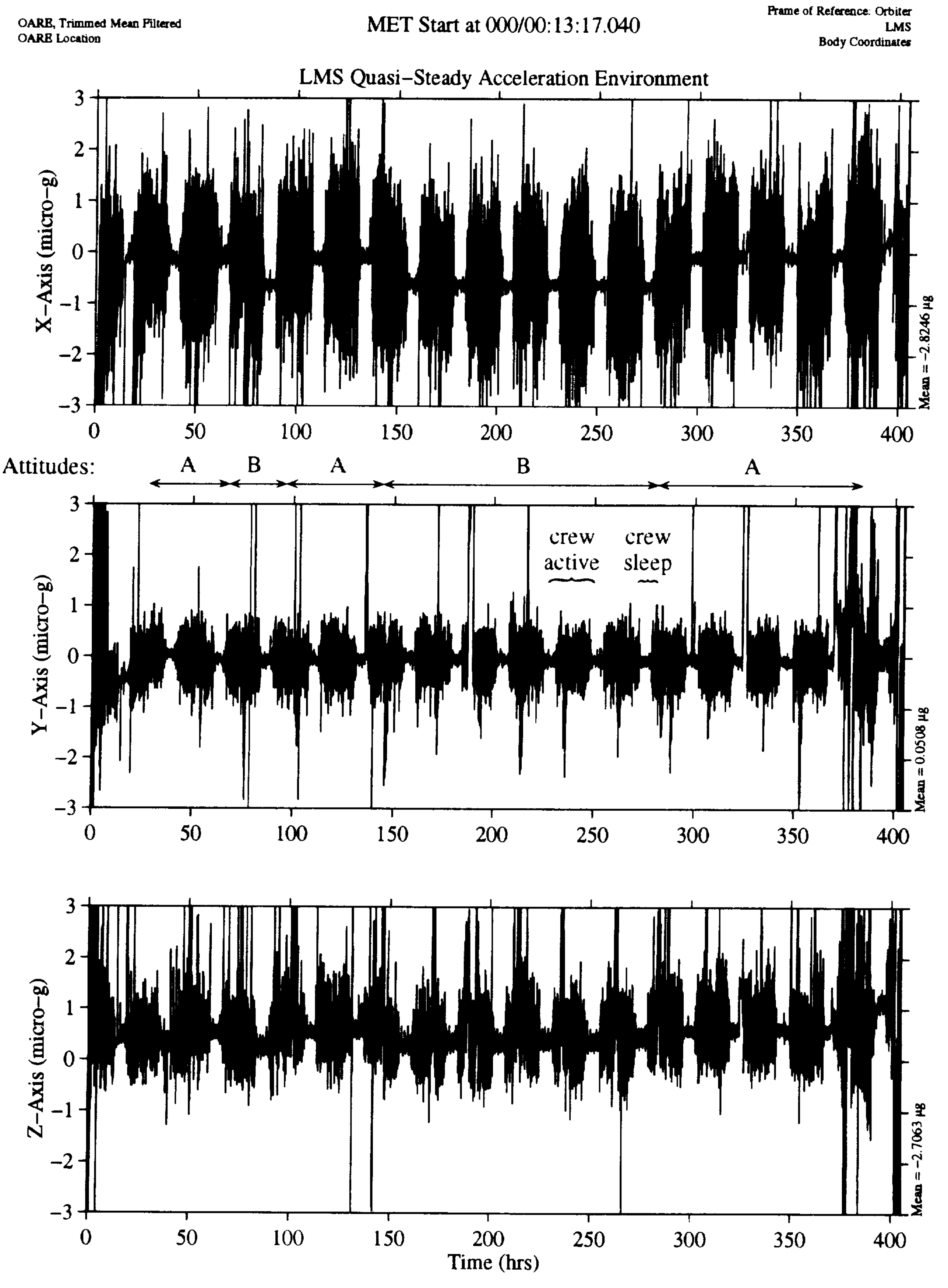
Attitudes: A: -ZLV/-XVV

B: -XLV/+ZVV



ORBITER ATTITUDE

MISSION

STS-62, March 1994, USMP-2

SOURCE OR ACTIVITY

The low-frequency or quasi-steady microgravity environment is a complex combination of many factors such as atmospheric drag, centripetal accelerations, gravity gradient accelerations, crew activity, venting, etc. The attitude of the Orbiter has an effect on the acceleration level of many of these components, such as atmospheric drag, centripetal acceleration, and gravity gradient acceleration. To a lesser degree, the attitude also affects the amount of water dumping required for thermal control.

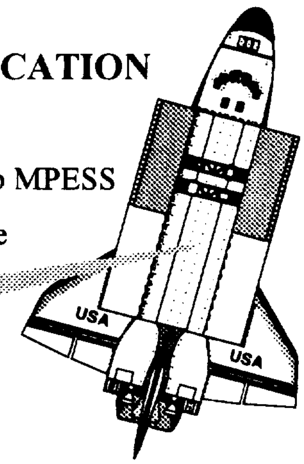
ACCELEROMETER

☐ SAMS ☑ OARE

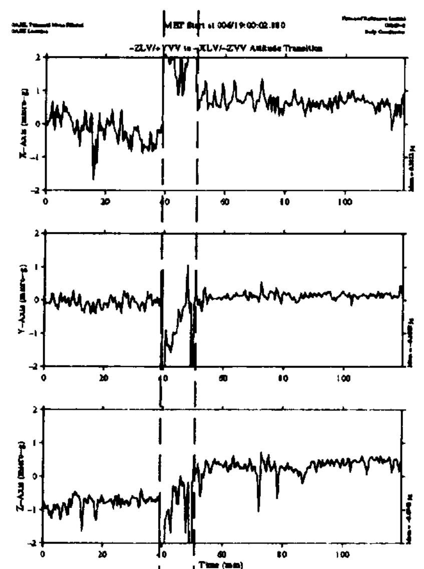
Frequency Range: 1 x 10^{-5} - 0.1 Hz
fs = 10 samples per second

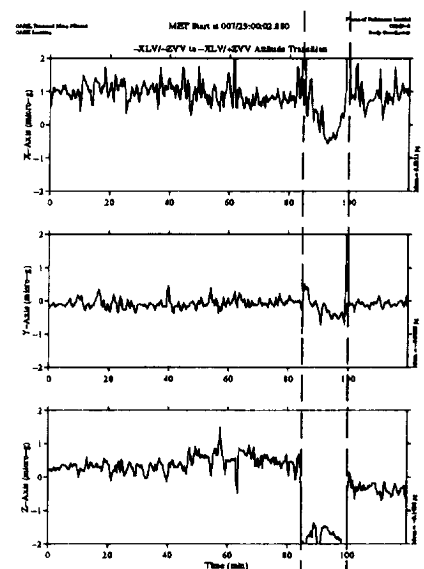
MEASUREMENT LOCATION

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



Larger plots on reverse





EFFECT ON MICROGRAVITY ENVIRONMENT

The low-frequency microgravity environment during two attitude transitions are shown in these figures. The different quasi-steady levels are apparent between the three attitudes illustrated there. The ten minute period in between attitudes (marked-off by the dotted lines) are the transition times. Some experiments are sensitive to the effective direction of the quasi-steady acceleration vector. As can be seen from the X_b, Y_b and Z_b components for the different attitudes, the direction of the quasi-steady acceleration vector is dependent on the Orbiter's attitude.

For further information, contact Duc Truong
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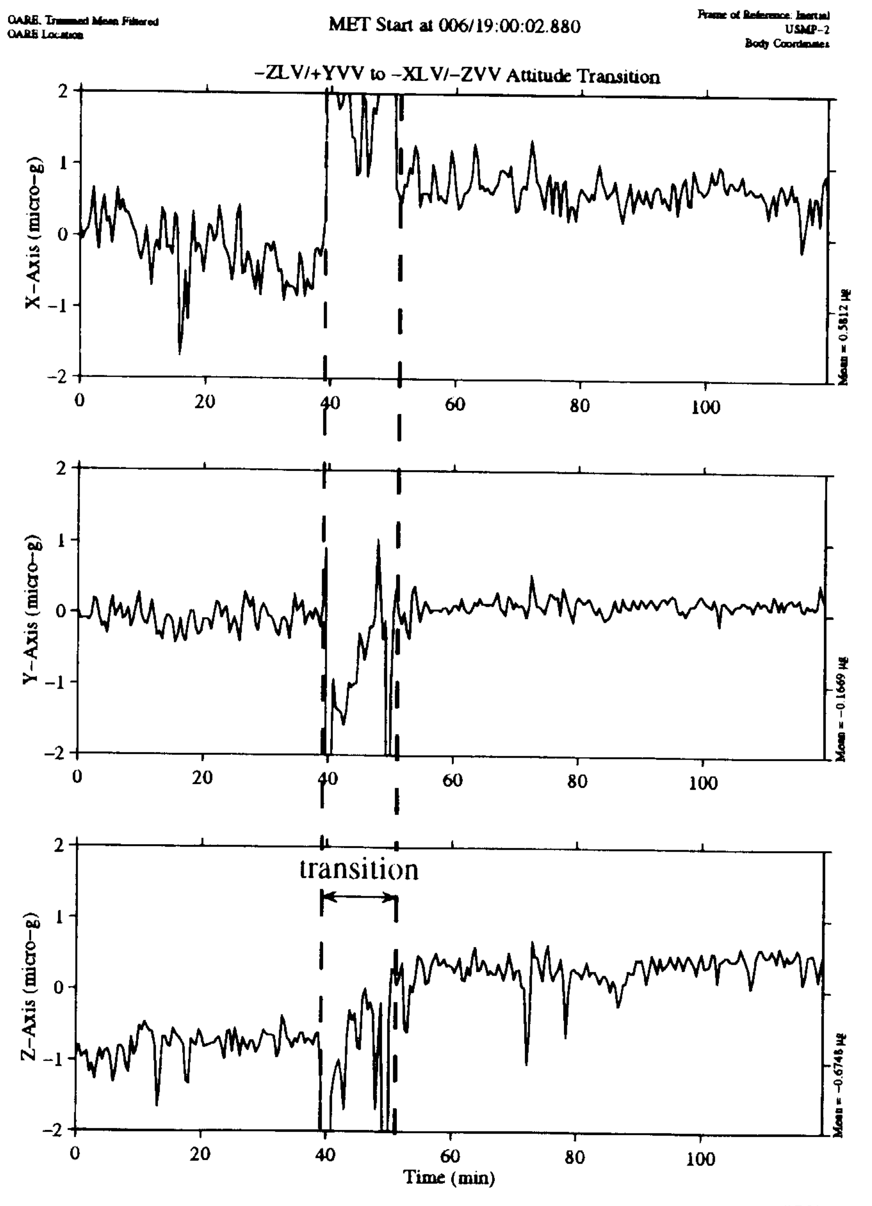
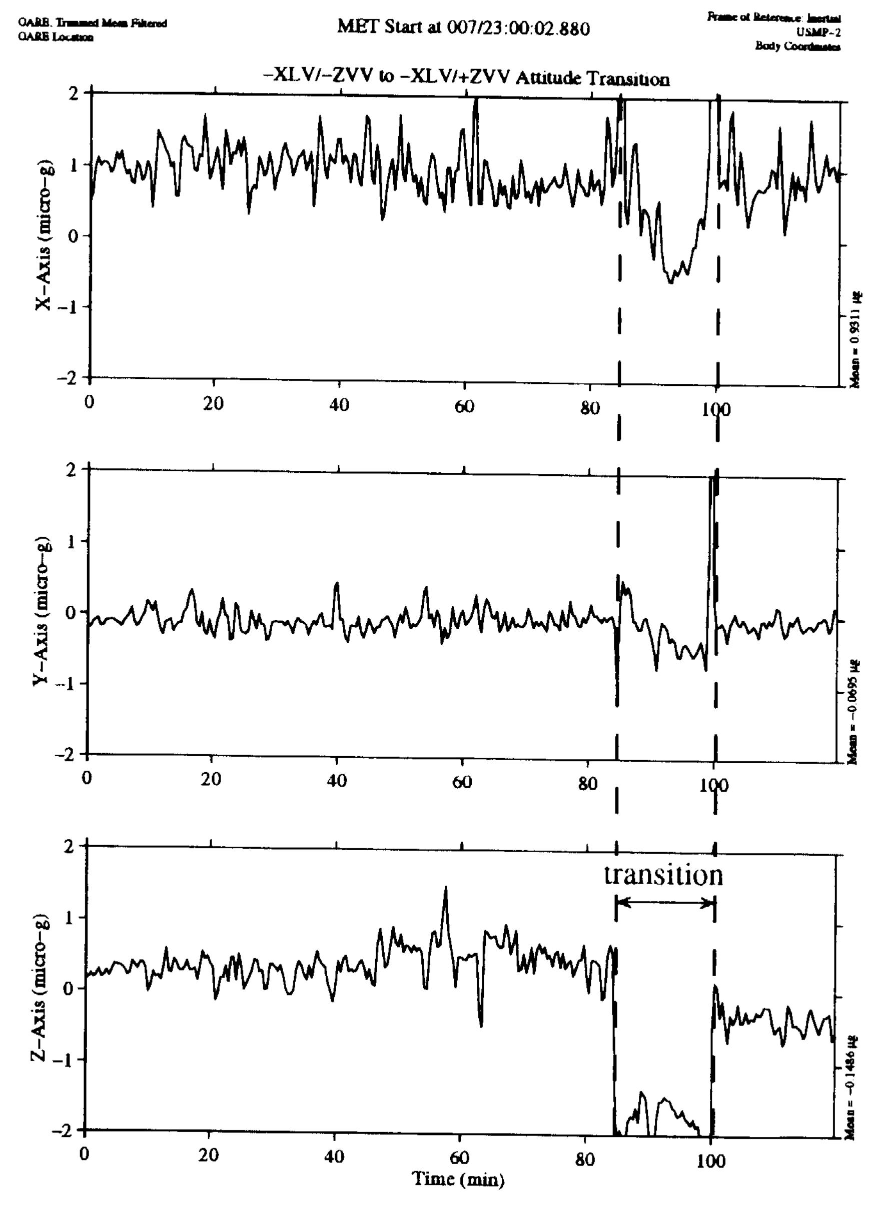
e-mail: pims@lerc.nasa.gov. URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


OARE, Trimmed Mean Filtered
OARE Location
MET Start at 006/19:00:02.880
Frame of Reference: Inertial
USMP-2
Body Coordinates
-ZLV/+YVV to -XLV/-ZVV Attitude Transition
X-Axis (micro-g)
Mean = 0.5812 μg
Y-Axis (micro-g)
Mean = -0.1669 μg
Z-Axis (micro-g)
Mean = -0.6748 μg
transition
Time (min)


OARE, Trimmed Mean Filtered
OARE Location
MET Start at 007/23:00:02.880
Frame of Reference: Inertial
USMP-2
Body Coordinates
-XLV/-ZVV to -XLV/+ZVV Attitude Transition
X-Axis (micro-g)
Mean = 0.9311 μg
Y-Axis (micro-g)
Mean = -0.0695 μg
Z-Axis (micro-g)
Mean = -0.1486 μg
transition
Time (min)

THRUSTERS
(*Quasi-steady effects*)

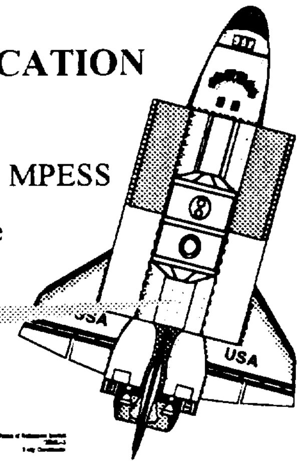
MISSION
STS-73, October 1995, USML-2

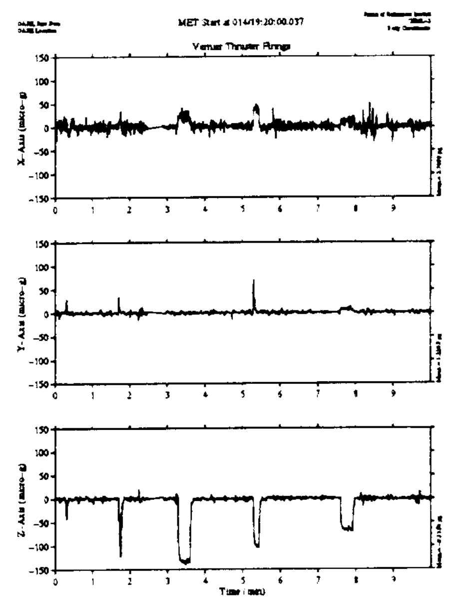
ACCELEROMETER
☐ SAMS ☑ OARE

Frequency Range: 1 x 10^{-5} - 0.1 Hz
fs = 10 samples per second

SOURCE OR ACTIVITY
The forward and aft Reaction Control System (RCS) thrusters provide the thrust for attitude (rotational) maneuvers (pitch, yaw and roll) and for small velocity changes (translation maneuvers). The forward RCS has 14 primary and two vernier engines. The aft RCS has 12 primary and two vernier engines in each pod. The primary and vernier RCS engines provide 870 and 24 pounds of vacuum thrust each, respectively. They may each be fired in increments of 80 milli-seconds. The vernier RCS thrusters are normally utilized for attitude control during the microgravity science missions. In the case of vernier thruster failure, the primary thrusters are used for attitude control.

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





Larger plot on reverse

EFFECT ON MICROGRAVITY ENVIRONMENT
The low-frequency microgravity environment during two thruster firings are shown in the figure. The event around 3 minutes, 30 seconds into the plot shows a 20 second duration simultaneous firing of two vernier thrusters (L5D and R5D). The event around 7 minutes, 40 seconds into the plot was a single vernier thruster (L5D), fired for about 20 seconds.

The effects on the microgravity environment do not occur solely in the quasi-steady frequency regime. Since the event is impulsive by nature, there are disturbances experienced over a broad frequency range. For further higher frequency information, see the PRCS and VRCS pages of this handbook.

For further information, contact Duc Truong
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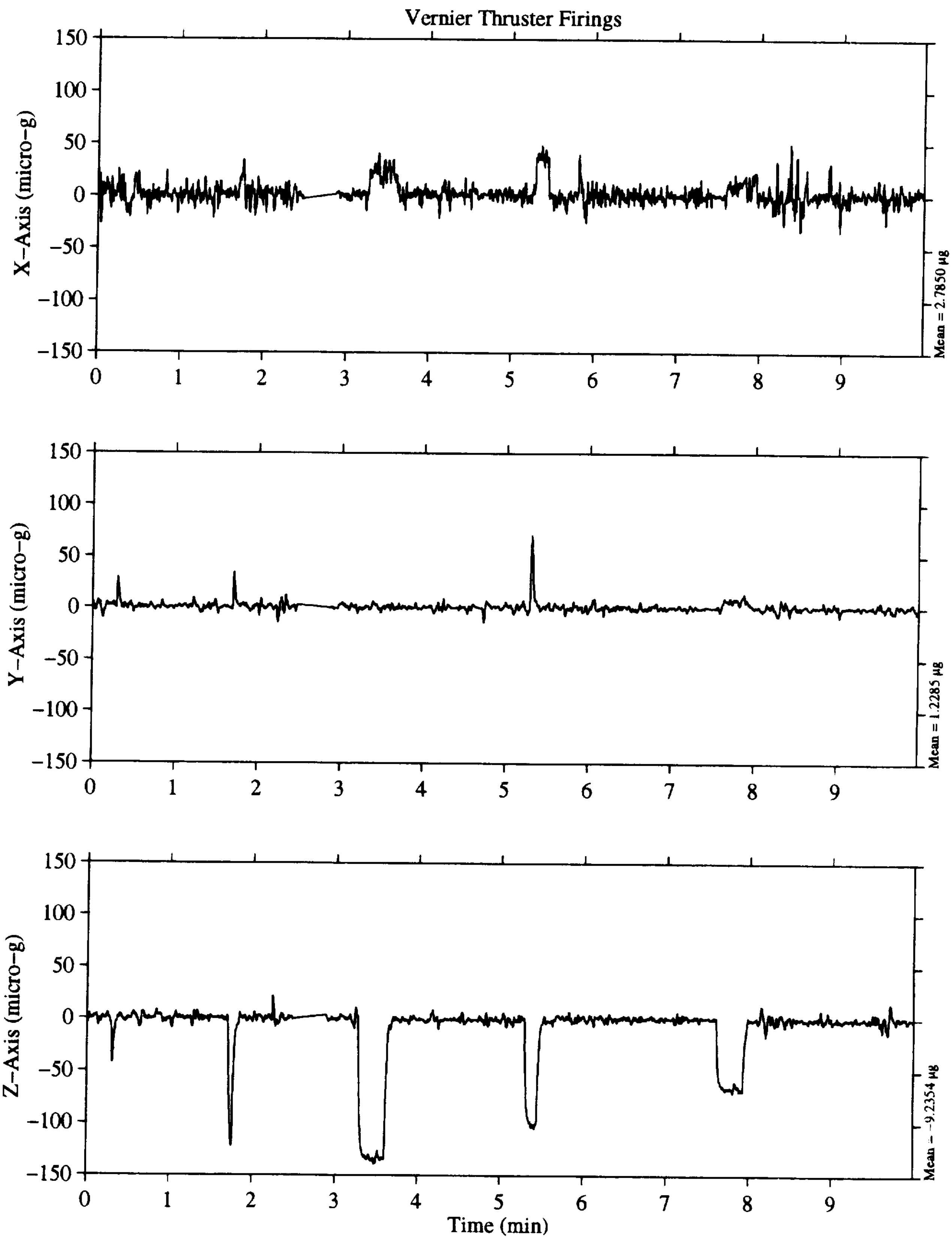
OARE, Raw Data
OARE Location

MET Start at 014/19:20:00.037

Frame of Reference: Inertial
USML–2
Body Coordinates



WATER DUMPS

(SUPPLY WATER DUMPS)

MISSION

STS-73, October 1995, USML-2
STS-78, June 1996, LMS

SOURCE OR ACTIVITY

The Orbiter food, water, and waste management subsystem provides storage and dumping capabilities for potable and waste water. Supply and waste water dumps are performed using nozzles on the portside of the Orbiter.

Supply water dumps typically cause a net acceleration in the Y_b-axis of the vehicle which triggers thruster firings to maintain attitude. As shown in the plots from the LMS mission, these dumps can cause a net acceleration in the Z_b-axis.

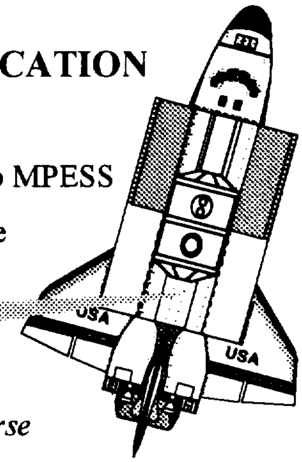
ACCELEROMETER

- [ ] SAMS
- [x] OARE

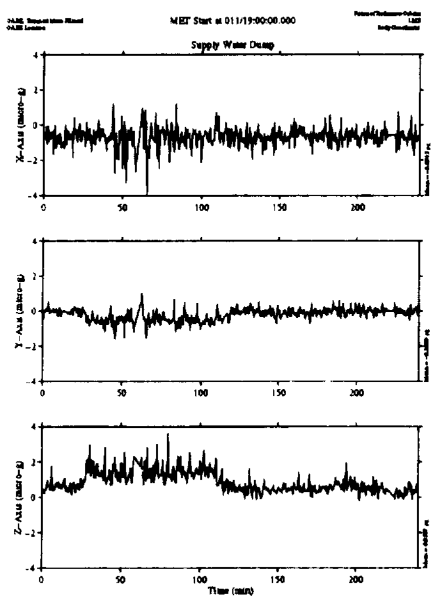
Frequency Range: 1 x 10^{-5} - 0.1 Hz
fs = 10 samples per second

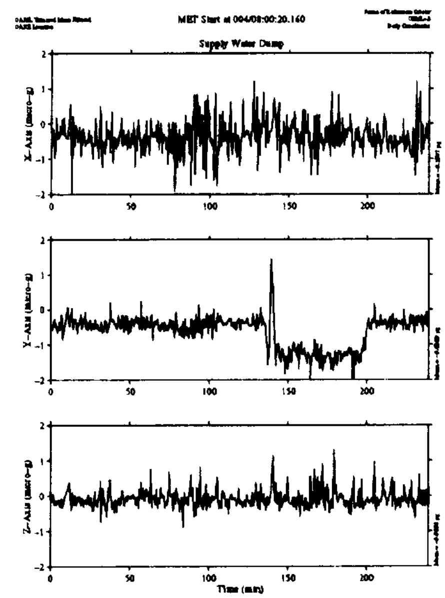
MEASUREMENT LOCATION

- [ ] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [x] Keel Bridge



Larger plots on reverse





EFFECT ON MICROGRAVITY ENVIRONMENT

The low-frequency microgravity environment for two missions are shown in these figures. The effect on the Y_b-axis is approximately 1.5 μg A similar effect of approximately 1.5 μg is possible on the Z_b-axis as well.

For further information, contact Duc Truong
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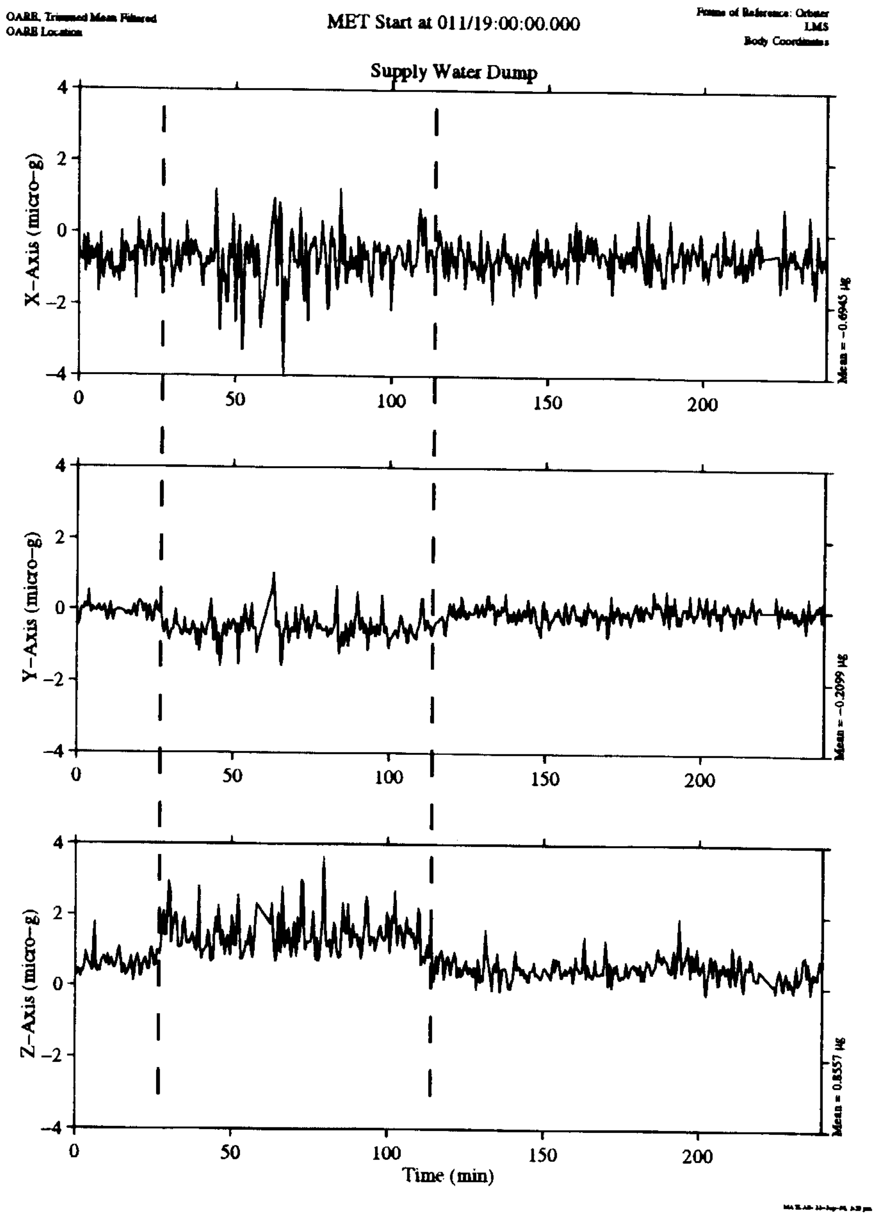
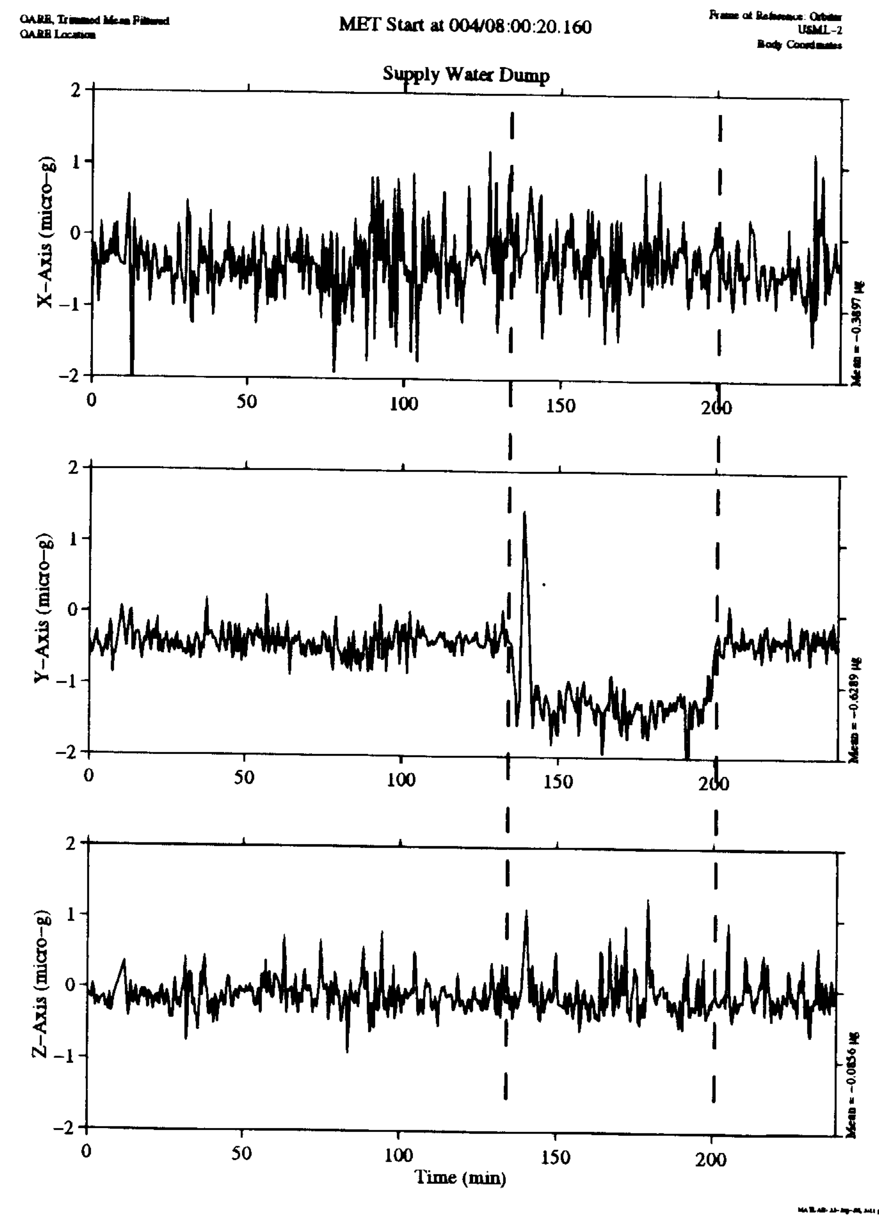
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



OARE, Trimmed Mean Filtered
OARE Location
MET Start at 011/19:00:00.000
Frame of Reference: Orbiter
LMS
Body Coordinates
Supply Water Dump
X-Axis (micro-g)
Mean = -0.6945 μg
Y-Axis (micro-g)
Mean = -0.2099 μg
Z-Axis (micro-g)
Mean = 0.8557 μg
Time (min)



OARE, Trimmed Mean Filtered
OARE Location
MET Start at 004/08:00:20.160
Frame of Reference: Orbiter
USML-2
Body Coordinates
Supply Water Dump
X-Axis (micro-g)
Mean = -0.3897 μg
Y-Axis (micro-g)
Mean = -0.6289 μg
Z-Axis (micro-g)
Mean = -0.0856 μg
Time (min)

WATER DUMPS
(WASTE WATER DUMPS)

MISSION
STS-78, June 1996, LMS

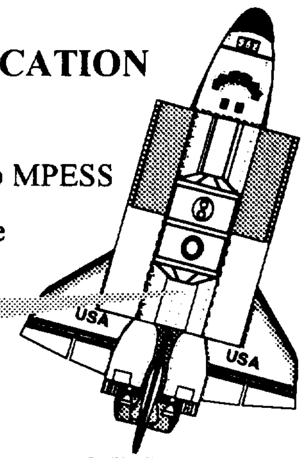
ACCELEROMETER
☐ SAMS ☑ OARE

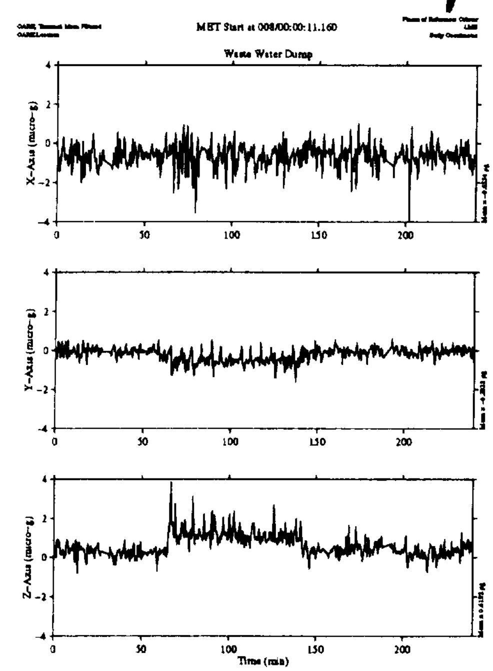
Frequency Range: 1 x 10^{-5} - 0.1 Hz
fs = 10 samples per second

SOURCE OR ACTIVITY
The Orbiter food, water, and waste management subsystem provides storage and dumping capabilities for potable and waste water. Supply and waste water dumps are performed using nozzles on the portside of the Orbiter.

Waste water dumps typically cause a net acceleration in the Y_b-axis of the vehicle which triggers thruster firings to maintain attitude. As shown in the plots from the LMS mission, these dumps can cause a net acceleration in the Z_b-axis.

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





Larger plots on reverse

EFFECT ON MICROGRAVITY ENVIRONMENT
The low-frequency microgravity environment for the LMS mission is shown in the figure. The effect on the Y_b-axis is approximately 1.0 μg. A similar effect of approximately 1.0 μg is possible on the Z_b-axis as well.

For further information, contact Duc Truong
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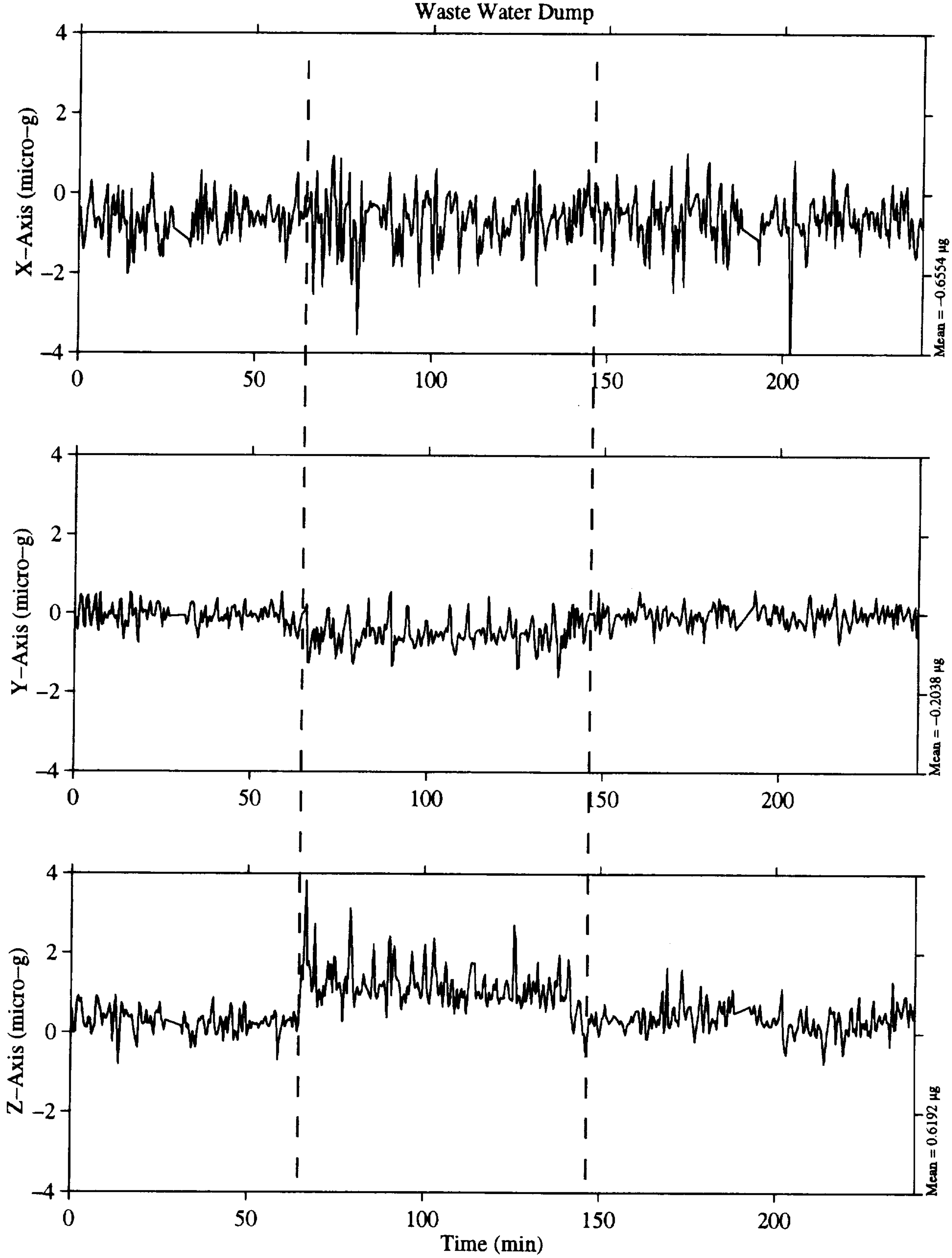
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

OARE, Trimmed Mean Filtered
OARE Location

MET Start at 008/00:00:11.160

Frame of Reference: Orbiter
LMS
Body Coordinates

Waste Water Dump



MATLAB: 23-Sep-96, 3:34 pm

WATER DUMPS

(SIMO DUMPS)

MISSION

STS-73, October 1995, USML-2
STS-78, June 1996, LMS

ACCELEROMETER

☐ SAMS ☑ OARE

Frequency Range: 1×10^{-5} - 0.1 Hz
fs = 10 samples per second

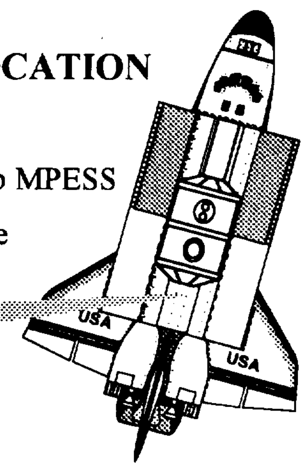
SOURCE OR ACTIVITY

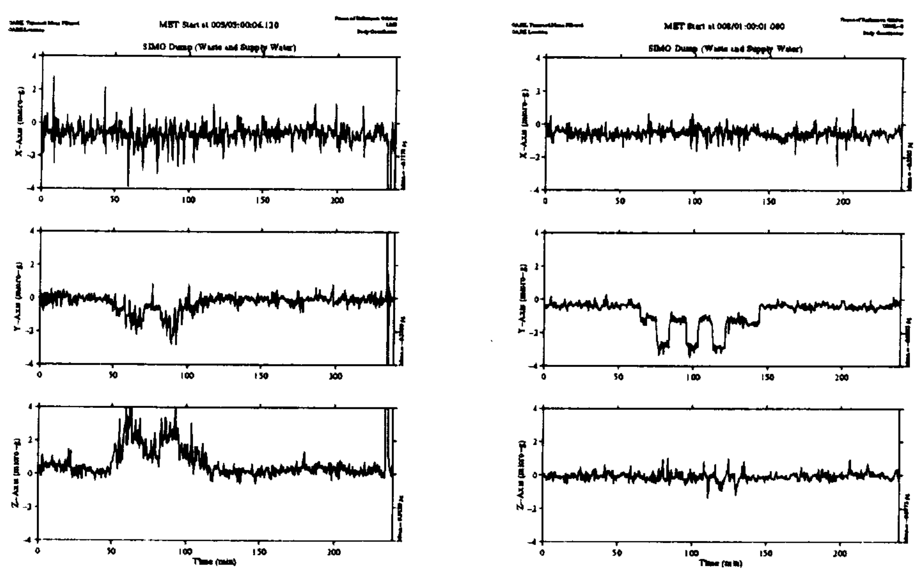
The Orbiter food, water, and waste management subsystem provides storage and dumping capabilities for potable and waste water. Supply and waste water dumps are performed using nozzles on the port side of the Orbiter. The two level effects observed in the figures results from the waste water dump being cycled on and off while the supply water dump stays on continuously. The term "SIMO" refers to a simultaneous supply and waste water dump.

This typically causes a net acceleration in the Y_b-axis of the vehicle which triggers thruster firings to maintain attitude. As shown in the plots from the LMS mission, these dumps can cause a net acceleration in the Z_b-axis.

MEASUREMENT LOCATION

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





Larger plots on reverse

EFFECT ON MICROGRAVITY ENVIRONMENT

The low-frequency microgravity environment for two missions are shown in these figures. The effect on the Y_b-axis is approximately 3 μg. A similar effect of approximately 3 μg is possible on the Z_b-axis as well.

For further information, contact Duc Truong
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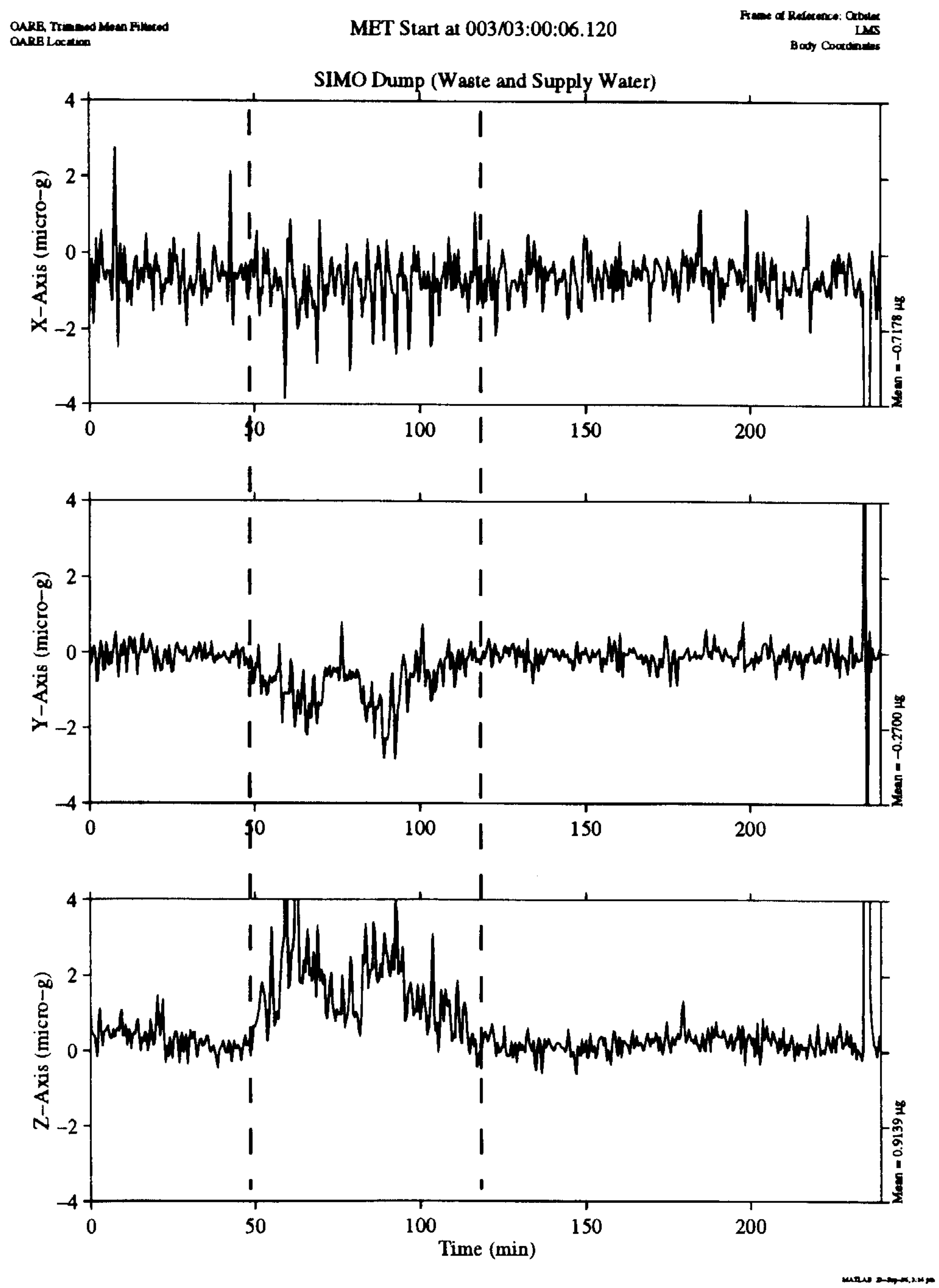
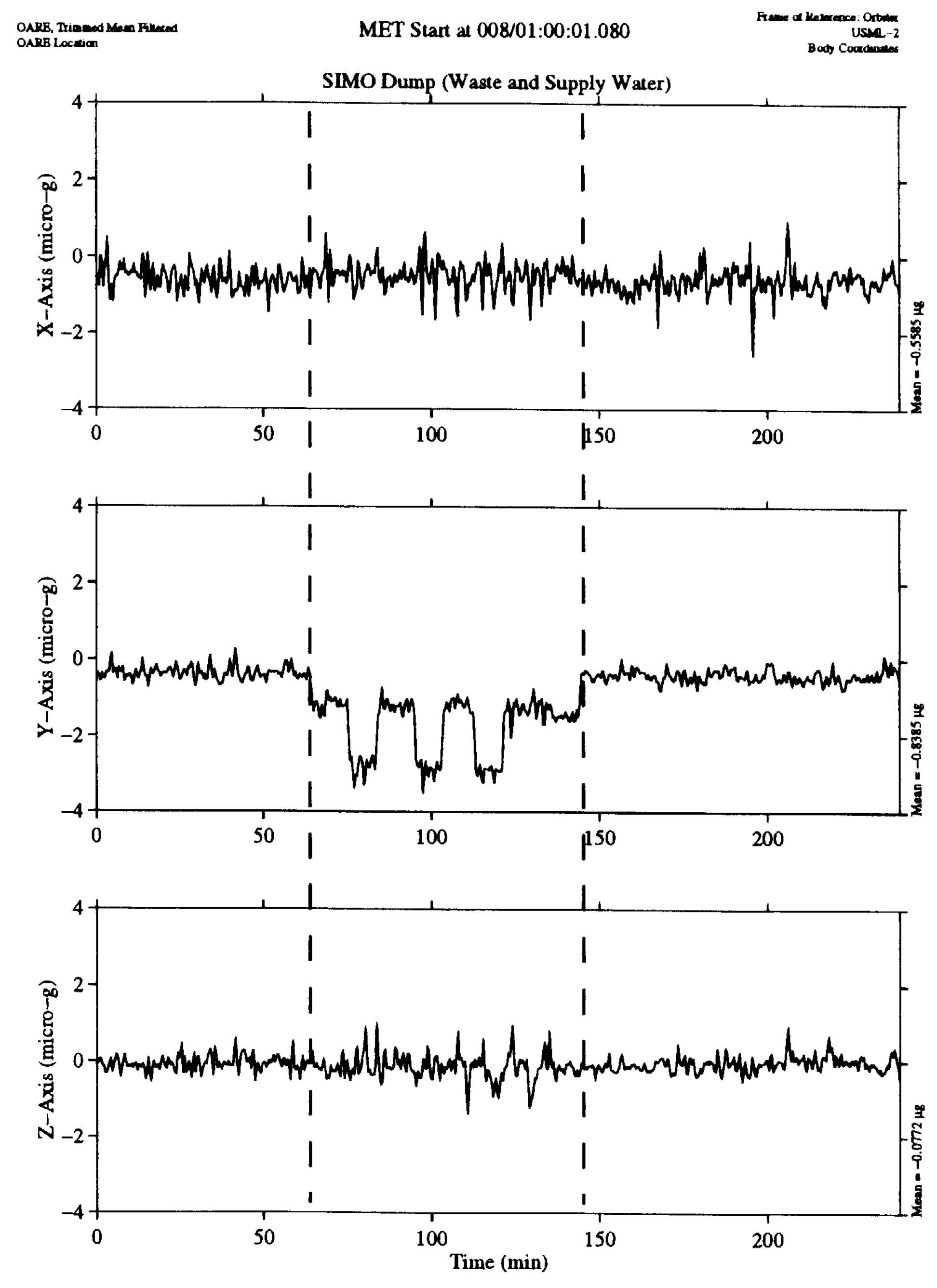
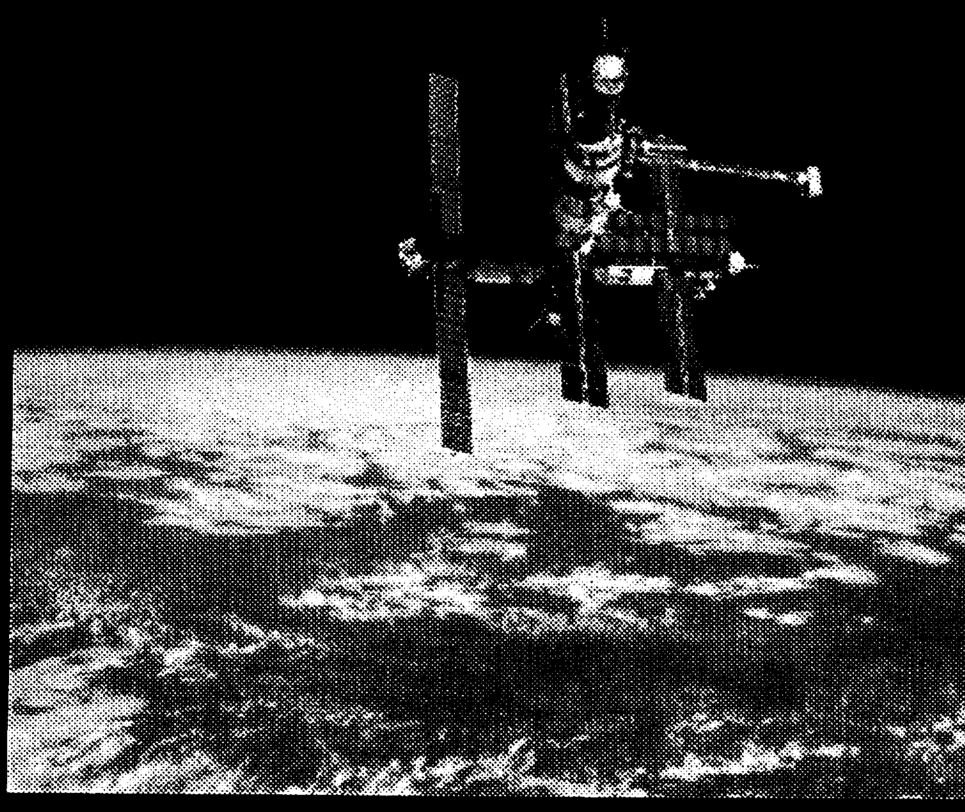
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/


OARE, Trimmed Mean Filtered
OARE Location
MET Start at 003/03:00:06.120
Frame of Reference: Orbiter
LMS
Body Coordinates
SIMO Dump (Waste and Supply Water)
X–Axis (micro–g)
Mean = –0.7178 µg
Y–Axis (micro–g)
Mean = –0.2700 µg
Z–Axis (micro–g)
Mean = 0.9139 µg
Time (min)


OARE, Trimmed Mean Filtered
OARE Location
MET Start at 008/01:00:01.080
Frame of Reference: Orbiter
USML–2
Body Coordinates
SIMO Dump (Waste and Supply Water)
X–Axis (micro–g)
Mean = –0.5585 µg
Y–Axis (micro–g)
Mean = –0.8385 µg
Z–Axis (micro–g)
Mean = –0.0772 µg
Time (min)

SECTION VI

Disturbances Measured in the Mir Space Station



PIMS

MIR / GYRODYNE ACTIVITY

MISSION

Mir Space Station, September 1995

SOURCE OR ACTIVITY

Within each module of the Mir Station, there is at least one bank of 6 gyrodynes, used to help maintain station attitude. These operate at a nominal rotational rate of 10,000 rpm (~166.6 Hz). This is normally a very well controlled signal (i.e. falling within a tight frequency band). Occasionally, one or more of these gyrodyne banks needs to be spun-down (i.e. turned-off), and then spun-up again later. By analysis of SAMS data, both the spin-up and spin-down operations take on the order of 3 hours.

Larger plot on reverse

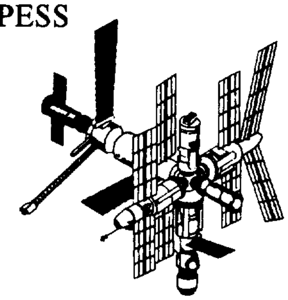
ACCELEROMETER

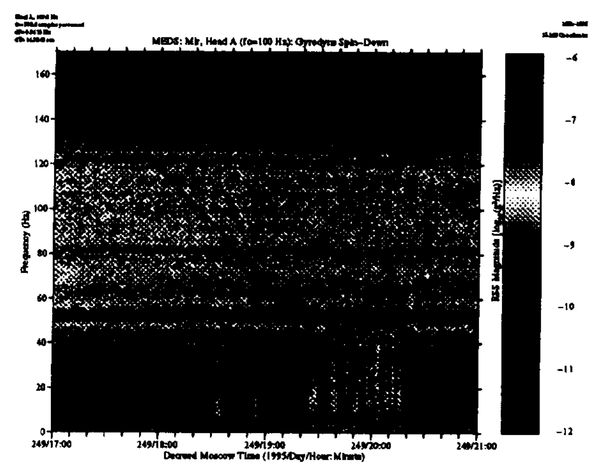
☑ SAMS ☐ OARE

Head A, 100 Hz
fs = 500 samples per second

MEASUREMENT LOCATION

- ☐ Spacelab Module
- ☐ Cargo bay / Spacelab MPESS
- ☐ SPACEHAB Module
- ☐ Middeck
- ☐ Keel Bridge
- ☑ Mir, Kvant





EFFECT ON MICROGRAVITY ENVIRONMENT

Due to the 100 Hz cutoff of the SAMS sensor head, SAMS data cannot be used to accurately determine the g_{RMS} level of the accelerations above 100 Hz, including the 166.6 Hz gyrodyne disturbance. Additionally, the g_{RMS} level for the disturbance would depend on the proximity of the sensor to the disturbance source. SAMS data from the Kvant module have suggested that the disturbance is 500 μg_{RMS} or more.

A spin-down operation may be seen in the figure, starting around DMT 249/17:05, where the diagonal trace begins its downward slope from 166 Hz, towards 0 Hz around DMT 249/20:15. Close examination of this plot shows multiple traces, each following different time vs. frequency paths, including one starting around DMT 249/18:40. However, all of the traces seem to converge at 0 Hz around DMT 249/20:15. This suggests that the spin-down procedure for the 6 gyrodynes in each bank is a well-controlled process, with a well-controlled end-time.

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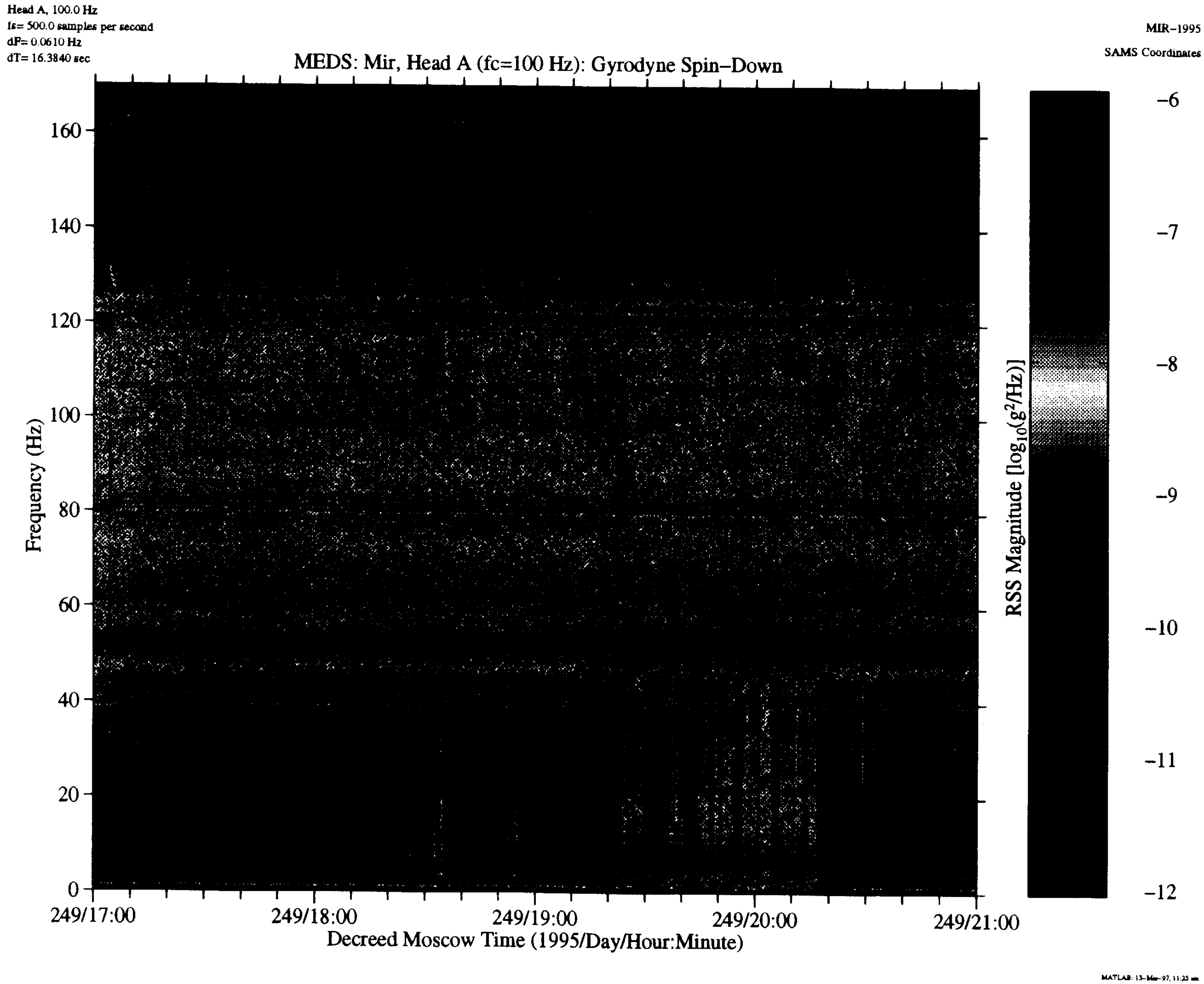
Telephone: 216-433-8394. Facsimile: 216-433-8660
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



Head A, 100.0 Hz
fs= 500.0 samples per second
dF= 0.0610 Hz
dT= 16.3840 sec
MIR-1995
SAMS Coordinates
MEDS: Mir, Head A (fc=100 Hz): Gyrodyne Spin-Down
Frequency (Hz)
160
140
120
100
80
60
40
20
0
249/17:00
249/18:00
249/19:00
249/20:00
249/21:00
Decreed Moscow Time (1995/Day/Hour:Minute)
RSS Magnitude [log10(g^2/Hz)]
-6
-7
-8
-9
-10
-11
-12

MIR / SHUTTLE DOCKING

MISSION

Mir Space Station, November 1995

SOURCE OR ACTIVITY

The docking of the Orbiter to the Mir Space Station is achieved through use of the docking ring adapter, attached to the extremity of the Kristall module. The docking operation is conducted in multiple steps, including a docking ring capture (soft-mate), followed by a ring retraction, and then a series of 12 latches are locked (hard-mate). This plot was produced from data collected during the STS-74 docking of Atlantis.

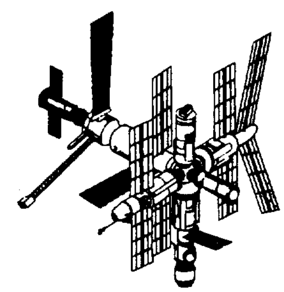
ACCELEROMETER

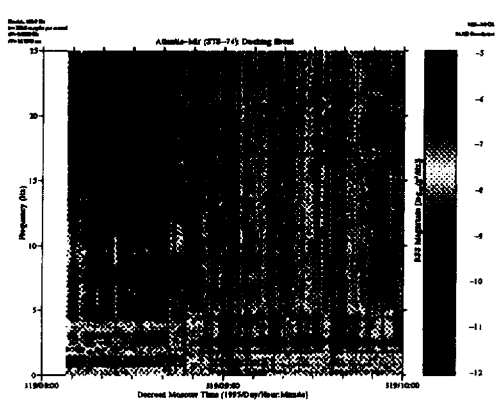
- [x] SAMS
- [ ] OARE

Head A, 100 Hz
fs = 500 samples per second

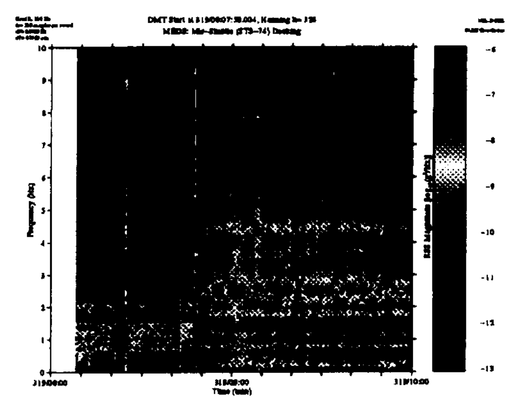
MEASUREMENT LOCATION

- [ ] Spacelab Module
- [ ] Cargo bay / Spacelab MPESS
- [ ] SPACEHAB Module
- [ ] Middeck
- [ ] Keel Bridge
- [x] Mir, Kristall





Larger plots on reverse



EFFECT ON MICROGRAVITY ENVIRONMENT

The broad-band impulse disturbance around DMT 319/08:42 is believed to be the initial contact of Orbiter to Mir. The impulse around DMT 319/08:47 is believed to be the hard-mate capture. Immediately following this disturbance, notice the addition of a 17 Hz signal to the environment. This is caused by the dither of the Ku-band communication antenna on the orbiter. Also notice a periodic 22-23 Hz signal (circled in black). This is due to the Enhanced Orbiter Refrigerator/Freezer (EORF) on the Shuttle. The EORF is similar in nature to the LSLE R/F, described in this handbook.

The spectrogram on the right (produced from head B data) shows a clearer picture of the lower frequency region, including the vehicle structural modes. Notice how some structural modes change (2.0 Hz before docking, 2.5 Hz after docking), and how other modes appear (4.5 Hz after docking).

These data show that the acceleration environment of the two vehicle complex results from the acceleration environment of both vehicles. In other words, microgravity disturbances are transmitted from one vehicle to the other.

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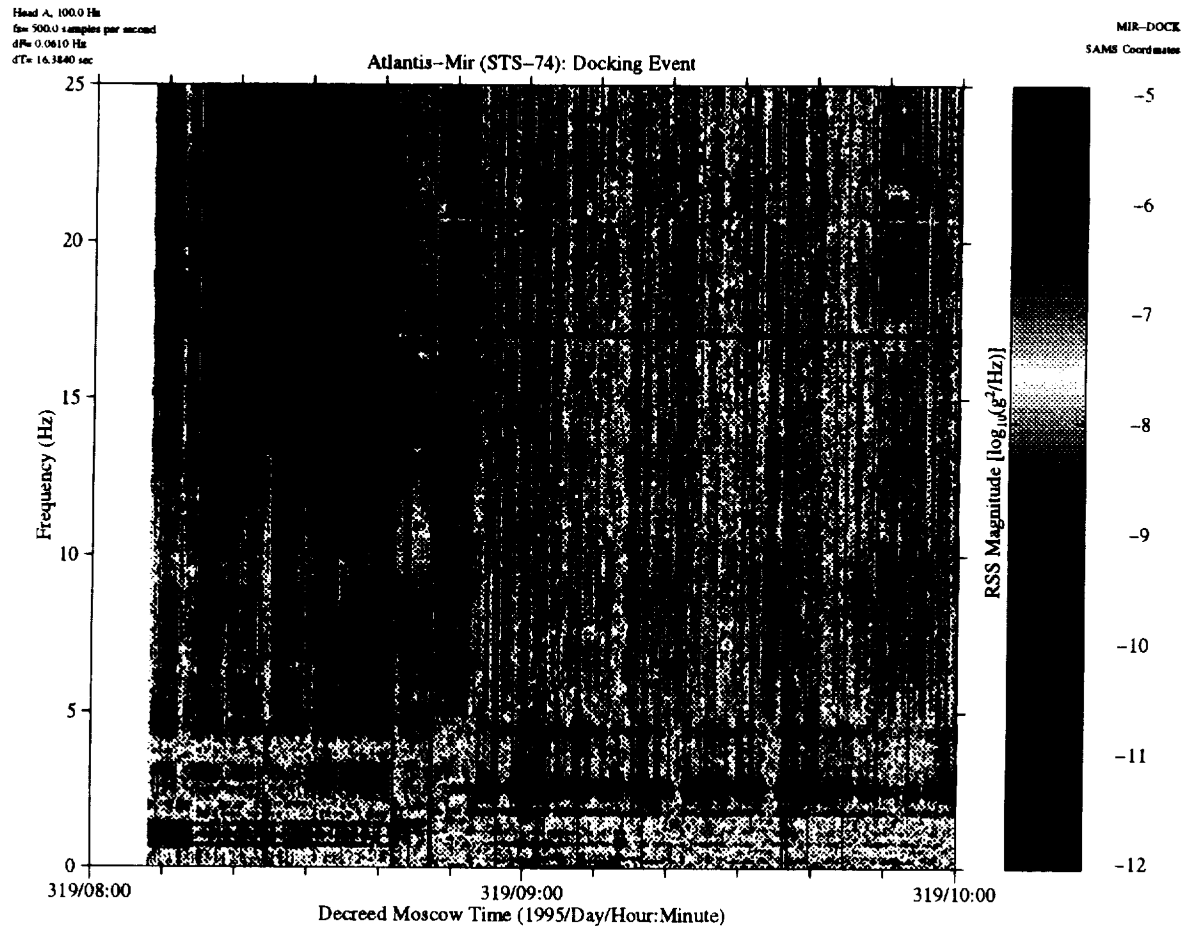
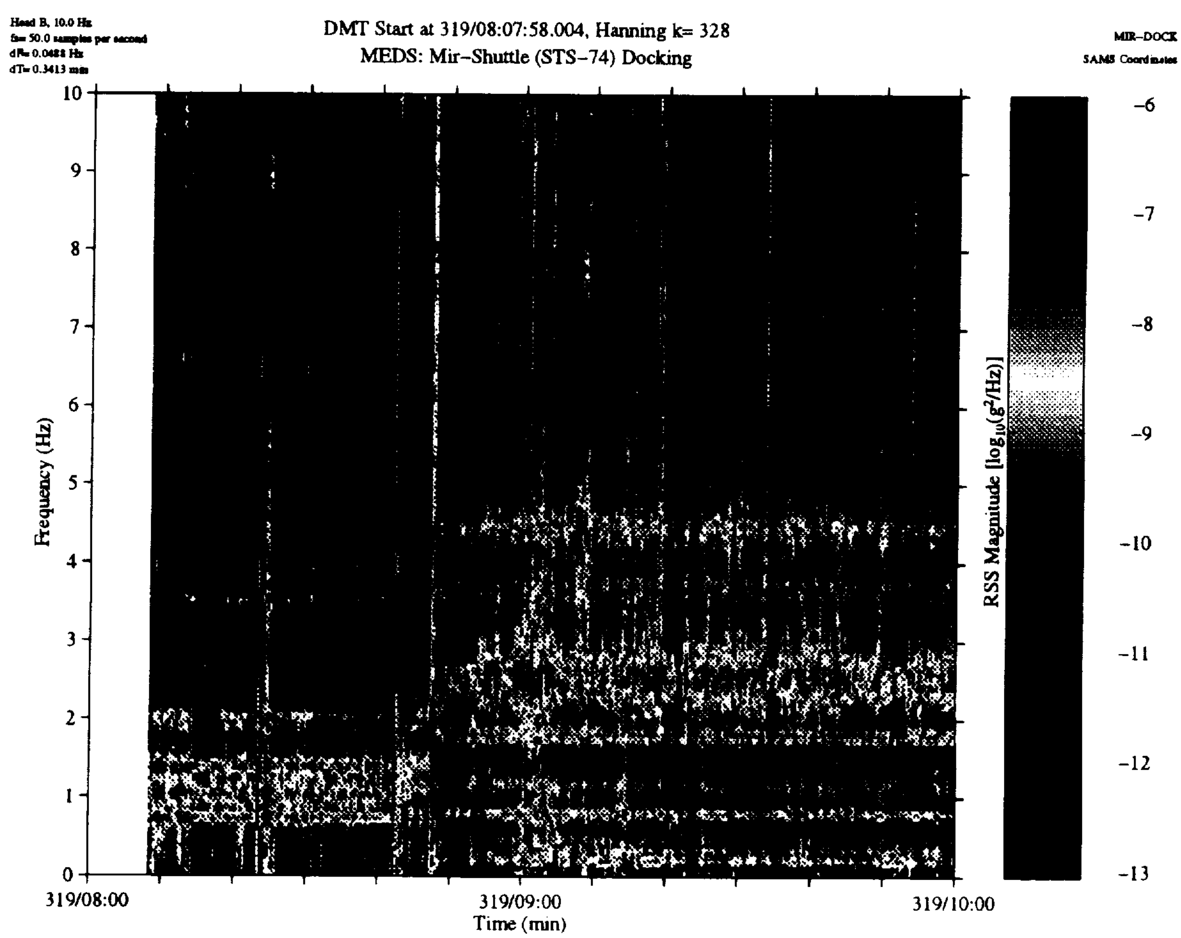
URL: http://www.lerc.nasa.gov/WWW/MMAP/PIMS/



Head A, 100.0 Hz
fs= 500.0 samples per second
df= 0.0610 Hz
dT= 16.3840 sec
Atlantis–Mir (STS–74): Docking Event
MIR–DOCK
SAMS Coordinates
Frequency (Hz)
RSS Magnitude [$\log_{10}(g^2/Hz)$]
319/08:00
319/09:00
319/10:00
Decreed Moscow Time (1995/Day/Hour:Minute)



Head B, 10.0 Hz
fs= 50.0 samples per second
df= 0.0488 Hz
dT= 0.3413 min
DMT Start at 319/08:07:58.004, Hanning k= 328
MEDS: Mir–Shuttle (STS–74) Docking
MIR–DOCK
SAMS Coordinates
Frequency (Hz)
RSS Magnitude [$\log_{10}(g^2/Hz)$]
319/08:00
319/09:00
319/10:00
Time (min)

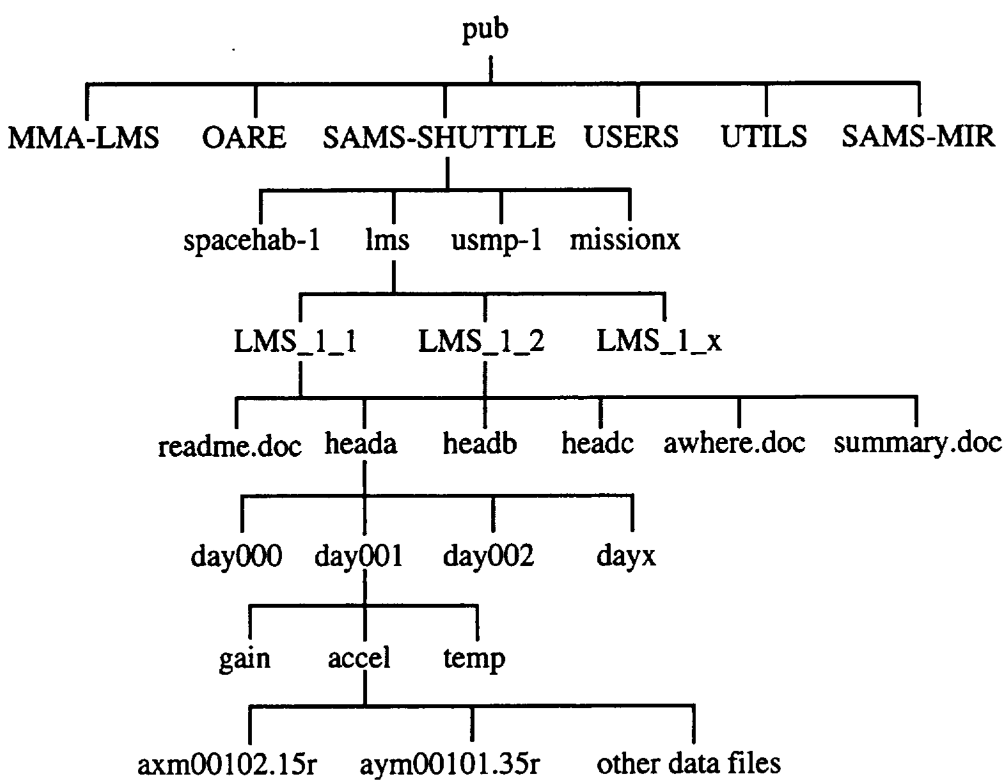
SECTION VII

Disturbances Measured in the Other Locations

Appendix A: Accessing Acceleration Data via the Internet

SAMS and OARE data are available over the internet from the NASA LeRC file server "beech.lerc.nasa.gov". Previously, SAMS data were made available on CD-ROM, but distribution of data from current (and future) missions will be primarily through this internet file server.

SAMS data files are arranged in a standard tree-like structure. Data are first separated based upon mission. Then, data are further subdivided based upon some portion of the mission, head, year (if applicable), day, and finally type of data file (acceleration, temperature, or gain). Effective November 1, 1996, there has been a minor reorganization of the beech.lerc.nasa.gov file server. There are now two locations for SAMS data: a directory called SAMS-SHUTTLE and a directory called SAMS-MIR. Under the SAMS-SHUTTLE directory, the data are segregated by mission. Under the SAMS-MIR directory, the data are segregated by year. The following figure illustrates this structure.



The SAMS data files (located at the bottom of the tree structure) are named based upon the contents of the file. For example, a file named "axm00102.15r" would contain head A data for the x-axis for day 001, hour 02, file 1 of 5. The readme.doc files give a complete explanation of the file naming convention.

OARE data files are also arranged in a tree-like structure, but with different branches. The data are first divided based upon mission, and then are divided based upon type of data. The OARE tree structure looks like this:

```
pub
├── MMA-LMS
├── OARE
│   ├── iml-2
│   ├── lms
│   └── usml-2
│       ├── canopus
│       │   └── filename
│       ├── msfc-raw
│       │   └── filename
│       └── msfc-processed
│           └── filename
├── UTILS
├── USERS
├── SAMS-MIR
└── SAMS-SHUTTLE
```

Files under the canopus directory are trimmean filter data, computed by Canopus Systems, Inc. Files under the msfc-raw directory contain the telemetry data files provided to PIMS by the Marshall Space Flight Center Payload Operations Control Center data reduction group. Files under the msfc-processed directory are raw files containing binary floating point values, listing the MET (in hours), and the x, y, and z axis acceleration in micro-g's. Selected MMA data files are located in the MMA-LMS subdirectory. See the readme files for complete data descriptions.

Data access tools for different computer platforms (MS-DOS, Macintosh, SunOS, and MS-Windows) are available in the /pub/UTILS directory.

The NASA LeRC beech file server can be accessed via anonymous File Transfer Protocol (ftp), as follows:

1) Open an ftp connection to "beech.lerc.nasa.gov"
2) Login as userid "anonymous"
3) Enter your e-mail address as the password
4) Change directory to pub
5) List the files and directories in the pub directory
6) Change directories to the area of interest
7) Change directories to the mission of interest
8) Enable binary file transfers
9) Use the data file structures (described above) to locate the desired files
10) Transfer the desired files

If you encounter difficulty in accessing the data using the file server, please send an electronic mail message to "pims@lerc.nasa.gov". Please describe the nature of the difficulty and also give a description of the hardware and software you are using to access the file server.

Appendix B: Bibliography

Summary Report of Mission Acceleration Measurements for SPACEHAB-1, STS-57, NASA Technical Memorandum 106514, March 1994, [launched 06/21/93]

Summary Report of Mission Acceleration Measurements for SPACEHAB-2, STS-60, NASA Technical Memorandum 106797, [launched 02/11/94]

Summary Report of Mission Acceleration Measurments for STS-62, USMP-2, NASA Technical Memorandum 106773, [launched 03/04/94]

Summary Report of Mission Acceleration Measurements for STS-65, IML-2, NASA Technical Memorandum 106871, [launched 07/08/94]

Quick Look Report of Acceleration Measurements on Mir Space Station During Mir-16, NASA Tecnical Memorandum 106835

Summary Report of Mission Acceleration Measurements for STS-66, ATLAS-3, NASA Technical Memorandun 106914, [launched 11/03/94]

Summary Report of Mission Acceleration Measurements for STS-73, USML-2, NASA Technical Memorandum 107269, [launched 10/20/95]

Summary Report of Mission Acceleration Measurements for STS-75, USMP-3, NASA Technical Memorandum 107359, [launched 2/22/96]

Further Analysis of the Microgravity Environment on Mir Space Station during Mir-16, NASA Technical Memorandum 107239

SAMS Acceleration Measurements on Mir From June to November 1995, NASA Technical Memorandum 107312

Summary Report of Mission Acceleration Measurements for STS-78, LMS, NASA Technical Memorandum 107401, [launched 6/20/96]

DeLombard, R.: SAMS Acceleration Measurements on Mir From November 1995 to June 1996, NASA TM-107435, 1997

DeLombard, R. and Finley, B.D.: Space Acceleration Measurement System Description and Operation on the First Spacelab Life Sciences Mission, NASA TM-105301, 1991.

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

Blanchard, R. C.; Hendrix, M. K.; Fox, J. C.; Thomas, D. J.; and Nicholson, J. Y.:Orbital Acceleration Research Experiment. Journal of Spacecraft and Rockets, Vol. 24, No. 6, 1987.

Blanchard, R. C.; Nicholson, J. Y. and Ritter, J. R.: STS-40 Orbital Acceleration Research Experiment Flight Results During a Typical Sleep Period, Microgravity Science Technology, Vol. V, No. 2, 1992.

DeLombard, R.: Compendium of Information for Interpreting the Microgravity Environment of the Orbiter Spacecraft, NASA TM-107032, 1996.

Shuttle Reference Document on the World Wide Web at URL: http://www.ksc.nasa.gov/shuttle/technology/sts-newsref/stsref-toc.html

DeLombard, R.; Moskowitz, M.E.; Hrovat, K.; and McPherson, K. M.: Comparison Tools for Assessing the Microgravity Environment of Missions, Carriers and Conditions, NASA Technical Memorandum 107446, April 1997.

Appendix C: User Comment Sheet

We would like you to give us some feedback so that we may improve the Microgravity Environment Description Handbook. Please answer the following questions and give us your comments.

1. Did the Microgravity Environment Description Handbook fulfill your requirements for acceleration and mission information? ______Yes ______No

If not why not?

Comments: ____

____

2. Is there additional information which you feel should be included in this Microgravity Environment Description Handbook? ______Yes ______No

If so what is it?

Comments: ____

____

3. Is there information in this report which you feel is not necessary or useful?

______Yes ______No

If so, what is it?

Comments: ____

____

4. Do you have internet access via: (__)ftp (__)WWW (__)gopher (__)other? Have you already accessed SAMS data or information electronically?

______Yes ______No

Comments: ____

____

Completed by: Name:______________________ Telephone ______________________

Address: ______________________ Facsimile ______________________

______________________ E-mail address ______________________

Return this sheet to:
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http://www.lerc.nasa.gov/WWW/MMAP/PIMS/

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13. ABSTRACT ***(Maximum 200 words)***

The Microgravity Measurement and Analysis Project (MMAP) at the NASA Lewis Research Center (LeRC) manages the Space Acceleration Measurement System (SAMS) and the Orbital Acceleration Research Experiment (OARE) instruments to measure the microgravity environment on orbiting space laboratories. These laboratories include the Spacelab payloads on the shuttle, the SPACEHAB module on the shuttle, the middeck area of the shuttle, and Russia's Mir space station. Experiments are performed in these laboratories to investigate scientific principles in the near-absence of gravity. The microgravity environment desired for most experiments would have zero acceleration across all frequency bands or a true weightless condition. This is not possible due to the nature of spaceflight where there are numerous factors which introduce acceleration to the environment. This handbook presents an overview of the major microgravity environment disturbances of these laboratories. These disturbances are characterized by their source (where known), their magnitude, frequency and duration, and their effect on the microgravity environment. Each disturbance is characterized on a single page for ease in understanding the effect of a particular disturbance. The handbook also contains a brief description of each laboratory.

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