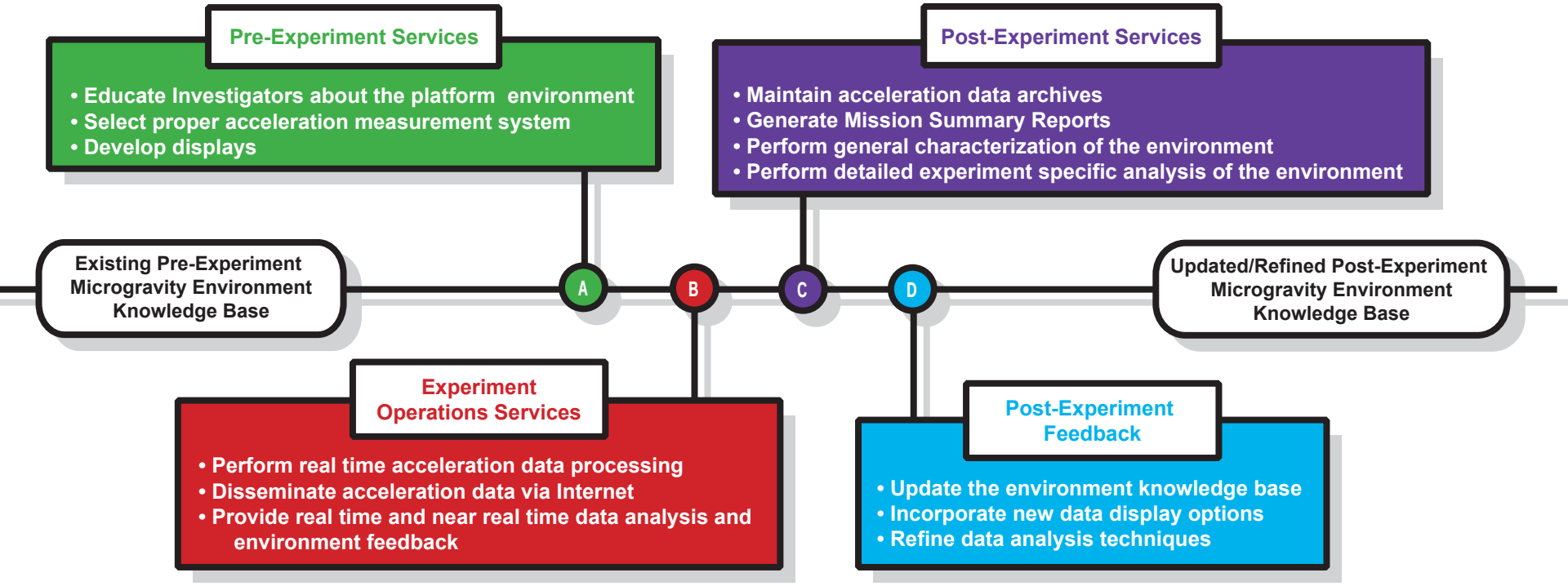
Section 12:

PIMS International Space Station Operations

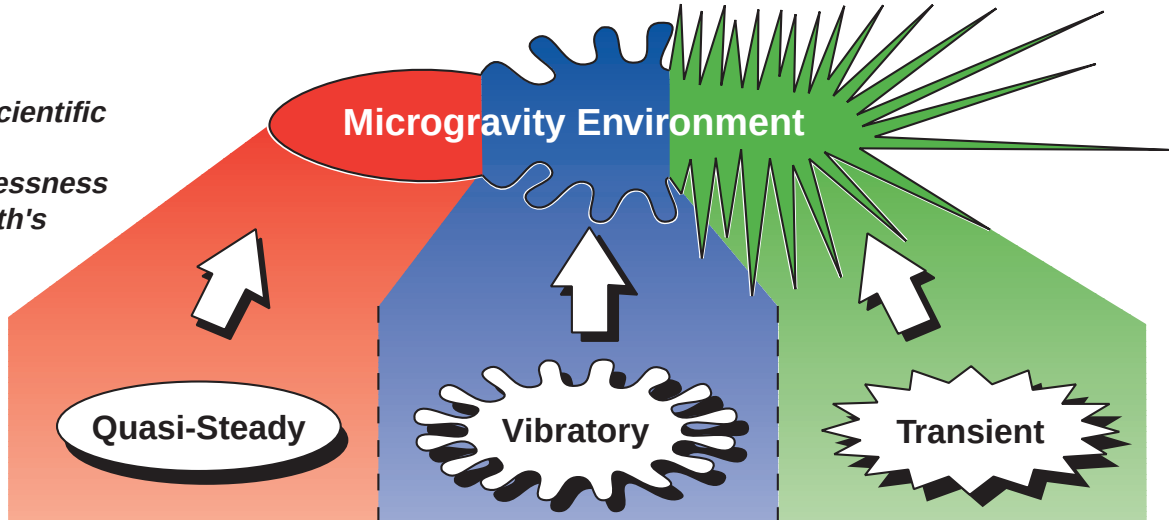
Kevin M. McPherson
PIMS Data Analyst
NASA Glenn Research Center

PIMS Functions During Experiment Life Cycle



Components of the Microgravity Environment

Microgravity is:
- ***a general label for scientific investigations that exploit near-weightlessness***
- ***one-millionth of Earth's normal gravity***
- ***a reduced gravity environment***



Component	Quasi-Steady	Vibratory	Transient
Frequency	$0 \leq f < 0.01$ Hz	$0.01 \leq f \leq 300$ Hz	broadband
Magnitude	μg's (or less) peak	tens to thousands μg_{RMS}	tens of mg's peak
Primary Sources	**gravity gradient & rotational effects:** not at center of mass **drag:** function of altitude, attitude, day/night, etc. **vehicle:** venting water or air	**equipment:** pumps, fans, centrifuges, compressors, etc. **crew:** ergometer or treadmill exercise **vehicle:** structural modes	**vehicle:** thrusters, dockings **crew:** pushoffs & landings, drawer/door closings, experiment setup **equipment:** machinery startup

Space Acceleration Measurement System-II

- **Provide distributed measurement of the vibratory and transient acceleration environment (0.01 ≤ f ≤ 300 Hz) on the ISS in support of various microgravity payloads**
- **Components**
  - **Control Unit**
    - Responsible for data and command routing
  - **Remote Triaxial Sensor (RTS) System**
    - Up to Ten RTS Electronics Enclosures (EE's)
    - Up to Two RTS Sensor Enclosures (SE's) per EE
- **Flight 6A configuration and operations**
  - **Three EE's and 5 SE's**
  - **Real-time data downlinked from the ISS**

Microgravity Acceleration Measurement System

- **Measure the ISS quasi-steady acceleration (f ≤ 0.01 Hz) and the ISS vibratory acceleration environment**
- **Components**
  - **Miniature Electro-Static Accelerometer (MESA)**
    - sensor is a flight spare from the OARE program
    - measure the quasi-steady acceleration environment
  - **High-Resolution Accelerometer Package (HiRAP)**
    - measure the vibratory environment at the MAMS location only
- **Flight 6A configuration**
  - **MESA and HiRAP instruments active**
  - **Real-time data downlink from the ISS**
- **Additional features**
  - **Quasi-steady acceleration data can be mapped to various locations within the ISS using ISS body rates and body angles**
  - **Provides on orbit bias calibration capabilities**

Operational Philosophy

- **Operations are divided into three sections:**
  - **1) Real-time operations**
  - **2) Near real-time operations**
  - **3) Offline operations**
    - general characterization and specialized analyses
- **Acceleration measurement using SAMS-II and MAMS planned for the duration of ISS operations beginning with Flight 6A operations**
- **Potential for nearly continuous operations to characterize the environment**
  - **includes measurement of the environment, where possible, outside of "microgravity mode"**
- **AOS/LOS profiles call for 30 - 60 percent AOS coverage**
  - **requires the ability to deal with AOS and LOS data streams**

Operational Philosophy

- **Flight 6A operational configuration calls for 5 SAMS-II Sensor Enclosures (SE), MAMS MESA, and MAMS HiRAP**
  - **not all sensors will be active all the time resulting in a variety of acceleration measurement profiles**
- **PIMS has developed a core set of techniques for processing and displaying the acceleration data**
  - **Based on real-time and offline experience gained from SAMS and OARE data during Space Shuttle and Mir operations**
  - **Customized processing or displays as required by the microgravity user community**
- **Microgravity acceleration data will be available to Principal Investigators**
  - **Working with international partners on establishing a universal file format standard for acceleration data**

PIMS Data Analysis Techniques

Display Format	Regime(s)	Notes
Acceleration versus Time	Transient, Quasi-Steady, Vibratory	• precise accounting of measured data with respect to time; best temporal resolution
Interval Min/Max Acceleration versus Time	Vibratory, Quasi-Steady	• displays upper and lower bounds of peak-to-peak excursions of measured data • good display approximation for time histories on output devices with resolution insufficient to display all data in time frame of interest
Interval Average Acceleration versus Time	Vibratory, Quasi-Steady	• provides a measure of net acceleration of duration greater than or equal to interval parameter
Interval RMS Acceleration versus Time	Vibratory	• provides a measure of peak amplitude for pure sinusoids
Trimmed Mean Filtered Acceleration versus Time	Quasi-Steady	• removes infrequent, large amplitude outlier data
Quasi-Steady Mapped Acceleration versus Time	Quasi-Steady	• use rigid body assumption and vehicle rates and angles to compute acceleration at any point in the vehicle
Quasi-Steady Three-Dimensional Histogram (QTH)	Quasi-Steady	• summarize acceleration magnitude and direction for a long period of time • indication of acceleration "center-of-time" via projections onto three orthogonal planes

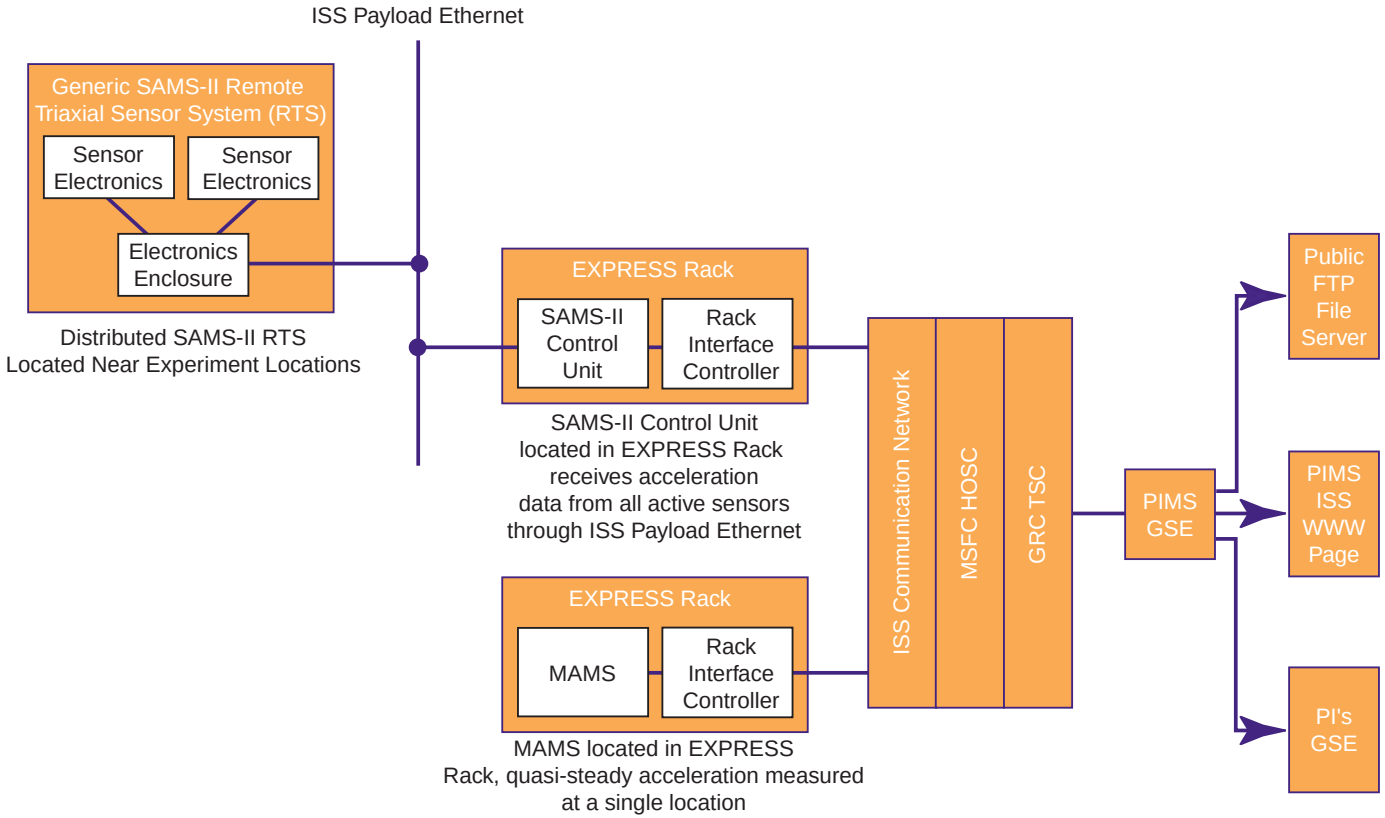
PIMS Data Analysis Techniques

Display Format	Regime(s)	Notes
Power Spectral Density (PSD) versus Frequency	Vibratory	• displays distribution of power with respect to frequency
Spectrogram (PSD versus Frequency versus Time)	Vibratory	• displays power spectral density variations with time • identify structure and boundaries in time and frequency
Cumulative RMS Acceleration versus Frequency	Vibratory	• quantifies RMS contribution at and below a given frequency
Frequency Band(s) RMS Acceleration versus Time	Vibratory	• quantify RMS contribution over selected frequency band(s) as a function of time
RMS Acceleration versus One-Third Frequency Bands	Vibratory	• quantify RMS contribution over proportional frequency bands • compare measured data to ISS vibratory requirements
Principal Component Spectral Analysis (PCSA)	Vibratory	• summarize magnitude and frequency excursions for key spectral contributors over a long period of time • results typically have finer frequency resolution and high PSD magnitude resolution relative to a spectrogram at the expense of poor temporal resolution

Real-Time Operations

- **Crux of real-time operations involves receiving, processing, and displaying microgravity acceleration data via the WWW**
- **Acceleration data displays via the WWW**
  - **PIMS displays are updated in real-time**
  - **Electronics snapshots are routed to the PIMS WWW page**
  - **Interested Principal Investigators can view the environment by accessing the PIMS WWW page**
- **Example real-time plots**
  - **Figure 12-1 USMP-4 (STS-87) IDGE Experiment Turn Off**
  - **Figure 12-2 USMP-4 (STS-87) Cabin De-Pressurization for EVA**
  - **Figure 12-3 LMS (STS-78) Nominal Microgravity Environment**

PIMS ISS Acceleration Data Flow



Near Real-Time Operations

- **Two primary functions performed**
  - **Merge AOS and LOS data streams**
  - **Generate processed (t,x,y,z) data files**
    - store the data in a universal storage format
- **Universal file format standard details**
  - **Develop a standard file format for ISS acceleration data from any ISS acceleration measurement system**
  - **Simplify access to acceleration data for Principal Investigators**
  - **Store ancillary data with acceleration data in a single file**
    - ancillary data describes the conditions and circumstances under which the acceleration data were obtained
    - current ancillary data parameters include: t-zero, t-end, sampling rate, cutoff frequency, head ID, gain, ISS CM, station configuration, location, orientation, coordinate system, bias coefficients, scale factor, and Data Quality Measure (DQM)

Offline Operations

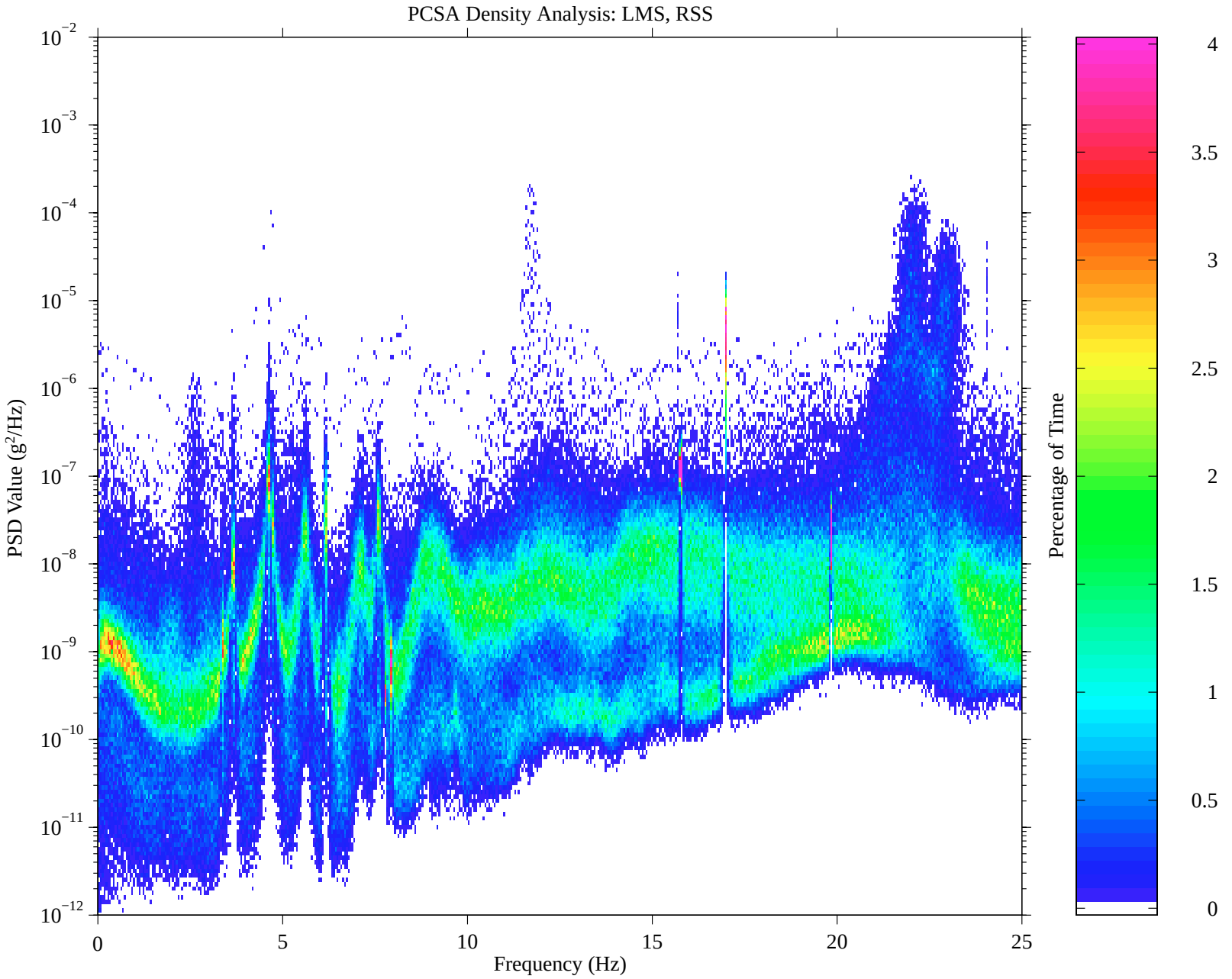
- **Primary function is to allow access to acceleration data for non-time-critical processing**
  - **In general, allows a more detailed analysis of the measured microgravity environment**
  - **Capable of processing and analyzing a long period of data**
  - **Overall access to acceleration data greatly simplified by a universal storage format**
- **PIMS WWW page offline functions**
  - **Provide the capability to request plotted data or data files**
  - **Provide the capability for submitting an electronic request for data processing**
  - **Provide means for anonymous FTP access to the processed acceleration data files**

Offline Operations

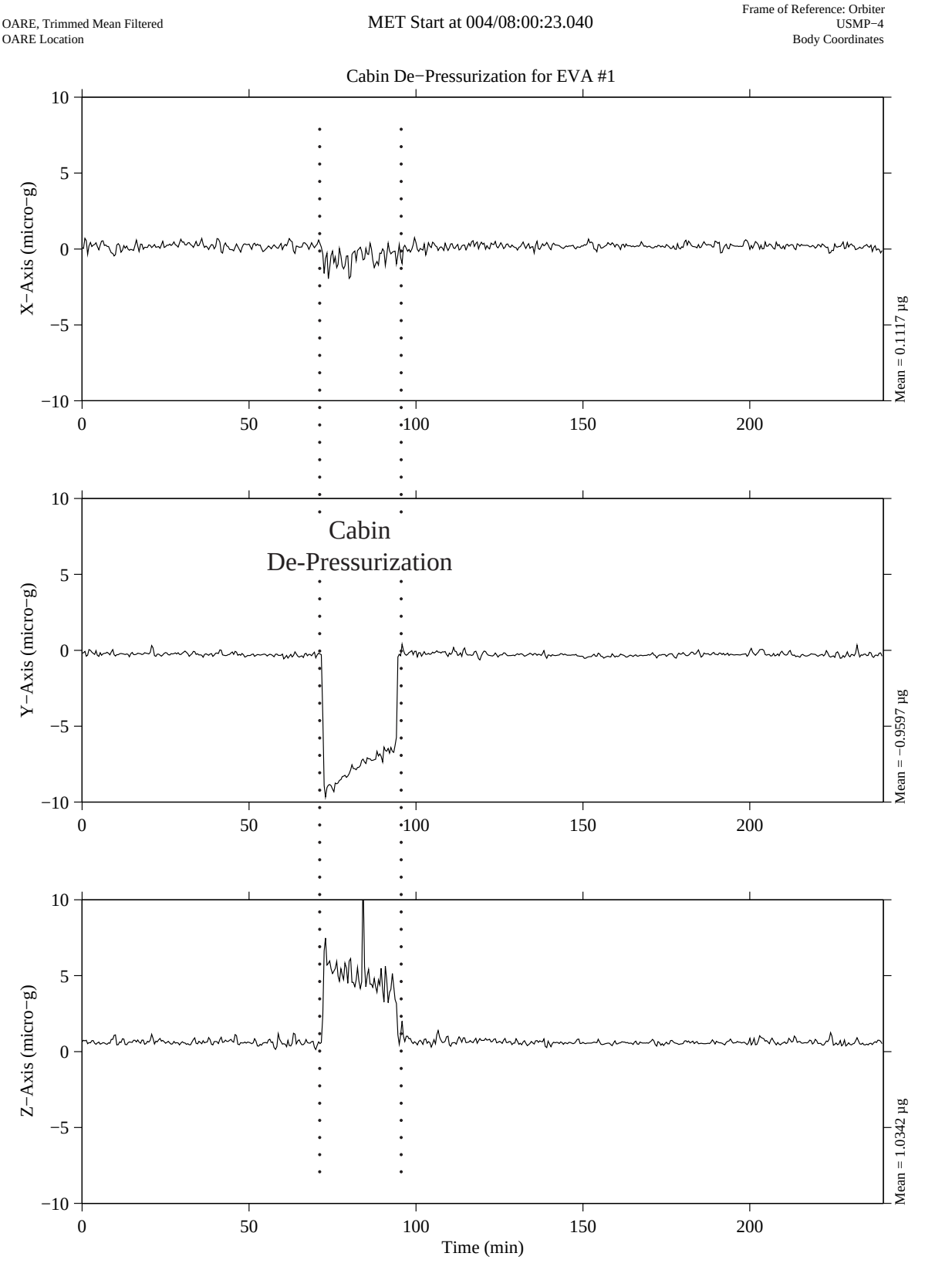
- **Example Near Real-time Plots**
  - **Figure 12-4 MSL-1 (STS-94) SOFBALL Radiometry Data**
- **Example Offline Plots**
  - **Figure 12-5 LMS (STS-78) Principal Component Spectral Analysis**

Summary

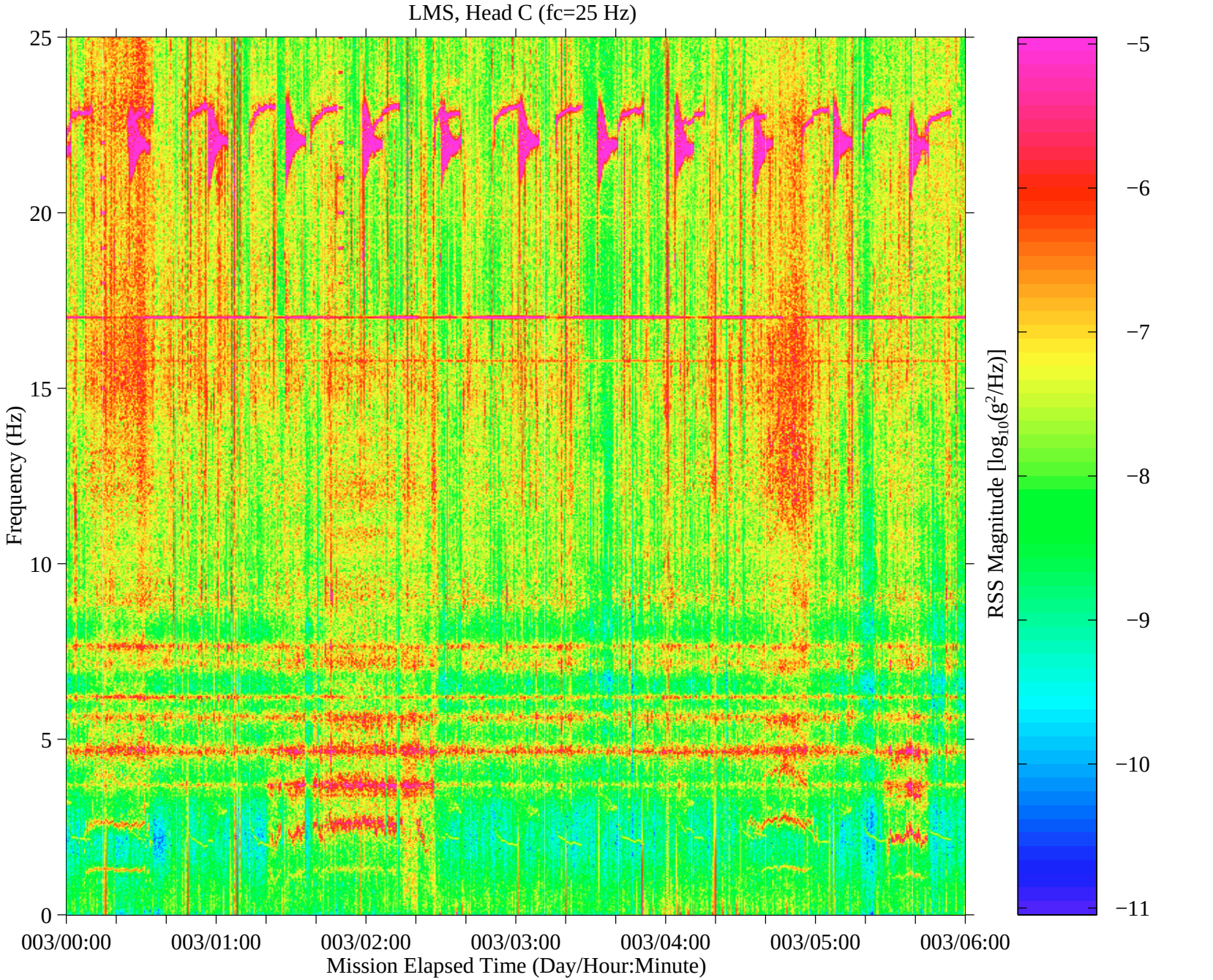
- **PIMS will receive, process, and store acceleration data for SAMS-II and MAMS data starting with flight 6A operations**
- **A universal storage format will be employed for data storage**
  - **simplify access to acceleration data**
  - **standardize formats for data storage to maximize access to all existing acceleration data by international partners**
- **Real-time data plots of the various available accelerometers will be available via the PIMS WWW page**
- **Offline access to plotted data and analysis capabilities available through PIMS and the PIMS WWW page**
- **General and specialized characterization of the ISS microgravity environment**



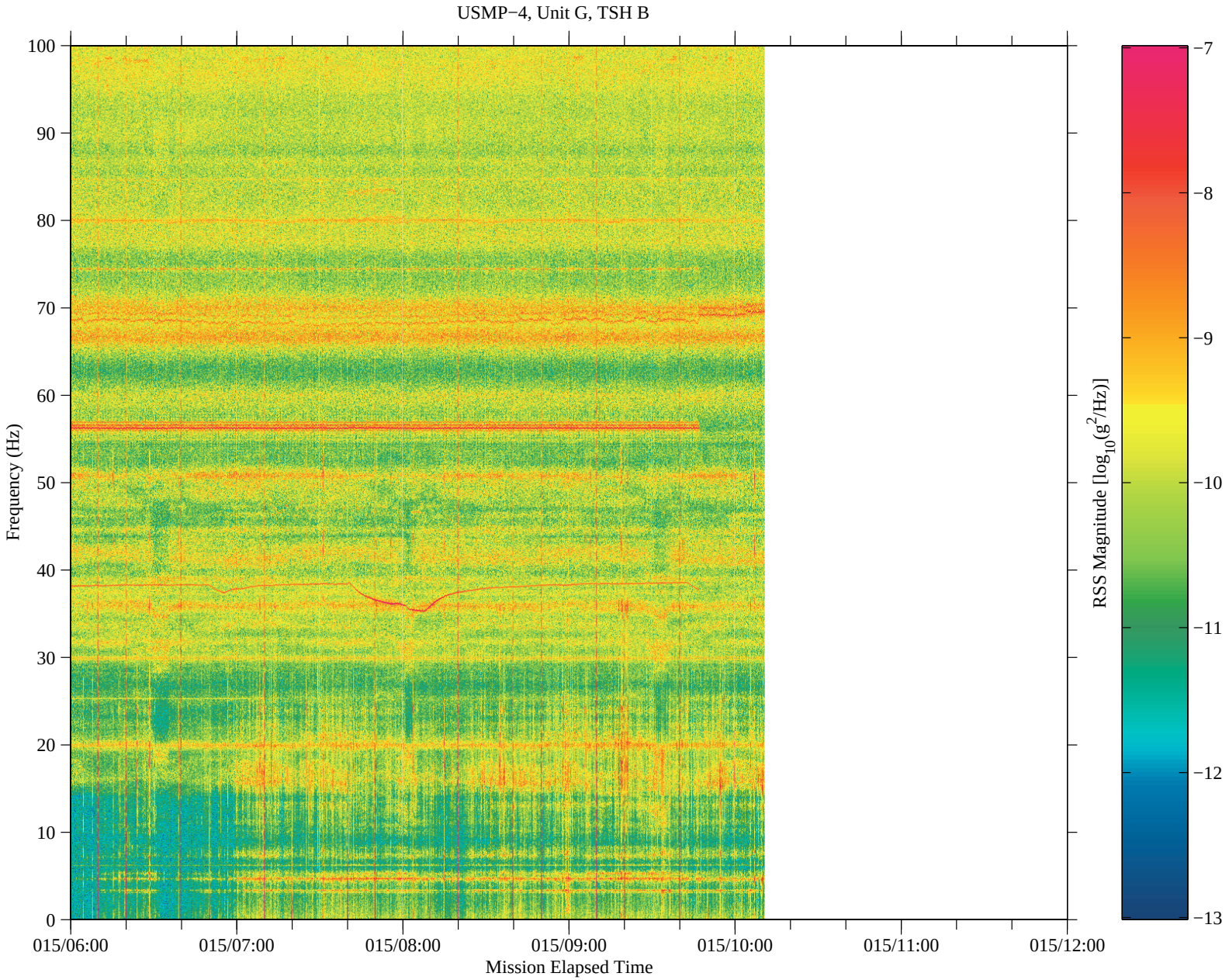
MEIT 1999 Figure 12-1: IDGE Experiment Turn Off from STS-87 Mission (USMP-4)



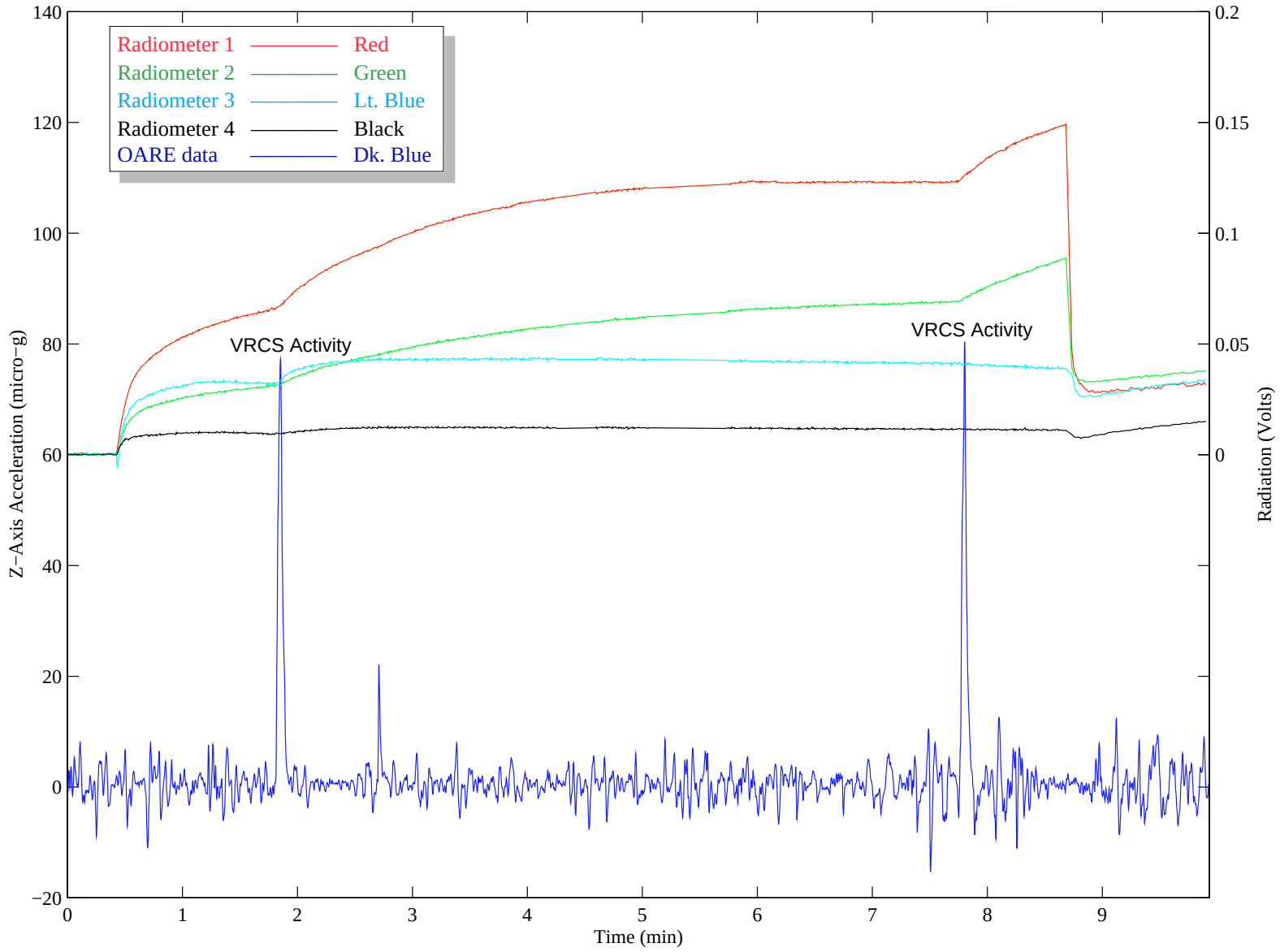
MEIT 1999 Figure 12-2: Cabin De-Pressurization from STS-87 Mission (USMP-4)



MEIT 1999 Figure 12-3: Nominal Microgravity Environment from STS-78 (LMS)



MEIT 1999 Figure 12-4: Raw OARE Data and SOFBALL Radiometry Data from STS-94 Mission (MSL-1R)



MEIT 1999 Figure 12-5: Principal Componet Spectral Analysis for the Entire STS-78 Mission (LMS)