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Principal Investigator Microgravity Services (PIMS)

International Space Station Increment-2 Quick Look Report

May to June 2001

Microgravity Measurement and Analysis Program

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Dedication

The PIMS project dedicates this report to the memory of William O. Wagar, the MAMS accelerometer project manager, who passed away recently.

PIMS ISS Increment-2 Quick Look Report: May to June 2001

Abstract

The objective of this quick look report is to disseminate the International Space Station Increment-2 reduced gravity environment preliminary analysis in a timely manner to the microgravity scientific community. This report is a quick look at the processed acceleration data collected by the Microgravity Acceleration Measurement System during the period of May 3rd to June 8th, 2001. The report is by no means an exhaustive examination of all the relevant activities, which occurred during the time span mentioned above for two reasons. First, the time span being considered in this report is rather short since the Microgravity Acceleration Measurement System was not active throughout the time span being considered to allow a detailed characterization. Second, as the name of the report implied, it is a quick look at the acceleration data. Consequently, a more comprehensive report, the International Space Station Increment-2 report, will be published following the conclusion of the Increment-2 tour of duty.

The National Aeronautics and Space Administration sponsors the Microgravity Acceleration Measurement System and the Space Acceleration Microgravity System to support microgravity science experiments, which require microgravity acceleration measurements. On April 19, 2001, both the Microgravity Acceleration Measurement System and the Space Acceleration Measurement System units were launched on STS-100 from the Kennedy Space Center for installation on the International Space Station. The Microgravity Acceleration Measurement System unit was flown to the station in support of science experiments requiring quasi-steady acceleration data measurements, while the Space Acceleration Measurement System unit was flown to support experiments requiring vibratory acceleration data measurement. Both acceleration systems are also used in support of the vehicle microgravity requirements verification.

The International Space Station reduced gravity environment analysis presented in this report uses mostly the Microgravity Acceleration Measurement System acceleration data measurements (the increment-2 report will cover both systems). The Microgravity Acceleration Measurement System has two sensors. The Microgravity Acceleration Measurement System Orbital Acceleration Research Experiment Sensor Subsystem, which is a low frequency range sensor (up to 1 Hz), is used to characterize the quasi-steady environment for payloads and vehicle. The Microgravity Acceleration Measurement System High Resolution Acceleration Package is used to characterize the ISS vibratory environment up to 100 Hz. This quick look report presents some selected quasi-steady and vibratory activities recorded by the Microgravity Acceleration Measurement System during the ongoing ISS Increment-2 tour of duty.

1. Introduction

The NASA Physical Science Division (PSD) sponsors science experiments on various reduced-gravity carriers/platforms and facilities such as the Space Transportation System (STS), parabolic aircraft, sounding rockets, drop towers and the International Space Station (ISS). To provide support for the science experiments, which require acceleration data measurement on the ISS, the PSD sponsors two microgravity accelerometer systems, the Space Acceleration Measurement System (SAMS) and the Microgravity Acceleration Measurement System (MAMS). SAMS measures vibratory acceleration data in the range of 0.01 to 300 Hz for payloads requiring such measurement. MAMS consists of two sensors. MAMS-OARE Sensor Subsystem (OSS), a low frequency range sensor (up to 1 Hz), is used to characterize the quasi-steady environment for payloads and vehicle (ISS) and MAMS-High Resolution Accelerometer Package (HiRAP) is used to characterize the ISS vibratory environment from 0.01 Hz to 100 Hz. Both accelerometer systems were flown to the ISS on STS-100, which was launched April 19, 2001, from the Kennedy Space Center (KSC).

The residual acceleration environment of an orbiting spacecraft in a low earth orbit is a very complex phenomenon [1]. Many factors, such as experiment operation, life-support systems, equipment operation, crew activities, aerodynamic drag, gravity gradient, rotational effects as well as the vehicle structural resonance frequencies (structural modes) contribute to form the overall reduced gravity environment. Weightlessness is an ideal state which cannot be achieved in practice because of the various sources of acceleration present in an orbiting spacecraft. As a result, the environment in which experiments are conducted is *not zero* gravity; therefore, experiments can be affected by the residual acceleration because of their dependency on acceleration magnitude, frequency, orientation and duration. Therefore, experimenters must know what the environment was when their experiments were performed in order to analyze and correctly interpret the result of their experimental data. In a terrestrial laboratory, researchers are expected to know and record certain parameters such as pressure, temperature, humidity level and so on in their laboratory prior to and possibly throughout their experiment. The same holds true in space, except that acceleration effects emerge as an important consideration.

The NASA Glenn Research Center (GRC) Principal Investigator Microgravity Services (PIMS) project has the responsibility for processing and archiving acceleration measurements, analyzing these measurements, characterizing the reduced gravity environment in which the measurements were taken, and providing expertise in reduced gravity environment assessment for a variety of carriers/platforms and facilities, such as the Space Shuttle, parabolic aircraft, sounding rockets, drop towers and the ISS in support of the NASA's PSD Principal Investigators (PIs). The PIMS project supports PIs from various science disciplines such as biotechnology, combustion science, fluid physics, material science and fundamental physics. The PIMS project is funded by the NASA Headquarters and is part of the NASA Glenn Research Center's Microgravity Measurement and Analysis Project (MMAP), which integrates the analysis and interpretation component of PIMS with the various NASA sponsored acceleration measurement systems. For the ISS, these acceleration measurement systems include SAMS and MAMS. The PIMS project is responsible for receiving, processing, displaying, distributing, and archiving the acceleration data for SAMS and MAMS during ISS operations. This report presents a quick look at the acceleration data collected mainly by the MAMS sensors during the period of May 3rd to June 8th. The acceleration data reported in this report for MAMS-OSS covers the following time periods: May 3rd to May 11th; May 21st to May 27th; May 28th to June 9th. The activation times for MAMS-HiRAP were the following: May 11th; May 22nd to May 23rd; May 29th to June 6th and June 7th to June 8th [2]. However, this report is by no means a comprehensive examination of all the relevant activities which occurred during the time periods mentioned above, since the intent here is to provide a quick look at the acceleration data collected by MAMS' sensors to the microgravity community. The upcoming ISS Increment-2 report, which will be published approximately 30 days following the conclusion of Increment-2, will cover both MAMS and SAMS.

2. International Space Station

2.1 Configuration at Assembly Complete

The ISS represents a global partnership of 16 nations. This project is an engineering, scientific and technological marvel ushering in a new era of human space exploration. Assembly of the ISS began in late 1998 [3] and will continue until completion sometime around the year 2004. During its assembly and over its nominal 10-year lifetime, the ISS will serve as an orbital platform for the United States and its International Partners to make advances in microgravity, space, life, and earth sciences, as well as in engineering research and technology development. The completed space station will have six fully equipped laboratories, nearly 40 payload racks [4] or experiment storage facilities, and more than 15 external payload locations for conducting experiments in the vacuum of space. The six main laboratories, which will house research facilities, are: Destiny (US), the Centrifuge Accommodations Module (CAM-US), Columbus (ESA), Kibo (NASDA) and two Russian Research Modules (yet to be named). The pressurized living and working space aboard the completed ISS will be approximately 43,000 ft^3 [5] (table 2.1-1). Its giant solar arrays will generate the electricity needed. An initial crew of three, increasing to seven when assembly is complete (figure 2.1-1), is living aboard the ISS. The space station represents a quantum leap in our ability to conduct research on orbit and explore basic questions in a variety of disciplines [5] such as biomedical, fundamental biology, biotechnology, fluid physics, advanced human support technology, material science, combustion science, fundamental physics, earth science and space science.

TABLE 2.1-1 ISS DIMENSIONS AT ASSEMBLY COMPLETE

Wingspan Width	356 feet (108.5 m)
Length	290 feet (88.4 m)
Mass (weight)	About 1 million pounds (453,592 kg)
Operating Altitude	220 nautical miles average (407 km)
Inclination	51.6 degrees to the Equator
Atmosphere inside	14.7 psi (101.36 kilopascals)
Pressurized Volume	43,000 ft^3 (1,218 m^3) in 6 laboratories
Crew Size	3, increasing to 7

2.2 ISS Analysis Coordinate System

PIMS will report acceleration data to the microgravity scientific community using the ISS analysis coordinate system or in the specific sensor's coordinate system. The ISS analysis system [6] is derived using the Local Vertical Local Horizontal (LVLH) flight orientation. When defining the relationship between this coordinate system and another, the Euler angle sequence to be used is a yaw, pitch, roll sequence around the Z_A, Y_A, and X_A axes, respectively (figure 2.2-1). The origin is located at the geometric center of Integrated Truss Segment (ITS) S0 and is coincident with the S0 Coordinate frame. The X-axis is parallel to the longitudinal axis of the module cluster. The positive X-axis is in the forward (flight) direction. The Y-axis is identical with the S0 axis. The nominal alpha joint rotational axis is parallel with Y_A. The positive Y-axis is in the starboard direction. The positive Z-axis is in the direction of nadir and completes the right-handed Cartesian system (RHCS). L, M, N are moments about X_A, Y_A and Z_A axes, respectfully; p, q, r are body rates about X_A, Y_A and Z_A axes; $\dot{p}$, $\dot{q}$, $\dot{r}$ are angular body acceleration about X_A, Y_A and Z_A axes. This analysis coordinate system will be used by PIMS in its analysis and reporting of the acceleration data measured on ISS.

2.3 ISS Flight Attitude at Assembly Complete

The basic flight attitude [7] for ISS is called XVV Z Nadir TEA, or XVV TEA for short. XVV Z Nadir (XVV for short) stands for X body axis toward the velocity vector, Z body axis toward Nadir/down, and TEA is for torque equilibrium attitude. The ISS vehicle design is optimized for the XVV attitude (figure 2.3-1). That attitude places the most modules in the microgravity volume, supports altitude reboosts, service vehicle dockings, and minimizes aerodynamic drag. The ISS is designed to tolerate deviations from perfect XVV Z Nadir of +/- 15 degrees in each axis. This envelope was expanded to -20 degrees in pitch.

2.4 United States Laboratory Module (Destiny) Coordinate System

The US Laboratory module makes use of the right-handed Cartesian [6] coordinate system, body-fixed to the pressurized module. The origin is located forward of the pressurized module such that the center of the bases of the aft trunnions have X_{LAB} components nominally equal to 1000 inches. The X-axis is perpendicular to the nominal aft Common Berthing Mechanism (CBM) interface plane and pierces the geometric center of the array of mating bolts at the aft end of the pressurized module. The positive X-axis is toward the pressurized module from the origin. The Y-axis completes the right-handed Cartesian system (RHCS). The Z-axis is parallel to the perpendicular line from the X-axis to the center base of the keel pin base, and positive in the opposite direction as shown in figure 2.4-1.

3. ISS Increment-2

3.1 Increment-2 Configuration

An increment should average about 4 months and is determined by crew rotations and flights to/from ISS. Each increment has a theme that focuses on the primary science or activities to be performed. This Increment is called Increment-2 or Expedition Two and its theme is: Radiation [8]. The 3-member crew for Increment-2 mission was launched to ISS on February 2001 on STS-102 from Kennedy Space Center. This Increment has four modules on-orbit [9]: Unity (Node), Zarya (Functional Cargo Block), Zvezda (Service Module) and Destiny, figure 3.1-1.

3.2 Increment-2 Coordinate Systems

The coordinate systems [10] shown in Figure 3.2-1 were used in performing the data analysis presented in this report. Figure 3.2-1 shows MAMS-OSS, MAMS-HiRAP and SAMS F06 positive acceleration axes alignment relative to ISS analysis coordinate system. However, the origin of the coordinate systems shown is not exactly at the location shown (except for the ISS analysis coordinate system). They are shown here for relative alignment only, not their origin. For their location relative to ISS analysis coordinate system, the reader should refer to Tables 4.2-1, 4.2-2 and 4.4-1. In Figure 3.2-1, XYZ_A refers to the ISS analysis coordinate system, XYZ_H refers to MAMS-HiRAP coordinate system, XYZ_{OSS} refers to MAMS-OSS coordinate system and XYZ_{F06} is The SAMS F06 alignment currently located on the PCS experiment. Figure 3.2-1 is applicable only to the Increment-2 configuration (6A configuration).

3.3 Increment-2 Overall Attitude

During the assembly stages (stages 2A through 12A.1), ISS will not be capable of generating enough power to sustain the required electrical loads in the XVV flight attitude at mid-to-high solar beta angles because these vehicle configurations have only a single solar array gimbal axis, which is aligned so that it only perfectly tracks the Sun when the solar beta angle is near zero. Therefore, ISS is designed to accommodate a second basic flight orientation for these increments. This attitude is referred to as XPOP, which stands for X principal axis perpendicular to the orbit plane, Z Nadir at orbital noon. The XPOP flight attitude [7] sets up geometry between the ISS and the Sun so that the Sun stays close to the ISS/XZ body axis plane. This allows all the solar arrays to track the Sun regardless of the solar beta angle. XPOP also places the dominant inertia axis in the local horizontal to minimize gravity gradient torques and allow Control Moment Gyro (CMG) non-propulsive attitude control.

3.4 Increment-2 Crew Members

During Increment-2 (Expedition Two) the crew will work with 18 different experiments. The Increment-2 is designed to characterize the space station environment by measuring effects such as radiation exposure and vibration, which could impact humans and experiments on the station. Other research includes studies of the human body in space, observations of the earth, crystal growth and plant growth in space [11]. Increment-2 has two astronauts and one cosmonaut. The commander is cosmonaut Yuri Usachev; Flight Engineer 1 is James Voss and Susan Helms as Flight Engineer 2. The crew was launched to the ISS on March 8, 2001 aboard the Space Shuttle Discovery STS-102 and will return no earlier than (NET) August 22th, 2001.

4. Accelerometer Systems’ Description and Locations

One of the major goals of ISS is to provide a quiescent reduced gravity environment to perform fundamental scientific research. However, small disturbances aboard the Space Station impact the overall environment in which experiments are being performed. Such small disturbances need to be measured in order to assess their potential impact on the experiments. Two accelerometer systems developed by NASA's Glenn Research Center in Cleveland, Ohio, are being used aboard the station to acquire such measurements. These two systems were flown to ISS on April 19, 2001 aboard the space shuttle flight STS-100.

4.1 Microgravity Acceleration Measurement System (MAMS)

MAMS measures acceleration caused by aerodynamic drag created as the space station orbits the earth. It also measures accelerations created as the vehicle rotates and vents water. MAMS consists of two sensors. MAMS-OSS, a low frequency range sensor (up to 1 Hz), is used to characterize the quasi-steady environment for payloads and the vehicle itself. MAMS-HiRAP [12], is used to characterize the ISS vibratory environment up to 100 Hz. For Increment-2, MAMS is located in a double middeck locker, in the US laboratory Module (Destiny) in the EXpedite the PRocessing of Experiments to the Space Station (EXPRESS) Rack 1 (figure 5.-1).

4.2 MAMS Coordinate Systems

MAMS is located in middeck lockers 3 and 4 of EXPRESS Rack 1 (6A configuration), in overhead bay 2 of the US Laboratory Module (LAB1O2). In the OSS coordinate system (X_{OSS}, Y_{OSS}, Z_{OSS}), $+X_{OSS}$ is aligned with $+X_A$, $+Y_{OSS}$ is in the direction of $+Z_A$, and $+Z_{OSS}$ is in the direction of $-Y_A$. The origin is located at the center of gravity of the OSS proof mass. Table 4.2-1 gives the orientation and location of the OSS coordinate system with respect to Space Station Analysis coordinate system.

TABLE 4.2-1 MAMS-OSS COORDINATE SYSTEM

Orientation (degrees)		
Roll	Pitch	Yaw
90	0	0
Location (inches)		
X_A	Y_A	Z_A
135.28	-10.68	132.12

Unit Vectors in Space Station Analysis Coordinates			
Axes	X_A	Y_A	Z_A
X_{OSS}	1	0	0
Y_{OSS}	0	0	1
Z_{OSS}	0	-1	0

The HiRAP coordinate system (X_H, Y_H, Z_H) origin is defined as the geometric center of the three accelerometer input axes. In the HiRAP coordinate system, $+X_H$ is aligned with $+X_A$, $+Y_H$ is in the direction of $-Y_A$, and $+Z_H$ is in the direction of $-Z_A$. Table 4.2-2 gives the orientation and location of the HiRAP coordinate system with respect to Space Station Analysis coordinate system.

TABLE 4.2-2 MAMS-HIRAP COORDINATE SYSTEM

Orientation (degrees)		
Roll	Pitch	Yaw
180	0	0
Location (inches)		
X_A	Y_A	Z_A
138.68	-16.18	142.35

Unit Vectors in Space Station Analysis Coordinates			
Axes	X_A	Y_A	Z_A
X_H	1	0	0
Y_H	0	-1	0
Z_H	0	0	-1

4.3 Space Acceleration Measurement System

SAMS measures accelerations caused by vehicle, crew and equipment disturbances. SAMS measures the vibratory/transient accelerations, which occur in the frequency range of 0.01 to 300 Hz. For Increment-2, there are five SAMS sensors along with experiments located in the EXPRESS Racks 1 and 2. The sensors measure the accelerations electronically and transmit the measurements to the Interim Control Unit (ICU) located in an EXPRESS Rack drawer. Data is collected from all the sensors and downlinked to Glenn Research Center's Telescience Support Center (TSC). The PIMS project processes, analyzes and then displays the data on the PIMS' Web site for ready access by the microgravity scientific community.

4.4 SAMS Coordinate Systems

For the time span covered in this report, only one SAMS SE head was activated, F06. This SE was mounted (6A configuration) on the front panel of the EXPPCS test section on EXPRESS Rack 2, in overhead bay 1 of the US Laboratory Module (LAB1O1). The F06 coordinate system (X_{F06}, Y_{F06}, Z_{F06}) was oriented so that the $+X_{F06}$ axis was aligned with $-Z_A$, $+Y_{F06}$ in the direction of $-Y_A$, and $+Z_{F06}$ in the direction of $-X_A$. The origin is defined as the triaxial center point of the three accelerometers that comprise the head. Table 4.4-1summarizes the F06 coordinate system information.

TABLE 4.4-1 SAMS SE F06 COORDINATE SYSTEM

Orientation (degrees)		
Roll	Pitch	Yaw
180	90	0
Location (inches)		
X_A	Y_A	Z_A
179.90	-6.44	145.55

Unit Vectors in Space Station Analysis Coordinates			
Axes	X_A	Y_A	Z_A
X_{F06}	0	0	-1
Y_{F06}	0	-1	0
Z_{F06}	-1	0	0

5. ISS Increment-2 Facilities Supported by PIMS

During Increment-2, the following facilities will be activated: the Human Research facility, two EXPRESS Racks, one of which equipped with the Active Rack Isolation System (ARIS) and the Payload Equipment Restraint System. Over the life of the Space Station, these facilities will support a wide range of experiments [11]. During Increment-2, the PIMS project is supporting EXPRESS Racks 1 and 2.

The EXPRESS Rack [13] is a standardized payload rack system that transports, stores and supports experiments aboard the International Space Station. The EXPRESS Rack system supports science payloads in several disciplines, including biology, chemistry, physics, ecology and medicine. The EXPRESS Rack with its standardized hardware interfaces enables quick, simple integration of multiple payloads aboard the station. Each EXPRESS Rack is housed in an International Standard Payload Rack – a refrigerator-size container that acts as the EXPRESS Rack's exterior shell-- and can be divided into segments. The first two EXPRESS Racks [14] have eight middeck locker locations and two drawer locations each (figures 5.-1, 5.-2).

6. ISS Increment-2 Experiments Supported by PIMS

During this increment, the PIMS project supports the following experiments, which require acceleration data measurement to assess the impact of the ISS reduced gravity environment on the science: Active Rack Isolation System ISS Characterization Experiment (ARIS-ICE), Protein Crystal Growth-Biotechnology Ambient Generic (PCG-BA) and Experiment of Physics of Colloids in Space (EXPPCS). Table 6.-1 [15] shows the experiments that were performed (or are being performed) by the Increment-2 crew.

TABLE 6-1 INCREMENT-2 PAYLOADS

Facility/Experiment	**Mission information**	**Duration**	**Location on ISS**	**Research Area**
Active Rack Isolation System	Mission 6A STS-100	15 years	Express Rack 2 Destiny module	
Express Racks 1 & 2	Mission 6A STS-100	15 years	Destiny module	Multidisciplinary
Human Research Facility	Mission 5A.1 STS-102	15 years	Destiny module	Human Life sciences
Payload Equipment Restraint System	Mission 5A.1 STS-102	15 years	Destiny module	
Advanced Astroculture (ADVASC)	Mission 6A STS-100	3 months (return on Mission STS-105, 7A.1)	Express Rack 1 Destiny module	Space Product Development Commercial biotechnology
Bonner Ball Neutron Detector Radiation	Mission 5A.1 STS-102	8 months	Destiny module	Human Life Sciences -- Radiation
Commercial Genetic Bioprocessing Apparatus (CGBA)	Mission 6A STS-100	3 months (return on Mission STS-105, 7A.1)	Express Rack 1 Destiny module	Space Product Development Biotechnology
Commercial Protein Crystal Growth—High Density (CPCG-H)	Mission 6A STS-100	3 months (return on mission STS-105, 7A.1)	Express Rack 1 Destiny module	Space Product Development--Protein crystallization
Crew Earth Observation	Mission 4A STS-97	15 years	Destiny and Zvezda modules	Space Flight Utilization Earth observation
Dosimetric Mapping (DOSMAP)	Mission 5A.1 STS-102	4 months	Destiny module	Human Life Sciences -- Radiation
Earth Knowledge Acquired by Middle Schools (EarthKAM)	Mission 5A STS-98	15 years	Destiny module window	Space Flight Utilization—Earth observation and outreach
H-Reflex	Mission 5A.1 STS-102	4 months (assigned for Exp. 2-4)	Human Research Facility Rack Destiny module	Human Life Sciences--- Neurovestibular
Interactions	Mission 5A.1 STS-102	2 years, 4 months assigned to Exp. 2-6)	Human Research Facility Rack Destiny module	Human Life Sciences-- Psychosocial
ARIS-ISS Characterization	Mission 6A STS-100	7 months (?)	Active Rack Isolation	Space Flight Utilization
Experiment (ARIS-ICE)		Mission UF1, STS-105)	System	Earth Observation and Outreach
Microgravity Acceleration Measurement System (MAMS)	Mission 6A STS-100	15 years	Express Rack 1 Destiny module	Physical Sciences-- Environmental
Phantom Torso	Mission 6A STS-100	3 months (return on mission STS-105, 7A.1)	Destiny module	Human Life Sciences-- Radiation
Physics of Colloids in Space (EXPPCS)	Mission 6A STS-100	1 year (return on mission UF2 STS-111)	Express Rack 2 Destiny module	Physical Sciences—Fluids science
Protein Crystal Growth—Biotechnology Ambient Generic (PCG-BAG)	Mission 7A STS-104	2 months (return on mission STS-105, 7A.1)	Destiny module stowage space	Physical Sciences—Protein crystallization
Protein Crystal Growth—Single Locker Thermal Enclosure System (PCG-STES)	Mission 6A STS-100 and 7A STS-104	2 months (return on mission STS-105, 7A.1)	Express Rack 1 Destiny module	Physical Sciences—Protein crystallization
Space Acceleration Measurement System II (SAMS-II)	Mission 6A STS-100	15 years	Destiny module	Physical Sciences-- Environmental
Sub-regional Assessment of Bone Loss in Axial Skeleton (Sub-regional Bone	Mission 5A.1 STS-102	2 years, 4 months (assigned to Exp. 2-6)	N/A—Preflight and post-flight data collection only	Human Life Sciences—Bone and muscle

7. Data Analysis Techniques and Processing

This section briefly describes some assumptions, considerations, and procedures used to analyze the acceleration measurements made by the two sensors collectively known as MAMS.

7.1 Quasi-steady Regime

MAMS-OSS data is collected at 10 samples per second, bandpass filtered with a cutoff frequency of 1 Hz and sent to ground support equipment (GSE) for further processing and storage. PIMS is currently storing the OSS data as raw acceleration files and also trimmean filtered data that are compensated for bias. At the time of this report, PIMS has collected approximately 26 days of raw OSS data, from three power on events. There are numerous gaps in the data, due to data transfer and other problems that come along with being a payload during early ISS operations. Table 7.1-1 shows the power on/off times for the MAMS-OSS sensor.

TABLE 7.1-1 MAMS-OSS POWER ON/OFF CYCLES

Power On (GMT)	Power Off (GMT)
May 03, 2001 123/15:58:24	May 11, 2001 131/16:08:26
May 21, 2001 141/07:35:22	May 27, 2001 147/11:05:40
May 28, 2001 148/13:53:08	June 09, 2001 160/13:54:11

7.1.1 Trimmean Filter

The OSS data is processed with an adaptive trimmean filter to provide an estimate of the quasi-steady acceleration signal by rejecting higher magnitude transients such as thruster firings, crew activity, etc. The trimmean filter algorithm used by the MAMS GSE operates on a sliding window of 480 samples, every 16 seconds. The filtering procedure sorts the data by magnitude, calculates the deviation from a normal distribution, and trims an adaptively determined amount from the tails of the data. The quasi-steady acceleration level is computed to be the arithmetic mean of the trimmed set. Further information concerning the trimmean filter can be found in [16-18].

7.1.2 OSS Bias Measurements

One of the initial goals during Increment 2 operations for MAMS is the characterization of the OSS sensor bias. In the past, MAMS predecessor, the Orbital Acceleration Research Experiment (OARE), showed a significant initial transient in the bias measurements that would take one to two days to settle out. This phenomenon was not observed in the MAMS-OSS data, most probably due to the 14-day interval between launch date and MAMS activation. At power up, the MAMS instrument takes roughly 4-6 hours to reach the nominal operating temperature of 40˚C, at which point, the bias values can be considered constant. However, there is a bias temperature dependency, seen only during these first 6 hours following a MAMS power on event. We are unable to characterize this temperature dependency at this time, due to an insufficient amount of bias points collected during the initial temperature turn on transient. For this reason, PIMS is recommending that users avoid OSS data within the first 12 hours after a MAMS power on event. When MAMS-OSS support is requested, this 12-hour "settling" time must be taken into consideration. A detailed look at the OSS bias calculations will be included in a later report.

7.1.3 Quasi-steady Plot Types

The two types of plots used in analysis of quasi-steady data are acceleration versus time and the quasi-steady three-dimensional histogram (QTH). Both of these plot types use trimmean filtered OSS data.

7.1.3.1 OSS Trimmed Mean Acceleration versus Time

These are single or three axes plots of acceleration in units of μg versus time. These plots give the best accounting of the quasi-steady acceleration vector as a function of time.

7.1.3.2 QTH

This type of analysis results in three orthogonal views of the quasi-steady vector. The time series is analyzed using a two-dimensional histogram method where the percentage of time the acceleration vector falls within a two-dimensional bin is plotted as a color. Areas showing colors toward the red end of the spectrum indicate a higher number of occurrences. Conversely, areas showing colors towards the blue end are indicative of a lower percentage, with no occurrences being shown as white. This plot provides a summary of the quasi-steady vector during the total time period considered. Exact timing of an acceleration event is lost in this type of plot.

7.2 Vibratory Regime

The frequency response of the accelerometer systems used to collect vibratory data may extend below 0.01 Hz down to DC, but those instruments are not optimized for making quasi-steady or DC measurements. The MAMS-OSS instrument is specialized for this purpose. Therefore, unless otherwise noted, it is assumed that the vibratory data have been demeaned for plots and analyses of vibratory data. That is, for the time interval under consideration, the average value is calculated and then subtracted off of each data point on a per axis basis. Table 7.2.-1 shows the power on/off cycles for MAMS-HiRAP for the time span analyzed in this quick look report.

TABLE 7.2-1 MAMS-HIRAP POWER ON/OFF CYCLES

Power On (GMT)	Power Off (GMT)
May 11, 2001 131/01:24:08	May 11, 2001 131/03:33:21
May 22, 2001 142/18:39:13	May 23, 2001 143/17:37:53
May 29, 2001 149/22:52:28	May 31, 2001 151/14:03:43
May 31, 2001 151/21:08:14	June 06, 2001 157/21:44:40
June 07, 2001 158/19:36:29	June 08, 2001 159/20:05:27

7.2.1 Interval Statistics

A plot of acceleration interval statistics in units of g versus time gives some measure of acceleration fluctuations as a function of time. This display type allows relatively long periods to be displayed on a single plot. There are three such interval statistic plots that are employed for this and other reasons as described below: (1) interval average, (2) interval root-mean-square, or (3) interval minimum/maximum.

7.2.1.1 Interval Average

Interval average plots show net accelerations which last for a number of seconds equal to or greater than the interval parameter used. Short duration, high amplitude accelerations can also be detected with this type of plot, however, the exact timing and magnitude of specific acceleration events cannot be extracted. This type of display is useful for identifying overall effects of extended thruster firings and other activities that tend to cause the mean acceleration levels to shift. This display type is rarely used for vibratory data.

7.2.1.2 Interval Root-Mean-Square

Interval root-mean-square (RMS) plots show oscillatory content in the acceleration data. For the period of time considered, this quantity gives a measure of the variance of the acceleration signal. This data representation is useful for identifying gross changes in acceleration levels usually caused by the initiation or cessation of activities such as crew exercise or equipment operations.

7.2.1.3 Interval Minimum/Maximum

An interval minimum/maximum plot shows the peak-to-peak variations of the acceleration data. For each interval, this plot type shows both the minimum and maximum values, and thereby shows the acceleration data envelope. This type of display is another way to track gross changes in acceleration.

7.2.2 Power Spectral Density

The power spectral density (PSD) is computed from the Fourier transform of an acceleration time series and gives an estimate of the distribution of power with respect to frequency in the acceleration signal. It is expressed in units of g^2/Hz. The method used for computation of the PSD is consistent with Parseval's theorem, which states that the RMS value of a time series signal is equal to the square root of the integral of the PSD across the frequency band represented by the original signal.

7.2.2.1 Power Spectral Density Versus Time (Spectrogram)

Spectrograms provide a road map of how acceleration signals vary with respect to both time and frequency. To produce a spectrogram, PSDs are computed for successive intervals of time. The PSDs are oriented vertically on a page such that frequency increases from bottom to top. PSDs from successive time slices are aligned horizontally across the page such that time increases from left to right. Each time-frequency bin is imaged as a color corresponding to the base 10 logarithm of the PSD magnitude at that time and frequency. Spectrograms are particularly useful for identifying structure and boundaries in time and frequency over relatively long periods of time.

7.2.2.2 RMS Acceleration Versus One-Third Octave Frequency Bands

This type of plot quantifies the spectral content in proportional bandwidth frequency bands for a given time interval of interest (nominally 100 seconds). The (nearly) one-third octave bands are those defined by the International Space Station microgravity requirements; see Table 4 [19]. The results of this analysis are typically plotted along with a bold stair step curve representing the International Space Station combined vibratory limits in order to compare the acceleration environment to these prescribed limits. These plots are not particularly useful for isolating the source of a disturbance for a band that exceeds the desired limits.

7.2.2.3 Cumulative RMS Acceleration Versus Frequency

A plot of cumulative RMS acceleration versus frequency quantifies, in cumulative fashion, the contributions of spectral components to the overall measured RMS acceleration level for the time frame of interest. This plot is also derived from the PSD using Parseval’s theorem. It quantitatively highlights key spectral regions - steep slopes indicate strong narrowband disturbances that contribute significantly to the acceleration environment, while shallow slopes indicate relatively quiet portions of the spectrum.

8. ISS Increment-2 Reduced Gravity Environment Description

8.1 Quasi-steady Microgravity Environment

The quasi-steady regime is comprised of accelerations with frequency content below 0.01 Hz and magnitudes expected to be on the order of 2 μg or less. These low-frequency accelerations are associated with phenomena related to the orbital rate, primarily aerodynamic drag. Depending on various conditions and location relative to the vehicle's center of mass, however, gravity gradient and rotational effects may dominate in this regime. A final source of acceleration to consider in this regime is venting of air or water from the spacecraft. This action results in a nearly constant, low-level propulsive force. The different quasi-steady environment characteristics seen on the ISS for the 6A configuration are primarily related to altitude and attitude of the station. Variation in atmospheric density with time and altitude contribute to the differences in the aerodynamic drag component. Different attitudes will affect the drag component due to the variation of the frontal cross-sectional area of the station with respect to the velocity vector. This section of this quick look report analyzes the effects of different station attitudes and crew activity on the quasi-steady acceleration environment. Also, the docking of the Russian Progress vehicle and the undocking of the Soyuz TM-31 are examined.

8.1.1 XVV Torque Equilibrium Attitude

Torque Equilibrium Attitude (TEA) is an attitude that balances the vehicle's gravity gradient and aerodynamic drag torques. This is the attitude that will be flown during microgravity mode to support research. However, TEA will vary with station configuration because of change in mass and aerodynamic properties. For the period covered in this report, the TEA attitude was nominally YPR = (350.0, 350.7, 0.0) relative to the LVLH coordinate system. Figure 8.1.1-1 shows a plot of trimmean-filtered data taken during a crew sleep period while the station was in TEA.

The low-amplitude, low-frequency component of the quasi-steady profile is more readily apparent during crew sleep periods because disturbances associated with basic crew activity tend to mask this low-level signal. The QTH plots shown in Figures 8.1.1-2 and

8.1.1-3 give a good comparison between the noise levels of crew active and crew sleep periods. Figure 8.1.1-2 is a 26.5-hour compilation of crew active periods when the vehicle was in TEA.

A similar QTH plot for 27.5 hours of crew sleep can be seen in figure 8.1.1-3. The quasi-steady vector shows much less variation, as indicated by the distribution among the bins, for crew sleep than for crew active periods. In order to aid in comparison, a red box was drawn in figure 8.1.1-2 that indicates the extents of the plot in figure 8.1.1-3.

8.1.2 XPOP (X-Axis Perpendicular to Orbital Plane) Inertial Flight Attitude

XPOP is a sun-tracking, quasi-inertial flight attitude used for power generation. In this attitude, the vehicle's X_A axis is maintained perpendicular to the direction of flight, while the Y_A and Z_A axes are alternately subjected to the drag vector as the vehicle completes an orbit. The time series plot for XPOP attitude in figure 8.1.2-1 illustrates this nicely, showing a fairly constant X-axis acceleration component near 2μg, compared to the Y and Z axes, which show a more pronounced cyclical drag profile. The cyclical variation at 45 minutes intervals is due to the twice-per-orbit variation of frontal area in the XPOP attitude.

Figure 8.1.2-2 is a QTH plot of crew sleep periods during XPOP attitude showing the characteristic “ring” profile in the YZ plane that was evident in OARE data when the shuttle was in similar solar inertial attitudes.

8.1.3 Docking and Undocking Events

In terms of the quasi-steady environment, the actual docking event is less of an impact than the attitude adjustments in preparation for the event. The first undocking event captured in MAMS-OSS data, was the Soyuz TM-31 undocking at GMT 126/02:20:49. Referring to figure 8.1.3-1, at GMT 126/00:19:58 (1.3 hours in the plot) the station began an attitude maneuver to change from +XVV/+ZLV to -XVV/+ZLV, which was a yaw of 180 degrees about the Z_A axis. This maneuvers is seen as an offset between 10-15 μg in the X_{OSS} axis, and to a lesser extent the Y and Z axes. The return to +XVV/+ZLV is also evident 2 hours later. Close inspection indicates an upward shift in all three axes of the quasi-steady vector for the period when the station was at -XVV/+ZLV.

For Figure 8.1.3-2, the Progress docking at GMT 143/00:24 was preceded by an attitude change from TEA to the docking attitude at approximately GMT 142/22:10. The docking attitude was a YPR = (231, 14.7, 54), relative to the J2000 coordinate system (inertial coordinate system). In this orientation, the X_A axis is close to alignment with the orbital plane. A profile similar to that found in the Y and Z axes during XPOP can be seen in the X-axis in figure 8.1.3-2.

8.2 Vibratory Microgravity Environment

The vibratory regime is comprised of the acceleration spectrum above 0.01 Hz, with magnitudes expected to vary greatly depending on the nature of the disturbance source and on the transmissibility from the source to the location of the measurement device. These higher frequency accelerations are associated with vehicle systems, experiment-related equipment, and crew activity. Table 8.2-1 shows a list of the Increment-2 disturbers [9] for 6A configuration.

TABLE 8.2-1 ISS INCREMENT-2 DISTURBERS

P6 Truss Segment	• Stick slip • Beta gimbal
Service Module	• Ergometer (unisolated) • High- Gain Antenna • Fans (VS, TCS, Hygiene) • TCS compressor • Treadmill (isolated) • Solar arrays • Pumps (TCS, WSS, Hygiene)
Node 1	• Interim Resistive Exercise Device (IRED) • Fans (CCAV, IMV)
US Lab	• Ergometer (isolated) • Fans (AAAs, IMV, THC) • Pumps (CDRA, MCA, water separator)
Z1 Segment	• Ku-band antenna • CMG
Transient Disturbances	• P6 beta gimbal • SM High-Gain Antenna • SM Solar array • Node 1 IRED • Crew push-off / landing

For the vibratory regime, this quick look report examines the impact of some of these disturbers. In section 8.2.2, the SKV-1 air conditioner/dehumidifier is identified and partially characterized. This piece of equipment is part of the vehicle's environmental control system. Section 8.2.3 discusses the impact of docking a Progress vehicle to the aft end of the Service Module. Section 8.2.4 points out apparent structural modes below 2 Hz, gleaned from acceleration spectra computed over more than 9 days starting in late May 2001. Section 8.2.5 compares a snapshot of acceleration measurements to the ISS vehicle vibratory requirements. Note that this comparison does not consider all of the stipulations specified in [19]. Section 8.2.6 highlights the tremendous impact that the EXPPCS sample mix equipment can have on the vibratory environment, while section 8.2.7 compares a couple of periods of crew activity.

8.2.1 Vehicle Operations

There are a number of ISS modes of operation, such as Standard, Reboost, Microgravity, and so on [3]. Depending on the objectives for a given mode, a different combination of vehicle systems are expected to be operating for at least part of the time. One such system is the Environmental Control and Life Support System (ECLSS), which has a number of components. For this quick look report, we identify one such component, the SKV-1 air conditioner/dehumidifier.

8.2.1.1 Air Conditioner/Dehumidifier

The PIMS TSC console logbook has an entry for SKV-1 air conditioner/dehumidifier turn off at GMT 08-June-2001, 09:42:12 in preparation for an EVA. This air conditioner is located in the FGB module and is part of the ECLSS. As first witnessed on a PIMS real-time display at the TSC (see Figure 8.2.1.1-1), the SKV-1 turned off just before GMT 08-June-2001, 09:42:00.

This is evident by the abrupt cessation of the horizontal yellow streak at that time. The PSDs shown in figure 8.2.1.1-2 were computed from HiRAP data not long before the turn-off time. These show that this air conditioner operates at a fundamental frequency of about 23.5 Hz. The spectral peak at this frequency seen on all three orthogonal sensor axes vanished when the SKV-1 was turned off as shown in figure 8.2.1.1-3. Further characterization of this disturbance source will seek to quantify the impact of this disturbance on the vibratory environment.

8.2.1.2 Progress Vehicle Docking

Mission ISS-4P used a Progress-M1 spacecraft (Progress M1-255) to deliver logistics and supplies to the ISS. This mission launched on 20 May 2001 from the Baikonur Cosmodrome in Kazakhstan, and docked at the aft docking port of the Service Module. After remaining docked for over two months, the Progress-M1 will be loaded with items to be disposed, undocked from the ISS, and commanded to perform a destructive reentry into the Earth's atmosphere.

The PIMS TSC console logbook indicates that the Progress vehicle docked at GMT 143/00:24:00, as noted from a call on the JSC Flight Director voice loop. The exact event within the docking procedure was not specified in this call, however, a large impulsive event was registered by the MAMS-HiRAP at about GMT 143/00:24:20 as seen in figure 8.2.1.2-1.

The 20-second timing discrepancy between the acceleration measurement and the time recorded from the voice loop call may stem from a number of factors: preciseness of voice loop call, actual stage in docking event called on voice loop, and MAMS-HiRAP timing may not be synchronized with other external sources. Regardless, the peak acceleration amplitude recorded by the MAMS-HiRAP during this docking event was approximately 13 mg.

The color spectrogram of figure 8.2.1.2-2 shows the impulsive docking at just before the 10-minute mark, then for the next several minutes some as-yet-to-be-identified events occur presumably to secure the vehicles for subsequent hatch opening.

8.2.1.3 Structural Modes

As opportunities arise, directional and precise frequency correlation between measurements and mathematical models will be undertaken. However, for the purpose of this quick look report we will touch on apparent structural modes gleaned from MAMS-HiRAP data recorded on GMT June 8, 2001. The major structural components during Stage 6A are: the Soyuz, Service Module, FGB, Progress M, Z1 Truss, Node 1, PMA-1, PMA-2, PMA-3, P6 segment (Long Spacer and IEA), US PV arrays, TCS radiators, Lab, MPLM, SpaceLab Pallet, and SSRMS. Most of these components are shown mated in figures 3.1-1, 3.2-1.

As cited in [20], key structural mode shapes of the ISS “backbone” are characterized by individual pressurized modules acting as rigid bodies connected at flexible interfaces. The “backbone” of the ISS is formed by the line of modules connected along the X_A-axis, which points in the general flight velocity vector direction for the Assembly Complete configuration. Also, from [20], some target modes selected for analysis are shown in Table 8.2.1.3-1.

TABLE 8.2.1.3-1 TARGET MODES FOR ISS ASSEMBLY COMPLETE CONFIGURATION

Target Mode #	Frequency (Hz)
297	0.44141
427	0.90176
454	1.01158

Limited computational resources prohibit computation of acceleration spectra with the resolution shown in the table above. To achieve the frequency resolution shown would require operating on over a day's worth of contiguous vibratory data. Direct comparison to predicted data is provisionary since the acceleration data currently available were collected in the Stage 6A configuration, and not in the Assembly Complete configuration. However, for the purpose of this quick look report, these target modes were used in lieu of mathematical model structural frequencies for the Stage 6A configuration. The color spectrogram of Figure 8.2.1.3-1 spans 8 hours starting at GMT 08-June-2001, 08:00:00.

It shows the acceleration spectra below 2 Hz in an effort to capture low frequency structural modes. The horizontal yellow or red streaks that span the duration of the spectrogram point to what appear to be vehicle structural modes. The exact nature of these is beyond the scope of this document, but the spectral peaks at about 0.4 and 1 Hz are close to the first two target mode values of Table 8.2.1.3-1. Spectral averaging of the constituent PSDs that comprise this spectrogram yields the blue trace of Figure 8.2.1.3-2. The black trace in the figure represents a non-averaged, snapshot PSD for comparison. Note from this figure that the averaged PSD shows spectral peaks at about 0.40, 0.56, and 0.93 Hz. Also, the averaged PSD shows that near 1.3 Hz there are at least 2 closely spaced spectral peaks and possibly another pair at about 1.8 Hz. Further analyses and correlations will be undertaken to study, characterize, and quantify these low frequency dynamics, particularly as the ISS is assembled.

8.2.1.4 Vehicle Vibratory Requirements

The current configuration of the ISS and sensor mounting locations do not meet the specifications called out in [19]:

> *The vibratory acceleration limits apply at the structural mounting interfaces to the internal user payload locations. In the case of the ISPR, this points to the structural interfaces between the rack and the payload, on the payload side of the interfaces. If an intermediate structure were incorporated into the design between the user payload and the ISPR, e.g. an active rack isolation system, the specification shall apply at the user payload side of its interface with such a system.*

… but that notwithstanding, measurements collected by SAMS RTS F06 were processed for comparison to the ISS system combined vibratory acceleration limits and the results are shown in Figure 8.2.1.4-1. It must be pointed out that the ISS requirement curve is only valid for assembly complete, ISS microgravity mode operations and with the ARIS Rack on. The data that are being compared here with the ISS requirement were not collected under the conditions mentioned above and are shown here only to illustrate how close the ISS microgravity environment is to the requirement at assembly complete. The reader should be careful in drawing any conclusion when looking at these two curves (6A configuration vs. ISS requirement at assembly complete).

8.2.2 Experiment Operations

Microgravity experiment procedures typically employ mechanical equipment to prepare, conduct, analyze, diagnose, or preserve some aspect of the investigation. The forces produced by the moving parts of such equipment are transmitted in varying degrees to the spacecraft structure depending on the operating characteristics and on any mechanisms for vibration isolation.

8.2.2.1 EXPPCS Sample Mix

The EXPPCS is located in ER 2. It has a number of moving parts, but the sample mixer is of particular interest from an acceleration environment perspective. In order to eliminate sedimentation and to produce uniform distribution, the initial EXPPCS procedures call for mixing each colloidal sample for a period of approximately one hour. The color spectrogram shown in Figure 8.2.2.1-1 shows an example of the sample mixer in operation starting at about GMT 04-June-2001, 22:20:40 and lasting for over an hour with a 50% duty cycle.

This spectrogram was computed from SAMS RTS F06 measurements and shows the acceleration spectrum as a function of time. The sensor head was located within about $1^1/_2$ feet of the mixer on the front-panel of the EXPPCS test section and expectedly registered extreme acceleration levels. The period shown starts at GMT 04-June-2001, 22:10:00 and covers an 80-minute span. The red vertical streaks mark portions of the duty cycle when the mixer was active. For improved temporal resolution and a more precise accounting of the measured accelerations, the interval minimum/maximum time history of Figure 8.2.2.1-2 was examined.

This figure clearly shows the large accelerations that occur while the mixer is preparing a sample cell for an operational run. The acceleration vector magnitudes detected by this sensor were nominally about 150 mg with peak values routinely in excess of 200 mg. As indicated by the time axis tick marks, this mixer has a 50% duty cycle with 30-second duration. For improved frequency resolution and a more precise accounting of the spectral content during sample mix operations, the PSDs of Figure 8.2.2.1-3 were computed.

From close inspection of this figure, we conjecture that the fundamental frequency of this disturbance was 12 Hz and with significant 2^{nd} through 16^{th} harmonics within the passband of this sensor. The 9^{th} harmonic at 108 Hz was the most pronounced component and was aligned primarily with the sensor's YZ-plane. In strong contrast to this, the acceleration spectra during a 25-second span when the sample mix operation was off are seen in the PSDs of Figure 8.2.2.1-4.

Closer examination by means of the cumulative RMS acceleration versus frequency plot of Figure 8.2.2.1-5, serves to quantify this disturbance as a function of frequency.

During this 25-second period while the mixer was on, the overall RMS acceleration was slightly more than 80 mg_{RMS} for the frequency range from 0.06 to 200 Hz. For this same range, but during a 25-second span while the mixer was off, the cumulative RMS acceleration versus frequency plot of Figure 8.2.2.1-6 yields an overall RMS acceleration value more than an order of magnitude smaller at about 1.7 mg_{RMS}.

8.2.3 Crew Activity

Experimental setups, equipment transfer or stowage, exercise, and simple locomotion all contribute to the category of disturbance called crew activity. These actions give rise to reactive forces, which are manifested as acceleration disturbances transferred through the vehicle's structure. In-depth analyses will seek to correlate acceleration effects with periods of crew inactivity, like sleep and Public Affairs Office (PAO) events. These PAO events are typically question-and-answer or demonstration periods with all or some of the crew gathered in one area. This has a quieting effect on the microgravity environment because crew activity is reduced from nominal conditions, that is, the crew is less likely to impart push-off and impact transients on the vehicle's structure. In addition, crew conferences and briefings may be examined and should result in a similar quieting. Exactly how much of a quieting effect these periods have remains to be analyzed, but for quick look analysis purposes, we consider a short period not long before the crew wakes with a period that starts soon after as shown in Figure 8.2.3-1.

This plot was derived from HiRAP measurements and shows a spectral comparison of two 4-minute periods. The black trace is the PSD for a time slice starting at GMT 03-June-2001, 08:40:00, which was near the end of a sleep period. The red trace is the PSD for a time slice starting at GMT 03-June-2001, 08:48:00, which was not long after the crew woke. This brief wake period does not encompass the full gamut of crew activity, but does serve to show how the crew impacts the low-frequency portion of the vibratory acceleration spectrum, particularly below about 6 Hz. Using Parseval's theorem, we can quantify the difference in this frequency range in terms of the RMS acceleration for the frequency band from 0.06 to 6 Hz. The RMS acceleration level in this range rose from about 9 μg_{RMS} during the sleep period to about 40 μg_{RMS} just after the crew woke up.

9. Unknown Disturbances

Since the PIMS project is at an early stage of characterization of the ISS reduced gravity environment, many of the disturbances recorded by either MAMS or SAMS are yet to be identified. Disturbance identification is a very challenging task. It will be an ongoing process as the ISS is being built from increment to increment. PIMS will start using the Mission Evaluation Workstation System (MEWS) along with our console log and timeline info in order to identify the disturbances presented in the spectrograms and PSD plots in this report. The ISS Increment-2 report, which will follow this quick look report, will focus on providing the microgravity scientific environment a more rigorous characterization of the environment for the ISS Increment-2.

10. Summary of Findings

Table 10.-1 is a summary of the various disturbances recorded by MAMS and SAMS that PIMS project analysts have briefly analyzed thus far for the period of May 3rd to June 8th. Note that, MAMS and SAMS were not continuously active during the time span

mentioned above. In the upcoming Increment-2 report, many of the disturbances listed below as unknown will be identified using the MEWS system, along with PIMS console logbook and previously performed simulations and prediction analyzes.

TABLE 10-1 SUMMARY OF FINDINGS

Frequency (Hz)	Observations
Below 5	ISS Increment-2 Structural modes (there appears to be 7 noticeable structural modes)
Below 6	Crew activity is noticeable
10.37	Tightly controlled in frequency, source unknown
12, follows by 2nd and up to 16th harmonics	EXPPCS experiment operation
20.5	Broadband disturbance, source unknown
23.4	SKV-1 Air Conditioner/Dehumidifier
26.36	Broadband disturbance, source unknown
49.1	Tightly controlled in frequency, source unknown
57.6	Tightly controlled in frequency, source unknown
61.40	Broadband disturbance, source unknown
67.7	Tightly controlled in frequency, source unknown
69.9	Tightly controlled in frequency, source unknown
75.1	Broadband disturbance, suspect this life-support equipment
85.3	Tightly controlled in frequency, source unknown
94.8	Strong spectral component, suspect this is life-support equipment

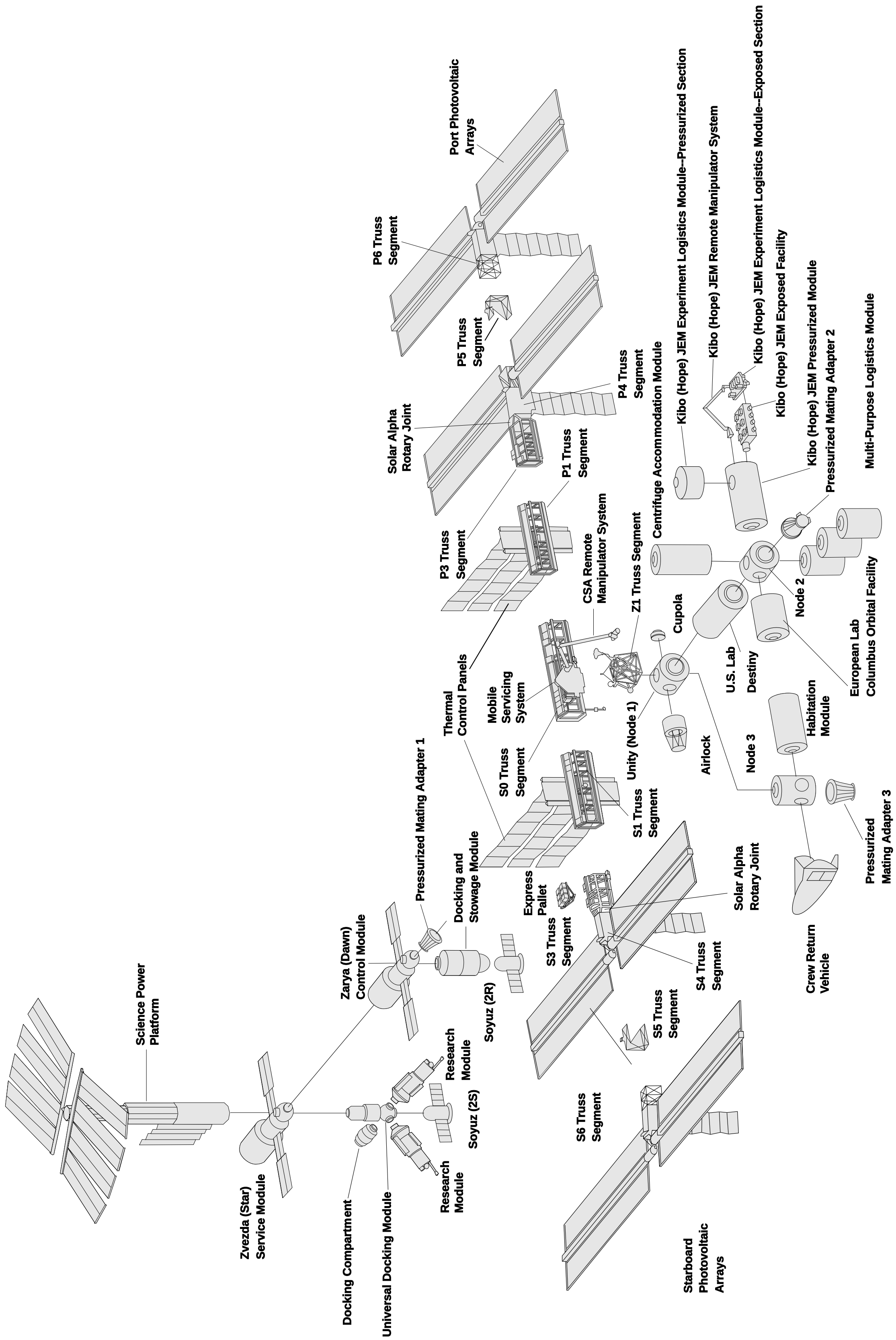

Figure 2.1-1 International Space Station at Assembly Complete

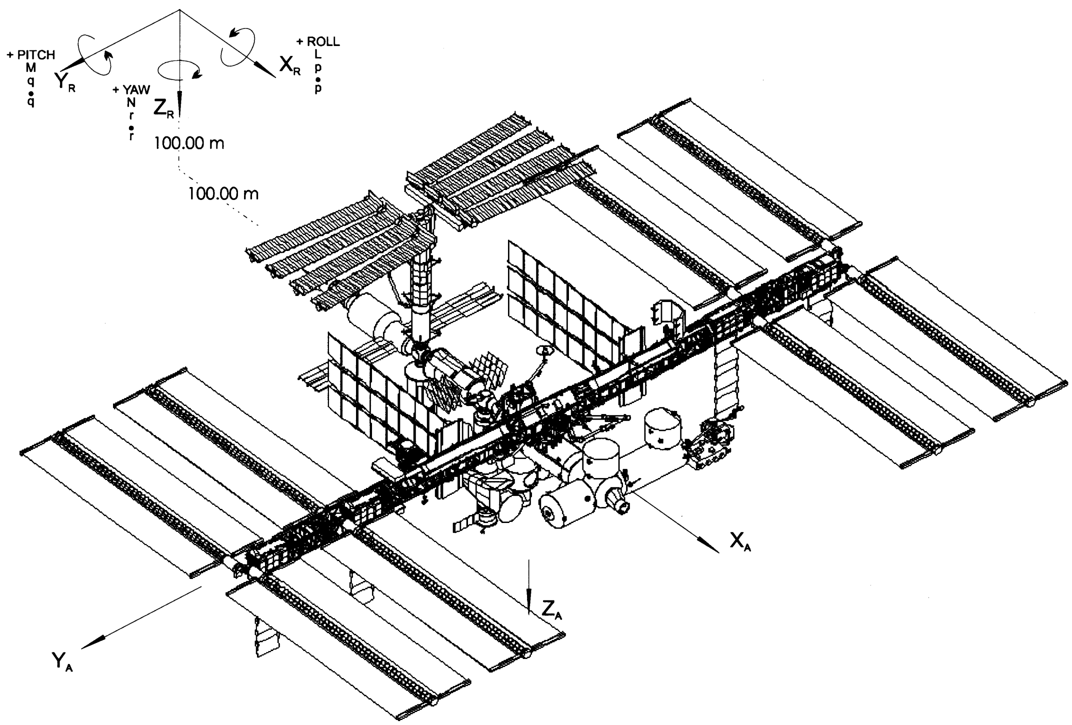

Figure 2.2-1 Space Station Analysis Coordinate System

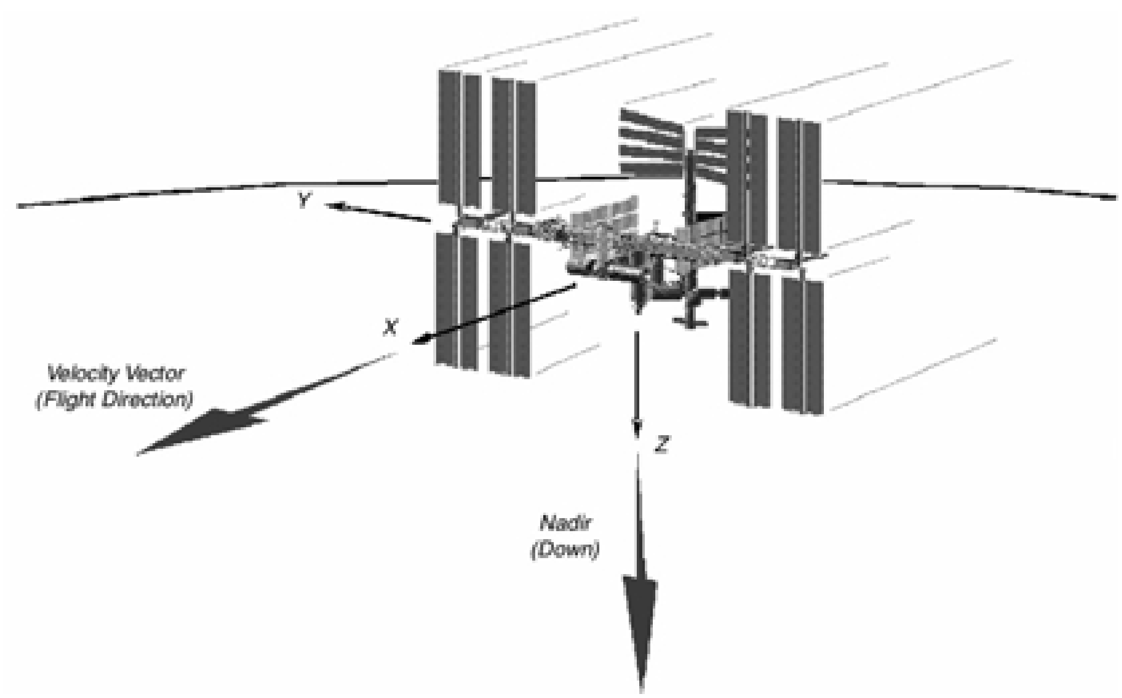

Figure 2.3-1 ISS XVV Flight Attitude

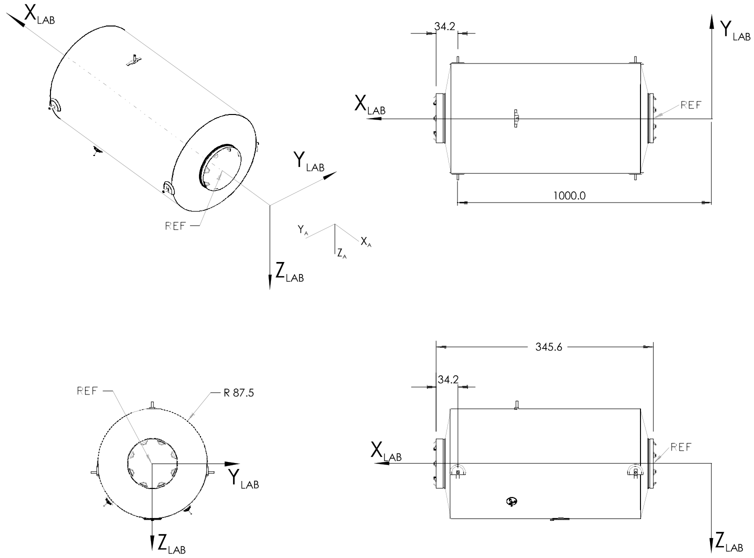

Figure 2.4-1 United States Laboratory Module (Destiny) Coordinate System

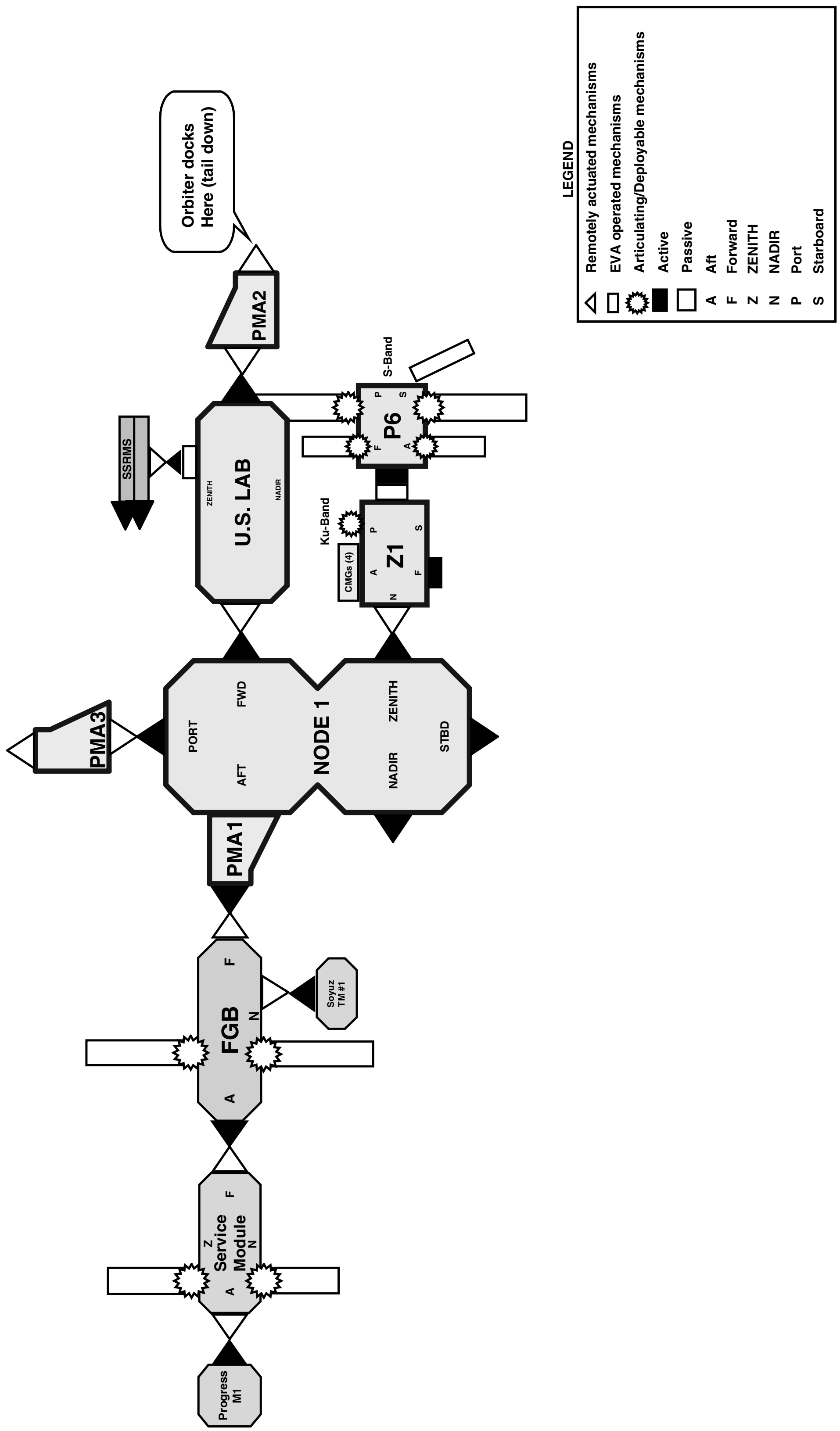

Figure 3.1-1 ISS Increment-2 Configuration

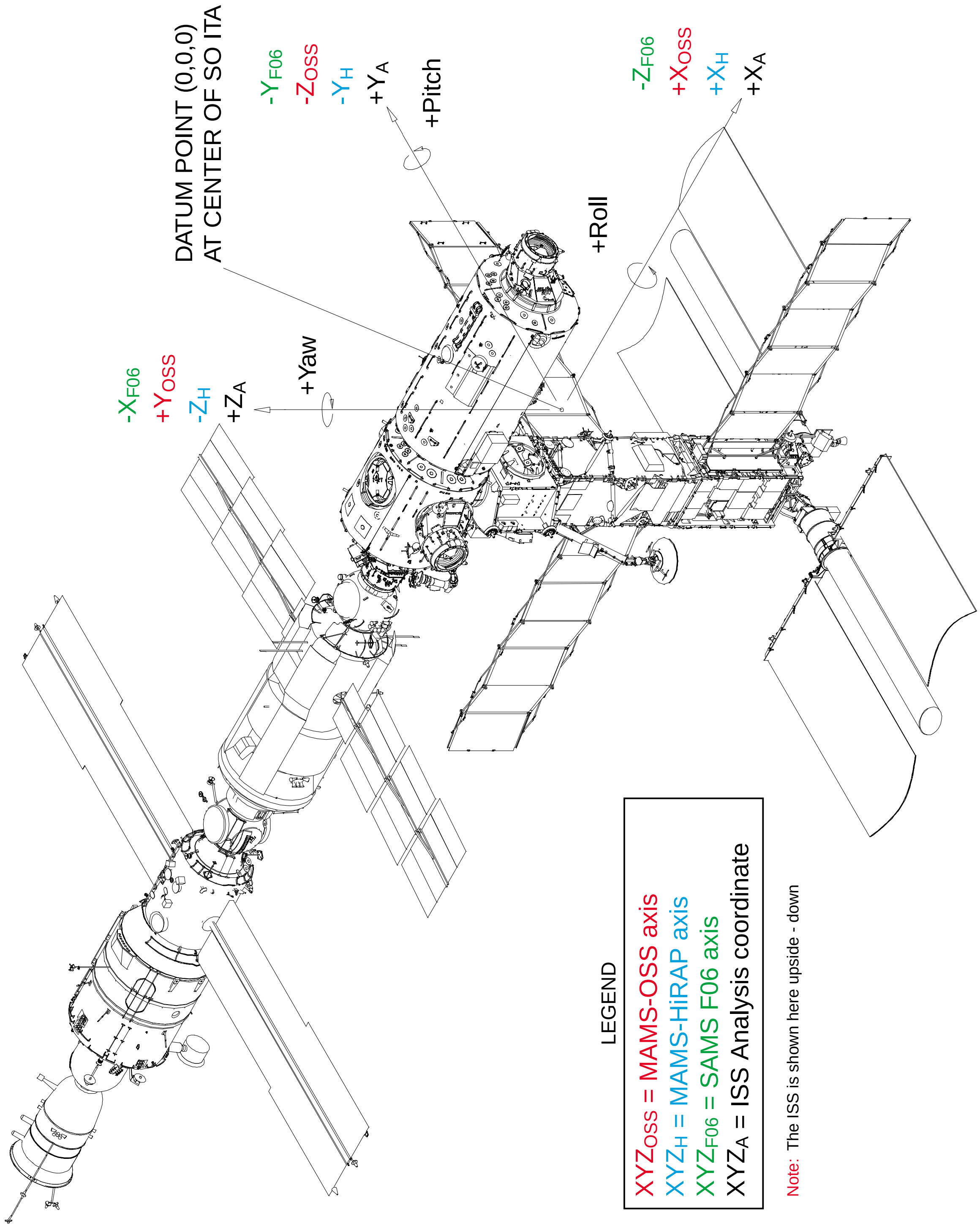

Figure 3.2-1 6A Configuration Coordinate Systems

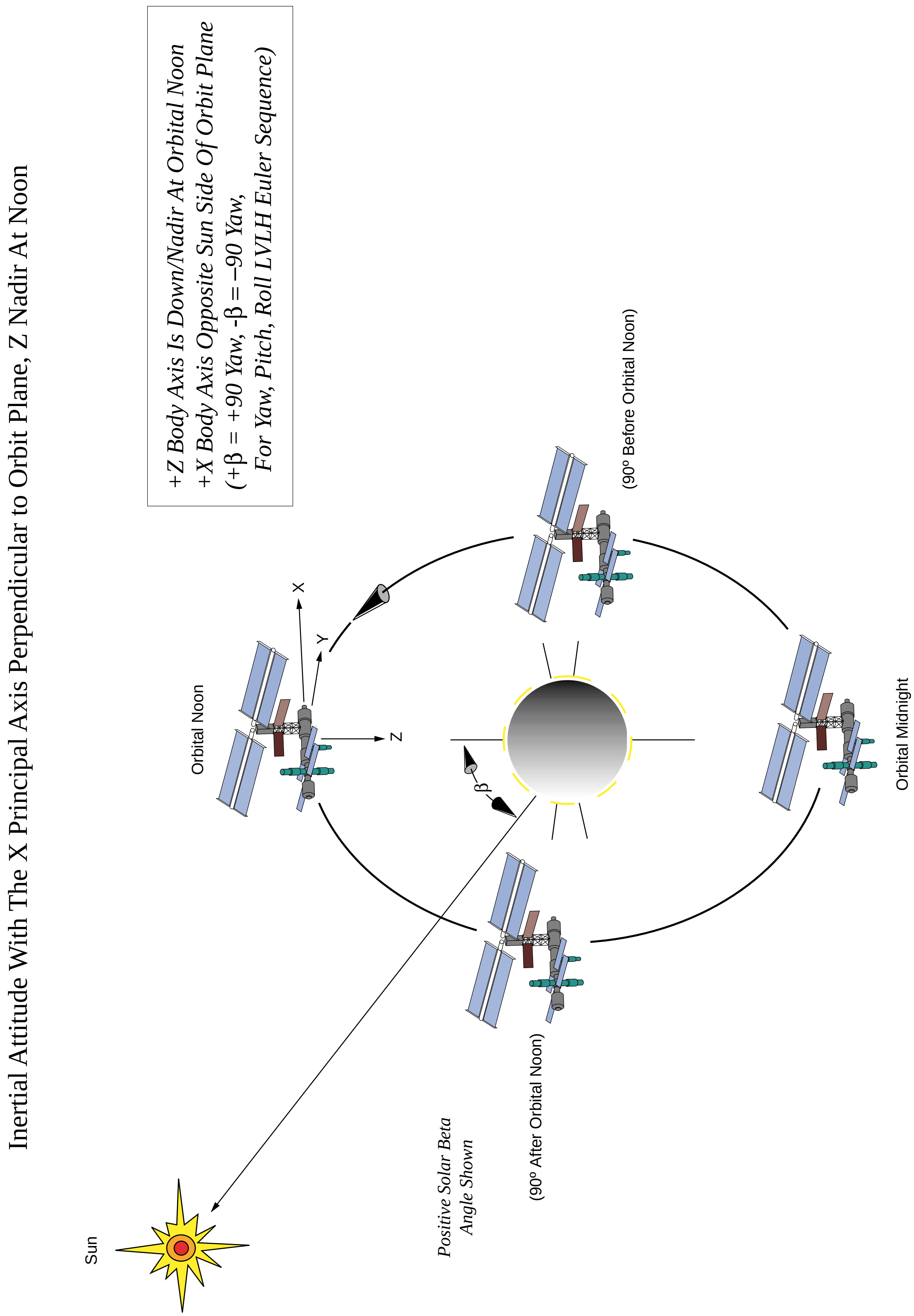

Figure 3.3-1 ISS in the XPOP Inertial Flight Attitude

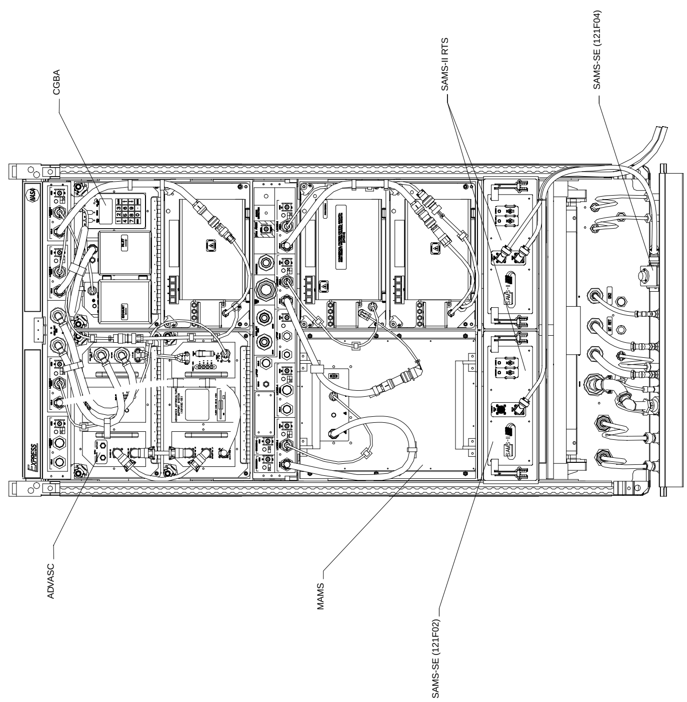

Figure 5-1 EXPRESS Rack 1 6A On-Orbit Configuration

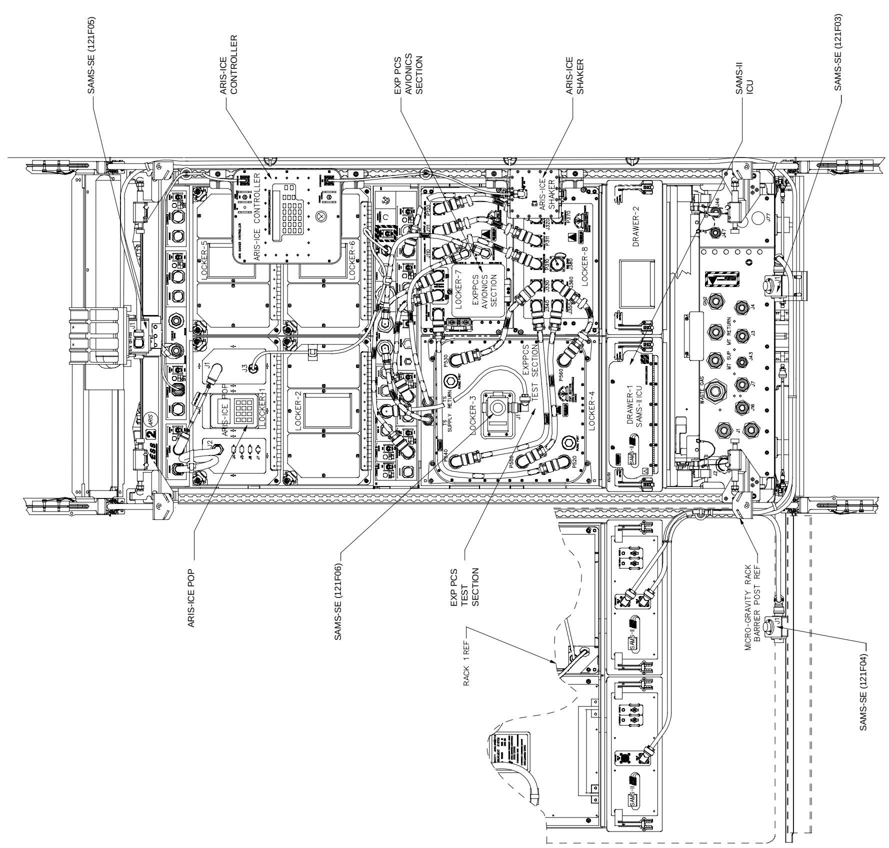

Figure 5-2 EXPRESS Rack 2 6A/7A On-Orbit Configuration

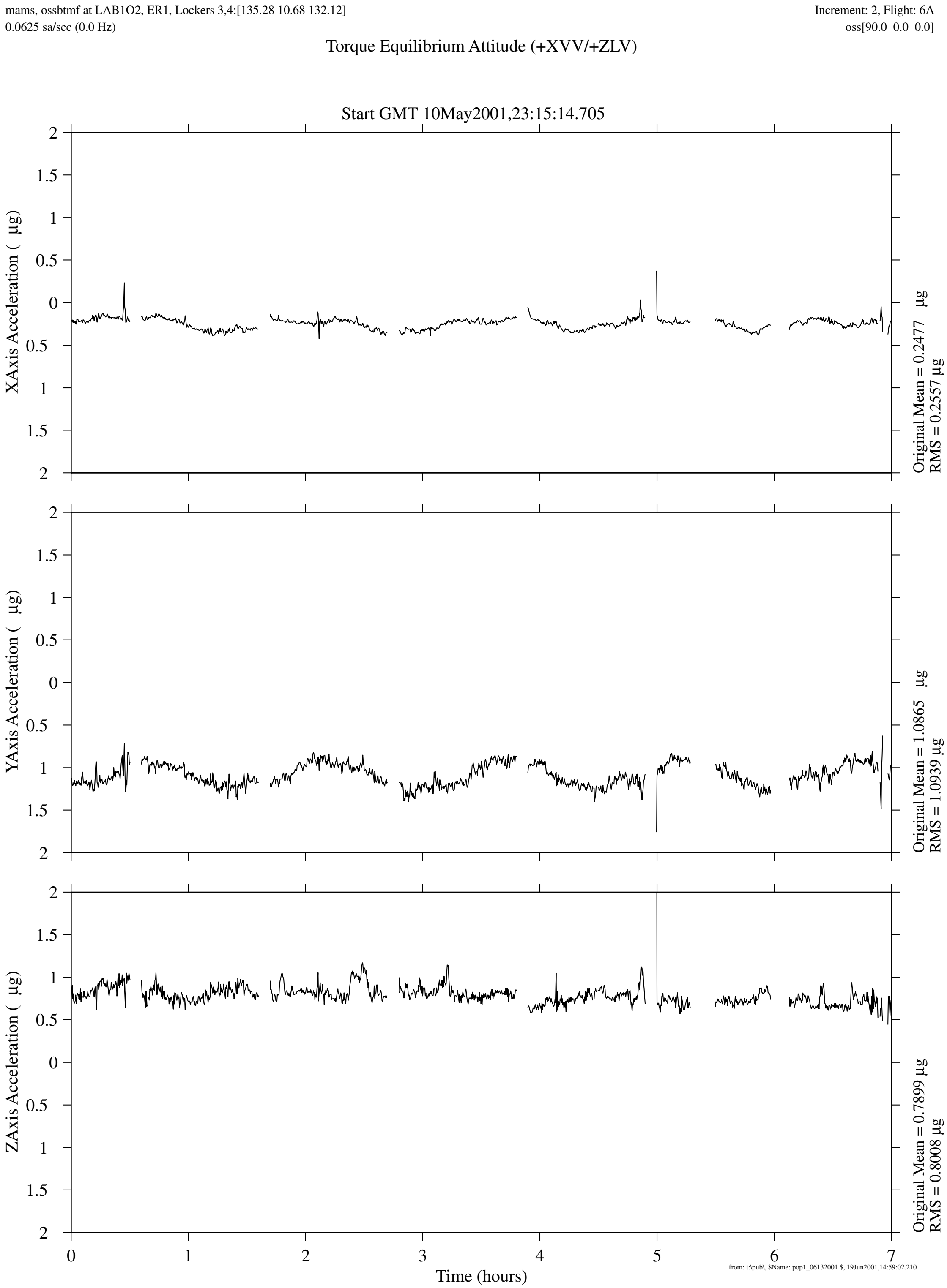

Figure 8.1.1-1 Torque Equilibrium Attitude

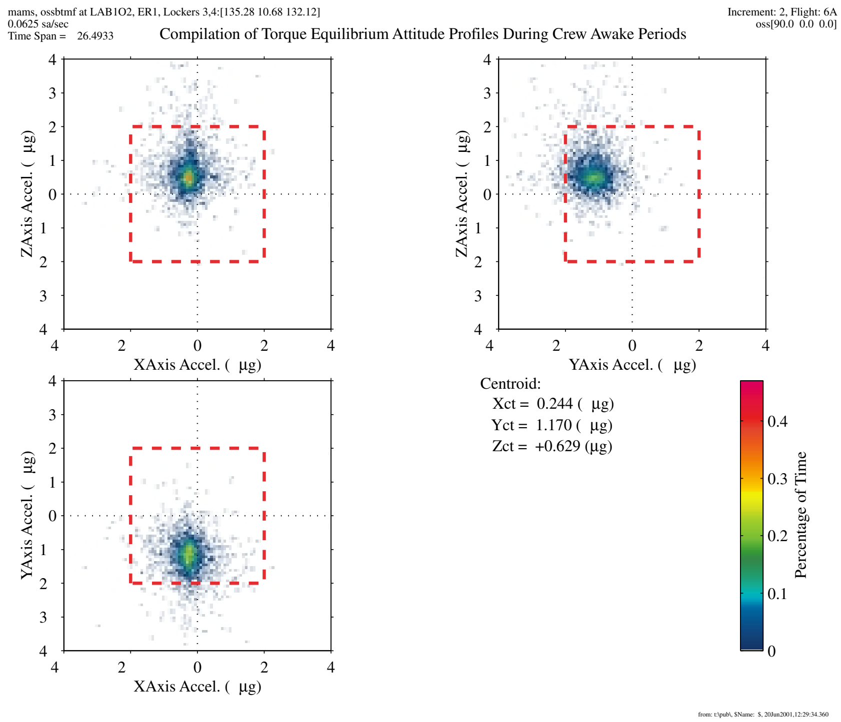

Figure 8.1.1-2 Crew Active Periods During TEA

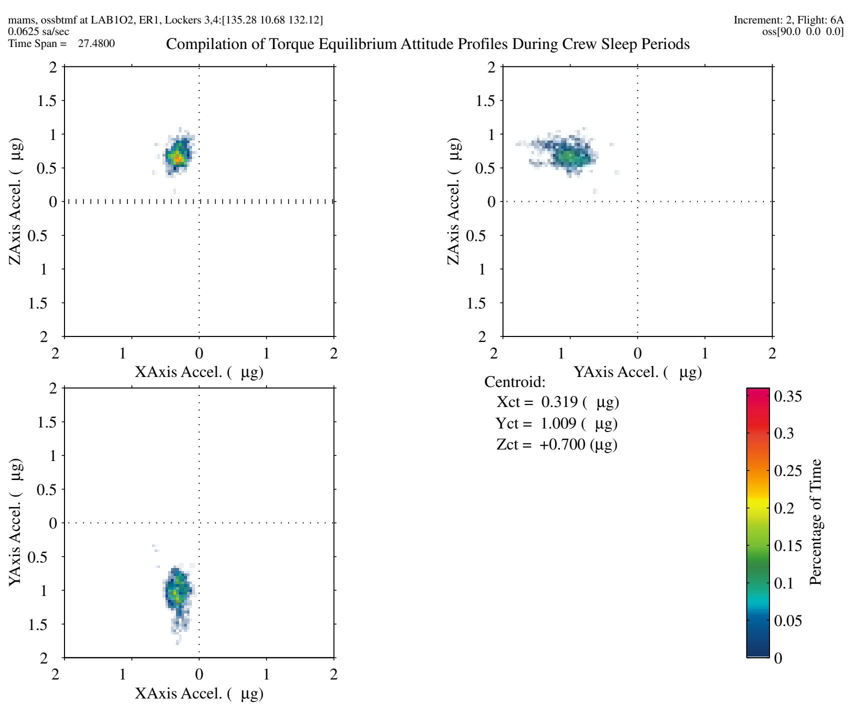

Figure 8.1.1-3 Crew Sleep Periods for TEA

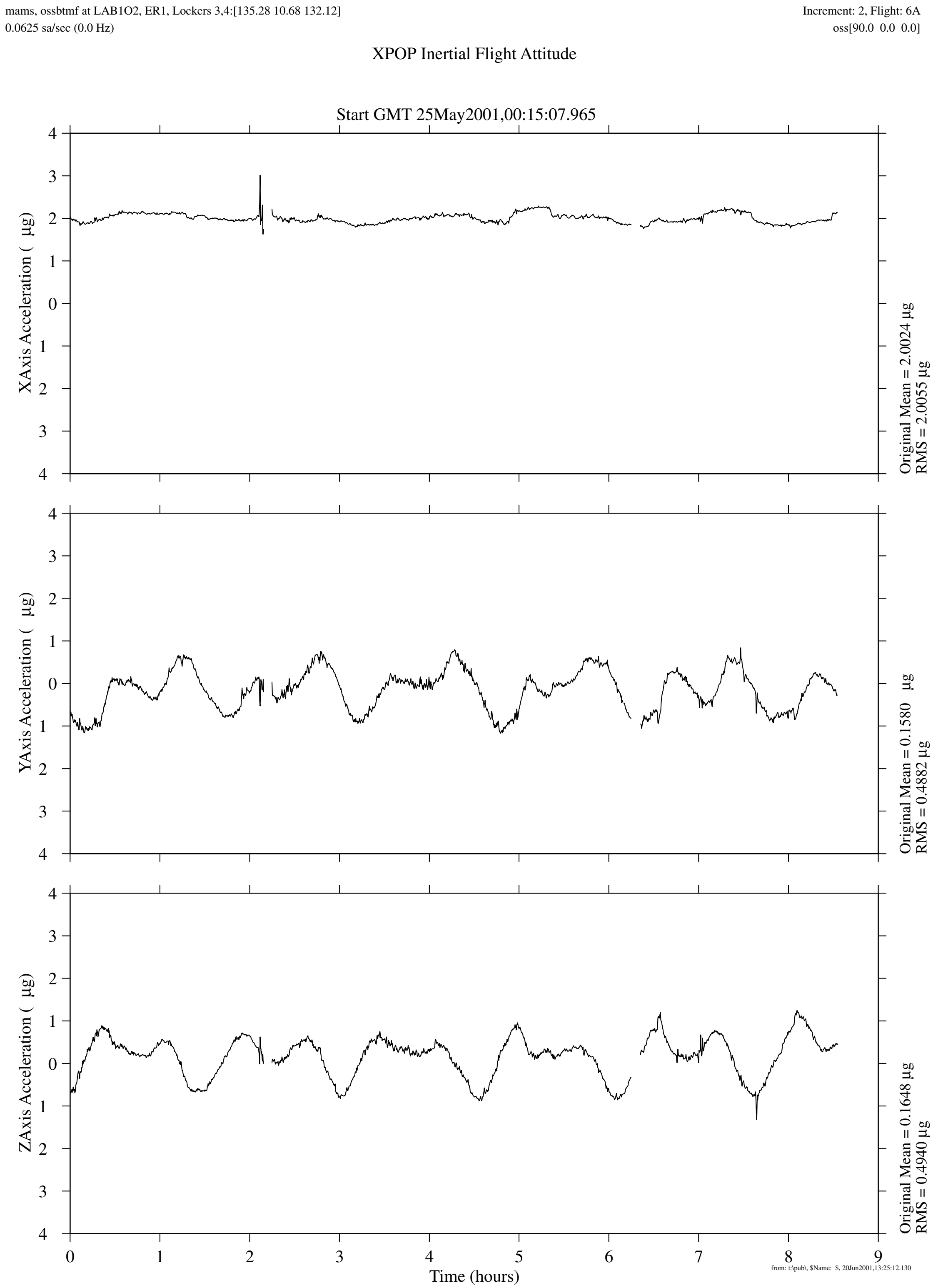

Figure 8.1.2-1 XPOP Attitude

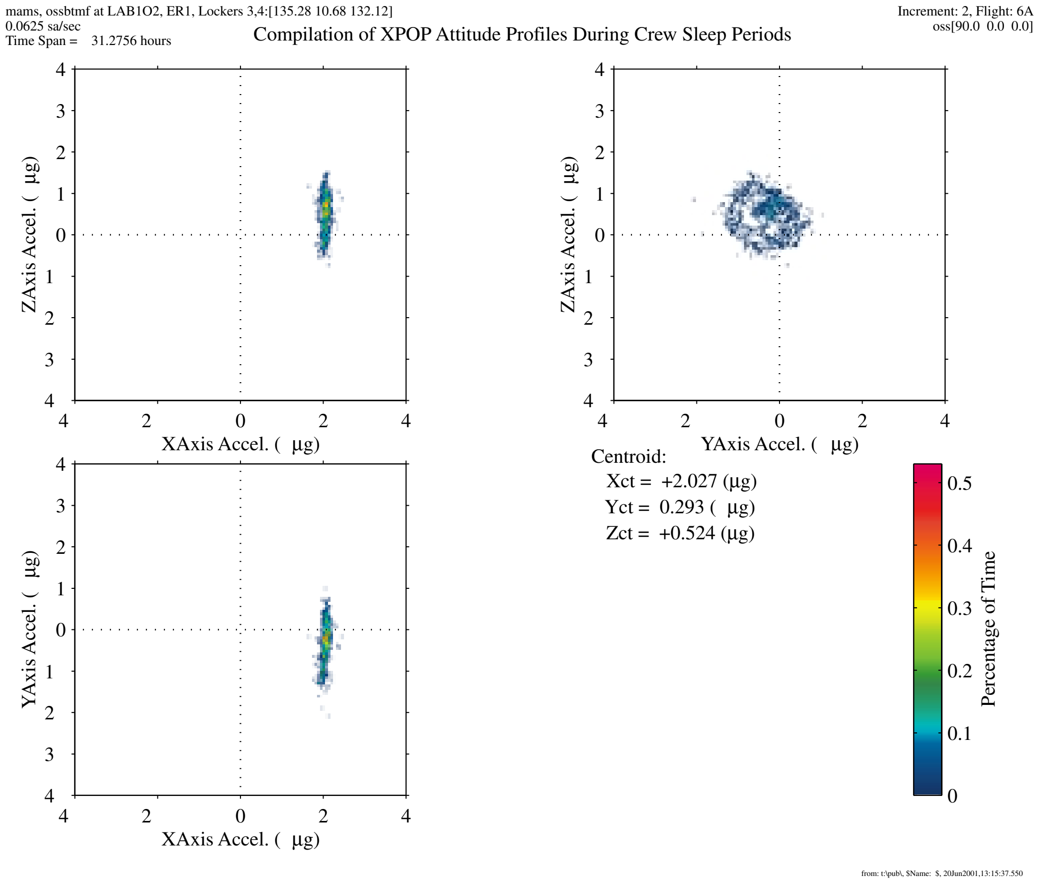

Figure 8.1.2-2 XPOP Attitude Profile for Crew Sleep Periods

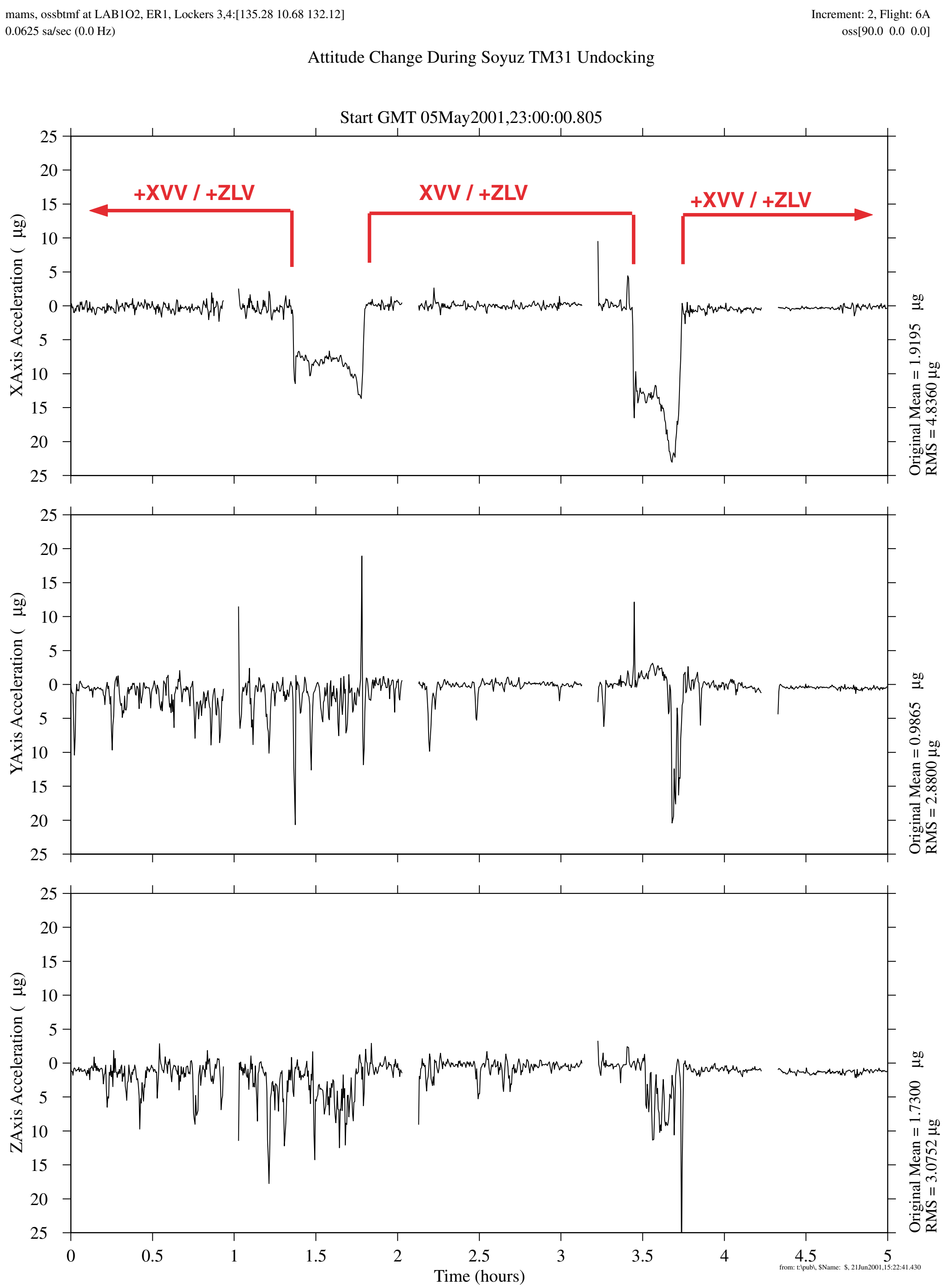

Figure 8.1.3-1 Undocking of Soyuz TM-31

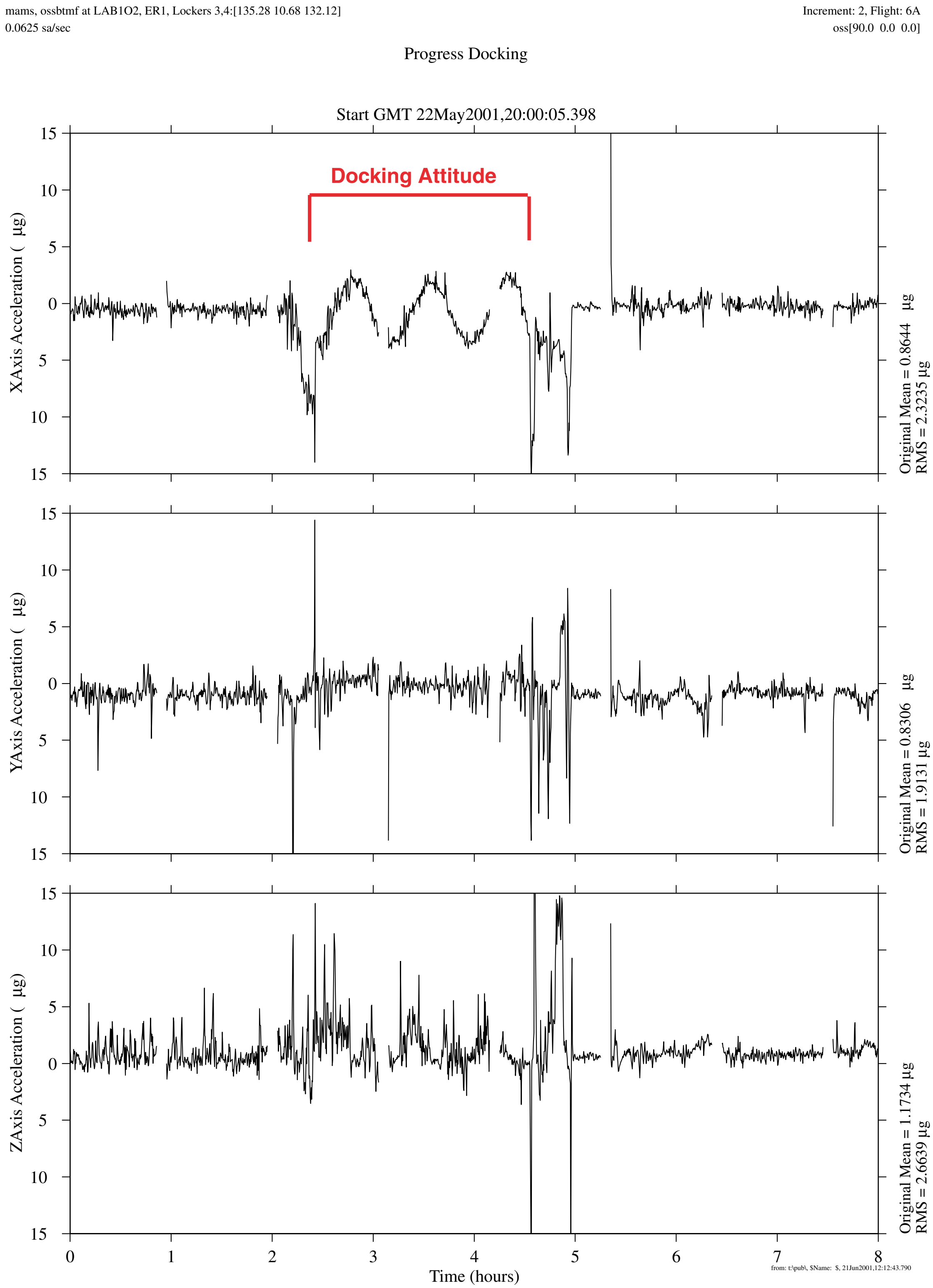

Figure 8.1.3-2 Progress Docking

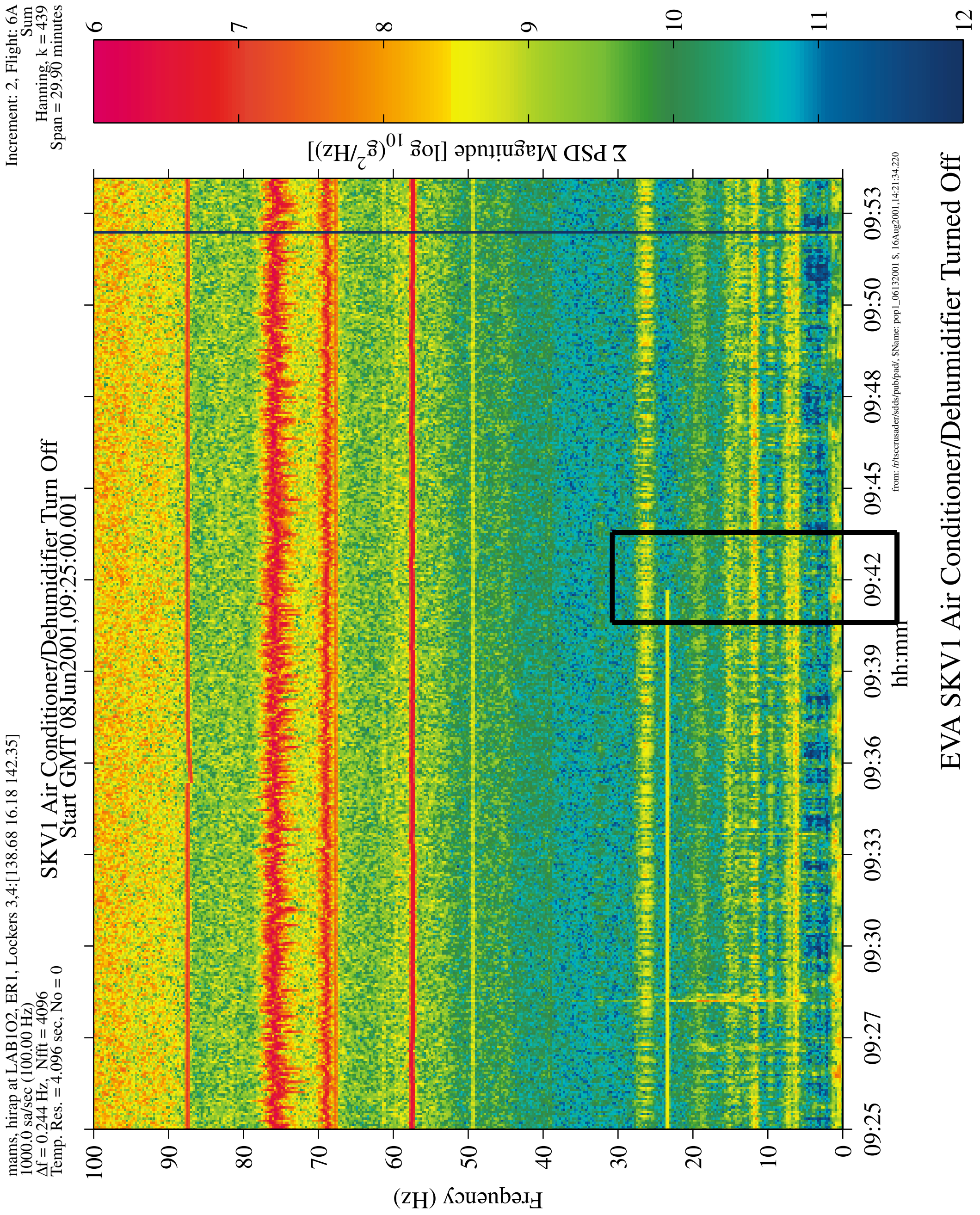

Figure 8.2.1.1-1 Color Spectrogram Showing SKV-1 Air Conditioner/Dehumidifier Turn Off

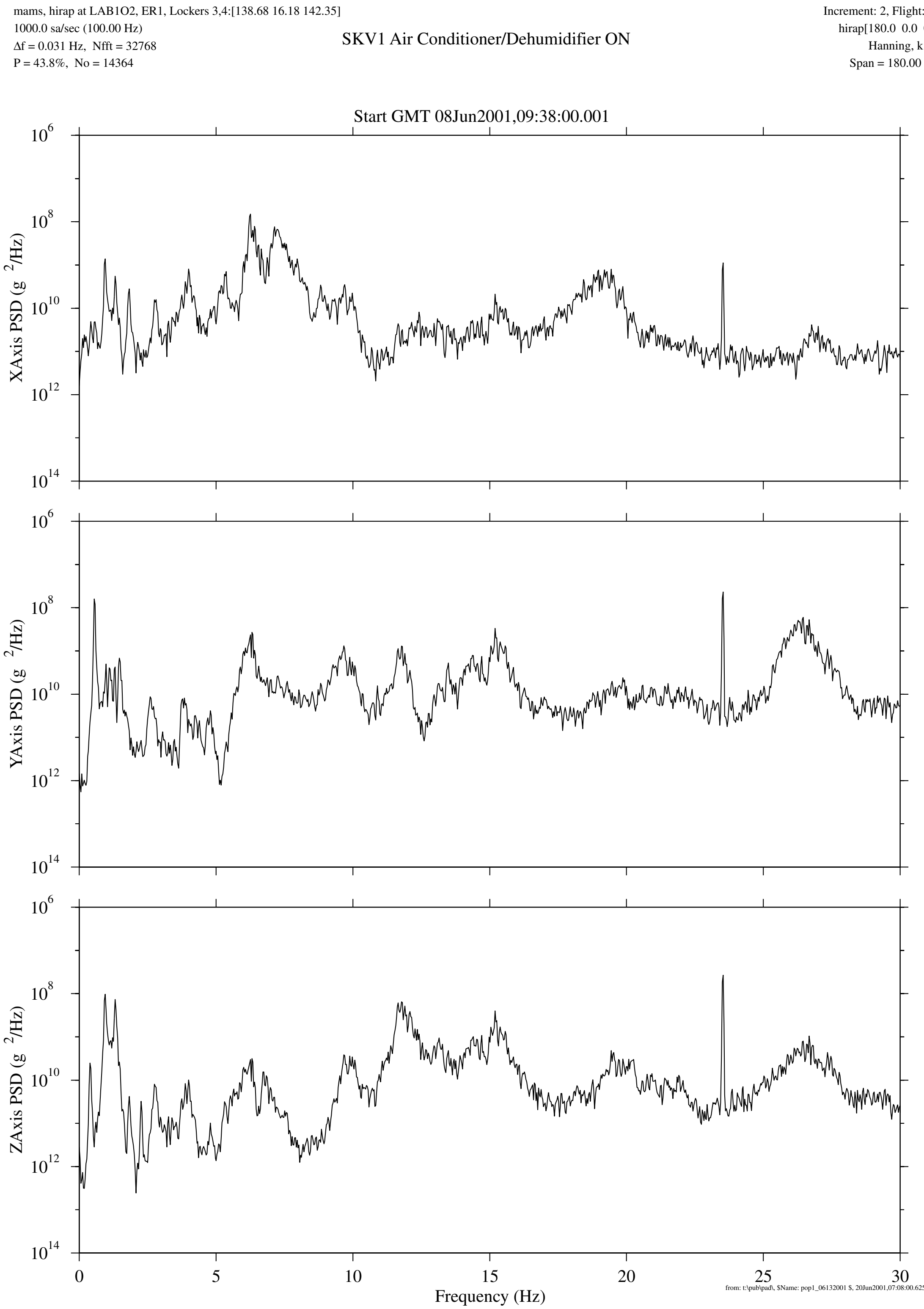

Figure 8.2.1.1-2 PSDs Showing SKV-1 Air Conditioner/Dehumidifier On

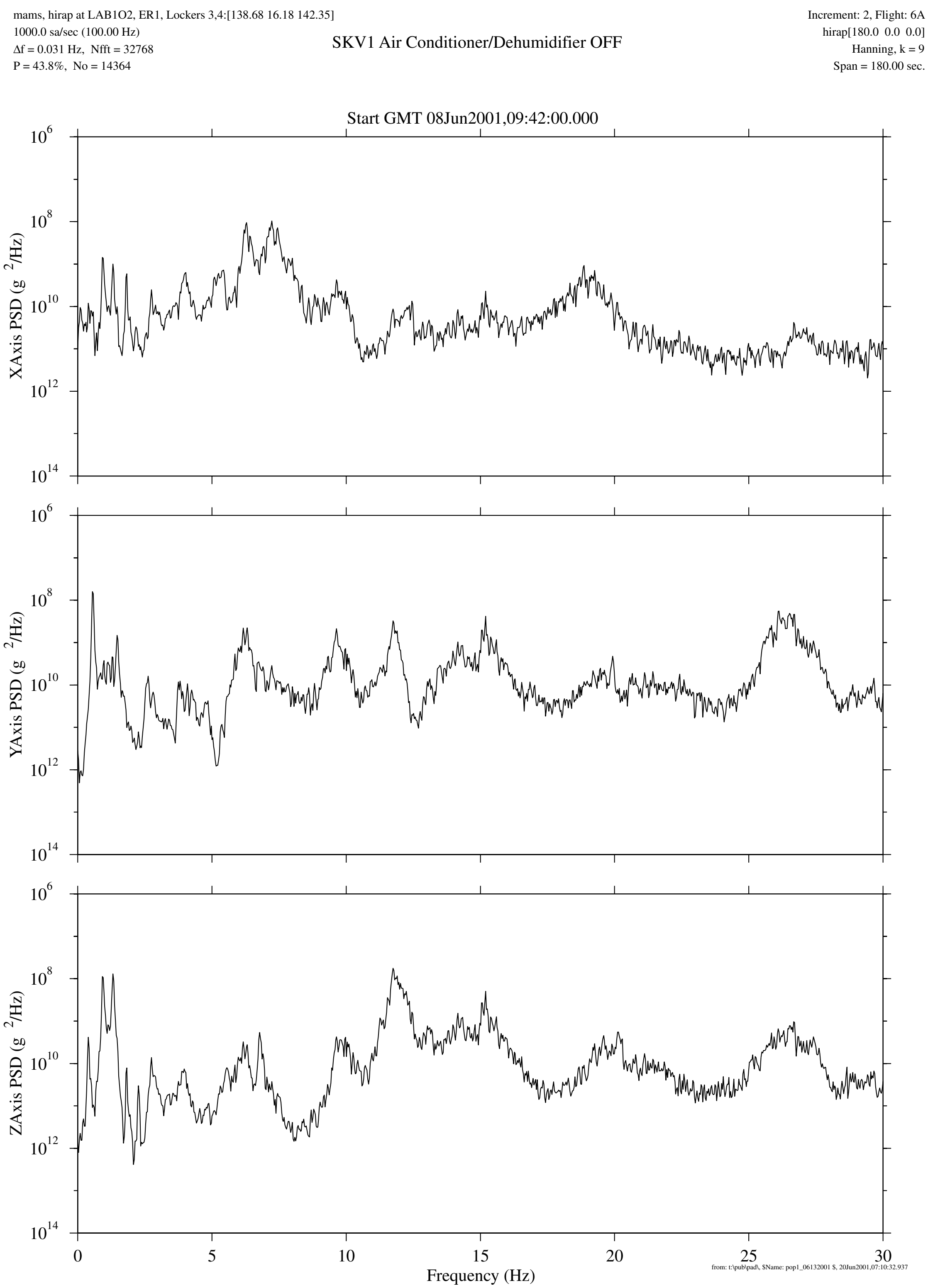

Figure 8.2.1.1-3 PSDs Showing SKV-1 Air Conditioner/Dehumidifier Off

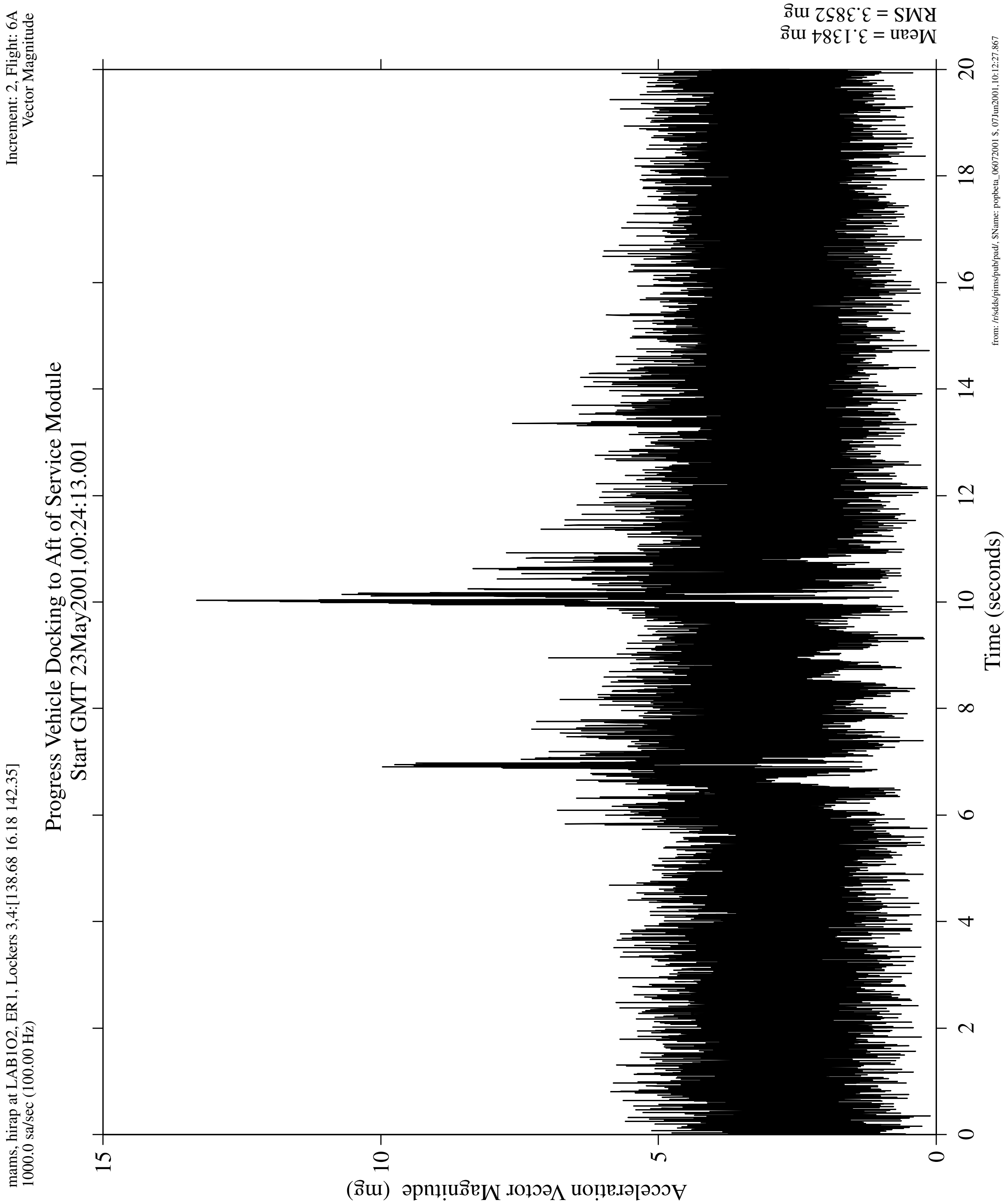

Figure 8.2.1.2-1 Acceleration Vector Magnitude Time History for Progress Vehicle Docking

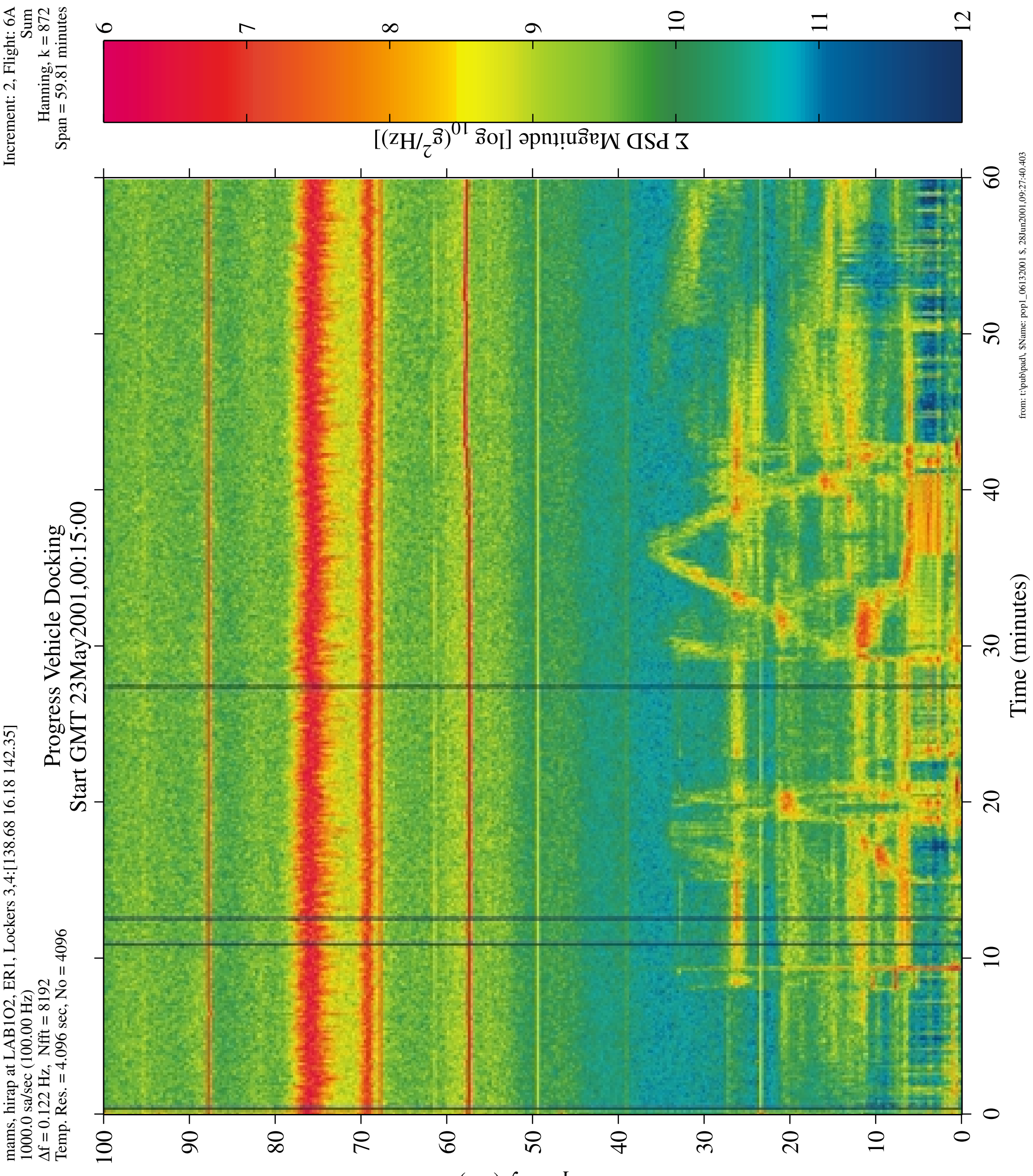

Figure 8.2.1.2-2 Color Spectrogram for Progress Vehicle Docking

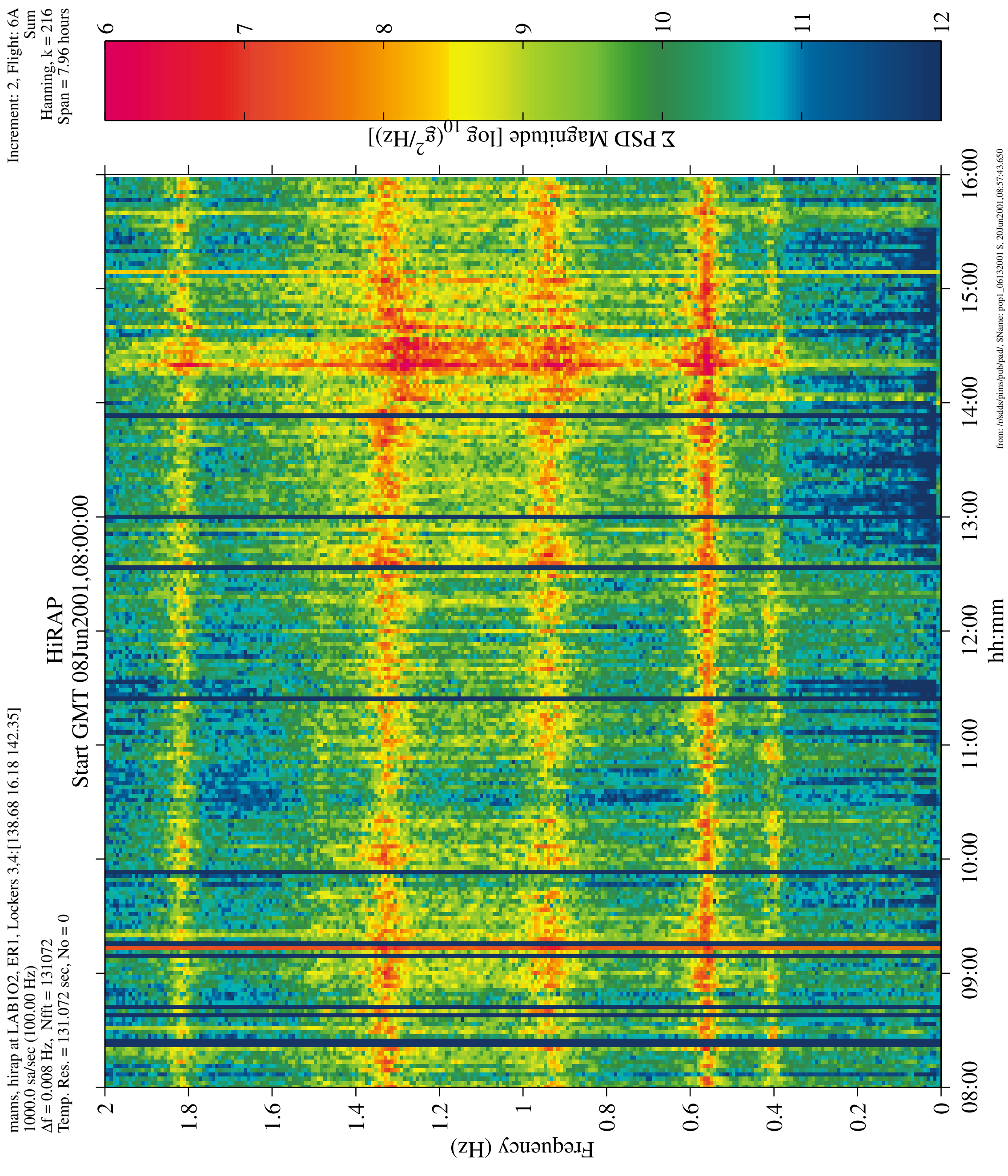

Figure 8.2.1.3-1 8-Hour Color Spectrogram Below 2 Hz of MAMS-HiRAP

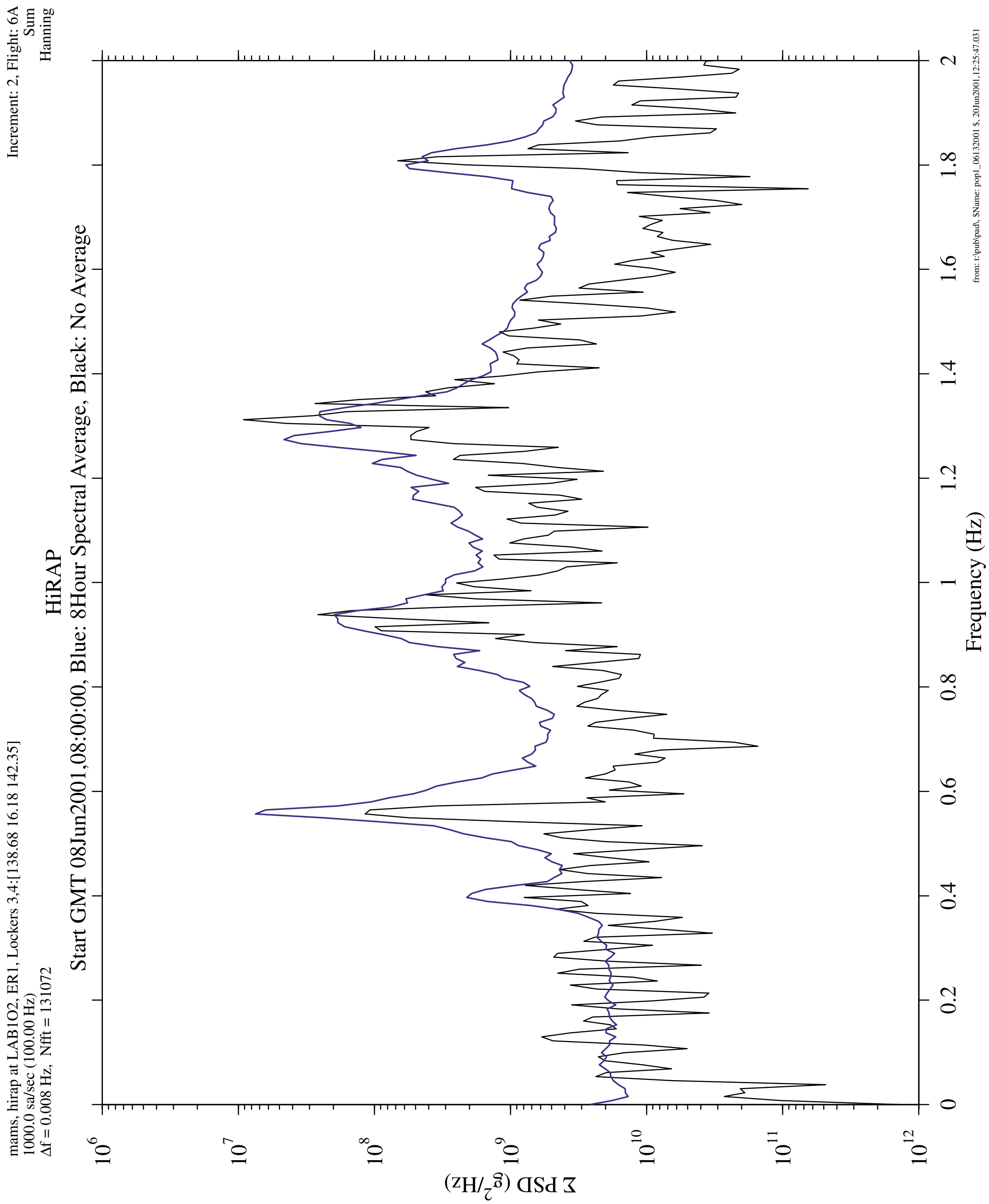

Figure 8.2.1.3-2 8-Hour Spectral Averaged PSD Below 2 Hz of MAMS-HiRAP

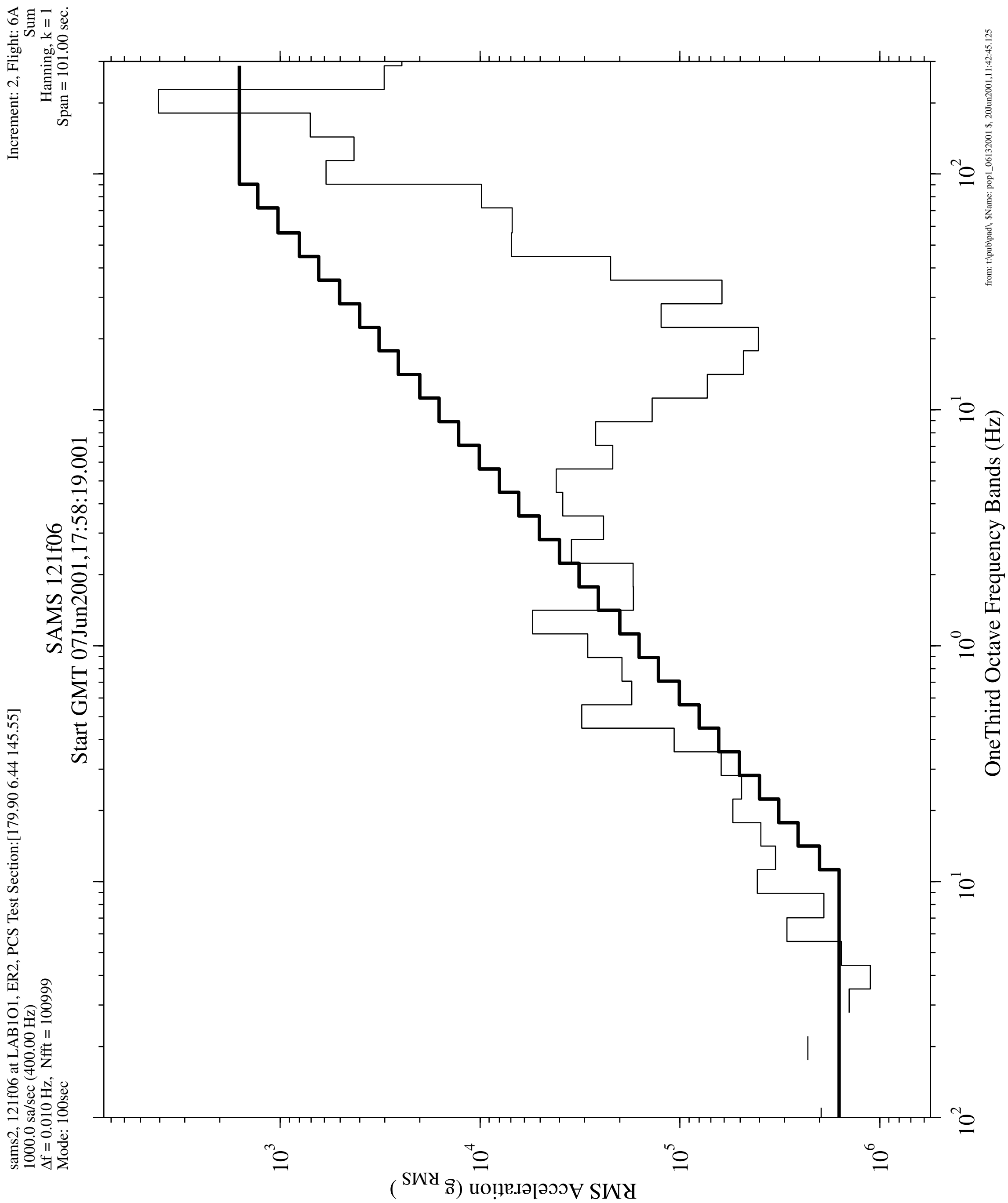

Figure 8.2.1.4-1 RMS Acceleration vs. One-Third Octave Frequency Bands for SAMS F06 Data (6A configuration)

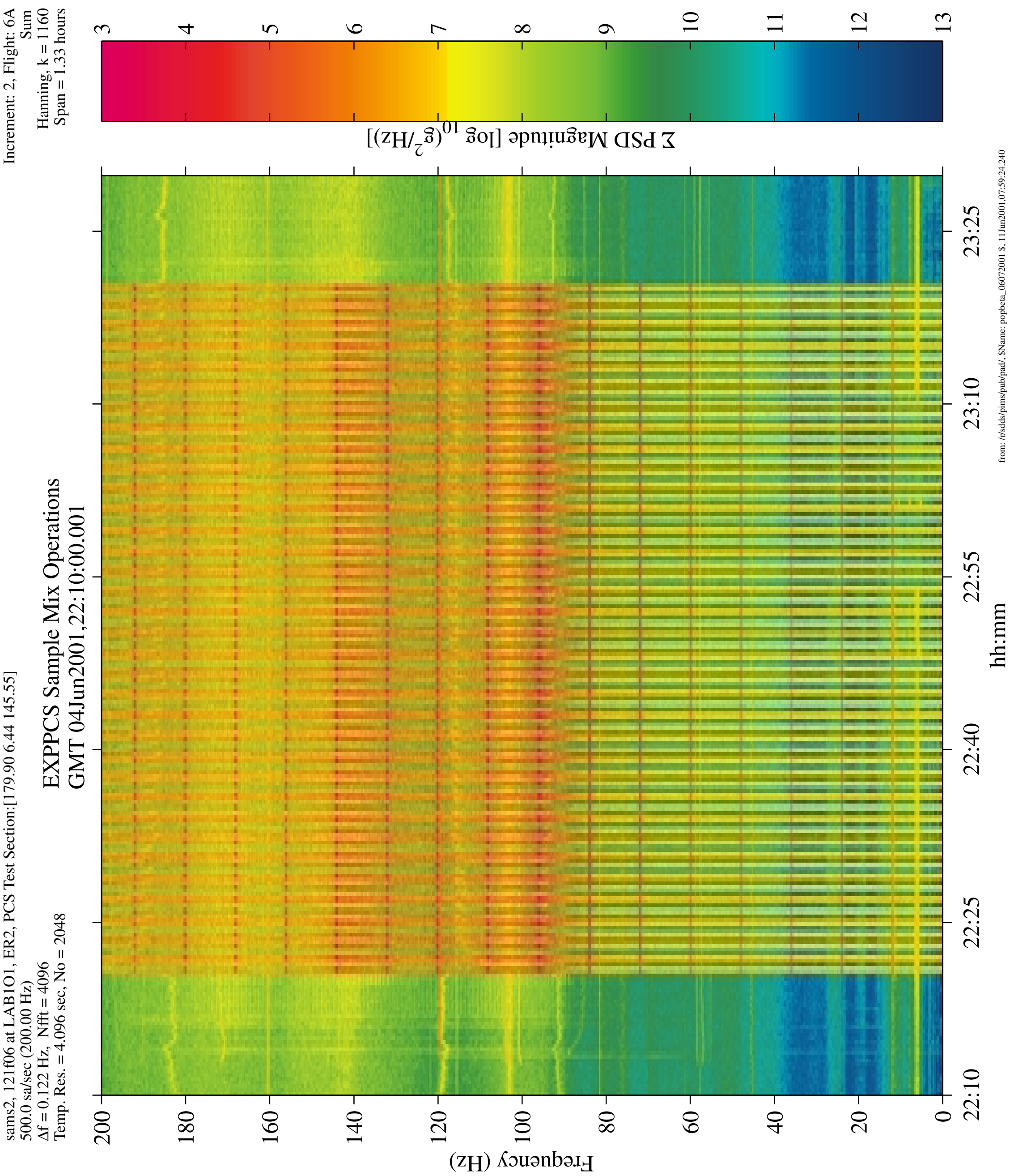

Figure 8.2.2.1-1 Spectrogram of EXPPCS Sample Mix Operation (6A configuration)

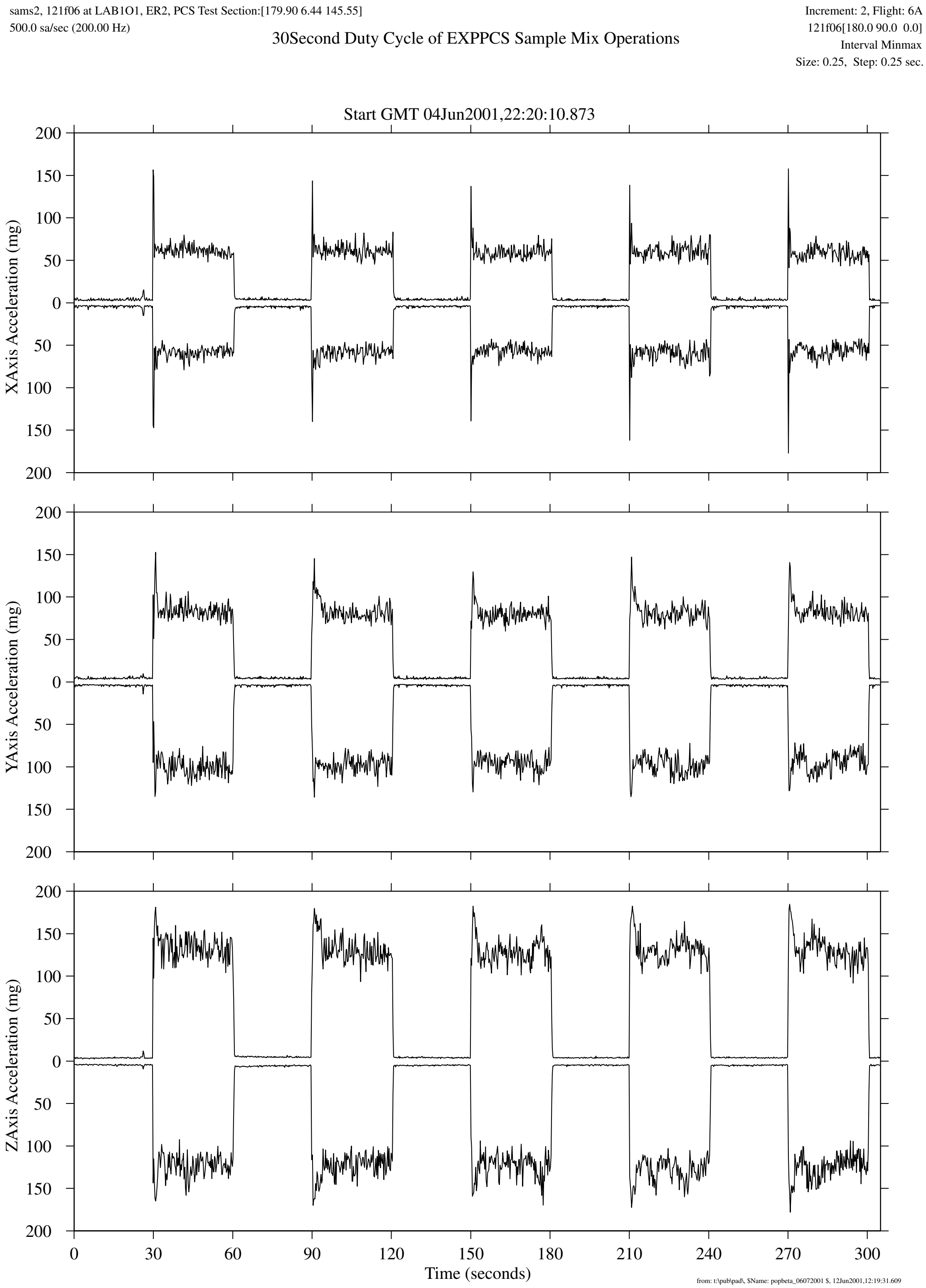

Figure 8.2.2.1-2 Interval Minimum/Maximum of EXPPCS Sample Mix Operation

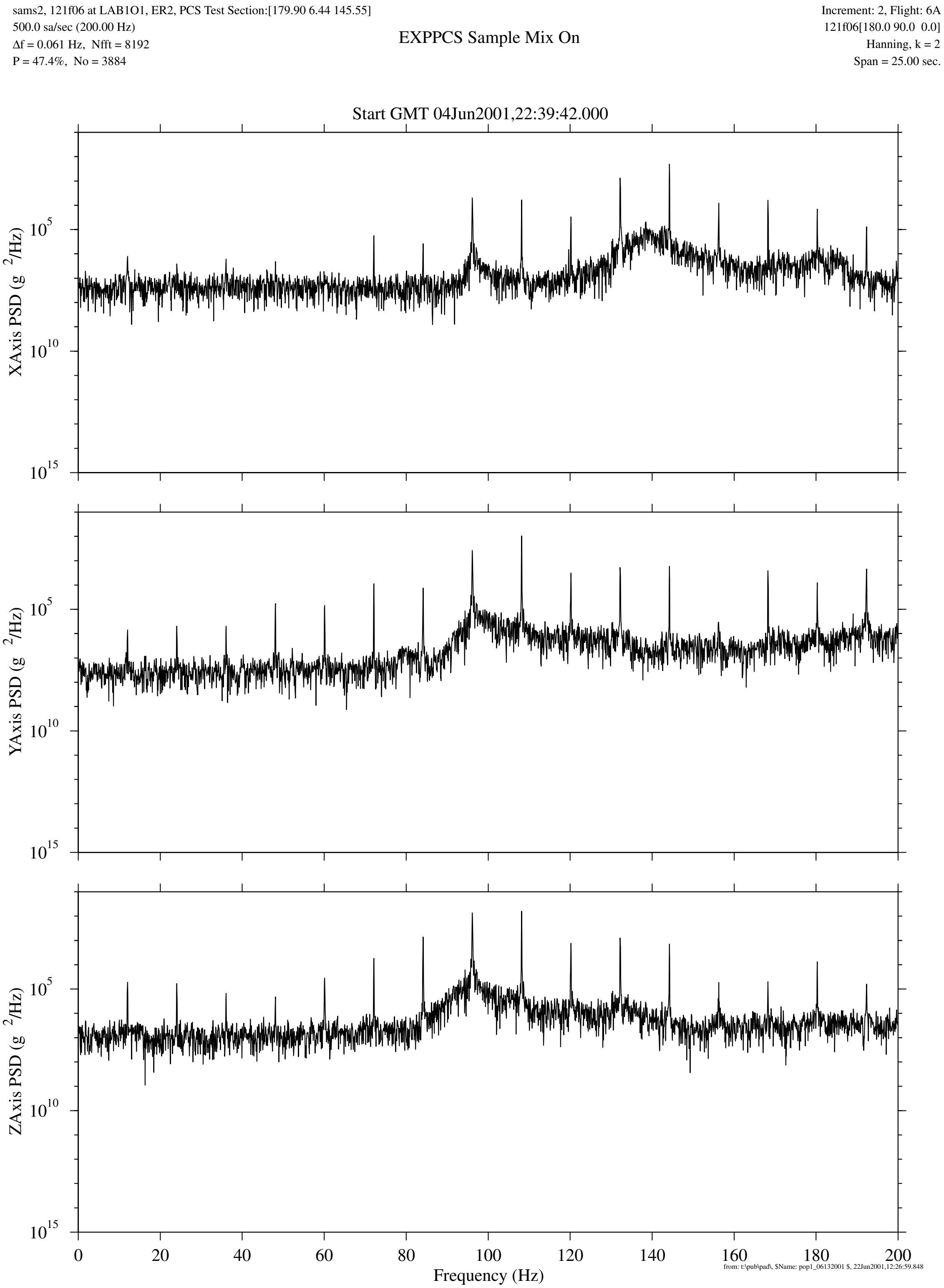

Figure 8.2.2.1-3 PSDs of EXPPCS Sample Mix Operation

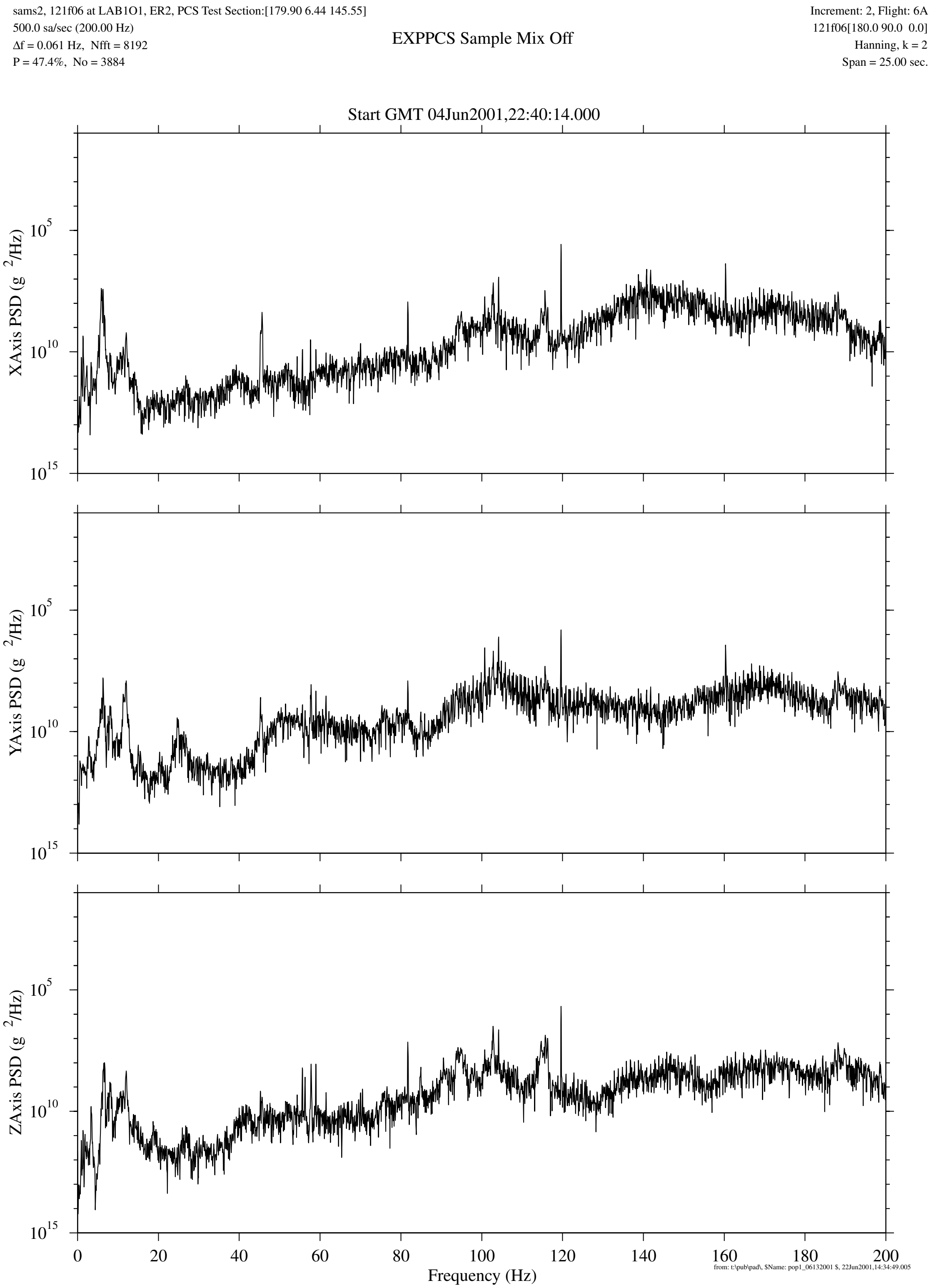

Figure 8.2.2.1-4 PSDs Without EXPPCS Sample Mix Operation

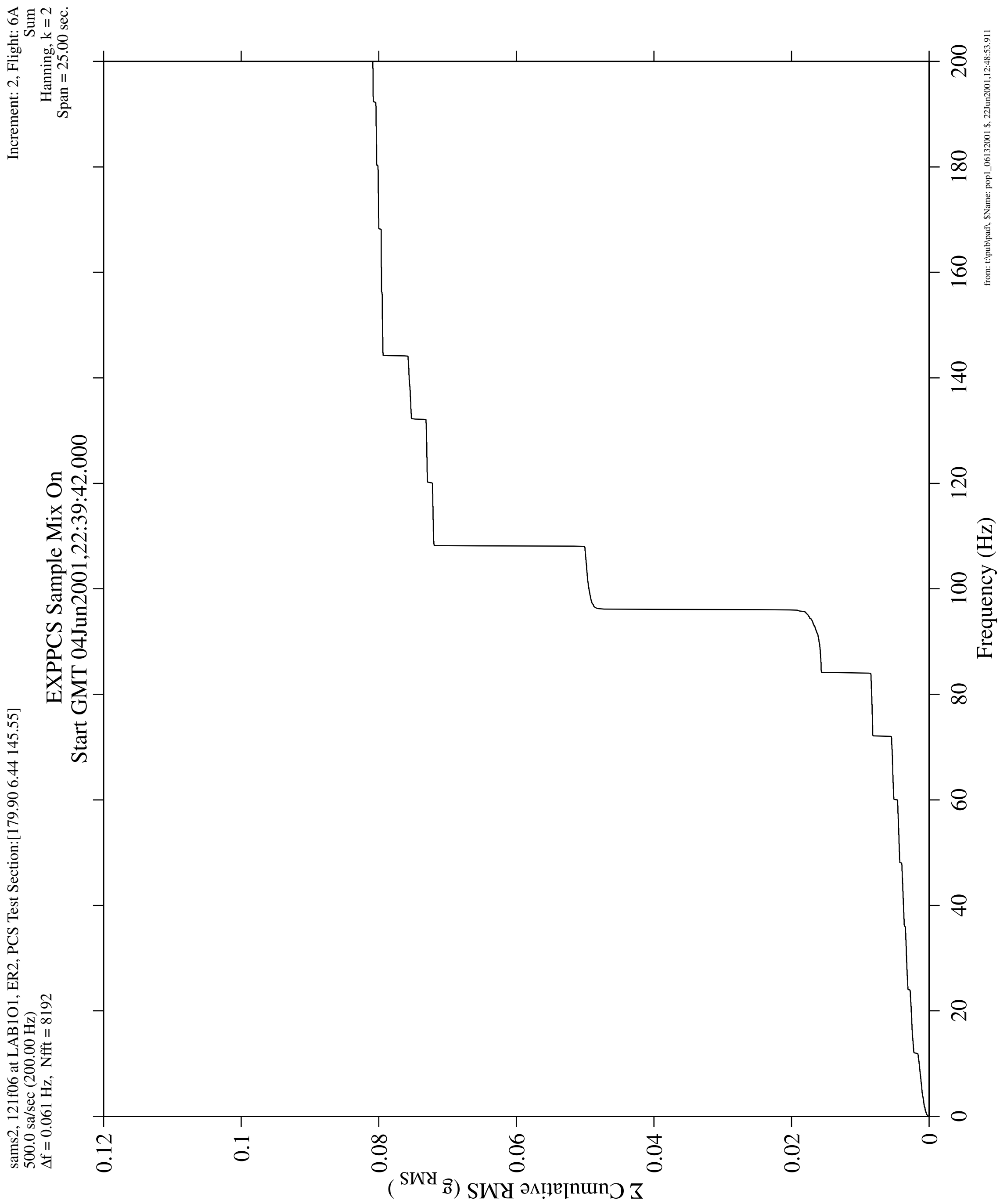

Figure 8.2.2.1-5 Cumulative RMS Acceleration vs. Frequency of EXPPCS Sample Mix Operation

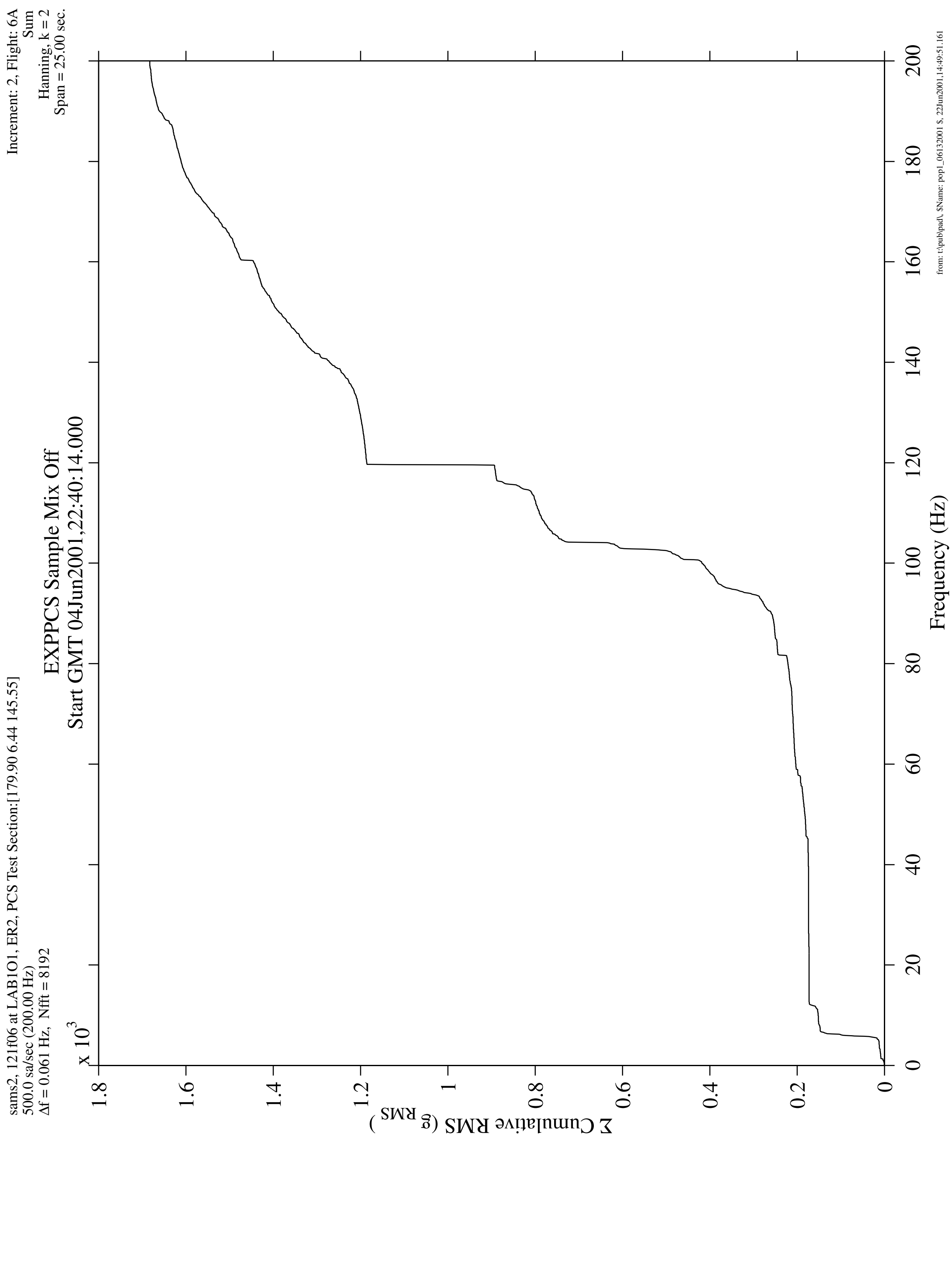

Figure 8.2.2.1-6 Cumulative RMS Acceleration vs. Frequency Without EXPPCS Sample Mix Operation

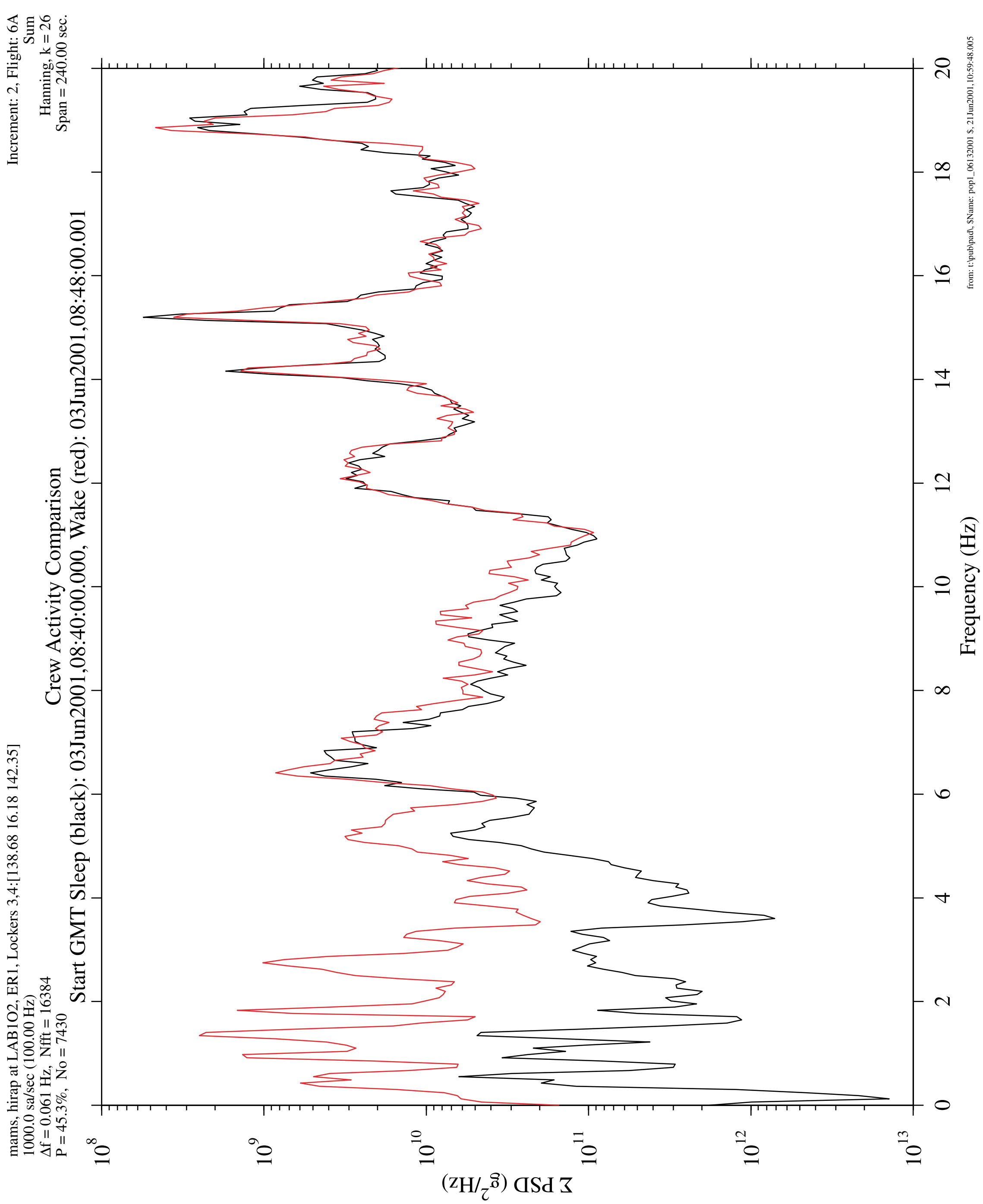

Figure 8.2.3-1 Spectral Comparison of Crew Activity Operation

Appendix A. References

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2. PIMS TSC On-console Logbook, May 2001.

3. International Space Station User's Guide Release 2.0, NASA.

4. Expedition Two (Press Kit): Open for Business- Shuttle Press kit March 6, 2001.0219

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11. Expedition Two Overview Fact Sheet, NASA, March 2001.

12. Microgravity Environment Interpretation Tutorial (MEIT), NASA Glenn Research Center, March 2001.

13. EXPRESS RACKS 1 and 2 Fact Sheet, NASA, February 2001.

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16. Canopus Systems, Inc., OARE Technical Report 149, STS-78 (LMS-1) Final Report, CSI-9604, September 1996.

17. Canopus Systems, Inc., OARE Technical Report 151, STS-94 (MSL-1) Final Report, CSI-9704, August 1997.

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19. Microgravity Analysis Integration Team, “Microgravity Control Plan (Revision B)”, Report No: SSP-50036 B, the Boeing Company, Houston, TX, NASA Contract No. NAS15-1000 (DRIVE-16), February 1999.

20. Bartkowicz, T., “Integrated Loads and Dynamics Verification Plan (Revision A)”, Report No: D684-10288-01, The Boeing Company, Houston, TX, NASA Contract No., NAS15-10000, August 1998.

21. Software Requirements for Processing Microgravity Acceleration Data from the International Space Station, PIMS-ISS-001, May 2000.

Appendix B. On-line Access to PIMS Acceleration Data Archive

On-Line Access To PIMS Acceleration Data Archive

Acceleration data measured by the MAMS and the SAMS on the ISS are available over the Internet via FTP from a NASA GRC file server. The flow chart shown in Figure Appendix B-1 diagrams a procedure that can be used to download data files of interest:

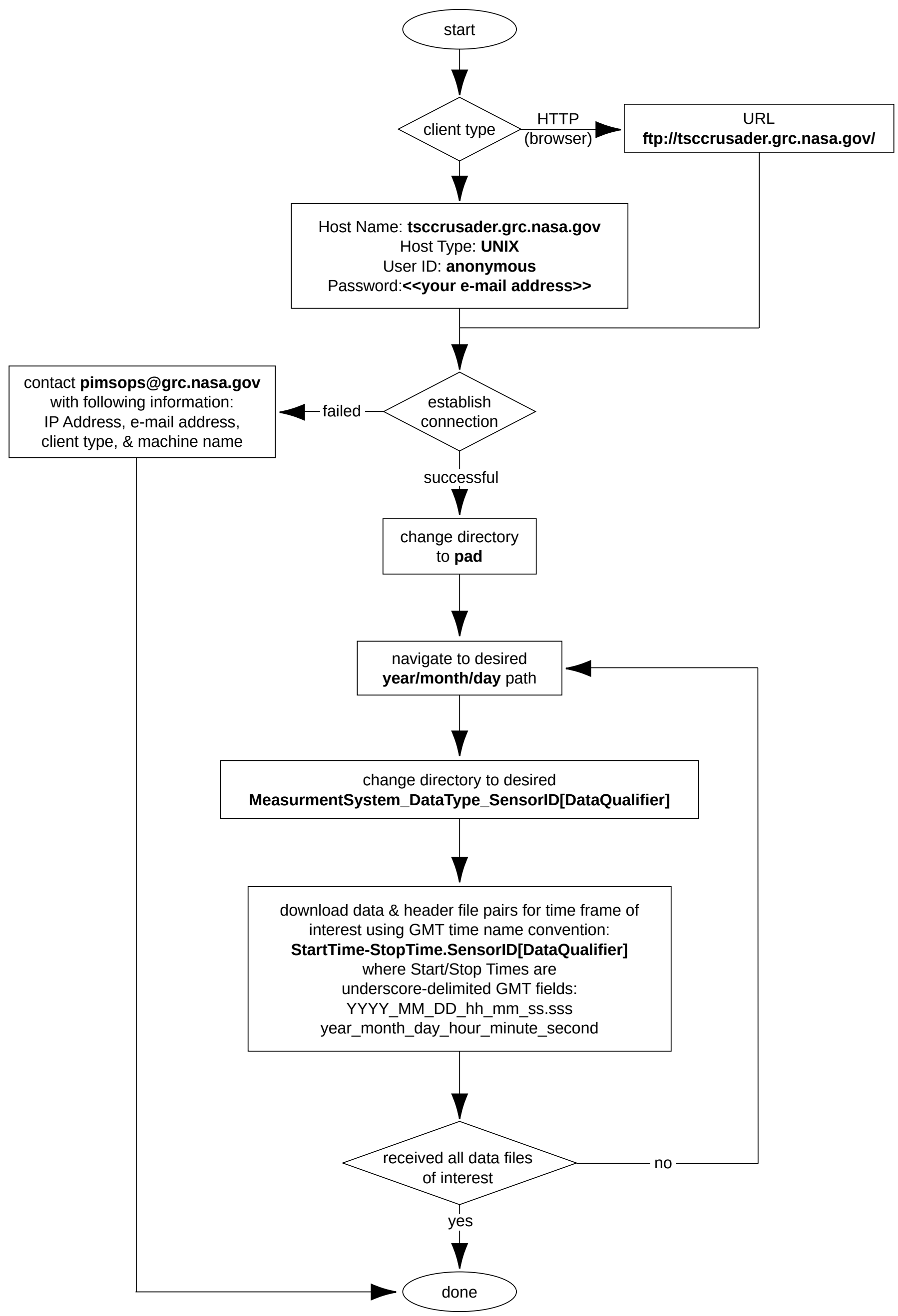

Figure Appendix B-1 On-Line Data Access Flow Chart

A fictitious file listing is shown in Figure Appendix B-2 depicting the PIMS Acceleration Data (PAD) file system hierarchy.

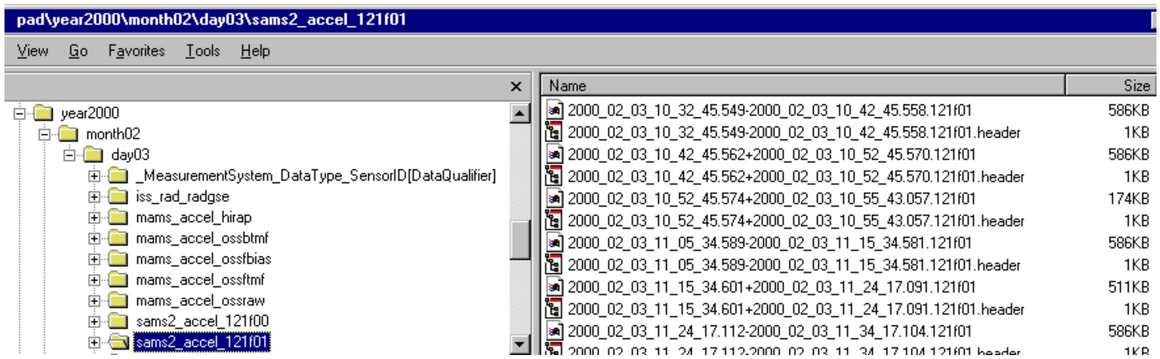

Figure Appendix B-2 Screenshot of Sample PAD File Listing

For the directory highlighted on the left of this sample listing, the measurement system is sams2 and the sensor identifier is 121f01 . On the right, there is a partial listing of the acceleration header and data files available for this sensor collected on the day indicated (day 3). These files are named according to the PIMS-ISS-001 document [21].

If you encounter difficulty in accessing the data using this procedure, then send an electronic mail message to pimsops@grc.nasa.gov. Please describe the nature of the difficulty, and give a description of the hardware and software you are using to access the file server, including the domain name and/or IP address from which you are connecting.

Appendix C. Some Useful Acceleration Data and Microgravity Related URLs

Below is a list of some URLs that the microgravity scientific community might find very useful. They are all microgravity related. NASA does not endorse or cannot be held liable for the information contained on any site, which is not NASA's. The PIMS Project provides this listing only as a service to the microgravity community.

1. For more information on the EXPPCS experiment go to:
   http://microgravity.grc.nasa.gov/6712/PCS.htm

2. For more information on EXPRESS RACK go to:
   http://liftoff.msfc.nasa.gov/Shuttle/msl/science/express.html

3. For more information on ARIS-ICE go to: http://www.scipoc.msfc.nasa.gov

4. For more information on Expedition Two go to:
   http://www1.msfc.nasa.gov/NEWSROOM/background/facts/exp2fact.html

5. For more information on Microgravity Acceleration Measurement go to:
   http://microgravity.grc.nasa.gov/MSD/MSD_htmls/mmap.html

6. For more information on MAMS-OSS, MAMS-HiRAP and SAMS go to:
   http://tsccrusader.grc.nasa.gov/pims

7. For information on MAMS, SAMS data request go to:
   http://tsccrusader.grc.nasa.gov/pims/html/RequestDataPlots.html

8. For information on upcoming Microgravity Environment Interpretation Tutorial (MEIT) go to:
   http://www.grc.nasa.gov/WWW/MMAP/PIMS/MEIT/meitmain.html

9. For information on upcoming Microgravity Meeting Group (MGMG) go to:
   http://www.grc.nasa.gov/WWW/MMAP/PIMS/MGMG/MGMG_main.html

10. For information on SAMS go to:
    http://microgravity.grc.nasa.gov/MSD/MSD_htmls/sams.html

11. For information on MAMS go to:
    http://microgravity.grc.nasa.gov/MSD/MSD_htmls/mams.html

Appendix D. Acronym list and definition

Acronyms used in this Quick Look Report are listed below. A more extensive list of NASA ISS-related acronyms can be found through the Internet at:

http://spaceflight.nasa.gov/station/reference/index.html

ACRONYM	DEFINITION
AAA	Avionics Air Assembly
AOS	Acquisition of Signal
ARIS	Active Rack Isolation System
ARIS-ICE	ARIS ISS Characterization Experiment
CBM	Common Berthing Mechanism
CDRA	Carbon Dioxide Removal Assembly
CMG	Control Moment Gyro
CPCG-H	Commercial Protein Crystal Growth-High Density
ECLSS	Environmental Control and Life Support System
ER 1/2	EXPRESS Rack 1 or 2
ESA	European Space Agency
EVA	Extravehicular Activity
EXPPCS	Experiment of Physics of Colloids in Space
EXPRESS	Expedite the Processing of Experiments to the Space Station
FGB	Functional Cargo Block (Russian translation: Functionalui Germatischeskii Block)
g	Gravity (9.81 m/s^2)
GMT	Greenwich Mean Time
GRC	Glenn Research Center
GSE	Ground Support Equipment
HiRAP	High Resolution Accelerometer Package
Hz	Hertz
ICU	Interim Control Unit
IMV	Intermediate Ventilation System
ISS	International Space Station
JSC	NASA Johnson Space Center
KSC	Kennedy Space Center
LAB	U. S. Laboratory Module
LOS	Loss of Signal
LVLH	Local Vertical Local Horizontal
MAMS	Microgravity Acceleration Measurement System
MCA	Major Constituent Analyzer
MEWS	Mission Evaluation Workstation System
MMAP	Microgravity Measurement and Analysis Project
MPLM	Mini Pressurized Logistics Module or Multipurpose Logistics Module
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
OARE	Orbital Acceleration Research Experiment
OSS	OARE Sensor Subsystem
PAD	PIMS Acceleration Data

PAO	Public Affairs Office
PDSS	Payload Data Services System
PI	Principal Investigator
PIMS	Principal Investigator Microgravity Services
PMA	Pressurized Mating Adapter
PSD	Power Spectral Density
PV	Photovoltaic
QTH	Quasi-steady Three-Dimensional Histogram
RMS	Root-Mean-Square
RSS	Root-Sum-Square
RTS	Remote Triaxial Sensor
SAMS	Space Acceleration Measurement System
SE	Sensor Enclosure
SO	Starboard Truss Segment 0
SSRMS	Space Station Remote Manipulator System
STS	Space Transportation System
TCS	Temperature Control System
TEA	Torque Equilibrium Attitude
THC	Temperature/Humidity Control System
TMF	Trimmean Filter
TSC	Telescience Support Center
VS	Vacuum System
XPOP	X Principal Axis Perpendicular to the Orbit Plane
XVV	X body axis toward the Velocity Vector
μg	Microgravity ($10E^{-6}$ g)
WSS	Water Separator System
WWW	World Wide Web