Section 21:

Microgravity Acceleration Environment of the International Space Station

Quasi-steady Regime

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Components of Quasi-steady Environment

- **Frequency content: DC to 0.01 Hz**
- **Magnitude typically 5 μg or less.**
- **Three main components of QS Vector**
  - **Aerodynamic Drag**
    - Attitude
    - Atmospheric density (time and altitude dependent)
    - ISS Configuration
  - **Rotational Effects**
    - Attitude
    - Angular velocity
    - Position relative to ISS Center of Mass
  - **Gravity Gradient**
    - Attitude
    - Position relative to ISS Center of Mass

- **Disturbances in the Quasi-Steady Environment**
  - **Crew Activity Effects**
  - **Air and Water Venting**
  - **EVA/SSRMBS Operations**
  - **Miscellaneous**

Space Station Analysis Coordinate System

- **PIMS uses Space Station Analysis Coordinate System (SSA) as a reference to define all its coordinate systems and sensor locations.**
- **Quasi-steady plots for ISS Increment Reports are generally displayed in SSA coordinates.**
- **Definition of the SSA coordinate system is found in Figure 1.**
  - **Taken from SSP 30219, Rev F, "Space Station Reference Coordinate Systems".**

Torque Equilibrium Attitude

- **Torque Equilibrium Attitude (TEA) is an "airplane like" attitude maintained relative to Local Vertical Local Horizontal (LVLH), a rotating coordinate system. (Figure 2)**

- **+XVV +ZLV, Station X-axis towards velocity vector, station Z-axis towards nadir.**

- **Actual orientation is dependent on ISS configuration.**
  - **For Most Recent Increments (4-6) YPR ≈ (350,352,0).**
  - **For Past Increments (2-3) YPR ≈ (350,350,0).**

Plots of Torque Equilibrium Attitude

- **Figure 3 is a time series from a TEA period during crew sleep.**
  - **Quasi-steady acceleration magnitude about 1.1 μg**
  - **Distance of MAMS OSS from ISS Center of Mass = [-42.8   0.57   10.3] (ft)**
  - **Red line is an estimate of the quasi-steady vector at the center of mass.**
- **Even though the MAMS location is furthest away in the X-axis, the difference between the CM location and the MAMS location X-axis accelerations is small. In the flight direction of TEA, the gravity gradient component cancels out the rotational component.**

X-axis Perpendicular to Orbital Plane (XPOP)

- ISS orientation is maintained relative to an inertial frame of reference. X-axis is perpendicular to orbital plane (Figure 4).

- Necessary for power generation and Beta Gimbal Assembly (BGA) life. BGA rotates the solar arrays.

- Rotational components are small compared to gravity gradient and drag.

Plots from XPOP

- Figure 5 is a time series during crew sleep when the ISS was in XPOP attitude. Y and Z components show cyclical variation as they are alternately subjected to the drag and gravity gradient vectors.

- Comparing the CM location to the MAMS OSS location in Figure 5, it can be seen that the X-direction component is almost completely due to gravity gradient effects (in XPOP, the ISS attitude is maintained relative to inertial space, therefore small rotational components).
  - X component dominates mean (~2 μg)
  - Y and Z vary between ± 1 μg

Effect of Crew Activity

- **Crew activity masks the quasi-steady vector.**
  - **Crew activity causes increased variation in quasi-steady vector.**

- **Figure 6: QTH Summary Plot of Crew Active Periods for TEA**
- **Figure 7: QTH of a Compilation of Crew Sleep Periods for TEA**
- **Figure 8: QTH Summary Plot of Crew Active Periods for XPOP**
- **Figure 9: QTH of a Compilation of Crew Sleep Periods for XPOP.**
  - **Without crew effects the characteristic "ring" profile is seen in the YZ plane.**

Effect of Crew Activity

•Extravehicular Activities (EVA)

- **EVAs seen to date have many disturbances yet to be characterized. These disturbances can be seen in Figure 10 to be on the order of 10-20 μg in the Y and Z axes.**

- **Dependent on activities performed**
  - Attitude changes
  - Space Station Remote Manipulator System (SSRMBS or Canadarm)
  - Airlock depressurization
  - Crew motion

- **Prior to Russian EVA 7 During Increment 5, the DC-1 airlock had to be depressurized twice due to the misconfiguration of an Orlan spacesuit.**
- **Figure 11 shows the dual-depressurizations evident in the X-axis.**
- **Figure 12 correlates the X-axis accelerations with DC-1 pressure data during the depressurizations.**

Venting Operations

- **Venting Operations are sometimes accompanied by attitude maneuvers.**
- **US Lab Condensate Water Dump (Figure 13)**
  - **Prior to water dump, ISS was maneuvered to an attitude that placed the vent in a retrograde (opposite velocity vector) position to minimize contamination (Yaw, Pitch, Roll) = [273., 356.7, 307.0].**
  - **Vent orientations**
    - **Lab2A: [0 -0.61 -0.79]**
    - **Lab2B: [0 0.61 0.79]**
  - **Vent is a non-propulsive T-type, however some propulsive effect is seen. About 6μg disturbance in negative Z-axis.**
- **Progress 5P fuel line purge (Figure 14)**
  - **Two stages**
    - fuel purge
    - oxygen purge
  - **Attitude hold**
  - **3-4 μg transient disturbances in Y and Z axes.**

Vehicle Dockings

- **ISS has frequent visitors**
  - **Russian Vehicles (Progress and Soyuz) and STS (Shuttle)**

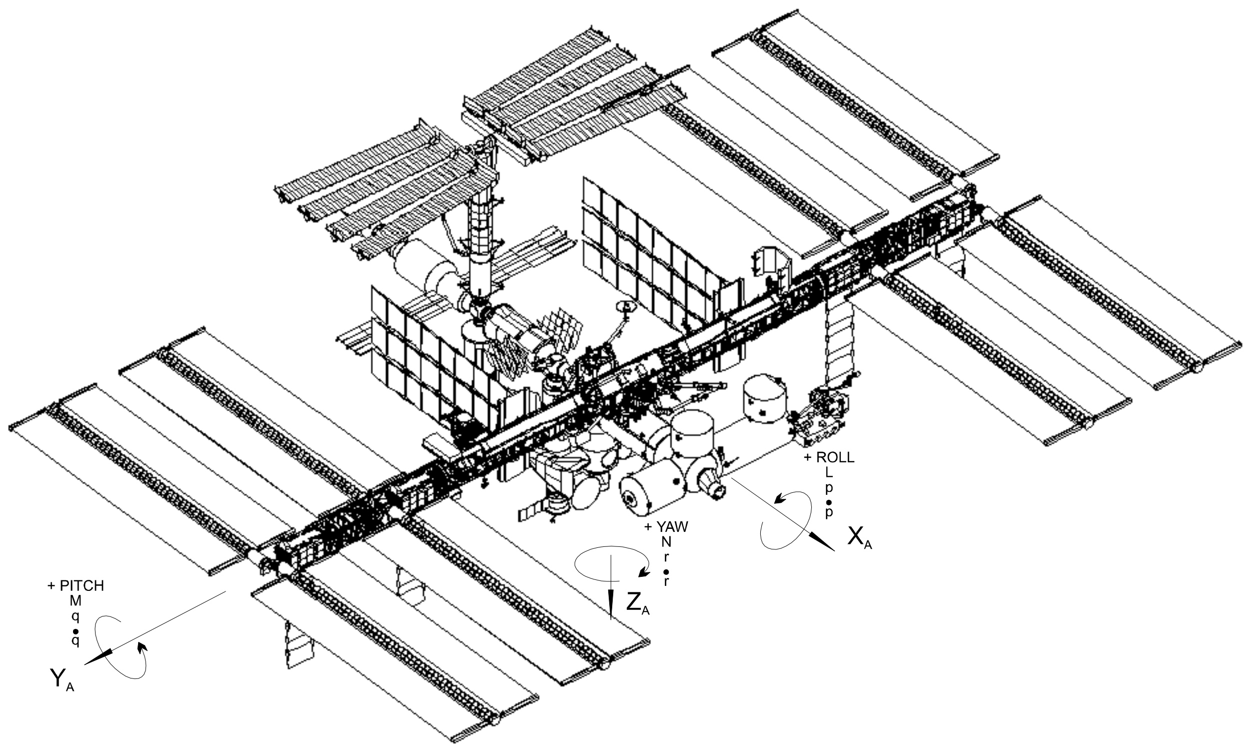
- **Large disturbances during attitude maneuvers to docking attitude.**
  - **Progress and Soyuz have small Center of Mass change (1-2 ft).**
  - **Shuttle has large CM change.**

- **Grab bag of Vehicle Dockings**
  - **Progress 8P Undocking (Figure 15)**
    - Attitude change from YPR=[359,355,3] to YPR=[180 0 73] (Also includes a relaxation attitude YPR=[180 90 0] after undock for Russian test.)
  - **Progress 7P Docking (Figure 16)**
    - Attitude change to an inertial attitude.
  - **STS-112 Docking Event (Figures 17 and 18)**
    - Large thruster firings evident in TMF data. Smaller ones are masked by the Trimmed Mean Filter process.

Docked Operations

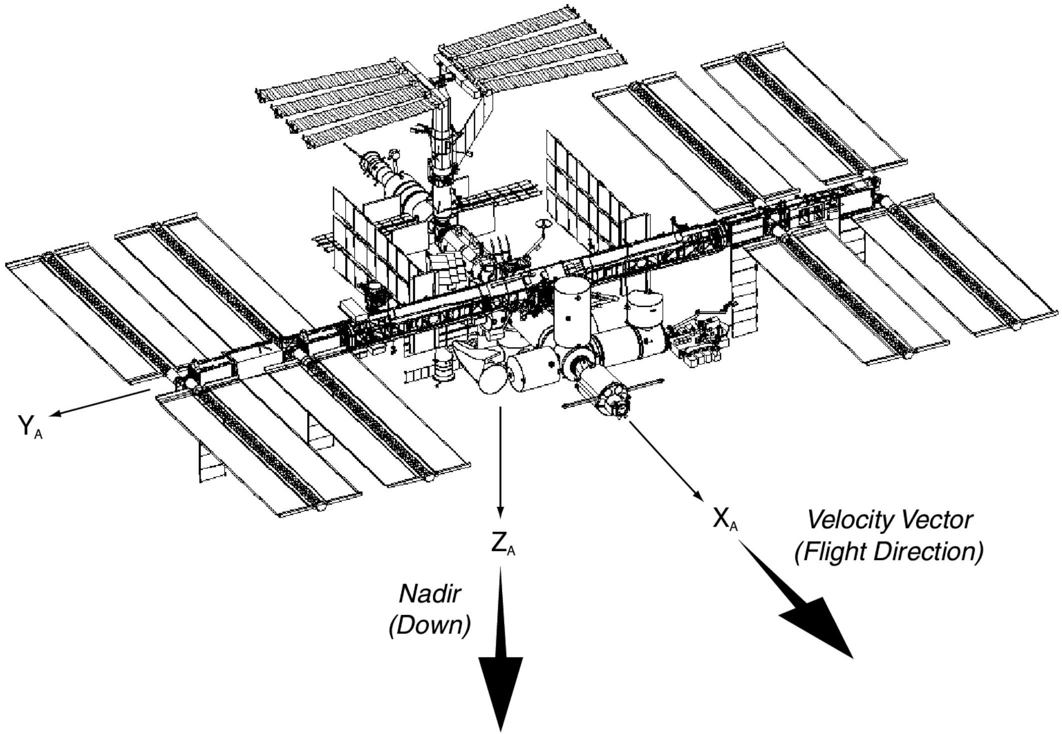
- **STS-112 Docking/Joint Operations (Figures 19 and 20)**

- **Differences in Quasi-steady vector due to increased drag, change in center of mass, new attitude.**
  - **Multiple CM location changes due to installation of S1 truss**
    - **Before Rendezvous [-33.47 3.70 7.84]**
    - **After Rendezvous (before installation) [-5.95 0.18 28.05] ***
    - **Intermediate (after installation) [-7.54 2.30 25.71]***
      - * estimate from ISS Mass Properties Databook
  - **Nominal Attitude**
    - **Before docking YPR = (350,352,0).**
    - **After docking YPR = (358,24,355)**
    - **Multiple attitude changes for reboosts, water dumps, etc.**

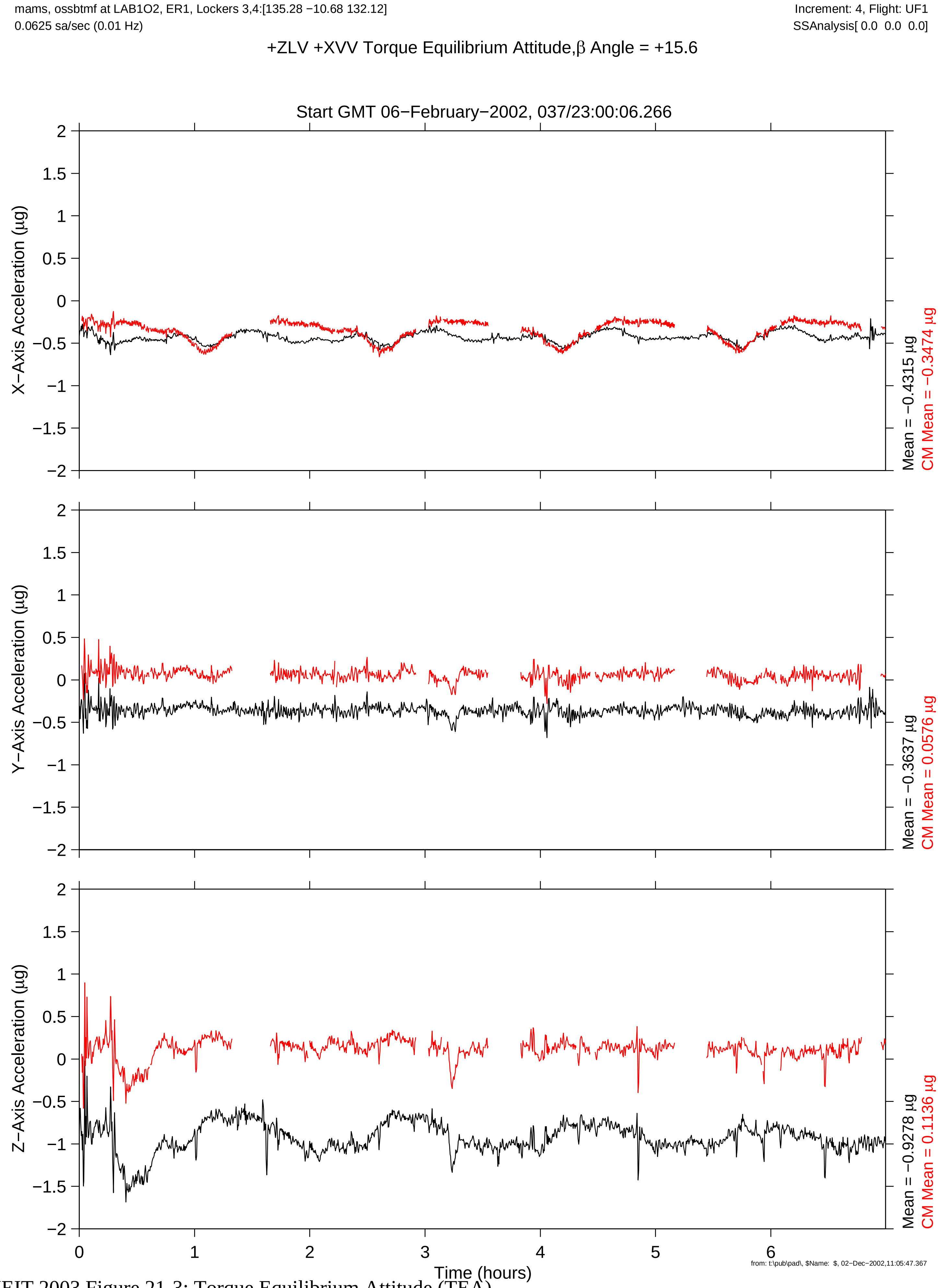


NAME:	Space Station Analysis Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	This coordinate system is derived using the Local Vertical Local Horizontal (LVLH) flight orientation. When defining the relationship between this coordinate system and another, the Euler angle sequence to be used is a yaw, pitch, roll sequence around the Z_A, Y_A, and X_A axes, respectively.
ORIGIN:	The origin is located at the geometric center of Integrated Truss Segment (ITS) S0 and is coincident with the S0 Coordinate frame. See figure 5.0–12, S0 coordinate frame for a more detailed description of the S0 geometric center.
ORIENTATION:	X_A The X–axis is parallel to the longitudinal axis of the module cluster. The positive X–axis is in the forward direction. Y_A The Y axis is identical with the S_O axis. The nominal alpha joint rotational axis is parallel with Y_A. The positive Y–axis is in the starboard direction. Z_A The positive Z–axis is in the direction of nadir and completes the right–handed Cartesian system. L, M, N: Moments about X_A, Y_A, and Z_A axes, respectively. p, q, r: Body rates about X_A, Y_A, and Z_A axes, respectively. $\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_A, Y_A, and Z_A axes, respectively.
SUBSCRIPT:	A

MEIT 2003 Figure 21-1: Space Station Analysis Coordinate System

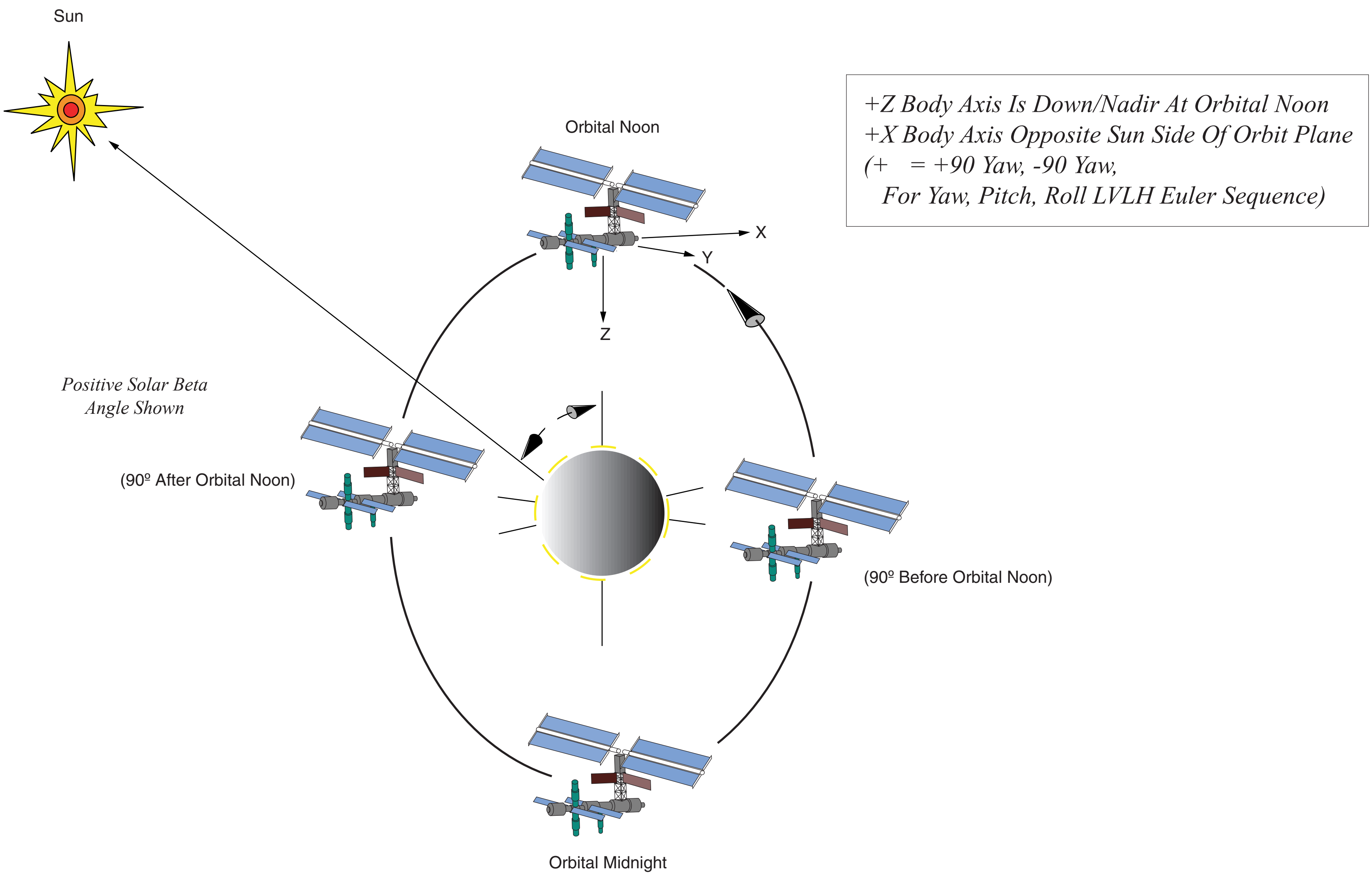


MEIT 2003 Figure 21-2: Local Vertical Local Horizontal (LVLH) Attitude

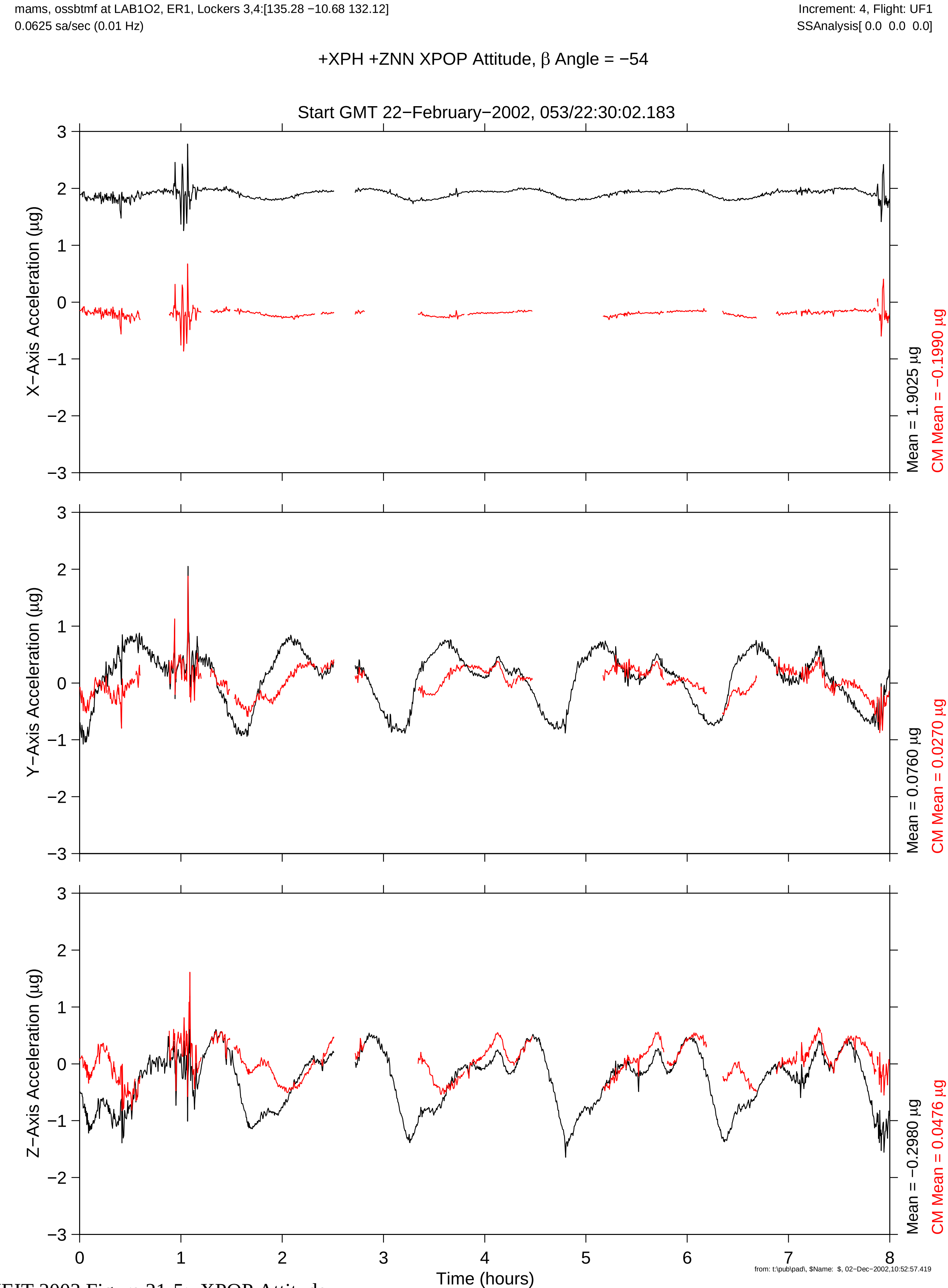


MEIT 2003 Figure 21-3: Torque Equilibrium Attitude (TEA)

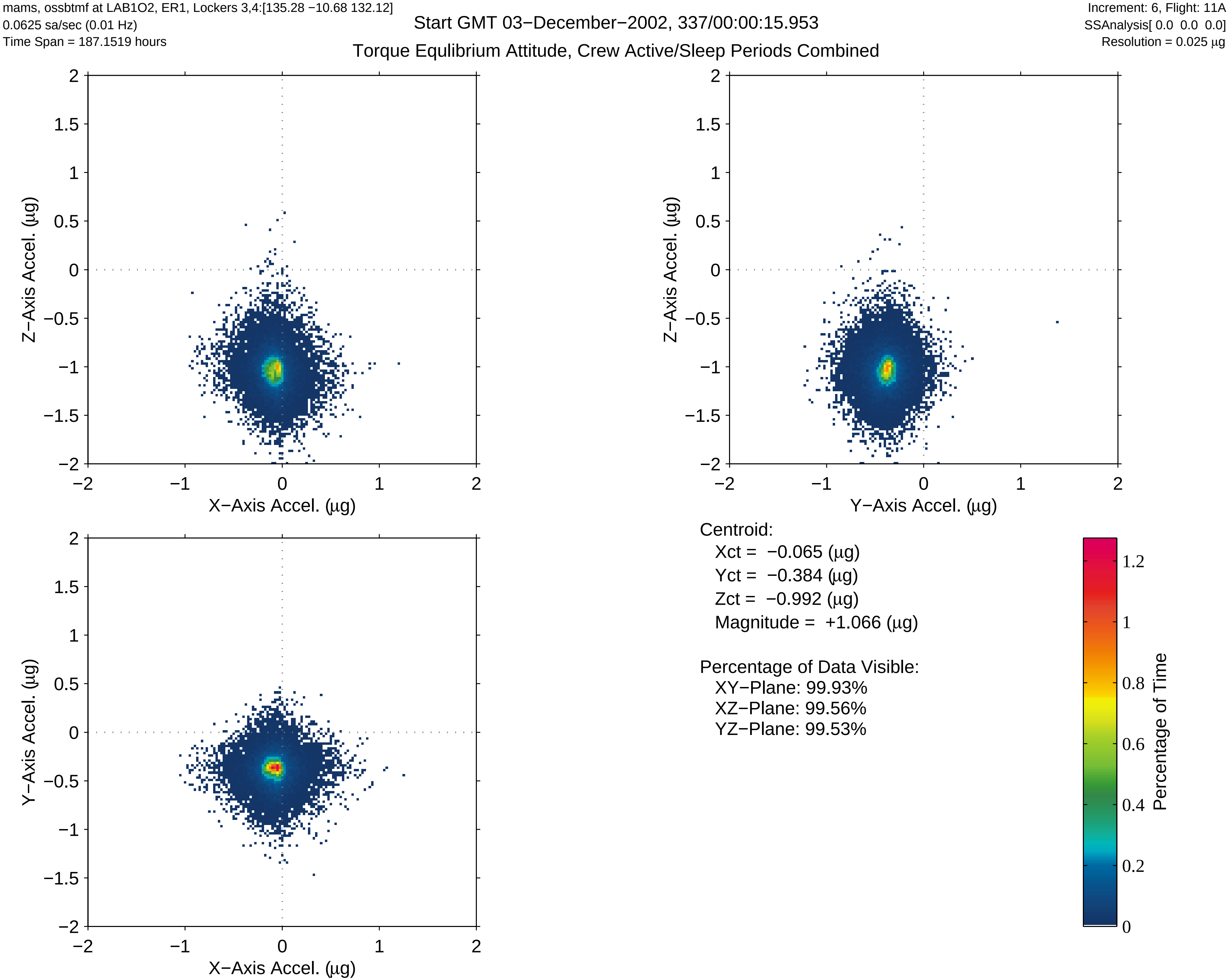
Inertial Attitude With The X Principal Axis Perpendicular to Orbit Plane, Z Nadir At Noon



MEIT 2003 Figure 21-4: X-Axis Perpendicular to Orbital Plane (XPOP) Attitude



MEIT 2003 Figure 21-5: XPOP Attitude



MEIT 2003 Figure 21-6: Torque Equilibrium Attitude (TEA), Crew

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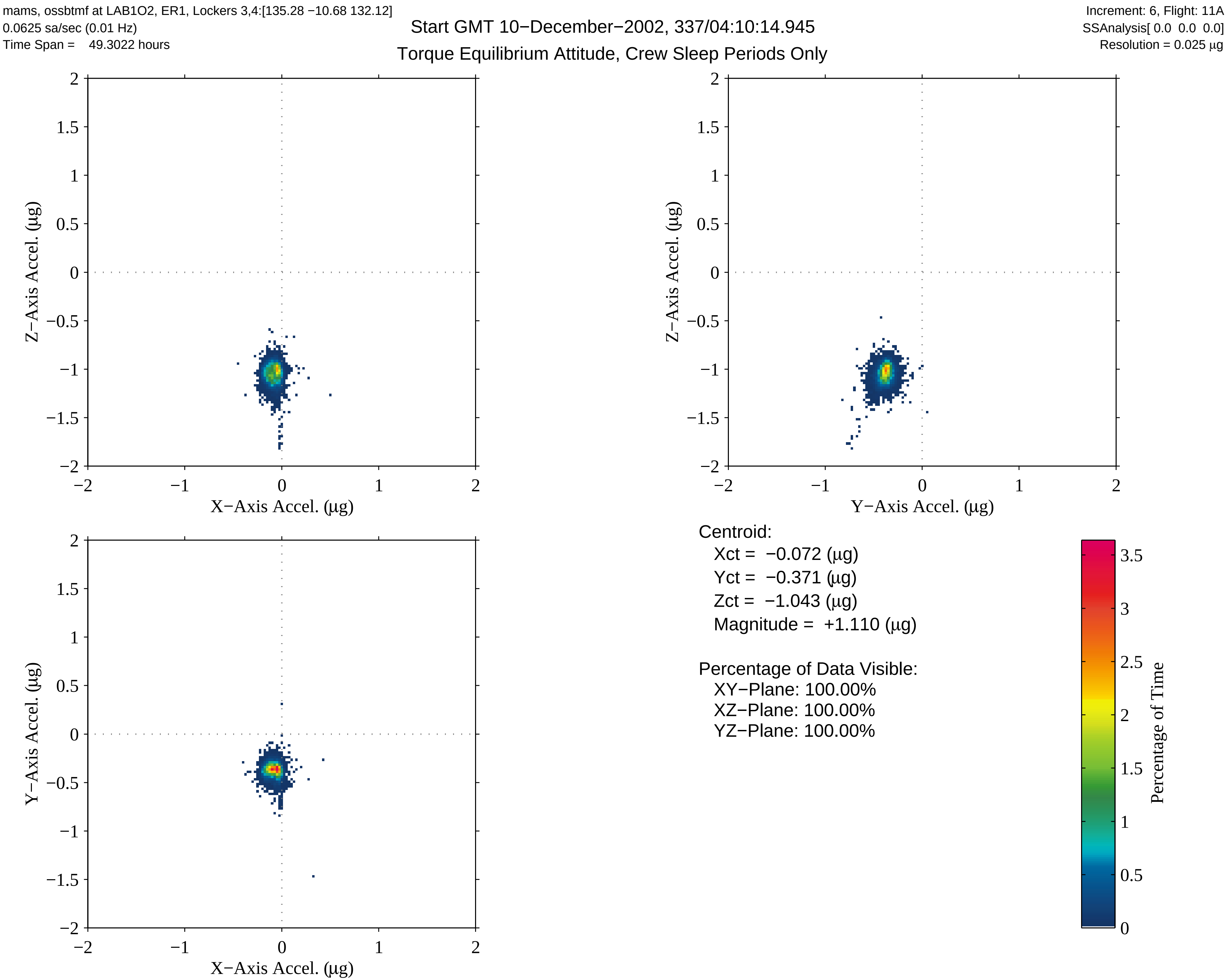

MEIT 2003 Figure 21-7: Torque Equilibrium Attitude (TEA), Crew Sleep

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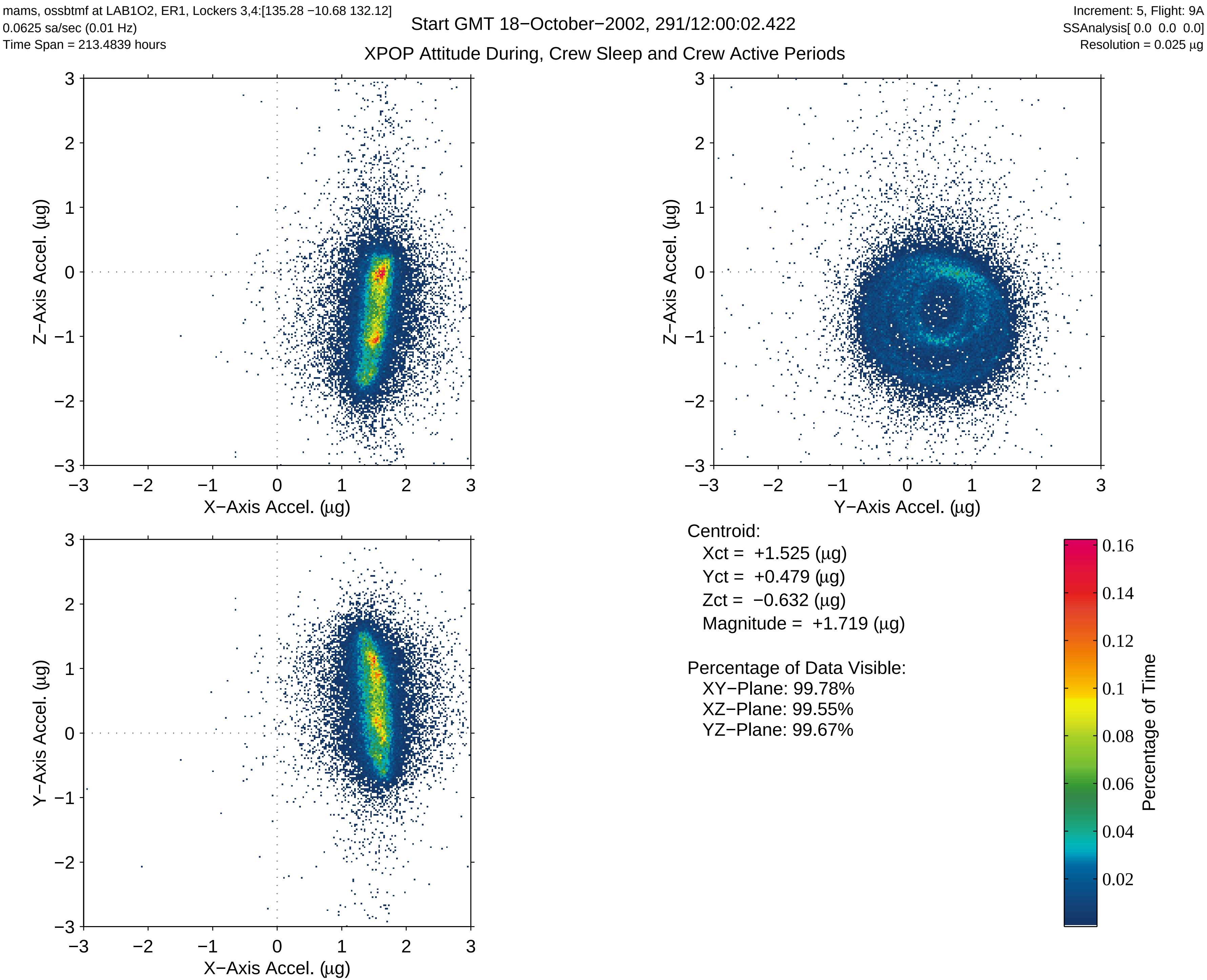

MEIT 2003 Figure 21-8: XPOP Attitude, Crew Active

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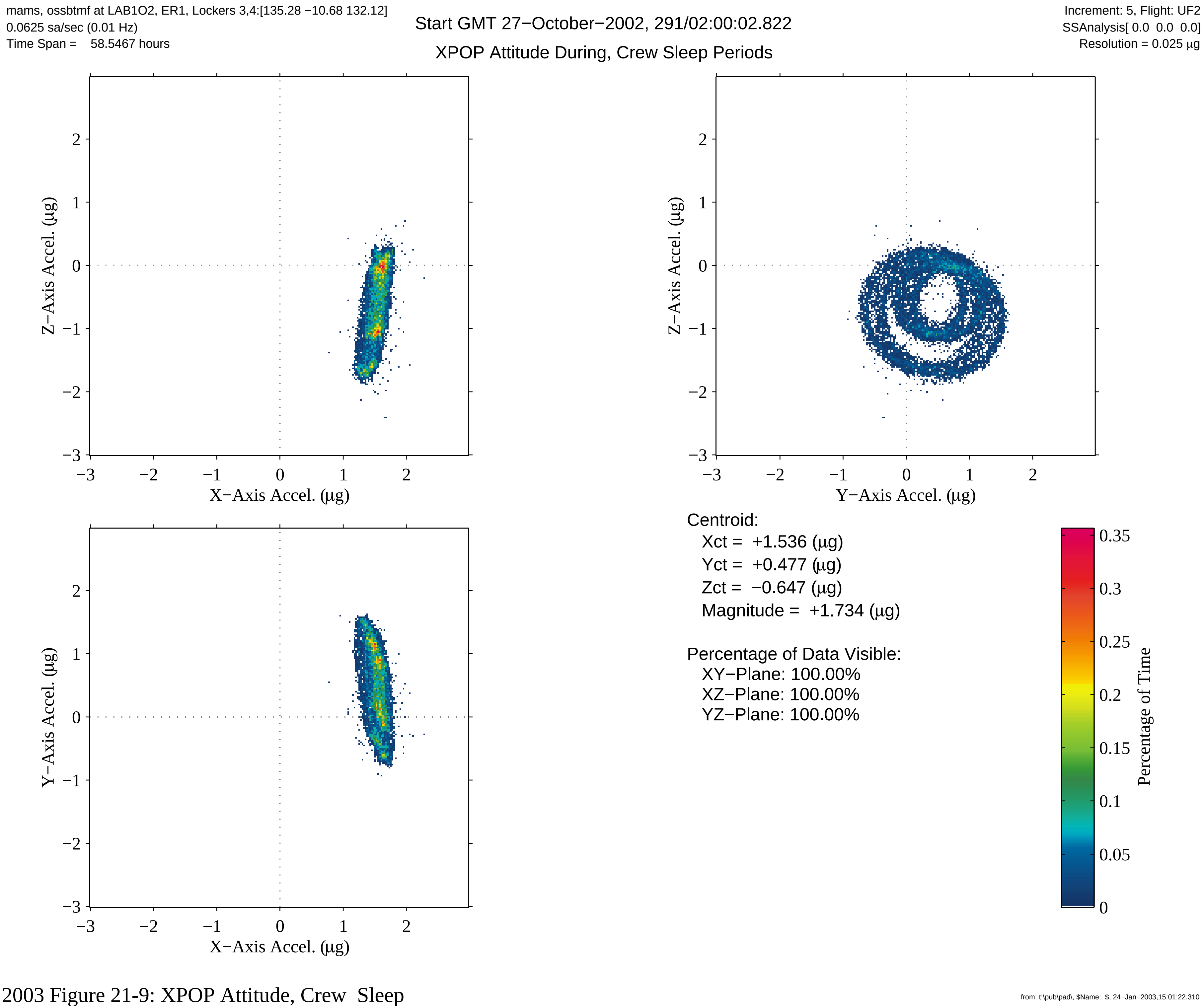
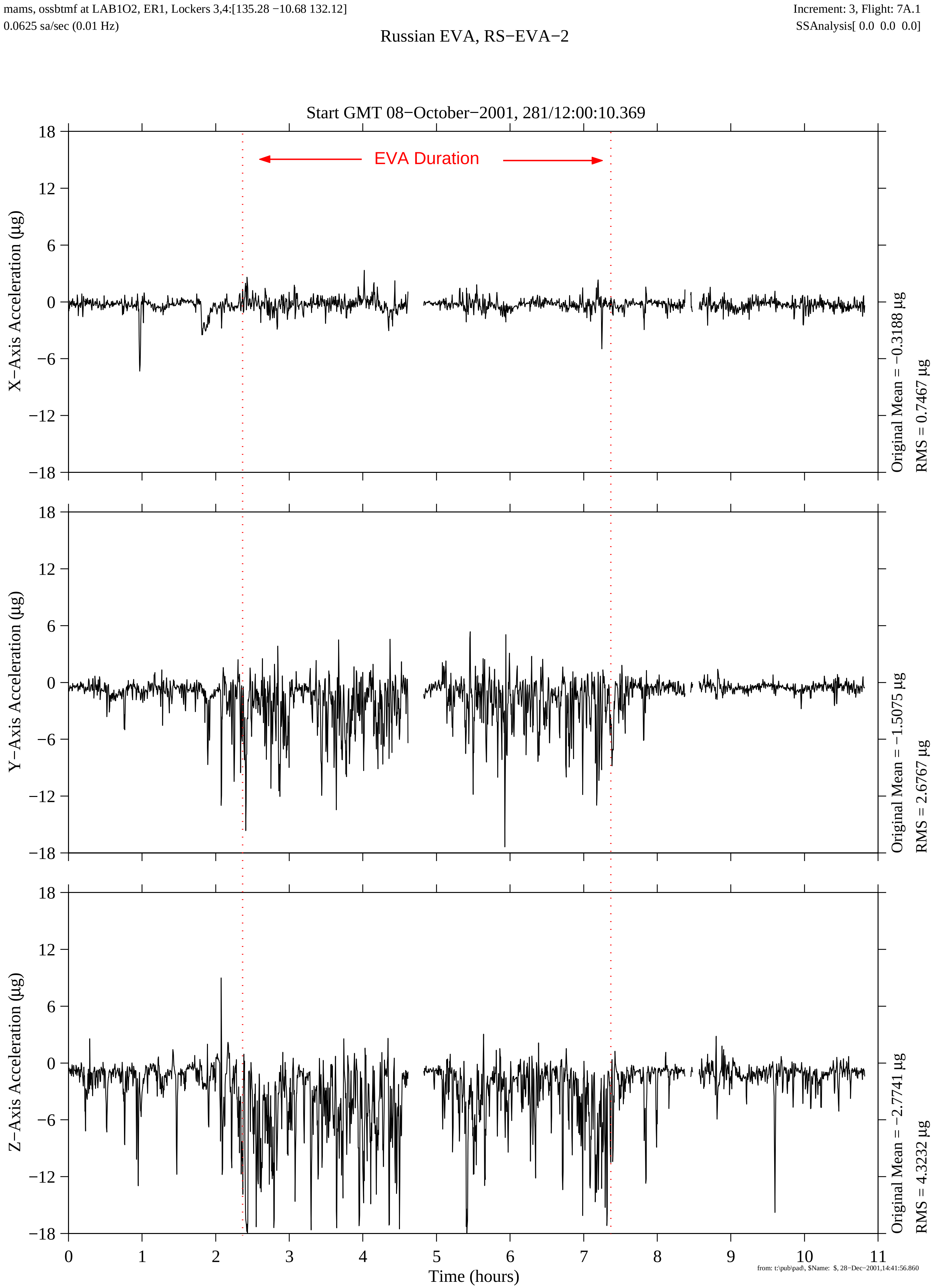
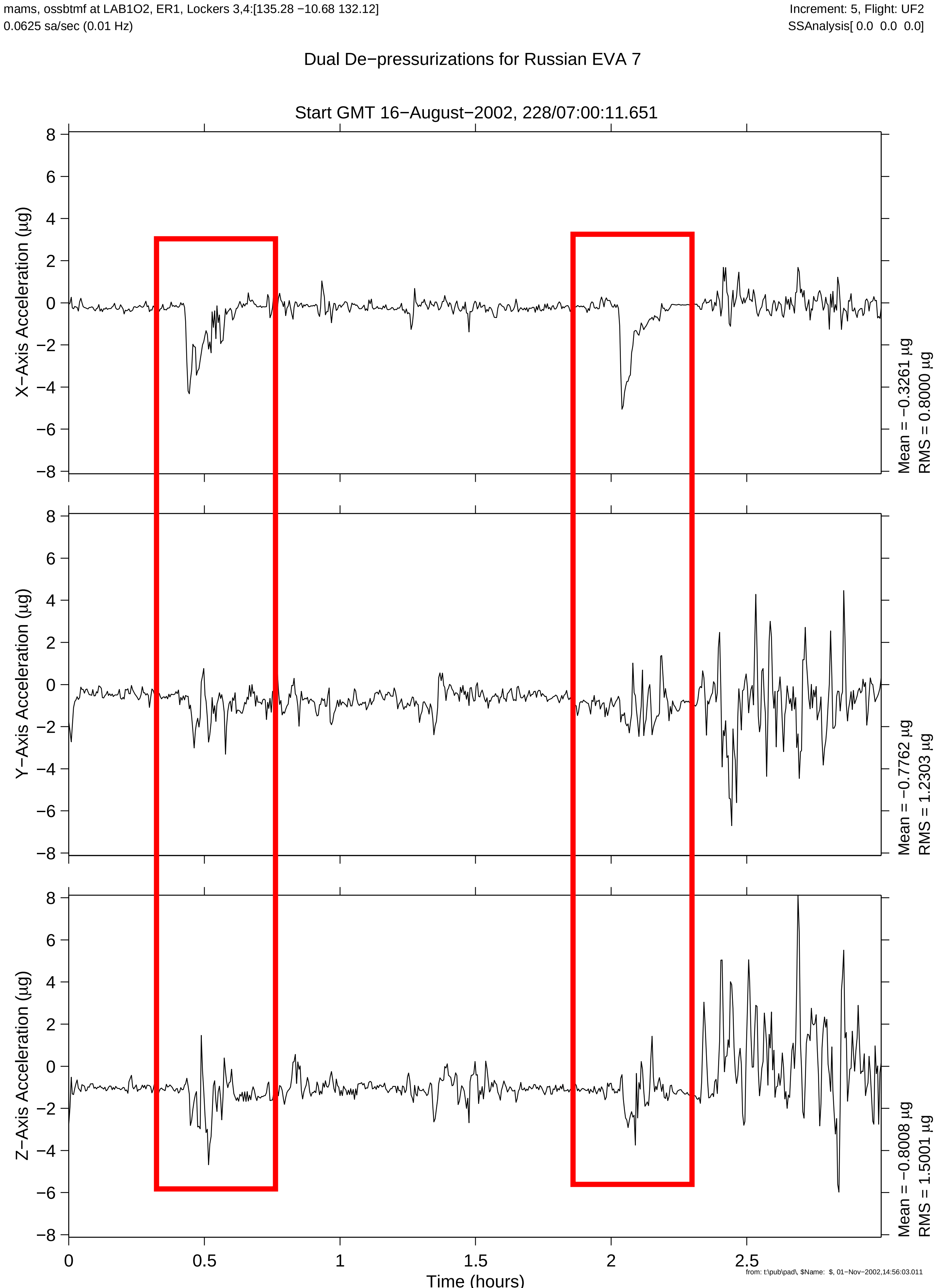


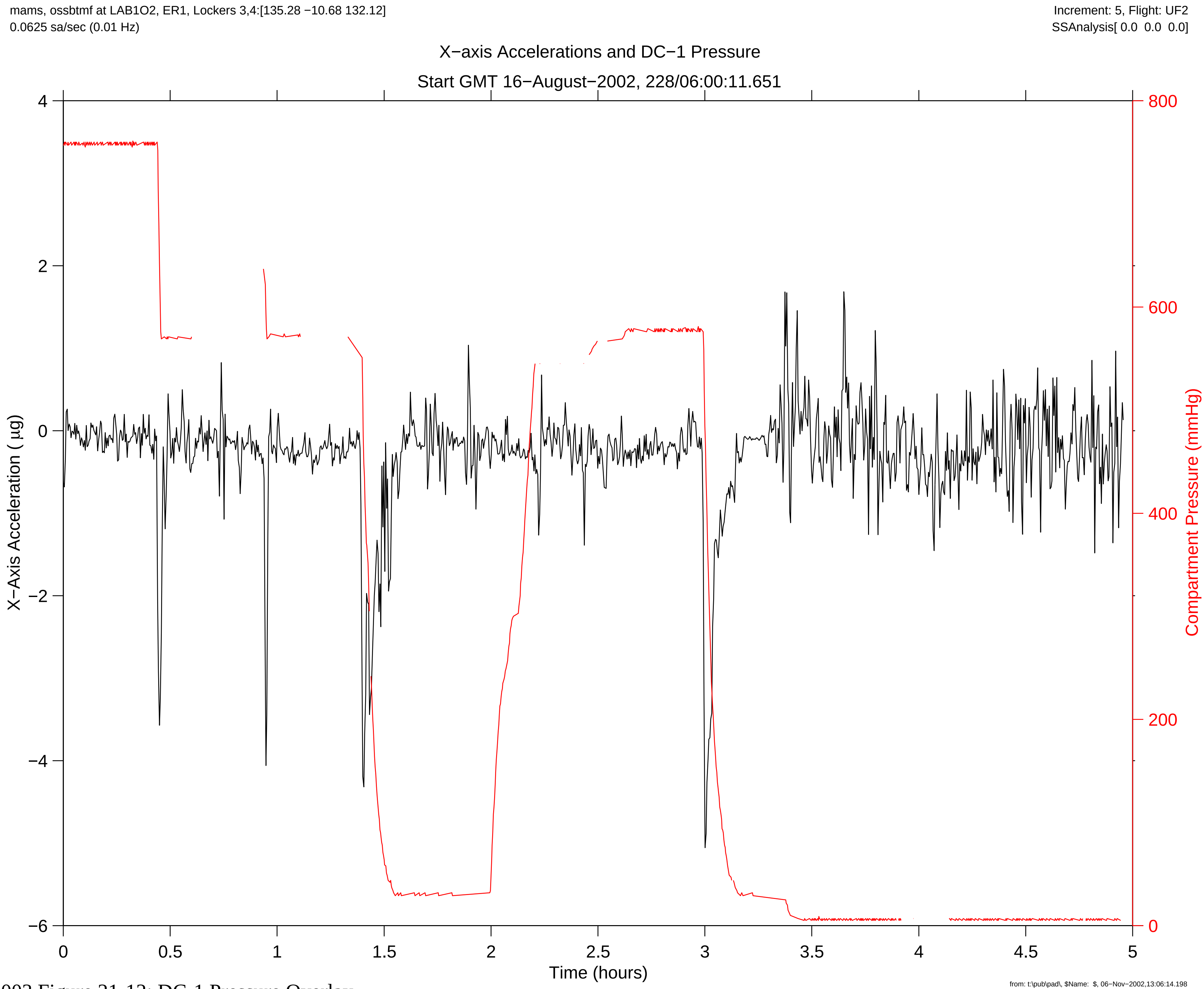
MEIT 2003 Figure 21-9: XPOP Attitude, Crew Sleep



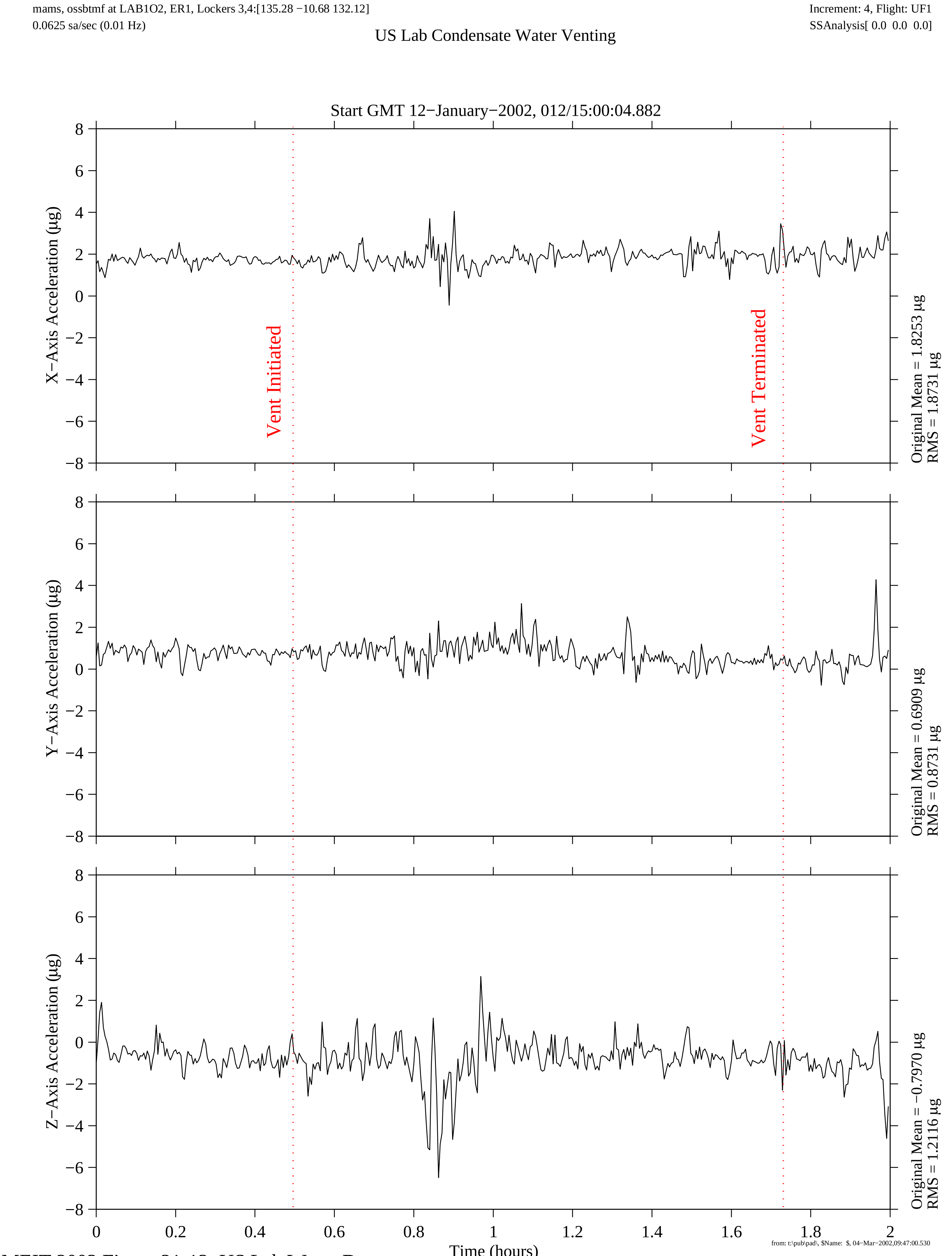
MEIT 2003Figure 21-10: Russian EVA-2



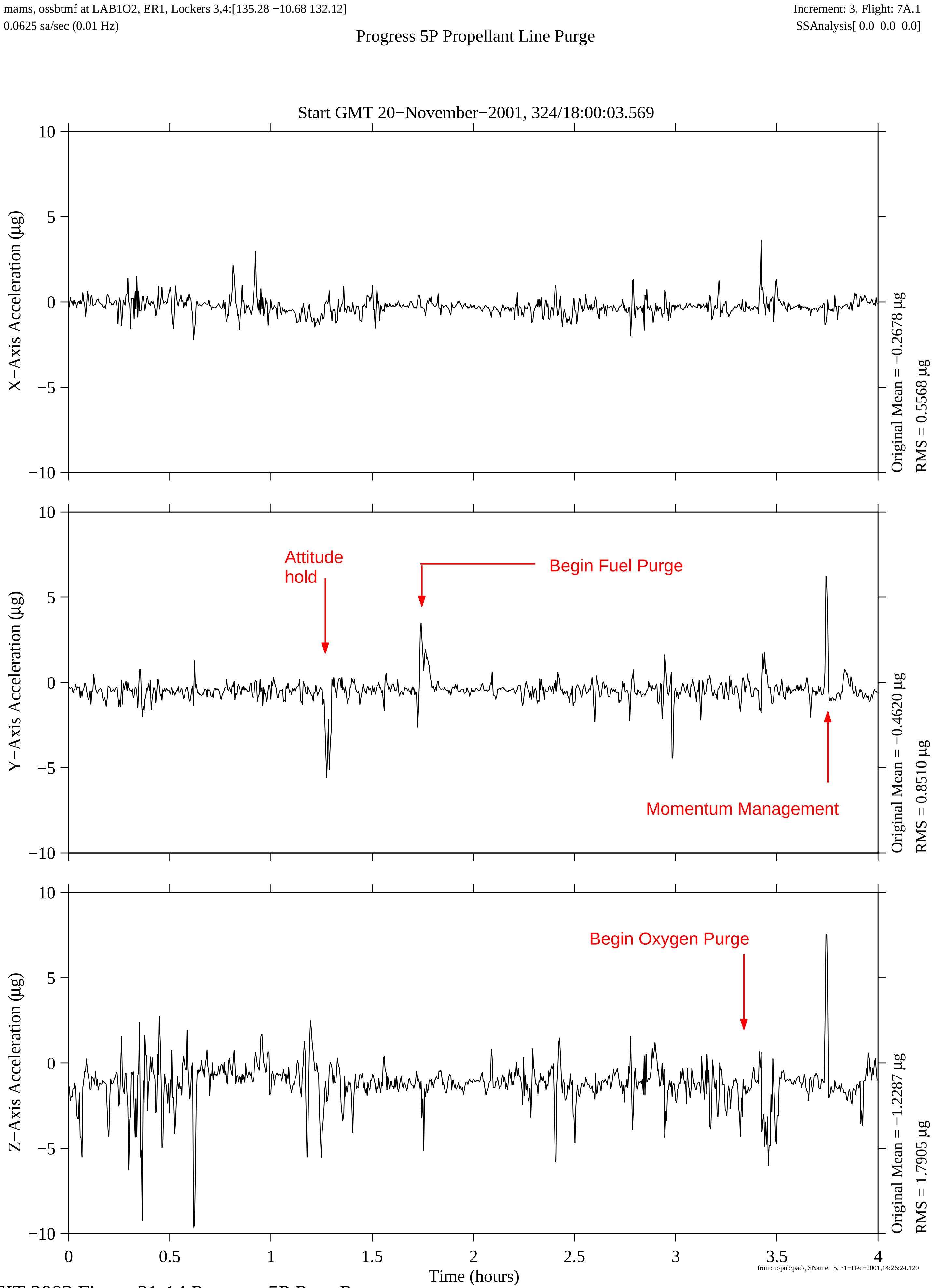
MEIT 2003 Figure 21-11: Dual DC-1



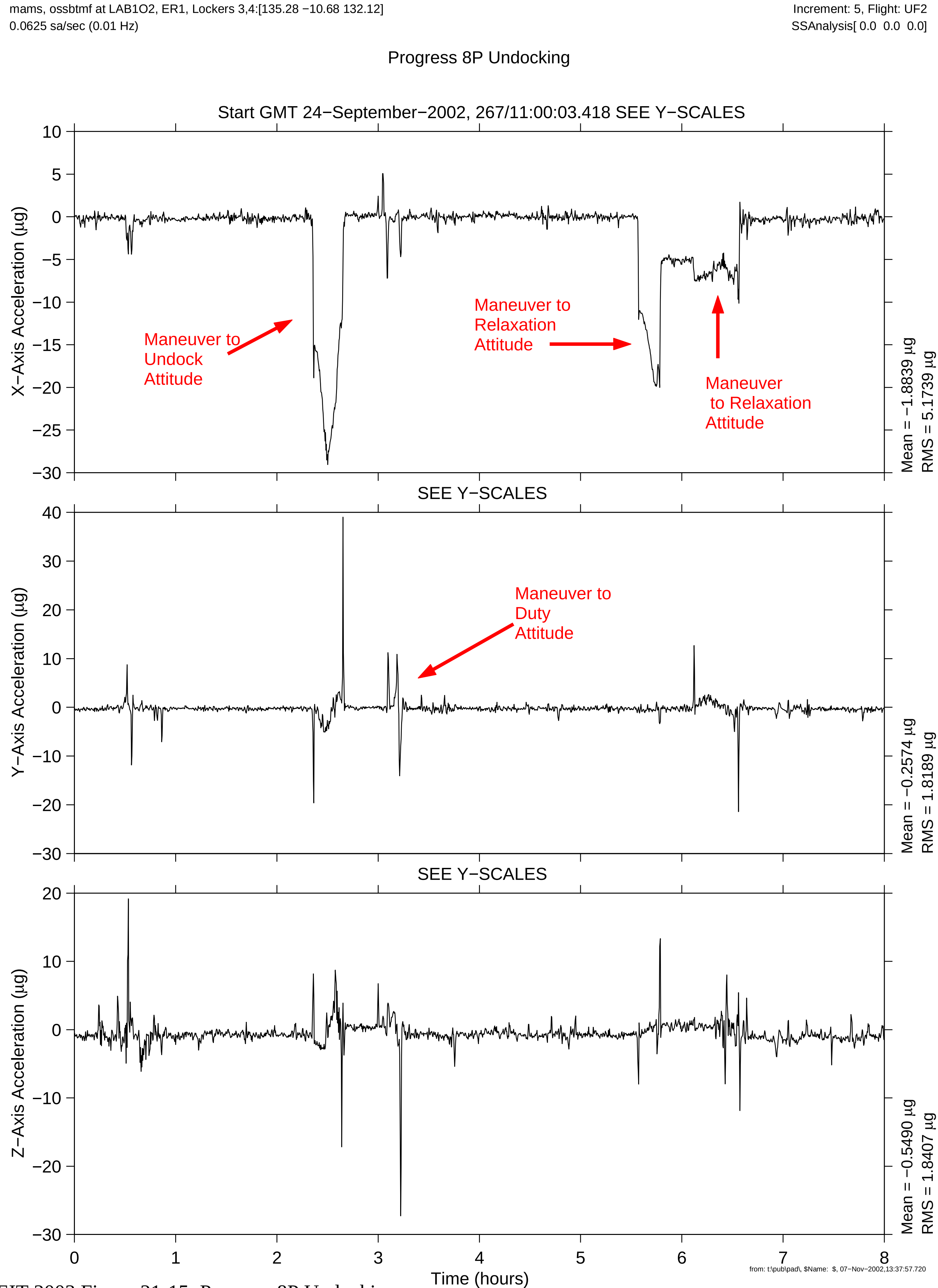
MEIT 2003 Figure 21-12: DC-1 Pressure Overlay



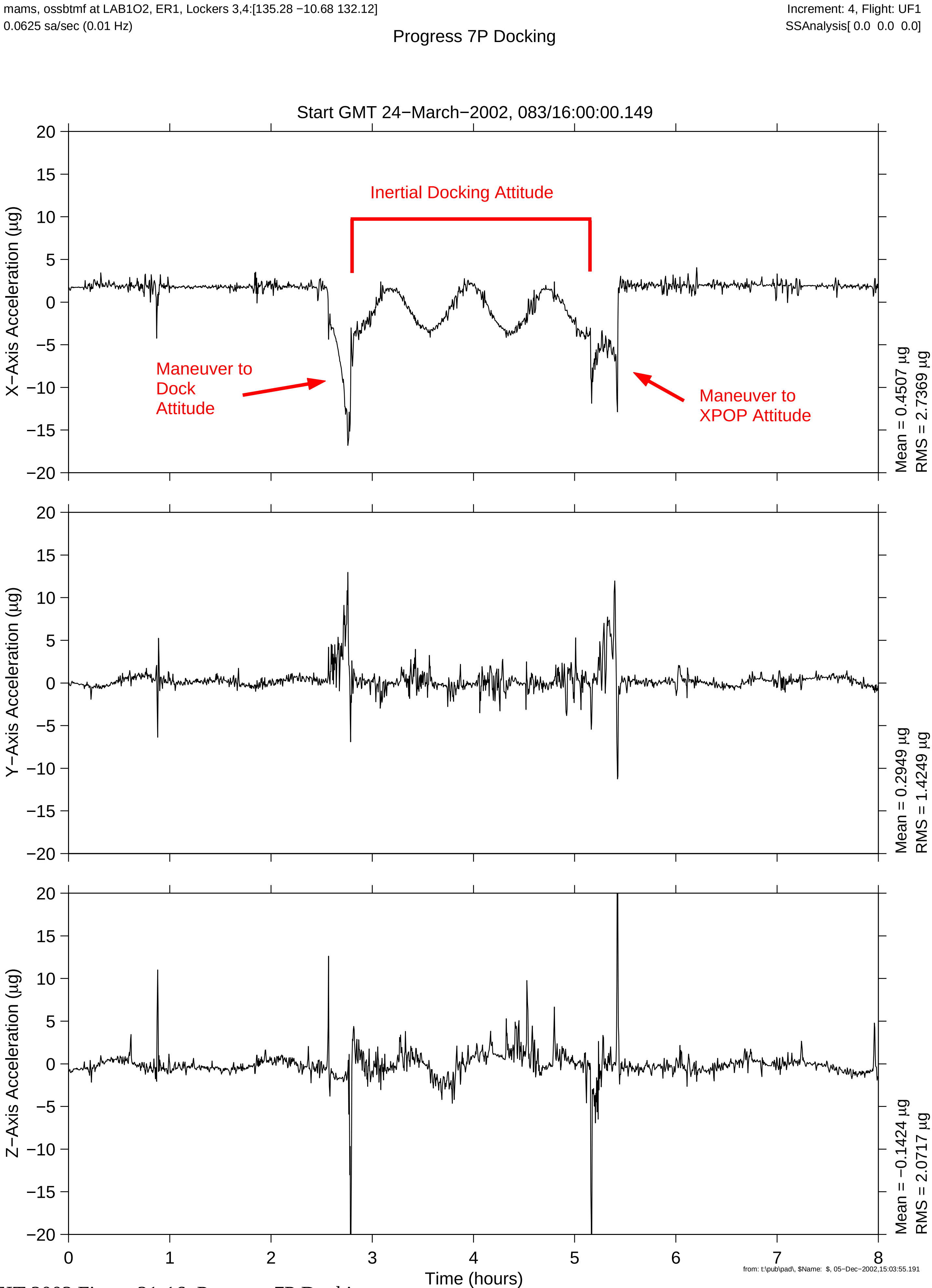
MEIT 2003 Figure 21-13: US Lab Water Dump



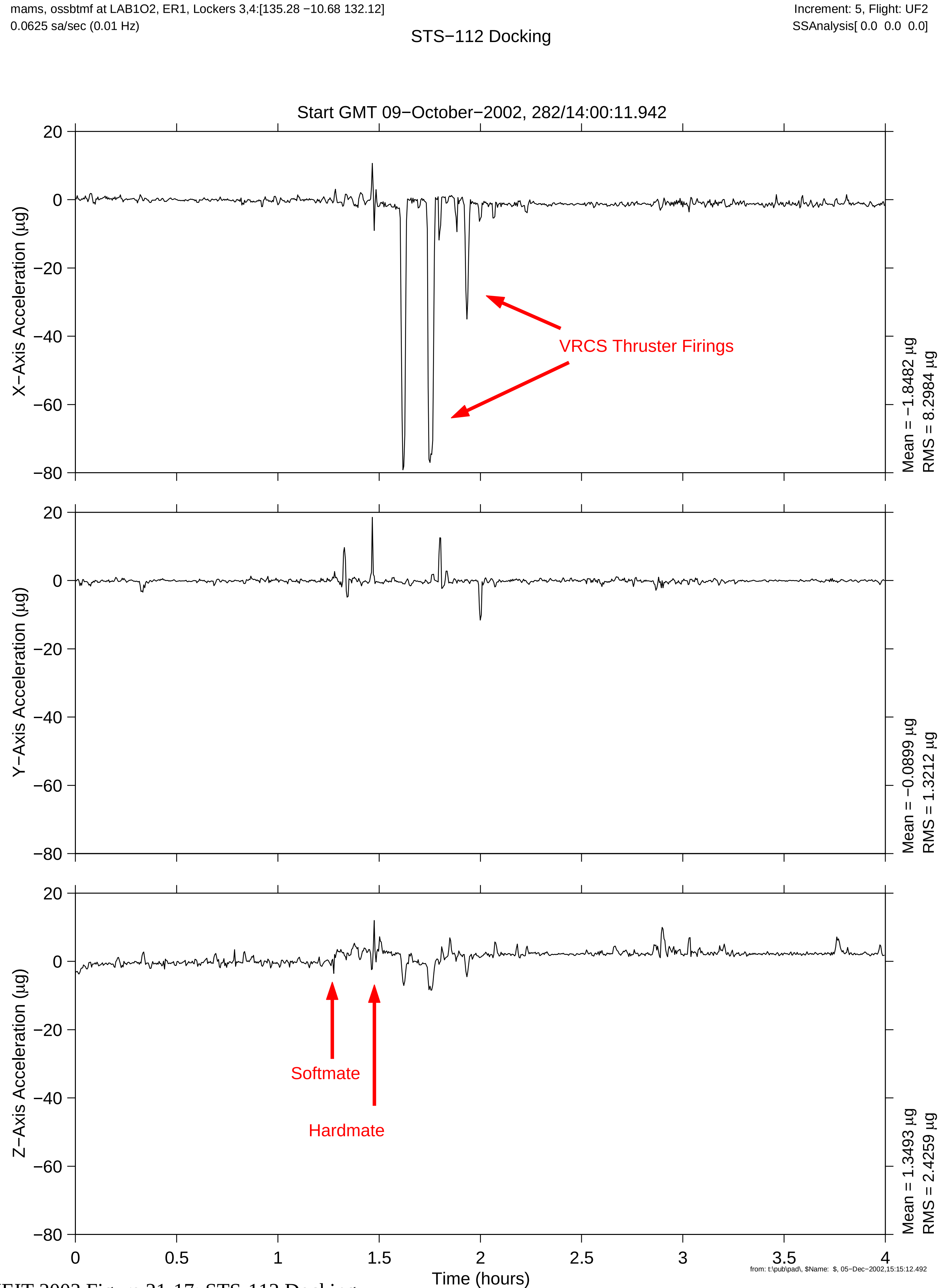
MEIT 2003 Figure 21-14 Progress 5P Prop Purge



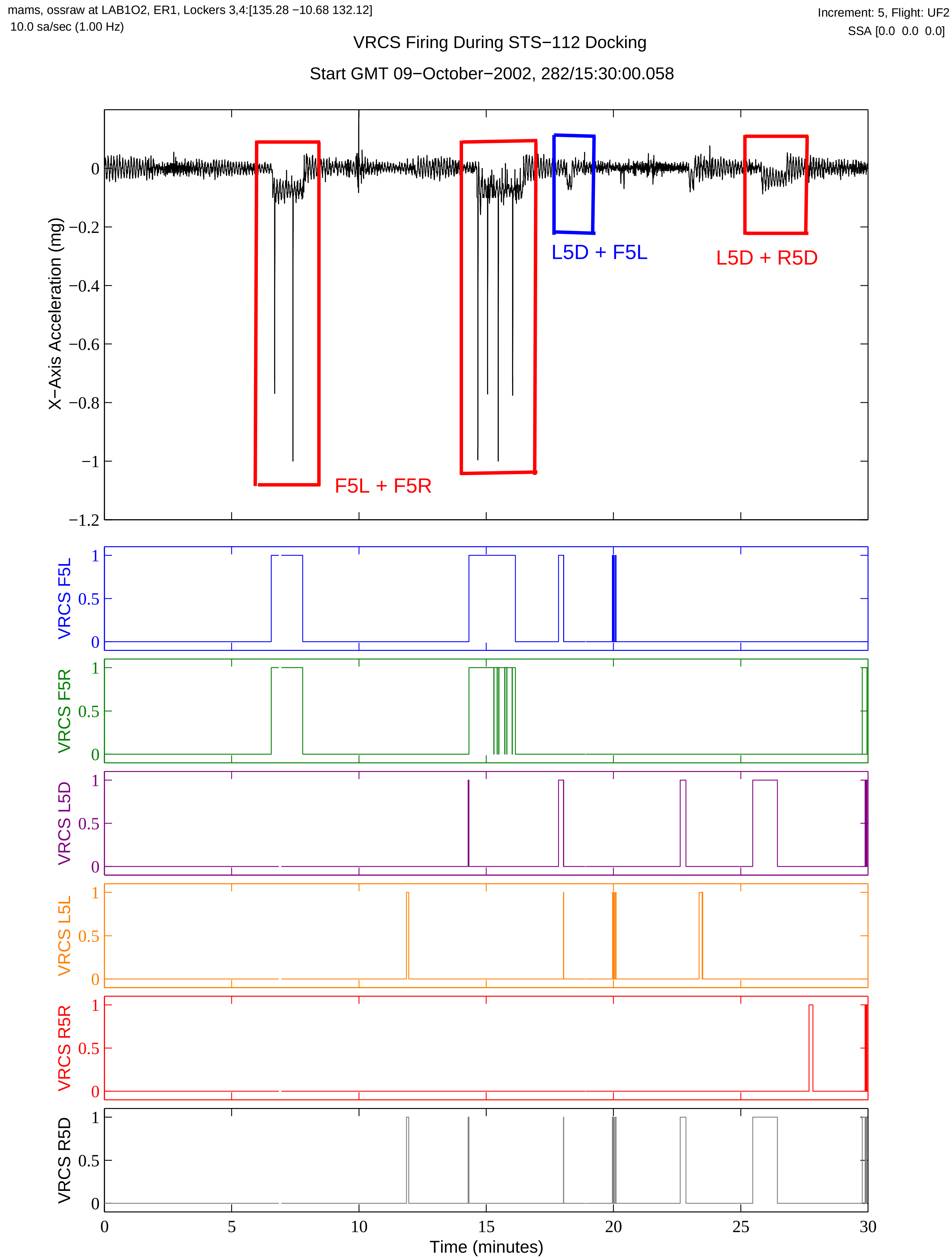
MEIT 2003 Figure 21-15: Progress 8P Undocking



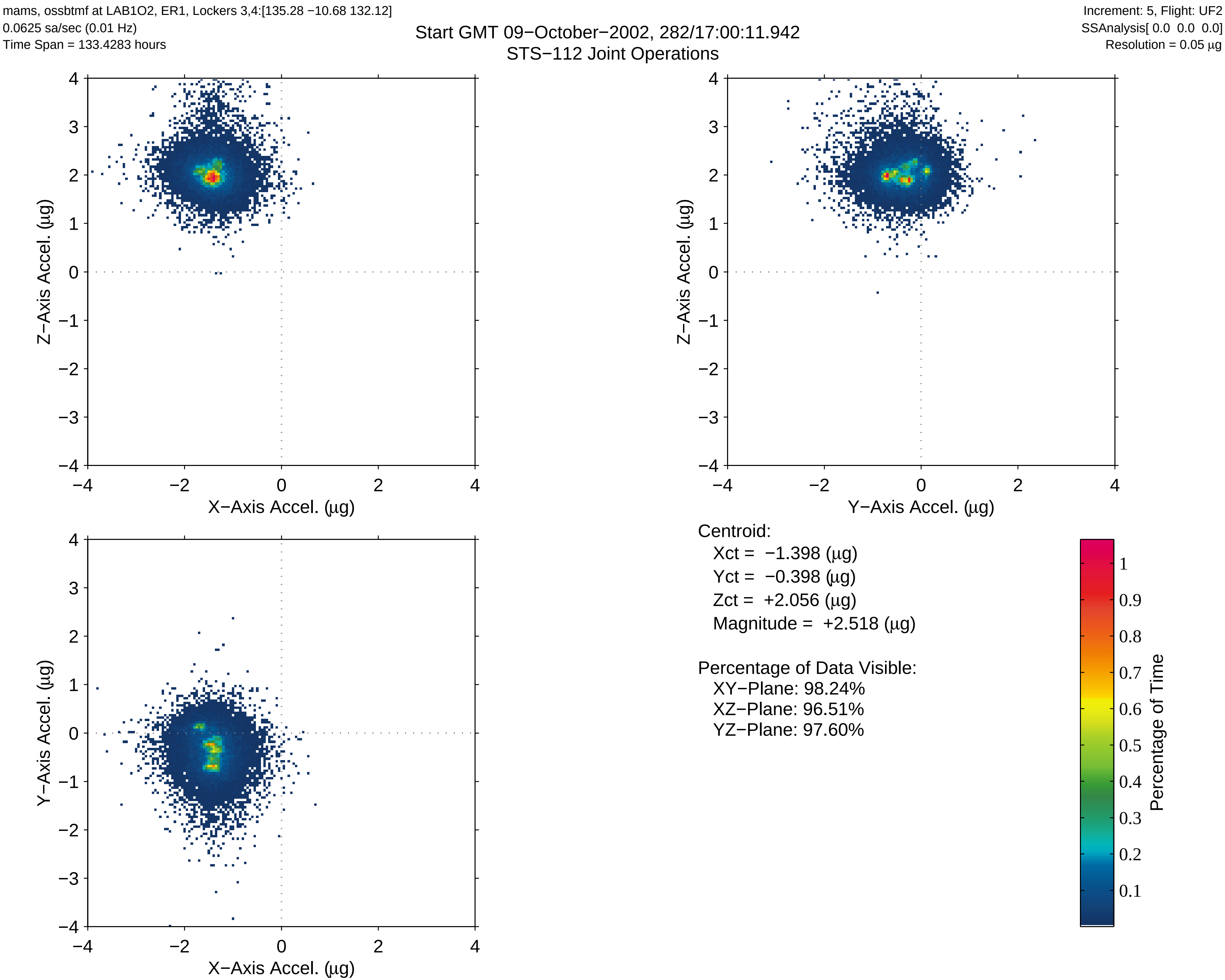
MEIT 2003 Figure 21-16: Progress 7P Docking



MEIT 2003 Figure 21-17: STS-112 Docking



MEIT 2003 Figure 21-18: Thruster Firings During STS-112 Docking



MEIT 2003 Figure 21-19: STS-112 Joint Operations

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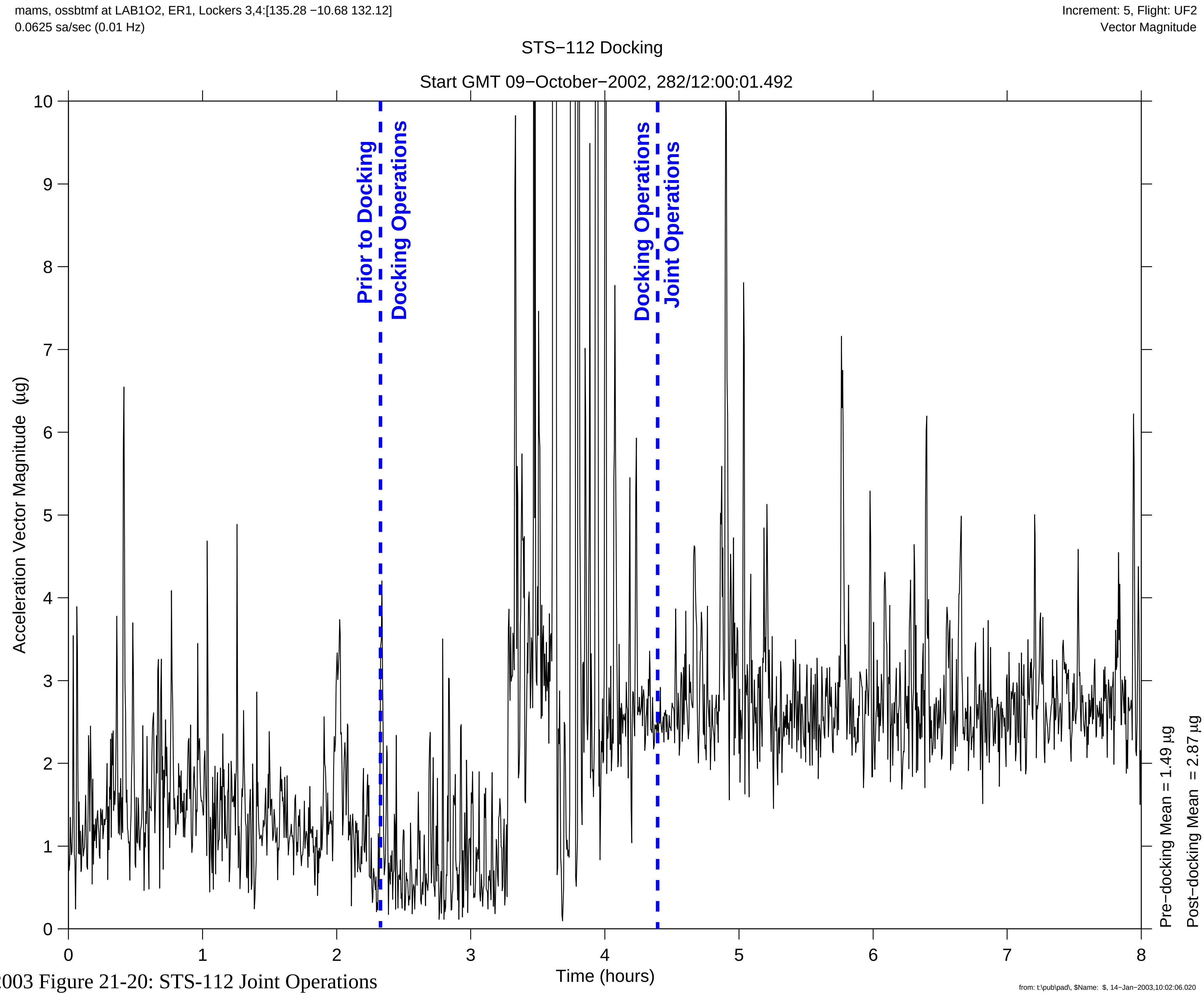

MEIT 2003 Figure 21-20: STS-112 Joint Operations