Section 21

International Space Station (ISS) Measured Quasi-steady Environment

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Acronyms and Abbreviations

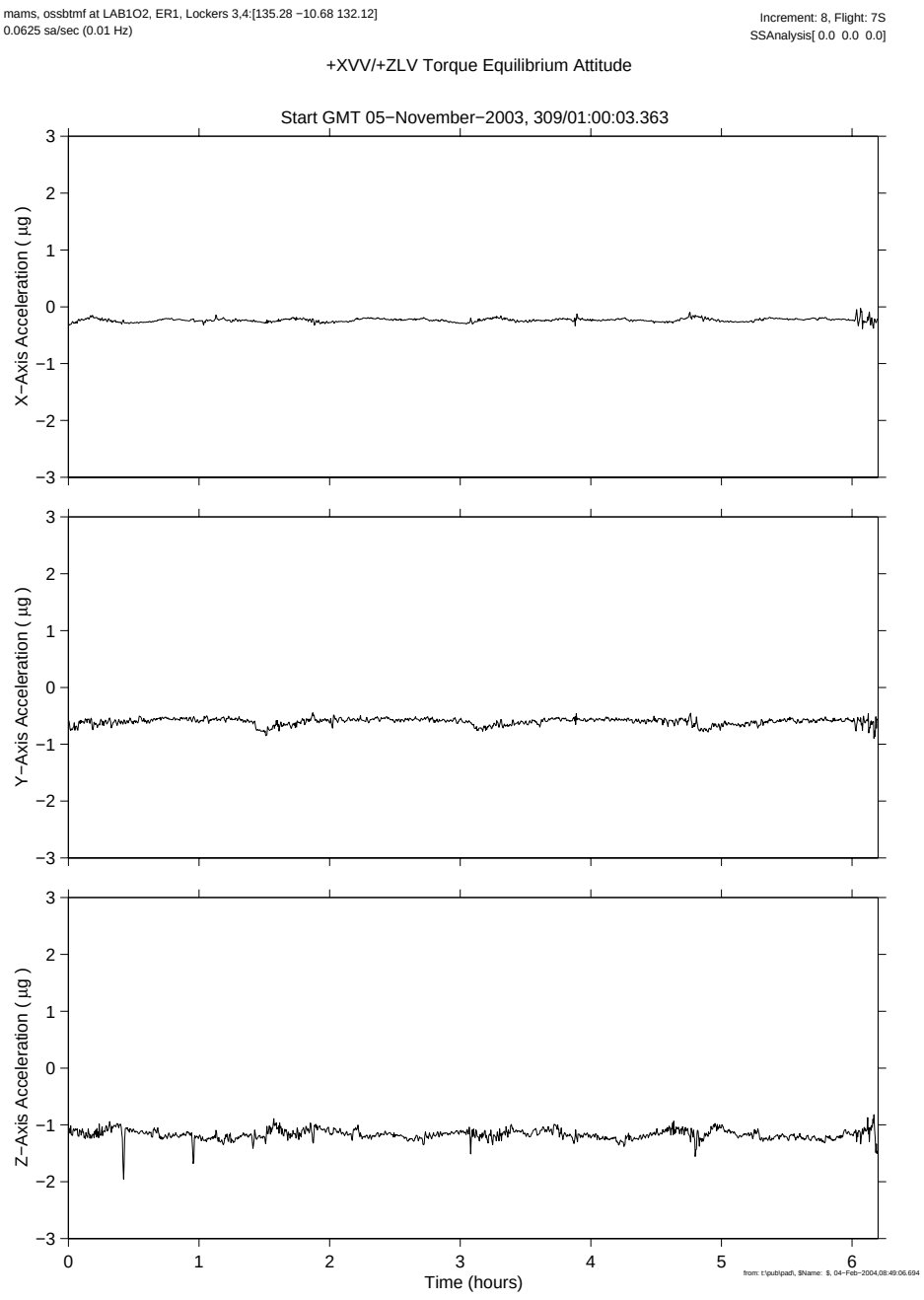
µg	micro-g, 10^{-6}g
#P	Number of Progress Flight (i.e. 4P, 7P, etc.)
#S	Number of Soyuz Flight (i.e. 4S, 6S, etc.)
ATL	Attitude Time Line
CM	Center of Mass
CMG	Control Moment Gyro
CMGTA	Control Moment Gyro Torque Attitude
CWC	Collapsible Water Container
DC	Direct Current (mean value)
DC-1	Docking Compartment
ER	EXPRESS Rack
EVA	Extravehicular Activity
EXPRESS	Expedite the Processing of Experiments to the Space Station
FGB	Functionalui Germatischeskii Block
g	acceleration due to free-fall (9.81 m/s^2)
GMT	Greenwich Mean Time
GNC	Guidance, Navigation and Contol
GRC	Glenn Research Center
HiRAP	High Resolution Accelerometer Package
Hz	Hertz
ISS	International Space Station
LAB	Laboratory
LAB1O2	US LAB Overhead 2
LVLH	Local Vertical Local Horizontal
MAMS	Microgravity Acceleration Measurement System
mg	milli-g, 10^{-3}g
m/s	Meters per second
MSG	Microgravity Science Glovebox

NASA	National Aeronautics and Space Administration
OARE	Orbital Acceleration Research Experiment
OSS	OARE Sensor Subsystem
PAD	PIMS Acceleration Data
PMA	Pressurized Mating Adaptor
QTH	Quasi-steady Three Dimensional Histogram
PIMS	Principal Investigator Microgravity Services
RMS	Root-Mean-Square
RPM	Revolutions Per Minute
RTS	Remote Triaxial Sensor
RSS	Root-Sum-Square
RS	Russian
SAMS	Space Acceleration Measurement System
sec	seconds
SM	Service Module
SSA	Space Station Analysis
STS	Space Transportation System
TEA	Torque Equilibrium Attitude
TVIS	Treadmill Vibration Isolation System
UF	Utilization Flight
US	United States
VRCS	Vernier Reaction Control System
XPH	X-axis is Parallel to the angular momentum vector
XPOP	X Principal Axis Perpendicular to the Orbit Plane
XVV	X body axis toward the Velocity Vector
YVV	Y-axis toward Velocity Vector
ZLV	Z-axis in Local Vertical
ZNN	Z-axis is pointing Nadir when the station is at orbital Noon

Outline

- **ISS Attitudes**
  - **XVV/ZLV Torque Equilibrium Attitude (TEA)**
  - **X-Perpendicular to the Orbital Plane (XPOP)**
  - **YVV/ZLV "Barbeque"**
- **Venting**
  - **Docking Compartment (DC-1) Cabin Depressurization**
  - **USLAB Condensate Water Dump**
  - **Progress Propellant Line Purge**
- **Docking Events**
  - **Progress**
  - **Shuttle**
- **Other**
  - **Russian/US Guidance Navigation and Control (GNC) Force Fight**
  - **Progress Reboost**

+XVV/+ZLV Torque Equilibrium Attitude (TEA)



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 8, Flight: 7S
Plot Type	Time Series

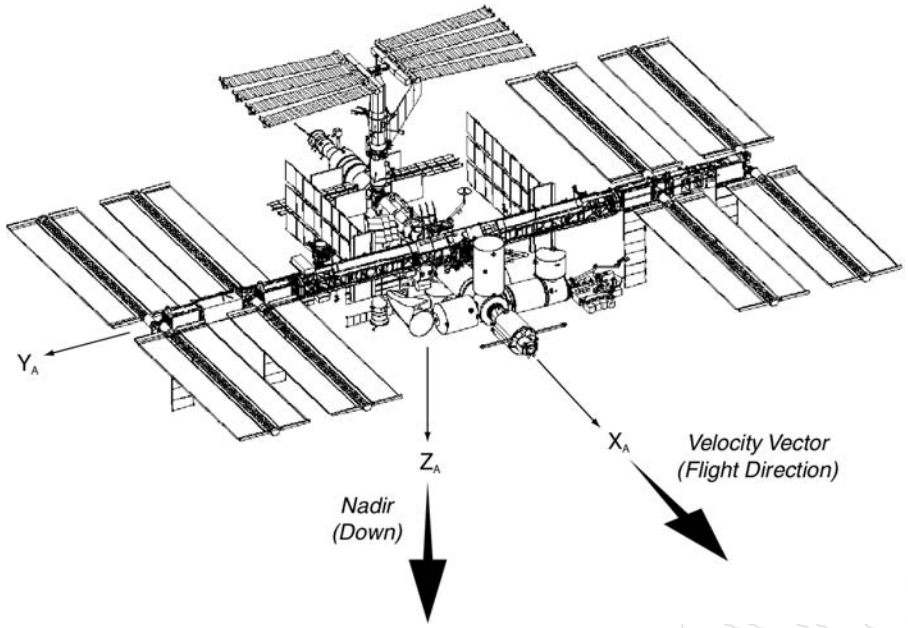
NOTES:

- TEA is an "airplane like" attitude maintained relative to the Local Vertical Local Horizontal (LVLH), a rotating coordinate system.
- In TEA, the gravity gradient and rotational components tend to cancel out, resulting in the near-zero X-axis component**.**
- +XVV / +ZLV indicates that the ISS positive X-axis is toward the velocity vector, the Z-axis is towards nadir.
- The time period covered in these plots is during crew sleep period (s). See Crew Active, Crew Asleep for comparison
- The means and RMS values per axis are tabulated below.

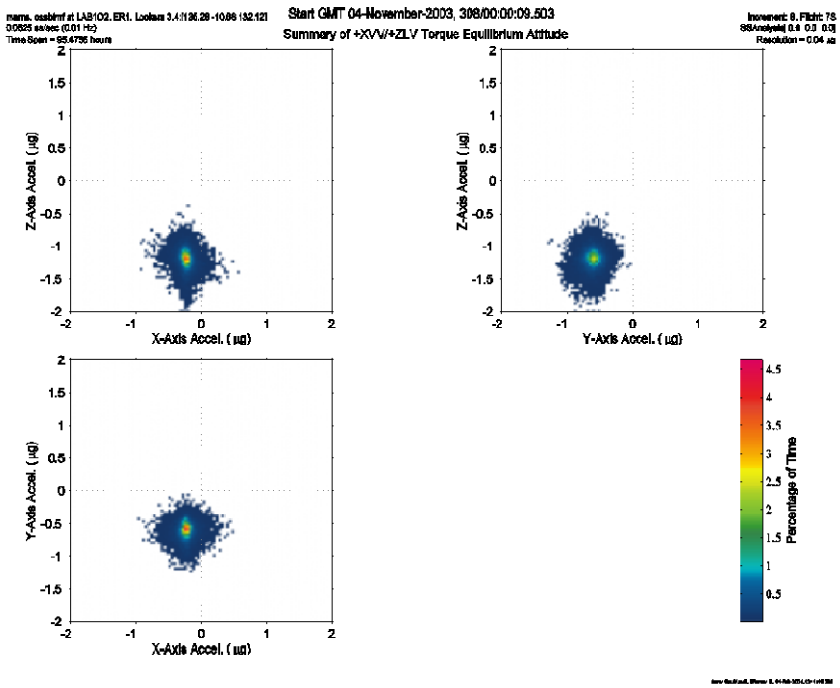
Axis	Mean (µg)	RMS (µg)
X	-0.24	0.24
Y	-0.60	0.60
Z	-1.17	1.17

Regime:	Quasi-steady
Category:	Vehicle
Source:	Attitude, TEA

+XVV/+ZLV Torque Equilibrium Attitude (TEA)



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 8, Flight: 7S
Plot Type	Quasi-steady Three Dimensional Histogram



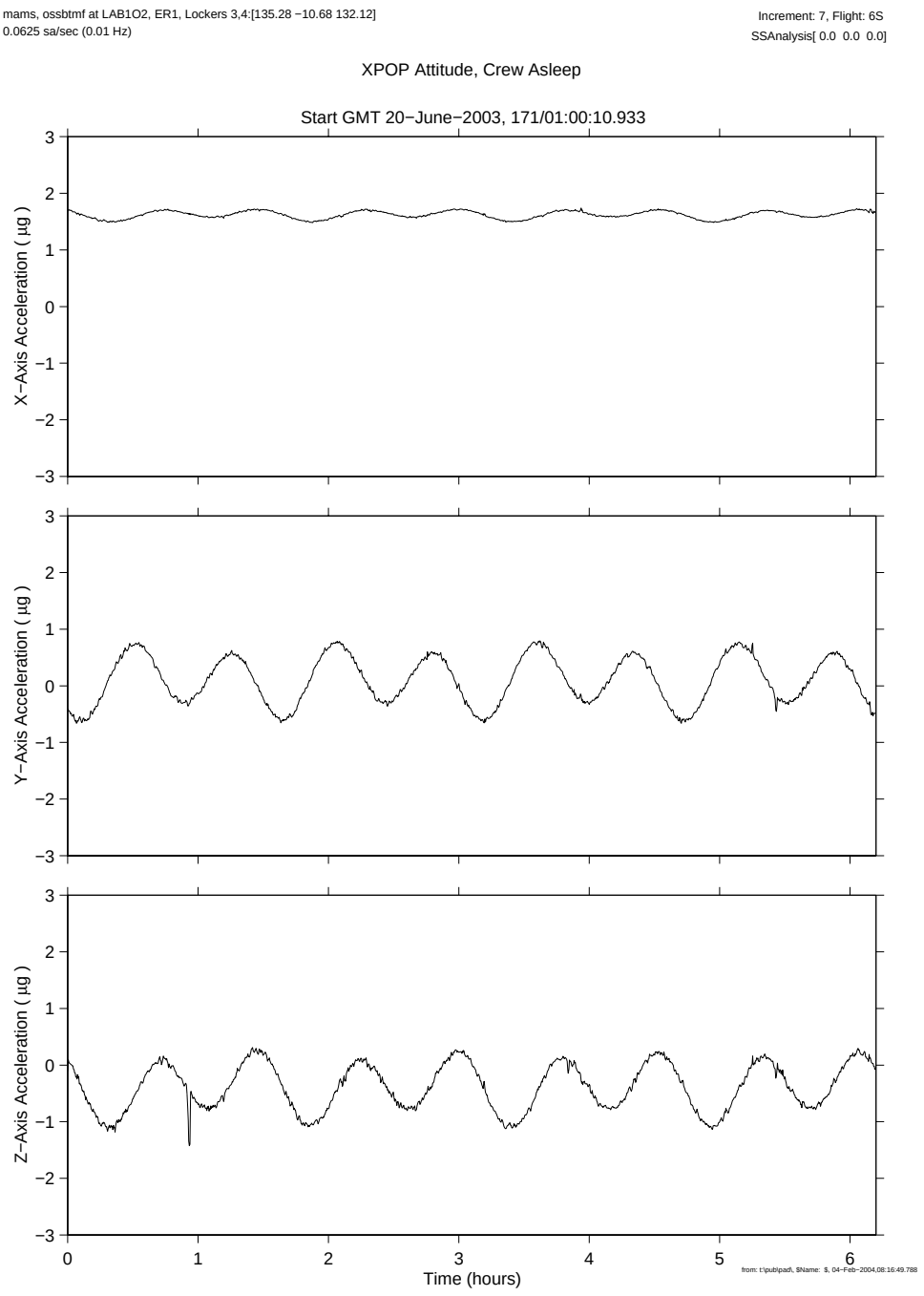
NOTES:

- Actual orientation dependent on ISS configuration. For time span of plot during Increment 8, attitude was nominally [yaw pitch roll] = [350.0 350.6 0]
- The time period covered in these plots is during crew sleep period (s). See Crew Active, Crew Asleep for comparison
- For the time period shown, the centroid is calculated as an estimate of the means for each axis. The results are tabulated below.

Axis	Centroid (µg)
X	-0.21
Y	-0.60
Z	-1.17
Magnitude	1.34

Regime:	Quasi-steady
Category:	Vehicle
Source:	Attitude, TEA

X-axis Perpendicular to the Orbital Plane (XPOP) Attitude



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 7, Flight: 6S
Plot Type	Time Series

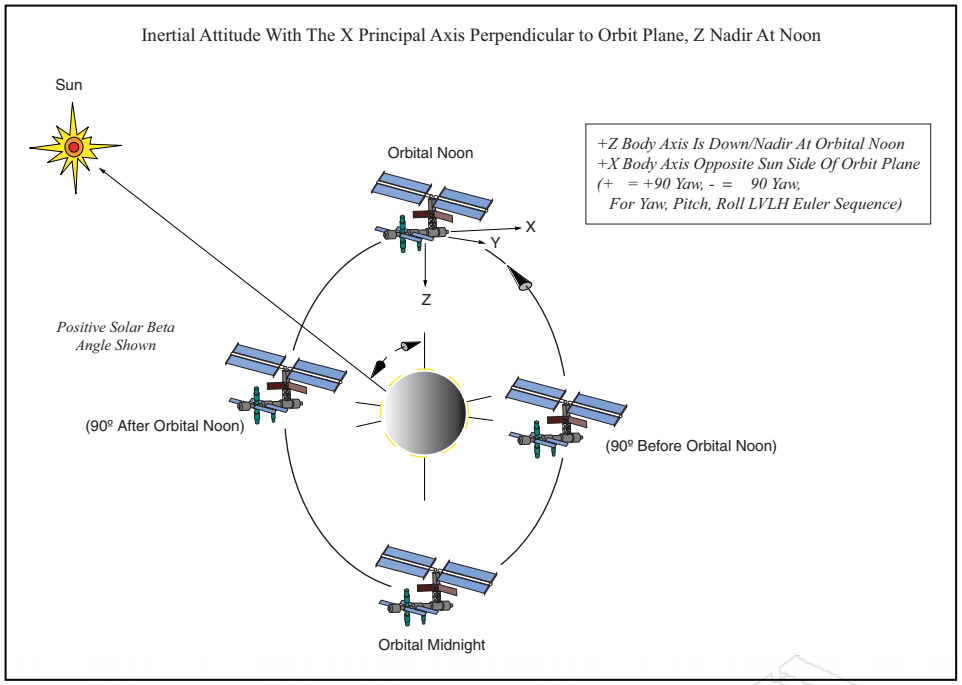
NOTES:

- The 1.62 µg offset in the X-axis is primarily gravity gradient effect, due to the sensor's distance from the ISS center of mass.
- Y and Z-axes show cyclical variation as they are alternately subjected to varying drag and gravity gradient vectors. These two components vary due to the stations rotation **with respect to the Local Vertical Local Horizontal (LVLH) frame of reference.**
- The time period covered in this plot is during a crew sleep period. See Crew Active, Crew Asleep for comparison.
- The means and RMS values per axis are tabulated below.

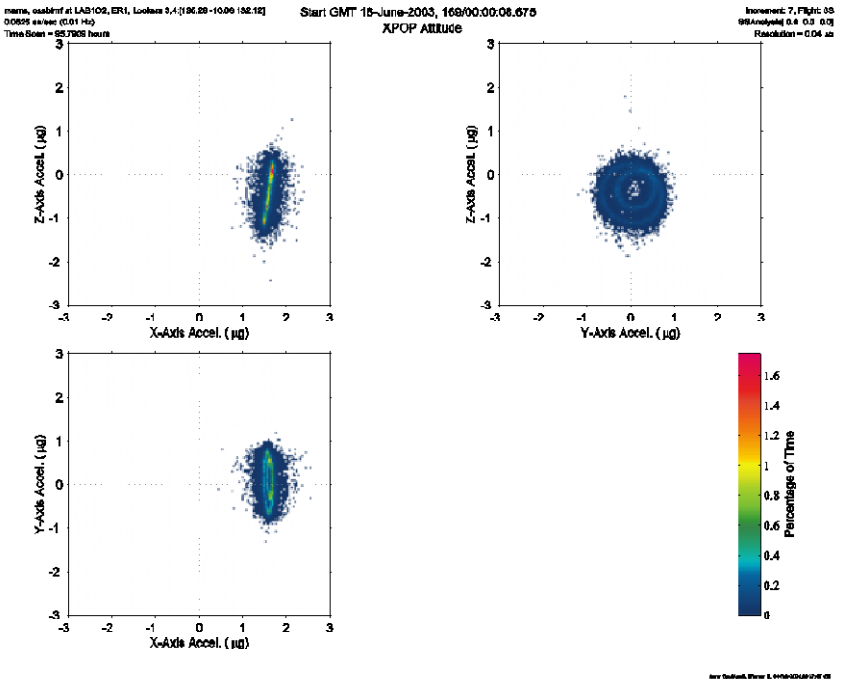
Axis	Mean (µg)	RMS (µg)
X	1.62	1.62
Y	0.10	0.43
Z	-0.39	0.56
RSS	1.76	1.77

Regime:	Quasi-steady
Category:	Vehicle
Source:	Attitude, XPOP

X-axis Perpendicular to the Orbital Plane (XPOP) Attitude



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 7, Flight: 6S
Plot Type	Quasi-steady Three Dimensional Histogram



NOTES:

- XPOP is a quasi-inertial attitude flown to provide solar array sun tracking for power generation purposes. This attitude was flown before ISS Flight 12A.1, at which point ISS began two axes Sun tracking, and XPOP became unnecessary.
- In XPOP, the ISS is maintained relative to inertial space, with X-axis perpendicular to the orbital plane, while the Y and Z-axes lie in the orbital plane.
- Plot is 96 consecutive hours beginning GMT 18-Jun-2003, 169/00:00. For the time period shown, the centroid is calculated as an estimate of the means for each axis. The results are tabulated below.

Axis	Centroid (µg)
X	1.62
Y	0.09
Z	-0.41
Magnitude	1.67

Regime:	Quasi-steady
Category:	Vehicle
Source:	Attitude, XPOP

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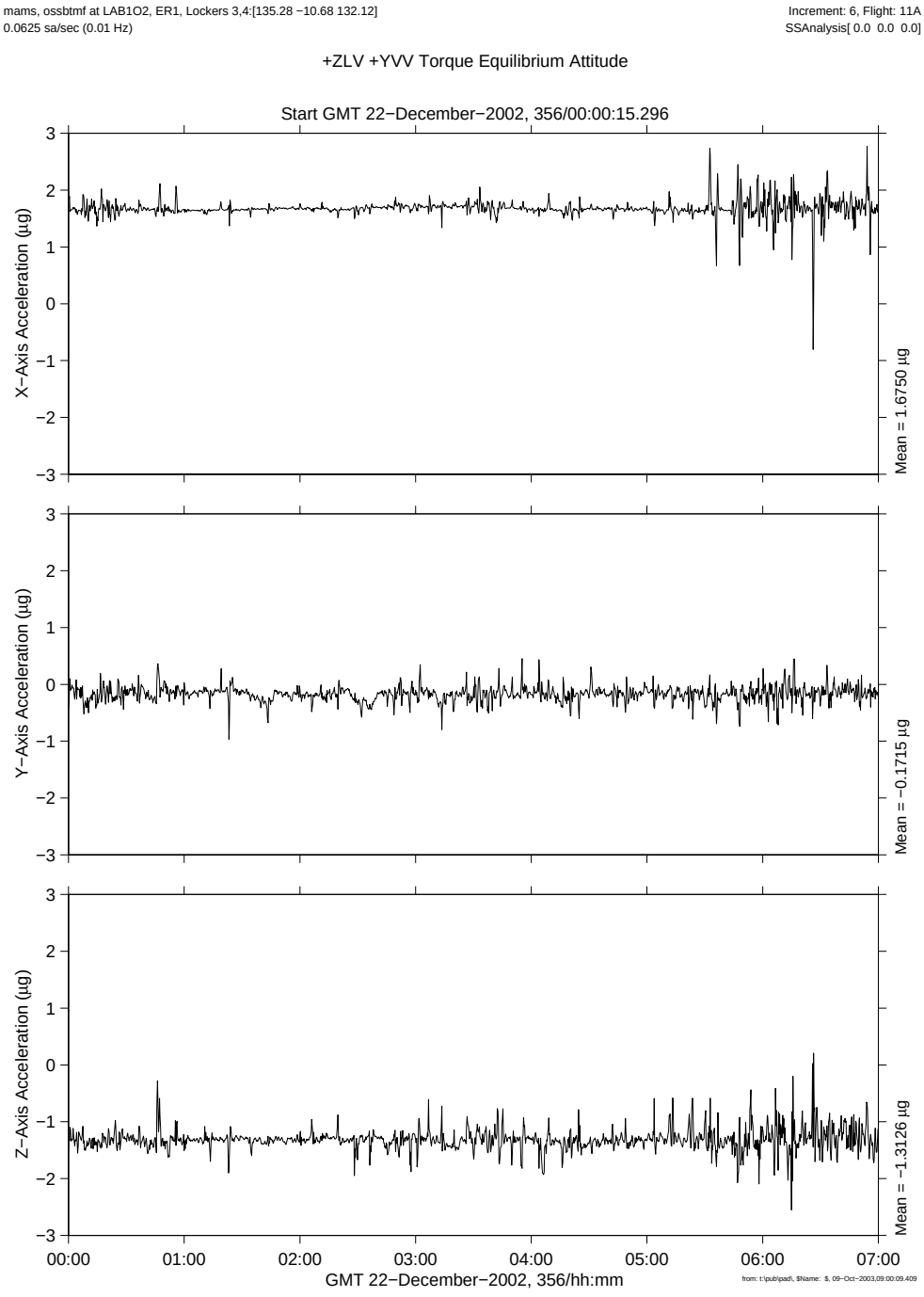
YVV / ZLV TEA Attitude



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 6, Flight: 11A
Plot Type	Time Series

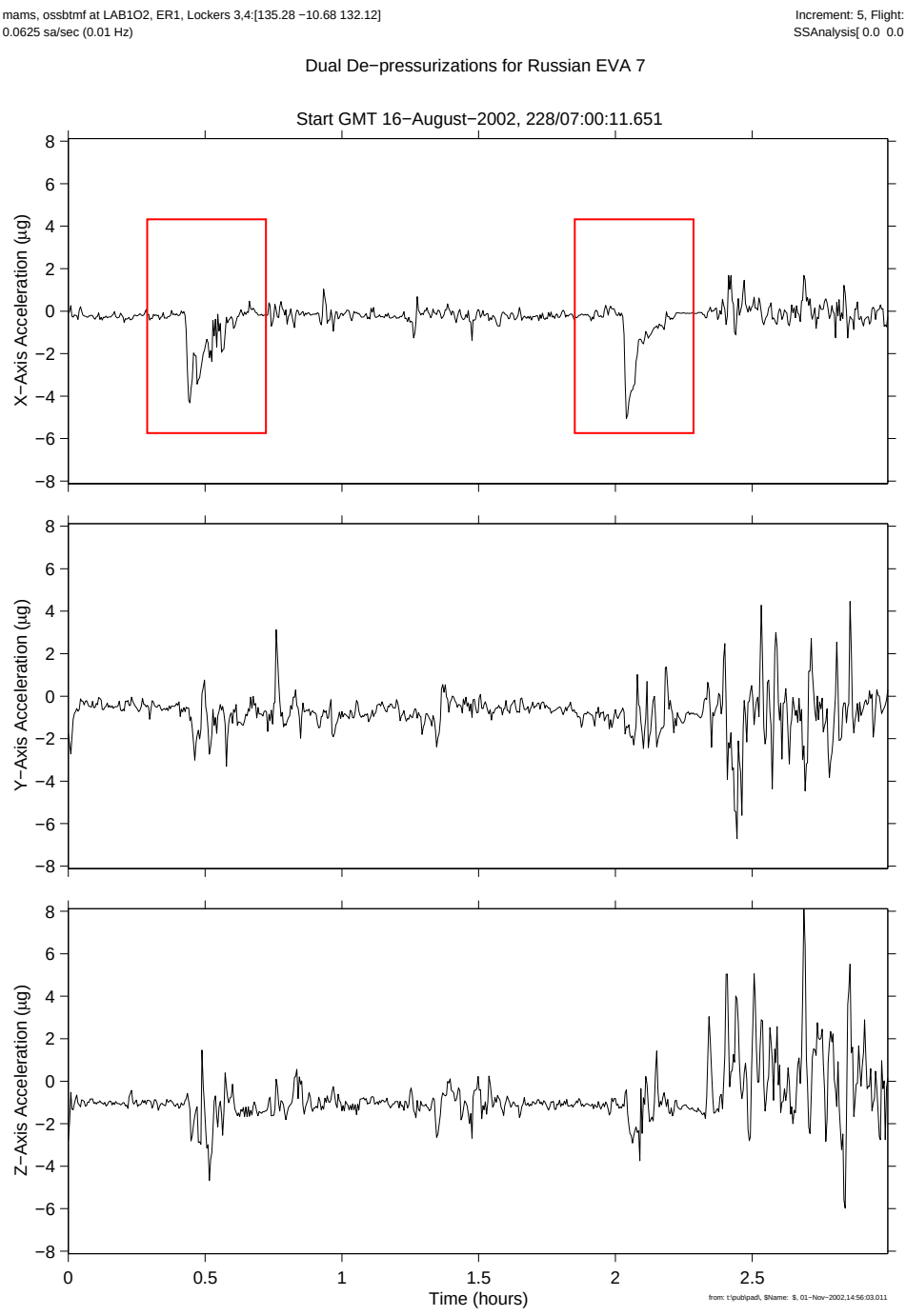
NOTES:

- YVV / ZLV is a Torque equilibrium attitude (airplane-like) in which the Y-axis is maintained in the velocity vector and the Z-axis is pointing nadir. The ISS will fly with either the +Y-axis or –Y-axis in the forward direction. In this attitude the X-axis is perpendicular to orbital plane.
- During high solar beta angles (>60 degrees) the ISS is flown in YVV attitude to avoid overheating of the Progress batteries. For this reason, YVV has been referred to as “barbeque” mode.
- The plot shown is of data taken during a crew sleep period. The mean values per axis are tabulated below.

Axis	Mean (µg)	RMS (µg)
X	1.68	1.78
Y	-0.17	0.50
Z	-1.31	0.61

Regime:	Quasi-steady
Category:	Vehicle
Source:	Attitude, YVV

DC-1 Cabin Depressurization



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 5, Flight: UF2
Plot Type	Time Series

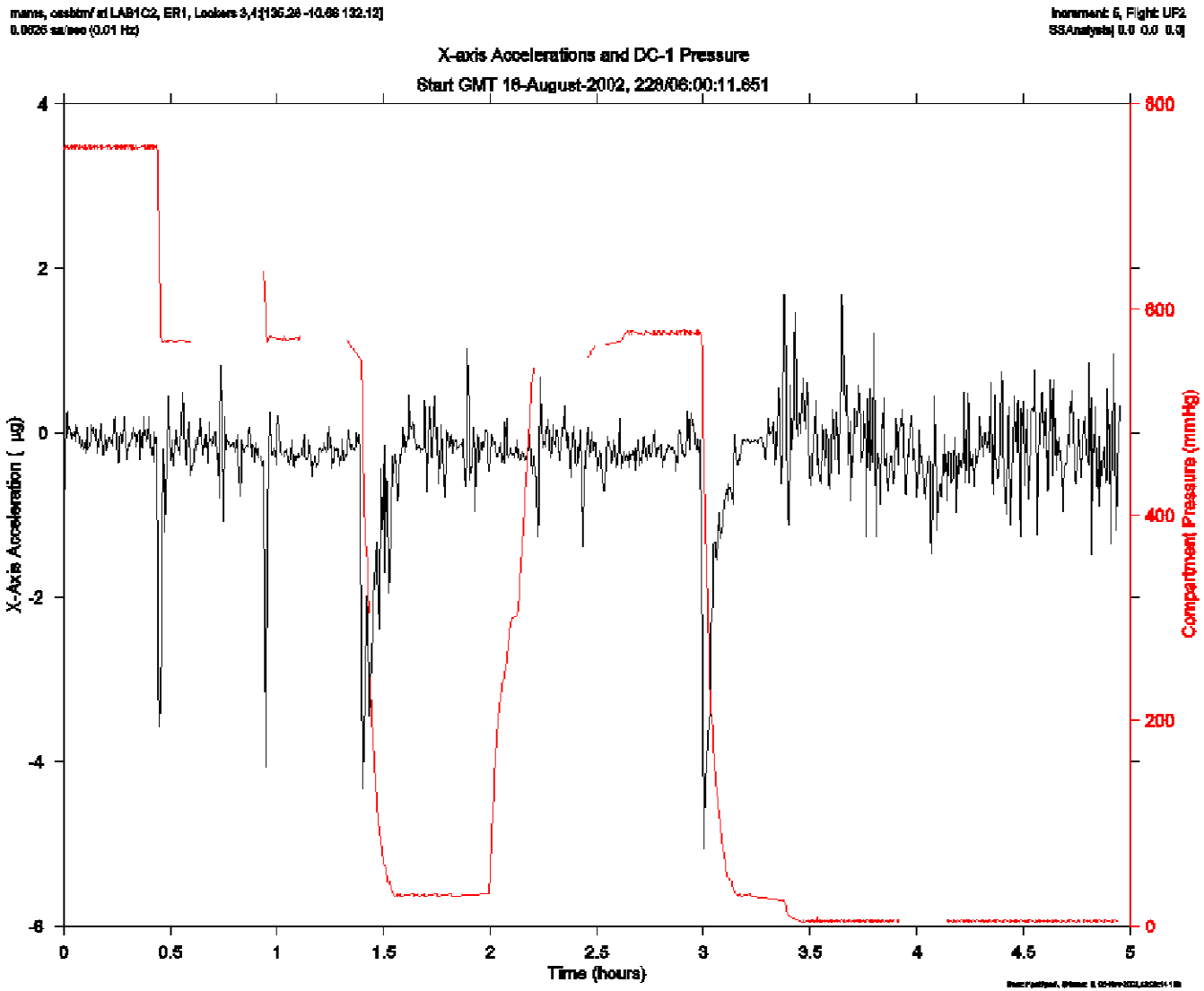
NOTES:

- Prior to Russian EVA-7, the Docking Compartment (DC-1) was depressurized. Due to misconfiguration in Orlan spacesuits, the cabin had to be depressurized twice. (outlined in red boxes)
- Vent type is momentless T-type nozzle.
- Vent position [-893.9 19.5 305.4] (inches, Space Station Analysis coordinates)
- Vent (RSAS10) Orientation: [-0.39 0.92 0] and [0.39 -0.92 0]. (Space Station Analysis coordinates)
- The peak values during the venting operations are tabulated below.

Axis	Maximum Δ from Baseline(µg)
X	-5.05
Y	-2.42
Z	-3.77

Regime:	Quasi-steady
Category:	Vehicle
Source:	DC-1 Vent

DC-1 Cabin Depressurization



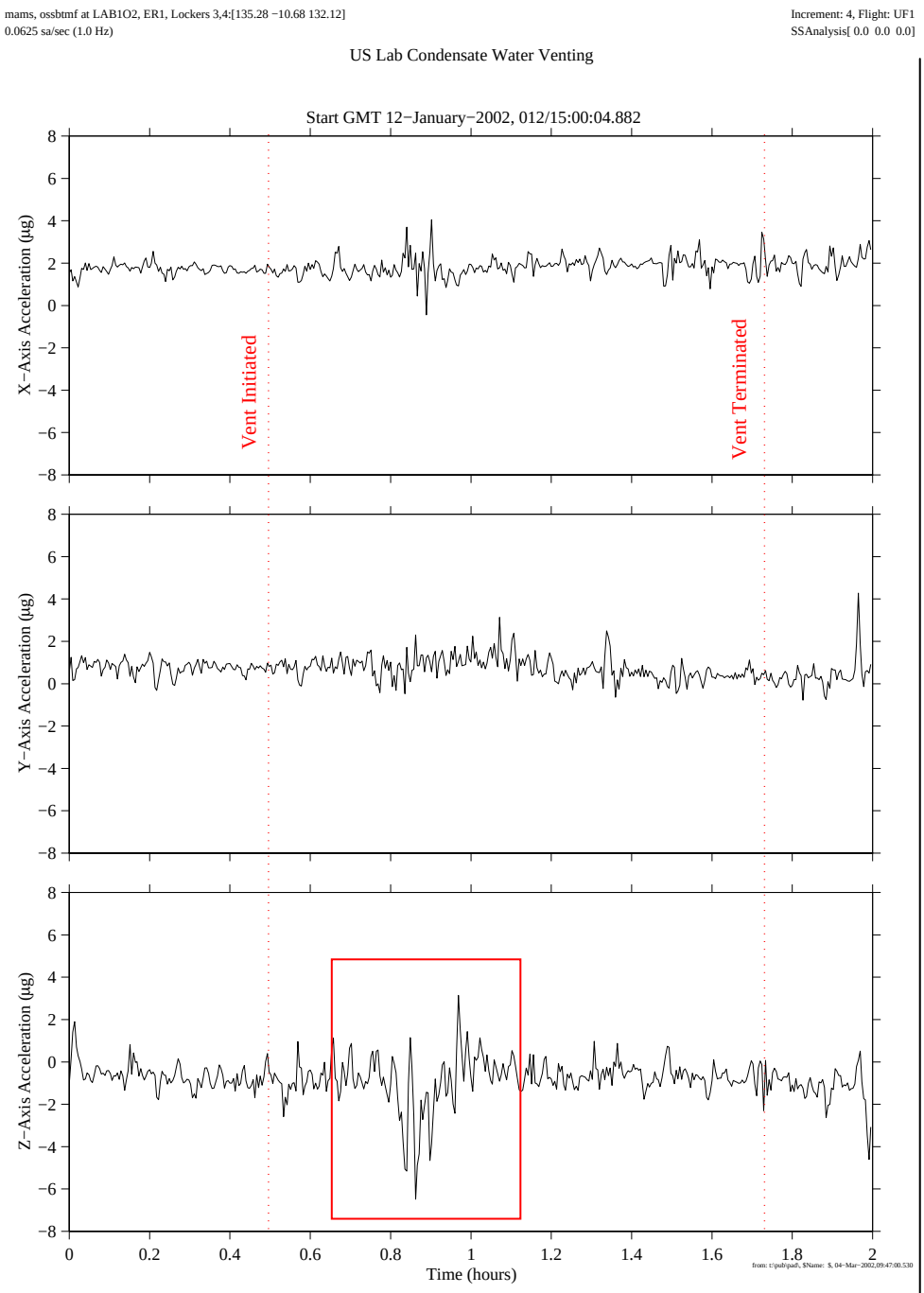
Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 5, Flight: UF2
Plot Type	Time Series, X-axis

NOTES:

- Red overlay is DC-1 cabin pressure during EVA preparations.
- Initial depressurization was from 760 mmHg to 550 mmHg (at the 0.4 hour mark)
- The first of the two large depressurizations was from 550 mmHg to 30 mmHg. Subsequent partial repressurization was to 550 mmHg. Second depressurization was complete, down to 10 mmHg.

Regime:	Quasi-steady
Category:	Vehicle
Source:	DC-1 Vent

US LAB Condensate Water Dump



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 4, Flight: UF1
Plot Type	Time Series

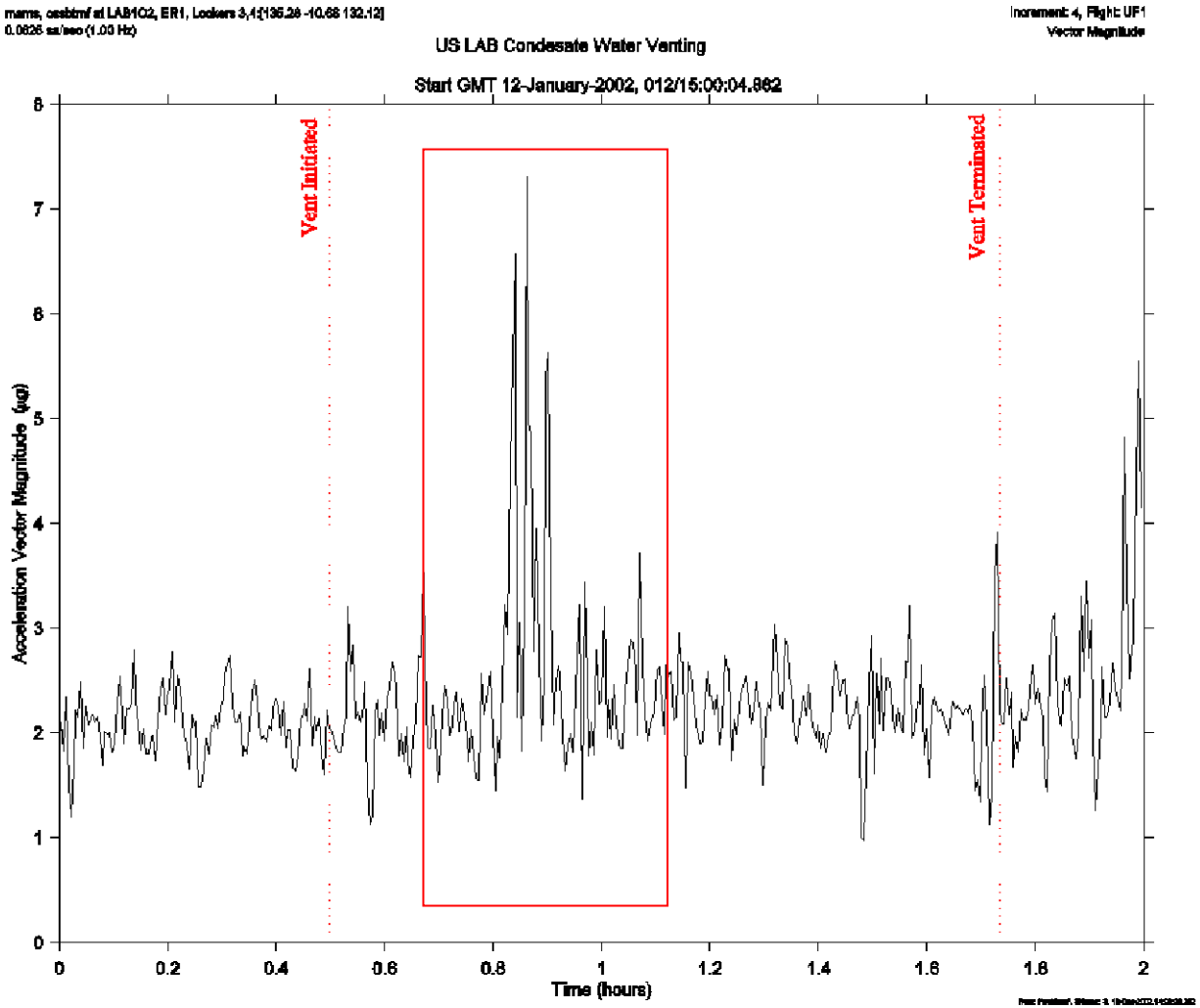
NOTES:

- Vent Orientations:
  Lab2A: [0 -0.61 -0.79]
  Lab2B: [0 0.61 0.79]. (Space Station Analysis coordinates)
- Prior to water dump, ISS was maneuvered to an attitude that placed the vent in a retrograde position to minimize contamination,
  Yaw = 273.3,
  Pitch = 356.7,
  Roll = 307.0.
- Waste water is held in a Collapsible Water Container (CWC).
- During dump a crew member put a “bear hug” on the CWC to facilitate venting. Crew member observed good flow coming from PORT (2A) vent. Red box indicates largest venting effect.
- The means and RMS values per axis are tabulated below.

Axis	Mean (µg)	RMS (µg)
X	1.83	1.87
Y	0.69	0.87
Z	-0.80	1.21

Regime:	Quasi-steady
Category:	Vehicle
Source:	Vent Lab2A,2B

US Lab Condensate Water Dump



Description	
Sensor	MAMS, ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 4, Flight: UF1
Plot Type	Acceleration Magnitude

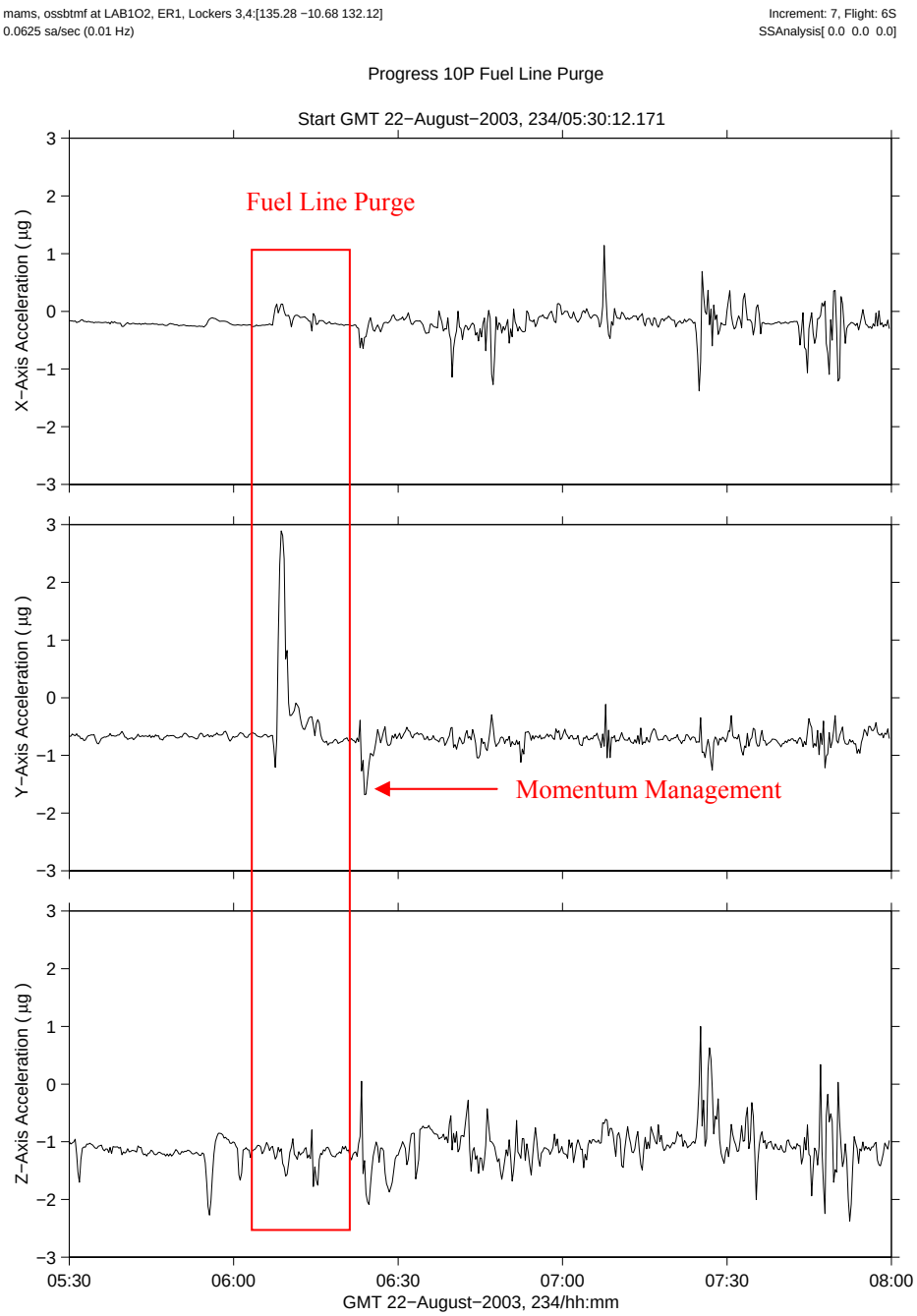
NOTES:

- Red box indicates largest venting effect on quasi-steady environment.
- Values below were calculated for the time period of the plot.

Parameter	Value (µg)
Mean	2.30
RMS	2.40
Peak	7.30

Regime:	Quasi-steady
Category:	Vehicle
Source:	Vent Lab2A,2B

Propellant Line Purge



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 7, Flight: 6S
Plot Type	Time Series

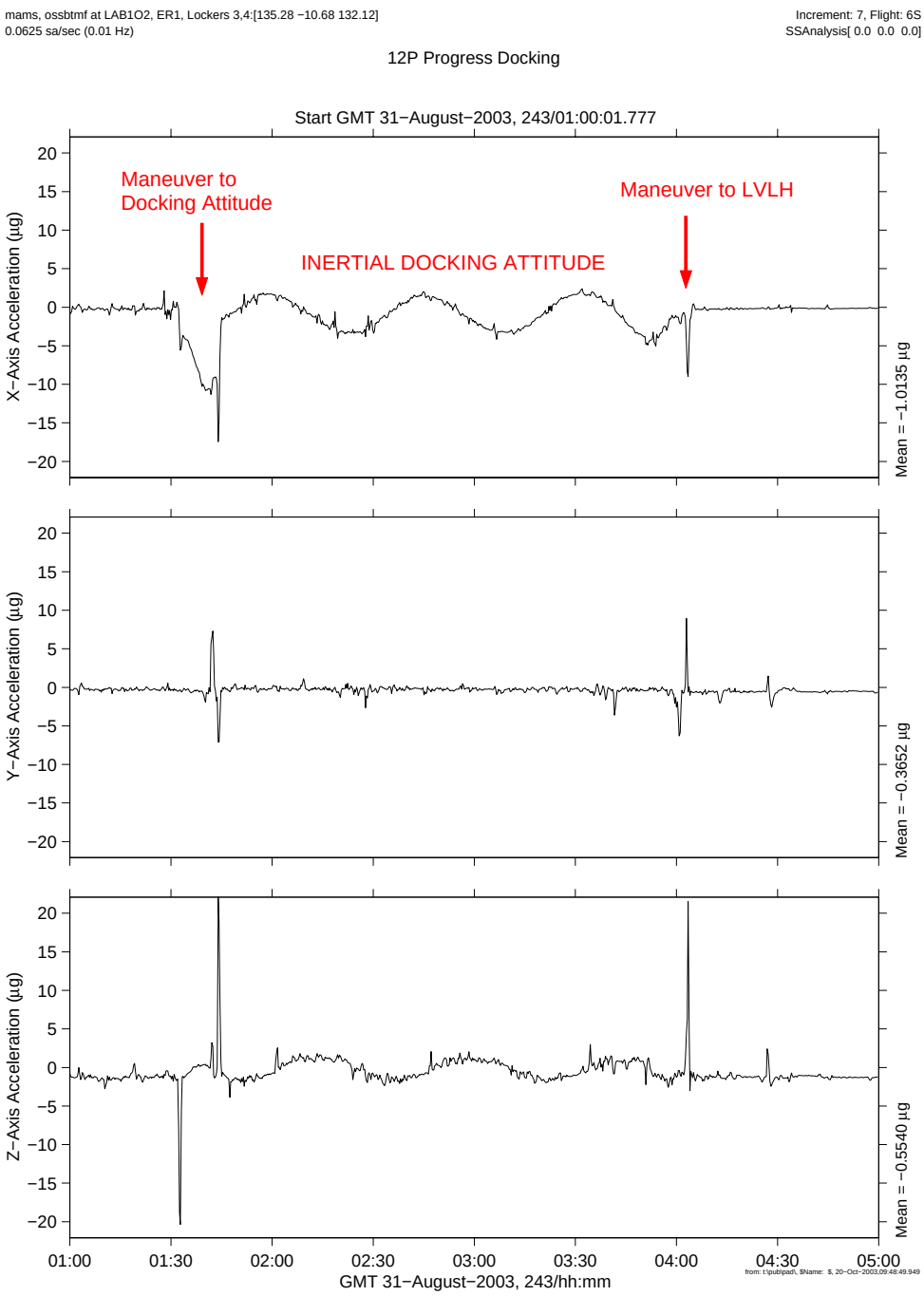
NOTES:

- As part of a propellant resupply procedure, fuel and oxidizer are transferred from a newly arrived Progress to the FGB storage tanks. During this procedure the line is purged between steps.
- The fuel line purge prior to Progress 10P undocking occurred at approximately GMT 22-Aug-2003 234/06:07 (see red box).
- A momentum management event is seen at GMT 06:22 which is used to desaturate the Control Moment Gyroscopes (CMG)
- The maximum Δµg during the purge are given for each axis in the table below.

Axis	Δ µg
X	0.35
Y	3.06
Z	-0.37

Regime:	Quasi-steady
Category:	Vehicle
Source:	Vent

Docking Events, Progress



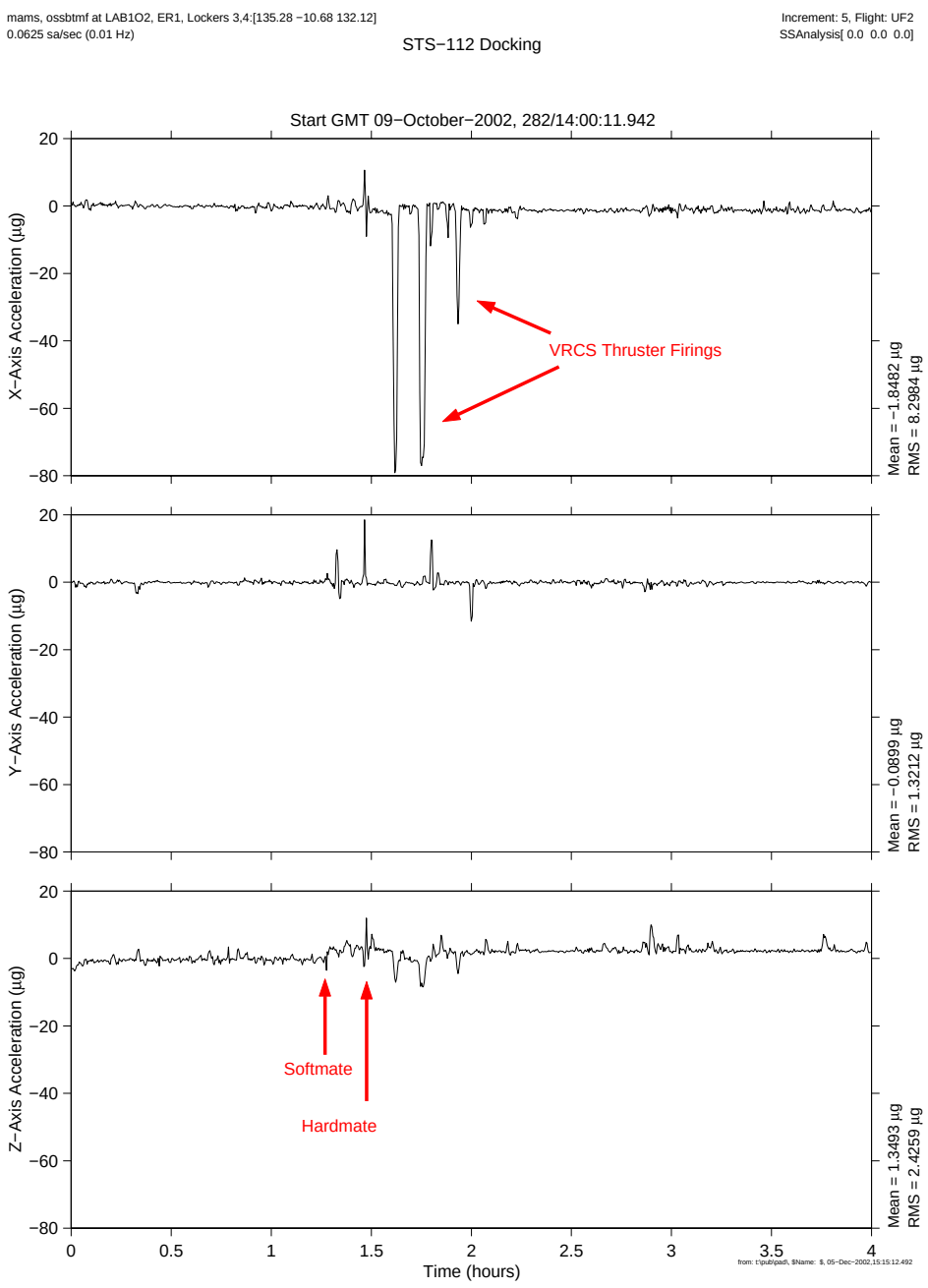
Description	
Sensor	ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 7, Flight: 6S
Plot Type	Time Series

NOTES:

- The Progress 12-P docked to Services Module's aft end port at GMT 31-Aug-03, 243/03:41.
- Effects of actual docking event cannot be seen in quasi-steady data. The trimmed mean filter process discards these transient effects.
- The large displacement occurring at 01:32 in the negative X-axis (10-15 µg) is the maneuver from LVLH to the inertial docking attitude. (yaw,pitch,roll) = [337.8, 31.8 311.8].
- The ISS is under Russian control during these dockings. Large spikes near attitude maneuvers are thruster firings.

Regime:	Quasi-steady
Category:	Vehicle
Source:	Docking Events

Docking Events, Shuttle



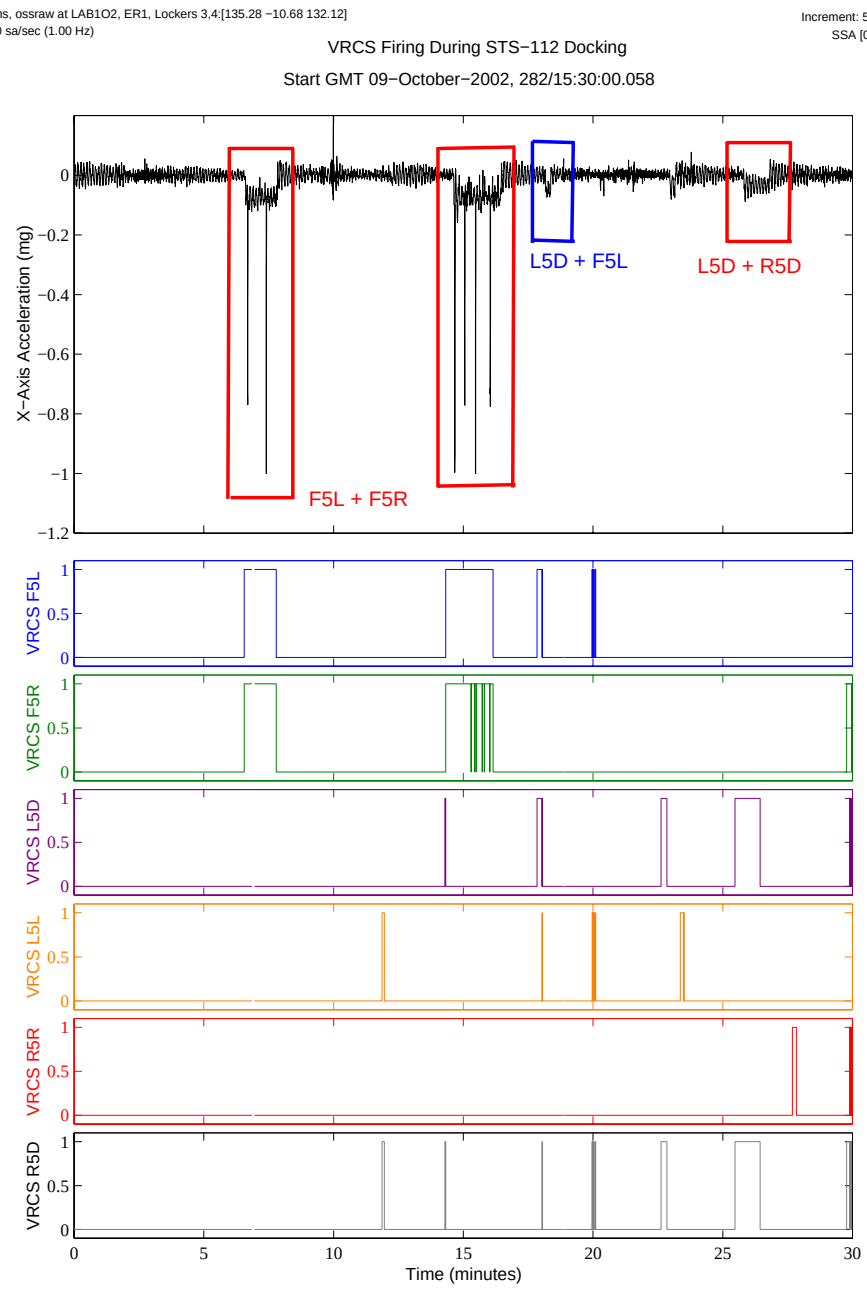
Description	
Sensor	ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 5, Flight: UF2
Plot Type	Time Series

NOTES:

- The Space Shuttle Atlantis docked to the PMA-2 port during the STS-112 mission at GMT 09-Oct-02, 282/15:16.
- Effects of softmate and hardmate can be seen in all three axes. However, due to their transient nature, these effects are best measured with in the vibratory regime (SAMS).
- Three large spikes in X-axis (-77.1, -75.4, and -33.5 µg) are Vernier Reaction Control System (VRCS) thruster firings of Atlantis. Similar spikes are seen in other STS docking events.
- Other, shorter duration, thruster firings have been removed by the trimmed mean filter process.

Regime:	Quasi-steady
Category:	Vehicle
Source:	Docking Events

Docking Events, Shuttle

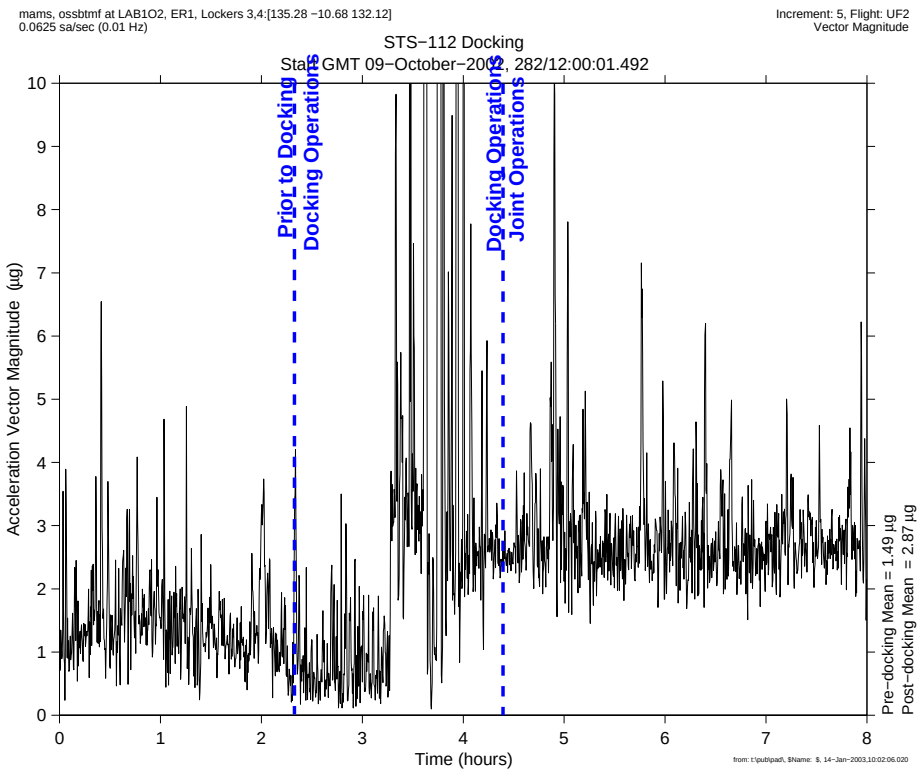


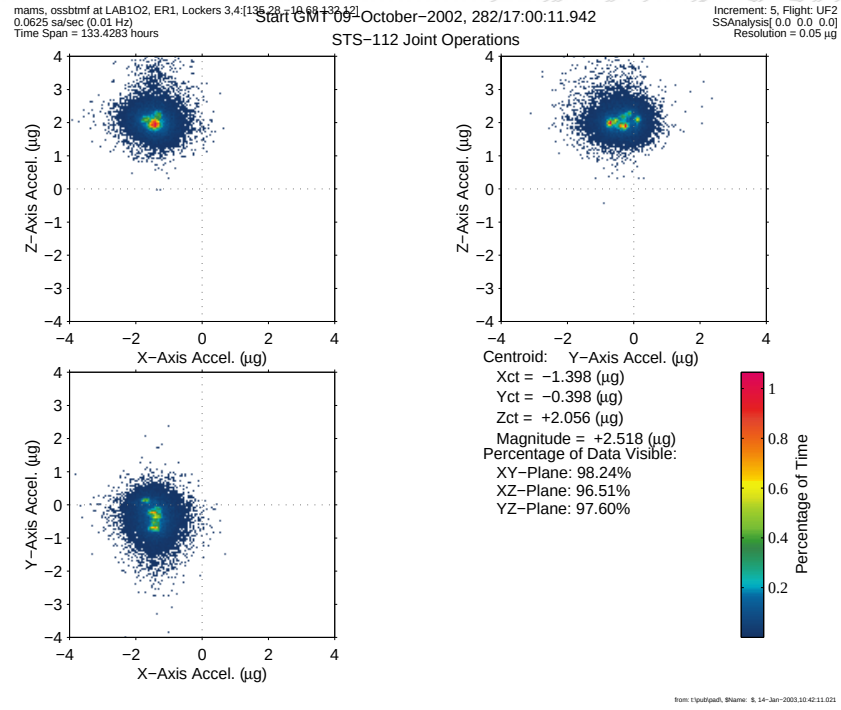
Description	
Sensor	ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 5, Flight: UF2
Plot Type	Time Series

NOTES:

- Plot shows MAMS OSSRAW data correlated with Shuttle VRCS firings during docking operations.
- F5L and F5R are thrusters located in the nose of the orbiter. These provide acceleration in the orbiter +Z-axis, which corresponds to the ISS -X-axis during docked operations.
- This plot is for correlation purposes only. SAMS data is preferred for a quantitative look at the effect of thruster firings.

Regime:	Quasi-steady
Category:	Vehicle
Source:	Docking Events





Description	
Sensor	ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 5, Flight: UF2
Plot Type	Quasi-steady Three Dimensional Histogram

NOTES:

- Mating of Shuttle to ISS results in a significant change in the quasi-steady vector due to center of mass (CM) shift away from the OSS sensor, detailed in the table below.

OSS Distance to CM (feet)		
ISS	**Joint Ops**	**Δd**
47.8	17.6	-30.2
-1.98	-1.52	0.46
2.33	-17.0	-19.3

- The top plot shows the mean acceleration magnitude at the OSS location increasing from 1.49 µg (prior to docking) to 2.87 µg (after docking).

- Results for entire STS-112 joint operations. Centroid is an estimate of the mean.

Axis	Centroid (µg)
X	-1.40
Y	-0.40
Z	2.06
Magnitude	2.52

Regime:	Quasi-steady
Category:	Vehicle
Source:	Joint Operations

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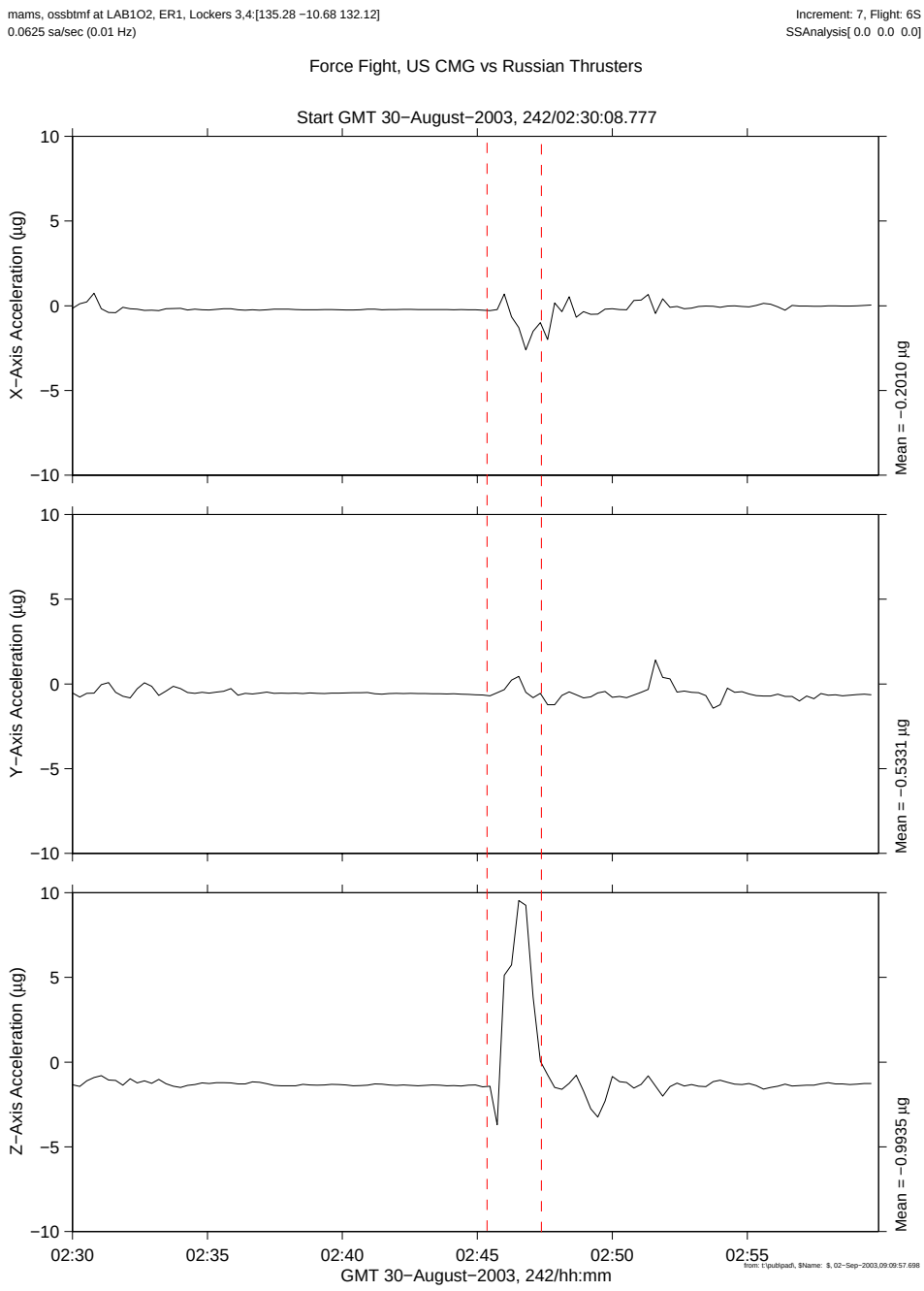
Russian / US GNC Force Fight



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 7, Flight: 6S
Plot Type	Time Series

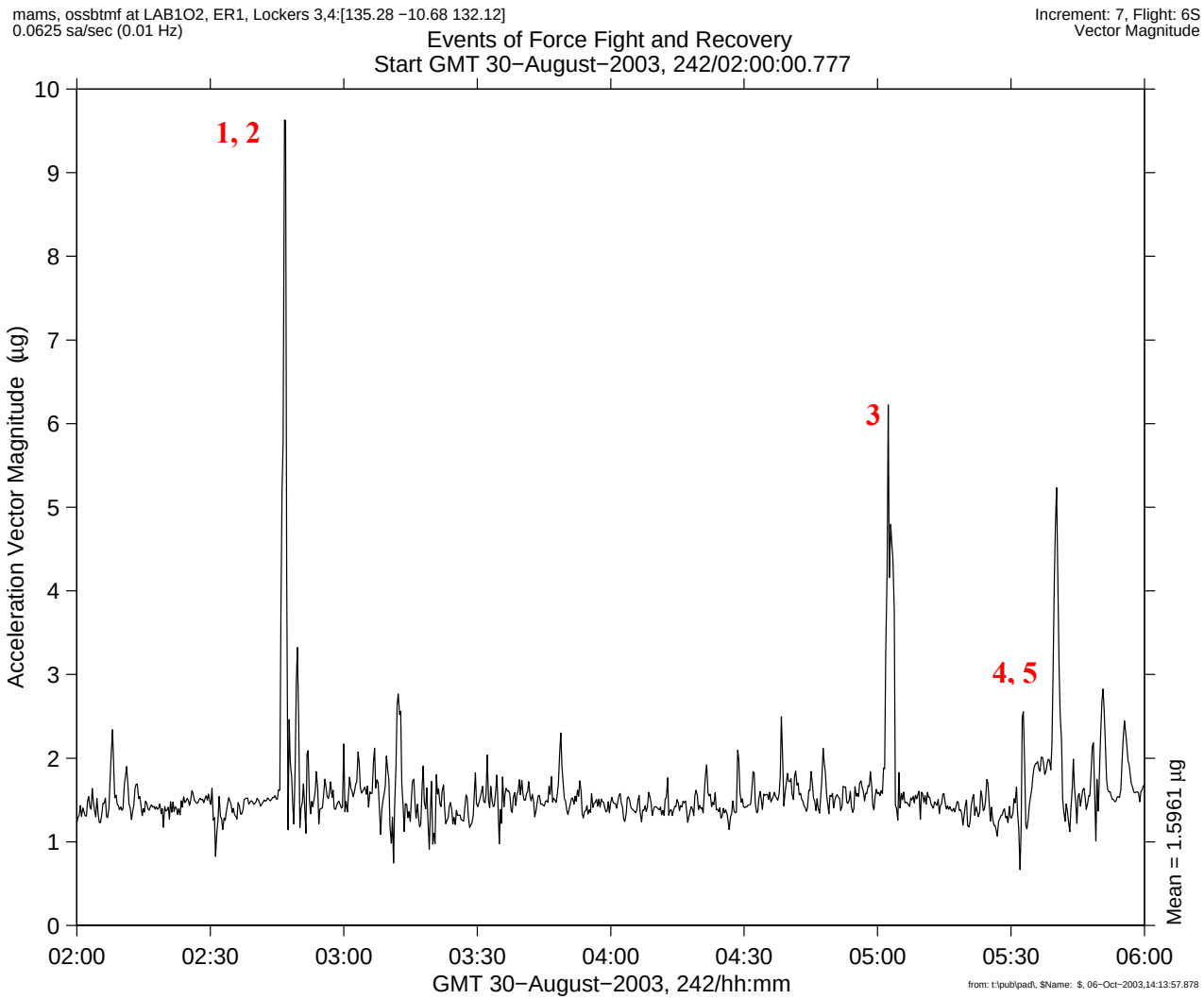
NOTES:

- On GMT 30-Aug-2003, 242/02:45 a Loss of Attitude Control (LOAC) recovery procedure was inadvertently invoked causing the Russian system to unconditionally take control of the ISS. This included ignoring the US Guidance, Navigation and Control (GNC) control status. This resulted in a 106 second "force fight" between the Russian thrusters and US Control Moment Gyroscopes (CMG). The CMGs torqued against an RS thruster pitch adjustment until the force fight ended with CMGs saturated and their gimbals' rates zeroed
- The peak values the quasi-steady environment during the force fight event are tabulated below.

Axis	Peak (µg)
X	-2.68
Y	0.37
Z	9.59

Regime:	Quasi-steady
Category:	Vehicle
Source:	Thrusters, CMG

Russian / US GNC Force Fight



Description	
Sensor	MAMS, ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 7, Flight: 6S
Plot Type	Acceleration Magnitude

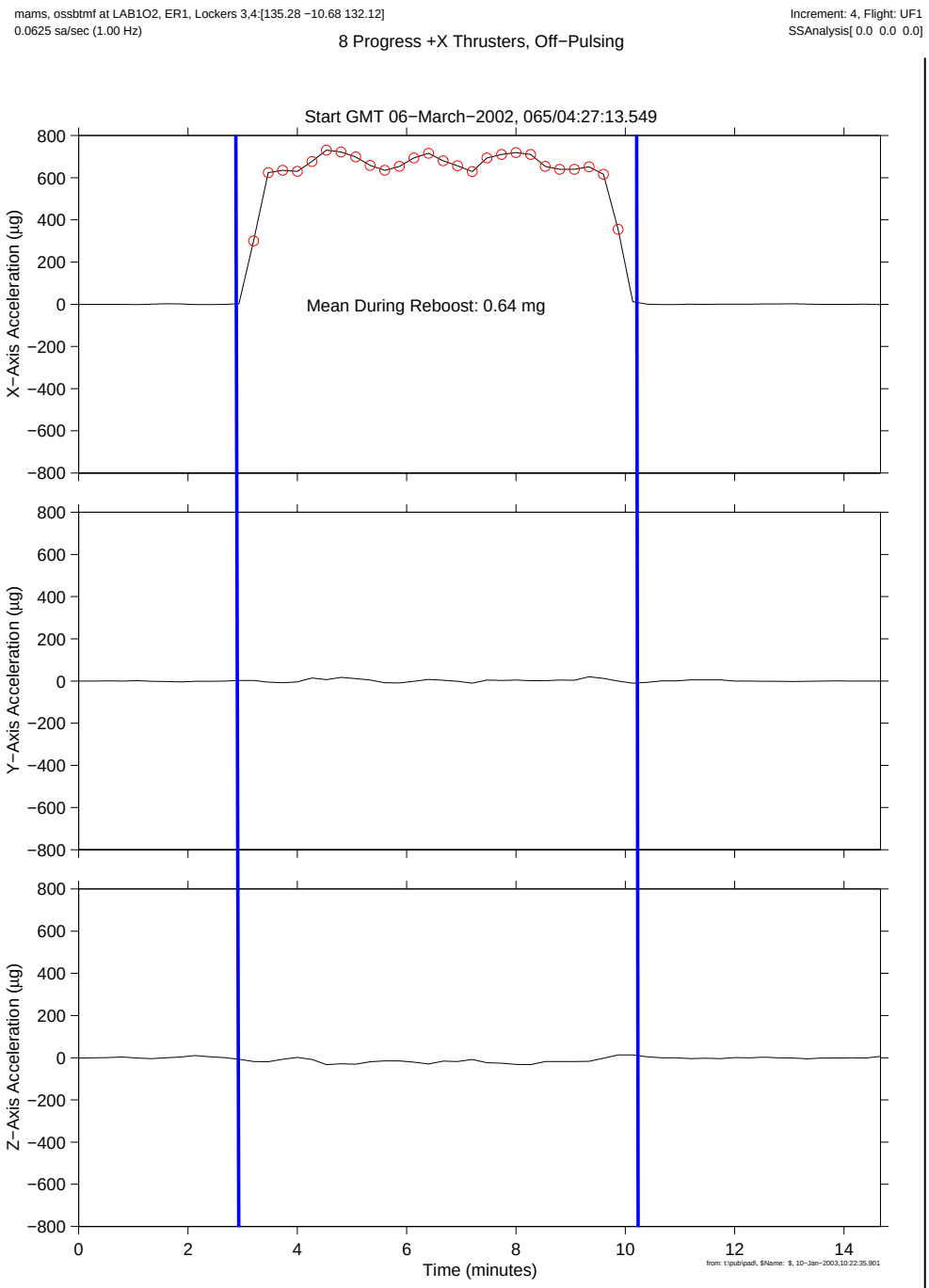
NOTES: Timeline of Events/GMT 242

1. **2:45 to 2:47** - Force fight between US CMGs and RS Thrusters.
2. **2:47:15** - Loss of attitude control due to the saturation of the CMGs, SM thrusters not available for desaturation.
3. **5:00** - US GN&C moded from CMGTA to Drift – Inertial
4. **5:30** - Final steps for Attitude Control Handover from RS to US begun.
5. **5:30:49** - Thrusters available for CMG desaturation

Event	Peak (µg)
1,2	9.83
3	6.20
4,5	5.21

Regime:	Quasi-steady
Category:	Vehicle
Source:	Thrusters, CMG

Progress Reboost



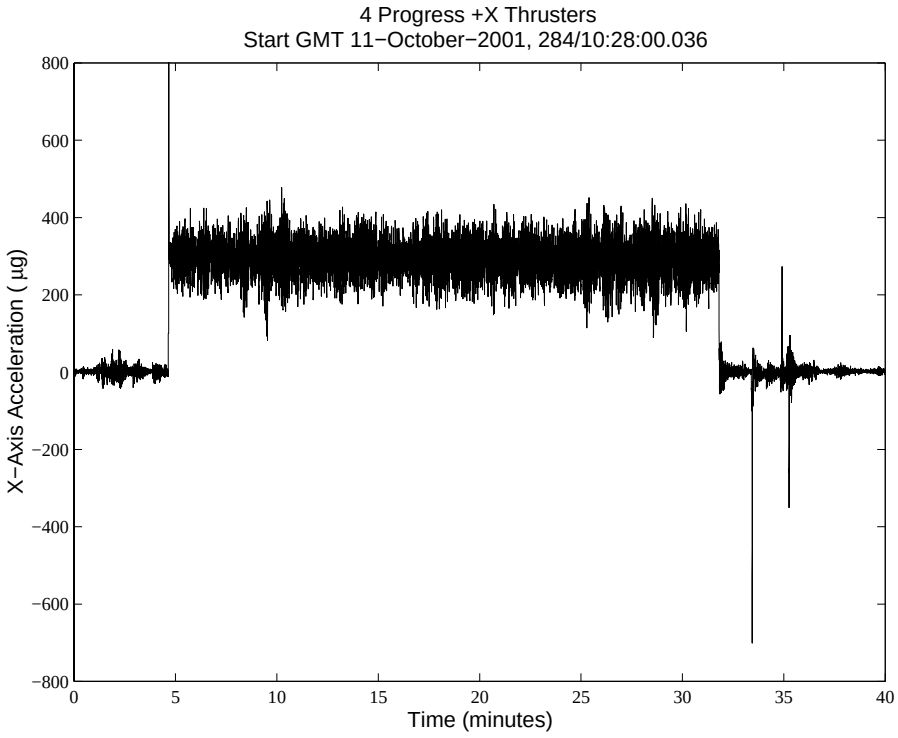
Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 4, Flight: UF1
Plot Type	Time Series

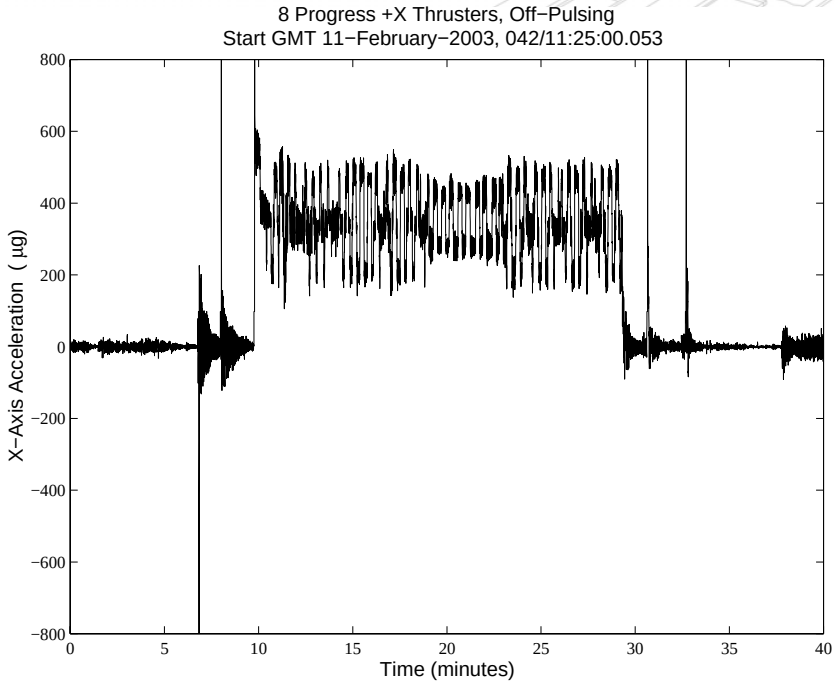
NOTES:

- Periodic reboosts of the ISS are necessary due to orbital decay.
- The primary method for conducting a reboost is using the aft facing attitude control thrusters of a docked cargo vehicle, typically a Progress.
- Station reboosts are open loop burns, where the firing is initiated at a prescribed time and place in orbit. Reboosts usually take two burns
- Data shown was for Burn #2 and lasted 401 seconds using 143.8 kg of propellant.

Regime:	Quasi-steady
Category:	Vehicle
Source:	Reboost

Progress Reboost





Description	
Sensor	MAMS,ossraw 10 sa/sec (1 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment: 3-7 Flight: Various
Plot Type	Time Series

NOTES:

- In the "4 Progress +X Thrusters", four thrusters are pointed in the $-X_A$ direction and four other YZ thrusters are used for attitude control.
- "8 Progress +X Thrusters, Off-Pulsing", all thrusters are $-X_A$ direction; four on continuous, other four pulse on/off.
- Bias compensated OSSRAW data is shown to highlight the different modes. The trimmed mean filtered process masks this detail.

Microgravity Science Division

Glenn Research Center

Regime:	Quasi-steady
Category:	Vehicle
Source:	Reboost

Progress Reboost

The table below compares average acceleration from vehicle data to the average acceleration calculated from MAMS

Reboost Information					Calculations from MAMS OSS data		
Ignition (GMT)	Comments	Δ V (m/sec)	Duration (sec)	ΔV/T (mg)	Duration (sec)	ΔV (m/sec)	X-Axis Mean (mg)
11-Oct-2001, 284/10:31	4 Progress +X Thrusters	4.7	1560	0.31	1,629.30	4.63	0.29
11-Oct-2001, 284/15:54	4 Progress +X Thrusters	4.5	1560	0.29	1,623.78	4.46	0.28
10-Jan-2002, 010/01:35:15	4 Progress +X Thrusters	5.4	1877	0.29	1,863.90	5.3	0.29
10-Jan-2002, 010/03:43:26	4 Progress +X Thrusters	4.8	1654	0.30	1,643.00	4.67	0.29
21-Feb-2002, 052/08:27	8 Progress +X Thrusters, Off-Pulsing	1.35	239	0.58	237.40	1.21	0.52
21-Feb-2002, 052/09:59	8 Progress +X Thrusters, Off-Pulsing	1.35	243	0.57	238.50	1.24	0.53
06-Mar-2002, 065/03:37:12	8 Progress +X Thrusters, Off-Pulsing	1.0	158.2	0.65	157.70	0.93	0.60*
06-Mar-2002, 065/04:29:07	8 Progress +X Thrusters, Off-Pulsing	2.5	395.1	0.65	398.80	2.5	0.64*
13-Mar-2002, 072/00:04:10	8 Progress +X Thrusters, Off-Pulsing	2.2	319	0.70	300.30	1.8	0.61*
13-Mar-2002, 072/00:52:49	8 Progress +X Thrusters, Off-Pulsing	4.0	636.1	0.64	609.70	3.94	0.66*
19-Apr-2002, 109/07:59	8 Progress +X Thrusters, Off-Pulsing	0.73	118	0.63	142.70	0.6	0.43
01-Aug-2002, 213/17:24:23	8 Progress +X Thrusters, Off-Pulsing	4.3	760	0.58	761.10	4.18	0.56
11-February-2003 042/11:34:30	8 Progress +X Thrusters, Off-Pulsing	5.1	~1200	0.43	1168	4.01	0.35
12-March-2003 071/22:58	Progress Manifold 1 4 Progress +X Thrusters	1.38	597	0.24	634	1.3	0.21
12-March-2003 072/23:37	Progress Manifold 2 4 Progress +X Thrusters	0.37	198	0.19	219	0.3	0.14
04-April-2003 094/12:59:18	8 Progress +X Thrusters Off-Pulsing	1.8	N/A	N/A	835	1.83	0.23
01-Oct-2003 274/13:11	8 Progress +X Thrusters Off-Pulsing	1.7	450	0.38	469	1.72	0.36

Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (1 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increments: 3-7 Flights: Various
Plot Type	Time Series

NOTES:

- Informaton in table from Rex Delventhal, GNC Daily Reports and On-Orbit Summary
- Values marked with an asterisk may be off by as much as 14 ug due to lack of bias compensation for OSS A-range data.

Regime:	Quasi-steady
Category:	Vehicle
Source:	Progress Thrusters