1. INTRODUCTION

At GMT 2022-10-17, 290/19:27:20, the International Space Station (ISS) began a ~10-minute reboost using the Progress 81P thrusters. Figure 1 shows that the Progress vehicle was docked with its thrusters facing aftwards, which put thrust and the necessary orbital mechanics into play so as to speed up the ISS in its direction of flight. This directional acceleration (increase in velocity), resulted in the altitude elevation of the space station during this dynamic event. **The intended ΔV objective of 1.0 m/s for the massive space station was achieved.** The reboost was originally planned for October 20, but was moved earlier as part of a Pre-determined Debris Avoidance Maneuver (PDAM) due to a conjunction with a piece of Cosmos debris. Although the risk of the conjunction decreased to low, due to the proximity of this PDAM to the planned reboost on GMT 293, ground teams decided to proceed with the PDAM for this object as the burn replaced the previously planned reboost.

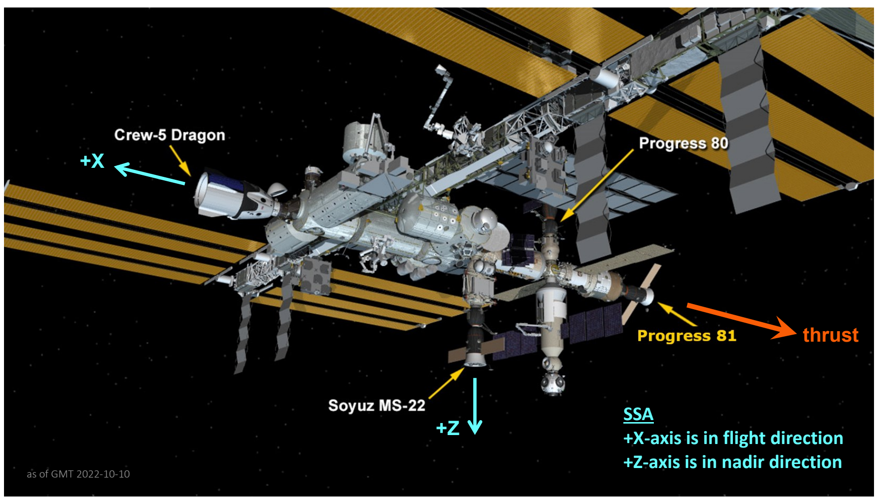

Fig. 1: Progress 81P's location and alignment during reboost.

2. QUALIFY

The information shown in Figure 2 on page 3 was calculated from the Space Acceleration Measurement System (SAMS) sensor 121f04 measurements made in the US LAB from a sensor mounted on the Cold Atom Lab facility, in the LAB1P2 rack. This color spectrogram plot shows increased structural vibration excitation contained mostly below 1 Hz or so, and the ~10-minute reboost (thruster firing) event itself is annotated in white starting not long before GMT 19:30. We attribute much of the structural vibration increase to Russian Segment (RS) attitude control since the as-flown timeline shows RS control from about GMT 18:17 to about 19:58 (as shown with other, non-white annotations). The RS thrusters were used for station attitude control during the time around the reboost activity. This is expected, and typical behavior. The increased structural vibrations are evident as more noticeable horizontal streaks (structural/spectral peaks) that change from quieter (green/yellow) to more energetic (orange/red) sporadically during this period of RS control spanning about 101 minutes. The flare up of these nebulous horizontal (spectral peak) streaks are the tell-tale signatures of large space station appendages as they flex, twist, or bend in reaction to impulsive attitude control thruster forces. The actual reboost activity itself lasted just over about 10 minutes as evidenced by slightly more pronounced, vertical orange-red streaks in Figure 2 starting around GMT 19:27. For science operations and general situational awareness, it is prudent to be aware that the transient and vibratory environment (primarily below about 10 Hz or so) is impacted not only during the relatively briefer reboost event itself, but also during the relatively longer span of Russian Segment (RS) attitude control too. The difference being that during the reboost itself, the dominant factor might be considered to be the highly-directional step in the X-axis acceleration , while in the much longer case of RS attitude control, the dominant impact was the excitation of lower-frequency vibrational modes of large space station structures.

Follow-Up Regarding 2 Features Seen in Acceleration Measurement & Analysis

Follow-up emails with the ISS Loads & Dynamics (Boeing) team at the Johnson Space Center (JSC) in Houston, Texas and the Russian Attitude Control team revealed the following 2 features observed in the acceleration measurement and analysis:

- *"The pattern [of **oscillations/dips**] in the acceleration [vs. time plot] makes sense for an Aft Progress Reboost. The Progress thrusters that are firing for the translational burn are controlling ISS attitude in Yaw and Pitch at the* *same time, through **"off-pulsing"**. So, a dip in acceleration is because some thrusters stopped firing momentarily to create an attitude control torque. It might not always be the same pattern and timing, that depends on ISS attitude and rate error throughout the burn."*

- *The **0.18 Hz excitation** seen in zoomed-in spectrogram of Figure 3 on page 4 was expected. This was cited as **excitation of a known XY-plane structural mode of the ISS main truss**. The graphic of Figure 4 on the subsequent page aims to crudely depict this forward-aft bending mode.*

3. Quantify

The as-flown timeline for this event indicated the reboost would start at GMT 19:27 and have a duration of 10 minutes and 31 seconds. Analysis of Space Acceleration Measurement System (SAMS) data recordings in the US LAB – see Figure 5 on page 6 – shows the tell-tale X-axis step that started at GMT 19:27:20 and had a duration of 10 minutes and 7 seconds. Information from flight controllers indicated that this reboost event provided a space station rigid body ΔV of about 0.996 meters/second and the SAMS analysis indicated with red annotations in Figure 5 match the expected value. The SAMS does not directly measure altitude, but flight controllers indicated that the ISS gained 1.61 km in altitude above the Earth as a result of this reboost activity.

Six more plots of 5-second interval average acceleration versus time for SAMS sensors distributed throughout the ISS are shown at the end of this document starting with Figure 6 on page 6. The interval average processing effectively low-pass filtered the data so as to help emphasize the acceleration step that occurs on the X-axis during the reboost event. It should also be noted that we flipped the polarity of each axis (inverted each) in the SAMS plots owing to a polarity inversion issue inherent in SAMS transducers. A somewhat crude quantification of the reboost as measured by the 7 distributed SAMS sensors is also given in Table 1 – expectedly consistent impact results measured by SAMS throughout the giant structure, that is, the space station.

Table 1. **X-axis** steps (mg) during reboost event for 7 SAMS sensors.

Sensor	X-Axis	Location
121f02	0.167	COL1A1 (ER3)
121f03	0.166	LAB1O1 (ER2)
121f04	0.167	LAB1P2 (ER7)
121f05	0.167	JPM1F1 (ER5)
121f08	0.167	COL1A3 (EPM)
es18	0.168	MSRR (ER6)
es20	0.168	4BCO2 (LAB1P4)

4. Conclusion

The SAMS measurements for 7 sensor heads distributed across all 3 main labs of the ISS was analyzed and showed an **X-axis step during the Progress 81P reboost of just under 0.2 mg**. Furthermore, calculations based on SAMS sensor (121f04) mounted on the Cold Atom Lab facility (LAB1P2) in the US LAB indicate a ΔV metric of 0.99 meters/second was achieved, and this result nearly matched flight controllers' desired value.

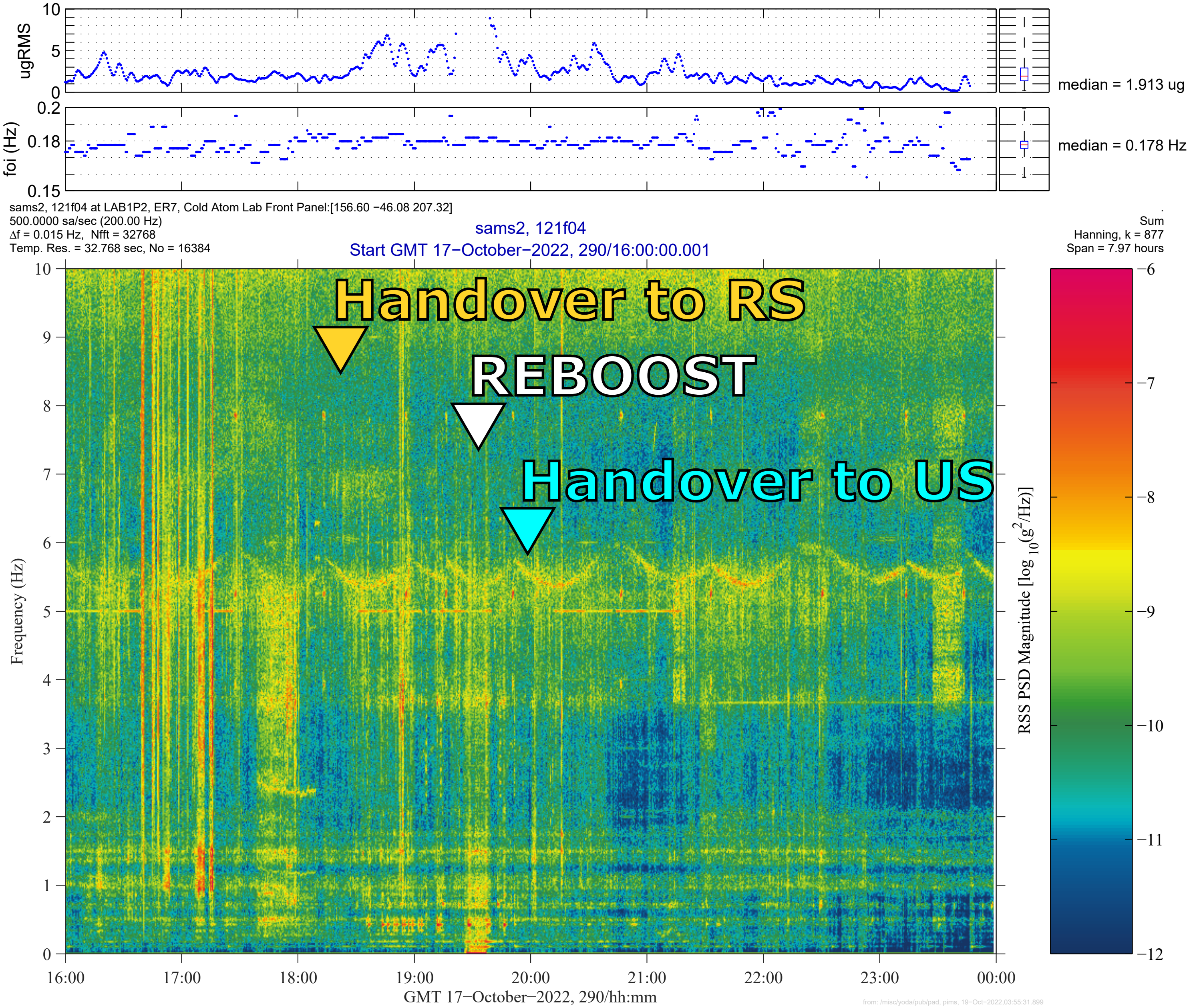

Fig. 2: Spectrogram showing Progress 81P Reboost on GMT 2022-10-17.

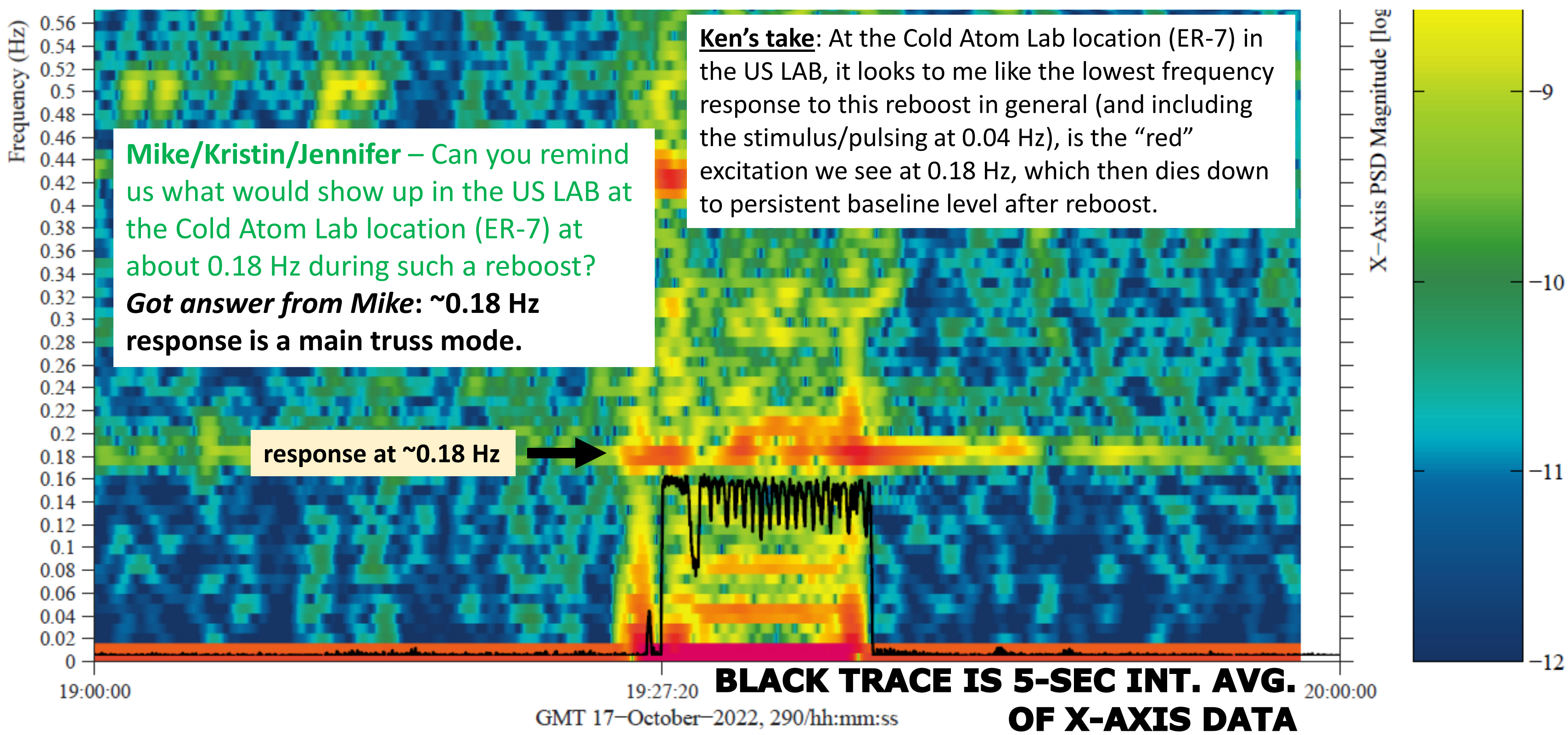

Fig. 3: Zoom-In Spectrogram showing ISS Main Truss XY-Bending Mode Excitation at about 0.18 Hz During Reboost.

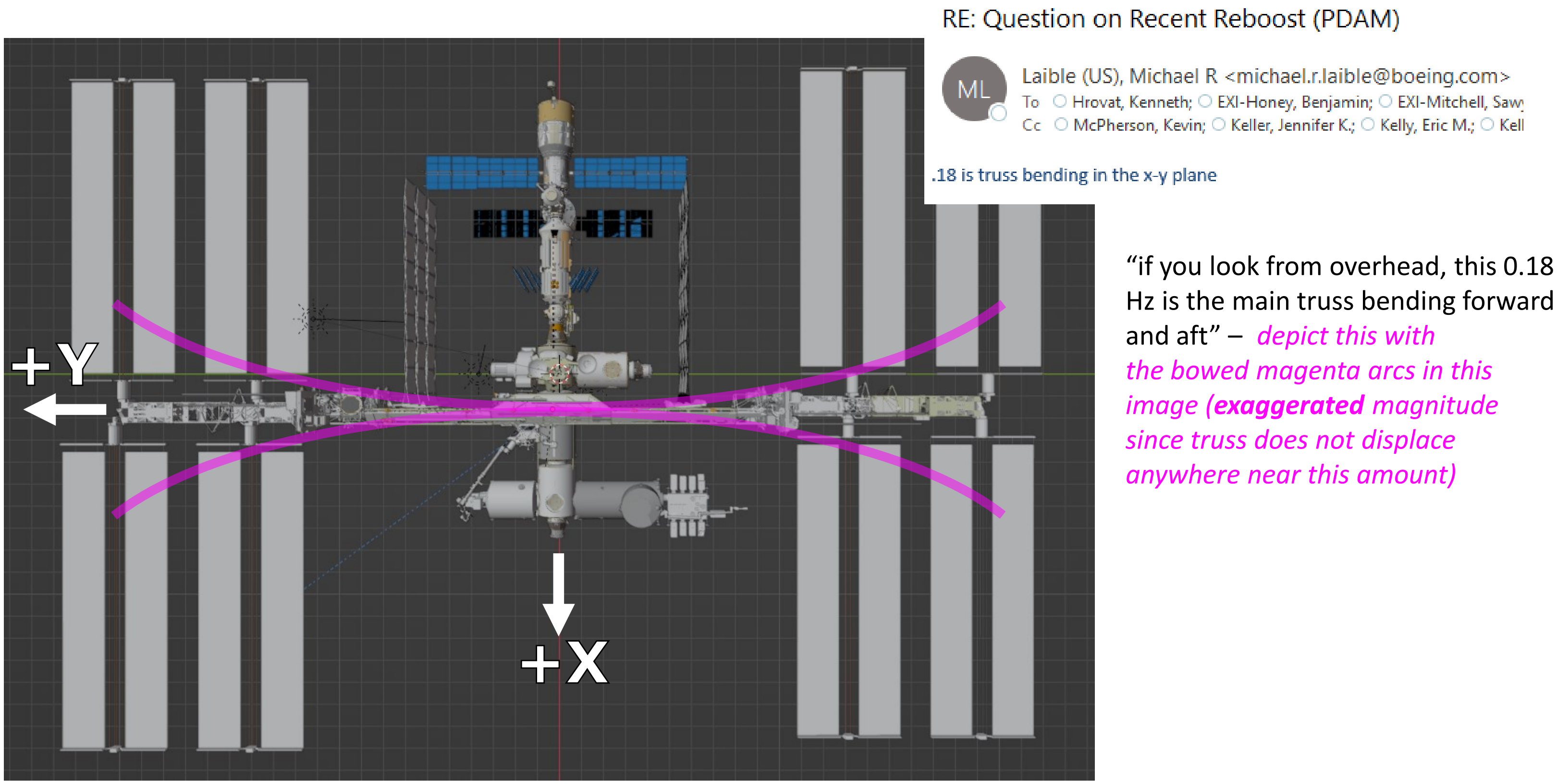

Fig. 4: Top Down, Overhead View of ISS to Depict 0.18 Hz XY-Plane Bending Mode of the Main Truss.

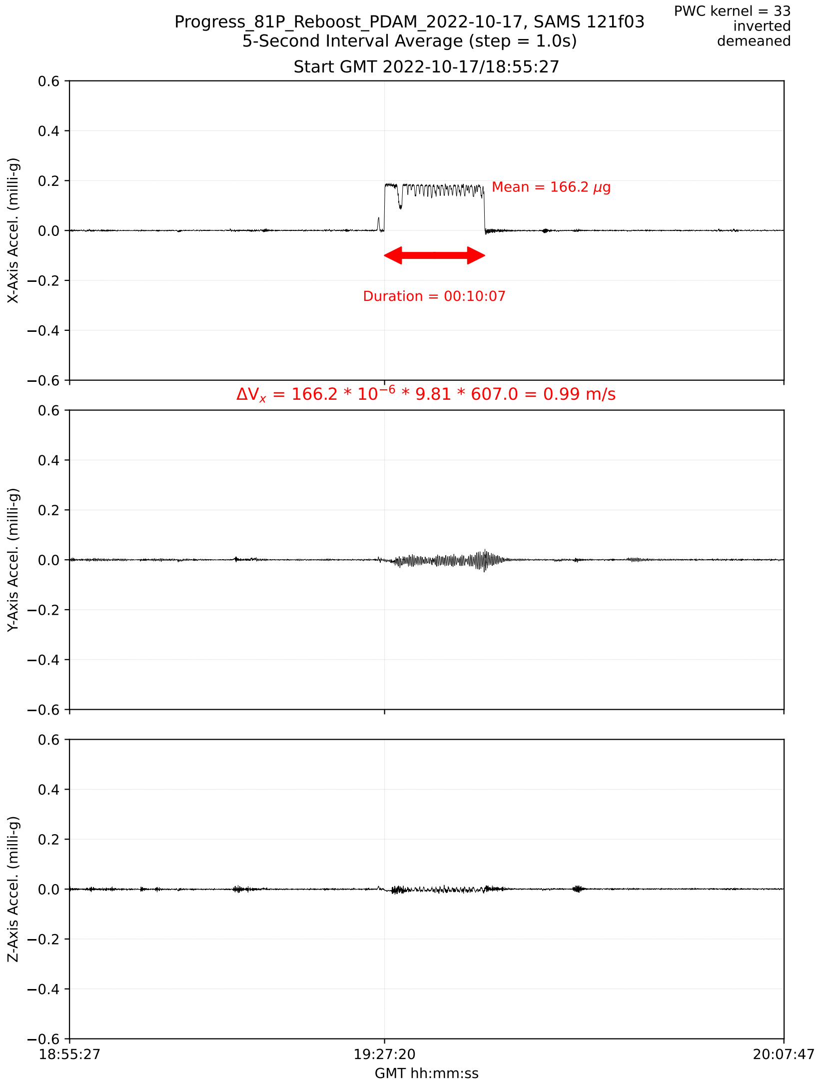

Fig. 5: 5-sec interval average for SAMS 121f03 sensor in the LAB.

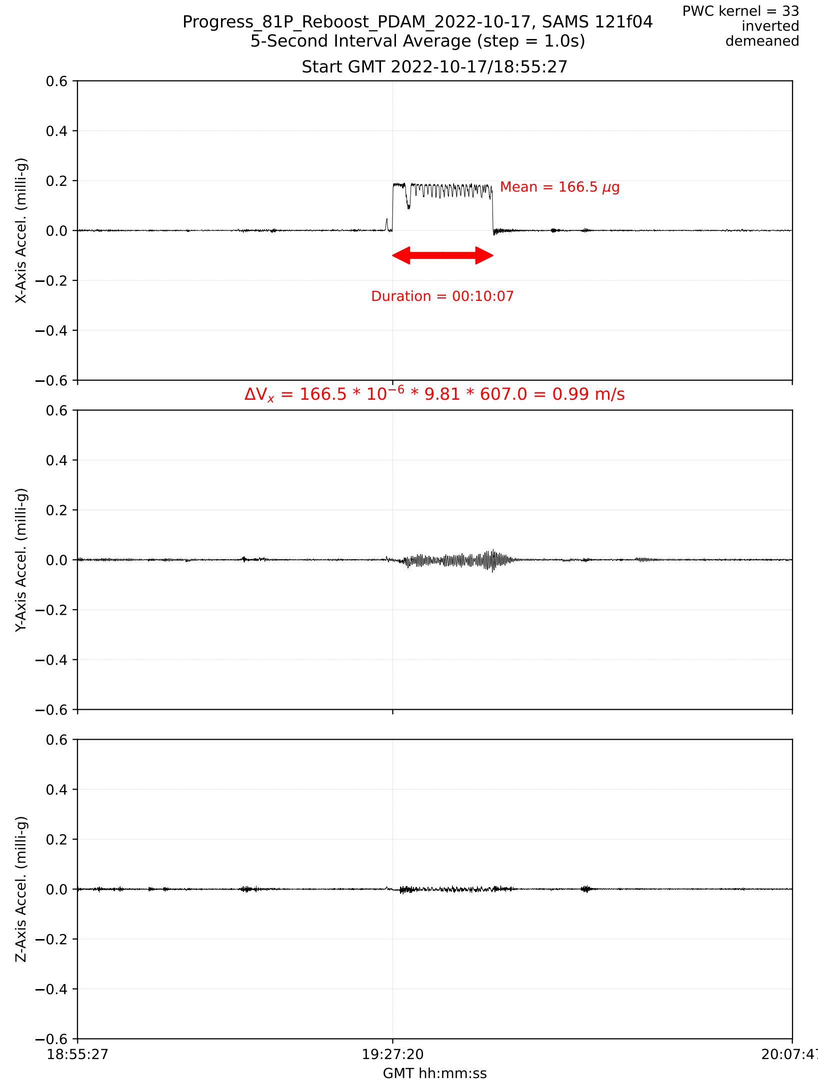

Fig. 6: 5-sec interval average for SAMS 121f04 sensor in the LAB.

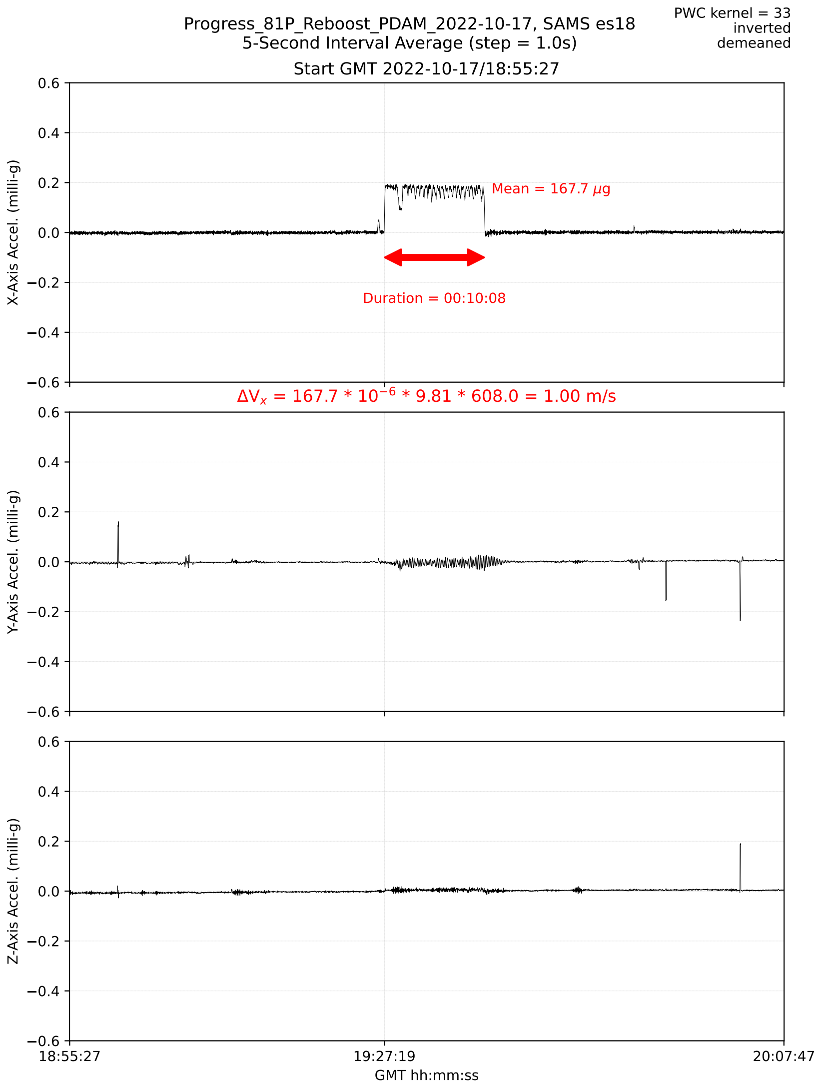

Fig. 7: 5-sec interval average for SAMS es18 sensor in the LAB.

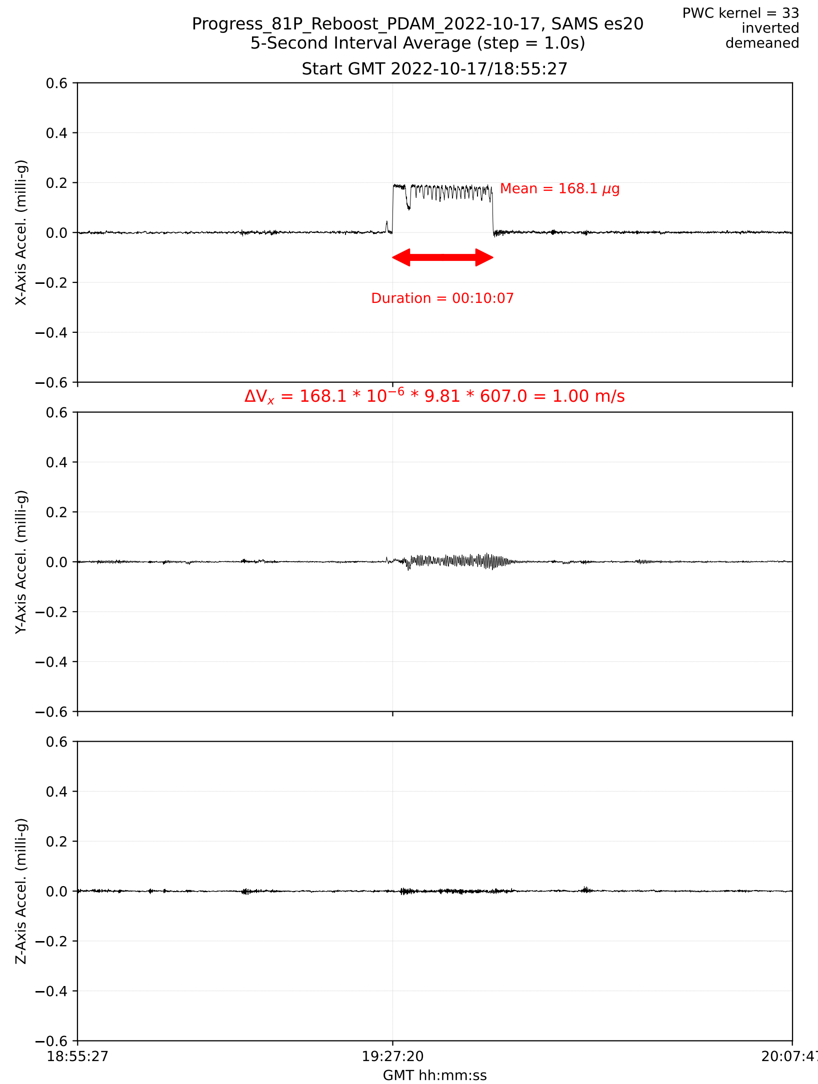

Fig. 8: 5-sec interval average for SAMS es20 sensor in the LAB.

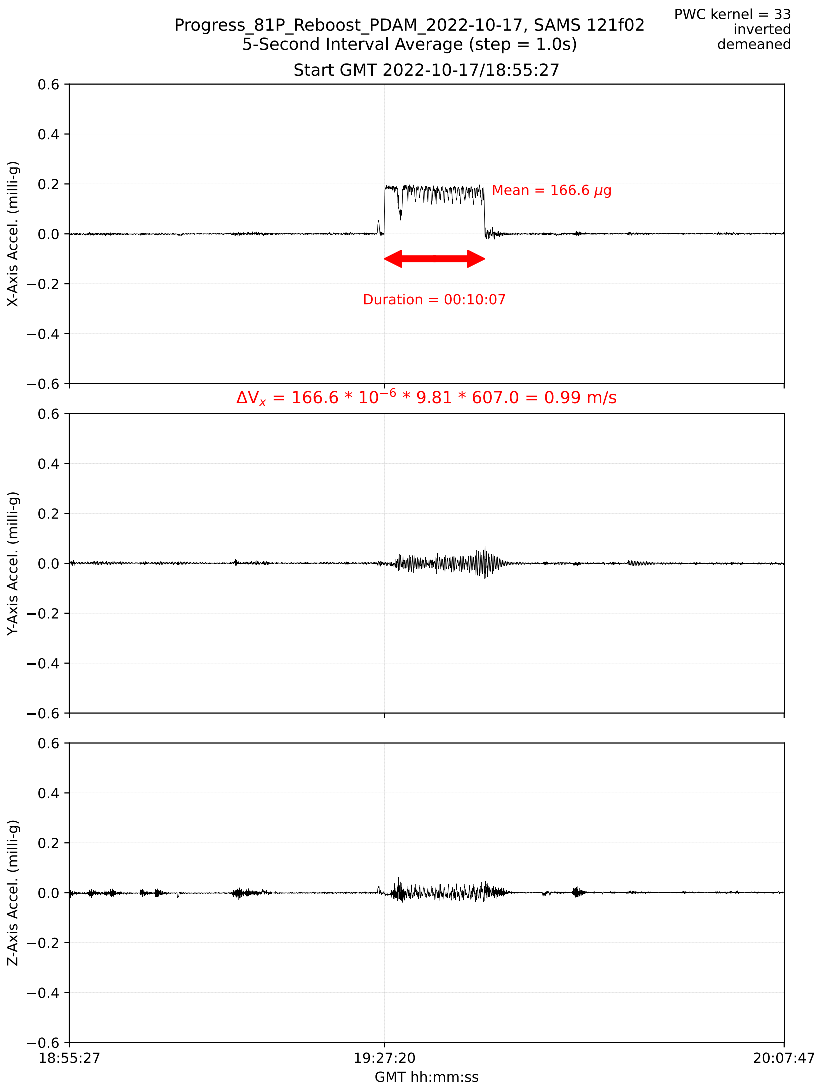

Fig. 9: 5-sec interval average for SAMS 121f02 sensor in the COL.

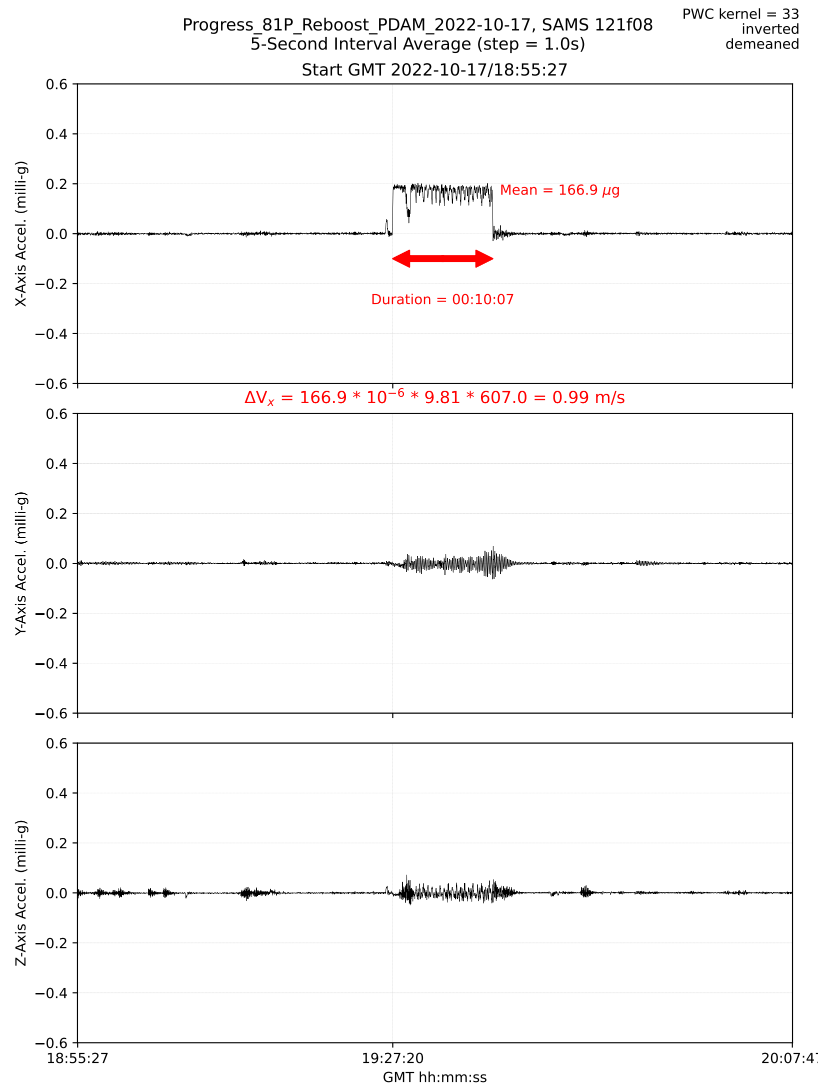

Fig. 10: 5-sec interval average for SAMS 121f08 sensor in the COL.

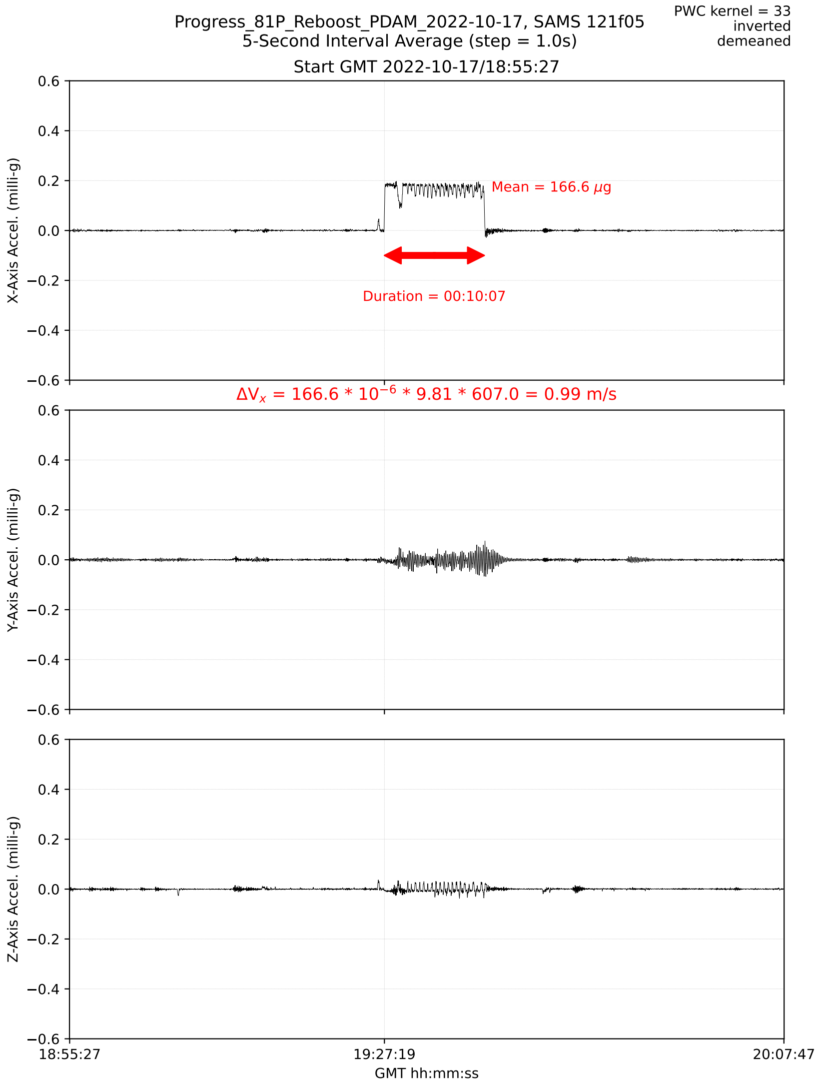

Fig. 11: 5-sec interval average for SAMS 121f05 sensor in the JEM.