1. INTRODUCTION

At GMT 2022-12-21, 355/13:42:20, 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 behemoth space station was achieved.** This reboost was also classified as a Pre-determined Debris Avoidance Maneuver (PDAM) due to an impending conjunction with space debris since tracking data showed a close approach to station.

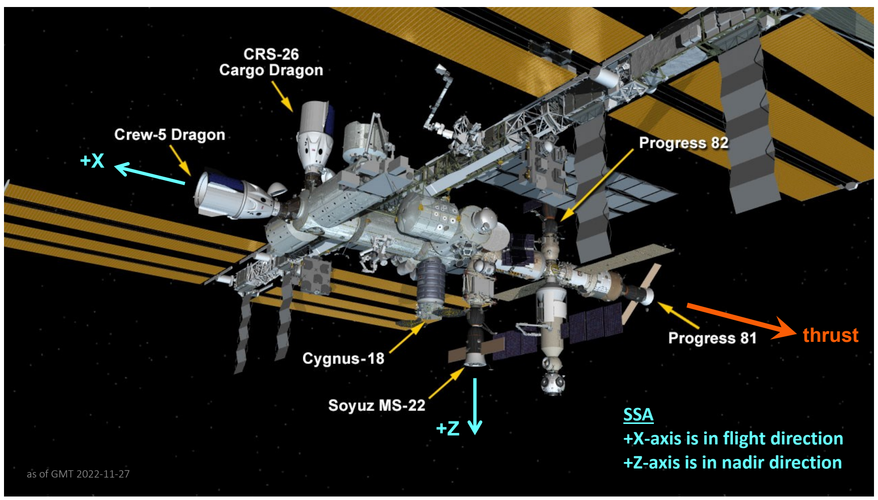

Fig. 1: Progress 81P's location and alignment during reboost.

2. QUALIFY

The information shown in Figure 2 on page 3 was calculated from the Space Acceleration Measurement System (SAMS) sensor 121f08 measurements made in the Columbus module from a sensor mounted on the European Physiology Module (EPM), in the COL1A3 rack. This color spectrogram plot shows increased structural vibration excitation contained mostly below 2 Hz or so, and the ~10-minute reboost (thruster firing) event itself is annotated in white starting not long after GMT 13:30. We attribute much of the structural vibration increase to Russian Segment (RS) attitude control, however, since the as-flown timeline was not updated in typical fashion, we only **speculate** that RS control was from about GMT 12:30 to about 14:30. The RS thrusters are ususally used for station attitude control during the time around the reboost activity. This is expected, and typical behavior, yet we do not have confirmation or documentation from flight controllers in as-flown timeline. 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. 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 just after GMT 13:42. 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 brief 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.

Two more SAMS sensors were analyzed in the time & frequency domain via the color spectrograms (below 10 Hz) starting on page 4 shown in Figure 3, for the JEM, and Figure 4, for the LAB.

Comparing the same reboost event across all 3 laboratories of the ISS via these color spectrograms we see the most energetic vibratory response from the SAMS sensor in the European lab (Columbus module), followed by the sensor in the Japanese lab (JEM), and lastly from the SAMS sensor in the US lab. This stems from the location of these sensors with respect to structural dynamics of large, massive space station. This analysis focused on the power spectral density of vibratory accelerations below 10 Hz, which provides a measure of the intensity of vibratory motion at the natural frequencies of the larger space station structures (e.g. solar array panels and main truss). At higher frequencies (up to 200 Hz), the SAMS sensors usually diverge greatly in terms of acceleration magnitude and frequency components as higher frequency vibrations tend to be more localized, i.e. “mostly” in/around the rack where the sensor is mounted, and due to equipment operations or crew activity in the vicinity.

3. Quantify

While the 3 spectrograms in the previous “Qualify” section crudely show acceleration magnitude on a color scale (actually, power spectral density magnitude), we now seek to better quantify the microgravity environment impact of the reboost event across 7 SAMS sensor heads distributed across all 3 main laboratories of the ISS. 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 13:42:20 and had a duration of 10 minutes and 28 seconds. Preliminary information from flight controllers indicated that this reboost event would provide a space station rigid body ΔV of 1.0 meters/second and the SAMS analysis indicated with red annotations in Figure 5 match the predicted value. The SAMS does not directly measure altitude, but flight controllers indicated that the ISS would gain about 1.8 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	0.161	COL1A1 (ER3)
121f03	0.161	LAB1O1 (ER2)
121f04	0.161	LAB1P2 (ER7)
121f05	0.161	JPM1F1 (ER5)
121f08	0.161	COL1A3 (EPM)
es18	0.162	MSRR (ER6)
es20	0.162	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 sensors indicate a ΔV metric of just about 1.0 meters/second was achieved, and this result matched flight controllers’ predicted value.

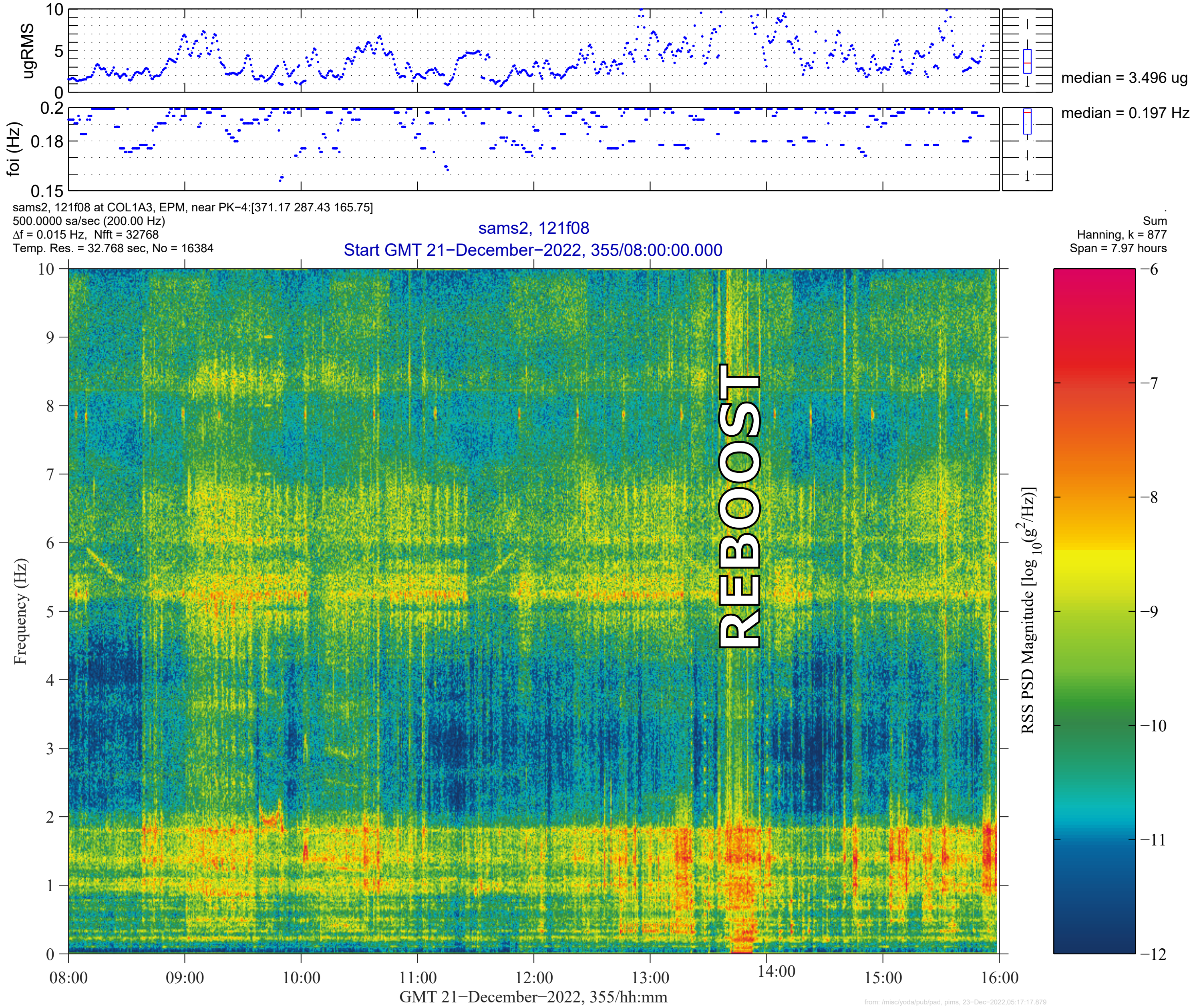

Fig. 2: Spectrogram showing Progress 81P Reboost on GMT 2022-12-21 from SAMS Sensor in Columbus Module.

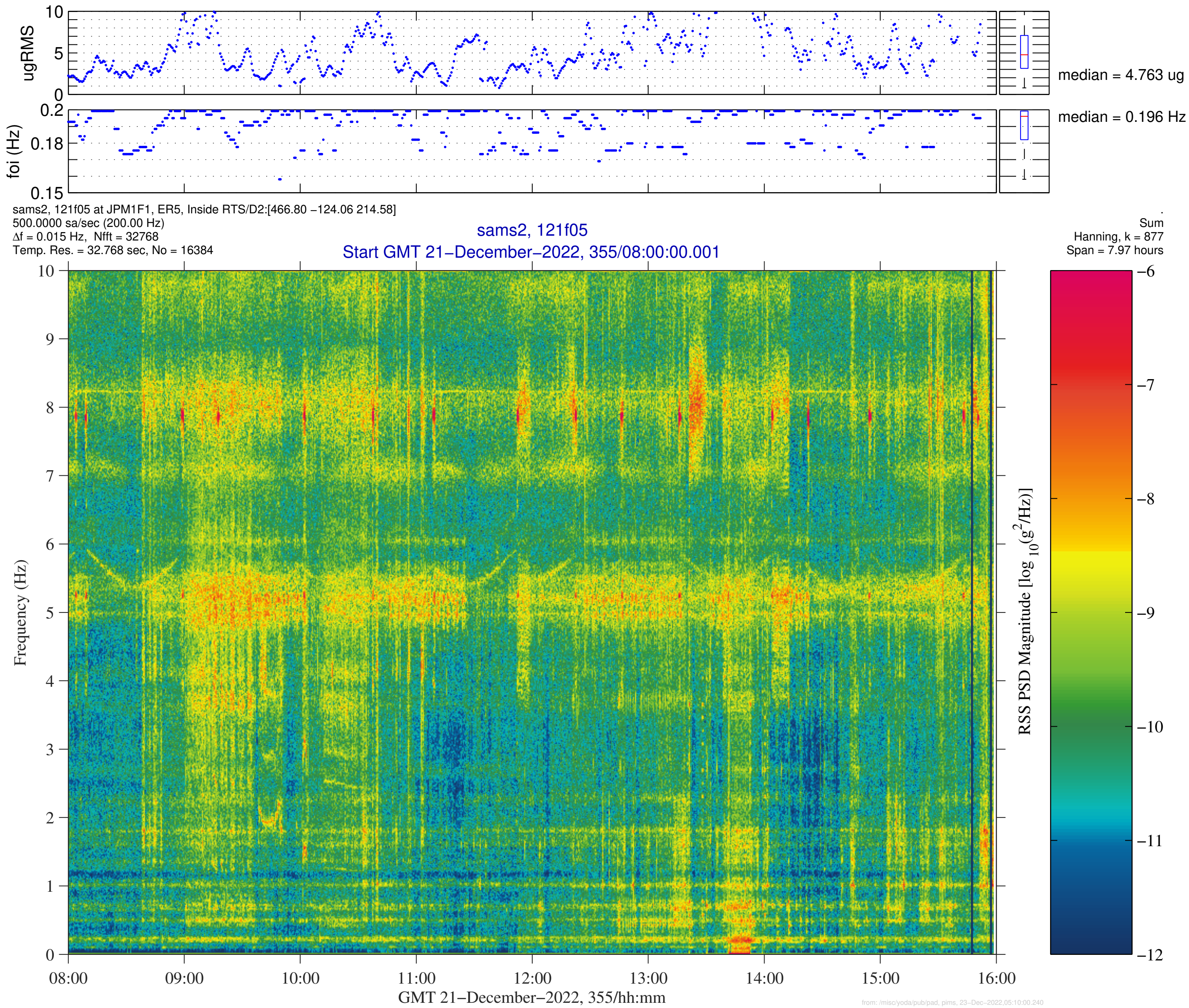

Fig. 3: Spectrogram showing Progress 81P Reboost on GMT 2022-12-21 from SAMS Sensor in Japanese Module.

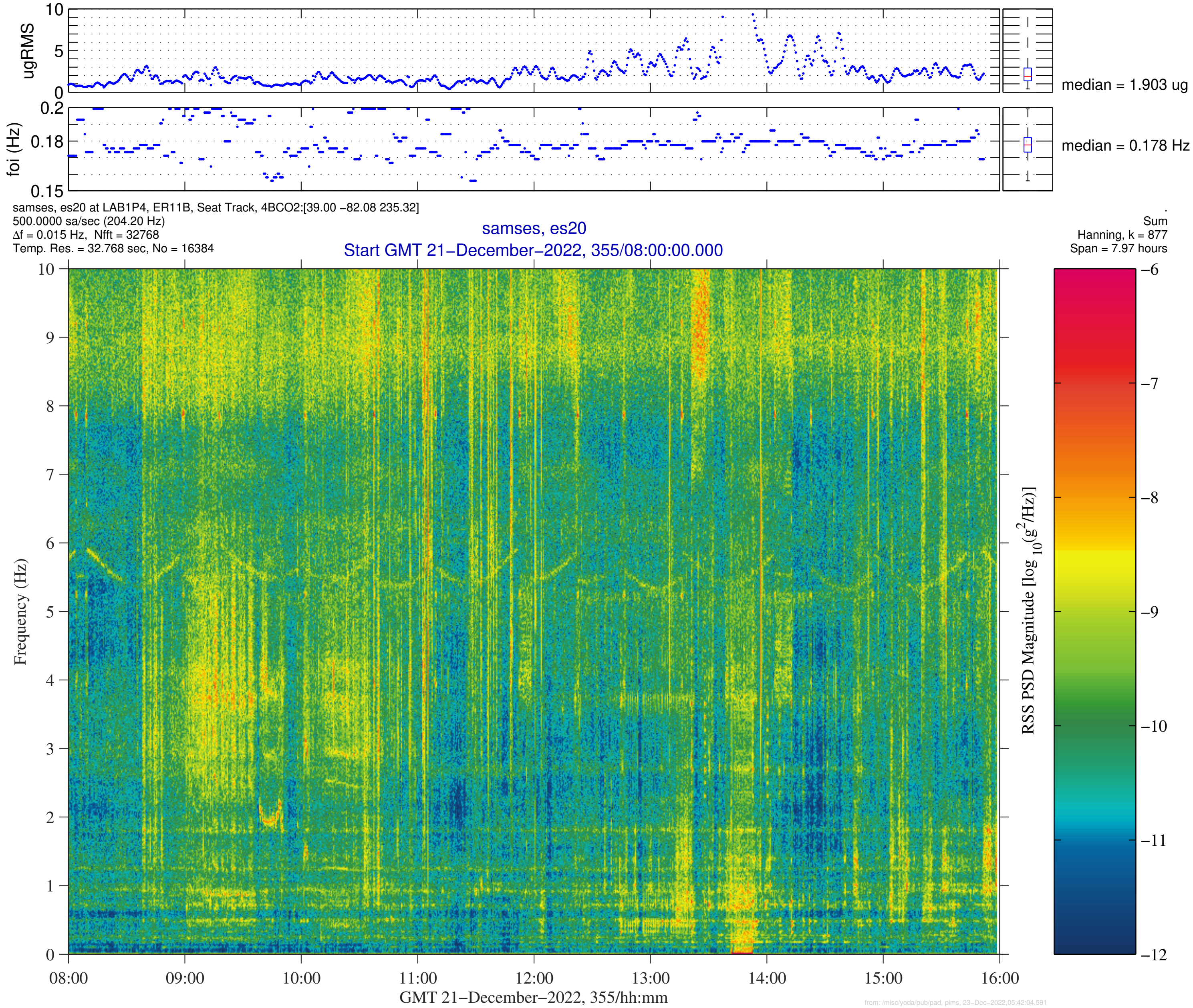

Fig. 4: Spectrogram showing Progress 81P Reboost on GMT 2022-12-21 from SAMS Sensor in US LAB Module.

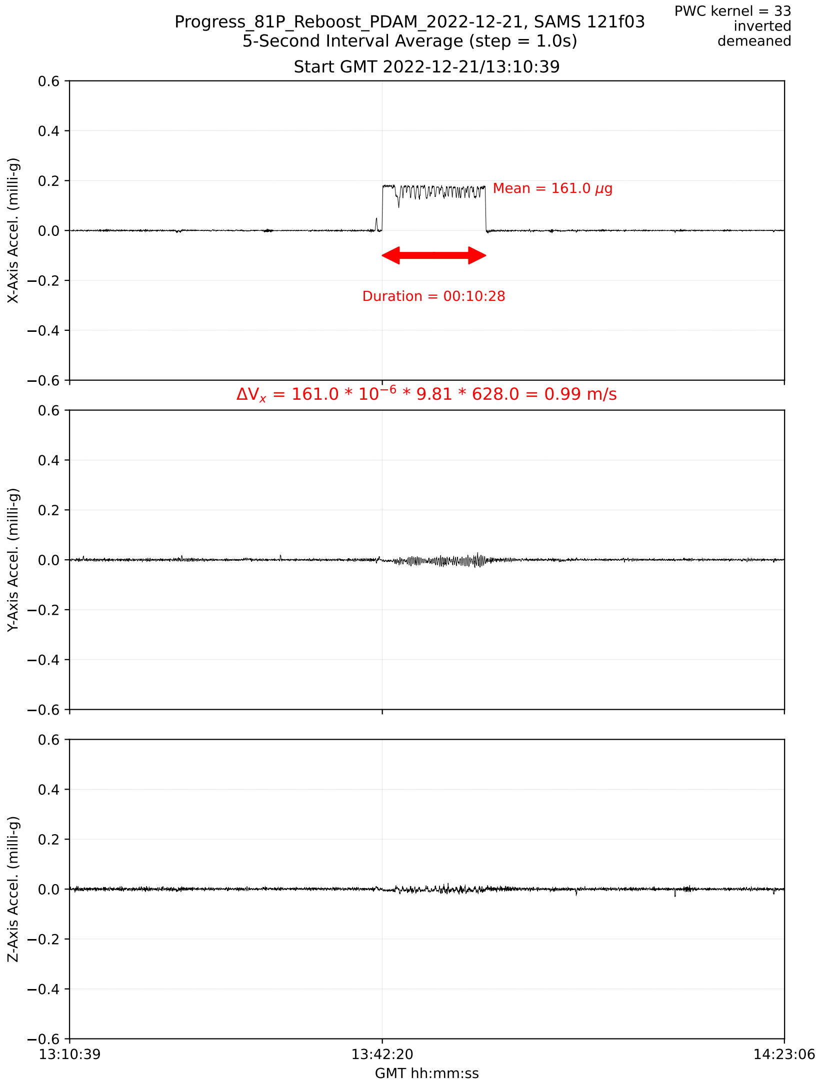

Fig. 5: 5-sec interval average for SAMS 121f03 sensor in the LAB.

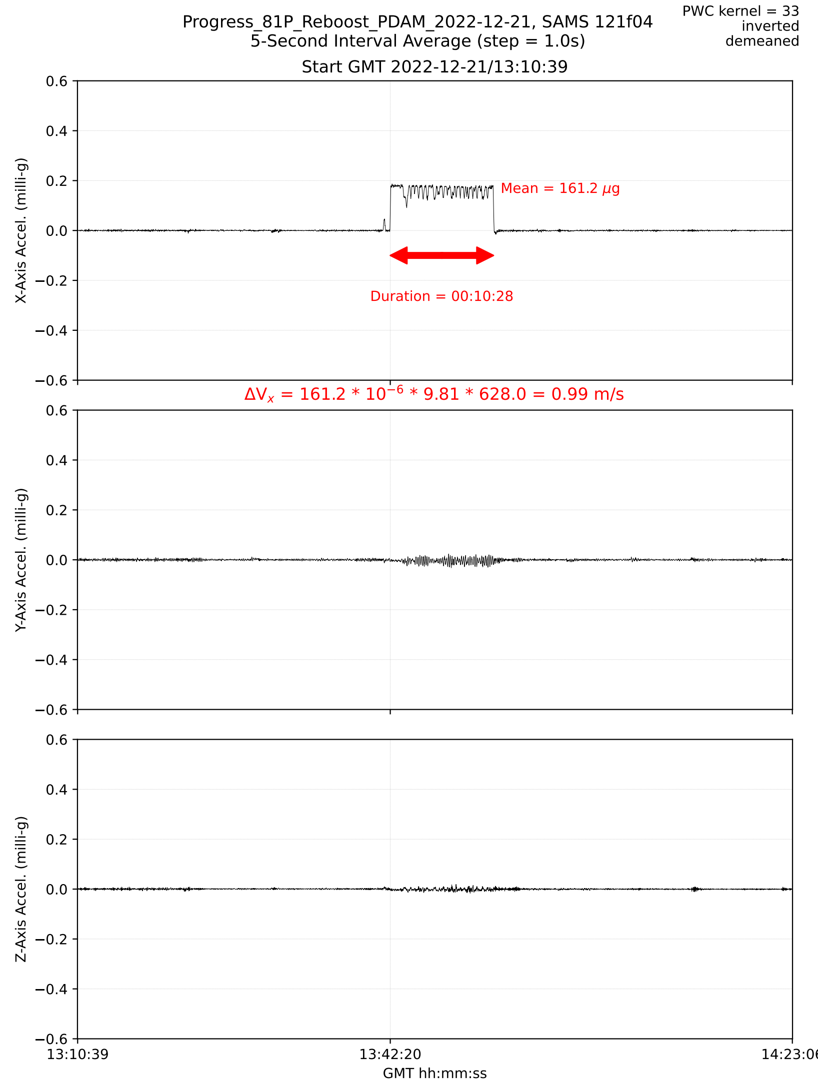

Fig. 6: 5-sec interval average for SAMS 121f04 sensor in the LAB.

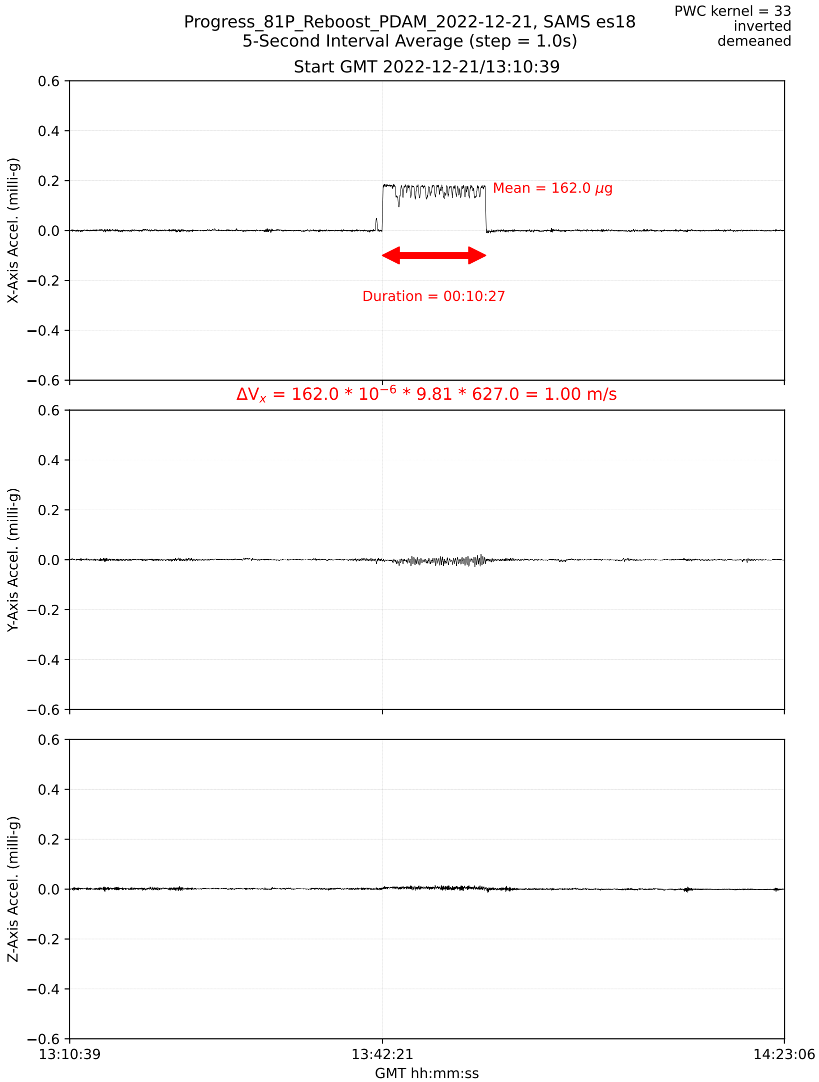

Fig. 7: 5-sec interval average for SAMS es18 sensor in the LAB.

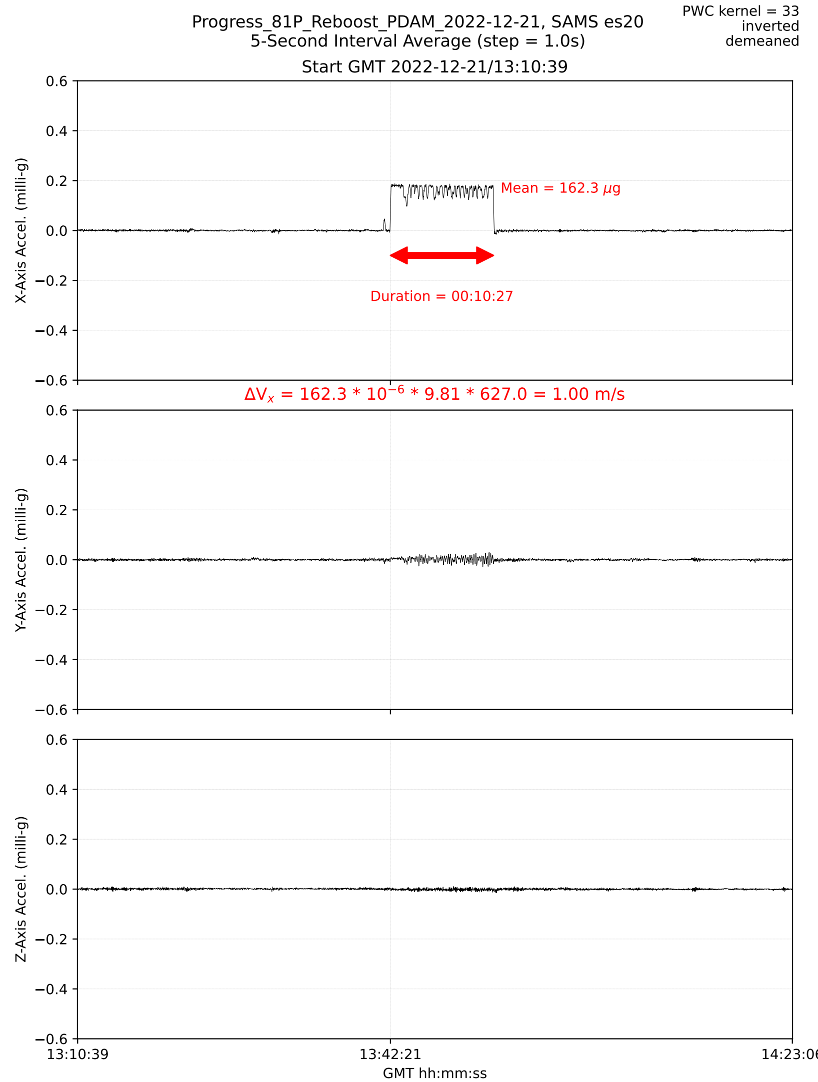

Fig. 8: 5-sec interval average for SAMS es20 sensor in the LAB.

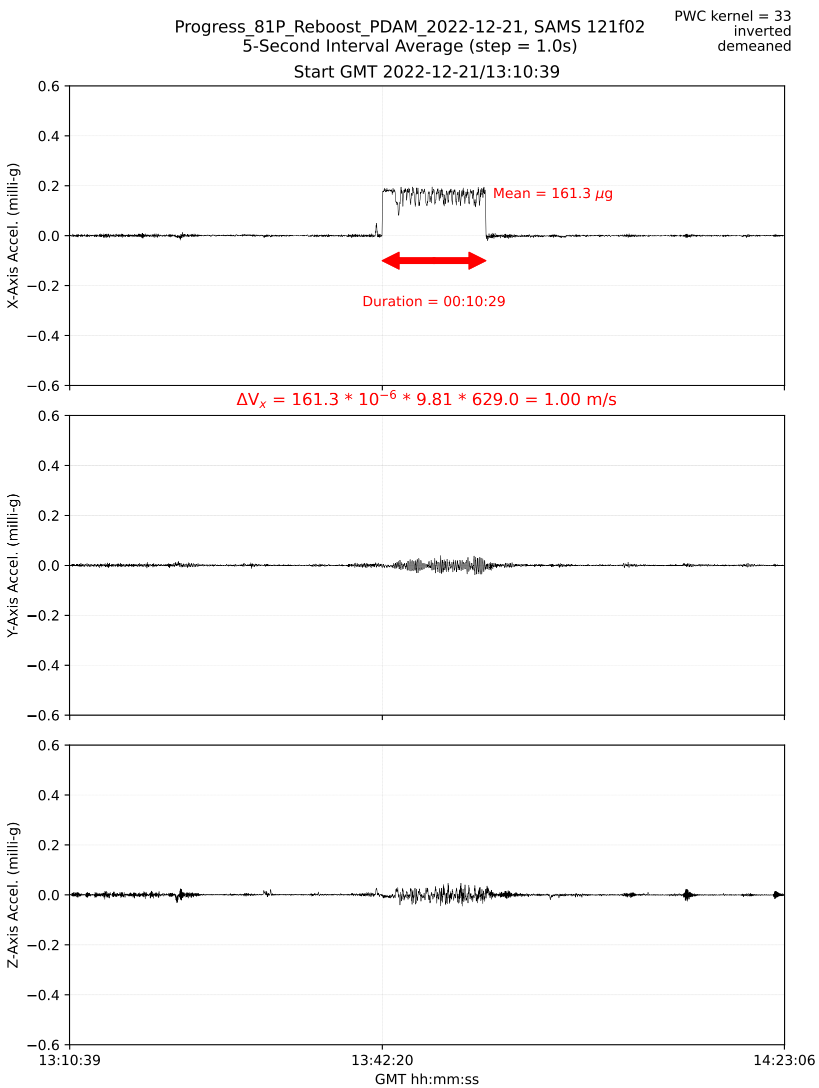

Fig. 9: 5-sec interval average for SAMS 121f02 sensor in the COL.

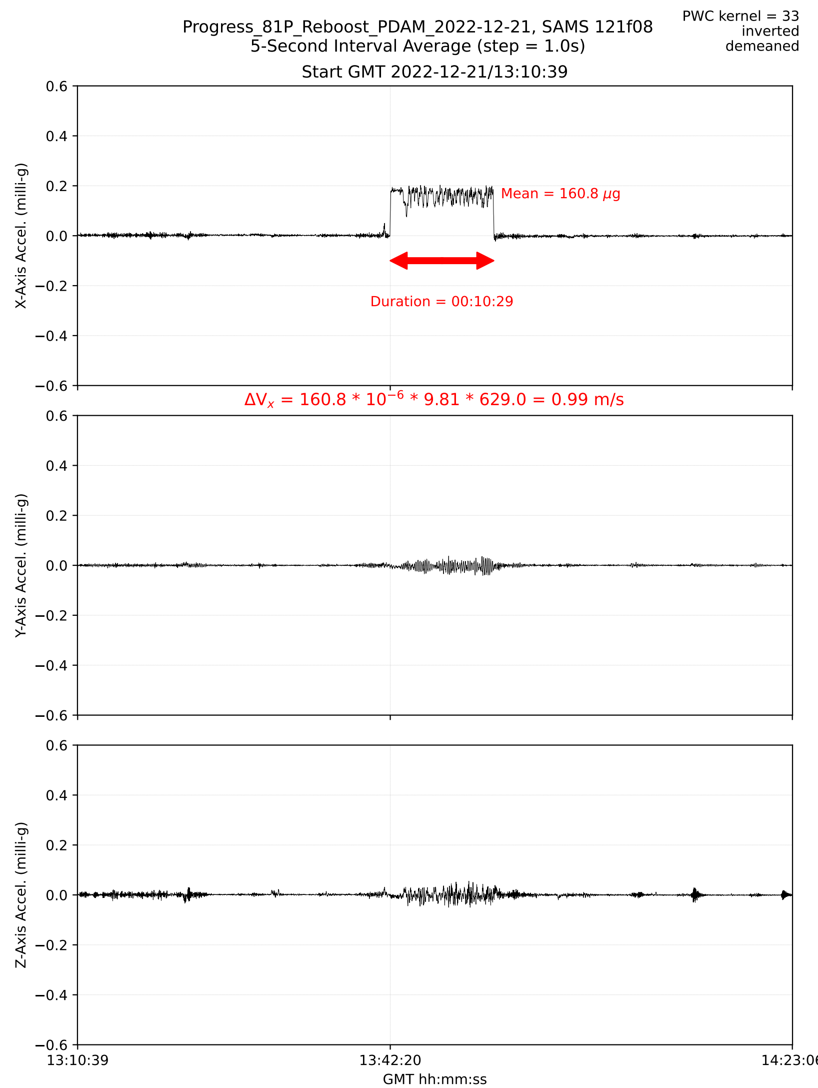

Fig. 10: 5-sec interval average for SAMS 121f08 sensor in the COL.

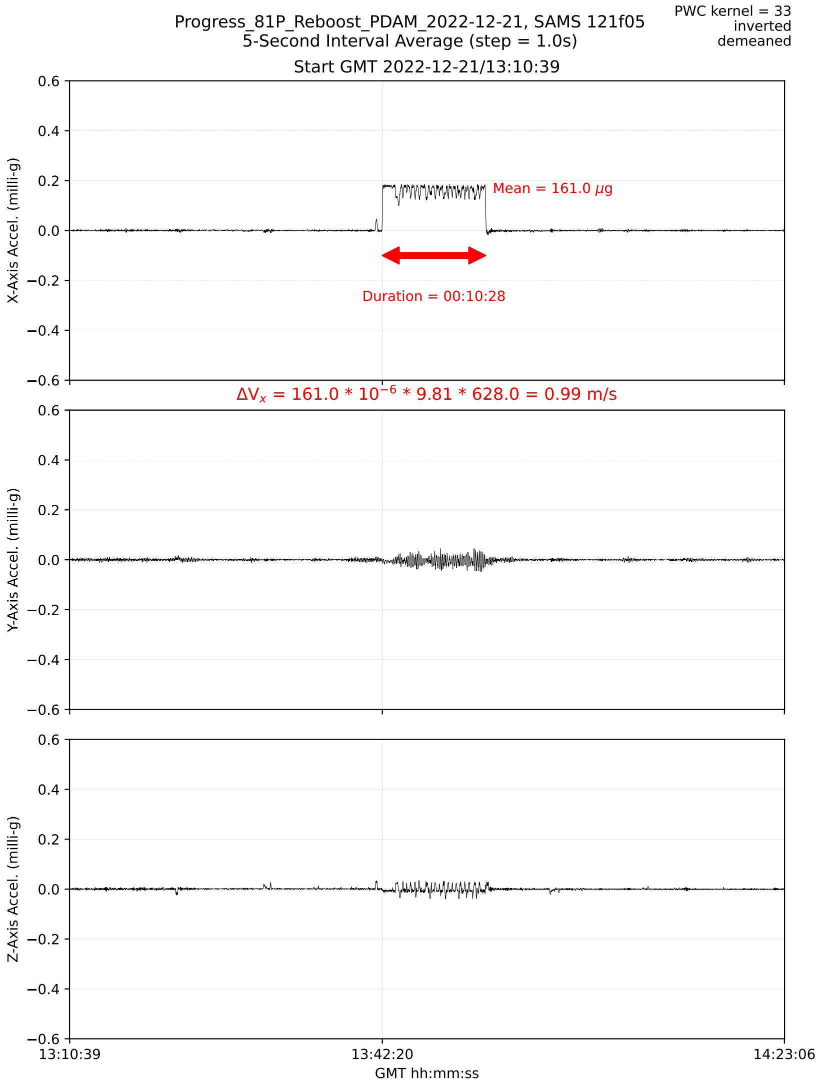

Fig. 11: 5-sec interval average for SAMS 121f05 sensor in the JEM.