1. Introduction

At GMT 2024-03-14, 074/13:11, the International Space Station (ISS) was to begin about an 18.3-minute reboost using the Progress 87P thrusters. Figure 1 shows vehicle layout updated as of 2024-03-11 with the Progress vehicle as it was docked with its thrusters facing aftwards, putting 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.

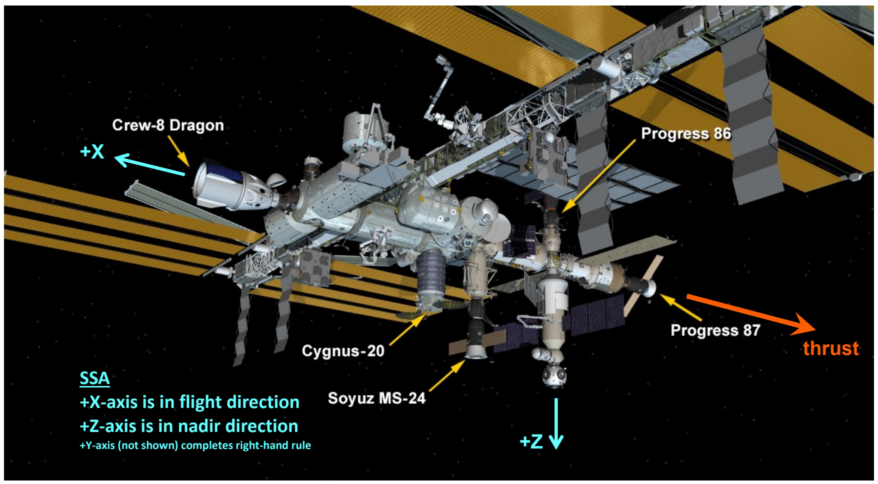

Fig. 1: Progress 87P's Location and Alignment during Reboost.

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 in the EPM (COL1A3) rack. This color spectrogram plot shows increased structural vibration excitation contained mostly below 2 Hz or so, and a **~17.1-minute** reboost (thruster firing) event was observed as annotated in black. We attribute much of the structural vibration increase to Russian Segment (RS) attitude control, which was documented by flight controllers to be from about GMT 12:21 to about 14:03. The RS thrusters are usually 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. 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 at their natural frequencies in reaction to impulsive attitude control thruster forces. The actual reboost activity itself lasted ~17.1 minutes as evidenced by slightly more pronounced, vertical orange-red streaks in Figure 2 starting about GMT 13:11:18.

Slight Confound

The color spectrogram shows ostensibly 2 exercise periods/bouts before the reboost activities. Both of those show up as exciting structural modes (red vertical splashes) in Figure 2, and the second of the two exercises ends at just around GMT 12:00 - before the time of handover of attitude control (via thrusters) to the Russian Segment.

Comparing the same reboost event across all 3 laboratories of the ISS we expect the most energetic vibratory response from the SAMS sensors in the Columbus module, followed by sensors in the Japanese lab (JEM), and lastly from SAMS sensors in the US lab. This stems from the location of these sensors with respect to structural dynamics of this large, massive space station along with its geometry, stiffness, and other factors. 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.

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 (typically) 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.

3. QUANTIFY

While the 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 multiple SAMS sensor heads distributed across all 3 main laboratories of the ISS with more intuitive metrics. Figure 3 on page 4 through Figure 8 on page 7 show interval average acceleration results computed from SAMS measurements. Note for each sensor the tell-tale X-axis step that started at GMT 13:11:18 and had a duration of ~17.1 minutes. Information from flight controllers indicating reboost event metrics was not available at the time this document was drafted, however, the SAMS analysis indicated these with red annotations in these interval average plots. Typically, these SAMS results closely match the predicted value.

Note that the interval average processing of SAMS data here 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 these distributed SAMS sensors is also given in Table 1 – expectedly consistent impact results measured by SAMS throughout the space station structure.

4. CONCLUSION

The SAMS measurements for multiple sensor heads distributed across all 3 main labs of the ISS was analyzed and showed an **X-axis step during the Progress 87P reboost of just under 0.2 mg**. Furthermore, calculations based on SAMS sensors indicate a ΔV metric of just about 1.58 m/s was achieved, while flight controllers predicts were not yet available.

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

Sensor	**X-Axis (mg)**	**Location**
121f02	0.157	COL1A1 (ER3)
121f03	0.157	LAB1O1 (ER2)
121f04	0.157	LAB1P2 (ER7)
121f05	0.157	JPM1F1 (ER5)
121f08	0.158	COL1A3 (EPM)
es18	0.160	LAB1O4 (ER6)

Progress 87P Reboost on GMT 2024-03-14

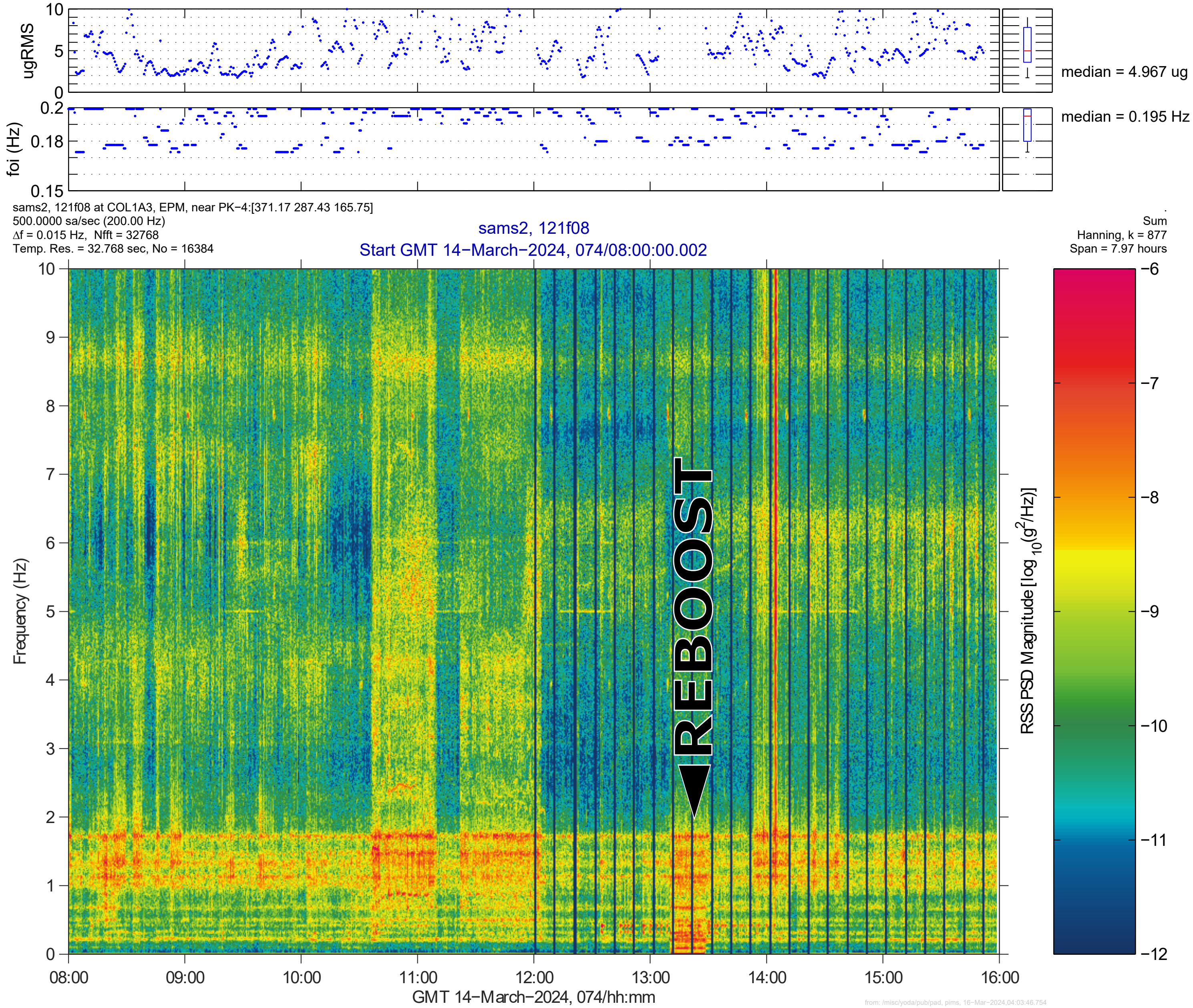

Fig. 2: 10 Hz Spectrogram showing Progress 87P Reboost on GMT 2024-03-14 from a SAMS Sensor in the Columbus module.

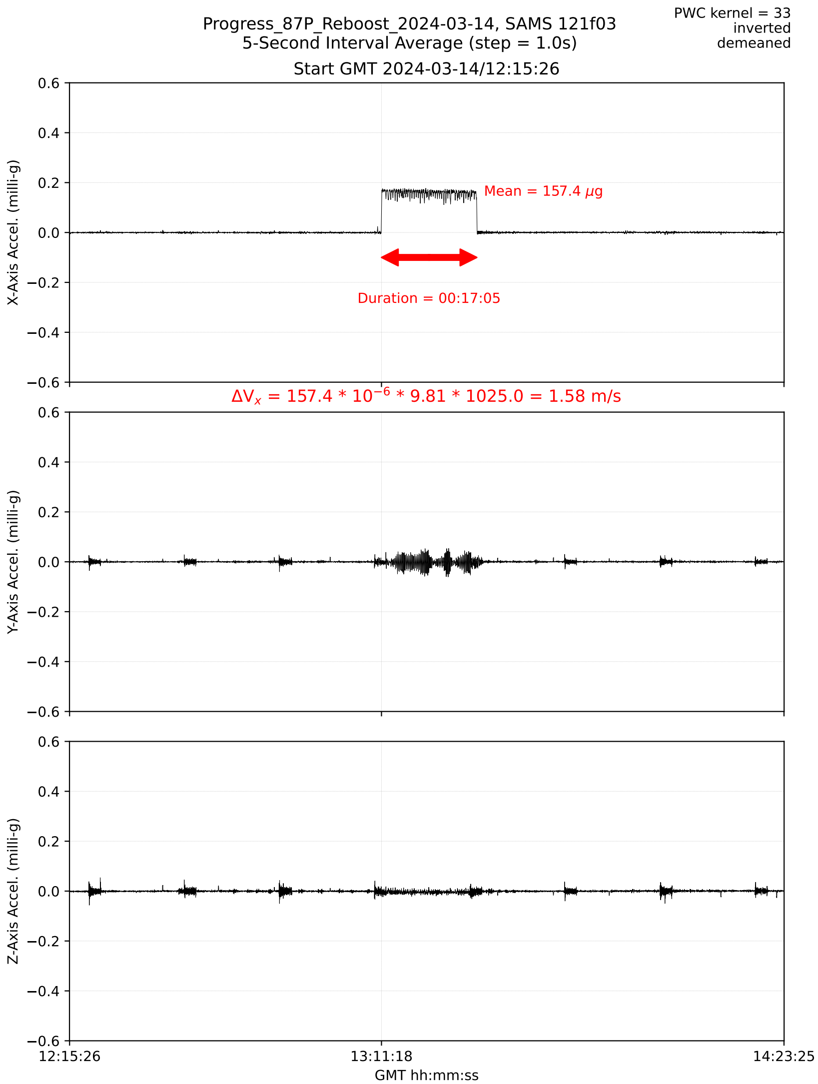

Fig. 3: 5-sec interval average for SAMS 121f03 sensor in the LAB.

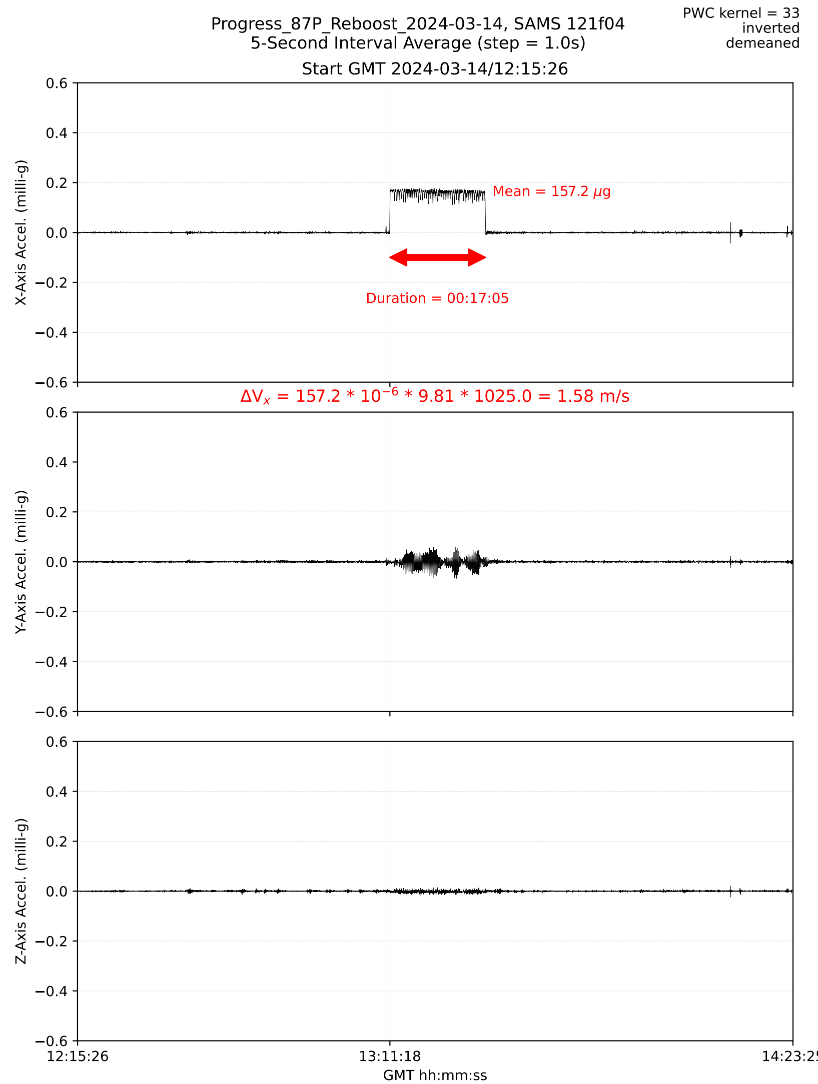

Fig. 4: 5-sec interval average for SAMS 121f04 sensor in the LAB.

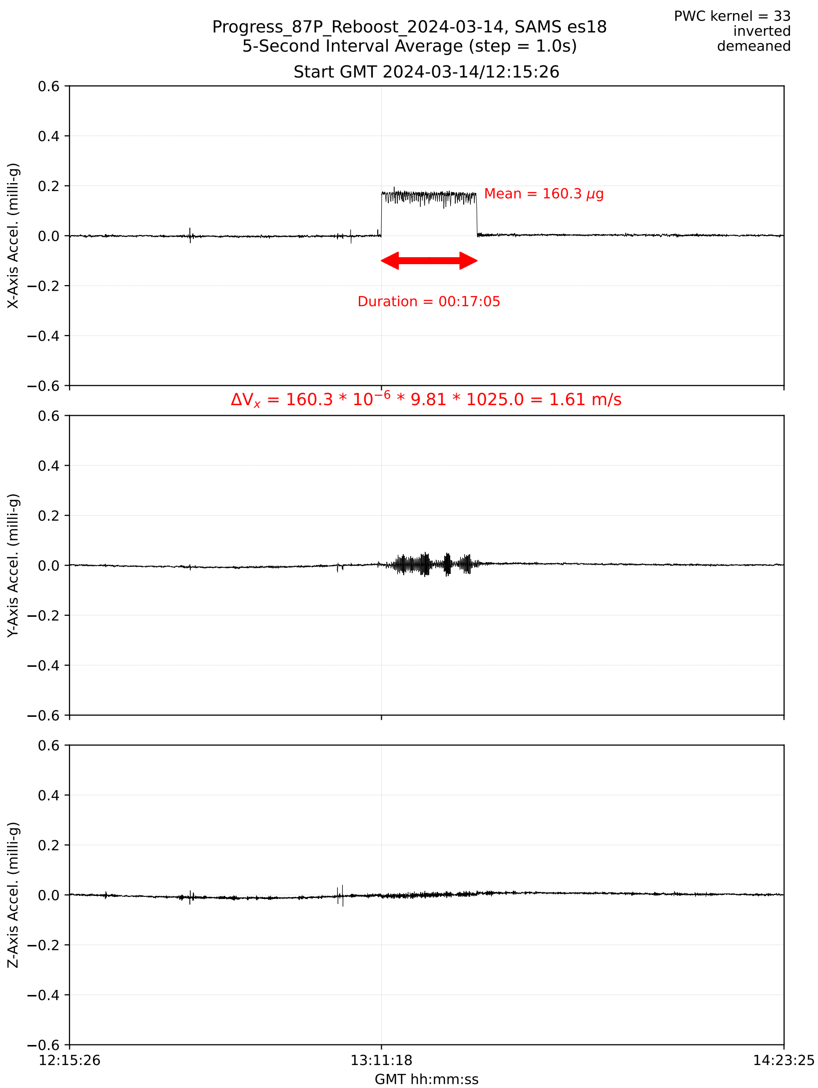

Fig. 5: 5-sec interval average for SAMS es18 sensor in the LAB.

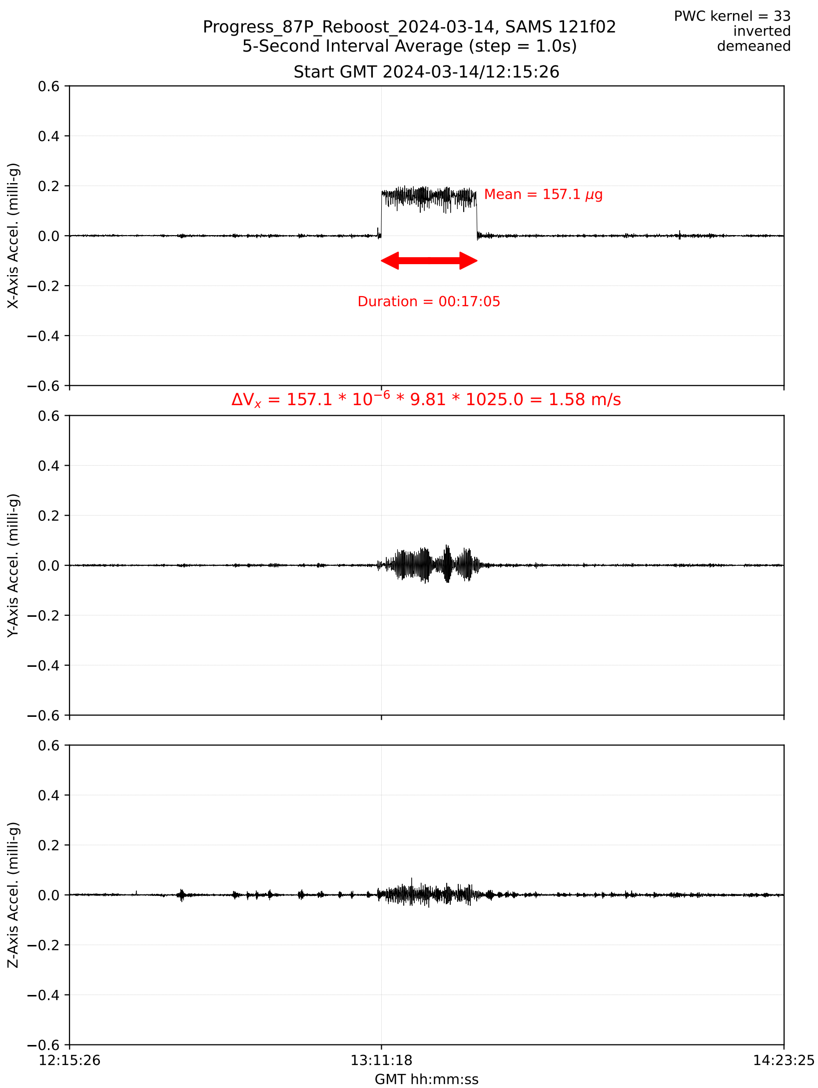

Fig. 6: 5-sec interval average for SAMS 121f02 sensor in the COL.

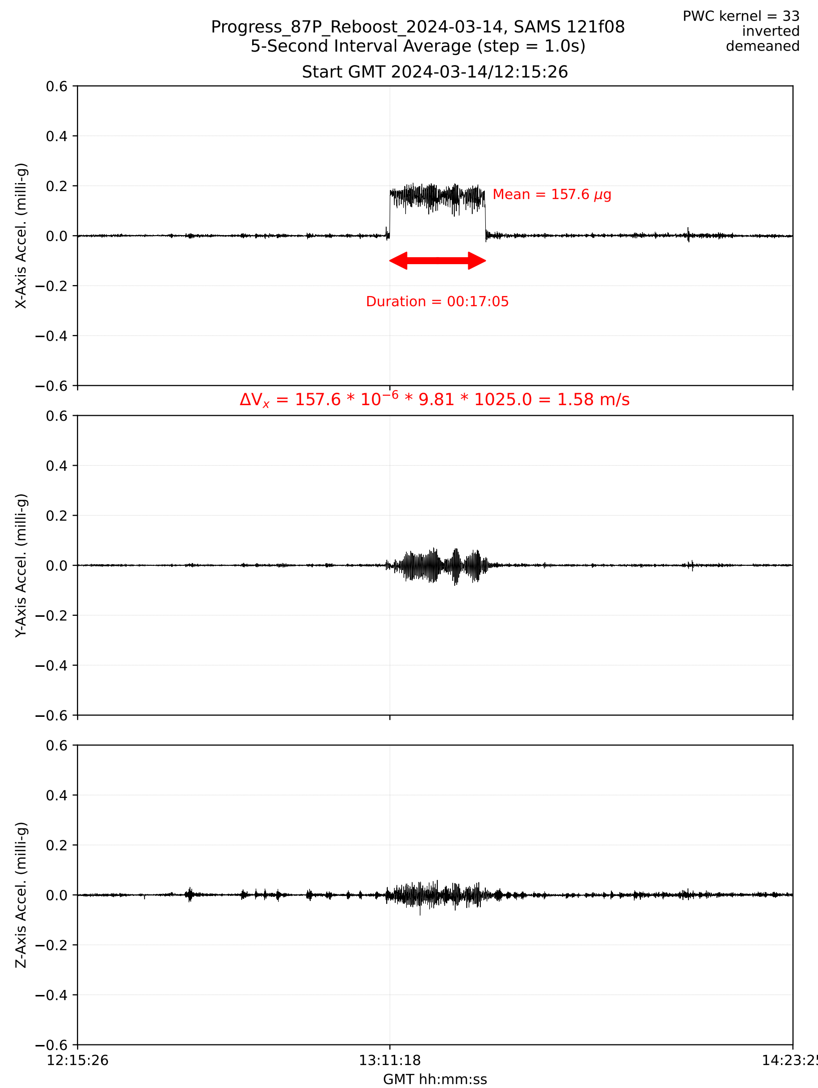

Fig. 7: 5-sec interval average for SAMS 121f08 sensor in the COL.

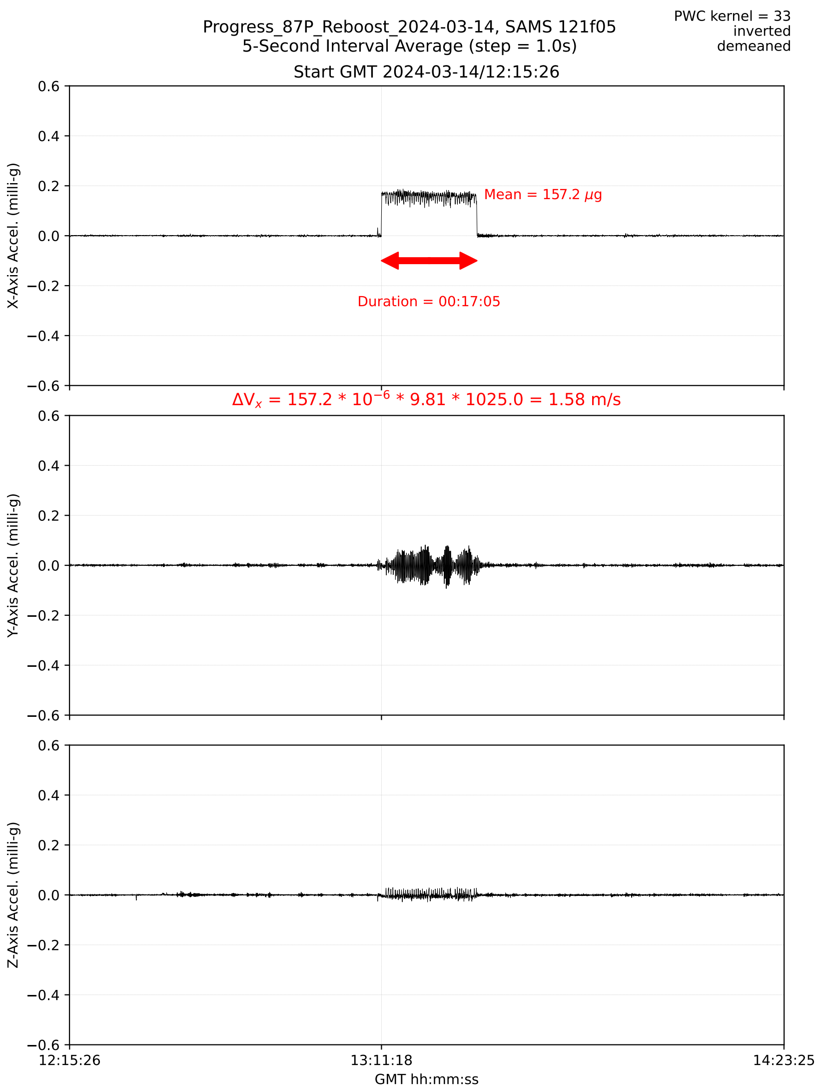

Fig. 8: 5-sec interval average for SAMS 121f05 sensor in the JEM.