

1. INTRODUCTION

At GMT 2025-11-19, 323/13:04, the International Space Station (ISS) was to begin about a 14.38-minute reboost using the Progress 93P thrusters. Figure 1 shows the visiting vehicles' layout updated as of 2025-10-29 with the Progress 93P vehicle as it was docked with its thrusters facing aft, putting thrust and the necessary orbital mechanics into play so as to speed up the ISS in its direction of flight, in direct opposition to its velocity vector. The thrusters' directional acceleration (increase in velocity), resulted in an altitude gain of ~2.68 km. An intended ΔV metric of 1.54 m/s for the space station was predicted.

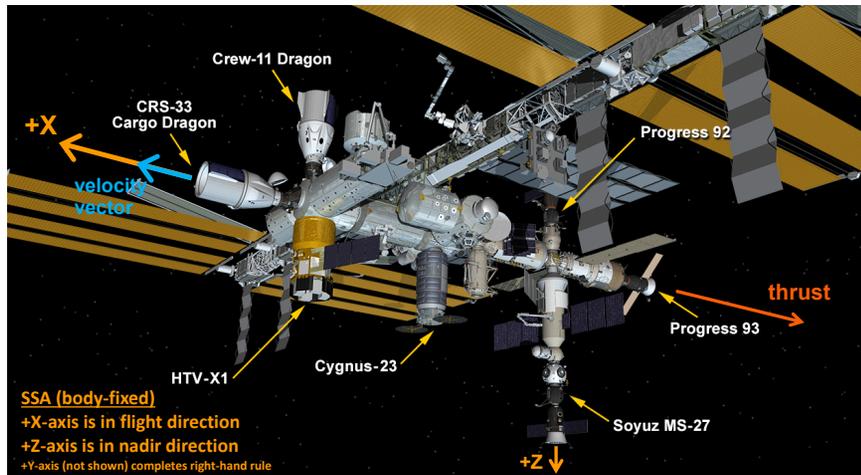


Fig. 1: Progress 93P's Location and Alignment during Reboost.

2. QUALIFY

The information shown in Figure 2 on page 4 was calculated from the Space Acceleration Measurement System (SAMS) sensor 121f02 measurements made in the COL module from a sensor mounted at the Columbus starboard endcone location. This color spectrogram plot focuses on the structural mode regime below 6 Hz and would typically show notably increased structural vibration excitation contained mostly below 2 Hz or so due to Russian Segment attitude control period,

which routinely leads up to and then ends sometime after the reboost event, but these signal features are not so evident here in the prescribed "RS Attitude Control" time span as annotated between the magenta arrows in Figure 2. We do, however, see the tell-tale signs of a ~14.48-minute reboost (thruster firing) event as seen starting just after hour 13:00 and as annotated between the white arrows. During the reboost event, we attribute structural vibration increase to Russian Progress 93P thruster firings, evident as unmistakable, horizontal streaks (structural/spectral peaks) that change to more pronounced, more energetic (orange/red) vibrations. The flare up of these nebulous horizontal (spectral peak) streaks are the signatures of large space station appendages as they flex, twist, or bend at their natural frequencies in reaction to thruster firing forces.

Comparing the same reboost event across all 3 laboratories of the ISS via 7 SAMS distributed sensor heads, we expect the most energetic vibratory response from the SAMS sensors in the European lab (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 the space station. This analysis focused on the power spectral density of vibratory accelerations below 6 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. Figure 2 on page 4 through Figure 8 on page 10 show the patterns, structures, and boundaries in time, frequency, and magnitude of these structural mode regime vibrations at various locations throughout the ISS.

For science operations and general situational awareness, it is wise 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 often times 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 would usually be 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.

Acceleration Interval Root-Mean-Square (RMS) Below 2 Hz

Figure 9 on page 11 through Figure 15 on page 17 show data from 7 SAMS sensor heads analyzed via Parseval’s theorem to reveal interval root-mean-square acceleration levels in a frequency band between 0.1 Hz and 2.0 Hz. This gives keen focus to vibrations of the space station’s largest structures as they respond to various stimuli. The first such figure on page 11 shows RMS acceleration levels lingering near 0.3 mg for about 14 minutes during the reboost event. This sensor showed the strongest response among the 7 SAMS sensor heads analyzed. Note that at other times in the 8-hour span of this plot, the RMS value approaches or exceeds these levels but not in the continuous, sustained fashion of a reboost. The remaining figures on page 11 through page 17 show a descending order of response RMS levels for the other sensor heads’ mounting locations and those do indeed follow the expected order.

Table 1 below shows this same order, but now via Parseval for the frequency range from 0.1 Hz to 3.0 Hz. The data here is a 10-minute subset of the reboost event starting at GMT 13:05. This table also gives a per-axis breakout in addition to total RMS acceleration.

5-Second Interval Average Acceleration

Figure 16 on page 18 through Figure 22 on page 21 show 5-second interval average acceleration results computed from SAMS measurements. Note that across all 7 of the SAMS sensor heads, the tell-tale X-axis step started at GMT 13:04:16 (within about 3 seconds) and had durations just around 14.5 minutes. These discrepant ranges fall within the 5-second averaging window used to glean this information, independently for each sensor head. Information from flight controllers indicated that this reboost event would provide a space station rigid body ΔV of 1.54 meters/second and the SAMS analysis indicated with red annotations in these interval average plots nearly match the predicted value. SAMS does not directly

Table 1. **Accel. RMS (0.1 < f < 3.0 Hz) (μg)** for 7 SAMS Sensors.

| Location | Sensor | X-Axis (μg) | Y-Axis (μg) | Z-Axis (μg) | Total (μg) |
|--------------|--------|-----------------------|-----------------------|-----------------------|----------------------|
| COL Endcone | 121f02 | 142.10 | 65.20 | 143.60 | 221.40 |
| JPM1F6 (ER4) | es19 | 131.10 | 62.87 | 86.21 | 172.20 |
| COL1A3 (EPM) | 121f08 | 103.00 | 52.89 | 98.34 | 158.70 |
| JPM1F1 (ER5) | 121f05 | 47.35 | 60.31 | 44.64 | 93.53 |
| LAB1S2 (MSG) | es20 | 43.55 | 58.79 | 45.06 | 89.55 |
| LAB1O1 (ER2) | 121f03 | 35.39 | 39.36 | 42.35 | 71.27 |
| LAB1O4 (ER6) | es18 | 36.57 | 33.27 | 42.52 | 69.85 |

measure altitude, but flight controllers indicated that the ISS would gain ~2.68 km in altitude above the Earth as a result of this reboost activity.

Table 2. **+X-axis Steps (mg)** during reboost event for 7 SAMS sensors.

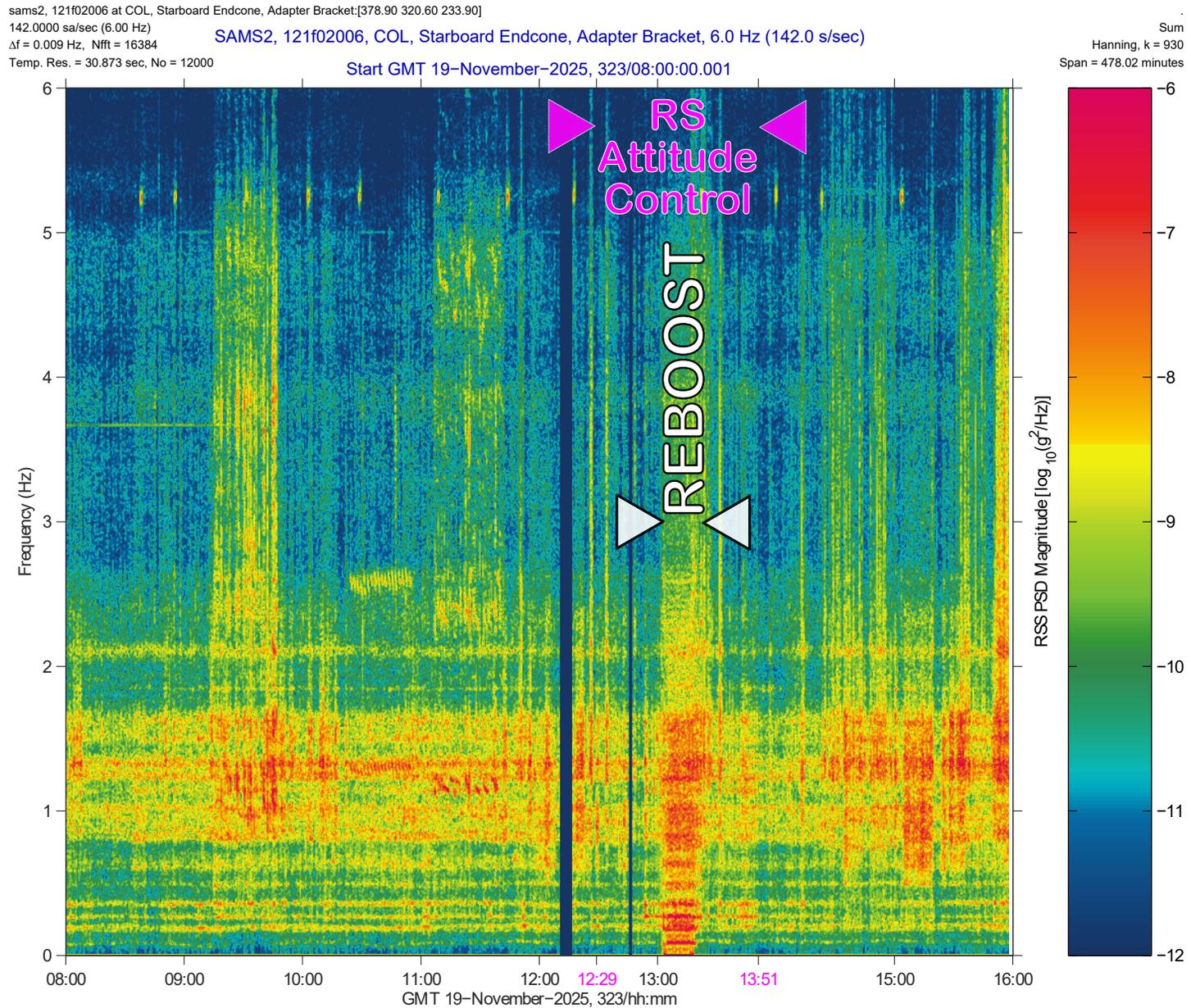
| Sensor Rack | Sensor | Step (mg) | TIG (hh:mm:ss) | Duration (mm:ss) | DeltaV (m/s) |
|----------------------|--------|--------------|-------------------|---------------------|-----------------|
| LAB1S2 (MSG) | es20 | 0.182 | 13:04:17 | 14:30 | 1.55 |
| JPM1F6 (ER4) | es19 | 0.182 | 13:04:17 | 14:26 | 1.54 |
| LAB1O4 (ER6) | es18 | 0.182 | 13:04:19 | 14:28 | 1.55 |
| LAB1O1 (ER2) | 121f03 | 0.180 | 13:04:16 | 14:31 | 1.54 |
| COL1A3 (EPM) | 121f08 | 0.180 | 13:04:15 | 14:27 | 1.53 |
| JPM1F1 (ER5) | 121f05 | 0.181 | 13:04:16 | 14:29 | 1.54 |
| COL Endcone | 121f02 | 0.181 | 13:04:13 | 14:29 | 1.54 |
| Average/Total | | 0.181 | 13:04:16 | 14:29 | 1.54 |

Note that interval averaging effectively low-pass filters the data, which emphasizes the acceleration step that occurs on the X-axis during a reboost. Also note that we inverted the polarity of each axis of the SAMS plots owing to a polarity issue inherent in SAMS signal handling. A somewhat crude quantification of the reboost as measured by these distributed SAMS sensors is also given in Table 2 – expectedly consistent response levels as measured by SAMS throughout the ISS.

4. CONCLUSION

SAMS measurements from seven distributed sensor heads across the U.S. Lab, JEM, and Columbus modules were analyzed for the Progress 93P reboost on GMT 2025-11-19. Using 5-second interval averages, all sensors show a clear rigid-body acceleration step primarily on the ISS +X axis beginning near GMT 13:04:16 and lasting approximately 14.5 minutes, with a mean step magnitude of about 0.18 mg. Integrating the measured +X acceleration over the burn duration yields an empirical ΔV of approximately 1.54 m/s, in close agreement with the predicted value.

Time–frequency spectrograms and narrowband RMS summaries further show increased vibratory response during the burn, with the strongest measured response at the Columbus starboard endcone mounting location and decreased response moving toward JEM and then the U.S. Lab, consistent with structural dynamics expectations.

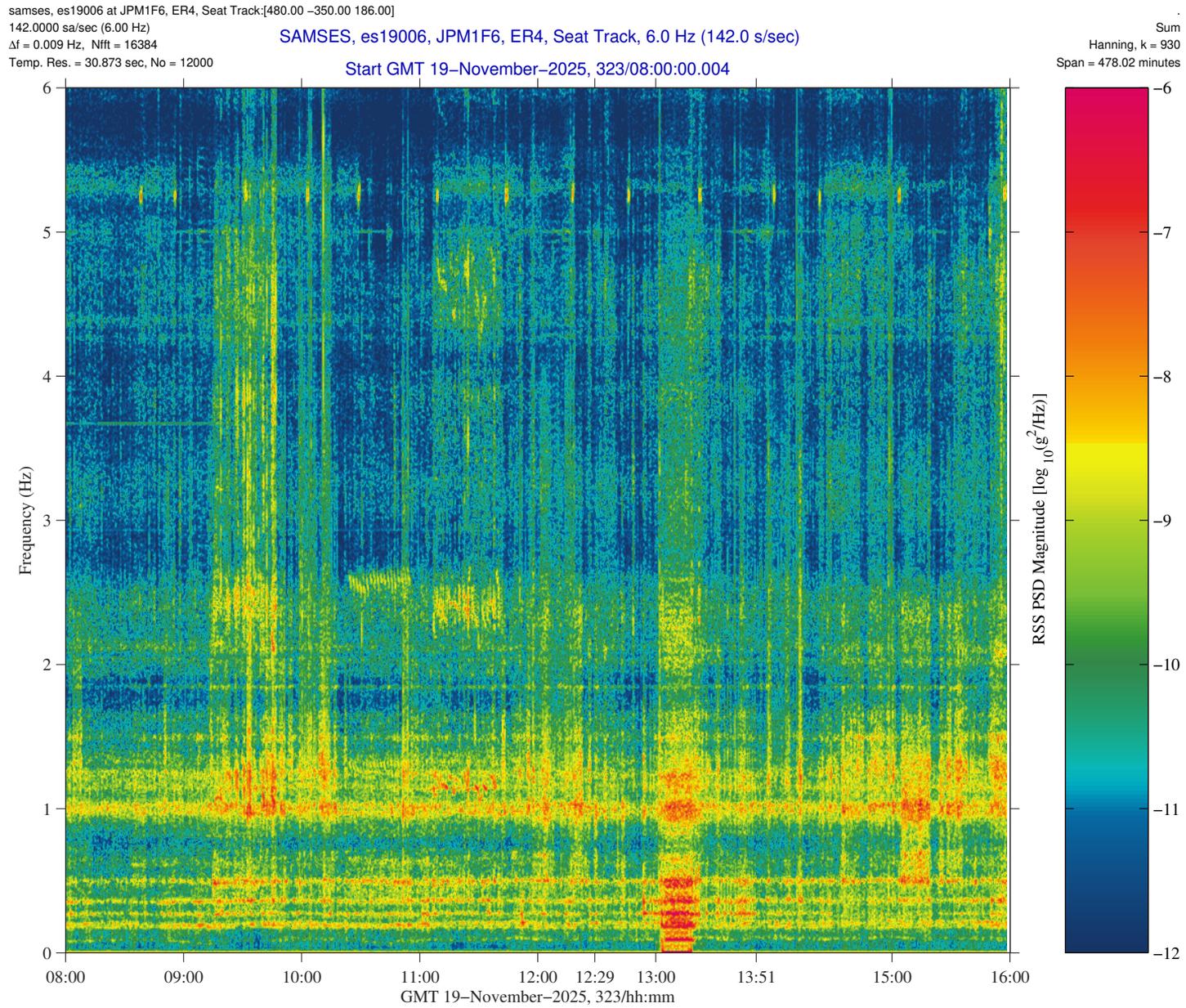


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Fig. 2: 8 Hour, 6 Hz Spectrogram shows Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor 121f02 on COL Endcone.

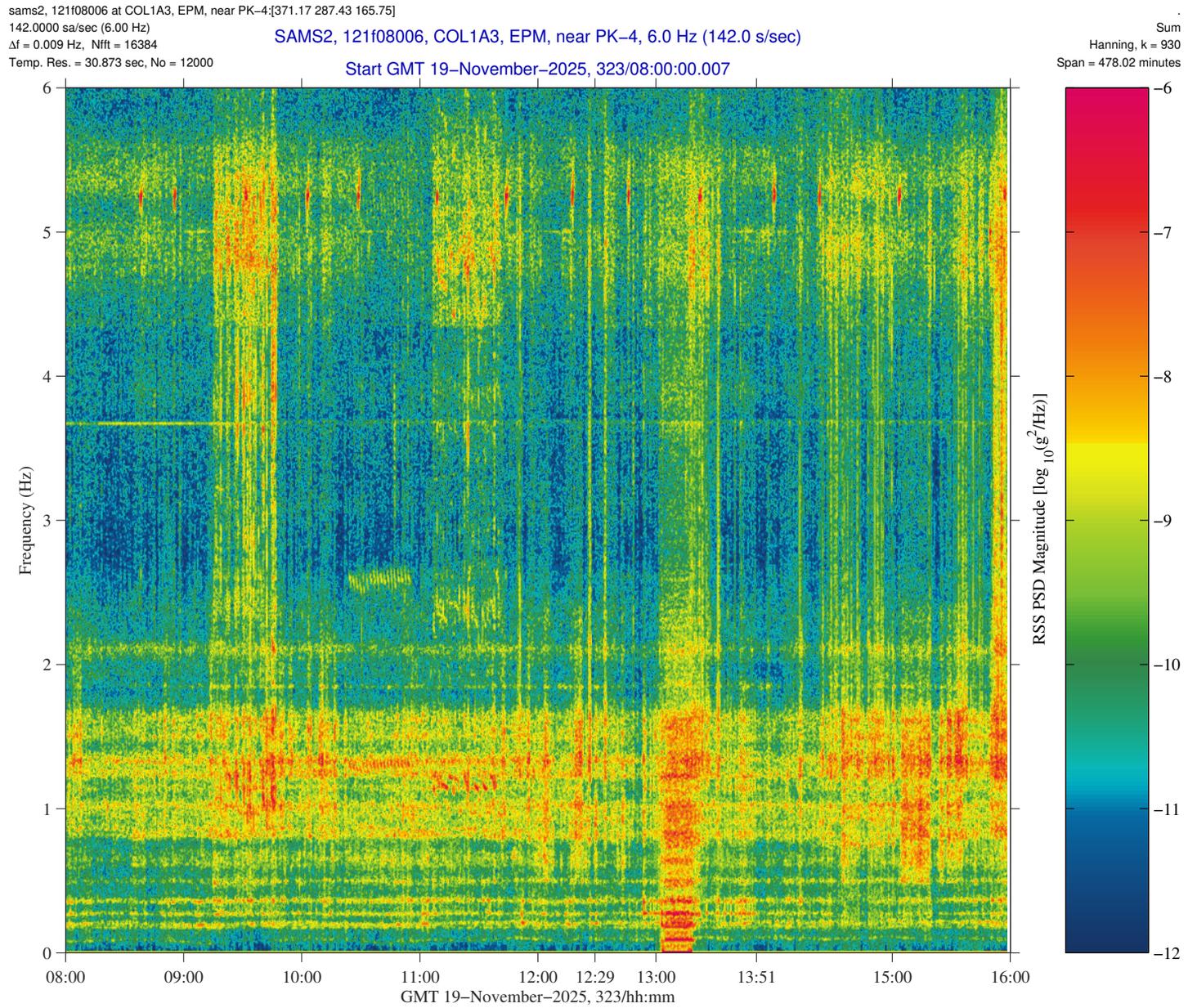


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Fig. 3: 8 Hour, 6 Hz Spectrogram shows Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor es19 on JPM1F5 (ER4).

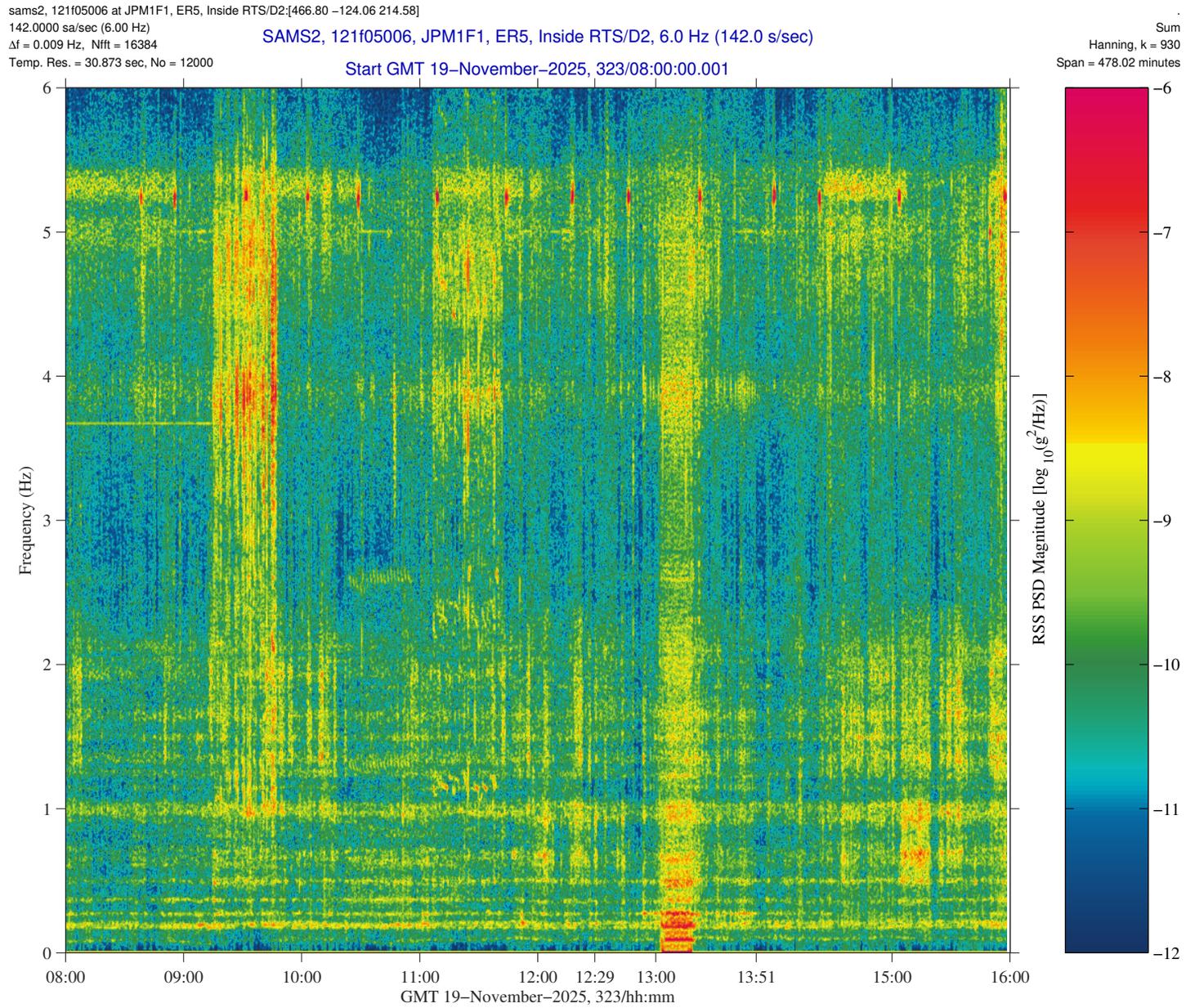


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Fig. 4: 8 Hour, 6 Hz Spectrogram showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor **121f08** on **COL1A3 (EPM)**.

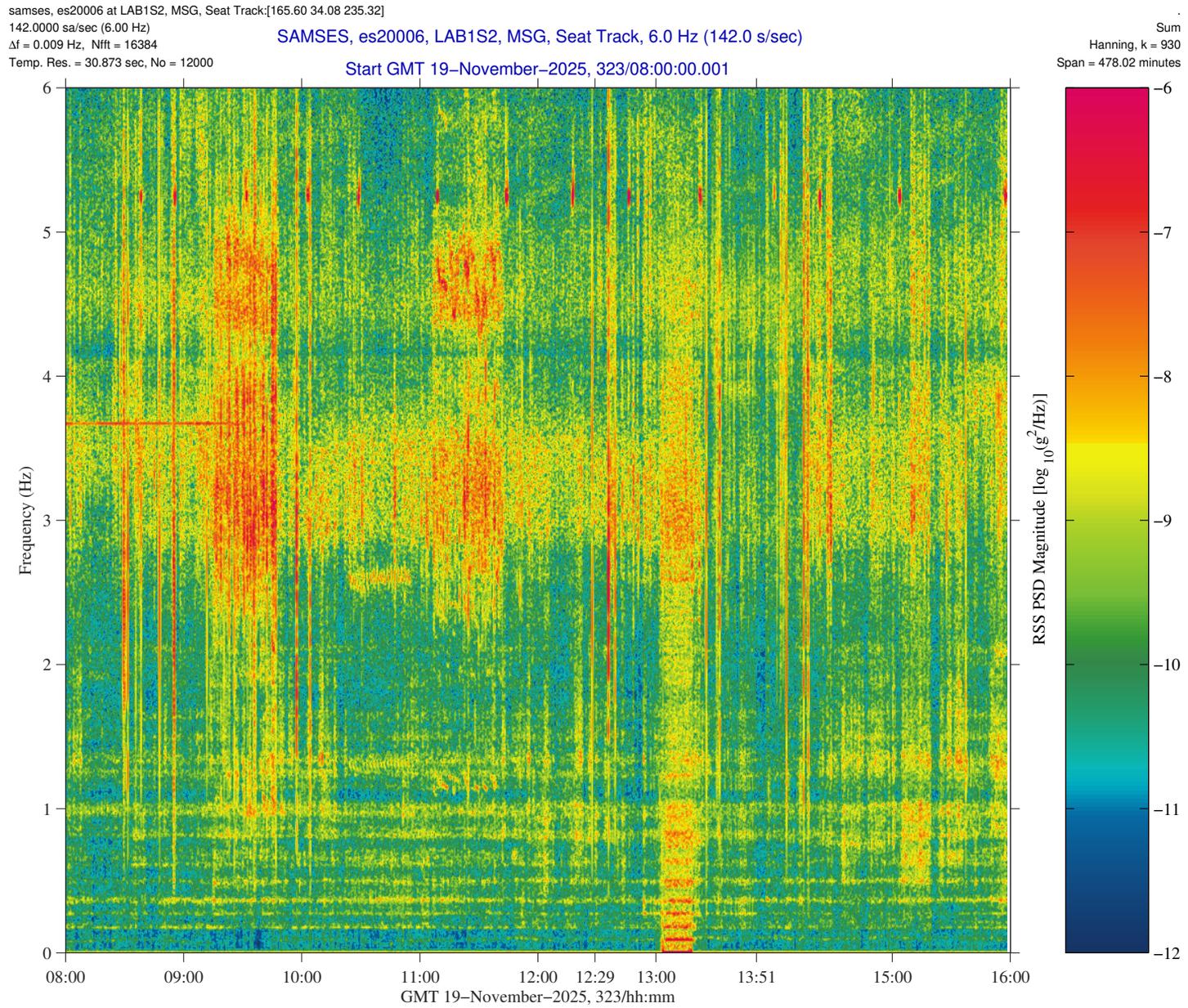


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Fig. 5: 8 Hour, 6 Hz Spectrogram showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor 121f05 on JPM1F1 (ER5).

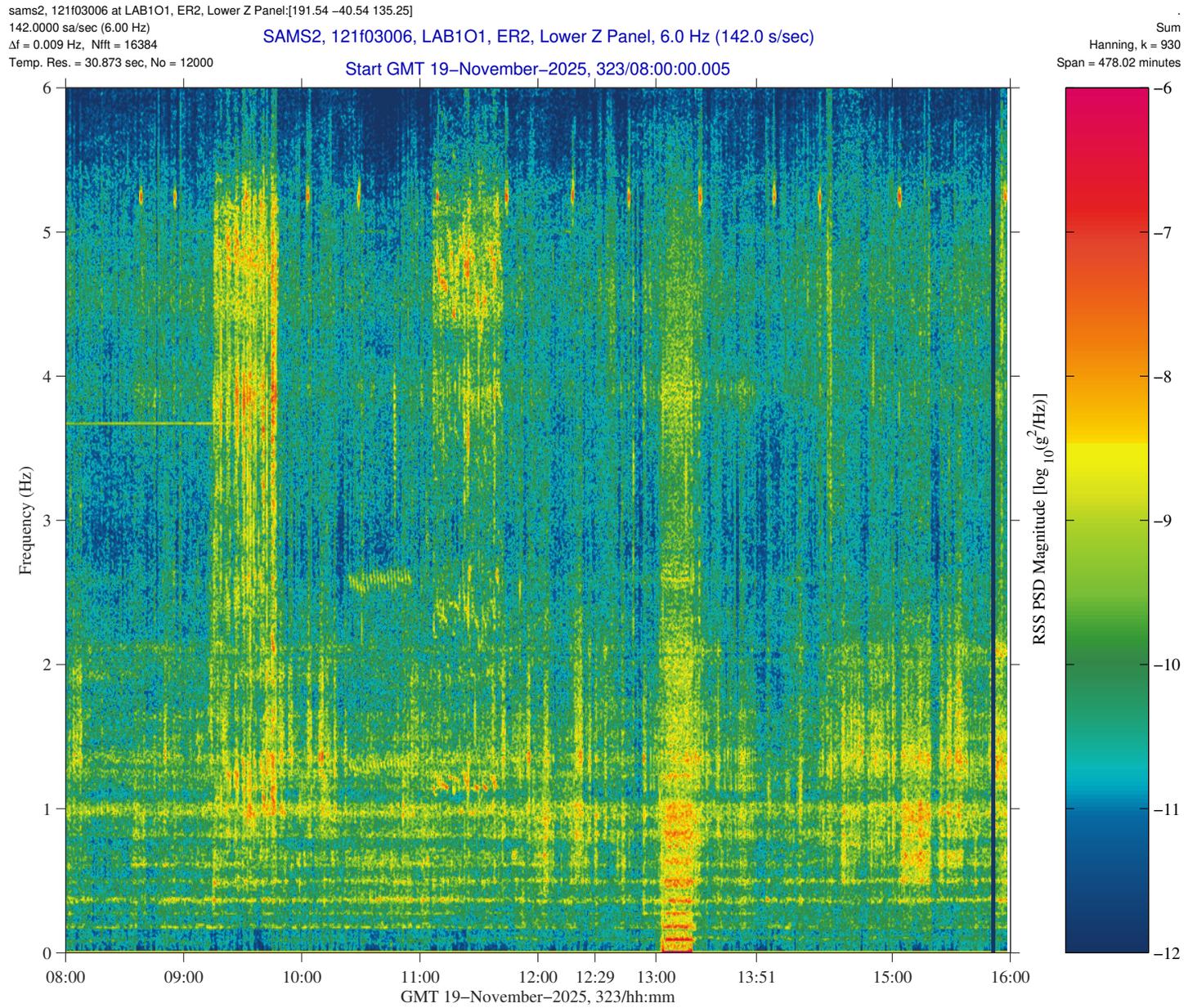


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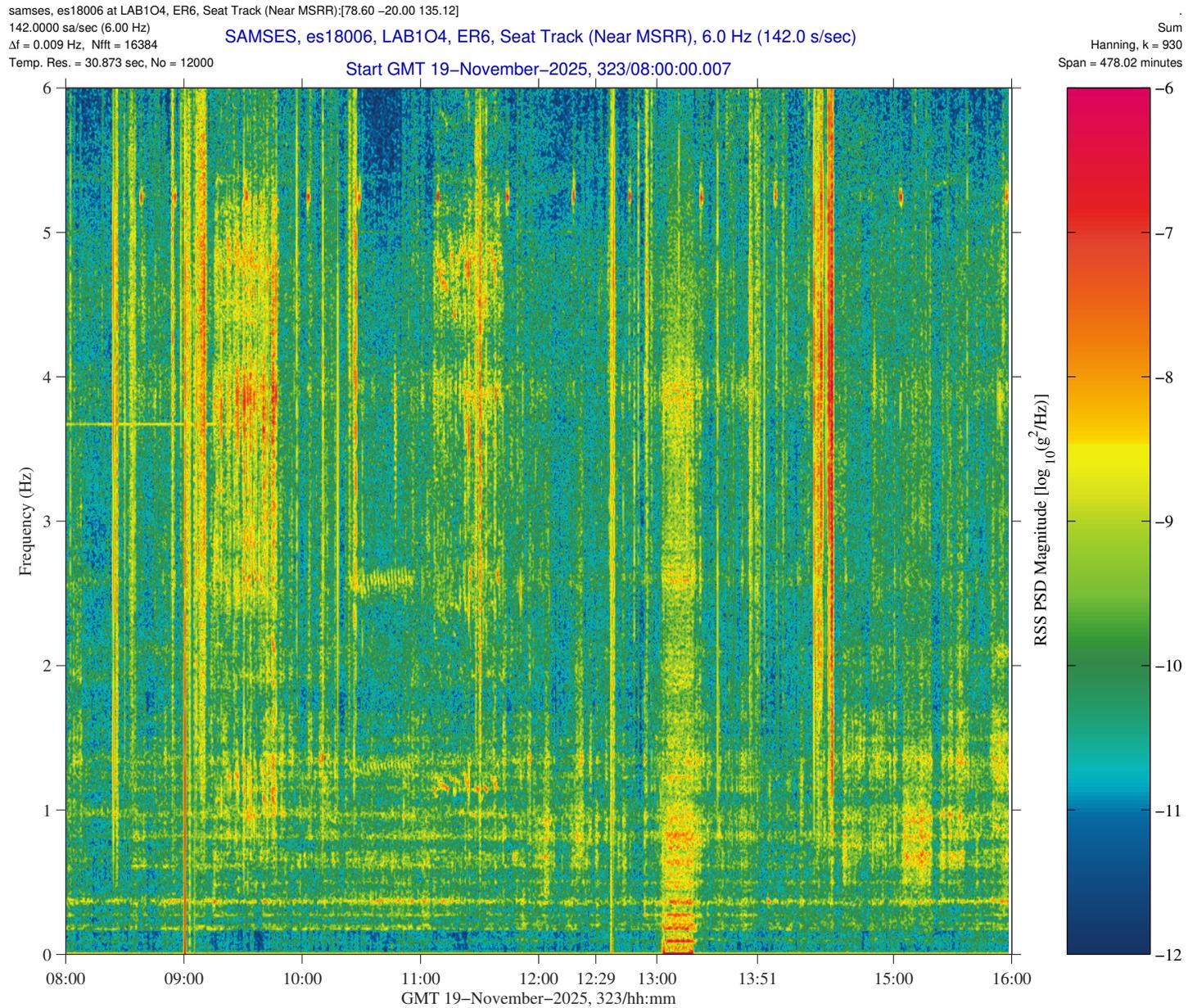
Fig. 6: 8 Hour, 6 Hz Spectrogram showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor es20 on LAB1S2 (MSG).



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Fig. 7: 8 Hour, 6 Hz Spectrogram showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor **121f03** on **LAB1O1 (ER2)**.



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Fig. 8: 8 Hour, 6 Hz Spectrogram showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor es18 on LAB1O4 (ER6).

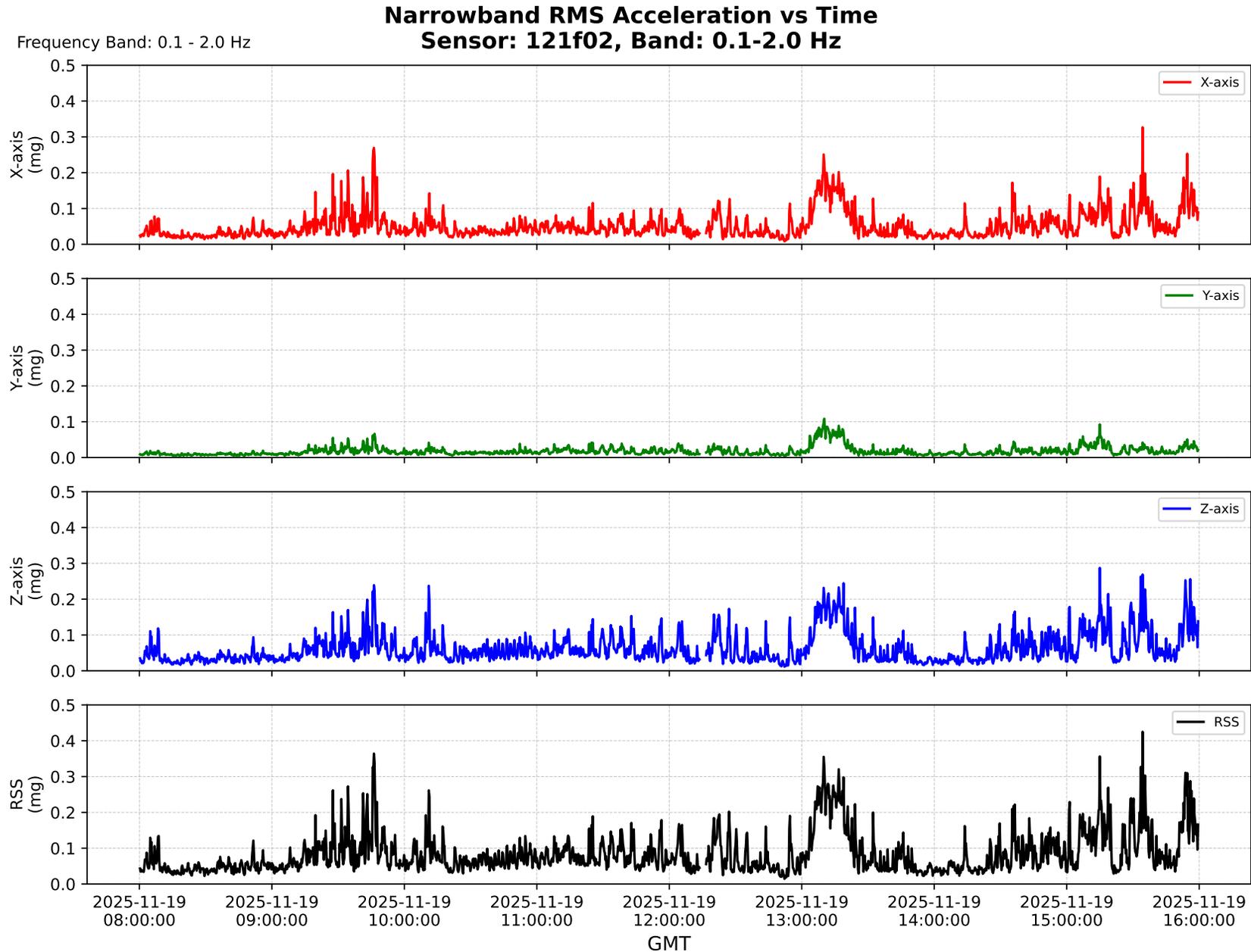


Fig. 9: 8 Hour RMS < 2 Hz shows Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor 121f02 on COL Endcone.

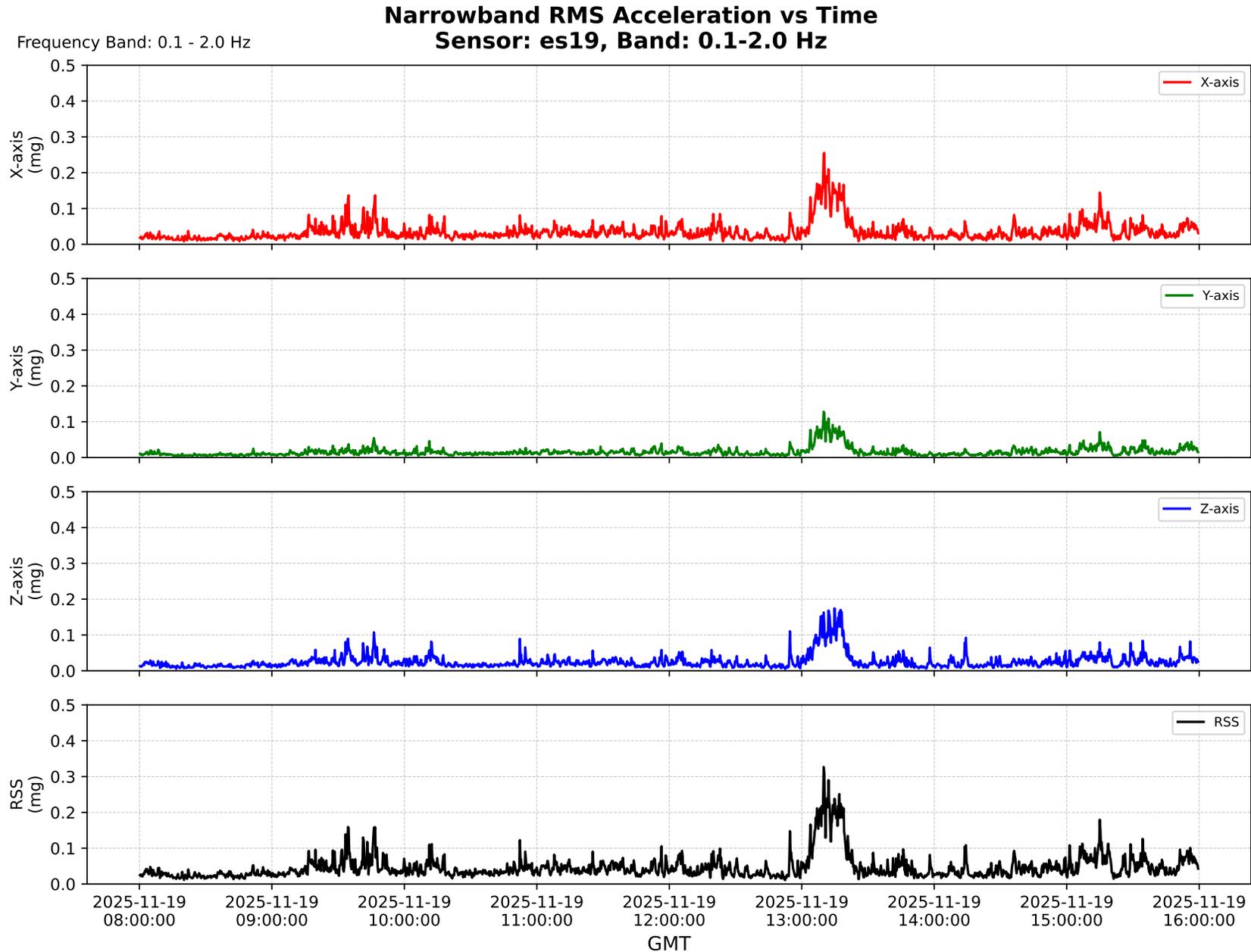


Fig. 10: 8 Hour RMS < 2 Hz shows Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor es19 on JPM1F6 (ER4).

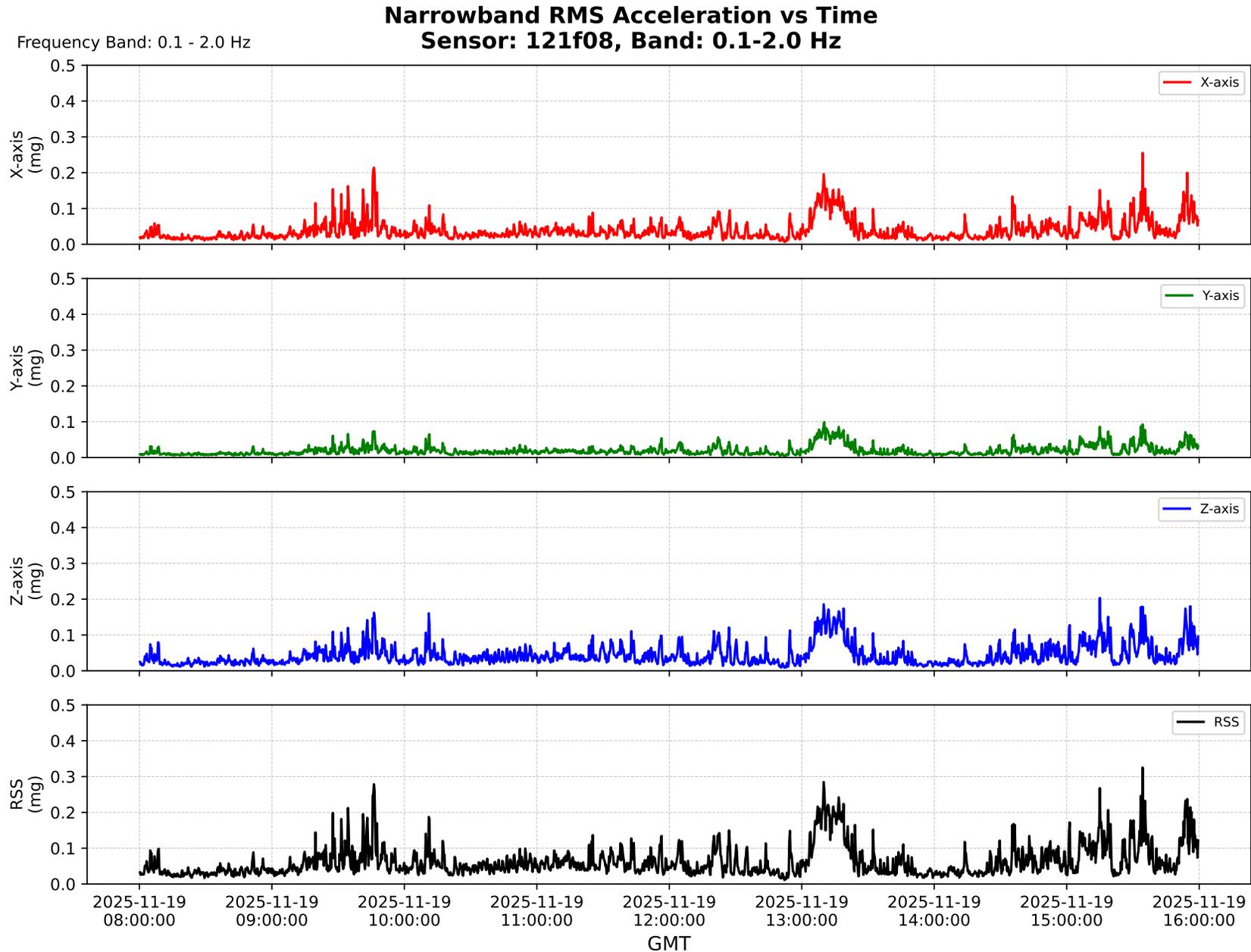


Fig. 11: 8 Hour RMS < 2 Hz showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor 121f08 on COL1A3 (EPM).

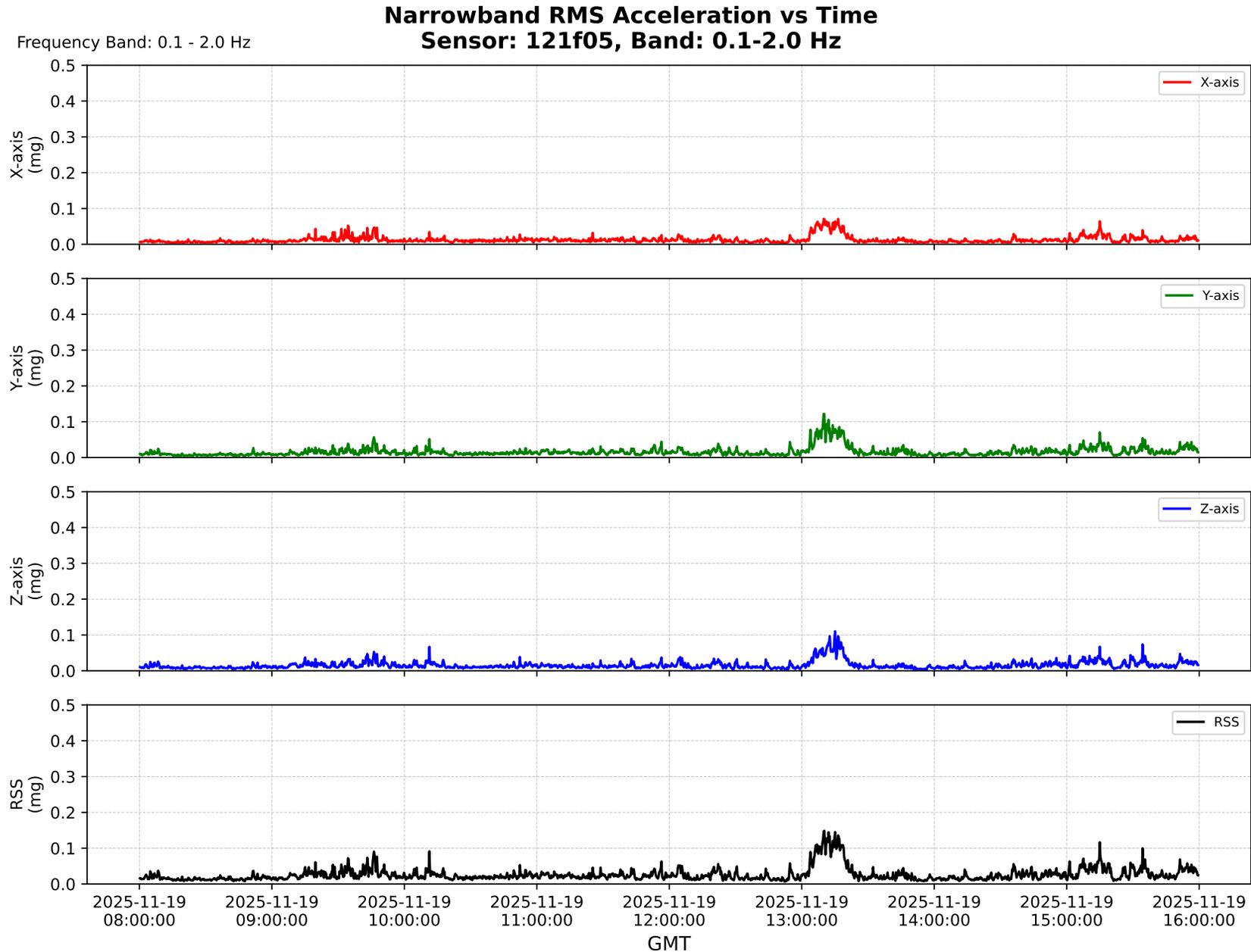


Fig. 12: 8 Hour RMS < 2 Hz showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor 121f05 on JPM1F1 (ER5).

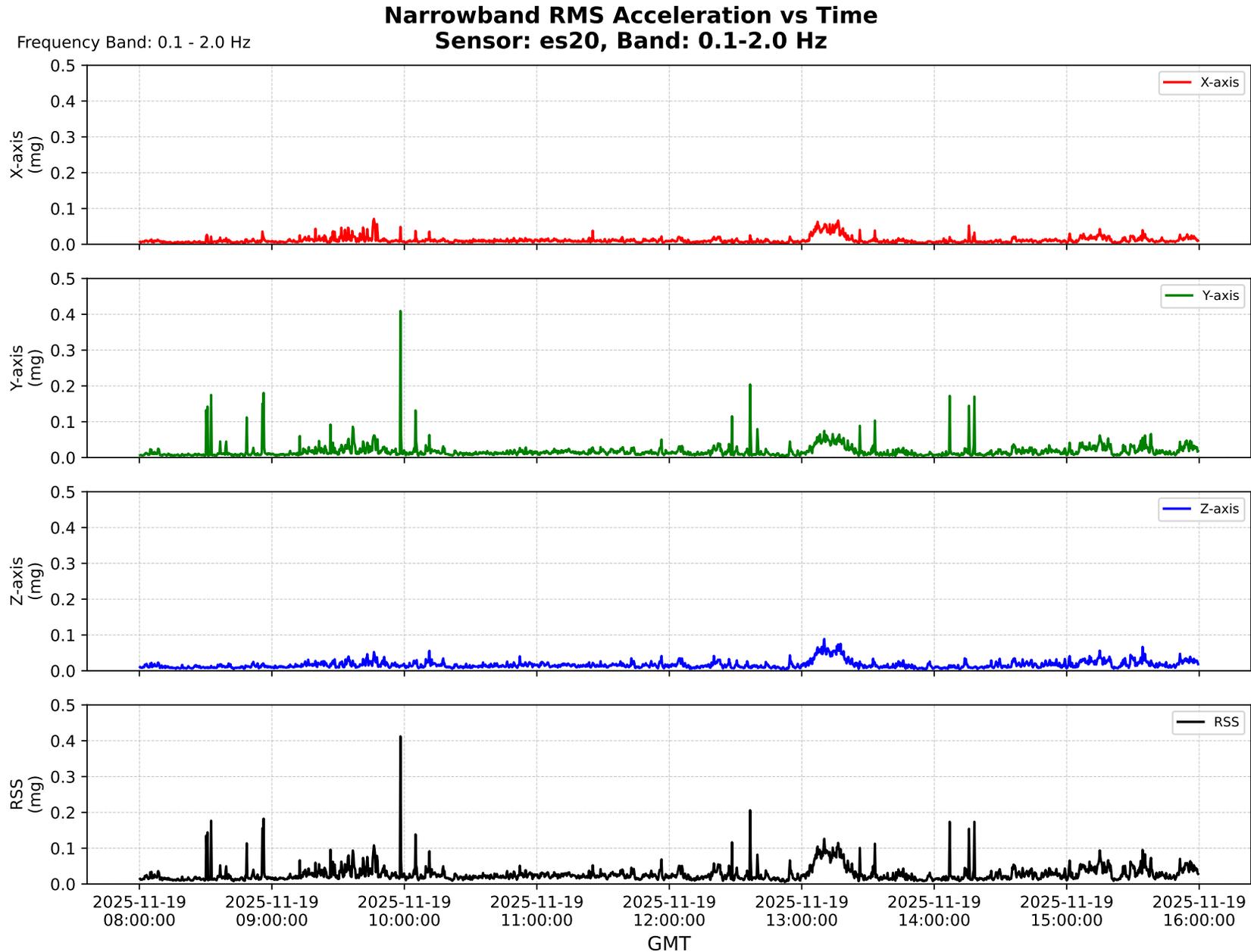


Fig. 13: 8 Hour RMS < 2 Hz showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor es20 on LAB1S2 (MSG).

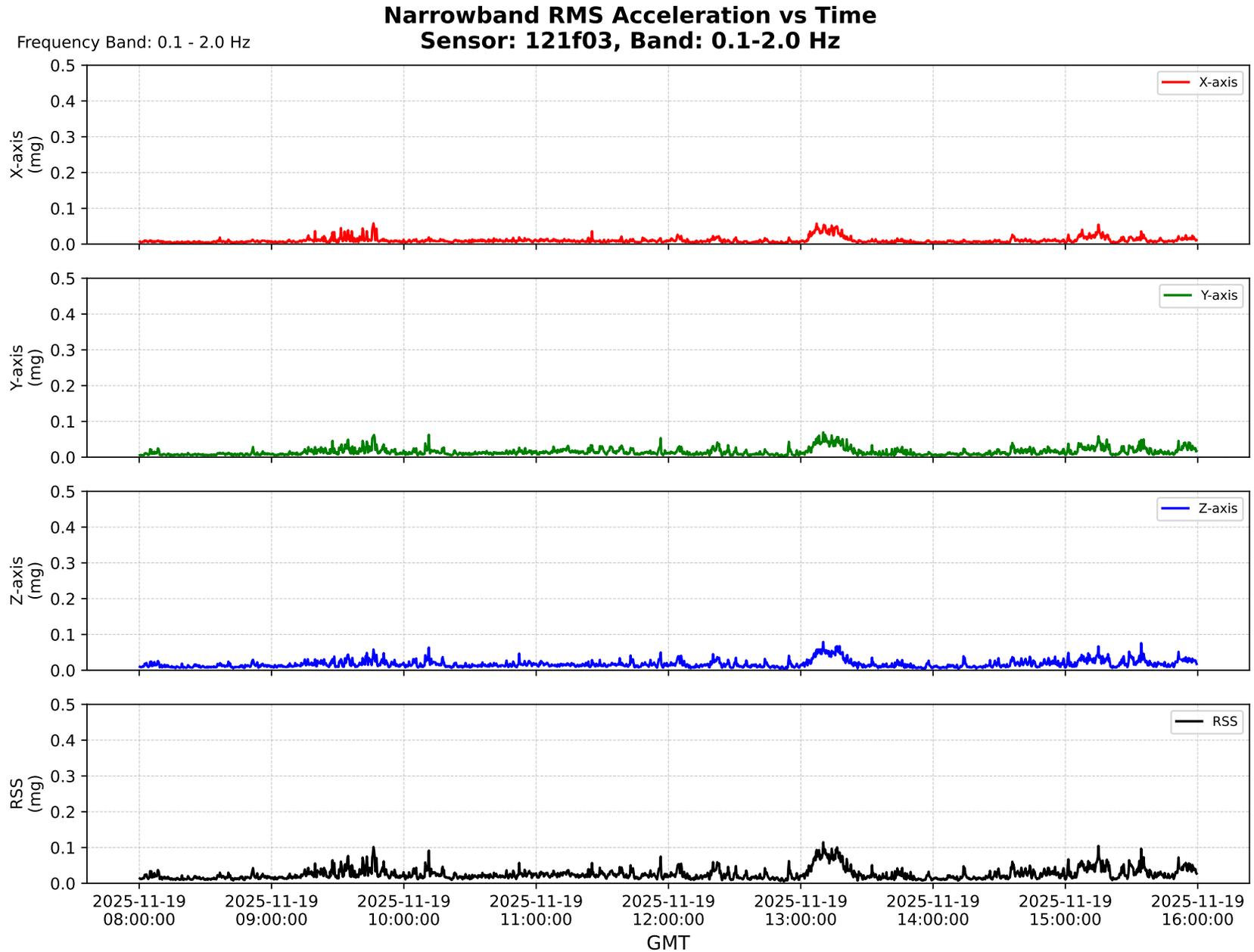


Fig. 14: 8 Hour RMS < 2 Hz showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor 121f03 on LAB101 (ER2).

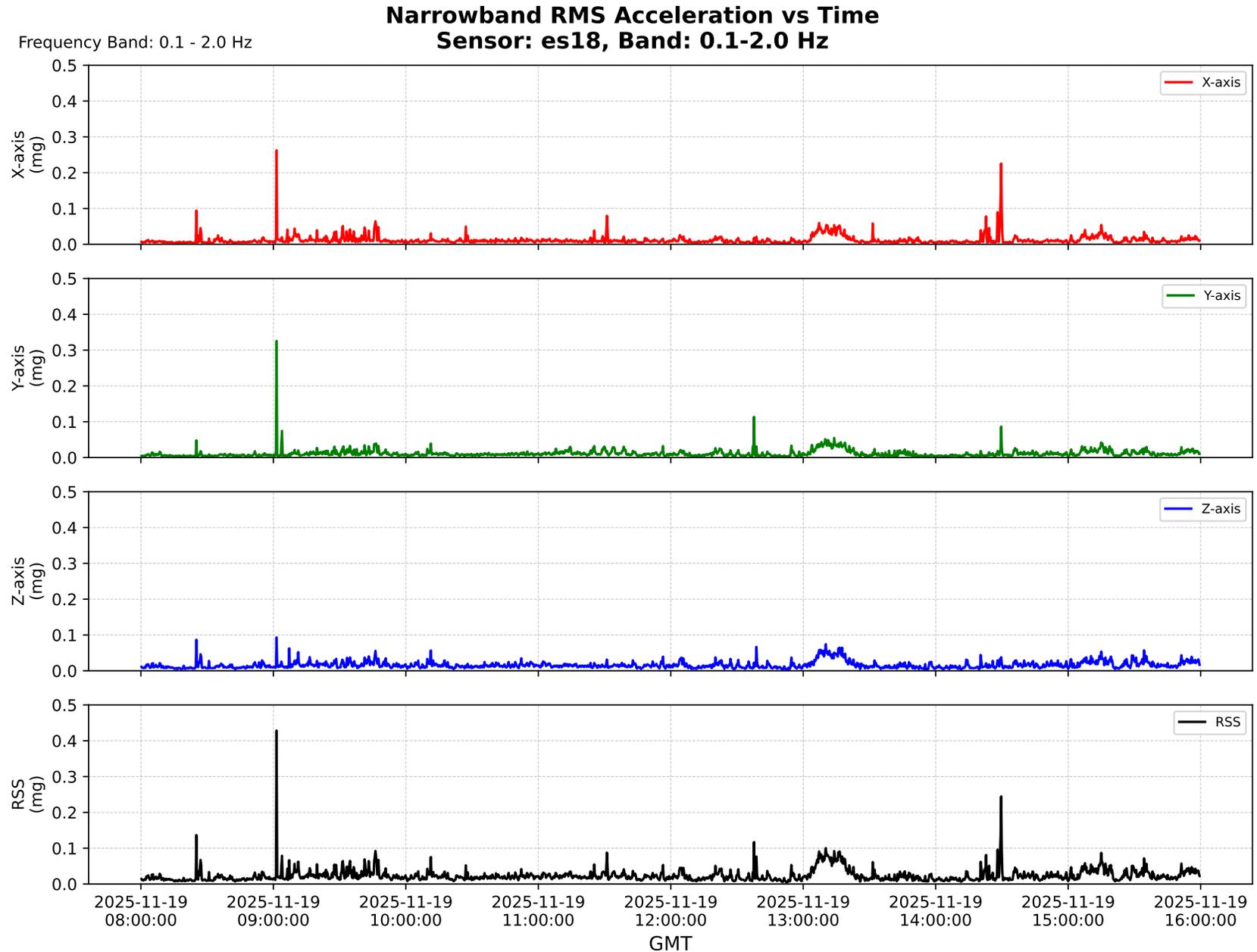


Fig. 15: 8 Hour RMS < 2 Hz showing Progress 93P Reboost on GMT 2025-11-19, SAMS Sensor es18 on LAB104 (ER6).

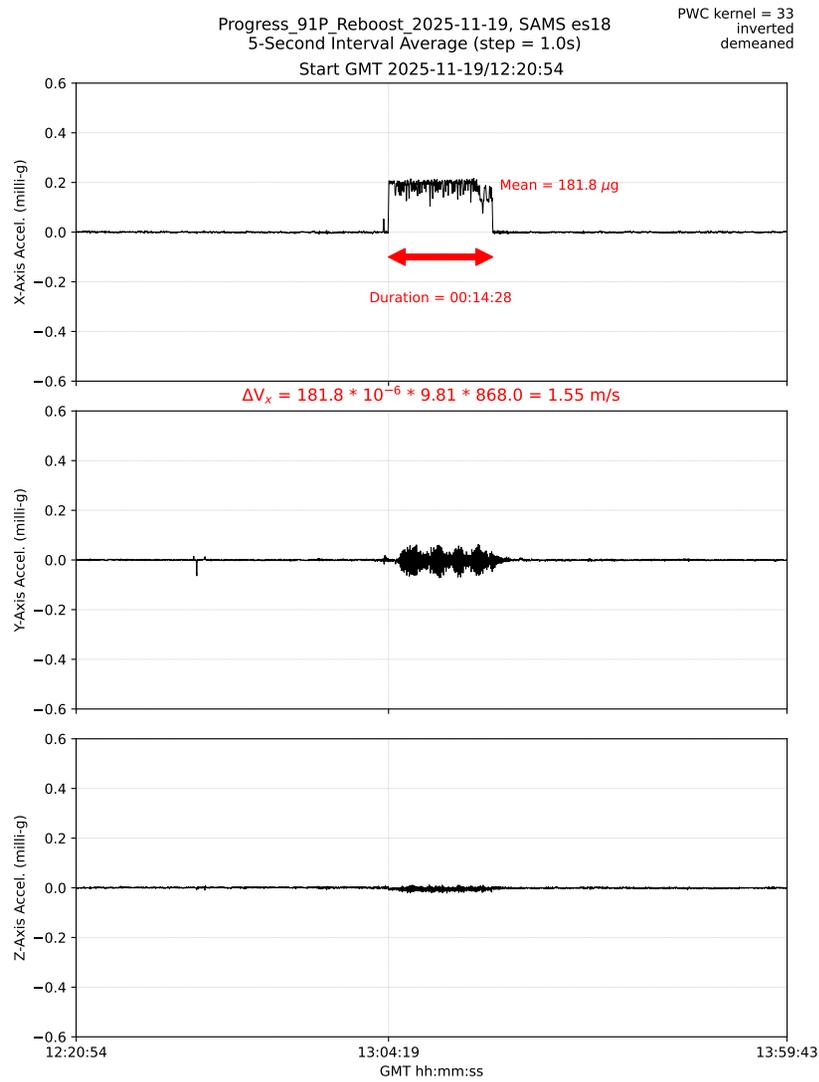


Fig. 16: 5-sec interval average for SAMS es18 sensor in the LAB.

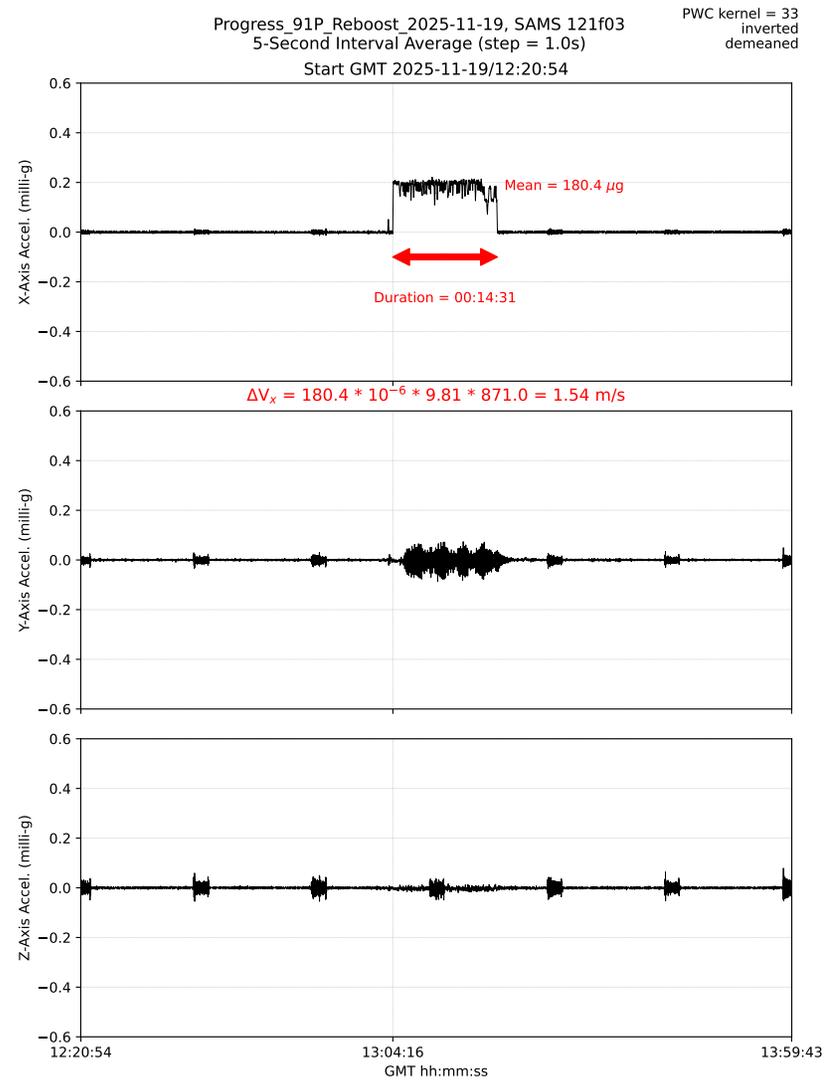


Fig. 17: 5-sec interval average for SAMS 121f03 sensor in the LAB.

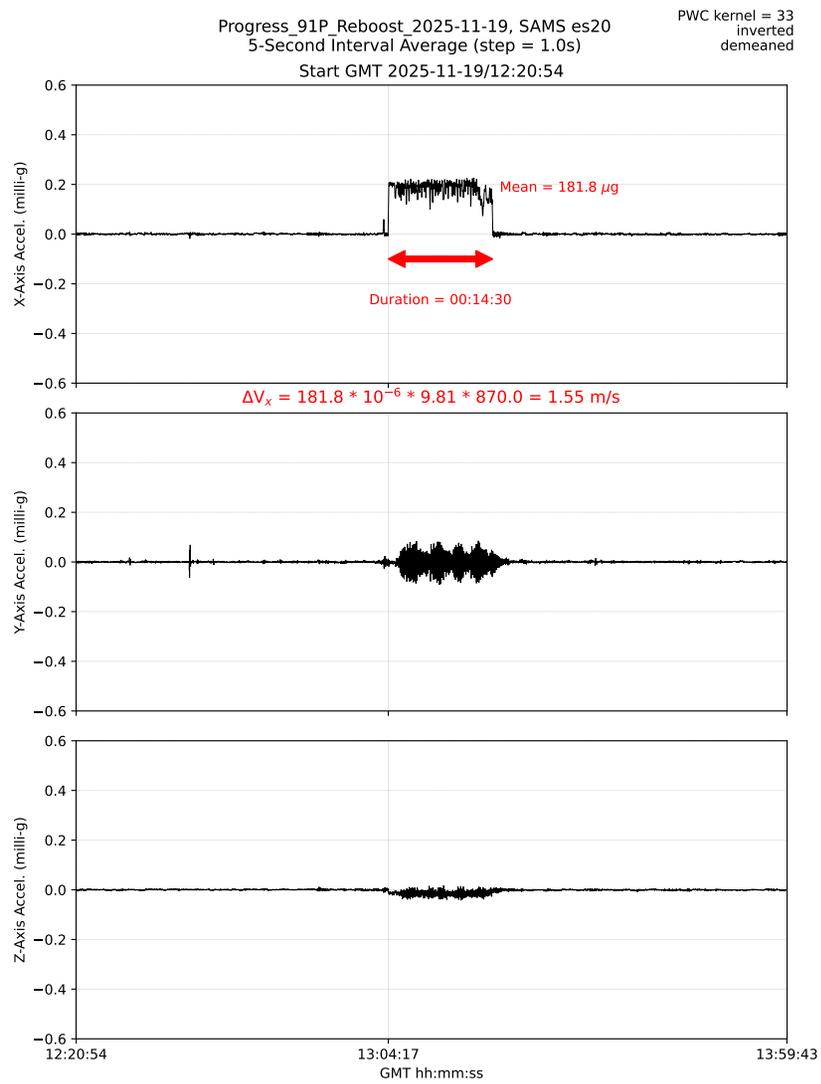


Fig. 18: 5-sec interval average for SAMS es20 sensor in the LAB.

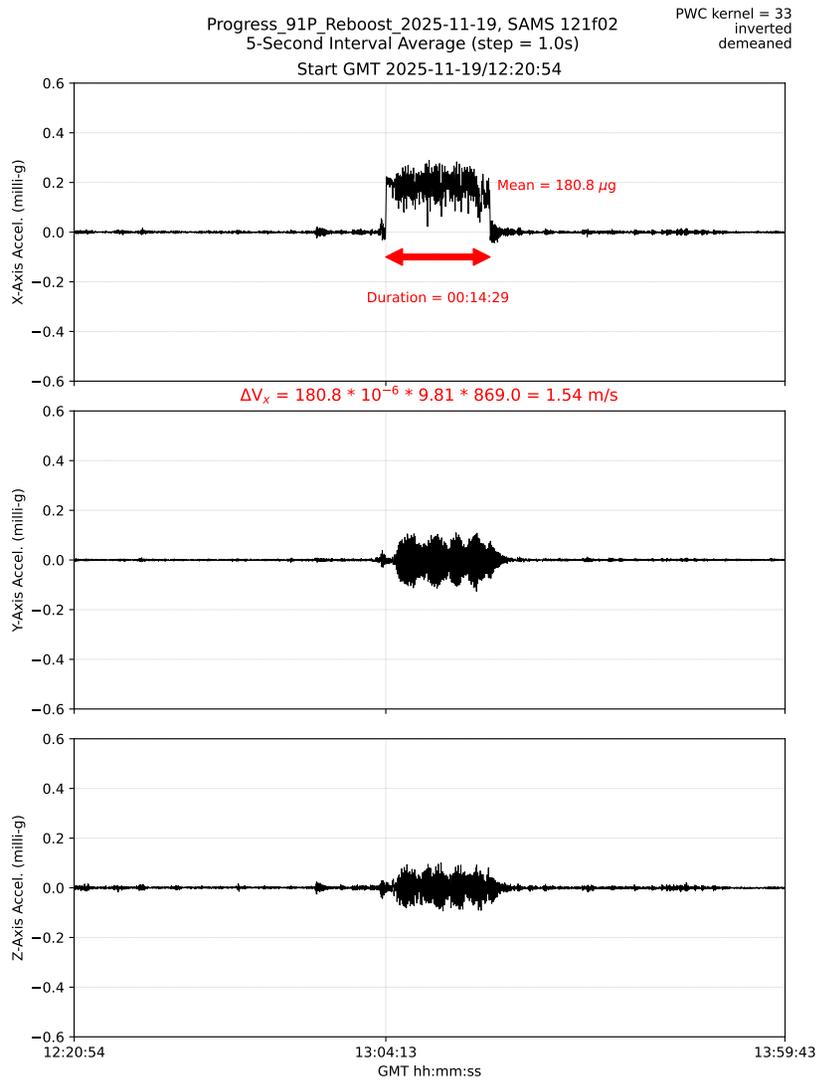


Fig. 19: 5-sec interval average for SAMS 121f02 sensor in the COL on Endcone.

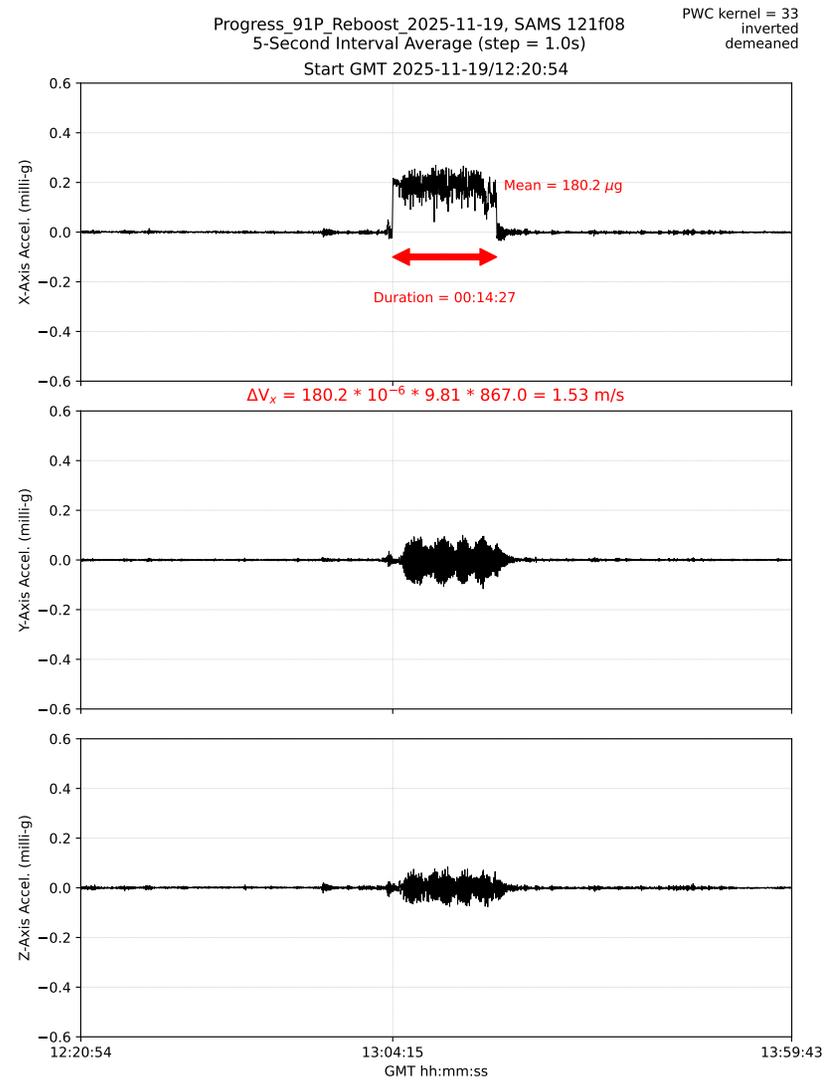


Fig. 20: 5-sec interval average for SAMS 121f08 sensor in the COL.

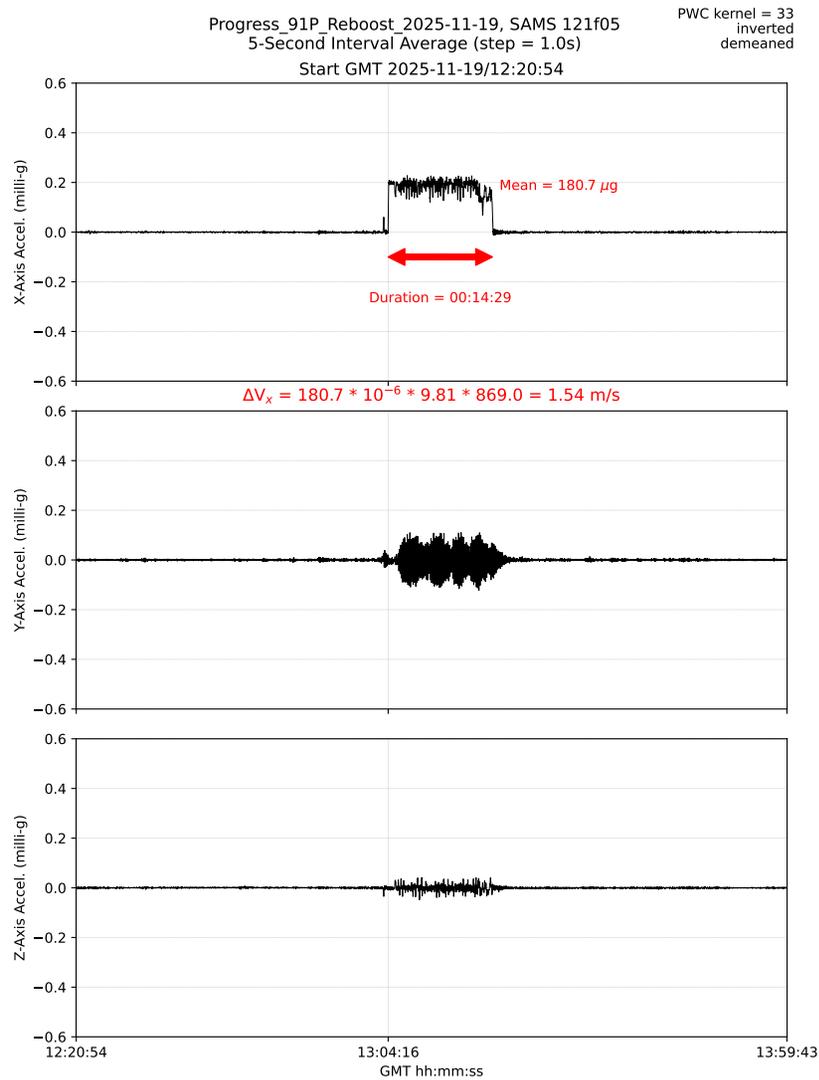


Fig. 21: 5-sec interval average for SAMS 121f05 sensor in the JEM.

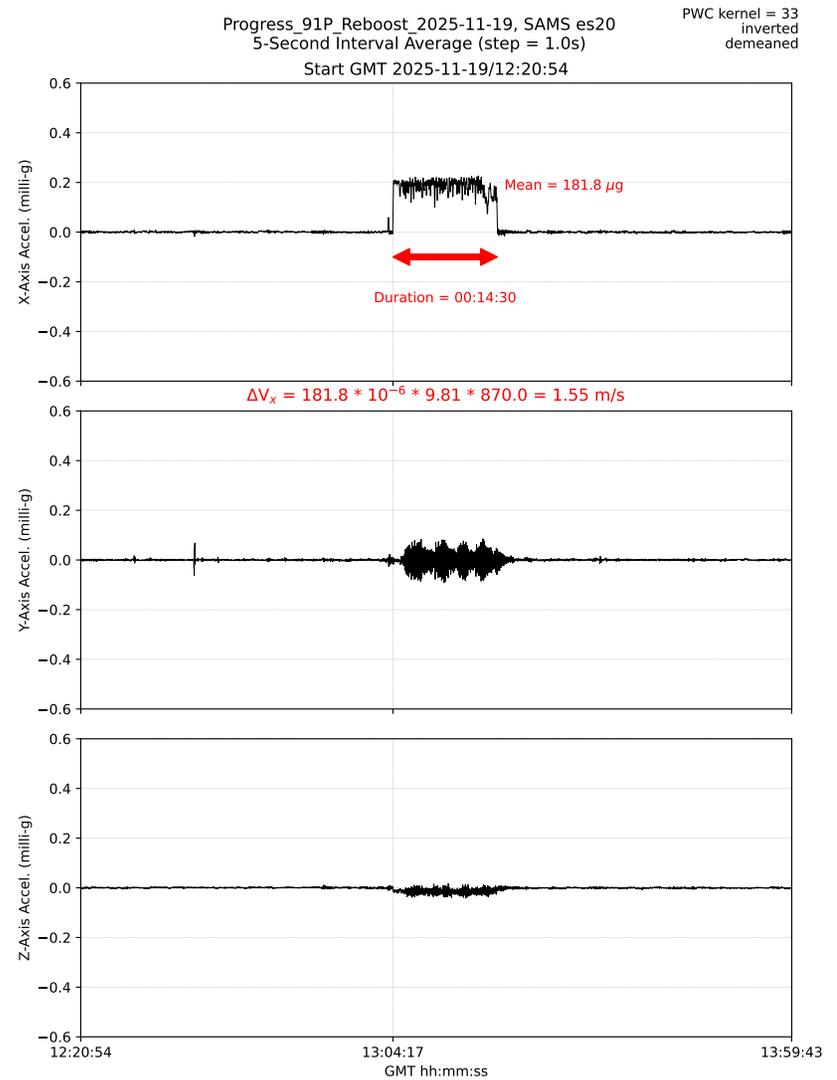


Fig. 22: 5-sec interval average for SAMS es20 sensor in the LAB.