

1. INTRODUCTION

On GMT 2025-05-16, between 10:25 and 11:00 GMT the Space Acceleration Measurement System (SAMS) head on rack LAB1P2 recorded a series of high-magnitude impulses while streaming real-time data from the International Space Station (ISS) to the NASA Glenn Research Center. The largest six events each integrated to more than 1000 mg²s, prompting this crude hypothesis:

Crude Hypothesis. If a sufficiently impulsive acceleration occurs at LAB1P2, then within ≤ 0.5 ms a correlated but attenuated pulse should appear at other, nearby sensor heads, with energy diminishing as a function of distance.

To address this, we have analyzed acceleration data from four triaxial SAMS heads in LAB1P2, LAB1O1, LAB1O3, and LAB1S2, combining time-history overlays, cross-correlation, frequency-band RMS, and an event-energy breakdown. Key metrics will include axis-specific lag results and those compared with the structural travel time over the rack-center spacing. Also, we note a strong, persistent 160 Hz single-axis *hum* local to the SAMS sensor head on the Materials Science Research Rack (MSRR) at LAB1O3.

Clarification

- *Terminology:* Throughout this document, we refer to impulsive accelerations in various ways, such as "bangs", "jolts" or "pulses". In all of these instances, we are referring to measured (or possibly low-pass filtered) accelerations that are "sudden, relatively high-magnitude acceleration events" as detected by one or more SAMS accelerometers. That is, on one or more axes of a given triaxial sensor head.
- *Sensor Designations:* Any "006" suffix (e.g. 121f04006) refers to 6 Hz low-pass filtered data sets, whereas without suffix (e.g. 121f04) refers to as-measured (up to 200 Hz) SAMS data sets.
- *SAMS Temporal Resolution:* Nominal SAMS sample rate is 500 samples per second ($\Delta t \leq 2$ ms), implying that the travel time referenced in our crude hypothesis as effectively *no discernible lag*, particularly for propagation from LAB1P2 to nearby LAB1O1.

2. QUALIFY

The information shown in Figure 1 on page 5 was calculated from the Space Acceleration Measurement System (SAMS) measurements made by the triaxial sensor head (121f04) on the LAB1P2 rack. This color spectrogram plot shows the spectral evolution (up to 200 Hz) over a 3-hour span of data that contains the impulsive span of interest between about GMT 10:25 and 11:00.

For science operations and general situational awareness, it is prudent to be aware that this type of overview plot is available on the web in near real-time.¹ When monitored via a browser, those interested can keep tabs as they may relate to their operations or for general awareness of potentially impactful impulsive accelerations. Typically, a red vertical streak across a wide swath of the acceleration spectrum.

Three other SAMS sensors located in the US Lab were also analyzed in this same way to examine the spectral evolution up to 200 Hz over the same 3-hour span:

- Figure 2 on page 6 for SAMS sensor 121f03 (LAB1O1)
- Figure 3 on page 7 for SAMS sensor es20 (LAB1S2)
- Figure 4 on page 8 for SAMS sensor es18 (LAB1O3)

These give minor indications that besides "ground zero" at the 121f04 (LAB1P2) location, the next most impacted sensor location was at LAB1O1. These spectrograms only weakly indicate magnitude, so we will dig deeper to better quantify the propagation.

3. QUANTIFY

The spectrogram for the SAMS sensor, 121f04, in the LAB1P2 rack seen in the previous section gave strong indication of acceleration impulses as narrow, vertical streaks on our color scale – actually, power spectral density magnitude scale – we now seek to better quantify the microgravity environment impact of these impulsive events and how they may have (or not) propagated from that "ground zero" location to other SAMS sensor head locations in the US Lab. We would not expect those to propagate to the Columbus module or the JEM.

¹For more info, email pimsops@lists.nasa.gov

Before tackling the details, let's tabulate figures we will discuss here:

Table 1. Figures, plot types, and their purpose.

Figures	Plot Type	Purpose
1–4	Spectrograms	Compare accel. spectra < 200 Hz
5–6	Per-axis accel. vs. time	Compare < 200 Hz
7	Zoom-in on Figure 5	Identify a pulse to compare
8	Overlays accel. vs. time	Show pulse comparison results
9–10	RMS accel. vs. time	Compare $100 < f < 200$ Hz

Examination and comparison of the figures in Table 1 highlights the dynamic and varied nature of the vibratory environment across the four SAMS sensor head locations within the U.S. Laboratory Module of the ISS. A key objective of this study was to investigate whether and how crew activity at a specific location—designated as "ground zero" near LAB1P2—propagates to other sensor head locations within the same module. While it is well-established that certain crew exercise-induced disturbances propagate across all three main laboratory modules, the impulsive accelerations observed at the LAB1P2 sensor location in this case are less distinct, making it challenging to confidently attribute them to a specific source.

Spectrograms

Figure 1 through Figure 4 show 3-hour, 200 Hz spectrograms for the 4 SAMS sensor head locations. Figure 1 for 121f04 sensor head on LAB1P2, shows notable, red, vertical streaks (impulsive accelerations) between about GMT 10:30 and 11:00, plus later on too. We see similar in Figure 2 for 121f03 sensor head on LAB1O1. These are the impulsive acceleration events we reference in the title of this document and what we will go more in-depth on below.

Per-Axis Accel. vs. Time

Figure 5 and Figure 6 show four 15-minute acceleration versus time plots for the 4 SAMS sensor head locations. Figure 5 for sensors 121f04 (LAB1P2) and 121f03 (LAB1O1) give plots that show notable impulsive accelerations between about GMT 10:45 and 11:00. The other 2 Lab sensor heads shown in Figure 6 did not.

Note that these four 15-minute acceleration versus time plots all have the same vertical scales of ± 50 mg except for the first where we needed ± 150 mg at "ground zero" of those impulses.

Zoom Per-Axis Accel. vs. Time to Identify a Pulse to Compare

Now we zoom-in to a 1-minute span to identify a pulse for more in-depth comparison. The red arrows in Figure 7 point to the Z-axis component of the pulse we have singled out for this purpose. As a first look on the left side plots, we overlay acceleration versus time plots (low-pass filtered below 6 Hz) for sensors: (*black trace*) 121f04 at LAB1P2, and (*red trace*) 121f03 at LAB1O1 in Figure 8. Here we show just an 8-second span and we scaled the 121f03 (red trace) data up by a factor of 10 to see it more clearly relative to the 121f04 (black trace) data.

Next, we used cross-correlation to calculate the lag/lead timing offset for the indicated pulse of the red trace relative to the black trace. The thought was that pulse would take some small amount of time to propagate through rack and space station structure to get from "ground zero" (the black trace) location to the other (red trace) location.

Technical Note

Cross-correlation measures how similar two signals are essentially by sliding one past the other to find the time offset where their patterns "match best". We shift one signal to find the time offset that makes the two most similar in shape, ignoring differences in size. For signals $x(t)$ (e.g., black trace) and $y(t)$ (e.g., red trace), the cross-correlation function $R_{xy}(\tau)$ is computed for different time shifts τ . The lag/lead is the τ value where $R_{xy}(\tau)$ peaks, showing the time offset of best alignment. A positive τ means $y(t)$ lags $x(t)$ (red occurs after black), while a negative τ means $y(t)$ leads $x(t)$ (red occurs before black). Signals are often preprocessed (e.g., mean-subtracted, sometimes filtered) to reduce noise, and normalized cross-correlation, scaled to equal amplitude, ensures reliable results. For example, in MATLAB's `xcorr` with `'coeff'`, the lag is the index of the maximum correlation times the sampling interval, giving the timing offset.

The right-hand plots in Figure 7 display the per-axis lag/lead time offsets applied independently to the red traces relative to the black traces, that is, the lag time from LAB1P2 to LAB1O1. The computed per-axis lags, determined via normalized cross-correlation, were as follows:

Axis	Lag (ms)
X	-915.3 ms
Y	-302.8 ms
Z	63.4 ms

Clarification: The negative lags force us to reject our crude propagation hypothesis for this specific impulse. Since the pulse we chose was the highest in magnitude at the LAB1P2 location, we would likely get similar hypothesis rejection for other, smaller pulses too. Some alternative explanations for seeing closely-timed pulses (within a second or so) at 2 different locations, we now suspect those were independent, localized sources at LAB1P2 and at LAB1O1. The most likely (speculated) source for those impulses at both locations was independent, localized crew activity.

In our cross-correlation analysis, we only checked the largest impulse as a test case. To be thorough, we could also test say the next 5 highest impulses in the same way. If all of those yielded lags < 100 ms, and/or mixed signs as we have seen in our test case, then further reinforcement of our assertions here. Possible future work.

Interpretation of Cross-Correlation (Time Lag) Analysis

Lag Definition: In our analysis software, the lag is computed as the time shift of the red trace relative to the black trace via cross-correlation. The table above could be captioned as “Lag (red vs. black) = -303 ms” for the Y-axis, meaning: A negative lag (-303 ms) indicates that the red trace’s pulse occurs *before* the black trace’s pulse in time.

Chronological Order: Since the lag is -303 ms, the red trace’s pulse occurs first, followed by the black trace’s pulse about 303 ms later. *Again, this contradicts our proposed hypothesis.*

This is the opposite of our hypothetical assertion, where we expected the black trace’s pulse (at the reference 121f04 sensor’s location) to occur first, with the red

trace’s pulse (at the other, somewhat distant 121f03 sensor) occurring later due to propagation through rack and space station structure, modeled roughly as “all aluminum” for this analysis.

Back-of-Envelope: Travel Distance & Time for Pulse Propagation

Rack Center Coordinates ²			
Sensor (Rack)	x (in)	y (in)	z (in)
121f04 (LAB1P2)	144.6	-58.08	193.32
121f03 (LAB1O1)	186.6	0.00	135.12

∴ Center-to-center separation: $d = 92.3 \text{ in} = 2.34 \text{ m}$.

Using aluminium’s longitudinal wave speed $v \approx 6000 \text{ m/s}$, the expected travel time is

$$t = \frac{d}{v} = \frac{2.34 \text{ m}}{6000 \text{ m/s}} \approx 0.39 \text{ ms.}$$

while the observed lags (e.g. -303 ms) are orders of magnitude larger—and of mixed sign—so the impulses at 121f03 (LAB1O1) do not plausibly stem from those at 121f04 (LAB1P2).

Root-Mean-Square (RMS) Acceleration versus Time, 100 to 200 Hz

Figure 9 and Figure 10 show root-mean-square (RMS) acceleration vs. time for the frequency band from 100 to 200 Hz. All 4 of the plots in these 2 figures are on the same vertical 0 to 20 mg scale for easy comparisons. We make these observations:

- The left-hand side plots of Figure 9 for the 121f04 (LAB1P2) location show what those impulses contribute in terms of RMS between 100 and 200 Hz.
- The right-hand side plots of Figure 9 for the 121f03 (LAB1O1) location show nothing remarkable or noteworthy...hence this note.
- The left-hand side plots of Figure 10 for the es18 (LAB1O3) location show an incredibly energetic, vibratory source in the 100 to 200 Hz range primarily aligned with the X-axis and to much lesser degree aligned with the Z-axis.
- The right-hand side plots of Figure 10 for the es20 (LAB1S2) location shows RMS levels similar to 121f03 (LAB1O1) location.

²Coordinates are in body-fixed Space Station Analysis (SSA) reference frame.

Event–Energy Plot

Figure 11(d) on the lower-right of page 15 shows a stacked bar chart of event energy for the top six impulses in the 121f04 (LAB1P2) dataset, illustrating the relative energy contributions from each sensor, but not necessarily the spatial attenuation of these impulses across the US Lab to other locations (as we originally intended). The main takeaway here is that the large dark blue portions for the 121f04 head on LAB1P2 appear simply because that sensor is sitting at “ground zero,” so it captures the full width-and-height of each jolt—all three axes register the peak of the event almost simultaneously. By contrast, the cyan slices from the es18 head on LAB1O3 look sizable not because the impulse travelled that far, but because that rack carries its own, persistent 100–200 Hz vibration that rings on inside the same 1-second integration window, inflating the energy tally for that sensor. In other words, dark blue means proximal amplitude (“ground zero”), while cyan means local high-frequency hum that happens to coincide with the impulse window. Not what we intended as propagation evidence, but noteworthy nonetheless.

Technical Note

Further Interpreting Event–Energy Plot of Figure 11(d)

- One bar = one impulse (GMT time shown under bar).
- Height = motion energy E . Taller means the jolt was *stronger and/or longer*.
- Four colors for four sensor heads. Bigger slice → that head “felt” more.
- Left → right in chronological order: *six strongest* impulses ranked by total energy based on 121f04 data.
- First bar is almost all dark blue (121f04 @ LAB1P2 “felt” most), while cyan bars come from local rack hum, *not* long-range propagation.

Energy metric:

Ideal (continuous-time) is:

$$E = \int_{t_0}^{t_1} \left(a_x^2(t) + a_y^2(t) + a_z^2(t) \right) dt$$

Actual/empirical (discrete-time) is:

$$E \approx \Delta t \sum_{n=n_0}^{n_1} \left(a_{x,n}^2 + a_{y,n}^2 + a_{z,n}^2 \right) \quad [\text{mg}^2 \cdot \text{s}]$$

4. KEY FINDINGS AND SPECULATION

Key findings included axis-specific time offset of nearly 1 second compared with the 0.39 ms structural travel time over the 2.34 m rack-center spacing distance, plus a strong, persistent 160 Hz single-axis *hum* local to the MSRR sensor head.

We speculate here that the es18 160 Hz *hum* was equipment with one revolution per cycle giving a 160 Hz peak (9,600 RPM). This could be a small centrifugal pump or maybe a compressor with piston-type actuation being used inside or nearby to the MSRR rack.

5. CONCLUSION

On GMT 2025-05-16, between 10:25 and 11:00, the LAB1P2 SAMS head (121f04) registered several large impulses whose peaks exceeded 50 mg; six of those events surpassed 1000 mg² s in integrated energy.

Cross-correlation of the single largest event, using sensors at LAB1P2 and LAB1O1, yielded axis-specific lags from −915.3 ms (X) to 63.4 ms (Z). Those mixed-sign lags are *over two orders of magnitude* larger than the expected structural travel time of ≤ 1 ms across the 2.34 m aluminium path. Together with an unchanged RMS trend at LAB1S2 and the locally high 100–200 Hz hum at LAB1O3, the evidence shows each rack experienced its own, independent jolt rather than a single propagating bang.

For the impulses analyzed here, microgravity investigators operating at that time could assume that experiments mounted more than one rack away from that crew activity near LAB1P2 would have seen no discernible increase above their local environment in the 0.1–200 Hz band. That is, we have shown the resulting shocks were LAB1P2 “rack-local”, and did not discernibly propagate to other LAB rack locations that were analyzed.

Future work could pair impulses with time-synchronised video to pin down specific operations, extend the analysis toward the critical 0.1–20 Hz structural-mode band, and develop a rack-to-rack transfer function so stakeholders can predict worst-case loads and augment standard SAMS measurements.

These findings underline the ISS’s complex vibratory environment and the need for targeted source identification to safeguard sensitive microgravity experiments.

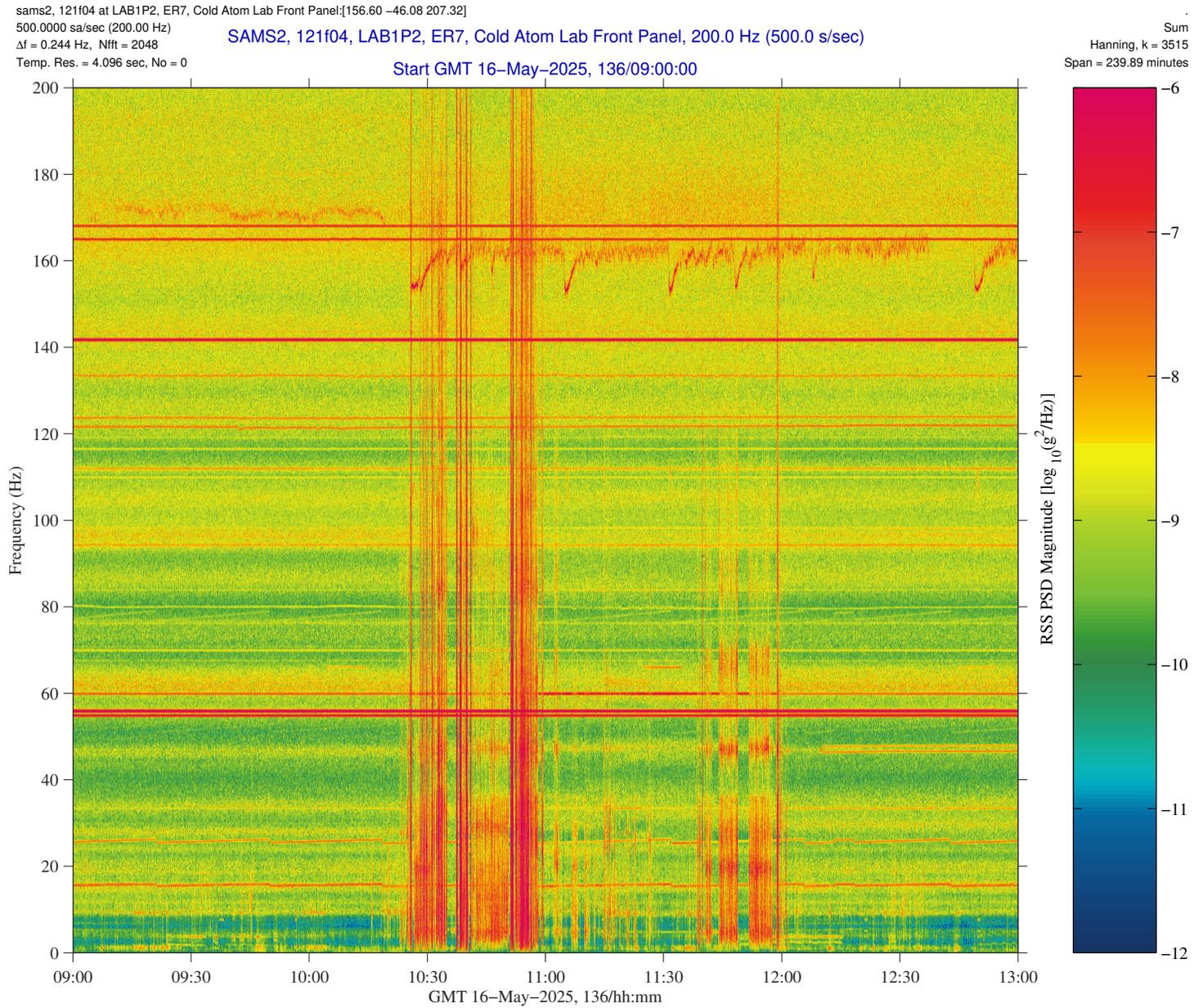
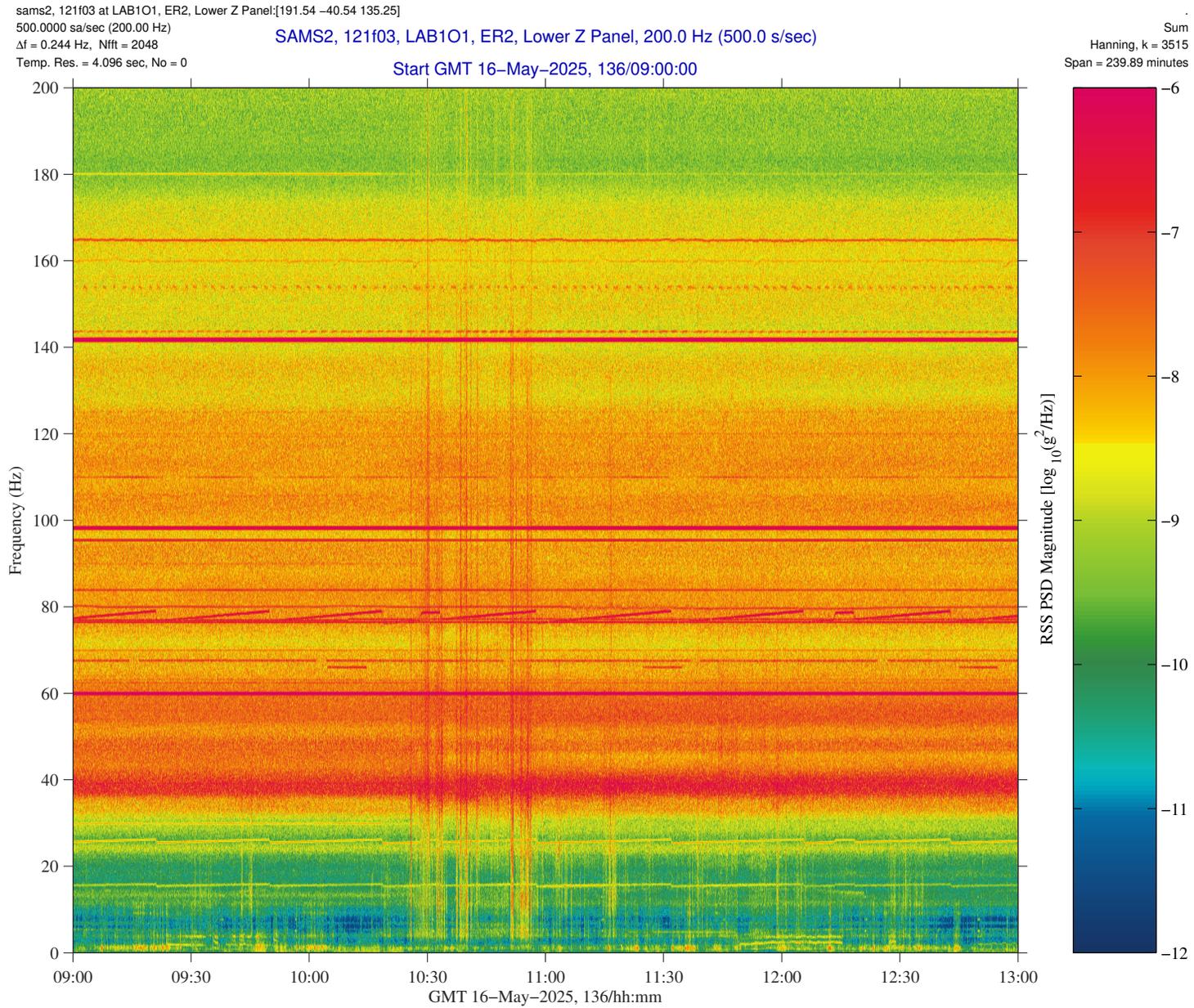


Fig. 1: 200 Hz, 3-Hour Spectrogram Computed from SAMS 121f04 (LAB1P2) Measurements.



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Fig. 2: 200 Hz, 3-Hour Spectrogram Computed from SAMS 121f03 (LAB1O1) Measurements.

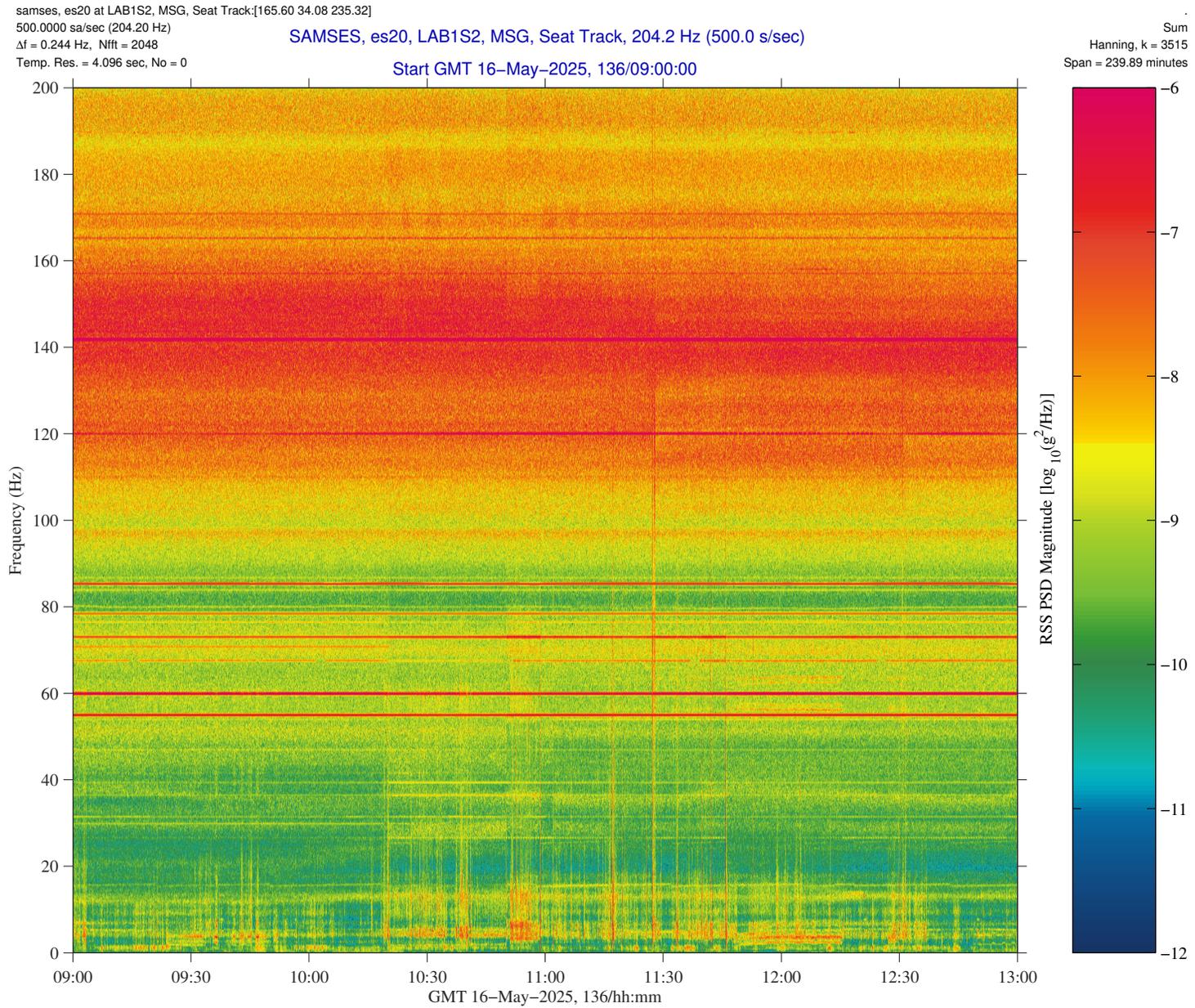


Fig. 3: 200 Hz, 3-Hour Spectrogram Computed from SAMS es20 (LAB1S2) Measurements.

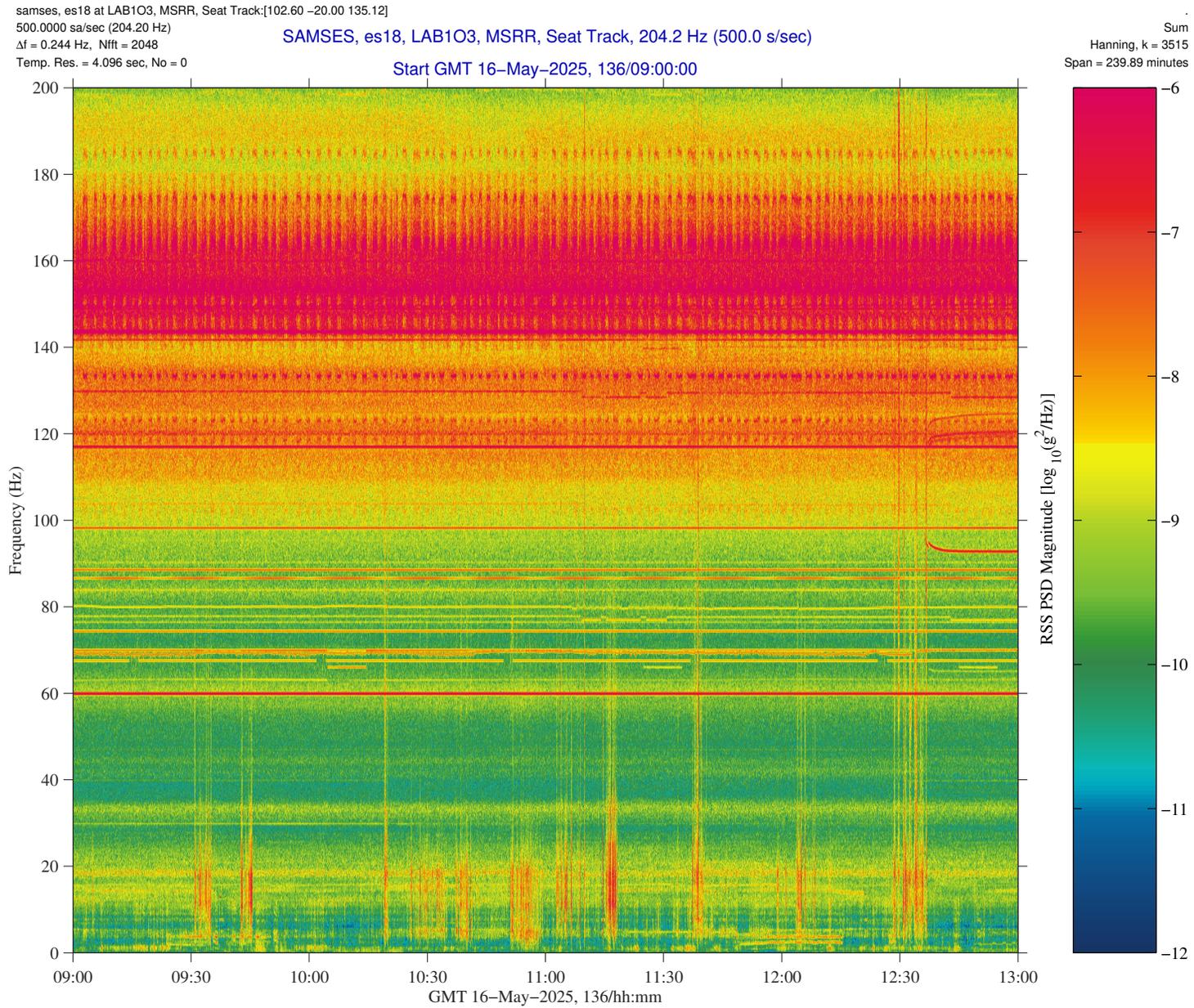


Fig. 4: 200 Hz, 3-Hour Spectrogram Computed from SAMS es18 (LAB1O3) Measurements.

sams2, 121f04 at LAB1P2, ER7, Cold Atom Lab Front Panel[156.60 -46.08 207.32]
500.0000 sa/sec (200.00 Hz) SAMS2, 121f04, LAB1P2, ER7, Cold Atom Lab Front Panel, 200.0 Hz (500.0 s/sec) SSAnalysis[0.0 0.0 0.0]

sams2, 121f03 at LAB1O1, ER2, Lower Z Panel[191.54 -40.54 135.25]
500.0000 sa/sec (200.00 Hz) SAMS2, 121f03, LAB1O1, ER2, Lower Z Panel, 200.0 Hz (500.0 s/sec) SSAnalysis[0.0 0.0 0.0]

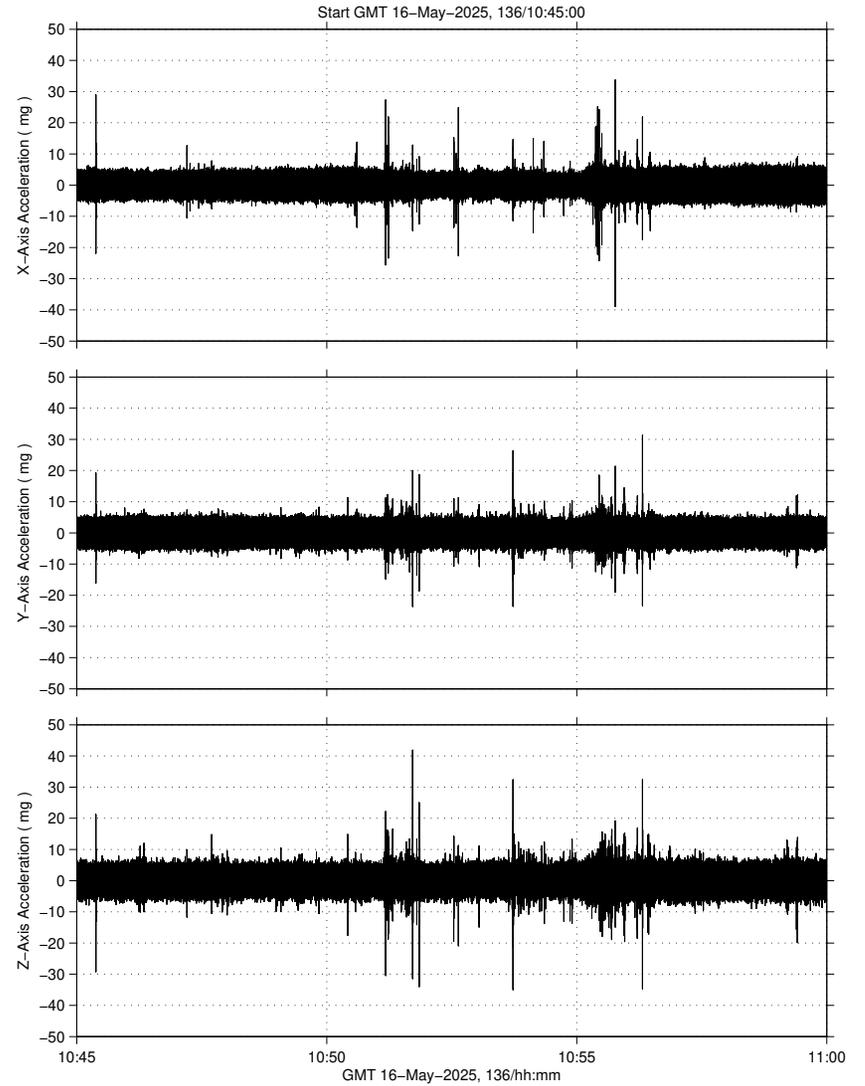
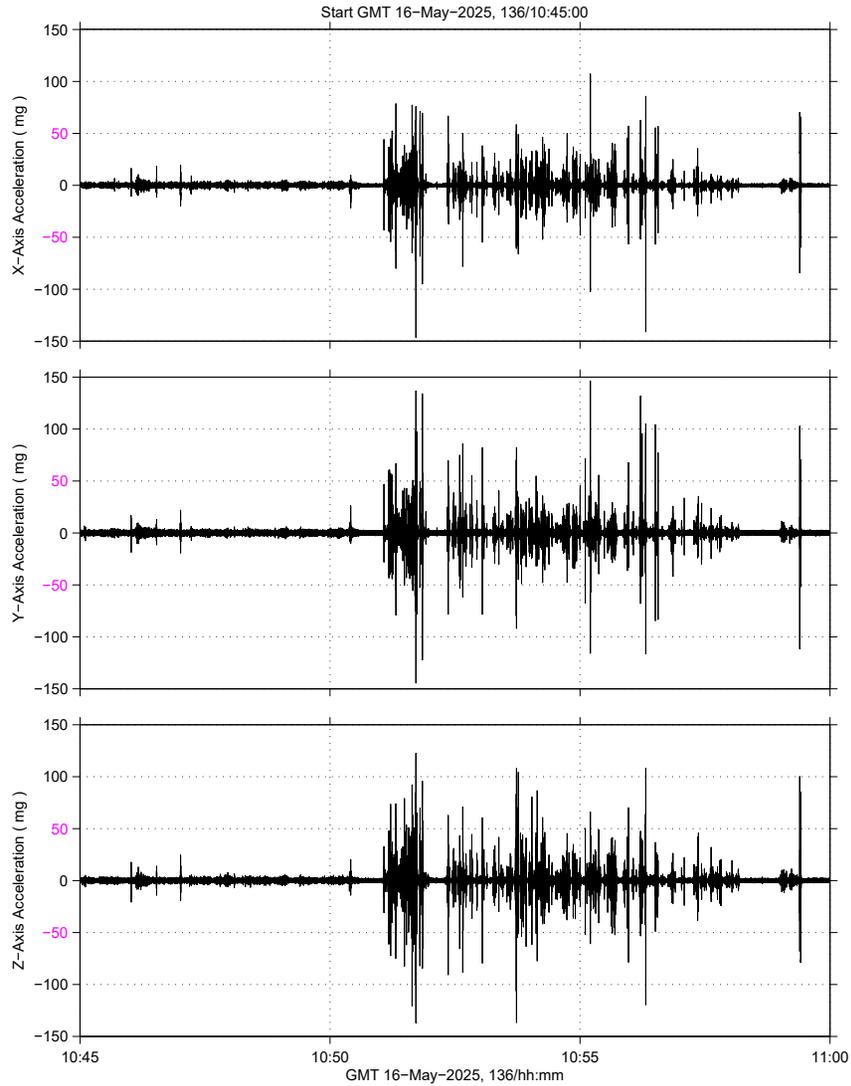


Fig. 5: Per-Axis Accel. vs. Time Showing 15-Minute Span on GMT 2025-05-16 for SAMS Sensors: **(left)** 121f04 at LAB1P2, and **(right)** 121f03 at LAB1O1.

sames, es20 at LAB1S2, MSG, Seat Track:[165.60 34.08 235.32]
500.0000 sa/sec (204.20 Hz)

SAMSES, es20, LAB1S2, MSG, Seat Track, 204.2 Hz (500.0 s/sec)

SSAnalysis[0.0 0.0 0.0]

sames, es18 at LAB1O3, MSRR, Seat Track:[102.60 -20.00 135.12]
500.0000 sa/sec (204.20 Hz)

SAMSES, es18, LAB1O3, MSRR, Seat Track, 204.2 Hz (500.0 s/sec)

SSAnalysis[0.0 0.0 0.0]

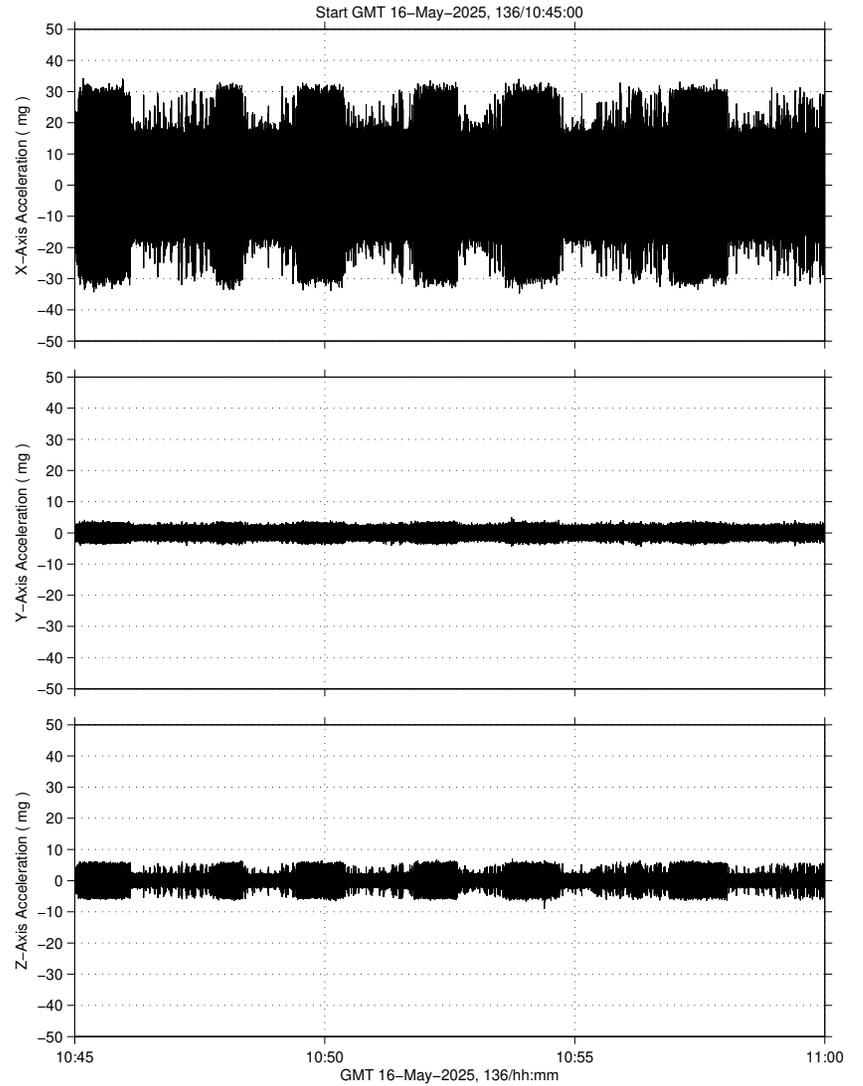
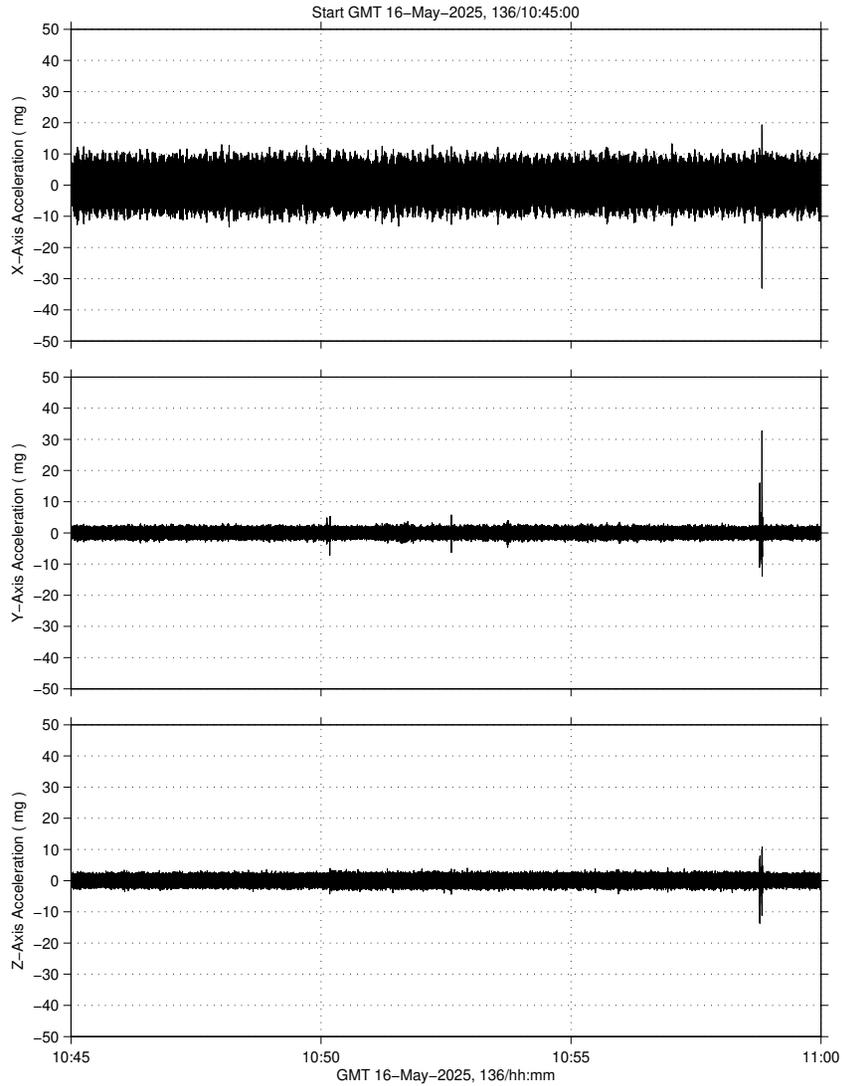


Fig. 6: Per-Axis Accel. vs. Time Showing 15-Minute Span on GMT 2025-05-16 for SAMS Sensors: (left) es20 at LAB1S2, and (right) es18 at LAB1O3.

sams2, 121f04 at LAB1P2, ER7, Cold Atom Lab Front Panel[156.60 -46.08 207.32]
500.0000 sa/sec (200.00 Hz) SAMS2, 121f04, LAB1P2, ER7, Cold Atom Lab Front Panel, 200.0 Hz (500.0 s/sec) SSAnalysis[0.0 0.0 0.0]

sams2, 121f03 at LAB1O1, ER2, Lower Z Panel[191.54 -40.54 135.25]
500.0000 sa/sec (200.00 Hz) SAMS2, 121f03, LAB1O1, ER2, Lower Z Panel, 200.0 Hz (500.0 s/sec) SSAnalysis[0.0 0.0 0.0]

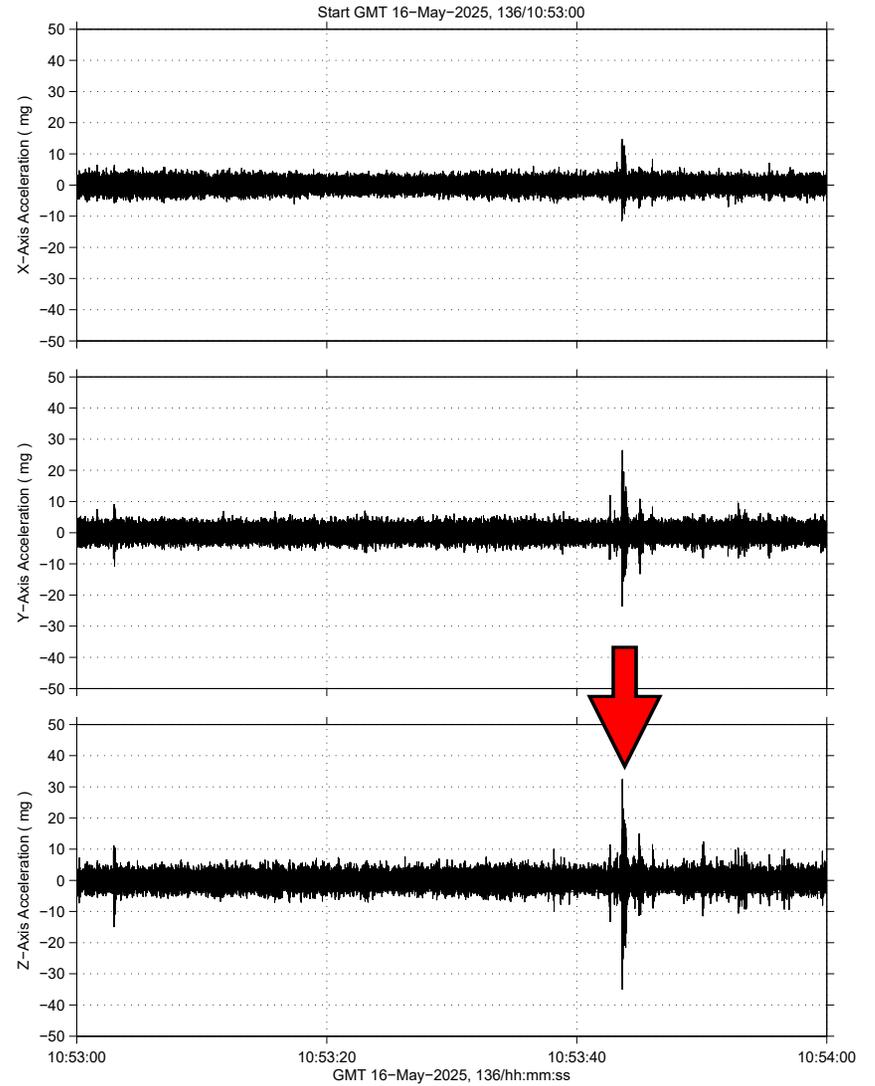
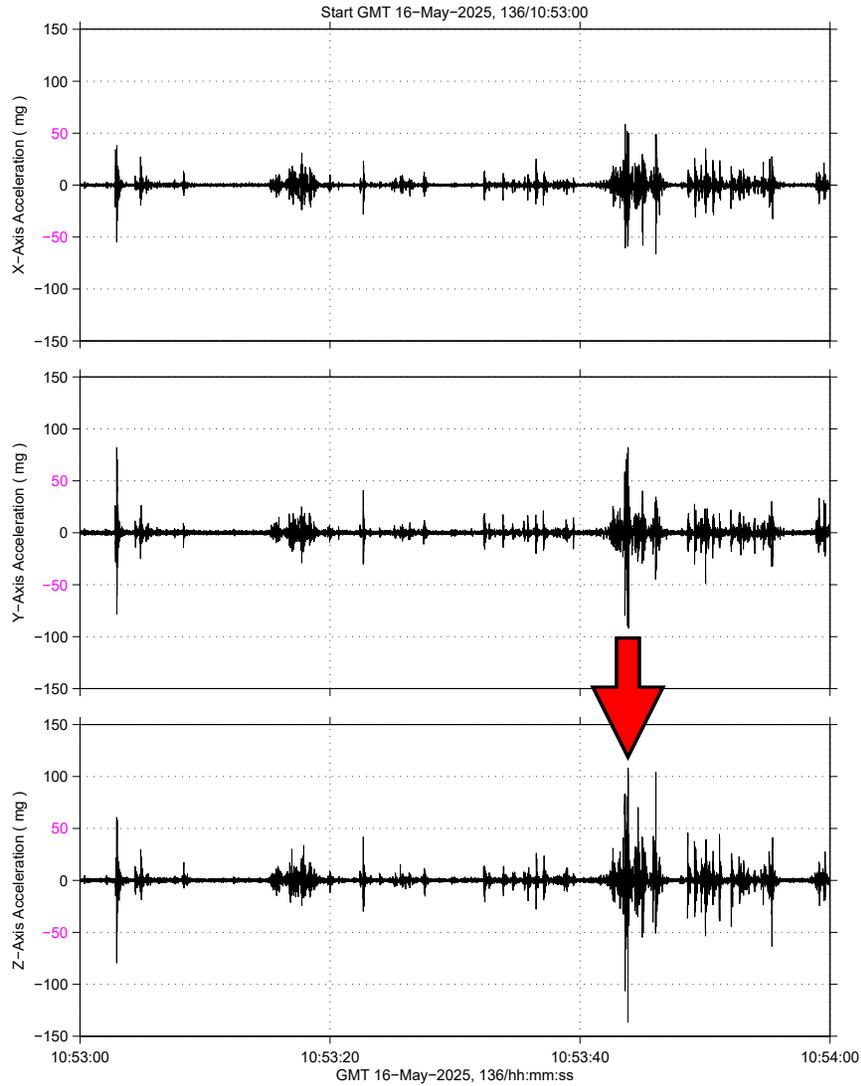


Fig. 7: Zoom-In Per-Axis Accel. vs. Time, 1-Minute Span on GMT 2025-05-16 for SAMS Sensors: **(left)** 121f04 at LAB1P2, and **(right)** 121f03 at LAB1O1.

inverted-sams2, 121f04006 at LAB1P2, ER7, Cold Atom Lab Front Panel[156.60 -46.08 207.32]
142.0000 sa/sec (6.00 Hz) SAMS2, 121f04006, LAB1P2, ER7, Cold Atom Lab Front Panel, 6.0 Hz (142.0 s/sec) SSAnalysis[0.0 0.0 0.0]

inverted-sams2, 121f04006 at LAB1P2, ER7, Cold Atom Lab Front Panel[156.60 -46.08 207.32]
142.0000 sa/sec (6.00 Hz) SAMS2, 121f04006, LAB1P2, ER7, Cold Atom Lab Front Panel, 6.0 Hz (142.0 s/sec) SSAnalysis[0.0 0.0 0.0]

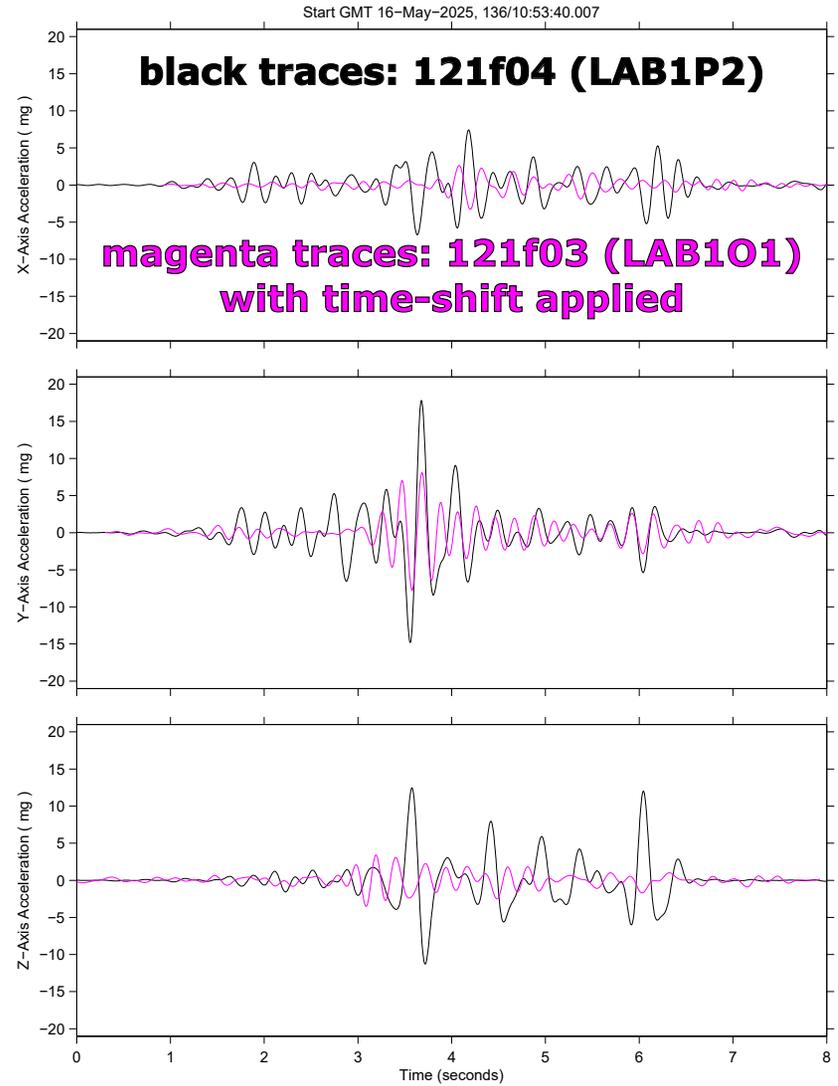
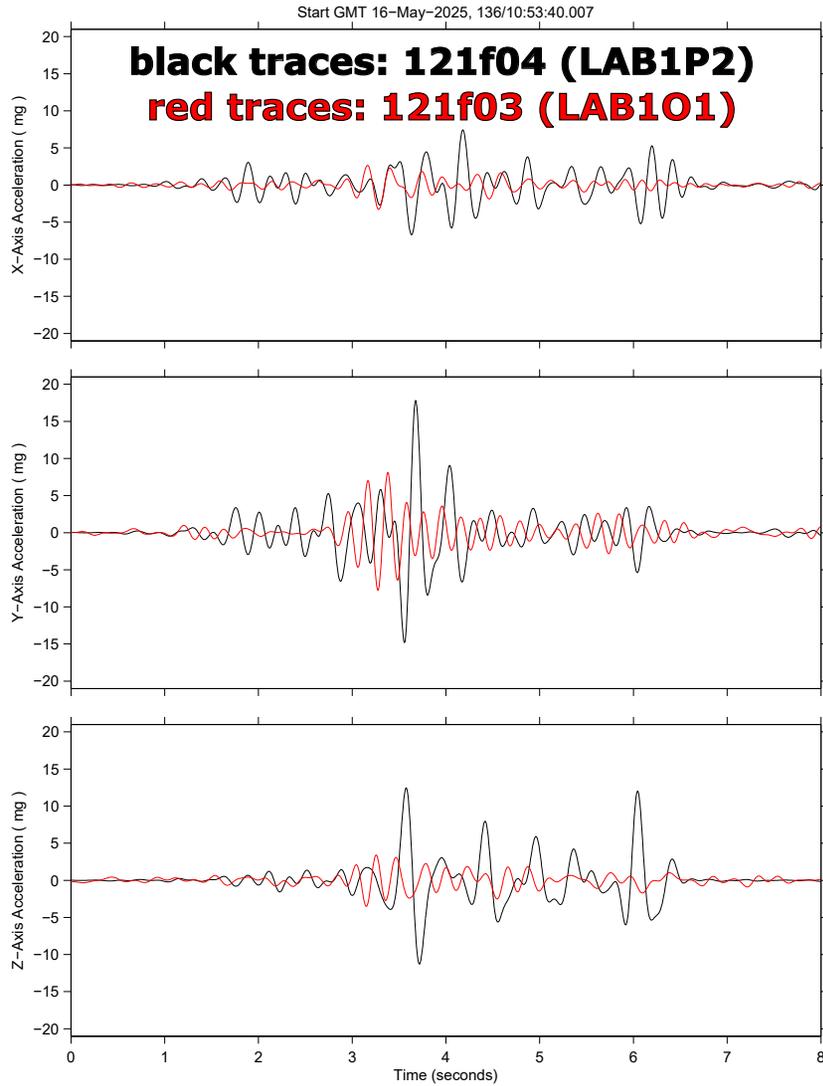


Fig. 8: Overlays Per-Axis Accel. vs. Time, 8-Second Span on GMT 2025-05-16 for SAMS Sensors: (left) original timing, and (right) lag/lead applied to 121f03 data.

121f04 Narrow Band RMS Accel. vs Time
 Interval: Size = 2.05, Step = 1.02 sec.
 Frequency Band: 100.0 ≤ f < 200.0 Hz
 Start GMT 2025-05-16, 136/10:45:00.000 (span = 00:00:15:00)

121f03 Narrow Band RMS Accel. vs Time
 Interval: Size = 2.05, Step = 1.02 sec.
 Frequency Band: 100.0 ≤ f < 200.0 Hz
 Start GMT 2025-05-16, 136/10:45:00.000 (span = 00:00:15:00)

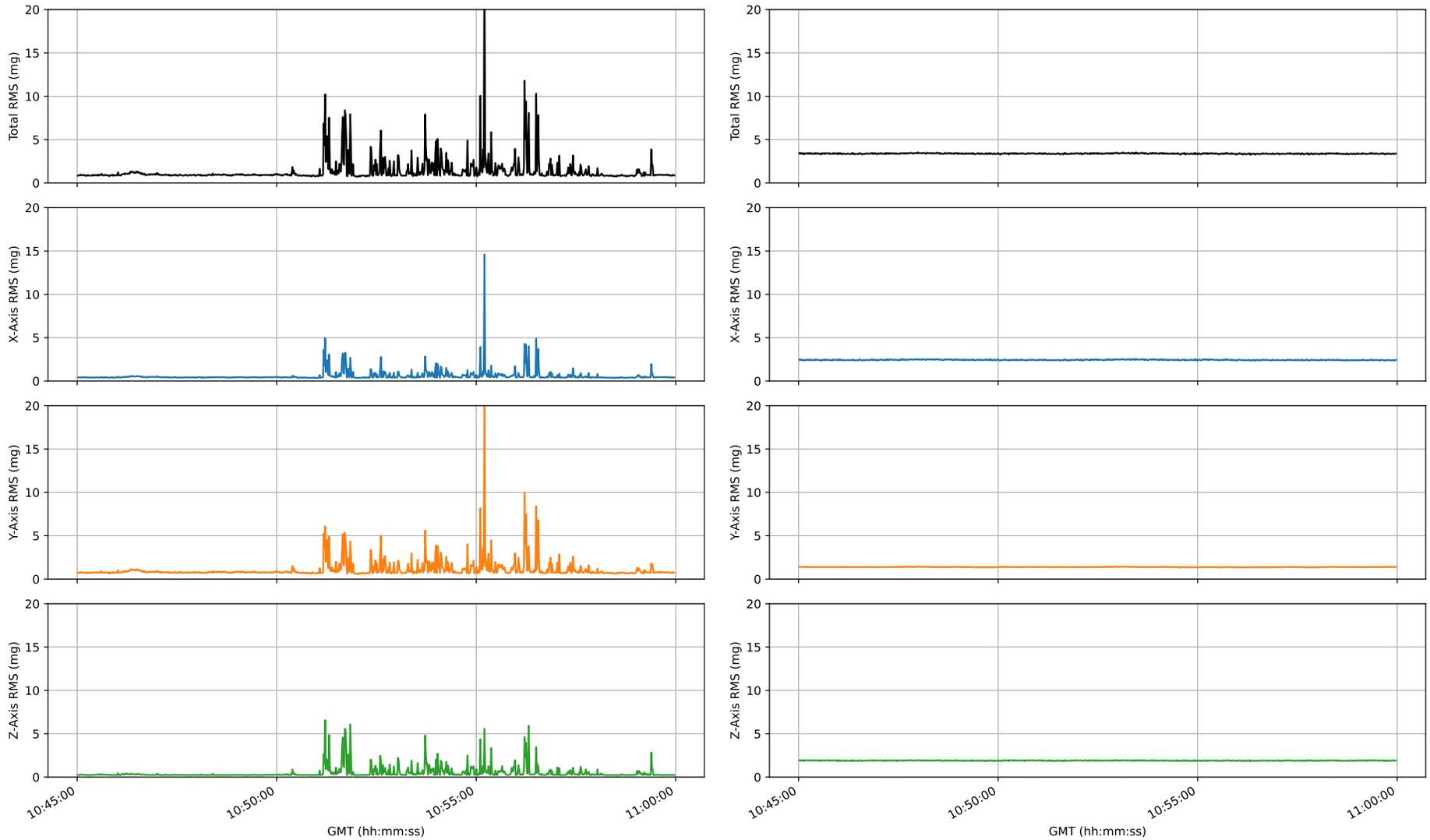


Fig. 9: RMS Acceleration vs. Time (100–200 Hz), 30-Minute Span on GMT 2025-05-16 for SAMS Sensors: (left) 121f04 at LAB1P2, (right) 121f03 at LAB1O1.

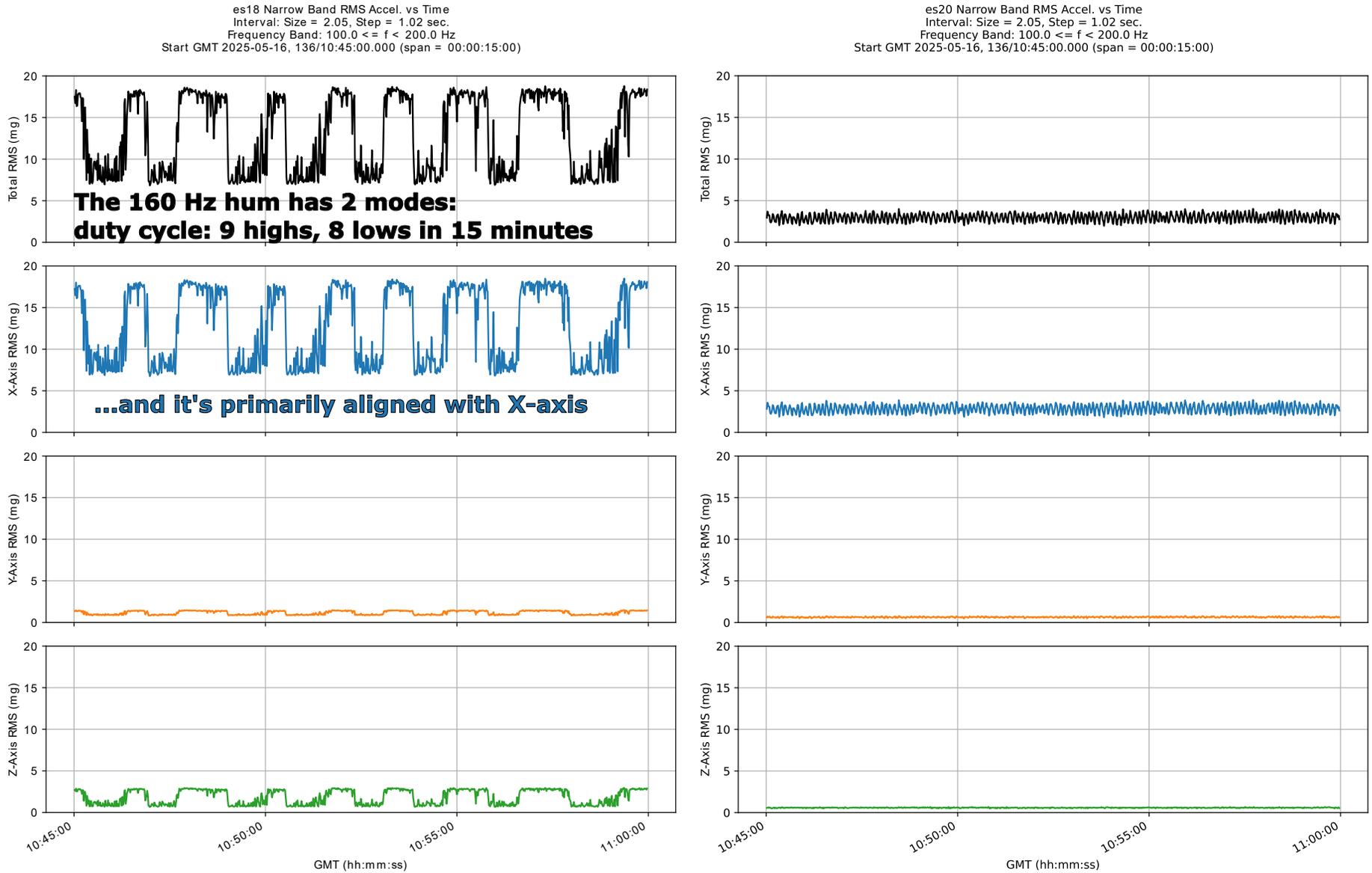
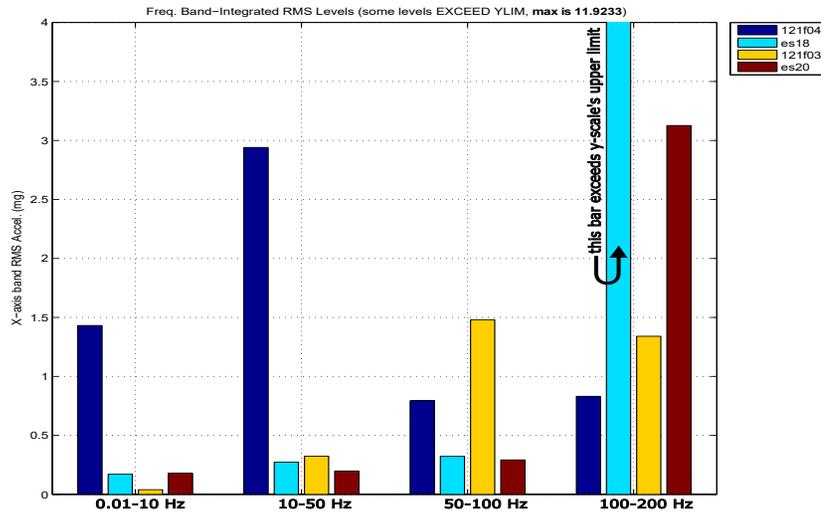
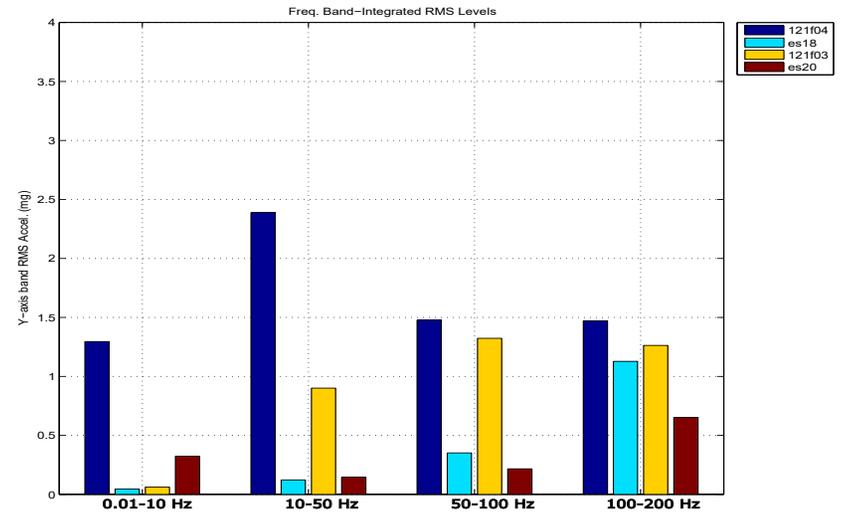


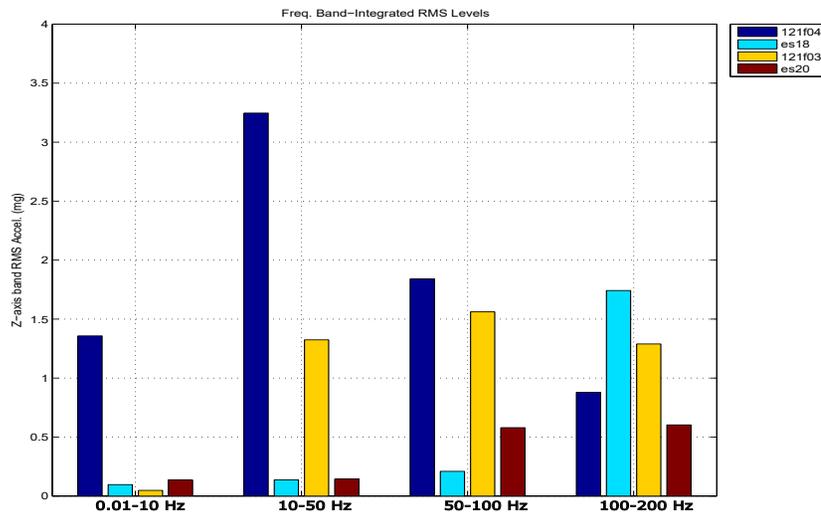
Fig. 10: RMS Acceleration vs. Time (100–200 Hz) Showing 30-Minute Span on GMT 2025-01-28, SAMS Sensor 121f03 in LAB.



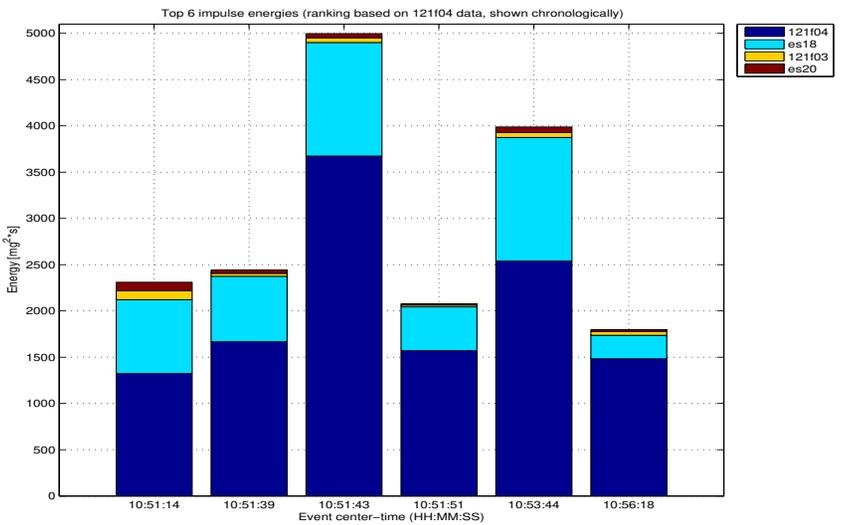
(a) X-Axis



(b) Y-Axis



(c) Z-Axis



(d) Event Energy for Top 6 Impulses in the 121f04 (LAB1P2) Data Set.

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Fig. 11: 4 SAMS Sensor Locations: (a,b,c) RMS in 4 Bands, and (d) Event Energy "Stack".