

1. INTRODUCTION

On GMT 2025-01-27, the Microgravity Acceleration Measurement System (MAMS), which typically operates continuously on the International Space Station (ISS), was powered down to facilitate the "Loop B Fill" activity and ensure proper equipment deactivation for that maintenance activity. The MAMS is housed in EXPRESS Rack 5 (ER5) in the Japanese Experiment Module (JEM) at rack location JPM1F1. For the duration of the MAMS shutdown and power-off sequence on this day, we also had a Space Acceleration Measurement System (SAMS) triaxial sensor head *in the same rack* and active while the MAMS was being deactivated and while it later was being activated. SAMS was able to capture some interesting acceleration signal features for these events, as we will show.

2. QUALIFY

In this document, we will discuss features associated with both the deactivation and the activation of MAMS. Our insight comes from measurements by a SAMS triaxial sensor head mounted in the same rack as MAMS in the JEM. We note that the SAMS sensor head was also powered off at some point along the timeline, but only *after* MAMS was powered off on GMT 2025-01-27. Further along, the SAMS sensor head was powered back on *before* MAMS was activated on GMT 2025-01-28. This timeline enabled us to characterize vibrations associated with MAMS deactivation, and then subsequently its activation.

MAMS Deactivation

Figure 2 on page 4 presents a color spectrogram computed from SAMS sensor head data (S/N 121F05, also known as SE-F05) recorded in ER5, located at rack position JPM1F1 within the Japanese Experiment Module (JEM). The acceleration data were measured within that rack's Drawer 2 location, while MAMS was situated within the same rack, in Locker 5. The spectrogram was captured in near real-time at the NASA Glenn Research Center (GRC) and is intended to show at a high-level some annotated time and frequency features of the vibratory measurements from the perspective of NASA GRC's near real-time, web-based plot routines. Key features include narrow, vertical yellow-red streaks, indicative of what we will call *gimbal bangs*, occurring between approximately 11:57 and 11:58. The term *gimbal bang* refers to the sudden stoppage of rotating fixtures within MAMS, which are mounted on a two-gimbal (nested) table assembly known as the Bias Capture Table Assembly (BCTA). See Figure 1.

Internal Bias Capture Table Assembly (BCTA)

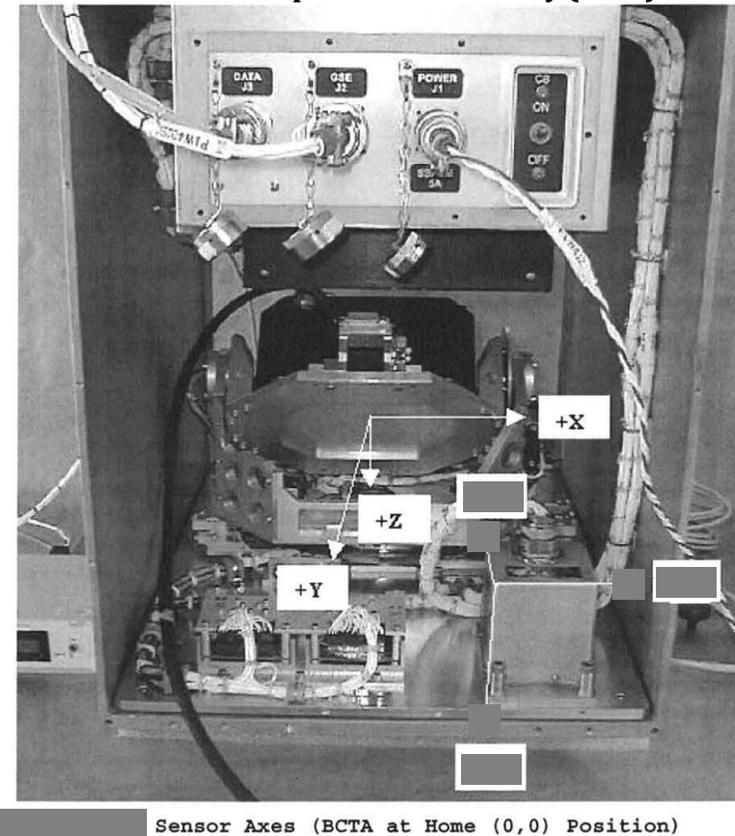


Fig. 1: Bias Capture Table Assembly (BCTA) used in MAMS.

In addition, on the near real-time spectrogram, a narrow horizontal red streak near 68 Hz marks the frequency (spin rate) for one of the two MAMS electronics cooling fans.

On GMT 2025-01-27, the MAMS shutdown and power-off came around the time of other impulsive vibratory events occurring near the SAMS sensor head, making it perhaps less distinctive among the other orange-red vertical streaks. However,

as observed, the MAMS *gimbal bangs* extend to higher frequencies, thereby distinguishing themselves as more impulsive bangs. In general, when the MAMS Ubuntu Linux operating system (OS) is shut down, the motors used to control its two gimbals remain powered but without active control. This results in the rotating fixtures randomly contacting mechanical stops, producing *gimbal banging* events. The operations team seeks to coordinate the two shutdown commands such that the MAMS OS has sufficient time for a graceful shutdown before power is removed. However, this process can still lead to a brief period of susceptibility to *gimbal banging* as illustrated in Figure 3 on page 5. In this figure, we also observe the cessation of the narrowband red spectral peak near 68 Hz for MAMS Fan 1 and similarly near 216 Hz for Fan 2.

MAMS Activation

Figure 4 on page 6 presents a color spectrogram, again computed from SAMS sensor (121f05) measurement data in the same rack as MAMS, but now during an activation sequence. Captured in near real-time at NASA GRC, this plot highlights annotated time and frequency features in the SAMS acceleration spectra versus time. Figure 4 on page 6 better depicts the patterns, structure, and boundaries in both time and frequency around the MAMS activation sequence, including going slightly above the SAMS sensor's cutoff frequency, which is 200 Hz, to reveal start of the MAMS Fan 2 spectral peak around 216 Hz.

Furthermore, just after power-on, the MAMS Fan 1 signature appears as a narrow red horizontal streak near 68 Hz. Additionally, narrow vertical yellow-red streaks indicate gimbals forcibly contacting mechanical stops, corresponding to the post-power-on, home-finding sequence of two internal rotating fixtures used for sensor bias captures. The sequence is depicted in Figure 4 on page 6 with small, upward-pointing arrows. These are repeated as larger arrows to clarify the sequence in legend/worded fashion. That is, a sequence that exercises each of 2 gimbals (an inner and an outer gimbal) by first moving it to an away position before returning it to its home position. The 2 gimbals are part of the MAMS Bias Capture Table Assembly (BCTA) depicted on page 1. Upon full MAMS OS boot-up, characteristic *gimbal bangs* emerge, but not from uncontrolled motors seen during deactivation. Instead, they come from the away-home positioning sequence for each of the inner, then outer gimbal mechanisms. See Figure 4 on page 6 and Figure 5 on page 7 for details.

3. QUANTIFY

In this section, we aim to quantify both the impact of the MAMS Fan 1 at 68 Hz and the so-called *gimbal bangs* around the time of deactivation. We cannot give true quantification of MAMS Fan 2 near 216 Hz since it spins at a rate above the SAMS sensor's cutoff frequency (200 Hz). We are only aware of its signature in the SAMS data because it falls below the Nyquist frequency of 250 Hz. We can estimate a lower bound on its RMS value, so if you are interested, then request so by contacting the SAMS team at pimsops@lists.nasa.gov.

MAMS Fan Vibrations Near 68 Hz

The left-side panel of Figure 6 (page 8) illustrates the impact of the MAMS fan within a narrow frequency band centered on ~68 Hz, specifically in the range $67.8 \text{ Hz} < f < 68.3 \text{ Hz}$. This figure comprises four subplots displaying root-mean-square (RMS) acceleration values in units of milli-g, arranged from top to bottom as follows: (1) Total RMS, (2) X-axis component, (3) Y-axis component, and (4) Z-axis component. The Total RMS is computed using the root-sum-of-squares (RSS) method, like so:

$$\text{RSS}(X, Y, Z) = \sqrt{X^2 + Y^2 + Z^2}.$$

Notably, vibrations from this MAMS fan predominantly affect the SAMS Z-axis accelerometer. Since acceleration is a vector quantity—*characterized by both magnitude and direction*—the proper method for obtaining a total acceleration in this context, across three independent axes, is the RSS. A simple arithmetic sum would be inappropriate, as it applies only to scalar quantities, which possess a magnitude but lack a directional component.

Vibratory Impact of MAMS Gimbals Without Motor Control During Deactivation

The right-side panel of Figure 6 (page 8) presents the per-axis acceleration as a function of time for a short span surrounding the largest recorded *gimbal bang* during deactivation. Notably, the Z-axis exhibits a sharp, impulsive peak, reaching just below +20 mg. The bang registers to a lesser extent on the other 2 axes. Figure 7 on page 9 also shows that largest bang, but in a longer time interval and during a span when there was notable other banging near this rack in the JEM.

Vibratory Impact of MAMS Gimbals With Motor Control During Activation

Using the legend in the spectrogram of Figure 5 (page 7) along with the acceleration vector magnitude versus time plot in Figure 8 on page 10, we note that the largest impact during activation came from driving the inner gimbal fixture to its home position as part of the initialization sequence just after power-on of MAMS. Figure 9 on page 11 gives us a bit more information as it reveals that the largest *gimbal bang* during activation aligned primarily with the Z-axis.

4. CONCLUSION

This document provides results from the analysis of SAMS measurements during the MAMS deactivation on January 27, 2025 and its subsequent activation early the next day. The results herein provide valuable insight for characterizing the microgravity environment related to MAMS system behavior and gimbal-induced, impulsive vibrations. The SAMS data reinforce expectations regarding the presence of distinct deactivation/activation signatures from MAMS, including transient gimbal impact events along with narrowband *gimbaling* and fan frequencies. These findings contribute to a good understanding of mechanical responses within the JEM rack environment when MAMS is deactivated or activated. Both of these events are expected to be rare as MAMS is intended to monitor the space station's quasi-steady environment continuously, 24x7.

Future work should be mindful of these characteristics and impacts, particularly those in or near ER5 in the JEM. This knowledge could help plan-around or otherwise mitigate potential disturbances for sensitive microgravity experiments.

MAMS Deactivation ~ GMT 2025-01-27/11:57

Annotated acceleration data features that occur between MAMS command to gracefully shutdown the operating system (OS) and a subsequent command to remove power from its rack location.

#	Comment
01	"Gimbal bang" broadband excitation from ~90 to 115 Hz
02	Narrowband (fan) stops at ~68 Hz
03	"Gimbal bang" broadband excitation from ~20 to 55 Hz
04	GMT span for features of MAMS OS shutdown & poweroff

When the MAMS operating system is shutdown, the motors controlling its 2 gimbals remain "powered without the smarts". This can result in turn mechanisms bumping into mechanical stops and thereby "gimbal banging" results. We seek to orchestrate the 2 commands such that the system has time to do graceful shutdown of the OS before power is removed. This can result in a brief period susceptible to "gimbal banging" as depicted here.

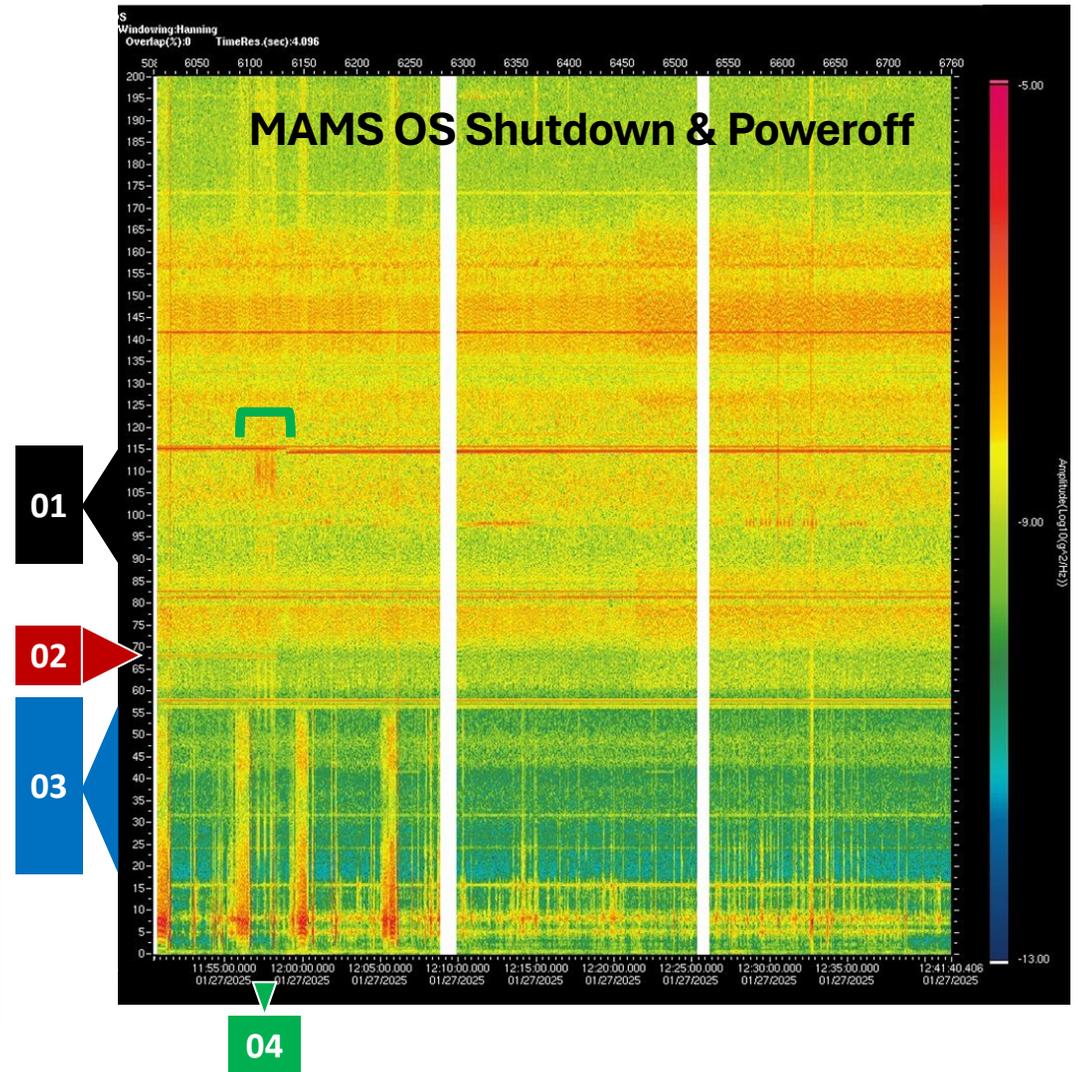


Fig. 2: Annotated Near Real-Time Spectrogram Showing MAMS Deactivation on GMT 2025-01-27.

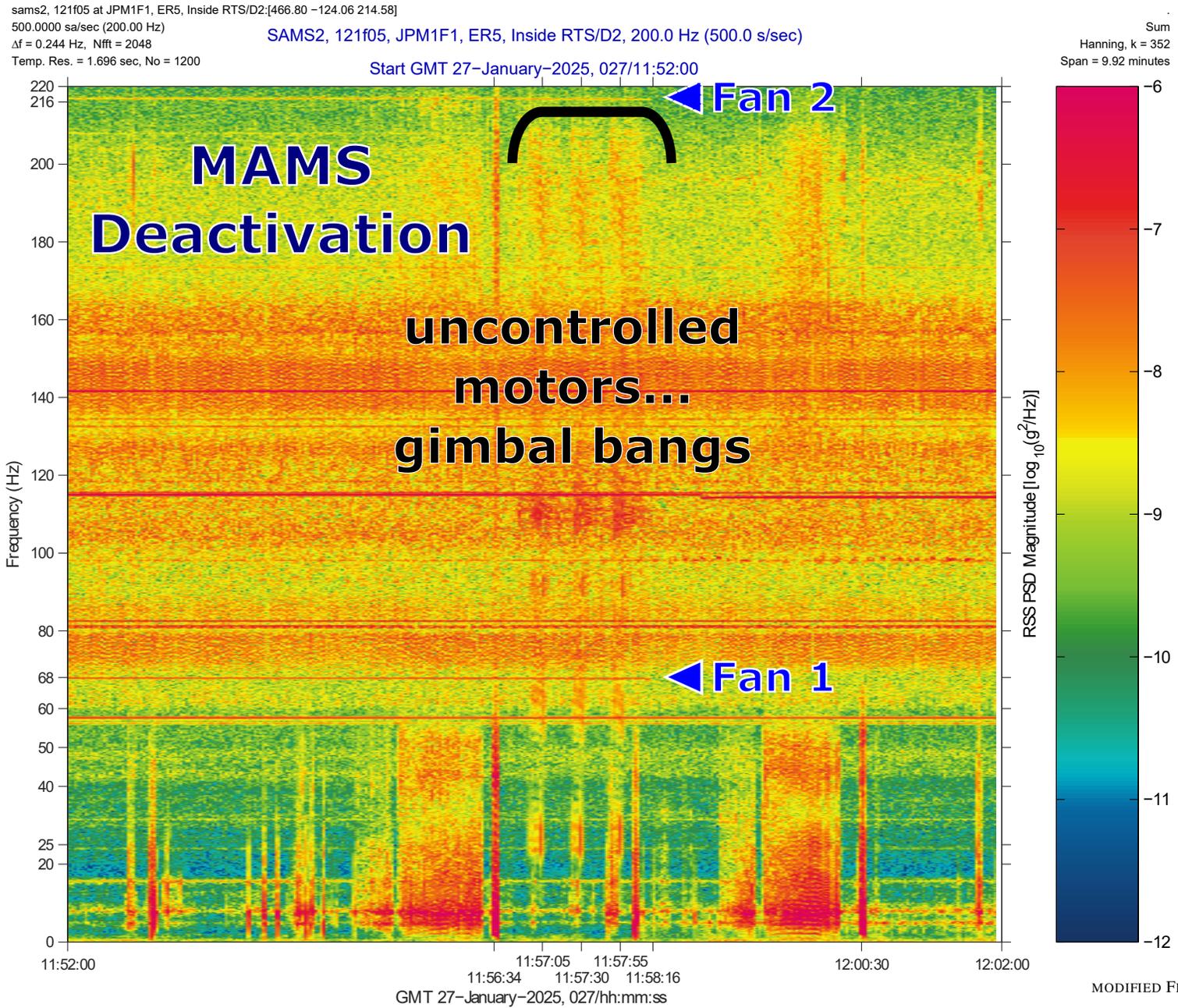


Fig. 3: SAMS Sensor 121f05 Spectrogram Showing MAMS Deactivation on GMT 2025-01-27.

MAMS Activation ~ GMT 2025-01-28/02:00

Annotated acceleration data features that occur between MAMS power-on, operating system (OS) boot-up and first bias capture period.

#	Comment
05	Narrowband (fan) starts at ~68 Hz
06	GMT span for features of MAMS power-on and boot-up
07	“Gimbal bang” broadband excitation from ~20 to 200 Hz

When the MAMS is powered-on, we almost instantly see the narrowband fan signature start near 68 Hz. Next, the OS boots-up, which leaves tell-tale vibratory signs as its start-up sequence exercises each of 2 gimbals to go to its away position, then to its home position. Each traversal comes with a “gimbal bang”, but this is not from uncontrolled motors. Instead, the bangs come ultimately from driving into mechanical stops, i.e. finding each home position for each of 2 rotating fixtures.

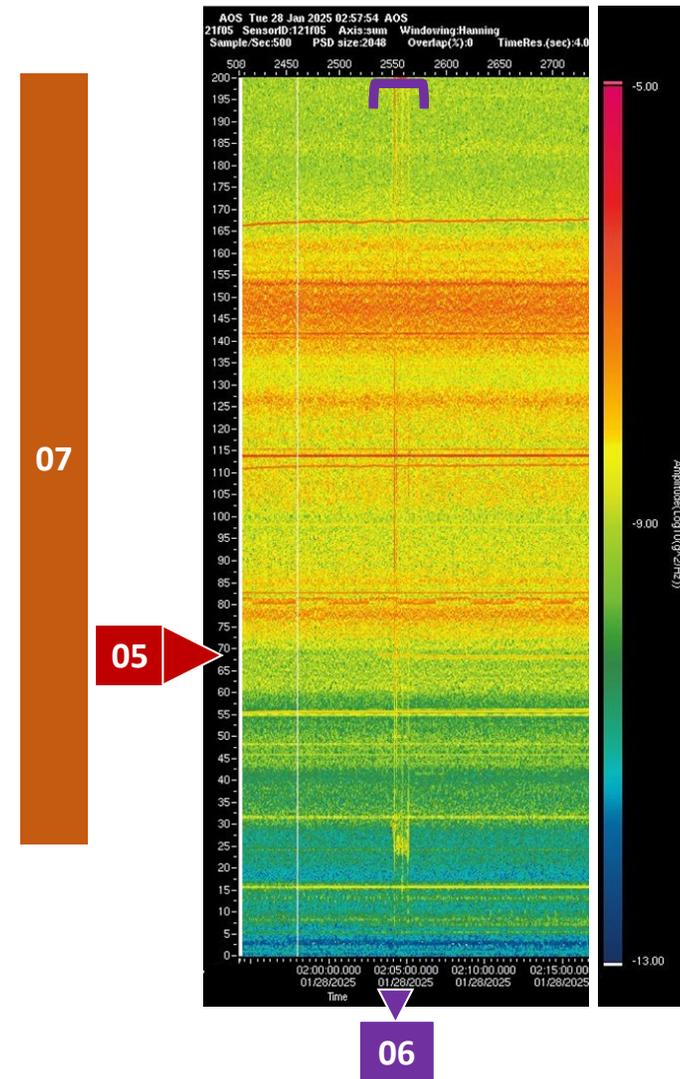
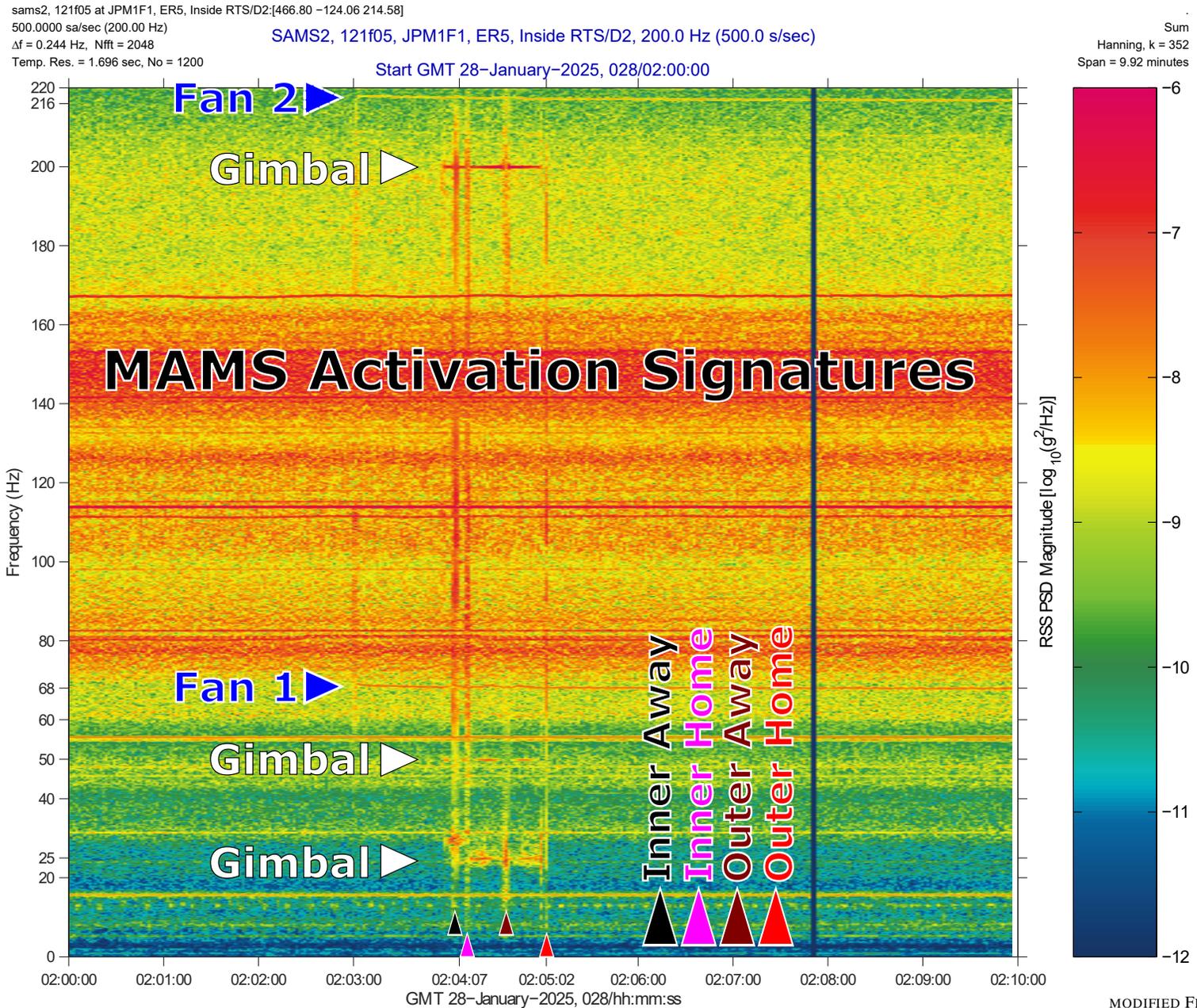


Fig. 4: Annotated Near Real-Time Spectrogram Showing MAMS Activation on GMT 2025-01-28.



VIBRATORY

MODIFIED FEBRUARY 6, 2025

Fig. 5: SAMS Sensor 121f05 Spectrogram Showing MAMS Activation Signatures Early on GMT 2025-01-28.

121f05 Narrow Band RMS Accel. vs Time
 Interval: Size = 16.38, Step = 8.19 sec.
 Frequency Band: 67.8 <= f < 68.3 Hz
 Start GMT 2025-01-27, 027/10:00:00.000 (span = 00:18:00:00)

inverted-sams2, 121f05 at JPM1F1, ER5, Inside RTS/D2,[466.80 -124.06 214.58]
 500.0000 sa/sec (200.00 Hz) SAMS2, 121f05, JPM1F1, ER5, Inside RTS/D2, 200.0 Hz (500.0 s/sec) SSAnalysis[0.0 0.0 0.0]

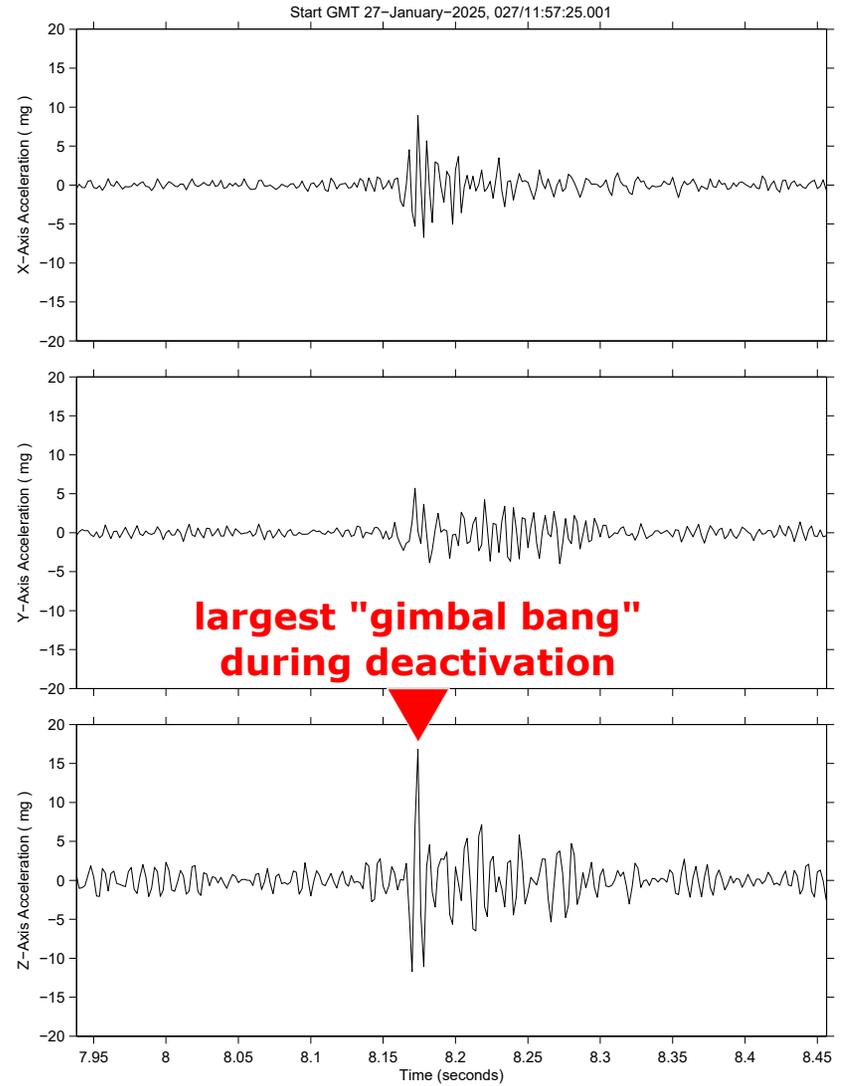
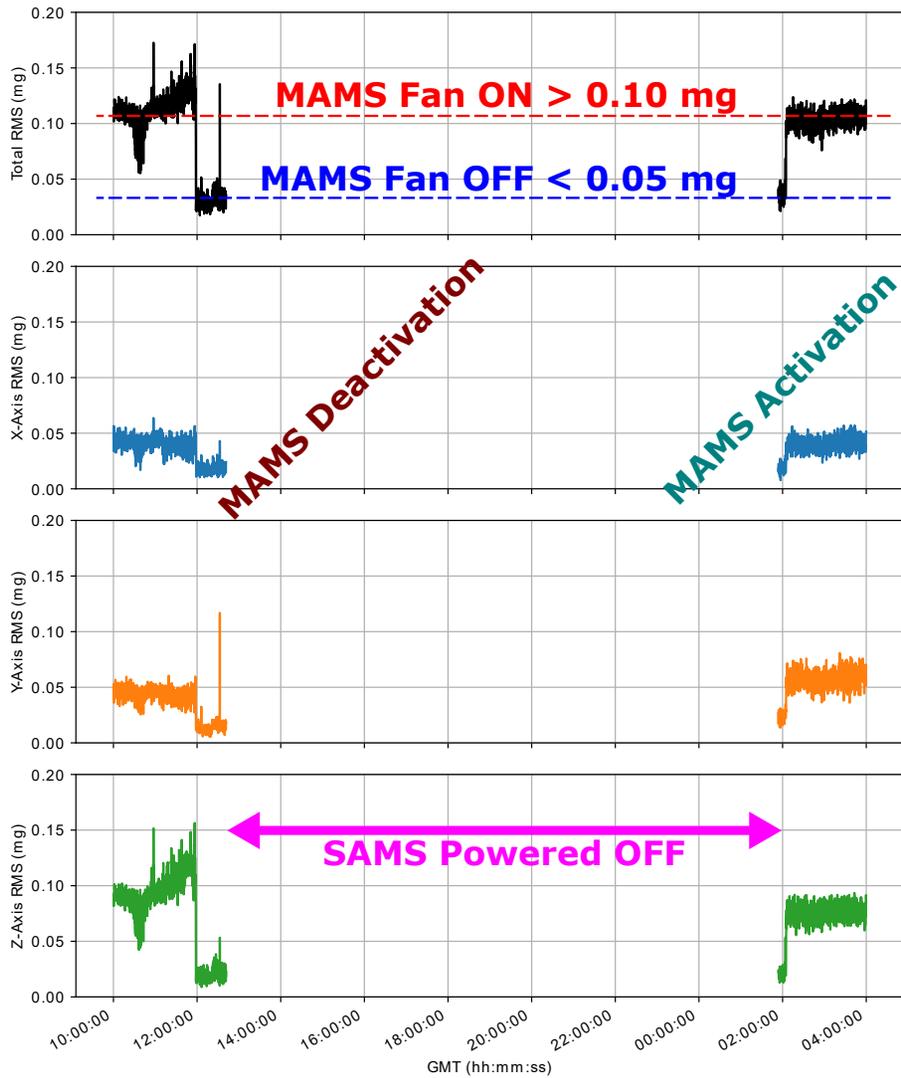


Fig. 6: SAMS Showing Deactivation of MAMS in JEM on GMT 2025-01-27: (Left) Narrowband Interval RMS Acceleration, (Right) Acceleration vs. Time.

sams2, 121f05 at JPM1F1, ER5, Inside RTS/D2:[466.80 -124.06 214.58]
500.0000 sa/sec (200.00 Hz)

SAMS2, 121f05, JPM1F1, ER5, Inside RTS/D2, 200.0 Hz (500.0 s/sec)

Vector Magnitude

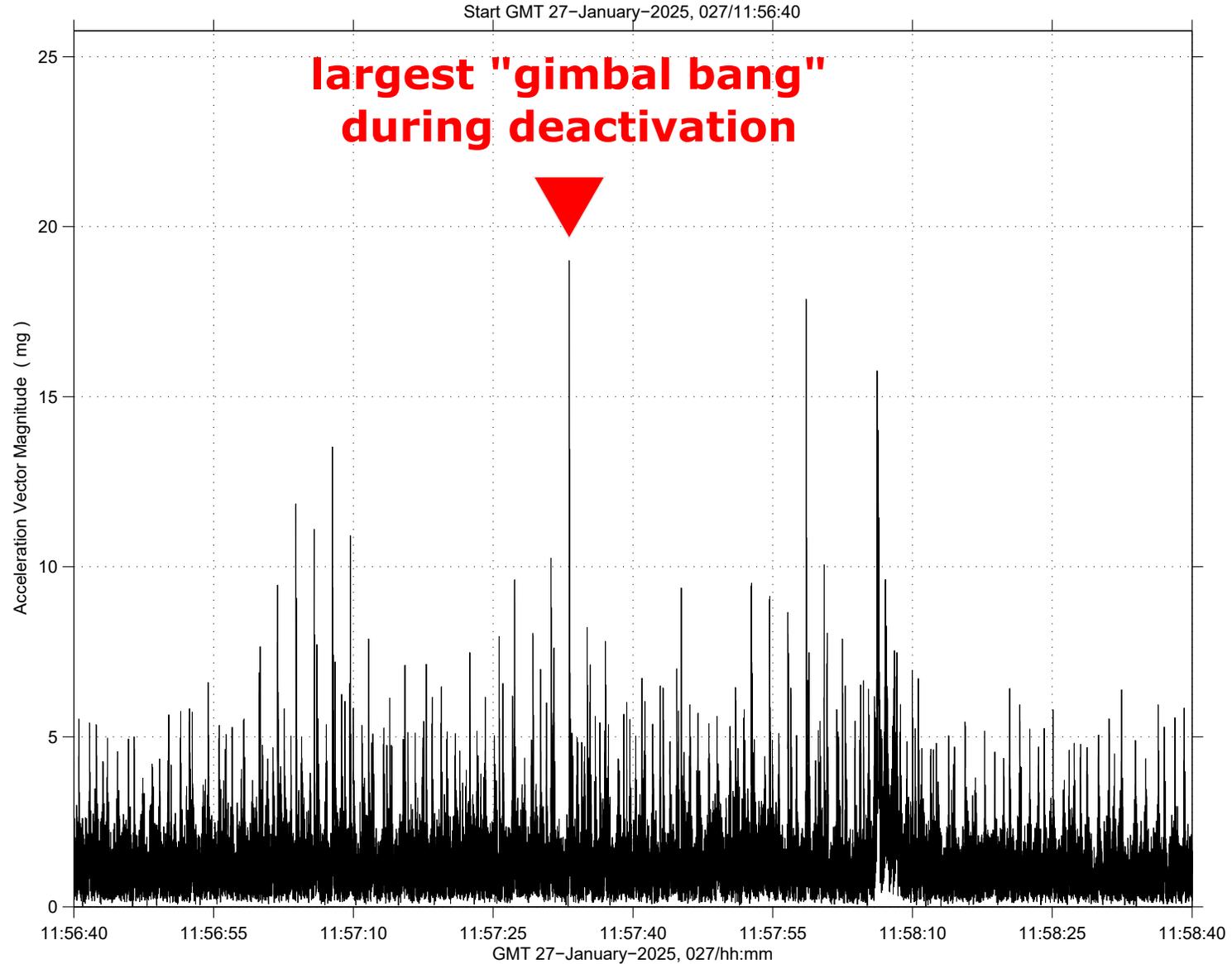
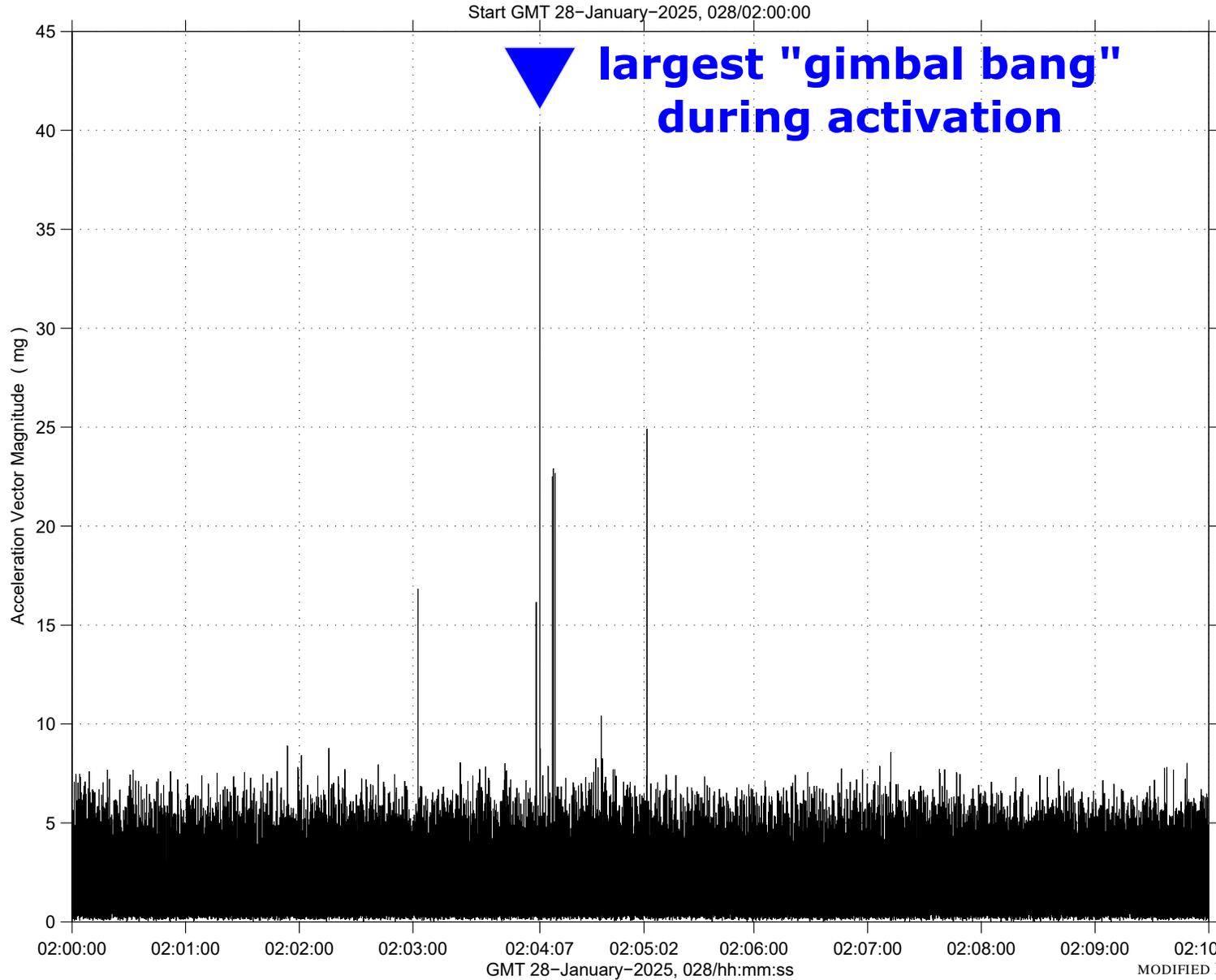


Fig. 7: Acceleration Vector Magnitude vs. Time During Deactivation on GMT 2025-01-27.

sams2, 121f05 at JPM1F1, ER5, Inside RTS/D2:[466.80 -124.06 214.58]
500.0000 sa/sec (200.00 Hz)

SAMS2, 121f05, JPM1F1, ER5, Inside RTS/D2, 200.0 Hz (500.0 s/sec)

Vector Magnitude



VIBRATORY

Fig. 8: SAMS Sensor 121f05 Acceleration Vector Magnitude for Same Span as Figure 5 During MAMS Activation.

inverted=sams2, 121f05 at JPM1F1, ER5, Inside RTS/D2[466.80 -124.06 214.58]
500.0000 sa/sec (200.00 Hz) SAMS2, 121f05, JPM1F1, ER5, Inside RTS/D2, 200.0 Hz (500.0 s/sec) SSAnalysis[0.0 0.0 0.0]

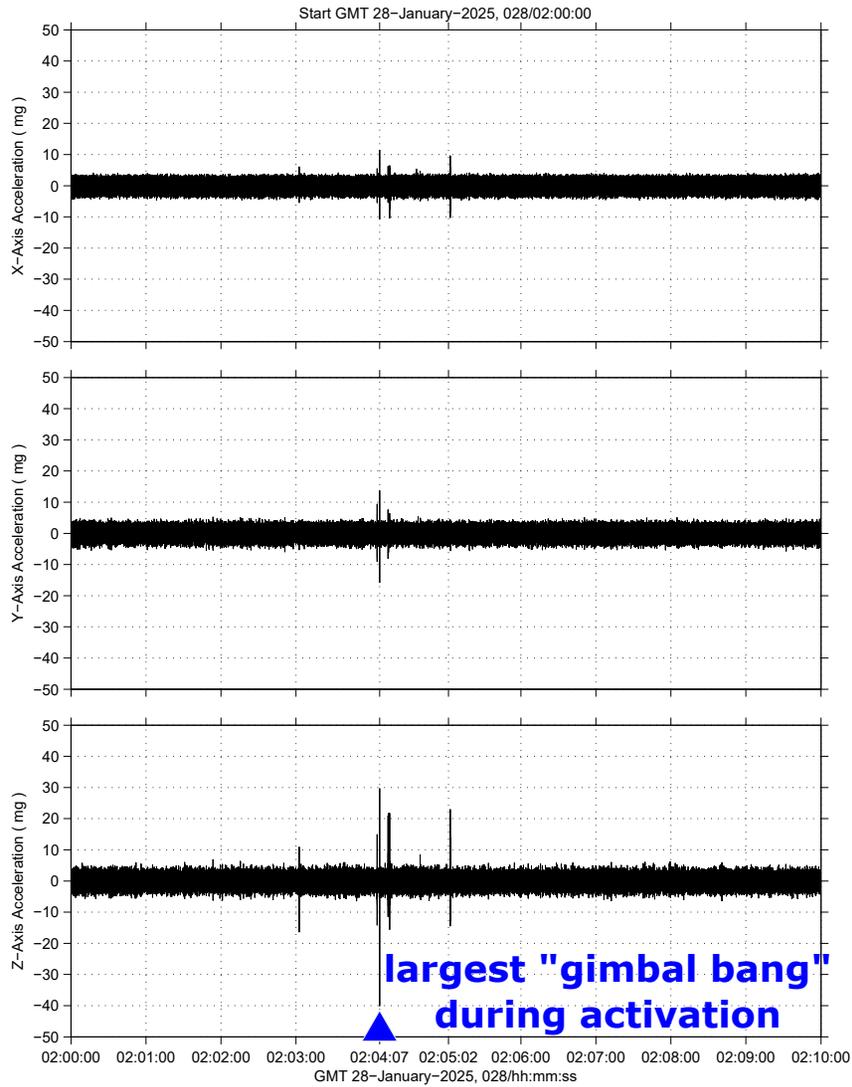


Fig. 9: SAMS 121f05 Per-Axis Acceleration vs. Time Showing Activation of MAMS in JEM on GMT 2025-01-28.