

## 1. INTRODUCTION

At GMT 2024-05-24, 145/14:16, the International Space Station (ISS) was scheduled to begin the first of two reboosts. The first, was about a 19-minute reboost using the Cygnus NG-20 thrusters. The second reboost, doing likewise starting at GMT 2024-05-24, 145/23:03 with a burn duration of just about 19 minutes as well. Figure 1 shows the vehicle layout as of 2024-05-24, with the Cygnus vehicle docked and its thrusters toward the nadir direction, that is, down toward the Earth during a nominal attitude. With this arrangement, in order for a reboost to increase the ISS's velocity in its direction of flight, the station first needed to be reoriented with a maneuver to change its attitude as shown by the cyan-colored annotations. Upon completion, this maneuver aligned the Cygnus thrust direction in opposition to the direction of flight (opposing the velocity vector, opposing the direction of free-fall), just as Sir Isaac would have called for. The resulting speedup in this new flight direction thereby boosted the altitude of the space station. An intended  $\Delta V$  metric of 1.13 m/s for the massive space station was predicted for each of the two reboosts.

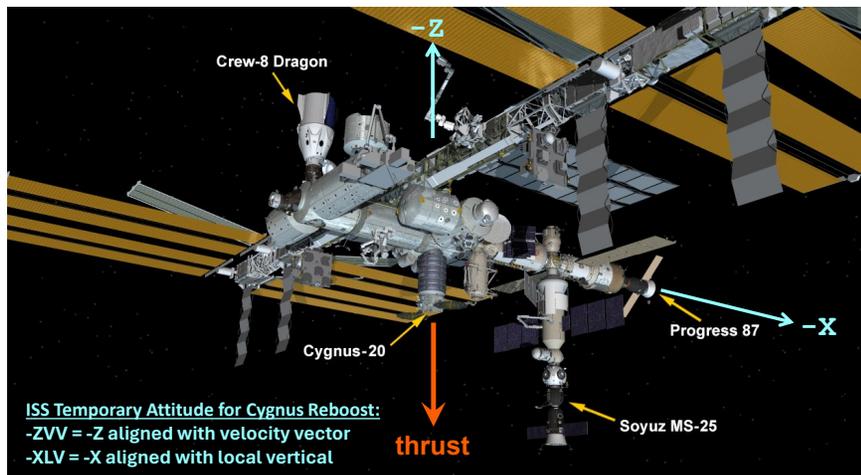


Fig. 1: Cygnus NG-20's Location and Alignment during Reboost.

## 2. QUALIFY

The information shown in Figure 2 on page 3 was calculated from the Space Acceleration Measurement System (SAMS) sensor 121f05 measurements made in the Japanese Experiment Module. This sensor was mounted in the JPM1F1 rack. This color spectrogram plot shows 4 events of interest from a microgravity acceleration environment viewpoint: (1) maneuver of the space station to the reboost attitude, (2) Russian Segment (RS) attitude control, (3) the reboost, and (4) maneuver back to a torque equilibrium attitude (TEA). We attribute much of the structural vibration increase to Russian Segment (RS) attitude control as marked with white annotations. 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 about 19 minutes as evidenced by the zoom-in seen in Figure 5 on page 5. In the time domain, the reboost event (for this Cygnus configuration) is characterized by a step in the negative Z-axis direction for the duration of the Cygnus thruster-firing event before returning to baseline. The maneuvers before and after the reboost event also excite vehicle structural modes, mainly below about 2 Hz, as evidenced by the neat, horizontal red streaks during those maneuvers.

The second of two reboosts followed the same pattern as described above and as shown in Figure 3 on page 4.

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 and (for Cygnus reboosts) during maneuvers to or from the required reboost attitude. The difference being that during the reboost itself, the dominant factor would be the highly-directional step in the negative Z-axis acceleration, while in the other cases, the dominant feature 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 two reboost events across three SAMS sensor heads, one in each of the 3 main laboratories of the ISS. Figure 4 on page 5 through Figure 11 on page 8 show interval average acceleration results computed from SAMS measurements. Note for each reboost event and for each SAMS sensor, the tell-tale negative Z-axis step starts at time-of-ignition (TIG) and lasts for a duration of ~19 minutes. Information from flight controllers indicated that each reboost event would provide a space station rigid body  $\Delta V$  of 1.13 meters/second, while SAMS crude analysis indicated a value closer to about 1.14 m/s for each event.

Note that the interval average processing used to quantify in this section effectively low-pass filtered the SAMS data so as to help emphasize the acceleration step that occurs on the Z-axis during the reboost events. 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.

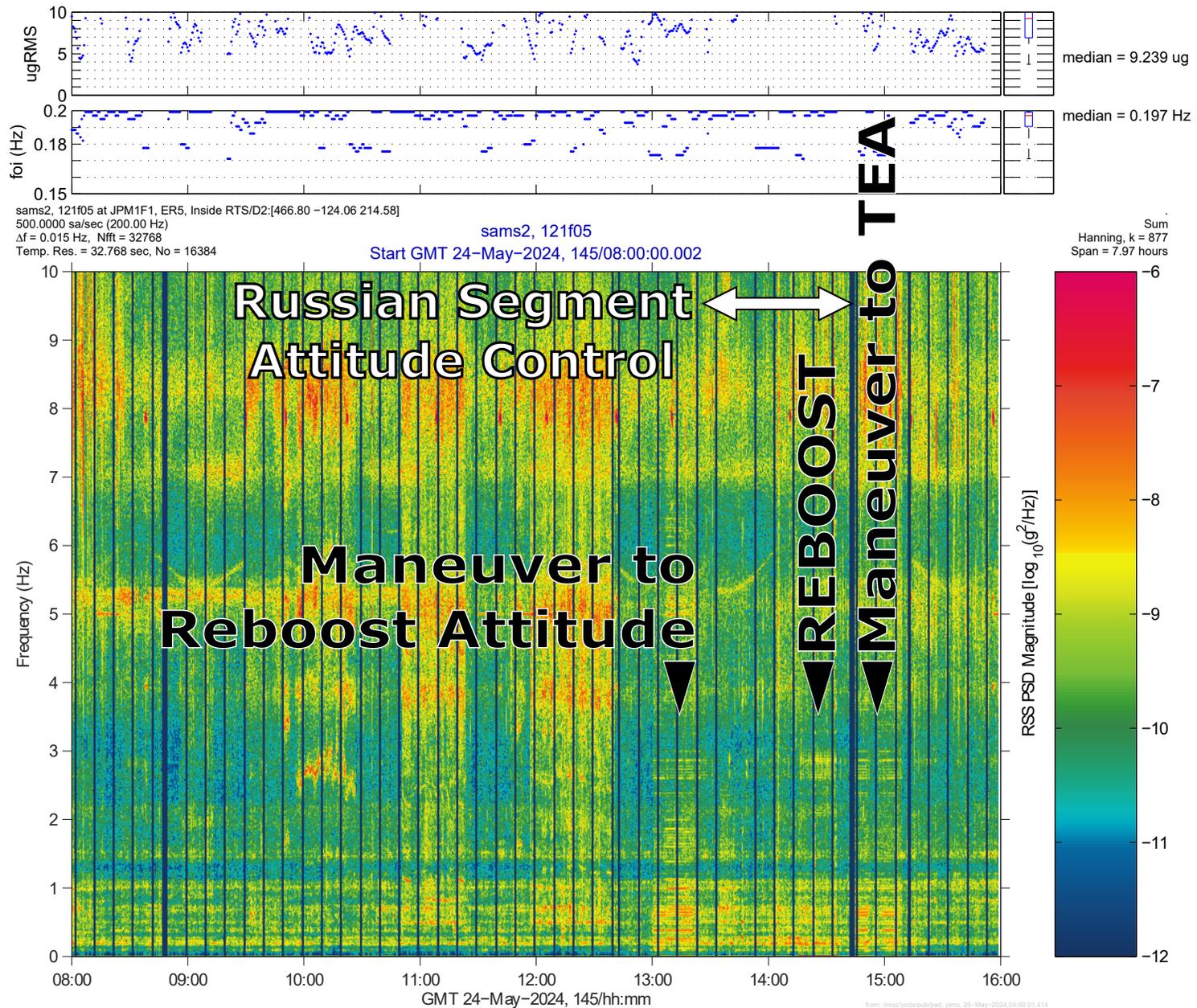
A somewhat crude quantification of the reboost as measured by three distributed SAMS sensors is given in Table 1. As expected, we saw consistent impact measured by SAMS throughout the space station for just about 19 minutes or so for each of the two reboosts via (effectively) the low-pass filtered results.

Table 1. **Z-axis** steps (mg) during reboost event for 3 SAMS sensors.

Sensor	Z-Axis	Location
121f04	-0.100	LAB1P2 (ER-7)
121f05	-0.100	JPM1F1 (ER-5)
121f08	-0.100	COL1A3 (EPM)

### 4. CONCLUSION

The SAMS measurements for 3 sensor heads, one in each of all 3 main labs of the ISS was analyzed and showed a **negative Z-axis step during the Cygnus NG-20 reboost events of just about 0.1 mg for each reboost event**. Furthermore, calculations based on SAMS sensors indicate a  $\Delta V$  metric of approximately 1.14 m/s was achieved, close to what flight controllers had predicted for this metric.



VIBRATORY

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Fig. 2: 10 Hz Spectrogram showing Cygnus **Reboost #1** on GMT 2024-05-24 from a SAMS Sensor in the Japanese Experiment Module.

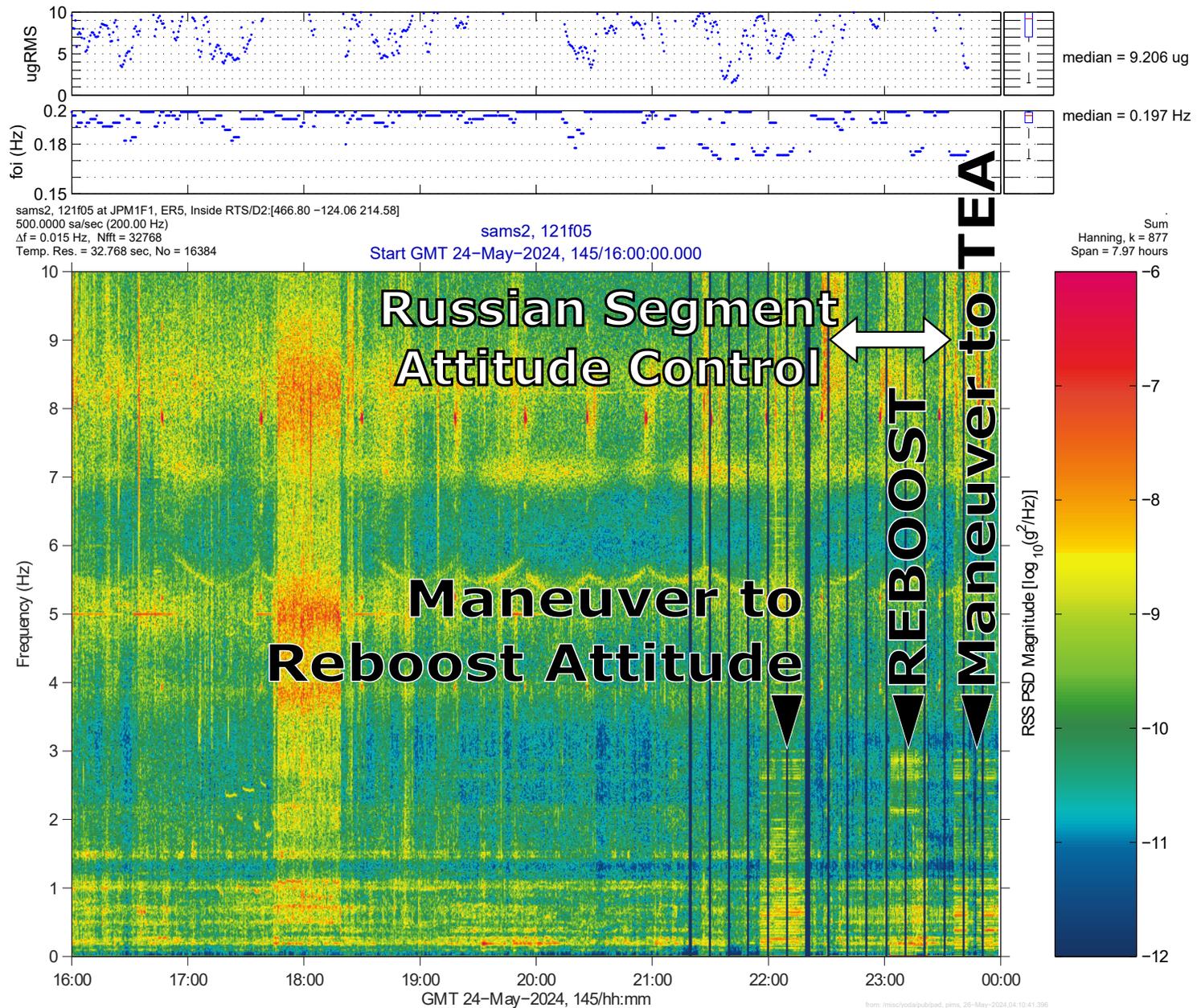


Fig. 3: 10 Hz Spectrogram showing Cygnus **Reboost #2** on GMT 2024-05-24 from a SAMS Sensor in the Japanese Experiment Module.

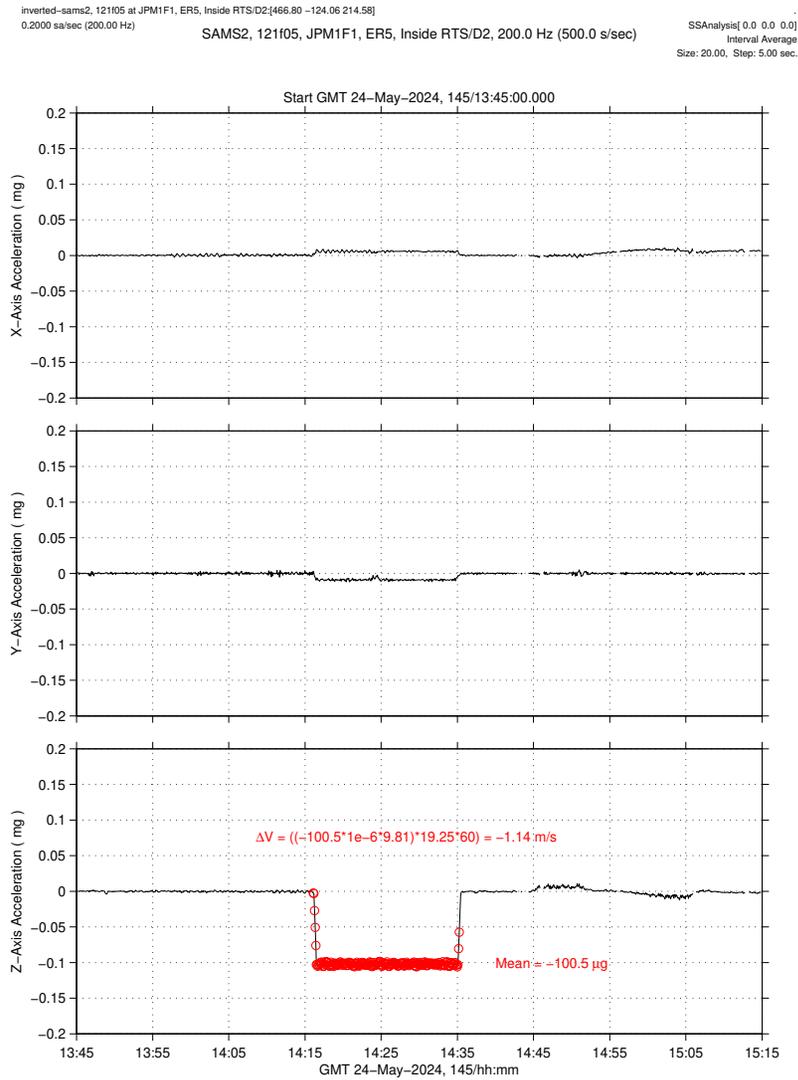


Fig. 4: 20-sec interval average for SAMS 121f05 sensor in the JEM.

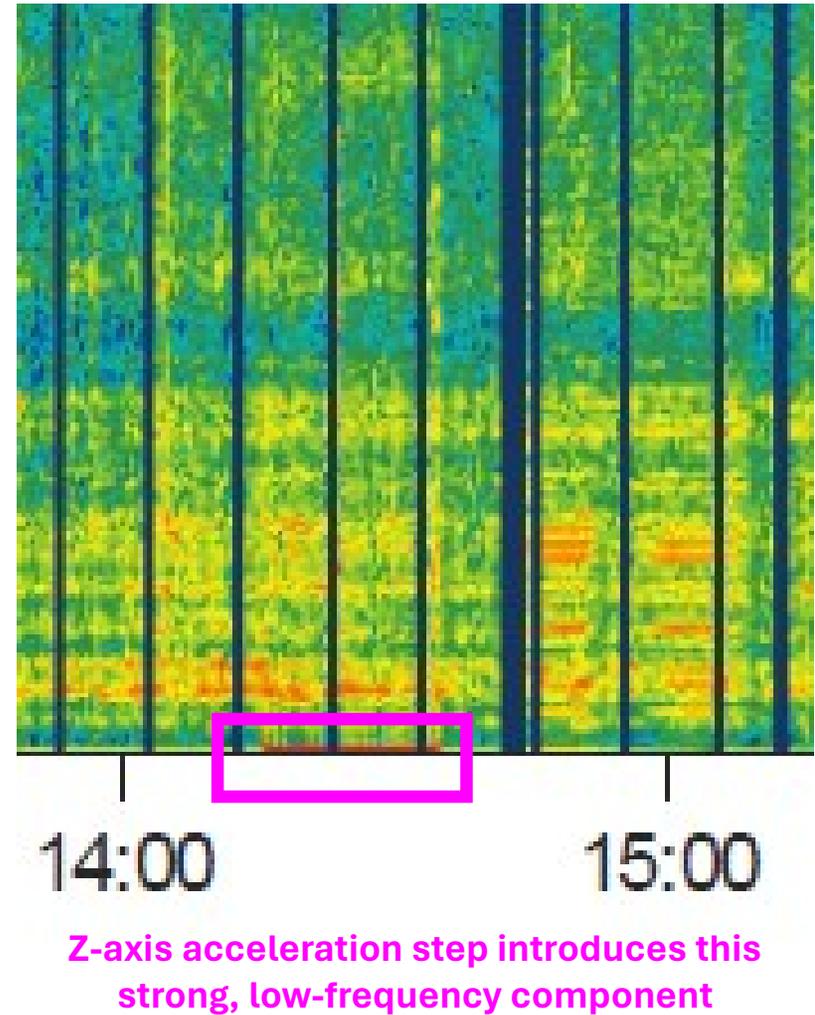


Fig. 5: Zoom-in on spectrogram of Figure 2 on page 3.

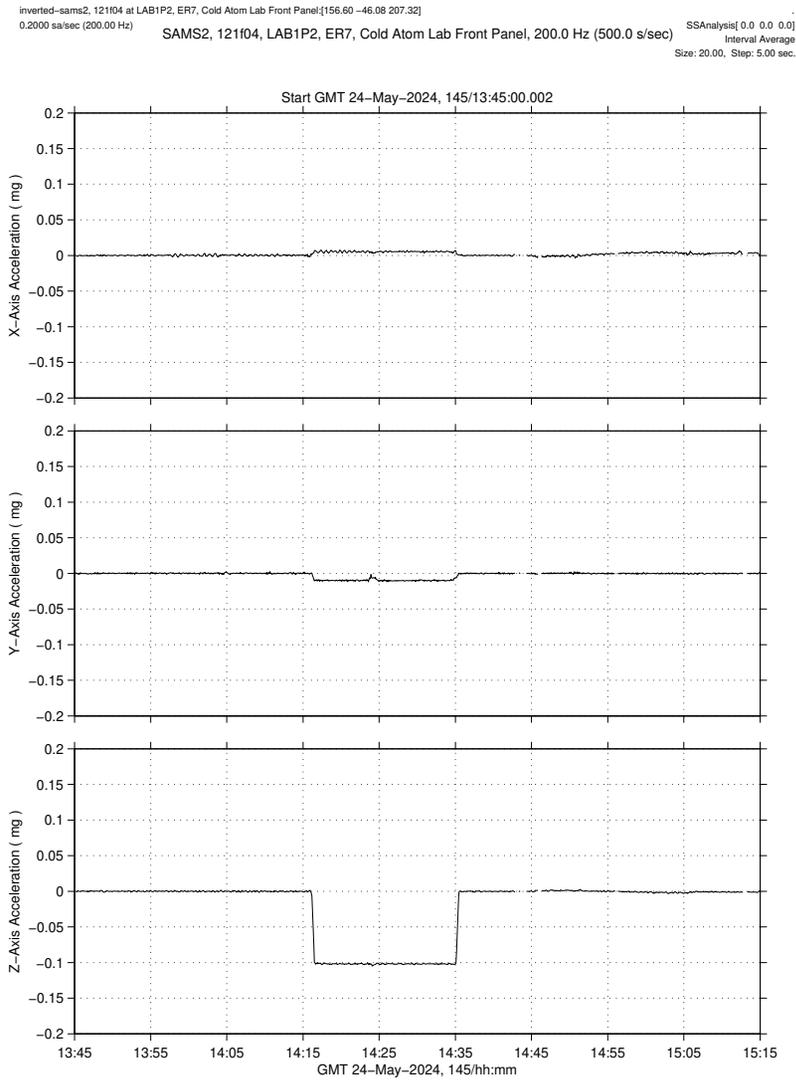


Fig. 6: 20-sec interval average for SAMS 121f04 sensor in the LAB.

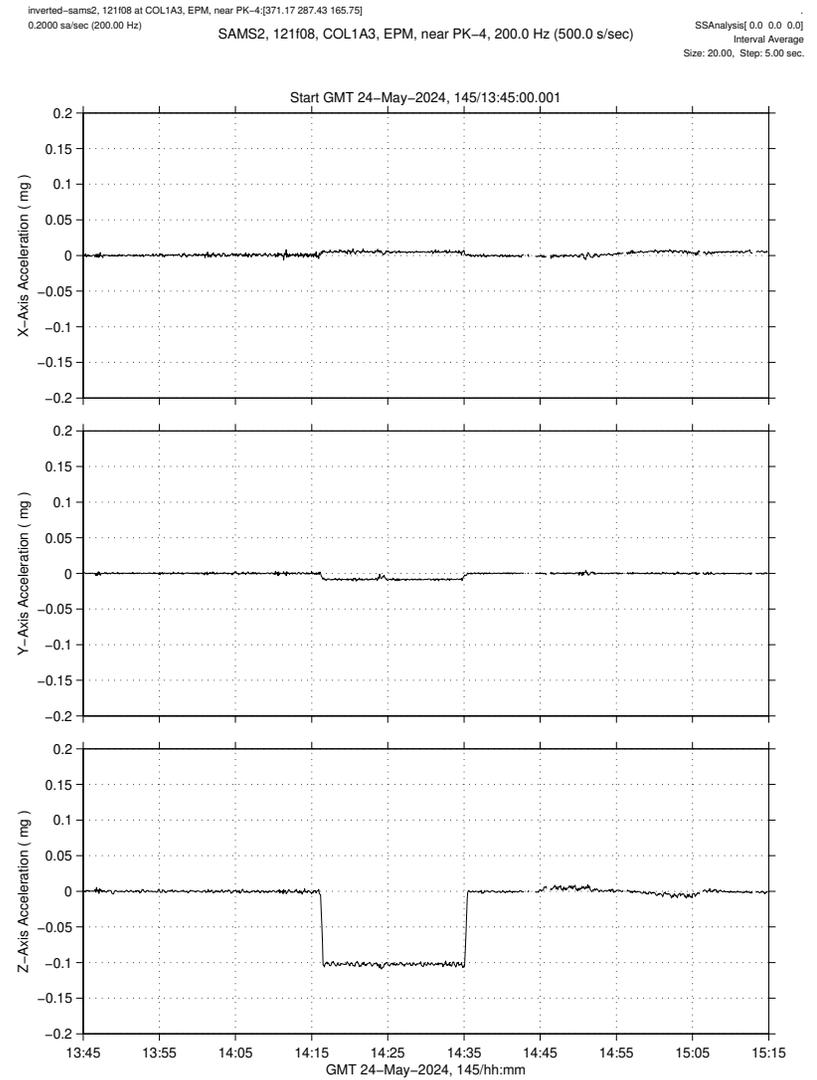


Fig. 7: 20-sec interval average for SAMS 121f08 sensor in the COL.

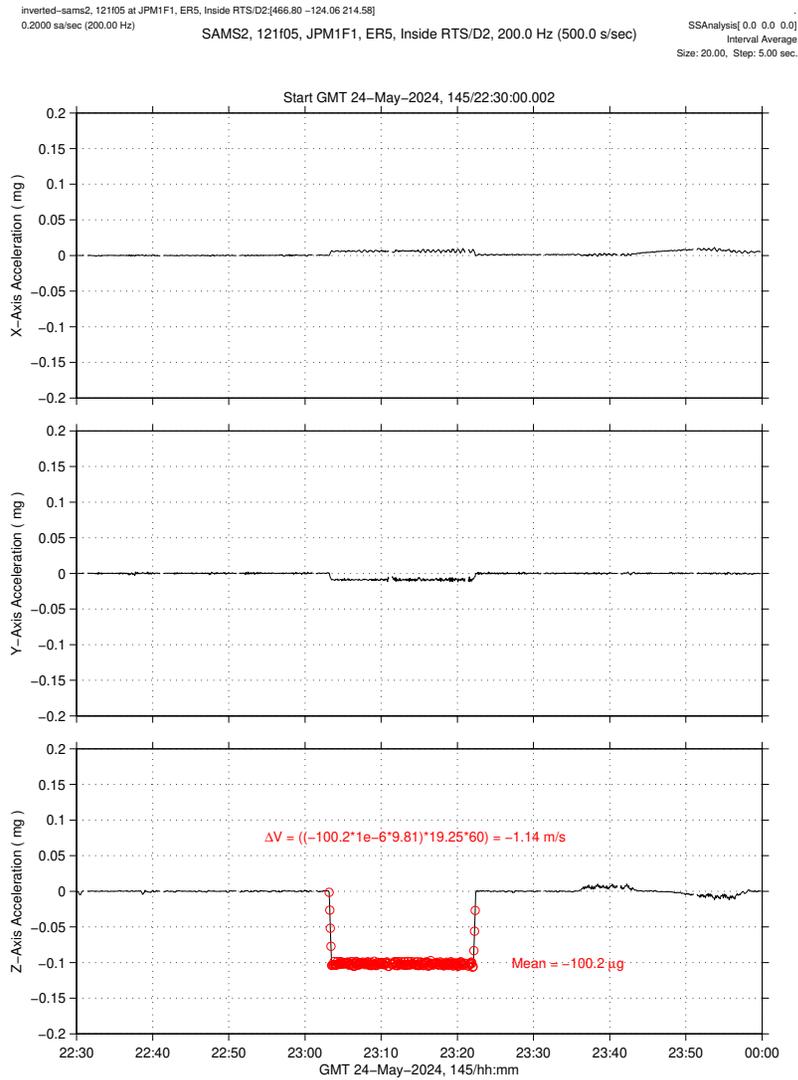


Fig. 8: 20-sec interval average for SAMS 121f05 sensor in the JEM.

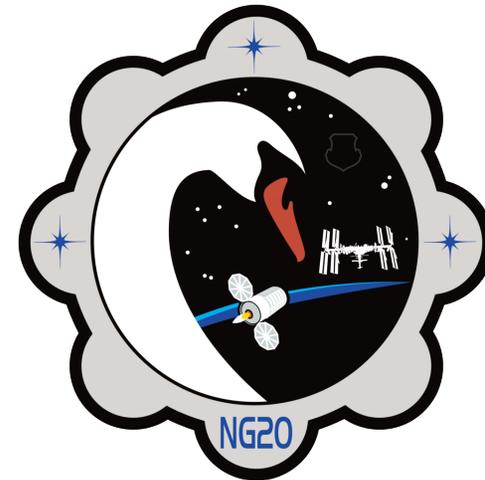


Fig. 9: The Cygnus vehicle and the NG-20 mission logo.

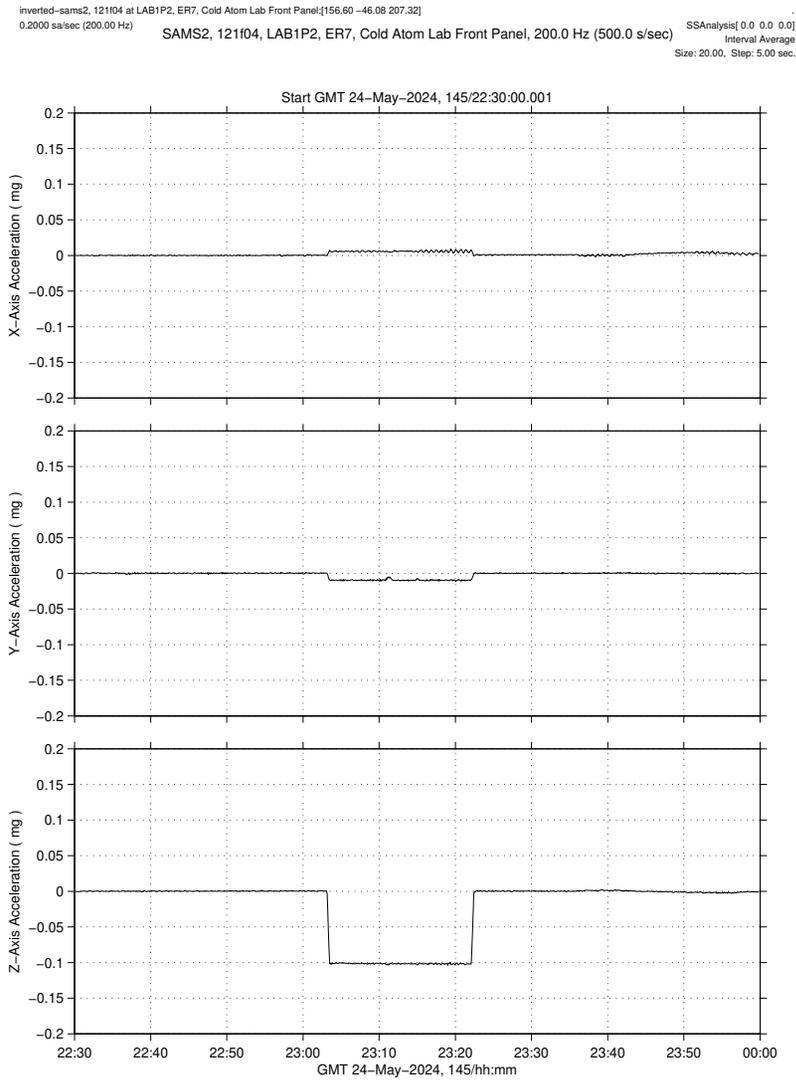


Fig. 10: 20-sec interval average for SAMS 121f04 sensor in the LAB.

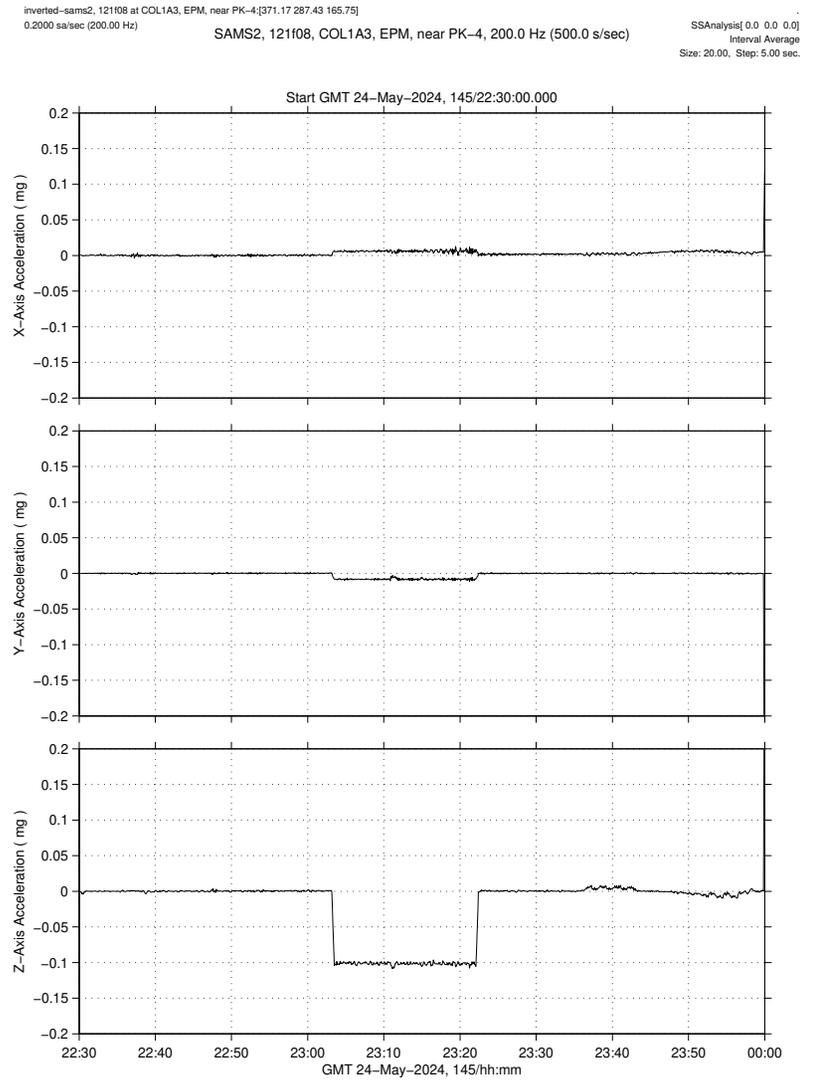


Fig. 11: 20-sec interval average for SAMS 121f08 sensor in the COL.