1. INTRODUCTION

On GMT 2024-06-08, at just about 15:52, the International Space Station (ISS) began about a 19-minute reboost using Northrop Grumman's Cygnus vehicle's (NG-20) with its Delta Velocity Engine (DVE). It elevated the station's altitude by about 1.93 km with a ΔV metric of just over 1 meters/second.

Figure 1 shows where the Cygnus vehicle was docked. This docking location and orientation required the space station to first get to the so-called "-ZVV" attitude before firing Cygnus' thrusters. This attitude pointed the Cygnus vehicle's thrust direction opposite to a vector aligned with the velocity vector (flight direction) of the space station. In this way, Newton's 3rd law of action/reaction could be brought into play for the necessary orbital mechanics to speed up the ISS in its direction of flight.

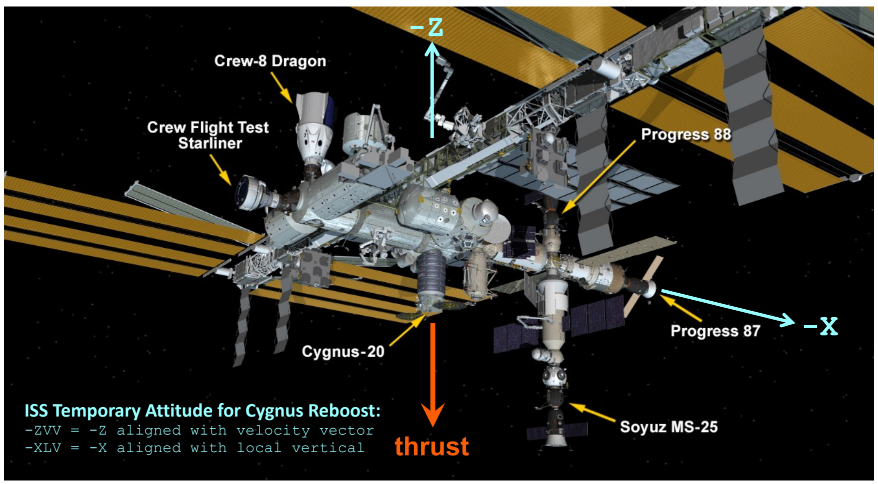

Fig. 1: Cygnus NG-20's Location and Alignment during Reboost.

2. QUALIFY

The information shown in Figure 2 was calculated from the Space Acceleration Measurement System (SAMS) sensor 121f08 measurements made in the Columbus module from a sensor mounting location on the European Physiology Module (EP-M) COL1A3 rack. This color spectrogram plot shows increased structural vibration excitation contained mostly below 2 Hz or so, and approximately a 20-minute reboost (thruster firing) event itself that started at about GMT 15:52 as indicated in blue along the horizontal axis of this plot. We attribute much of the structural vibration increase evident in the span of this spectrogram plot to maneuvers to the "-ZVV attitude" and back to the "-XVV attitude" along with during the reboost itself and the handover to Russian Segment (RS) attitude control around the time of the reboost as indicated in magenta on the horizontal axis of the plot. The increased structural vibrations are evident as more noticeable horizontal streaks (structural/spectral peaks) that change to more energetic (orange/red) sporadically throughout these events. 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 in reaction to impulsive thruster forces. 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 just during the actual reboost event itself, but also during maneuvers and RS attitude control before and after the event. The difference being that during the reboost itself, the dominant factor is a highly-directional step on an axis aligned with the velocity vector of the space station, while in the much longer case of attitude control or changes, the dominant impact was mostly the excitation of lower-frequency vibrational modes of large space station structures. We see from the as-flown timeline and in the SAMS spectrogram of Figure 2 that there was a maneuver to get to reboost attitude compatible with Cygnus' docking location, the "-ZVV" attitude, from GMT 14:40 to 15:00 and another maneuver back to "-XVV attitude" from GMT 16:24 to 16:42, after the reboost ended. These maneuvers show in the SAMS spectrogram as a regular train of red/yellow, horizontal streaks below 3 Hz for both maneuvers.

3. QUANTIFY

The as-flown timeline for this event indicated the reboost started at GMT 15:52. Analysis of Space Acceleration Measurement System (SAMS) data recordings in the US LAB, the Japanese Experiment Module (JEM), and the Columbus Module – see Figure 3, Figure 4, and Figure **??** starting on page 4 – shows the tell-tale Z-axis step (*in the negative direction*) that started at that time, with a step duration of just over 19 minutes or so. The data in this plot are 30-second interval average of the SAMS data (with polarity inverted due to intrinsic polarity flip in SAMS transducers). Interval average processing was used to glean the "reboost step" signal feature from otherwise noisy measurements, and this processing effectively low-pass filtered the data so as to help emphasize the acceleration step that occurred on the Z-axis during the reboost event. In addition, we see the impact of the pre- and post-reboost attitude maneuvers on the low-frequency environment in those modules, ostensibly due to relative distances from from the eigen axis of rotation of those maneuvers.

Information from flight controllers indicated that this reboost event provided a rigid body ΔV of just under 1.1 meters/second and the SAMS analysis nearly agreed that this magnitude was achieved – see red annotations in Figure 3 through Figure 6.

A somewhat crude quantification of the reboost as measured by three distributed SAMS sensors is also given in Table 1. As expected, we saw consistent impact measured by SAMS throughout the space station for just over 19 minutes or so via (effectively) 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)

Progress vs. Cygnus Reboost Note

Historically, a Russian Progress cargo vehicle docked on the after end of the ISS with its thrusters already pointing aftward in its docked position, required neither pre- nor post-maneuvers to adjust attitudes surrounding a reboost. With Cygnus (NG-20) vehicle docked as shown in this document, we need those maneuvers to properly put orbital mechanics and Newton's 3rd law into play.

4. CONCLUSION

The SAMS measurements for 3 sensor heads distributed across all 3 main labs of the ISS were analyzed and showed a **-Z-axis step magnitude of about 0.1 mg during the reboost**. Furthermore, calculations based on these sensors indicate **a ΔV metric of about 1.2 meters/second was achieved**, and this result derived from SAMS measurements was a bit more than what the flight controllers' were expecting of just under 1.1 meters/second.

Notes on SAMS Sensor (121f08) Low-Frequency Undulations

Figure 5 and Figure 6 on page 5 are shown side-by-side to compare and contrast interval average (i.e. low-frequency) accelerations that should bear a strong resemblance to each other despite being in 2 separate laboratory modules as we see in the 2 figures (for 2 SAMS sensors in 2 laboratory modules) on the previous page. We do this to make note of the unexpected (bogus) low-frequency undulations seen on the X-axis of the SAMS sensor, 121f08 (COL), data. The engineering data to back up the following assertion has not been extracted or analyzed, but it is strongly asserted here that we are seeing the influence of temperature compensation on this low-frequency regime. We routinely ignore the low-frequency environment when analyzing SAMS data since effects such as temperature compensation can show up as acceleration artifacts as is the case here.

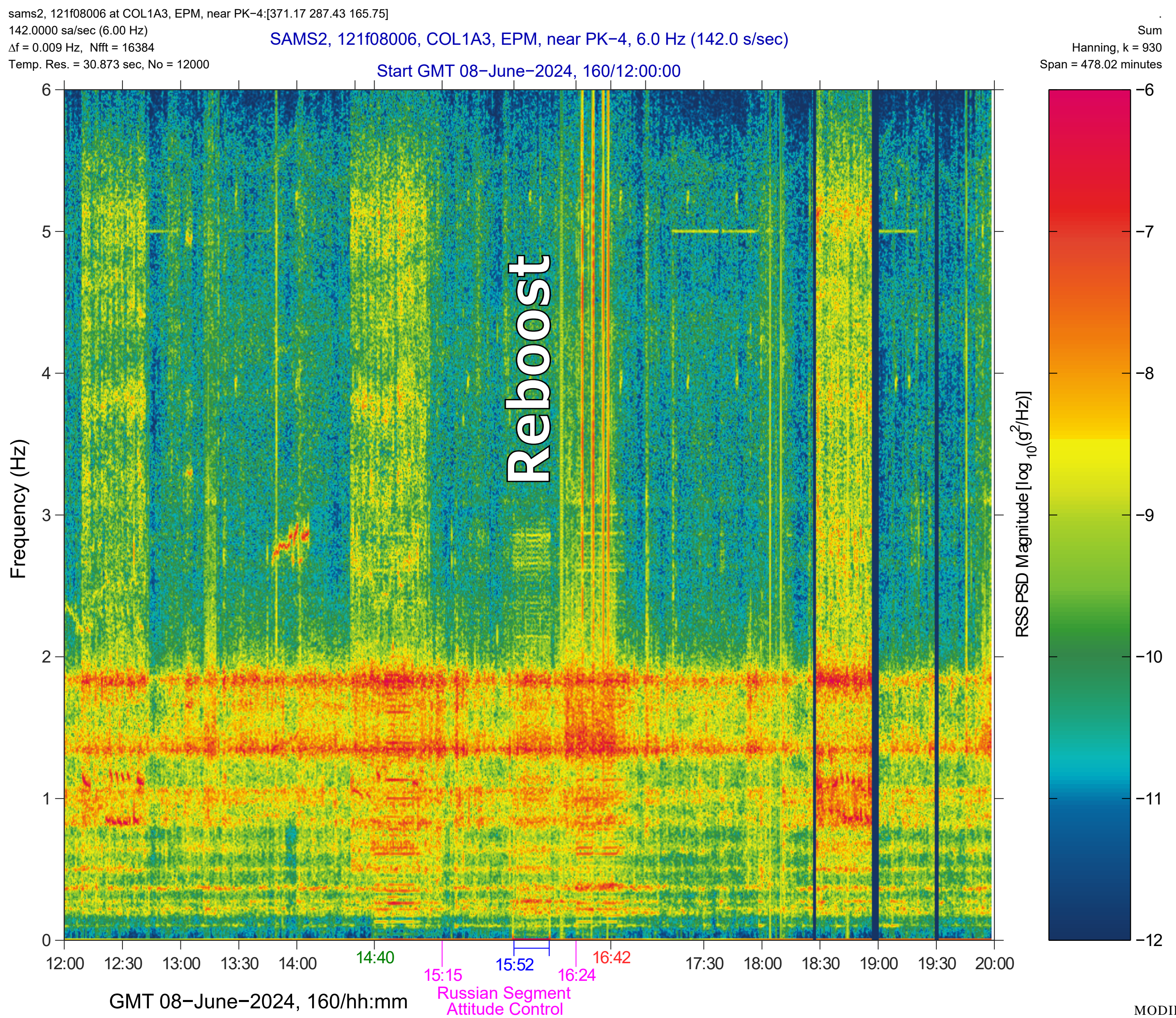

Fig. 2: 10 Hz Spectrogram showing Cygnus Reboost from a SAMS Sensor in the Columbus Module.

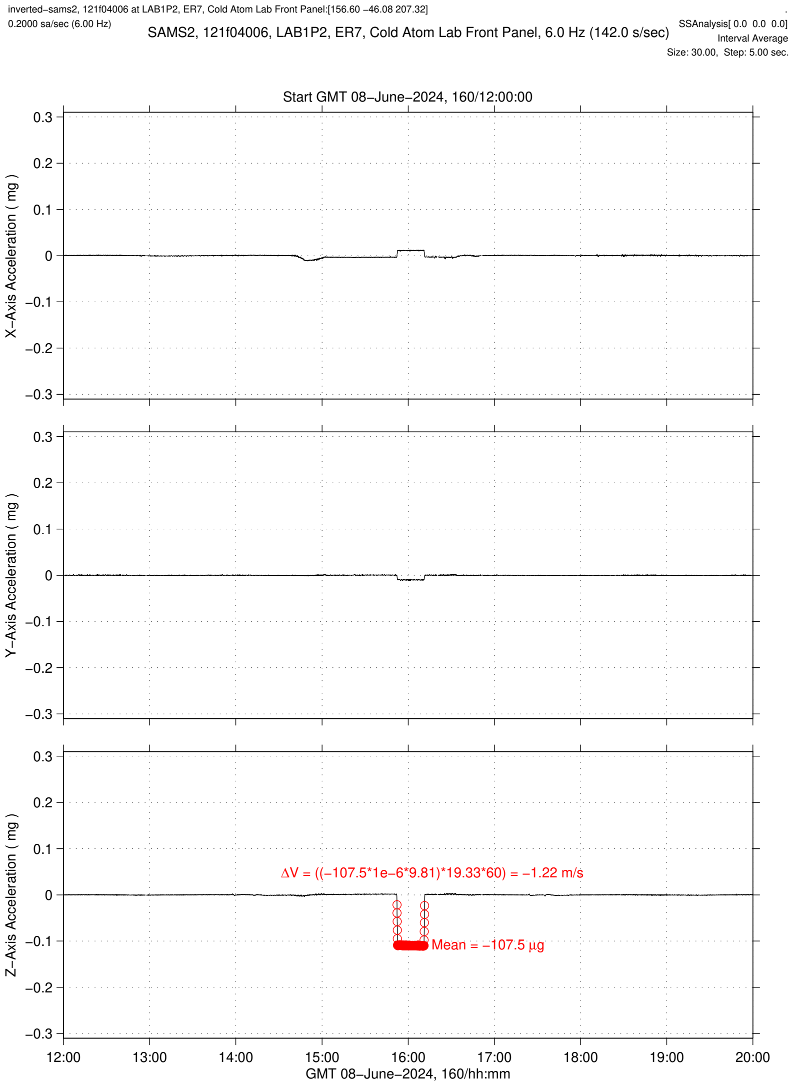

Fig. 3: 30-sec interval average for SAMS 121f04 sensor in the LAB.

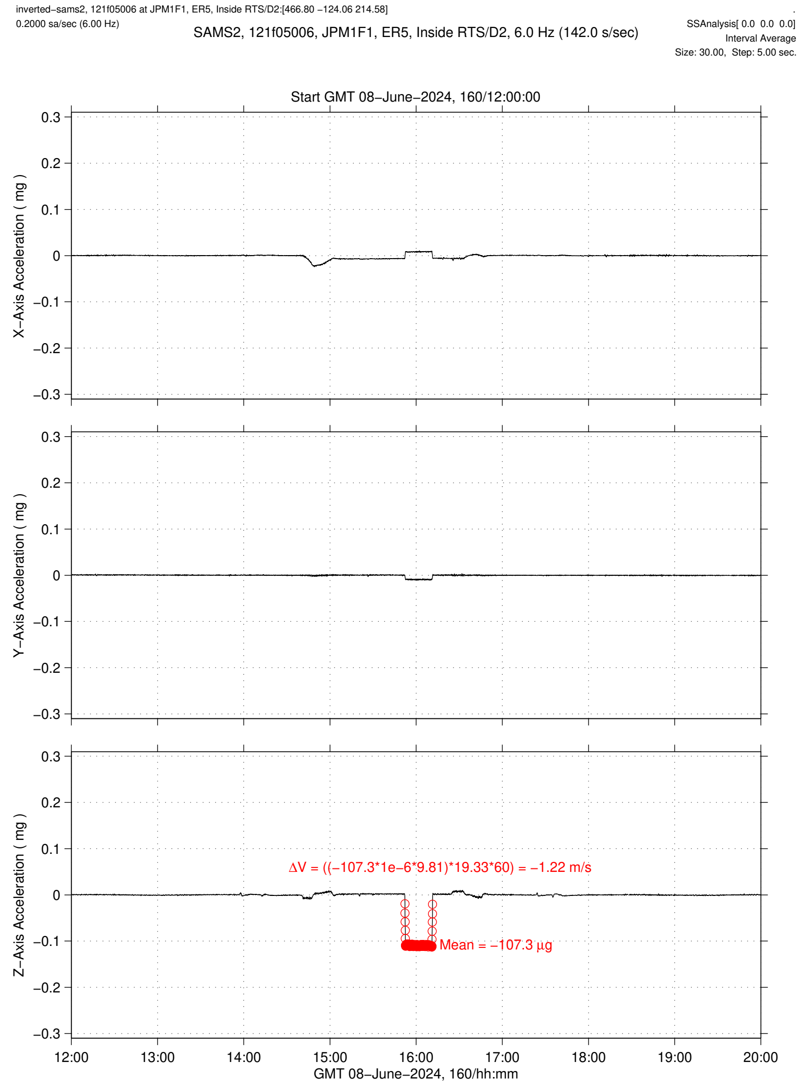

Fig. 4: 30-sec interval average for SAMS 121f05 sensor in the JEM.

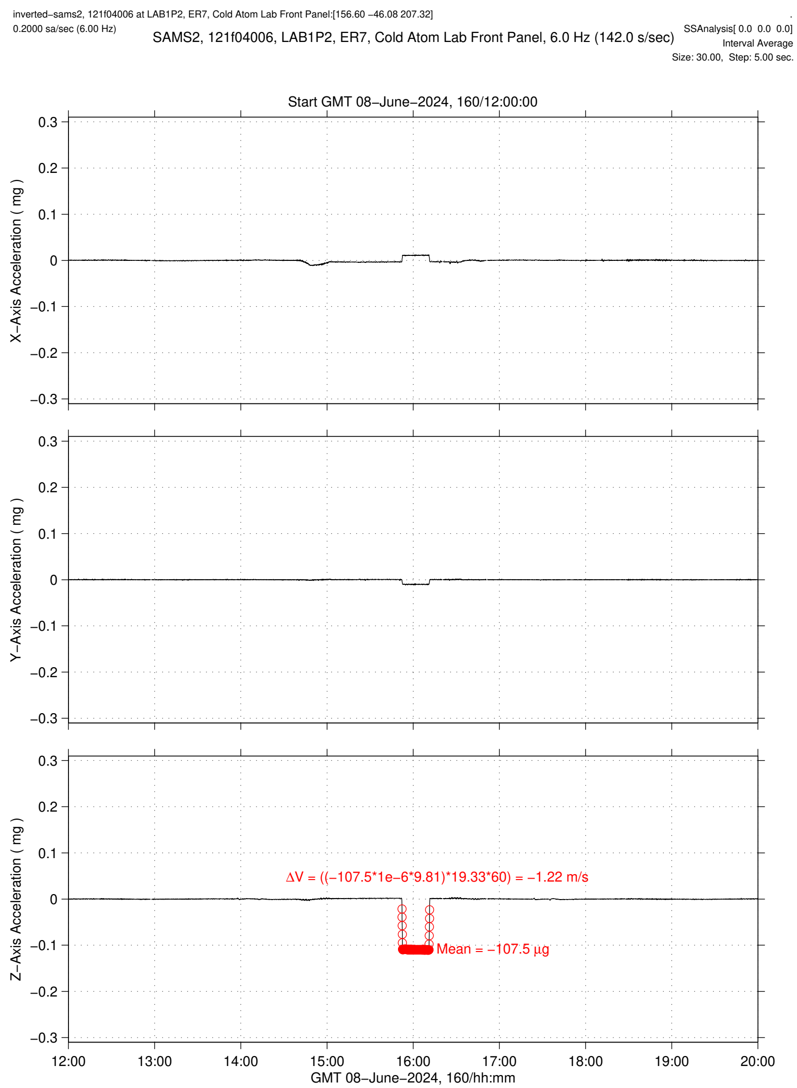

Fig. 5: 30-sec interval average for SAMS 121f04 sensor in the LAB.

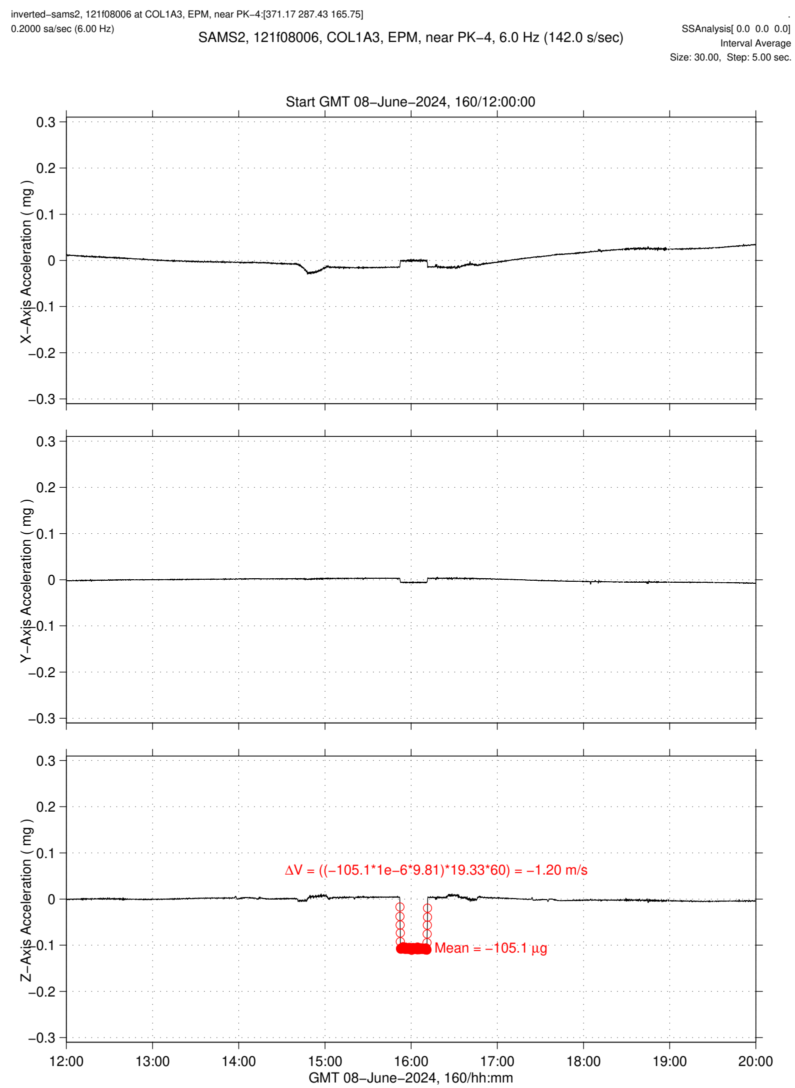

Fig. 6: 30-sec interval average for SAMS 121f08 sensor in the COL.