-ZVV Cygnus NG-17 Reboost Aborted on GMT 2022-06-20

1. INTRODUCTION

On GMT 2022-06-20, at about 171/15:20, the International Space Station (ISS) was to a reboost using Northrop Grumman's Cygnus vehicle (NG-17) engine. It was scheduled to fire for several minutes to test the cargo craft's ability to reboost the ISS again in the future. The engine firing was aborted after just six seconds. No details from ground controllers beyond Cygnus' Mission Director's report that the cause for the abort was understood and being reviewed. The reboost was designed to provide Cygnus with an enhanced capability for station operations as a standard service for the National Aeronautics and Space Administration (NASA). Figure 1 shows that the Cygnus vehicle was docked with its thrusters facing toward the Earth (nadir, +Z-direction), which required the space station to 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 colossal 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. ***This brief/aborted attempt, however, only resulted in a negligible reboost.***

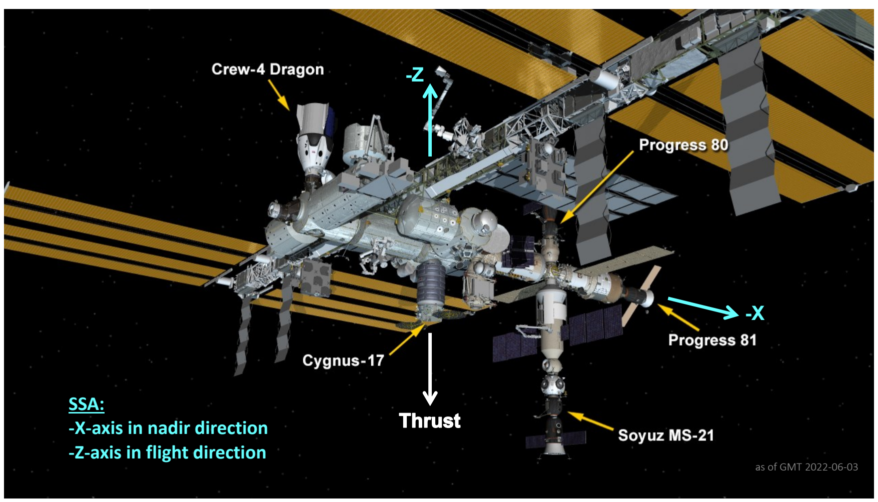
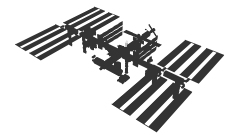


Fig. 1: Cygnus NG-17 vehicle's location and alignment for intended reboost.



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 (EPM) COL1A3 rack. This color spectrogram plot shows increased structural vibration excitation contained mostly below 2 Hz or so, and approximately a 6-second reboost (thruster firing) event itself that started just before GMT 15:20. We attribute much of the structural vibration increase evident in the span of this spectrogram plot to Russian Segment (RS) attitude control since the as-flown timeline shows RS control from about GMT 14:40 to about 15:35. During this time, the RS thrusters were used for station attitude control leading into and after the brief/aborted reboost activity. This RS attitude control and vibratory impact 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 spanning about an hour or so. 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 attitude control thruster forces. The actual reboost activity itself had measurable effect, but acceleration environment impact well below typical for a reboost event. 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 a relatively short reboost event itself, but also during the much longer span of Russian Segment (RS) attitude control leading up to and afterwards too. The difference being that during the reboost itself, the dominant factor would typically be considered to be a highly-directional step on an axis aligned with the velocity vector of the space station, while in the much longer case of RS attitude control, the dominant impact was the excitation of lower-frequency vibrational modes of large space station structures. We see from and as-flown timeline and in the SAMS spectrogram of Figure 2 that there was an maneuver to get to reboost, "-ZVV", attitude from GMT 14:05 to 14:27 and another maneuver back to "-XVV attitude" from GMT 15:35 to 15:55, after the brief/aborted reboost. 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 15:20 with a duration of 6 seconds. Analysis of Space Acceleration Measurement System (SAMS) data recordings in the US LAB – see Figure 3 on page 4 – shows the tell-tale Z-axis step (in the negative direction) that started at GMT 15:20:13 and had a duration of 6 seconds. The data in this plot are 10-second interval average of the SAMS data. 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 brief/aborted reboost event.

Information from flight controllers indicated that this reboost event provided a rigid body ΔV of about 0.001 meters/second and the SAMS analysis indicated a magnitude closer to 0.002 meters/second – see red annotations in Figure 3.

Two more plots of interval average acceleration versus time for two more SAMS sensor heads distributed throughout the ISS are shown at the end of this document starting with Figure 4 on page 4. 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 the distributed SAMS sensors is also given in Table 1. As expected, we saw fairly consistent, ableit minimal impact measured by SAMS throughout the space station for about six seconds or so.

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

Sensor	Z-Axis	Location
121f03	-0.036	LAB1O1 (ER2)
121f05	-0.035	JPM1F1 (ER5)
121f08	-0.037	COL1A3 (EPM)

4. CONCLUSION

The SAMS measurements for 3 sensor heads distributed across all 3 main labs of the ISS were analyzed and showed an abbreviated **-Z-axis step of about 0.036 mg during the brief/aborted reboost**. Furthermore, calculations based on SAMS sensor (121f03) mounted on EXPRESS Rack 2 (LAB1O1) in the US LAB indicate a ΔV metric of about 0.002 meters/second was achieved, and this result nearly matched flight controllers' value of 0.001 meters/second.

NOTES ON DIRECTIONALITY

SAMS sensors (and data alignment) are fixed to the ISS, so when it changes attitude/orientation, so too does the Space Station Analysis (SSA), *fixed body*, coordinate system used by the SAMS. Figure 6 shows a typical reboost attitude, while the reboost orientation shown in figure 7 was used for this brief/aborted attempt via Cygnus on GMT 2022-06-20.

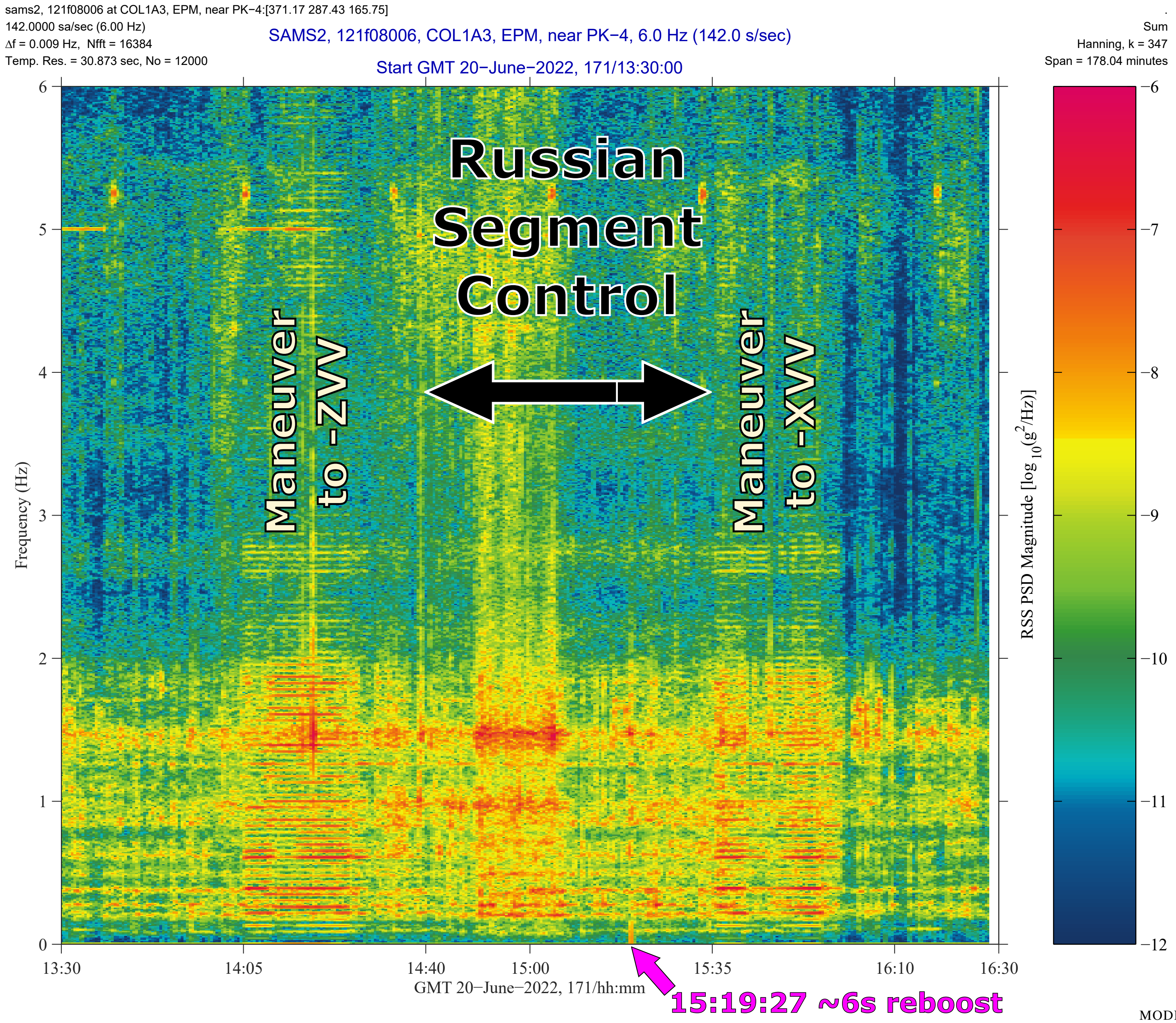


Fig. 2: Spectrogram showing Aborted Cygnus Reboost on GMT 2022-06-20.

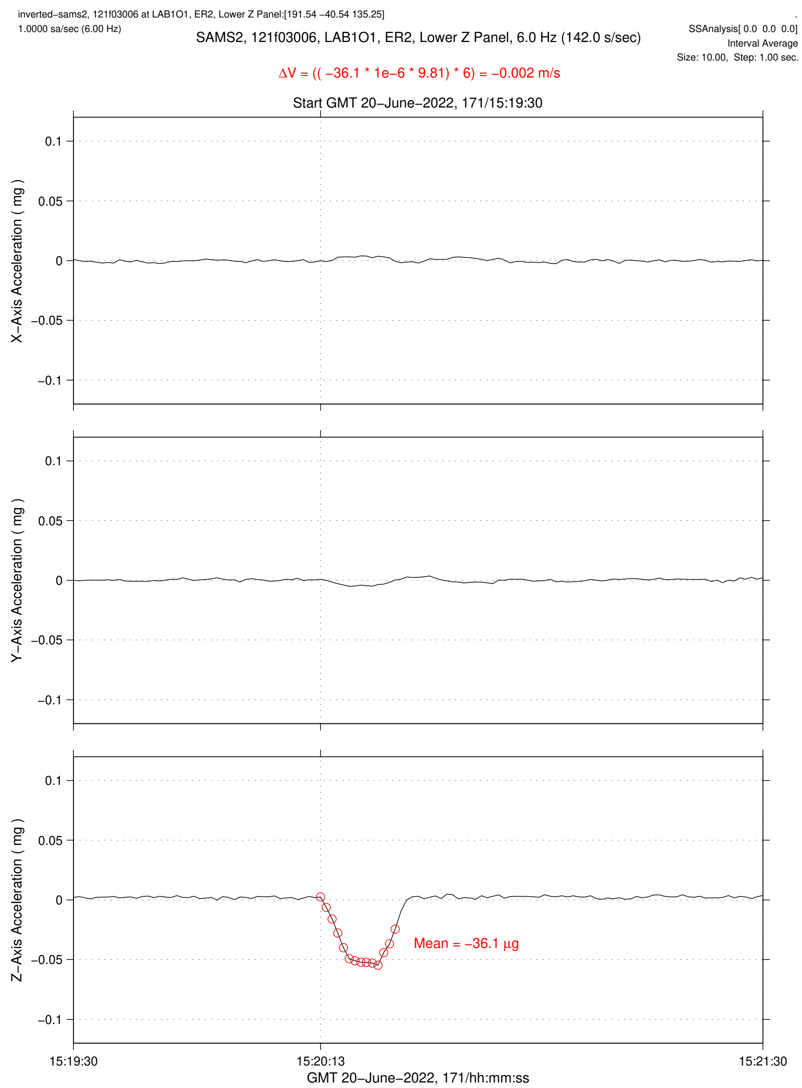


Fig. 3: 10-sec interval average for SAMS 121f03 sensor in the LAB.

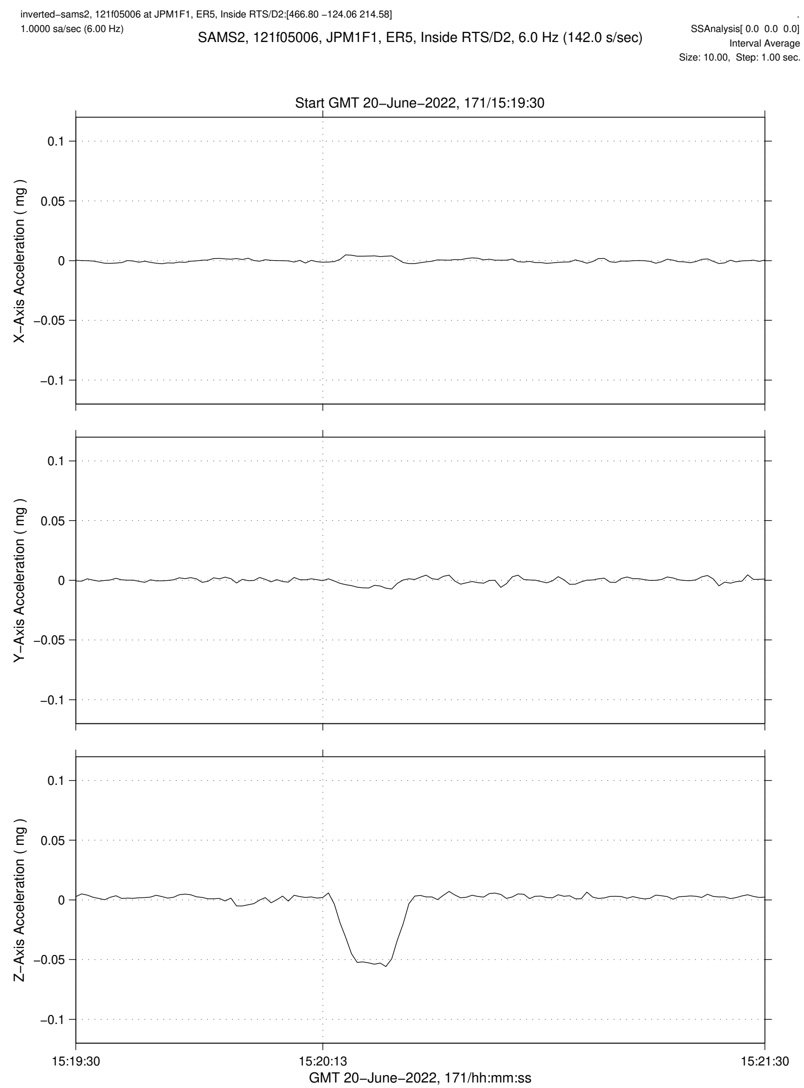


Fig. 4: 10-sec interval average for SAMS 121f05 sensor in the JEM.

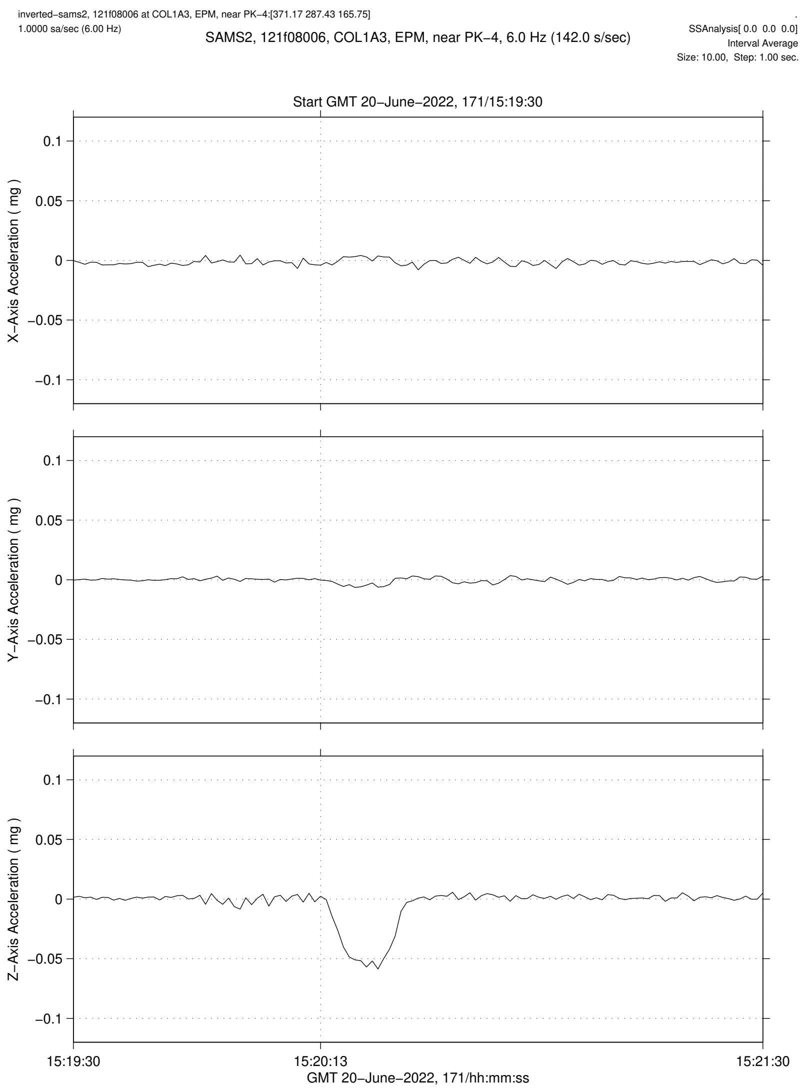


Fig. 5: 10-sec interval average for SAMS 121f08 sensor in the COL.

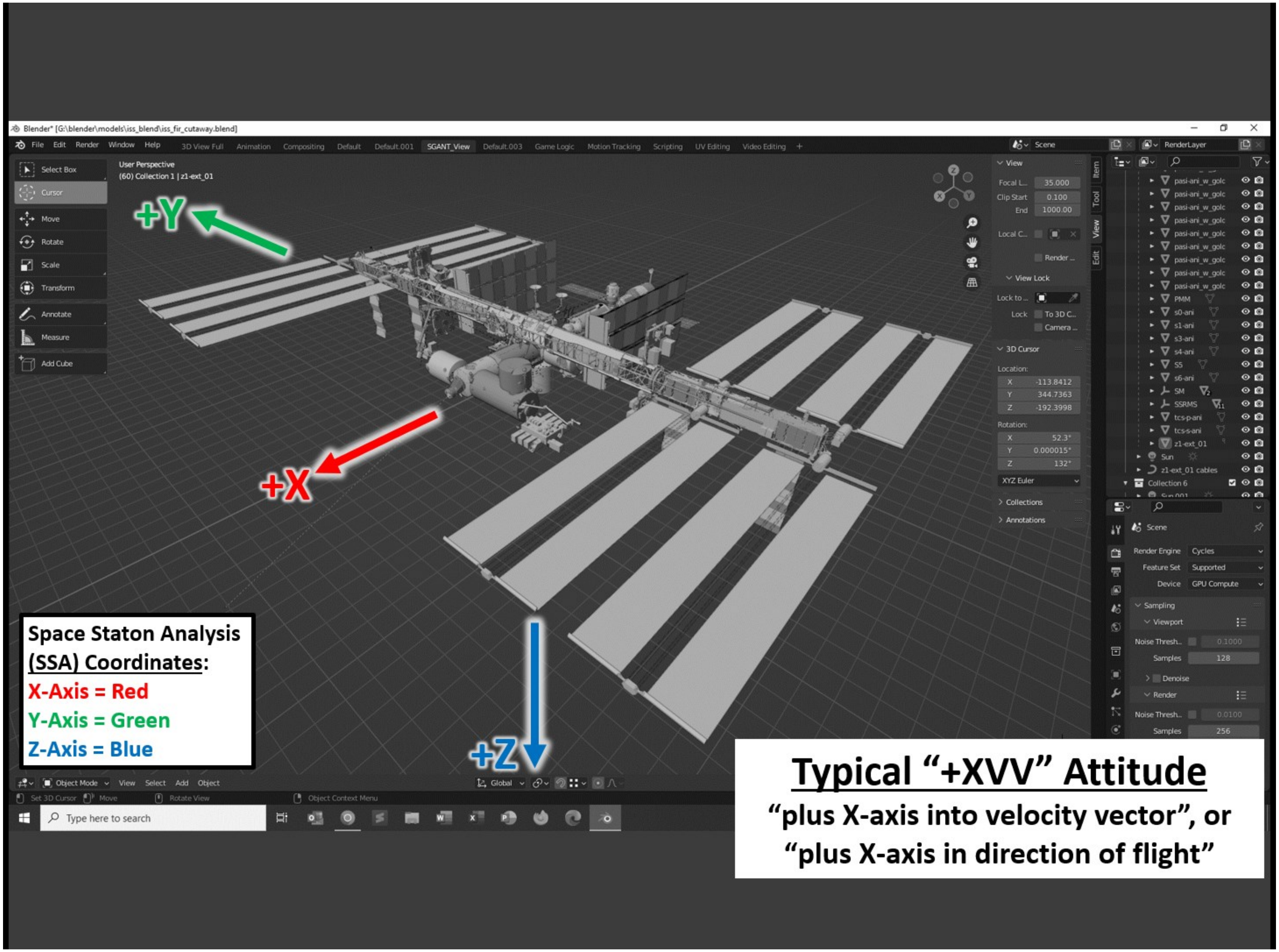


Fig. 6: Typical “+XVV” Attitude for Reboosts.

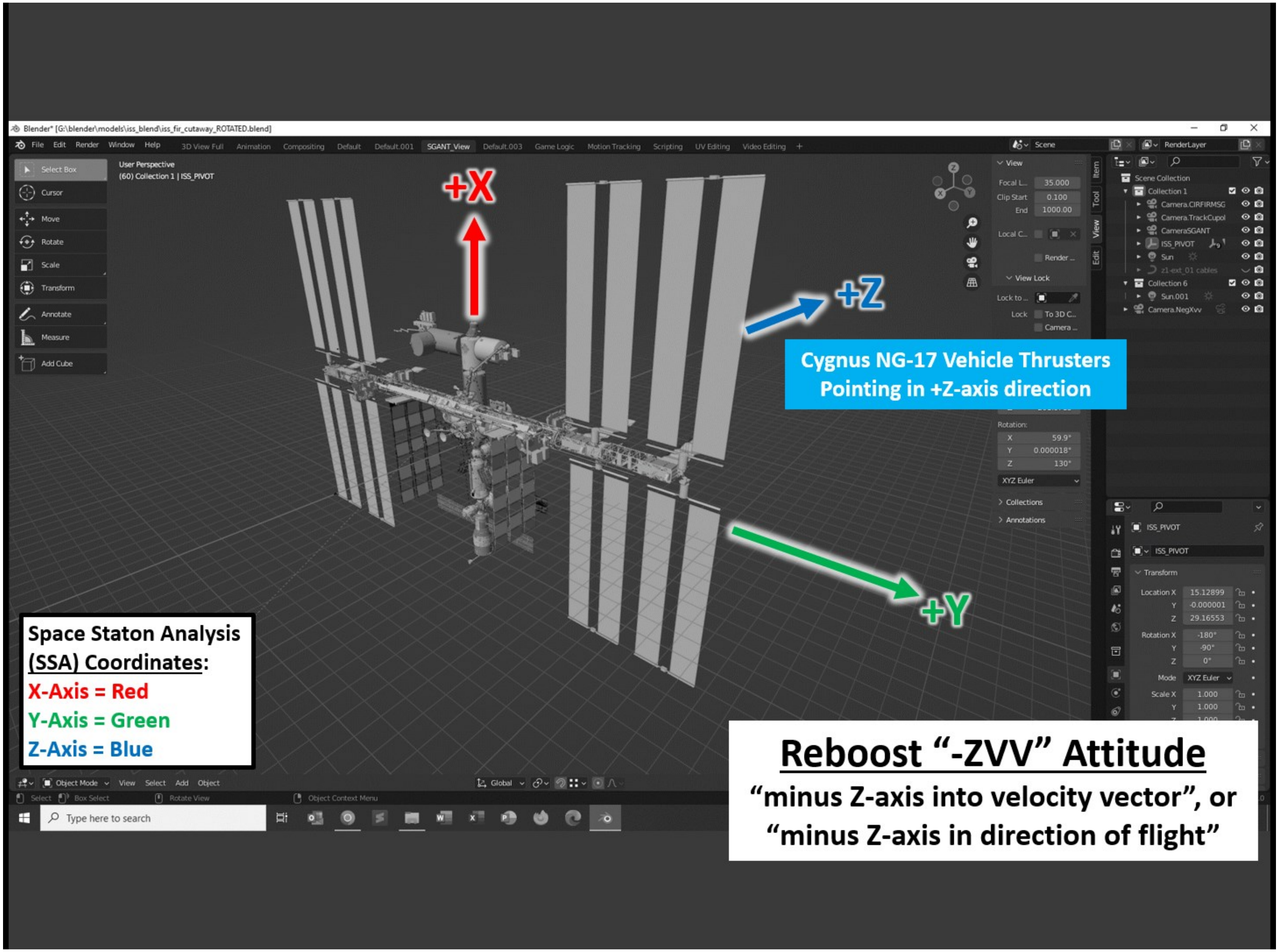


Fig. 7: The "-ZVV" Attitude for Brief/Aborted Cygnus Reboost.