1. INTRODUCTION

On GMT 2022-06-25, at just after 176/17:27, the International Space Station (ISS) began about a 5-minute reboost using Northrop Grumman's Cygnus vehicle's (NG-17) engine. This completed the first limited reboost of the International Space Station via Cygnus' gimbaled delta velocity engine. It elevated the station's altitude 1/10 of a mile at apogee and 1/2 of a mile at perigee. This Cygnus mission is the first to feature this enhanced capability as a standard service for NASA. Cygnus arrived to the ISS in February 2022 and is slated to depart from space station on GMT 2022-06-28, where it will burn up in the Earth's atmosphere.

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 huge 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. See direction notes on page 2.

Figure 2 for reference, shows a typical "+ZLV" attitude with Cygnus' thrusters pointing "down toward the Earth" (nadir facing).

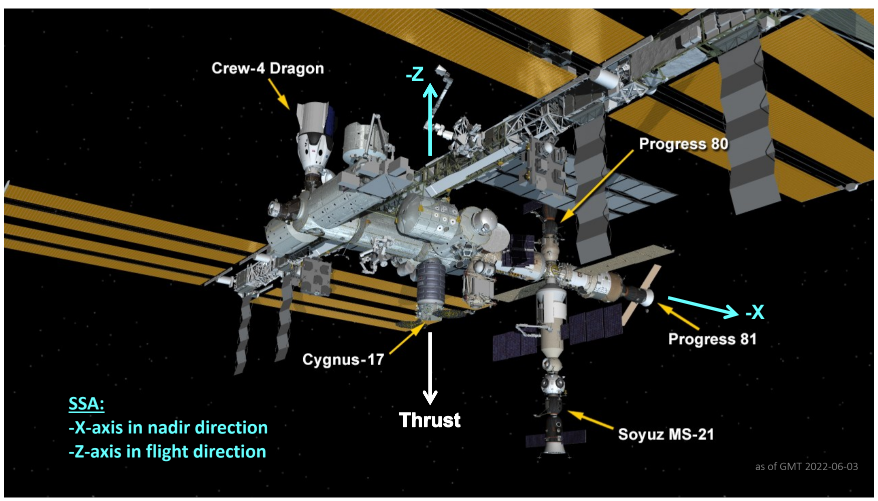

Fig. 1: Cygnus vehicle's location and alignment for GMT 2022-06-25 reboost.

Fig. 2: Nominal +ZLV attitude, Cygnus' thrusters point toward Earth (nadir).

2. QUALIFY

The information shown in Figure 3 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 307-second reboost (thruster firing) event itself that started just after GMT 17:27. 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 16:47 to about 17:42. During this time, the RS thrusters were used for station attitude control leading into and after the 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. 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 is 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 the as-flown timeline and in the SAMS spectrogram of Figure 3 that there was an maneuver to get to reboost, "-ZVV", attitude from GMT 16:12 to 16:32 and another maneuver back to "-XVV attitude" from GMT 17:42 to 18:02, 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 17:27. Analysis of Space Acceleration Measurement System (SAMS) data recordings in the US LAB – see Figure 4 on page 4 – shows the tell-tale Z-axis step (in the negative direction) that started at GMT 17:27:13 and had a duration of 5 minutes 7 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 reboost event.

Information from flight controllers indicated that this reboost event provided a rigid body ΔV of about 0.283 meters/second and the SAMS analysis indicated a magnitude closer to 0.33 meters/second – see red annotations in Figure 4.

Three more plots of interval average acceleration versus time for additional SAMS sensor heads distributed throughout the ISS are shown at the end of this document starting with Figure 5 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 consistent impact measured by SAMS throughout the space station for just over 5 minutes or so.

Table 1. **Z-axis** steps (mg) during reboost event for 4 SAMS sensors.

Sensor	Z-Axis	Location
121f03	-0.111	LAB1O1 (ER-2)
121f04	-0.112	LAB1P2 (ER-7)
121f05	-0.113	JPM1F1 (ER-5)
121f08	-0.113	COL1A3 (EPM)

4. CONCLUSION

The SAMS measurements for 4 sensor heads distributed across all 3 main labs of the ISS were analyzed and showed a **-Z-axis step magnitude of about 0.11 mg during the reboost**. Furthermore, calculations based on SAMS sensor (121f03) mounted on EXPRESS Rack 2 (LAB1O1) in the US LAB indicate a ΔV metric of about 0.33 meters/second was achieved, and this derived result was just a bit more than the flight controllers' cited value of 0.283 meters/second.

NOTES ON DIRECTION

SAMS sensors (and data alignment) are fixed to the ISS, so when the space station changes attitude/orientation, so too does the Space Station Analysis (SSA), *fixed body*, coordinate system used by the SAMS. Figure 8 shows a typical reboost attitude, while the reboost orientation shown in figure 9 was used for this reboost event via Cygnus on GMT 2022-06-25.

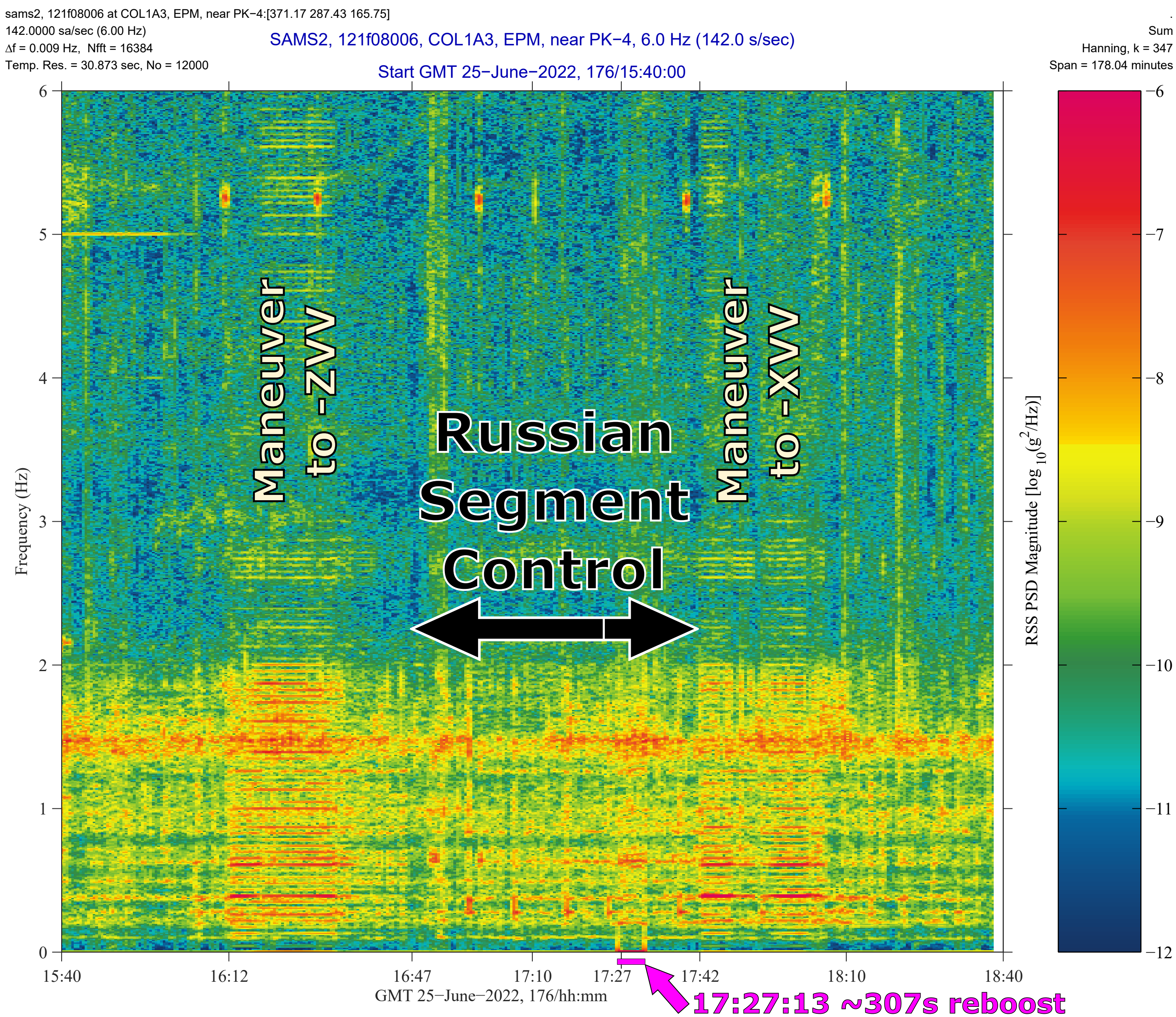

Fig. 3: Spectrogram showing Cygnus Reboost on GMT 2022-06-25.

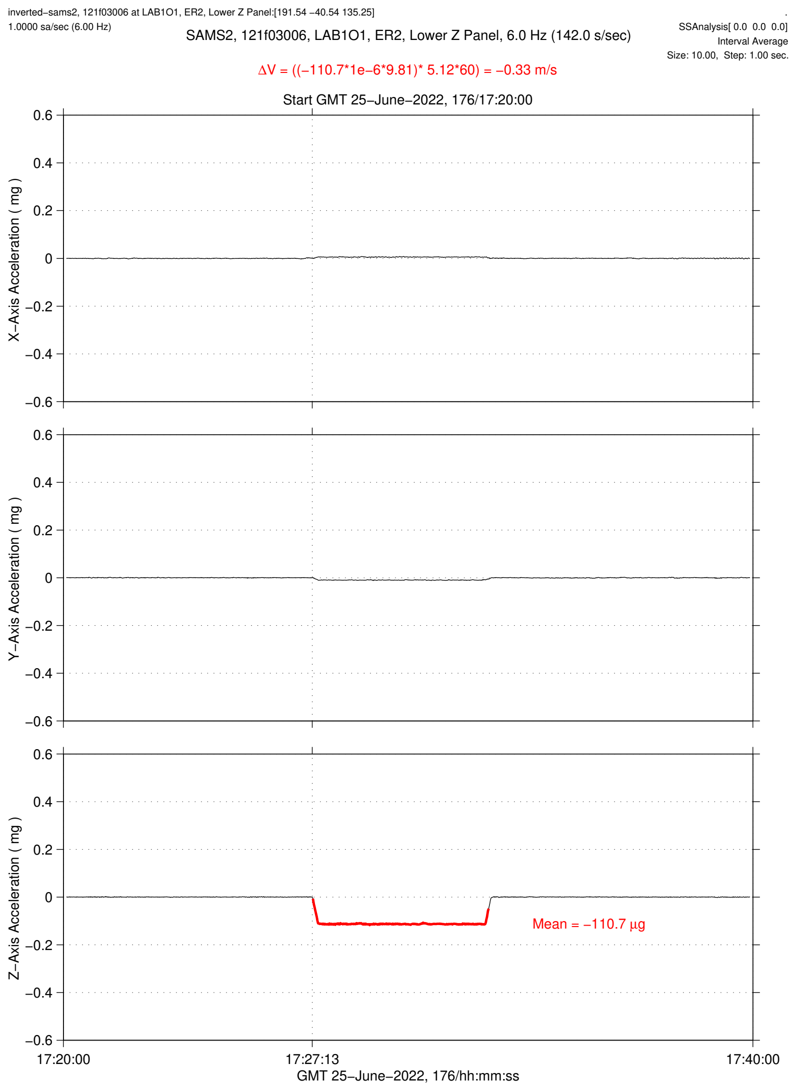

Fig. 4: 10-sec interval average for SAMS 121f03 sensor in the LAB.

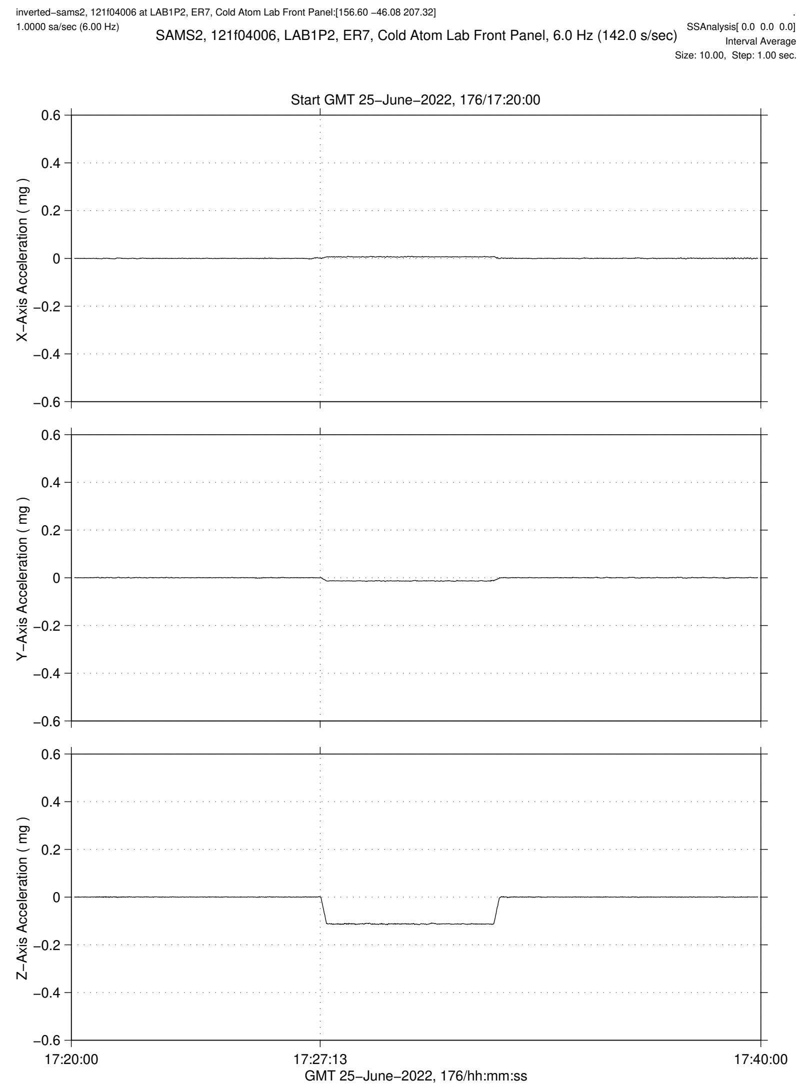

Fig. 5: 10-sec interval average for SAMS 121f04 sensor in the LAB.

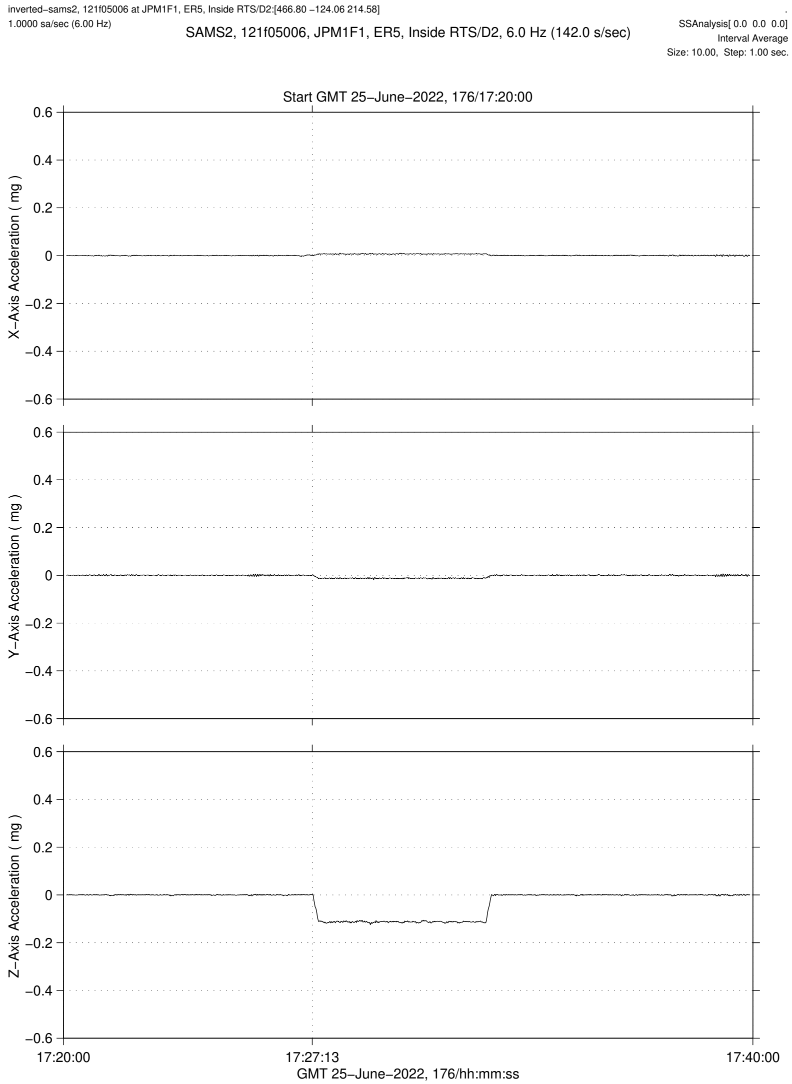

Fig. 6: 10-sec interval average for SAMS 121f05 sensor in the JEM.

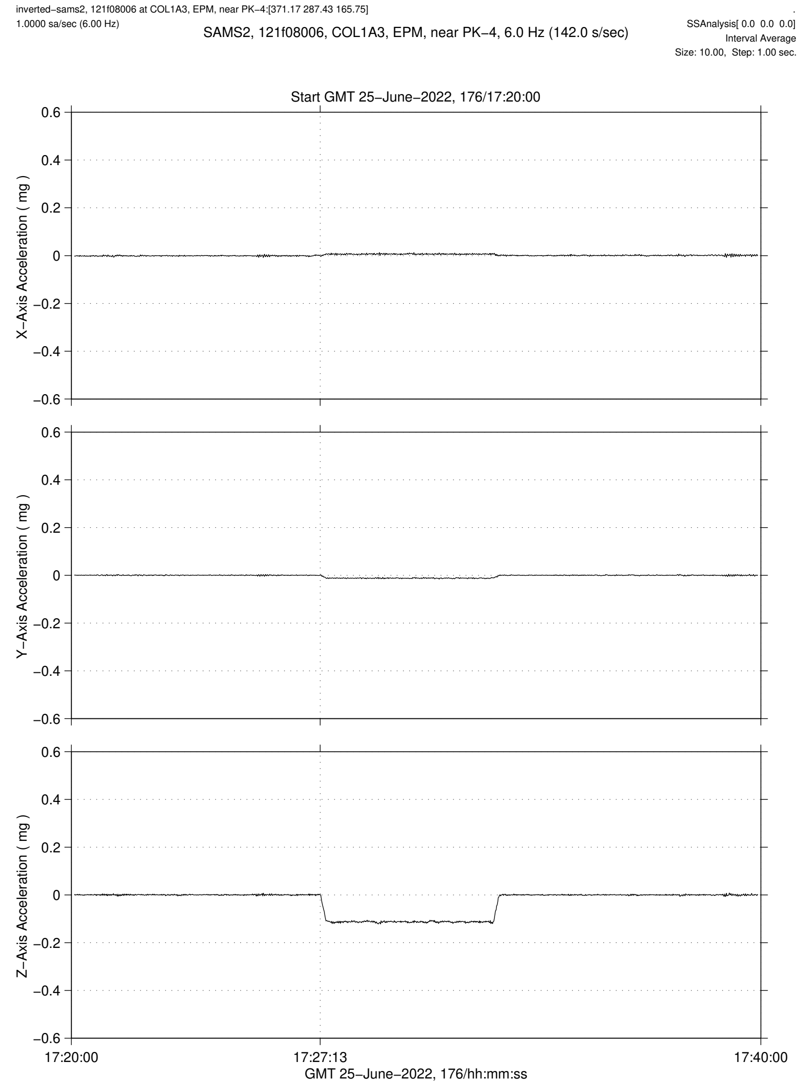

Fig. 7: 10-sec interval average for SAMS 121f08 sensor in the COL.

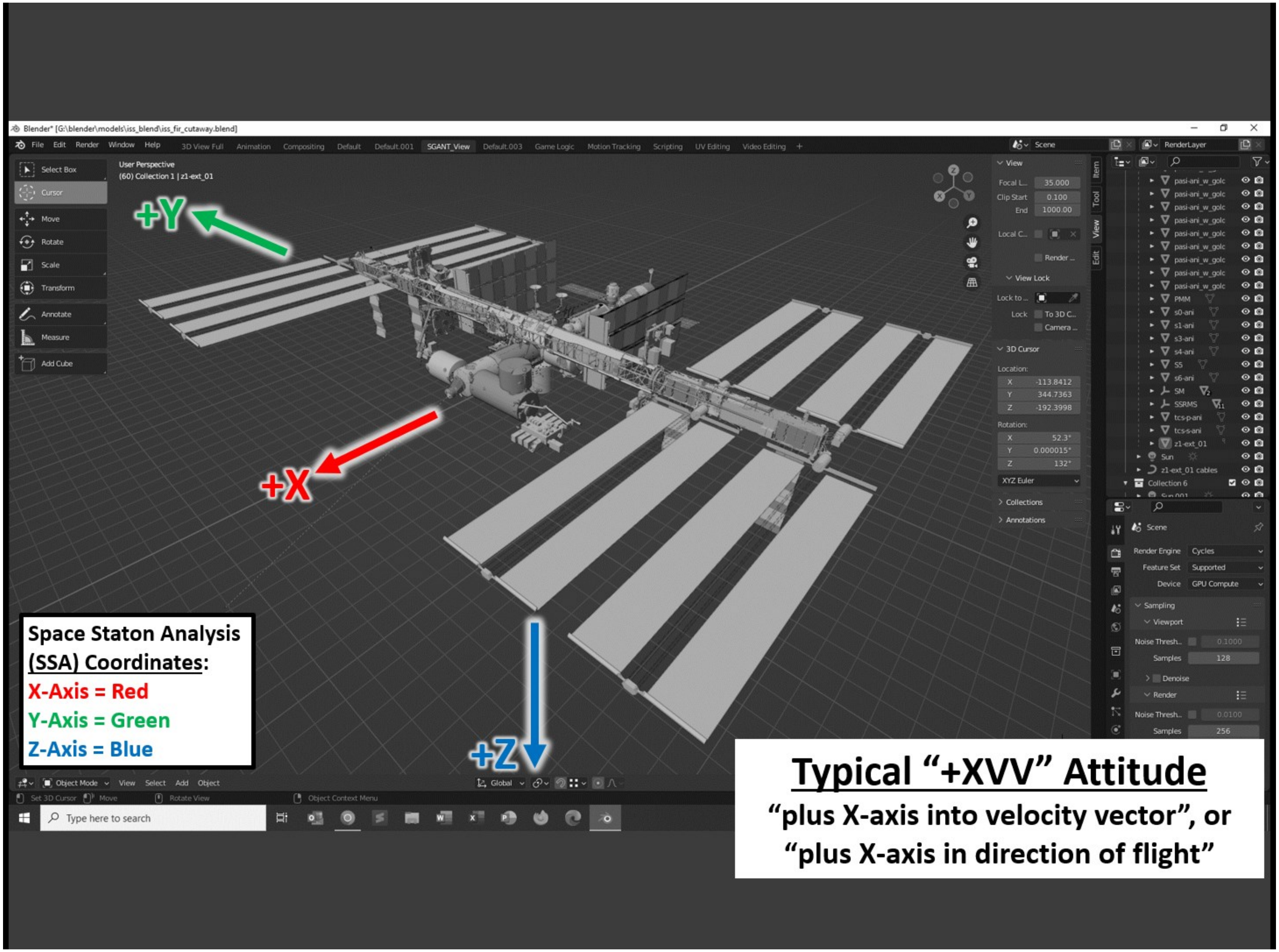

Fig. 8: Typical "+XVV" Attitude for Reboosts.

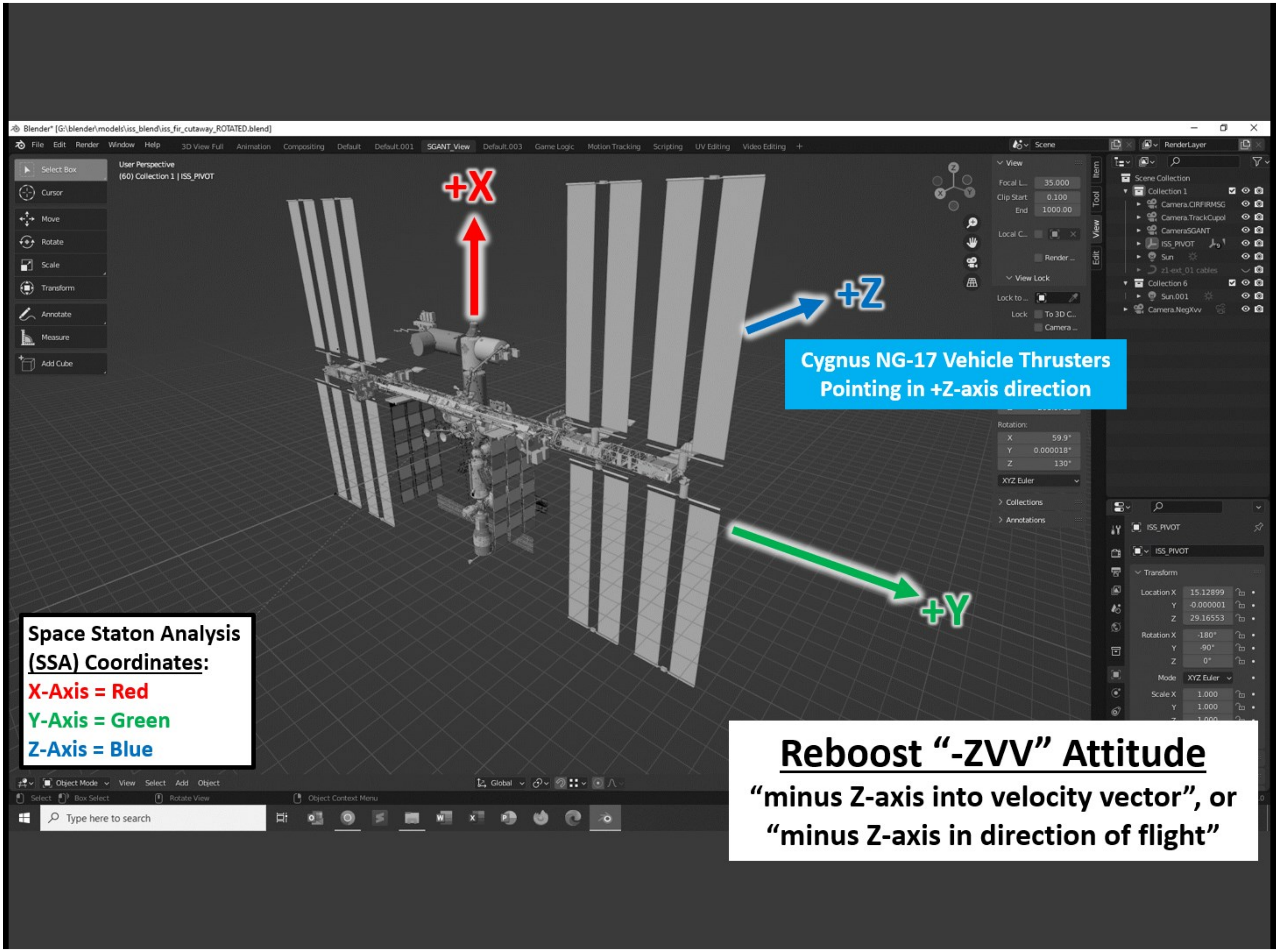

Fig. 9: The "-ZVV" Attitude for Cygnus Reboost.