1. INTRODUCTION

At about GMT 2022-08-10, 222/07:16, the International Space Station (ISS) began about a 2-minute, 32-second reboost using the Progress 81P thrusters. Figure 1 shows that the Progress vehicle was docked with its thrusters facing afterwards, which put thrust and the necessary orbital mechanics into play so as to speed up the ISS in its direction of flight. This directional acceleration, increase in velocity, resulted in a reboost of altitude of the space station during this dynamic event.

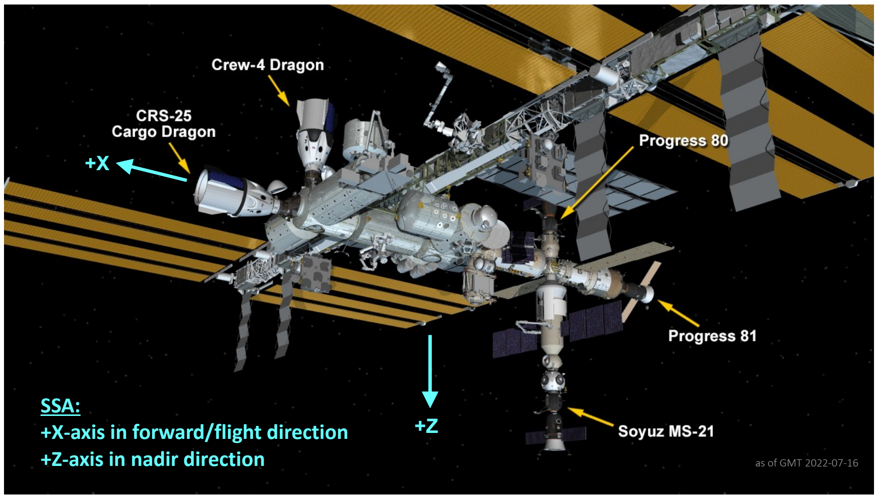


Fig. 1: Progress 81P's location and alignment during reboost.

2. QUALIFY

The information shown in Figure 2 on page 3 was calculated from the Space Acceleration Measurement System (SAMS) sensor 121f04 measurements made in the US LAB from a sensor mounting location on the Cold Atom Lab facility of the LAB1P2 rack. This 4-hour, 200 Hz color spectrogram plot is shown solely to give as-measured context. It does not provide a good focus on the vibratory impact and just demonstrates how an event such as a reboost might be "hidden" in overview plots such as this. On the other hand, the 4-hour color spectrogram of Figure 3 on page 4 is the same SAMS data set now with a focus now below 6 Hz that does show us a good look at the vibratory impact of events related to this reboost. Note the increased structural vibration excitation (transition from blue to yellow) mostly below 2 Hz that comes with handover to Russian attitude control. Also here we see the roughly 3-minute reboost (Progress 81P thruster firing) event itself as annotated in black starting at about GMT 07:16 (within the crude temporal resolution of spectrogram plot). The as-flown timeline calls out Russian Segment (RS) attitude control from about GMT 06:26 to about 08:11, as shown with white annotations. The RS thrusters were 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 (blue/green) to more energetic (yellow/orange) sporadically during this period of RS control spanning about 100 minutes. 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 lasted less than 3 minutes as evidenced by slightly more pronounced, vertical orange-red streaks in Figure 3 starting around GMT 07:16. We will see better temporal resolution via different plot types below. For science operations and general situational awareness, it is prudent to be aware that the transient and vibratory environment (contained primarily below about 10 Hz or so) is impacted not only during the reboost event itself, but also during the much longer span of Russian Segment (RS) attitude control too. The difference being that during the reboost itself, the dominant factor might be considered to be the mostly-directional step in the +X-axis, 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.

3. QUANTIFY

The as-flown timeline for this event indicated the reboost would start at GMT 07:16 and have a duration of 2 minutes, 45 seconds. Analysis of Space Acceleration Measurement System (SAMS) 121f04 data recordings at the Cold Atom Lab in the US LAB – see the left-side of Figure 4 on page 5, shows the tell-tale X-axis step that started at GMT 07:16:18 and had a duration of 2 minutes, 32 seconds – about 13 seconds shy of the advertised duration. Two other notes on this set of figures: (1) the red "intrinsic inversion" annotation is to note that SAMS data (as-measured) flips the polarity on each of the 3 (XYZ) axes – we show an intuitive rendition "unflipped" in a later plot, and (2) the as-measured (right-side) plot of Figure 4 on page 5 shows vibrations up to 200 Hz and those higher-frequency, larger-magnitude vibrations tend to swamp and mostly obscure what we consider to be the reboost signature.

Information from flight controllers indicated that this reboost event provided a space station rigid body ΔV metric of about 0.298 meters/second and the SAMS analysis indicated with red annotations in 4 figures for 8 SAMS sensor heads starting with Figure 5 on page 6 all closely match the expected velocity change value. The SAMS does not directly measure altitude, but flight controllers indicated that the ISS gained 0.53 km in altitude above the Earth.

The 4 figures (8 SAMS XYZ plots) starting with Figure 5 on page 6 are 5-second interval average acceleration versus time for SAMS sensors distributed throughout the ISS. The interval average processing effectively low-pass filtered the data so as to help emphasize the acceleration step that occurs on the X-axis during the reboost event. It should also be noted that we flipped the polarity of each axis (inverted each) in the SAMS plots owing to an intrinsic polarity inversion issue in SAMS transducers. A somewhat crude quantification of the reboost as measured by the 8 distributed SAMS sensors is also given in Table 1 – expectedly consistent impact results measured by SAMS throughout the gigantic space station.

Side note: the time hacks on the last 4 figures of this document come via signal processing automation and are consistent within the resolution of the plot type (5-second interval average).

Table 1. **X-axis** steps (mg) during reboost event for 8 SAMS sensors.

Sensor	X-Axis	Location
121f02	0.197	COL1A1 (ER3)
121f03	0.197	LAB1O1 (ER2)
121f04	0.196	LAB1P2 (ER7)
121f05	0.197	JPM1F1 (ER5)
121f08	0.198	COL1A3 (EPM)
es09	0.198	LAB1S2 (MSG)
es18	0.199	MSRR (ER6)
es20	0.199	LAB1P4 (4BCO2)

4. Conclusion

The SAMS measurements for 8 sensor heads distributed across all 3 main labs of the ISS was analyzed and showed a positive **X-axis step during the Progress 81P reboost of just under 0.2 mg**. Furthermore, calculations based on SAMS sensor (121f04) mounted on the Cold Atom Lab (LAB1P2) in the US LAB indicate a ΔV metric of about 0.3 meters/second was achieved, and this result closely matched flight controllers' advertised value.

5. Follow-Up

Added two more 6 Hz low-pass filtered plots of SAMS sensor on Cold Atom Lab to partially address the question *"What happened about 4-5 minutes before reboost TIG (time of ignition)?"* as follows:

Figure 9, left-side of page 10 shows about 20-minutes roughly centered on reboost with [my assertions] several Russian Segment thruster firings for attitude control leading up to reboost event shown with GMT time hacks in magenta (the last magenta hack is TIG for reboost).

Figure 9, right-side of page 10 shows a zoom-in on plot from the left-side plot on this same page to better show "the biggie" just before reboost's TIG at about GMT 07:15:35, which [to my eye] looks almost like premature start of reboost.

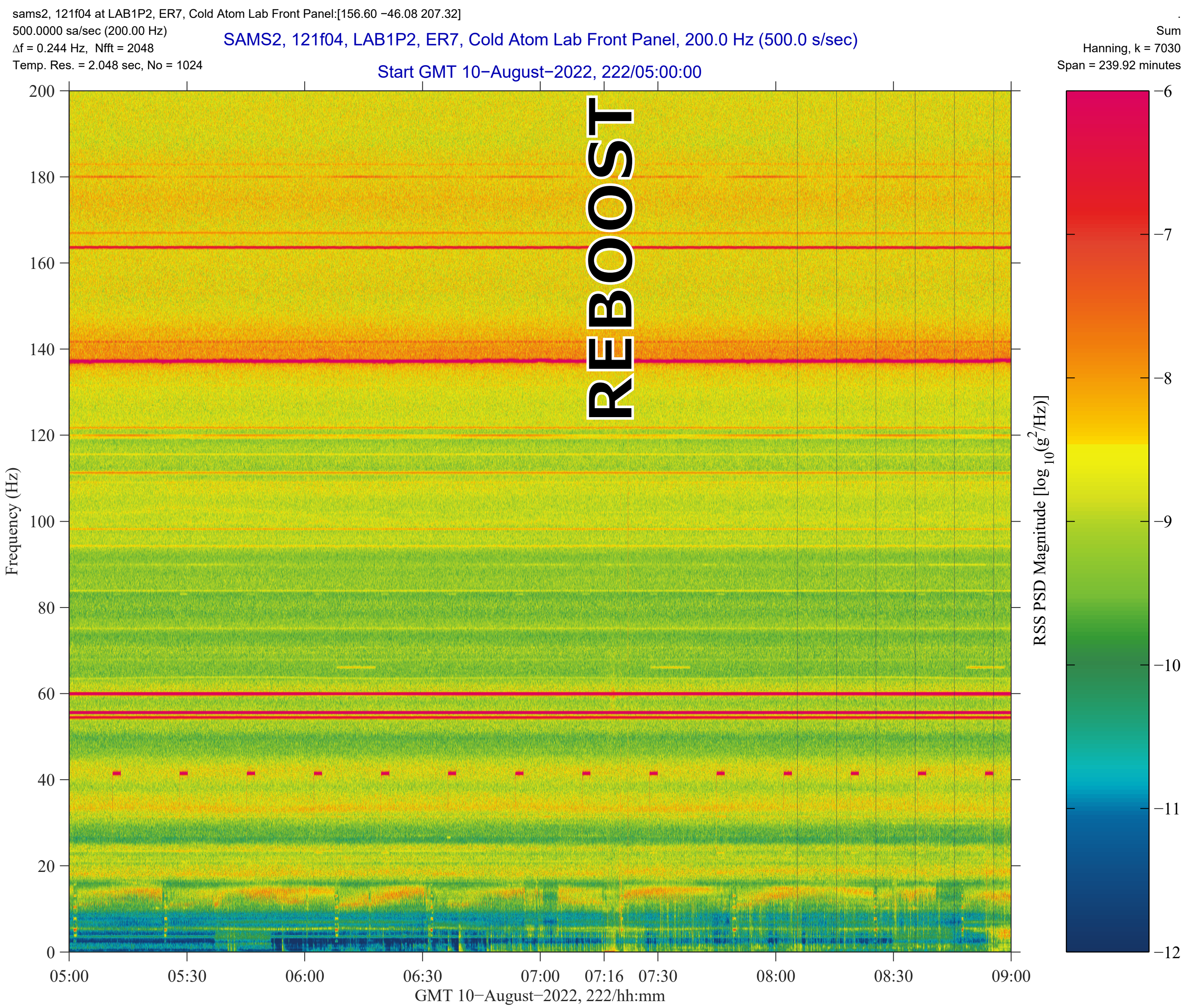


Fig. 2: 200 Hz, 4-Hour Spectrogram Showing Context for Progress 81P Reboost on GMT 2022-08-10.

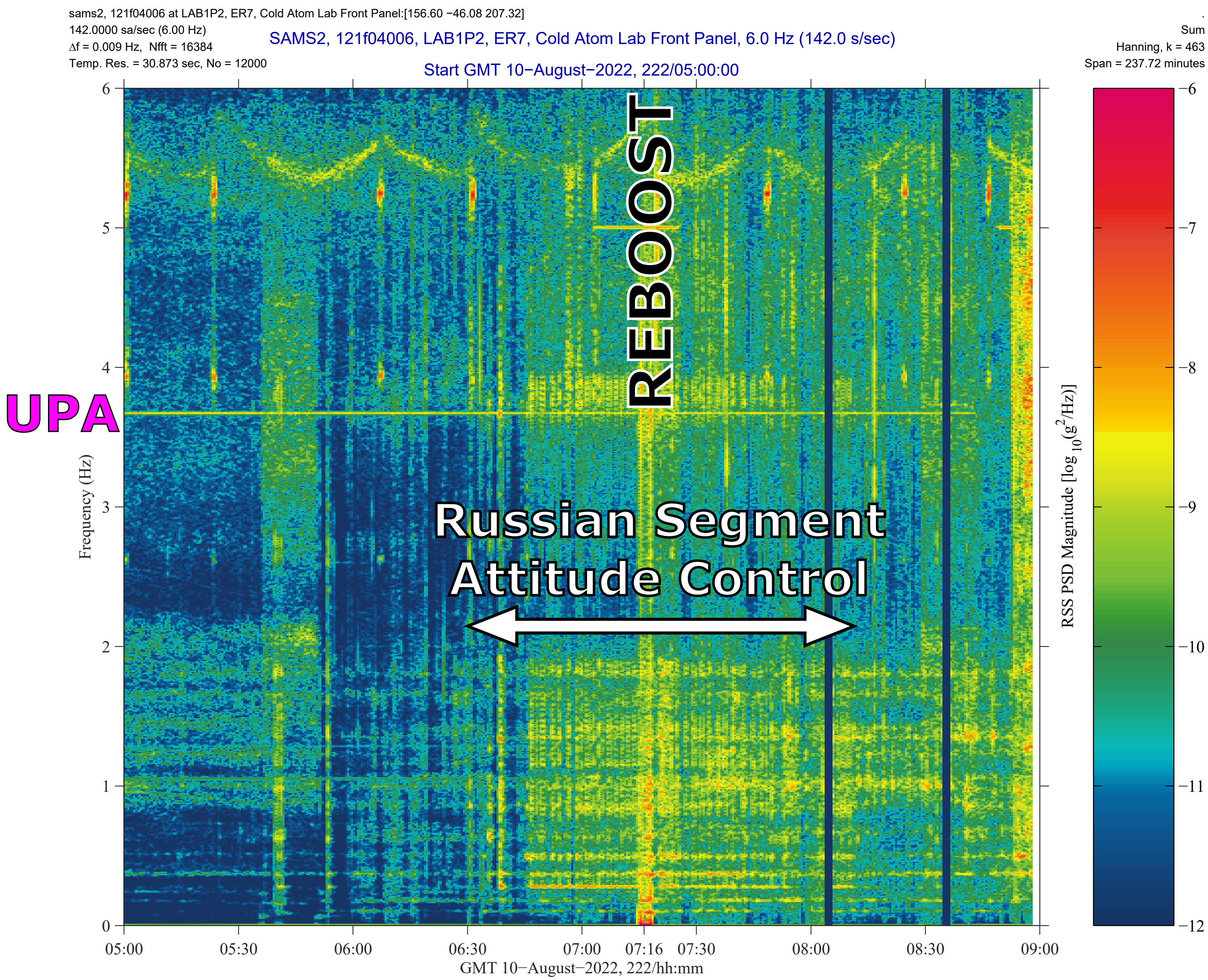
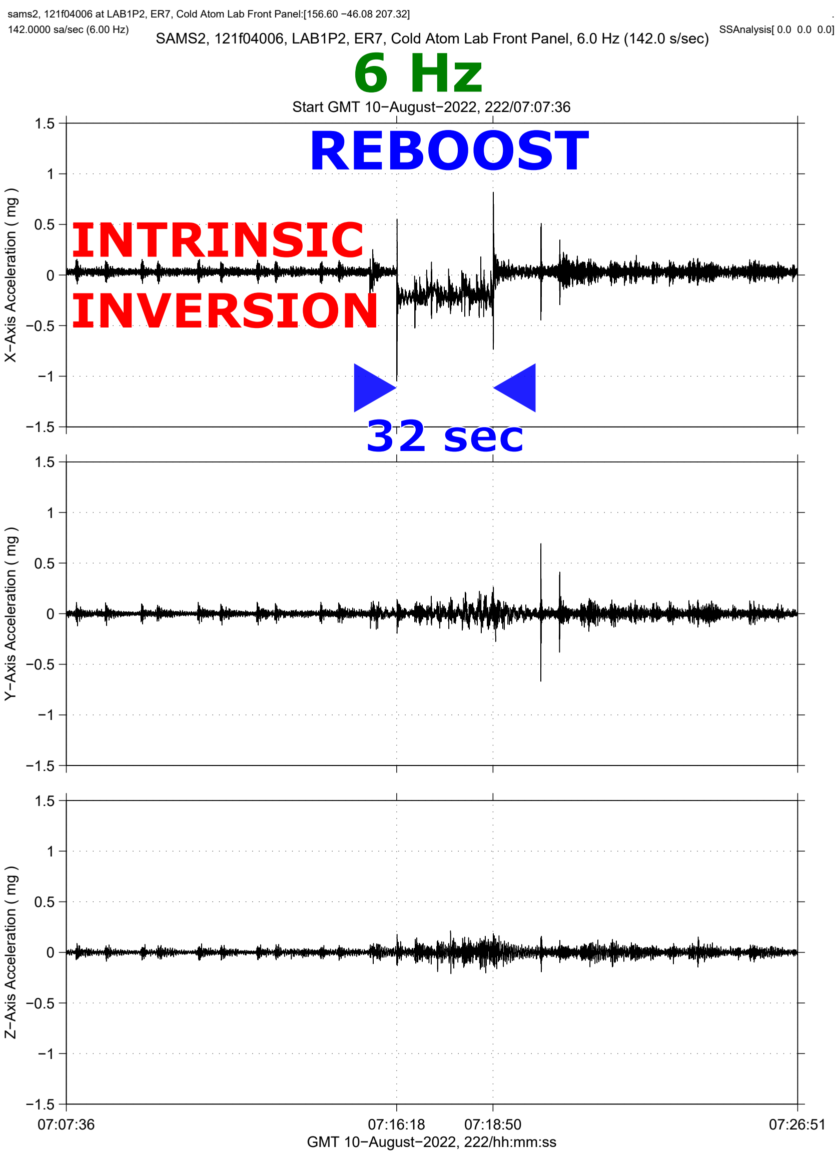


Fig. 3: 6 Hz, 4-Hour Spectrogram Better Showing Vibratory Impact of Progress 81P Reboost on GMT 2022-08-10.



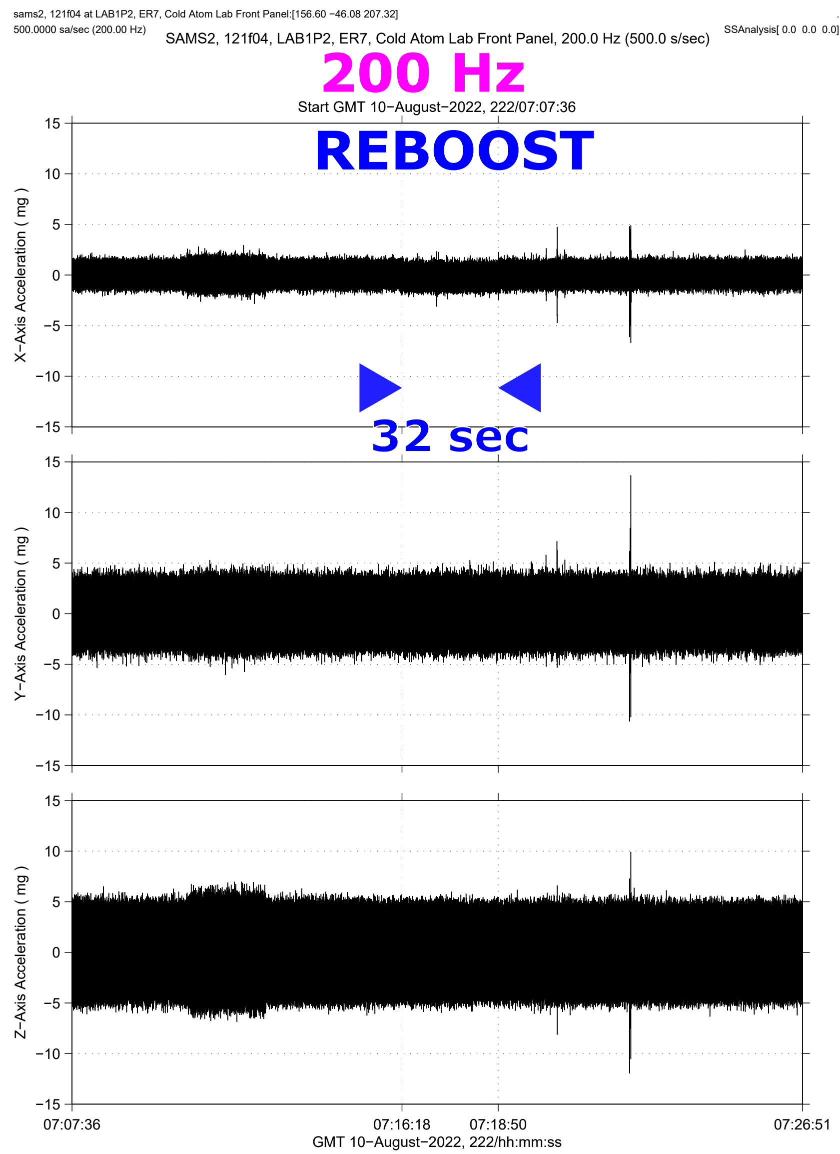
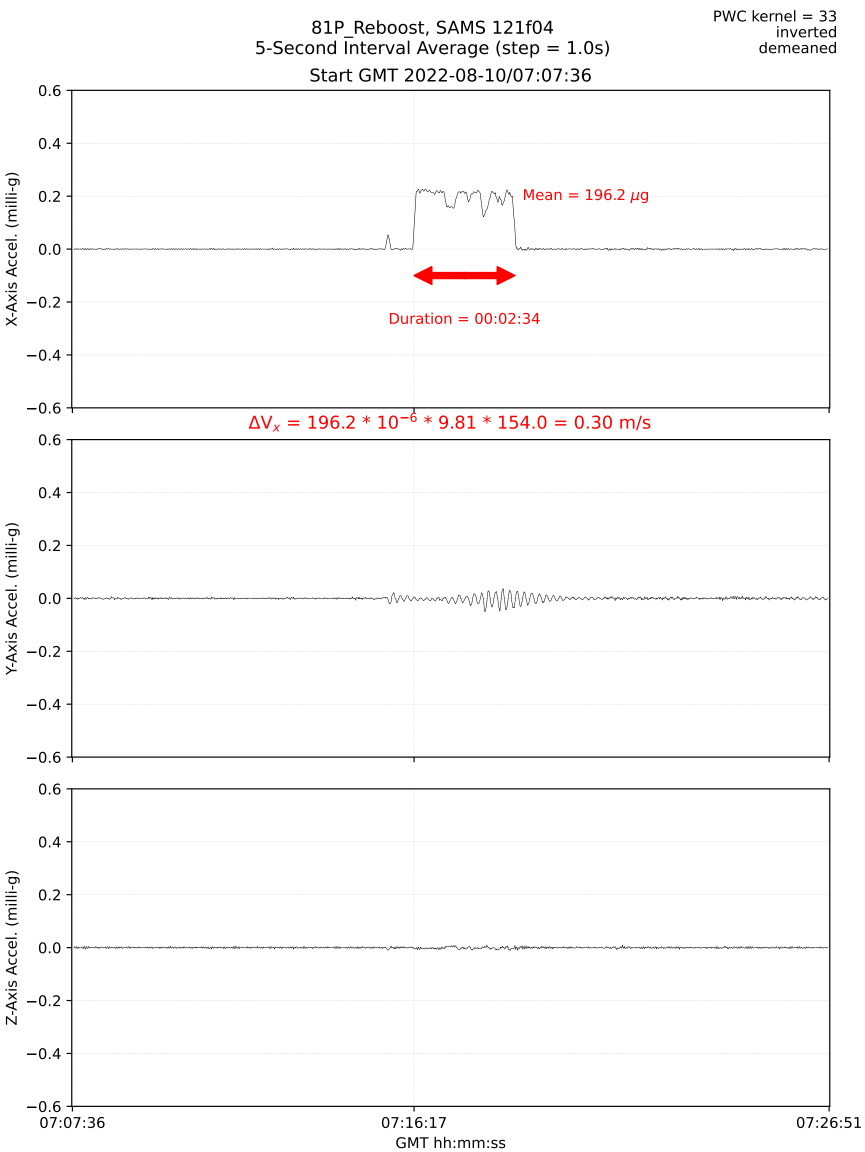


Fig. 4: SAMS 121f04 Cold Atom Lab XYZ vs. Time Plots for (**left**) 6 Hz LPF & (**right**) 200 Hz As-Measured.



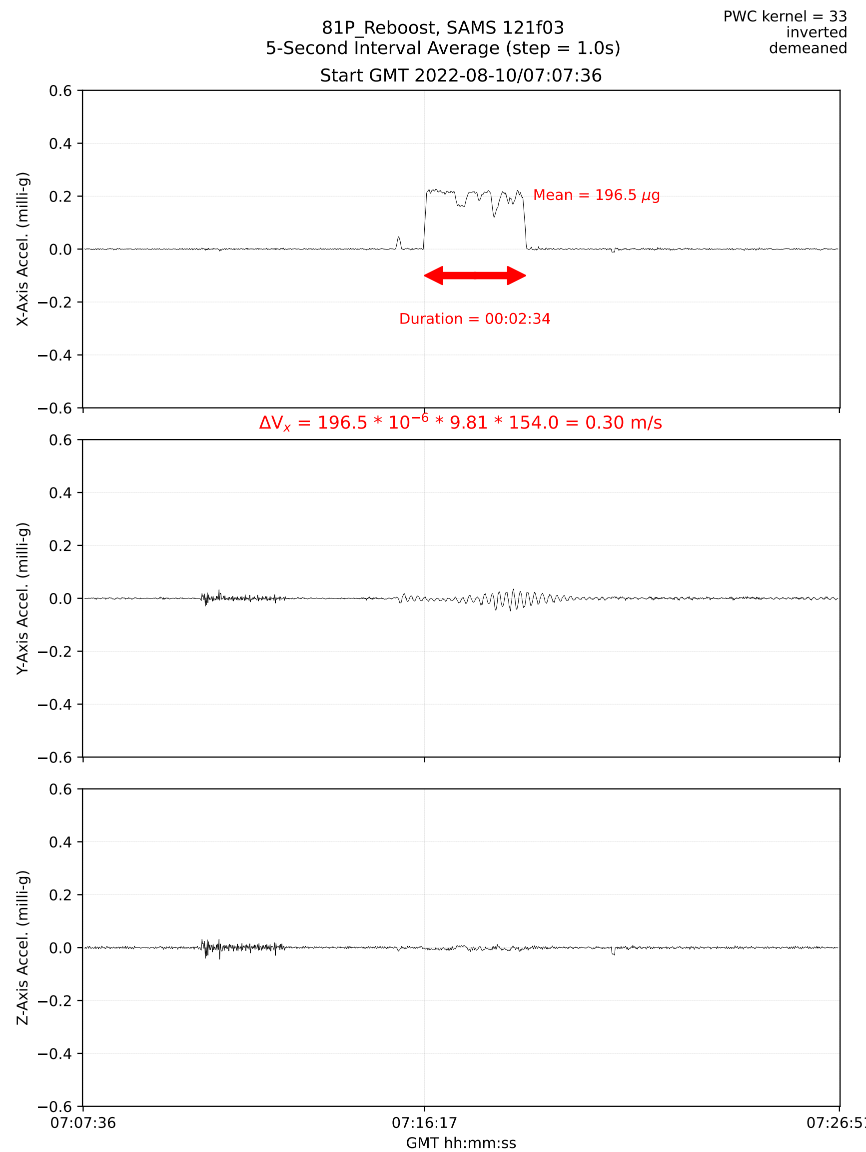


Fig. 5: SAMS 5-Sec, XYZ Interval Average Plots for (**left**) 121f04, Cold Atom Lab at LAB1P2 & (**right**) 121f03, ER-2 at LAB1O1.

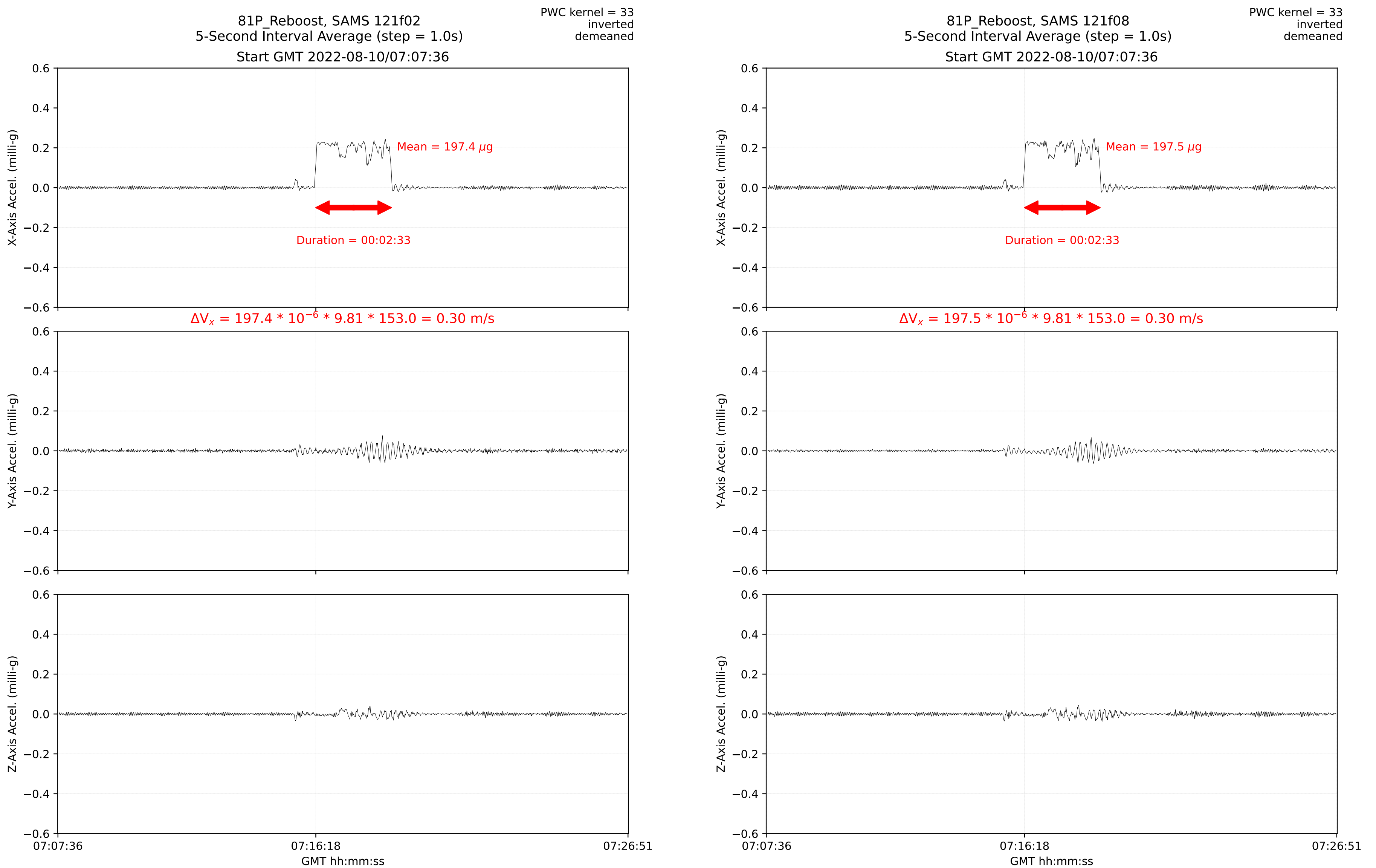


Fig. 6: SAMS 5-Sec, XYZ Interval Average Plots for (**left**) 121f02, ER-3 at COL1A1 & (**right**) 121f08, EPM at COL1A3.

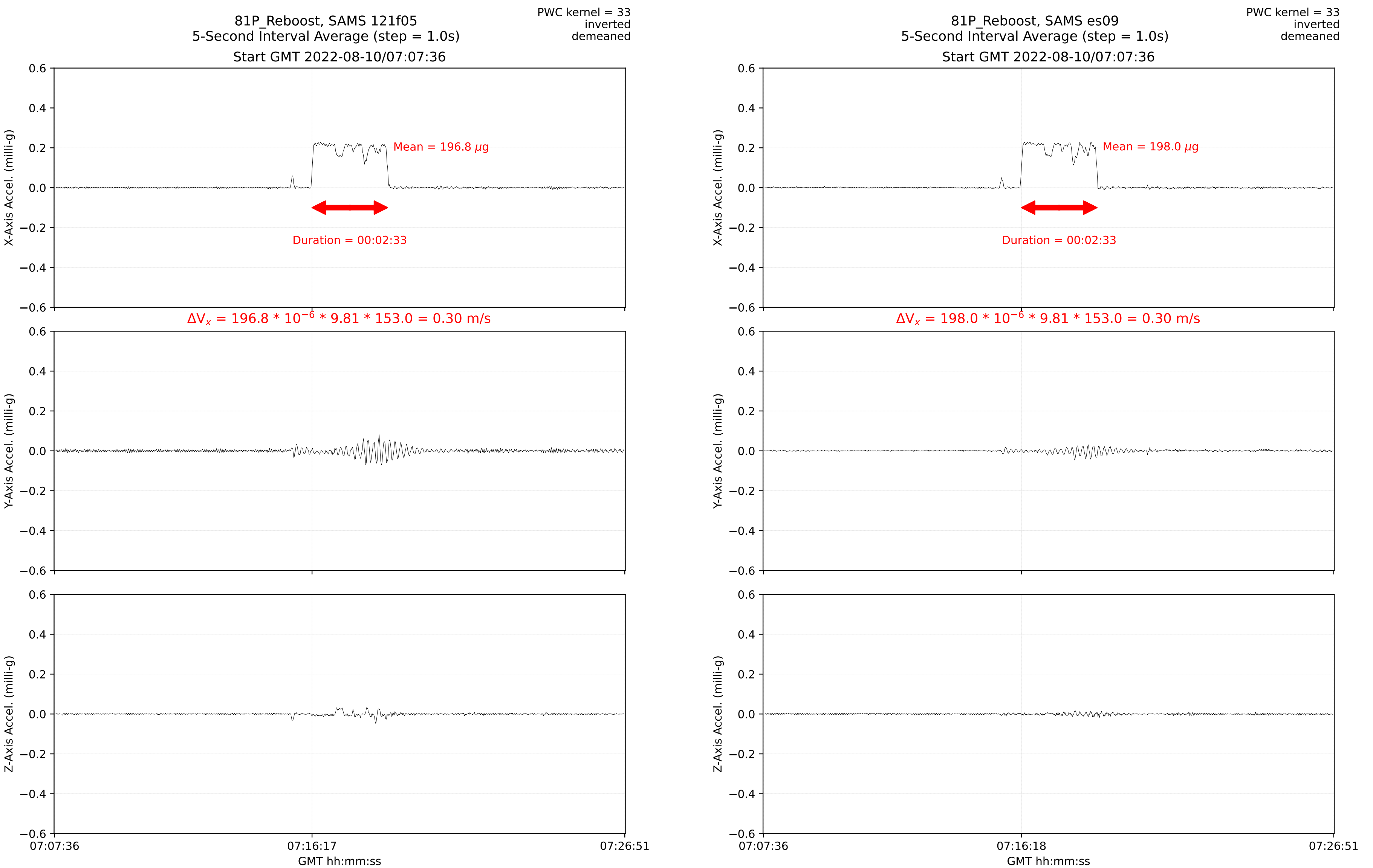


Fig. 7: SAMS 5-Sec, XYZ Interval Average Plots for (**left**) 121f05, ER-5 at JPM1F1 & (**right**) es09, MSG at LAB1S2.

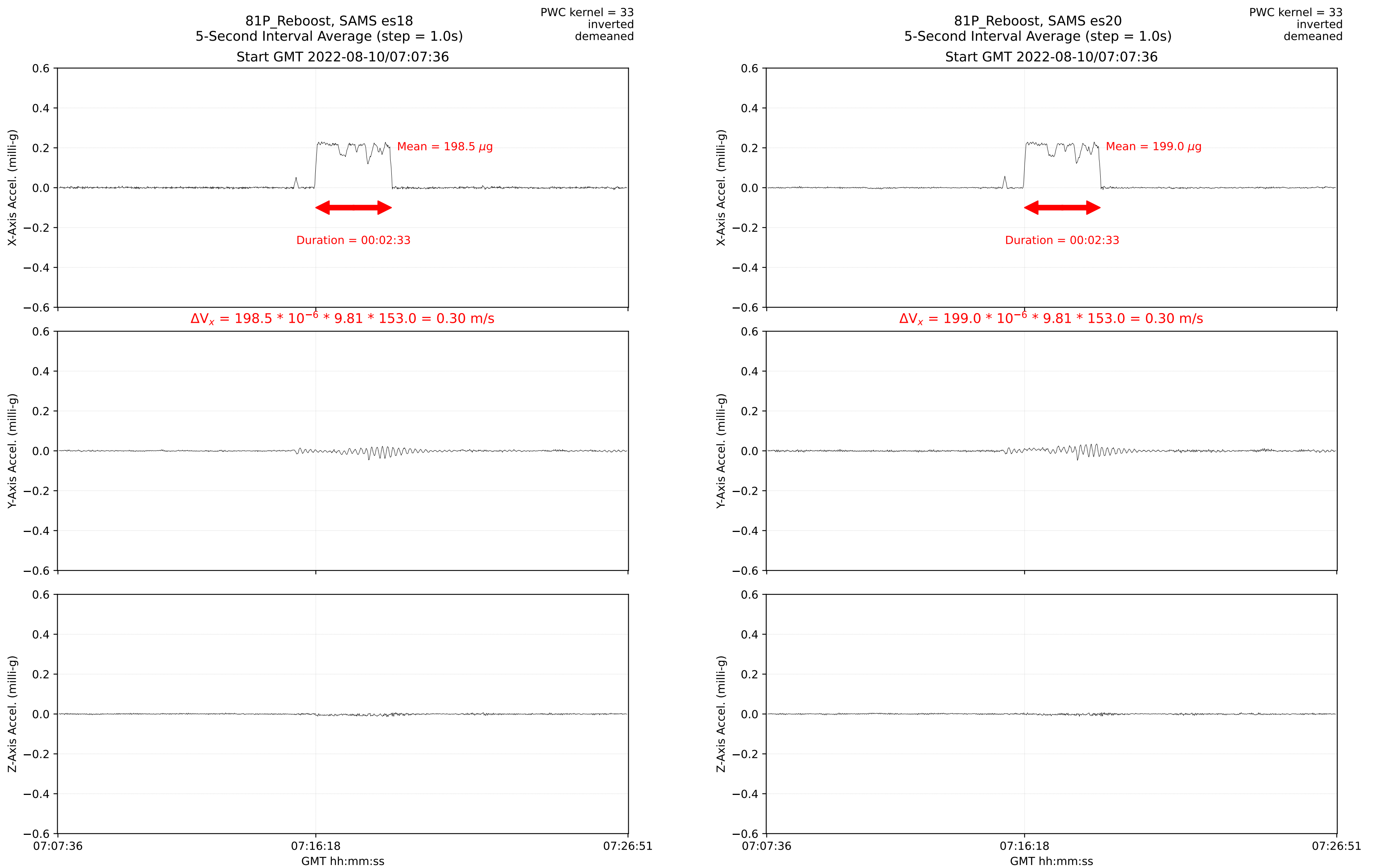


Fig. 8: SAMS 5-Sec, XYZ Interval Average Plots for (**left**) es18, MSRR at ER-6 & (**right**) es20, 4BCO2 at LAB1P4.

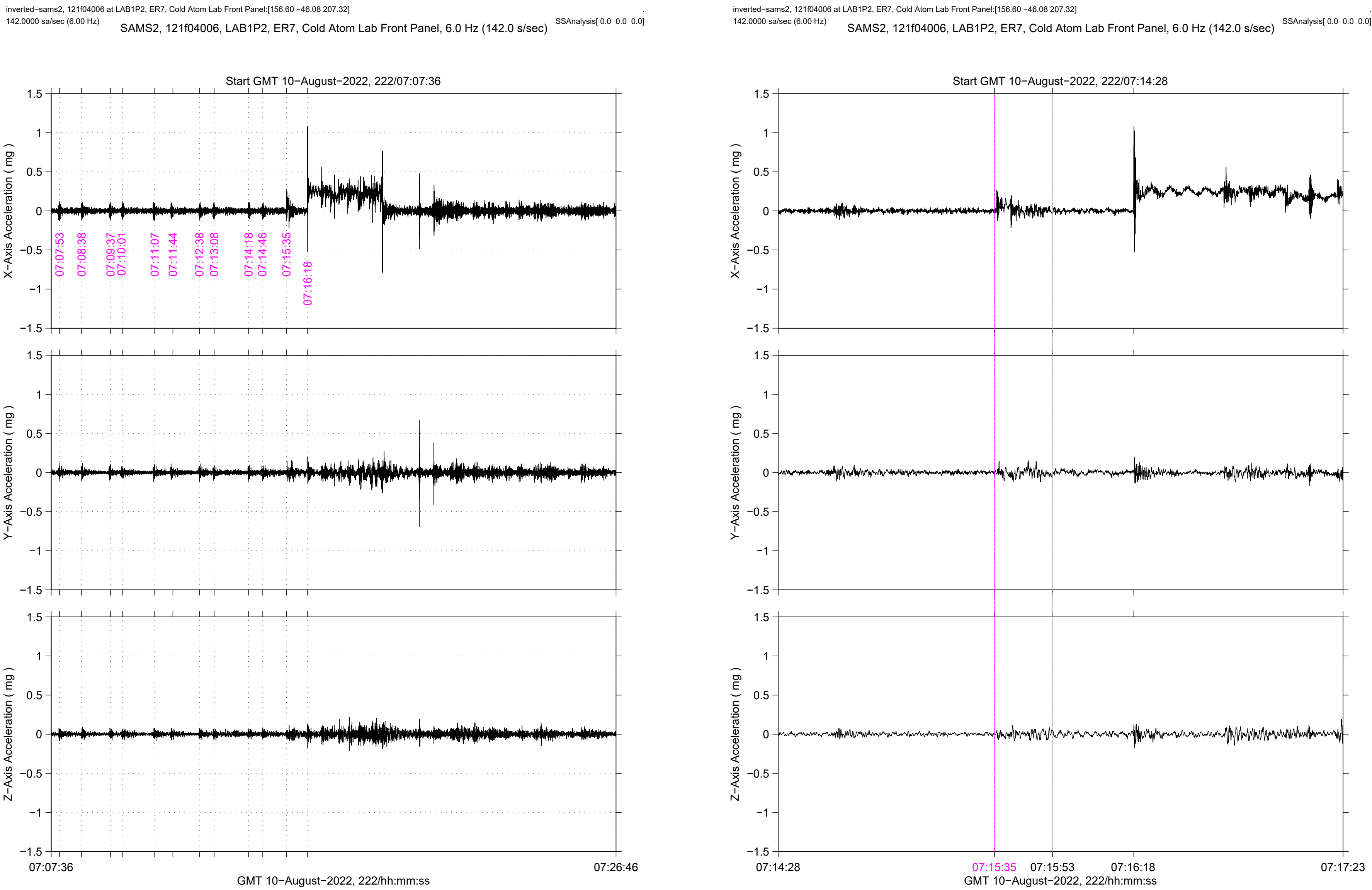


Fig. 9: SAMS 121f04 Accel vs Time for (**left**) about 20-min roughly centered on reboost & (**right**) zoom-in to show “biggie” just before TIG.