1. INTRODUCTION

This Wikipedia page has a section that describes how a cluster of control moment gyroscopes (CMGs) can become saturated resulting in loss of attitude control. It also states that "The only remedy for this loss of control is to desaturate the CMGs by removing the excess angular momentum from the spacecraft. The simplest way of doing this is to use Reaction Control System (RCS) thrusters."

2. QUALIFY

Information supplied by the Attitude Determination and Control Officer (ADCO) indicated thruster firings to desaturate the International Space Station's CMGs occurred on GMT 2020-05-11 from 15:15 to 16:07. The spectral information shown in Figure 1 was computed from SAMS sensor 121f08 measurements made in the Columbus Module (COL) at the time.

Note the train of vertical orange/red streaks in the spectrogram over that span below 2 Hz. These mark structural excitation extending down below 1 Hz where these structural resonances (ringing) are due to the impulsive nature of the desaturation thruster firings. Figure 2 and Figure 3 show similar characteristics from SAMS measurements made in the US Laboratory and the Columbus module, respectively. The structural response was greatest in the Columbus module, followed by the JEM and weakest in the US Lab.

The annotation on Figure 2 also marks a crew exercise period, likely a deviation from the timeline/plan, as it shows up in the data earlier than expected. Notice how the SAMS measurements tracks the pedaling rate of the crew as that rate undulates around 2.5 Hz.

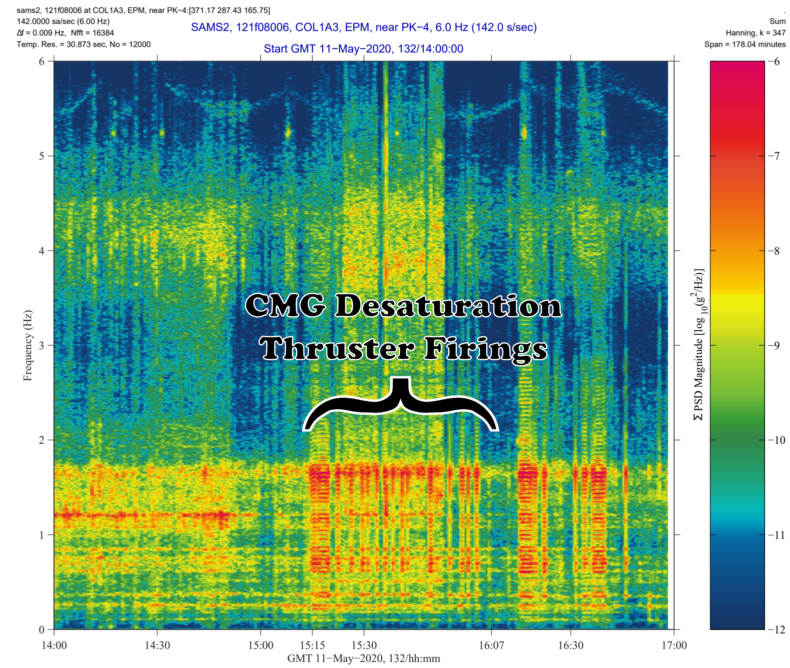

Fig. 1: Spectrogram from SAMS in COL: CMG Desaturation Start GMT 15:15.

3. QUANTIFY

The acceleration vs. time plot of Figure 4 on page 3 shows Space Acceleration Measurement System (SAMS) data recorded in the Columbus (COL) Module during the desaturation event up to a cut-off frequency of 200 Hz. Note that these data are relatively-free of higher-frequency (mostly localized) vibrations near the sensor head's mounting location. You can see this reinforced when you look at Figure 5 where we low-pass filtered these data down to 6 Hz. We did this filtering for direct comparison to other SAMS sensors onboard and located elsewhere. For those other sensor locations, higher-frequency vibrations masked the impact of the desaturation event. The desaturation thruster firing event's impulses are not as clear in the as-measured (non-filtered) data for those other sensor locations. For the SAMS data measured in the US Lab and the JEM, it is only after you filter the data and thus focus more narrowly on the vehicle structural mode regime below 6 Hz, that you see what is shown in Figure 7 on page 4 and in Figure 9 on page 5. Also, we point out that the y-scale in Figure 5 for the Columbus module was selected for direct comparison to corresponding figures for measurements in other parts of the space station, namely Figure 7 for the US Lab and Figure 9 for the JEM.

Okay, now let's zoom-in temporally to get a fine accounting of part of the desaturation thruster firings starting with the Columbus module measurements in Figure 10 on page 6. This figure shows some ringing that begins with the desaturation thruster firing impulse just before GMT 15:36:30, and has impact over several seconds as a vehicle structural mode rings-out and decays over that span.

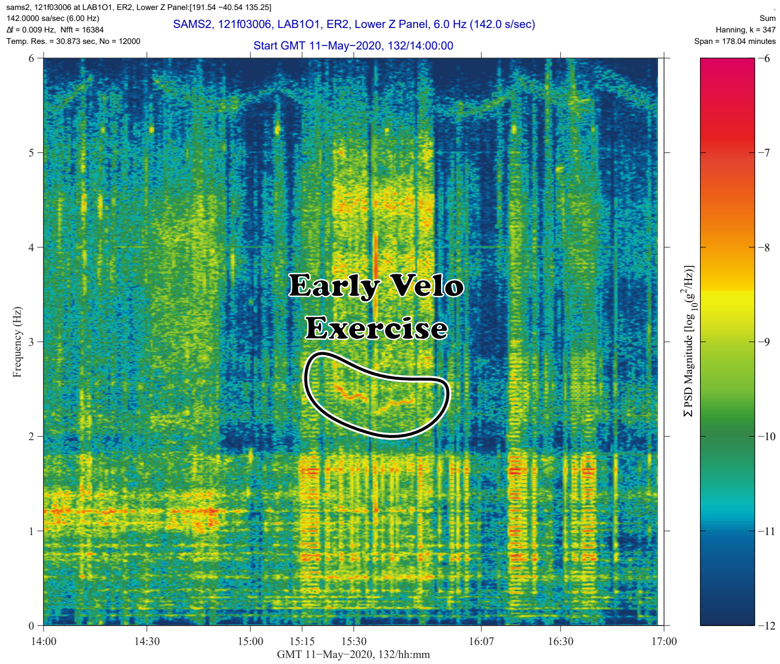

Fig. 2: Spectrogram from SAMS in LAB: CMG Desaturation Start GMT 15:15.

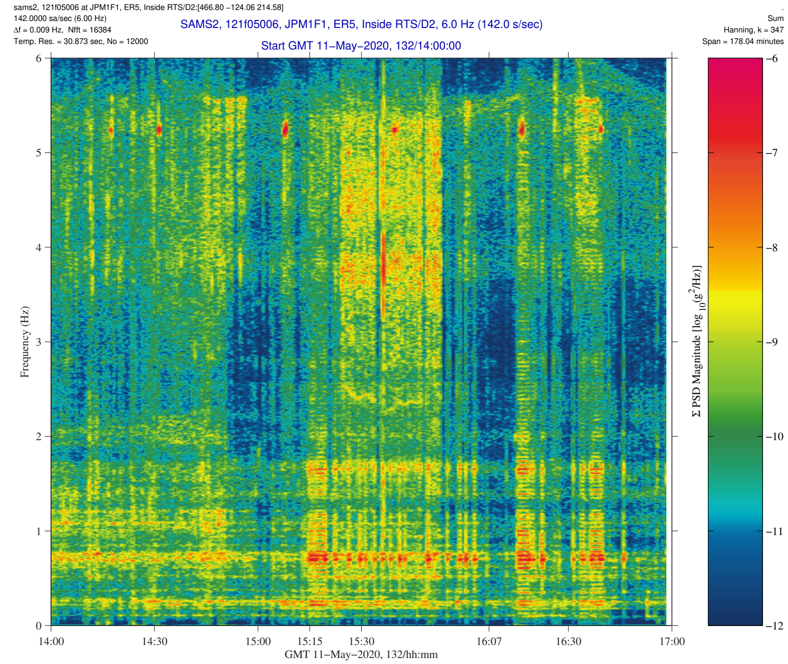

Fig. 3: Spectrogram from SAMS in JEM: CMG Desaturation Start GMT 15:15.

Figure 11 on page 7 shows similar (not same) characteristics in the US Lab (most notably on the Y-axis), and Figure 12 on page 8 does likewise for measurements in the JEM.

4. CONCLUSION

The three SAMS sensors used for analysis here all registered the CMG desaturation thruster firing event, but to differing degrees and with slightly different characteristics ostensibly due to geometry and the fact that the ISS is not a rigid body. Furthermore, it was shown the as-measured (200 Hz) data can significantly hamper detection of this event without first low-pass filtering the data (except perhaps in the Columbus module where the SAMS sensor mounting location was not dominated by higher-frequency ambient vibratory disturbances). For this desat event on GMT 2020-05-11 when considering the structural mode regime (below 6 Hz), the largest excursion appeared on the X-axis for the SAMS sensor (121f08) in the Columbus module, with ringing peak-to-peak value of no more than 2.7 mg.

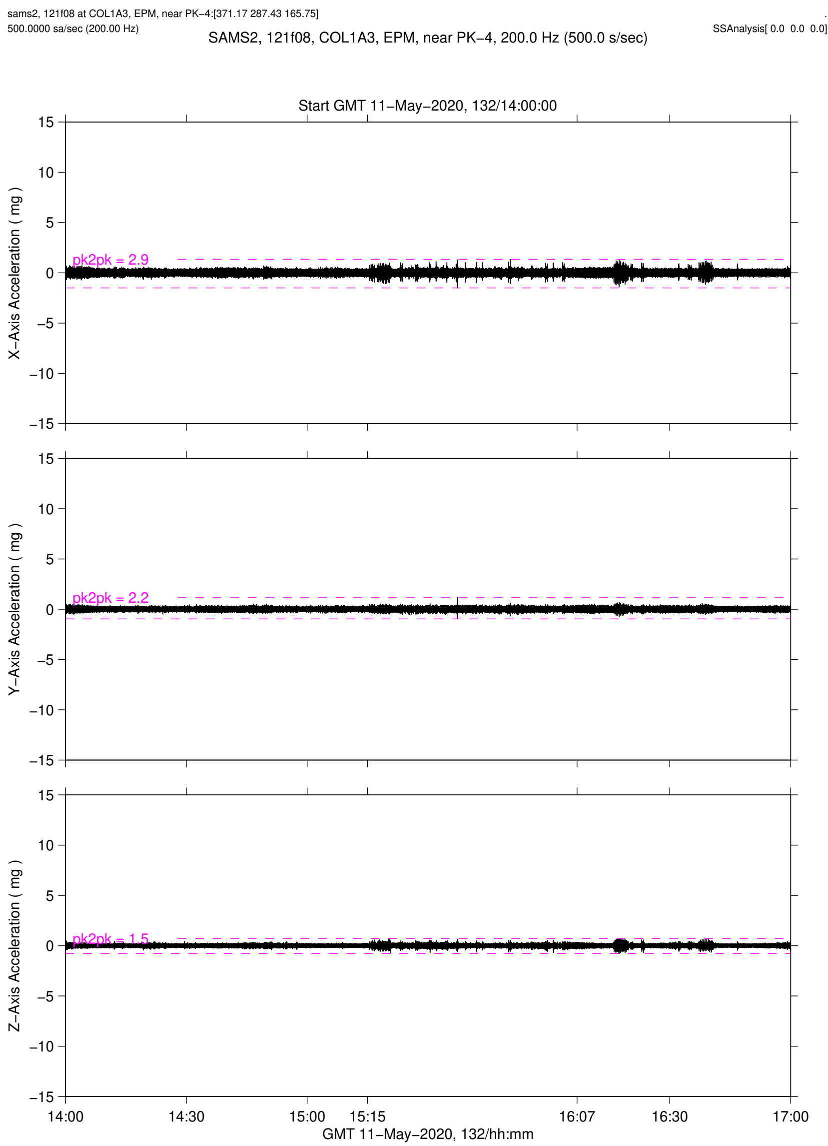

Fig. 4: SAMS COL 121f08 acceleration data (up to 200 Hz) for desat firings.

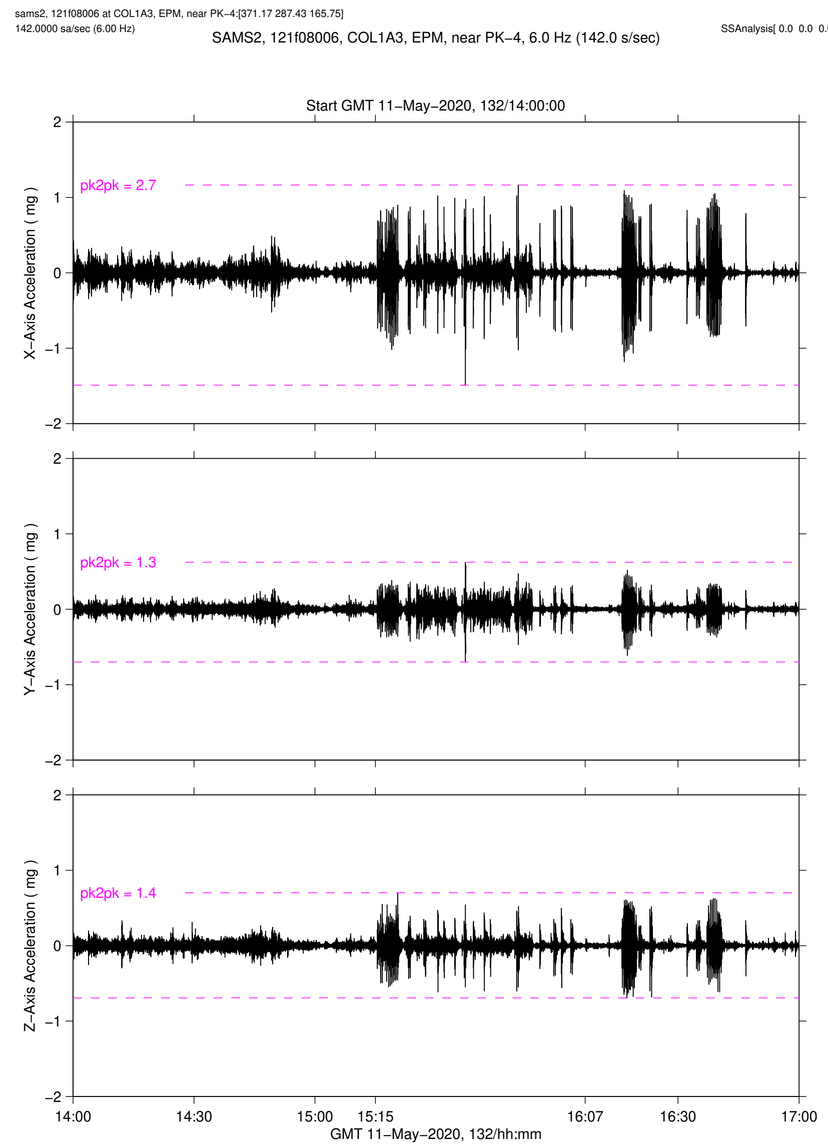

Fig. 5: SAMS COL 121f08 acceleration data (f < 6 Hz) for desat firings.

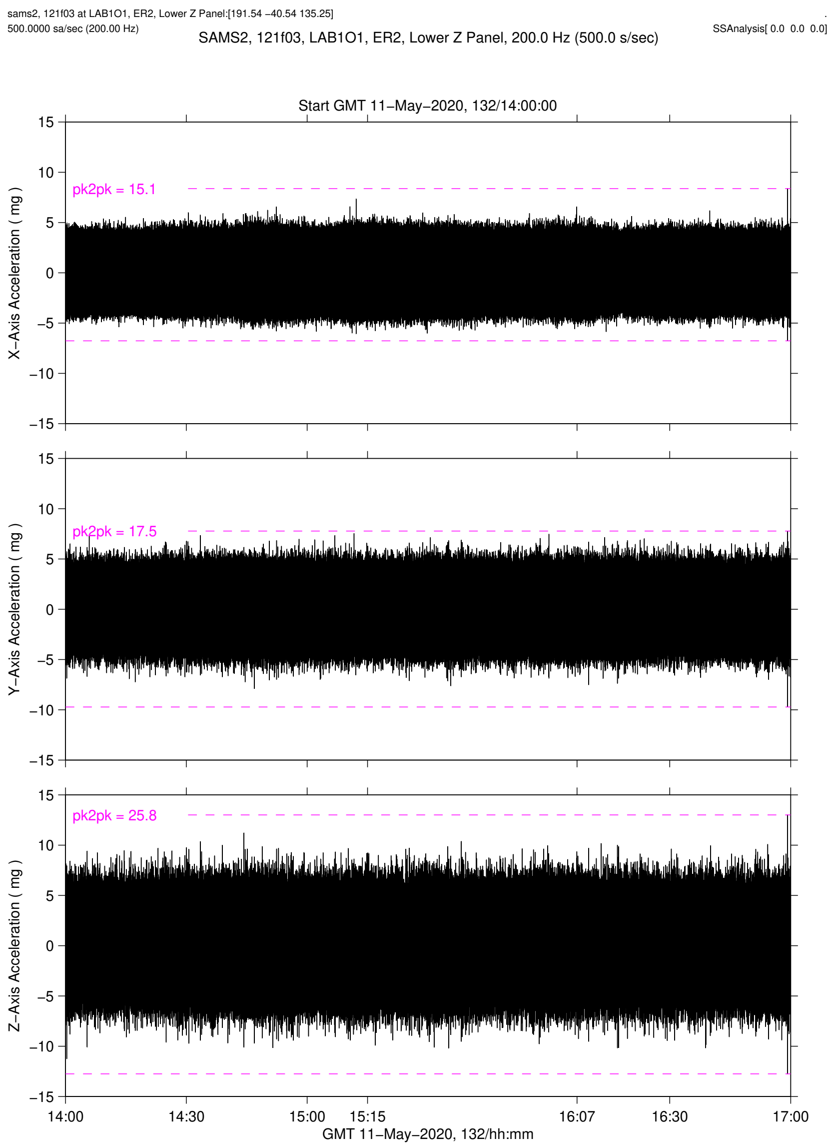

Fig. 6: SAMS LAB 121f03 acceleration data (up to 200 Hz) for desat firings.

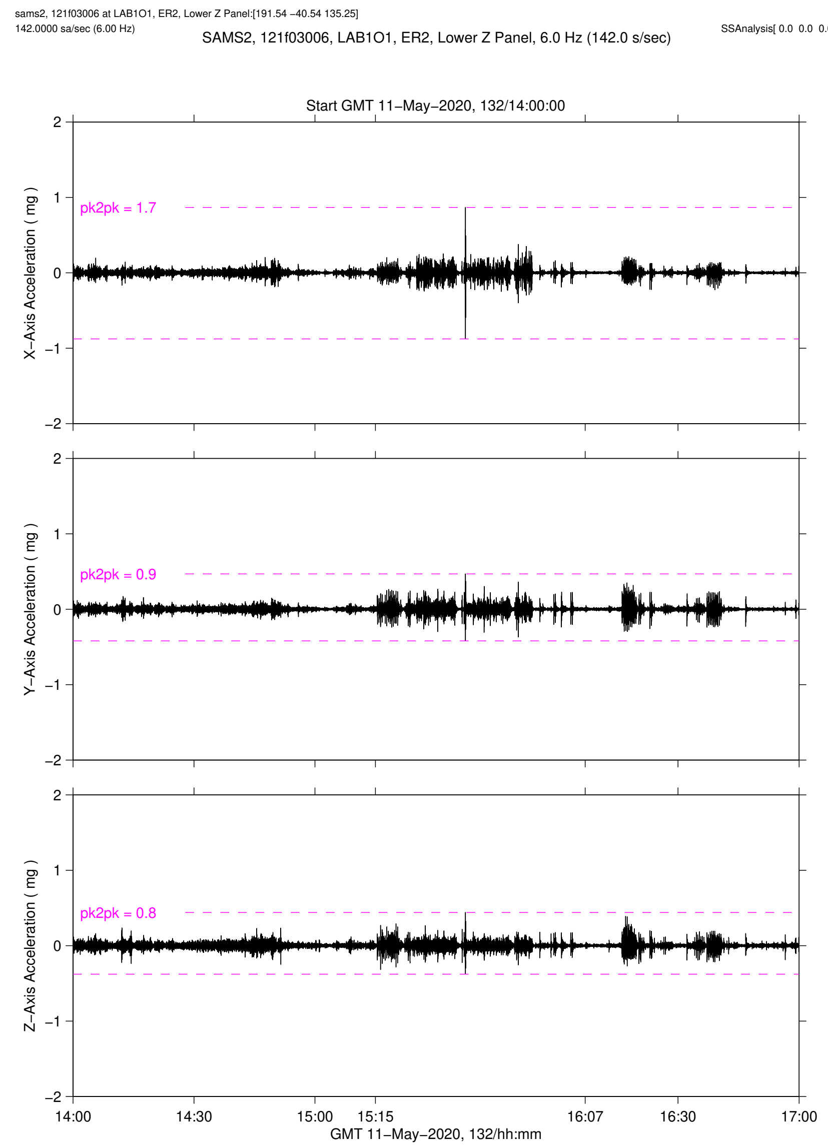

Fig. 7: SAMS LAB 121f03 acceleration data (f < 6 Hz) for desat firings.

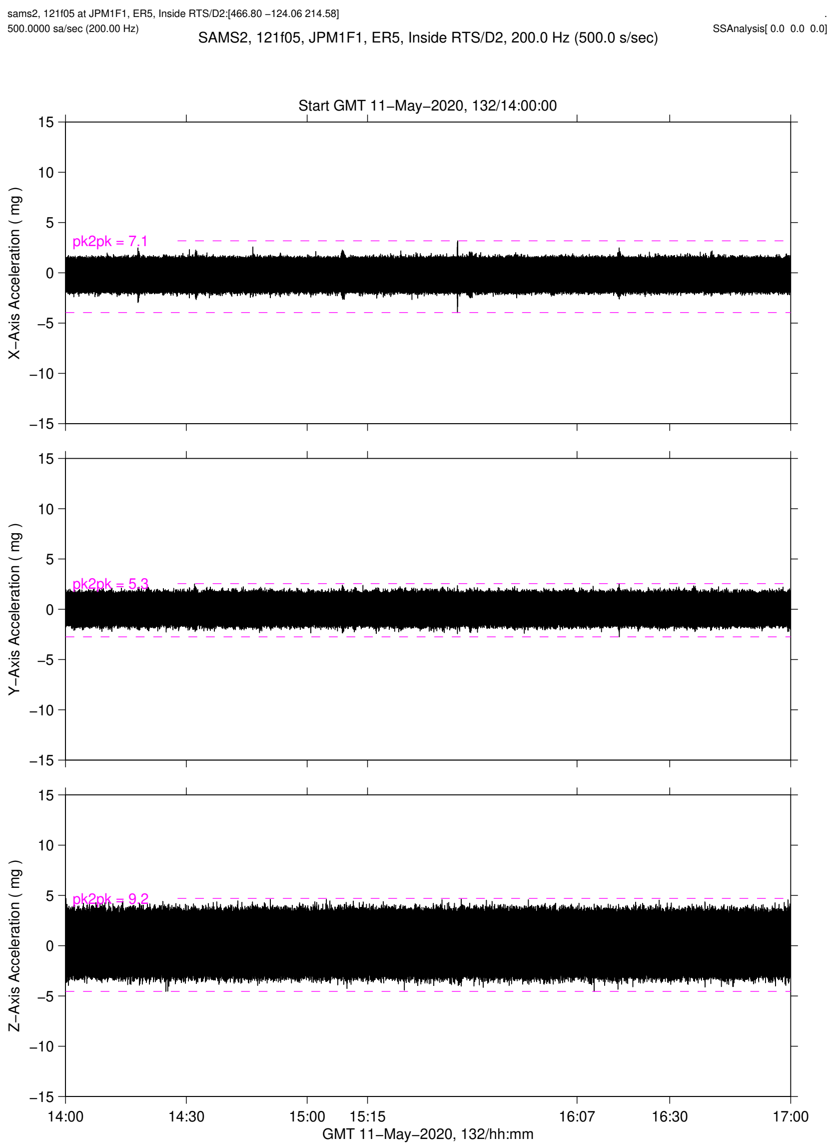

Fig. 8: SAMS JEM 121f05 acceleration data (up to 200 Hz) for desat firings.

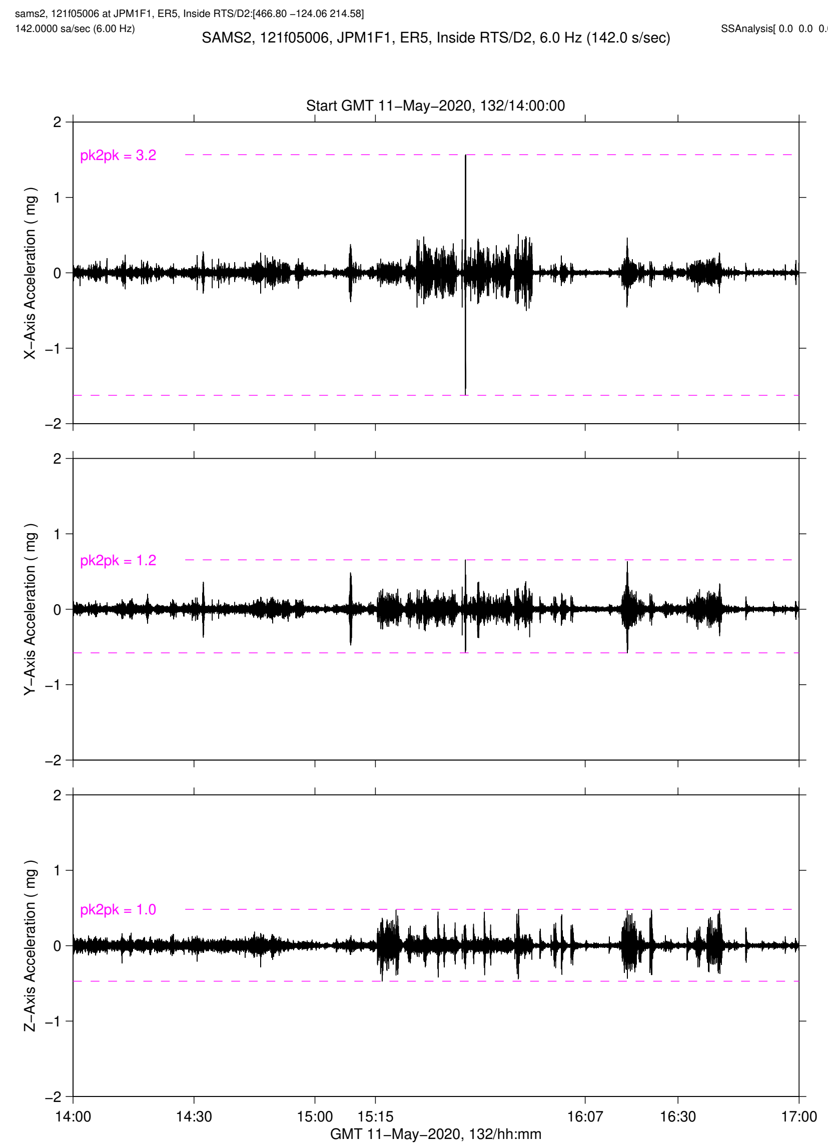

Fig. 9: SAMS JEM 121f05 acceleration data (f < 6 Hz) for desat firings.

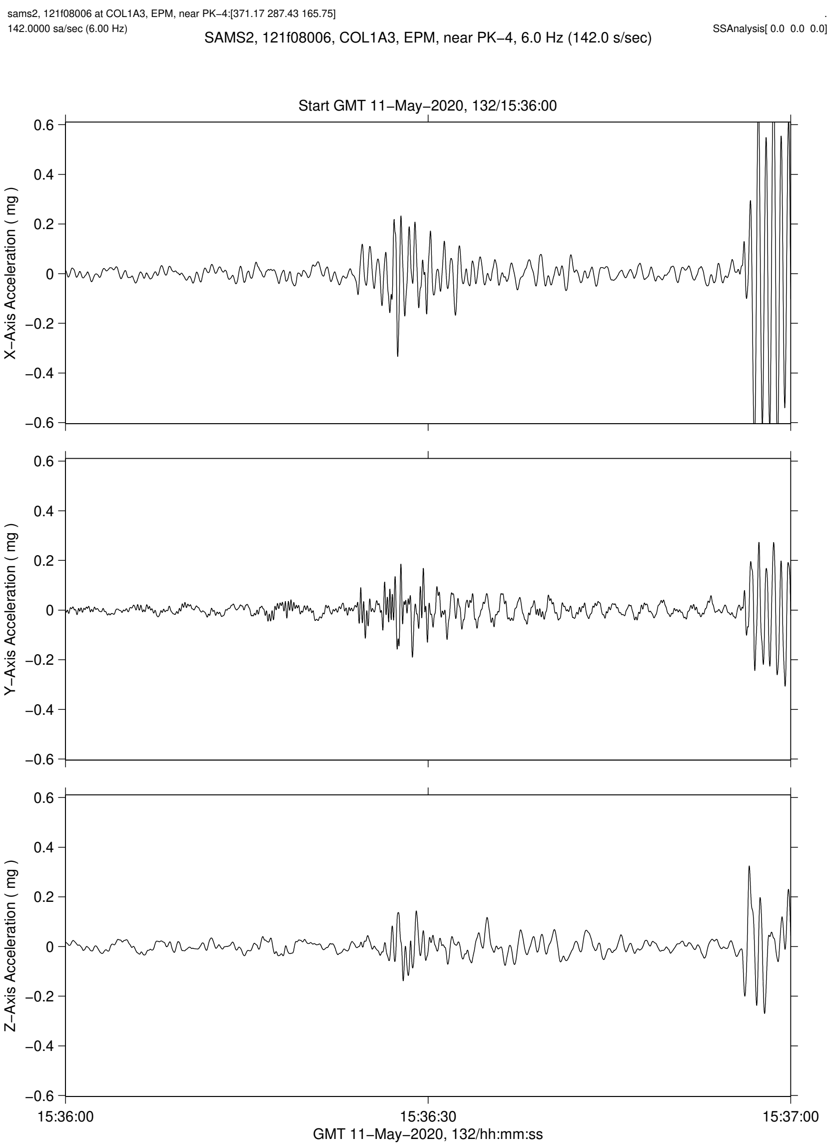

Fig. 10: SAMS COL 121f08 acceleration data (f < 6 Hz) for desat firing zoom.

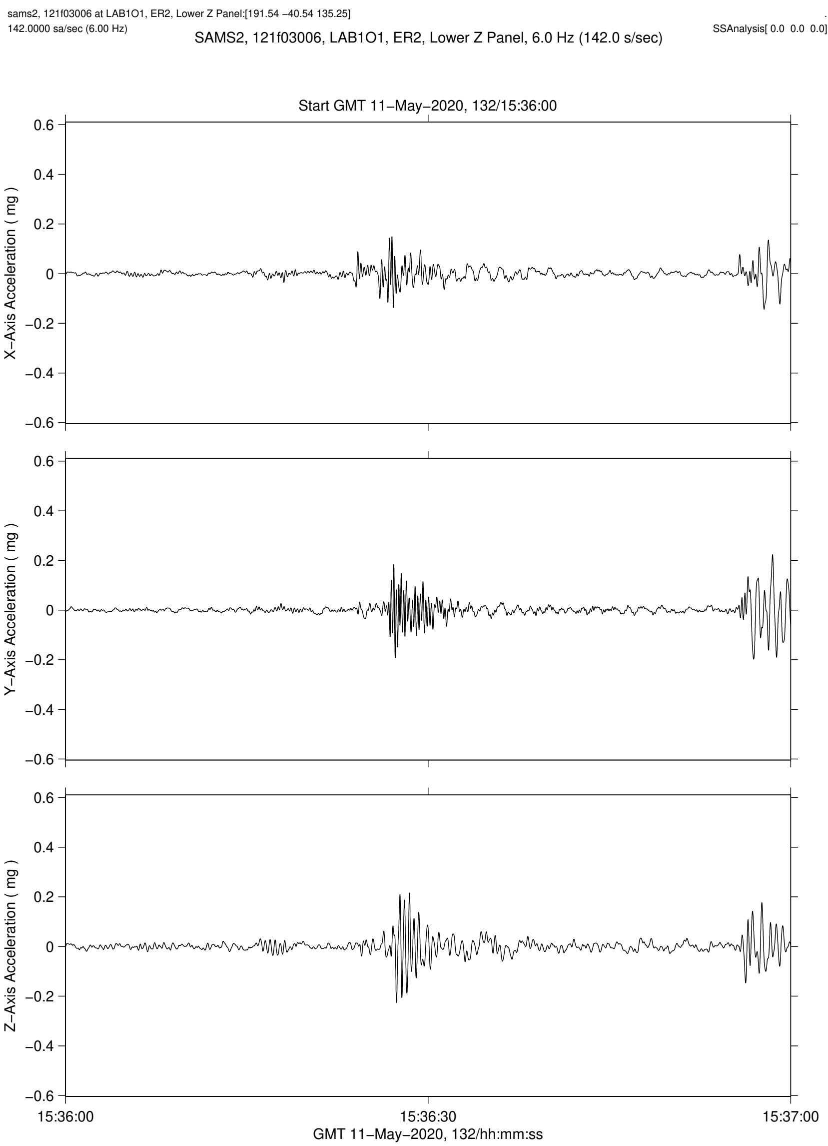

Fig. 11: SAMS LAB 121f03 acceleration data (f < 6 Hz) for desat firing zoom.

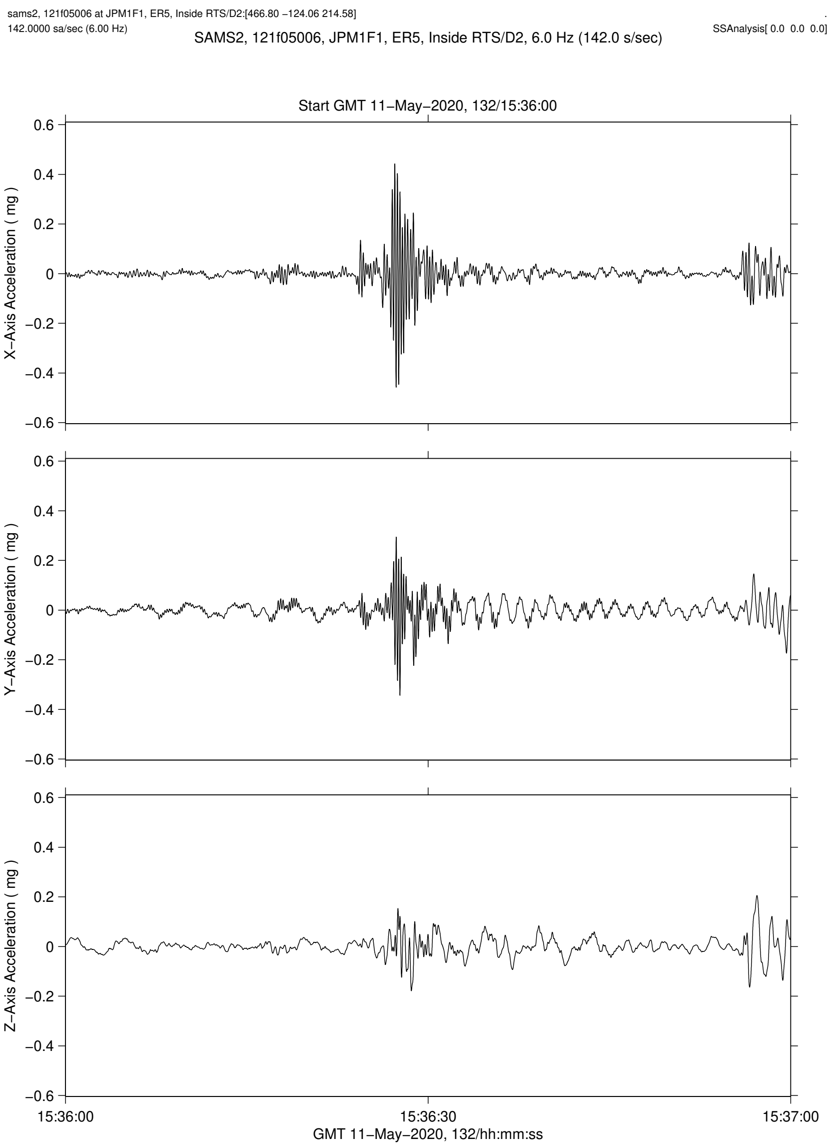

Fig. 12: SAMS JEM 121f05 acceleration data (f < 6 Hz) for desat firing zoom.