1. INTRODUCTION

An Optimized Propelland Maneuver (OPM) is used to perform flight attitude maneuvers of the International Space Station (ISS) using less propellant compared to traditional ISS flight software. The savings are achieved by commanding the ISS to follow a pre-planned attitude trajectory, which was optimized to take advantage of naturally occurring environmental torques and available control authority from the thrusters. The trajectory was obtained by solving an optimal control problem that did not require any modifications to flight software. This approach is reported to be applicable to any spacecraft controlled with thrusters.

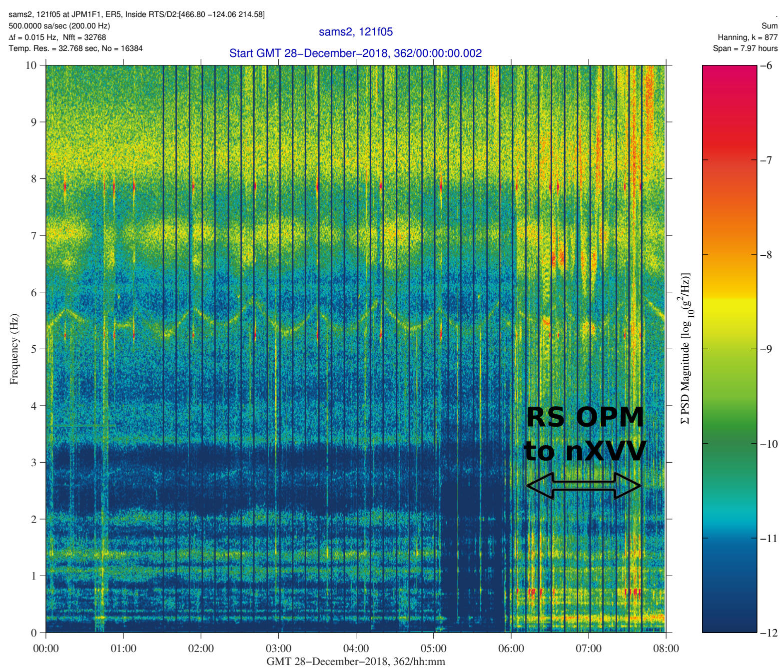

Fig. 1: Spectrogram showing RS OPM to -XVV on GMT 2018-12-28.

2. QUALIFY

Figure 1 is a color spectrogram computed from Space Acceleration Measurement System (SAMS) sensor 121f05 measurements made in the Japanese Experiment Module (JEM). The arrow annotation shows a 90-minute span for the first of two OPMs over the course of 2 days. This first was a maneuver from +X-axis in Velocity Vector (+XVV) to –X-axis in Velocity Vector (–XVV) flight attitude on GMT 2018-12-28. It was performed by the Russian Segment just after a maneuver to the -XVV OPM starting attitude. The ISS GN&C was in +XVV momentum management prior to, then transitioned to RS control to perform this maneuver. Ultimately, the ISS was transitioned back to the momentum manager to maintain -XVV attitude after the maneuver. The initial and final Local Vertical Local Horizontal (LVLH) attitudes were [+356.0, +359.5, +0.7] degrees and [+177, +359.8, +0.7] degrees (YPR order), respectively.

The second OPM involved a maneuver from –XVV to +XVV flight attitude the next day, GMT 2018-12-29. The ISS GN&C would be in -XVV momentum management, then transition to RS control to perform the maneuver and then ultimately transition back into the +XVV momentum manager. The initial and final Local Vertical Local Horizontal (LVLH) attitudes were [+177, +359.8, +0.7] degrees and [+356.0, +359.5, +0.7] degrees (YPR order), respectively. The RS OPM to +XVV duration was also 90 minutes.

3. QUANTIFY

The Microgravity Acceleraion Measurement System (MAMS) would have been the instrument to best measure these OPMs in terms of quasi-steady acceleration events. However, the MAMS was out of service during these events, so here we take a look at low-pass filtered SAMS data in an attempt to quantify these quasi-steady events. For an OPM reference using MAMS data in 2012, see the handbook page at this link. In particular, page 4 shows a high-fidelity rendering via MAMS measurements of a low-frequency, low-magnitude OPM from +XVV to -XVV using US thrusters at that time. Also, page 5 shows a an OPM from -XVV to +XVV. Note there the bipolar swing of about 4 μg peak-to-peak on the Y-axis while at the same time a step on the X-axis of just under 1 μg.

RS OPM to -XVV on GMT 2018-12-28

Figure 2 on page 2 shows a 60-second interval average versus time computed from low-pass filtered SAMS sensor 121f05 measurements made in the Japanese

Experiment Module (JEM) on GMT 2018-12-28. Between GMT 06:10 and 07:40, we clearly see the bipolar signature again of about 4 μg peak-to-peak, this time on the X-axis. We also observe a step (offset) of about 2 μg on the X-axis, albeit this step's return to baseline was not evident. Instead, on the Y-axis of Figure 2 we note a slow drift upward starting at GMT 07:40 when we would otherwise expect the signal to return and settle back down near zero after the step. SAMS was designed for vibratory measurement and, as a result, temperature dependency can dominate at low frequencies. This accounts for the mismatch between the 2012 MAMS data and the 2018 SAMS data for OPMs.

RS OPM Back to +XVV on GMT 2018-12-29

Figure 3 on page 3 shows a 60-second interval average versus time computed from low-pass filtered SAMS sensor 121f03 measurements made in the US LAB on GMT 2018-12-29. Between GMT 06:25 and 08:25, we again see the bipolar signature of about 4 μg peak-to-peak on the Y-axis. At the same time, we see what appears to be a step on the X-axis in that same span, however, the data is obscured by a large drift as the signal swings negative off the bottom of the plot.

At the same time, figure 4 on page 3 shows a 60-second interval average versus time computed from low-pass filtered SAMS sensor 121f08 measurements made in the Columbus module (COL) on GMT 2018-12-29. Between GMT 06:25 and 08:25, we see the bipolar signature of about 8 μg peak-to-peak on the Y-axis. At the same time, we see what appears to be a step on the X-axis in that same span, however, the data is obscured by a large drift as the signal swings negative off the bottom of the plot.

4. CONCLUSION

SAMS vibratory sensors cannot fully characterize the low-frequency, low-magnitude impact of OPMs due to transducer temperature dependency. The reader is redirected to see the MAMS data in this link for a better characterization in this low-frequency regime.

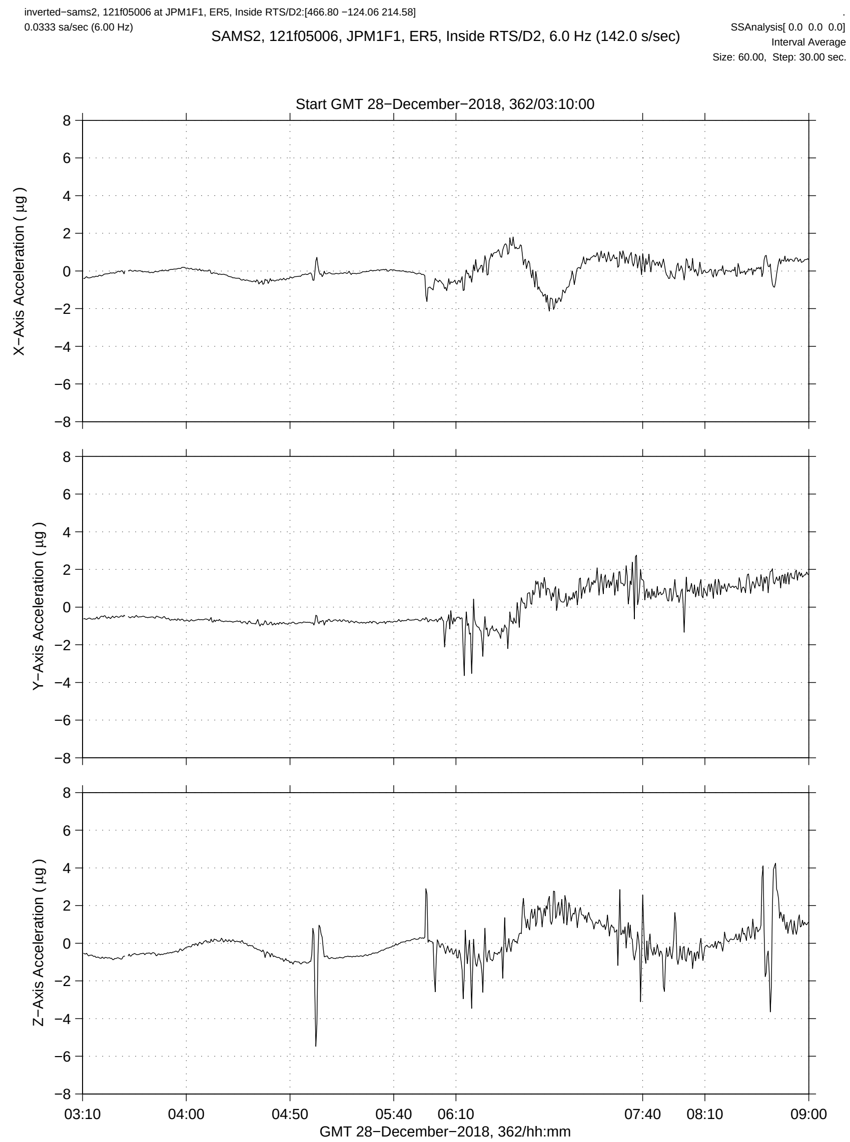

Fig. 2: 60-sec. interval average (121f05) for OPM to -XVV on GMT 2018-12-28.

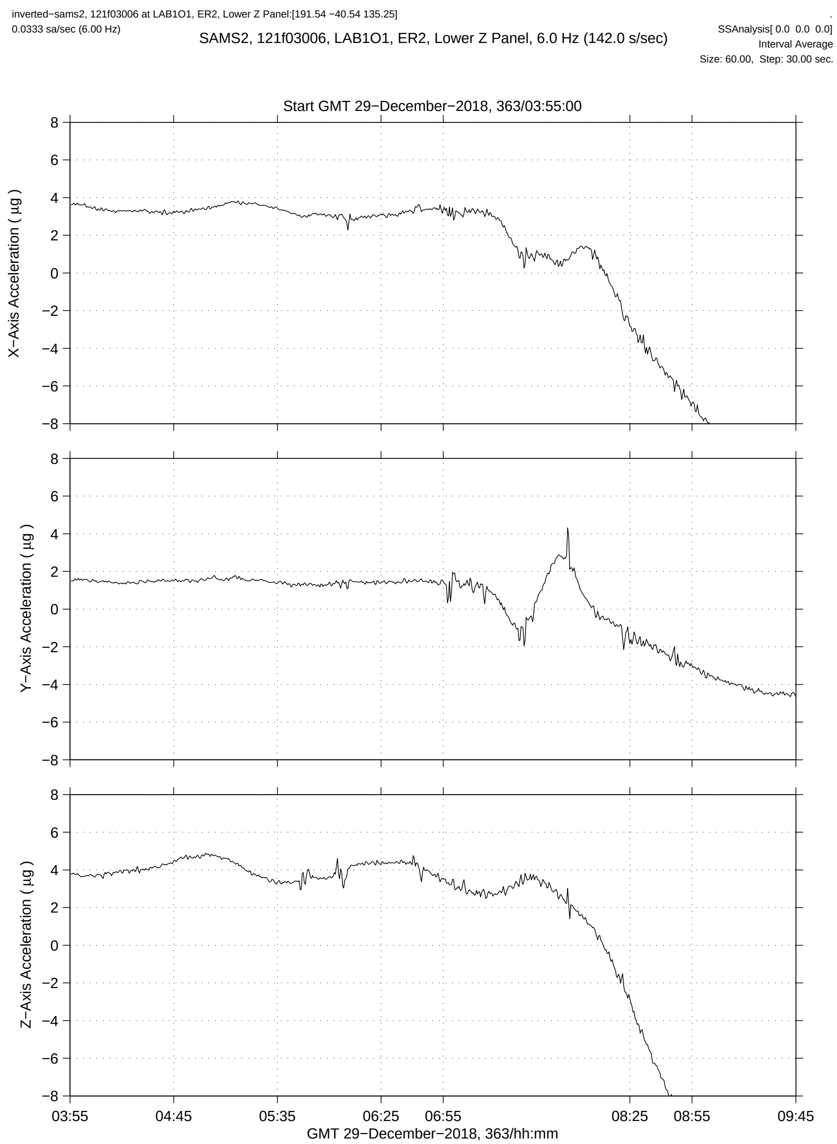

Fig. 3: 60-sec. interval average (121f03) for OPM to +XVV on GMT 2018-12-29.

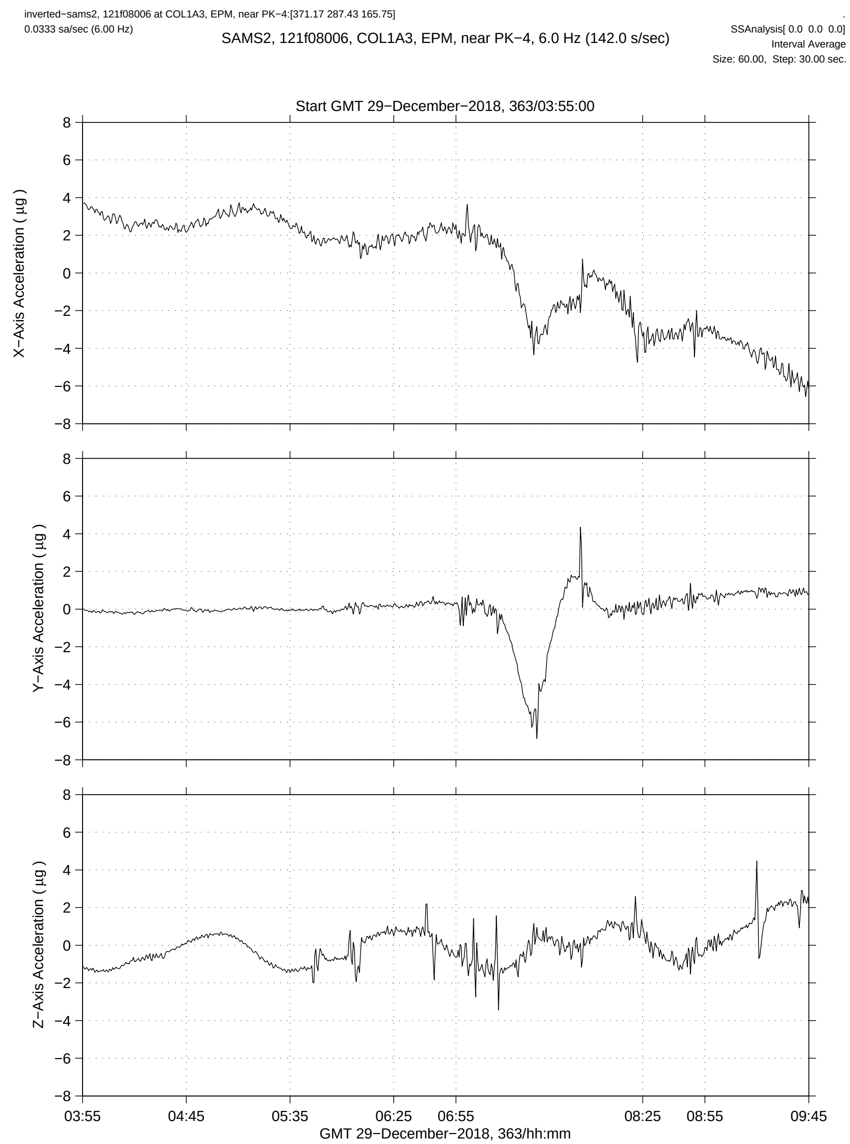

Fig. 4: 60-sec. interval average (121f08) for OPM to +XVV on GMT 2018-12-29.