1. INTRODUCTION

This document serves as a high-level summary of the local vibratory environment as measured by a Space Acceleration Measurement System (SAMS) sensor head mounted on the Materials Science Research Rack (MSRR) – rack location LAB1O3 of the US Laboratory of the International Space Station (ISS). The focus here is on a test period that took place on GMT 2021-07-22, which was intended to record and help characterize representative activities by the crew operating the KEyence Research MIcroscope Testbed (KERMIT) in the MSRR while the SAMS Triaxial Sensor Head - Ethernet Standalone (TSH-ES S/N 18) was mounted on the seat track of the MSRR near the base of the KERMIT.

2. QUALIFY

Figure 1 on page 3 is an 8-hour color spectrogram computed from measurements made by SAMS before, during, and after the KERMIT Operations test period from GMT 2021-07-22/08:30 to about 13:15. The black arrows in this figure are bounded in time (left/right) by 2 SAMS sensor relocation activities performed by the crew. Typically, for a SAMS sensor move, the SAMS equipment is powered off, but since no cable connections needed to be changed, these moves were done with the SAMS sensor continuously powered. The two sensor moves were: (1) from the lower part of the seat track of the MSRR to just below the KERMIT, and (2) from the KERMIT location to the seat track of the rack adjacent to the MSRR, that is, EXPRESS Rack 6 (ER6) at rack location LAB1O4 of the US Laboratory.

Figure 2 on page 4 is a 5-hour color spectrogram computed from measurements made by SAMS, but just during the KERMIT Ops test period from GMT 2021-07-22/08:38 to about 13:13. This is the period when the sensor was located near KERMIT. Using this overview spectrogram serving as a roadmap, there are several features that become evident across time and frequency that can be further pursued, but for this overview document, we will discuss a few as annotated in Figure 3 on page 5.

Figure 3 shows 2 zoom-in regions taken from Figure 2. The inset in the upper right shows the start of a strong, narrowband trace initially at about 199.8 Hz (steady-state at about 200.4 Hz) and this starts during KERMIT ops at about GMT 12:09:30. The blue ticks are frequency in Hertz, and the purple ticks are GMT hour:minute. The lower left portion of Figure 3 shows several more features during the KERMIT ops test period as described below.

Numbered Annotations in Figure 3 on Page 5:

1) The start of just one in a series of narrowband 41 Hz peaks that turn on/off (mostly off). This is likely the cycling of Thermal Amine Equipment.
2) The start at about GMT 08:57:18 (near the end of "Configure KERMIT") of a nearly continuous ON narrowband spectral peak just at 40 Hz or so that continues during KERMIT ops. This disturbance cycles OFF a few times, the first OFF from GMT 09:24:41 to about GMT 09:26:47. This disturbance finally turns OFF for good at about GMT 13:09:53. This is most likely KERMIT-associated equipment as it correlates well with time hacks from the KERMIT ops test period activities.
3) The first, 2-minute OFF period of narrwoband twin peaks at just about 40 Hz.
4) **[White arrows, white numeral] A set of 6 regularly-time-spaced, impulsive (vertical streaks) marked by six tightly-packed white arrows that seem to correlate with the KERMIT ops timeline entry for "images taken of Slide 8 using 6 different lenses".** The SAMS data show these impulses were like clockwork, precisely a minute apart, and the first of six starting at GMT 09:46:30.
5) Second, brief OFF period of the narrowband twin peaks at just about 40 Hz.
6) A strong, narrowband peak at about 24 Hz turns OFF at about GMT 10:52:41. This is likely the cycling off of a Russian air conditioner.
7) A strong, narrowband (unknown) disturbance at about 200 Hz that started at about GMT 12:09:30. This time was roughly midway through the KERMIT ops timeline entry for "moves to image 48 wells".

3. QUANTIFY

As an initial attempt to quantify the vibratory environment in the frequency domain during ALL of the KERMIT ops, Figure 4 shows each axis' acceleration power spectral density (PSD) for the entirety of the approximately 5-hour period. In general, long-duration PSDs such as these have limits to their usefulness in that peaks that are not always on (or not at the same magnitude) get their magnitude misrepresented in the inherent spectral averaging over time. The overwhelming distinction here though does show that the X-axis is dominated by a narrowband disturbance at about 145 Hz. The Y- and Z-axis also carry the 145 Hz peak, but to a much smaller degree.

Another attempt to quantify the vibration environment during KERMIT ops is shown in 2 figures, side-by-side starting with Figure 5 on page 7 on the left side, and

Figure 6 on the right. The figure on the left shows **as-measured data up to 204.2 Hz with vertical-scale limits of 200 milli-g**. Note the thick, black envelope for the X-axis is mostly attributed to the narrowband vibrations at 145 Hz as the PSD had shown previously. Figure 6 on the right is a **100 Hz** low-pass-filtered rendition of the as-measured data with vertical-scale **limits of 60 milli-g**. Here we again, and more clearly see the set of 6 regularly-time-spaced, impulsive accelerations, the first starting at GMT 09:46:30 associated with "images taken of Slide 8 using 6 different lenses". One of the largest excursions came during a span when KERMIT was "moving among 48 wells (one lens and filter for each)" at about GMT 12:13:40.

To compare and emphasize the impact of the 145 Hz disturbance, the 2 figures shown side-by-side on page 7 are overlayed in Figure 7 on page 8, with the 204.2 Hz data in black, and the 100 Hz (low-pass filtered) data in red. Note that some impulsive peaks on the X-axis only become evident after filtering such as done here. Those otherwise get swamped by the 145 Hz vibrations, particularly on the X-axis. Also, the values shown in Table 1 on page 8 are per-axis acceleration magnitude percentile values in milli-g for the test period during KERMIT ops.

KERMIT Operations Timeline

Figure 8 on page 9 shows a crude quantification/comparison of interval RMS acceleration values (below 100 Hz) across the entirety of the KERMIT ops test period. It suggests that activities like installing well plate, handling sample holder and moves to wells can bring large impulsive accelerations near the KERMIT location. For details that accompany each color-shaded section on this figure, see the 3 pages that follow, starting on page 10.

Three SAMS Sensor Locations

While the objective up to this point in this document was to characterize at the KERMIT location, we take this opportunity to crudely compare (via interval RMS acceleration levels) the 3 sensor locations visited by SAMS near MSRR on GMT 2021-07-22. The 2 figures on page 13 shown side-by-side serve this comparison, with Figure 12 on the left side for 204.2 Hz (as-measured) data, and Figure 13 on the right for 100 Hz (low-pass filtered) SAMS data. These show interval RMS acceleration values for the entire day. The table of values shown on the left-side figure's Z-axis give the median values for each condition. Note that the 100 Hz data in the right-side figure have a much smaller vertical scale and the 3 different locations are referenced in 3 different color fonts as follows:

1) BASELINE at the lower seat track location of the MSRR (LAB1O3).
2) KERMIT at seat track location on MSRR (LAB1O3), just under the KERMIT.
3) ER6 at the lower seat track location of EXPRESS rack 6 (LAB1O4).

4. CONCLUSION

SAMS vibratory sensor measurements near KERMIT reveal a number of disturbances that can be tied to the KERMIT ops timeline and also reveal a few, significant narrowband, but as-yet undetermined disturbance sources. The analysis here serves as an overview and further, in-depth (better targeted) analyses can be pursued to fit the science and planning teams' objectives.

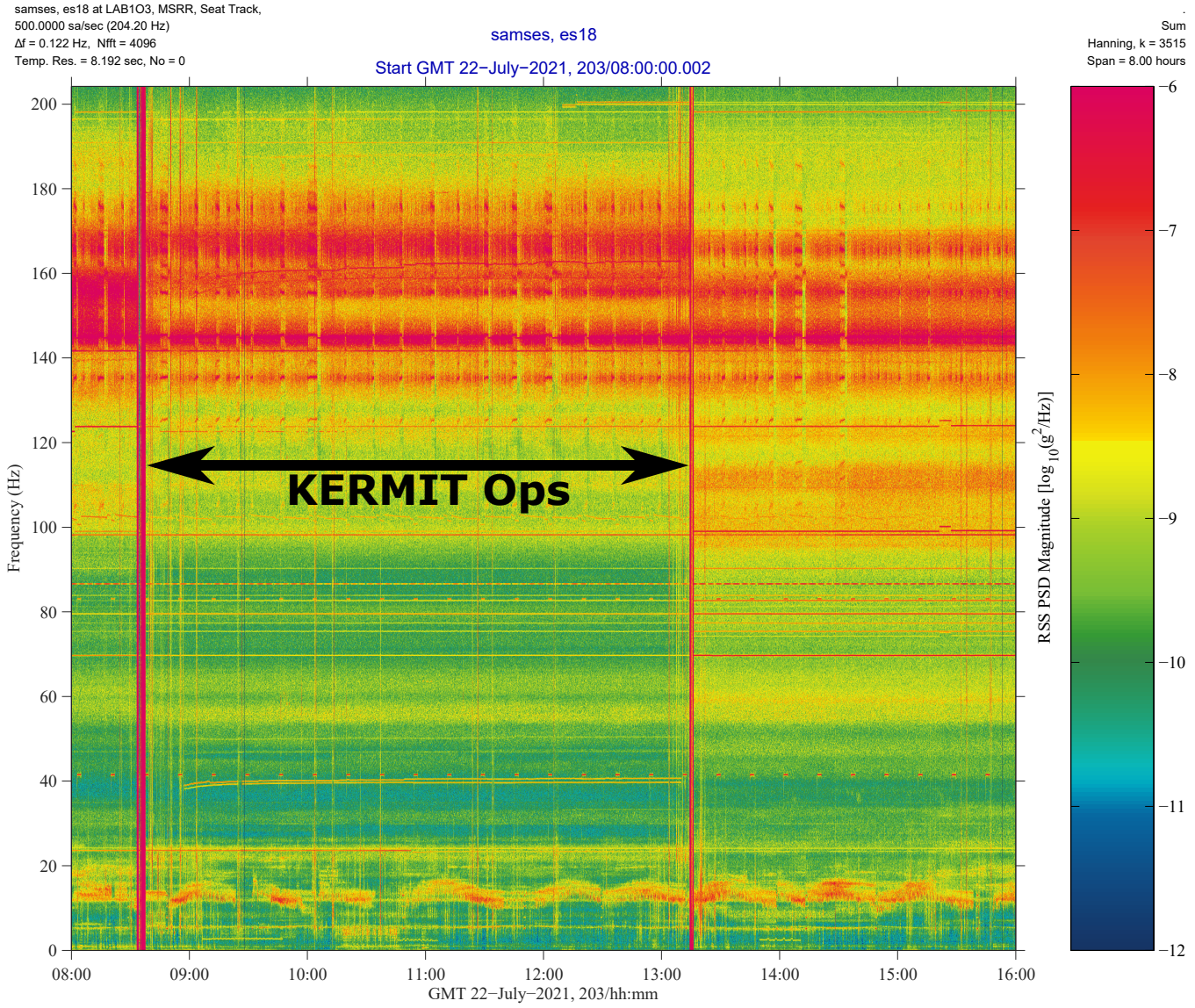

Fig. 1: Spectrogram showing 8-hour span before, during, and after KERMIT operations on GMT 2021-07-22.

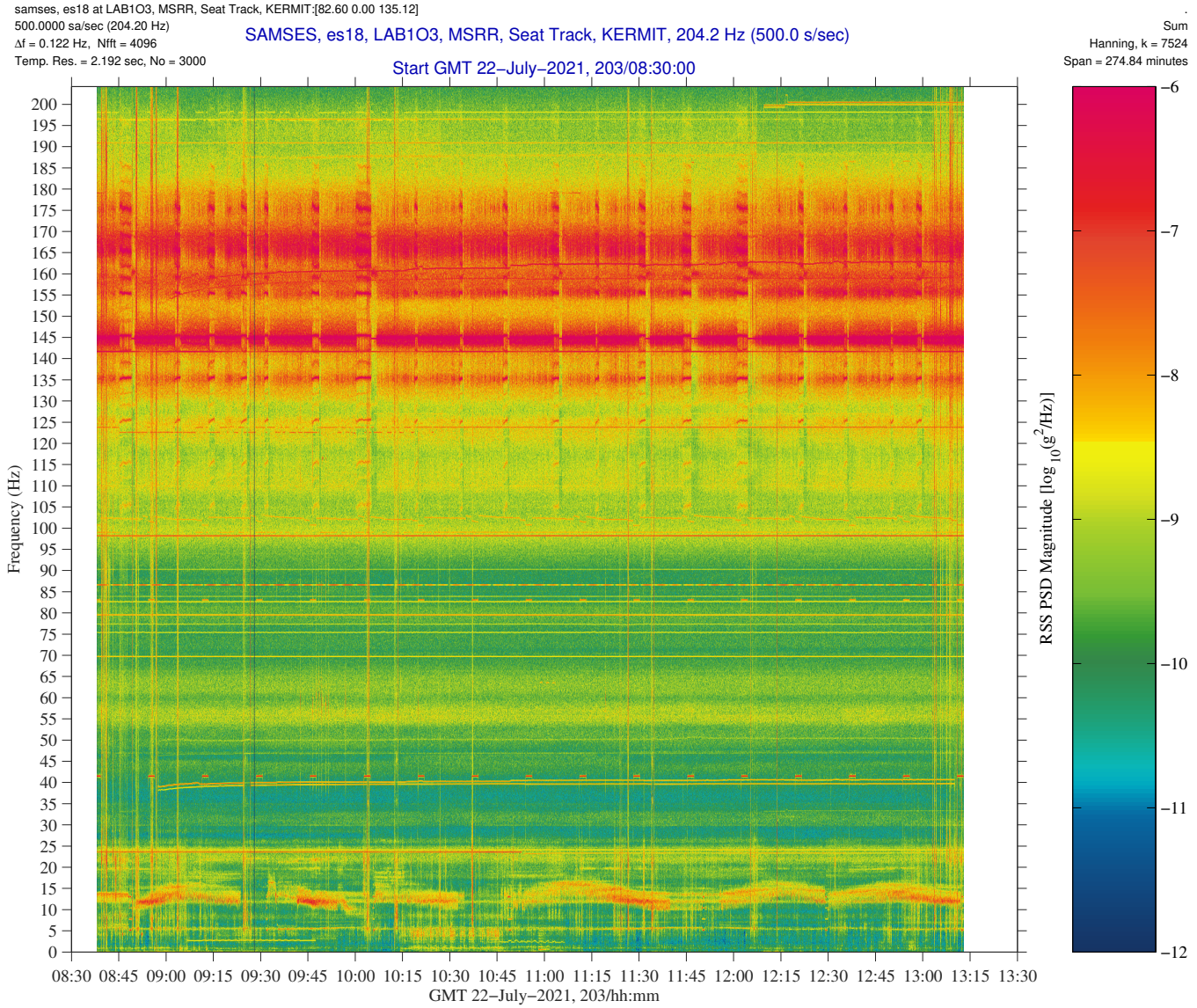

Fig. 2: Spectrogram showing 5-hour span just during KERMIT operations on GMT 2021-07-22.

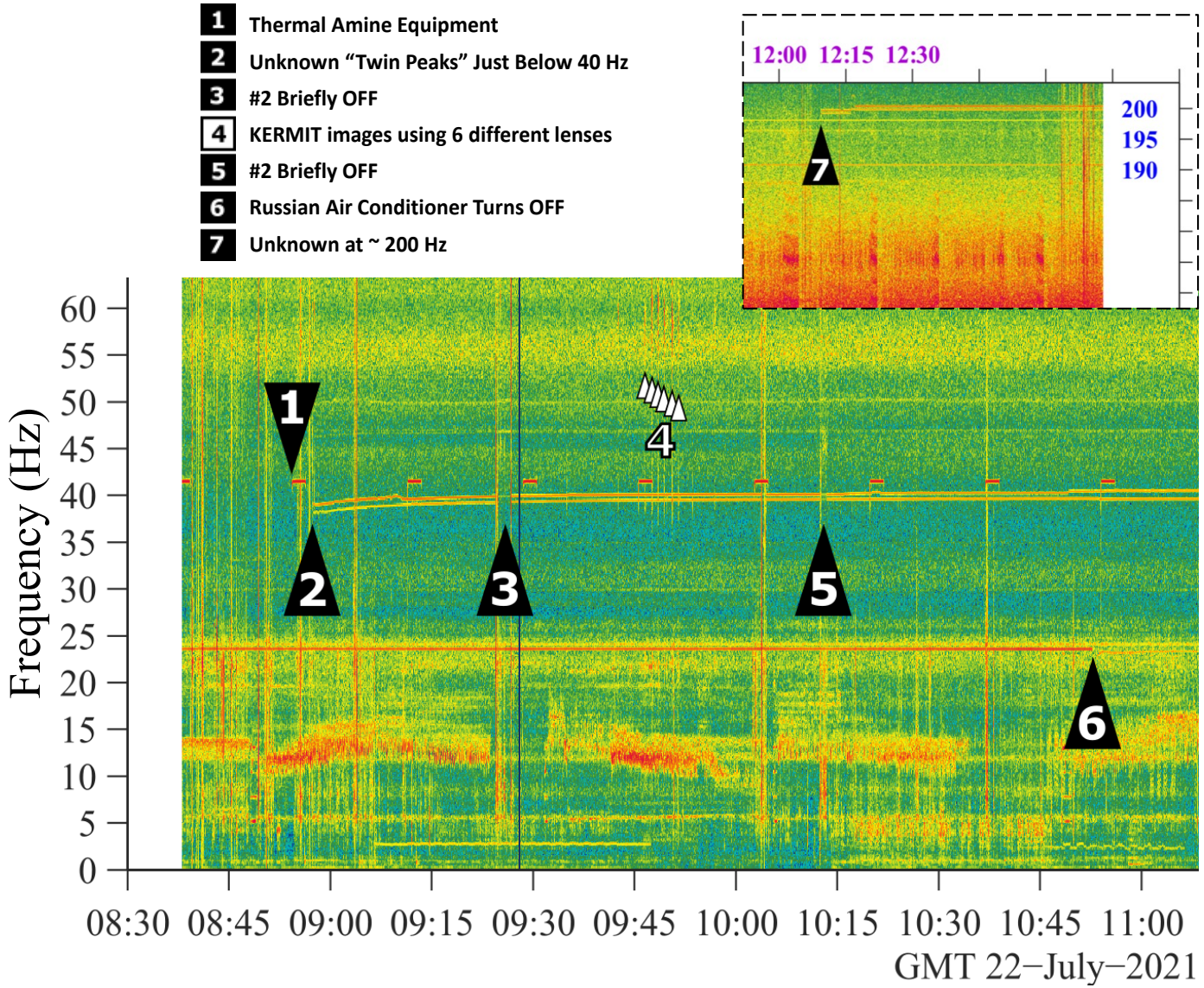

Fig. 3: Zoom-In of Spectrogram during some of KERMIT operations on GMT 2021-07-22.

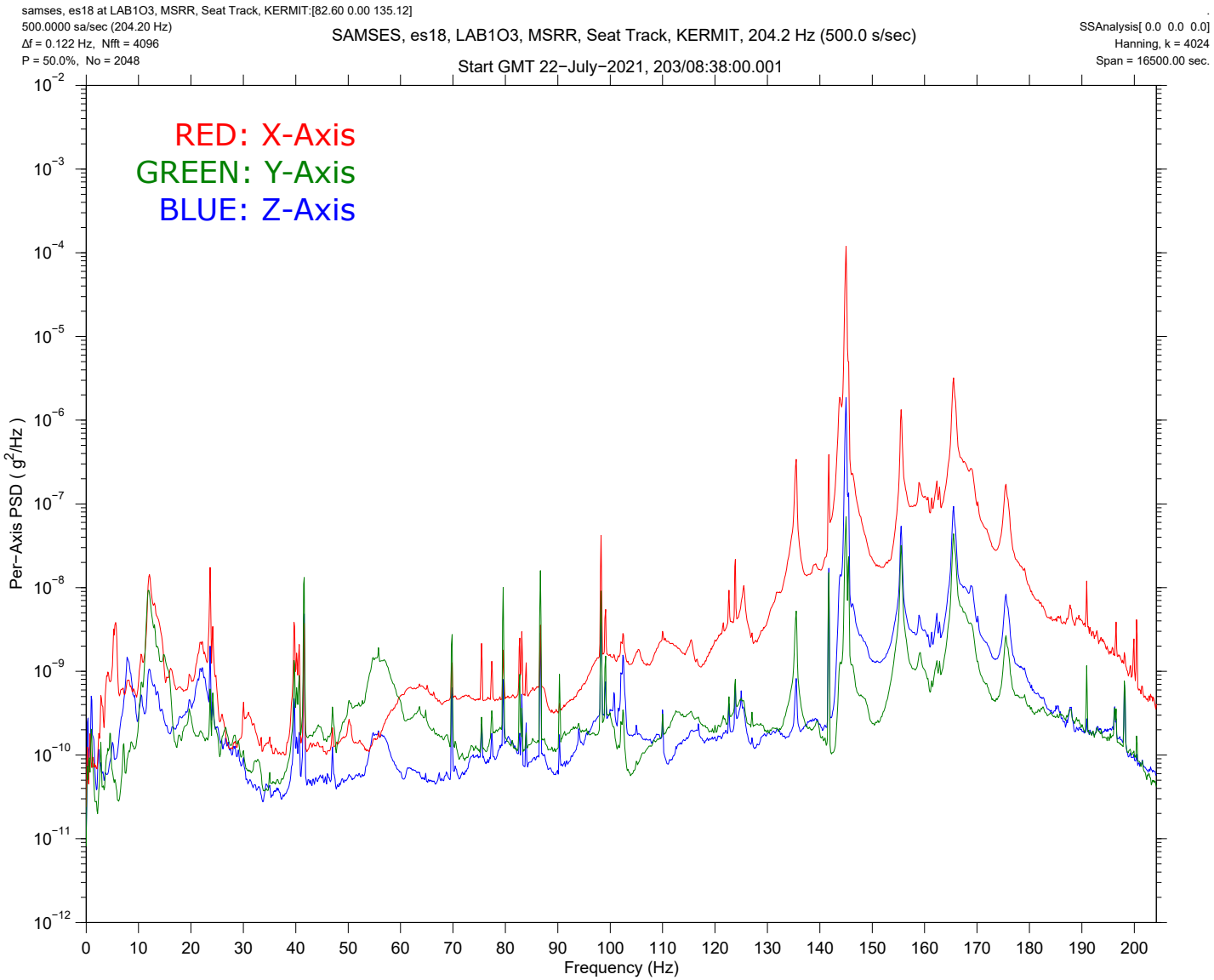

Fig. 4: Per-axis power spectral density for entire span of KERMIT operations on GMT 2021-07-22.

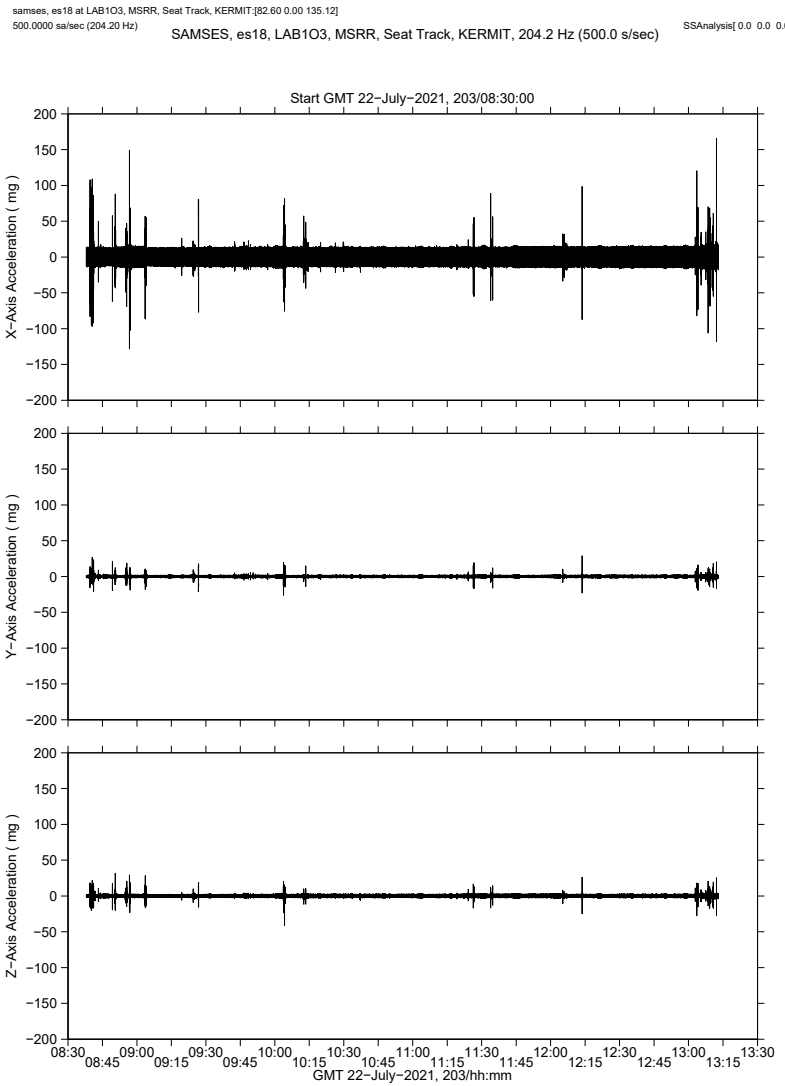

Fig. 5: Per-Axis **204.2 Hz** Accel. vs. Time during KERMIT Ops.

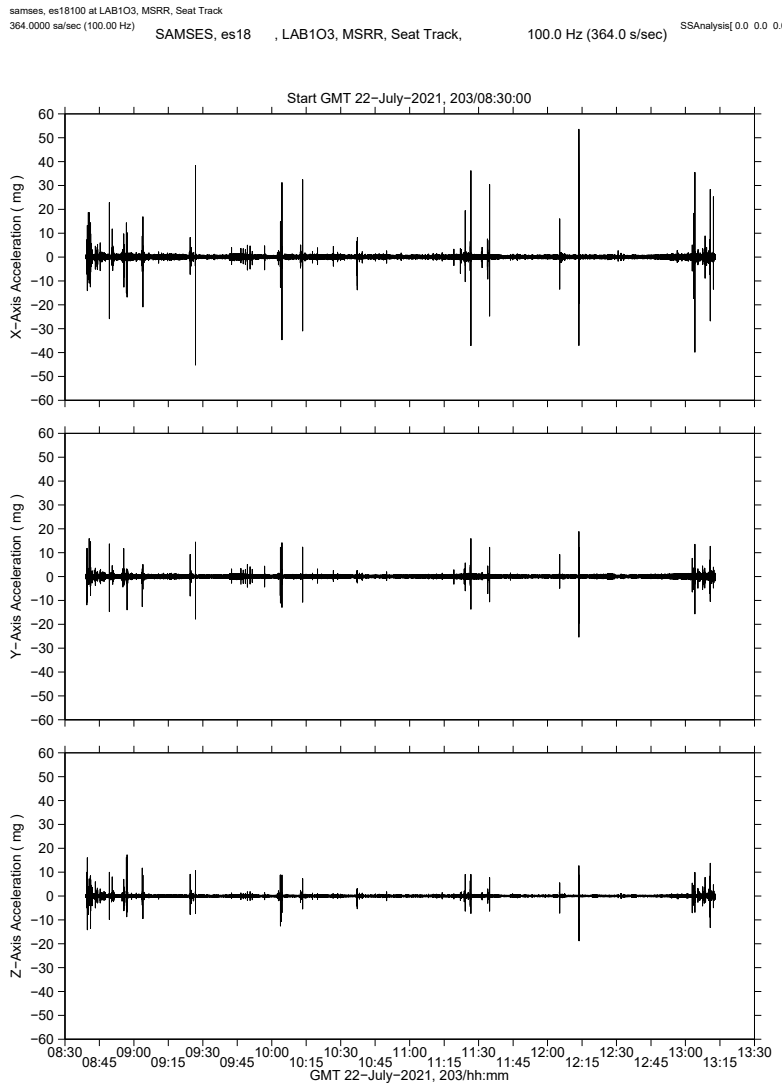

Fig. 6: Per-Axis **100.0 Hz** Accel. vs. Time during KERMIT Ops.

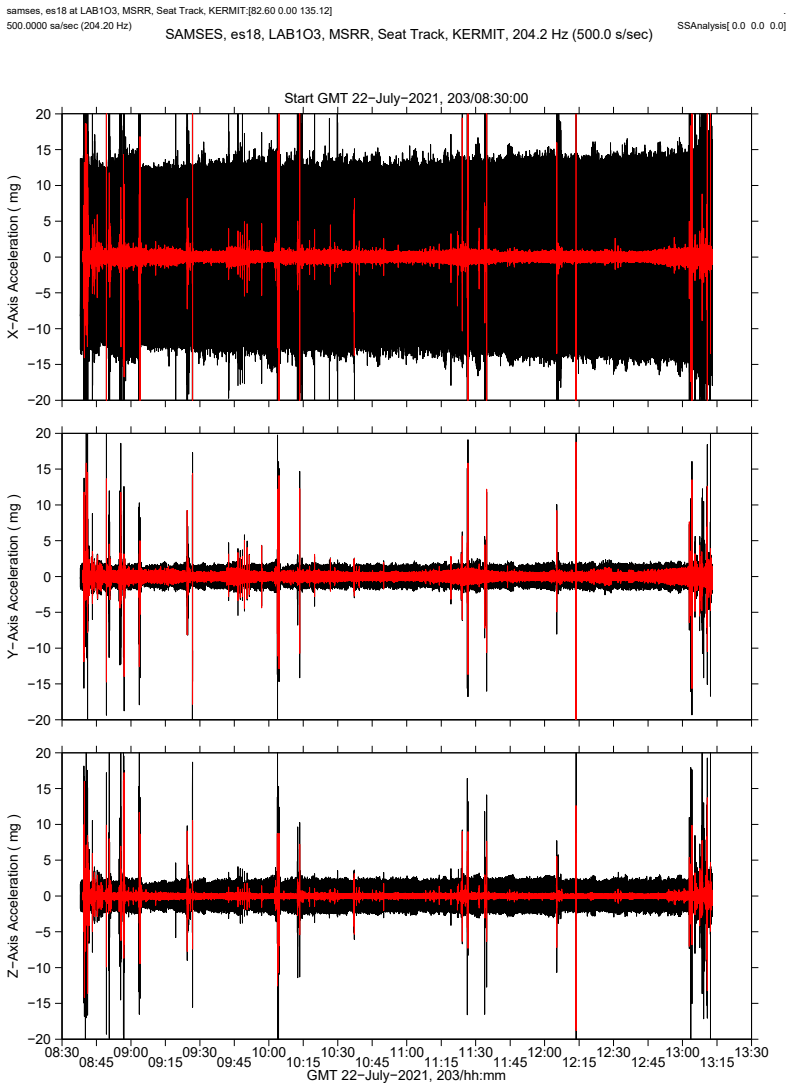

Fig. 7: Per-Axis **Zoom** Accel. vs. Time during KERMIT Ops

The zoom-in on the left shows data **low-pass filtered at 100 Hz in red** on top of the as-measured data (in **black with cut-off frequency of 204.2 Hz**).

KERMIT Ops Per-Axis Accel. Mag. Percentiles (mg)						
Cut-Off (Hz)	**Axis**	**50th**	**75th**	**95th**	**99th**	**Max**
204.2	**X**	6.04	8.63	11.05	12.40	165.30
	Y	0.25	0.45	0.89	1.28	28.67
	Z	0.77	1.14	1.60	1.95	40.86
100.0	**X**	0.14	0.25	0.47	0.74	53.52
	Y	0.12	0.21	0.40	0.61	25.34
	Z	0.07	0.12	0.22	0.36	18.80

Table 1. Accel. Magnitude Percentiles during KERMIT Ops, GMT 2021-07-22.

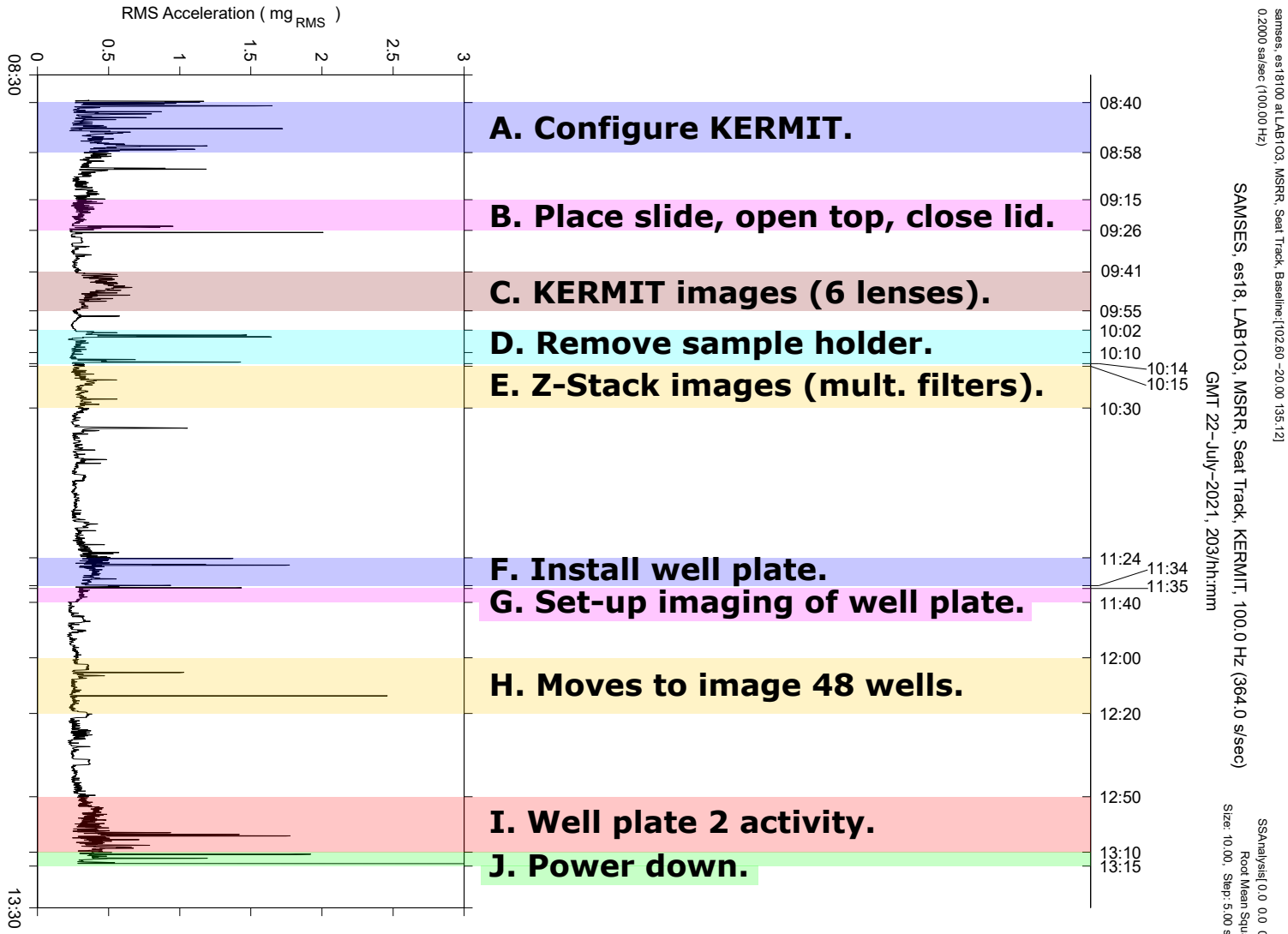

Fig. 8: 100 Hz Interval RMS Accel. for KERMIT Ops, GMT 2021-07-22, See next 3 pages for details.

KERMIT Vibe Test July 22, 2021 (GMT 203)

8:30 – started sensor move (8:33 AOS)

- Relocated SAMS sensor from bottom of MSRR, opened MSRR left faceplate, secured sensor to MSRR left seat track next to KERMIT
- Installed MSRR Protective Cover

A. CONFIGURE KERMIT.

~8:40 – 8:58 – Configured microscope cables underneath KERMIT

- Switched power on to KERMIT
- LED on front of KERMIT is ON (KERMIT has been powered ON)

B. PLACE SLIDE, OPEN TOP, CLOSE LID.

~9:15 – Thomas was given a go to start the steps in the 10:10 scheduled activity KERMIT-H/W-CHK P1 (Step 1 of 1.001 KERMIT INSTALL AND REMOVE SLIDE)

- Placed slide onto sample holder slide
- Opened top panel of KERMIT
- Aligned thumb screws on sample holder and microscope stage and tightened thumb screws

~9:26 – Closed the lid of KERMIT microscope

C. KERMIT IMAGES (6 LENSES).

~9:41 – 9:55 – KERMIT images taken of Slide 8 using 6 different lenses

D. REMOVE SAMPLE HOLDER.

~10:02 – Thomas was given a go to start the steps in the 10:55 scheduled activity KERMIT-H/W-CHK P2 (Step 2 of 1.001 KERMIT INSTALL AND REMOVE SLIDE)

- Removed sample holder slide from KERMIT
  - Opened top panel
  - Loosened thumb screws
  - Removed sample holder from microscope

Fig. 9: Description of KERMIT Ops on GMT 2021-07-22 (part 1 of 3).

KERMIT Vibe Test July 22, 2021 (GMT 203)

- Closed top panel
- Removed slide from sample

~10:10 - struggled with slide not fitting in middle slot and lever not holding in place. Reported lever was slightly bent. Moved slide to another slot.

~10:14 – reported slide is successfully installed and secured. Closed lid of KERMIT.

E. Z-STACK IMAGES (MULT. FILTERS)

~10:15 – 10:30 – z-stack images taken of Slide 6 using multiple filters

F. INSTALL WELL PLATE

~11:24 – 11:34 – Thomas was given a go to start 12:30 scheduled activity KERMIT-H/W-CHK P3A (Step 2 of 1.001 KERMIT INSTALL AND REMOVE SLIDE) and KERMIT-H/W-CHK P3B

- Removed sample holder: opened top panel, loosened thumb screws on sample holder, removed sample holder from microscope, closed top panel of microscope.
- Removed slide 6 from sample holder slide
- Installed well plate into KERMIT

G. SET-UP IMAGING OF WELL PLATE

~11:35 – 11:40 – setting up imaging of well plate then went LOS

H. MOVES TO IMAGE 48 WELLS

~12:00 – 12:20 – one lense and filter for each of the 48 wells, KERMIT moving between each one

I. WELL PLATE 2 ACTIVITY

~12:50 – 13: 10 – Thomas was given a go to start the steps in the 14:10 scheduled activity KERMIT-H/W-CHK P4 (Step 2 of 1.002 KERMIT INSTALL AND REMOVE WELL PLATE)

Fig. 10: Description of KERMIT Ops on GMT 2021-07-22 (part 2 of 3).

KERMIT Vibe Test July 22, 2021 (GMT 203)

- Removed sample holder custom with installed well plate 2 from microscope
  - Opened top panel
  - Loosened thumb screws on sample holder securing it to the microscope
  - Removed sample holder from microscope
  - Closed top panel
- Lifted well plate 2 from sample holder custom

J. POWER DOWN

~13:10 – 13:15 – Powered down KERMIT in procedure 2.003 KERMIT POWER OFF, De-Cabling and Stow of Fluorescence Microscope

- Disconnected microscope cable from ELC
- Temp stowed microscope usb cable to underside of microscope mounting plate
- Powered microscope off
- Configured cables

~13:16 – relocated SAMS sensor from MSRR to ER6 lower right seat track

~13: 24 – removed MSRR Protective Cover and stowed next to KERMIT

- End of test

Fig. 11: Description of KERMIT Ops on GMT 2021-07-22 (part 3 of 3).

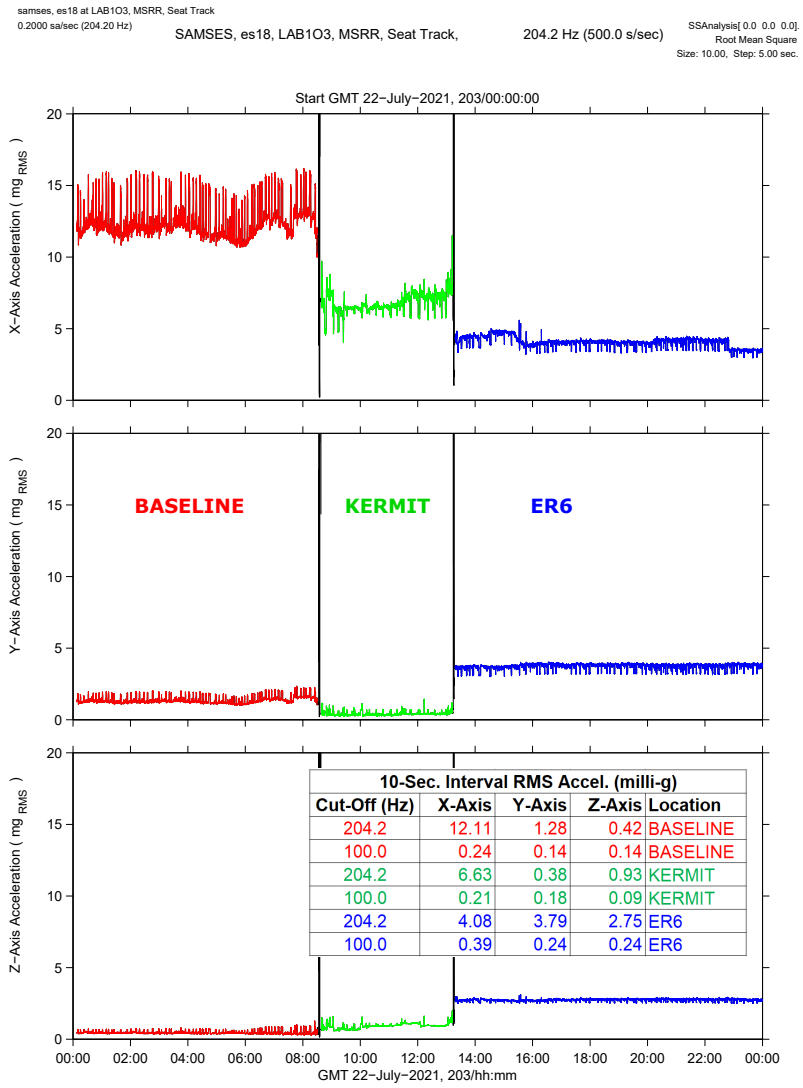

Fig. 12: Interval RMS Accel. **(204.2 Hz)** for entire day.

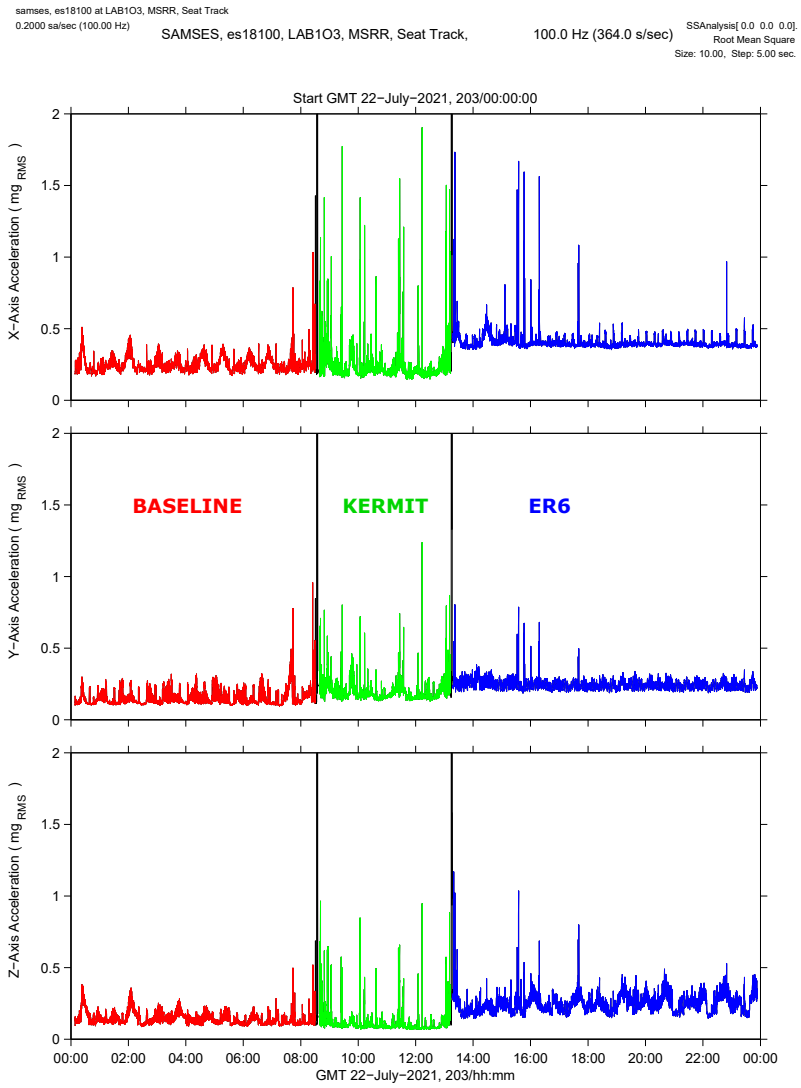

Fig. 13: Interval RMS Accel. **(100.0 Hz)** for entire day.