INL/MIS-20-59008-Revision-0

Fission Gas Monitoring for the AGR-5/6/7 Experiment

Dawn M Scates, Edward L Reber, Ryan G Fronk, Cam Binh T Pham

August 2020

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Fission Gas Monitoring for the AGR-5/6/7 Experiment

D.M. Scates, E.L. Reber, R.G. Fronk, B.T. Pham

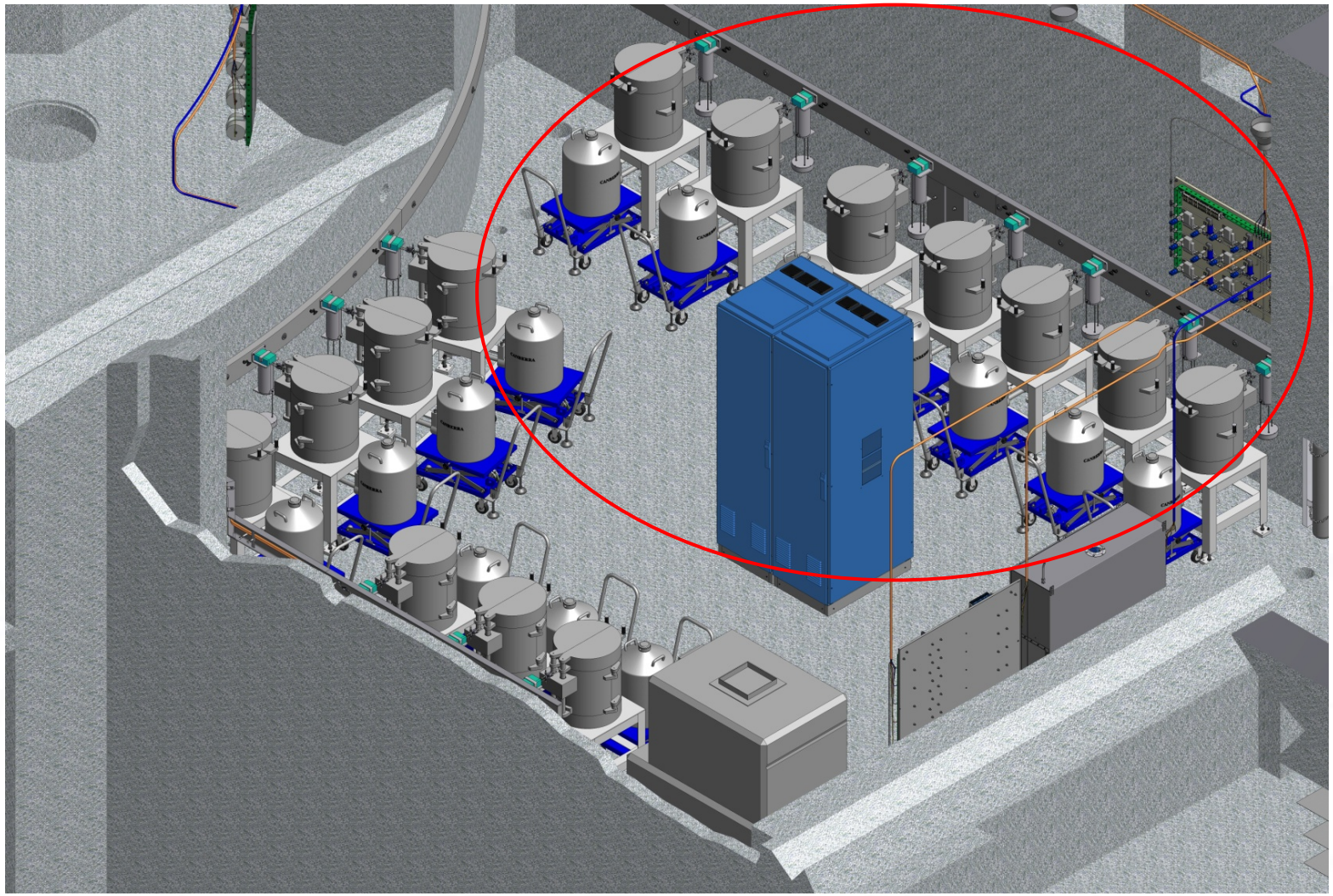
Presented at the Gas-Cooled Reactor Program Annual Review
July 14, 2020 via Videoconference from Idaho National Laboratory

ADVANCED REACTOR TECHNOLOGIES

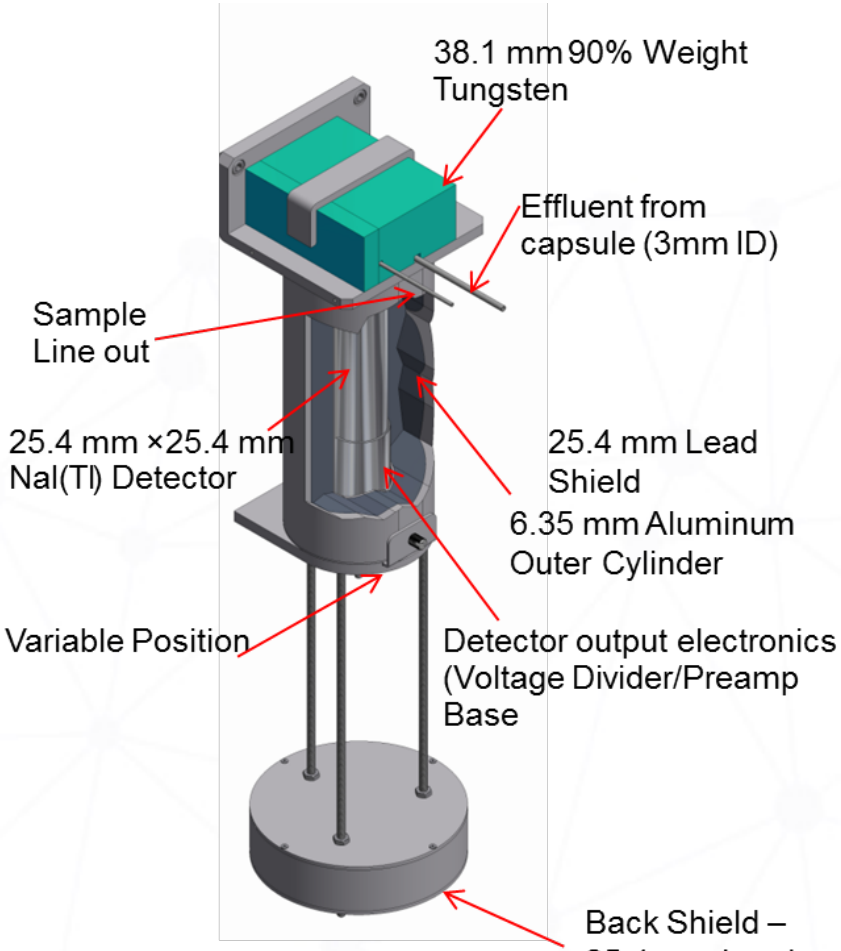
Outline

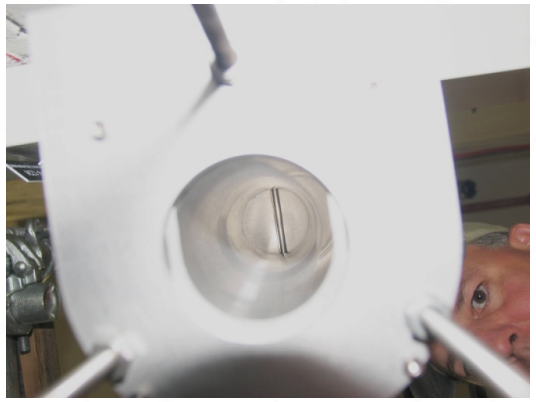
- What is the Fission Product Monitoring System (FPMS)?
- AGR-5/6/7 Data Collection
- Continuing work
- Conclusion

Fission Product Monitoring System (FPMS)

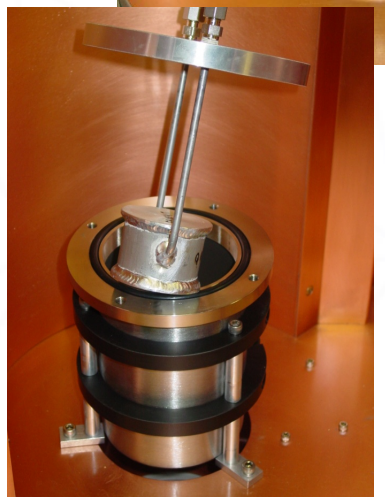


Gross Monitor System

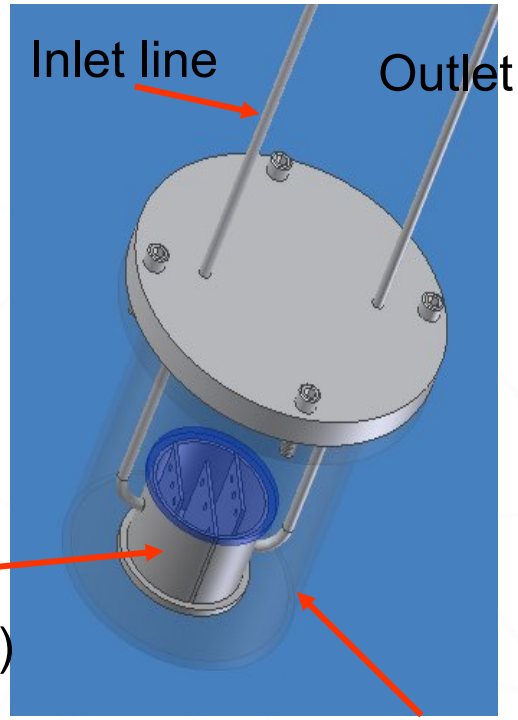




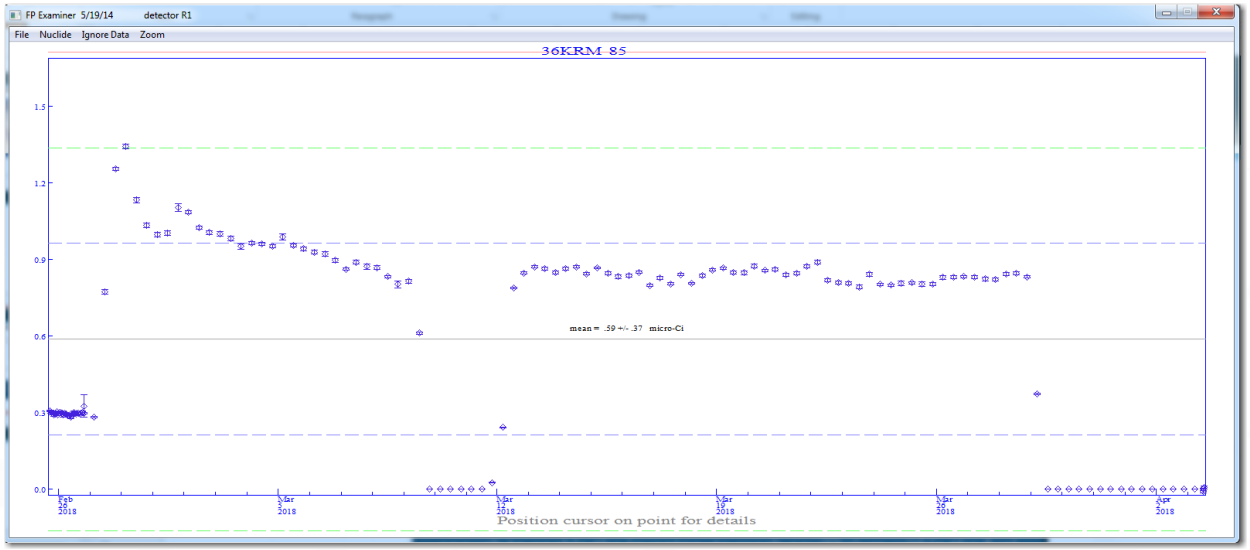
FPMS – Gamma Ray Spectrometer System



Sample chamber (lid removed)



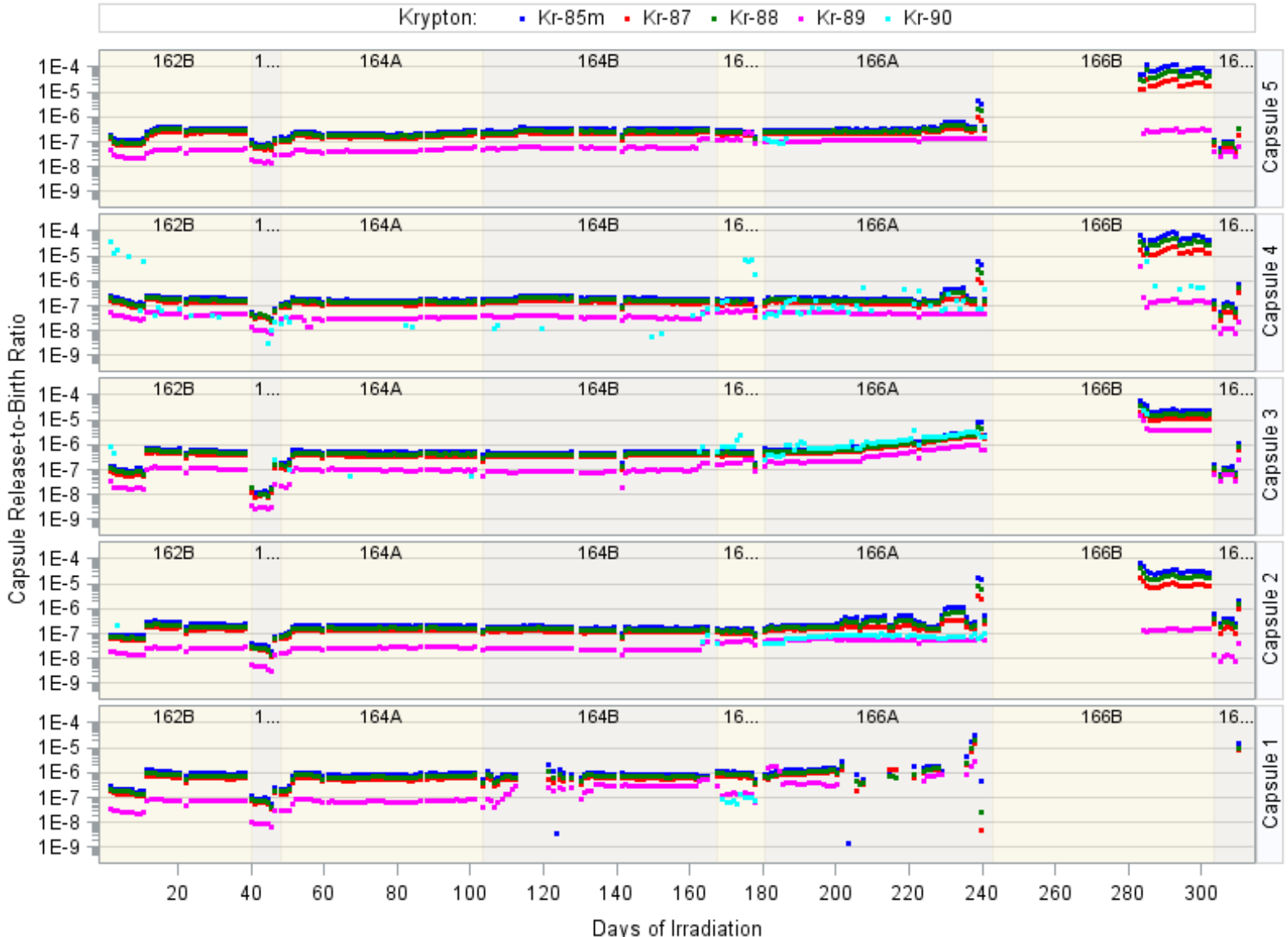
FPM – Data Reprocessing, Analysis and Auxiliary Programs



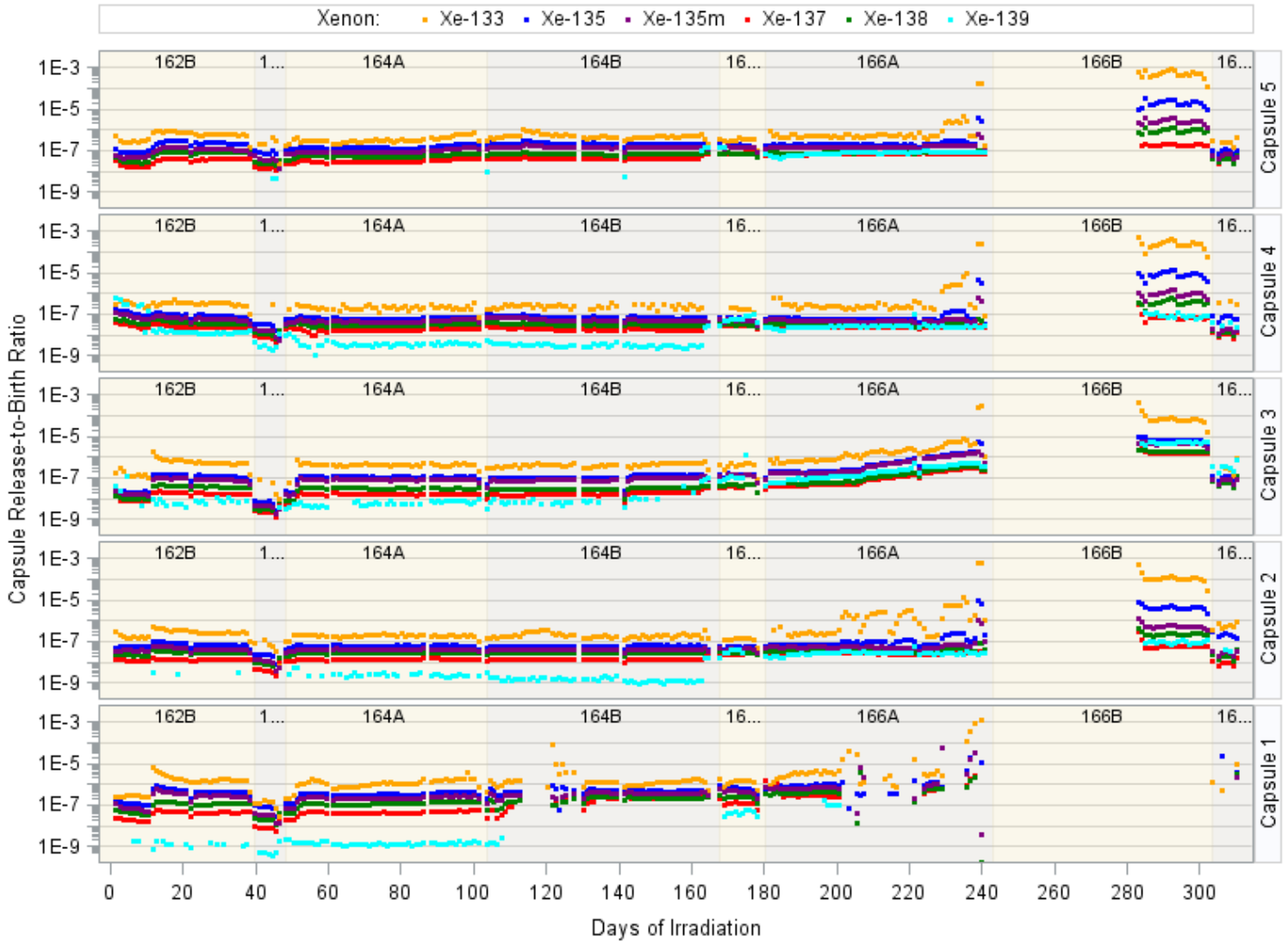
Isotope:	
Kr-85m	Xe-131m
Kr-87	Xe-133
Kr-88	Xe-135
Kr-89	Xe-135m
Kr-90	Xe-137
	Xe-138
	Xe-139

Isotopes were selected because the half-life for each isotope is short enough to enable the inventory to reach equilibrium within the fuel. Optimal half lives for the AGR-5/6/7 experiment range from 30 seconds to less than 10 hours.

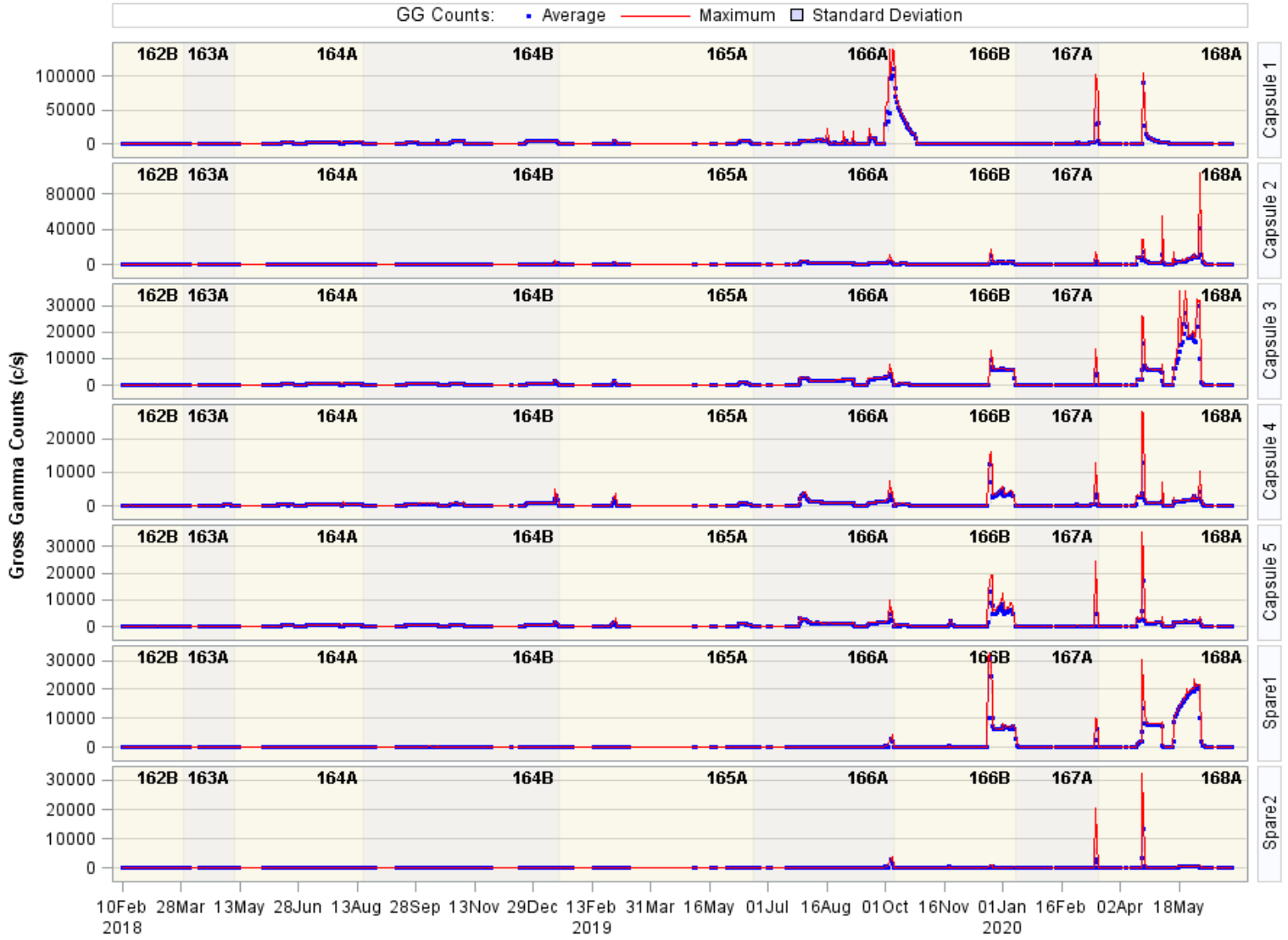
Summary of Preliminary Release to Birth Ratios – Krypton



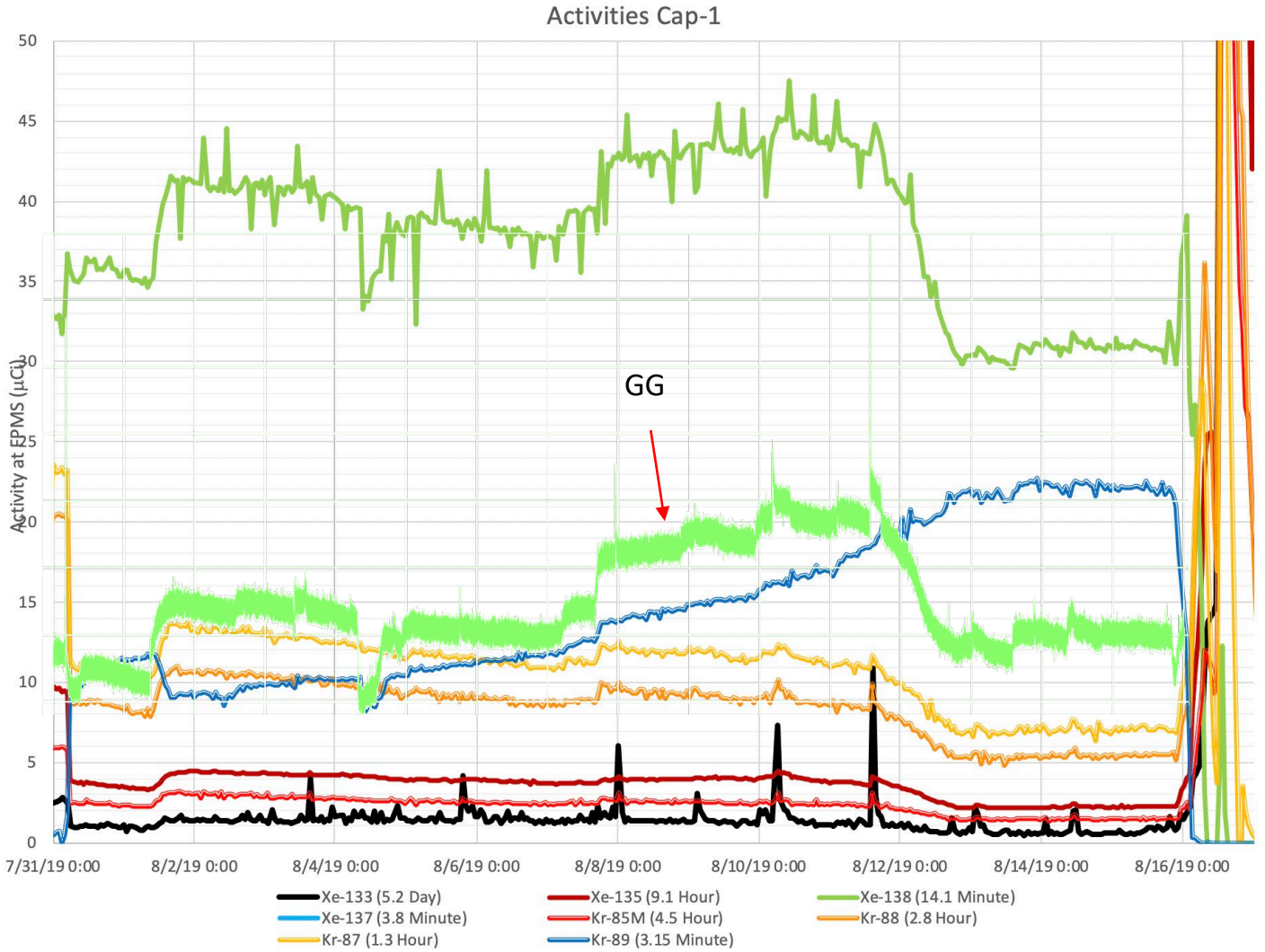
Summary of Preliminary Release to Birth Ratios – Xenon



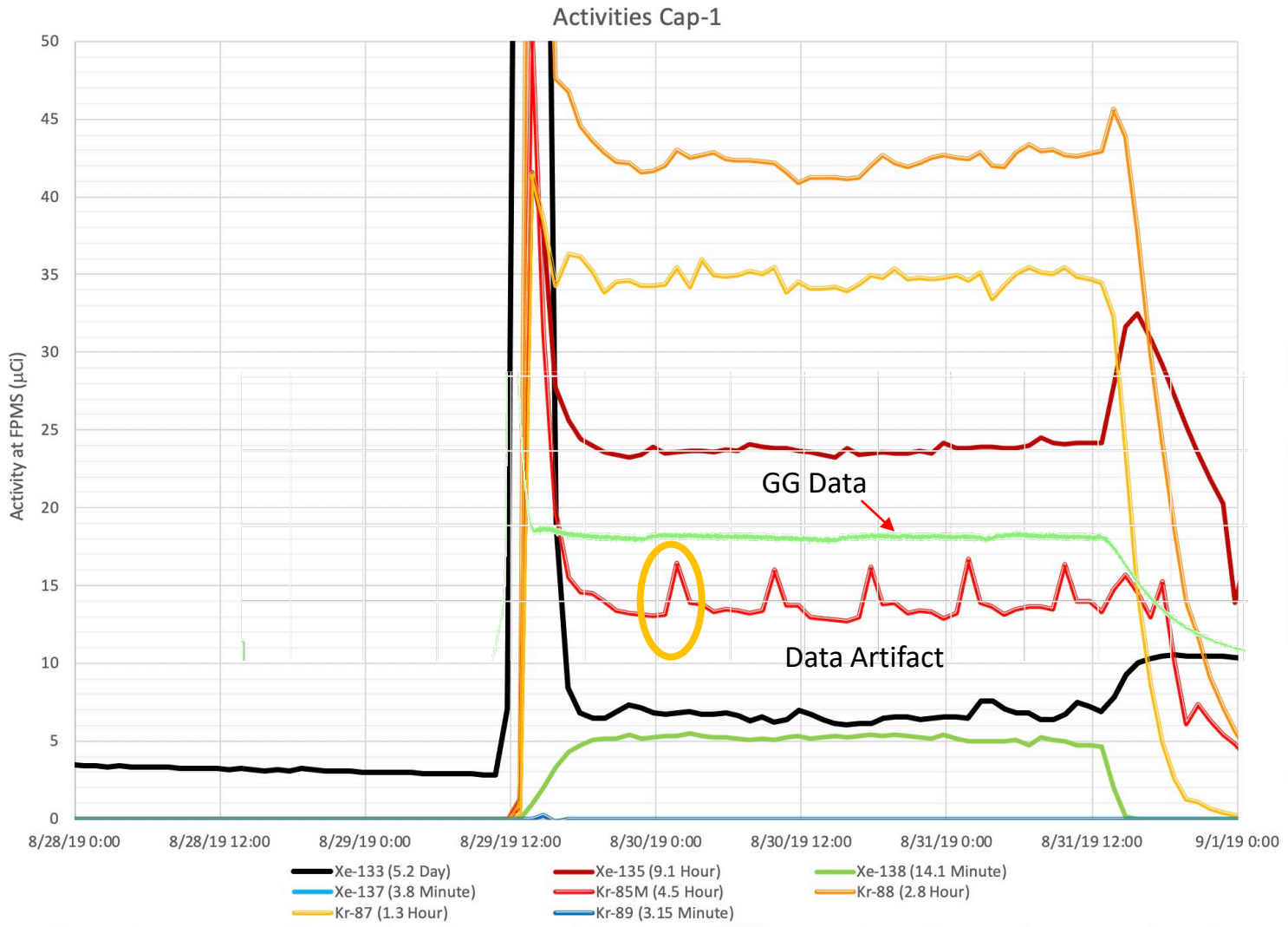
Daily Gross Gamma for all Cycles



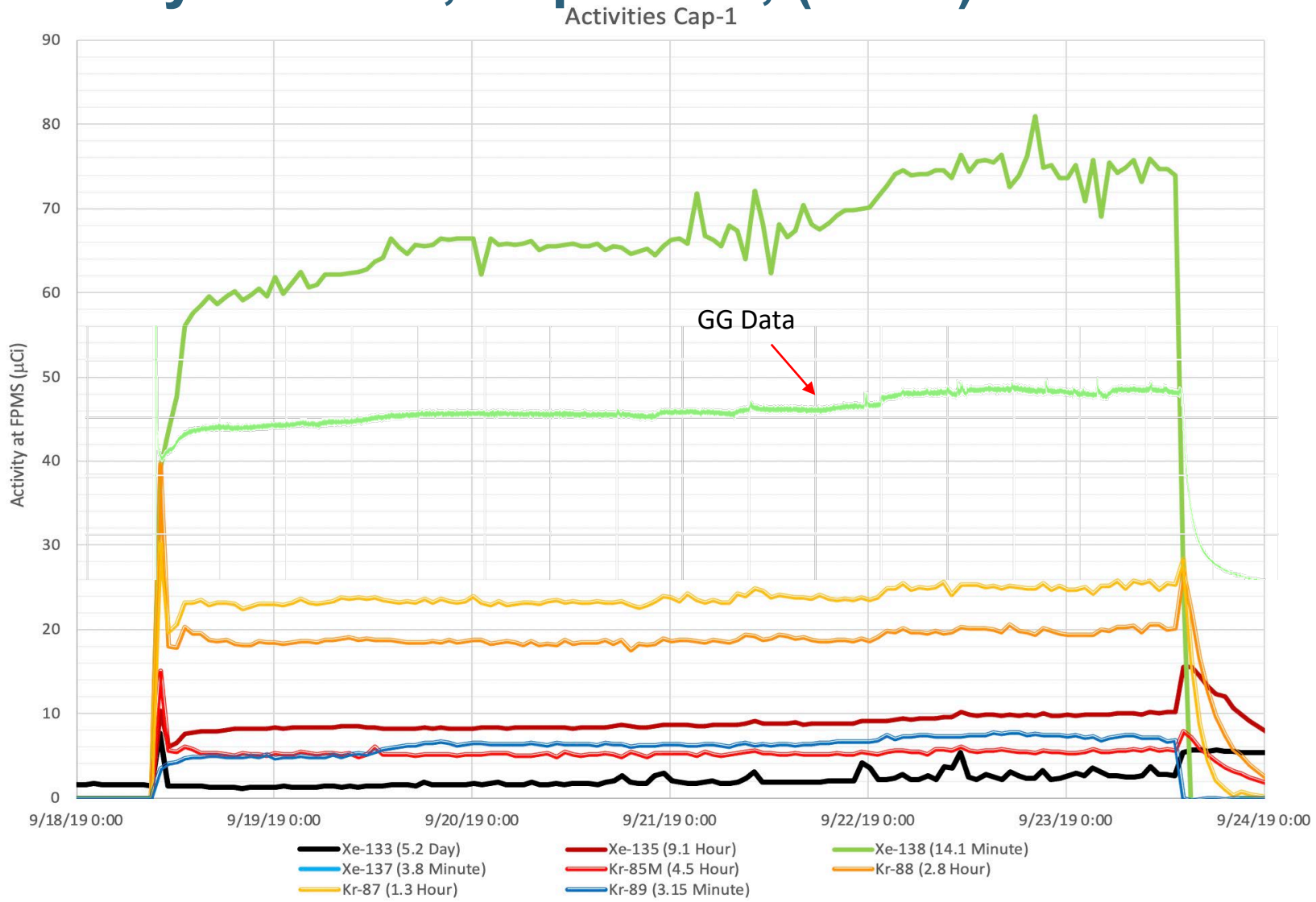
A Closer Look at Cycle 166A, Capsule 1



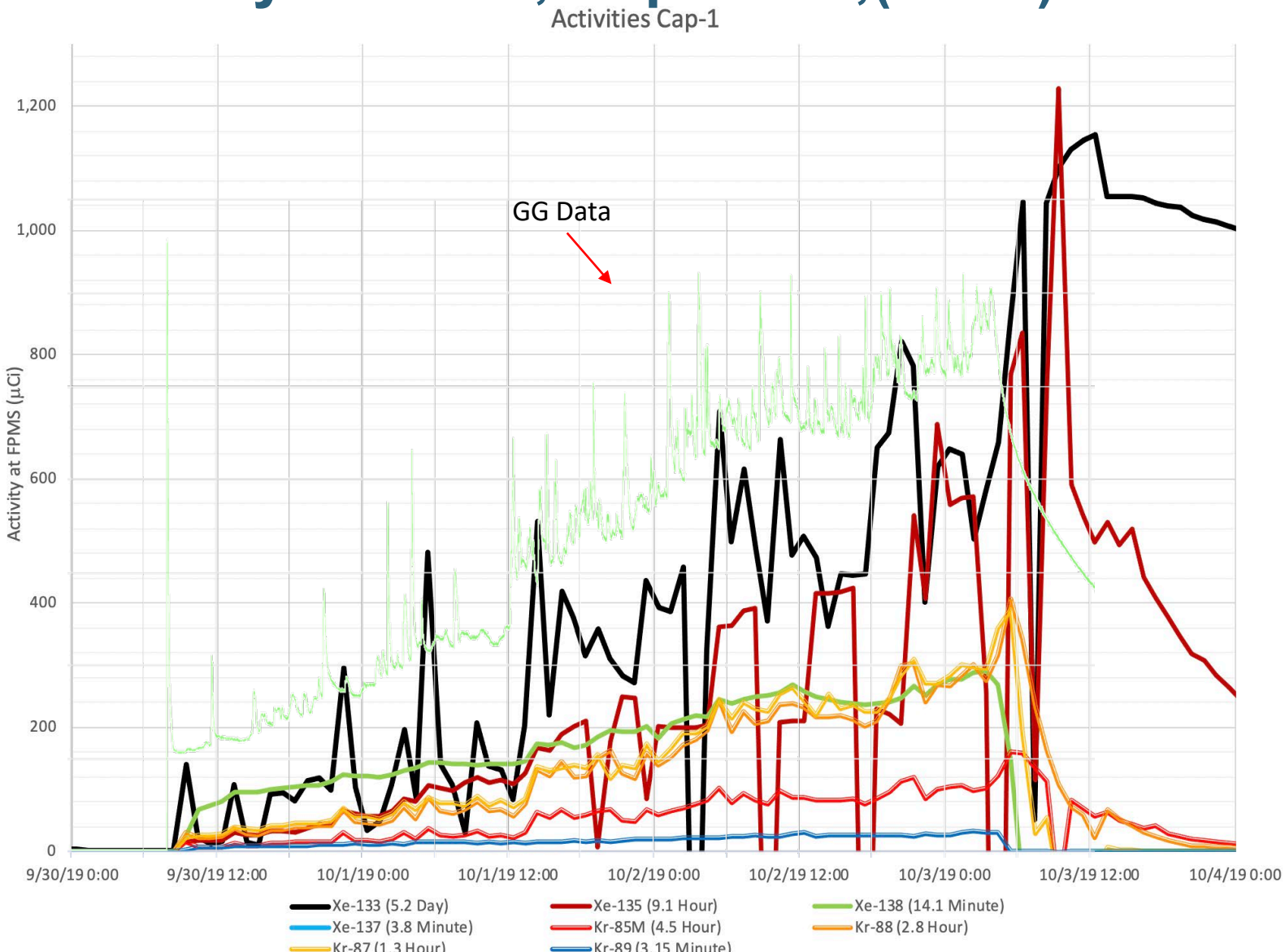
A Closer Look at Cycle 166A, Capsule 1, (cont.)



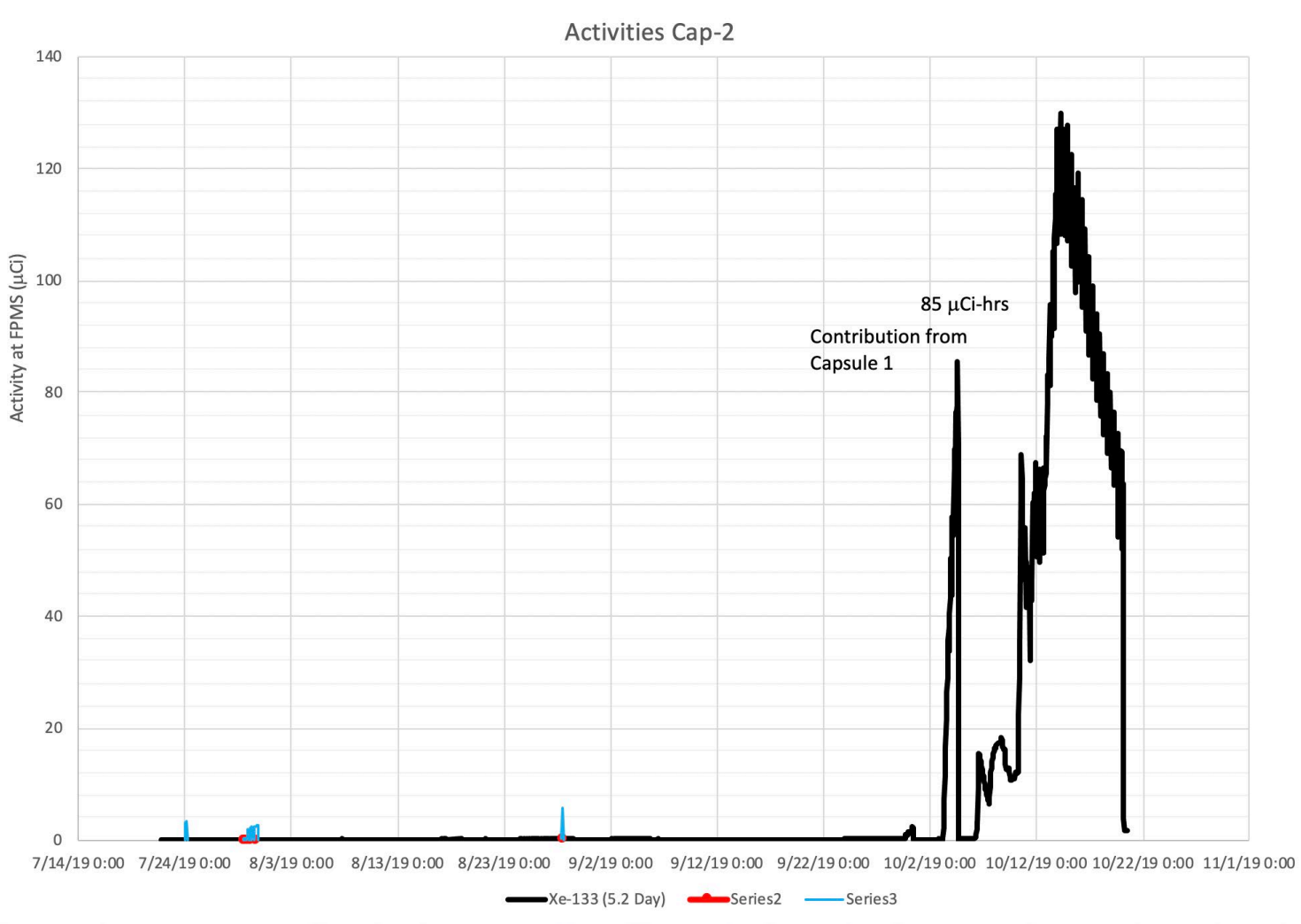
A Closer Look at Cycle 166A, Capsule 1, (cont.)



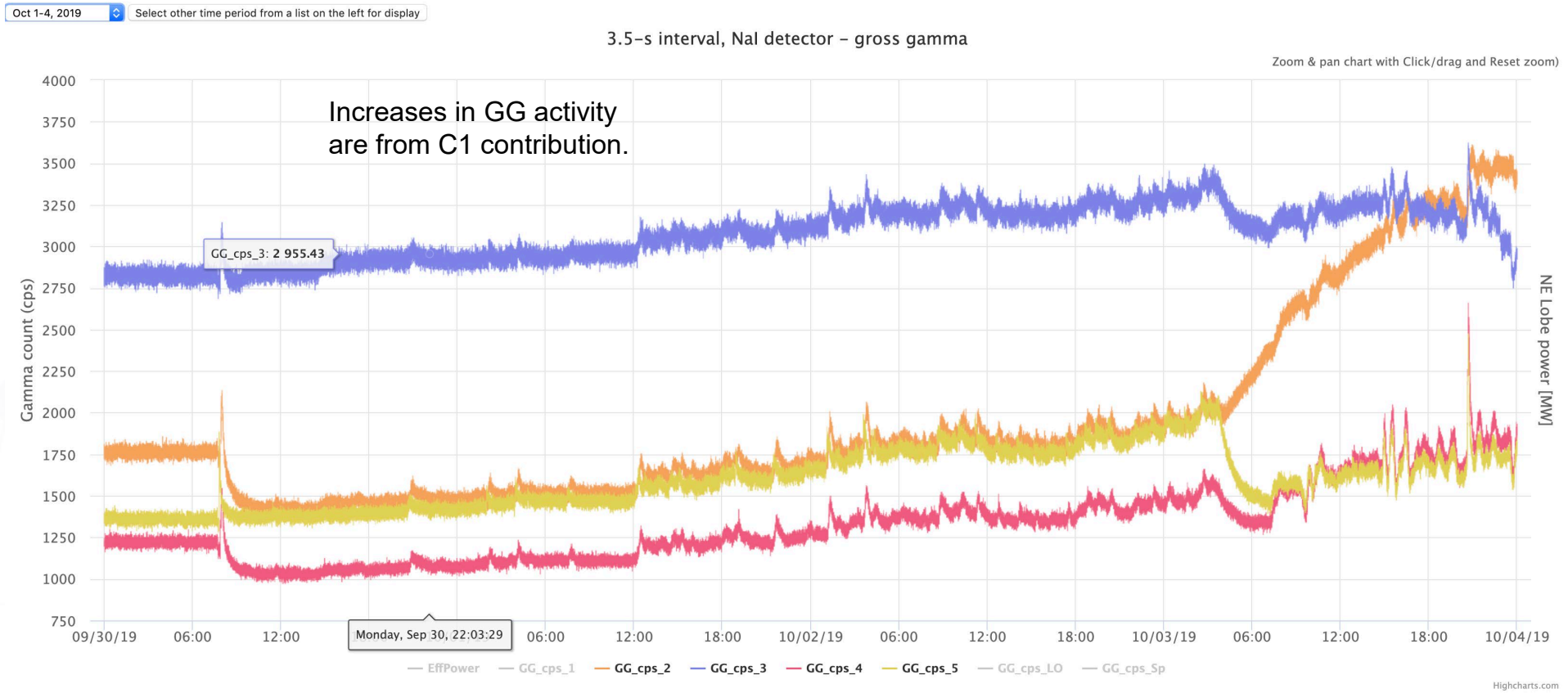
A Closer Look at Cycle 166A, Capsule 1,(cont.)



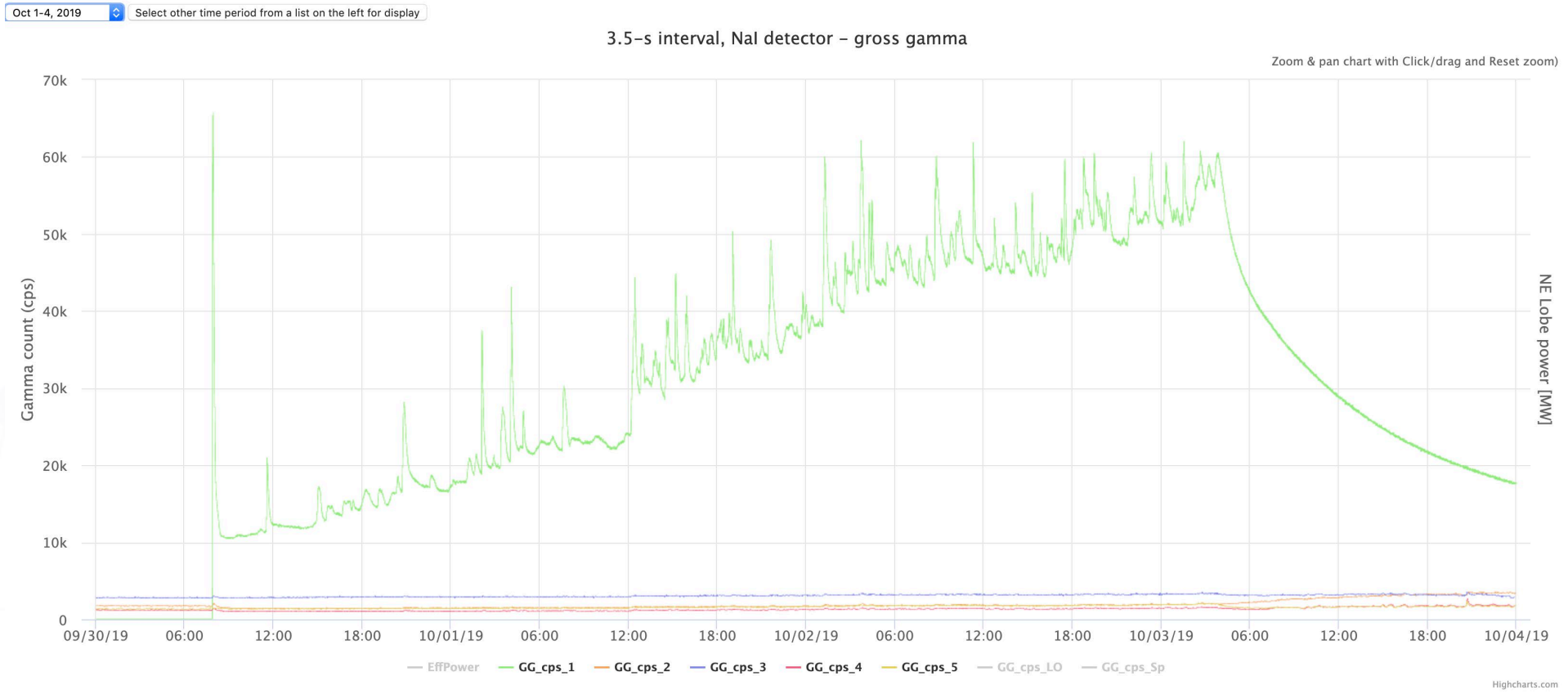
A Closer Look at Cycle 166A, Capsule 2



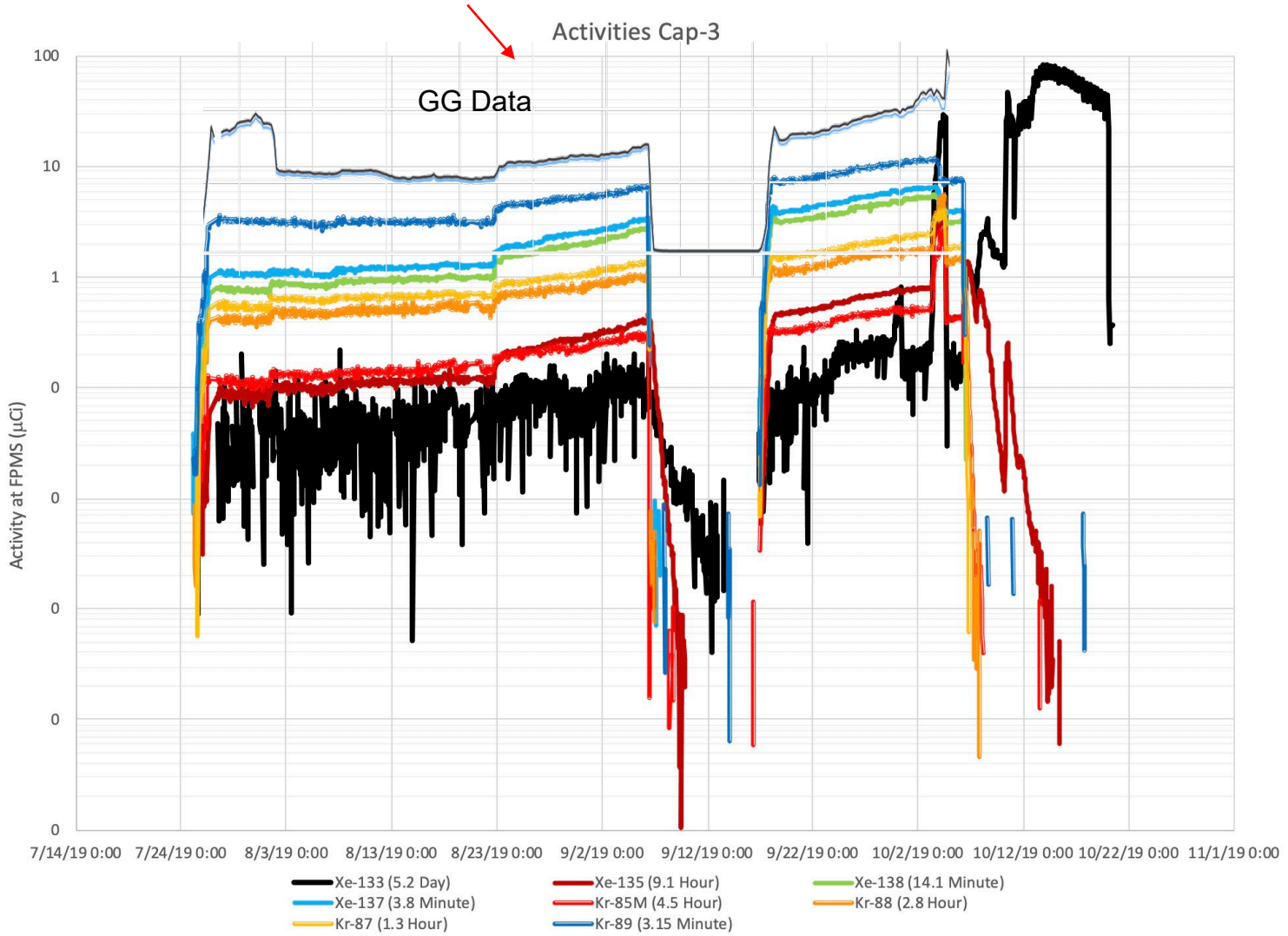
A Closer Look at Cycle 166A, Capsule 2,3,4 and 5 Gross Gamma



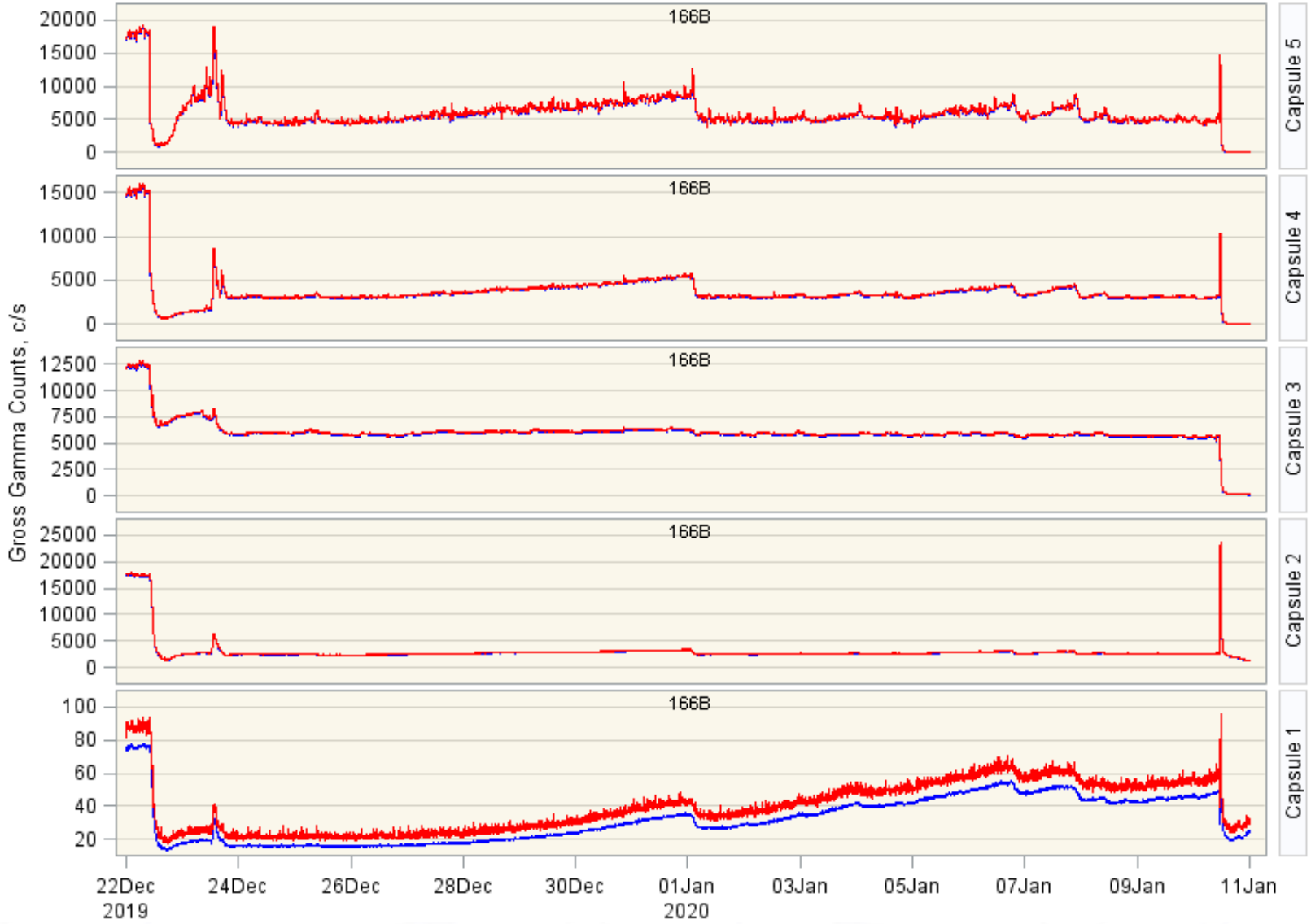
A Closer Look at Cycle 166A, Capsule 1 GG



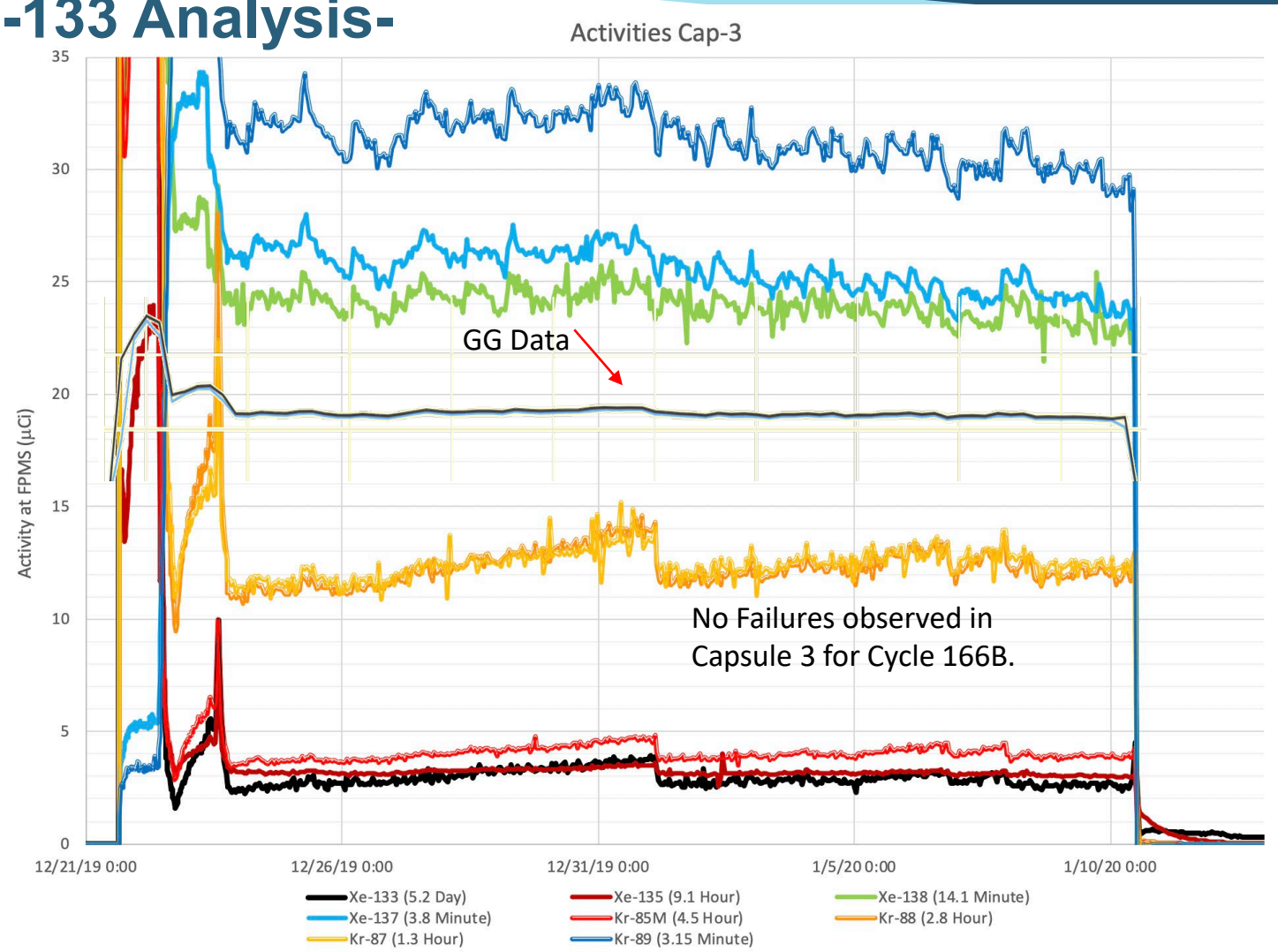
Capsule 3 – Xe-133 Analysis- Cycle 166A



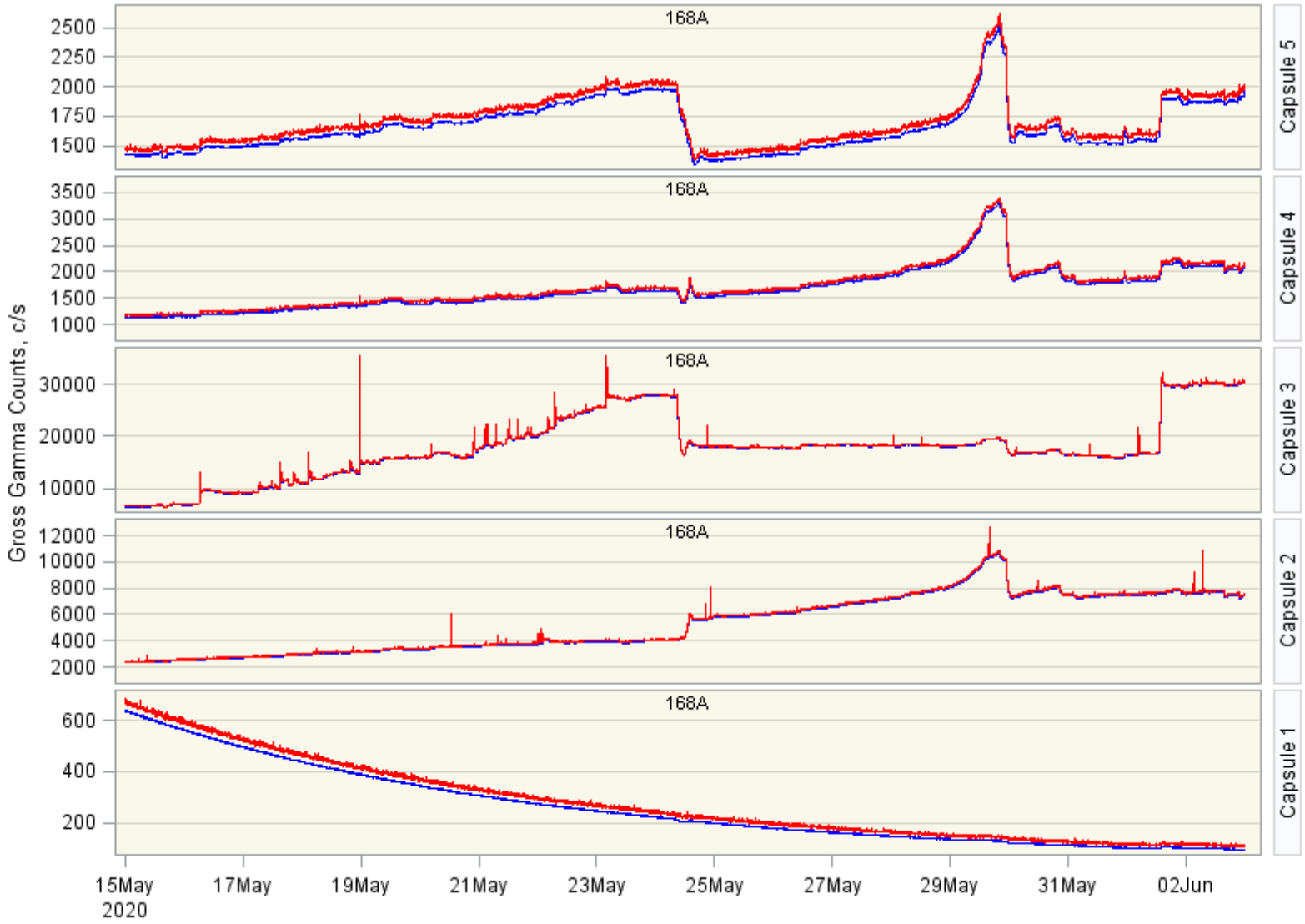
GG Cycle 166B



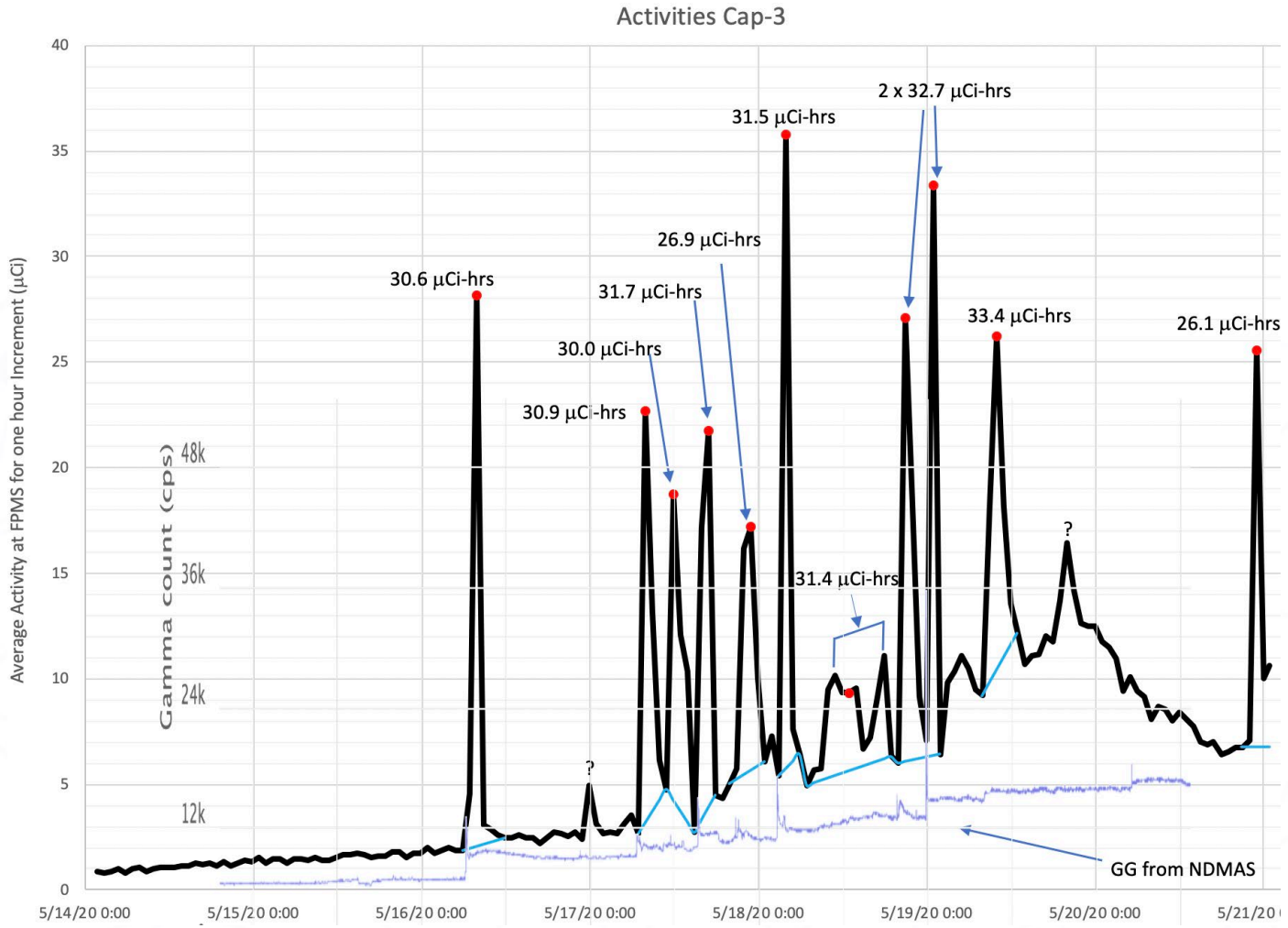
Capsule 3 – Xe-133 Analysis- Cycle 166B



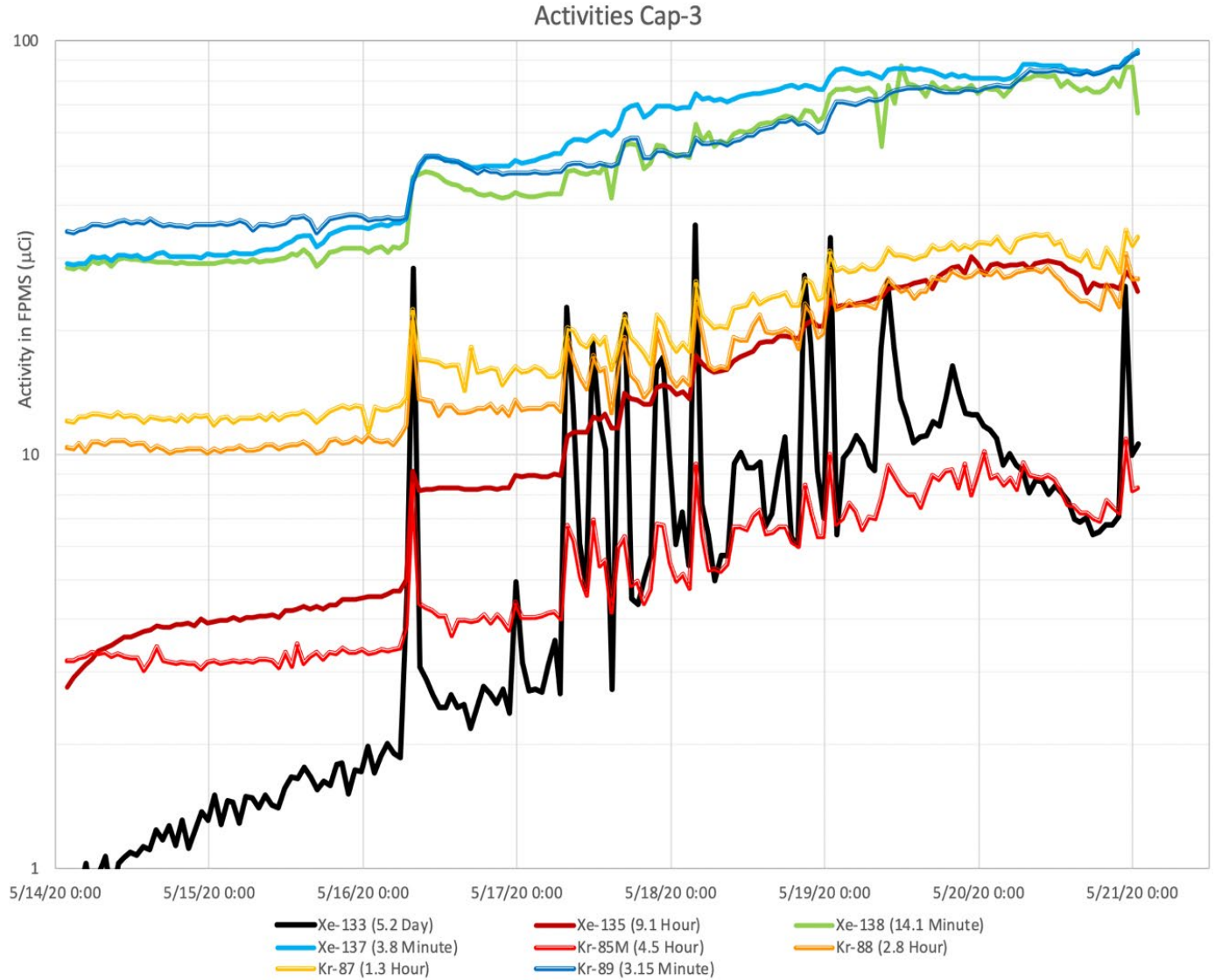
GG Cycle 168A- Current Cycle



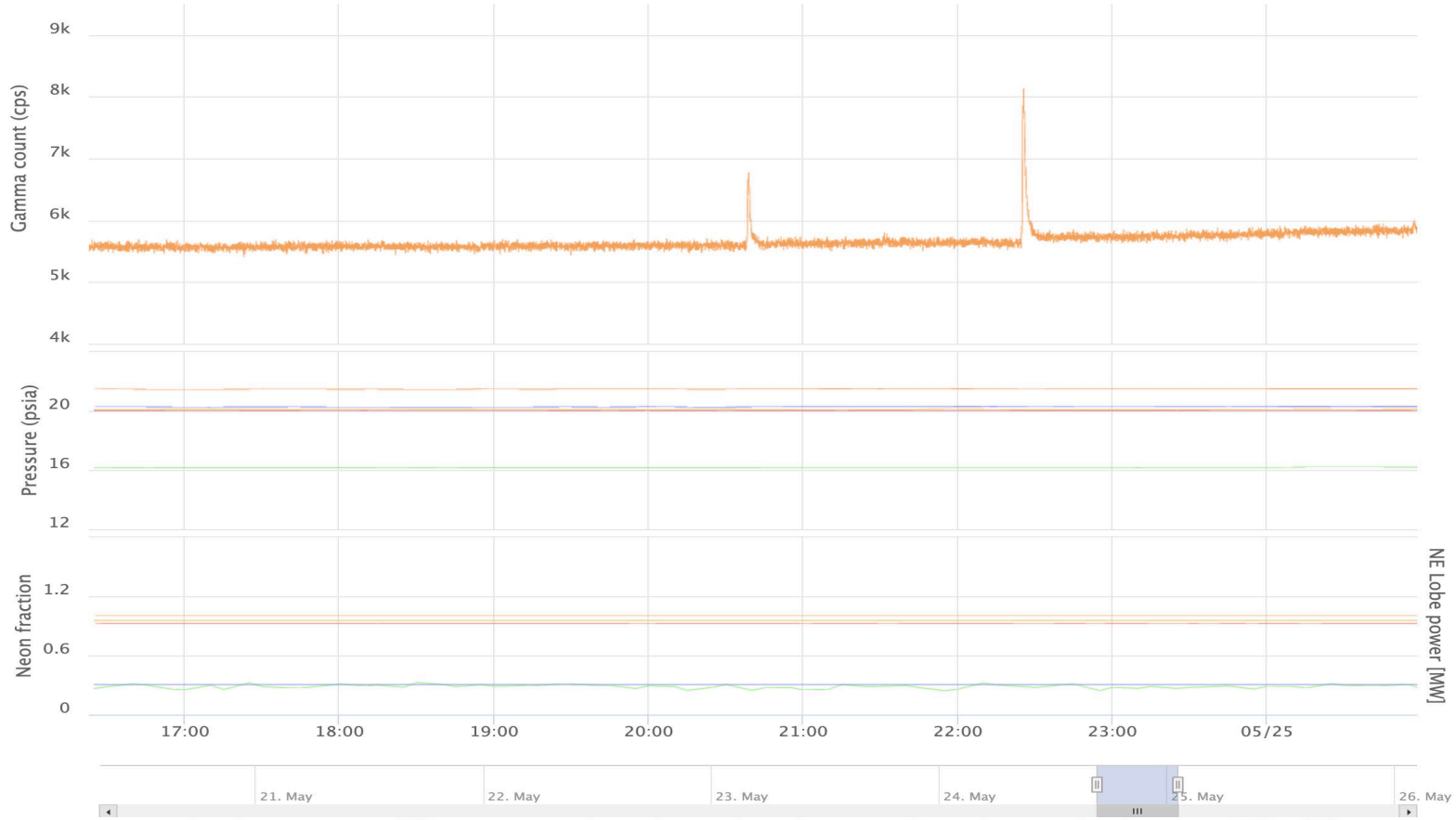
Capsule 3 – Xe-133 Analysis- Cycle 168A



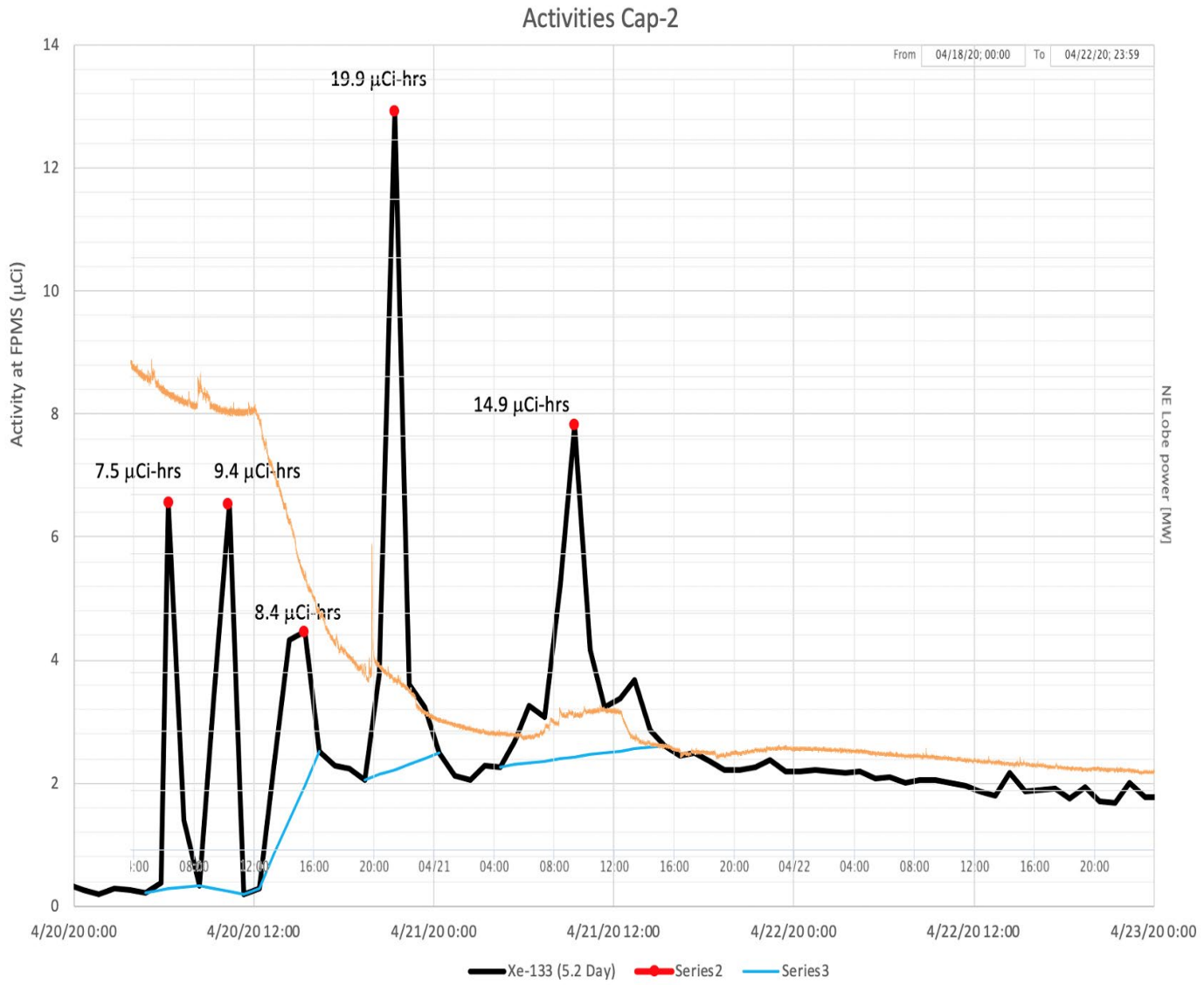
Cycle 168A – All Isotopes, Capsule 3



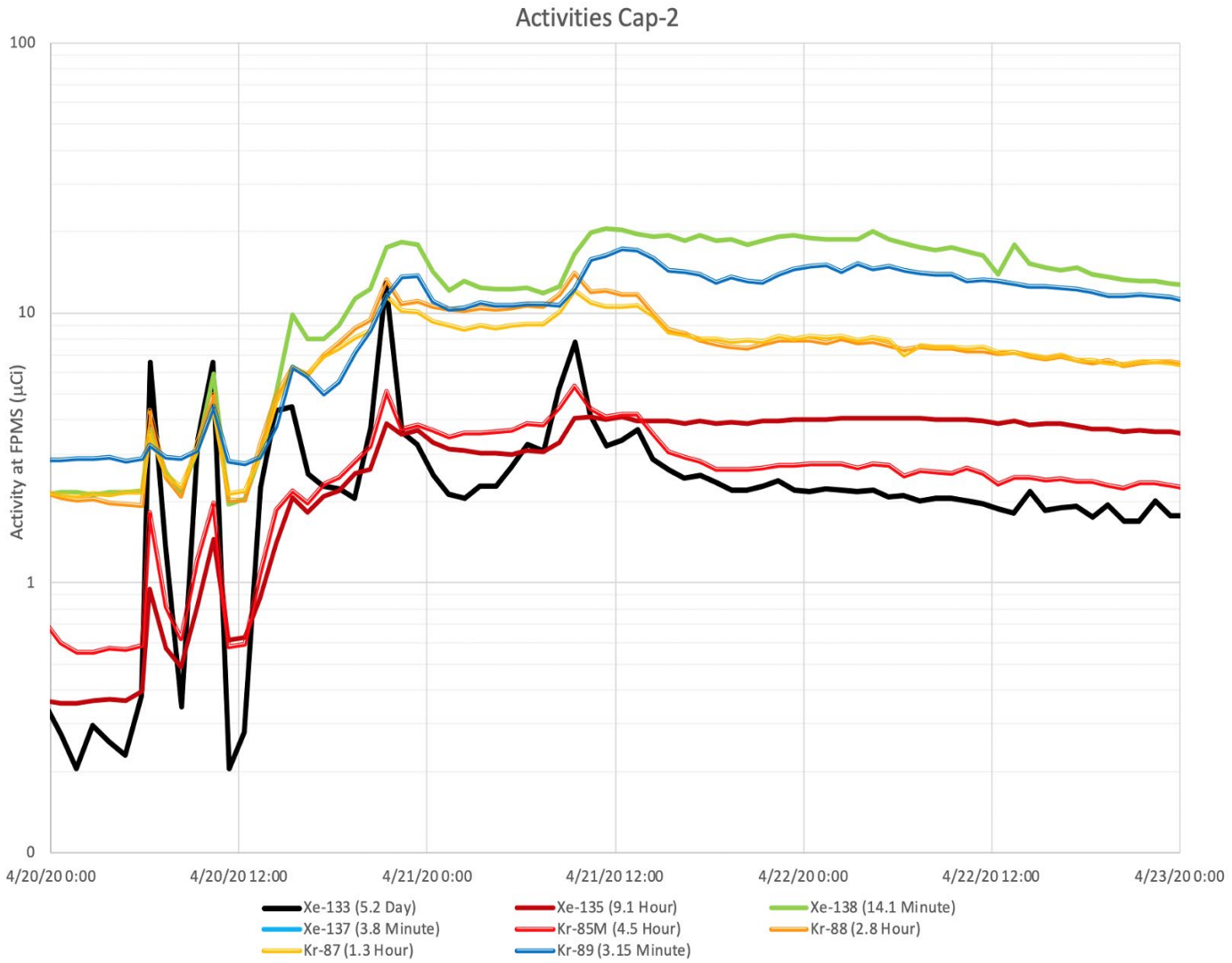
Cycle 168A – Capsule 2



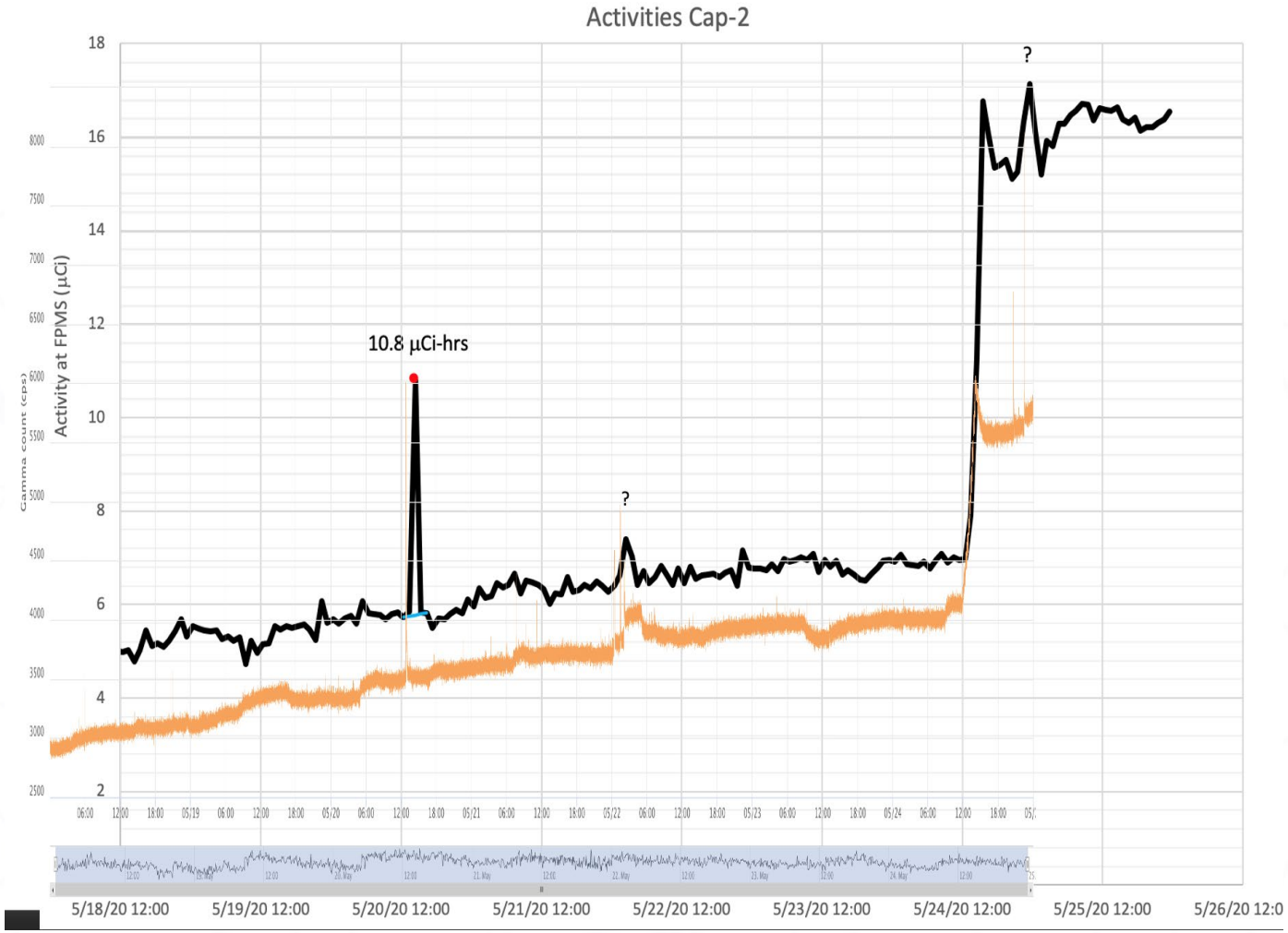
Cycle 168A, Capsule 2, Xe-133



Cycle 168A, Capsule 2 – All Isotopes



Cycle 168A, Capsule 2, GG and Xe-133 (Black Line)



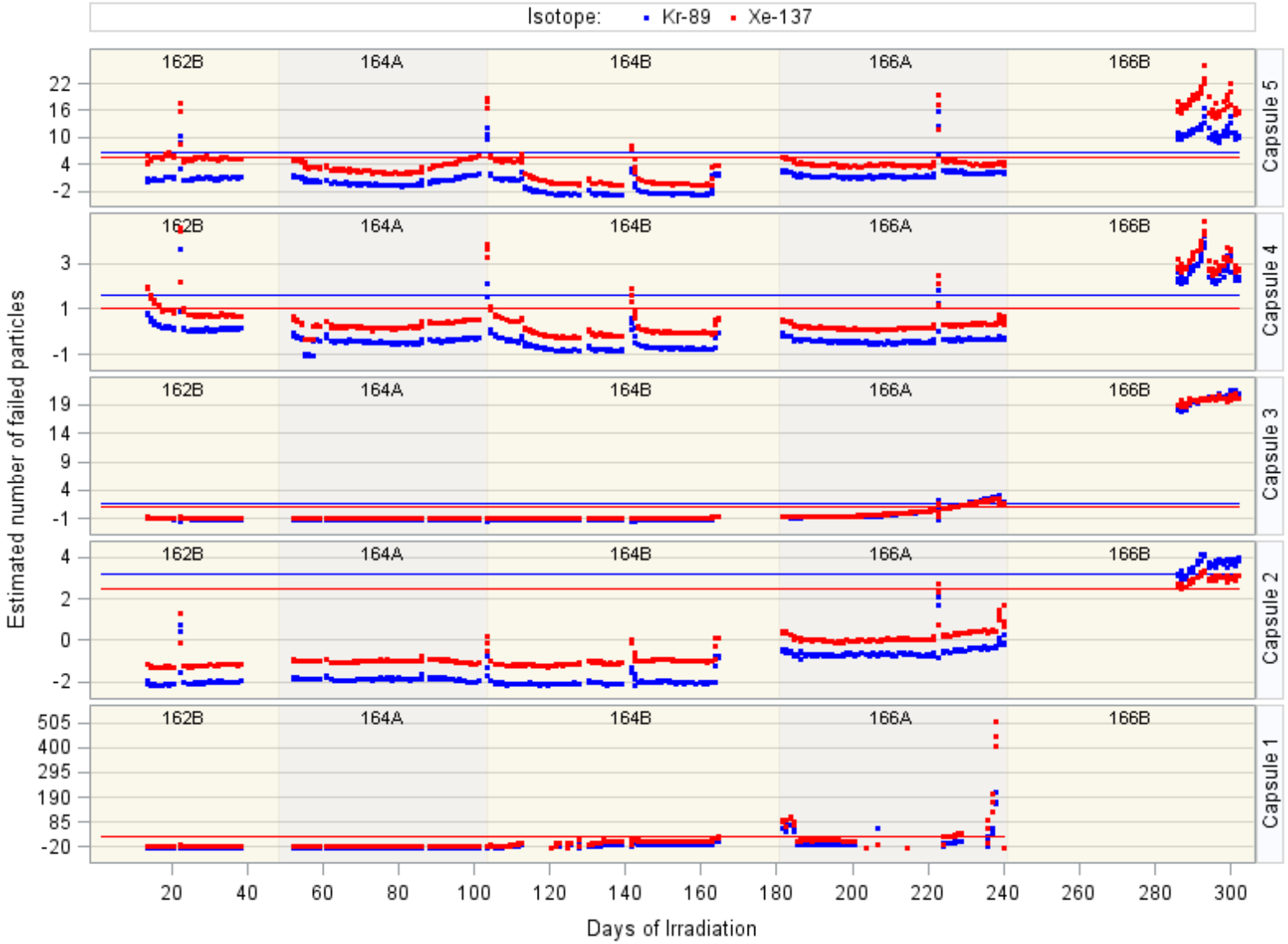
Particle Failure Estimation

- Number of in-pile particle failures ($N_{irr\_failures}$):

$$N_{irr\_failures} = \frac{R/B_{measured} * N_{particles}}{R/B_{1\_predicted}} - N_{equiv\_EKs}$$

- N_{equiv_EKs} is number of equivalent EK defects based on EK and DU fractions with DU release factor based on AGR-1 and AGR-3/4 R/B data.
- $N_{particles}$ is number of particle per capsule.
- $R/B_{measured}$ is measured R/B per capsule.
- $R/B_{1\_predicted}$ is predicted R/B per EK based on AGR-3/4 data applied to AGR-5/6/7 fuel temperatures.

Estimated number of Particle Failures



Accomplishments Since May 2019

- Successfully monitored 8 irradiation cycles and are currently monitoring cycle 9.
- Integrated an On-the Fly energy calibration routine.
- From experiment data, thousands of spectroscopy files were analyzed and release to birth ratios were determined.

Path Forward

- Continue daily monitoring of the experiment.
- Determine I-135 per cycle.
- Continue to review AGR-5/6/7 collected data and fine tune the number of particle failures and the method to determine particle failures.

Conclusion

- AGR-5/6/7 is the fourth and last experiment in the “AGR-experiment” series which is being performed and funded by the United States Department of Energy (DOE) as part of the INL Advanced Reactor Technologies (ART) program.
- Larger capsule volumes and an increase in the amount of fuel per capsule impact how gaseous fission products, such as longer- and shorter-lived isotopes of Kr and Xe are transported to the FPMS thus impacting the release activity calculations that are used in conjunction with birth rates as a metric of fuel performance.
- R/B and GG indicated that there were no particle failures through Cycle 165A.
- Particle failures were observed in Capsule 1 starting in cycle 166A and in Cycle 168A for Capsule 3 and possibly Capsule 2 however this data is still under severe scrutiny.
- Data and test conditions will be re-evaluated as needed.

- Dr. Edward L. Reber
- Dr. Ryan Fronk
- Dr. Binh Pham
- Thomas Nance
- RML (ATR - Radiation Monitoring Lab)
- ATR LOC (Loop Operation Control)

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AGR-5/6/7 Fuel Parameters

Capsule	No. of Particles	Packing Fraction
1	309,060	40%
2	72,448	25%
3	54,360	25%
4	52,728	25%
5	81,432	40%

AGR Temperature Goals

AGR-5/6: The time average temperature distribution goals:

- **≥ 600°C - < 900°C for 30% of the fuel**
- **≥ 900°C - <1050°C for 30% of the fuel**
- **≥1050°C - <1250°C for 30% of the fuel**
- **≥1250°C - <1400°C for 10% of the fuel**

AGR-7 (Capsule 3): The time average, peak temperature:

- **1350± 50°C - 1500 ± 50°C**

- TRISO-particle fuel in the form of cylindrical compacts.
- Nominally 25.0mm in length and 12.3 mm in diameter.
- 194 compacts distributed within 5 capsules that contain a U-235 content of 35.7 grams and total uranium content of 230.3 grams.
- The particles are UCO low enriched uranium (LEU) fuel kernels with an enrichment level of 15.5wt%.
- The TRISO over-coating process yields AGR-5/6/7 fuel particles that have 870-µm nominal diameter.
- Number of particles per capsule are obtained by dividing the uranium mass content of a compact by the uranium mass content of a particle.