

Lunar Demonstration of the RadPC Fault-Tolerant Space Computer

Presented by
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Montana State University

Project - RadPC Lunar

NASA Funded Technology Demonstrator

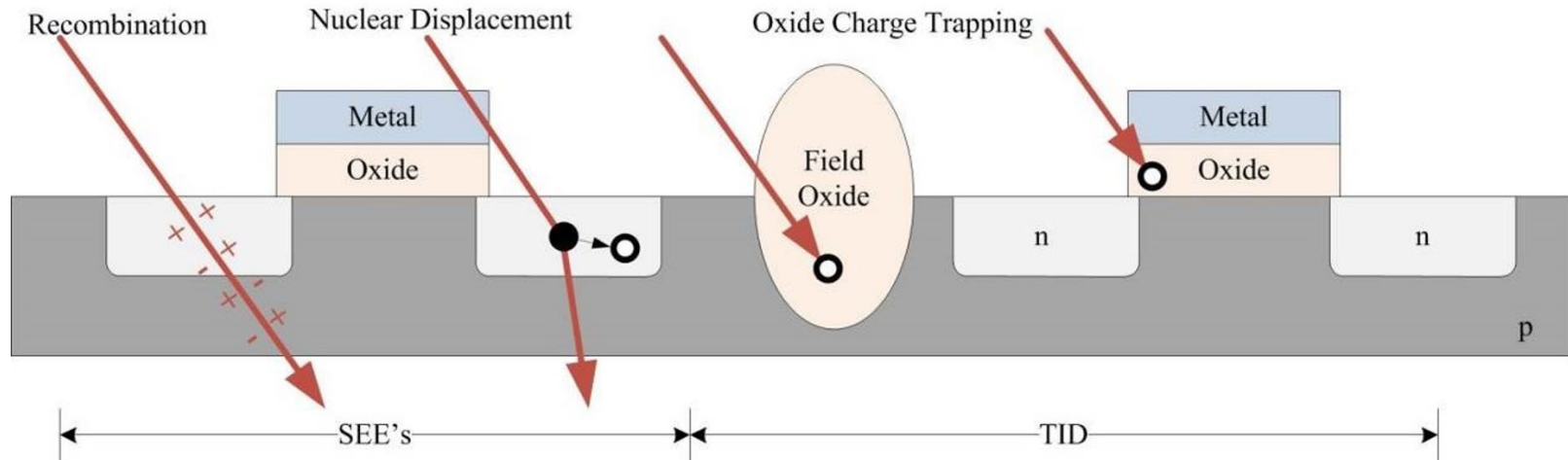
Payload on Firefly's Lunar Lander Blue Ghost One

Six Operational Passes through Van Allen Belts

Operational on Lunar Surface



Mitigation of SEEs



Single Event Effect

Free Charge from Ionizing Particle

Tempory Damage

Total Ionizing Dose

Physical Degradation of Material

Charge Trapped in Transistor

Payload Mission



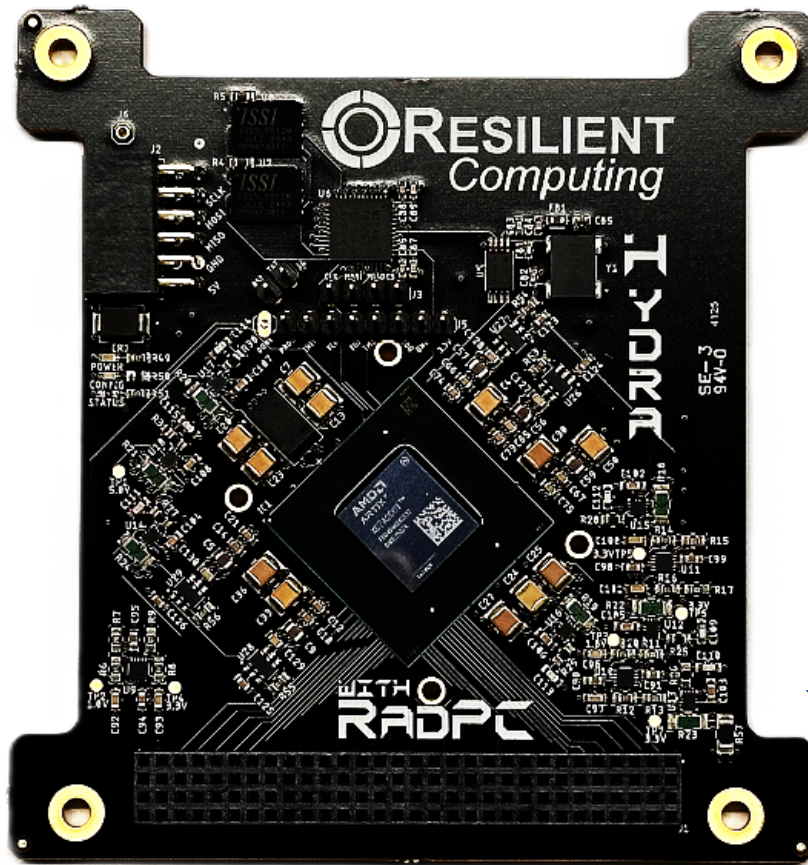
Objective 1: Operate commercial FPGA Based Computer, RadPC, In A Harsh Radiation Environment

Objective 2: Observe Radiation Environment During Computer Operation

Objective 3: Detect and repair faults from SEEs during operation

RADPC

Radiation Tolerant Space Computer



1. Off-the-Shelf Programmable Part

- Lower cost.
- Higher performance.

2. Redundancy

- Four redundant softcores
- Vote on the outputs

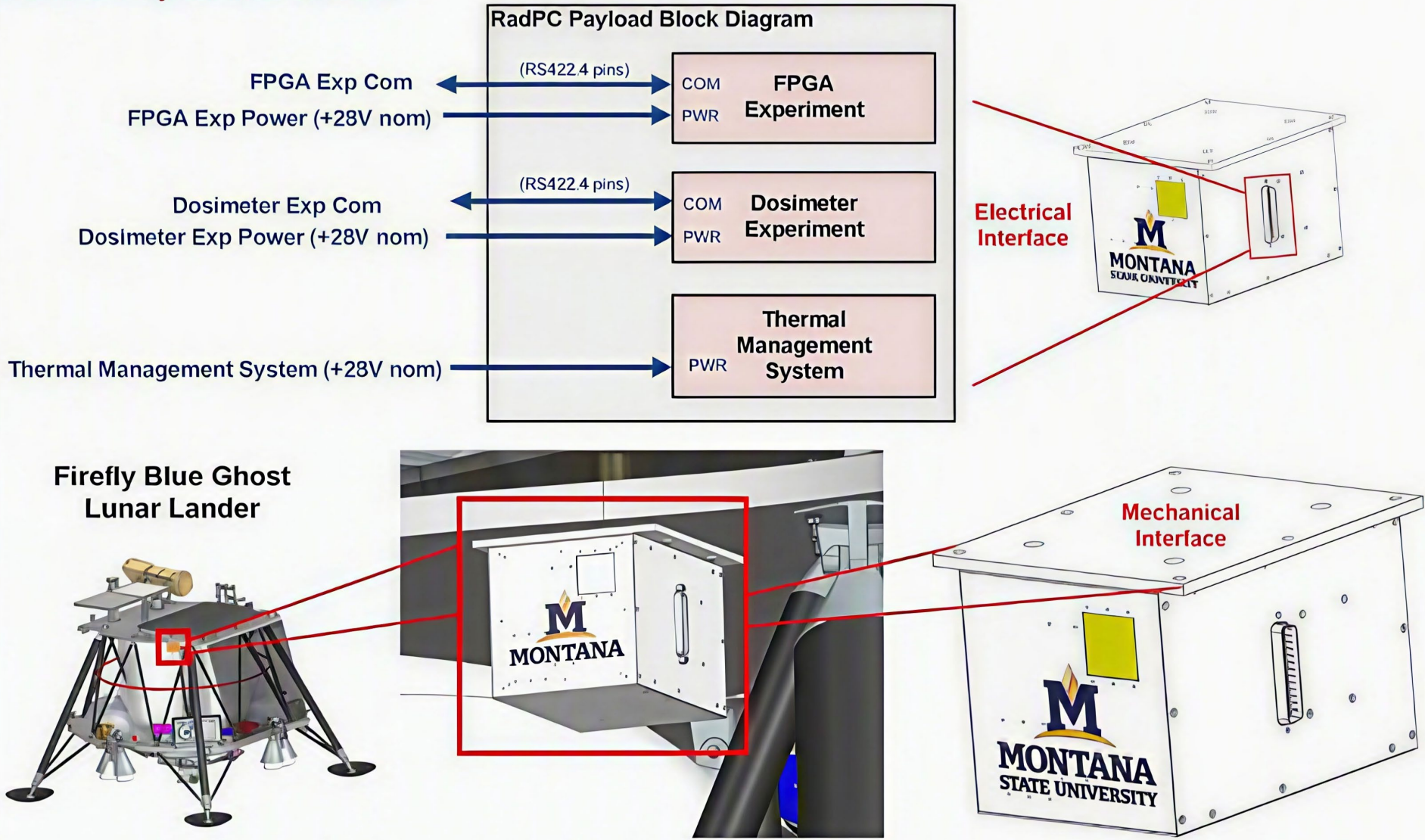
3. “Scrub” Memory Errors

- Compare values and auto-fix.

4. “Fix” Errors in the Background

- Reprogram the damaged region.
- Reconfigure FPGA to clear faults.

RadPC Payload Overview



Payload Design

Three Dosimeters Radiation Sensors

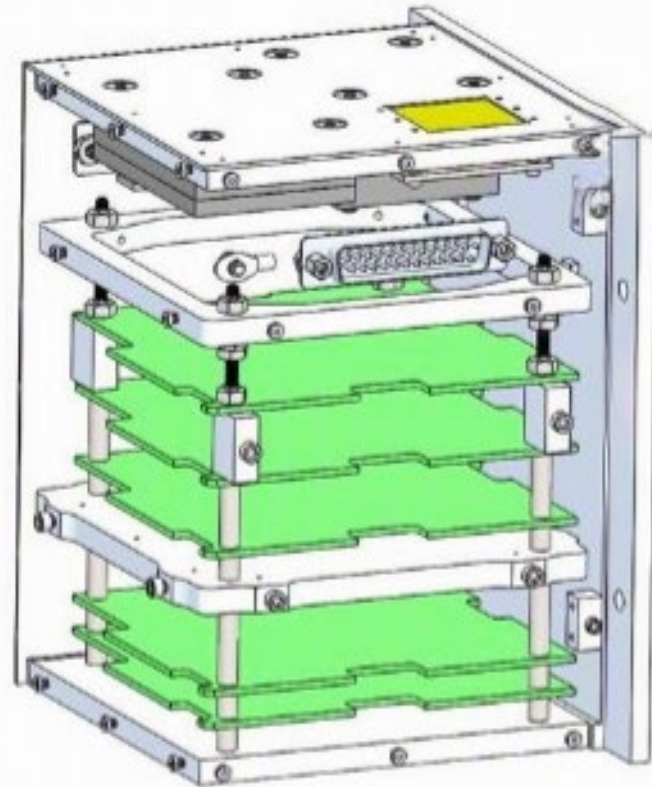
Spacecraft Interface Board

Dosimeter Processing Board

First RadPC Single Board Computer

Second RadPC Single Board Computer

Memorabilia Board



Blue Ghost Lander Integration

Integrated on Blue Ghost One's Top Deck

RadPC Payload Facing Outward on Sunny Side of Lander When Landed

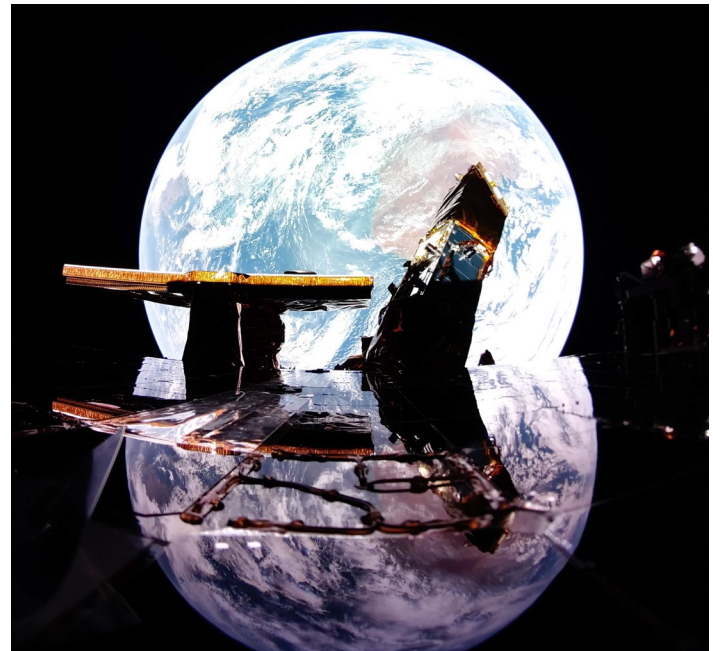
Launch from Kennedy Space Center

SpaceX Falcon 9

1:11 am, January 15, 2025

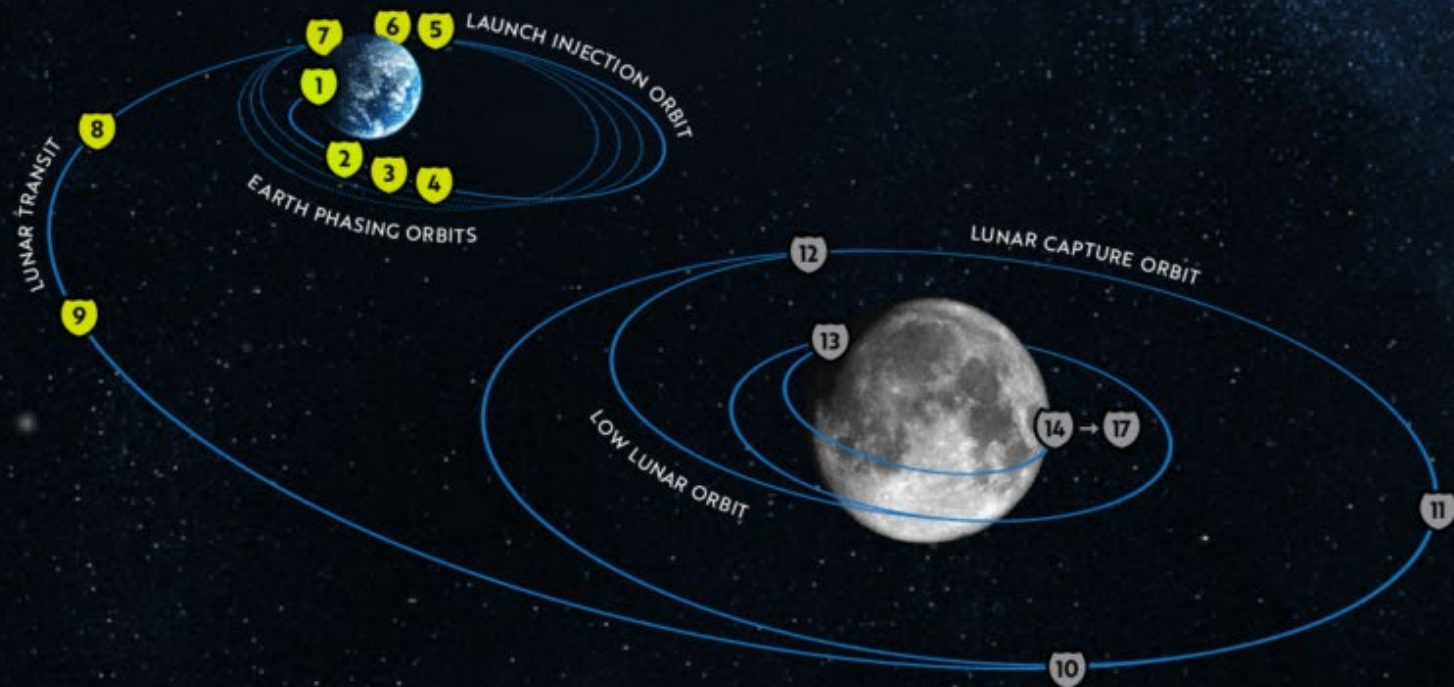
Launch Complex 39A KSC





Mare Crisium, March 2nd, 2025





LAUNCH 1 HOUR	ON-ORBIT COMMISSIONING 8 HOURS	EARTH ORBIT 25 DAYS	LUNAR TRANSIT 4 DAYS	LUNAR ORBIT 16 DAYS	DESCENT 1 HOUR	SURFACE OPERATIONS 14 DAYS
1 LAUNCH	3 SIGNAL ACQUISITION	6 EARTH ORBIT PHASING	8 TRANS LUNAR INJECTION	10 LUNAR ORBIT INSERTION	13 DESCENT ORBIT INSERTION	15 SURFACE COMMISSIONING
2 LAUNCH VEHICLE SEPARATION	4 ELECTRICAL & PAYLOAD CHECKOUTS	7 ON-ORBIT PAYLOAD SCIENCE BEGINS	9 TRAJECTORY CORRECTION MANEUVER(S)	11 VISION NAVIGATION CALIBRATION	14 TOUCHDOWN	16 SURFACE PAYLOAD SCIENCE
	5 ENGINE CALIBRATION			12 LOW LUNAR ORBIT INSERTION		17 LUNAR NIGHT OPERATIONS

Course

RadPC Power on outside of Van Allen Belts (< 6 hr of launch)

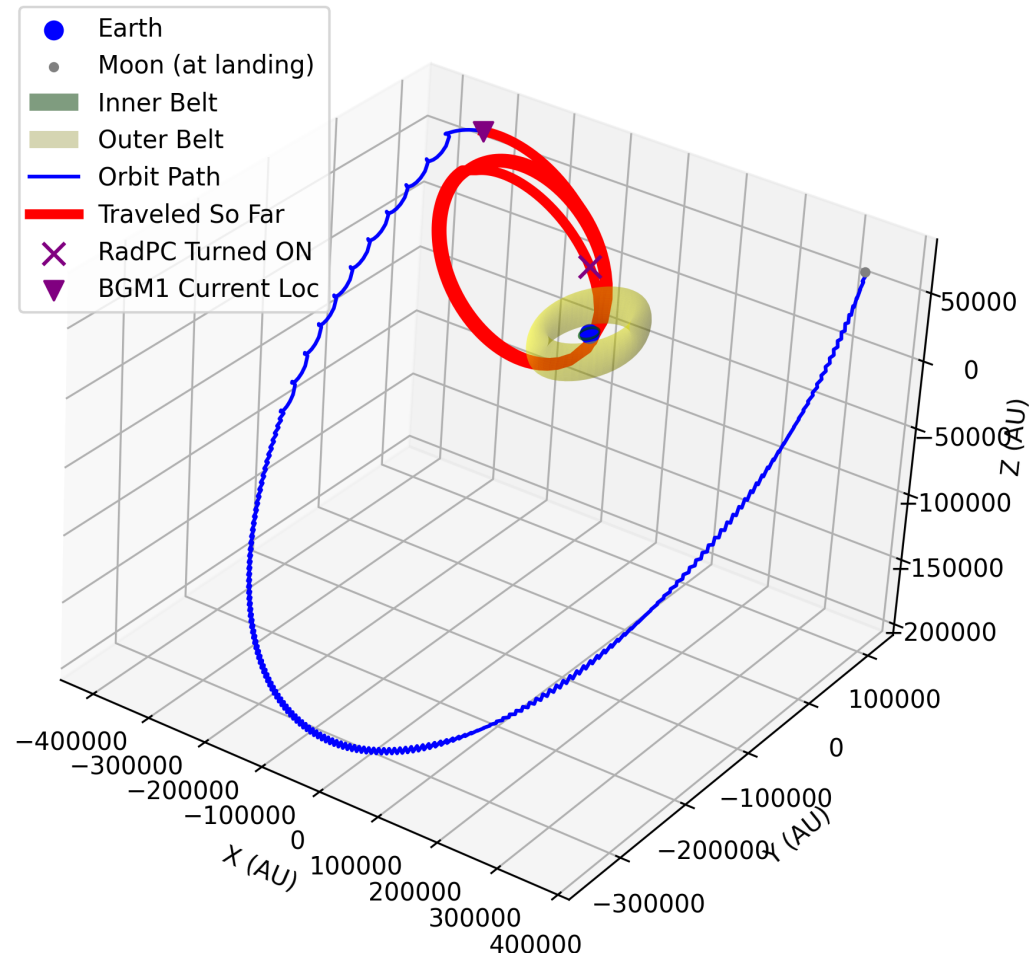
6 Passes through Van Allen Belts with RadPC operational

16 Days of Lunar Orbits with RadPC operational

RadPC powered down for lunar descent

14 Days of Lunar Surface with RadPC operational

BGM1 Path (updated 2/11/25 @ 7 pm MT)

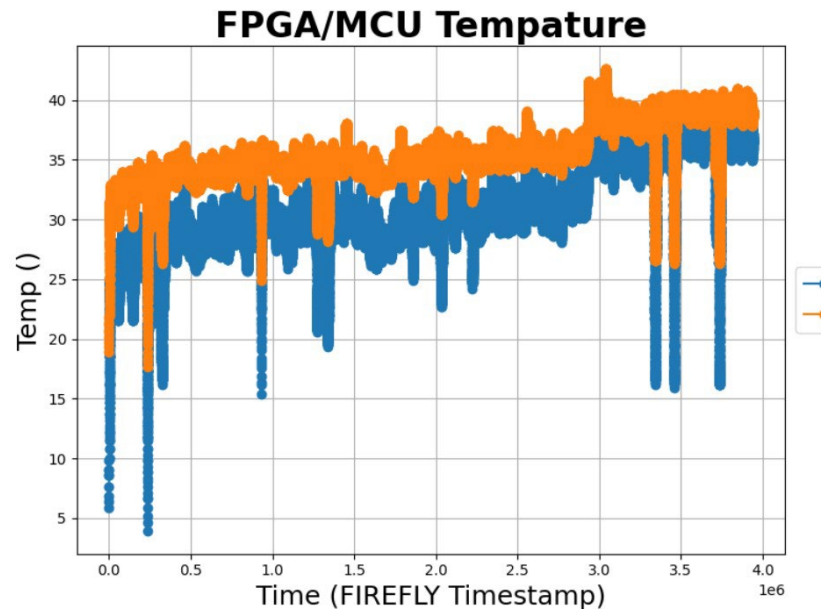
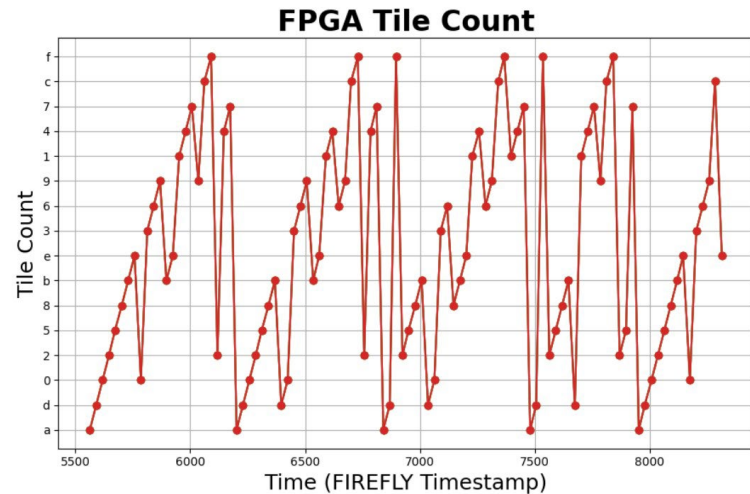


In-Transit Monitoring

Radiation via dosimeters

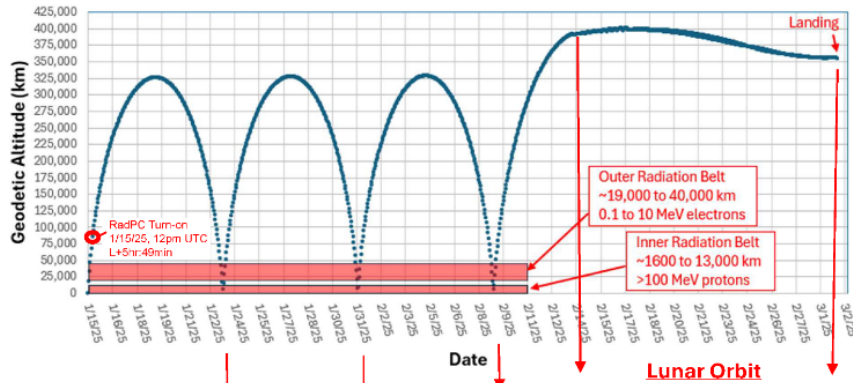
RadPC board internal fault monitoring

Temperature monitoring of FPGA die and watchdog microcontroller



Radiation

BGM1 Earth Altitude vs. Mission Time

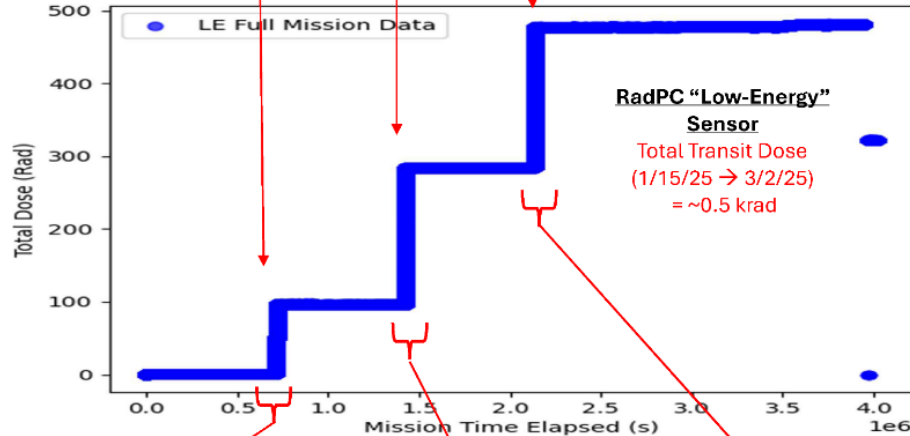


6 Total Van Allen Belt transits

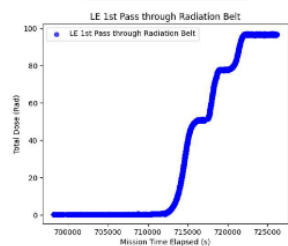
0.5 kRad of observed radiation by payload per Van Allen Belts transit

SEE faults were repaired by RadPC internal error repair subsystems

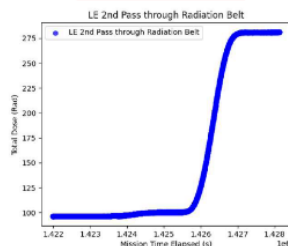
RadPC maintained functionality



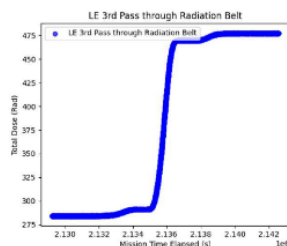
Zoom of 1st Pass



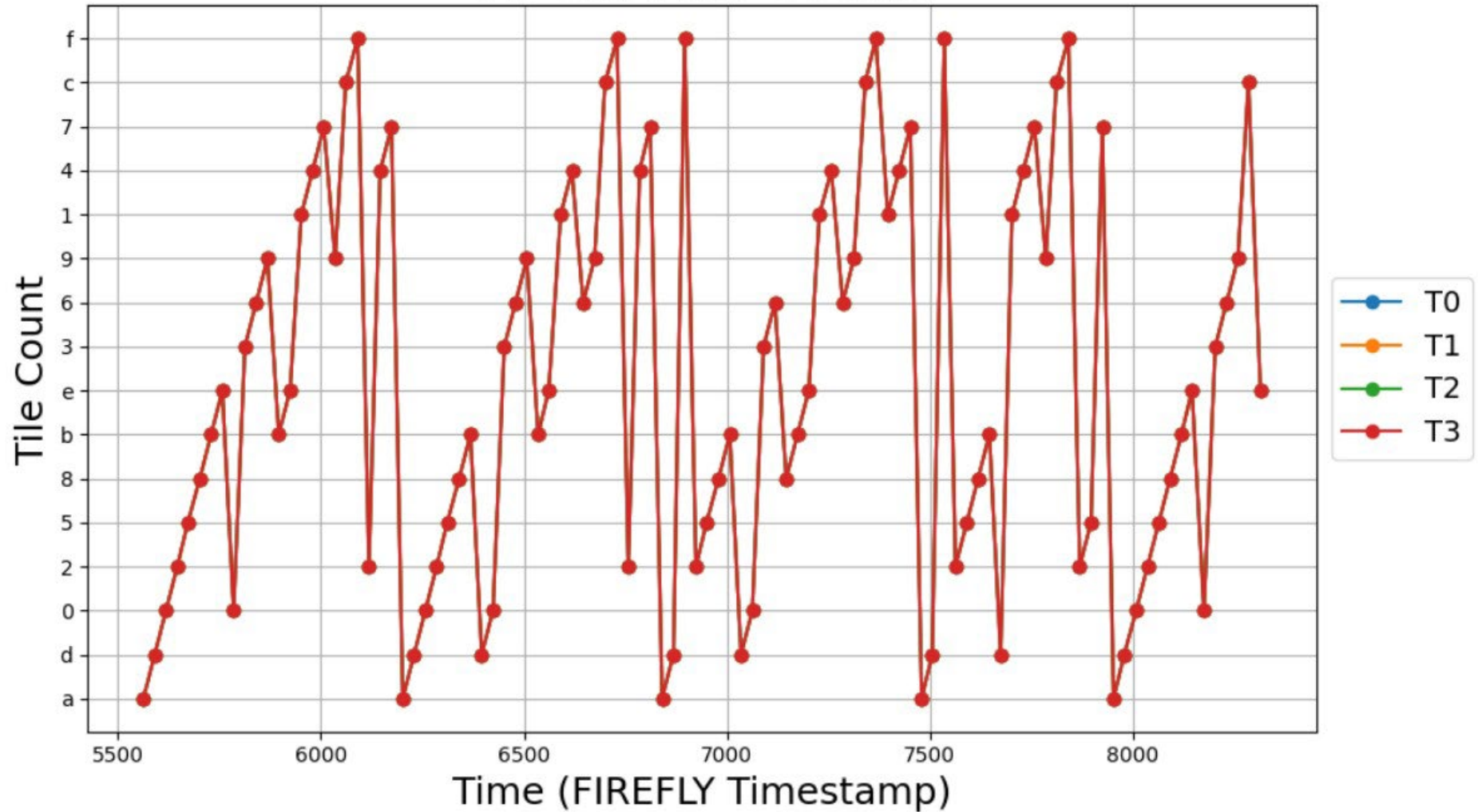
Zoom of 2nd Pass



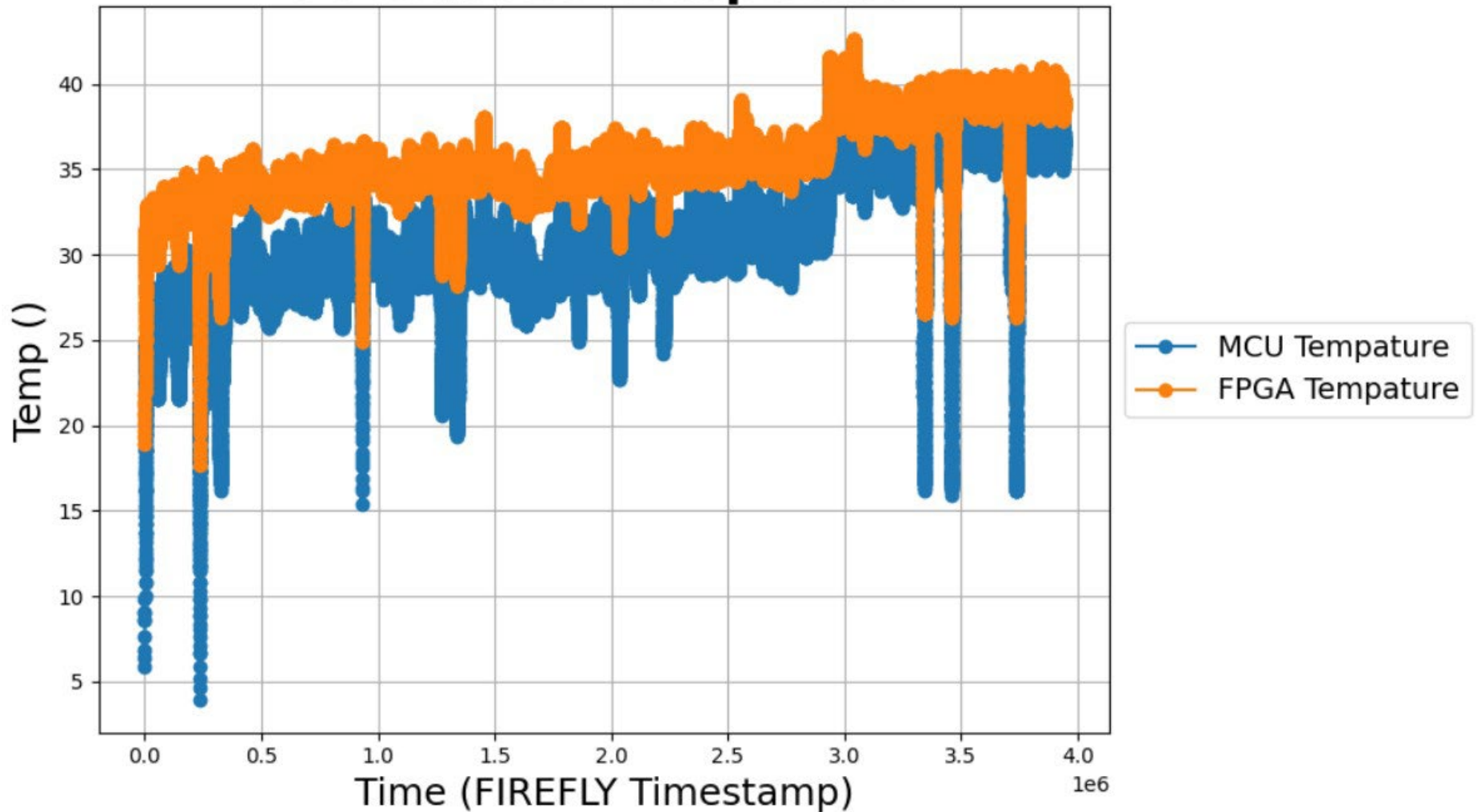
Zoom of 3rd Pass



FPGA Tile Count



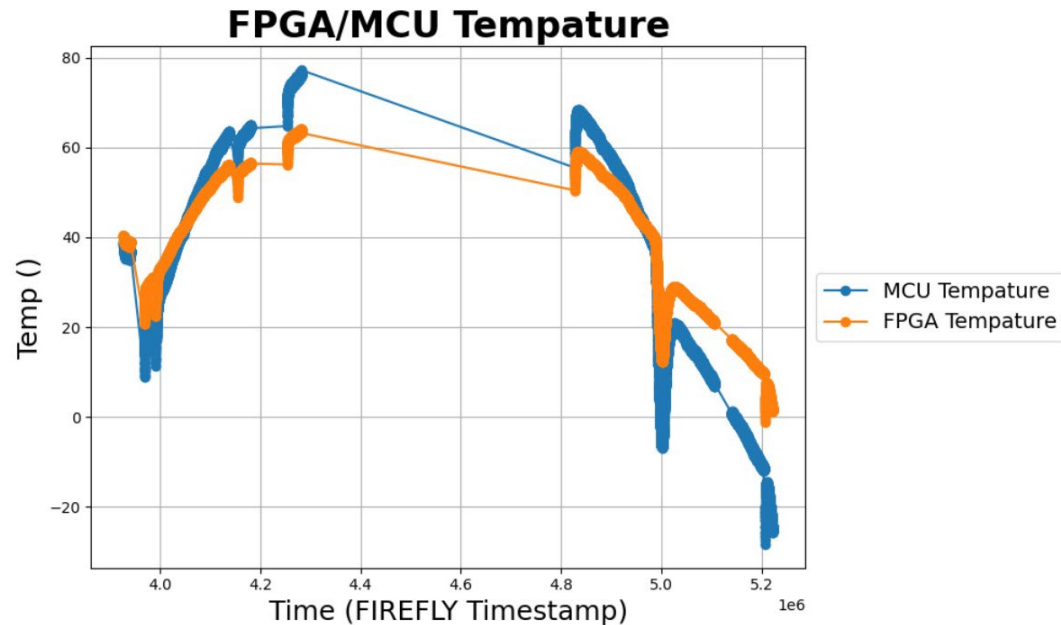
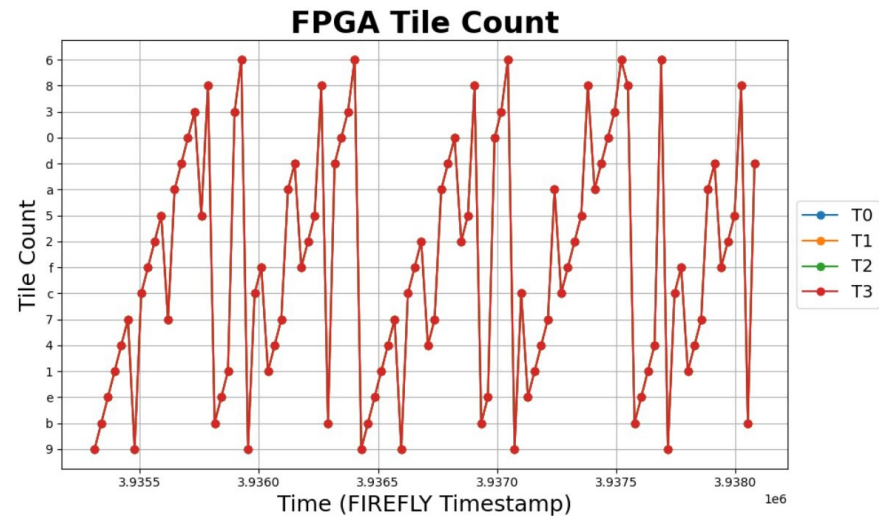
FPGA/MCU Temperature



Lunar Surface Monitoring

RadPC board internal
fault monitoring
detected and repair
faults

Temperature monitoring
of FPGA die and
watchdog microcontroller
on lunar surface



Lunar Noon, Solar Eclipse, and Dying of the Light

RadPC Payload Power on

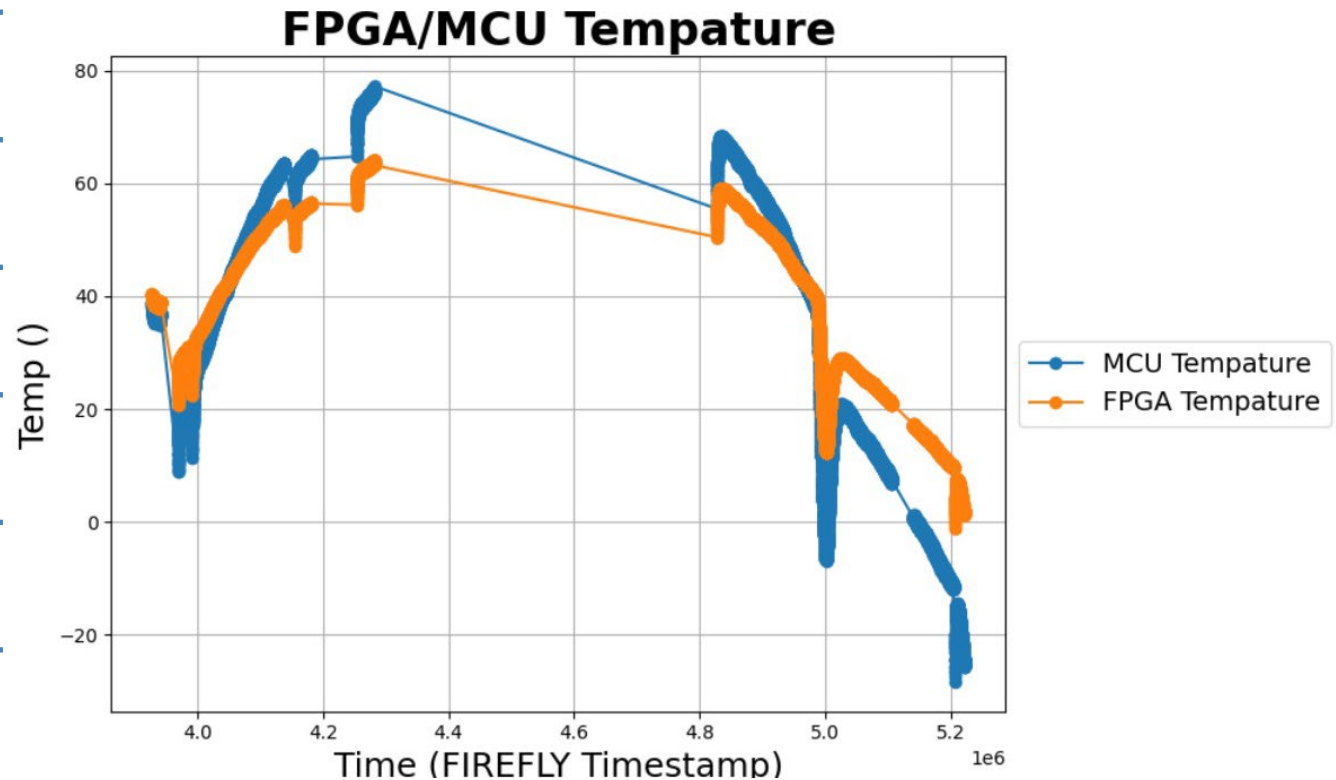
Raising temperature from lunar noon

RadPC Payload shutdown due to raising temperatures on lander

RadPC Payload power on and operation following end of lunar noon

Solar Eclipse

Lunar Twilight



Questions