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Detection and Classification of High Energy Beta Radiation Induced Damage of Raspberry Pi Zero Intended for OPAL CubeSat

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MATERIALS PHYSICS GROUP

Detection and Classification of High Energy Beta Radiation induced Damage of Raspberry Pi Zero intended for OPAL CubeSat

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Overview

- Purpose of the Experiment
- The Space Environment
- Ionizing Radiation
- Experimental Design
- Equipment
  - Space survivability Test (SST) Chamber
  - The Raspberry Pi Zero
- Testing Procedures
  - Dose Rate and Time of Exposure
  - Thermal Conductivity
- Questions

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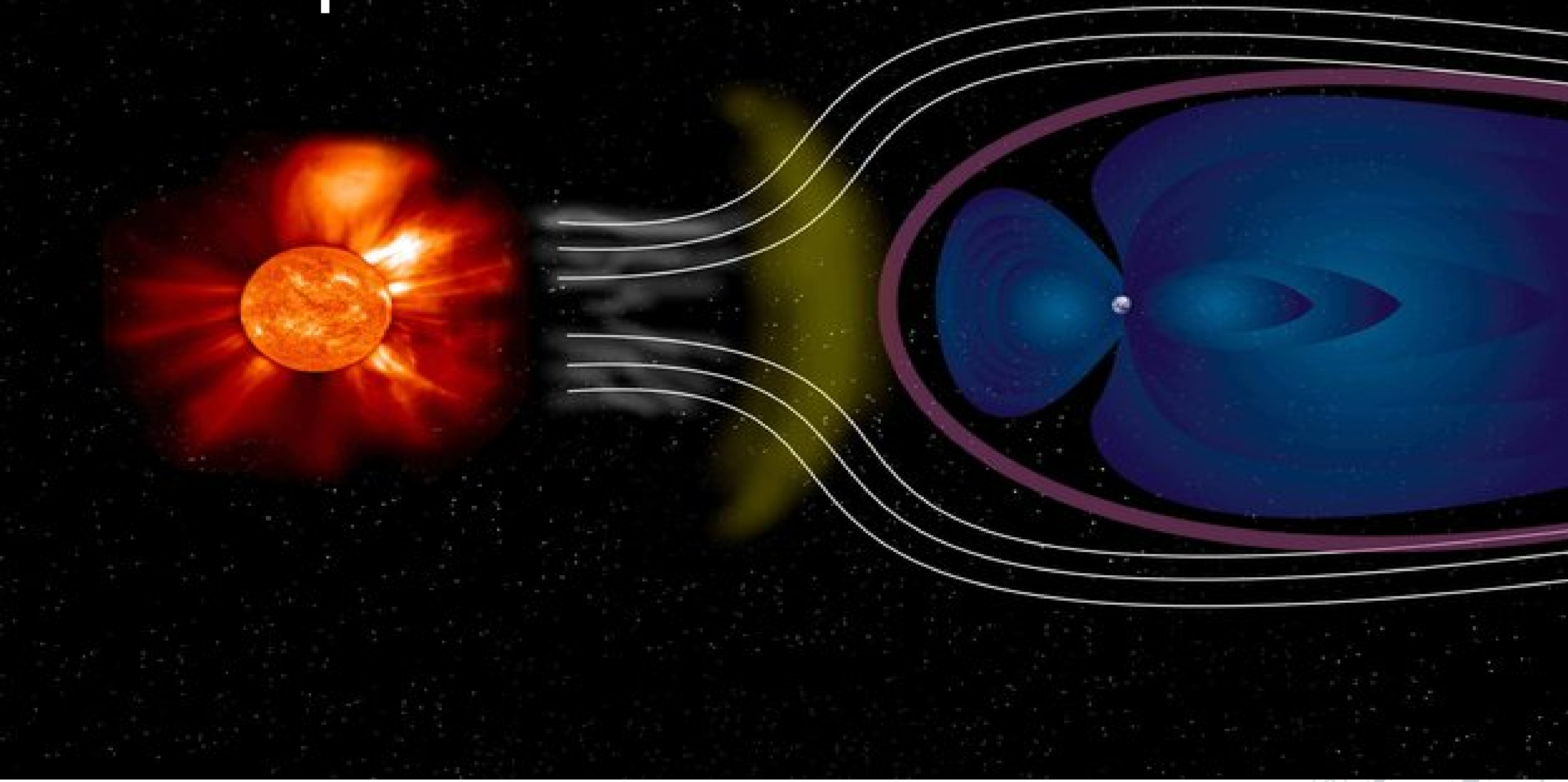
Purpose of the Experiment

To determine the amount of ionizing radiation that the memory and processor units of a Raspberry Pi Zero can be exposed to before they exhibit radiation-induced damage or stop working altogether.

The Space Environment



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- Space debris
- Neutral Thermosphere
- Thermal Environment
- Plasma
- Solar Environment
- Magnetic Field
- **Ionizing Radiation**

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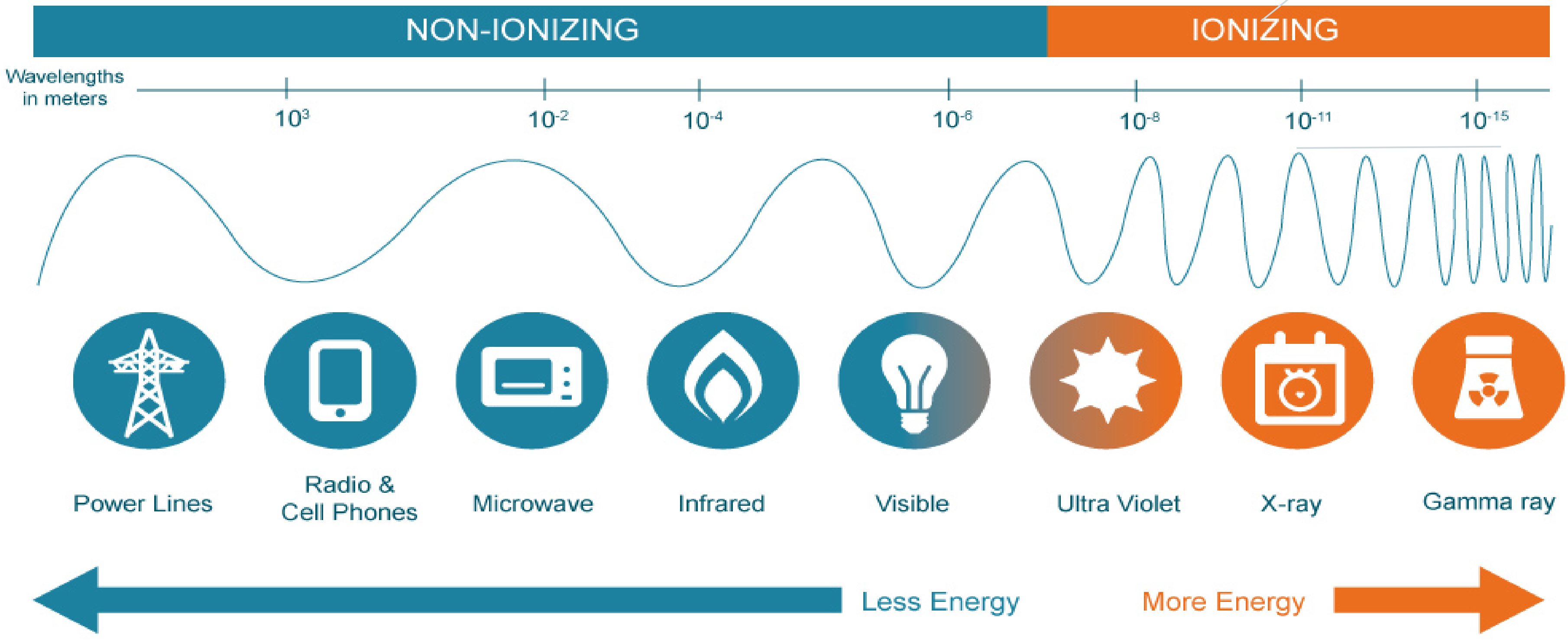
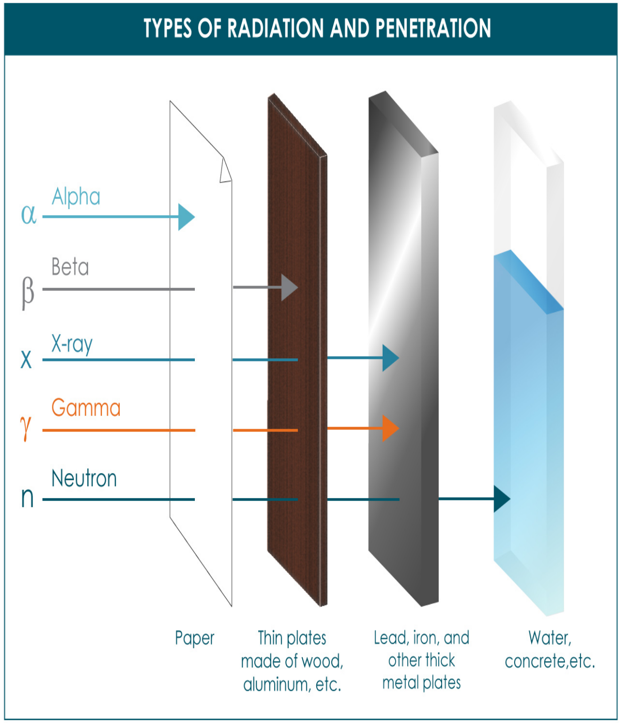
Ionizing Radiation (IR)



- IR Generate electron hole pairs in semiconductors and insulators.
- The accumulated effect of ionizing radiation is called the total ionizing dose (TID)
- TID can cause single even effects (SEE) in electronics components.



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- **Single event upsets** (SEU) are unexpected bit changes in the memory.
- **Single event latch-up** (SEL) can be manifested in unexpected high currents that will radically affect the device.

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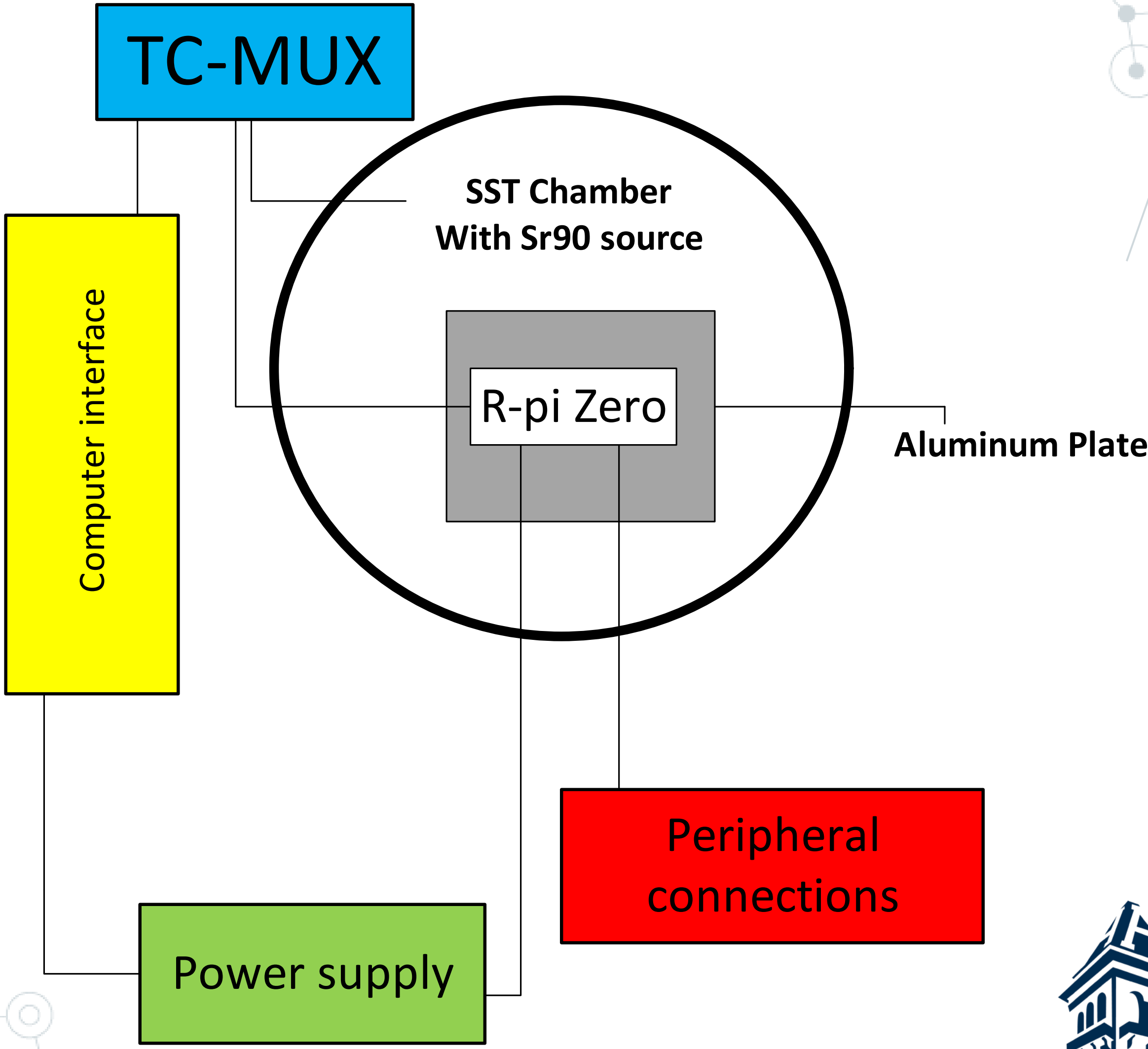
Experimental Design



Equipment

- Space Survivability Test (SST) chamber
  - Sr^{90} source
  - TC-MUX
  - Power supply monitor program
- Raspberry Pi Zero
  - SEU detector program
- Peripheral connections

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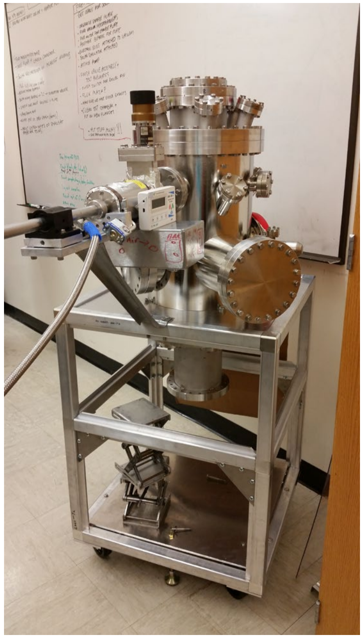
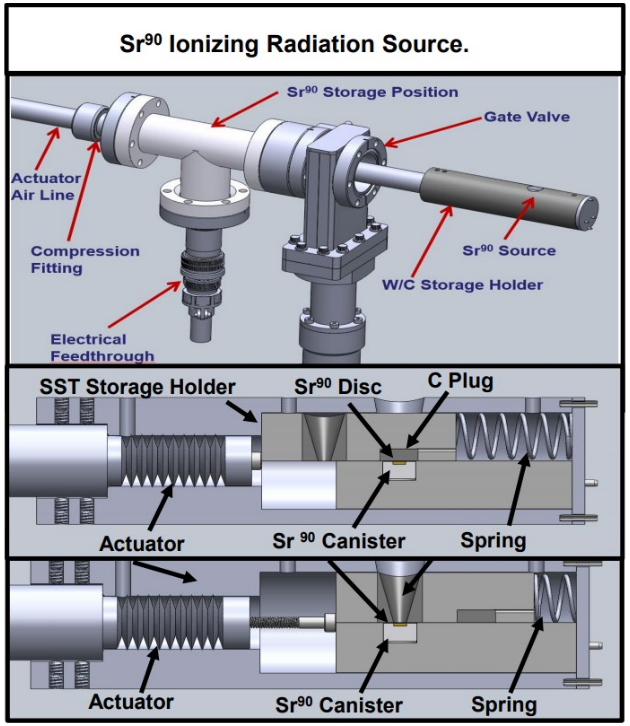
SST Chamber

Can simulate various aspects of a space environment.



Sr^{90}

Is a beta radiation source emitting particles of 0.2 to 2.5 MeV.



Thermocouple Multiplexer (TC-MUX)

Is an eight-channel multiplexer for type K thermocouples.

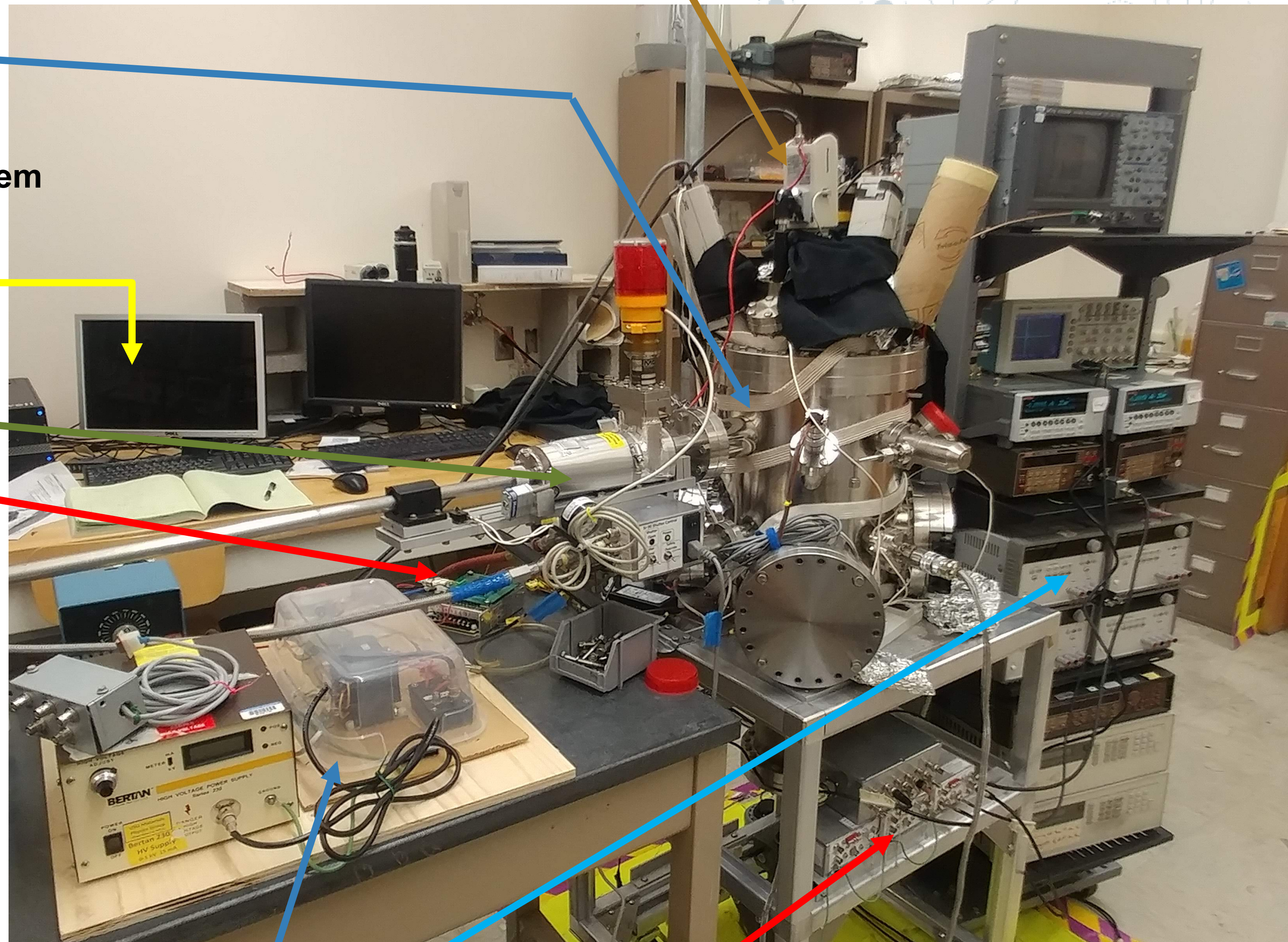
Cameras

SST Chamber

Computer monitoring system

Sr^{90} source

TC-MUX



Power supply

Arc thief

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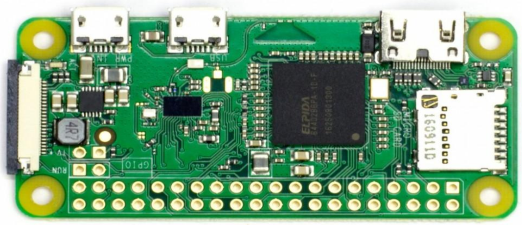
The Raspberry Pi Zero



- Small, inexpensive, reliable
- Common used for CubeSat and robotics
- Commonly operated with Raspbian

Testing Procedure

Dose Rate and Time of Exposure.

- The OPAL CubeSat mission will last 1-2 years in Low Earth Orbit (LEO)
- for LEO the TID is $\sim 1 \frac{krad}{yr}$
- The Dose Rate of the Sr^{90} is $0.1 \frac{krad}{hr}$ at 12in distance and falls as $\frac{1}{r^2}$ in an area with 6in diameter

$$DR_o := 0.1 \cdot \frac{\text{krad}}{\text{hr}}$$

$$DR := DR_o \cdot \left(\frac{6 \cdot \text{in}}{2.75 \cdot \text{in}} \right)^2 = 10.476 \cdot \frac{\text{krad}}{\text{hr}}$$

$$TID_{yr} := 2 \cdot \frac{\text{krad}}{\text{yr}}$$

$$T_{mission} := 1\text{yr}$$

$$sf := 2$$

$$TID_{Mission} := TID_{yr} \cdot T_{mission} \cdot sf = 40 \frac{m^2}{s^2}$$

$$T_{exp} := \frac{TID_{Mission}}{DR} = \boxed{8.403\ \text{hr}}$$

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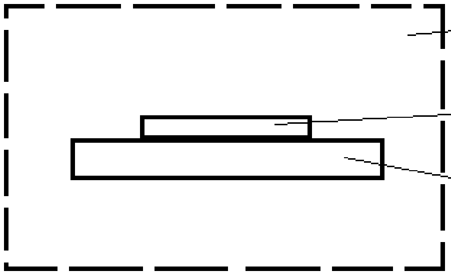
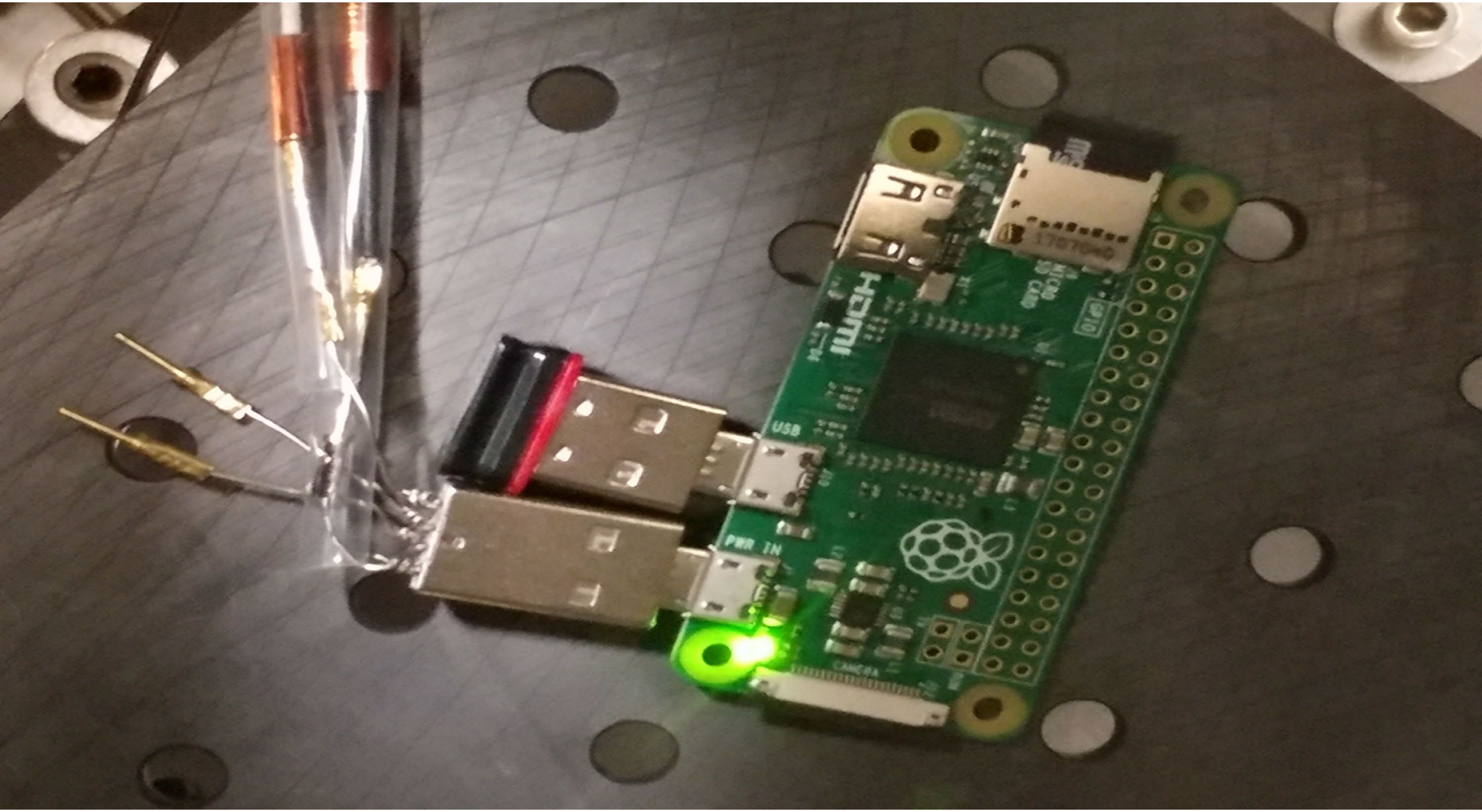
Thermal conductivity



$$Q = \frac{tkA\Delta T}{d}$$

- $t = time$
- $k = thermal\ conductivity$
- $A = surface\ area$
- $\Delta T = change\ in\ temperature$
- $d = thickness\ of\ the\ material$
- $K_{Si} = 149W/mK$
- $K_{Al} = 237W/mK$
- $A_{Al} = 4\frac{1}{2} \times 4\frac{1}{2}\ in$
- $A_{Si} = \frac{1}{2} \times \frac{1}{2}\ in$
- $d_{Al} = \frac{1}{4} in$
- $d_{Si} = \frac{1}{40}\ in$


USB
PWR IN

What's next?

- In the upcoming weeks we will proceed to our test run in the chamber.
- Determining the probability of SEU and their location in the SRAM
- Determining the thermal conductivity to determine the reliability of COTS component

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Thanks!