Towards a Radiation-Tolerant Display System

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Acronyms

COTS: Commercial-Off-The-Shelf

CPU: Central Processing Unit

FPGA: Field-Programmable Gate Array

GPU: Graphics Processing Unit

LCD: Liquid Crystal Display

OLED: Organic Light-Emitting Diode

Rad-Hard: Radiation-Hardened

Rad-Tol: Radiation-Tolerant

SEE: Single-Event Effect

SEFI: Single-Event Functional Interrupt

SEL: Single-Event Latchup

SoC: System-on-Chip

STAR: Space Technology Application Renderer

TID: Total Ionizing Dose

Acknowledgements

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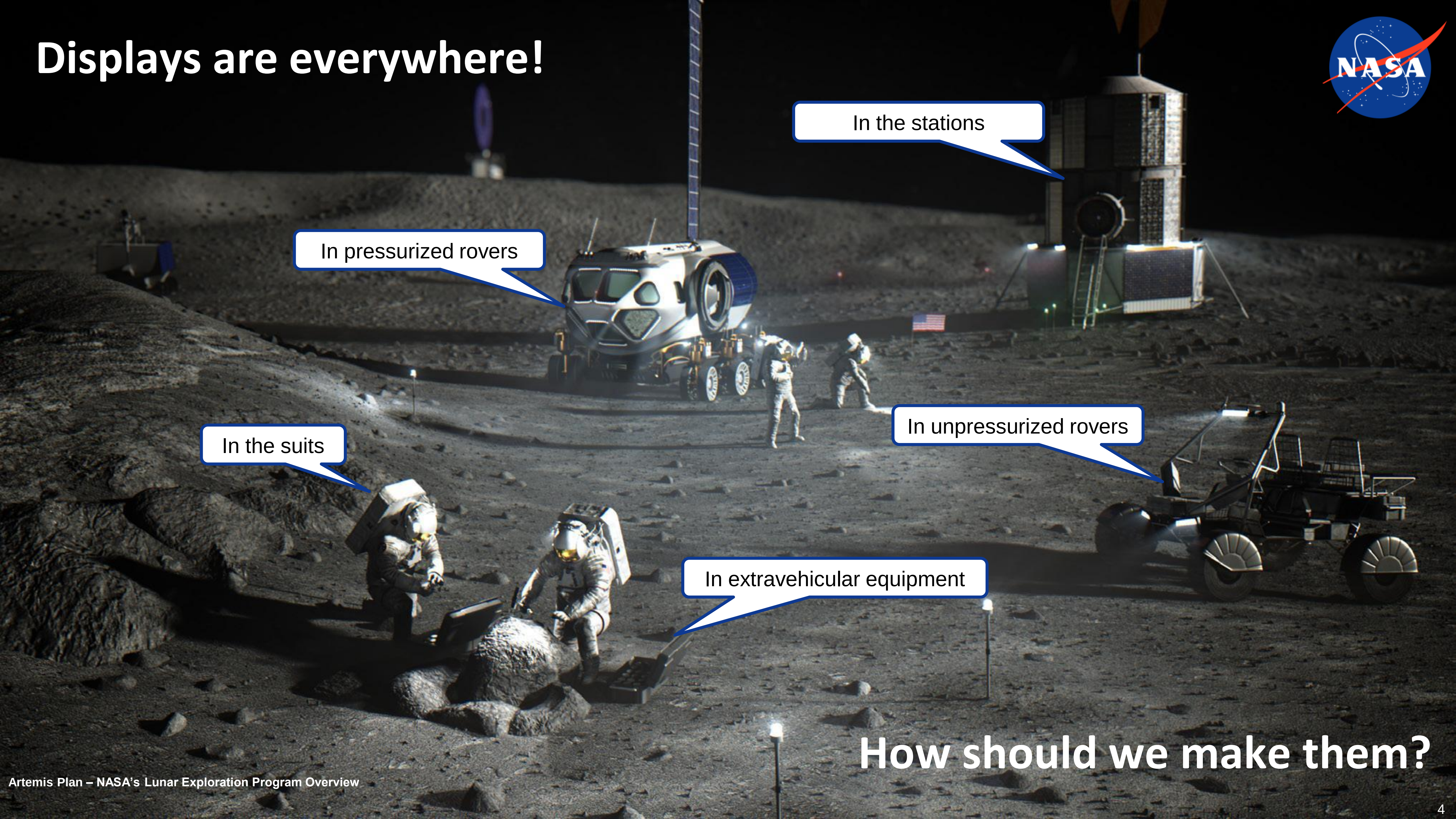
Mission-Critical Computing

NSF CENTER FOR SPACE, HIGH-PERFORMANCE, AND RESILIENT COMPUTING (SHREC)

Displays are everywhere!

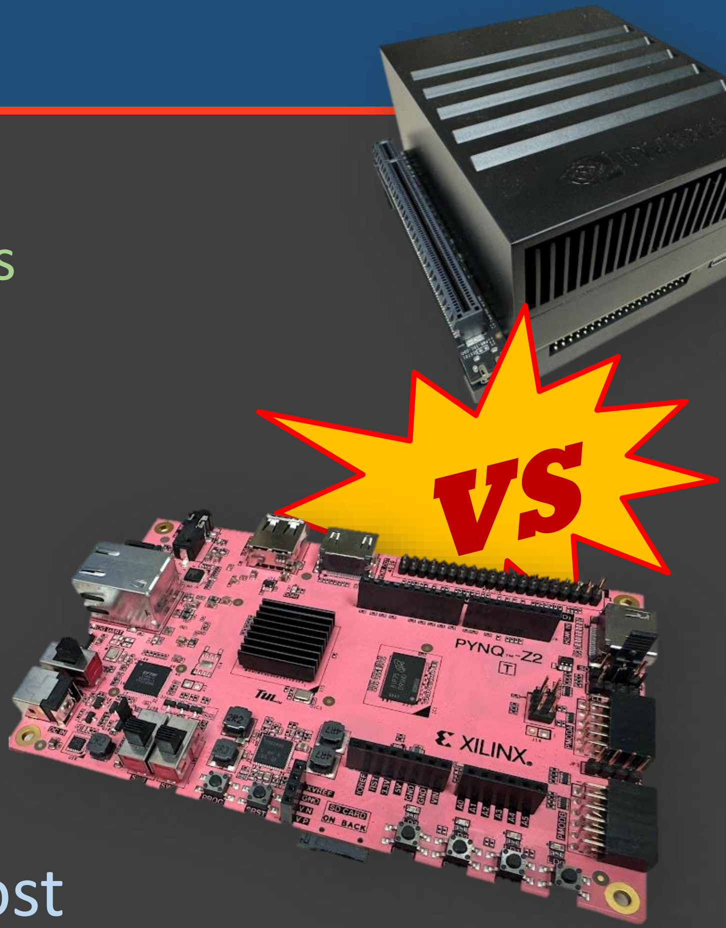


How should we make them?

Artemis Plan – NASA’s Lunar Exploration Program Overview

Problem Statement

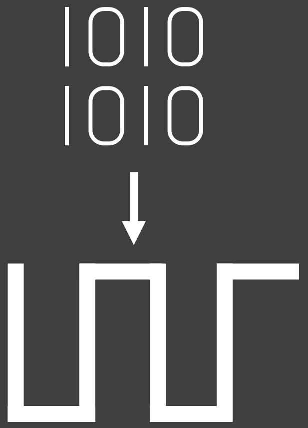
- Inspired from NASA 2020 Taxonomy
  - Crew and display systems are **essential** for NASA functions
- Need scalable architecture to drive display systems
  - Current rad-hard processors do **not** have the processing capabilities for graphics rendering
  - COTS processors more performant, less reliable
  - Rad-hard GPUs unavailable
- Need to understand interoperability of the system
- Engineering trades of reliability, performance, and cost
  - Reliable system architecture using COTS and rad-hard parts



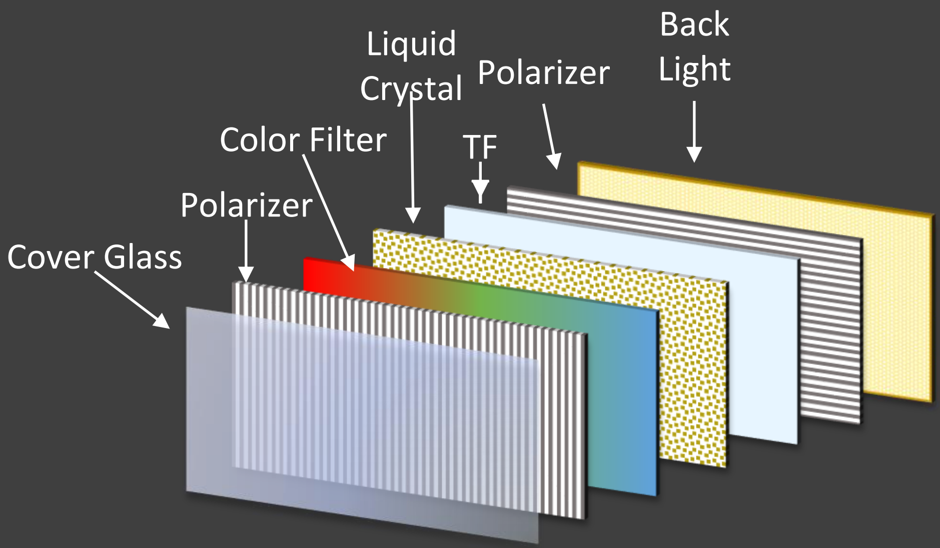
Display Pipeline

Processing Elements → Display Driver Circuitry → Display Medium

Produces frames to be displayed

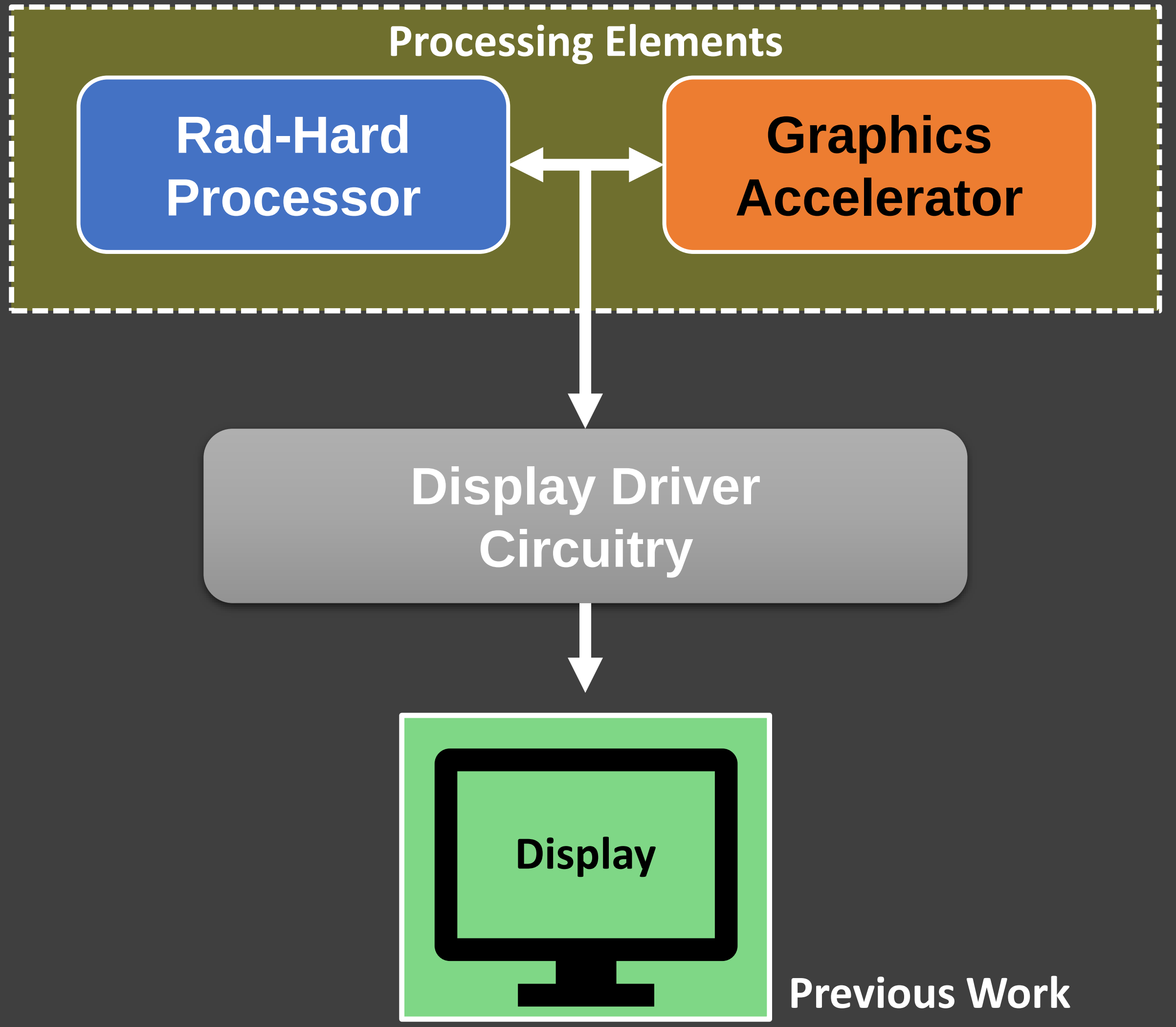


Decodes and translates frame data into control instructions



Physical display stackup

Previous Project Scope



Rad-hard: Radiation-Hardened

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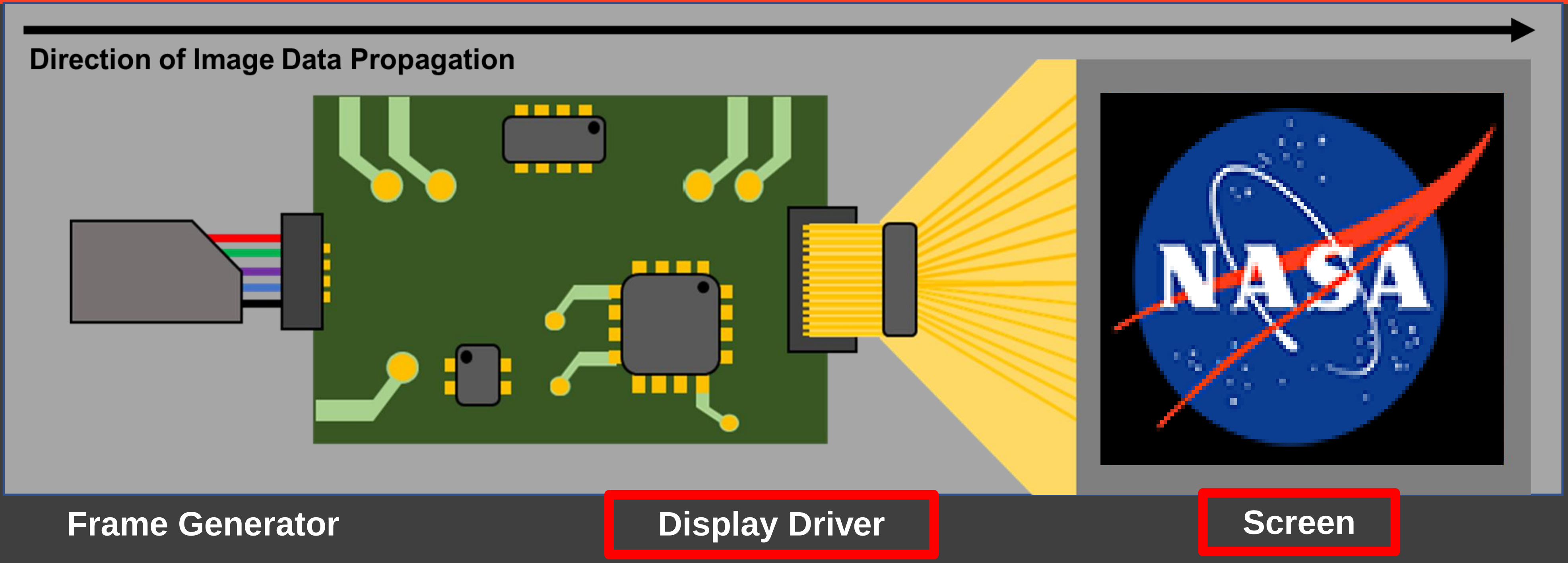
Previous Work - Rad. Resistant Displays

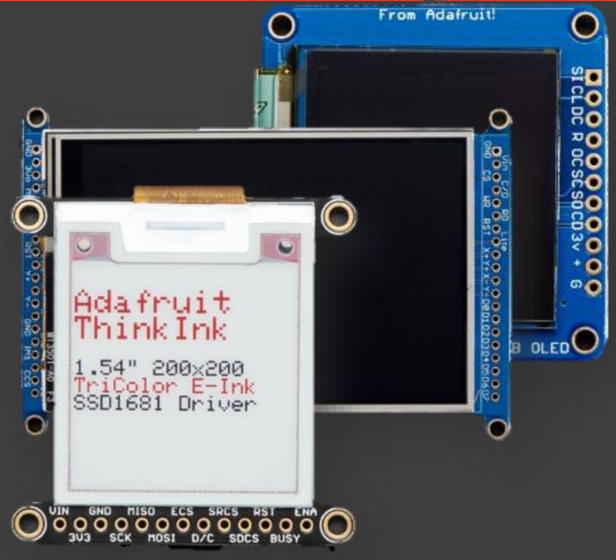


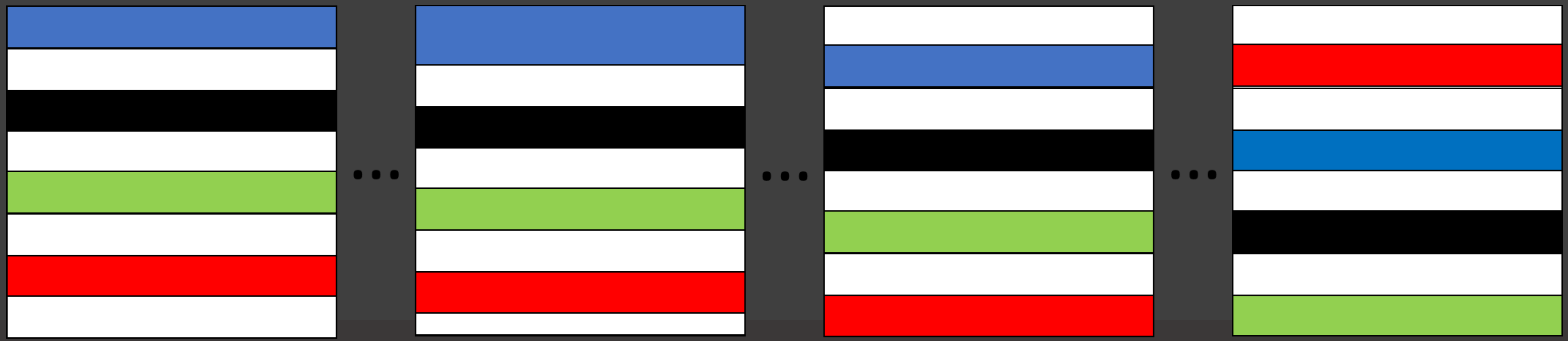
- Focused on exploration of components unique to electronic display systems
  - Display Drivers – convert image data into temporal drive signals to drive screens
  - Electronic Screens – addressable arrays of optical emission/modulation pixels
- Developed test methodologies and metrics for characterizing future displays needs
- SEFIs in configuration registers main driver of availability requirements

SEFI: Single-Event Functional Interrupt

Previously, On Resilient Displays…

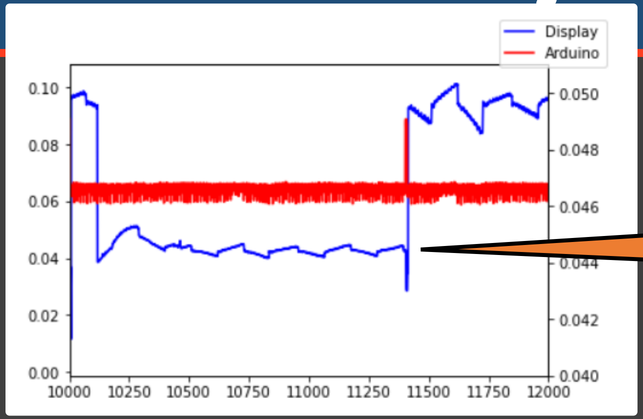
- Lawrence Berkeley National Labs
  - 16 MeV/n tune
  - Moving color patterns
  - OLED, LCD, eInk
- Scrolling color pattern
- Looking for single-event effects





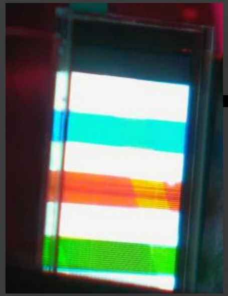
Heavy Ion Results Summary

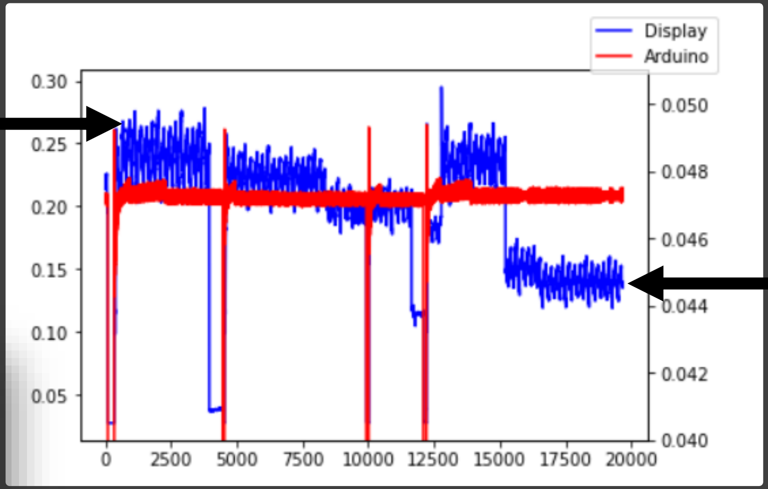
- Black screen occasionally with OLED
- Elevated Brightness on one OLED
- Destructive effects @ highest LET on OLED



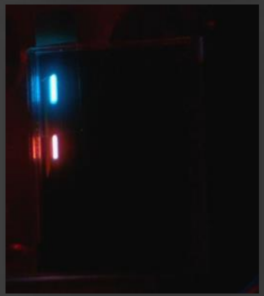
Pattern during black screen

- No upsets in eInk observed





- LCD upsets cleared when LCD memory rewritten



- **Moving forward with LCDs**

OLED: Organic Light-Emitting Diode
LCD: Liquid Crystal Display

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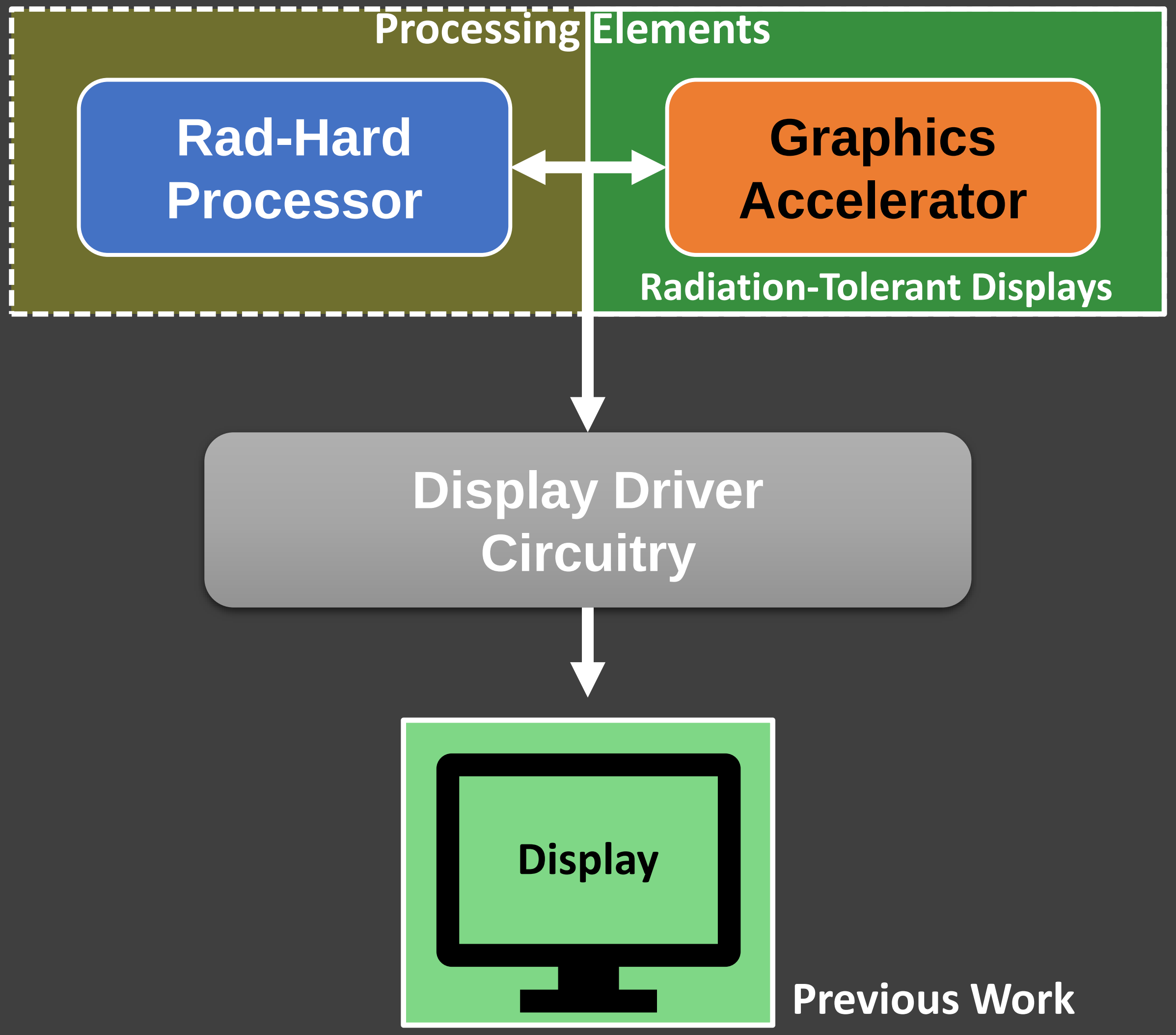
Project Scope – Now Avionics



Rad-hard: Radiation-Hardened

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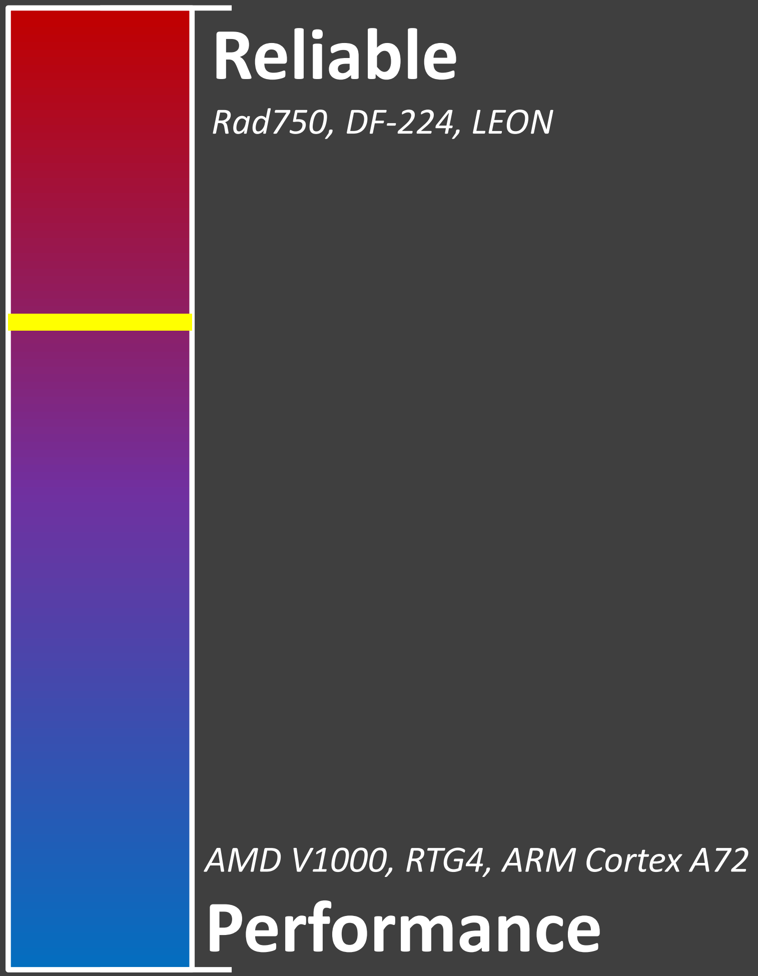
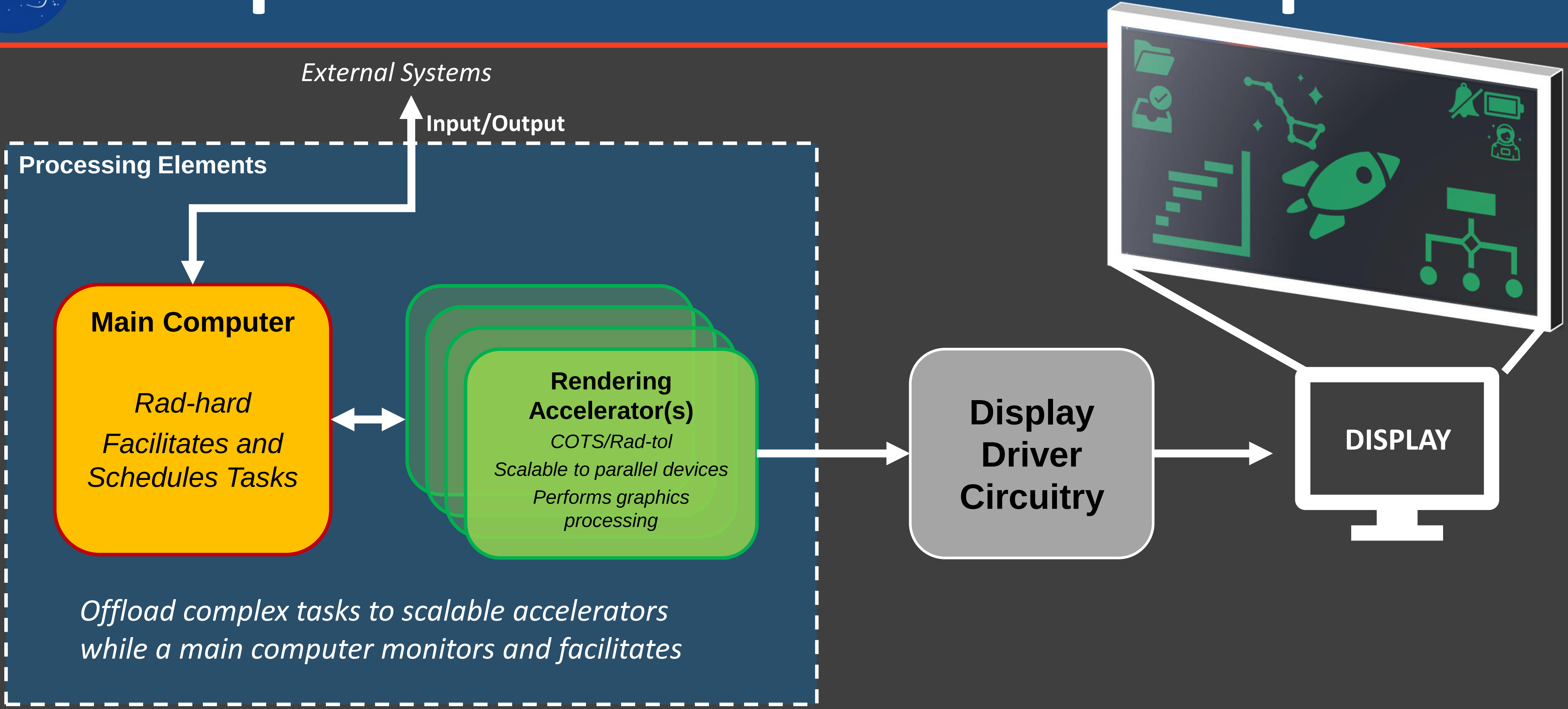
Tradeoffs

- Computational Performance
  - Need to be able to perform application needs
- Radiation Reliability
  - **Minimize** TID and SEE effects
  - **Maximize** availability
- Scalability
  - Scalable to fit various requirements
  - Size/power/form factor/etc.
  - Allow for replacements with minimal work



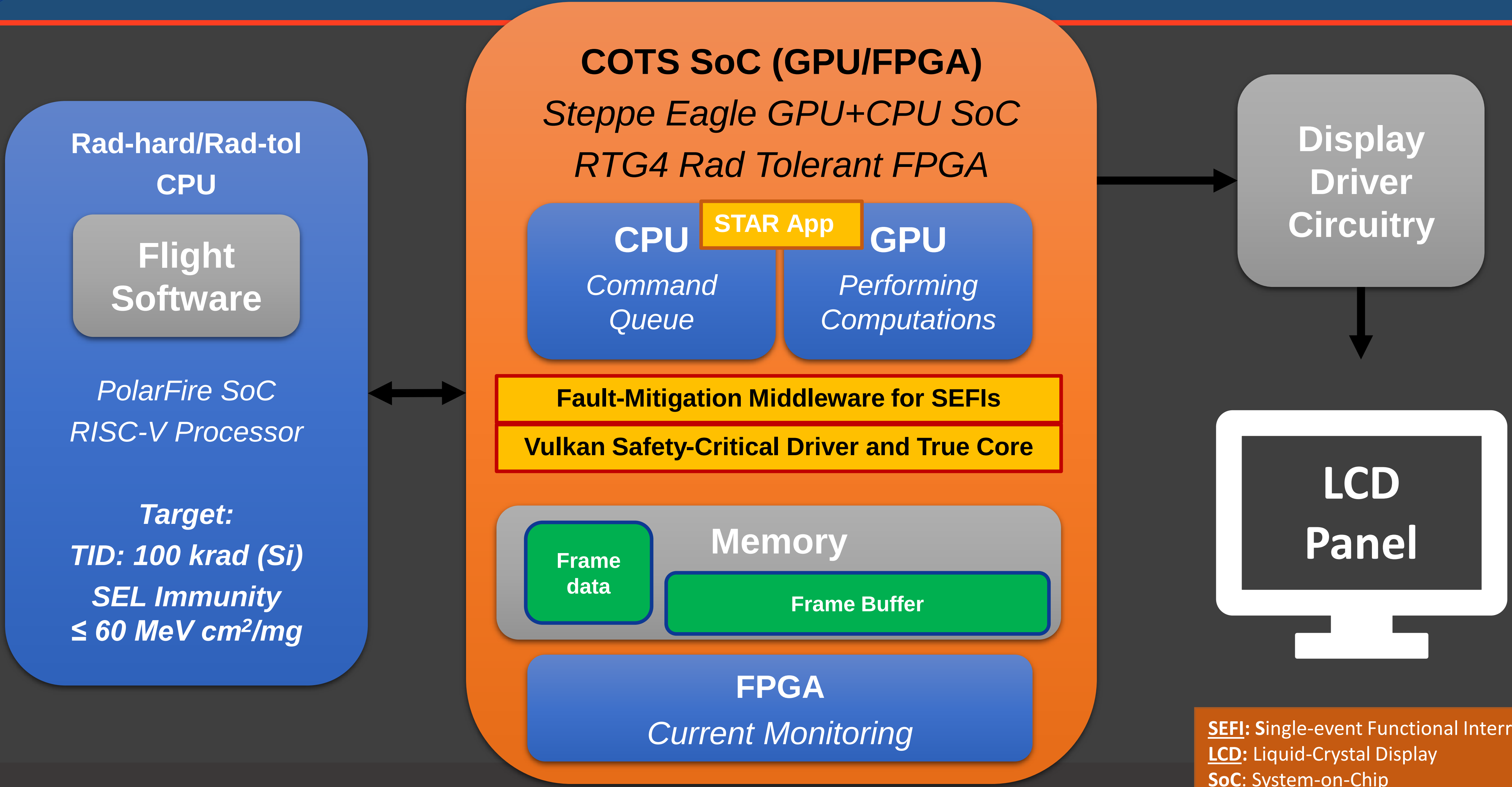
TID: Total Ionizing Dose
SEE: Single-Event Effect

Proposed Architectural Concept



Rad-hard: Radiation Hardened
Rad-tol: Radiation Tolerant

Let’s Get More Specific - Architecture Demo



SEFI: Single-event **F**unctional **I**nterrupt
LCD: Liquid-Crystal Display
SoC: System-on-Chip

Current Demo

- Main Computer
  - Planned: PolarFire SoC RISC-V processor
- Hardware accelerator (Moog Sierra)
  - AMD Steppe Eagle GPU SoC
  - x86 processor
  - RTG4 Radiation-tolerant FPGA

- STAR application running on devkit

Moog Sierra GPU Single-Board Computer

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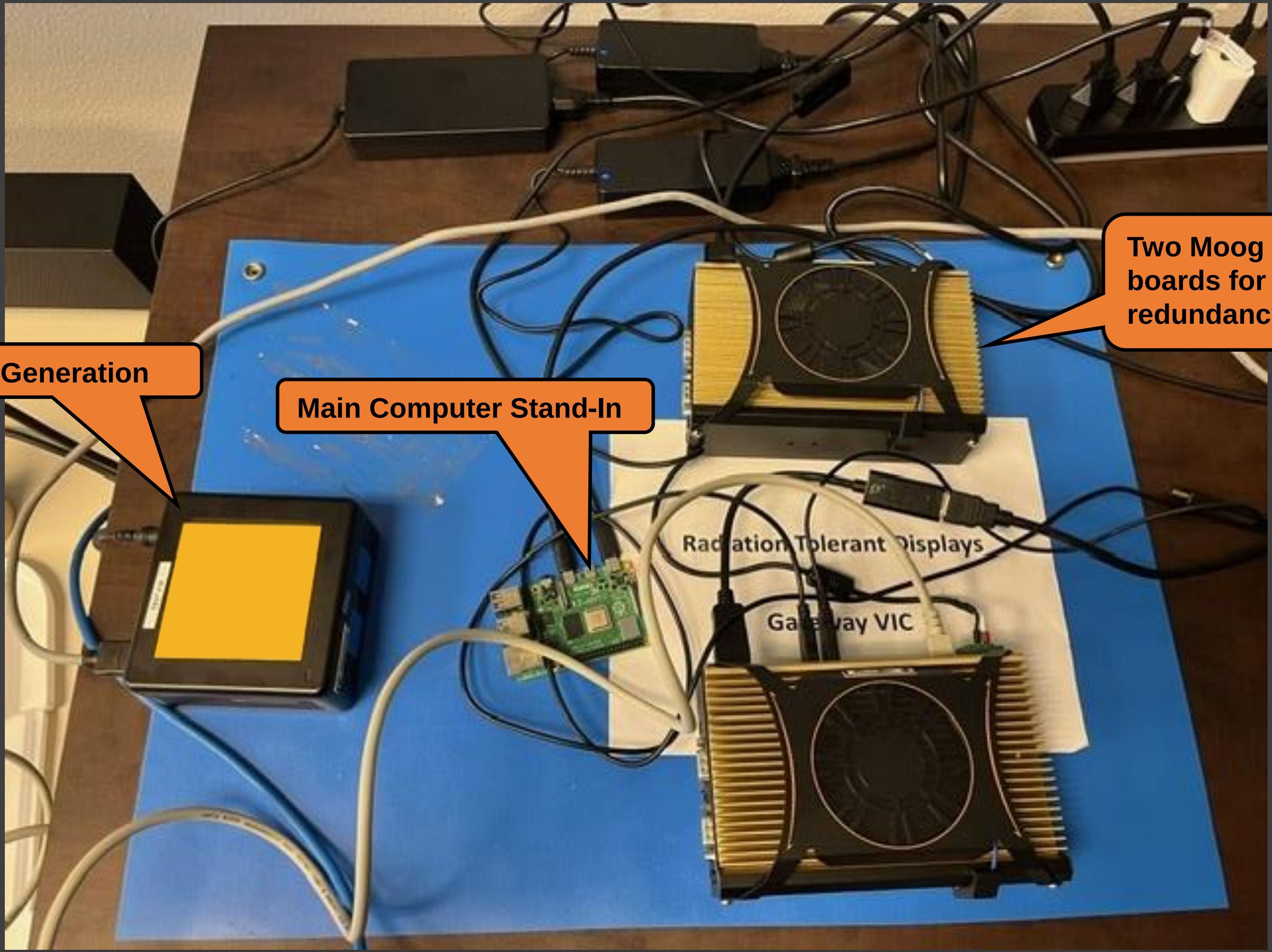
Demo Setup

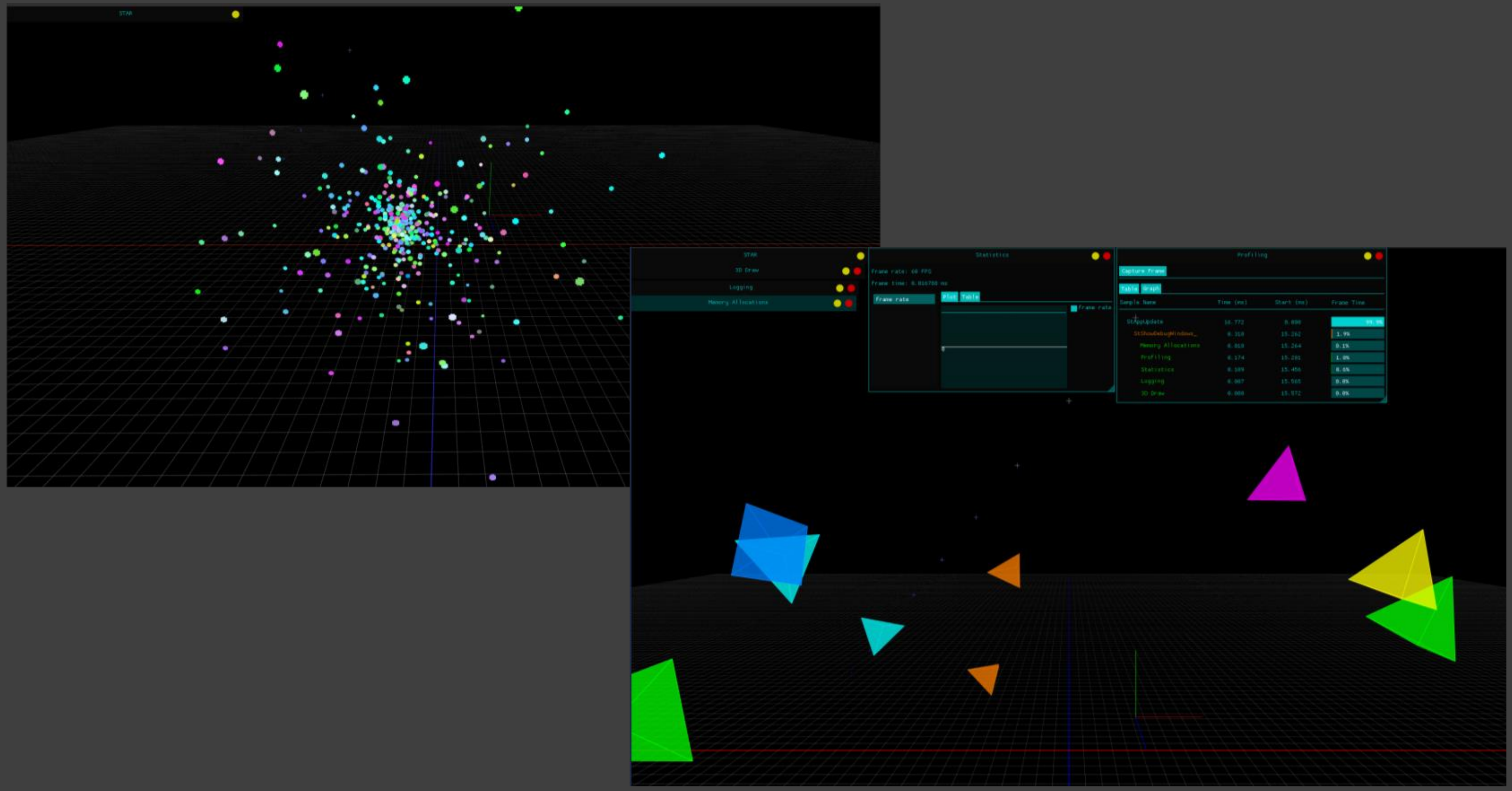


Two Moog Sierra boards for hardware redundancy
Telemetry Generation
Main Computer Stand-In
Radiation Tolerant Displays
Gateway VIC

Use-Case Examples of STAR Apps

Low End: Text-based GUI

Depicted on MSP430



High End: 3d rendering

STAR: Space Technology Application Renderer

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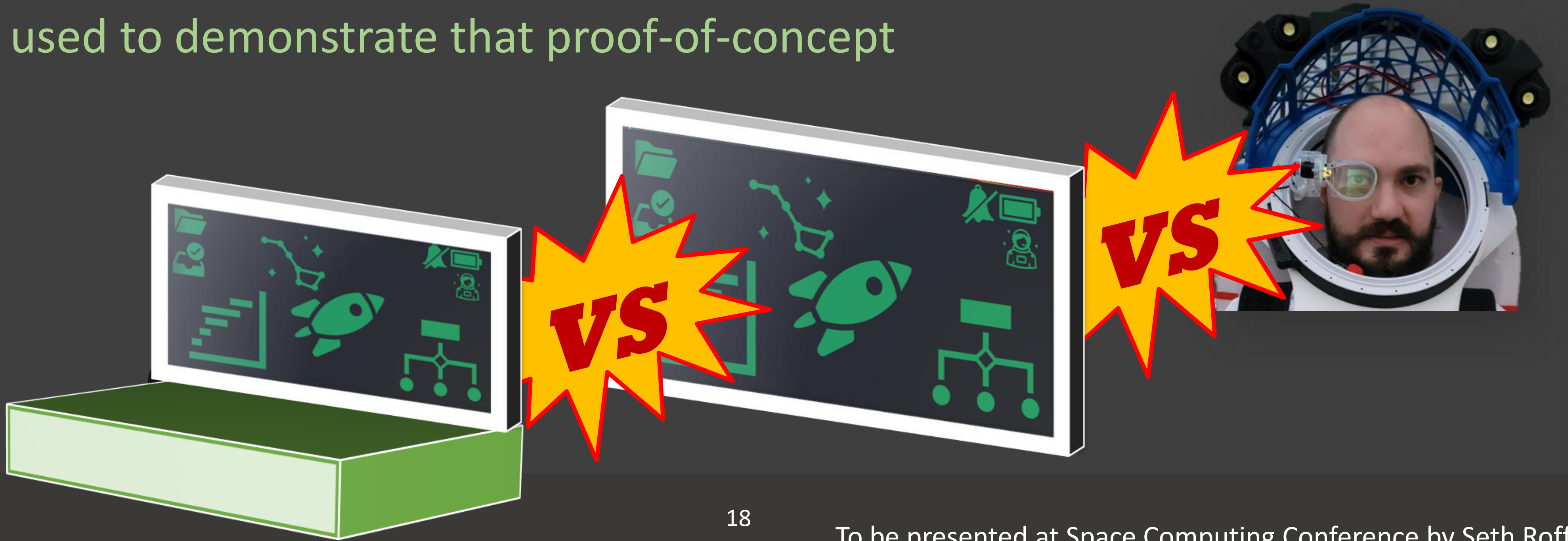
⚠ Hold on one second! ⚠

- Proposal not an off the shelf solution
  - It is to understand architectural feasibility
- The idea is to be as **scalable as possible**
- Choice of processor(s) or display system entirely dependent on missions
- Proof-of-concept of augmenting rad-hard processing with COTS accelerators
  - Demo used to demonstrate that proof-of-concept



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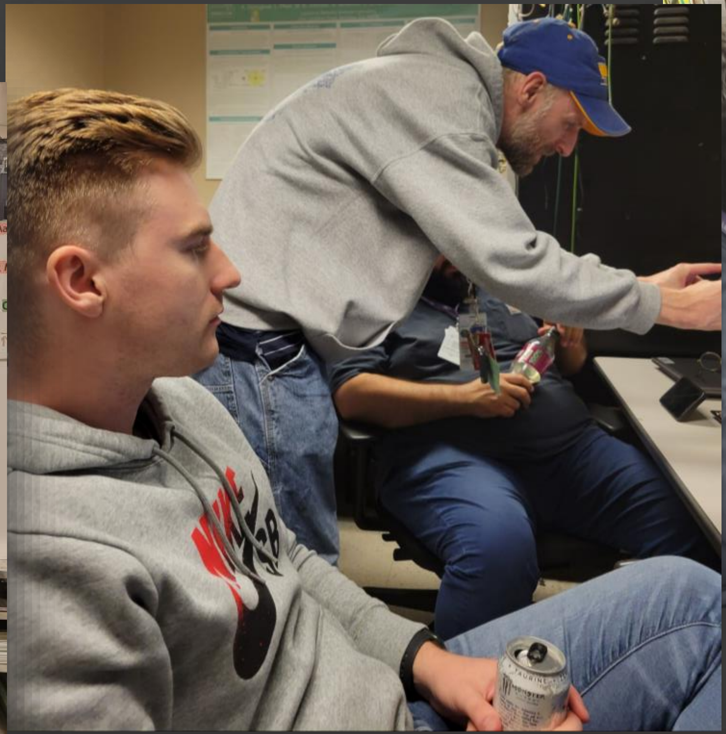
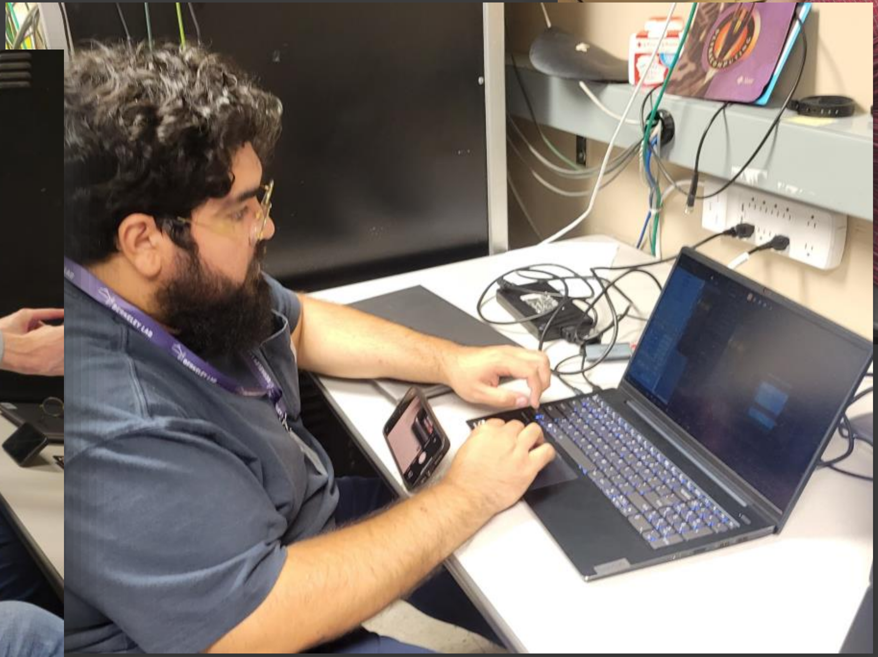
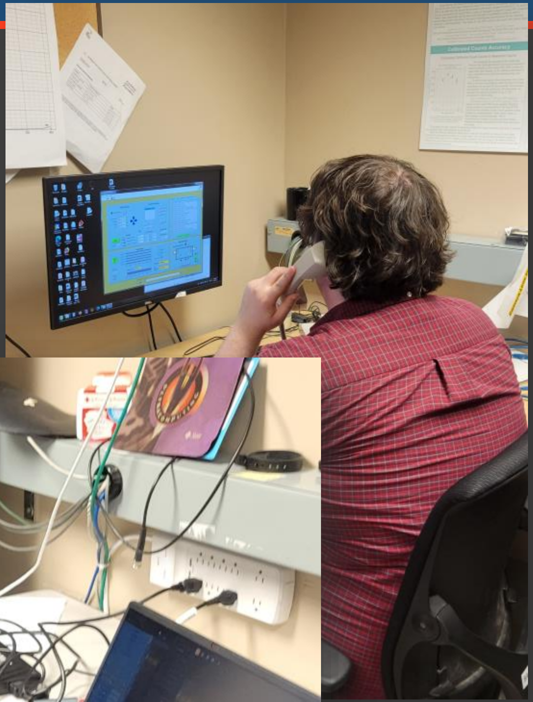
Where Do We Go From Here?

- Receiving LCD panels from selected vendor
- Heavy ion testing panels in the Fall
- Develop and demo use cases for different mission concepts



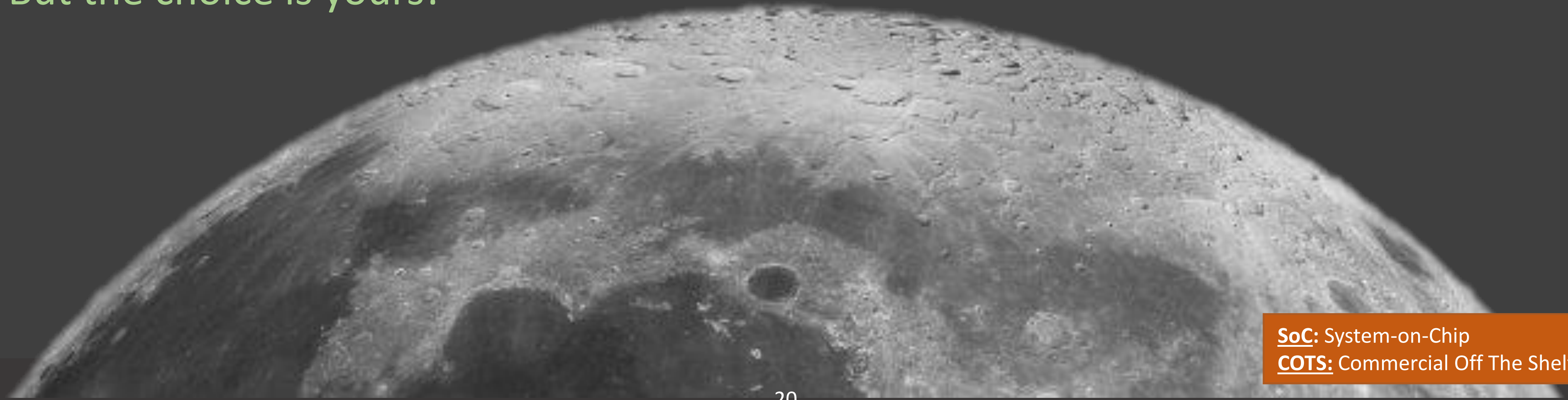




LCD: Liquid-Crystal Display

Conclusions

- Design a proof-of-concept of reliable, scalable display system architecture
- Previously irradiated display panels
  - Current work is on avionics
    - Using a radiation-hardened processor alongside a COTS accelerator
    - Working with industry for new use cases and design needs
- Demo using AMD Steppe Eagle GPU SoC with RISC-V processor
  - But the choice is yours!



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COTS: Commercial Off The Shelf