P4-24: Resilient Systems

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

SHREC Annual Workshop (SAW23-24)

Dr. Alan George
Mickle Chair Professor of ECE
University of Pittsburgh

Mike Cannizzaro
Dhinar Gayatri
Nicholas Schmidt
Cole Bowman
Noah Perryman
Peter Drum
Graduate Students
University of Pittsburgh

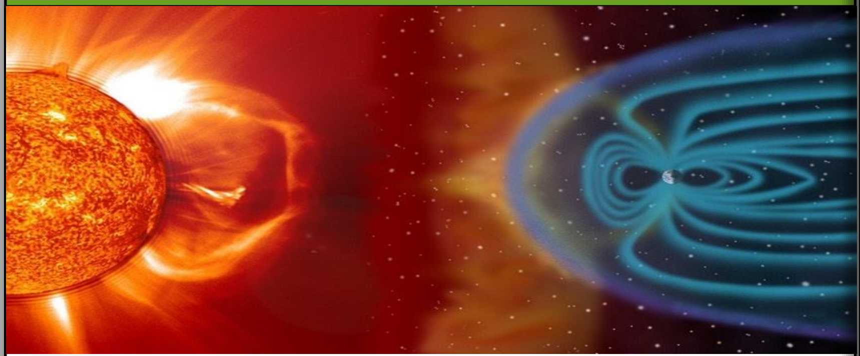
University of Pittsburgh · BYU Brigham Young University · Virginia Tech · UF University of Florida

January 17-18, 2024

Number of requested memberships ≥ 6

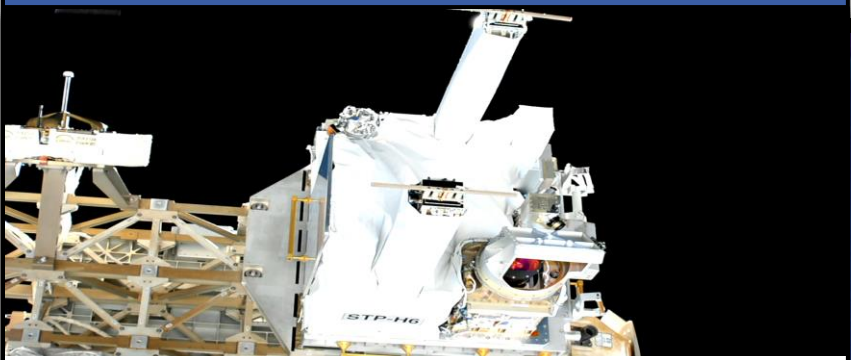
P4

Goals, Motivations, Challenges



CHALLENGES

- **Complex systems with challenging objectives** are difficult to formulate, create, validate, and reproduce
- High-performance systems require **robust software and complex scheduling** that employ end-to-end reliability

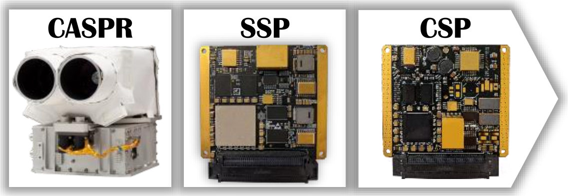


GOALS

- Evaluate viability and efficacy of **novel technology platforms** for performance, SWaP, affordability, and reliability
- Explore simulation tools, deep-learning techniques, and graphics processing techniques for **reliable mission software**

MOTIVATIONS

- Need for **high-performance**, energy-efficient, resilient, and affordable systems
- Demand for **efficient onboard data-processing and mission management** for big-data apps



Mission-Critical Computing
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STP-H6 Photo
This payload was integrated and flown under DoD STP - Houston leadership; photo credit NASA

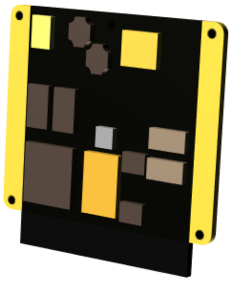
SWaP:	Size, Weight, and Power
CASPR:	Configurable & Autonomous Sensor Processing Research
SSP:	SHREC Space Processor
CSP:	CHREC Space Processor
SoM:	System-on-Module

University of Pittsburgh
BYU BRIGHAM YOUNG UNIVERSITY
VIRGINIA TECH
UF UNIVERSITY of FLORIDA

Tasks for 2024

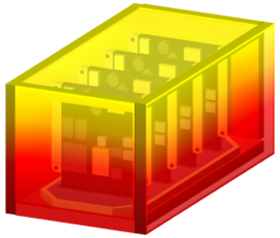
1) Hybrid Flight Hardware

- Evolve Hybrid Computing Hardware to Enhance Embedded Space Platforms



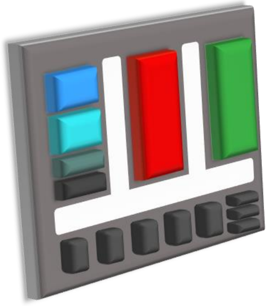
2) Mechanical and Thermal Systems

- Explore Mechanical Structures and Thermal Models for Systems and Missions



3) Adaptable Versal Computing

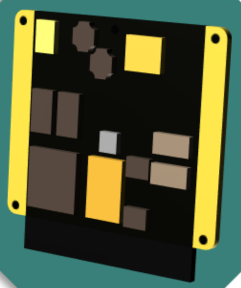
- Employ Fault-tolerant Strategies for Heterogeneous Versal Space Computing



4) Emerging RISC-V Architectures

- Evaluate RISC-V Architectures for SWaP-C-constrained Embedded Systems

SWaP-C: Size, Weight, Power, and Cost

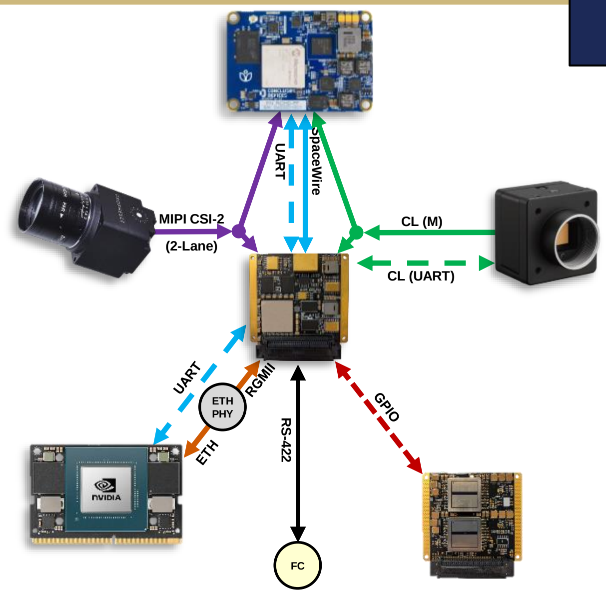


Task 1
Hybrid Flight Hardware

Research novel system architectures to enable hybrid computing for advanced space missions

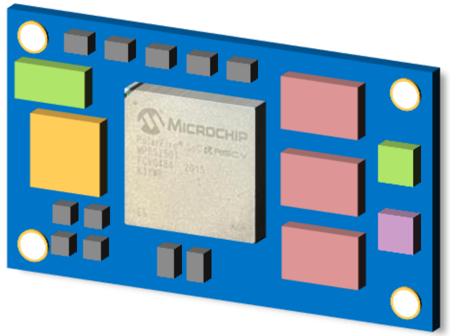
Task Leader
Mike Cannizzaro

T1: Hybrid Flight Hardware



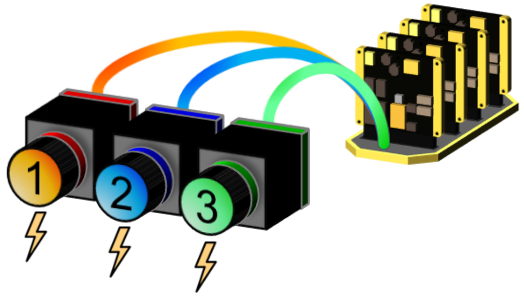
1 Novel Earth Sensing Solutions

- Complete **visual sensor** and **optical system** selections for **STP-H12**
- Incorporate finalized **sensor I/O** into STP-H12 system architecture



2 Rapidly Deployable Systems

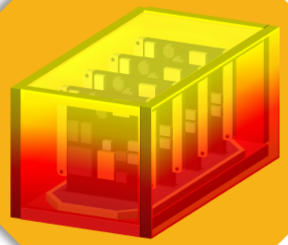
- Leverage **hybrid SoM carrier architectures** to develop STP-H12 flight card designs
- Manufacture and test **prototype carrier cards** for PolarFire SoC SoM and NVIDIA GPU



3 Mission Backplanes and Supporting Hardware

- Leverage **standard interconnects** to minimize STP-H12 backplane development overhead
- Develop, manufacture, and test **supporting hardware** (development boards, etc.) for sensor systems and SoMs

STP: Space Test Program
SoM: System-on-Module
SoC: System-on-Chip



Task 2
Mechanical and Thermal Systems

Create mechanical structures and thermal models for systems and missions, and explore new methods for thermal modeling of space computers

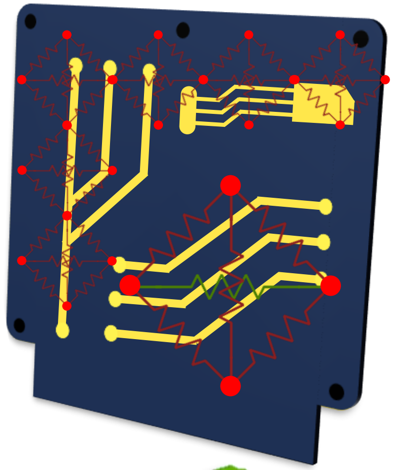
Task Leader
Cole Bowman

T2: Mechanical and Thermal Systems

1

Mechanical Structure Design

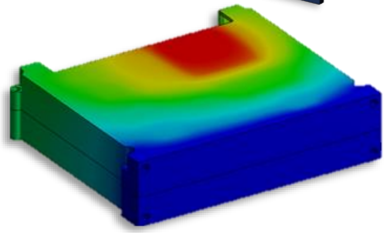
- **Design STP-H12 structure** to house all necessary components and meet NASA guidelines for spaceflight
- Ensure mechanical enclosure design **meets structural and manufacturing requirements**



2

Thermal and Structural Analysis

- Build and test **ANSYS model for structural/vibration analysis** of STP-H12 mechanical enclosure
- Build and **test Thermal Desktop model for thermal analysis** of STP-H12 mechanical enclosure



3

Manufacturing and Verification

- **Verify all elements of mechanical and thermal systems** are feasible for manufacture and meet STP requirements
- **Manufacture, assemble and perform thermal/vibrational testing** to ensure STP-H12 structural requirements are met

STP: Space Test Program

Task 3
Adaptable Versal Computing

Explore adaptive, dependable, and high-performance techniques for heterogeneous computing on Versal ACAP platforms

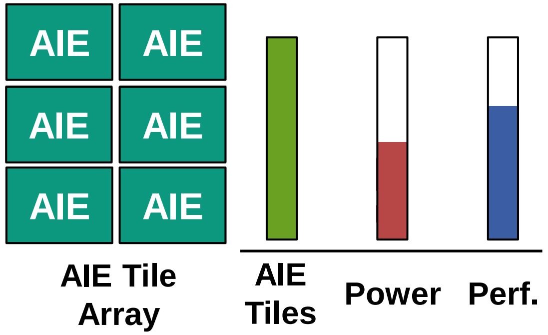
Task Leader
Noah Perryman

ACAP: Adaptive Compute Acceleration Platform

T3: Adaptable Versal Computing

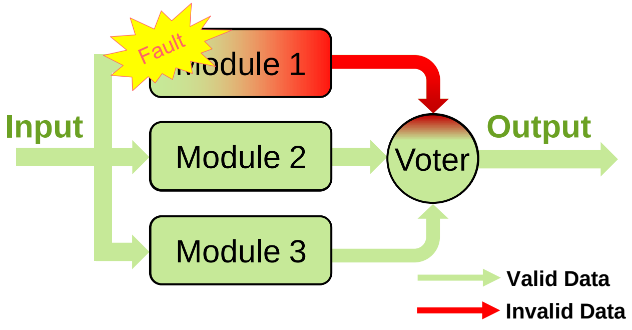
1 Dynamic Versal Computing

- Create **adaptable framework to dynamically swap Versal configurations** by leveraging dynamic reconfiguration
- Evaluate **scalability and partial reconfigurability** of DPU on Versal ACAP devices with AI Engines



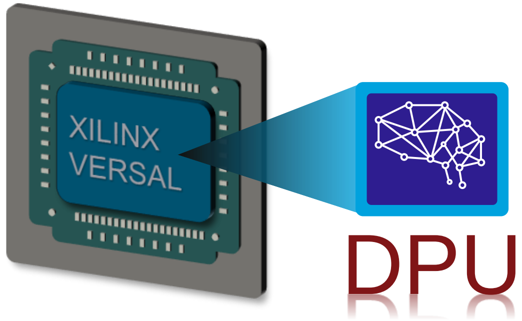
2 Reliable Versal Computing

- Explore **fault tolerance techniques** for Versal ACAP PL and AI Engine fabrics
- Perform **reliability analysis** on Versal ACAP AI Core VCK190 development board



3 Adaptable Versal Computing

- Develop **resilient framework for Xilinx DPU** deployment on Versal PL and AI Engine fabrics
- Analyze **performance, power consumption, and reliability tradeoffs** for different Versal DPU PR configurations



ACAP:	Adaptable Compute Acceleration Platform
AIE:	AI Engine
PL:	Programmable Logic
DPU:	Deep Learning Processing Unit
PR:	Partial Reconfiguration

Task 4
Emerging RISC-V Architectures

Investigate and compare RISC-V performance, power consumption, and radiation susceptibility to characterize viability for SWaP-C-constrained embedded systems

Task Leader
Mike Cannizzaro

SWaP-C: Size, Weight, Power, and Cost

T4: Emerging RISC-V Architectures

1 Hybrid SoM Carrier Development

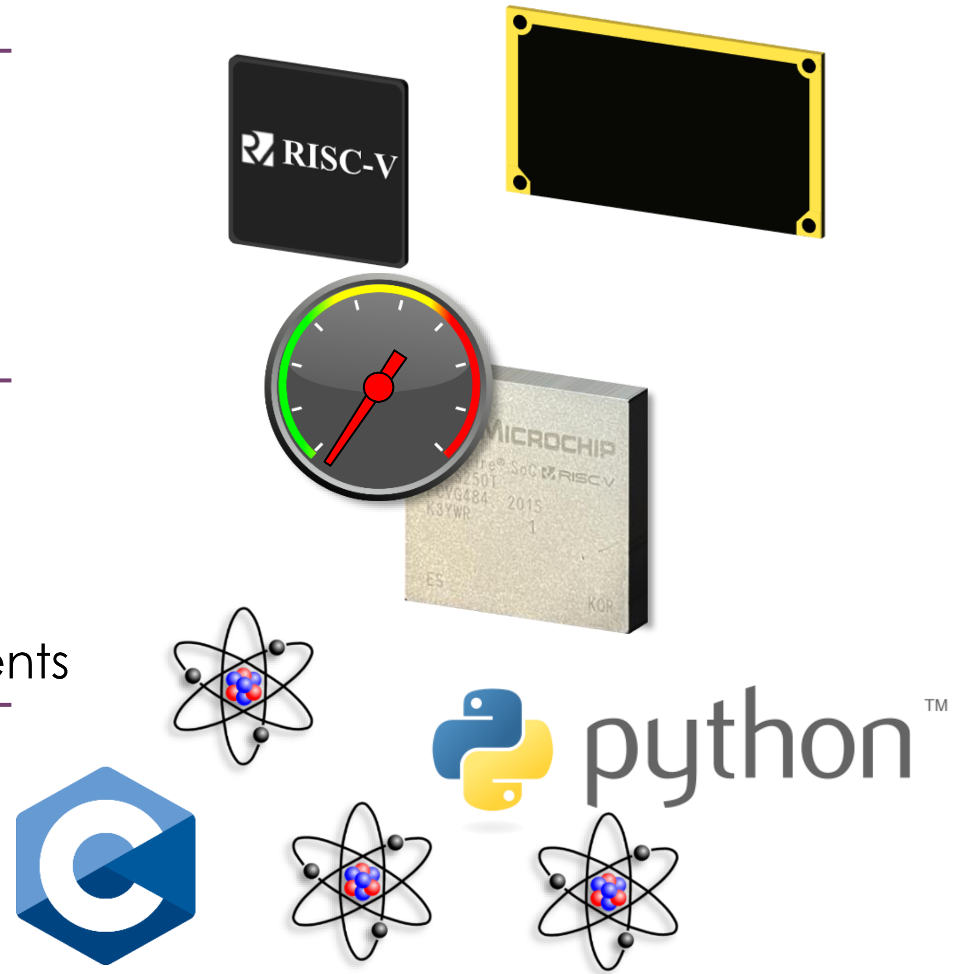
- Leverage PolarFire SoC SoM trade study results to **develop hybrid carrier architecture** for maximizing system reliability
- Develop and **test prototype** COTS carrier card

2 Expanded PolarFire SoC Benchmarking

- Leverage programmable power supply for **more detailed power consumption metrics**
- Accelerate RISC-V vector computations with FPGA fabric and determine **performance/power consumption tradeoffs**

3 Compiled and Interpreted Languages in Harsh Environments

- Conduct RISC-V **benchmarking using compiled and interpreted languages** in neutron radiation
- **Compare reliability metrics** between application types



SoC: System-on-Chip
SoM: System-on-Module
COTS: Commercial-Off-The-Shelf

Milestones and Deliverables

- Milestones
  - SMW (June/July 2024): Showcase midterm results on all projects
  - SAW (Jan. 2025): Demonstrate completion of all projects

- Deliverables
  - Monthly progress reports from all projects
  - Midyear and end-of-year full reports from all projects
  - 3-4 conference/journal papers (~1 per project)
- Budget (**6 +** memberships, or **300+** votes)

Conclusions & Member Benefits

- Evolve Hybrid Computing Hardware to Enhance **Embedded Space Platforms**
- Explore **Mechanical Structures and Thermal Models** for Systems and Missions
- Explore Fault-tolerant Strategies for Heterogeneous **Versal Space Computing**
- Evaluate **RISC-V Architectures** for SWaP-C-Constrained Embedded Systems

- Member Benefits
  - Direct influence over research direction and projects
  - Direct benefit from hardware designs, software applications, and architecture investigations
  - Direct benefit from research study insights

SWaP-C: Size, Weight, Power, and Cost