New Mexico
Research Spotlight Forum

ADVANCING RESILIENCE FOR SPACE SYSTEMS

JOIN US FOR FUTURE EVENTS:

6/4/19	Quantum Information Sciences
7/16/19	Social Sciences and Decision Making
8/27/19	Resilient Infrastructure (SMART Grid)
10/8/19	Advanced Manufacturing and Robotics
11/19/19	Biomedical Engineering and Informatics

SAND2019-4775 PE

STARCS

Science and Technology Advancing Resilience for Contested Space

MISSION CAMPAIGN

16 April 2019

Champions

Doug Bruder, ALD, 6000

John Zepper, Director, 6300

Toby Townsend, Director, 6700

Charles Barbour, Director, 1300

Management Team

Steve Gianoulakis, Sr. Mgr., 6350

Jeff Mercier, Sr. Mgr., 6770

Drew Woodbury, Mgr., 6354

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2019-4663 M

National Security Mission Challenge

The key to survivability and deterrence against adversarial engagement in space is ***systems resilience*** with the ability to ***operate through***

"Longstanding technological and cost barriers to space are falling, enabling more countries and commercial firms to participate in satellite construction, space launch, space exploration, and human spaceflight." "…Having seen the benefits of space-enabled operation, some foreign governments are developing capabilities that threaten others' ability to use space."

– 'Challenges to Security in Space', U.S. Defense Intelligence Agency, January 2019

"Adversaries believe they can erode the U.S.'s economic and strategic advantage by disrupting and/or destroying U.S. (and our Allies and Partners) satellites providing space-based capabilities essential to our economic vitality and national security."

– General John E. Hyten, Commander, USSTRATCOM, June 22, 2018

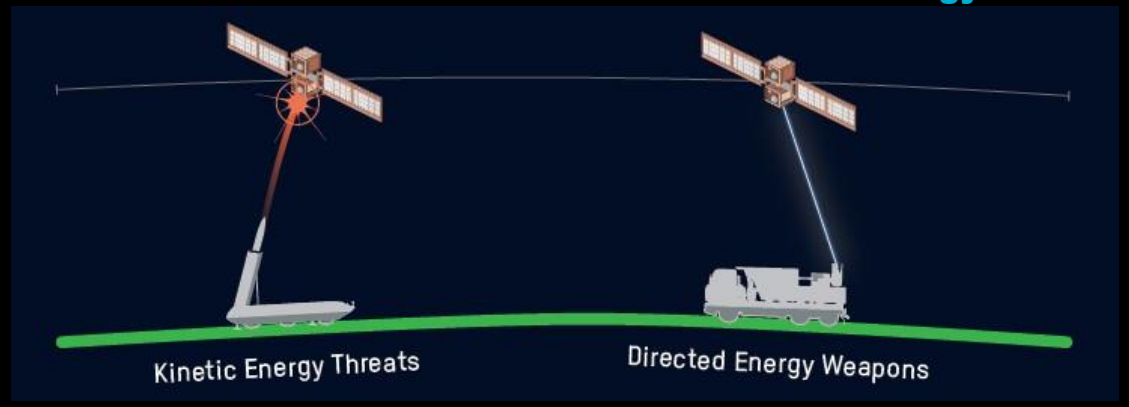
"Different from the past, potential adversaries are rapidly developing and fielding a diverse and capable range of counter-space capabilities able to hold our space systems at risk, on orbit, in cyberspace, and from the air, land, and maritime domains."

– General John W. Raymond, Commander, USAF Space Command, March 15, 2018

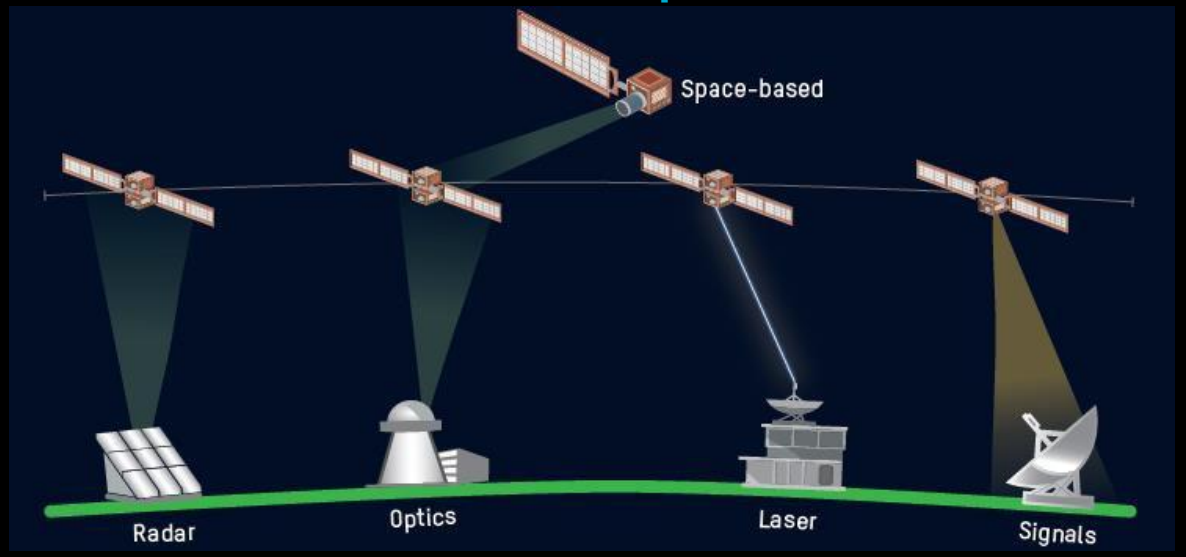
National Security Mission Challenge

Counterspace Threats

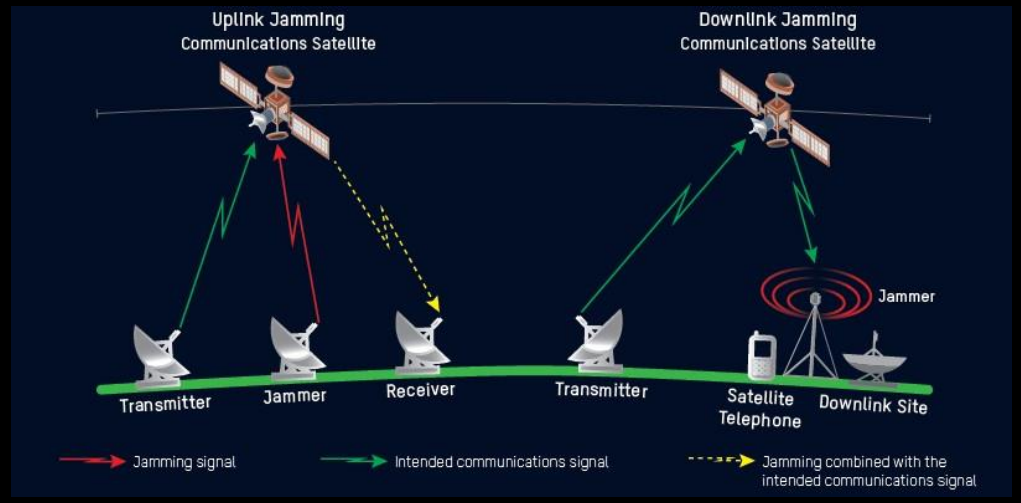
Kinetic / Directed Energy Threats



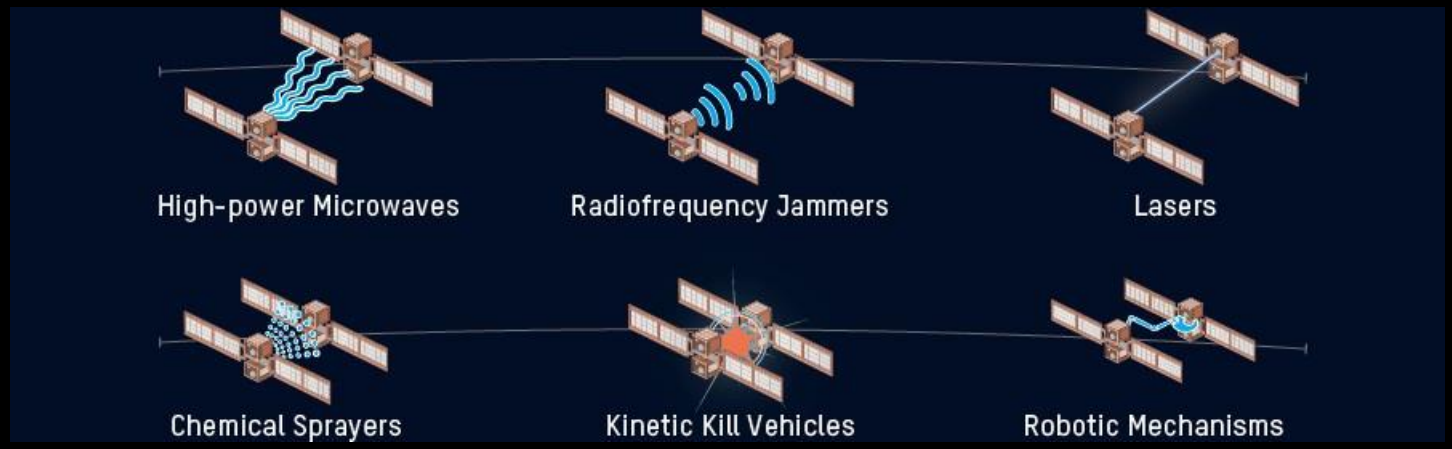
Space Situational Awareness



Electronic Warfare Threats



Orbital Threats



Graphics courtesy of ‘Challenges to Security in Space’, U.S. Defense Intelligence Agency, January 2019

STARCS Overview

What

- Champions innovative research and development that preserves the mission capability of the U.S. Space Enterprise by ensuring the survival of mission-critical hardware through an adversary attack

Goal

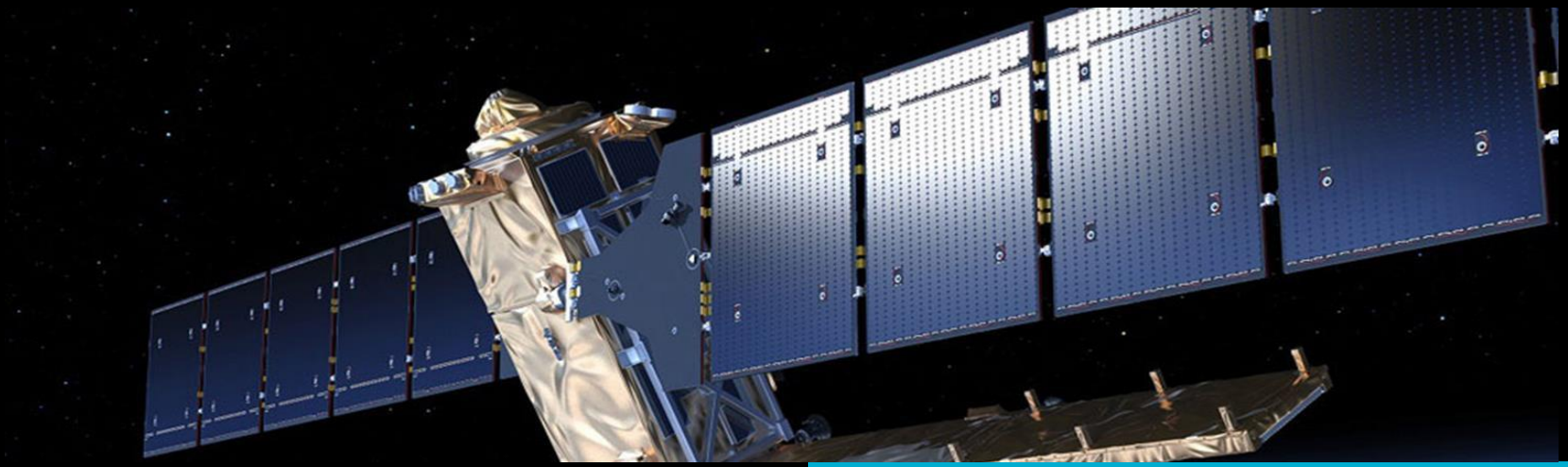
- Deliver innovative research and development that significantly advances the nation's capabilities to maintain and expand its unfettered use of space
- Advance space system resilience technologies to protect and defend the nation's freedom of action in space

Scope

- Preservation of optical, radio frequency, reconnaissance, and communications assets in the face of adversary kinetic energy, directed energy, cyber, and radiation attacks
- While of interest, natural space background radiation and damage from micrometeorites and other space debris are not the focus

Mission focused R&D for ~$35M over 7 years

STARCS Interdependent Technical Thrust Areas & Goals



The Technical Thrust Areas interlink to develop *the science, technologies, and architectures* needed for "Hardened by Engineering" autonomous protection systems

Threat-Defended Hardware

- Develop modeling, and design tools
- Environmentally-testable Hardware
- Run cognitive analytics algorithms
- Demonstrate resilience to attack

Sensor Protection

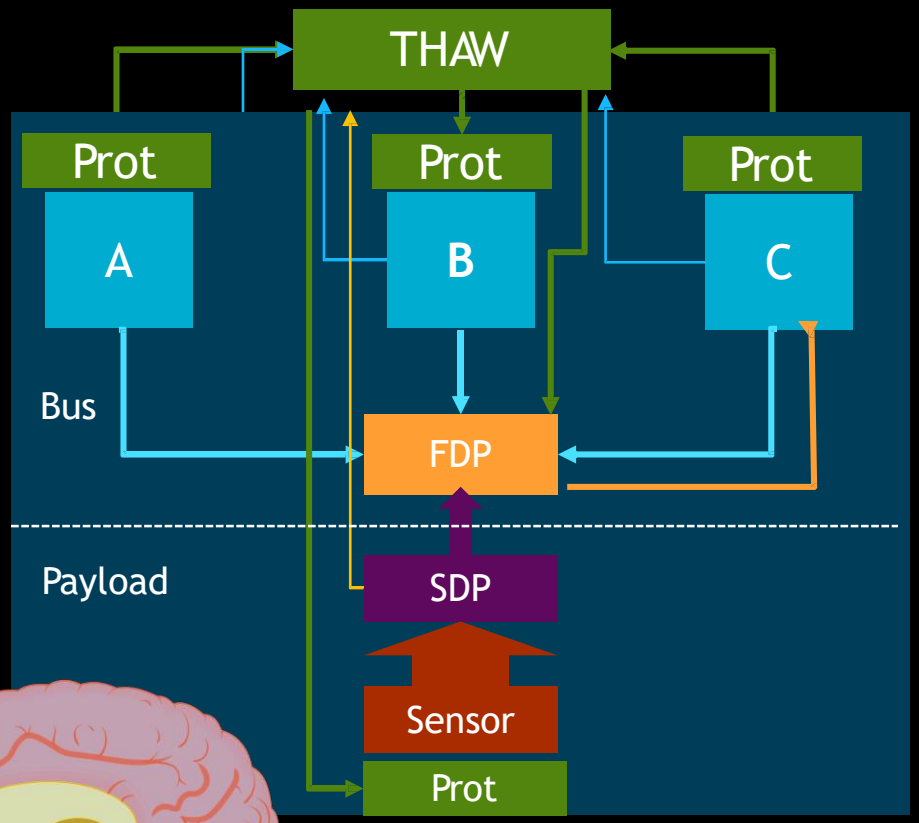
- Materials/system to block high energy attacks
- Threat-degraded data recovery techniques
- Demonstrate protection against threats
- Operate algorithms on threat-defended HW

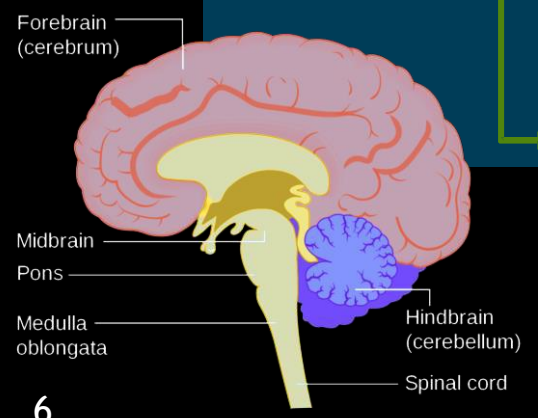
Cognitive Analytics

- Analytics tools to identify attacks
- Adaptation software to operate-through
- Demonstrate on threat-defended hardware
- Operate with Hardware In the Loop (HWIL)

A Proposed Architecture for Resilience:

Threat-Hardened Autonomous Watchdog (THAW)





- Biologically-inspired architecture
  - Balances robustness with Agility
- Threat-Hardened
  - Simple, rugged, & robust to survive threats
- Autonomous
  - Distinguish normal from abnormal
- Watchdog:
  - Identify the attack
  - Enable survivability measures to protect the system

THAW concept needs hardening, cognition and protection to **Operate Through an Adversary Attack**

It's not Artificial Intelligence: It's *Artificial Instinct*

Sandia Academic Partnerships

Objective:

- Build and nurture strategic research partnerships with faculty and students to:
  - Provide needed expertise to complete Sandia's missions
  - Expose students to possible careers in national security
  - Develop opportunities for joint funding from external sources

Methods of Support for STARCS:

- Principal Investigators (PIs) from Sandia will identify university, professor, funding request and describe collaboration
- Funding to individual LDRD projects is generally $50K - $100K / year
  - Funding is provided either through Academic Alliance or directly from Mission Campaign
- Funding is intended to support research contracts and/or faculty sabbaticals
- Student internships aligned with Mission Campaign projects

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4/17/2019 Advancing Resilience for Space Systems

UNM ECE Space Systems Online Program Overview

PRESENTED BY:

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The University of New Mexico

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Managed Online Program in M.Sc. EE or ME with Concentration on Space Systems Engineering

- Launched Fall 2018: https://eespaceonline.unm.edu or https://mespaceonline.unm.edu
- 8-week courses offered in carousel format, starting up to 5 times a year
- Requires 34 credit hours for ME or 31 hours for EE degree
- Class quality reviewed and certified through UNM online
- Requires bachelor's degree in an engineering-related field from an accredited university.
- Requires proficiency in proficiency in English (reading and writing), programming and mathematics.
- Available to ALL UNM students as Online courses
- Advisor to ECE MOP students: Prof. Marios S. Pattichis

Keywords:

Online program, M.Sc. in EE, M.Sc. in ME, Space Systems Engineering.

Certified MOP ECE Courses for Internet of Things (IoT) and Space Systems Engineering

ECE 595 – Introduction to the Internet of Things
ECE 522 – Hardware/Software Codesign with FPGAs
ECE 517 – Machine Learning
ECE 540 – Advanced Networking
ECE 529 – Introduction to Cybersecurity
ECE 537 – Foundations of Computing
ECE 514 – Nonlinear and Adaptive Control

Certified MOP Courses for M.Sc. in Space Systems Eng

EE and ME Degree Requirements

ME 595 – Orbital Mechanics
ME 596 – Spacecraft Altitude Dynamics and Control
ME 594 – Space Situational Awareness
ME 597 – Small Spacecraft Design I
ECE 595 – Satellite Communications

ME Degree Only

ME 542 – Deformation Analysis and Modeling (reviewed through the Golden Paw process)
ME 500 – Numerical Methods in Mechanical Engineering
ME 530 – Theoretical Fluid Mechanics I
ME 501 – Advanced Mechanics of Materials

More MOP Courses for 2019-2020

MOP Version Development (ITV and f2f available now)

ECE 500 Theory of Linear Systems
ECE 541 Probability Theory and Stochastic Processes
ECE 439 Introduction to Digital Signal Processing
ECE 522 Hardware/Software Codesign with FPGAs
ME 559 Design Project
ECE 590/ME 591/ME 592 Graduate Seminar in Space Systems

New MOP Courses (Courses previously offered)

ECE 5xx Radiation Effects on Space Electronics
ECE 5xx Foundations of Cybersecurity
Additional courses in Cybersecurity …

FUNDING SOURCES

Funding originated from UNM Provost office

Heavily subsidized by UNM ECE and ME Departments

MS EE Focus on Cyber Security* – Can Relate to Space Systems

- MS focus with a certificate option would give students a unique understanding of offensive cybersecurity software and systems development.
- This kind of program is currently not offered in the United States, though the material is covered within inhouse programs privately and through other organizations, though not in the depth proposed.
- This program is modeled on a program offered in China to select members of the PRA. This is based on expanding and unmet demand for offensive cybersecurity experts by various US Government organizations, including but not limited to USCYBERCOM2.
- MS Program Structure: Core classes are required, for a total of 9 credit hours.
- Certificate Structure: A certificate would include 9-12 credit hours of coursework focused on Cybersecurity.

* Proposal by Chris Lamb, SNL

Cybersecurity Focus – Online or On Campus

Existing Required Classes:

ECE 536: Computer System Software

ECE 538: Advanced Computer Architecture

ECE 540: Advanced Networking Topics

Cybersecurity Core Classes, In Order of Completion:

- (Completed) Foundations of Cybersecurity: An introduction to cybersecurity topics and existing tools including but not limited to Metasploit, Powershell, NMAP, and Masscan.
- Analysis & Exploitation: Studying static and dynamic analysis of programs, various kinds of stack exploits, heap exploits, return-oriented-programming, web exploits, and other initial penetration vectors.
- Payload Development & Communication: Ways to develop malware to avoid detection and removal, and how to effectively hide command and control traffic.

Cybersecurity Focus – Optional Courses

- Web Exploitation: Exploiting and using web browsers as initial system entry points, for reconnaissance, and for command and control communication.

- Applied Cryptology: Cryptography algorithms, details of implementation, how to use them, and how to attack them.

ECE@UNM PROGRAM NEEDS

- Need help recruiting students from Sandia, AFRL, LANL, and Aerospace industry.
- Collaborate to create and offer additional courses as needed.
- Additional instructors from Sandia, AFRL, and LANL.
- Internships as part of partnership would enhance impact and visibility.
- We would love to offer jointly-funded Design Projects.

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Resilient and Adaptive communication systems and network, design, and testing:

PRESENTED BY:

Matthew Hannon, Senior Engineer COSMIAC@UNM, matthew.hannon@cosmiac.org

Brian Zufelt, Director of Engineering Services COSMIAC @ UNM, Brian.Zufelt@cosmiac.org

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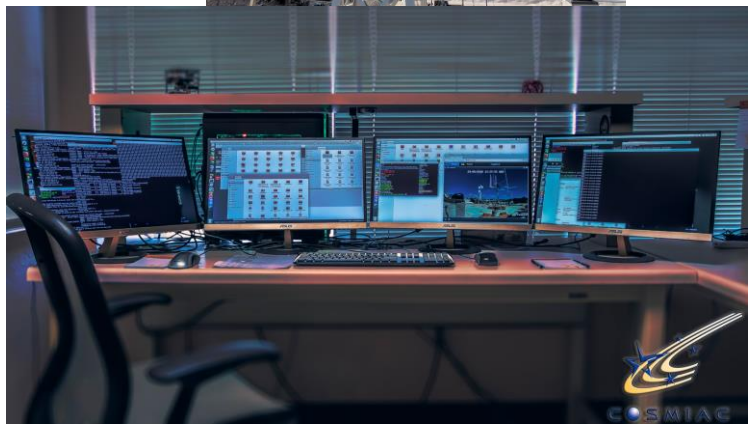
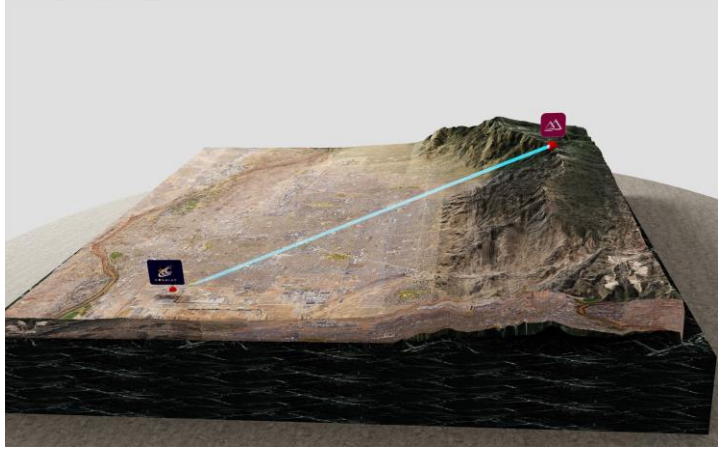
COSMIAC @ University of New Mexico

CURRENT WORK IN ADVANCING RESLIENCE FOR SPACE SYSTEMS

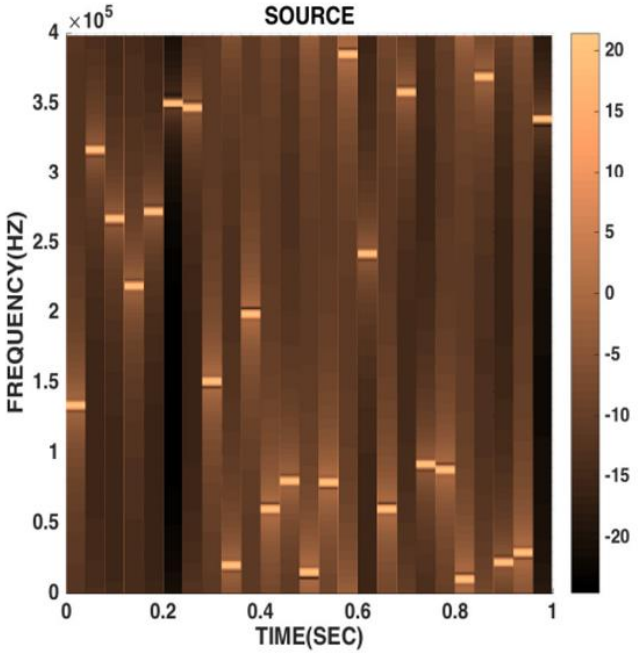
Combining Radio and Laser Communications





CURRENT WORK IN ADVANCING RESLIENCE FOR SPACE SYSTEMS

Reconfigurable Waveform



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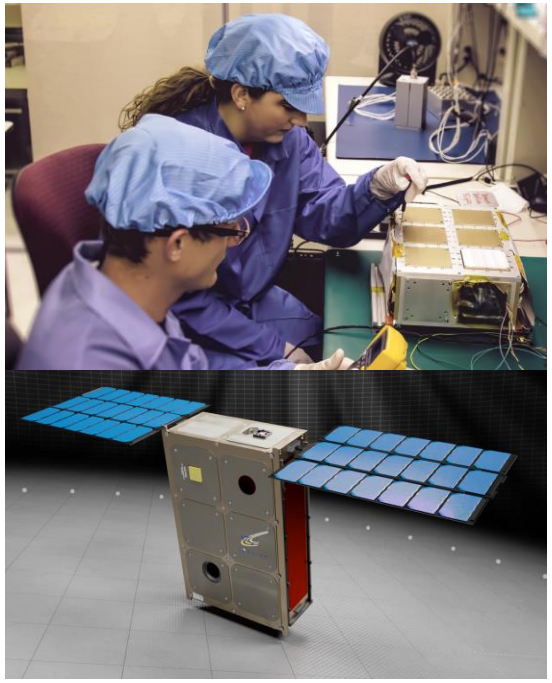
Reconfigurable Satellite



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Big Antenna

= Space Resilience

Satellite Launches this year!

PARTNERS

- AFRL Space Vehicles and Directed Energy Directorates
- National Aeronautics and Space Administration Defense Threat Reduction Agency
- Millennium Engineering and Integration Company
- Northrop Grumman
- KBRWyle Corporation
- AEgis Technologies
- Lockheed Martin
- ATA
- Blue Origin
- Verus Research and other small businesses

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Strategic Space Industry Leadership Development: Sow, Grow, Prune, Reap

PRESENTED BY:

Erich Brown,
Senior Engineer COSMIAC@UNM,
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Jonathan Carter Hebert,
Deputy Director of COSMIAC @ UNM,
jchebert@cosmiac.unm.edu, 505-659-7219

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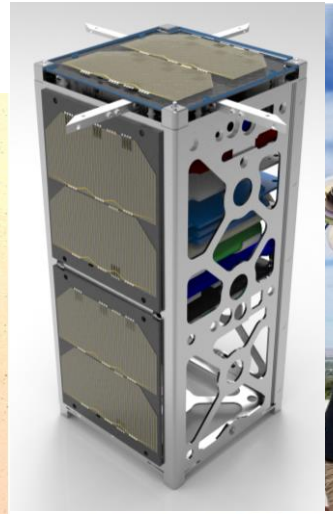
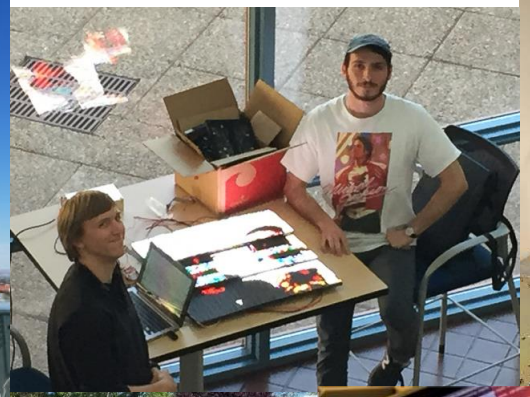
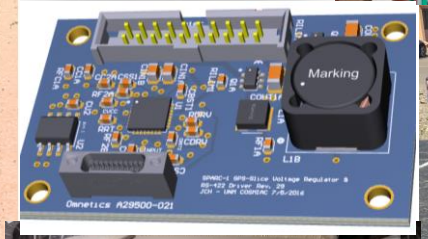
COSMIAC is a UNM SOE Research Center

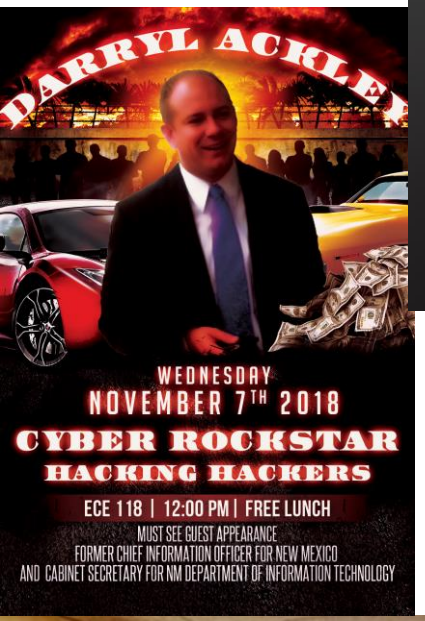
CURRENT WORK IN ADVANCING RESLIENCE FOR SPACE SYSTEMS

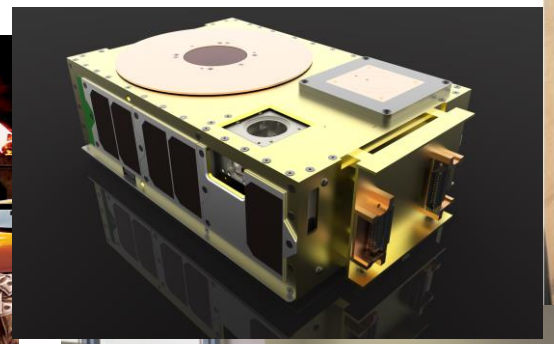


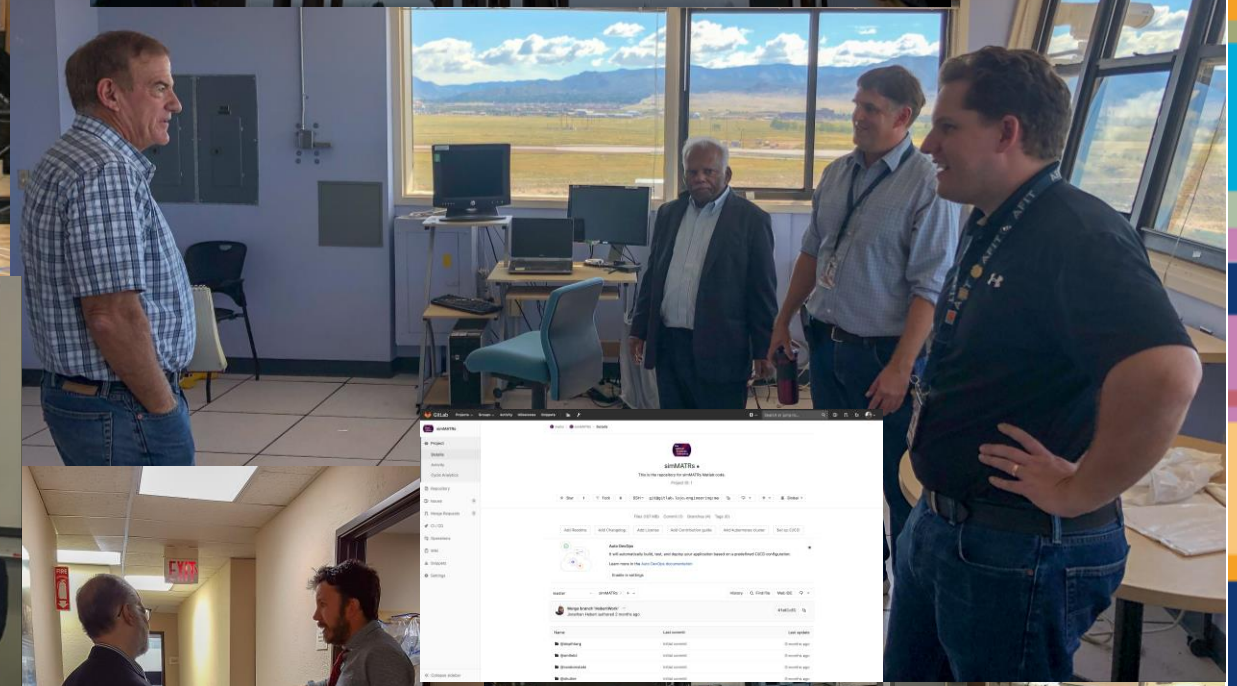


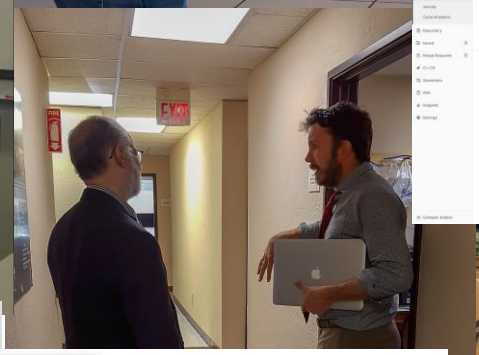


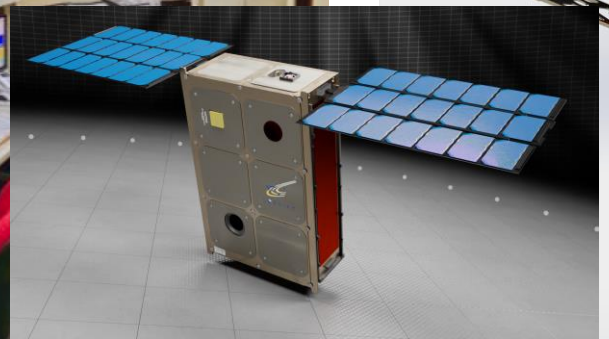
FUNDING SOURCES

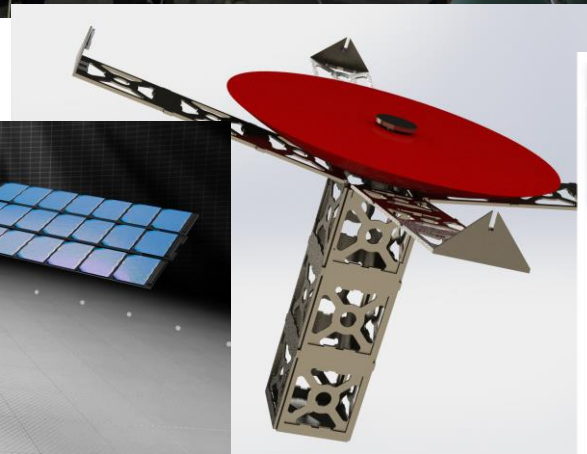


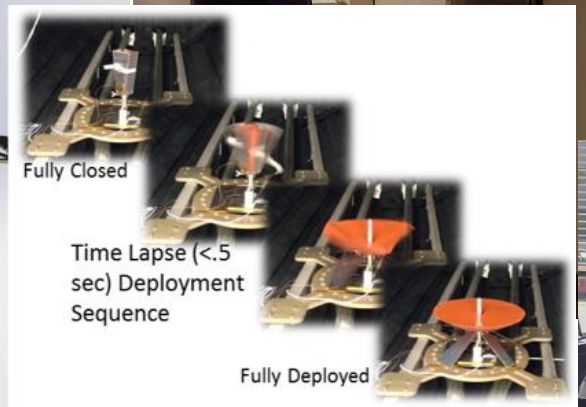








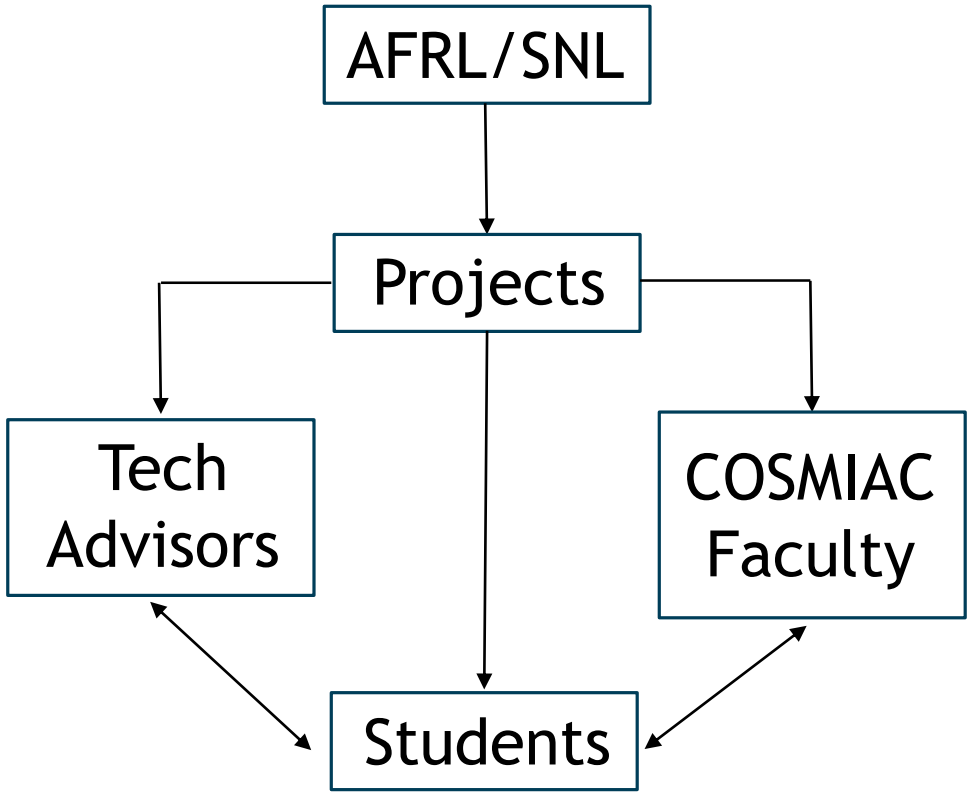




RESEARCH NEEDS

HOW IT WORKS

- Tech advisors meet once a week to provide detailed oversight and answer project specific questions



- COSMIAC takes over the logistic portion of hiring interns
- Provides day to day guidance and can answer/guide the research
- Office and lab space for work to be conducted

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4/17/2019 Advancing Resilience for Space Systems

radionuclide source based device testing

PRESENTED BY:

Adam Hecht

Department of Nuclear Engineering

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ABOUT YOURSELF

Brief biography: Nuclear Engineering professor at UNM since 2008.

- PhD Physics Yale in low energy particle physics (nuclear structure),
- postdoc Argonne National Laboratory physics division,
- postdoc U. W. Madison medical physics writing particle interaction simulations

- Research areas:
  - Radiation detector development,
  - detection technique and algorithm development,
  - device development and experiments for fission data

- Research group: 4 grad students + hiring, several undergrads, female and minority demographics

- **Keywords:** radiation interactions, damage, dose quantification

Note: Prior simulation and experiment work on dose to individual components on circuit board in radiation tests.

CURRENT WORK IN ADVANCING RESLIENCE FOR SPACE SYSTEMS

overview: We are looking at implementing radionuclide sources for radiation damage tests on electronics,

looking at single event effects (SEE).

Cf for fission fragments and neutrons, Am etc for alpha, various for beta/gamma.

problem: Large scale testing facilities such as ion beam labs are expensive and require waiting.

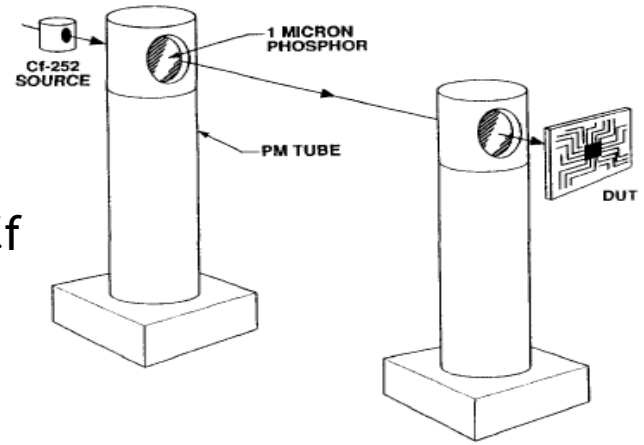
solution: We can develop benchtop electronics testing with radionuclide sources. Electronics can be run while irradiated.

Lower flux but far cheaper and far more accessible; there is a sweet spot.

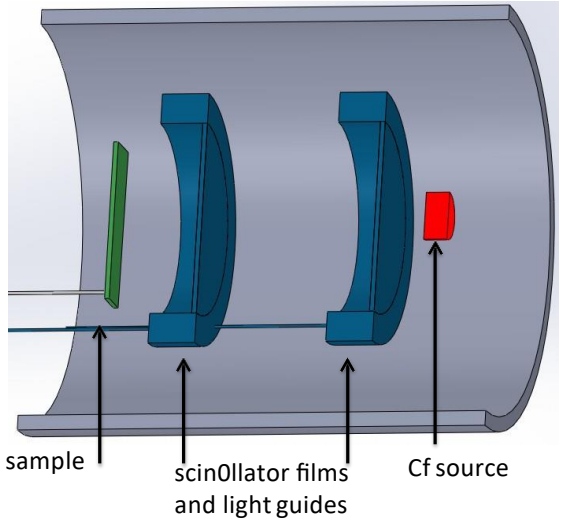
history: Prior work by JPL with ^{252}Cf fission source. TOF to discriminate light/heavy fission fragments.

Can reproduce with thin scintillator foils.

JPL
with ^{252}Cf



UNM
proposed



FUNDING SOURCES

For this project:

Looking

Current funding for other projects:

Sandia Academic Alliance on detector development and characterization

NNSA Stockpile Stewardship Academic Alliance on highly correlated fission data measurements

NNSA-MTV (U Mich heading) on muon imaging of used fuel storage casks

DTRA on neuromorphic computing

unfunded collaboration with LLNL on machine learning on gamma spectra for nuclear threat identification

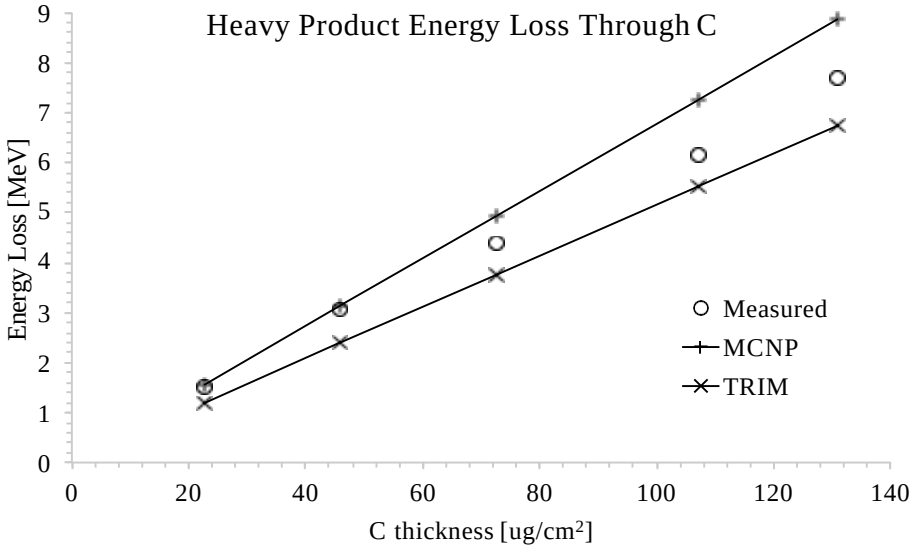
RESEARCH NEEDS

We can apply this capability to electronics testing and examining radiation hardness. This has a direct application to space electronics needs.

This is **enabling technology** which will produce a level of testing that is extremely accessible.

For research, this will allow direct measurements for comparison with simulations on radiation interactions.

For example, we just wrote a paper on fission fragment energy loss in C and SiN foils comparing data with SRIM and MCNP. For heavy fragments MCNP was consistently 10-20% above data, and SRIM 10-20% below. Energy loss rates are not well characterized for these heavy ions.



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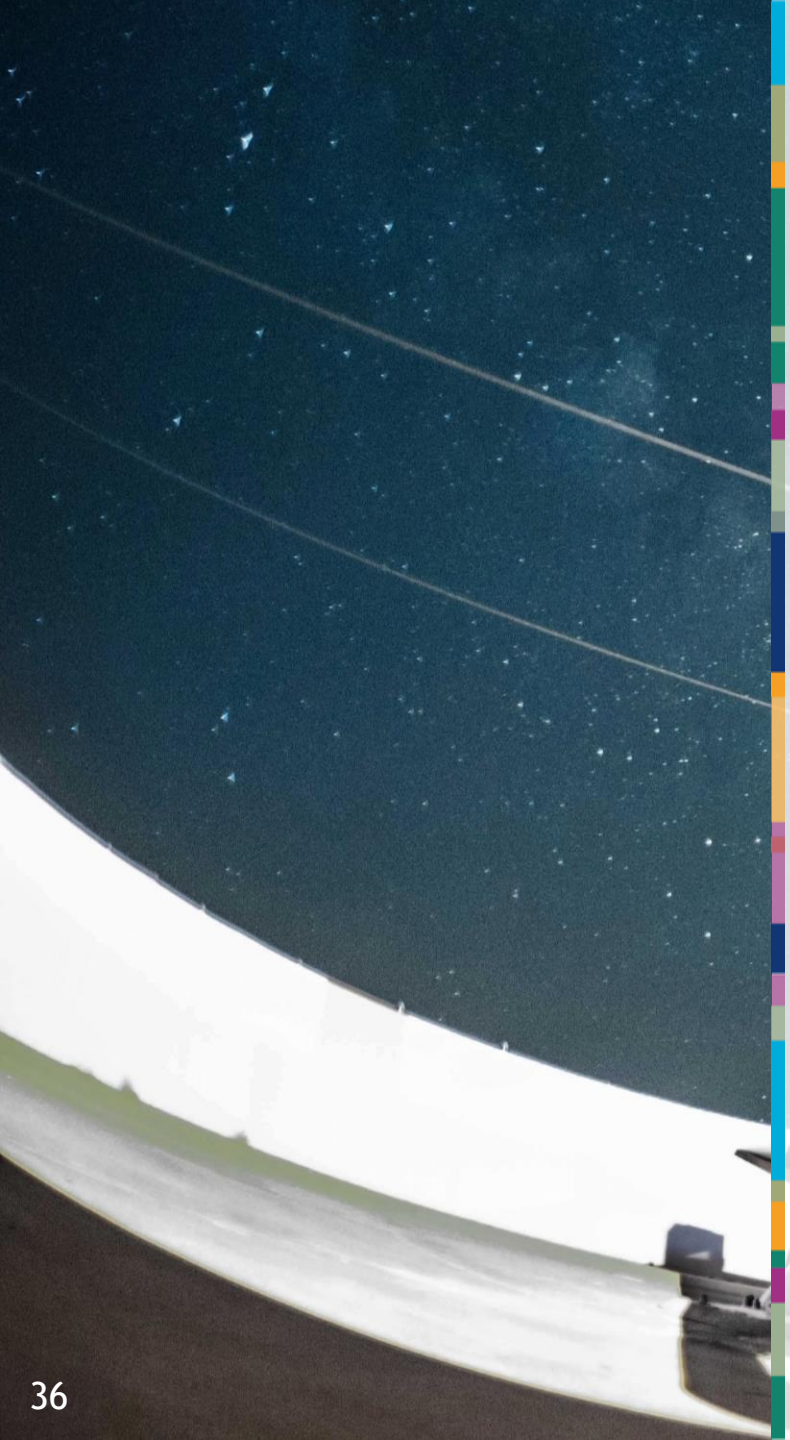
ADVANCING RESILIENCE FOR SPACE SYSTEMS

NETWORKING BREAK



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4/17/2019 Advancing Resilience for Space Systems

ADVANCING RESLIENCE FOR SPACE SYSTEMS: Mechanical Engineering Perspective

PRESENTED BY:

Andrei Zagrai, New Mexico Tech, Mechanical Engineering

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https://nmt.edu/academics/mecheng/faculty/azagrai.php

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ABOUT YOURSELF: Andrei Zagrai, Professor, Dept. Chair, Mech. Engr, NM Tech

- **Brief biography**: BE, BS, ME – TSURE, Taganrog, Russia, 1996-97. PhD in Mechanical Engineering, University of South Carolina, 2002, Post-Doc Stevens Institute of Technology, NJ
  Assist 2006, Assoc 2011, Full 2017 Professor at New Mexico Tech. Mech. Engr. Department Chair since 2014

- **Research areas and research group interests**:

  Space systems and structures: design and practical realization of condition monitoring solutions for space systems; real-time SHM of satellites, spacecrafts and other space vehicles; spacecraft assembly, pre-launch, launch, in-space, and re-entry diagnosis; mechanical engineering of space systems.

  Sensors and structural health monitoring (SHM): active and passive technologies for structural monitoring; structural analysis and condition assessment; detection and evaluation of incipient structural/material damage; exploiting the damage-induced material nonlinearity as a diagnostic feature; material characterization; structural identification and damage features extraction algorithms.

  Intelligent systems, structures, and mechanisms: analysis and design of the smart/intelligent/adaptronic structures and mechanisms incorporating active materials, smart controls and embedded intelligence; Mechatronics, networks of sensors and actuators for global and local sensing methodologies, artificial intelligence decision support for sensor networks.

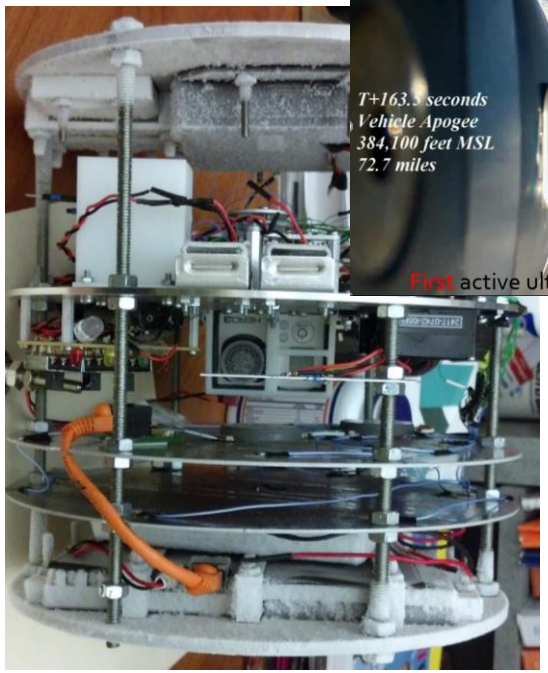
  Structural dynamics: vibration of discrete, continuous, and complex structures; dynamics of structural systems interacting with granular medium (landmines, soil, sand); linear and nonlinear wave propagation in solids, liquids and gases.

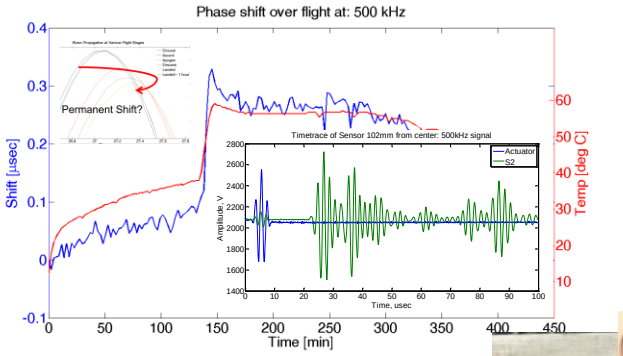
- **Research group size and demographics**: currently 1 PhD, 2 MS and 1 UG; 75% male, 25% female.

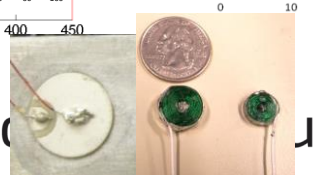
Keywords: Space systems, smart structures, sensors, structural health monitoring (SHM), NDE, flight experiments, structural dynamics, joints.

CURRENT WORK IN ADVANCING RESLIENCE FOR SPACE SYSTEMS

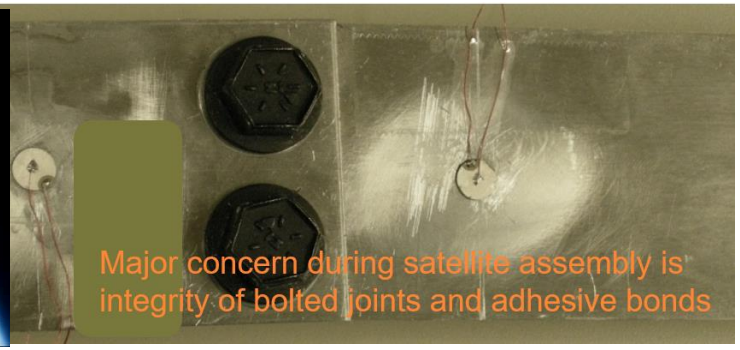
Space structures assessment during flight







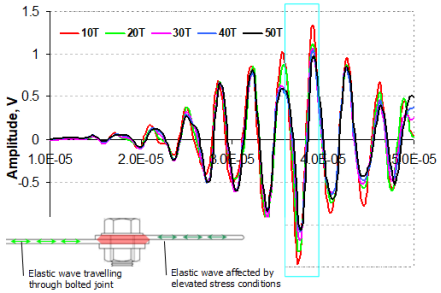
Nonlinear ultrasonic evaluation of bolted joints

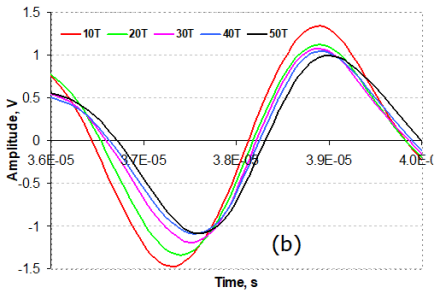


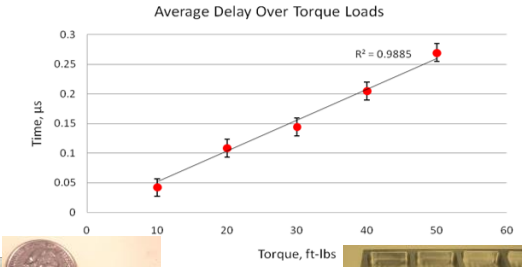
Sound speed — Stress

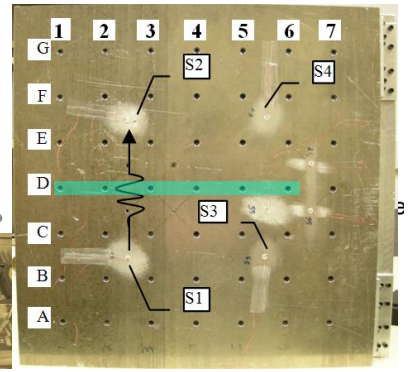
$$\rho c_{l\perp}^2 = \left(K + \frac{4\mu}{3}\right) + \frac{\sigma}{3K}\left(4K - \frac{8\mu}{3} + \frac{2(K-2\mu/3)^2}{\mu} + \frac{K-2\mu/3}{\mu}\cdot A + \frac{2(K+5\mu/3)}{\mu}\cdot B - 2C\right)$$

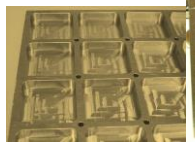
Linear parameters (bulk and shear moduli) — Non-linear parameters



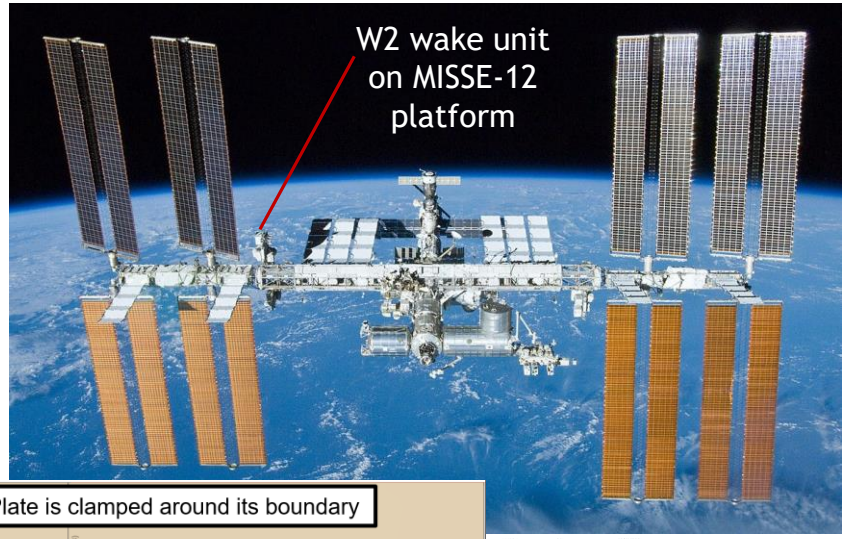


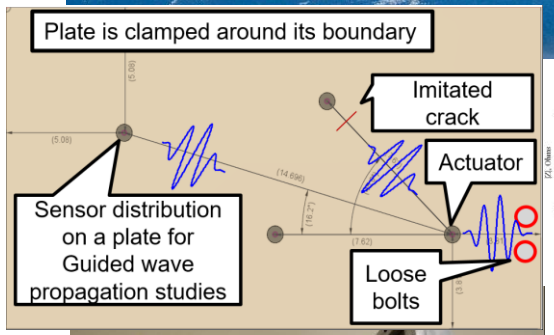


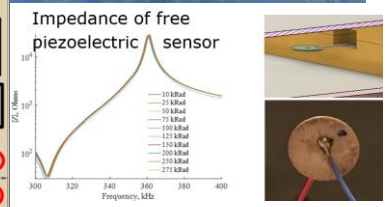


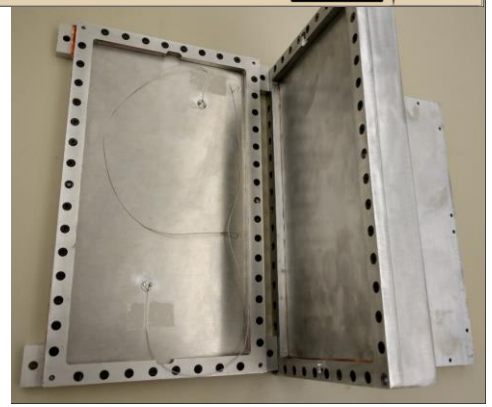


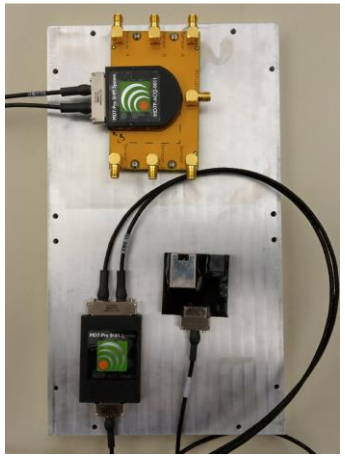
ISS SHM Experiment











New Mexico Research Spe[illegible]um

FUNDING SOURCES 2018-2019

"Autonomous Structural Composites for Next Generation Unmanned Aircraft Systems", NASA EPSCoR grant August 2017 – August 2020. Co-PI. Strain-based structural dynamics and impedance assessment

"In Orbit Structural Health Monitoring of Space Vehicles", NASA EPSCoR grant for developing and testing SHM experiments on International Space Station (ISS). Technical Principal Investigator, August 2017 – August 2020.

"Structural Health Monitoring (SHM) Framework for Commercial Space Transportation," FAA Office of Commercial Space Transportation, Center of Excellence for Commercial Space Transportation, 2015-2018, PI. SHM aspects for commercial space transportation, flight testing

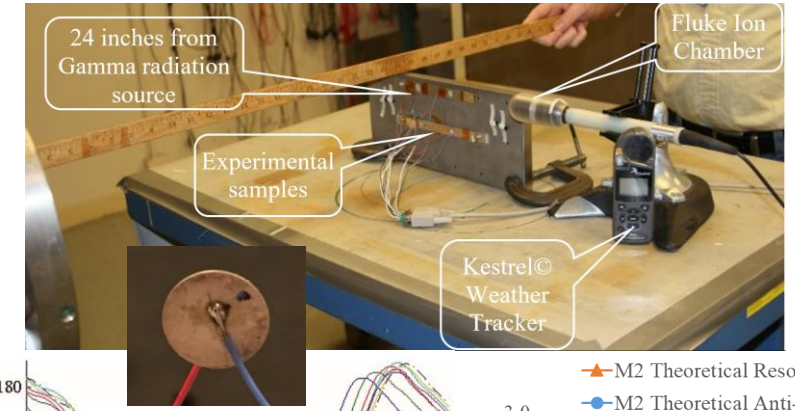
"Intelligent Energetic Systems Engineering (INTENSE) Research Experiences for Undergraduates", NSF, 2018-2021, Senior Personnel. Education

NM Collaborators: NMSU MAE Igor Sevostiyanov – projects, proposals, collaborative research

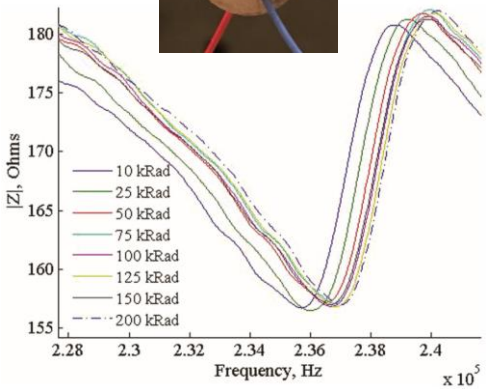
Past: Sandia SURP: "Control of the Structural Boundary Conditions using Piezoelectric Elements and Shunt Circuits."

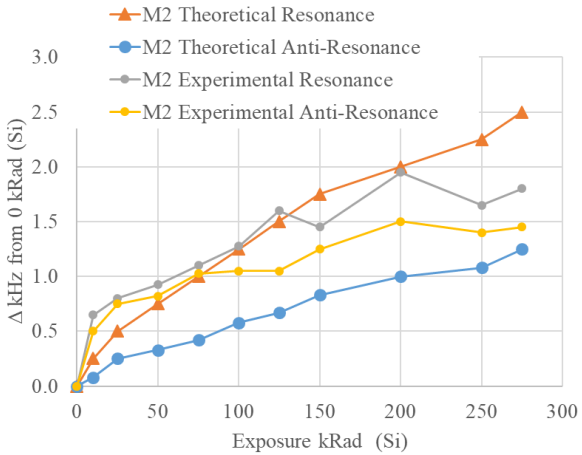
RESEARCH NEEDS

Radiation effects on piezoelectric sensors



Optical surfaces are typically tuned using piezoelectrics





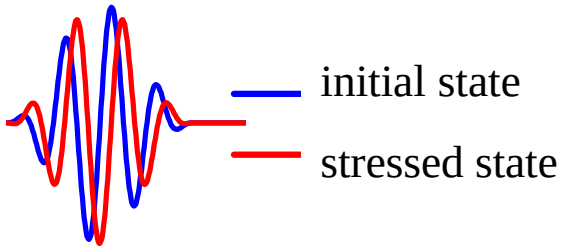
Research will benefits from exposure to different radiation sources and tuning to SNL applications

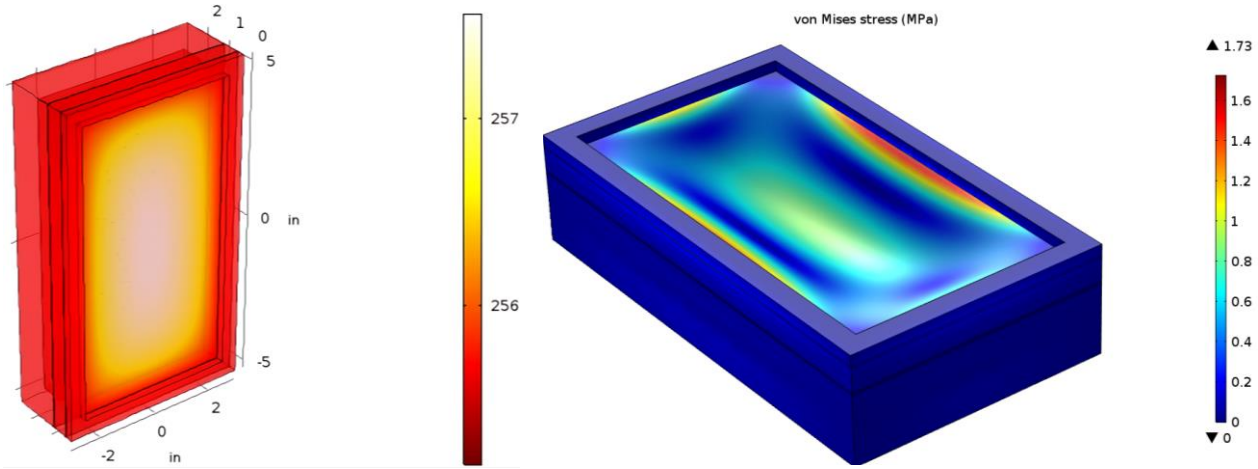
Anderson, M., Zagrai, A., Daniel, J.D., Westpfahl, D.J., Henneke, D., (2018) "Investigating Effect of Space Radiation Environment on Piezoelectric Sensors: Cobalt-60 Irradiation Experiment," ASME Journal of Nondestructive Evaluation, Diagnostics and Prognostics of Engineering Systems, Feb. 2018, Vol. 1, pp. 011007-011007-11.

Mechanical Effects on Optical and Electromagnetic systems (metamaterials, optical surfaces, electronic systems, etc.)

- On-orbit environment changes mechanical state of structure which alters optical and electromagnetic properties
- By monitoring mechanical state, it should be possible to tell how optical and electromagnetic properties have changed
- Suggest adjustment and possibly deliver corrected action.

Example: thermal gradient changes state of stress in structural material, which can be assessed using embedded ultrasonic SHM in real time.





Embedded SHM system may also passively listen to any external (e.g. laser)/internal influences to spacecraft structure

New Mexico Research Spotlight Forum

4/17/2019 Advancing Resilience for Space Systems

Predictive and Robust Guidance and Control for Space Systems

PRESENTED BY:

Hyeongjun Park, Ph.D.

Mechanical and Aerospace Engineering

New Mexico State University

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ABOUT MYSELF – HYEONGJUN PARK

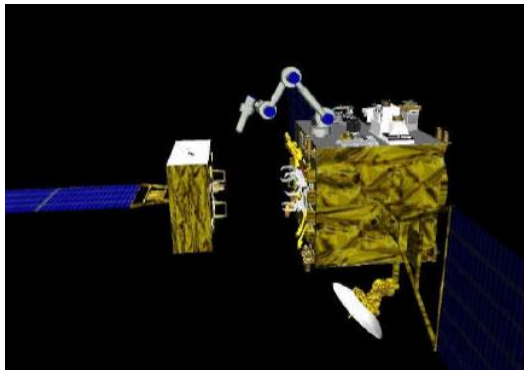
- **Brief biography**
  - Education
    - Ph.D., Aerospace Engineering, University of Michigan 2014
    - B.S./M.S., Aerospace Engineering, Seoul National University, South Korea, 2003/2008
  - Professional Experience
    - Assistant Professor, Mechanical and Aerospace Engineering, New Mexico State University, 2018-present
    - National Research Council Research Associate, Spacecraft Robotics Lab, Naval Postgraduate School, CA, 2015-2017
- **Research areas**
  - Onboard real-time spacecraft guidance and control
  - Precision spacecraft attitude control and failure analysis
  - Real-time model predictive control
  - Applications: spacecraft rendezvous and docking, precision satellite attitude control, hypersonic vehicles

Keywords:

Real-Time Optimal Guidance and Control; Robust Attitude Control; Failure Analysis

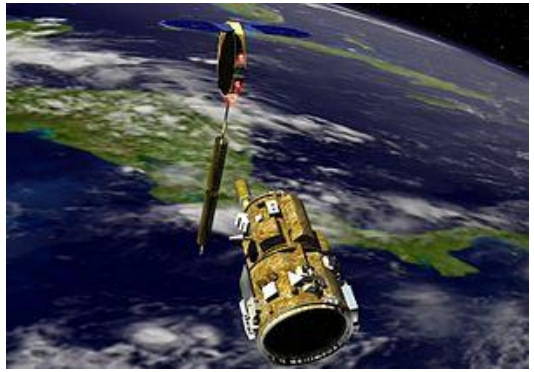
CURRENT WORK I – Spacecraft Onboard Guidance & Control

- **Rendezvous and Proximity Operations (RPO)**
  - Docking, berthing, servicing, inspection, active debris removal, etc.



ETS-VII (1998, JAXA)

Image Courtesy of JAXA



DART (2005, NASA)

Image Courtesy of NASA

ATV (2008, ESA)

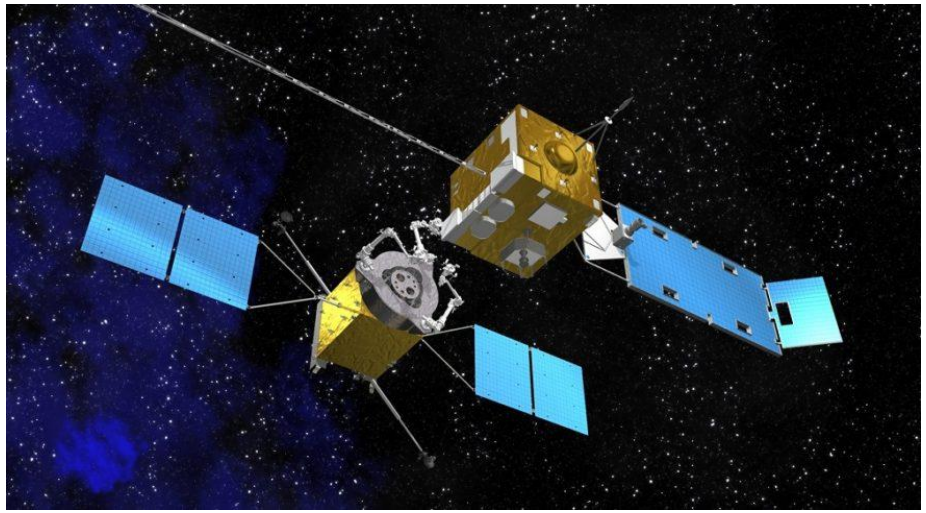
Image Courtesy of ESA

Dragon (2019, SpaceX)

Image Courtesy of NASA

CURRENT WORK I – Spacecraft Onboard Guidance & Control

- **Docking with a rotating/tumbling target platform**
  - Recovery of out-of-control satellite
  - Advanced future missions for Mars and deep space explorations



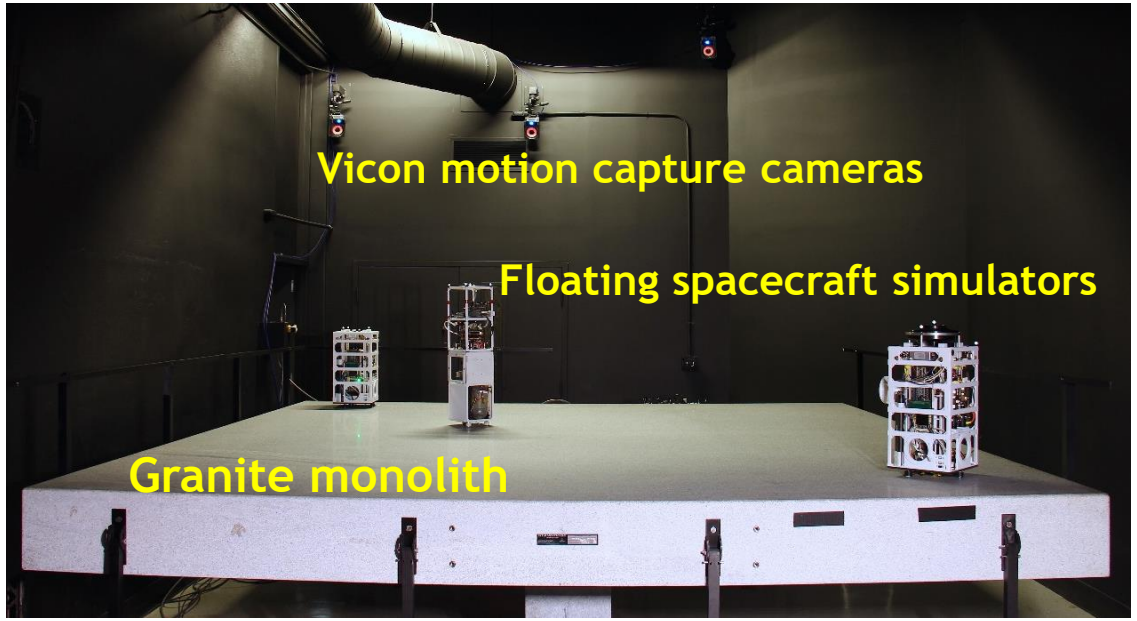
→ **Autonomous real-time collision-free mission strategies and algorithms are necessary for autonomous inspection, recovery, and removal capabilities**

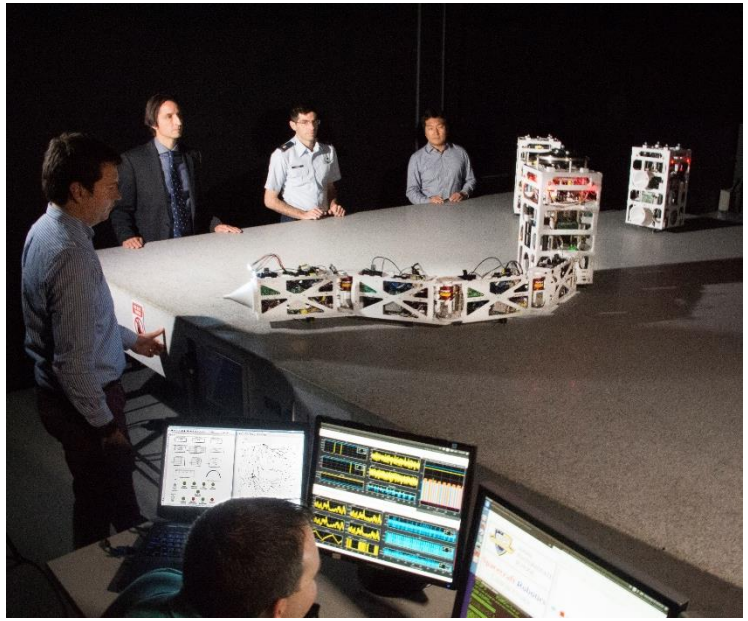
CURRENT WORK I – Spacecraft Onboard Guidance & Control

- **Experimental Testbed**

NPS-POSEIDYN testbed for quasi-frictionless environment

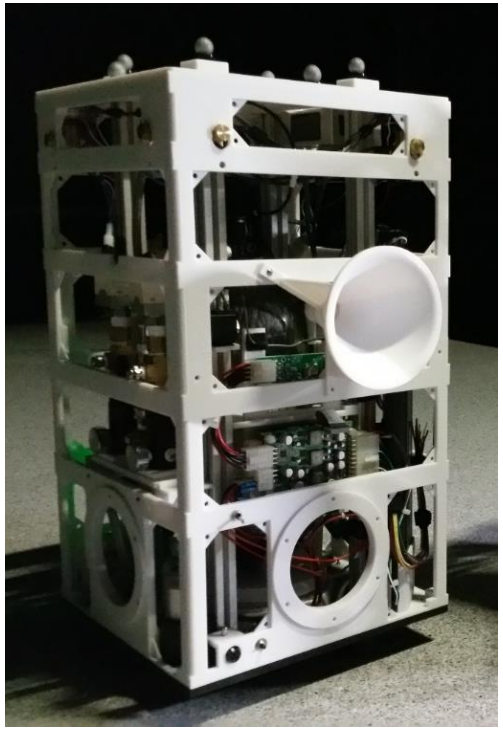
- Naval Postgraduate School – Proximity Operation of Spacecraft: Experimental hardware-In-the-loop DYNamic simulator test bed





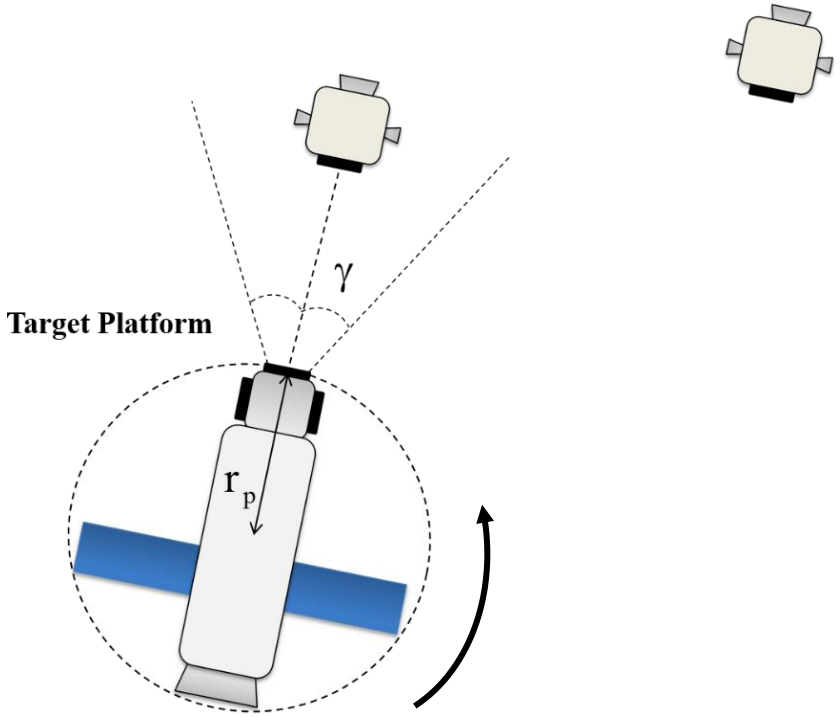
CURRENT WORK II – Spacecraft Onboard Guidance & Control

- **Floating Spacecraft Simulators**
  - ~10 kg vehicle
  - 3000 psi 1.8L compressed air tank
  - 3x air bearings (at 60 psi)
  - 8x thrusters (~0.16 N each)
  - Onboard computer
    - PC104-Plus board with Intel Atom 1.6GHz 32-bit with 2GB DDR2 RAM and 8GB SSD
  - Software
    - Ubuntu 14.04 LTS 32 bit edition
    - RTAI kernel patch for real-time execution



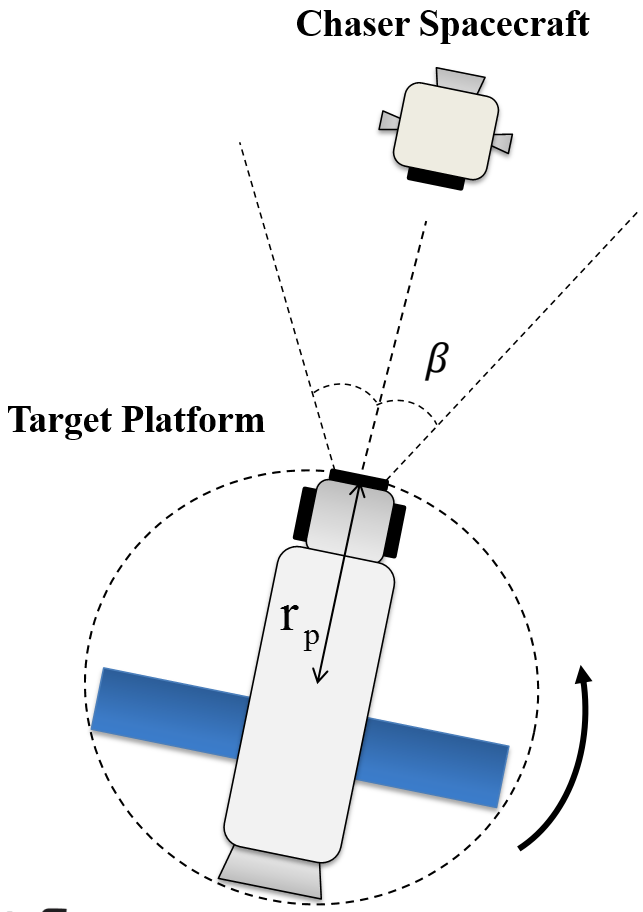
CURRENT WORK I – Spacecraft Onboard Guidance & Control

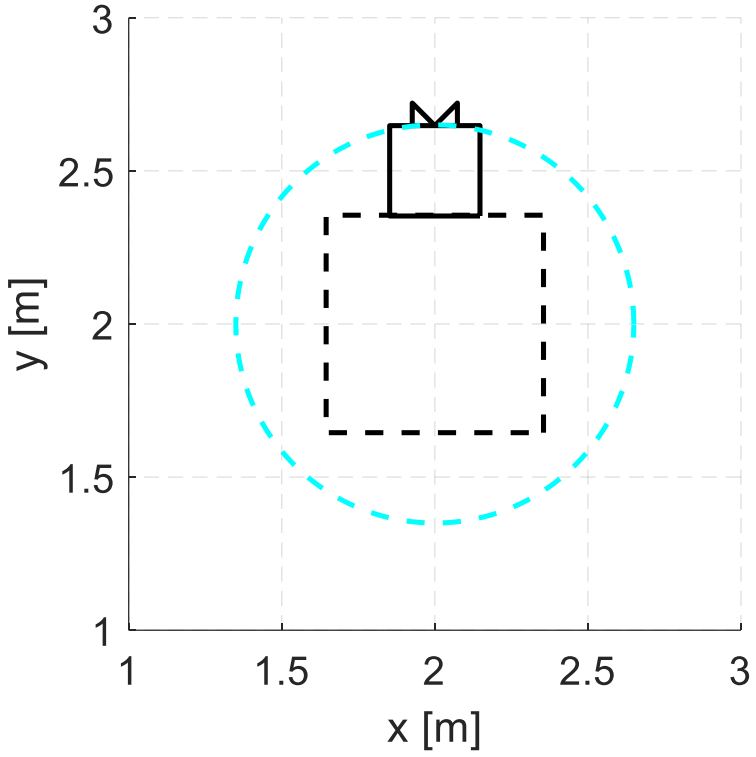
- **Rendezvous and docking strategy to design a computationally applicable**
- **Based on Nonlinear Model Predictive Control (NMPC) approach**
  - Phase 1: Free Flying
  - Phase 2: Final Docking Approach
  - Set a holding position as the desired positon of Chaser



CURRENT WORK I – Spacecraft Onboard Guidance & Control

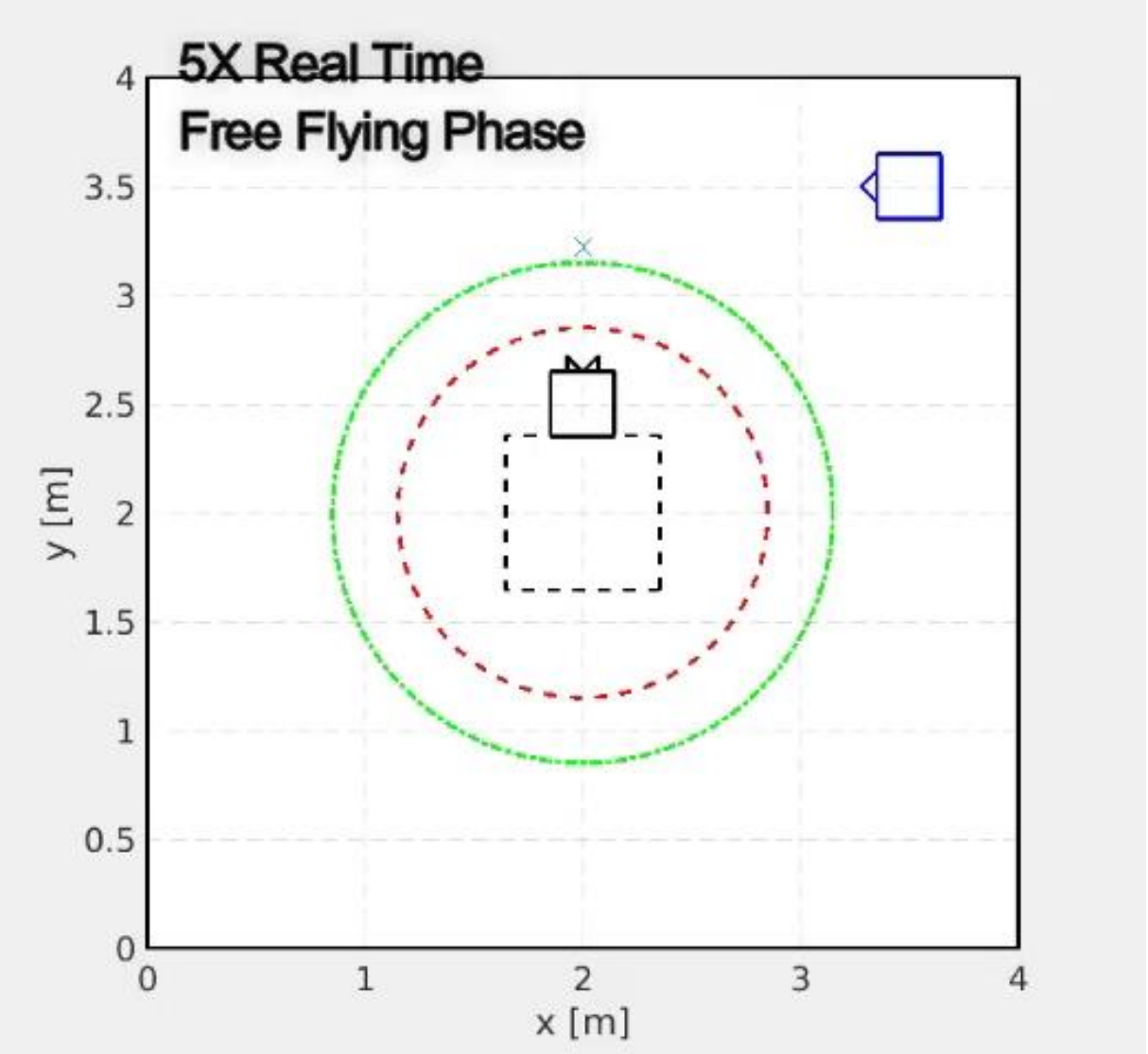
- **Mission design**
  - Emulating a docking port of a target platform using an FSS





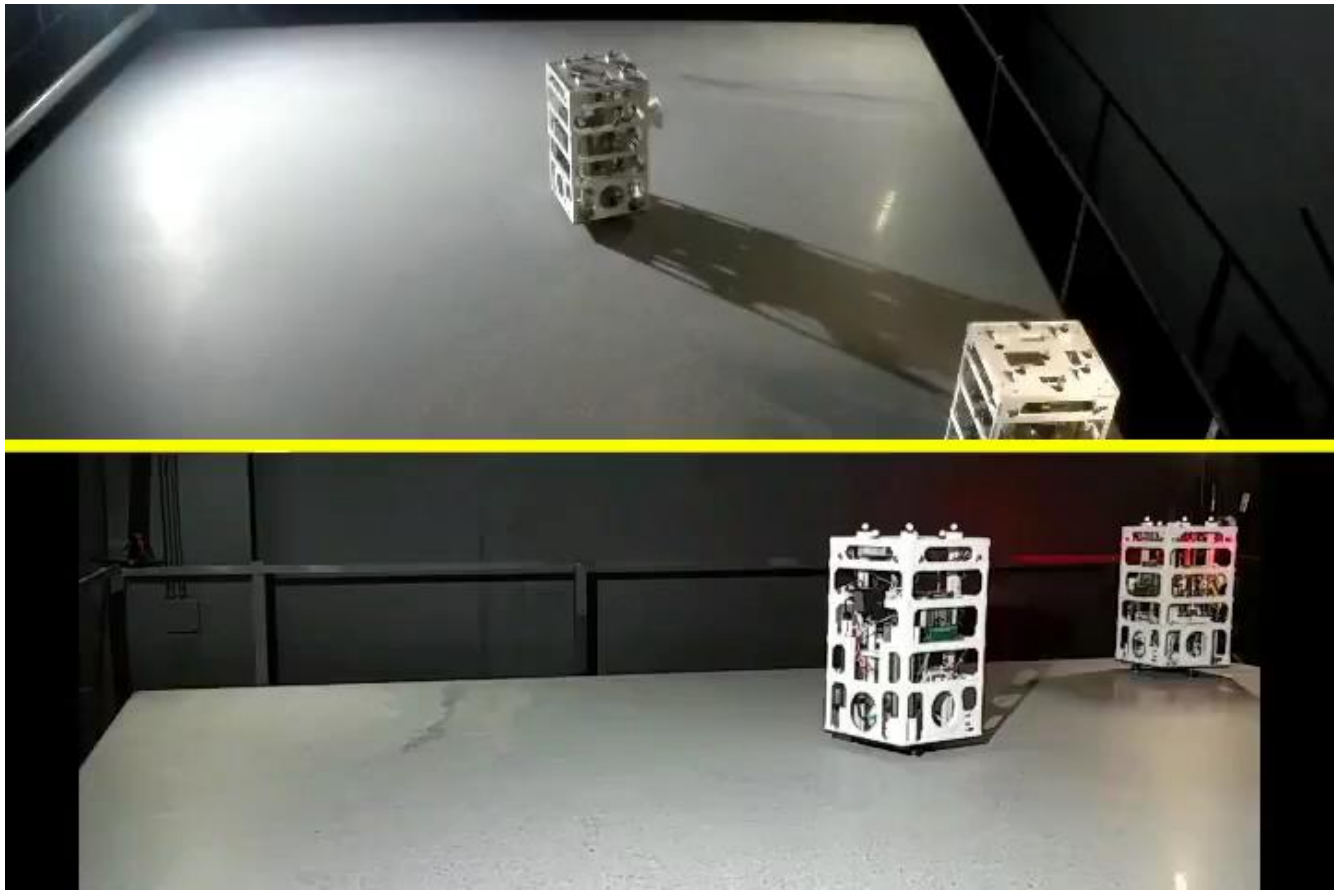
CURRENT WORK I – Spacecraft Onboard Guidance & Control

- **Simulation result**
  - IPOPT solver
  - Sample time: 2 s
  - Prediction horizon: 40
- Simulation: Agular rate: 1 deg/s



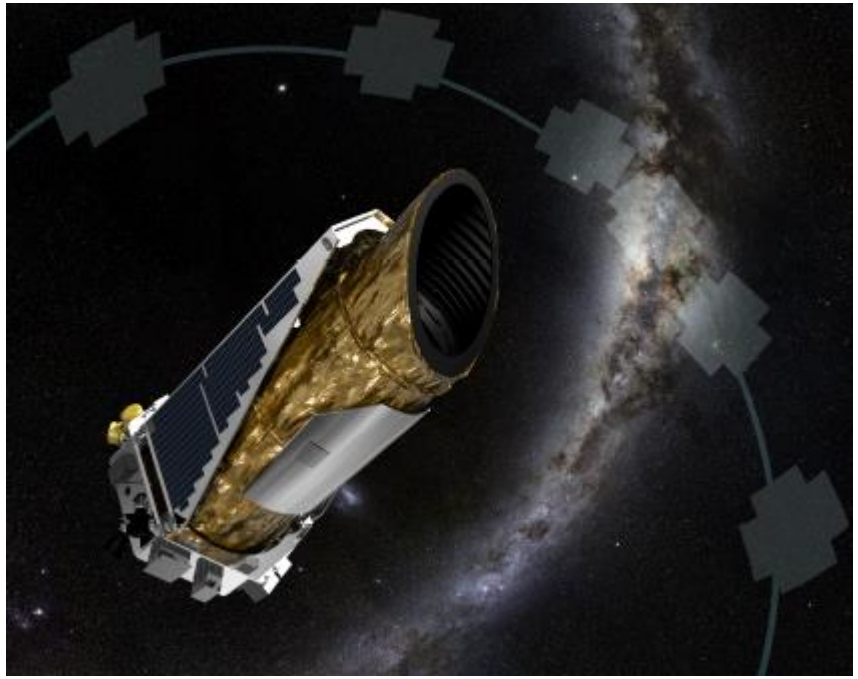
CURRENT WORK I – Spacecraft Onboard Guidance & Control

- **Experimental result: 0.5 deg/s, 4x real-time**
  - Avg & Max computation time: 0.04 s & 0.09 sec



CURRENT WORK II – Robust Attitude Control & Failure Analysis

- **Motivation**
  - Robust spacecraft attitude control: Design an H_∞ controller with Linear Matrix Inequalities (LMI) formulation
  - Fault detection method considering reaction wheel failure
  - Real mission scenarios



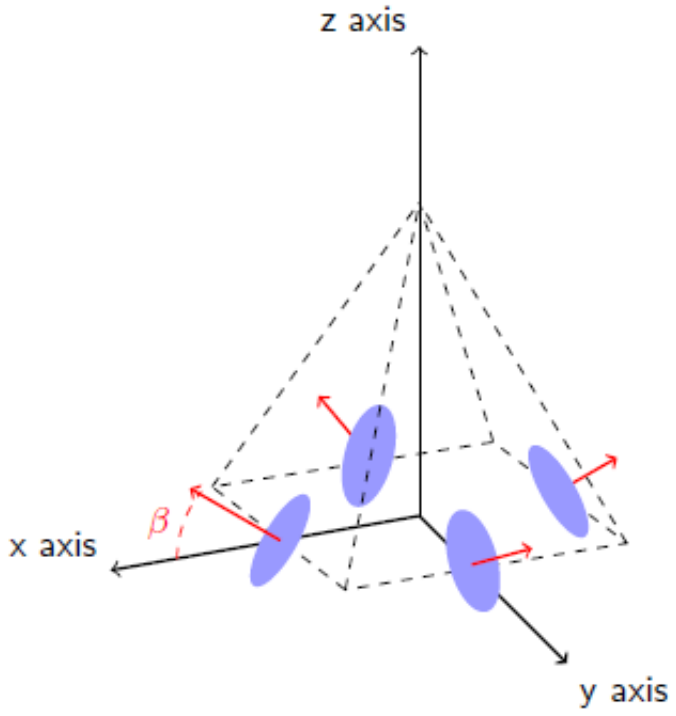
Artistic Concept of Mission Kepler, NASA

Image Courtesy of ESA

CURRENT WORK II – Robust Attitude Control & Failure Analysis

- **Mission scenario**
  - Small satellite of 200 kg, 0.8 m × 0.8 m × 1.2 m
  - Pyramid reaction wheel configuration of Honeywell HR16-50

Model	Mass [in Kg]	Max Angular momentum [in Nms]	Max torque [in Nm]	Inertia [in Kgm^2]
HR16-50	6	50	0.1	0.02



- Let consider this LTI system: $\begin{cases} \dot{x} = Ax + B_w w + B_u u \\ z = C_z x + D_{zw} w + D_{zu} u \end{cases}$
- State-feedback controller: $u = -Kx$
- Transfer function of the closed-loop system:

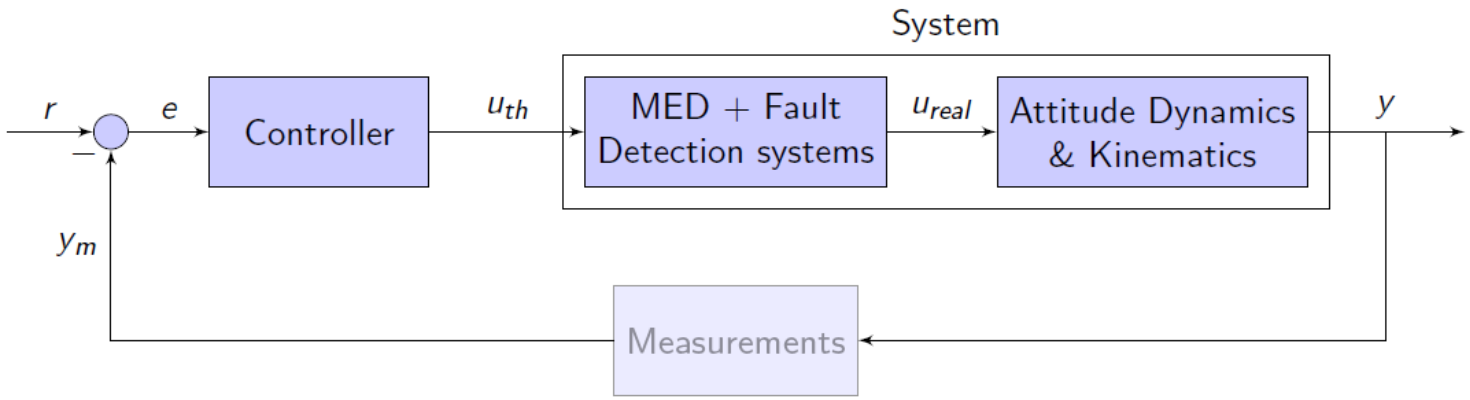
$$G(s) = D_{zw} + (C_z + D_{zu}K)(sI - A - B_u K)^{-1} B_w$$

Suboptimal H_∞ control

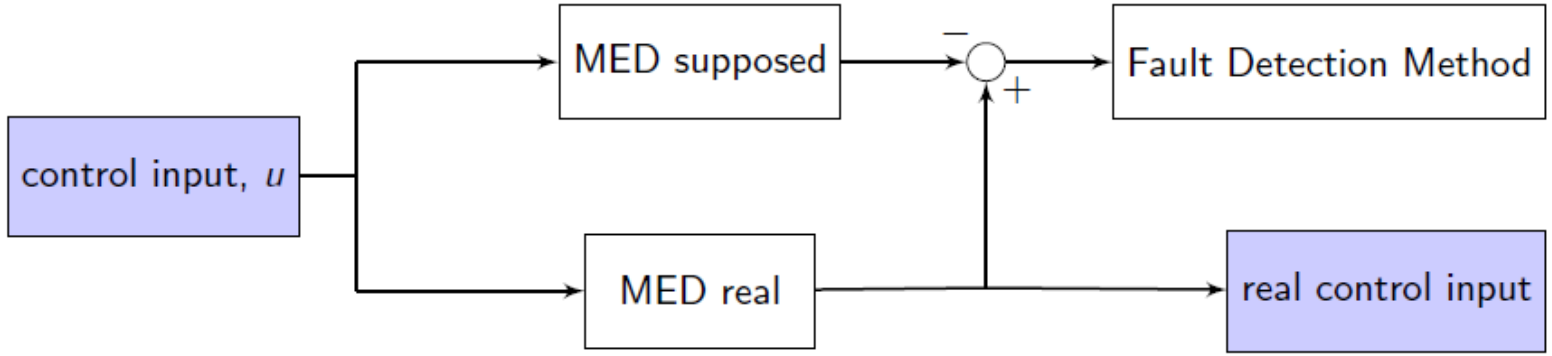
Given $\gamma > 0$, find all admissible controllers $K(s)$, if there are any, such that $\|G(s)\|_\infty = \max_\omega \bar{\sigma}(G(j\omega)) \leq \gamma$

CURRENT WORK II – Robust Attitude Control & Failure Analysis

- **System description**



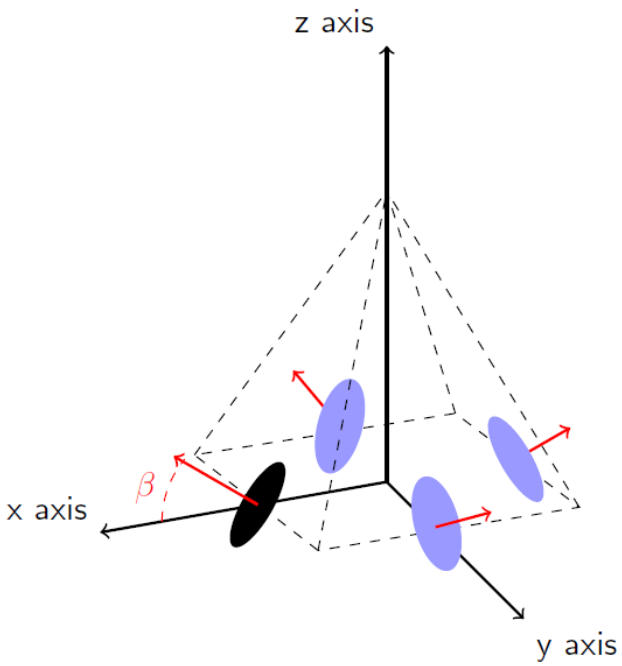
- **Fault detection method:** Parity equations method based on analytical redundancy

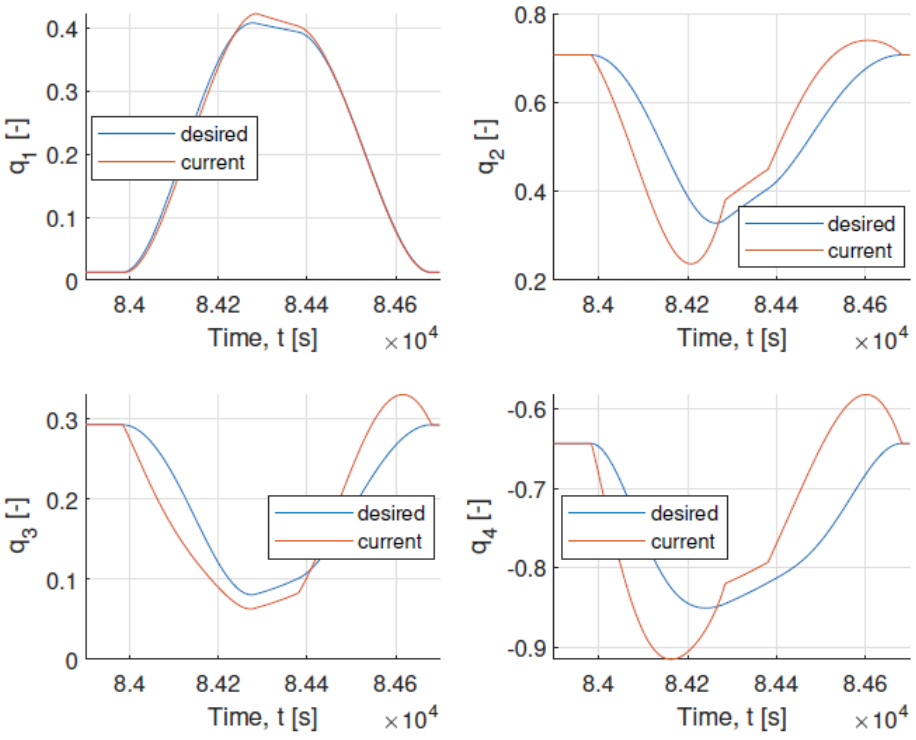


CURRENT WORK II – Robust Attitude Control & Failure Analysis

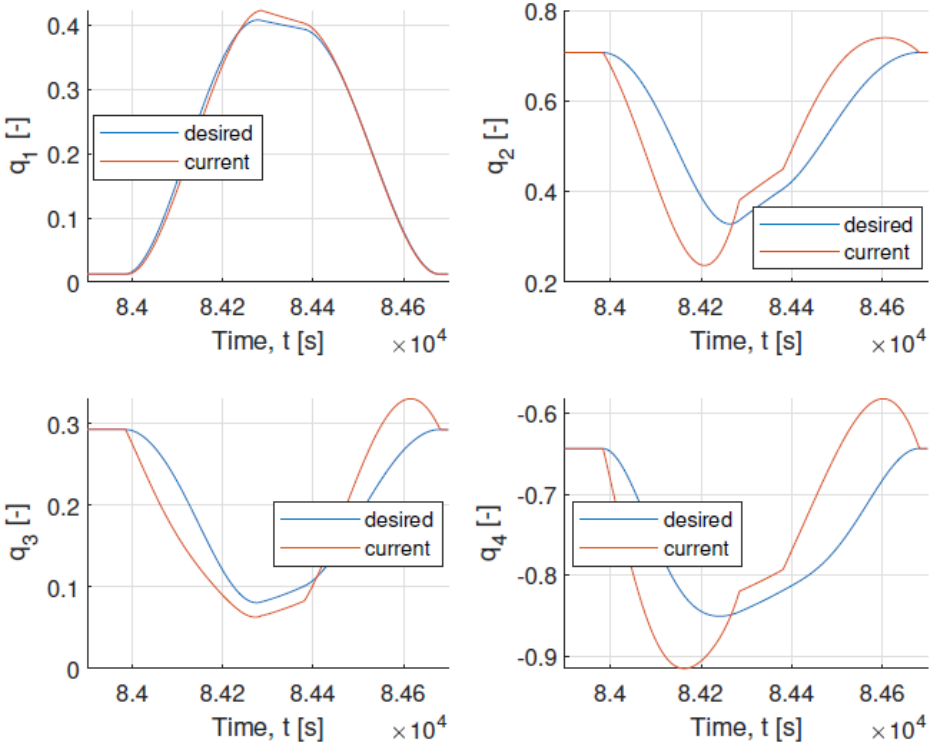
- **Simulation results**

1st Reaction wheel failed





No failure: Quaternions



1st RW failure: Quaternions

FUNDING SOURCES

- **PI**
  - Predictive guidance and control of NASA Astrobee robots in the International Space Station funded by NASA EPSCoR, New Mexico Space Grant Consortium
    - Collaboration with NASA Ames Research Center

- **Co-PI**
  - Space virtual telescope for X-ray observation (VTXO) sponsored by NASA
    - Formation flying of two small satellites for virtual telescoping
    - Work with NASA Goddard Space Flight Center
  - Satellite alignment system satellite (SAS-SAT) project funded by Northrop Grumman
    - Autonomous alignment and navigation through an optical relative alignment
    - Launch two sets of two CubeSats

RESEARCH NEEDS

- Mission scenarios for advancing resilience for space systems
- Onboard real-time guidance and control requirements
- Possible topics for collaboration

New Mexico Research Spotlight Forum

4/17/2019 Advancing Resilience for Space Systems

Cyber Resilience for Space Systems

PRESENTED BY:

Eric Vugrin

Cyber Resilience R&D Org. 5821,Sandia National Laboratories

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ABOUT YOURSELF

- Background
  - Degrees in (applied) mathematics
  - 15 years at Sandia, performing numerical modeling and analysis across a variety of systems
- Current research areas
  - Security and resilience modeling design, and analysis for cyber applications
  - Applying these techniques to space platforms…
- Research group
  - Interests: "all-things" cyber security and resilience for industrial control systems (modeling, experimentation, intrusion detection, defenses, etc.)
  - Size: variable, but my "group" consists of ~80 folks, with outreach across SNL
  - Demographics: info/cyber security, engineers, computer scientists, industrial controls,

Keywords:

Cyber security and resilience, threat modeling, intrusion response

Experiences at Sandia

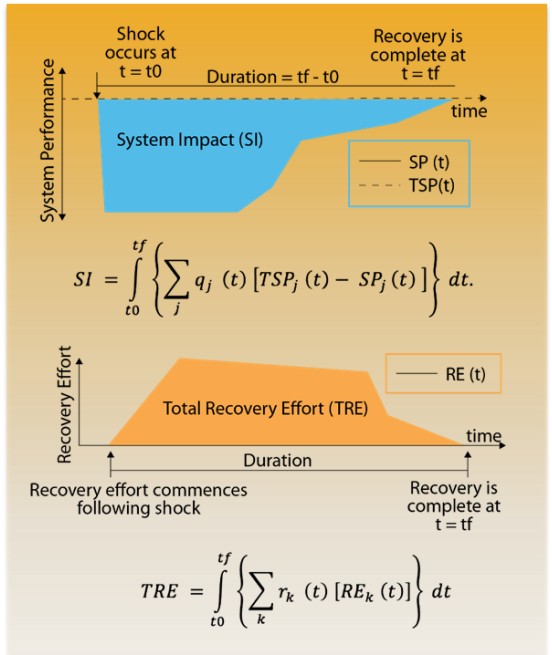
Risk Analysis for the WIPP

Infrastructure Consequence Modeling & Analysis

Cyber Security & Resilience

CURRENT WORK IN ADVANCING RESLIENCE FOR SPACE SYSTEMS

- Quantitative resilience analysis: how can we rigorously evaluate and design resilience into critical systems?
  - Metrics, mathematical modeling and optimization
  - Design of experiments and validation
- Modeling the cyber threat: how do we credibly represent threats in cyber experiments?
  - Development and validation of game theory & network interdiction models
  - Generation of synthetic data sets to represent previous and potential threats
- Automated, intrusion response algorithms: how do we create systems that (more) "automatically" respond to cyber threats without disrupting normal operations?
  - Leveraging mathematics of control, game theory, optimization
  - Operate in real-time, subject to size, weight, and power limitations



RESEARCH NEEDS & FUNDING SOURCES

Research Needs

- Data, data, data …of satellite function performance: normal and "attack" conditions
  - Obtaining data
  - Generating synthetic data sets
  - Development of benchmarks
- Simulation and emulation of space systems
  - Communications
  - Satellite buses
  - Payloads
- Cyber threats to space systems: understanding and representing concerns specific to space systems

Funding sources: best option for collaboration is likely Laboratory Directed Research and Development (internal SNL research funds)

New Mexico Research Spotlight Forum

4/17/2019 Advancing Resilience for Space Systems

Satellite Command and Control Resilience

PRESENTED BY:

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ABOUT YOURSELF

Education
- BSEE from UIUC in 1999
- MSEE from USC in 2001

Employment
- TRW/Northrop Grumman Space Technology from 1999-2004
- Sandia National Labs, 2004 – Present
- > 15 years experience in space systems

Research Areas
- Modulation classification
- Protocol discovery
- RF fingerprinting
- Emitter geolocation
- Signal disambiguation

Keywords:

Machine learning, conditional random fields, emitter identification

CURRENT WORK IN ADVANCING RESLIENCE FOR SPACE SYSTEMS

Lab-directed R&D (LDRD)

- Conceptual payload development for space-based sensor to monitor command signals to US spacecraft
  - Identify emitters and classify interferers (RF fingerprinting, modulation, protocol, etc.)
  - Future work on disambiguating signals to operate through

Air Force Satellite Control Network (AFSCN) Resilience Project for US Air Force Academy Operational Research (OR) Capstone Project

- Working with an OR senior project on generating metrics for satellite resiliency in AFSCN communication with satellites

RESEARCH NEEDS

Looking for interested parties in working on:

- Modulation classification
- RF fingerprinting
- Signal separation and disambiguation

- Software defined radio work using GNU Radio

New Mexico Research Spotlight Forum

4/17/2019 Advancing Resilience for Space Systems

Trusted Systems

PRESENTED BY:

Sudeep Mitra, Proliferation Signatures R&D, 505-284-0738

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THE UNIVERSITY OF NEW MEXICO

NM STATE UNIVERSITY

NEW MEXICO TECH
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ABOUT YOURSELF

PhD – Nuclear and Radiation Chemistry (India)

Post-doc-Department of Surgery, Auckland Hospital, New Zealand

Nuclear Engineer-Brookhaven National Laboratory, NY

Nuclear Engineer – Sandia National Laboratories

- Research areas: Active neutron interrogation -In vivo body composition using prompt gamma neutron activation analysis, terrestrial carbon sequestration studies using pulsed neutron generators, Unexploded ordnance identification using neutron time-of-flight,
- Research group interests: Sensor Science - Terrestrial and space based

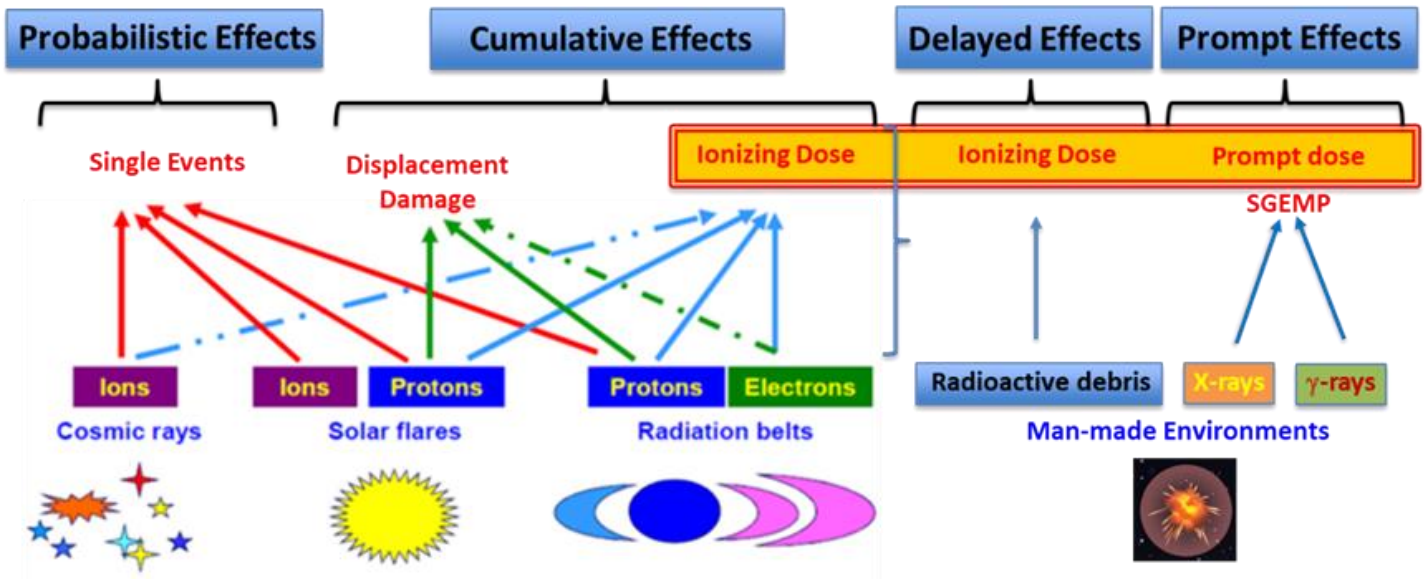
Lead for the Radiation Effects Qualification team for payload systems

Keywords:

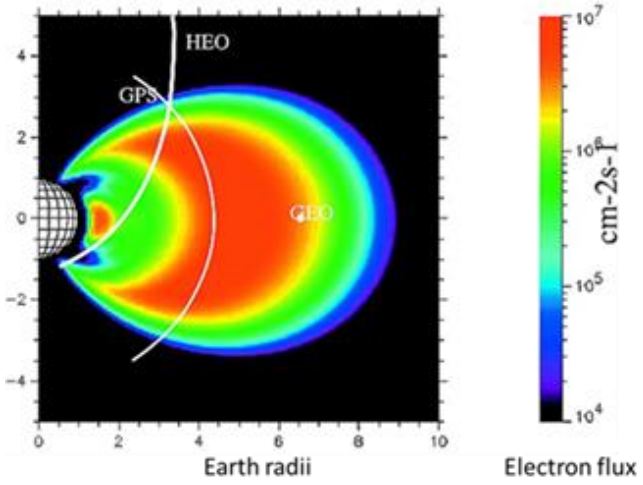
Neutron interrogation, space radiation effects, radiation testing

CURRENT WORK IN ADVANCING RESELIENCE FOR SPACE SYSTEMS

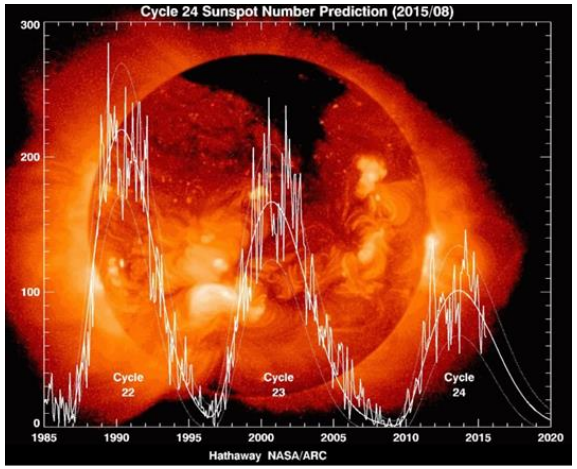
Detrimental effects due to space radiation environment



Electron flux at different distances



11 year solar cycle



Mitigation

- Model the environment
- Design the shielding (Cumulative Effects)
- EDAC (Probabilistic Effects)

Radiation Effects testing

SNL Co-60 Gamma Irradiation Facility

(1) TID (Total Ionizing Dose) -

(2) Single Event Effect- Heavy Ion, proton accelerators

- Expensive, bookings need to be made much ahead of time

FUNDING SOURCES

- No joint work with Universities

RESEARCH NEEDS

- **Require low cost testing tools for SEE**

- **Directly relevant for quick testing of COTS parts for "Trusted Systems"**

New Mexico
Research Spotlight Forum

ADVANCING RESILIENCE FOR SPACE SYSTEMS

JOIN US FOR FUTURE EVENTS:

6/4/19	Quantum Information Sciences
7/16/19	Social Sciences and Decision Making
8/27/19	Resilient Infrastructure (SMART Grid)
10/8/19	Advanced Manufacturing and Robotics
11/19/19	Biomedical Engineering and Informatics