Secretary of the Navy

NAVAL SPACE SUMMIT

9-11 July 2024

“Critical Capabilities for the Next War”
Commercial Partner: TrustPoint, Inc.

- 5 collaborative research and development agreements (CRADAs) to date for supporting payload development and STTR/SBIR efforts
  - Collaborate on technical design, development, and testing of a compact, multi-source timekeeping module for on-orbit applications
  - USN SBIR Phase I Award to evaluate interoperability of TrustPoint’s commercial system and aPNT service with existing Navy user equipment
  - USAF STTR Phase I & II Award to further mature the GPS Interference Monitoring Payload concept and Data Services
  - USFF SBIR Phase II Award to mature preliminary designs for the Low Earth Orbit Navigation System (LEONS) from TRL-2/3 through TRL-6

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TrustPoint and Naval Postgraduate School Announce Collaboration to Advance Next-Generation GPS Technologies

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OV-1: High Performance Ensemble Clocks for Reliable and Accurate Timing Signals to Forward-Deployed US Navy Maritime Platforms

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aPNT Payload Design & Navy-Centric Mission Architecture

- Mission statement, mission objectives, and system requirements are driven by Naval and intelligence requirements
- aPNT payload is an example of how research is leveraged to achieve learning objectives and expose students to emerging technologies
- Acquisitions cycle milestones are used as deliverables

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Modeling and Simulation for Navy Interoperability Requirements

- A proposed commercial pLEO constellation was modeled in STK including an overwater aviation scenario
- Calculating carrier to noise ratio and over determined geometric dilution of precision for a single satellite in the constellation resulted in navigation accuracy under 0.15 meters from the commercial LEO constellation

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PI:
Wenschel Lan, Research Associate Professor, wlan@nps.edu

Student Participation:
591 Space Systems Engineering Cohort, Graduated Sep 2024; Capt Michael “Tofu” Spain, USMC (366 Space Operations student)
People’s Republic of China (PRC) Activities in the South China Sea (SCS) & Cislunar Space

- Comparative analysis of the PRC’s coercion and intimidation tactics in the SCS, and similar actions that may be taken in Cislunar Space and on the lunar surface.
- Conduct analysis of the PRC’s objectives and strategies in the SCS region
- Understand the stratagems the PRC employs to achieve its objectives, and use the findings to anticipate future actions in Cislunar Space
- Formulate counter-strategies to overmatch the PRC in the pursuit of each of its cislunar objectives

PRC Activities in Cislunar Space:
- Strategic positioning of satellites as part of a Cislunar SDA and PNT infrastructure
- Planned lunar territory and resource exploitation activities as part of the International Lunar Research Station (ILRS)
- ILRS positioned as a direct competitor to the US-led Artemis coalition for soft power benefits in the space domain

Develop Counter-Strategies to Maintain U.S. Leadership in Space Exploration

- Leverage large and continuously growing coalition of allies and partners (Artemis Accords)
- Integrate private commercial enterprise to offset cost and encourage innovation to support mission accomplishment (SpaceX, Blue Origin)
- Raise awareness to the importance of the Cislunar Domain and the implications to national security

Pi:
James Clay Moltz, Professor, Academic Associate, jcmoltz@nps.edu

Student Participation:
696 Strategy (Space Operations) Cohort, Graduated Sep 2024;
LT Conor P. Murtha, USN
Mission Statement

- MC3 is a community-based ground network to support research and development for US government small satellite missions.
- MC3’s ten sites are located at partner institutions that all contribute to US government small satellite research. NPS manages the operations and maintenance of the network.
- Mission operators utilize MC3 as a bent-pipe for spacecraft communications from their operations center.
- MC3 is a major participant in the FVEY International SmallSat Command and Control Network (ISC2N).

Key Specifications

- 3m and 3.7m parabolic reflectors. 30-50W TX power, 34-36 dBi gain, 8-13 dB/K G/T S-Band, 28 dB/K G/T X-Band.
- Yagi antennas for UHF, 100W TX power 18 dBi gain.
- Radios Utilized
  - National Instruments USRP 2922, Kratos qRadio, Aemergint SatTRAC, Newtec MDM6000
- DoD cybersecurity accreditation and encrypted connections.
- De-centralized cloud-based architecture in AWS GovCloud.
- Ten US sites, three FVEY collaborator sites.

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequencies</th>
<th>Designator</th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHF uplink</td>
<td>449.75 – 450.25 MHz</td>
<td>12K5F1D, 4K80F1D</td>
<td>PCH, NPS, SDL, USM, AFT, SMDC, USNA [USCGA]</td>
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<td>902 - 928 MHz</td>
<td>11K5G1D</td>
<td>SDL, USM, AFT</td>
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<tr>
<td>S-band downlink</td>
<td>2000 – 2290 MHz</td>
<td>1M6M5G1D, 2M0M0G2D, 2M4M5G1D</td>
<td>PCH, NPS, SDL, UAF, SMDC, AFT, USCGA, USM, USNA [USCGA]</td>
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<tr>
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<td>7190-7250 MHz</td>
<td>1M0M3G1D</td>
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<td>8025 – 8460 MHz</td>
<td>3T7M5G1D, 4U5M5G0X</td>
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</tbody>
</table>

Frequencies Supported

Research Areas

- Schedule optimization for constellation management.
- Software-defined radio waveform creation/evaluation.
- Topics in machine learning for predictive failure analysis.
- Integration of commercial pLEO internet terminals.
- Development of optical communications capabilities.

Researcher(s): Dr. Giovanni Minelli, Dr. Lara Magallanes, Alex Savattone, Noah Weitz
Topic Sponsor: DoD Space
Spacecraft Design Course Project: Lunar Search and Rescue

**Mission Statement**

Develop a search and rescue system to support the timely detection of distress signals on the Moon’s surface, utilizing Lunar Gateway to facilitate recovery.

**Mission Objectives**

1. Detect and decode distress signals and LunaNet Position, Navigation and Timing information in the southern 6 degrees of latitude in support of Moon exploration and habitation.

2. Transmit distress information and location to Lunar Head Quarters within 5 minutes of activation to support NASA’s 1 hour recovery requirement.

3. Ensure Lunar Search and Rescue capability is in place prior to Artemis 5 mission.

**Education Through Hands-On Research**

- Naval officer students fulfill program manager, systems engineering, and subsystem engineering roles
- Working closely with the sponsor, students tackled current and pressing Naval and intelligence requirements, leveraging their Naval experience and hands-on skills to develop possible solutions
- Space systems engineering knowledge and skill sets developed in this course sequence include:
  - Constellation design was conducted and analyzed utilizing an industry standard software package, System Tool Kit (STK)
  - Software defined radio (SDR) communications payload was programmed and tested using MATLAB Simulink
  - Trade studies were conducted at various system levels to assess size, weight, power, and cost (SwaP-C) as well as risk and reliability

**PI / Payload & Spacecraft Design Course Instructor:**
Wenschel Lan, Research Associate Professor, wdlan@nps.edu

**Student Participation:**
591 Space Systems Engineering Cohorts, Graduating by June 2024 & 2025
Purpose

As the Navy’s technological capabilities evolve, the responsibilities of communicators grow, necessitating advanced monitoring tools to detect anomalous signals and safeguard command and control systems from adversarial interference. The deployment of cloud-based ML algorithms offers a practical solution to augmenting these capabilities without the logistical challenges of physical hardware constraints, providing resilience to command and control operations abroad.

Method

This research focused on training a dense and long short-term memory (LSTM) autoencoder on the In-Phase and Quadrature (I&Q) data from a QPSK waveform experiencing no interference. An autoencoder accurately recreating the signal indicates that no signal abnormalities are present, which results in a low reconstruction error. If that signal experiences interference the characteristics of that waveform will change enough that an autoencoder will less accurately reconstruct that waveform resulting in an increased reconstruction error.

Data

The autoencoders were trained to accurately recreate a signal experiencing no interference, which resulted in a baseline reconstruction error. This baseline was used to establish a threshold based on standard deviation of errors, which, when surpassed, would trigger a warning to the communicator. The ability of the autoencoders to detect interference in the I&Q data from six different demodulation steps was examined. The entire process was conducted in Microsoft Azure using a Python-based machine learning process. Azure and Python were chosen to examine their ease of distribution and accessibility.

Results

The dense autoencoder performed quickly with less sensitivity to weak interference, performing well when compared against I&Q data beyond the carrier synchronizer. The LSTM autoencoder was extremely sensitive to changes in signal but took more time to analyze the data. This autoencoder performed well on I&Q data beyond carrier synchronization.

Researcher(s): Capt Jason Turdo (USMC), Dr. Wenschel Lan, Dr. Mark Karpenko
Space Systems Academic Group
Topic Sponsor: N2/N6 - Information Warfare

This research is supported by funding from the Naval Postgraduate School, Naval Research Program (PE:0605/83/N2/2018). Approved for public release; distribution is unlimited.
Overview and Objectives

The project aims to design, develop, and validate a rocket-based system for payload delivery, prioritizing affordability by incorporating consumer-grade commercial off-the-shelf (COTS) components. The process spans from theoretical design and hands-on construction of subsystems to comprehensive test-flight validation.

- Develop an affordable high-altitude delivery system with COTS components.
- Achieve system validation via flight tests to confirm reliability and potential for fast-fielding in mission-critical scenarios.

System Design and Cost Efficiency

The current rocket utilizes consumer-grade components and materials, featuring a 4-inch canard-based design with a free-to-spin tail. This design emphasizes an exponential decrease in the cost of systems, enhancing both production efficiency and system capacity.

- **Consumer-Grade Components**: Utilizes readily available, affordable components to ensure cost-effectiveness.
- **4-inch Canard-Based Design**: Optimized for stability and control during flight.
- **Free-to-Spin Tail**: Enhances aerodynamic efficiency and stability.

Impacts of Research

- Facilitates swift provision of temporary BLOS capabilities to maintain operational functions in disrupted environments.
- Pioneers adaptable, cost-efficient rocket technologies enabling short-term support for space-related missions.
- Dramatically reduces expenses associated with the quick deployment of temporary space-related capabilities.
- Enhances rapid response capabilities for emergency situations, providing timely deployment of communication and surveillance resources.
MIXED TIME-FREQUENCY OPTIMIZATION FOR FLEXIBLE SPACECRAFT MOTION CONTROL

Introduction

Residual vibrations are an unavoidable result of reorientating flexible space systems. Conventional wisdom says, the faster a spacecraft rotates, the more vibration that is introduced. Therefore, current approaches trade maneuver time for reduced vibration in the flexible appendages(s). This thesis explores model-based trajectory optimization as a mechanism for increasing rotational agility while simultaneously managing flexible effects for reduced residual vibrations. To make the approach suitable for practical systems, a key innovation is to utilize a new mixed time-frequency approach where the modal response is managed in the frequency domain. The development uses a flexible link system for laboratory proof-of-concept.

Current Results

Optimal Input Trajectory  
Link Angle Trajectory  
Flexion Limited To 1 Deg  
Comparison with Classical Ramp Input

Next Steps

- The next step for this work is to create a higher fidelity model to capture the multi-mode response of the laboratory system

- A trajectory optimization problem control problem is constructed and solved to create a command profile to drive the system from 0° to 45°.
- Vibration are managed using the time-domain flexion path constraint which restricts the allowable flexion in the flexible link to less than 1°.
- Unlike classic control inputs, the optimal control input has almost no residual vibrations after the completion of the maneuver (see plots below)
- Optimized solution allows maneuver time to be reduced (increasing agility) while simultaneously reducing residual vibrations for more accurate pointing

- A frequency-based path constraint will be developed to manage the uncertain frequency response of the residual vibrations. This is in line with 'practical engineering logic'

- The results of this thesis can be applied to any space system to improve agility and stability of the bus and/or its payload(s).

PI: Dr. Mark Karpenko, Research Professor, Mechanical and Aerospace Engineering Department

Student Researcher: UT Kelli M. Sciarilla, Space Systems Engineering (591), Space Systems Academic Group

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SLaM TIME

Satellite LEO and MEO Technical Information Meeting & Exchange
October 07-11 2024 | 0800-1600

Fostering active dialog among industry and Government entities that are looking to employ Non-Geostationary Satellite Orbit (NGSO) constellations for a variety of military and Government applications
The Naval Services need Space-educated requirement developers and technically astute operational practitioners dedicated to Maritime Operations

Naval Officers must be able to affect the Space domain from the Sea
Naval Officers must be able to leverage effects from the Space Domain to the Sea

The Space Systems Academics Group (SSAG) is pleased to present a series of drop-in lectures by guests from diverse offices of practice. This series is a portion of SS3001 dedicated to learning about new and refreshed space systems and what they offer the Warfighter in a classified environment. Registering for SS3001 is not necessary to attend drop-in sessions.

**Drop-In Lecture Schedule • Tuesdays & Thursday 0800–09:50am • SCIF CR2**

- 08 – 11 Jul: 2nd Annual SecNav Naval Space Summit *(see separate notification & schedule)*
- 18 July: Cislunar Competition
- 19 July: History of the National Reconnaissance Office
- 23 July: Electro-Optical Space Systems Part I
- 25 July: Electro-Optical Space Systems Part II
- 30 July: Overhead Persistent Infra-Red Space Systems
- 01 Aug: Overhead Radar Space Systems
- 06 Aug: Low Earth Orbit Signals Intelligence Space Systems
- 08 Aug: Highly Elliptical and Geo Signals Intelligence Space Systems
- 13 Aug: Commercial Electro-Optical Space Systems
- 03 Sep: Proliferated Space Systems
- 05 Sep: Protection & Resiliency of Space Systems

Open to all cleared faculty and students interested in learning more about the space systems competing in the ultimate high ground. The lectures will be at the Top Secret SCI – level with SI/TK caveats. Seating limited in SCIF Classroom 2, first come first serve.

For more information:
Visit the Space Systems Academic Group at nps.edu/web/ssag
Contact Mr. Gary “Grinch” Thomason, Space Systems Academic Group, gary.thomason@nps.edu
Contact SSO for clearance related questions sso@nps.edu
NAVAL POSTGRADUATE SCHOOL SPACE SYSTEMS ACADEMIC GROUP
IN COORDINATION WITH FVEY PARTNERS PRESENTS:

MOLA & OTTER
LAUNCHING: MAR 2024 & OCT 2024

MISSION OBJECTIVE: DEMONSTRATE THROUGH RESEARCH AND DEVELOPMENT OF PATHFINDING AND ON-ORBIT ACTIVITIES, A FVEY FEDERATED SPACE SYSTEM BY 2025 THAT ENHANCES COALITION ADVANTAGES IN AN INCREASINGLY CONTESTED SPACE ENVIRONMENT.

SPECIFICATIONS:
2U CUBESATS USING ASTRO DIGITAL'S CORVUS-6 BUS IN LEO

FVEY PAYLOADS:
KORIMAKO - BEACON PAYLOAD TO MEASURE DOWNLOAD CAPACITY PER GROUND STATION NODE
TUI - RISK REDUCTION EFFORT FOR SPACE-BASED MARITIME DOMAIN AWARENESS CAPABILITIES

NPS PAYLOADS:
TERAHERTZ IMAGER - EXAMINE THE POTENTIAL IMAGING AND DETECTION OF ATMOSPHERIC OXYGEN CONCENTRATION
X-BAND SOFTWARE DEFINED RADIO - ON-ORBIT TEST PLATFORM FOR MC3 GROUND STATION TESTING
LED COMMUNICATIONS - PROTOTYPE DEMONSTRATION CAPABILITY FOR LOW-COST, ENHANCED LP/LPD DATA RELAY SERVICES FOR GLOBAL C2

ON-GOING RESEARCH:
DEVELOP SPACE-BASED CAPABILITIES AND DIRECT TASKING OF SPACE ASSETS WITH FVEY PARTNERS
MULTI-PAYLOAD INTEGRATION AND ENVIRONMENTAL TESTING
END-TO-END GROUND SYSTEM INTEGRATION AND TESTING
MISSION AND ON-ORBIT CONCEPT OF OPERATIONS DEVELOPMENT
ON-ORBIT SPACECRAFT OPERATIONS AND DATA PROCESSING, INCLUDING MACHINE LEARNING APPLICATIONS AND CYBER RESILIENCE

POCs:
Dr. Wenschel Lan, wdlap@nps.edu
Dr. Giovanni Minelli, gminelli@nps.edu