AEROSPACE

OCTO iLAB

UPDATE

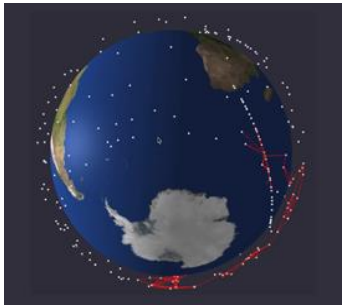
Highlighting efforts to foster our innovation ecosystem

Programs to explore new ideas

Outreach to the space tech sector

Pursuing solutions to hard problems

May 2021



INNOVATION

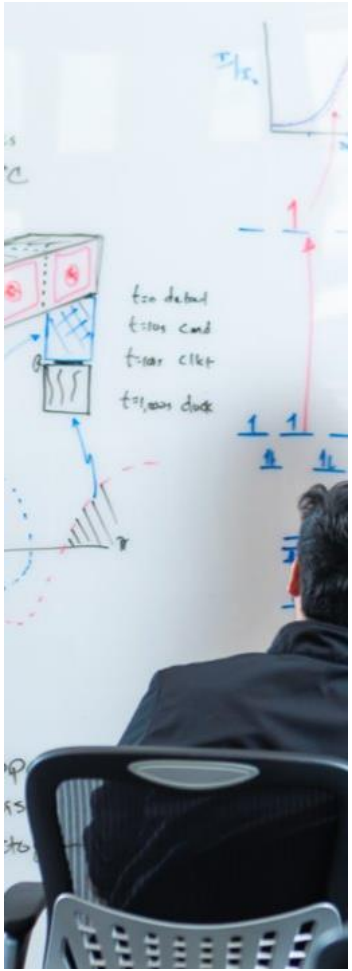
OCTO's iLab fosters the company's innovation ecosystem through programs that inspire staff, development activities to connect with external partners, and investments in technologies, know-how, and innovative solutions to our customer's hardest problems.

This update captures the highlights from iLab activities to help raise awareness among staff and customers on one aspect of how Aerospace is helping our customers innovate for the future.

Sincerely,

Randy Villahermosa
General Manager, iLab

Front Cover and Bottom Image: Prairie digital gaming simulation environment (Tanner Stevens); Upper Image: Tuning the IronSight robotics testbed (Alonzo Lopez); Middle Image: Space Pitch Day



THANK YOU TO ALL THE INNOVATORS THAT MAKE THIS POSSIBLE

The **Annual Update** showcases great examples of innovation happening at Aerospace. The project teams and individuals that turn creative ideas into reality are the real stars of the show who make this all possible.

It is through collaboration, diversity, and their passion to help our customers that drive these innovations and successes. The iLab team cherishes the opportunity to foster an environment of collaboration and diversity that is so essential for innovation to thrive.

Please join us in thanking the Aerospace staff who put in the effort and time to innovate on behalf of our customers.

Sincerely,

The iLab Team

CONTENTS

May 2021

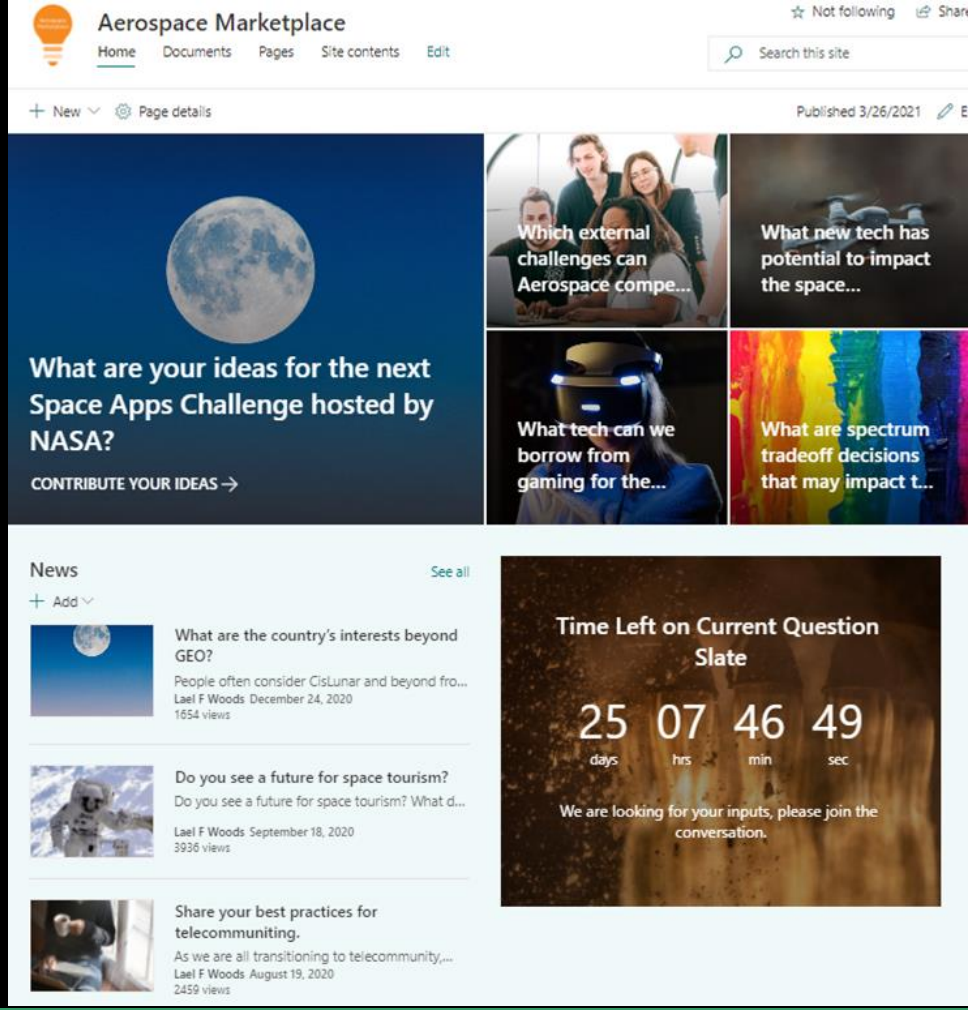
PART ONE

NURTURING AN INNOVATION CULTURE

The Aerospace Corporation's Innovation Lab (iLab) office and Innovation Initiative were started in 2017 to energize the culture of innovation at Aerospace, foster our innovation ecosystem, and accelerate the transition of new technologies and capabilities to our customers. In this section, we highlight programs and processes iLab uses to unleash the creativity of our staff, including the Marketplace platform, the Sabbatical Program, our R&D portfolio structure and funding methodology, and the University Partnership Program.

1.1 Crowdsourcing through Aerospace Marketplace

We established The Aerospace Marketplace to explore crowdsourcing as a means of asking pointed questions and obtaining impactful answers to our customers' hard problems. Crowdsourcing answers to big questions is possible at Aerospace due to the large workforce of talented staff. This process yields diverse ideas and encourages cross-organizational collaboration.



Marketplace Pilot Continues to Build Momentum

The Answers Are Out There

Customers need answers, and they come to Aerospace. Sometimes, the expertise is hidden, or partial, and opportunities can be missed in responding to some of the nation's most pressing issues. iLab explored new ways to connect staff and take advantage of current communication tools to connect anyone, from anywhere, at any time.

If We Build It, They Will Come

iLab created a new communication site designed to promote collaboration and ideation on topics of interest to our customers. The vision is to have staff use Marketplace to post questions. The collaborative tool provides a robust forum to explore interactions and crowdsource information.

Crowdsourcing is a Challenge

Adoption of any new process takes time. Marketplace is the foundation, and it will continue to create a feed-forward approach to engage staff so they regularly return and collaborate on the site.

Progress in 2020

iLab posed 17 questions in 2020 that sparked collaboration across the corporation with over 15,000 hits on the site. We expect staff engagement to continue to grow as content is updated.

CROWDSOURCING SOLUTIONS

How do we take advantage of the in-house expertise that we have, and encourage collaboration on our customer's hardest problems?

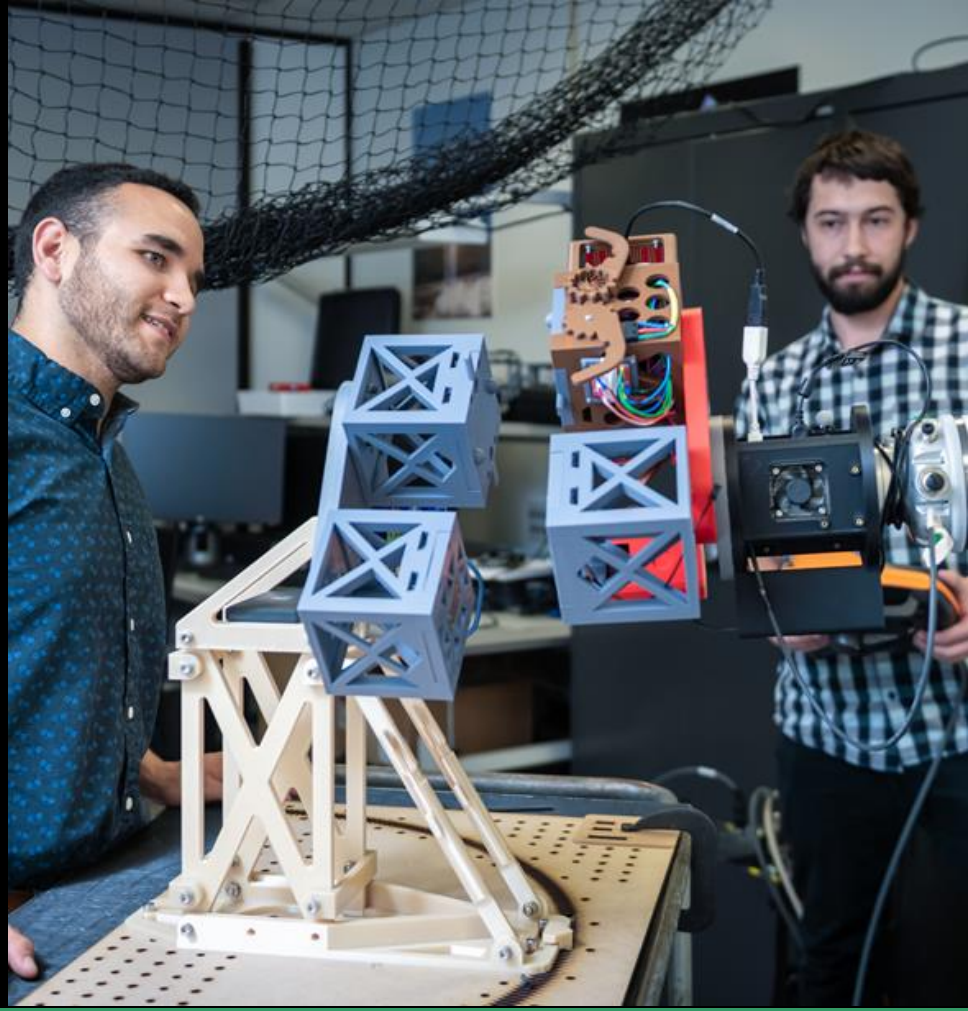
1. Get great prompts from Program Office staff knowledgeable about customer needs
2. Spread the word about the platform
3. Fund great ideas

Aerospace Marketplace
Internal Crowdsourcing

Lead: Dr. Lael Woods (OCTO)

1.2 University Partnership Program

UPP gives Aerospace access to a diverse talent pool and forms collaborative relationships with top universities to help us recruit the best talent. The program does this by funding interactions between our staff and students through sponsored R&D projects, guest lectures, seminars, and capstone classes. With UPP, Aerospace can extend its innovation ecosystem through collaborating with universities and top researchers and help our customers gain access to cutting edge technologies and help universities better align to our customers' needs.



Collaborating with Universities to Create an Innovation and Talent Pipeline

What is the UPP?

UPP is a partnership between iLab and University Relations and Recruiting (UR&R) to increase access to university innovation and top talent, through a combination of technical/research projects coupled with targeting recruiting events. The current program is composed of twelve strategic schools and includes recruiting activities, technical projects, capstone classes, and summer internship opportunities. Schools are scored by an advisory group on a range of factors including diversity, quality, and research strengths.

What Makes It Unique

The partnership between UR&R and iLab has enabled increased coordination between the technical project and recruiting teams.

FY2021 Status

The FY21 portfolio contains over 20 projects at 10 UPP partner schools. The collaborations include both capstone projects and sponsored research in a variety of departments, including engineering, AeroAstro, computer science, and cybersecurity departments.

2020-2021 UPP SCHOOLS

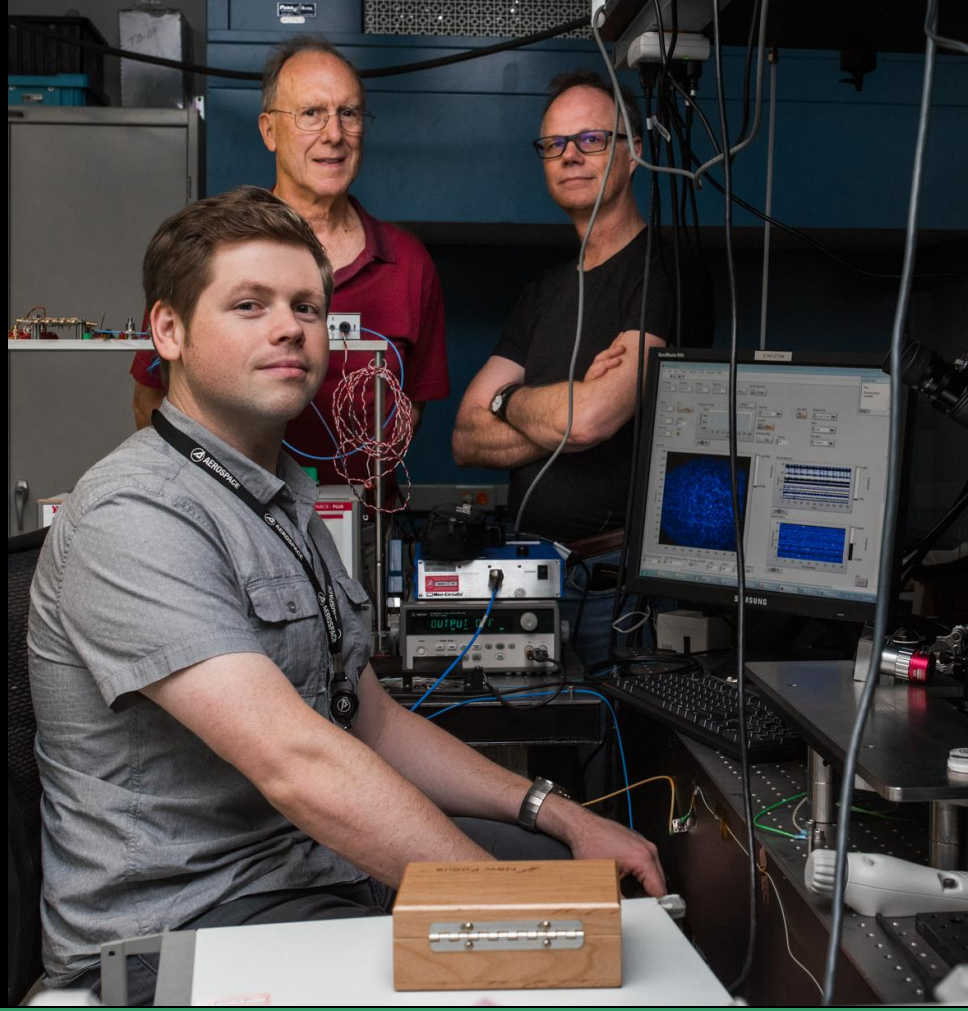
- California State University Long Beach
- University of Colorado Boulder
- Georgia Institute of Technology
- Massachusetts Institute of Technology
- University of California, Los Angeles
- University of Illinois Urbana-Champaign
- University of Southern California
- Virginia Tech
- California Institute of Technology
- Purdue
- Stanford
- U. of Maryland, College Park

University Partnership Program
Innovation and Talent Pipeline

Erica Deionno (iLab)
Angela Couture (UR&R)

1.3 Sabbatical Program: Enabling the Innovator

The Sabbatical Program provides staff with the opportunity to explore their innovative ideas in a flexible environment with minimal investment by the company. In FY20, there were 37 sabbaticals. Several projects successfully adapted their projects in order to continue work through the unique conditions brought upon by the global pandemic.



Exploring New Ideas with iLab Sabbaticals

Why Sabbaticals?

Our customers depend on Aerospace to deliver outstanding technical advice and to be on the forefront of science, technology, and engineering. Often the company must commit large amounts of funding to explore concepts. The Sabbatical Program was designed to allow staff to explore their creative ideas in small steps to prove concepts.

What's New with Sabbaticals?

This year, iLab introduced the Sabbatical 2.0 concept to allow staff increased flexibility in completing their sabbatical work. Rather than focusing 40 hours in a single week on the problem, they now can spend those hours over several weeks to adjust for customer required meetings or other obligations.

How Do You Test New Concepts?

The Sabbatical Program gives staff the opportunity to explore their ideas in a safe space, where they can build prototypes, test feasibility, write code, model, test something new, or develop a concept. The program is designed to enable staff to explore ideas that are relevant to all customers, without having the burden of the cost of development falling on a single customer.

Progress in 2020

In FY20, 37 Sabbaticals projects were completed by teams of varying sizes from groups across the company. Each Sabbatical team maintained a blog documenting their progress and findings. They also held an outbrief for the iLab team and other interested staff members.

SABBATICAL PROGRAM FEEDBACK

"We performed work that was crucial for giving us a good understanding of what we needed to know for future customer advice and work."

"[I] Love the iLab sabbatical program as it gives me time to be creative. No recommendations for improvement- I like it the way it is. Minimal paperwork required with time to complete work…"

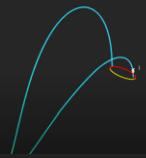
"…the program is brilliant, and allows employees to explore concepts and projects that they are passionate about."

Sabbatical Program
Explore Your Ideas
Leads: Dr. Lael Woods, Mackenzie Puig-Hall (OCTO)

1.4 Ventures Portfolio: Mission-Oriented R&D

The Ventures portfolio experiment with innovative solutions to help our customers solve their hardest problems. The Ventures portfolio helps our customers stay ahead of space threats through innovative ideas and solutions. Projects in this portfolio include prototype customer applications of commercial technology and agile solutions as well as projects that push the boundaries of human space exploration with new mission concepts and prototypes new ways for our customers to be more agile and to harness commercial technologies.

VENTURE LINES

FUTURES	COMPUTE	GALACTIC
		
Emerging Technologies	Edge Computing	Missions Beyond GEO

CAPABILITY

GREENFIELD	PRAIRIE	DYNAMIC	SPOON
			
Proliferated Systems	Interactive Simulations	Robotics & Autonomy	Modularity For Space

AGILITY | ADAPTABILITY

Ventures R&D Portfolio

Solving Hard Problems Through Innovation

Ventures is internally-funded, mission-oriented R&D focused on enhancing agility, adaptability, and the capability to stay ahead of threats and expand the limits of space exploration.

Anticipating the Future

Ventures embraces the adage that success happens when opportunity meets preparation. We anticipate questions and problems customers will bring us in the near-future and work on them now.

Incubating High-Impact Ideas

Hard problems often require paradigm-shifting technologies, mission concepts, or operating models. With Ventures, we create these and incubate them into transition-ready solutions.

Enabling Bold Moves

Ventures' investments support the goals of the corporation to achieve success from bold moves to grow our value and transform our business.

Harnessing Disruption

Disruptive technologies fundamentally shift how value is created and business is performed. With Ventures, we experiment with how to harness these innovations to strengthen the agility of our customers and corporation.

Portfolio Focus

The portfolio is split into seven lines focusing on agility, adaptability, and capability. Each line has one or more technical expert leads, along with a Mission Cell of customer-facing advisors. Every project in each Ventures line starts as a Blitz project.

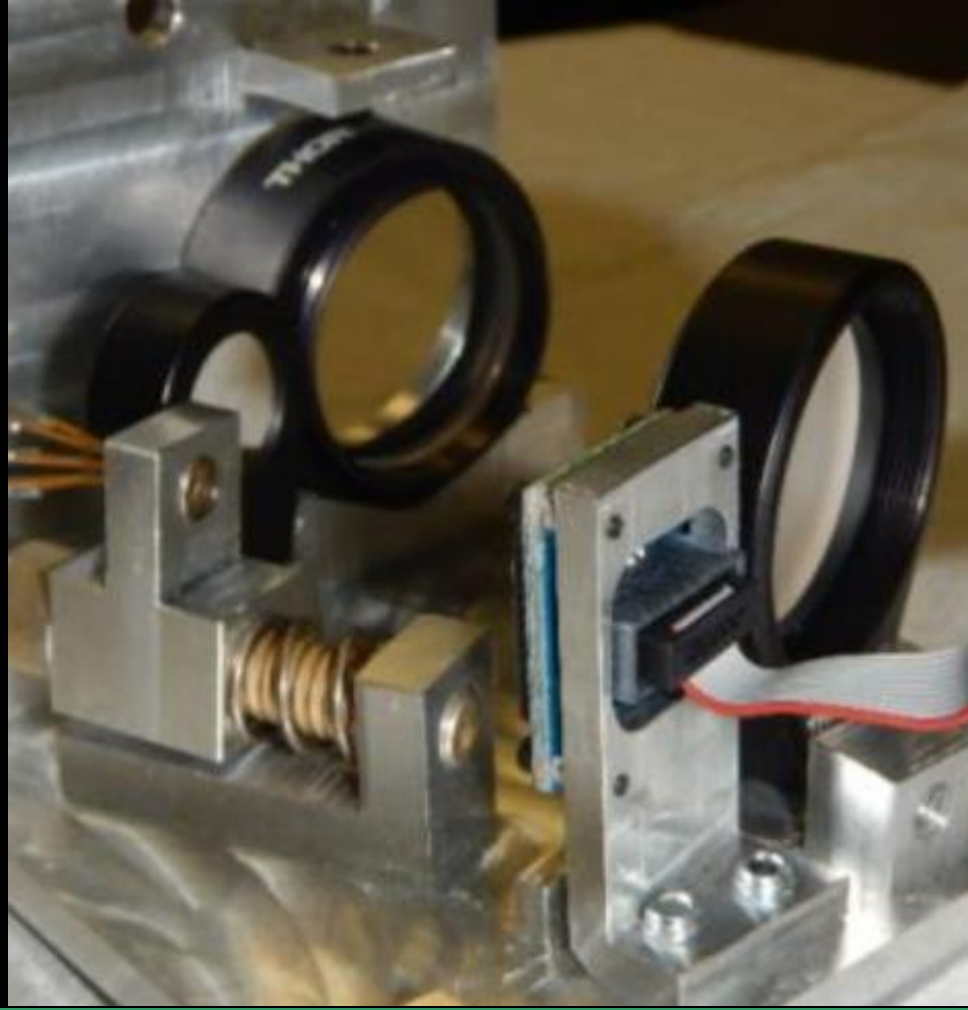
FY21 VENTURES PORTFOLIO:

- 49 new projects in FY21
- 106 FY21 continuing projects
- Emphasis on proliferated systems, gaming for space, robotics & autonomy, modularity, emerging tech, edge computing, and missions beyond GEO
- Team-of-teams approach to portfolio management, with line leads and customer-facing advisors
- All new Ventures projects start as a Blitz

Ventures
Mission-oriented R&D
Leads: Dr. Erica Deionno, Ann Mazuk, Dr. Randy Villahermosa, Dr. Diane Paulson (OCTO)

1.5 Agile Investments with Blitz Funding

Blitzes provide a small amount of seed funding as an entry point into the Ventures portfolio. The initial investment is used to mature an idea to determine viability and applicability to the portfolio. The projects in the portfolio are cross-disciplinary, immune to conventional thinking, and require holistic solutions that deliver a direct and game-changing impact.



Seed Funds for Innovative Research

Investment in Our Customer's Hardest Problems

Venture Line strategies are designed to address the long-term needs of a broad swath of our customers. Proposals that contribute to fulfilling these strategic needs are selected for initial investment through the Blitz program.

Seed Funding

Blitzes provide scientists and engineers funding for higher-risk concepts and allow them to refine their ideas. Traditional funding sources tend to support low-risk projects with an immediate path for transition to customer adoption. Ventures' funding allows for a higher risk tolerance. Even unsuccessful projects are seen as an opportunity to learn and essential for nurturing innovative thought.

Expanding Beyond the Blitz

Upon conclusion of the first three-month sprint, projects are evaluated for further investment in our Incubator program or for follow-on Ventures sprints. These continuing projects will have sufficiently demonstrated that they contribute to an integrated solution for the Venture Lines that address cross-customer needs.

Some of the successful Blitz programs that continued in the Ventures portfolio included further payload development for Slingshot 1, advanced algorithms to support Prairie's wargaming platform, algorithms for robotic autonomy, and AI algorithms designed for onboard processing.

FY21 BLITZ PROGRAM

- Projects funded for 120 hours and given a 3-month sprint for completion
- 49 Blitz projects awarded
- 24 projects selected for follow on funding after the initial Blitz sprint

Ventures Blitz Program
Internal R&D Seed Funding
Leads: Dr. Erica Deionno, Ann Mazuk, Dr. Randy Villahermosa, Dr. Diane Paulson (OCTO)

PART TWO

CUSTOMER INNOVATION SUPPORT

Long before iLab was formed, Aerospace employees addressed customer's hardest problems with innovative solutions. With the creation of iLab and the start of the Innovation Initiative in 2017, Aerospace expanded the intentional exploration of innovative tools and methods to provide rapid, responsive, and adaptable support to customers. This section highlights several efforts to support customers' innovation needs, including work with the USSF, NASA, DHS, and SOCOM.

2.1 Innovation Development in the Space Technology Ecosystem

iLab is boosting the Aerospace brand in the space enterprise by impacting the commercial and DoD space ecosystem in multiple ways, including helping the United States Space Force (USSF) spin-in innovation and collaborating with the Special Operations Command (SOCOM) on agile space. iLab facilitates access to Aerospace's research portfolio and integration of relevant technology. Customers have access to iLab lessons learned during our innovative development processes.

Innovating to Win in a Competitive Space Marketplace

The Threat

Historically, the United States has enjoyed preeminence in space marked by many "firsts". Today, shrinking technology and falling prices means there are 72 nations with space programs, with 14 having space launch capabilities. China, Russia, and India have major space programs with successful Lunar and Mars missions. Foreign governments and companies are focused on winning in today's highly competitive space environment.

The Opportunity

iLab creates new partnerships, transactions, and technology insertions that advance the innovation needs of the national security space enterprise. Effectively leveraging the academic and commercial communities ensures that the United States Government maintains its status as the global leader in space.

Progress in 2020

iLab is executing a multi-year plan to build an ecosystem of start-ups, accelerators, venture capitalists, consortia, universities, and customers that creates a blueprint for sustained discovery, evaluation, and adoption of emerging technologies and services. Through this collaborative ecosystem, Aerospace brings space domain expertise to unique and critical opportunities where technology can solve pressing problems.

Innovating to win

- Increase the volume and quality of emerging commercial space technology for evaluation by the national security space enterprise
- Support planning and transition of Aerospace technology research programs
- Raise the innovation profile and brand of Aerospace in the marketplace

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Innovation Department

Lead: Andre Doumitt (OCTO)

Spinning-in New Technologies with the Space Force

Spinning-in technology requires a disciplined and focused process with just enough chaos and creativity to spark success. Since 2017, iLab programs, including university and commercial partnerships with the University of Southern California, the Massachusetts Institute of Technology, Cross Campus, Starburst Aerospace, and Space Accelerators at Catalyst Campus, have enhanced our support to government customers. Lessons on technology outreach, evaluation, and transition have been captured, shared, and integrated into new United States Space Force (USSF) programs and processes.

The Balancing Act of Spinning-in Technology

Innovation Spin-In
Development Programs

Lead: Andre Doumitt

Creating a system and method for identifying and evaluating emerging technology from internal and external sources for space mission needs

The Dao of Innovation
The balance between chaos and process is the hardest trick of all for an innovation program. Both are key and the risks are great: too much open-loop energy and enthusiasm risks "innovation theater" with spent budgets and low output. Too much process wrings out enthusiasm and creativity, again with disappointing results.

What Makes it Unique
iLab has developed a system and method for identifying and evaluating emerging technology and mapping it to end-user utility in a high-tolerance atmosphere for new ideas. Sharing Aerospace's innovative programs with our customers helps them establish and succeed with their own innovation programs.

Progress to Date
Many of iLab's foundational ideas on program development, funding options, cultural environment, outreach and evaluation, and transition and insertion have been formally adopted by the Space and Missile Center, Air Force Research Laboratory (AFRL) and USSF's new SpaceWERX organization.

Highlights
- Balance of process and creative freedom
- Linked, but not shackled, to end-user and operator needs
- Cultural reinforcement of idea generation and development
- Forethought of end-user/operator's work environment and technology stack

Transition Opportunities
The knowledge base, system and method have been shared and transitioned to USSF's SpaceWERX program office

POC
Andre Doumitt (OCTO)

2.2 Discovering Solutions through Aerospace's Marketplace

In response to a Department of Homeland Security (DHS) research request, the Marketplace provided an opportunity to identify a range of Aerospace experts and forward-leaning ideas on approaches to bring thoughtful solutions to a hard problem facing undersea cable infrastructure owners and operators in our global communications network. The significant amount of feedback and inputs led to a diverse solution set, customer deliverables, and a potential roadmap. Marketplace has successfully and efficiently reached the breadth and depth of Aerospace expertise.

Crowdsourced Answers to a UCI Problem

Undersea Cables Infrastructure (UCI)
Marketplace Solution

Lead: Lori Gordon

Aerospace assessed the risks and plausible technical and policy mitigations to UCI

What are Undersea Cables
Undersea cables comprise the network of physical and cyber infrastructure across land and sea that carries 99% of global telecommunication signals. Until the massive dot-com boom in the early 2000's, satellites hosted the majority of these signals.

What Makes them Unique
Global telecommunications support U.S. critical national functions that underpin human life and government operations. Reducing physical and cyber risk to this network is essential to maintaining our way of life.

Progress to Date
Aerospace delivered a technical report, executive briefing, and policy paper to the Department of Homeland Security in September 2020. In addition, the Center for Space Policy and Strategy (CSPS) policy paper "Undersea Cables Infrastructure: Threats and Opportunities" will be released in 2021.

Key Product Details

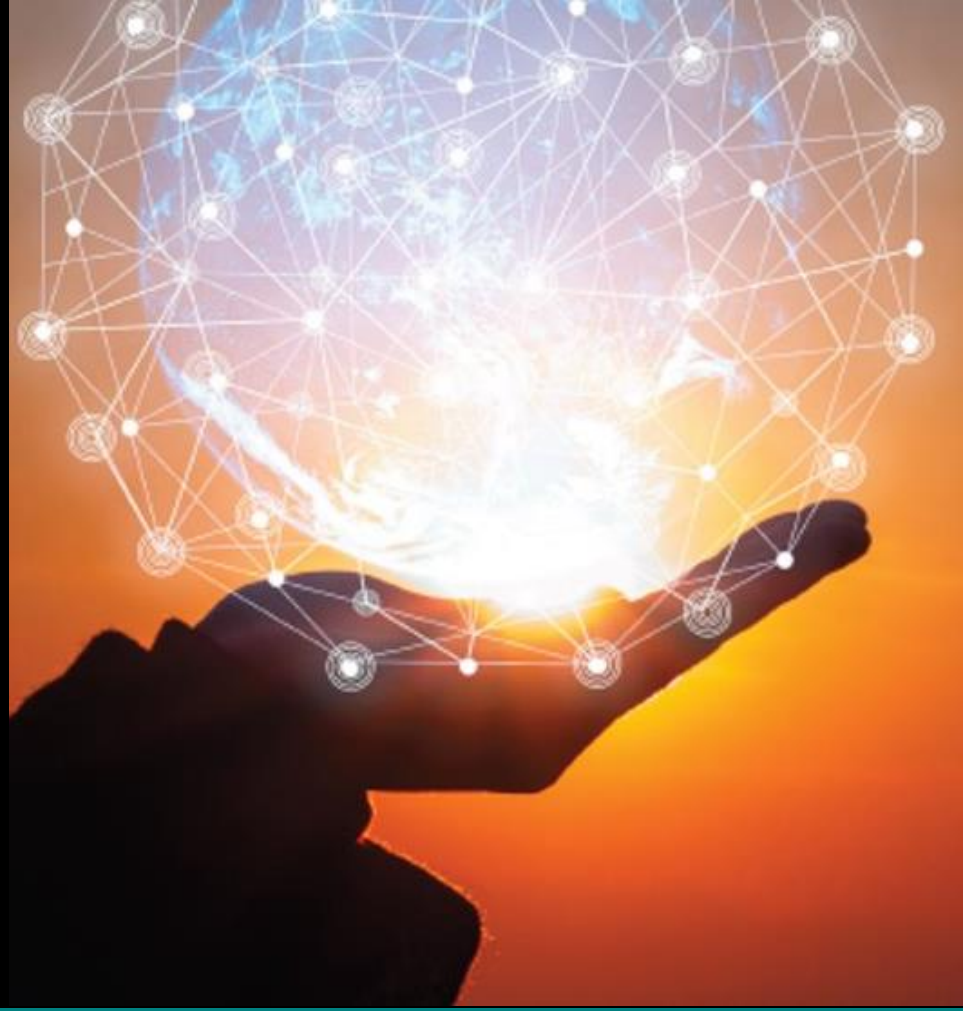
- Provides overview of the undersea cables' infrastructure – history and importance on a global scale
- Provides overview of the risks to UCI from data exfiltration and other threats, and the policy options that could mitigate risk
- Details mitigations to data exfiltration to UCI
- Details satellite-enabled solutions and cost to augment UCI

Maturity
Customer deliverables and publicly-accessible policy paper completed

POCs
Lori Gordon (CSG), Tom Axberg, Dr. Ramin Sadr (ETG)

2.3 Supporting NASA's Innovation Ecosystem

The Seedling Accelerator is a collaborative partnership between the National Aeronautics and Space Administration (NASA) Headquarter's Chief Technologist's Office and The Aerospace Corporation's iLab Office. The Accelerator is based on techniques developed at Aerospace to foster growth of NASA's culture of innovation through challenges and "ideas to value" sessions to promote diverse ideation and collaboration across Centers.



NASA Seedling Accelerator

The Need for Diverse Ideas

NASA looks to diversify their ideation processes and extract value out of those ideas. Traditionally, each NASA Chief Technologist receives a small funding allocation to make individual seedling investments. These have been apportioned in informal ways across Centers. The NASA Lead for Innovation sought to create a new way to explore options to diversify solution spaces and encourage cross-Center collaboration.

Looking to Aerospace

Aerospace had a similar experience in developing such programs. The Aerospace iLab Playbook caught the attention of the NASA Lead for Innovation. An Aerospace team advised in the development of the Seedling Accelerator. In addition to co-creating the program, the Aerospace team has provided technical expertise on individual challenges by pulling in technical experts as consultants to the Center Chief Technologists.

Why This is Hard

Challenging the status quo is never easy and overcoming the desire to keep funding within the Center is complex. Aerospace continues to work with the leadership teams at each Center to create new out-of-the-box opportunities.

2020 Progress

Aerospace hosted the Seedling Accelerator experiment of the Flexible Operations Via Universally Reconfigurable Mobile Interrogation Systems (FOURMIS) Challenge out of Glenn Research Center. During the challenge, Aerospace provided procedural and technical inputs, advised on evaluating hundreds of proposals for COVID response measures at NASA, and met with the NASA Chief Medical Officer.

NAVIGATING DIVERSE IDEAS

- Develop methods to encourage collaboration in an open competition environment
- Enable cross-Center collaboration
- Develop challenges with wide-open solution spaces
- Encourage online collaboration on peer ideas
- Evaluate ideas in work sessions to allow creation of new ideas in real-time

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NASA Seedling Accelerator
Enabling Ideas and Collaboration

Lead: Dr. Lael Woods (OCTO)

2.4 NASA Glenn's Lunar Challenge

To support NASA Glenn Research Center's Lunar Flexible Operations Via Universally Reconfigurable Mobile Interrogation Systems (FOURMIS) Challenge, an Aerospace team was assembled to evaluate proposals received internally by NASA. The Aerospace team used a mind mapping methodology to rank and collect proposals into topics and ultimately describe how these proposals can be formed into larger mission concepts.

Developing Mission Concepts in Creative Ways

Lunar FOURMIS Evaluation
iLab Programs

Lead: Dr. Lael Woods

Space enterprise leadership through agency collaboration

What is Lunar FOURMIS Evaluation
The NASA request for proposals for the Lunar Flexible Operations Via Universally Reconfigurable Mobile Interrogation Systems (FOURMIS) Challenge resulted in a deluge of project and concept submissions. The team at NASA's Glenn Research Center requested the assistance of Aerospace subject matter experts (SMEs) to assist in evaluating and ranking these proposals. Aerospace's team found additional value by employing a mind mapping technique. Proposals were formed into topic groups and ranked based on their merit according to typical metrics (cost, technical readiness level, completeness, etc.). The combination of these ranking and scoring processes illustrated that mission concepts could be formed from these proposals.

What Makes it Unique
Aerospace SMEs demonstrated the potential of evaluating proposals at a system level. Intra-proposal connectivity and synergies, along with linking component ideas to mission concepts fostered effective teaming of ideas.

Progress to Date
Aerospace's methodology and ranking was presented to NASA Glenn's proposal evaluation team.

Key Features

- Forming topics for proposals
- Viewing proposals as mission components to identify synergies
- Mind mapping techniques aid in structuring sprawling sets of creative input
- SME engagement from multiple disciplines aids proposal selection

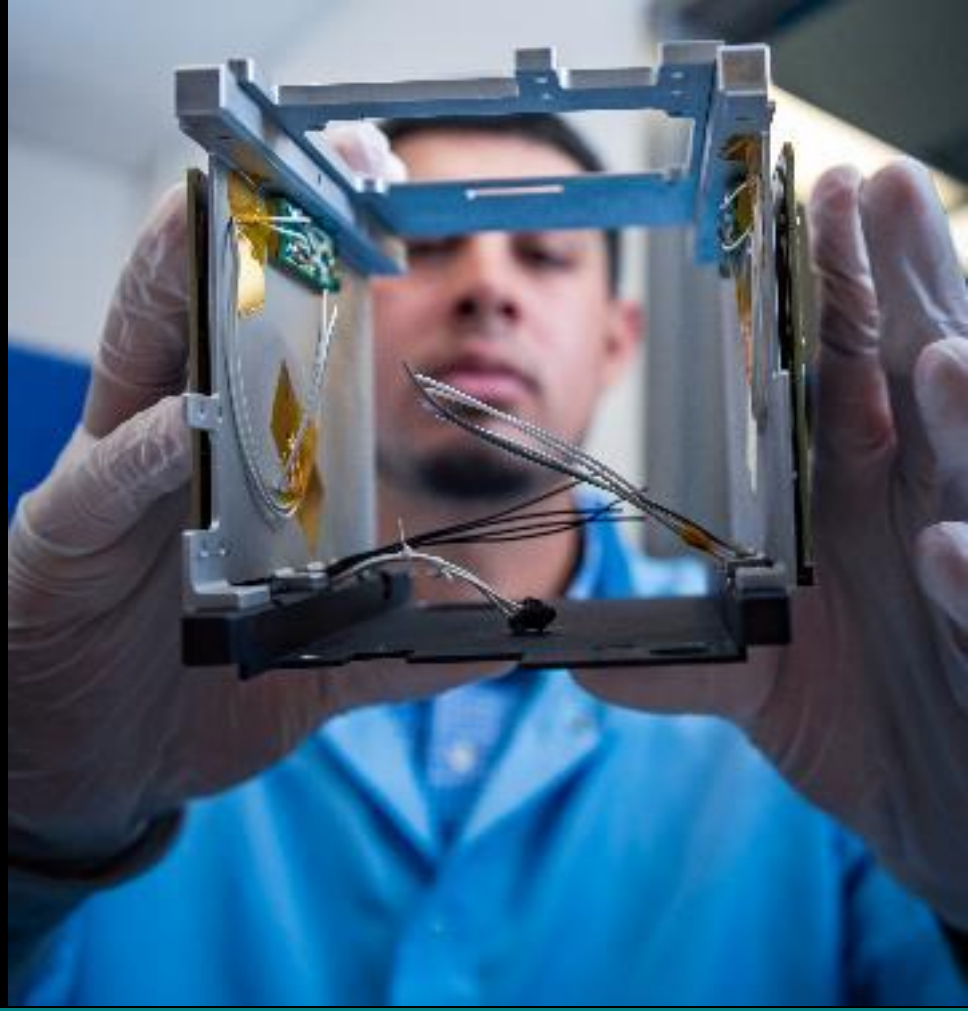
Maturity
The process is currently in use and will be refined according to customer need.

Transition Opportunities
The team is poised to participate in additional proposal evaluation efforts.

POCs
Dr. Lael Woods (OCTO), Ben Bycroft, Dr. Evan Ulrich (ETG), Dr. Henry Helvajian (PSL)

2.5 Collaborating with Special Operations Command

For the past decade, the Special Operations Command (SOCOM) Program Executive Office for Special Reconnaissance, Surveillance, and Exploitation (PEO-SRSE) has been developing and demonstrating space technologies that support operational requirements, including modular intelligence, surveillance, and reconnaissance (ISR) payloads using a standardized satellite bus. This approach allows for a "plug-and-play" integration and enables maximum mission flexibility. Aerospace has been collaborating with SOCOM since July 2020 and executed the first CRADA in March 2021.



Accelerating Insights from ISR

Program Transitions
iLab Development Programs

Lead: Andre Doumitt

Testing Aerospace-developed hardware and software in the mission context of SOCOM Special Operations Forces

SOCOM Intelligence, Surveillance and Reconnaissance (ISR) Goal

The mission of the Special Reconnaissance group at SOCOM is to lead the rapid and focused acquisition of state-of-the-art sensors and associated C2, emplacement, recovery, and specialized communication systems across all domains to enable total situational awareness for the special operations force (SOF) warfighter.

How it Works

SOF warfighters operate in near-peer and non-permissive environments. Working with low-signature, remote and unattended sensors requires integrated and cooperative special reconnaissance and alternate position, navigation and timing (PNT) during missions, including counter-terrorism and countering violent and extremist organizations. SOF warfighters require air, sea, ground and space sensors to coordinate and integrate for mission success.

Progress to Date

Aerospace signed a CRADA agreement with SOCOM and a software license agreement with a SOCOM supplier for a program to flight test Slingshot technology on a research mission in 2022.

Key SOCOM Priorities

- Interoperability using modular payload compliant and software defined interfaces
- Information assurance and risk management
- Frequency-agile sensors
- Cyber-enabling capabilities

Areas of Collaboration

SOCOM is developing modular ISR payloads and is collaborating with Aerospace on Slingshot-Handle

Transition Opportunities

Licensing to commercial companies and adoption by customers for payload interfaces

POCs

Andre Doumitt (OCTO), Madison Piechowski, Alex Utter (ETG), Hannah Weiher, Dan Mabry (OCTO)

PART THREE

CREATING OPPORTUNITIES FOR STAFF

The iLab office serves Aerospace by creating and incubating pilot programs to address the needs of the company. Programs are typically collaborative efforts with stakeholders across the corporation. In this section, the responses to the unique challenges facing the workforce during the COVID-19 pandemic are highlighted, including the SARP program for full-time staff and the iSARP program for summer interns. In addition, the Innovator in Residence Program, that identifies internal early career talent and provides growth and leadership opportunities, is introduced.

3.1 Advancing Research in the Era of a Pandemic

When COVID-19 caused facility closures, the company responded by establishing the Studies, Analysis, and Research Projects (SARP) Telework Program. This program enabled staff members to pursue customer-relevant research from home.

Wide-Ranging Studies Enhance Aerospace Capabilities

Sustaining and Developing our Workforce

During the COVID-19 pandemic, Aerospace made a commitment to keep staff actively engaged by allowing them to learn new skillsets, explore and demonstrate new capabilities, and apply innovative ideas to future customer needs.

Projects Relevant Right Now

A range of topics included those that pertain to current customer focus areas and short-term needs. For example, One project explored the use of Blockchain methods for assured supply chains in the Department of Defense. Additionally, a white paper was written for a mobile weather monitoring system, Range in a Box. Range in a Box could decrease the frequency of scrubbed launches due to uncertain weather conditions resulting in increased launch capacity.

Projects Addressing Future Needs

Several projects explored topics relevant to missions beyond the GEO Belt. One team investigated the potential of utilizing a feedback control law to compute low thrust transfers in the cislunar domain. This would be critical to conducting a cargo geosynchronous transfer orbit to a Lunar Gateway mission. Another team explored the requirements and workflows for automated data anomaly resolution of vehicle systems that would be required for Earth-Mars missions.

PROGRAM HIGHLIGHTS

- In calendar year 2020, 108 staff participated in the program
- Over 50 projects completed
- Each project submitted a white paper, ATM, briefing package or proposal
- 58 posted opportunities available for staff
- Cross-corporate coordination for developing opportunities, managing the program, and deconflicting with other corporate initiatives such as the Work Exchange

SARP

Leads: Dr. Diane Paulson, Dr. Erica Deionno, Ann Mazuk (OCTO)

3.2 Innovator in Residence Program: Unleashing Innovative Spirits

Innovator in Residence is an iLab Venture Pilot Program aimed at identifying top talent internally and providing new opportunities to early career staff. Members are selected based on their existing Venture projects and potential to benefit long-term from the opportunity. Participants receive hands-on experience with incubating ideas from inception to transition.

Incubating Ideas for the Projects of Tomorrow

Dedicated Project Time

The Innovator in Residence Program participants receive the funding necessary to turn their ideas into reality. Also referred to as the 50/50 program, innovators are funded for 20 hours a week to pursue their Ventures project.

iLab's Unique Innovation Process

Members of the Innovator in Residence program work as a team to build planning, marketing, and transition development for their project that aligns with iLab's innovation techniques.

Career Growth Through Innovation

Through this program, participants receive project management and strategy development skills they may not typically receive early in their careers. They grow this skillset while maintaining their technical work through funded projects.

Progress in 2020

This year's Innovators in Residence are Alonzo Lopez (Ironsight), Dr. Andrew Abraham (Blinker), Hannah Weiher (Spoon Vertigo), Madison Piechowski (HyPer), and Dr. Todd Sheerin (ExoRomper). The team is finalizing their projects for flight on iLab's first Slingshot launch.

The Innovator program also aided participants in enhancing their technical writing skills by attending a workshop and one-on-one writing sessions. At the workshop, they developed marketing material for the next phase of their projects.

INNOVATOR PROGRAM SPECIFICS:

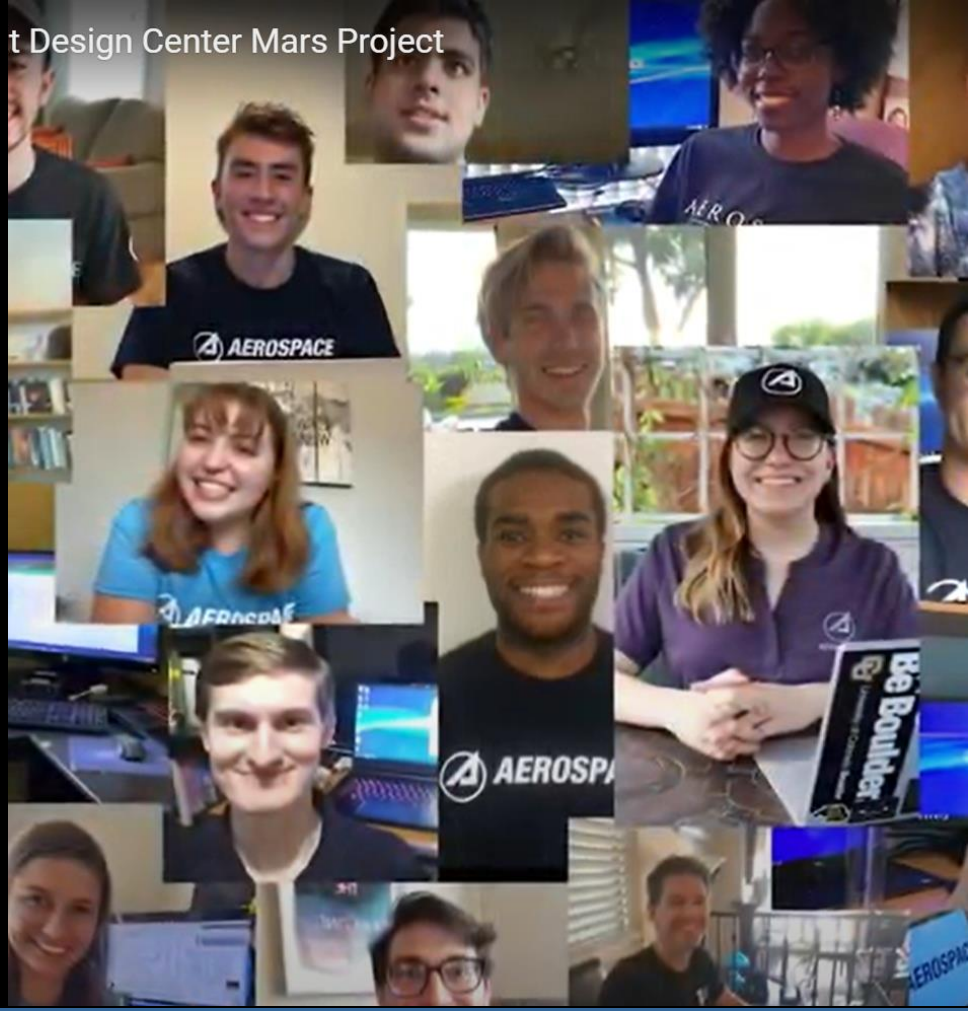
- Monthly meetings ensure collaboration within the team
- Creation of project marketing material for project transition
- Participate in iLab-hosted workshops
- New Innovators in Residence are selected annually

Innovator in Residence Pilot Program

Lead: Dr. Erica Deionno (OCTO)

3.3 iSARP Program: Virtual Experiences for Summer Interns

The iSARP Intern Program was developed for interns who were displaced from their on-site work due to the pandemic. Several Aerospace mentors were assigned to develop projects that interns could perform remotely. These projects ranged from space policy concepts and satellite designs to other mission-specific innovations.



Meaningful Intern Experiences in a Remote-Working Environment

Successful Remote Program

In response to the pandemic in 2020, Aerospace converted its summer intern program to 100% virtual. Aerospace did an exceptional job transitioning interns to this new "work at home" ecosystem, providing interns with necessary access and IT setups. Several interns were displaced from customer-funded programs in this transition, resulting in the need for a new program. iSARP was established to fulfill this need. For these interns, iLab worked with People Ops and technical staff to develop meaningful, telework-friendly projects.

Intern Teams

The iSARP program consisted of several projects that had a supporting intern team, ranging from groups of 2-20 interns. One team combined their mechanical, electrical, and aerospace experience to assist with a conceptual design of a 12U modular CubeSat, with results presented to Aerospace technical experts across the company. A second team of interns focused on designing a first-of-its-kind mission to collect samples from a transiting interstellar object. This team performed concurrent engineering design for the mission with an all-virtual Concept Design Center (CDC) study.

Aerospace Mentorship

For each iSARP intern project, several Aerospace technical staff mentored and provided feedback to interns daily. Other technical experts from Aerospace were consulted throughout the internship program. This mentorship and consultation was critical to the program's success, and it provided each intern with a unique experience remotely.

ACHIEVING VELOCITY IN UNCERTAIN TIMES

- iSARP interns completed a CDC study and 4 projects
- CDC study took place over 3 weeks and the 4 other iSARP projects each lasted 8-10 weeks
- Projects were telework-friendly and did not require any travel
- Interns were still able to work closely with Aerospace mentors and technical experts

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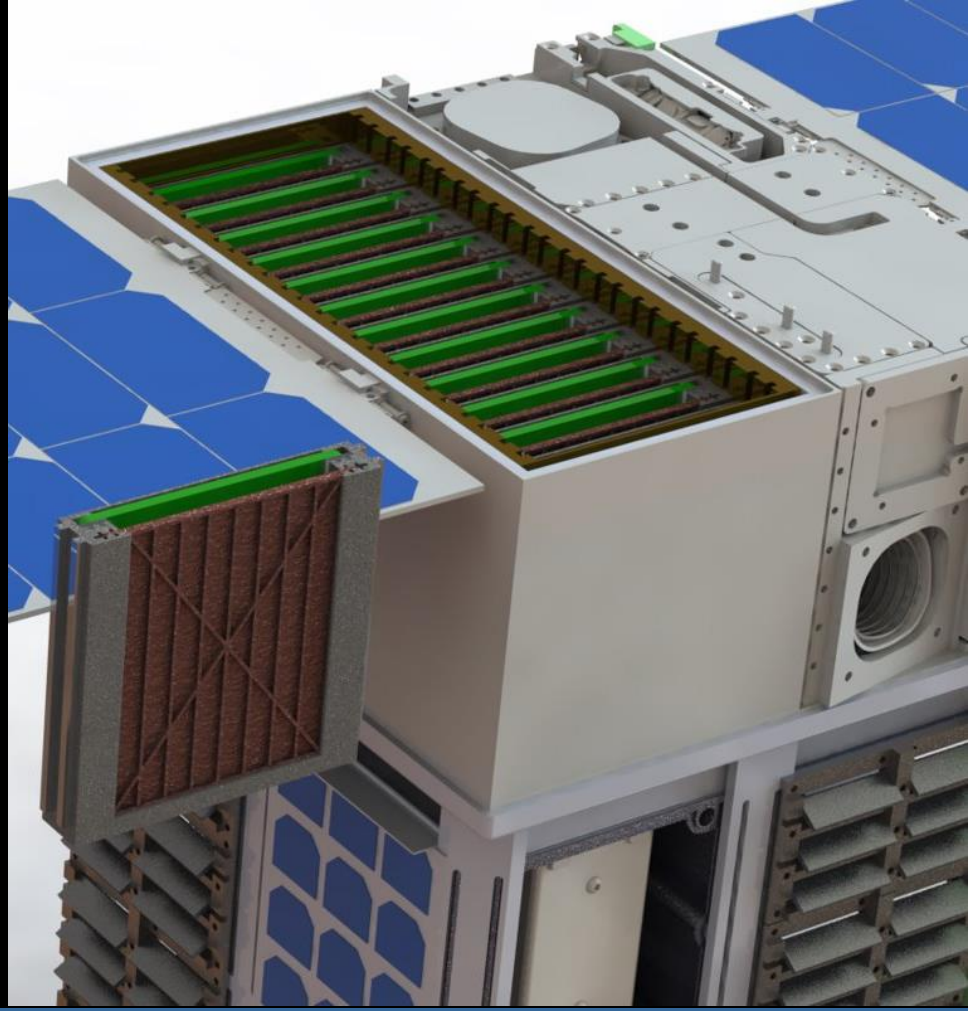
iLab Team
iSARP Leadership Team

Leads: Dr. Randy Villahermosa, Dr. Erica Deionno, Mackenzie Puig-Hall (OCTO), Chris Hartney, Dr. Todd Sheerin (ETG)

3.4 Innovating Future Designs with CubeSats

Research efforts at Aerospace have been focused on satellite modularity, including Slingshot and other modularity efforts in the iLab Ventures' portfolio. For this iSARP project, interns were asked both to develop a 12U CubeSat using Slingshot 1 as an example and to investigate increased modularity concepts via mechanical and electrical technologies. Next generation payloads were also considered in this design.



CubeSat Modularity in the Hands of Interns

CubeSat Modularity
Ventures Project

Leads: Chris Hartney, Madison Piechowski, Marcus Bailey

Investigating CubeSat modularity mechanically and electrically, while also designing state-of-the-art CubeSat payloads

What is CubeSat Modularity
Traditionally, CubeSats have been built and designed to a specific form factor (1U, 3U, etc.). Being able to rapidly configure these satellites from 1U to 3U is not possible. This project explores options of making distinct form factors to combine to make a larger CubeSat. A 6U can be configured to be one 3U and three 1Us, for example.

What Makes it Unique
Building on the success of Project Slingshot, a group of interns did a deep-dive into other modular concepts for CubeSats. They developed a "brain and spine" concept, where there is an electromechanical backplane that runs down the center of the 12U CubeSat frame. This allows easy modular access to the "brain", which will store the electronics and bus/avionics for the spacecraft.

Progress to Date
Several of the modular ideas from this study are continuing to be investigated for Slingshot 2.

Key Features

- Plug-and-play design concept for CubeSats
- iLab and Engineering Applications Department partnership expanded to assist interns to achieve excellent internship experience while working remotely

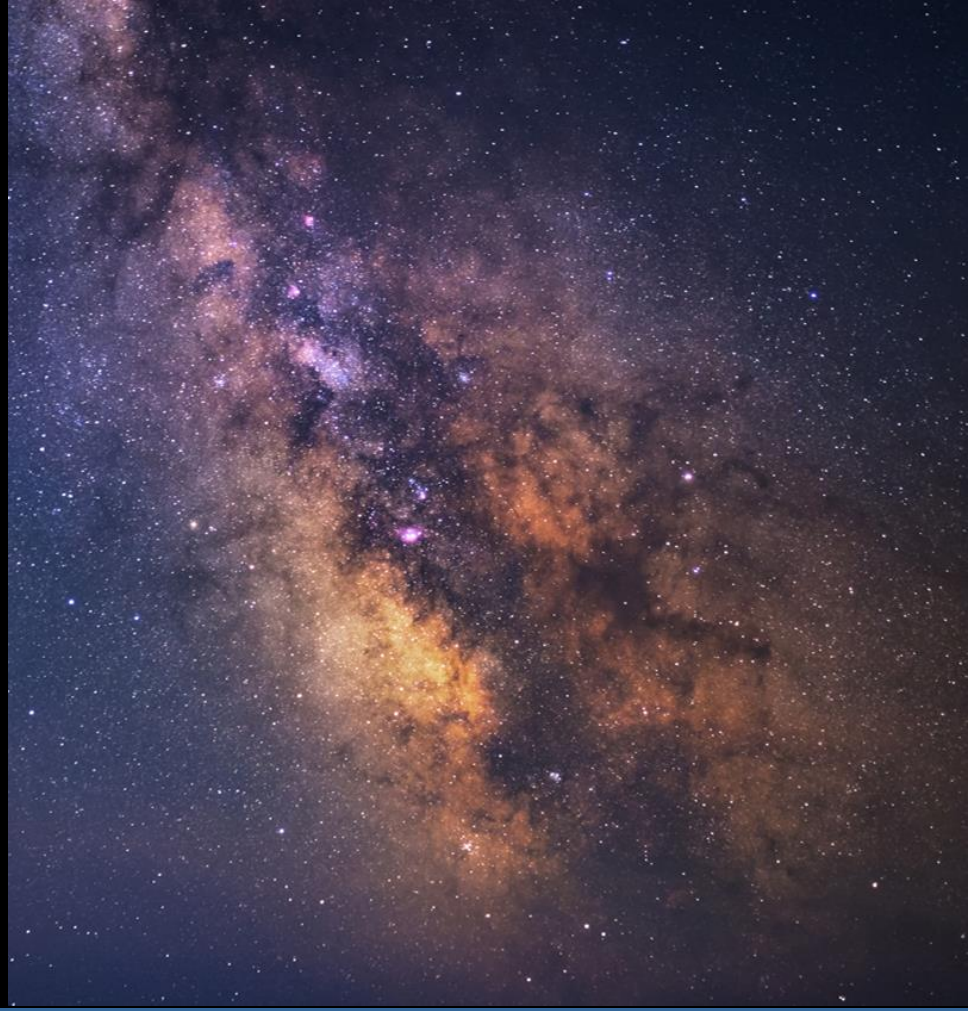
Maturity
Intern research project, with potential connection to future Slingshot projects

Transition Opportunities
Potential use on Slingshot 2

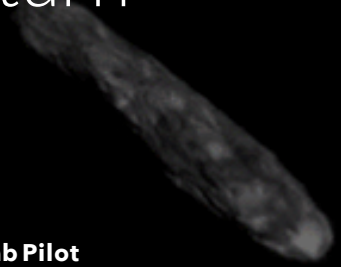
POCs
Christopher Hartney, Madison Piechowski (ETG), Marcus Bailey (CSG)

3.5 Concept Design Center Pilot: Interstellar Object Sample Return

The Concept Design Center (CDC) is a concurrent engineering capability used to rapidly create concept designs for complex systems. During the summer of 2020, iLab tested a pilot program inspired by the successful intern CDC program in the Architecture and Design Subdivision. The iLab study focused on an ambitious interstellar object sample return mission.



Interstellar Object Sample Return



CDC iLab Pilot
iSARP

Lead: Dr. Todd Sheerin

Piloting an iLab version of the successful CDC intern studies in ADS/ETG for transformative mission concept development – interns were asked: can you bring home samples of an interstellar object?

What is the CDC iLab Pilot

The Concept Design Center (CDC) is a concurrent engineering facility at Aerospace. In the summer of 2020, iLab fielded a project with 17 undergraduate and graduate interns from across the Corporation, where they led design investigations for a first-of-its-kind interstellar object sample return mission, producing baseline mission and vehicle designs.

What Makes it Unique

This was the first iLab CDC study designed for interns (and one of the only all-virtual CDCs), building off of ETG's existing summer program. The iLab version was designed with an accelerated schedule (three weeks as opposed to six to eight) and ambitious goals.

Progress to Date

Results from the CDC iLab Pilot directly supported a NASA Innovative Advanced Concepts Phase 1 grant proposal by Aerospace engineers and industry partners at Xplore. It built off the on-going Solar Gravity Lens NIAC Phase III study at Aerospace. Results from the 2020 summer study will continue to inform future science and planetary defense objectives relying on similar architectures.

Key Features

- Concurrent engineering capability at Aerospace
- Developed from ADS/ETG intern program
- 17 interns, 13 Aerospace SMEs, and one commercial space SME
- Dual-spacecraft mission was investigated to enable sample return and persistent observations

Transition Opportunities

The CDC iLab Pilot was successful and will be repeated during the summer of 2021.

POCs

Dr. Todd Sheerin, Rob Stevens, Dr. Nahum Melamed,
Dr. John McVey (ETG)

PART FOUR

R&D SPOTLIGHTS

The iLab R&D portfolio includes the Sabbatical, Incubator, Jumpstart, and Ventures Programs. The duration of projects last from one-week to multi-year efforts. iLab R&D serves multiple needs of the corporation – both directly supporting customer needs and preparing staff to provide expertise to future customer needs. Included in this section are projects that range from using drones to understand the dynamics of satellite swarms to exploring the potential of a space-based internet.

AEROSPACE PROPRIETARY | UNCLASSIFIED

4.1 Emulating Satellite Motion in the Lab Using Drones

GuiltySpark Swarm is a testbed that uses drones to simulate satellite motion with a full six degrees of freedom (6DoF) for emulating CubeSat dynamics in the laboratory. During an FY20 GuiltySpark sabbatical, an omnidirectional drone was designed for use in rendezvous and proximity operations (RPO) and autonomy demonstrations. Following that effort, GuiltySpark Swarm produced a fully realized prototype of that concept vehicle. The GuiltySpark drone is a 6DoF platform for CubeSat dynamics emulation.

Using Drones to Simulate Satellites

GuiltySpark Swarm
iLab Sabbatical

Lead: Ryan S. Williams

The prototype of the 6DoF GuiltySpark drone provides the path for future testing of RPO missions using CubeSat vehicle-level dynamics.

What is GuiltySpark Swarm?

The GuiltySpark Swarm sabbatical is an effort to build and integrate hardware for the omnidirectional drone that was designed in a previous FY20 Sabbatical. It fits into a larger effort for GuiltySpark Missions, which is building to demonstrate RPO and space autonomy capabilities of hardware and software in an emulated space environment.

What Makes it Unique

Testing of satellite swarm and RPO missions on the ground in a low-cost, scalable, and realistic way is a capability that does not currently exist. The GuiltySpark drone fulfills that need by providing a 6DoF platform capable of emulating flight-like satellite vehicle dynamics in a space environment. Accuracy of both satellite dynamics, vehicle- and swarm-control algorithms can be realized in hardware and validated via the Swerve environment.

Progress to Date

The first iteration of the GuiltySpark prototype is complete with functioning motors. Flight software development was the next step for first flight, which is continuing through GuiltySpark Missions. The first flight (with help from a test stand) occurred in early March in the lab. Tests are ongoing to improve and ready the system for independent flight.

Key Features

- 6DoF stable control (unlike a traditional quadcopter)
- Cost is less than $1K using commercial-off-the-shelf (COTS) components
- Skewed-axis design allows for decoupling of translational and rotation motion
- Scalable to build a swarm of drones to fit mission-specific needs

Maturity

First prototype is built and is currently undergoing lab tests.

Transition Opportunities

Members of the GuiltySpark team are in coordination with CSG, and have spoken with external customers

POCs

Ryan S Williams (ETG), Erin Hong (ETG)

4.2 Artificial Intelligence-Aided Disaster Relief

Aerospace engineers test an unmanned aircraft system (UAS) with an embedded artificial intelligence (AI) payload to autonomously detect and geo-tag both humans and animals. Such a capability could aid search and rescue in disaster scenarios and save lives.

Improving Disaster Operations with AI

AI for Disaster Relief
iLab Sabbatical

Lead: Alison Kremer

Prototype AI-enabled drone to detect and geo-tag humans and their pets in a disaster scenario

What is AI for Disaster Relief

With climate change increasingly driving natural disasters, AI-enabled drones have the potential to penetrate difficult to reach disaster zones and tip-off rescue personnel. A real-time object detection model trained to identify people and dogs was embedded on a Jetson Nano integrated with a Raspberry Pi Camera V2 and GPS. This payload was hosted on an unmanned aerial system (UAS).

What Makes it Unique

The rapid, innovative commercial-off-the-shelf (COTS) hardware and software development and integration was a prime example of collaboration across multiple Aerospace departments with critical support from iLab, EHS, and Security.

Progress to Date

The team completed a successful proof-of-concept demonstration by flying the Tarot 680 hexacopter on the El Segundo campus at 50 ft altitude in windy conditions. The object detection model (which the team trained on videos from the internet) successfully detected human and canine volunteers with reasonable accuracy as a proof-of-concept. The team has plans for future iterations that will significantly improve performance.

Key Features

- Hexacopter UAS
- Jetson Nano Payload
- GPS with u-blox chip
- YOLOv3 Object Detection

Maturity

Early proof-of-concept flight demonstration

Transition Opportunities

Working with agencies to overcome UAS regulatory hurdles; industry and customer partnerships

POCs

Alison Kremer (ETG), Andrew Brethorst, David Cape, Michael Hale, Jeffrey Lang (ETG)

4.3 Reconstructing the Dynamics of Space on Earth

The Dynamic Venture Line teams are constructing an ecosystem that enables rapid development and testing of technology for multi-vehicle Rendezvous and Proximity Operations (RPO). Ironsight is a platform within that ecosystem that leverages robotic manipulators to reconstruct the dynamics of space in an Earth lab. Ironsight enables users to safely and quickly iterate on software and hardware intended for orbit.

Rendezvous and Proximity Operations in the Lab

Ironsight
Ventures Project

Lead: Alonzo Lopez

Building a lab test bed using highly dexterous robotic manipulators to test autonomous satellite software and hardware

What is Ironsight
Ironsight is a lab-testing capability leveraging two highly dexterous robotic manipulators. The manipulators recreate the six degrees of freedom (6DoF) dynamics of space, giving engineers the ability to rapidly develop and test RPO hardware and software.

What Makes it Unique
Ironsight's multiple mobile manipulators provide precise control of payloads, easy mechanical mounting, data transfer over Ethernet, and synchronized data capture across the robots. The accompanying simulation environment allows for safe testing before taking tests to the lab. This platform is complementary to other robotic platforms in Dynamic's ecosystem.

Progress to Date
A basic docking operation, with sensing and motion planning algorithms running onboard an autonomous payload has demonstrated Ironsight's underlying capabilities as a lab test bed for RPO technologies. In FY21, Ironsight will integrate with other robotics platforms and simulation environments in the Collaborative and Autonomous Vehicles Environment to test a wider variety of multi-vehicle scenarios.

Key Features

- Two mobile seven-jointed manipulators with real-time communications from tool to computer
- Supports integrated testing of sensing and guidance, navigation and control (GNC) algorithms
- Precisely position payloads weighing up to 8.8 lbs with a 0.9m reach

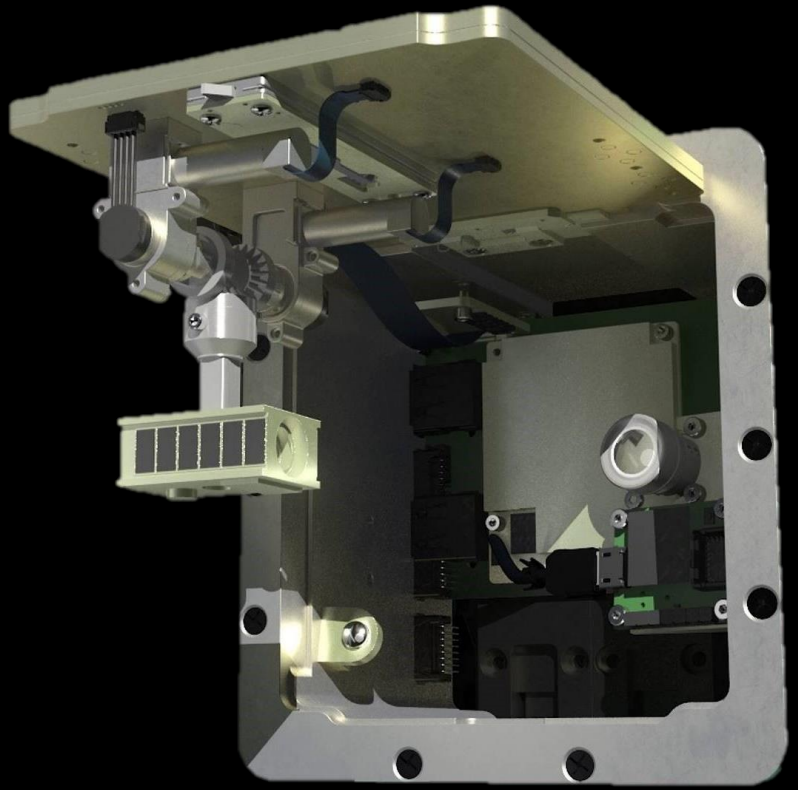
Maturity
Lab-based platform ready to facilitate integrated testing of software and hardware for autonomous SmallSats

Transition Opportunities
Leverage Ironsight for collaborative iteration in technical development cycles or for independent V&V of customer solutions

POC
Alonzo Lopez (ETG)

4.4 Ground-to-Orbit Artificial Intelligence Training for Satellite Vision

ExoRomper, a payload flying on Slingshot 1, is a safe, low-cost platform for high-tempo machine vision algorithm development enabled with reprogrammable ground and space assets. Artificial intelligence (AI) algorithms for satellite vision in variable lighting conditions will be developed using two methods: (1) ground-based training with synthetic data and (2) laboratory experiments informed and validated by on-orbit operations. These objectives are enabled by a commercial-off-the-shelf, ultra-low size, weight, power, and cost AI processor hosted by a sister payload, Coralreef.



Establishing An AI Training Ground

ExoRomper
Ventures Project

Lead: Dr. Todd Sheerin

ExoRomper is a reprogrammable machine vision experiment designed for rapid AI algorithm DevOps. Identical ground and space assets provide a flexible, responsive platform to explore AI vision training methods for autonomous RPO.

What is ExoRomper
Artificial Intelligence (AI) training requires huge volumes of data, making AI for space particularly challenging given downlink constraints. ExoRomper will enable rapid exploration of machine vision AI training methods to maximize use of limited on-orbit data. ExoRomper's primary focus is developing AI algorithms that calculate relative distance and orientation of satellites in variable lighting conditions.

What Makes it Unique
ExoRomper will pioneer a new process for coupling ground efforts to on-orbit AI machine vision DevOps. ExoRomper relies on the commercial-off-the-shelf (COTS), low size, weight, power, and cost (SWaP-C) Google Coral AI processor of a sister payload, Coralreef. It has one of the smallest SWaP-C of any AI processor flown to-date. Parallel ground and on-orbit testing will enable safe, flexible algorithm development to accelerate the transfer of new AI vision capabilities to space.

Progress to Date
ExoRomper has been delivered for Slingshot 1 integration and lab investigations with the ground unit are underway.

Key Features

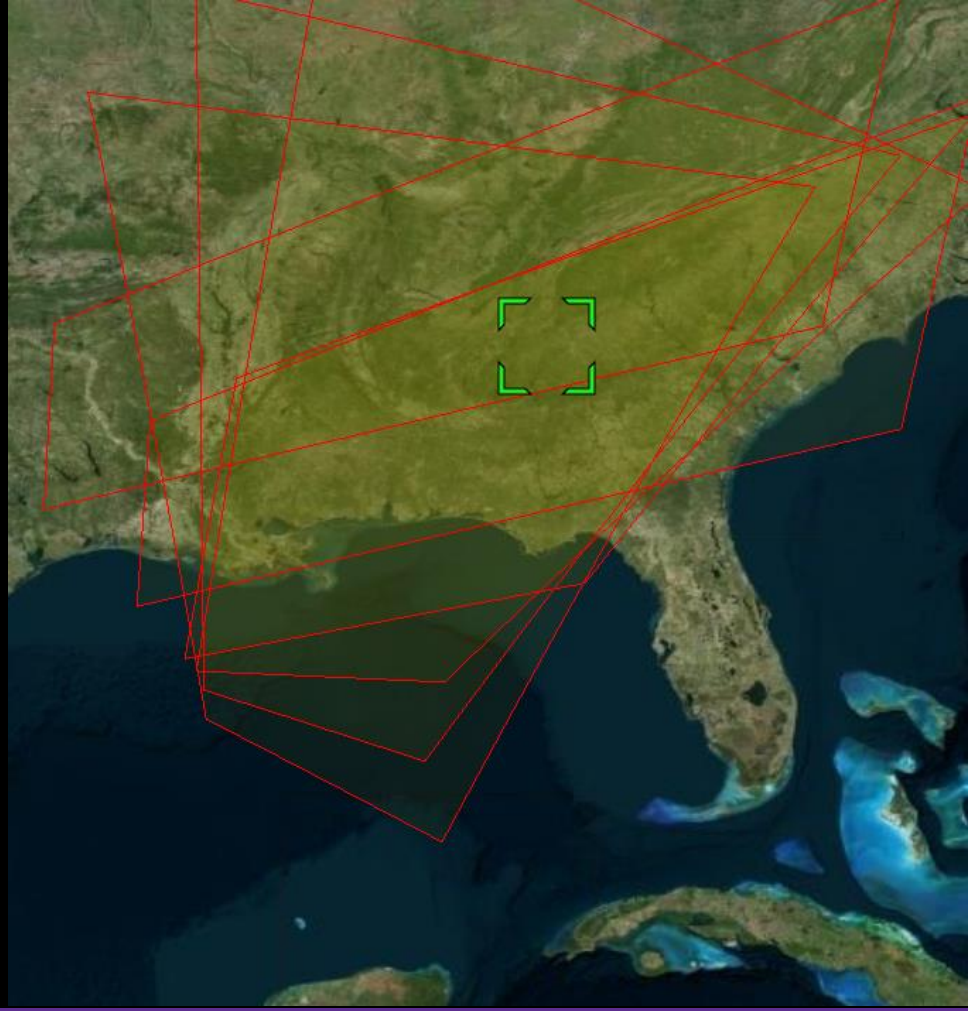
- Safe, low-cost platform for high-tempo machine vision algorithm DevOps enabled with reprogrammable assets
- Enhancing AI training methods for space machine vision in variable lighting conditions
- On-orbit operations will inform and validate AI training and laboratory experiments
- Applications for rendezvous, proximity, docking, and undocking ops
- An ultra-low SWaP-C platform, featuring a COTS AI processor

Transition Opportunities
Internal user base can be extended to USG, industry, and research institutions

POCs
Dr. Todd Sheerin (ETG), Adam Vore (xLab), Andrew Keene, Jerry Fuller (ETG)

4.5 Empowering Data Analysts with the Tactical Browser

The Tactical Browser seeks to create an intuitive and visually intriguing web application which allows investigation and access of all Aerospace satellite imagery data and products to data analysts and general data users. The application is being upgraded for larger input data streams and supports the Prairie Constant Operating Picture (COPs) Venture line.



Accessible CubeSat Imagery

Geoportal For Large CubeSat Datasets, Tactical Browser, R3 Georegistration
Studies, Analysis and Research Projects (SARP) Program

Lead: Kevin Mercy

Providing a consistent and responsive web application that permits high-level query, exploration, and dissemination of Aerospace CubeSat imagery products.

What is R3 Georegistration, Tactical Browser, and Geoportal For Large CubeSat Datasets

Aerospace CubeSat imagery products are created through a semi-automated processing pipeline developed under the R3 Georegistration Ventures project. Imagery products from the pipeline are directly ingestible into the Tactical Browser, which is the user interface of the geospatial imagery portal. Work under the Geoportal for Large Cube Satellite Datasets SARP program has enabled changes within the pipeline and browser to equip both systems for larger and more diverse datasets.

What Makes it Unique

The processing pipeline and browser are specifically geared for Aerospace CubeSat products. It now supports multiple Aerospace payload datasets. The Tactical Browser interface has been developed and geared towards the data analyst, providing specific and routine tactical queries within the user interface.

Progress to Date

Several iterations of user testing have been performed. The application and all input data streams are available to all Aerospace staff.

Key Features

- Semi-automated processing of CubeSat imagery products
- Interactive geospatial imagery portal for CubeSat products
- Support for Aerospace data streams from CUMULOS, R3, NIRAC, and AC-15 A/B payloads

Maturity

Several rounds of beta user testing from an Aerospace demonstration website

Transition Opportunities

The web application is accessible from an internal website. The creation of a more robust enterprise application will enable integration in the cloud or the use of distributed systems.

POCs

Kevin Mercy (ETG), Cameron Purcell, Patrick Johnson, Dr. Timothy Wilkinson (ETG)

4.6 Exploring the Foundations of a Space Internet

The space-borne internet is a near-term reality and, while useful, is not an end unto itself. Rather, it is the infrastructural enabler for new and enhanced systemic capabilities. Internetworking is a required capability, for example, for pushing significant mission processing and decision making to the edge. The Greenfield Line in the Ventures portfolio has projects that anticipate and explore the devices, technologies, methods and integration underlying a space internet.

The Full Stack

Promising New Capabilities …

Proliferated constellations incorporated into the space enterprise enable families of new end-user functionalities. Notional possibilities include: persistent surveillance with distributed and synthesized apertures, integrated and self-organizing communication nets, and alternate position and timing facilities.

… With Certainty of New Challenges

Fundamentally, a key infrastructure requirement is seamless and effortless internetworking. Ideally, it carries forward the syntax and semantics of our existing terrestrial internet and extends it skywards.

The space environment is different, however, and our customers' mission requirements impose even more differences. For example, adversarial pattern-of-life harvesting via passive traffic pattern analysis is an unlikely concern in civilian deployments.

Thus, the goal of our research is to anticipate the challenges likely unique to space. The projects within the portfolio build the infrastructure to enable commensurate exploration and evaluation.

The Path Forward

Aerospace researchers built a generalized simulation infrastructure over the past year, which leverages the proven ns-3 discrete event engine, but amends it with modern, ubiquitous microservices interfaces and semantics. In addition, we've invested in technologies relevant to space networking.

The cross product will enable quick, wide, joint evaluations of specific technology characteristics, iterated holistically at the mission scale. For example, novel approaches to optical PHY may expose superior non-traditional constellation network architectures.

SCALABLE FIDELITY AND THE DIGITAL TWIN

- What does the joint evaluation process look like?
- Stipulate a locally clustered, turnkey optical terminal prototype
- Incorporate key device characteristics into system level ns-3 simulation to indicate potential superiority of constellation leveraging ad-hoc ground relays
- Iterate with successively finer grained device profiles for higher fidelity system results

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Greenfield Venture Line
Proliferated Systems

Lead: Chang "Robert" Lee (OCTO)

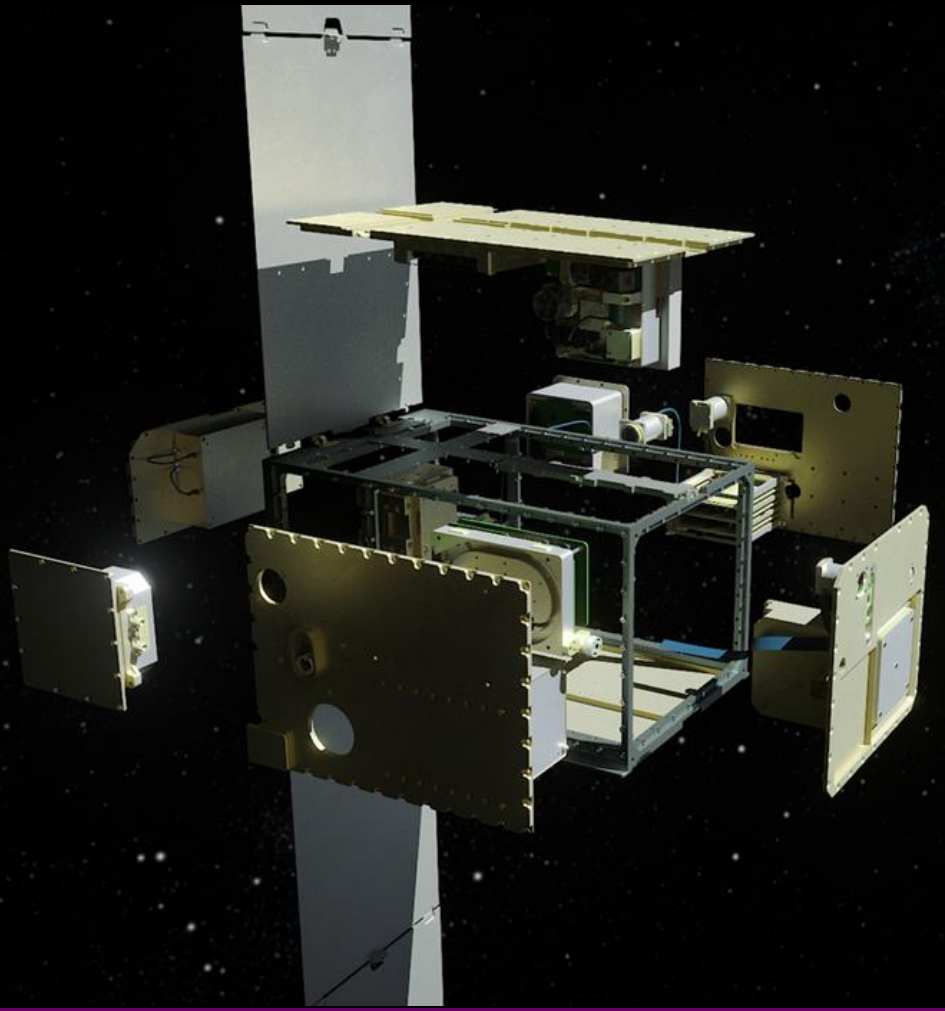
PART FIVE

SOLVING HARD PROBLEMS

Customers rely on Aerospace to solve hard problems ranging from mission design through launch and on-orbit operations. Problems typically require deep expertise in a specific area in addition to foundational knowledge of space systems. This section highlights a selection of projects in the iLab portfolio that address customer problems, both current and anticipated.

5.1 Satellite Modularity to Support Continuous Production Agility

Modular satellite technologies are an important aspect of achieving continuous production agility. This is a concept developed by Aerospace for enhancing flexibility and efficiency when designing and building satellite systems. The Spoon Venture Line is experimenting with modular technologies, utilizing SmallSats as testbeds to gain insights that can be applied to larger systems.



Experimenting With Plug-N-Play Satellite Technologies

The Need for Speed

Production agility and speed are critical enhancements that are needed to stay ahead of evolving threats to space systems and push the limits of space exploration. Aerospace captured a potential solution in the Continuous Production Agility (CPA) concept, where satellite development shifts to shorter production schedules for greater flexibility.

Looking To Commercial Practices

The commercial sector has great examples of leveraging modular technologies to gain greater flexibility and production speed. Developing these technologies for satellites will be a key enabler to achieving the benefits of agility-enhancing initiatives.

Why Modularity Is Hard

The challenge is not only developing the modular technologies but also the business model that will drive user adoption. Modular technologies provide the most benefit when there is a strong and vibrant user community. It is the dual challenge of developing modularity and driving user adoption that is the strategic focus of the Spoon Venture Line.

Progress in 2020

The initial focus of modularity efforts in the Ventures portfolio is on payload integration and cross-payload data communications. The teams achieved major milestones in developing modular payload interfaces, data networking and interface standards. This is leading up to an on-orbit demonstration of unique modular technologies that Aerospace has developed.

INNOVATING HARD PROBLEMS

How do we go about developing modular satellite interfaces that will gain wide adoption?

The Spoon Venture Line is tackling this hard problem with a strategy for winning over users.

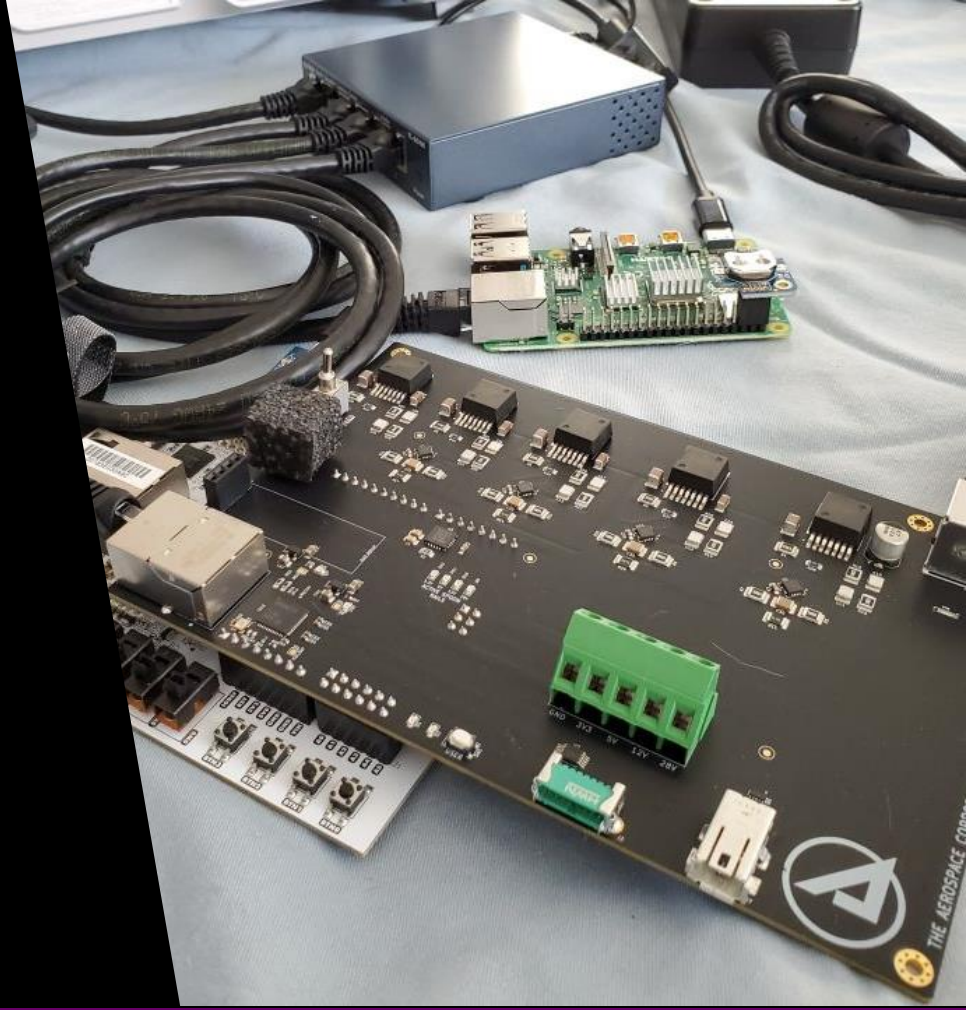
1. Develop interfaces that engineers will love
2. Enable capabilities that end-users want
3. Form a business model companies find compelling

Spoon Venture Line
Smart Satellite and Modularity Tech

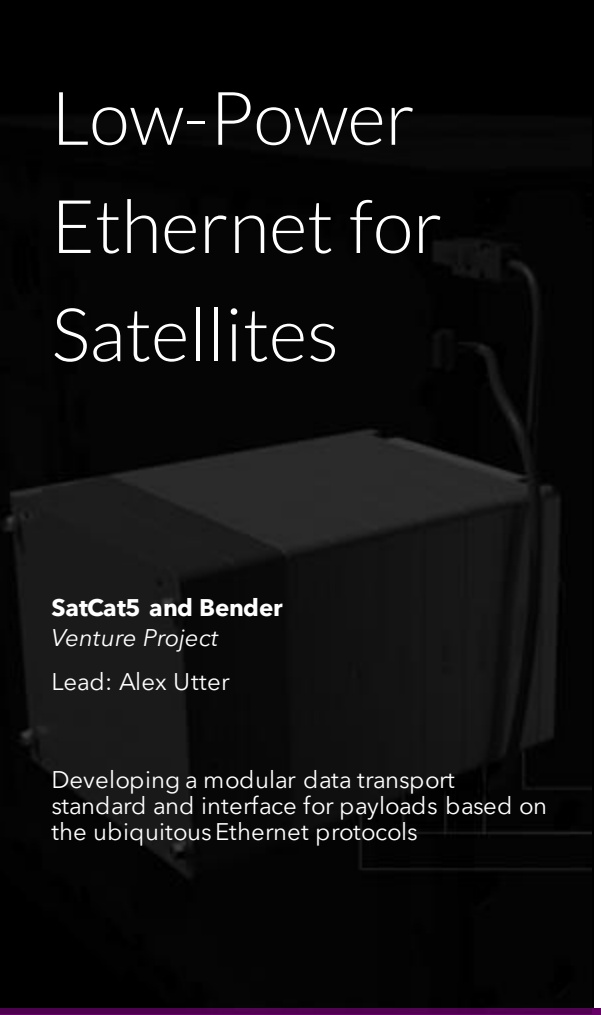
Lead: Hannah Weiher (OCTO)

5.2 Bringing Ethernet to Satellites with SatCat5

The Spoon Venture Line teams are experimenting with modular satellite technologies. An example of this is Handle, a modular plug-n-play interface unit that creates a 'payload of payloads' architecture. With Handle, a common interface provides regulated power and low-power Ethernet called SatCat5 to an array of payloads.



Low-Power Ethernet for Satellites



SatCat5 and Bender
Venture Project

Lead: Alex Utter

Developing a modular data transport standard and interface for payloads based on the ubiquitous Ethernet protocols

What is SatCat5 and Bender

Ethernet is a highly versatile data interface standard that powers the internet and cloud. SatCat5 is an Ethernet implementation developed by Aerospace to connect satellite payloads to one another and the satellite bus. It will be demonstrated onboard Slingshot 1 as a key component of the Handle plug-n-play interface.

What Makes it Unique

SatCat5 is a patent-pending solution to address the relatively high-power requirements for traditional Ethernet implementations. This enables applications where power is a constraint, which is particularly relevant to SmallSats.

Progress in 2020

The software for SatCat5 has been released as open-source and a patent application was filed for the hardware implementation. A flight demonstration payload will be used as the data interface for all 17 Slingshot 1 payloads.

Key Features

- Low-power Ethernet suitable for SmallSats and hosted payloads.
- Provides Open Systems Interconnection (OSI) Levels 1 and 2 (Phy and Data Link layers)
- Modular form factor
- 1 watt average power
- Bender's slice is 3.7 in x 3.3 in x 0.65 in

Maturity

Flight demonstration payload developed for on-orbit testing

Transition Opportunities

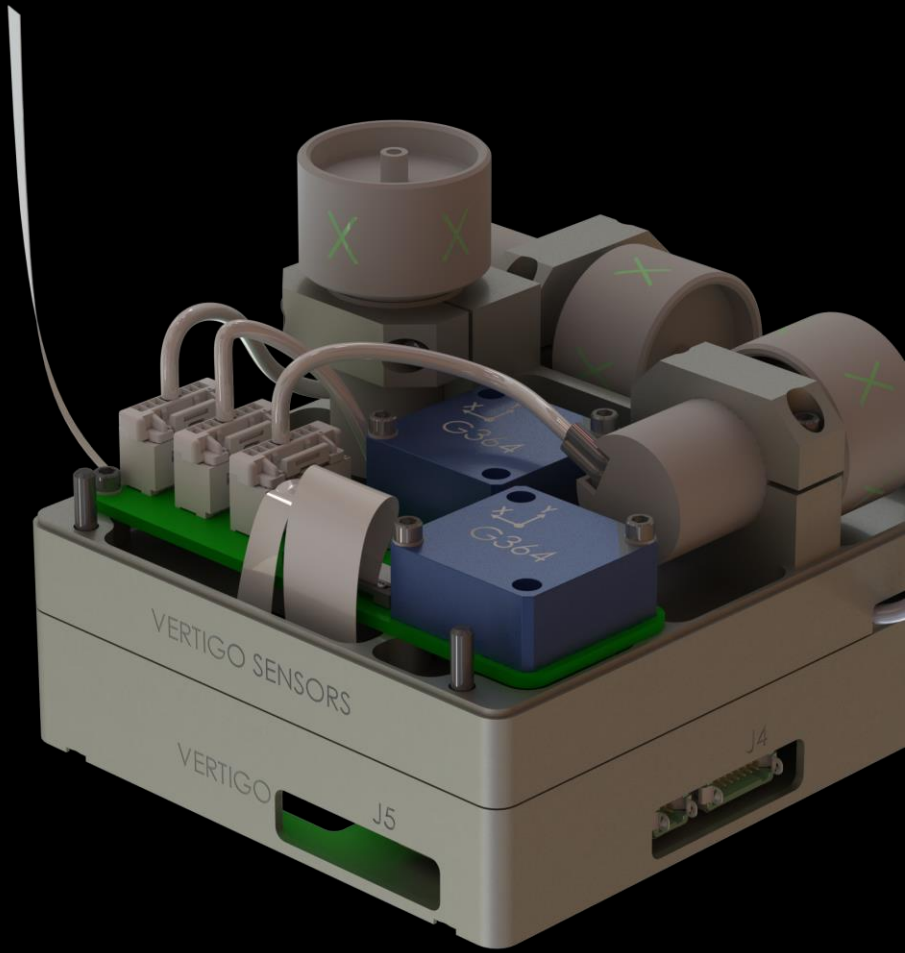
Licensing to commercial companies, adoption by customers for payload interfaces

POCs

Alex Utter (ETG), Dan Mabry, Hannah Weiher (OCTO)

5.3 Launch Satellites Faster with Vertigo

Rapid access to space requires new methods for configuring spacecraft. With Vertigo's novel autonomous system identification approach for configuring the attitude control system on-orbit, payloads can be added or removed late in the game allowing for more responsive space launch.



On-Orbit Satellite Initialization

Vertigo
Ventures Project

Lead: Hannah Weiher

Vertigo is an attitude control system platform for stabilizing a satellite without prior knowledge of payload design

What is Vertigo
Vertigo is a configurable attitude control system payload that enables initialization of a satellite on-orbit. It is made up of sensors and actuators that perform system identification to determine the dynamics model for the satellite. These models are critical for designing a robust attitude control system used to accurately point and control the satellite.

What Makes it Unique
Vertigo's ACS will take place on-orbit without prior knowledge of spacecraft design. This shortens the satellite development process and enables rapid launch. Vertigo modernizes system identification in a novel way by automating the process and executing it multiple times to improve the dynamics model at each iteration. Finding the optimal spacecraft model in this manner vastly improves the spacecraft's ability to operate as designed and fulfill its mission.

Progress to Date
Vertigo has a patent application filed, is verified on hardware, and is planned to be integrated as a test payload for launch on Slingshot 1.

Key Features
- Modular plug-n-play design
- Requires no prior knowledge of bus configuration or design
- On-orbit system identification
- Redundant control architecture

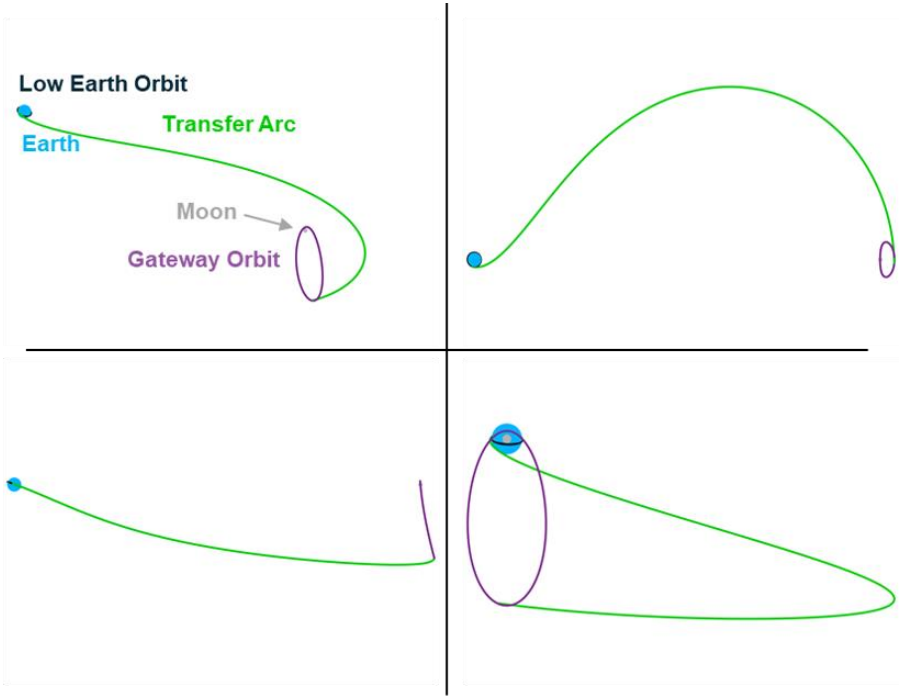
Maturity
Flight demonstration payload developed for on-orbit testing

Transition Opportunities
Customers can either adopt the hardware platform as a payload or the software using their current ACS hardware

POCs
Hannah Weiher (OCTO), Dr. Evan Ulrich, Dan Hernandez, Dr. Evan Sperber, Dr. Mitch Craun, Alex Harpenau, Dr. Richard Chiang (ETG)

5.4 Charting Lunar Courses with Atlas

Atlas is a database containing trajectories for exploring cislunar space and Mars. Atlas lays out trajectory options and features for a broad survey of transit options. The data and supporting tools provide clean-cut graphics for explaining near-term exploration options, and starting points for analysis.



A Trajectory Database for Cislunar Space

Beyond-GEO Atlas
Ventures Project

Lead: Dr. Jonathan Aziz

The Beyond-GEO Atlas connects users to metadata and trajectories for transiting cislunar space and between the Earth and Mars.

What is Beyond-GEO Atlas

Beyond-GEO Atlas is a database of trajectories in cislunar space and between the Earth and Mars. Beyond-GEO Atlas gathers high-level information of transit requirements, like flight time and ΔV, in addition to raw trajectory data. Data can be leveraged as a springboard for trajectory analyses or as a teaching tool for cislunar transit.

What Makes it Unique

The broad survey of transit lanes and methods backs an effort to convey the diverse set of exploration options to non-expert audiences but is tied to an evolving technical analysis capability.

Progress to Date

A database was implemented for storing Beyond-GEO Atlas trajectories, and complementary analysis tools were developed. Data and analysis capabilities include high and low-thrust cislunar and Earth-Mars transfers, Earth-Mars cyclers, historical mission trajectories, and aerobraking.

Key Features

- Database hosted online
- High/low-thrust cislunar and Earth-Mars transfers and cyclers
- Transfers modeled in circular-restricted three-body problem and ephemeris
- Implemented a simplified aerobraking model

Maturity

Initial implementation poised for proof-of-concept as data source for separate visualizations and analyses

Transition Opportunities

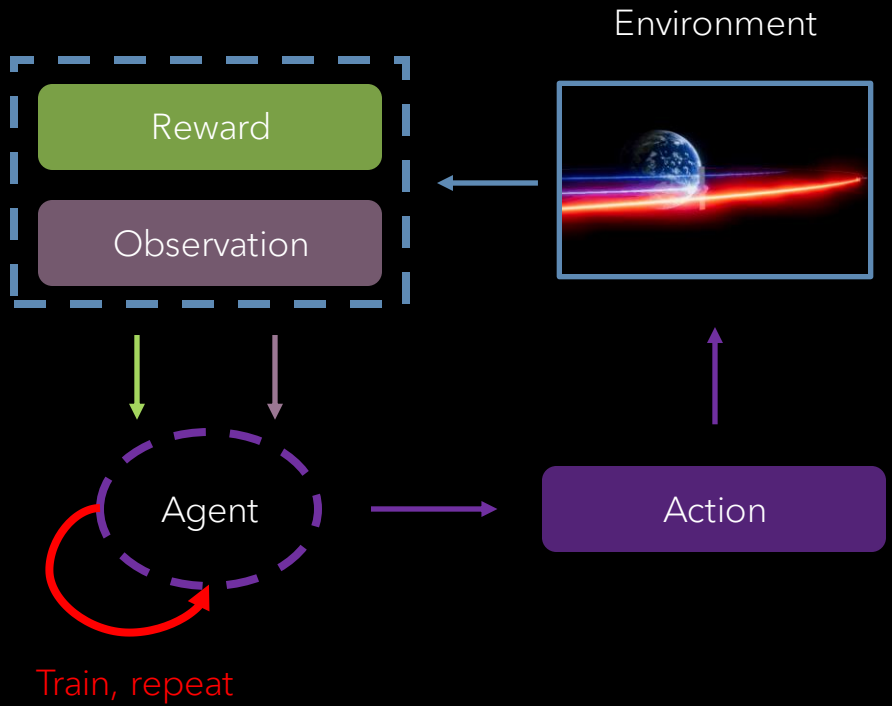
Customer access to raw data and/or metadata. Enhanced capability for analysts and tools to support requests

POC

Dr. Jonathan Aziz (ETG)

5.5 Deep Reinforcement Learning for RPO with LEAP

Dynamic space environments (such as non-cooperative assets maneuvering) make it very difficult to perform effective mission planning. Traditional control and optimization methods begin to fail as the complexity and uncertainty of the environment grow over long time horizons. Deep Reinforcement Learning (DRL) provides a flexible framework to intelligently react to changes in the environment while maintaining mission objectives.



Responding to Dynamic Environments with DRL

Leap
Ventures Project
Lead: Nick Zolman

Using deep reinforcement learning to respond to dynamic environments

What is Leap
Leap seeks to use deep reinforcement learning (DRL) to create intelligent, autonomous agents that can respond to dynamic space environments.

What Makes it Unique
Traditional approaches to enable autonomy in space rely on assumptions about the environment and how other agents will behave in it. While these approaches have been successful in the past, there are always going to be new environments where the assumptions break down. This will be especially true as space becomes more contested and congested. DRL relaxes the assumptions required and offers a way to train generic agents to respond to these dynamic environments.

Progress to Date
Preliminary results comparing DRL to a traditional solver shows that there are missions where a DRL agent can find a solution that traditional solvers cannot. Recently, imitation learning (using "expert" trajectories as a seed for DRL) has shown promise increasing stable trajectories where agents have full autonomy.

Key Features

- DRL allows agents to respond agilely to generic environments
- Imitation learning allows us to use existing solvers to seed initial policies
- DRL found solutions that some traditional solvers could not
- Generative Adversarial Imitation Learning (GAIL) creates stable trajectories that can be improved upon with DRL

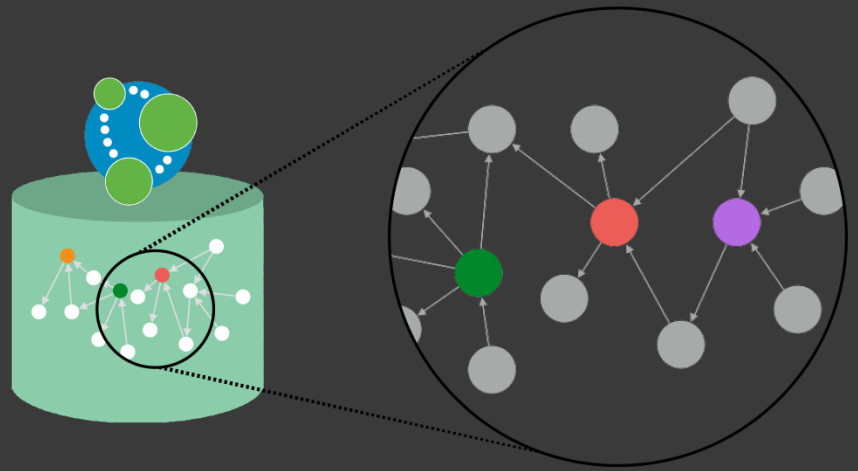
Maturity
This effort is still in a research and prototyping state.

Transition Opportunities
Space Security and Defense Program (SSDP) has funded a spin-off project for using DRL for inspection missions

POCs
Nick Zolman, Hairuo Guo (ETG)

5.6 End-to-End Versioning and Tracking for ML Development

Developing machine learning models that can be audited and trusted requires tracking of data, code, trained models, and results. Although different versioning utilities exist for each of these components, they are not meant to work in tandem. Thus, audits that cover the entire ML pipeline are not possible. The MLOps Software Package is a lightweight tool that coordinates between data version control and Git. It generates versioning metadata that is stored as a Neo4j graph connecting all the stages of the machine learning project.



DevOps for Auditable ML Development

teKi MLOps
Jumpstart Program*

Lead: Hairuo Guo

Bringing a thread of audibility, traceability and reproducibility to AI/ML Development

What is teKi MLOps

In 2020, Aerospace developed a lightweight beta version ML Ops Software Package that is composed of two industry standard machine learning operations (MLOps) tools – DVC and MLFlow. MLOps is targeting individual developers to enable more uniform AI/ML development practices with auditability in mind.

What Makes it Unique

The teKi MLOps Software Package's usage of the Neo4j database allows for the structure of the project to be captured. It also tracks important states pertaining to the data and code used to run experiments. Aerospace's implementation enables auditing of the entire pipeline.

Progress to Date

The teKi MLOps component was included in the minimum viable product (MVP) internal release of the MLOps Software Package Developer Edition.

**The Jumpstart Pilot Program provides start-up funding for potential Ventures projects.*

Key Features

- Stages of a ML project captured as an interpretable graph
- Key tracking information from experiments stored as node properties
- Neo4j interactions handled entirely by control code
- Graph serves as ledger for all experiments in project

Maturity

Released as part of the MVP of the MLOps Software Package (Developer Edition)

Transition Opportunities

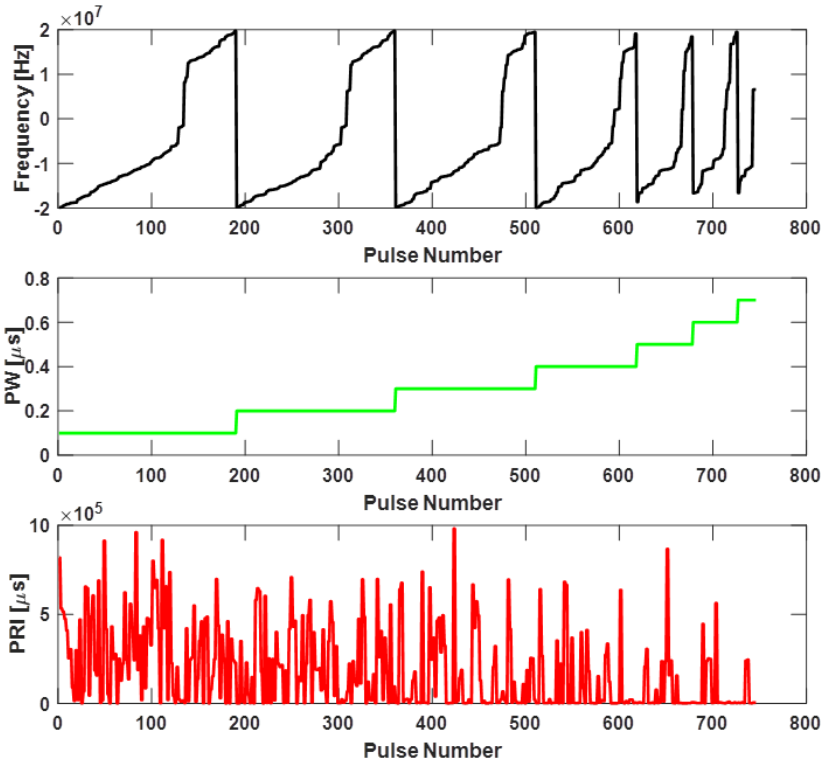
MVP released and available through Aerospace Nexus

POCs

Hairuo Guo (ETG), Max Spolaor (ETG)

5.7 Overcoming Unknown, Time-Varying, and Noisy Signals

Blind source separation (BSS) is a difficult problem that limits the ability of satellite systems to perform their missions. This is because signals are unknown, time-varying, and noisy. Aerospace created new algorithms, including a modified Singular Spectral Analysis (SSA), to overcome these limitations. This method can be used to detect many signals, including electronic, instrumentation, communications, and radar.



Blind, Non-Stationary, Co-Channel Signal Separation

Haystack
Ventures Project

Lead: Dr. Seema Sud

Novel signal processing solution for detecting and separating signals in unknown, dynamic environments

What is Haystack
Haystack applies novel signal processing solutions to blindly extract weak, overlapping, time-varying signals in a noisy environment that could not previously be detected. Techniques such as Singular Spectrum Analysis (SSA) or variational mode decomposition (VMD) are modified to optimize performance for a specific problem.

What Makes it Unique
The algorithms overcome limitations of past methods by not requiring any prior signal knowledge, adapting to non-stationary (i.e., time-varying) environments, enhancing the ability to suppress receiver noise, and separating multiple overlapping signals.

Progress to Date
Customer provided data has been successfully processed. A paper has been published: Sud, S., "Combined Variational Mode Decomposition and Singular Spectral Analysis for Blind Source Separation in Low Signal-To-Noise Ratio Environments", *Proc. IEEE SoutheastCon*, Mar. 10-14, 2021.

Key Features
- Detect signals with no prior knowledge
- Adapts to changing signals or a changing environment & performs well when several signals overlap
- Wide applicability because is agnostic to the type of signals
- Modified SSA algorithm detected over 700 emitter pulses vs. 75 by conventional energy detectors (see fig. on previous page)

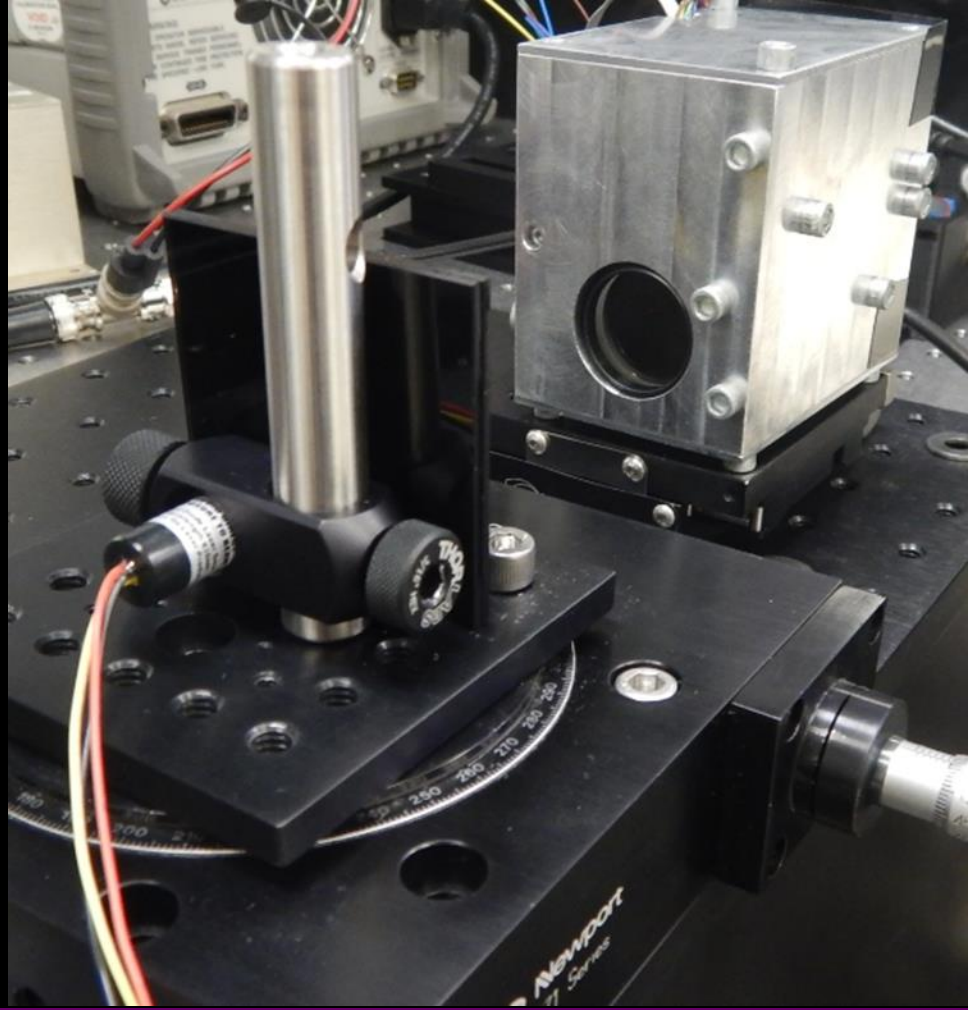
Maturity
Software-based algorithms have been developed and tested on both simulated and real data

Transition Opportunities
Received customer funding to process real data and submitted white paper to obtain follow on funding from interested customers in the National Systems Group

POC
Dr. Seema Sud (ETG)

5.8 Low-SWaP Laser Communications

The Greenfield Venture Line teams are developing mission concepts and reference designs that mature key elements of strategy and position Aerospace to be a thought-leader by expanding the range of options for next-generation systems. To satisfy the needs of proliferated missions, laser communications (lasercom) terminals must become smaller and cheaper. This requires creative solutions to push the bounds of the industry. The Aerospace reference design offers a unique solution to continue pushing these limits.



Enabling Lasercom Through Miniaturization

Miniaturized Gbps Lasercom Terminal Development for Cubesat Demonstration
Ventures Project

Lead: Ryan Miller

A Low-SWaP Gbps Lasercom Terminal for CubeSats

What is Miniaturized Gbps Lasercom Terminal Development for CubeSat Demonstration

This miniaturized lasercom terminal offers an impressive transmit data rate in a compact design. Utilizing a unique architecture and low size, weight, and power (SWaP) components for the pointing, acquisition, and tracking (PAT) hardware, this reference design enables new opportunities to minimize SWaP and lower the cost for a lasercom terminal.

What Makes it Unique

This unique design incorporates a concept that replaces a focal plane array's functionality in acquisition with a Micro-Electro-Mechanical-System (MEMS) fast steering mirror (FSM) and quad detector. This concept is currently patent pending. Elimination of the focal plane array significantly lowers the SWaP. The use of a MEMS FSM allows for tip/tilt pointing at a much lower SWaP than voice coil or piezo FSMs.

Progress to Date

The Aerospace team designed and built a receive terminal prototype to validate unique acquisition and tracking concept. The team successfully acquired incoming beam and transitioned to tracking mode using the prototype.

Key Features

- Low SWaP PAT prototype <100g, <1W, 1U
- Pointing accuracy < 30 µrad
- Acquisition field of view = ±1 deg
- Transmit data rate = 1 Gbps, Beam divergence < 300 µrad

Maturity

Concept validated by laboratory demonstration of acquisition and tracking functions. Developing concepts for a flight prototype with bi-directional laser communications.

Transition Opportunities

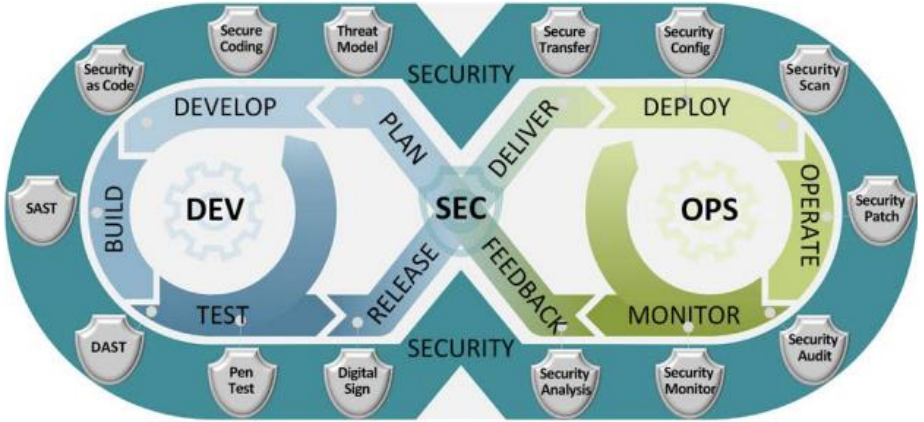
Flight design and prototype build for on-orbit demonstration, licensing to commercial companies

POCs

Ryan Miller (ETG), Dr. Austin Lee (ETG)

5.9 Transitioning Machine Learning Development to Operations

Shift left is a new paradigm in DevSecOps to shift security and test to earlier in the development process to realize time and cost savings that are especially important to support continuous Authority To Operate (cATO)



Security and Cyber Risk Assessment in DevSecOps

Continuous Security Testing and Automated Cyber Risk Assessment
Studies Research and Analysis Projects (SARP) Program

Lead: Robert Lai

Explore security testing and automated cyber risk assessment possible in DevSecOps

What is Continuous Security Testing and Automated Cyber Risk Assessment in DevSecOps
This study explored the techniques and tools to make continuous security testing and automated cyber risk assessment possible in DevSecOps and advance security in two of the four DevSecOps Pillars – process and technology.

What Makes it Unique
Unlike standard security practices that begin after the deployment of software, continuous security testing is a holistic approach to assure security in every step of continuous integration and continuous deployment (CI/CD) by integrating security and compliance into the software development lifecycle (SDLC).

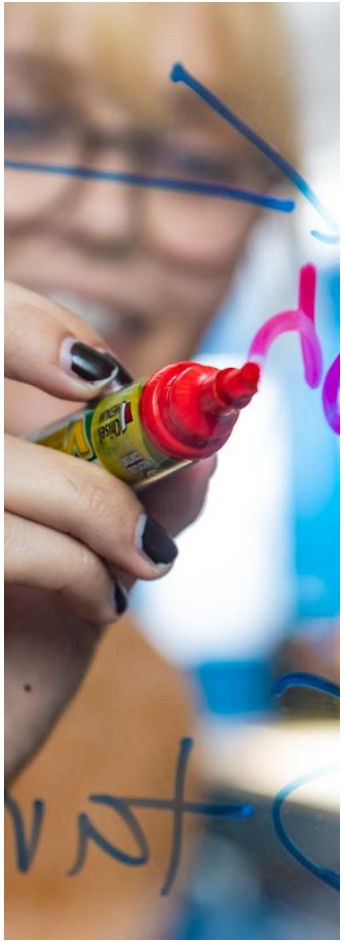
Progress to Date
The team authored a report to identity the security tools and processes for the continuous security testing in all the DevSecOps phases (i.e., Plan, Build, Test, Deploy, and Run), and the mapping of controls in automated cyber risk assessment.

Key Features
- Security tools for Plan, Build, Test, Deploy and Run phases
- Mapping of controls for automated cyber risk assessment

Maturity
Ready for proof-of-concept and implementation in DevSecOps projects

Transition Opportunities
Look into Air Force and Space Force programs that are interested in security testing tools and techniques to speed up DevSecOps.

POC
Robert Lai (ETG)



INTERESTED IN FINDING OUT MORE?

Follow the links below to learn more or get involved.

- Contact the iLab team at iLab@aero.org
- Visit the iLab website at iLab.aero.org
- Search ideas for project details at ideas.aero.org