National Aeronautics and
Space Administration

The Early Career Initiative

Presented to the
NASA Advisory Council

October 29, 2019

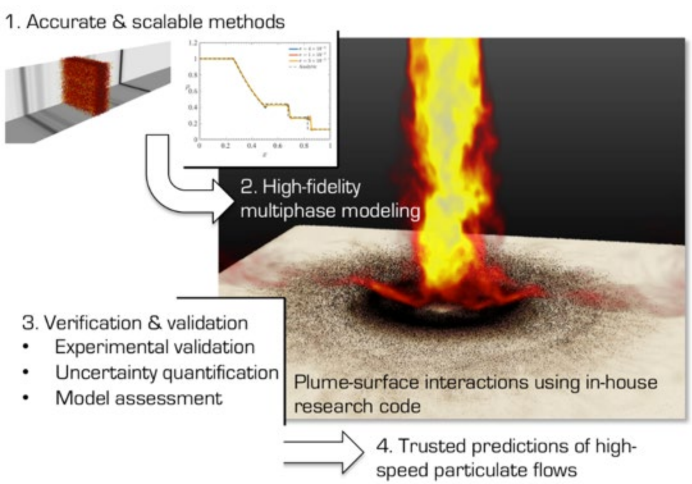
Ricky Howard
Program Executive – Center Innovation Fund

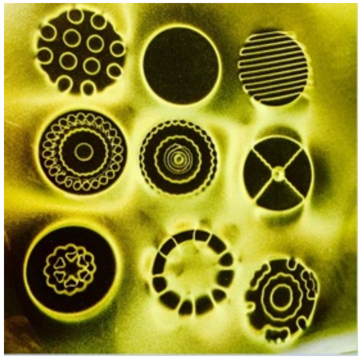
Presentation Outline

- CIF Program and the Early Career Initiative (ECI)
- ECI Goal
- ECI Background
- ECI Past projects
- ECI Portfolio
- Individual ECI projects
- ECI Summary

Center Innovation Fund Program has 2 Components

- Center Innovation Fund (CIF)
  - $14M budget
  - Typical projects $100K for 1 year
  - Ideas come from Center employees
  - ~130 projects per year
- Early Career Initiative (ECI)
  - $13M budget
  - Typical $1.25m/year for 2 years
  - Early-career civil servant led
  - Requires external partner
  - Require alternative project management





Patterned Magnetic Hold-Separate Techniques

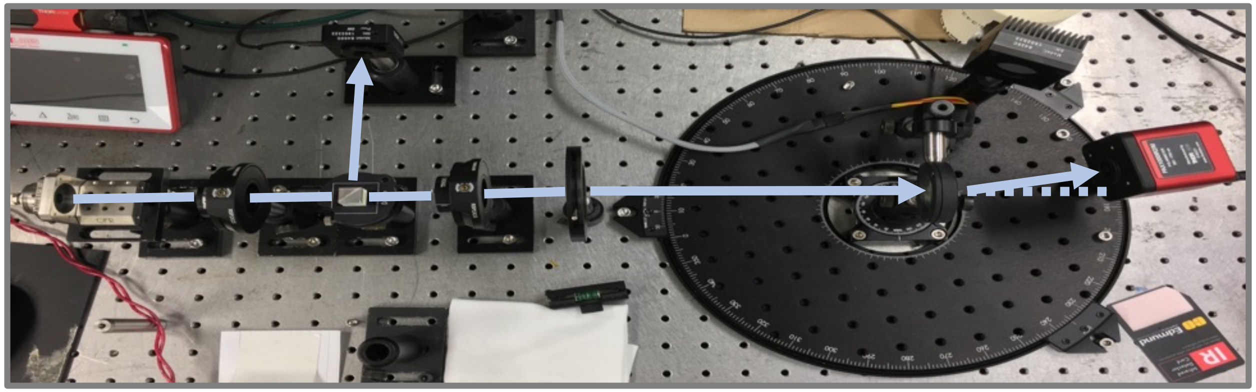
ECI Goal and Funding

Initiative Goal

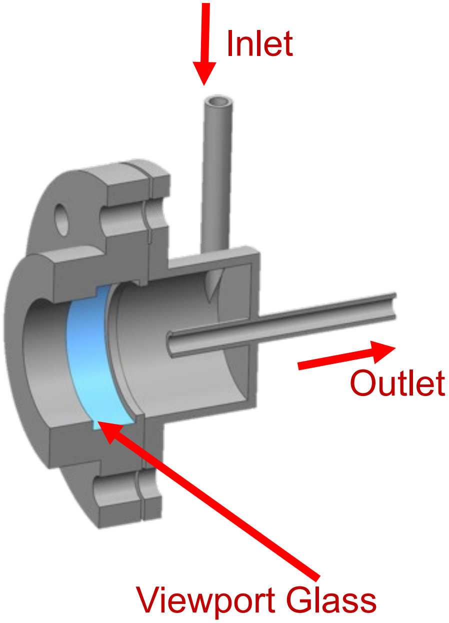
Invigorate NASA's technological base and best practices by partnering early career NASA leaders with world class external innovators.

ECI Projects by year:

FY15 $5M – 4 projects initiated; completed in FY17
FY18 $2.5M – 2 Projects initiated; completing in FY20
FY19 $6.5M – 3 Projects initiated
FY20 $13M – 7 Projects initiated



Electro-Optical Technology Development In Liquid Crystal Beam Steering



OSCAR

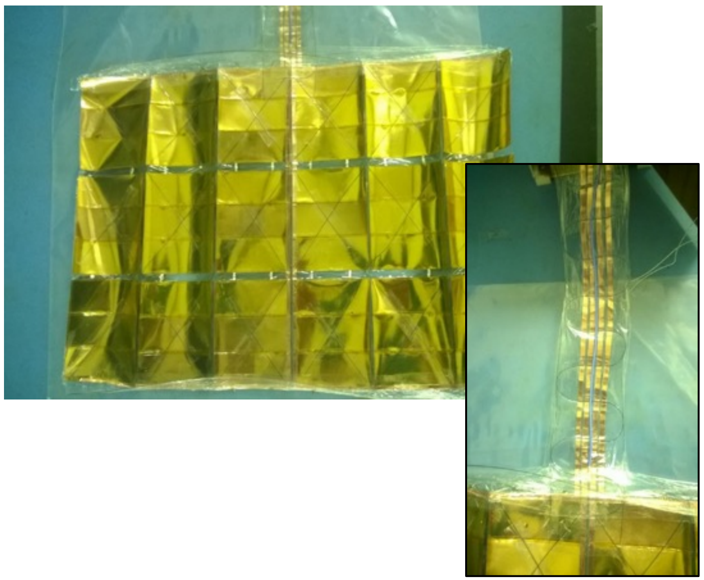
Why an Early Career Initiative?

Initiative Goal
Invigorate NASA's technological base and best practices by partnering early career NASA leaders with world class external innovators.

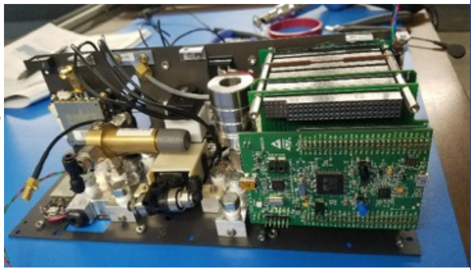
- NASA needs top-notch employees to fill gaps that are growing as people retire.
  - **Initiative to accelerate some early career Civil Servants' capabilities with in an exciting and challenging fashion.**
- STMD is looking for effective management approaches for technology development projects.
  - **Initiative requires alternative management approach (not NPR 7120-based)**
- NASA should work with appropriate partners when possible, to gain access to knowledge, technology, and/or expertise.
  - **Initiative requires partnering with a non-NASA entity (University, other government Agency, business, non-profit).**

Early Career Initiative – Pilot Projects (2015)

MSFC LISA-T (Lightweight Integrated Solar Array and Transceiver) self-unfolding system worked well. Investigating flight system for cubesat. Flying various elements on MISSE 10.

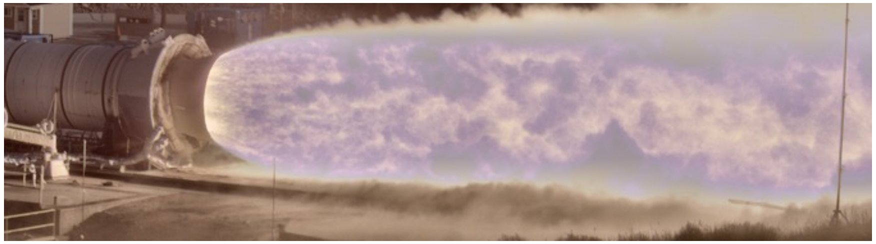


LaRC OOAAN (On-Orbit Autonomous Assembly from Nanosatellites) – team is working to fix flaws in epoxy floor. Applying experience to SAGE-IV.



KSC IDEAS (Integrated Display and Environmental Awareness System) is continuing development with GSDO funds; still partnered with small business. Collaborating with JSC.

SSC HiDyRS-X (High Dynamic Range Stereo-X) is advancing with other funds and commercial partnerships. Currently working to integrate it onto a single mask/imager system.



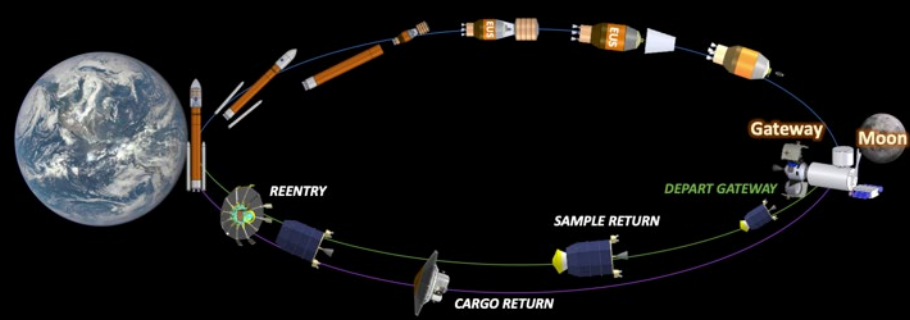
ECI Portfolio – FY18 and FY19

ECI Title	Project PI	Lead Center	Partner
Autonomous Guidance and Control System for Deployable Entry Vehicles (Project Pterodactyl)	Sarah D'Souza	ARC	UC Davis, Johns Hopkins University Applied Physics Laboratory
Orbital Syngas/Commodity Augmentation Reactor (OSCAR)	Anne Meier	KSC	Blue Origin
Electro-Optical Technology Development In Liquid Crystal Beam Steering (E-OpTICS)	Devin Pugh-Thomas	LaRC	Boulder Nonlinear Systems
Smart Habitat Robotics: Manipulation Technology to Enable Autonomous Uncrewed Habitats	Evan Laske	JSC	Woodside Energy
Autonomous Multifunctional Sensor Platform	Mahmooda Sultana	GSFC	Northeastern University

Pterodactyl: Precision Targeting of Deployable Entry Vehicles [ARC]

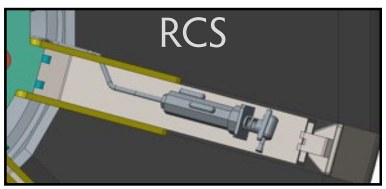
Dr. Sarah D'Souza, Principal Investigator, sarah.n.dsouza@nasa.gov

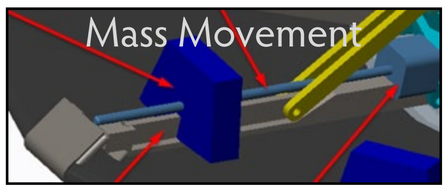
Imagine delivering payloads to planetary bodies with the <u>ease</u> you send packages using UPS and at a <u>reduced cost</u> because you can deliver direct to your precise destination!

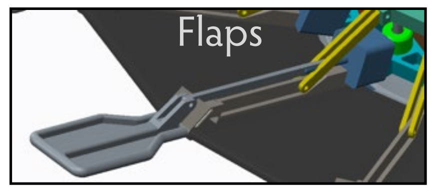


NEED: Technologies to enable safe & autonomous precision landing of sensitive payloads

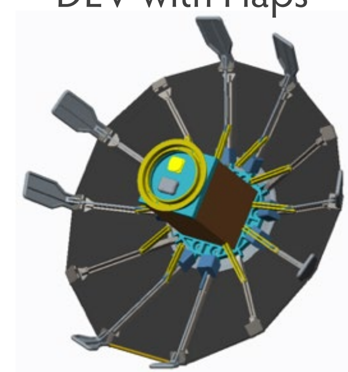
SOLUTIONS







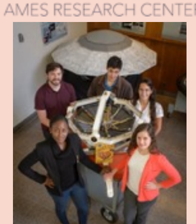
DEV with Flaps



Using an integrated SW & HW design approach, Pterodactyl has developed multiple **innovative guidance & control systems** for precision targeting of deployable entry vehicles (DEVs) that increase maneuverability and maximize useable payload volume.

The Team

NASA SILICON VALLEY
AMES RESEARCH CENTER



- ARC, Lead Center: Project Management, Mission Design, Control Systems Design, Aero/Aeroheating, Mechanical Design and Structures, Heatshield Design
- JSC: Guidance & Trajectory Design
- **JHU Applied Physics Laboratory: Flight Operations, Systems Engineering**
- UC Davis: Aerodynamics Research

Hybrid Project Management

Leveraged agile and traditional approaches for parallel development of software and an integrated hardware prototype to **deliver a feasible, innovative flap control system**

Orbital Syngas/Commodity Augmentation Reactor (OSCAR) [KSC]

<u>Goal and Technology Development Approach Summary:</u>

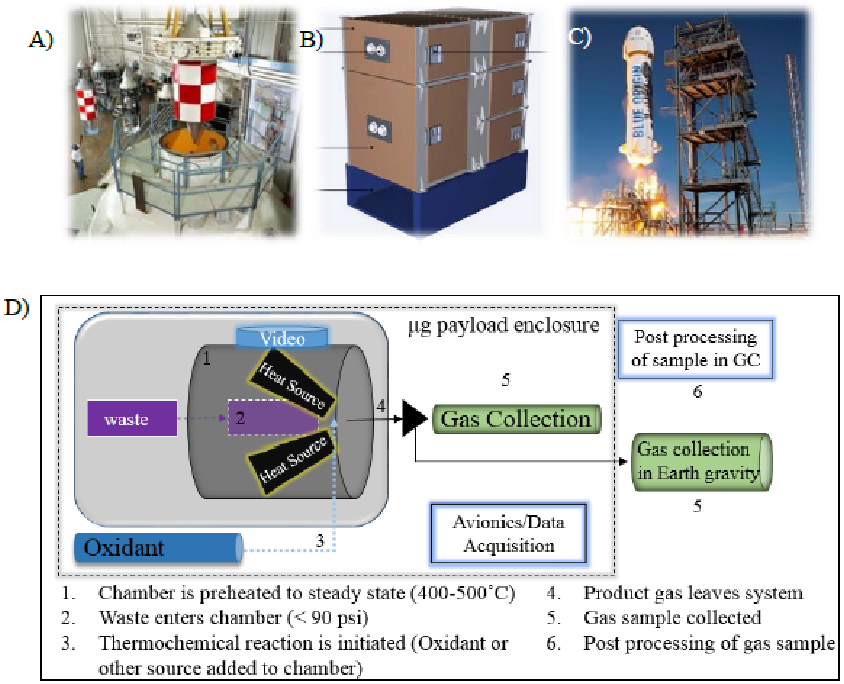
Demonstrate hardware for useful conversion of mission logistical waste via thermal degradation in a relevant microgravity (μg) environment with an agile, iterative development and testing regime.

The reuse of waste generated throughout a long duration crewed mission would yield substantial benefit by reducing overall launch mass requirements, increasing usable spacecraft and habitat volume, and augmenting supplies of propellant, water, and other relevant material.

This project will validate the Trash to Gas (TtG) concept in μg, elevating reactor hardware from TRL 4 to TRL 6. Tests will also attempt to thermally degrade materials which have never before undergone the process in μg, and will yield significant insight into the key physical phenomena involved in degradation.

The following knowledge gaps must be satisfied to design a μg-compatible TtG reactor:

1. *Does the steam reforming, pyrolysis or gasification process (or other thermochemical process) behave similarly in μg as on Earth?*
2. *How does the altered heat transfer regime of μg affect reactor performance, and what design changes are required to compensate for the lack of natural convection?*
3. *How is waste introduction and product gas collection modified in μg, and what design features are required to optimize the mechanical and fluid dynamic aspects of the reactor?*



A) GRC Zero Gravity Research Facility, B) Blue Origin payload racks, C) Suborbital flight on New Shepard, D) payload concept

NASA KSC Core Team: all early career (EC)

- **Anne Meier:** Team Lead
- **Malay Shah:** Test and Analysis Development
- **Evan Bell:** Mechanical and Fluids Design
- **Jared Berg:** Thermal and Fluids Design

Partner Core Team:

- **Erika Wagner, Ph.D.,** Blue Origin: Business Development Manager
- **Sapan Shah,** Blue Origin: Cabin Payload CSE

Agency Collaboration at NASA GRC:

- **Robert Green, Ph.D.:** μg and Fluid Physics
- **Juan Agui, Ph.D.:** μg payload development

KSC EC Support Team: Emily Forrester (SA), Cristina Oropeza, Ph.D. (NE), Joshua Santora (PX). Non-EC: Matt Nugent (ESC), Jon Bayliss (NE).

<u>**Project Management Approach:**</u>

We will create a <u>hybrid</u> from the industry methods ***Lean Project Management*** and ***Agile Manifesto.*** We need **BOTH** because legacy payload development & flight demonstration methodology is NEITHER method. We need to improve what we can control, in order to reduce the overall schedule and process inefficiencies.

- Fast paced iteration of design and test
- Crisp decision making
- 'Backlogs' kept to prioritize requirements
- Kanban boards (work flow visual) to emphasize work pull, not push
- Learning orientation & mentorship
- Multimedia documentation of lessons learned

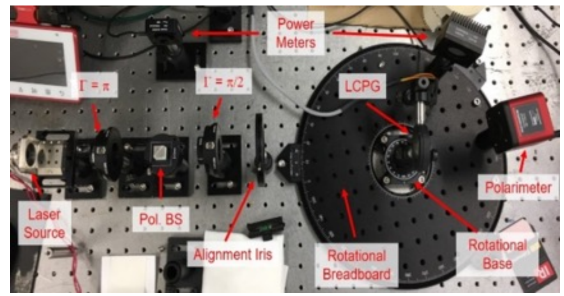
Electro-Optical Technology Development In Liquid Crystal Beam Steering (E-OpTICS) [LaRC]

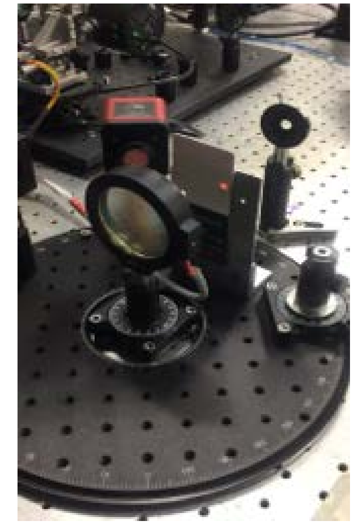
Project Goal

- To develop and demonstrate a non-mechanical beam steering (NMBS) system based on liquid crystal polarization gratings (LCPGs) for infusion into NASA lidar instruments.
- To investigate the advantages and limitations of LCPG-based NMBS for NASA lidar.

Innovation- Gimbal-free laser beam steering and pointing capability on NASA laser/lidar systems.
Alignment- NASA Technology Taxonomy, TX8: Sensors and Instruments and TX 9: Entry, Descent and Landing (EDL)
Space- precision navigation and hazard avoidance.
Technology Infusion- NDL, lunar CubeSats,…

E-OpTICS Laboratory Setup: Test Equipment





E-OpTICS NMBS system (video)

Team Overview

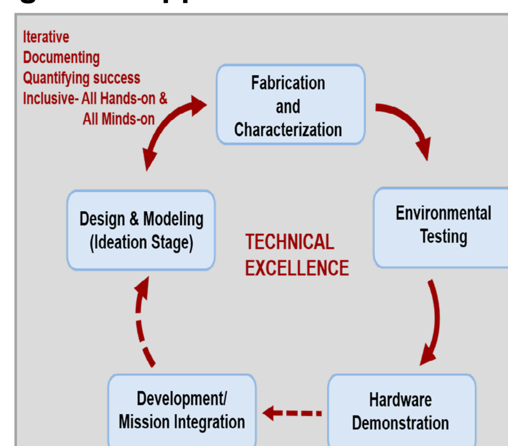
Core Team
Devin Pugh-Thomas, Ph.D., Project Manager
Stanley Ikpe, Ph.D., COR
Aram Gragossian, Ph.D., Design & Modeling Lead
Frederick "Guy" Wilson, Characterization Lead
Jacob Follman, Electronics Lead
Samantha Applin, Thin Films Technologist

ECI Mentors
Larry B. Petway, Ph.D.
William "Chris" Edwards
Stephen Horan, Ph.D.

External Partner
Boulder Nonlinear Systems, Inc. supports iterative NMBS system design and fabrication.

Project Management Approach

- Hybrid-Agile
- Individuals and interactions
- Iterative R&T development
- Streamlined documentation
- 10-Minute Stand-ups



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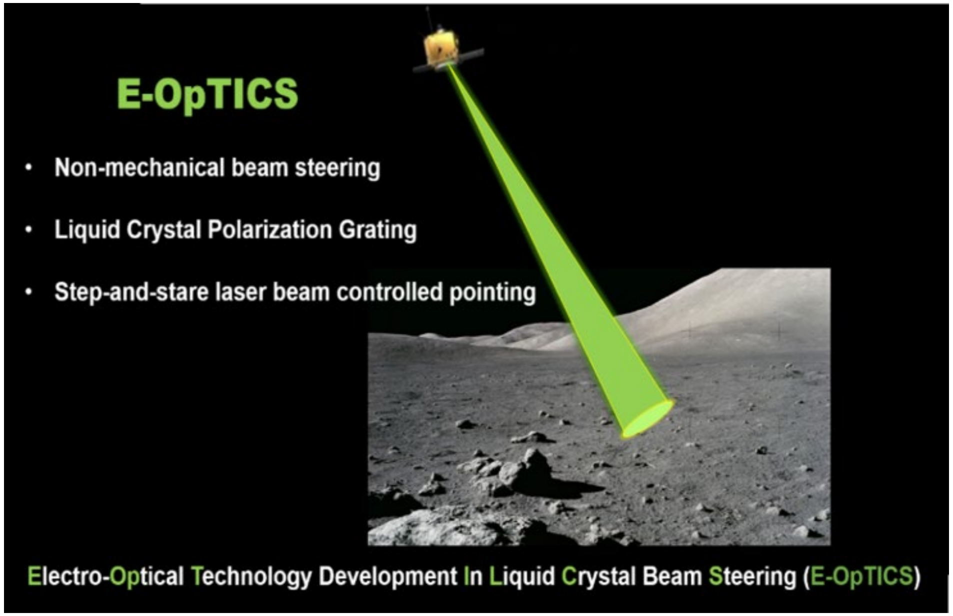

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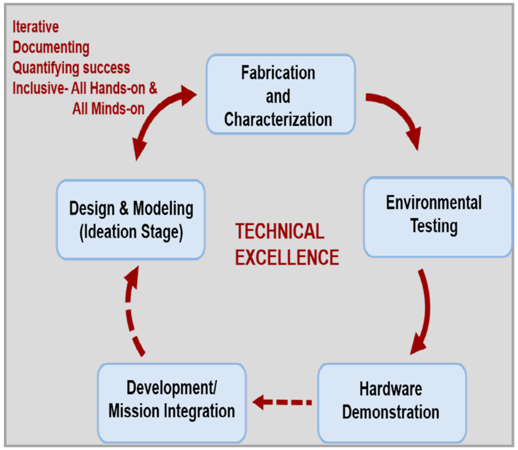


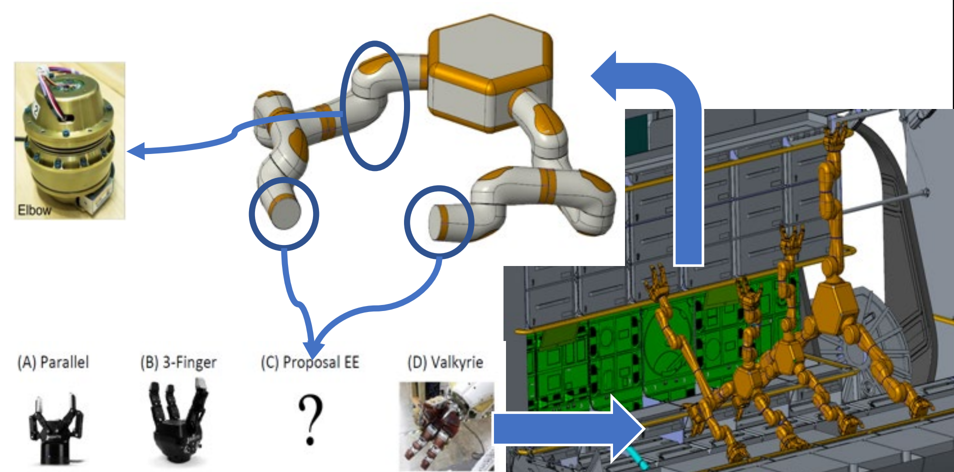
Smart Habitat Robotics: Manipulation Technology [JSC]

Goal: Enable logistics management and uncrewed utilization on Gateway by advancing key robotics technology gaps:

- **Actuators** – designed for reliability and automated fault recovery
- **End-Effectors** – designed for reliability and manipulation

Strategy: Refine technology and iterate with tight design-build-test cycles to gain insight and guide current and higher TRL development.

Gateway Manipulation Concept



Team Overview

- Evan Laske (EC) – Principal Investigator
- Austin Lovan (EC) – end-effector + joint mechanical
- Justin Bautista (EC) – actuator & end-effector electrical
- Amy Fritz (EC) – End-effector / tool changer mechanical
- Dr. Andrew Sharp (EC) – Manipulator software
- Chris Beck – Actuator embedded software / control
- Ed Herrera – end-effector mechanical
- Dr. Julia Badger – Project Mentor, Gateway Autonomy/VSM System Manager

Provides

External – Woodside Energy Technologies Pty, Ltd.

- Relevant test environments on real, operational, remote assets on Earth
- Integration efforts to help feed back other autonomy + manipulation technology to NASA
- Collaboration on developing / refining Project Management Approach

Project Management Approach

Modified Agile adapted from Woodside Energy where they focus on quarterly field tests and iteration:

- 3-month short-term plans
- 2-week Sprints with Scrum

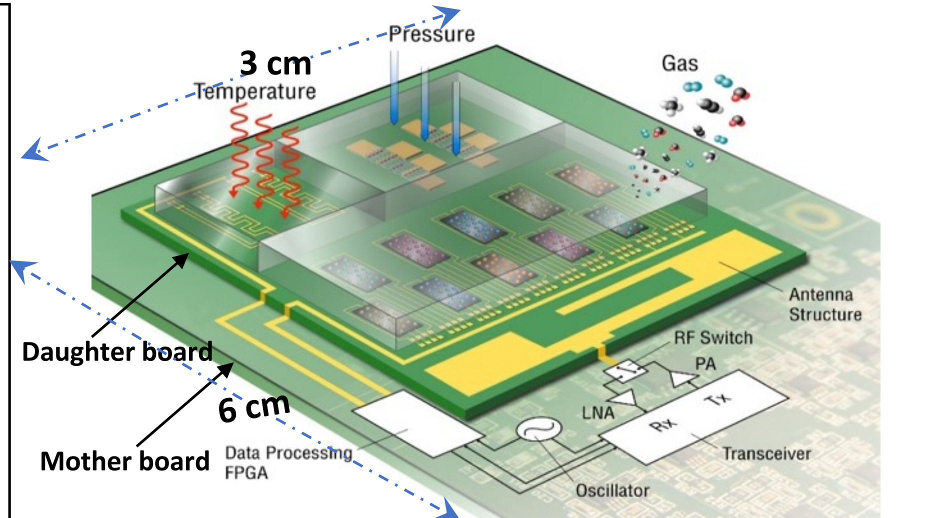
Enables rapid iteration, technical evolution, and team adaptation.

Autonomous Multifunctional Sensor Platform [GSFC]

Goal: Develop a low resource, highly sensitive, *in situ* multifunctional sensor platform that will enable a broad range of missions across planetary science, earth science and human exploration.

Strategy: A suite of highly sensitive environmental sensors made of nanomaterials, and other device components are printed directly on a substrate using an innovative additive manufacturing technique.

This approach minimizes the integration and packaging challenges typically present in multifunctional sensor platform, while increasing the yield and reproducibility of nanomaterial-based sensors.



Multifunctional sensor platform with a sensor suite, microheaters and antenna printed on a daughter board, which is integrated to the mother board containing readout electronics.

Team Overview

- Mahmooda Sultana (EC) – PI, sensor design, instrument design, electronics, packaging and data analysis
- Norvik Voskanian(EC) – Sensor testing, data analysis
- Stephen Ambrozik (EC) – Sensor functionalization
- Wing Lee – (EC) – Wireless antenna
- Jennifer Stern – Science input
- Jesse Leitner – Project management mentor
- Conor Nixon – Technical mentor

External Partner: Professor Busnaina at Northeastern U.- Additive manufacturing techniques for nanomaterials

Project Management Approach

A unique combination of agile and risk-based project management approach is implemented. The fast speed and low cost of the printing process lends itself to iterative development.

- 3 iterations will be conducted to optimize the overall platform for resource footprint, yield and sensor response.
- The key risks are identified and prioritized for decision making between each iterations.

ECI Portfolio –FY20

ECI Title	Project PI	Lead Center	Partner
Development of a Thermal Control System to Survive the Lunar Night	William Johnson	MSFC	Astrobotic
In-Space Assembly of Perovskite Solar Cells for Very Large Arrays: Space power at terrestrial costs	Lyndsey B. McMillon-Brown	GRC	University of California Merced, National Renewable Energy Lab (NREL)
Molten Regolith Electrolysis (MRE) – Starter Device	Kevin Grossman	KSC	Honeybee Robotics
Joint Augmented Reality Visual Informatics System (JARVIS): xEMU Spacesuit Heads-In Display Visual Aid to Enable Crew EVA Autonomy	Paromita Mitra	JSC	MIT.nana, Microsoft (Hololens team)
Extractor for Chemical Analysis of Lipid Biomarkers in Regolith (ExCALiBR)	Mary Beth Wilhelm	ARC	Shell Global Solutions
A Mobile Frequency-Modulated Continuous-Wave (FMCW) Light Detection and Radar (LiDAR) System for Lunar Surface Terrain-Mapping and Navigation	Michael Zanetti	MSFC	Torch Technologies
Assemblers: A modular and reconfigurable manipulation system for autonomous in-space assembly	James Neilan	LaRC	Honeybee Robotics, Virginia Tech

Development of a Thermal Control System to Survive the Lunar Night [MSFC]

Project PI: Will Johnson, MSFC
Project Mentor: Dr. Jeff Farmer, MSFC

Goal and Technology Development Summary

Goal: This proposal serves to enable near-term robotic exploration of permanently shadowed regions and lunar night survival by maturing and combining existing technologies, of varying TRLs, such as loop heat pipes (LHPs), variable conductance heat pipes (VCHPs), embedded heat pipe plates (EHPPs), phase change materials (PCMs), thermal electric coolers (TECs), and thermal switches to develop an adaptable vehicle thermal control system (TCS) for landers of the 50-500 kilogram payload class. **This will enable new science goals to be met and close several Strategic Knowledge Gaps currently open for Lunar exploration.**

Technology Development: Currently, the state of the art is to use radioisotope heating, however this is difficult to sustain due to cost, integration challenges, and sociopolitical concerns. **To solve this problem, the team will leverage individual thermal control technologies – both heritage components (TRL9), as well as advanced, mid-TRL (4-6) components – to develop an innovative non-nuclear solution.** This solution will be designed in collaboration with Astrobotic to leverage their experience in commercial lunar landers and to enable their business case for surviving the lunar night. In addition, new thermal modeling techniques will be developed that will enhance the current analysis toolbox of NASA and its commercial partners. **The culmination of this effort will be a flight demonstration on Astrobotic's second mission to raise the system to TRL 7.**

Team Overview

- Core ECI team members, roles and responsibilities:
  - Will Johnson: Project Lead
  - Travis Belcher: Project Management and Testing
  - Parker Weide: Analysis and Testing
  - Alex Szerszen: Analysis and Testing
  - Dr. Erin Hayward: Test Instrumentation and Data Collection
- External Partner Mentor:
  - Jeff Hopkins: Astrobotic Chief Engineer
- Project Technical Mentor: Dr. Jeff Farmer
- Project Management Mentor: Dr. John Carr

Astrobotic Peregrine

Project Management Approach and Resources

- An integrated NASA-Astrobotic team will utilize an Agile project management philosophy with a combination of a Scrum, Kanban, and QFD (Quality Functional Deployment) framework for execution
  - To provide structure, some Scrum-style techniques will be implemented: tasks, problems-to-solve, etc. will be organized and prioritized onto a project backlog, with sprints to reach releases
  - To encourage a more rapid design flow, some Kanban-style techniques will be implemented: a rapid, continuous workflow will be used to iterate constantly through the design process
- Astrobotic brings managerial excellence in Agile
  - They have been successfully implementing their own, tailored 'NASA Traceable' version of Agile during the Peregrine CATALYST program
  - They will 'teach by showing' the team their management style through project execution

In-Space Assembly of Perovskite Solar Cells for Very Large Arrays: *Space power at terrestrial costs* [GRC]

Principal Investigator: Lyndsey McMillon-Brown, PhD (GRC-LEX)

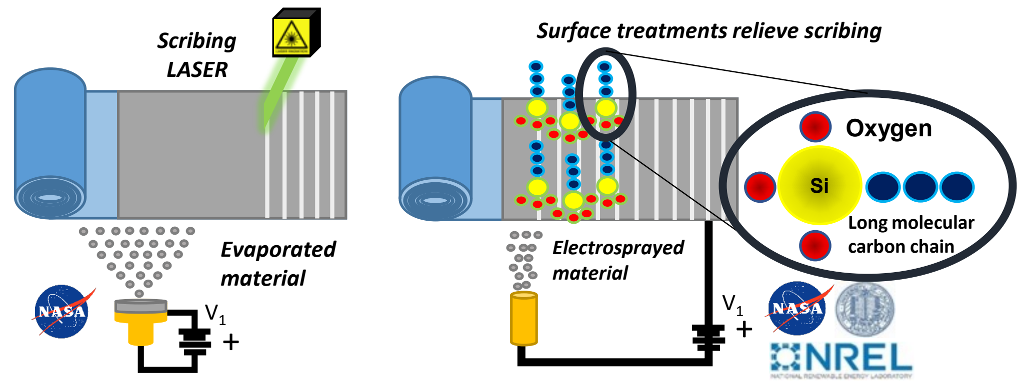
Goal: Enable in-space assembly of large area (>100kW), flexible thin film perovskite solar arrays on flexible substrates for lunar surface habitats.

Strategy:

Develop high efficiency space qualified perovskite solar arrays. Deposition techniques are restricted to in-space compatible methods. Develop a suitable in-space fabrication of perovskites for use on a CubeSat mission.

Agency Need

Lunar surface power is unlike most other space power: the need is for very large areas, significantly reduced cost and ability to fabricate/repair in space. These goals are more readily met by perovskite thin films than by SOA.



Team Overview

GRC Dr. Lyndsey McMillon-Brown (EC) – PI, cell development

Dr. Timothy Peshek (EC) – cell development, EPICC design

Justin Fada (EC) – model based systems engineering

Abigail Rodriguez (EC) – PM and quality assurance

Kurt Sacksteder – Project Mentor

MSFC Ian Small (EC) – design of in-space evaporator

NREL Dr. Mikel van Hest – perovskite ink development

UC-Merced Prof. Sai Ghosh – electrospray perovskite cells

Project Management Innovation: *From Lab to Space*

- Data driven techniques for automated decision making and critical path analysis – real time forecasting of project schedule risks.
- This invokes a novel system for Evolving Project Integration Innovation and Collaboration, or EPIIC
- EPIIC utilizes a model-centric approach – here we develop new data driven, machine learning models for decision making related to technical information
  - Dashboarding allows all stakeholders to instantaneously see project progress, review criteria, risks and technical outputs. Project is always connected to real time data collection
  - A quality management system for data is prescribed to reduce the incidence of non trustworthy or useless data to ensure model accuracy and validation
- Can be used to formalize a Do No Harm payload requirement and couple tailored 7120.5 requirements into the R&D process – training researchers in flight requirements and reducing barriers to go from Lab to Space.

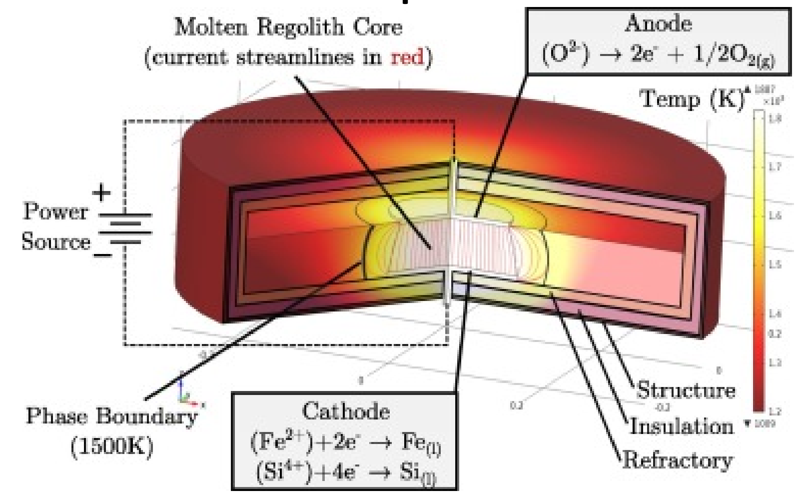
Molten Regolith Electrolysis- Starter Device [KSC]

Goal: Enable lunar oxygen production via electrolysis of molten regolith

- **Problem:** Melting an entire bed of regolith is extremely harmful to the reactor walls and unnecessary when only the volume between electrodes needs to be melted.

Strategy: Develop localized melting technologies to enable minimal viable melting pools of regolith, and demonstrate end-to-end oxygen production from lunar regolith.

Cold-Wall Reactor Concept



Samuel S.Schreiner (2016)

Team Overview

- Dr. Kevin Grossman. (EC) – PI, Materials Engineering
- Elspeth Petersen (EC) – Oxygen Production and analysis
- Jerry Wang (EC) – Simulation and Analysis
- Evan Bell (EC) – Mechanical Engineering
- Jaime Toro Medina – Mechanical Engineering
- Mark Lewis – Systems Engineering
- Dr. Laurent Sibille – Molten Regolith Electrolysis subject Matter Expert
- Dr. Luke Roberson – Project Mentor
- Dr. Anne Meier – Project Mentor

External Partner – Honeybee Robotics , Engineering, rapid prototyping mentors

Project Management Approach

Modified Agile focused on short, interative hardware development cycles in parallel

- 3-month short-term plans

Enables rapid iteration, technical evolution, and team adaptation.

JARVIS (Joint Augmented Reality Visual Informatics System): [JSC]

xEMU Spacesuit Head-In Display Visual Aid to Enable Crew EVA Autonomy

Problem: As NASA extends its stay on the Moon via Artemis crew autonomy will become critical as EVA demands increase. The xEMU Spacesuit defines requirements for a visual display system, however there are no plans by the project to increase TRL beyond the 'state of art' due to the compressed "Boots on Moon by 2024" schedules.

JARVIS is the display & controls of xEMU which will aid EVA, improve crew communication, and enable NASA to innovate optics within the AR technology field -- *a field with a compound annual growth rate (CAGR) of 75% to reach $17.42B by 2025.*

Solution: The JARVIS team will build the xEMU display via design, development and testing of novel optics, AR, user interface, and EVA con-ops solutions. FY20 demo for xEMU PDR. FY21 begin flight qual.

HMD = short eye relief | HID = medium eye relief | HUD = large eye relief

Tech Gaps:

Gap 1) optics solution for heads-in display (HID) hardware a medium eye relief distance in contrast to the small and large eye reliefs associated with head-mounted and head-up displays. Hence the term, "heads-in display".

Gap 2) scope, design, develop con-ops and prototype user interfaces (UIs) to introduce this new agent to the EVA environment, and

Gap 3) integrate hardware into the xEMU suit along with analog testing of UIs in a hybrid reality environment

Personnel:

Paromita Mitra – PI
Briana Krygier – ME Lead
Ricco Aceves – EE Lead
Kristine Davis – Helmet Component Lead
Aly Shehata – SE support
Matthew Noyes – SE Lead
Matthew Miller – Con-ops/UI Dev
Daren Welsh – Mission Ops Lead
Yun Kyung Kim – Human Factors
Skye Raye – Ui/U X Dev
Mentors: Glen Steele (EV), Lui Wang (ER), CB support, xEMU Project Engineer

Approach:

Waterfall requirements + Agile test sprints = Rational Unified Process (RUP)

RUP combines requirements/con-ops development with short sprint human in the loop tests. JARVIS has adopted this adaptive PM style to meet the xEMU requirements process while utilizing sprint-style work to meet a compressed "Boots on the Moon" schedule.

External Partner:

MIT.nano

JARVIS intends to fund an optics/photonics post-doc and utilize state of the art clean room, nano-electronics manufacturing facilities via MIT.nano.

Via an existing SAA, JARVIS will interface on an advisory-level with experts on the Microsoft HoloLens team on AR development.

Extractor for Chemical Analysis of Lipid Biomarkers in Regolith (ExCALiBR) [ARC]

Goal: Prototype automated fluidic system for lipid biomarker analysis that integrates "gold standard" organic solvent-based techniques.

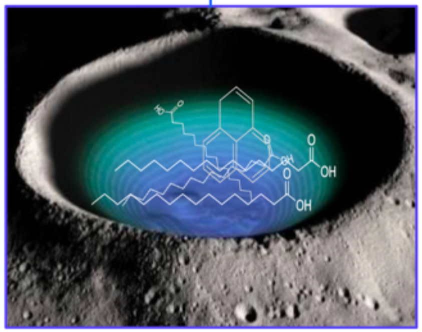
Application:

(1) Lunar volatile-rich regolith to determine potential hazards or resources, abiotic organic content.

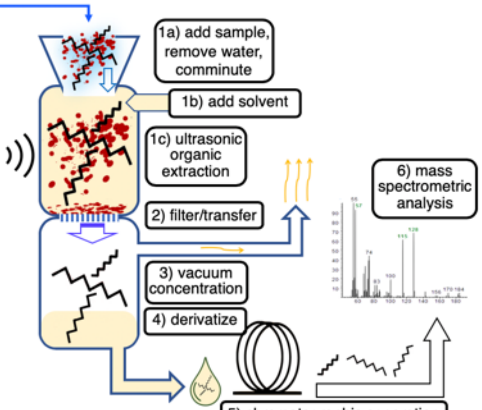
(2) Future life-detection missions to Mars and beyond. Enables optimal analysis of biological or non-biological organic material for in-situ and returned samples.

Tech Development: Maturation of novel fluidic system to extract and concentrate (1000x) lipid biomarkers from planetary analog samples. Automated decision-making chain informs sample processing steps.

ExCALiBR Instrument



Primary Target: Lunar Ices Containing Organics



ExCALiBR Sample Processing Steps

Team Overview

Leverages NASA Ames expertise & heritage:

1. Spaceflight microfluidic systems
2. Analytical biochemists & astrobiologists
3. Machine learning & autonomous science

Composition & Partners:

- *NASA Ames Core Team*: All early career (5), advised by senior members in astrobiology, space fluidics, machine learning.
- *NASA Partner*: Goddard Planetary Environments Lab to provide "dirt to data" demonstration with flight breadboard analytical instrumentation.
- *External Partner*: Shell Global Solutions for biogeochemical input on extraction methods.

NASA SILICON VALLEY
AMES RESEARCH CENTER

NASA Goddard SPACE FLIGHT CENTER

Shell

Project Management Approach

Modified Scrum approach:

- Define requirements & functionalities and select highest priority (science and engineering) tasks.
- 30-day deliverable-producing sprints.
- Daily core team meetings and monthly review with advisors and partners.
- Web-based tools track tasks, facilitate collaboration.

(1) Sprints 1-6 to TRL 3:

Minimally Viable Product (MVP) Free-standing system breadboard-level prototype

(2) Sprints 7-10 to TRL 3+:

Expanded design past MVP

(3) Sprints 11-18 TRL4 :

Iteration on design

(4) Final "dirt to data" demonstration with analytical flight breadboard

A Mobile Frequency-Modulated Continuous-Wave (FMCW) LiDAR System for Lunar Surface Terrain-Mapping and Navigation [MSFC]

ECI Project Lead: Dr. Michael Zanetti (MSFC-ST13) **External Partner:** Torch Technologies

Goal and Technology Development Approach

Goal: Develop velocity-sensing, scanning FMCW-LiDAR technology as a tool for GPS-denied navigation and terrain-mapping in the lunar environment

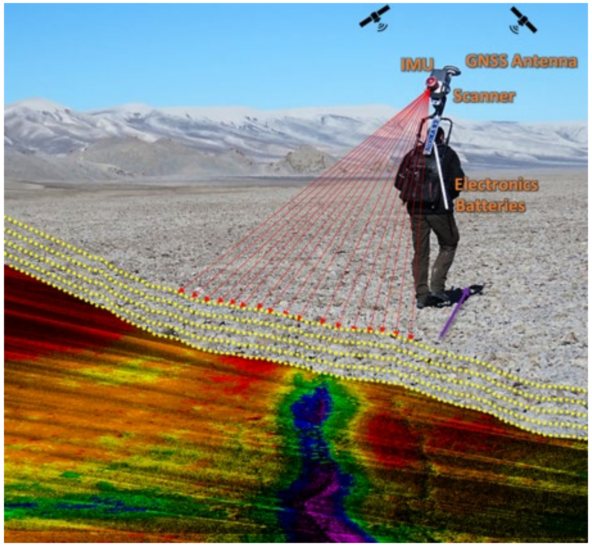
Objective 1: Build a GPS-enabled *Kinematic Navigation and Cartography Knapsack (KNaCK) LiDAR system* as a development test article using COTS FMCW-LiDAR hardware.

Objective 2: Using *KNaCK* test-article, develop position-from-velocity solution and SLAM algorithms to enable GPS-denied (e.g. off-Earth) operation.

Objective 3: Develop FMCW-LiDAR space-implementation roadmap for TRL-5 and validate COTS shielding and component modifications in MSFC's Lunar Environment Test System

Current State-of-the-Art Kinematic LiDAR Scanning requires GPS, but produces incredible results (right: previous PI collaboration with A. Kukko, Finnish Geospatial Research Institute).

KNaCK will use a velocity-sensing FMCW-LiDAR sensor to enable GPS-denied navigation and mapping and produce future results of this nature.



Team Overview:

ECI Core Team	FTE	Responsibilities
Michael Zanetti	0.9	Project management and system design
Bridgette Steiner	0.9	Algorithm and software design
Kyle Miller	0.7	System integration and interface management
Brian DeLeon Santiago	0.75	Lunar environment LiDAR design and testing
Erin Hayward	0.5	Environmental effects testing, LETS operator
NASA Mentoring Team	**0.25**	**Responsibilities**
Todd Holloway		Project Management
Marlyn Terek		Software Systems
Evan Anzalone		Guidance, Navigation, Control
Brandon Phillips		LETS Facility
Larry Petway **(LaRC)**		Laser Remote Sensing
Torch Technologies	**-- / --**	**Responsibilities**
Dr. Brian Robinson		Autonomous vision and trajectory reconstruction
Josh Walters		LiDAR Sensor design, modeling, and integration
Blake Anderton		3D scene and trajectory reconstruction
Dr. Daniel Schumacher		**Mentor:** Agile project management
Dr. Bruce Peters		**Mentor:** Senior Sensor Design

Recent Hires: 2017-2018 Talented Enthusiastic Engaged

Providing mentorship and professional development

Bring technical excellence and vested interest in final product

Torch has a demonstrated track record of LIDAR sensor and software development

Kinematic Navigation and Cartography Knapsack (KNaCK) LiDAR system

Allows for novel Technical and Earth and Planetary Science Research for **Navigation and 3D environment reconstruction** (e.g. terrain mapping or building surveying) and potentially ***Dust motion*** (e.g. rocket exhaust/ejecta plume velocity measurement; Dust-Devils on Mars)

Project Management Approach

Agile Project Management and Model-Based Systems Engineering (MBSE)

- Agile provides the environment for continual iterative improvements and will let us re-prioritize the most valuable/workable solutions. MBSE will let us explore potential hardware solutions

Assemblers

A modular and reconfigurable manipulation system for autonomous in-space assembly [LaRC]

Goal: Assemblers will develop a robust autonomous in-space assembly architecture with advanced error detection and correction capabilities.

Research and develop autonomy methods for improved robustness and reliability:

- Sensor fusion for state estimation
- Motion planning for collaborative manipulation and assembly
- Sensing and machine learning for error detection

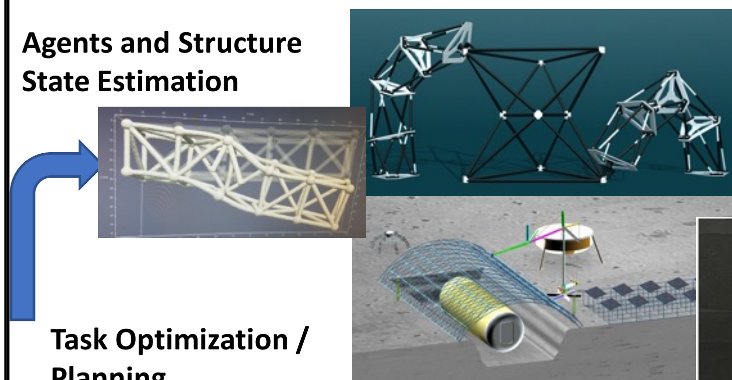
Research, prototype, and **test** assembly system:

- Assemblers modules: i.e. stackable Stewart platforms for high precision payload manipulation
- Task management optimization for heterogeneous multi-agent systems
- Demonstrate surface construction of solar array or other applicable structure as an analogue lunar surface robotic construction task.

Assemblers System Components

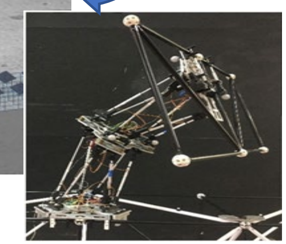
Build / Correct / Modify Plan

Agents and Structure State Estimation



Task Optimization / Planning

Robot Description	Manipulation	Alignment	Locomotion
Manipulator	2	10	5
Jigging Robot	5	2	10
Walker	5	10	2



Stacked Stewart Platform

Core Team Overview

- Jim Neilan (EC) – Project Lead
- John Cooper (EC) – Lead Dynamic Controls and Sensing
- Matt Mahlin (EC) – Mechanical Systems Lead
- Iok Wong (EC) – In-Space Assembly Lead
- Evan Dill (EC) – Sensing and Assurance Lead

External Partner

- Virginia Tech – Dr. Erik Komendera, FASER Lab lead. Collaborate in the design, test, and analysis of methods for scheduling, error detection, correction, state estimation, and optimal assembly
- Honeybee Robotics – Micheal Maksymuk, Project leader, will supply strut attachment system and consulting.

Project Management Approach

GO LIVE EXPLORE

Scrum framework for Agile Project Management:

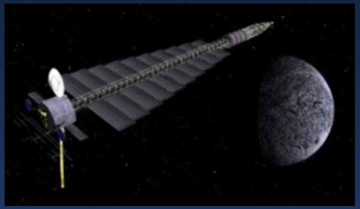
- 2 week Sprints cycles
- 2 Partner tags -ups per month
- 3-4 month iterative project scheduling with 12 and 24 month master schedule and milestones
- Monthly TIMs, technology deep dive for team education, and mentor review/coaching.
- Scrum framework enables rapid iteration, technical evolution, and team adaptation to project demands

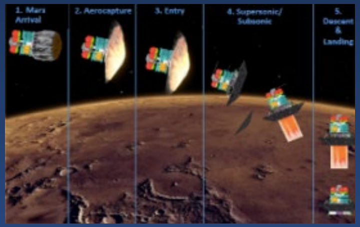
Early Career Initiative Summary

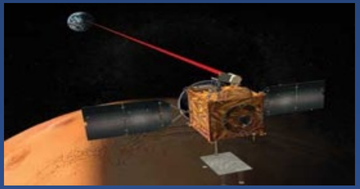
- PI Feedback: “Great opportunity!” “Huge learning experience.” “Very helpful even going through the proposal process.”
- Every proposer gets a feedback session to help with future proposals
- High percentage of ECI technologies have continued development
- Diverse projects and diverse Principal Investigators
- Future: Enough new project management techniques will have been utilized in order to show that they can be recommended for adaptation in other Programs. Probable infusion path would be a paper and potentially a NASA PM Challenge presentation.

Key Technology Focus Areas

- ❖ Advanced environmental control and life support systems and In-Situ Resource Utilization
- ❖ Power and propulsion technologies
- ❖ Advanced communications, navigation and avionics
- ❖ In-space manufacturing and on-orbit assembly
- ❖ Advanced materials
- ❖ Entry, Descent and Landing
- ❖ Autonomous operations
- ❖ Research to enable humans to safely and effectively operate in various space environments





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