National Aeronautics and Space Administration

Design and Application of Tethered Spacecraft Simulators

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NASA Marshall Space Flight Center

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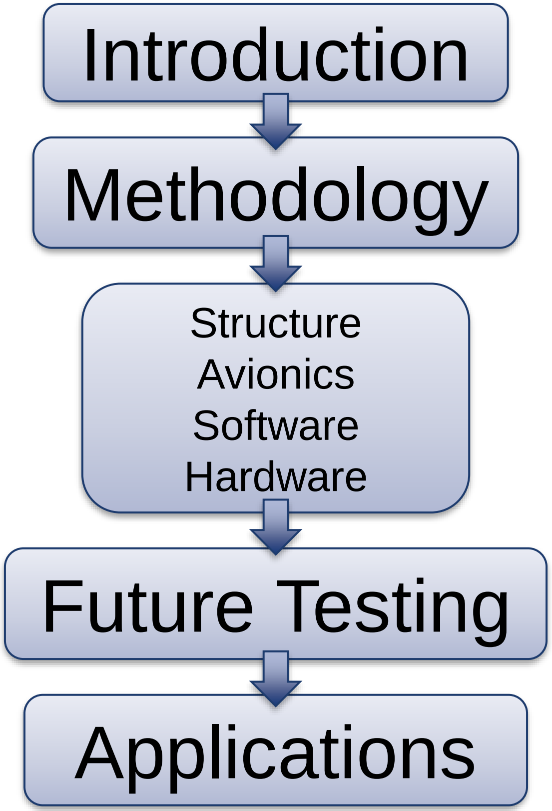
EXPLORE
MARSHALL

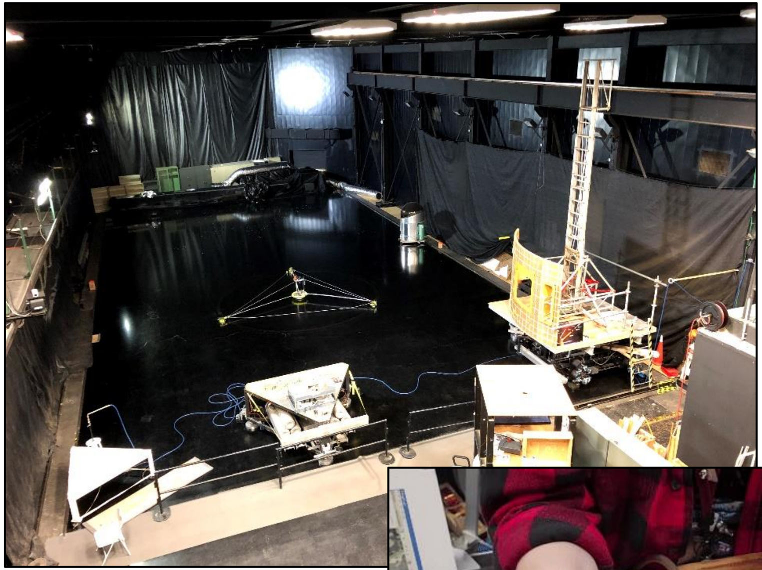
Overview


Introduction
Methodology
Structure
Avionics
Software
Hardware
Future Testing
Applications

Introduction

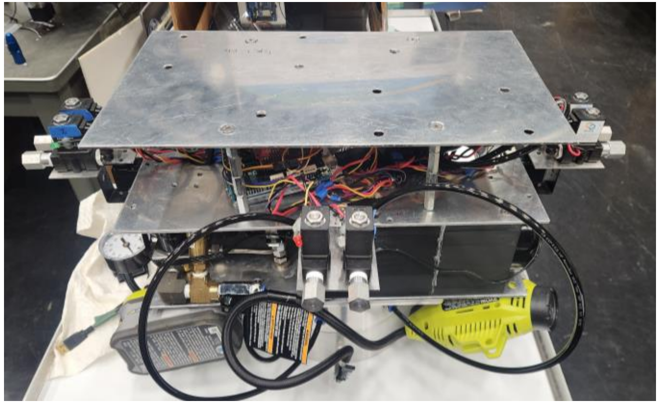
- NASA history of tethered spacecraft development going back to 1966
- Small tethered spacecraft have several key applications for space operations
  - Small vehicles that can be deployed from larger spacecraft, and reeled back in on a mechanical tether after performing required tasks

- 44 x 86-foot air bearing epoxy floor
- Bearings float on the floor with minimal friction
- Air bearing platforms and spacecraft simulators of varying size



Spherical air bearings allow up to 5 degrees of freedom

Introduction – Flat Floor Robotics Laboratory (FFRL)



- Small spacecraft simulators (‘microbases’) needed to match shrinking size of spacecraft/CubeSats

- **Maneuverable Autonomous Tethered Spacecraft (MATS) –** next generation of small simulators in the FFRL

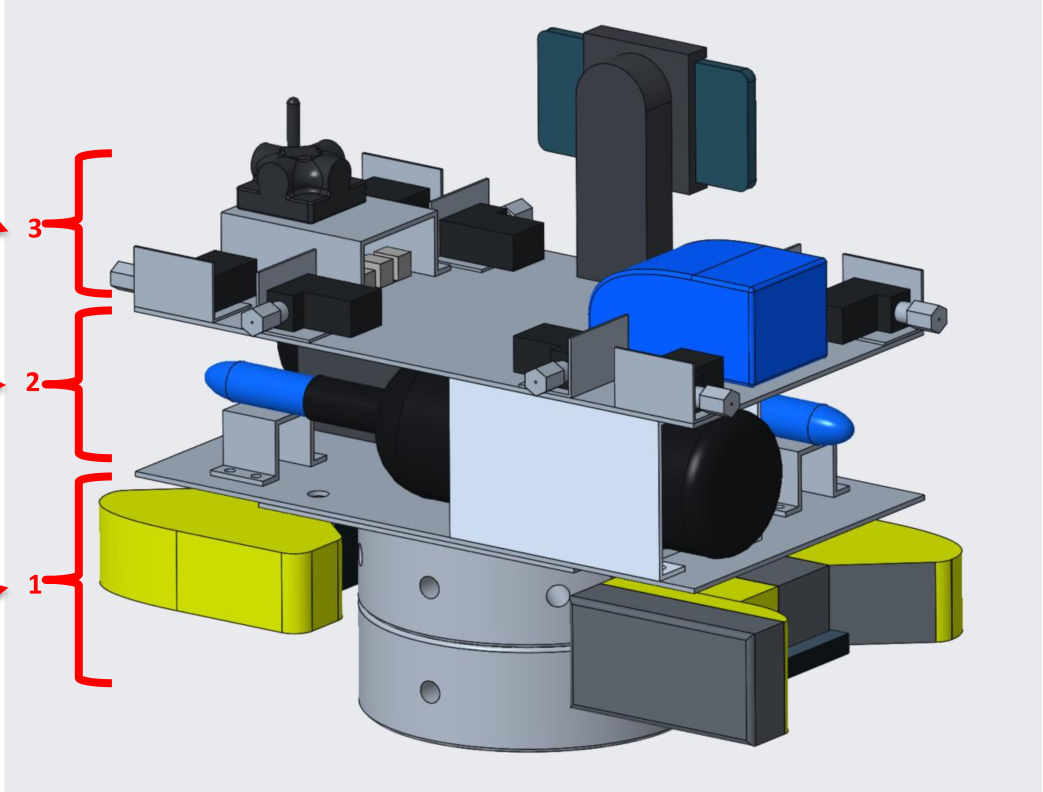
Introduction – Small Spacecraft Simulators

MATS Methodology – Structure

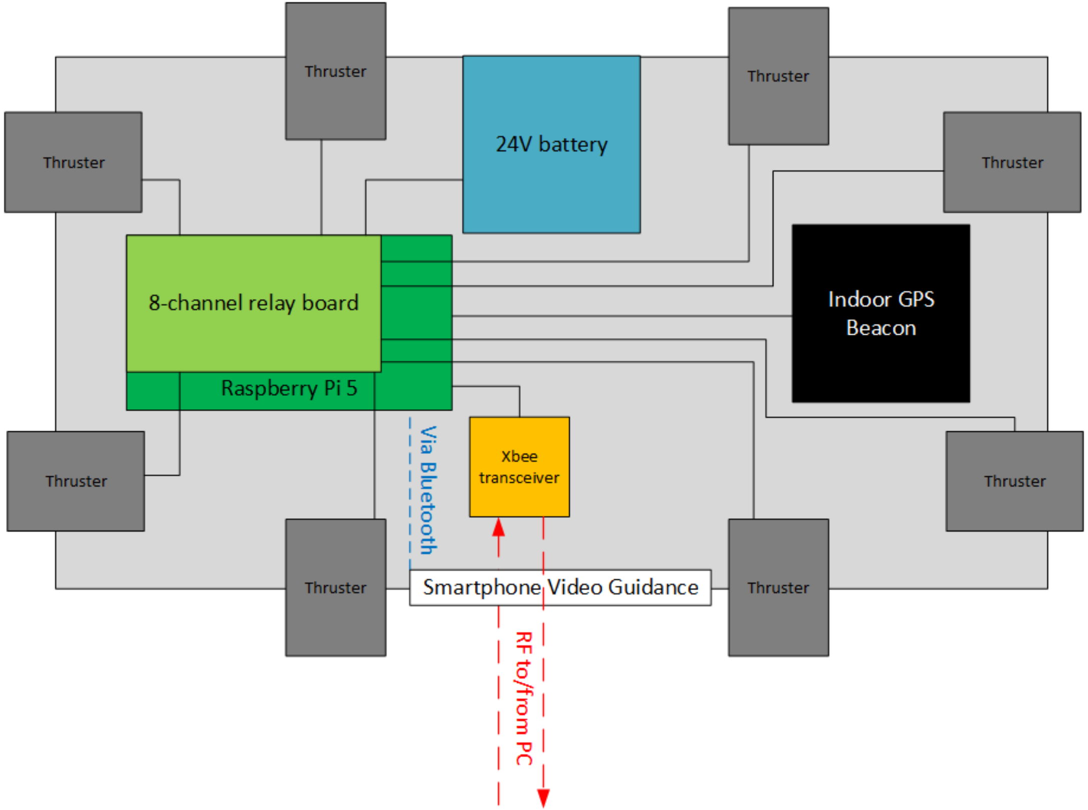
Electronics Deck
Houses thrusters, battery, avionics

Pneumatic Deck
High Purity Air (HPA) system for thrusters

Air Bearing Deck
Air bearing/plenum platform, battery powered pumps to float bearing



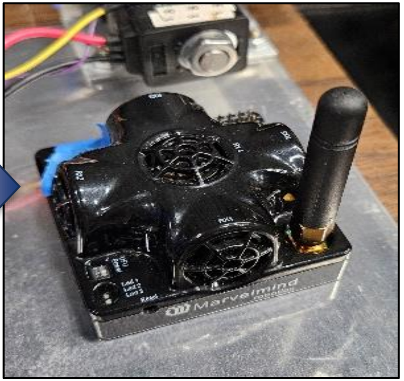
- Raspberry Pi 5
- 24V battery with 5V USB powers Raspberry Pi 5 and 8x thrusters
- Digi XBee Zigbee 3.0 module communicates with ground station PC

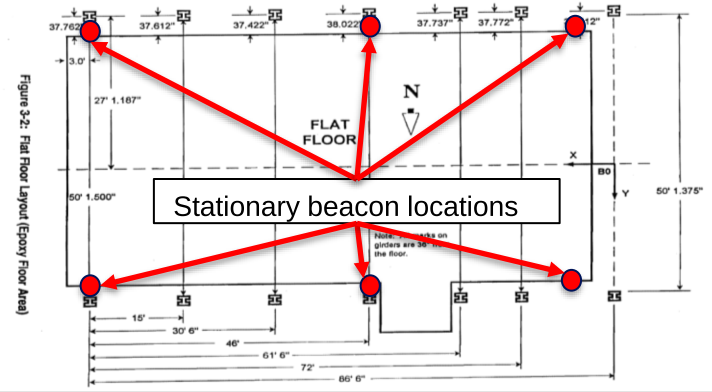


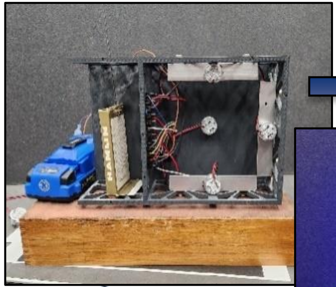
MATS Methodology – Avionics

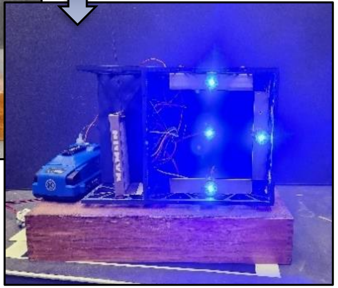
Indoor GPS

- Marvelmind Robotics
- Ultrasonic beacons used to build submap that can locate mobile beacons within +/- 2cm









Smart Video Guidance Sensor (SVGS)

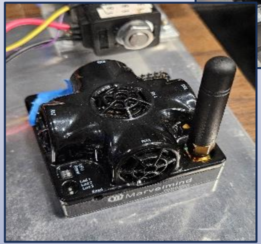
- Smartphone camera captures blue LED target
- NASA-developed Android app uses collinearity equations to determine relative position and attitude

MATS Methodology – Avionics

MATS Methodology – Software

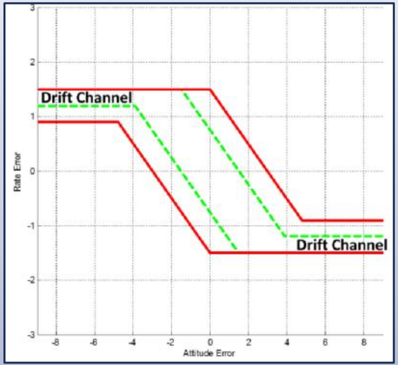
Navigation

- Indoor GPS
- SVGS



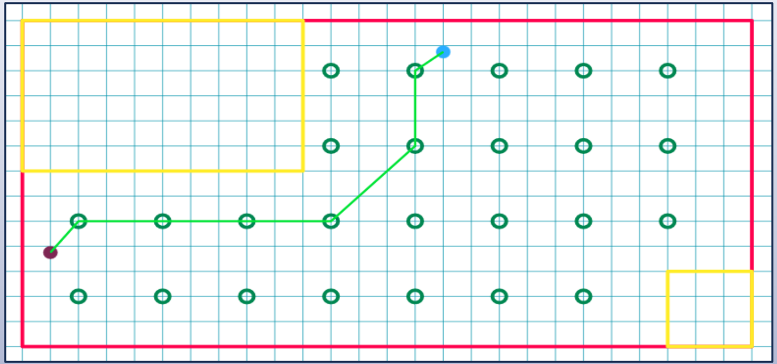
Control

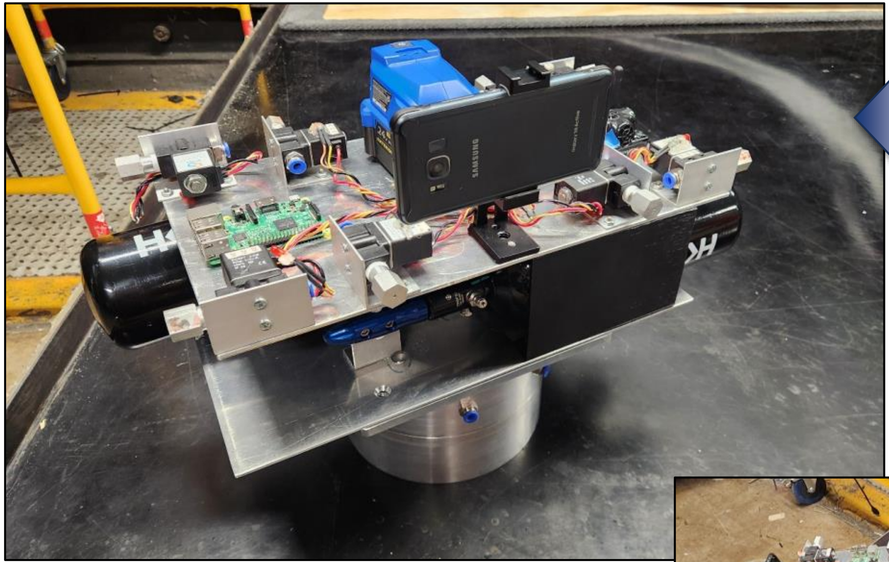
- Phase plane controller
- Tuned to account for speed limitations



Guidance

- Path creation & path following
- A* and Nearest Node algorithm





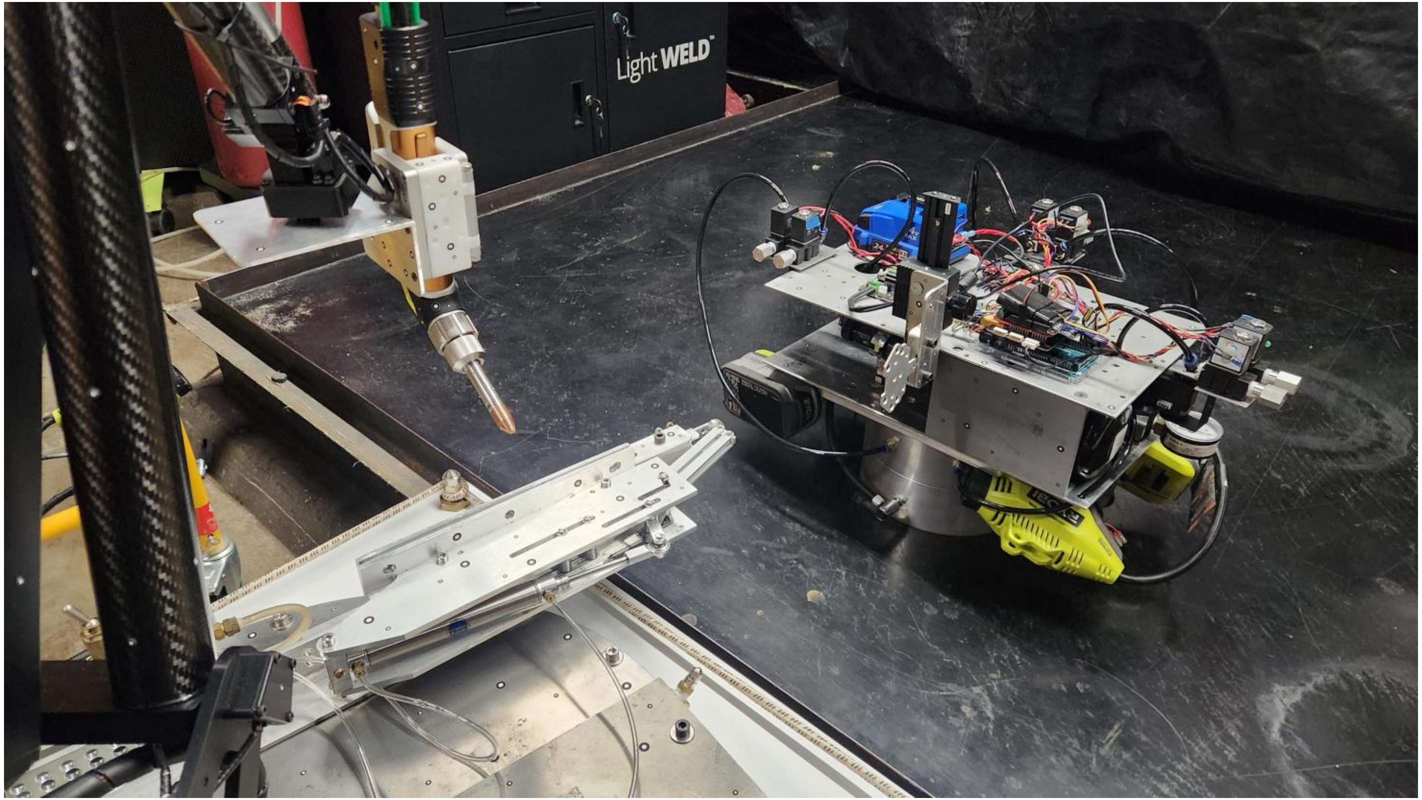
Constructed MATS simulator hardware

Tether mechanism with flexible boom

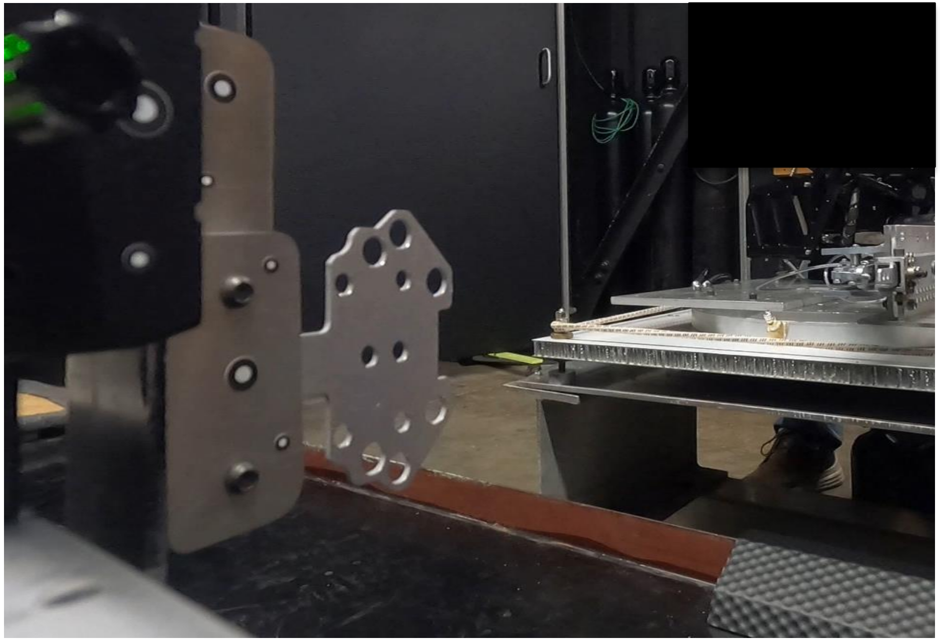
MATS Hardware

MATS Next Steps/Testing

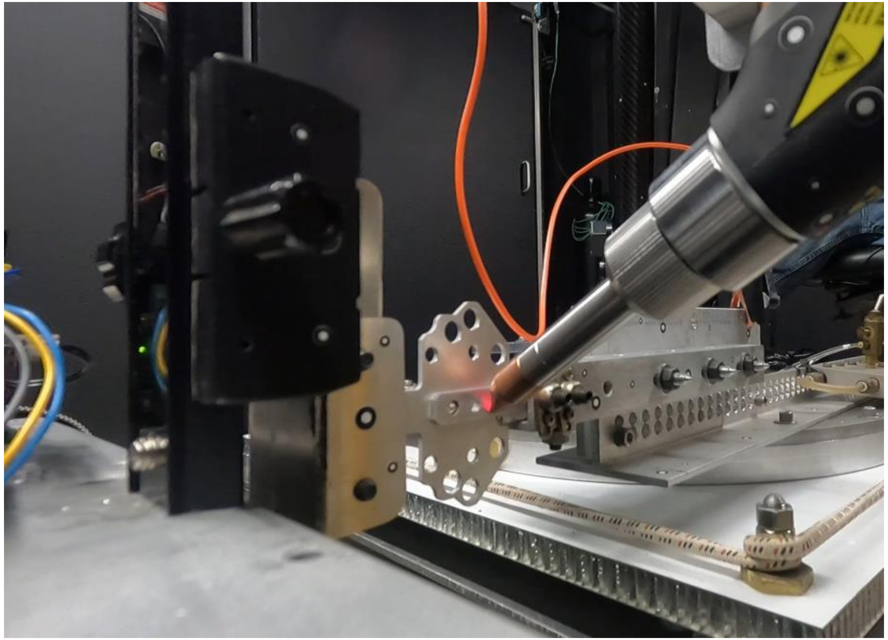
- Simulink model adapted to Python
- Avionics integration
- GNC algorithm refinement
- Performance testing
- Documentation, iteration



Applications – In-Space Servicing/Assembly/Manufacturing

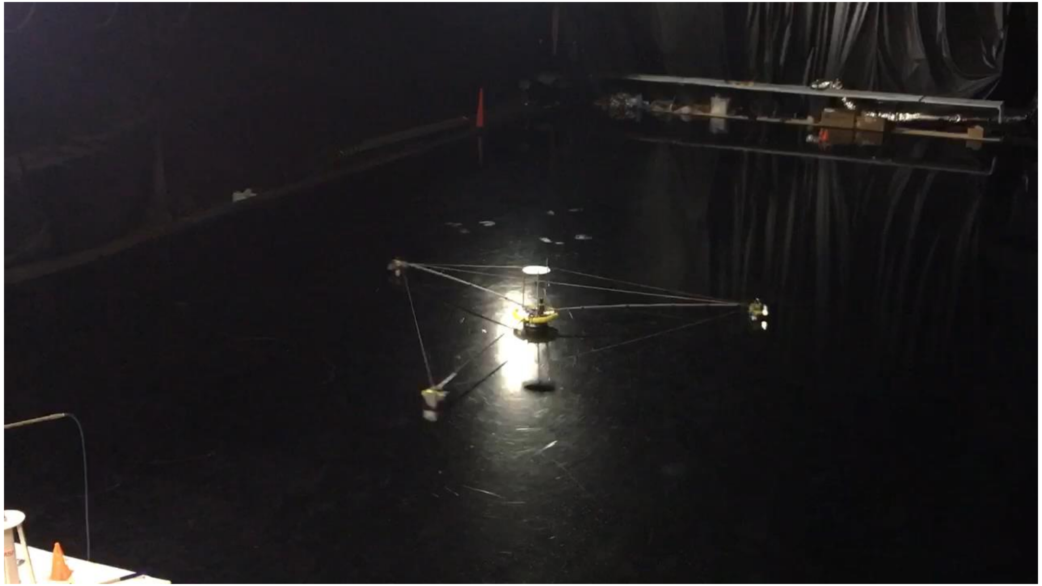


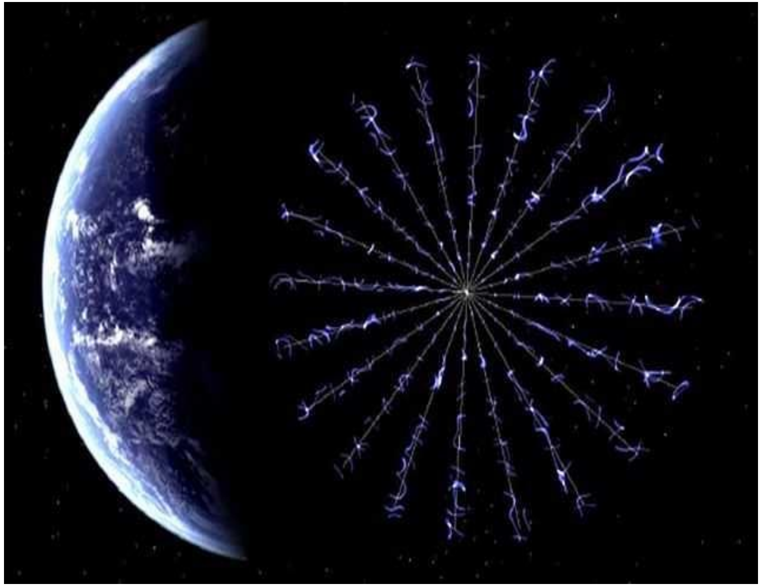
Approach/position



Weld

Applications – In-Space Servicing/Assembly/Manufacturing





- Electric Sail (E-Sail) concept requires deployment and positioning of km-long, conductive tethers
- Tethered spacecraft simulators on flat floor enables testbed for controls development

Applications – Electric Sail Deployment

- This project is funded by the Marshall Space Flight Center (MSFC) Technology Investment Program (TIP)
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Acknowledgements

Thank you!

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