Space-Based Robotic Truss Construction

Two Sentence Elevator Pitch:
Students on the Northrop Grumman team will develop a robotic arm for assembling beams to create trusses for a roll out solar panel. Additionally, the students must demonstrate that such an assembly method could be accomplished in zero-g by developing a mass-balance simulator to assemble up to a 3m truss section.

Abstract:
With NASA's new timeline for returning humans to the Lunar surface by 2024, new mapping data is needed for safe expeditions. Apollo 11 suffered from mapping resolutions that did not adequately provide information on the boulder field, causing a manual takeover to fly to a safe location. The current state of the art radar resolution for the Moon is approximately 30 m/pixel, far above the threshold for collision avoidance from features such as boulders. To enable a closed loop navigation and collision avoidance guidance system, radar resolutions at or better than 0.5 m/pixel must be acquired. A barrier to this resolution is the power required for the radar mapper (approximately 6kW). Sending this on a rideshare to Lunar orbit means that the spacecraft must fit in an ESPA-Grande bus. In this project, students will utilize space based manufacturing and assembly technologies that Northrop Grumman Corporation is developing in partnership with Made in Space to design a spacecraft assembly method that minimizes for delivered mass to Low Lunar Orbit (LLO). The students will develop the robotic arm for assembling beams to create trusses for a roll out solar panel.

Additionally, the students must demonstrate that such an assembly method could be accomplished in zero-g by developing a mass-balance simulator to assemble up to a 3m truss section. The robotic arm must fit within a 60 cm x 60 cm x 60 cm box and account for operation in zero-g. As an initial goal, the students must demonstrate that they can repeatedly assemble a 1m truss (in their zero-g mass balance simulator) before graduating to a 3m truss section. The spacecraft where this robotic arm would be applied must be able to autonomously construct necessary trusses/structures and deploy instruments and/or solar panels as necessary. It is anticipated that the robotic arm will need to be a 2-3DOF (degrees of freedom) system to accomplish the assembly of pre-fabricated trusses. Students will design, build, and operate this robotic system either through human in the loop or machine vision such as ArUco markers with Open CV. Additionally; the robotic arm must simulate operation in zero-g.

Scope:

Minimum Viable Product Deliverable (Minimum level of success)

- An operational 2-3DOF robotic arm that can be packaged into a 2ft x 2ft x 2ft box.
- Control software for a 2-3DOF robotic arm.
- Pre-fabricated trusses that are representative of a geometry for deployment of a flexible solar array.
- A mass balance simulator for the trusses and robotic arm that balances for 2 DOF.
- Demonstrated robotic assembly of a 1-meter truss.
- Demonstration merits a TRL 4 rating.

Expected Final Deliverable (Expected level of success)

- Machine vision automated assembly using ArUco tags or similar.
- Design and assembly of a zero-g mass balance simulator for 3DOF.
- Fabricated expandable truss segments that can be assembled together to reduce launch payload volume.
- Validate the system on a 3m truss section.

Stretch Goal Opportunities (High level of success - May include one or more of the following)

- Automated assembly of a 3 meter truss.
- An operational 3DOF robotic arm that can redeploy itself on multiple interfaces on a spacecraft.
- Demonstrated operation in a thermal-vac environment.
- Space hardened hardware identified and implemented for all systems and sub-systems
- Demonstration merits a TRL 6 rating.

Student Skills:

MDP Sponsored Projects are both a professional and academic learning experience for students. By participating in this program, students are actively preparing for graduate school and a professional career. As part of the experience, MDP expects professional behavior. To best prepare you for future professional opportunities, your experiences on this MDP team will be very broad. In addition to key technical skills that you will bring to the team, you will engage deeply in the self-directed learning of new and important concepts, demonstrate flexibility, collaboration, and cooperation, and develop strong professional communication skills. This also means that you will need to be able to work outside of your traditional area of study in the true multidisciplinary nature of our projects. You won't always be able to anticipate how your skills and expertise will be used, so the MDP Sponsored Project will challenge you to grow and develop as a professional.

Project Area	Specific Skills	Likely Majors
Mechanical Design (3-4 students)	Innovative Design, Fast Prototyping	MECHENG ROB Space
Embedded Systems (1-2 students)	Integration circuitry, intermediate processing requirements, data storage	CE EE

Machine Vision (1-2 students)	Applied Machine vision skills / willing to learn	EECS ROB or skills/experience
Advanced Robotics (1 student)	Robotic Arm Design Experience	ROB MECHENG SPACE

Additional Desired Skills/Knowledge/Experience

Any of the following Skills, Knowledge, Experience, Interest or Outlook, would be valuable to the 2020 team. We don't expect students to be familiar all or even most of the technical items, but strong candidates will have familiarity or experience with *some* of them and a positive attitude to learn what is necessary as the project gets underway. Please highlight your experience with any of the items on this list in your personal statement on the application.

- Passion for space exploration and research.
- Intellectual Creativity. Interest in technology development.
- Excellent "hands-on" team working skills.
- The challenge of problem solving with unclear set of requirements.
- Experience developing a research inquiry
- Experience with team based design
- Robotics experience
- Maker-space, Fabrication, Fast Prototyping experience

Location:

Meetings and work will take place on campus.

Sponsor Mentor:

Dr. Anthony J. DeCicco
Systems Engineer

Dr. Anthony DeCicco works on transformative space technology programs within the Northrop Grumman Corporation (NGC). Anthony joined NGC after receiving his Ph.D. in Aerospace Engineering from the University of Maryland under the NASA Space Technology Research Fellowship. Anthony has experience in research-driven work environments working at MIT-Lincoln Labs and NASA on programs in additive manufacturing, composites, material survivability, and advanced propulsion technologies. At NGC, he is a Systems Engineer in the Future Technology Leaders program and works on human spaceflight systems. Anthony received his Bachelor's and Master's degrees in Mechanical Engineering in 2014 from Worcester Polytechnic Institute and his Ph.D. in Aerospace Engineering in 2018 from the University of Maryland.

Executive Mentor:

Andy Kwas,
Tech Fellow/Engineering Systems Architect

Andrew Kwas graduated from the University of Michigan in 1980 with a Masters degree in Aerospace Engineering. He has 38 years with TRW/NGC working in advanced projects specializing in logistics, astrophysics projects and weapon system developments. In Mr. Kwas' role as a manager in Engineering and Technology reporting to our Sector Corporate Technology Officer, he supports NASA, AFRL, NRO, DARPA, SMDC, ORSO and the Navy in high tech programs. Mr. Kwas is on the Technical Advisory Board for Cornell, U Michigan, Virginia Tech, Georgia Tech and U New Mexico. He is considered one of the prominent additive manufacturing (AM) experts in the country and has produced numerous papers in AM, advanced satellite technology, unique logistics solutions, and miniaturization of components. Mr. Kwas is an appointed Research Scholar at the University of New Mexico.

Faculty Mentor

Amy Hortop
Experiential Learning Coordinator, Integrative Systems + Design

Hortop earned her B.S. in Mechanical Engineering from Michigan Technological University and her M.S. in Mechanical Engineering from Rochester Institute of Technology. Her industry experience has primarily been in the automotive field, both here and in Germany. Most recently, she had taught in Mechanical Engineering as the ME 450 (Capstone Design) coordinator, and now coordinates the Capstone course in Integrative Systems + Design (ISD 503). Amy has previously mentored MDP projects.

Legal Requirements:

Citizenship Requirements:

- Student team members must have authorization to work in the United States without restriction in ITAR location.

Intellectual Property Agreements / Non-Disclosure Agreements

- Student team members will sign IP/NDA document(s) that are unique to Northrop Grumman.

Summer Project Activities

- No summer activity will take place on the project.

Company Information:

At Northrop Grumman, our work with cutting-edge technology is driven by something human: the lives our technology protects. It's not the systems that drive us: it's the soldier our systems bring

home. It's not just the equipment that motivates us: it's the people our equipment protects. It's not the innovation that gets us up in the morning: it's whom those innovations serve. We're united by our work to help people. And that mission makes our team even stronger.

When you work with Northrop Grumman, you'll have the opportunity to connect with coworkers in an environment that's uniquely caring, diverse, and respectful. Employees share experiences, insights, perspectives, and creative solutions with some of the best minds in the industry. We collaborate through integrated product teams, cross-functional teams, and employee resource groups, while thriving through the support of training, mentors, and extensive benefits.

Wherever we work in the company and whatever our role, we're united by our mission to protect the world. And no matter how innovative our technology, we think that united front is the most impressive thing of all.

Our top level qualifications include:

- Leading global security company
- $45 billion sales in 2018
- Leading capabilities in:
  - Space products
  - Cyber
  - Logistics
  - Autonomous Systems
  - C4ISR
  - Strike