3D Printing on Mars

Description of Project

Applications of additive manufacturing (AM) are advancing at an astounding pace. Northrop Grumman Corporation (NGC) is already engaged in printing articles in space. Printing in space saves considerable money over building the articles on Earth. The printed structural mass can be lighter and larger as it does not need to survive launch loads. However, even sending compact raw materials into space for printing is costly. The most efficient way to print away from Earth is to obtain a significant amount of the materials from the planet, moon, or asteroid that the printer resides on. The desire is to bypass shipping raw materials to a remote body and mine the needed resources from the local terrain.

Though space based systems are under development by Industry, such as NGC and Made in Space Inc, the ability to develop a machine that is functional in non-terrestrial locations is not trivial due to the different environments experienced in space vs Earth. In related work, NASA and others, are investigating using regolith materials to print building blocks that resemble adobe bricks. This MDP is not intended to build regolith-based structures, but to build highly refined and more complex objects, utilizing the material available in the environment.

Mars rovers and satellites have identified locations of potential natural resources which contain the right raw materials and elements that make up the same products that we feed into our printers here on Earth- both metallic and silicaceous. This project will leverage off the 2018 MDP and NGC on the subject and assess the challenges associated with mining candidate materials. This will support the goal of designing a future lander with an on-board, autonomous AM fabrication facility.

The student team investigation will begin with a review of the NGC-provided candidate materials available in Martian regolith. They will draw upon the 2018 MDP’s assessment of the capability of 3D printing technologies and the most beneficial types of fabricated objects. The student team will deliver the user requirements for a range of the provided materials suitable for printing from those present in the Mars regolith and a prototyped separation/purification process for at least one of the materials demonstrating the feasibility of separation/purification of the material(s) to a state suitable for printing. Reagents and additional equipment could be included, but the ideal solution will minimize the additional materials/equipment required for transport to Mars. The non-Earth operational conditions of this prototype (gravity, wind, humidity, temperature ranges, etc.) will complicate both the design and testing steps of the process. The team will then print test articles with their material and determine basic printed material properties.
Phase I (Base Level Goal, end of first term)

Deliver initial analytic results evaluating the potential feasibility of various separations/purification methods. With mentor’s input on raw materials, prioritize the options identified for a separation/purification. Determine appropriate printing test cases and develop requirements for printed output. Determine the feasibility/control limits of printing with varying purity of feed stocks. Complete first rough end-to-end prototype process construction.

Phase II (Target Goal, end of project)

Deliver a refined separation/purification process for the chosen material(s) that has been validated against the original user requirements. Validate the quality of the printed output under operating purity delivered by the separation/purification process. Final report will include recommendations on any necessary refinements.

Long Term Stretch Goals (one or more of the following)

1. Investigate different regolith compositions and environmental (gravity, temperature, etc.) considerations.
2. Identify regions on Mars suitable for resource acquisition and a permanent base.

Location

During the academic term work will take place on campus in the Chemistry department’s analytic lab and in student work spaces on north campus. The final report will be presented to senior-level technical managers from NGC and NASA.

Project Faculty Mentor

Prof. Stephen Maldonado
Chemistry

Prof. Maldonado’s research focuses on understanding, designing, and developing more efficient electrode surfaces for systems based on interfacial charge transfer. His work spans inorganic, analytical, and materials science themes, with emphases on solar energy technologies and semiconductor syntheses.
**Project Sponsor Mentor**

Dr. Anthony J. DeCicco

Anthony joined Northrop Grumman Corporation (NGC) after receiving a Ph.D. in Aerospace Engineering from the University of Maryland. His research focused on a novel asteroid deflection method that controls both the rotational and orbital motion. This enables moving asteroids to orbits suitable for mining. At NGC, he is a Systems Engineer in the Future Technology Leaders program and works on range of near and long-term AM applications.

Evan Tomita

Evan joined Northrop Grumman Corporation (NGC) after receiving a BSE in Industrial and Operations Engineering from the University of Michigan. While working at NGC, he has been involved in the Professional Development Program and has worked primarily in the Technology Services Sector as a Quality Systems Engineer. As a Systems Engineer, he was worked on a variety of programs and projects ranging from quality engineering and process improvement to web development and additive manufacturing.

**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. He Mr. Kwas is an appointed Research Scholar at the University of New Mexico.
Key Skills & Project Roles

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 will not 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.

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<tr>
<th>Project Roles</th>
<th>Key Skills and/or Knowledge</th>
<th>Likely Majors</th>
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<tbody>
<tr>
<td>Chemistry (3 or 4 Students)</td>
<td>Inorganic, materials, and analytical chemistry.</td>
<td>Chemistry, Materials Science, Chemical Engineering, Geology</td>
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<tr>
<td>Process Development (2 Students)</td>
<td>Bulk processing, mining techniques, material separation, equipment development</td>
<td>Chemical Engineering, Material Science,</td>
</tr>
<tr>
<td>Mechanical Design (1 or 2 Students)</td>
<td>Mechanical Design, Manufacturing Process Equipment, mechatronics</td>
<td>Mechanical Engineering</td>
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Additional Desired Skills/Knowledge/Experience

Any of the following Skills, Knowledge or Experience would be valuable to the 2019 team. We don’t expect students to be familiar all or even most of these 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 Additive Manufacturing techniques and equipment
Company Overview

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

Legal Requirements

Citizenship and Right to Work:

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

Intellectual Property Agreements / Non-Disclosure Agreements

• All student team members must sign the IP/NDA to Northrup Grumman Corporation
Internship Information

Internships may be available to student team members. Information will be available at a later date.