Novel Mini-Grant Program to Broaden Participation of Faculty and Students at an MSI with NASA's Artemis Mission

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Abstract

NASA-MSTAR program has selected the three-year proposal titled "DREAM: Developing Robotic Explorations with Agrobots and Moonbots" at the University of Maryland Eastern Shore(UMES) as one of the nine recipients of their PHASE-III awards in September 2023. The MSTAR is an amalgamation of two acronyms the 'M' stands for 'Minority University Research and Education Program (MUREP) and the STAR can be expanded as 'Space Technology Artemis Research'. The broad goals for the NASA Artemis mission include landing the first woman and first person of color on the Moon as well as establishing long-term human presence on the Moon. The overarching goals of the funded project at UMES include (i) engaging UMES and non-MSI partner students in experiential and research efforts involving lunar rovers for exploration and autonomous navigation, (ii)preliminary trials with growing plants using robotic platforms in lunar regolith in controlled indoor environments, and (iii) broadly engage the UMES campus community through curriculum integration and innovative projects aligned with the long term vision of the NASA Artemis project.

In alignment with the scope of the 3rd objective listed above the UMES project leaders have incorporated an innovative mini-grant program that solicits proposals that will address any aspect of NASA's Artemis project from UMES faculty and student teams from all disciplines in late fall. Two of these mini-proposals will be selected for funding to be implemented in the spring semester annually for the duration of the project (2023-2026). This paper will highlight the implementation, impact, student engagement, and achievements of the two mini-grants that were selected for the first year of the funding cycle**.**

1.0 Introduction

The Artemis program, led by NASA, aims to return humans to the Moon and establish a sustainable presence there by the late 2020s and early 2030s and lay the foundation for future missions to Mars. "Artemis" is the Greek goddess of the Moon, and the twin sister of "Apollo". As we all know the Apollo program was NASA's first major human space exploration initiative, culminating in the historic landing of humans on the Moon on July 20, 1969. By naming the mission after Artemis, NASA emphasizes the involvement of women and underrepresented groups in space exploration. Artemis-I has tested NASA's new Space Launch System (SLS) and the Orion spacecraft for a lunar flyby in preparation for a crewed mission in Artemis II that will follow soon. Artemis-III has the goal of landing the first woman and the first man of color on the Moon, (specifically near the south pole of the Moon) and initiating the setup of infrastructure for long-term human presence on the lunar surface. Artemis IV will build upon the foundation to establish a lunar gateway to facilitate future space missions to Mars and beyond.

The NASA MUREP Space Technology Artemis Research (M-STAR) program aims to increase the involvement of minority-serving institutions in the development of space technologies that will support NASA's Artemis program and help diversify NASA's workforce. M-STAR emphasizes hands-on experience, mentorship, and professional growth for students and faculty at historically underrepresented institutions in the STEM fields in general and the aerospace sector in particular.

The DREAM (Developing Robotic Explorations with AgroBots and MoonBots) project at UMES draws inspiration from NASA's Space Technology Mission Directorate (STMD) objectives and strategic thrust areas under the overarching paradigm of *Go, Land, Live, and Explore* in alignment with the Artemis program. Interdisciplinary research efforts are underway at UMES in collaboration with UMD in addressing MoonBot exploration [1, 2] and AgroBot driven plant growth trials in regolith simulants [3] by the core project team. An innovative component incorporated in the DREAM project is the "Mini-Grant" program that provides a vehicle for engaging a broader base of the faculty, students, and the overall campus community at UMES with relevant aspects of NASA's Artemis endeavor through semester-long initiatives (Spring) by way of course integration and/or enrichment activities. Appendix (a) provides a sample call for proposals for the Mini-Grant solicitation. All faculty at UMES are invited to form teams with two students selected by them and submit a proposal to the project collaborator at UMD who serves as the evaluator towards the end of the fall semester. The evaluator selects two of the submissions and informs the UMES PI and Co-PI. The Mini-Grant faculty leads are informed during the winter session in January and instructed to initiate efforts at the start of the spring semester. The Mini-Grant project teams are required to give two online presentations of their efforts in the middle and end of the spring semester and submit a final report by the beginning of the summer.

The following sections of the paper highlight the scope and accomplishments of the two mini-grants titled: (i) *Extravehicular Activity Smart Toolset for Planetary Surface Field Geology Exploration*, and (ii) *Incorporate the topics of distinct chemical properties of lunar soil and detection of its various elements into Chem 422/622 Bio-Inorganic Chemistry and Chem 420/620 Advanced Inorganic Chemistry courses*; that were supported by the DREAM project funds in the inaugural year of the project.

The mini-grant awards were awarded in early January and the proposed efforts commenced in early spring and were executed throughout the semester. The awardees presented the progress of their work online to the NASA MSTAR activity managers, Maryland Space Grant directors, and the DREAM project leaders at UMES and UMD in March. Final presentations were scheduled at the end of the semester. The mini-grant project leads were required to submit a final report by early June (see Appendix a).

2.0 Overview (Mini Grant-1)

An engineering faculty member teamed up with two undergraduate students to work on the mini-grant related to *"EVA Smart Toolset for Planetary Surface Field Geology Exploration".* An additional third student also volunteered to participate in the efforts from its inception to design and test a new smart toolset for lunar surface geology exploration. The goal was to give the students the experience of creating a tool that could efficiently collect, analyze, and catalog lunar samples, with a long-term mission of identifying potential water deposits. The toolset, consisting of a spring-activated scoop and a wheeled camera-and-scale system, was developed to potentially improve the efficiency and reduce the physical strain on astronauts compared to Apollo-era tools. Rigorous testing, including biomonitoring of operators, demonstrated significant improvements in speed and energy usage. The project resulted in a proceedings publication and presentation at the International Astronautical Congress [4]. Future work will focus on creating a flight-ready version and further analysis of collected biometric data.

To create a realistic testing environment for the EVA tools the team built a 12 ft x 6 ft x 2 in lunar yard with variable topography and a light source mimicking lunar sunlight in the High Bay area in the engineering building. The yard could be reconfigured to add craters, inclines, and hard/soft surfaces and be used for rover testing, gravity offset systems, and other applications besides EVA testing. The light source included in the setup could simulate sunlight and shadows during the lunar day, and the High Bay lights could be turned off to simulate complete darkness akin to lunar night.

Figure 1: . The Lunar Yard: fully lit with High Bay lights (left), and only lit by the simulated sunlight resulting in cast shadows (right).

The team tested the rock collection with different toolsets including tools they designed, tools that were similar to Apollo-era tools (such as rakes and angled shovels/scoops), as well as a commercial off-the-shelf grabber tool. The team observed that, on average, the grabber tool was twice as fast as the rake and was lighter, shorter, and required less energy to operate compared to the more traditional lunar tools.

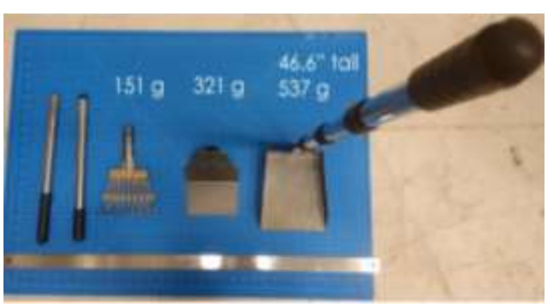

Figure 2: Classical Tools (COTS)

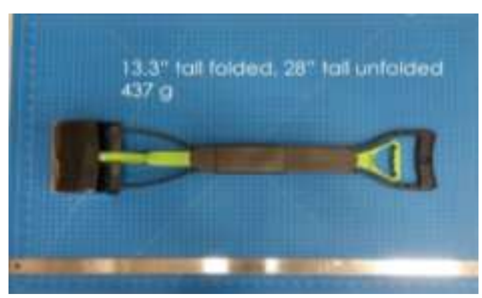

Figure 3: Grabber Tool (COTS)

The project team also used a BioPac System (https://www.biopac.com/) to measure the activity of the operator's dominant hand using EMG and a grip force sensor and Hexoskin Smart Shirt (https://hexoskin.com/) to monitor heart rate as well as, breathing volume and rate, and body motion. These biomonitoring systems allowed the team to perform a basic analysis of the physiological effort and strain associated with tool usage. The project lead also arranged for a real intravehicular activity (IVA) spacesuit to expose students to challenges with visibility, restricted movement, and the impact of pressure on comfort and motion while in the spacesuit. Interested readers can find additional details in reference [4].

3.0 Overview (Mini-Grant 2)

The 2nd Mini Grant proposal selected for funding by the DREAM project was submitted by a Chemistry professor at UMES. She teamed up with two undergraduate female students and their focus was on incorporating *NASA's Artemis related theme into CHEM 422/622 Bio-Inorganic Chemistry classes*.

In the spring 2024 offering of the Chem 422/622 Bio-Inorganic Chemistry courses concepts of special chemical properties of lunar soil and detection of its various elements were incorporated. The lectures focused mainly on various elements that exist in lunar surface soil such as oxygen, silicon, and many other metals such as aluminum, calcium, and iron. It was noted that traces of water were also found within glass beads as a consequence of solar wind and space weathering on the lunar surface in samples from China's Chang'e-5 2020 robotic mission [5]. It was also observed that NASA's Artemis III and IV missions are primarily aimed at exploring the "Lunar South Pole", as this area is thought to hold substantial deposits of water ice trapped in permanently shadowed craters. These reserves could serve as a vital resource for future lunar missions, supplying drinking water, irrigation water for food crops, oxygen, and even rocket fuel, making it a crucial location for establishing a sustainable human presence on the Moon (https://www.nasa.gov/feature/artemis/). The lectures also covered that the regolith (lunar soil) is the direct result of space weathering: cosmic rays or astroparticles, solar wind particles implantation, and meteorite bombardment [6, 7]. The students were made aware that while terrestrial soils are made from biological or chemical interactions, lunar soils result only from the mechanical bombardment of meteoroids and interactions with the solar wind and other energetic particles. The students learned that since lunar regolith does not encounter water and wind like the soils on Earth, as a result, lunar soils could not be graded or classified on their chemical properties, size, and shape. While on Earth, water and wind can round off the sharp edges, lunar soil keeps its sharp edges and freshly fractured surfaces [7]. All of these unique characteristics of lunar soils provided an exciting opportunity for students in Chem 422/622 to explore and learn.

Chem 422/622 Bio-Inorganic Chemistry class typically emphasizes the topic of Iron (Fe) due to its importance as an essential metal. Discussions were held in class about the biological significance of iron, for instance it was noted that Iron plays a key role in bioinorganic chemistry, Magnetotactic bacteria use magnetite (Fe_3O_4) as an internal compass to navigate and avoid harmful oxygen levels by aligning with Earth's magnetic field. When moved to the opposite hemisphere, they become disoriented. Iron also functions as a trigger for specific cellular functions and helps regulate gene expression[9]. For relevance to the lunar context, some of the lectures focused on the differences between lunar and terrestrial soil iron. On Earth, iron primarily exists as Fe2+ and Fe3+ cations, with iron concentrations typically calculated as Fe_2O_3 due to the higher presence of Fe3+. However, on the Moon, there is no atmosphere and consequently no oxygen, so iron exists only as Fe2+ in minerals like ilmenite, olivine, and pyroxene, with some metallic iron from meteorites. Lunar iron concentrations are typically reported as total iron or FeO, ferrous iron, or ferrous oxide. Understanding these differences helped students grasp the chemical and biological significance of iron, an essential micronutrient, particularly in the context of bioinorganic chemistry.

Class discussions also noted that freshly ground lunar soil generates a significant amount of hydroxyl radicals in solution, demonstrating high reactivity. This activity is directly linked to the amount of nanophase metallic iron in the lunar soil particles. This unique property of metals in lunar soil sets it apart from terrestrial soil [9].

4.0 Student Outcomes and Accomplishments

The inaugural mini-grant implementation at UMES including award, stipend allocation, presentations, final report, and student engagement and beyond, went through smoothly. The overarching goal of broad dissemination and awareness of NASA's Artemis mission within a minority campus was achieved. The UMES Provost's office and human resources provided the necessary support to overcome the logistics challenges.

The lead faculty for the *EVA Smart Tool* project engaged the participating students in hands-on and professional skill development. CAD using Solidworks, use of machine shop tools, literature review, thinking critically, problem-solving, distributing tasks, troubleshooting, and working as a team towards successful project completion were emphasized. Besides the two students who were supported by the DREAM project funds, the EVA activity attracted several more undergraduate students to participate in related endeavors.

Figure 4: Students at UMES Club Expo 24

Figure 5: Students holding UMES flag at IAC 24

Furthermore, they also partnered with UMES 4-H and the UMES Engineering Club to study the moon using telescopes, discussing features such as craters, lunar day and night cycles, extreme temperature fluctuations, lunar highlands, mares, and lunar soil (regolith). The students presented their work at the UMES Club Expo in April 2024 (see Figure 4). The core group of students for the mini-grant and the lead faculty also put together a paper that was presented at the International Astronautical Congress (IAC) in October 2024 and published in its proceedings [4]. Figure 5 shows the three students holding the university flag photographed at the IAC in Milan Italy. The UMES Provost's office provided the travel funds for the lead faculty and the participating students.

The Bioinorganic Chemistry course (Chem 422/622) in spring 2024 as in prior semesters was open to both seniors and graduate students. It was offered by the faculty who led the 2nd mini-grant funded by the DREAM project. The lead faculty adapted the 2024 spring offering of the course to incorporate a theme relevant to NASA's Artemis mission. Seven of the eight students enrolled in the course were from underserved populations. Two female minority undergraduate students supported by the mini-grant worked closely with the lead faculty for the course modification and development of associated laboratory activities.

The course provided students with valuable research, analytical, and leadership skills, while also deepening their understanding of lunar soil chemistry and its relevance to bioinorganic chemistry. The training specifically focused on techniques and knowledge relevant to NASA's Artemis mission, demonstrating a practical application of their learning.

Students, especially the two that were supported by DREAM project funds were trained in conducting literature searches using SciFinder, a tool providing access to chemical substance information. The two students were also trained as teaching assistants. They took a leadership role in organizing chemistry labs, preparing solutions, and setting up equipment.

Students were trained on using ICP-MS (Inductively Coupled Plasma Mass Spectrometry) to detect concentrations of various metals in soil samples. This included training on sample collection, equipment usage, and data analysis.

Students received training on using a microwave digestion system to prepare samples for ICP-MS analysis and training on the use of the Flash EA 2000 analyzer to detect nitrogen and carbon concentrations in soil. Students gained experience in sample preparation and analyzing data from both the ICP-MS and Flash EA 2000 analyzer.

As mentioned before particular attention was paid to comparing the chemistry of lunar soil (simulant) with earth soil.

The lead faculty also engaged the two students funded by the mini-grant to develop their seminar presentation skills.

Both student-faculty teams that received the mini-grants were required to give online presentations one at the intermediate stage of project execution in the middle of the semester and one at the end of the semester. NASA MSTAR activity manager and coordinator, Maryland Space Grant Directors, UMD collaborators, and the UMES PI and Co-PI of the DREAM project attended presentations, participated in the Q&A session that followed, and engaged with the students to encourage and motivate them.

Figure 6 shows a screenshot of the participants during the mini-grant final online presentation on May 17th, 2024.

Figure 6: Screen Shot of Participants during the Mini Grant Final Online Presentation on May 17th, 2024

5. Sustained Impact and Future Directions

The mini-grants are embedded within the DREAM project, supported by the NASA-MSTAR program at UMES, as semester-long initiatives but with the intent to create lasting impacts on campus. The project leads for the mini-grants funded by the DREAM project during its inaugural year have actively sought to sustain and expand upon the work initiated during the formal mini-grant period.

The faculty lead for the first mini-grant project plans to continue integrating the Artemis theme into the CHEM 420/620 (Advanced Inorganic Chemistry) courses at both junior and senior levels. She has also expressed her intention to broaden the inclusion of Artemis-related content across other chemistry courses she teaches.

The second mini-grant enabled the creation of a simulated lunar yard within the "High Bay" area of the engineering building, which continues to be utilized by the faculty lead for demonstrations to K-12 students and other visitors. Additionally, the faculty lead is engaging UMES students in the ongoing development of the EVA Smart Tool throughout 2025. He has outlined specific plans for 2026, which include an additional peer-reviewed publication as well as expanding the student participant pool to collaborate on the design and construction of a high-fidelity "Grabber Tool" for use on the lunar surface. He is also partnering with the International Institute for Astronautical Sciences to continue testing the EVA Smart Tool with astronaut candidates in a pressurized EVA space suit and gravity-offset system. Efforts are underway to secure funding from state and federal funding agencies to support these activities.

As of the time of writing this paper, two mini-grants have been awarded for the second year of the DREAM project, and initial efforts are already underway.

The mini-grant initiatives have been carried out under the auspices of the DREAM (Developing Robotic Explorations with Agrobots and Moonbots) project at UMES, which contributes to NASA's Artemis mission objectives for long-term human presence on the Moon. Robotic exploration and automated food production on the lunar surface will be key to achieving these goals. The core project team at UMES, alongside non-MSI partners at UMD, is advancing the "MoonBot" and "AgroBot" efforts to support this ambitious mission. These ongoing endeavors are enhancing the capabilities of the UMES robotics and automation laboratory while providing graduate and undergraduate students with valuable experiential learning and research opportunities using cutting-edge equipment. Several of these efforts have been published[1-3], with more submissions currently under review. It has also generated a lot of interest among UMES undergraduates to pursue summer internships related to the Artemis mission at various NASA centers. Aspects of the DREAM project have also been integrated with the annual summer exchange internship program at UMES supported by the Maryland Space Grant Consortium(MDSGC). Maryland higher education institutions that are MDSGC affiliates participate in the exchange program. It is anticipated that the work begun under the DREAM project will form the foundation for continued education and research in alignment with NASA's goals and UMES's mission well beyond the 3-year funding cycle that ends in August 2026.

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