# NASA EPSCoR
# Research Performance Progress Report (RPPR)
# Seed Award

## I. Collaborating Organizations

### A. Academic Collaborators *(do not include names of minors)*

| Name | Academic Affiliation | RID Project Role | Nearest person month worked | Contribution to Project | Funding Support |
|---|---|---|---|---|---|
| Kelvin Fu | University of Delaware | PI | 6 | Conceptualization of lunar habitat, Supervision | NASA EPSCoR |
| | | | | | |

### B. NASA Collaborators

| Name | Title | NASA Center | Nature of the Collaboration |
|---|---|---|---|
| N/A | | | |
| | | | |
| | | | |

### C. Industry Collaborators

| Name | Title | Industry/Company Name | Nature of the Collaboration |
|---|---|---|---|
| N/A | | | |
| | | | |

### D. New non-EPSCoR grants

| Funding Entity | Award Name | Value of New Grant |
|---|---|---|
| N/A | | |
| | | |
| | | |

E. Other Organizations Involved as Partners

| Organization | Nature of the Partnership | Benefit of the Partnership |
|---|---|---|
| N/A | | |
| | | |
| | | |

## II. Products

A. List Journal publications – Please only list papers that have been published. **Please do not remove the table; or alter columns, add additional rows as required.**

| Date Published | Published Paper (APA format) |
|---|---|
| N/A | N/A |
| | |
| | |

**B.** List Conference Papers – Please only list papers that are included in conference proceeding. **Please do not remove the table; or alter columns, add additional rows as required.**

| Conference Date | Conference Paper (APA format) |
|---|---|
| N/A | N/A |
| | |
| | |

C. List Conference Presentation – Please list conference presentation. **Please do not remove the table; or alter columns, add additional rows as required.**

| Conference Date | Presentation Topic (APA format) |
|---|---|
| N/A | N/A |
| | |

D. List Books and/or other Publications – Please include explanations, help us to learn about your accomplishments. **Please do not remove the table; or alter columns, add additional rows as**

**required.**

| Date | Explanations (APA format -Book, Newspaper Op-Ed, …) |
|---|---|
| N/A | N/A |
| | |
| | |

**E.** List talk/presentation/event/outreach activity – Please include explanations, help us to learn about your accomplishments. **Please do not remove the table; or alter columns, add additional rows as required.**

| Date | List talk/presentation/event/outreach activity (APA format if applicable) |
|---|---|
| N/A | N/A |
| | |
| | |

F. List of new or updated Website(s) or other Internet site(s). **Please do not remove the table; or alter columns, add additional rows as required.**

| URL | Short description of purpose of site |
|---|---|
| N/A | |
| | |
| | |

G. Technology/Technique – **Please do not remove the table; or alter columns, add additional rows as required.**

| Technology/Technique | Short description of technologies or techniques |
|---|---|
| In-space additive manufacturing of load-bearing continuous fiber composite shielding for lunar habitats | Hybrid 3D printing of PLA/regolith simulants with continuous basalt-fiber reinforcement to create strengthened lunar habitat dome structures. |
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|---|---|
| | |

H. List patent – Please include Patent Number/Patent Title/ Patent Abstract (or link to it). **Please do not remove the table; or alter columns, add additional rows as required.**

| Date Patent Issued | Patent Number/Patent Title/ Patent Abstract (or link to it) |
|---|---|
| N/A | |
| | |
| | |

I. List Inventions – Please include Invention Title, List of Inventor(s) and Description. **Please do not remove the table; or alter columns, add additional rows as required.**

| Invention Title | List Inventor(s) | Invention Description |
|---|---|---|
| N/A | | |
| | | |
| | | |

J. List Licenses – Please include license issued, Invention Title, List of Inventor(s) and Description. **Please do not remove the table; or alter columns, add additional rows as required.**

| Date License Issued | License Assignees | License Title |
|---|---|---|
| N/A | | |
| | | |
| | | |

K. List New/Revised Courses – Please include new/revised courses. **Please do not remove the table; or alter columns, add additional rows as required.**

| Course Number | Course Name/Title | Offering Institution |
|---|---|---|

| | | |
|---|---|---|
| N/A | | |
| | | |

L. Others: List Databases, Physical collections, Audio or video products, Software or NetWare, Models, Instruments or equipment, Data & Research Material (e.g., cell lines, DNA probes, animal models) related to your EPSCoR research. **Please do not remove the table; or alter columns, add additional rows as required.**

| Accomplishments title | Short Description of accomplishments |
|---|---|
| N/A | |
| | |
| | |

## III. Changes/Problems

*A. Actual or anticipated problems or delays and actions or plans to resolve them*

During the reporting period, technical challenges were encountered related to fabrication and component-level testing of regolith-based additively manufactured structures. Specifically, initial printing iterations of pellet-extrusion with lunar regolith simulants required filament fabrication to ensure extrusion quality and dimensional stability of dome structures. In addition, reinforcement trials required refined fiber winding strategies to achieve uniform coverage and satisfying mechanical performance during load-bearing and impact testing.

These challenges were inherent to the development and validation of a new hybrid manufacturing process and did not result in schedule delays. They were addressed through iterative adjustment of filament synthesis with appropriate material ratios and fiber winding path planning optimization. All planned fabrication and component-level mechanical and impact tests were completed within the reporting period. No additional delays are anticipated for future project activities.

*B. Changes that have a significant impact on expenditures*

There were no changes during the reporting period that had a significant impact on project expenditures. The need for additional fabrication and testing iterations resulted in modest increases in material usage (printing feedstock and reinforcement materials); however, these costs were accommodated within the existing approved budget and did not require reallocation of funds or changes in project scope. No changes in staffing, equipment purchases, or primary performance activities occurred that would affect overall project costs.

## IV. Impact

*Include article and photo w/caption (see instructions). Obtain permission to publish photo from any recognizable person via NASA Media Release Form. Do not include photos of minors.*

This project advances a practical pathway for building safe, resilient, and cost-effective lunar surface infrastructure by combining in-situ resource utilization (ISRU) with advanced additive manufacturing and composite reinforcement technologies. By demonstrating that lunar regolith-based materials can be transformed into load-bearing, impact-resistant structures using minimal Earth-supplied materials, this research directly supports NASA's long-term goal of a sustained human presence on the Moon.

A key outcome of this work is the development of a hybrid in-space manufacturing approach that integrates large-scale additive manufacturing with continuous fiber reinforcement, as shown in Figure 1. The results show major improvements in mechanical strength and structural performance compared with unreinforced regolith composites, addressing a major barrier to lunar construction: achieving sufficient durability under mechanical loading while minimizing launch mass. These findings help bridge the gap between laboratory-scale ISRU concepts and realistic habitat-scale performance requirements.

This improved structural performance is further supported by the impact testing results shown in Figure 2. Drop-tower testing showed that the reinforced dome specimen exhibited no visible indentation at 40 J. At higher energies, the structure remained intact but developed measurable damage, with an indentation depth of 7.5 mm at 60 J and 12.0 mm at 80 J. Only at 100 J did catastrophic perforation occur. These results demonstrate that the developed material system can tolerate moderate impact energies before severe failure, providing important experimental evidence for impact resistance relevant to lunar surface hazards such as debris strikes and micrometeoroid exposure.

Beyond lunar exploration, the techniques developed in this project have broader impacts for terrestrial and space-based manufacturing. The continuous-fiber-reinforced additive manufacturing methods demonstrated here are applicable to lightweight infrastructure, protective structures, and disaster-resilient construction on Earth, where reducing material usage and improving structural efficiency are critical.

This research establishes foundational knowledge and experimental validation that can inspire future NASA habitat designs, guide industry partnerships, and reduce long-term mission costs by lowering launch mass requirements. Overall, the project demonstrates how federally funded research can translate into tangible capabilities that advance national space exploration objectives while generating technologies with lasting societal and economic value.

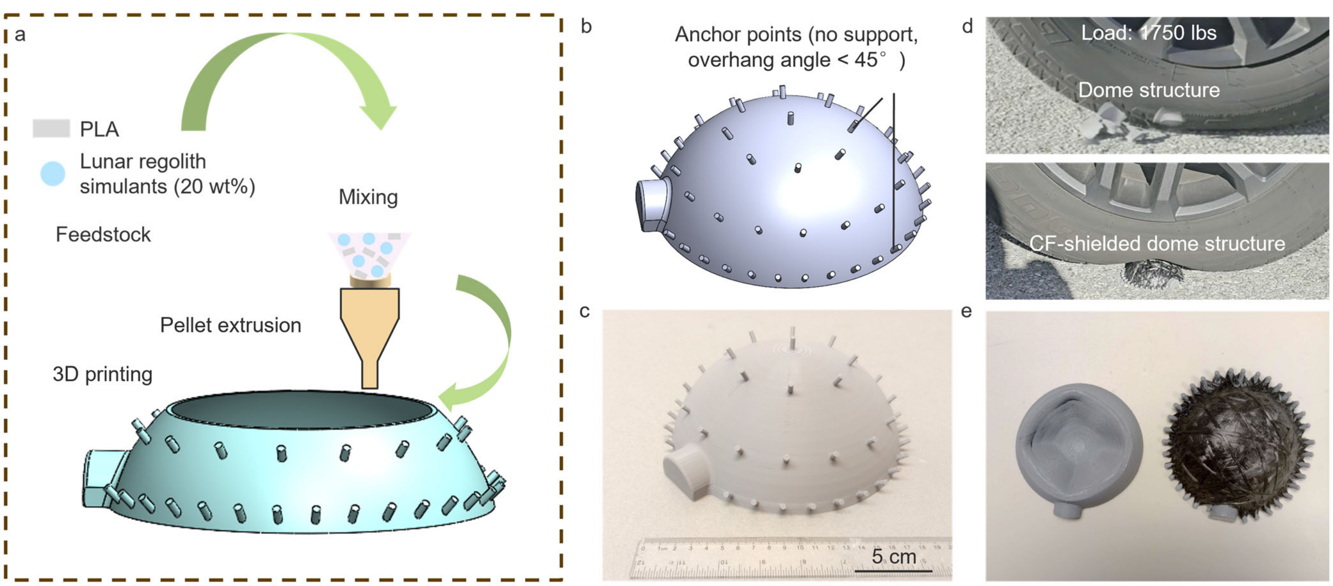


**Figure 1. Representative images from ongoing research demonstrating the fabrication and mechanical validation of a regolith-based, additively manufactured dome structure**, including the printing process, as-fabricated components, and comparative load-bearing performance with and without fiber reinforcement.

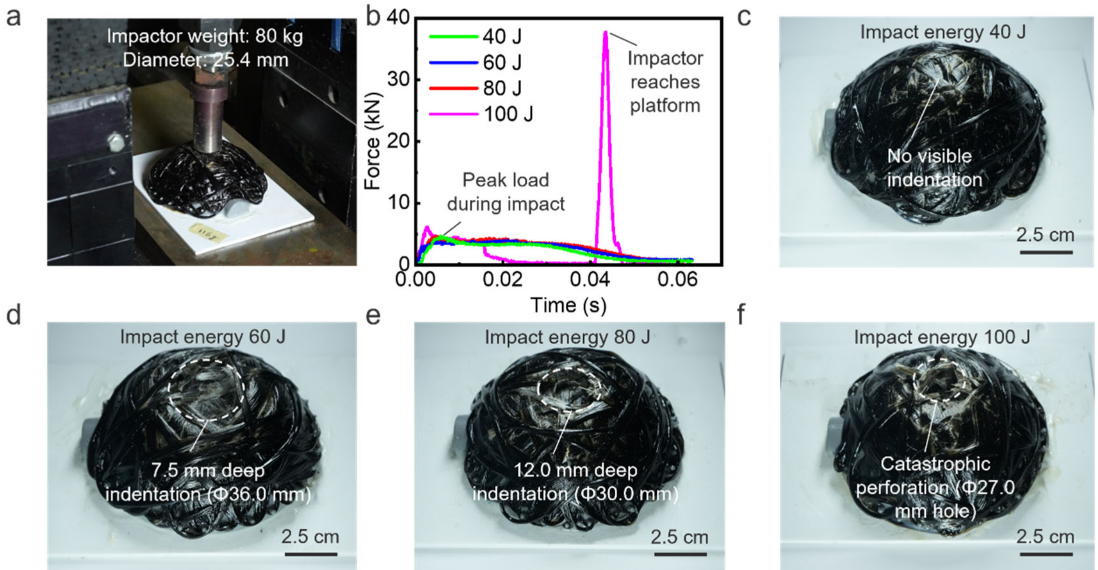


**Figure 2. Impact testing performances of 3D-printed lunar habitat components.** It showed that the 3D-printed lunar habitat dome could withstand moderate impact loads with little or no visible damage at 40 J, while higher impact energies caused increasing indentation and eventual perforation at 100 J.