Engineering and Innovation Research Studentship 2024/2025

1roject title:	**Extra-Terrestrial Applications of Aperiodic Porous Structures**
Discipline	Materials Engineering
Key words:	Construction, Geometry, Habitat, Mars, Moon, Structure
Supervisory team:	Dr James Bowen, Dr Richard Moat, Dr Iestyn Jowers
URL for lead supervisor's OU profile	https://www.open.ac.uk/people/jb36559

Project Highlights:

- Aperiodic designs afford desirable mechanical properties in porous structures
- Manufacture habitats which resist micrometeorite impacts and seismic events
- Applied to the Lunar and Martian surfaces

Overview:

Over the last decade, Space Architecture – the theory and practice of designing and building an environment for humans in outer space – has become an emerging issue in the context of future space exploration. Habitat design and construction on the Lunar and Martian surfaces are fundamental challenges which must be addressed in order for humanity to achieve long-term settlement and exploration of the solar system. These challenges must be investigated and overcome here on Earth to mitigate the risks involved.

Although the gravity on the Moon and Mars is lower than the gravity on Earth, structures built on their surfaces will be required to withstand hazards including solar radiation and micrometeorite impacts (Moon), dust storms (Mars), and seismic events (both). Construction using *in situ* resources is likely, given the difficulty and costs associated with lifting high-mass materials such as steels into Earth orbit. There is already significant research into using native regolith and additive manufacturing for creating habitats and structures in extra-terrestrial environments. But the unanswered question here is: which geometries offer the best protection?

Ongoing research into the mechanical properties of three-dimensional aperiodic lattices (Figure 1) has generated materials with highly porous structures which exhibit excellent weight-to-strength characteristics. Further, depending on their design and structural orientation with respect to the direction of an applied stress, these honeycomb-like systems have been found to exhibit desirable features including non-linear compressibility and zero Poisson's ratio.

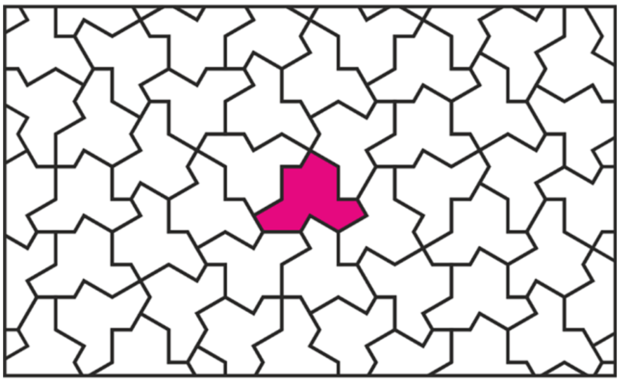

Figure 1. An aperiodic tiling based on the 'hat' monotile derived from a hexagonal grid structure.

This research will generate significant advances in our understanding of the durability and structural integrity of new human in extra-terrestrial environments. This project will explore the potential of these aperiodic, porous designs for creating low-mass, fracture-resistant, impact-tolerant structures, suitable for extra-terrestrial applications. The results will advance our understanding of the architectural structures which might be constructed on the Lunar and Martian surfaces.

This research will consider how these designs might be used to create highly deformable, energy-absorbing structures, which could be used as coatings around habitats for resisting micrometeorite impact. The project will also explore how these coatings might fare if applied to the exterior of cargo delivery vectors, whereupon they might undergo rapid deceleration if dropped onto the surface of low gravity bodies attached to a parachute (Mars) and without a parachute (Moon).

References & Further Reading:

The project team consists of Dr James Bowen, Dr Richard Moat, and Dr Iestyn Jowers. The following list includes some of the critical literature associated with this project.

1. Lim, S.; Degli-Alessandrini, G.; Bowen, J.; Anand, M.; Cowley, A.; The microstructure and mechanical properties of microwave heated lunar simulants at different input powers under vacuum conditions. *Sci. Rep.*, **2023**, 13:1804.

2. Lim, S.; Reeve, S.; Lekuona, E.; Garbayo, A.; Le Toux, T.; Morse, A.; Bowen, J.; Anand, M.; Challenges in the microwave heating of lunar regolith – analysis through the design of a Microwave Heating Demonstrator (MHD) payload. *Adv. Space Res.*, **2022**, *69*, 751-760.

3. Lim, S.; Bowen, J.; Degli-Alessandrini, G.; Anand, M.; Cowley, A.; Prabhu, V.L.; Investigating the microwave heating behaviour of lunar soil simulant JSC-1A at different input powers. *Sci. Rep.*, **2021**, *11*, 2133.

4. Clarke, D.J.; Carter, F.; Jowers, I.; Moat, R.J.; An isotropic zero Poisson's ratio metamaterial based on the aperiodic 'hat' monotile. *Appl. Mater. Today*, **2023**, *35*, 101959.

5. Clarke, D.J.; Imediegwu, C.; Moat, R.J.; Jowers, I.; A systematic numerical and experimental study into the mechanical properties of five honeycombs, *Compos. Part B-Eng*, **2023**, *264*, 110895.

6. Imediegwu, C.; Grimm, I.; Moat, R.J.; Jowers, I.; A computational method for determining the linear elastic properties of 2D aperiodic lattice structures. *J. Strain Anal. Eng.*, **2023**, *58*, 590-602.

7. Moat, R.J.; Muyupa, E.; Imediegwu, C.; Clarke, D.J.; Jowers, I.; Grimm, U.G.; Compressive behaviour of cellular structures with aperiodic order. *Res. Mater.*, **2022**, *15*, 100293.

8. https://science.nasa.gov/science-news/science-at-nasa/2006/15mar_moonquakes

Further details:

We are looking for highly motivated individuals with a strong background in engineering or physics. Strong enthusiasm for mathematical modelling and simulation would be a plus.

Applicants should have a first-class or upper second-class MSc degree (or equivalent) in a relevant discipline, including Engineering, Materials, Mathematics, or Physics.

Applications should include:

- A 1,000-word cover letter outlining why the project is of interest to you and how your skills match those required
- An academic CV containing contact details of three academic references
- An Open University application form, downloadable from: http://www.open.ac.uk/postgraduate/research-degrees/how-to-apply/mphil-and-phd-application-process
- IELTS test scores where English is an additional language

Enquiries should be addressed to the Lead Supervisor, Dr James Bowen james.bowen@open.ac.uk