This PhD project builds on an ongoing research programme led by Dr Lim to explore sintering-based additive manufacturing (a.k.a. 3D Printing) techniques to be used in extra-terrestrial construction processes, particularly in lunar and Martian surface environments. The Shackleton Crater at the south pole of the Moon, which is mostly covered by shadow, is currently one of the most anticipated lunar exploration sites for NASA and ESA scientists, and both space agencies are debating various plans for human exploration of the solar system. Establishing permanent bases on a target site is thus a fundamental requirement for long-term exploration and settlement.

Issues of interest are robotic construction techniques (as may be applicable in a lunar context, or in environments unsafe for human workers). Extraterrestrial contexts raise issues of a lack of water and extremely low ambient atmospheric pressure (even potentially a vacuum). There are also radiation concerns (solar wind/storms etc.) These considerations motivate the need for significant construction effort for any long-term settlement. In such contexts, additive manufacturing is an attractive proposition.

It is highly likely that the large-scale of robotic construction will necessitate careful energy management planning and high energy density options, such as nuclear power could be highly advantageous. In an additive manufacturing approach the printing robots will need to climb the structure while they print the habitat. Each major construction robot would require access to significant amounts of electricity. Various local electricity distribution options are possible.

The possibility of high levels of electrical power motivates researchers investigating the potential of microwave radiation as a sintering method, because microwave stabilisation will be better-suited to large open areas where the heat of sintering can be tolerated. Sintering operations require relatively high-power microwaves – e.g. a typical 2.45GHz, 6-kW microwave generator requires 10kW of electrical power.

According to a World Nuclear Association (WNA) report, the USA launched SNAP-10A – a 45 kWt thermal nuclear fission reactor capable of producing 650 watts in 1965. Over thirty critical fission reactors including the Romashka and Topaz series were launched by the former Soviet Union.1 Since 2014, NASA’s Glenn Centre has progressed a 4 kWt / 1 kWe KiloPower project, under US National Nuclear Security Administration (NNSA)’s permission, using High-Enriched Uranium (HEU) to generate electricity. Based on their Proof-of-Concept tests, NASA intends to carry out more critical experiments using this core in fiscal 2017 as part of the Department

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of Energy’s Criticality Safety Program.

This MRes/PhD study programme will explore various conceptual construction operation scenarios in extra-terrestrial environments placing particular emphasis on energy options. The intention is to assess outline concept designs for small nuclear reactor systems suitable (in particular) for powering a mobile printing platforms. Concepts and schemes will be assessed and compared and a preferred option identified. While the research is “whole system” in its approach particular expert knowledge will be required for assessing the nuclear components.

Interactions with key stakeholders in the field of Space Architecture, Construction, Nuclear Engineering and Technology Policy will facilitate the proposed research which is located at the interface of technology and policy. Space experts from governmental space agencies including NASA and ESA, and from industry and academia will be consulted. Such nuclear experts are accessible to us via ICO-CDT networks. In the policy context, there are potential interests from the United Nations’ Office for Outer Space Affairs, an implementation body for the Committee on the Peaceful Uses of Outer Space (COPUOS).