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A Robotic Constructor-Excavator for NEO quarrying

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With new initiatives towards exploiting extraterrestrial resources motivate studies of the machines that will be be needed in this endeavor. Some of the solutions that we have developed in the course of our work on the concept of Tailored Force Fields (TFF), are presented in this paper. The TFF project explores the possibility that very large, massive structures for human habitats may be formed in microgravity vacuum from rubble, automatically using resonant electromagnetic fields. This creates a requirement for a spacecraft that can redezvous with a Near Earth Object, attach itself, and generate a slow-moving cloud of stone blocks, the blocks being roughly 20 cm on a side. The requirements are somewhat different from those for craft intended to mine regolith on planetary surfaces, or to drill into small NEOs. The same craft would be called upon to do robotic manipulation and final assembly of components of the habitat.

This paper advances the design of such a "Rockbreaker" craft from previous work[1]. It also considers how the craft design would differ for varying construction requirements, ranging from large blocks to much finer-grade rubble, and varying excavation/ construction times. The different subsystems of the craft are developed further from previous work, and design choices are presented.

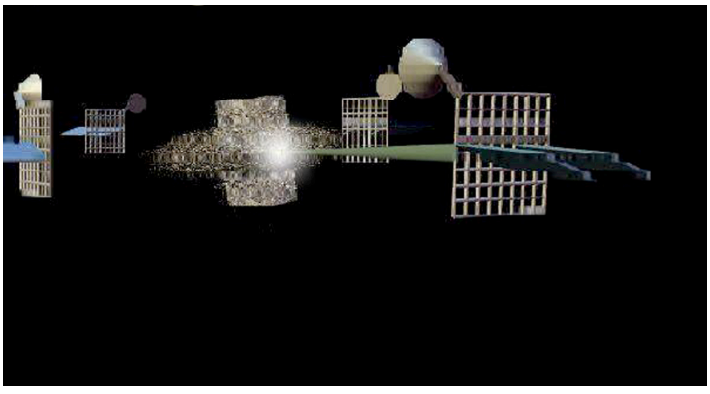

Figure 1: Tailored force fields concept: Resonator forms around cloud of rubble and forms it into cylindrical shape.

The Tailored Force Field (TFF) concept uses the radiation pressure and gradient forces in potential fields to organize random collections of objects into desired shapes such as walls. As shown in Figure 1, the present concept for the process envisages a Fabry-Perot resonator constructed by linking 4 spacecraft, with a cloud of rubble floating into it in Space. Operated at its 220 mode, the solar-powered radio resonator forms the rubble into cylindrical walls, which are then sintered in place. Since the TFF craft come with a surfeit of solar power generation capability, beamed microwaves from these craft are used to power the Rockbreakers considered here.

Ref. 1 describes the initial design of the Rockbreaker. With a total mass of 25,000 kg awhen boosted to its solar transfer orbit from LEO, the system will be powered by a 1sq.km solar sail for continuous thrust to reach L-4 or equivalent NEO location. Upon maneuvering and attaching to the NEO, the craft will receive beamed microwave power from one of the solar collector/ converters attached to the TFF craft. Two or four telescoping arms, each carrying several cutting heads, start spinning slowly around the craft axis, with integrated laser/ plasmajet cutters digging out blocks 20cm on a side. The pressure from the plasma inside the cutting trench forces the blocks to float gently out of the trench. The cutting arms telescope outward radially, thus executing a spiral cutting pattern and sending blocks floating up.

In this paper, the design of the Rockbreaker is re-examined to optimize the overall system. The issues of material heating and block size are examined to optimize the construction parameters in time, energy demands and overall system mass. The design of the cutting arms is examined in greater detail, as are the issues of active control of the cutting arms to control vibrations induced by pulsed thruster and pulsed cutter operations.

Conclusions to-date

This is conceptual and preliminary design of a completely new space system, and as such the results are in the closing of the design, and the performance of various designs. Designs for a large-scale habitat application are first considered, showing that the design is constrained mainly by how many cutting tools can be operated simultaneously with the given mass constraints of the Rockbreaker. By relaxing the requirement for 2m thick walls, and going to smaller module sizes, the effects on Rockbreaker design are re-examined. The role of the robotic assembly requirements on the design of the Rockbreaker are also considered.

Acknowledgements

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[1] Ravi Vanmali, Brandon Tomlinson, Bryan Li, Sam Wanis, Narayanan Komerath, "Engineering A Space-Based Construction Robot". SAE Paper 05WAC44, World Space Congress, Dallas, TX, October 2005.