

KARMAN+ MISSION ONE: A FULLY-FUNDED PRIVATE SAMPLE-GATHERING MISSION TO A NEAR-EARTH ASTEROID. L. Siltala^{1,2}, D. Crull¹, A. Deutch¹, C. Purrington¹, L. Whittle¹, K. M. Cannon^{3,4} and M. Granvik^{2,5}, ¹Karman+, 2301 Blake Street, Suite 100, Denver, CO, 80205, USA (L.siltala@karmanplus.com), ²Department of Physics, PO Box 64, 00014 University of Helsinki, Finland, ³Department of Geology and Geological Engineering, Colorado School of Mines, Golden, CO, 80401, USA, ⁴Space Resources Program, Colorado School of Mines, Golden, CO, 80401, USA, ⁵Asteroid Engineering Laboratory, Luleå University of Technology, Box 848, SE-98128 Kiruna, Sweden

Introduction: Karman+ is a U.S.-based startup seeking to make asteroid mining a reality. As the first step towards that goal, we are currently developing a fully-funded sample-gathering mission, designated Mission 1, to an easily-accessible carbonaceous near-Earth asteroid. The fundamental objective of this mission is to land on our target asteroid and retrieve a kilogram-scale sample from the asteroid's surface, thus demonstrating our extraction technology developed in-house, as cost effectively as possible. In this talk, we will detail our overall concept for Mission 1, our target selection approach and potential target asteroids, and the scientific challenges we currently face, including avenues for research.

Mission Concept: The idea behind Mission 1 is to demonstrate that Karman+ is capable of executing spacecraft missions to near-Earth asteroids (NEAs) and carry out tasks critical for resource harvesting at scale. The proposed Concept of Operations (ConOps) is to: successfully rendezvous with the target asteroid, perform autonomous proximity operations, map the target asteroid and decide on a landing site, land on the asteroid, and extract a sample of several kilograms from the asteroid; a larger sample than what the past scientific missions Hayabusa, Hayabusa2 and OSIRIS-REx have achieved. The target asteroid and the retrieved sample will also be characterized so as to understand the composition of the sample; it is critical to understand the material we are bringing back to assess the viability of the target for commercial mining operations to follow. This must be done as cost effectively as possible with using off-the-shelf components wherever possible so as to be able to demonstrate a path towards profitability and scalability. Karman+ believes collaboration with the scientific community to be mutually beneficial, and as such it is our intent to make our measurements available for the scientific community to use.

Target Selection, Characterization and Open Questions: For our asteroid mining operations to reach eventual profitability, our target asteroids must be easily reachable both in terms of delta-V and time of flight so as to minimize propellant mass and spacecraft mass, size, and complexity. While there are a large number of known NEAs, the number of them that meets our chosen criteria in this end is small. Most of these are also very small, with diameters estimated in meters to tens of meters – a size class which we

have never visited before. Can we expect regolith on the surface of such asteroids, and if so, how much of it? If the asteroid is a solid monolith, what is its tensile strength and density? Clearly, these are important questions when considering landing operations and, even more so, for designing our sample extraction mechanism. Additionally, the small size of these asteroids makes them very difficult to observe, which leads to a lack of available data; in particular there are very few NEAs on our list which have spectra, let alone which are confirmed to be carbonaceous by their spectra. Some of these are even classified to different taxonomies by different studies, which compounds the uncertainty. Nonetheless, a number of interesting, potentially suitable asteroids do exist. Our objective in communicating our intent is to identify possible areas of research that would benefit from such a mission and provide meaningful mutual impact both on our effort as well as the scientific community.