Space Mining – Managing astronomical complexity

K. Markovic1, D. Brown2

1. Systems Engineer, Nova Systems, Southbank VIC 3006. Email: kristina.markovic@novasystems.com

2. Systems Engineer, Nova Systems, Fremantle WA 6160. Email: daniel.brown3@novasystems.com

3. Systems Engineer, Nova Systems, Fremantle WA 6160. Email: zachary.tabor@novasystems.com

Keywords: systems engineering, systems thinking, complexity management, space mining

**ABSTRACT**

From ancient times to the modern world, the mining industry has played a pivotal role in shaping the society that we live in today. It remains an integral part of everyday life and is a catalyst for both technological and economic growth. With finite resources on Earth, and growing pressures surrounding climate change and the environment, space mining opportunities have become of increasing interest. Recent discoveries have shown celestial bodies including the Moon and surrounding asteroids, contain an abundance of critical minerals, as well as resources necessary to sustain human life. These discoveries coupled with a transition into the digital and autonomous age, offer an innovative solution to solving some of the mining challenges currently being faced on Earth. Similarly, they also offer a pathway to enabling deep space exploration and off Earth exploratory missions. However, like with mining operations on Earth, space remains and immensely challenging and complex operational environment. The inhospitable nature of space poses new challenges, including communication barriers, lunar dust, cosmic radiation, and gravity. The challenges and risks are not just technological, as ESG factors must also be considered to prevent unintended consequences and hazards. Furthermore, future workforce, law, financial, and security systems must evolve to enable space mining to take place. These are all known aspects to begin with, but as the complexity of the space grows it becomes apparent that a holistic approach to assess and manage these factors will be required.

Systems engineering is a multi-disciplinary approach that incorporates engineering management to design, integrate and sustain complex systems. Its application in space mining will be vital to ensure all systems, factors, and constraints are defined. Through a system-of-systems method the interfaces and connections between all the factors can be established to ensure safe and effective practices are sustained across the industry, with all risks appropriately managed. This paper aims to explore the key challenges, barriers, and interfaces that underpin the feasibility of the space mining industry. Furthermore, it seeks to discuss how systems engineering principles can be applied to overcome some of these challenges, and in doing so help create a sustainable and operational industry for the future of humankind.