IAF SPACE SYSTEMS SYMPOSIUM (D1)
Space Systems Architectures (2)

Author: Dr. Rafal Graczyk
University of Luxembourg, Luxembourg , rafal.graczyk@uni.lu

Mr. Saad Memon
University of Luxembourg, Luxembourg , saad.memon@uni.lu
Mr. Aleksandar Matovic
University of Luxembourg, Luxembourg , aleksandar.matovic@uni.lu
Dr. Federico Lucchetti
University of Luxembourg, Luxembourg , federico.lucchetti@uni.lu
Prof. Marcus Völp
University of Luxembourg, Luxembourg , marcus.voelp@uni.lu

FACING THE COMPUTATIONAL COMPLEXITY THREAT OF AUTONOMOUS LUNAR MINING

Abstract

Humankind is returning to the Moon, not only to continue crewed exploration, but to stay, build fuel harvesting infrastructure and to process materials in cislunar space. While humans will be permanently present around and, on the Moon, a lot of activities related to the operations, planning, construction, and maintenance the lunar industrial base will be autonomous, with teleoperation limited to those corner cases that machines cannot properly handle.

Analyzing the algorithms proposed today for surface operation, regolith processing, power management, construction and to operate transportation from Moon's surface to the fuel depot in one of the local libration points, we found that the computational complexity required by these algorithms amounts to between 2E+04 and 2E+05 million instructions per second (MIPS), in particular if algorithms leverage artificial intelligence and if results should be available and optimized well before the first maneuver has to be performed, thrusters need to be controlled for autonomous landing or rover path planning is executed before collision with other rover or surface obstacle. This envelope is currently unreachable for existing space qualified computers (RAD750, GR712, GR740) and barely on the horizon for future such systems (e.g., Teledyne LS1046), in particular if launch mass and power demand are added to the equation. On the other hand, computer architectures such as Tesla's FSD hardware or NVIDIA's Jetson TX2 easily meet these performance goals, albeit without the robustness that space computing requires.

The above reveals a strong mismatch between expectations of the space community regarding scale and efficiency of autonomy for operations on the Moon and in cislunar space and the actual computational capabilities that are available for implementing the above algorithms in this environment. To face the challenges that originate from this mismatch, a focused development effort is needed along the following three paths. We need: (1) new, efficient space-qualified accelerators for autonomous algorithms, (2) new ways of ensuring robustness and resilience in existing computing modules used for autonomous operation (on Earth and beyond), and (3) new algorithm optimizations for lowering the computational complexity and resources of autonomous operations.

In this paper, we detail the analysis leading to our recommendations, sketch pathways how to achieve them and how to enable cost-efficient "tera-instruction-per-second" computation in space.