IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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FROM MINES TO MOON: LEVERAGING A DECENTRALIZED MULTI-ROBOT AUTONOMY PLATFORM FROM TERRESTRIAL MINERAL EXPLORATION FOR LUNAR RESOURCE PROSPECTING

Abstract

The evolution of terrestrial mineral exploration technologies is now shaping the next frontier of lunar resource prospecting. By leveraging a decentralized multi-robot autonomy platform, robotic swarms can transition from Earth-based mining to lunar regolith excavation, enabling sustainable space exploration and off-world resource utilization.

Primary challenges on the moon are a) Inability to Reason in Dynamic Terrains b) Limited Communication with Earth c) GPS-Denied Navigation with Obstacles d) Energy Constraints

Our decentralized robotic intelligence developed for mineral exploration capable of working in hostile, remote, and high-risk environments is now being adapted for lunar conditions. Some key features include:

1. Swarm Robotics for Lunar Prospecting:

Terrestrial mining robots already use AI-driven swarms for autonomous resource extraction. On the Moon, multi-agent collaboration enables real-time exploration of polar ice deposits metal-rich regolith. Swarm coordination algorithms ensure optimized search, mapping, and excavation.

2. AI-Driven Autonomous Mapping Navigation:

Multi-Agent SLAM (Simultaneous Localization and Mapping) enables decentralized robotic navigation. We use LiDAR, radar, hyperspectral imaging, and machine learning for terrain analysis. Mesh networking enables seamless robot-to-robot data exchange without relying on Earth-based control.

3. Advanced Lunar Resource Detection Extraction:

AI-powered spectral imaging geochemical analysis for detecting water ice, metals, and rare minerals. Autonomous drillers extractors optimized from Earth-based robotic mining systems.

In-Situ Resource Utilization (ISRU) methods adapted from terrestrial automation for 3D-printing infrastructure on the Moon.

4. Energy Management Sustainability:

Lunar-adapted solar power systems with peer-to-peer energy sharing. Smart battery power optimization algorithms ensure longevity in the harsh lunar environment. Wireless energy transfer nodes for sustainable operations beyond sunlight-exposed regions.

We discuss field results from our engagements with terrestrial mining industry that has provided critical insights for lunar resource prospecting. Several pilot programs with leading mining companies that have tested our proprietary AI-driven robotic swarms, autonomous navigation algorithms, and real-time resource extraction technology are validating the feasibility of these systems for extraterrestrial environments like the Moon.

Our swarm intelligence solution ensures continuous mining without a central command, ideal for Moon missions where communication delays exist. Dynamic role switching (scout, digger, hauler) reduces downtime in unpredictable lunar terrain.

Based on our observations, our solutions developed for terrestrial mining companies have proven that autonomous robotic swarms can function without human intervention in remote, hazardous locations.

These real-world field results provide a direct roadmap for deploying decentralized AI-powered robots in lunar resource prospecting, ensuring a self-sustaining, automated mining ecosystem on the Moon.