MULTI-ROVER TEST BED FOR TELE-CONDUCTED AND AUTONOMOUS SURFACE OPERATIONS FOR THE MOON AND MARS

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Introduction: With multinational lunar and Mars exploration programs currently underway, robotic reconnaissance operations are called for in extreme environments such as space, including planetary atmospheres, surfaces, and subsurfaces, as well as in potentially hazardous or inaccessible operational areas on Earth. Future reconnaissance missions will require increasing degrees of operational autonomy [5], such as:

- Automatic mapping of an operational area from different vantages (i.e., spaceborne, airborne, surface, subsurface);
- Automatic feature extraction and target/region-of-interest/anomaly identification within the mapped operational area;
- Automatic target prioritization for follow-up or close-up (in-situ) examination;
- Subsequent automatic, targeted deployment and navigation/relocation of agents/sensors (e.g., to follow up on transient events).

We report on the continued development and implementation of an Earth-based (outdoors) test bed for *Tier-scalable Reconnaissance*, originated by Fink et al. [1-7], that allows for distributed, science-driven, and less constrained reconnaissance of prime locations on Mars, the Moon, Titan, Venus, etc. Such a test bed opens up the opportunity for a wide scientific target audience (planetary geologists, hydrologists, astrobiologists, mission architects, physicists, roboticists, etc.) to develop and field-test remote planetary exploration strategies and tools, ranging from algorithms to hardware.

For example, in the case of the Moon, the autonomous exploration of craters devoid of sunlight and the exploration of the far side of the Moon are of high importance to determine whether there are permanent water ice deposits for a potential human base on the Moon. Similarly, on Mars, autonomous robotic exploration of high-risk high-yield sites as well as local tele-operations of robots for the purpose of resource exploitation and transport of supplies in support of a human base are among the high priority goals of future planetary exploration.

Test Bed Description: We have reported earlier on the development of a 4WD remote controllable robotic platform (Fig. 1) as a ground-tier representative of a tier-scalable reconnaissance test bed at Caltech [4, 5]. This rover platform is TCP/IP enabled (wireless LAN) and allows for different operation modes: (1) interactive (remote) tele-commanding via joystick and user-controllable on-board camera with wireless video link to investigate, test, and demonstrate tele-operations on the Moon; (2) autonomous self-commanding to field-test and validate navigation and exploration, navigation algorithms/software and strategies; and (3) autonomous tele-commanding and scientific exploration as part of an integrated tier-scalable reconnaissance mission architecture [1-5, 7].

Thanks to its powerful onboard computing capabilities and long battery life, this platform is ideally suited to perform complex and numerically intensive onboard calculations. Due to its wireless capability, hot-swapping of new exploration algorithms can be accomplished while the rover is en route.

Implications and Outlook: The rover test bed as described above allows for near real-time interactive (or automatic) control from anywhere in the world [4, 5]. It enables the implementation, field-testing, and validation of algorithms/software and strategies for navigation, exploration, feature extraction and anomaly detection (e.g., *Automated Global Feature Analyzer (AGFA)* [8-10]), and science goal prioritization (e.g., AGFA [8-11] and Fuzzy Logic-based Expert Systems [12, 13]) for planetary exploration. Furthermore, the rover permits field-testing of (novel) instrument and sensor equipment.

We have developed several rover platforms as described above, enabling testing of cooperative multi-rover scenarios and distributed scientific exploration of operational areas.

This test bed will enable the development, implementation, field-testing, and validation of software packages for inter-rover communication and coordination to navigate and explore operational areas with greatly reduced (and ultimately without) assistance from ground operators, thus affording more mission autonomy/flexibility and increased science return.

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Fig. 1. 4WD remote controllable rover platform as a test bed for lunar and martian surface operations.