Hercules et al: Recent Canadian Exploration Rover Prototypes*

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In 2010, the Canadian Space Agency (CSA) commenced a large development program of exploration prototypes geared towards rapid technology advancement, community development and international collaboration in preparation for future planetary exploration. Termed the "Exploration Surface Mobility" initiative [1] the program funded the development of an architecture of systems with a central focus on surface mobility, including vehicles, subsystems, utility payloads and science instrumentation. In 2012 and 2013, many of these systems were delivered and tested at the CSA Analogue Terrain (AT) near Montreal, Canada.

Hercules is a class of lunar rover prototype developed by MDA in conjunction with a team of 14 partners for CSA under the Lunar Exploration Light Rover (LELR) project [2]. Each Hercules rover (Fig. 1) is a medium-class lunar mobility platform designed for science, prospecting, surveying and early *in situ* resource utilization (ISRU) mission scenarios, with full upgradability to short distance crew capability. The vehicle chassis is based on a rugged, custom-designed mobility platform built by the advanced technology centre of worldwide terrestrial vehicle leader Bombardier Recreational Products (BRP). Substantial payload accommodation is provided via several payload plates, with the largest available space accommodating up to 300 kg and 1.5 x 1.0 x 1.0 m.

Figure 1.   Hercules surveys the Analogue Terrain at CSA

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A comprehensive onboard sensor suite provides feedback and situational awareness to support high speed tele-operation under lunar-representative communication conditions, onboard autonomy for safe, precision driving and full compatibility with crewed drive modes. Modular software ensures future upgradeability while providing features such as real-time absolute localization without external navigation aids and a visual teach and repeat mode, developed by in collaboration with the University of Toronto Institute for Aerospace Studies (UTIAS) Autonomous Space Robotics Laboratory (ASRL) [3].

Two Hercules rovers were put to the test at a variety of points throughout the program. Mobility testing at BRP's vehicle proving grounds demonstrated 25° gradeability under maximum payload, and autonomous guidance, navigation and control testing demonstrated 5 km/h autonomous driving. The culminating activity was analogue field testing at the CSA AT, demonstrating tele-operation at up to 10 km/h under the challenging conditions of lunar communication latency and bandwidth constraints.

The SL-Commanders (Fig. 2) are a second pair of vehicles developed under the ESM program as early testbeds for Hercules to support manned, tele-operated and autonomous modes of operation. The mobility platform of the SL-Commander is based on an electric version of a commercial all-terrain vehicle from BRP. As a direct result, the SL-Commander program helped catalyze a new line of commercial electric vehicles which is manufactured exclusively in Quebec, Canada. This represents a significant direct and tangible return on national space exploration technology investment, stemming from CSA's ESM program.

Figure 2.   SL-Commander

The Mars Exploration Science Rover (Fig. 3) primarily supports autonomous science prospecting and *in situ* geological analysis operations [4]. The chassis and locomotion system has excellent obstacle crossing and continuous steering from low curvatures down to point turns. The power system is path-to-flight based on nanosatellite heritage from the UTIAS Space Flight Laboratory. The onboard sensor suite provides excellent situational awareness, and enables fully autonomous precision traverses to sites of interest. The software architecture supports a Mars-representative command scheme, providing a mission scripting language for use under limited communication windows and bandwidth constraints. Modularity and flexibility have been built into the architecture for future upgradeability.

An example of the potential future use of the ESM prototypes is the CSA Mars Sample Return Technology Deployment [5,6,7], which was carried out in 2010 near SP Crater in Arizona, USA. This field test combined a European Space Agency ExoMars mission-based mobility platform with a field tested autonomous control system and small coring instrument (Fig. 4) to simulate a Mars sample return mission scenario. The integrated system was operated remotely from the CSA in Montreal, Canada using both tele-operation and autonomous control under the direction of a remote science team led by the University of Western Ontario. Excellent mobility over the rugged terrain coupled with situational awareness, 3D modeling for target selection and science image acquisition all contributed to the mission success.

Other systems developed as part of the ESM program include next generation power, communications and vision systems as well as science payloads such as a 3D microscope, ground penetrating radar and Raman spectrometer. Hercules and other ESM systems are now available to support planetary analogue scenarios, as cooperative elements alongside international lander and / or mobility systems, or as host vehicles for international exploration science and ISRU payloads. This has collectively advanced both partnerships and technology developments ahead of a number of upcoming international exploration missions from lunar precursor missions such as RESOLVE to future Mars missions like ExoMars and Mars2020.
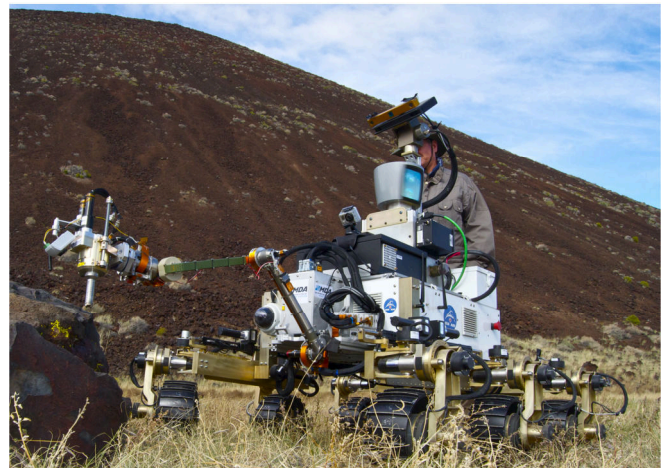

Figure 4. Mars Science Technology Demonstration Mission

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Figure 3. Mars Exploration Science Rover