"PREPARING FOR LUNAR EXPLORATION - CONCEPTS, TECHNOLOGIES, PARTNERSHIPS IN AN AGE OF UNCERTAINTY" N. Ghafoor[1], C. Dickinson[1], R. McCoubrey[1], L. Chappell[1], M. Barnet[1], P. Dietrich[1], F. Teti[1], and Christian Sallaberger[1], [1]MDA, 9445 Airport Road, Brampton, Ontario, CANADA, nadeem.ghafoor@mdacorporation.com, ryan.mccoubrey@mdacorporation.com, laurie.chappell@mdacorporation.com, mark.barnett@mdacorporation.com, peter.dietrich@mdacorporation.com, cameron.dickinson@mdacorporation.com, christian.sallaberger@mdacorporation, frank.teti@mdacorporation.com

Introduction: The landscape of lunar exploration has changed considerably in recent years, owing to both changes in near-term objectives by international space agencies, and the current state of the world economy. Throughout this challenging period, the Canadian Space Agency (CSA) has embarked on a clear path towards delivering surface mobility for potential use on future Lunar and Martian missions. Of particular note are those facing Canada's largest space manufacturer, MDA, in a variety of tasks including: several Phase 0 studies for a variety of Lunar vehicle classes; Terrestrial rover prototypes; and Analogue Science deployments employing these prototypes. The present work will provide an overview of these developments within the international lunar framework, as well as provide future possibilities for their deployment.

Phase 0 Studies: Commencing in 2007, MDA was funded by CSA to conduct a trio of surface mobility concepts. The first was the **T**errainable, **R**econfigurable **A**utonomy-**C**apable **T**ool-using **E**xploration and **U**tility **R**over (TRACTEUR), which was to assess a large, modular "work-horse" rover chassis. The chassis was to be configurable for autonomous activities as well as movement of payloads via trailers, modular tools, or additional interfaces. The main operation of the vehicle was: to support unmanned operations and exploration; cargo and habitation relocation; site preparation and base construction (including regolith handling); and finally pressurized and unpressurized manned operations and exploration (including ISRU).

The second such study was the **L**unar **E**xploration **M**anned **U**tility **R**over or LEMUR. Several key technical innovations were investigated including human-rated safety, autonomy & telerobotic operation, multi-configuration rover traction & terrainability, architecture expansion options, power and telecommunications.

Finally, the **R**obotic **A**ssistant and **P**recursor **I**nvestigation **E**xploration **R**over (RAPIER) was identified to advanced key technology requirements for lunar exploration, most notably autonomous surface mobility. This dexterous vehicles would nominally navigate tens of kilometres of difficult terrain carrying sensitive analytical instruments, transmit results and images, drop-off instrument packages and collect samples for detail analysis. All three concepts are shown in Figure 1.

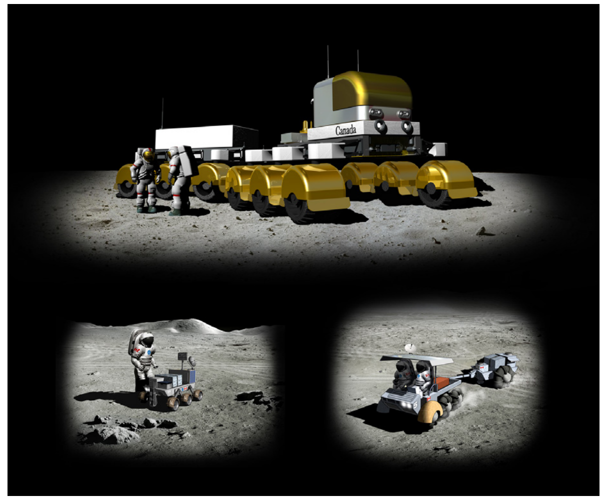

Figure 1 – TRACTEUR (top), LEMUR (bottom right) and RAPIER (bottom left)

MDA conducted two additional Phase 0 mission studies beginning in 2008, building on previous concepts and successes. The first was a concept for a Canadian rover as part of NASA's proposed Constellation framework known as **M**anned **L**unar **M**ission (MLM) that, much like TRACTEUR and LEMUR, would provide a modular chassis system and configurable control systems for transport of crew, pressurized modules, or even a crane, known as CRADLE (**C**anadian **R**econfigurable **A**dapter for the **D**eployment of **L**arge **E**lements). CRADLE would be capable of moving up to 9000 kgs of payload such as a habitation modules for a lunar base.

The second study during this period was the development of a Canadian node of the **I**nternational **L**unar **N**etwork (ILN). ILN provided the necessary architecture for a Lunar Landed system, tailored specifically to objectives derived from it's Canadian science team.

Additional studies have been conducted focusing on rover payloads including a novel Ground Penetrating Radar, as well as studies looking at the optimal architecture of robotic manipulator systems (i.e. robotic arms) for planetary exploration. Such systems are the signature technology of MDA, makers of the shuttle Canadarm, Space Station Canadarm 2 & Dextrous Manipulator systems.

Prototyping: MDA is currently developing or co-developing several Lunar prototypes for CSA, including an analogue rover, advanced navigational vision system, and a suite of scientific instruments such as ground penetrating radar, as part of CSA's **E**xploration **S**urface **M**obility (ESM) program. The rover system, known as **L**unar **E**xploration **L**ight **R**over (LELR, shown in Figure 2), builds upon the advancements made during the MLM program, and has configurable design to accommodate scientific exploration, **I**n **S**itu **R**esource **U**tilization (ISRU) activities, or be upgraded to facilitate crew transport within it's 300 kg payload capacity.

Figure 2 – Concepts illustrating the uses of LELR

In support of science and ISRU type investigations, a **L**unar **G**round **P**enetrating Radar (GPR) prototype is also currently under development. Based upon niche Canadian technology, the LGPR project promises to deliver a state of the art instrument.

Finally, an intelligent sensor system prototype is being developed that will integrate the strengths of lidar in providing highly precise short- to long-range 3D imaging with the strengths of stereoscopic cameras in allowing high-resolution texture mapping and scene modeling. The resulting product will be an innovative compact system for navigation, path planning, hazard mapping and scientific use.

Analogue Deployments: MDA has been involved in an increasing number of analogue deployments to field test their technologies. Most recently (2010) a sample return deployment to SP and Meteor craters was undertaken to demonstrate the capabilities of the CSA's **C**anadian **B**readboard **R**over (CBR), built by MDA. The rover, in conjunction with a suite of autonomous navigational sensors and camera systems, robotically explored the surrounding terrain, while being teleoperated from CSA headquarters in St. Hubert, Canada (see figure 3).

Figure 3 – CBR rover at SP Crater in Arizona

In addition to testing the technical aspects, several scientific studies were also carried out, most notably through US partnerships that provided a robotic arm and mini-corer. Decisions affecting the operational tasks of the rover were made by a Science Team stationed at CSA, thus testing a variety of operational scenarios, and providing a wealth of information for future missions planning.

Future Activities: Given the current uncertainty surrounding Lunar exploration, it is more important then ever to harness international partnerships in both science exploration and technology development in the development of future missions. The technologies, and more importantly the lessons learned, lay the framework for future development that is capable of covering a variety of future Lunar robotic exploration missions.