POTENTIAL CANADIAN CONTRIBUTIONS TO CHALLENGE AREA 3 – SURFACE SYSTEMS

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Introduction: The Canadian Space Agency (CSA) has been an active partner in NASA's planetary science program in the last decade, contributing the lidar-based MET weather station to the NASA Mars Phoenix Scout Mission, APXS on Mars Science Laboratory, and the OSIRIS REx Laser Altimeter (OLA). Participation in a Mars Sample Return mission is a goal of the CSA.

Surface System Technologies: From a technology perspective, Canada is a leader in the design, construction and operation of space robotic systems, and is well known for success stories such as the Canadarm (the space shuttle robotic arm), Canadarm2, and Dextre (two robotic systems on the International Space Station). As the CSA plans to continue making strategic investments to achieve global leadership in a few selected technology areas, the concept of signature technologies has been introduced. The list is provided in Table 1. Established technologies are those that have flown successfully on multiple missions and for which there is good potential in the future. Emerging technologies respond to the future needs of multiple potential missions and are important contributions for those missions. A significant investment in advanced prototyping of signature technologies in areas of Canadian strengths followed the 2009 Canadian Government Economic Action Plan resulting in the creation of the Next Generation Canadarm (NGC) and the Exploration Surface Mobility (ESM) projects. ESM project's objectives are to develop a suite of terrestrial rovers prototypes and related payloads being delivered between 2010 and 2012. These prototypes have and will be integrated and tested during analogue deployments.

CSA ESM Project:

Mars Exploation Rovers: Two main prototypes are included as part of the ESM project to form the basis of a Mars Sample Return type mission. The initial prototype named Robotics Explorer (REX) shown in Figure 1 was delivered to the CSA and deployed to Flagstaff Arizona in October 2010 for a period of 14 days. Equipped with a LIDAR, stereo cameras, IMU, odometry and a driving camera the rover has been remotely operated from the CSA Exploration Development & Operations Centre (ExDOC) by a team of scientifics and engineers. In addition to the rover, an arm and a corer were included to perform Mars Sample Return scenarios.

Established Canadian signature technologies	
Manipulators and Robotic Servicing	Including integrated technologies enabling automated or tele-operated servicing of spacecraft and planetary vehicles
Optical Metrology Systems	Vision systems, LIDAR/LASER-based techn. for manipulator ops., nav., control of autonomous sys., metrology, science instruments, material, environmental analysis; fine guidance sensors for precise pointing knowledge in inertial space and/or precise pointing stability of satellites
Radiation Mitigation	Radiation prediction, monitoring , protection technologies and methods crucial for assuring radiation health of space crews during long-duration exploration-class missions
Spectrometers	Fourier transform spectrometers ;alpha-particle X-ray spectrometer
Emerging Canadian signature technologies	
Advanced Crew Medical System	Suite of integrated technologies required for medical support of crew members on long-duration, exploration-class missions
Drilling and Sample extraction	Planetary drilling techn. for geological and astrobiology studies, and resource extraction
Rovers	Planetary rovers for surface mobility, including micro-rovers for scientific measurements and scouting, to human-rated rovers and rovers for infrastructure and logistics support.

Table 1: Cdn Exploration Signature Technologies

Fig. 1: Robotics Explorer deployment Oct. 2010.

The REX rover design was based on the ExoMars previous design with a capability for the rover to perform point turns, crabbing, and "walking". As part of ESM, two main concepts of rovers applicable to Mars exploration have emerged: a MER class rover referred to as the Mars Exploration Science Rover (MESR) and micro-rovers targeted for Moon or Mars exploration.

The MESR is planned for delivery by June- July 2012 and will then go through a period of test and icharacterization and then be integrated with the CSA exploration development central mission planning and control system Symphony.

The MESR core specifications and a representation of the rover with and without payloads is shown in Figure 2. The rover will be equipped with a small manipulator, a microscope and a mini-corer developed under 3 different contracts for Mars Sample Return scenarios development, evaluation and simulation in analogue environments. The basis for operation is that the rover shall be able to recharge its battery using its solar array at the end of an operational day to survive the night and operate the next day.

Mass	Dim. [mm]	Mean Pwr , up time	sensors
~260 kg + 60kg pld	2280 (l) 1620 (w) 1922 (h)	796 W, 7.75 Hrs ops, 12 hrs rechar.	Lidar, stero cams., IMU, odom., bump detect., drive cam.

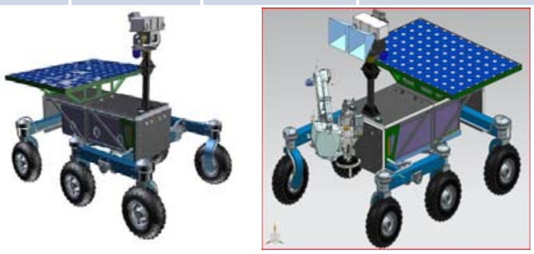

Fig. 2: MESR rover

To the rover will be attached three key components to a MSR type mission: a mini-corer with a sample capture device as well as an arm and a microscope. These payloads will be used together for capturing low to very high resolution 3D images of rocks before samples are being captured using the mini-corer and sample hadling system referred to as the caroussel.

A Small Manipulator Arm (SMA) equipped with advance control algorithm and visual servoing will be available to position the instruments at the right position using rover and arm cameras. The microscope is currently going through characterization at the CSA, the SMA and the mini-corer will be integrated along with the microscope on a MESR mock-up by June-July 2012. Figure 3 illustrates the SMA, the microscope and mini-corer.

Fig. 3: Mini-corer, microscope and SMA

In addition to the MESR, two micro-rover prototypes: MRPTA and Kapvik are planned for delivery in May 2012. With a mass requirement of 30 kg , a range greater than 500 m and unaided operations on slope >30º and tether operations on steep slopes > 65º, the micro-rovers will also include autonomous navigation, tele-operations capabilities, manipulator and science instruments.

The Kapvik micro-rover shown in Figure 4a, includes a robotic mast with end effecter that enables acquisition of selected samples and subsurface trenching. It also includes a Multispectral imaging UV-Vis/IR sensors providing in-situ analysis and 2-D mapping of mineralogy, water/ice content and planetary resources.

Fig 4: Kapvik & MRPTA micro-rovers

The MRPTA micro-rover presented in Figure 4b provides a multitude of configurations given its two arms, tracks option and different set of wheels. It also includes a tooling arm to capture soil samples and two scientific instruments: XRF and LIF.

Potential near-term mission contributions: *Low-cost or improved performance in Mars surface mobility***:**
The critical objectives pursued by the development of the Mars class rovers under ESM are to minimize the power required by the rover, maximize its autonomy and increase its capability to move from science point A to point B in order to maximize the time available for science investigations, or minimum the duration of surface operations to achieve a particular task.

A particular strength being developed in Canada is the combination of advanced vision systems, navigation algorithms and data fusion that is pushing the limit, bringing navigation of the rover to within 1% relative localization.