INSTRUMENTS AND ENABLING TECHNOLOGIES FOR PLANETARY EXPLORATION.
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Introduction: MDA and SSL have been consistent partners on planetary missions and have developed a suite of flight-ready instruments and mechanical systems.

Mission involvement includes:

- Psyche Discovery Mission
- ESA ExoMars
- OSIRIS-REx New Frontiers Mission
- Lunar Atmospheric and Dust Environment Explorer
- Phoenix Scout Mission
- Curiosity Mars Rover
- InSight Discovery Mission
- Mars Exploration Rovers Opportunity & Spirit

Lidar systems: Lidar systems such as the OSIRIS-REx Laser Altimeter (OLA, **Fig 1**) provide ranging, shape modelling and mapping capabilities [1]. These systems can be customized to operate over a wide range of altitudes.

Scientific and Operational Gains. Some scientific and operation gains from lidar investigations include:

- Determine shape of asteroids/comets
- Determine shape of fine-scale surface features on planets, moons, etc.
- Support safe sample acquisition via high resolution target shape information
- Constrain surface material properties using high-resolution shape information

Lidar systems can also yield significant information about planetary atmospheres, as was the case for the Meteorological Station (MET [2], see **Fig 2**), a Canadian payload contribution to the Phoenix Mars Lander. The low-mass MET lidar system conducted successful *in situ* measurements of dust, clouds, ground fogs and snow falling in the Mars atmosphere.

APXS: Alpha-particle X-ray spectrometry yields elemental abundance of targets of scientific interest. MDA partnered with the University of Guelph to build the APXS instrument [3] for the Curiosity Mars rover. APXS has more than 2000 hours of operation on the Curiosity rover (**Fig 3**).

Robotic Arms, Rovers and Mechanisms: High reliability mission / safety critical electromechanical manipulator systems such as the robotic arms SSL developed for the InSight Discovery Mars mission, Mars Curiosity Rover, Mars Exploration Rovers and Mars Phoenix Lander enable operations under challenging conditions. These manipulator systems allow for surface sampling, sample delivery, excavation, and accurate placement of science instruments. Control algorithms allow for large scale manipulation, fine scale delicate tasks, and active damping.

Careful processing of data returned by robotic manipulators and by mobility systems such as the system MDA is building for the ExoMars rover allow for insight into regolith physical properties (**Fig 4**).

Cameras: Several cameras have been built for NASA, CSA, JAXA, DARPA, Lockheed Martin, Boeing, and Urthecast. One such camera is the MicroCam (**Fig 5)** for deep space applications. MicroCam is a 6 Megapixel monochrome CMOS camera with a high dynamic range, auto exposure, adjustable gains and levels. This broadband camera is radiation hardened and sensitive from 400 – 900 nm. MicroCam mass is 220 g unshielded and 600 g shielded.

Scientific and Operational Gains. Cameras such as MicroCam have significant scientific and operational gains, including:

- Sample imaging after acquisition and before insertion: visual inspection of sample brightness, clumping, grain size
- Image areas of spacecraft to assess stability

Cost-Effective, Commercial Solutions to Enable Greater Science Return: SSL's spacecraft solutions enable greater return on science missions, including the recently-selected Psyche Discovery mission. For Psyche, SSL will provide a highly capable composite structure spacecraft platform equipped with a high-power solar electric propulsion system. The Psyche spacecraft design is based on the SSL 1300 platform, which has been proven on more than 100 missions. This platform has the flexibility to support a variety of applications.

Antennas: MDA provided a high data rate X-band antenna with high accuracy pointing for the ExoMars Trace Gas Orbiter.

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References: [1] Daly M. et al. (2017) *LPS XLVIII*, this issue. [2] Whiteway J. et al. (2008) *JGR*, *113 (E3)*. [3] Gellert R. et al. (2009) *LPS XL*, Abstract #2364.

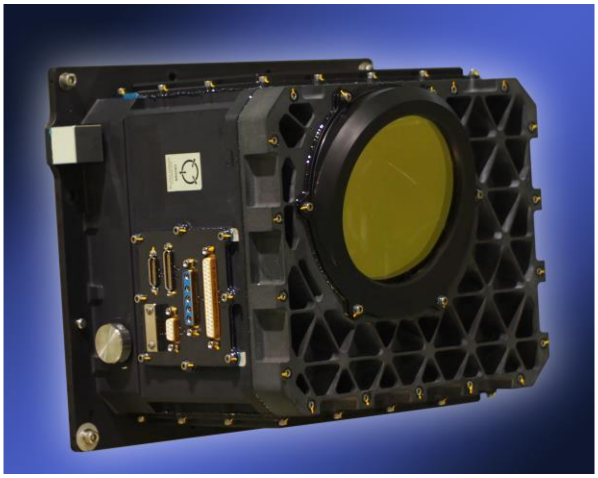

Fig 1. OSIRIS-REx Laser Altimeter (OLA).

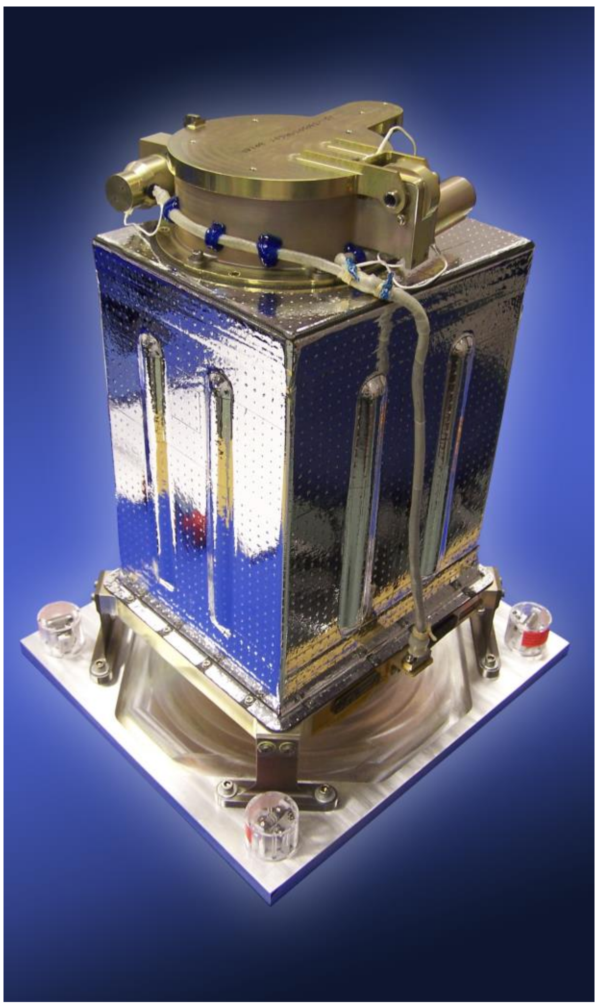

Fig 2. Lidar for Meteorological Station (MET) on Phoenix Mars Lander.

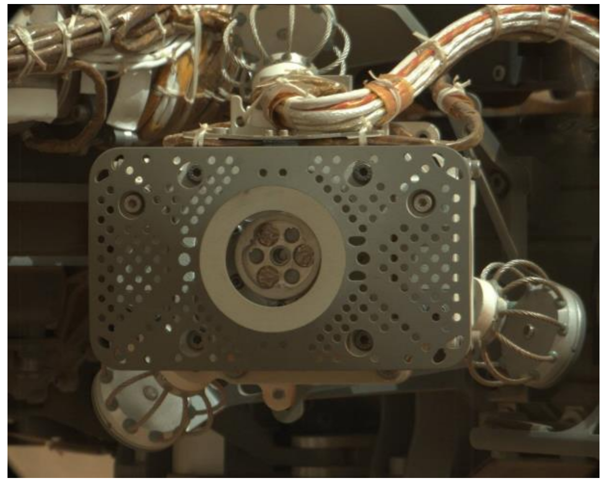

Fig 3. Alpha-Particle X-Ray Spectrometer (APXS). Image courtesy of NASA.

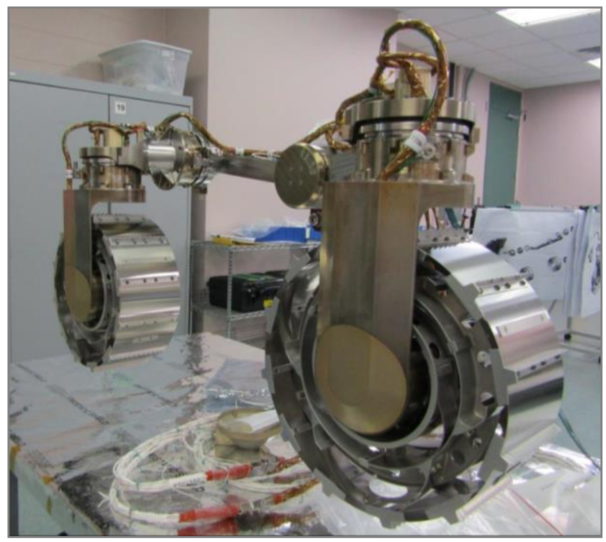

Fig 4. ESA ExoMars Rover Locomotion System.

Fig 5. MicroCam camera.