9445 Airport Road
Brampton, ON
Canada, L6S 4J3
December 1, 2022

To Whom It May Concern:

The Robotics & Space Operations Division at MDA would be pleased to attend the upcoming 2023 Technology Showcase for Future NASA Planetary Science Missions in Galveston, TX. In particular, we would like to provide information about the following technologies (details of which are enclosed):

1. Alpha Particle X-ray Spectrometer (APXS)
2. ExoMars Stereo Camera
3. Light Exploration Robotic Arm (LERA)
4. Laser Rangefinder (LRF) Altimeter
5. Meteorology Package (MET)
6. Mobility & Locomotion Systems
7. OSIRIS-REx Laser Altimeter (OLA)

All of the listed technologies are relevant to the NASA SMD science mission priorities highlighted by the abstracts published in conjunction with this event. Our solutions are particularly relevant for investigations requiring in-situ measurements of surface elemental composition, surface mobility, visible-light imaging and situational awareness, LIDAR-based ranging and topographical measurements, and robotic deployment & manipulation in a mass and power range suitable for a lander- or rover-based platform. The table below gives a more detailed mapping between the above technologies, and relevant published abstracts.

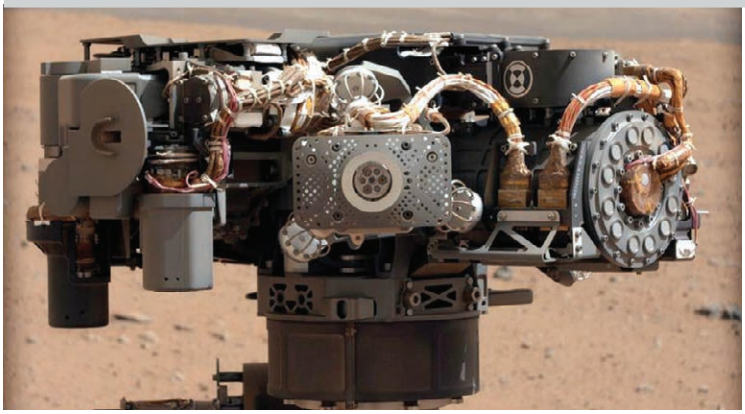
	APXS	**ExoMars Cam**	**LERA**	**MET**	**LRF/OLA**	**Mobility**
A South Pole-Aitken Basin Sample Return Mission Using Commercial Rovers and Landers	•		•			•
Endurance: Lunar South Pole–Aitken Basin Traverse and Sample Return Rover	•		•			•
Collecting In Situ Observations of Meteorological and Aeolian Processes on Mars			•	•		
An Incoherent Scatter Radar Mission to Mars (ISRMM)			•			
A Mercury Lander Mission Concept Study	•	•				
Optical Sensor for ISRU Minerals (OSIM)			•			
Centaur ORbiter And Lander (CORAL)		•	•		•	

Sincerely,

Dr. Jamil A. Shariff
Senior Member of Technical Staff
Systems Design
MDA Robotics & Space Operations
jamil.shariff@mda.space

ROBOTICS AND SPACE OPERATIONS

Alpha-Particle X-Ray Spectrometer (APXS)



Developed for the Mars Science Laboratory Mission, the Alpha-Particle X-Ray Spectrometer (APXS) is a contact instrument that uses X-ray spectroscopy to determine the elemental composition of soils and rocks. The science objective of the APXS is to produce an understanding of the formation, evolution, and biological potential of the landing site environment through analysis of the variations in elemental composition and distribution of elements comprising the Martian materials.

KEY FEATURES:

1/ Assess the geological context of the rovers site along its traverse, in combination with other contact instruments, sample preparation tools, and remote sensing instruments

2/ Determine and characterize rock types along the rover traverse

3/ Constrain the mineralogy of rocks and soils

4/ Perform stand-alone science investigations to determine weathering rinds on rocks

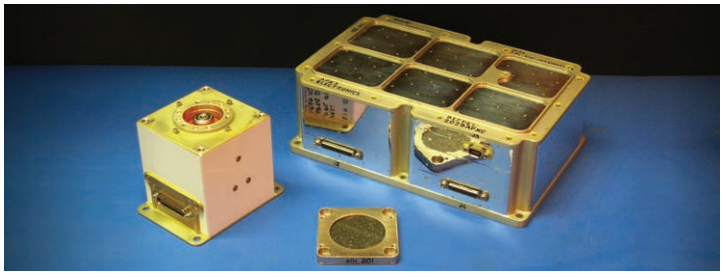
5/ Map the variability of mobile elements on rock surfaces, and determine the elemental composition of abraded rocks.

6/ Determine local chemical anomalies along the rover traverse

7/ Determine the elemental composition of the soils, subsurface soils and fragments

8/ Document and compare the homogeneity of in-situ and processed samples along their way through the sample processing stages

9/ Assess the suitability of in-situ samples for insertion into the sample processing unit and analytical laboratory instruments



PERFORMANCE
RESOLUTION: 145 EV AT 5.89 KEV
DATA VOLUME: 32KBYTE CAPACITY OF ONBOARD MEMORY (VOLATILE)
DATA STORAGE: 32KBYTE
INTERFACES
MECHANICAL: FOUR FASTENERS AT CORNERS OF MOUNTING INTERFACE
ELECTRICAL: +28V DC +8/-6V
DATA: DUAL REDUNDANT, RS-422, UART
HERITAGE
APXS WAS PART OF THE MARS SCIENCE LABORATORY ROVER (CURIOSITY) LAUNCH IN 2011 AND LANDED IN 2012. OPERATED PAST ITS 2 YEAR MISSION LIFETIME.
BUDGETS
DIMENSIONS: · SENSOR HEAD: 82 MM X 60 MM X 78.5 MM (3.2" X 0.9" X 3.1") · ELECTRONICS: 80 MM X 119 MM X 60 MM (7.1" X 4.7" X 2.4") · CALIBRATION TARGET: 50 MM X 50MM X 60 MM (2" X 2" X 2.4")
MASS: 1.7 KG (3.75 LB) EXCLUDING HARNESS
POWER: 6 - 8 W
ENVIRONMENT
QUALIFIED FOR MARTIAN ENVIRONMENT
OPERATIONAL TEMPERATURE: · SENSOR: -130°C TO +20°C (-202°F TO +68°F) · ELECTRONICS: -55°C TO +45°C (-67°F TO +113°F) · CALIBRATION TARGET: -130°C TO +20°C (-202°F TO +68°F)
NON-OPERATIONAL TEMPERATURE: · SENSOR: -45°C TO +55°C (-49°F TO +131°F) · ELECTRONICS: -45°C TO +55°C (-49°F TO +131°F) · CALIBRATION TARGET: -130°C TO +50°C (-202°F TO +122°F)
RADIATION: 1.4 KRAD

ROBOTICS AND SPACE OPERATIONS

EXOMARS CAMERA (EXMC)

EXMC is MDA's visible light stereo camera for rover navigation and localisation. It boasts a mass of less than 700 g, peak power consumption less than 2.5 W, wide FOV, automatic distortion correction of images and delivers unprecedented accuracy over a wide temperature range. The EXMC provides both situational awareness of the rover in its environment and 3D information of the terrain for path planning. In addition to acting as a navigation and localization camera, the EXMC has also been modified to allow its use as a sun-sensing device. When required, the EXMC can acquire a precise image of the sun to support the RV Autonomous Mobility System in determining the Rover's absolute localization when on the surface of Mars.

KEY FEATURES:

1/ Navigation

2/ Localisation

3/ Sun-sensing device

4/ Capable of survival in harsh Martian environment without heaters

PARAMETER	VALUE
OVERALL DIMENSIONS	290 MM X 82 MM X 79 MM
MASS	< 700 G
POWER CONSUMPTION	< 2.0 W (STANDBY), < 2.5 W (OPERATION)
TEMPERATURE RANGE	-120°C TO +110°C (STORAGE), -50°C TO +40°C (OPERATION)
STEREO BASELINE	150 MM
IMAGE RESOLUTION	1024 X 1024
FIELD OF VIEW	67 X 67 DEG
EXPOSURE TYPE	GLOBAL SHUTTER
EXPOSURE TIME	0.02 MS … 1000 MS
F-NUMBER	F/8
FOCAL LENGTH	4.0 MM
DATA INTERFACE	SPACEWIRE
LIFETIME	9 MONTHS TRANSIT; AND 218 MARTIAN SOLS

ABOUT MDA

MDA is an international space mission partner and a robotics, satellite systems and geointelligence pioneer with a 50-year story of firsts on and above the Earth. With a track record of making ambitions come true, MDA enables highly skilled people to continually push boundaries, tackle big challenges, and imagine solutions that inspire and endure to change the world for the better, on the ground and in the stars.

CONTACT

FOR MORE INFORMATION, CONTACT:
BRUNO SYLVESTRE AT
BRUNO.SYLVESTRE@MDA.SPACE
TELEPHONE: 613-599-7603 X 517

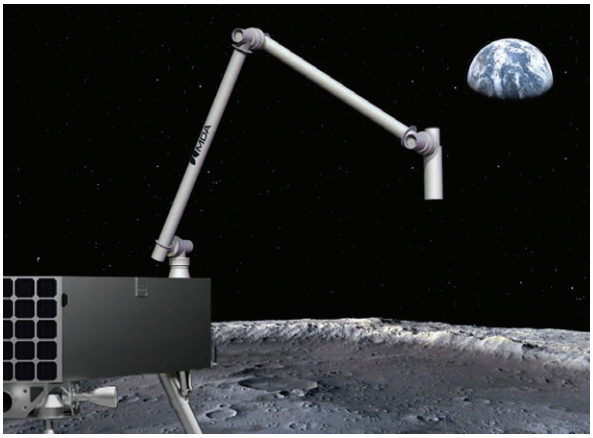
MDA
302 LEGGET DRIVE, SUITE 202,
KANATA, ONTARIO, K2K 1Y5
CANADA
WWW.MDA.SPACE

ROBOTICS AND SPACE OPERATIONS

LIGHT EXPLORATION ROBOTIC ARM (LERA)

The Light Exploration Robotic Arm (LERA) is a four degree of freedom (DOF), 3m-class robotic manipulator that is capable of operating in the harsh environment on the lunar surface. The LERA can enable science missions through:

- Lander or rover payload handling and/or deployment
- Precision positioning and/or pointing of instruments
- Supports tools for a variety of mission needs such as payload relocation, scooping/trenching, or sample transfer to science instrumentation
- Positioning for in-depth imaging surveys
- Option to add extra degrees of freedom, power and/or data connection to instruments, and tools.



KEY FEATURES:

1/ Dust-tolerant actuators for long life on lunar surface

2/ 20+kg payload capability for lander/rover offloading

3/ High-heritage software for mission-critical operations

4/ Scripting for autonomous operations

5/ Single fault tolerant

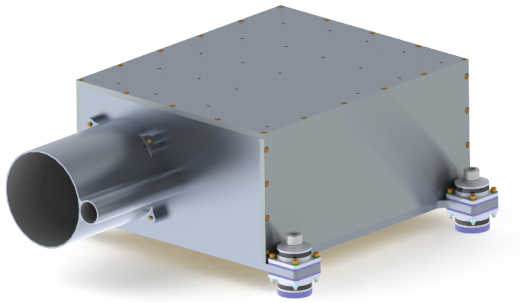
PARAMETER	VALUE
DEGREES OF FREEDOM (DOF)	4
PAYLOAD CAPABILITY*	70KG @ 1m WORKSPACE, 20KG @ 2.5m
LENGTH/REACH	3m/2.5m
MASS	<40KG
COMMUNICATION	1553 OR RS-422
LIFE	10 YEARS
VOLTAGE	28VDC
CONTROL SOFTWARE	DERIVED FROM FLIGHT-PROVEN ISS ROBOTICS SOFTWARE
END EFFECTOR	OPTIONAL AS REQUIRED BY CUSTOMER

*Payload capability for fully configured arm, including end effector. Final capability may change based on desired architecture and tools.

ROBOTICS AND SPACE OPERATIONS

LASER RANGE FINDER (LRF) ALTIMETER

MDA's Laser Range Finder (LRF) altimeter provides time-critical range measurements to a host spacecraft to support deep space landing applications such as to asteroids, comets or planets. Derived from MDA's proven TriDAR architecture, the LRF is based on a custom LiDAR and processing package and it consists of an Integrated Optics Assembly, an Integrated Electronics Assembly and housing. It uses Time-of-Flight (TOF) technology to perform fast and accurate range measurements.



KEY FEATURES:

1/ Accurate and precise altimetry

2/ Designed for interplanetary missions

3/ Can be used in redundant mode (with two units operating simultaneously)

PARAMETER	VALUE
DIMENSIONS	346 X 270 X 135 MM
MASS	5.4 KG
POWER	20 W (STANDBY), 40 W (OPERATION, AVERAGE)
TEMPERATURE RANGE	-50°C TO +70°C (NON-OPERATION) -50°C TO +60°C (OPERATION)
COMMAND/DATA INTERFACE	RS422
POWER INTERFACE	33.0 TO 50.2 VDC
RANGE	1 M TO MAX RANGE (DEPENDS ON TARGET REFLECTIVITY; NOTIONALLY 3.8-7.5 KM FOR MARS & UP TO 2.2 KM FOR PHOBOS)
RANGE MEASUREMENT ERROR	< 77 CM + 0.01% OF RANGE ERROR AT SHORT RANGE CAN BE IMPROVED USING ADDITIONAL TECHNIQUES (< ~10 CM)
MEASUREMENT TELEMETRY RATE	1 HZ
RADIATION ENVIRONMENT	TID > 20 KRAD SEE (SEU AND SET) IMMUNE LETTH > 37 MEVCM2/MG SEL IMMUNE LETTH > 60 MEVCM2/MG SEB IMMUNE LETTH > 60 MEVCM2/MG SEGR IMMUNE LETTH > 60 MEVCM2/MG

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MDA
302 LEGGET DRIVE, SUITE 202,
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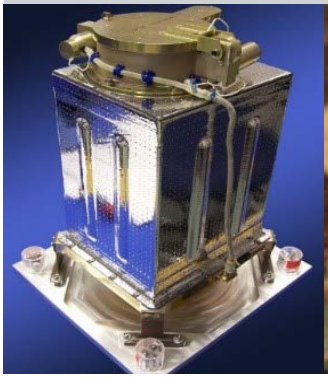
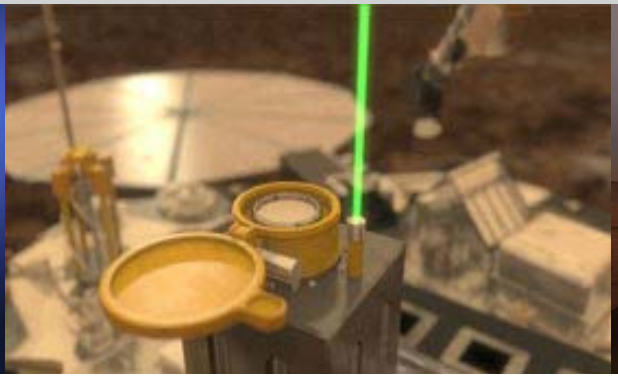
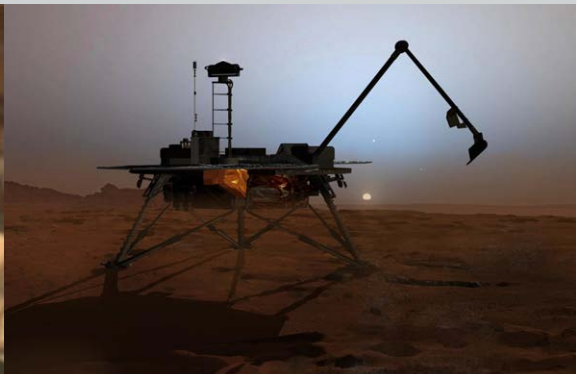
WWW.MDA.SPACE

ROBOTICS AND SPACE OPERATIONS

Meteorological Sensing On Mars







MDA developed the Meteorology package (MET) on the Phoenix Mars Lander, to provide characterization of the Martian climate. The MET consisted of a lidar, three thermocouples and a pressure sensor.

KEY FEATURES:

1/ High performance sensors

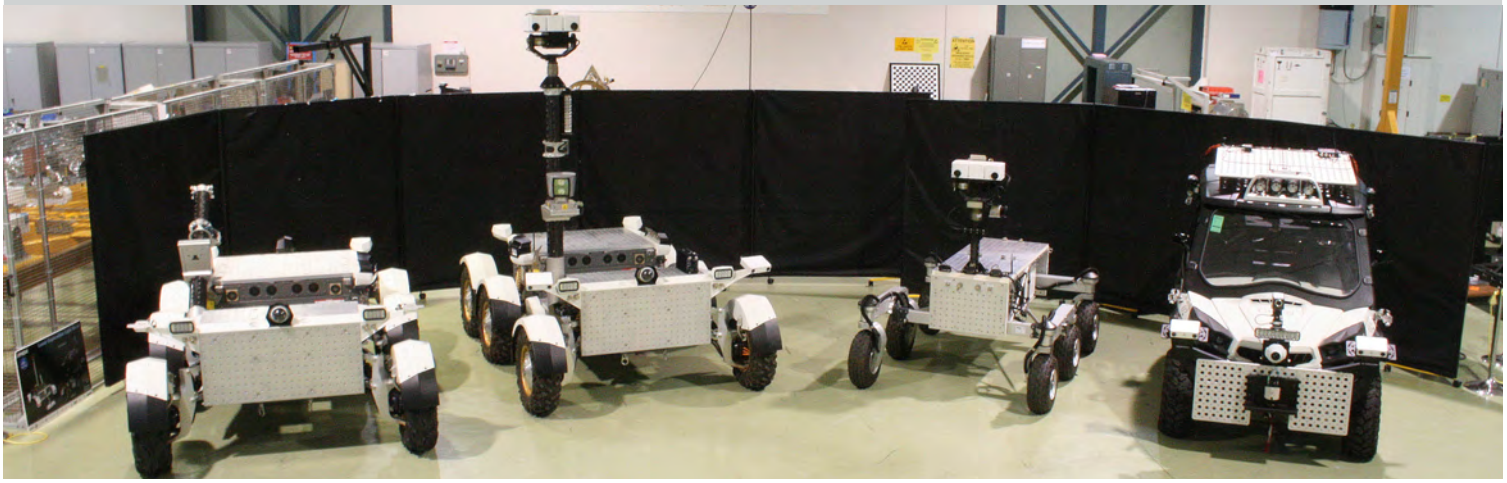
2/ Low mass and small volume solutions

3/ Proven for the Martian environment

KEY FEATURES
• HIGH PERFORMANCE SENSORS • LOW MASS AND SMALL VOLUME SOLUTIONS • PROVEN FOR THE MARTIAN ENVIRONMENT
PERFORMANCE
• LIDAR
• WAVELENGTH: 532 NM TO 1064 NM • RANGE: 50M TO 20KM • RESOLUTION: 5M (NOMINAL 50M)
• THERMOCOUPLE
• MEASUREMENT RANGE: 140 TO 280 K • ACCURACY: ± 1 K • PRECISION: 0.1 K • FREQUENCY: 0.5 HZ • RESPONSE TIME: < 1S
• PRESSURE SENSOR
• MEASUREMENT RANGE: 0.5 TO 1.5 KPA • ACCURACY: ± 10 PA • PRECISION: 1 PA • FREQUENCY: 0.5 HZ • RESPONSE TIME: 2S
FLIGHT HERITAGE
• MET WAS PART OF THE PHOENIX MARS, WHICH OPERATED ON THE SURFACE OF MARS FROM MAY 2008 TO NOVEMBER 2008.

ROBOTICS AND SPACE OPERATIONS

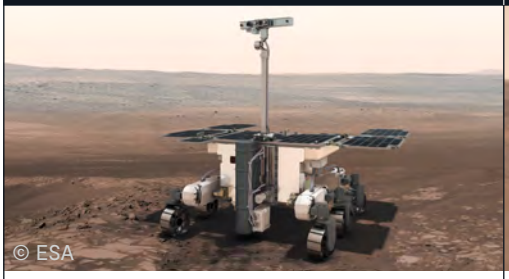
MOBILITY AND LOCOMOTION SYSTEMS



MDA has accumulated almost 20 years of experience in developing rovers, mobility subsystems, sensors, navigation systems, and payloads used for lunar and planetary exploration. MDA is uniquely positioned by its extensive heritage in both autonomous and co-operative robotic operation to take on mission critical elements and account for the appropriate operational and safety requirements required by the mission.

RECENT PROJECTS INCLUDE:

EXOMARS ROVER LOCOMOTION SYSTEM AND NAVIGATION SENSORS



MDA provided the electromechanical components required for all on-surface rover locomotion and deployment after landing. These operations are enabled through the use of BEMA's 18 active DOFs which are enabled via 3 bogies, each connected to a wheel pair. All wheels can be pivoted to adjust the rover height and angle with respect to the local surface, and to provide walking ability, particularly useful in soft, non-cohesive soils like dunes.

SAMPLE FETCH ROVER

Sample Fetch Rover (SFR) is ESA's contribution to NASA's Mars Sample Return mission and is expected to launch in 2026. MDA will be providing the Sample Fetch Rover Actuator System for Traverse (FAST), which is responsible for the mobility of the rover and includes the bogies, actuators and wheels. SFR will be a 4 wheeled system with all wheel drive and explicit steering to efficiently traverse and navigate the Martian terrain.

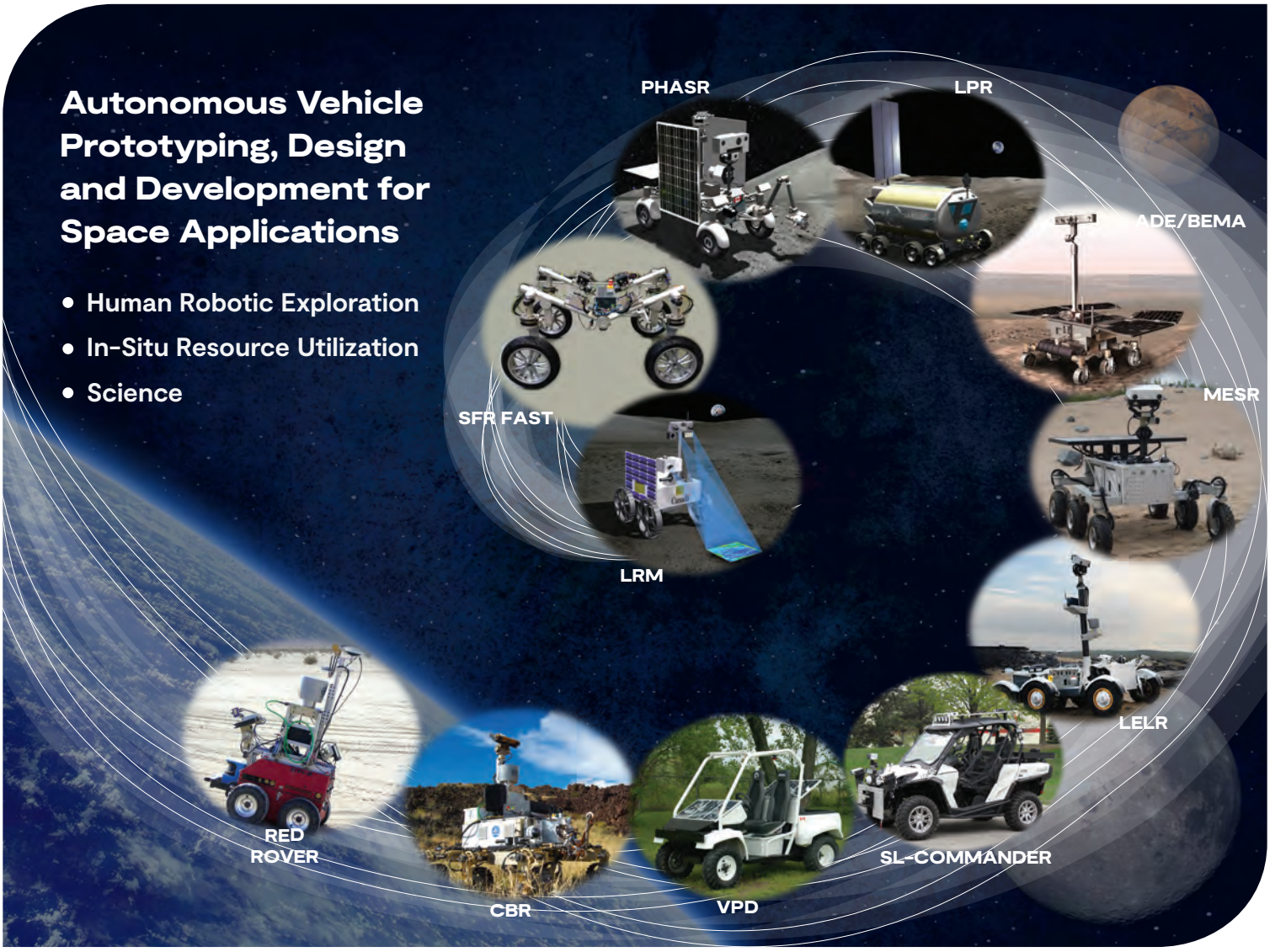
LUNAR ANALOG MISSIONS

MDA has developed several lunar analog rovers to advance key rover technologies for manned and un-manned operations. Key technologies include:

- Autonomous Rover Navigation
  - Localization
  - Path tracking
  - Mapping
  - Autonomy
  - Terrain assessment
- Mobility
- In-situ geological analysis operations
- End-to-End mission simulators

Autonomous Vehicle Prototyping, Design and Development for Space Applications

- Human Robotic Exploration
- In-Situ Resource Utilization
- Science



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ROBOTICS@MDA.SPACE

MDA
302 LEGGET DRIVE, SUITE 202,
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CANADA
WWW.MDA.SPACE

ROBOTICS AND SPACE OPERATIONS

OSIRIS-Rex Laser Altimeter (OLA)

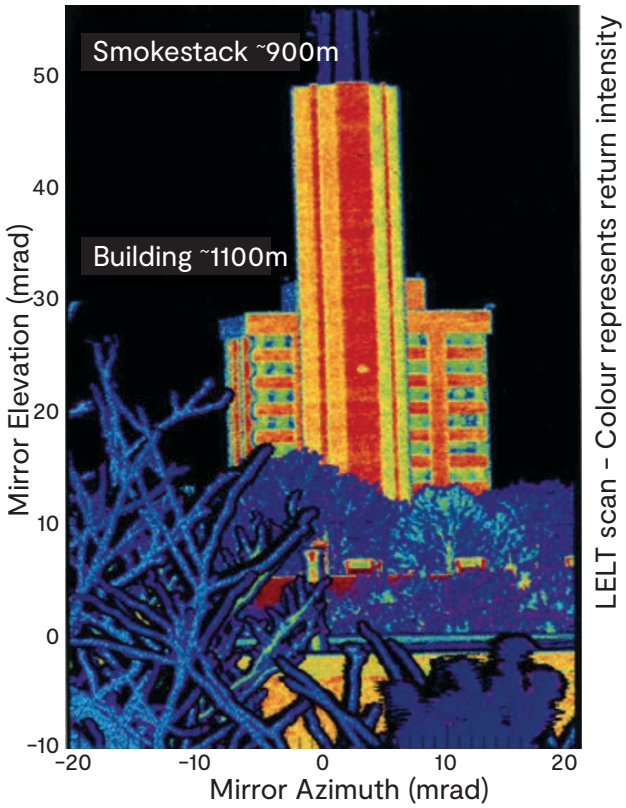
Scanning Lidar Sensorhead

The OSIRIS-Rex Laser Altimeter is a fast scanning lidar system with a single receiver providing 3D point cloud data. OLA was flown in the NASA New Frontiers OSIRIS-Rex Mission and will be responsible for mapping the surface of the Bennu astreroid.

KEY FEATURES:

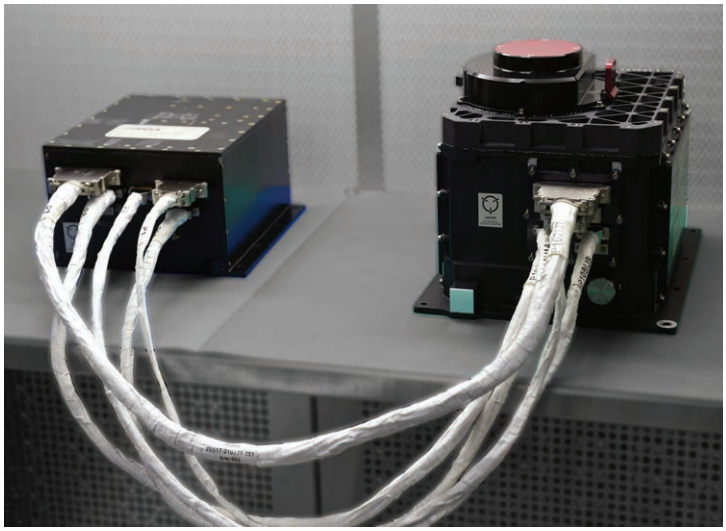
1/ Precision fast scanning Lidar for NASA New Frontiers OSIRIS REx Mission

2/ Single receiver with high and low energy laser transmitters generate precision 3D point cloud altimetry and surface mapping data.



PERFORMANCE
ACCURACY <5 CM
PRECISION <1 CM (1Σ)
RESOLUTION 1 CM
MINIMUM SPOT-TO-SPOT SPACING 50µRAD
ANGULAR KNOWLEDGE ACCURACY 1.5MRAD
FIELD OF REGARD AZ: +/- 10°, EL: +/- 6°
SCAN TIME AT MAX RESOLUTION <18 S
MODES
HIGH ENERGY MODE · MAXIMUM RANGE (AGAINST A 3% TARGET): 8 KM · MINIMUM RANGE (AGAINST A 3% TARGET): 100 M (3 M)* · WAVELENGTH: 1064 NM · FIRING RATE: 100 HZ · LASER DIVERGENCE: 200 µRAD
LOW ENERGY MODE · MAXIMUM RANGE (AGAINST A 3% TARGET): 1.2 KM · MINIMUM RANGE (AGAINST A 3% TARGET): 50 M (3 M)* · WAVELENGTH: 1064 NM · FIRING RATE: 10,000 HZ · LASER DIVERGENCE: 100 µRAD
INTERFACES
ELECTRICAL INTERFACE: RS422
MECHANICAL INTERFACE: STANDARD FASTENERS
HERITAGE
OLA WAS LAUNCHED IN 2016, STARTED OPERATIONS IN 2018.

*With decreased range accuracy



OLA Flight Hardware

DIMENSIONS
· SENSOR: 321.4 MM X 270 MM X 230 MM · E-BOX: 249.2 MM X 285.2 MM X 141.5 MM
MASS:
· SENSOR: 11.8 KG · E-BOX: 9.3 KG
POWER:
· STANDBY: < 50 W · LOW ENERGY MODE: 80 W · HIGH ENERGY MODE: 85 W
ENVIRONMENT
LIFE TIME OF 5 YEARS
SENSOR: · OPERATIONAL TEMPERATURE: -5°C TO +30°C (+23°F TO +86°F) · NON-OPERATIONAL TEMPERATURE: -30°C TO 45°C (-22°F TO +113°F)
ELECTRONICS · OPERATIONAL TEMPERATURE: -10°C TO +50°C (14°F TO +122°F) · NON-OPERATIONAL TEMPERATURE: -20°C TO 65°C (-4°F TO +149°F)
RADIATION: 5.8 KRAD

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