Mars Exploration Ice Mapper

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New MEP Mission Initiatives

President’s FY21 Budget Request supports essential Mars precursors

“The Budget also funds the robotic exploration of Mars, in cooperation with international partners, as a precursor to human exploration. In addition to performing cutting-edge scientific investigations, a new Mars Ice Mapper mission would provide data for potential landing sites, and a Mars Sample Return mission would demonstrate the ability to launch from Mars’ surface.”

- **Mars Sample Return** - humanity’s 1st roundtrip to another planet
  - Returning samples from an ancient habitable zone
  - NASA/ESA partnership
  - 6 year development cycle - 2026 LRD (2031 return)

- **Mars Exploration Ice Mapper** - searching for habitable environments and accessible ISRU resources
  - Joint NASA/CSA Exploration initiative
  - Implementation assumes substantial partnership collaboration
  - 5 year development cycle - 2026 LRD
NASA Moon to Mars (M2M) studies identified ice as a critical element of human exploration of Mars
- Accessible Ground Ice as a Resource
- Accessible Ground Ice as rich in Science Potential
- Accessible Ground Ice as an Exploration Destination Driver

Planning for Human Exploration in the mid-2030s requires knowledge of location, character, and extent of accessible ice beforehand
- Data needed by late 2020s
- Leveraged prior NASA/CSA collaboration studies to jump start planning
  - CSA L-band radar
  - Multiple JPL/GSFC/Industry studies

Exploring potential partnership interests to jointly fly mission
- Potentially as early as 2026
- Both NASA and CSA have received funding for planning and preparation
  - MEP leading the effort
  - Assessing communications/data relay needs
Exploration Ice Mapper: Objectives

EXPLORATION OBJECTIVES

- Ground Ice as a Resource
  Is there water ice contained within the first 10m of the surface?
  What are the spatial extents of the deposits?

- Landing Site Geotechnical Properties
  How rough are the surface and shallow subsurface?
  How compact are the potential landing sites?

SCIENCE OBJECTIVES (notional)

- Distribution & Origin of Ice Reservoirs
  Quantify extent and volume of water ice in non-polar regions

- Dynamic Surface Processes on Mars
  Establish role of liquid water in Recurring Slope Lineae

- Geological Evidence for Environmental Transitions
  Evaluate fine-scale morphology in ancient terrains ("dust removal")
Exploration Ice Mapper: Approach

“RECONNAISSANCE ZONE”

- Exploration objectives focus on regions where human landing sites may be possible
  - Equatorward of 40° for solar conditions
  - Poleward of 25° to maximize possibility of locating ground ice
  - Elevation < -2km from MOLA datum for EDL considerations

- Science objectives – planet wide characterization

KEY OUTPUTS

- Exploration: “Critical Data Products”
  - CDP-1: Reconnaissance Zone Shallow Subsurface Ice Map
  - CDP-2: Reconnaissance Zone Surface & Shallow Subsurface Physical Properties Map

- Science: “High Priority Investigations” (notional)
  - HPI-1: Martian Ice Reserves & Surface Morphologies
  - HPI-2: Radar Imaging of Recurring Slope Lineae
  - HPI-3: Ancient Mars Channel ‘Excavation’

- Strengthened communication infrastructure
The Science Case for Synthetic Aperture Radar (SAR)

Community Support

- Various concept studies/proposals over the past 20 years
- Most recently outlined in Science Definition Team report for NASA's Next Mars Orbiter (NeMO)

Advantages

- Polarization of signal allows for interpretation of surface/subsurface materials
- Increased center frequency permits resolution of finer layers in the near subsurface
SAR Development: Prior Investments

CANADIAN SAR HERITAGE

- Radarsat (C-band) family of spacecraft
  - Radarsat (1995-2013): exceeded 5 year design lifetime
  - Radarsat-2 (2007-present): over 34 billion km² of imagery
  - Radarsat Constellation (2019-present): completed commissioning

MARS SAR CONCEPT RECENT HISTORY

- 2017
  - Canadian Federal Budget announces support for Mars SAR
  - First iteration design completed for NeMO
- 2018
  - Second iteration design completed for NASA rideshare concept
  - Technology development contract to prototype feed array
- 2019
  - Third design iteration completed for notional ice-mapper mission
SAR Payload Concept

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Frequency</td>
<td>930 MHz</td>
</tr>
<tr>
<td>Antenna</td>
<td>6 m deployable mesh</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>-35 db as NESZ</td>
</tr>
<tr>
<td>Power</td>
<td>500-1000 W</td>
</tr>
<tr>
<td>Configuration</td>
<td>Multi-feed offset fed reflector</td>
</tr>
<tr>
<td>Operational Modes</td>
<td>SAR and Sounder</td>
</tr>
<tr>
<td>Polarization</td>
<td>Hybrid (circular transmit, dual linear reception)</td>
</tr>
</tbody>
</table>

**SAR**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swath Width</td>
<td>30 km</td>
</tr>
<tr>
<td>Incidence Angle</td>
<td>40-45°</td>
</tr>
<tr>
<td>Horizontal Resolution</td>
<td>5-30 m</td>
</tr>
<tr>
<td>Penetration Depth</td>
<td>&gt; 6 m</td>
</tr>
</tbody>
</table>

**Sounder**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Resolution</td>
<td>&lt; 1 m</td>
</tr>
<tr>
<td>Along-track Resolution</td>
<td>30 m</td>
</tr>
<tr>
<td>Across-track Footprint</td>
<td>1.5 km</td>
</tr>
</tbody>
</table>
SAR Mode

Strip map swath width: 30 km
Incidence angle: 40-45°
Horizontal Resolution: 30 m
Highest Resolution: ~ 5 m
Penetration Depth: 6 m
Polarization: hybrid (circular transmission and dual linear reception)
Modes: Repeat pass InSAR and tomography possible
Sounder Mode

Ground-track spacing: 20 km at the equator
Vertical resolution: 1 m in free space
Along-track resolution: 30 m
Across-track footprint: 1.5 km
Modes: single track and repeat track
Mars SAR Technology Readiness

- Heritage TEM line slices
- HPA, EPCs and LNAs flight heritage from multiple previous payloads
- Radar Elements
- Passive feed array components with polarizer
- Successfully RF tested using 3D printed components
Nominal Mission Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mars Radius</td>
<td>3390</td>
<td>km</td>
</tr>
<tr>
<td>Orbital Altitude</td>
<td>250-320</td>
<td>km</td>
</tr>
<tr>
<td>Data Allocation</td>
<td>48000</td>
<td>Mbits/day</td>
</tr>
<tr>
<td>SAR Ground speed</td>
<td>~3</td>
<td>km/s</td>
</tr>
<tr>
<td>Radar Swath (side-looking)</td>
<td>32</td>
<td>km</td>
</tr>
<tr>
<td>Orbits</td>
<td>13</td>
<td>day⁻¹</td>
</tr>
<tr>
<td>Sounder Ground Track Spacing at equator</td>
<td>20</td>
<td>km</td>
</tr>
</tbody>
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Assumptions

- Cover ~ 50% of entire ±25-40° band for human exploration goals
- 50% of orbit time used for data transmission, not data collection
Concept of Operations

YEAR 1
- primary focus on generating Critical Data Products 1 and 2
- opportunistic science data can be collected on any orbit if sufficient data and power are available

YEAR 2
- scientific investigations are prioritized
- data for higher order mapping products (e.g. SAR tomography) collected when orbit crosses high priority landing sites
## Relevance to MEPAG Goals (Exploration)

<table>
<thead>
<tr>
<th>Relation to NASA Goals</th>
<th>Human Exploration Objective</th>
<th>Investigation</th>
<th>Required Measurements</th>
<th>MEPAG Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISRU Water Resources &amp; Civil Engineering, Properties</td>
<td>HE O1. Ground Ice as a Resource</td>
<td>Detection of Shallow Water Ice</td>
<td>Identification of Regions with Water Ice Present within 10 m of Surface</td>
<td>Goal I: Life</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Characterize Material Properties &amp; Thickness of Dry Overburden</td>
<td>Identification of Regions where depth of Dry Overburden is &lt; 2 m, and Estimation of Material Thickness &amp; Consolidation</td>
<td>Goal II: Climate</td>
</tr>
<tr>
<td></td>
<td>HE O2. Landing Site Geotechnical Properties</td>
<td>Surface Properties</td>
<td>Roughness; Slopes; Surface Texture, and Load-bearing Strength</td>
<td>Goal III: Geology</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td>Goal IV: Human</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Goal I</th>
<th>Goal II</th>
<th>Goal III</th>
<th>Goal IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>B4.2</td>
<td>C2.1</td>
<td>C2.2</td>
<td>D1.1</td>
</tr>
</tbody>
</table>
# Relevance to MEPAG Goals (Science)

<table>
<thead>
<tr>
<th>Relation to NASA Goals</th>
<th>Science Objective</th>
<th>Investigation</th>
<th>Required Measurements</th>
<th>MEPAG Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Decadal Survey Priority</strong></td>
<td>S O1. Distribution &amp; Origin of Ice Reservoirs</td>
<td>Distribution of Buried Water &amp; CO₂ ice plus Relationship to Surficial Polar Deposits</td>
<td>Extent and Volume of Water Ice in Non-polar Regions</td>
<td>Goal I: Life</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extent &amp; Volume of Buried CO₂ Ice in the Polar Caps</td>
<td>Goal II: Climate</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Shallow Subsurface Structure of Polar Cap &amp; Layered Terrain</td>
<td>Goal III: Geology</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Goal IV: Human</td>
</tr>
<tr>
<td><strong>New Discoveries / High MEPAG Priority</strong></td>
<td>S O2. Dynamic Surface Processes on Mars</td>
<td>Role of Liquid Water in Recurring Slope Lineae (RSL)</td>
<td>Surface / Shallow Subsurface Hydration State as a Function of Season &amp; Time of Day</td>
<td>A2.1</td>
</tr>
<tr>
<td></td>
<td>S O3. Geologic Evidence for Environmental Transitions</td>
<td>Diversity of Ancient Aqueous Deposits</td>
<td>Fine-scale Composition &amp; Morphology in Ancient Terrain</td>
<td>A1.2 A2.5 A3.2 C2.1</td>
</tr>
</tbody>
</table>
Next Steps

PARTNERSHIPS

- Commitment from partners required to proceed
- Once critical partnerships solidify, opportunities for secondary participants will be explored
- Pre-formulation planning target start October 2020

SCIENCE TEAM

- Will be populated once mission collaborations are formalized
- International investigators would be solicited on the SAR payload team
Ground ice detection is critical to support human exploration and advance international science objectives

Canadian SAR concept and heritage can meet the need

Appropriate to pursue this enabling Exploration objective with a heavily partnered collaboration

This initiative will provide significant opportunities for Mars science community to engage
Backup
# High Level Science Questions

<table>
<thead>
<tr>
<th>WATER-ICE RESOURCES</th>
<th>How much water ice exists below the surface?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>How thick/deep are the deposits?</td>
</tr>
<tr>
<td></td>
<td>How much &quot;soil&quot; &amp; rocks are on top of them (thickness of cover)?</td>
</tr>
<tr>
<td></td>
<td>What are the seasonal variations within them?</td>
</tr>
<tr>
<td>TERRAIN</td>
<td>What is the distribution of materials (e.g., bedrock vs. regolith)?</td>
</tr>
<tr>
<td></td>
<td>How porous is the soil at prospective landing sites?</td>
</tr>
<tr>
<td></td>
<td>How rough is the terrain at lander and human scales?</td>
</tr>
<tr>
<td>MARTIAN ENVIRONMENT</td>
<td><strong>FOLLOW THE WATER:</strong> What does subsurface water ice reveal about the possibility of life (or habitats) and the identification of potential &quot;special regions&quot;?</td>
</tr>
<tr>
<td></td>
<td>What geologic features lie under all of the dust and &quot;soil&quot; on Mars?</td>
</tr>
<tr>
<td></td>
<td>What do they reveal about the volcanic, fluvial, impact, &amp; other processes in Mars' history?</td>
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<tr>
<td></td>
<td>What can we learn about Mars' climate from seasonal water ice/atmospheric exchanges?</td>
</tr>
</tbody>
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Concept of Operations

1. Checkout and Calibrations (1 month)
   - Confirm that instrument is working properly

2. Ice Retrieval Algorithm Evaluation (3-6 months)
   - Confirm data processing techniques are capable of detecting subsurface ice

3. Resource Reconnaissance (3 months)
   - Near-global survey, with focus on medium-resolution compact-pol SAR in mid-latitudes (± 25-40°)

4. Resource Identification (2 months)
   - Select up to three sites of interest

5. Mission Science (1 year)
   - Address Level 1 science objectives + supplement data collection on sites of interest