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

Mars Exploration Ice Mapper Evolution

- 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

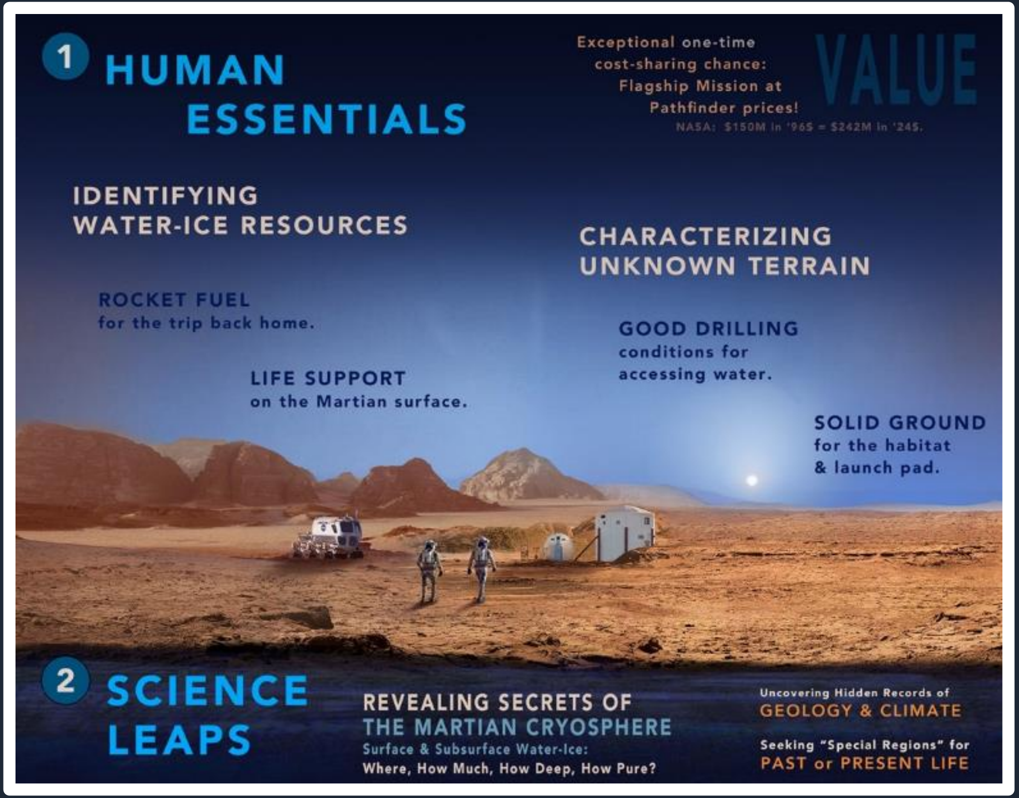
Exploration Ice Mapper: Objectives

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)

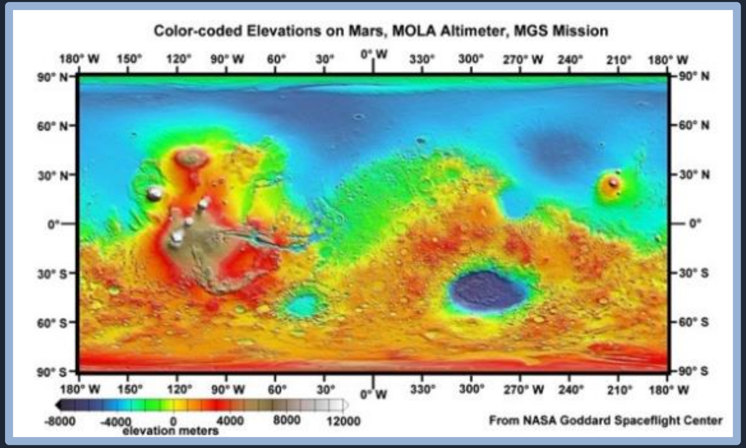
- ❑ Distribution & Origin of Ice Reservoirs
  - Quantify extent and volume of water ice in non-polar regions
- ❑ Dynamic Surface Processes on Mars
  - Establish role of liquid water in Recurring Slope Lineae
- ❑ Geological Evidence for Environmental Transitions
  - Evaluate fine-scale morphology in ancient terrains (“dust removal”)



Exploration Ice Mapper: Approach

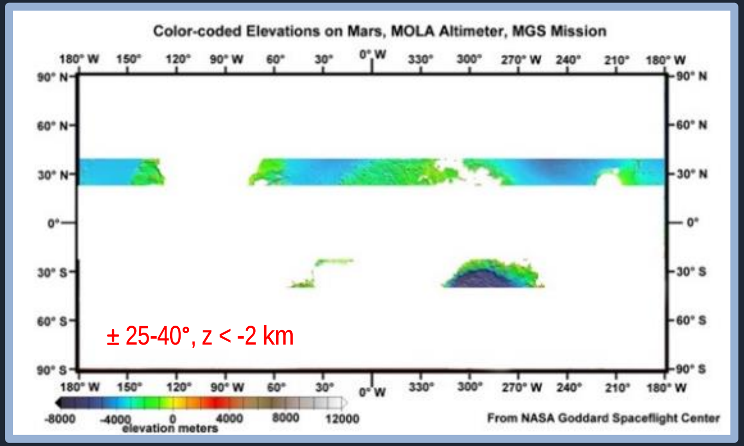
“RECONNAISSANCE ZONE”

- ❑ 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

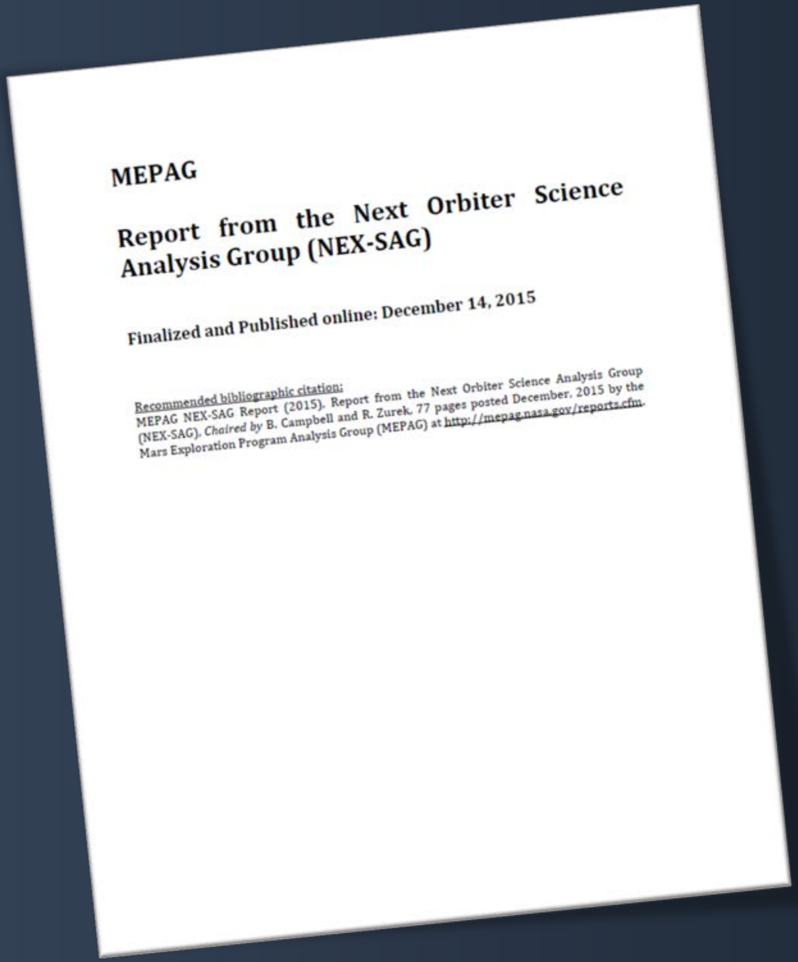


KEY OUTPUTS

- ❑ 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)



MEPAG

Report from the Next Orbiter Science Analysis Group (NEX-SAG)

Finalized and Published online: December 14, 2015

Recommended bibliographic citation:
MEPAG NEX-SAG Report (2015). Report from the Next Orbiter Science Analysis Group (NEX-SAG). *Chaired by* B. Campbell and R. Zurek. 77 pages posted December, 2015 by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.nasa.gov/reports.cfm.

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

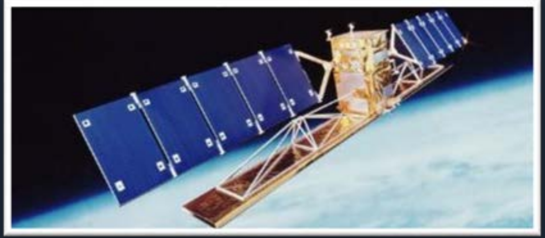
SAR Development: Prior Investments

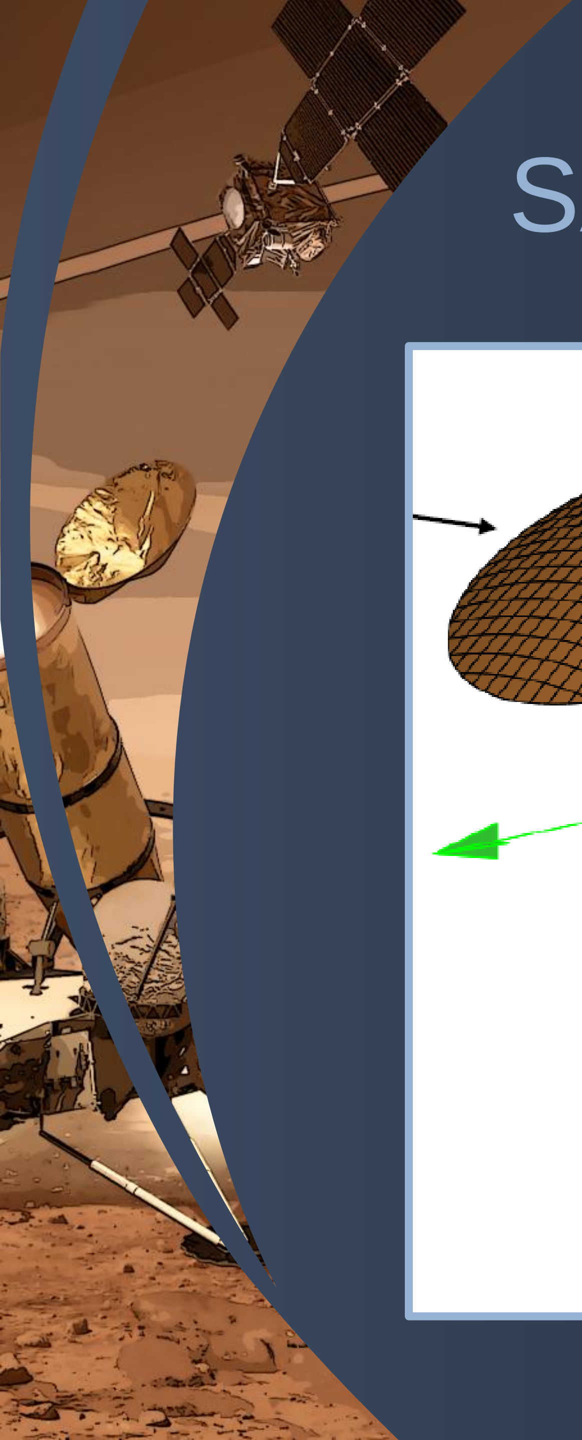
CANADIAN SAR HERITAGE

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

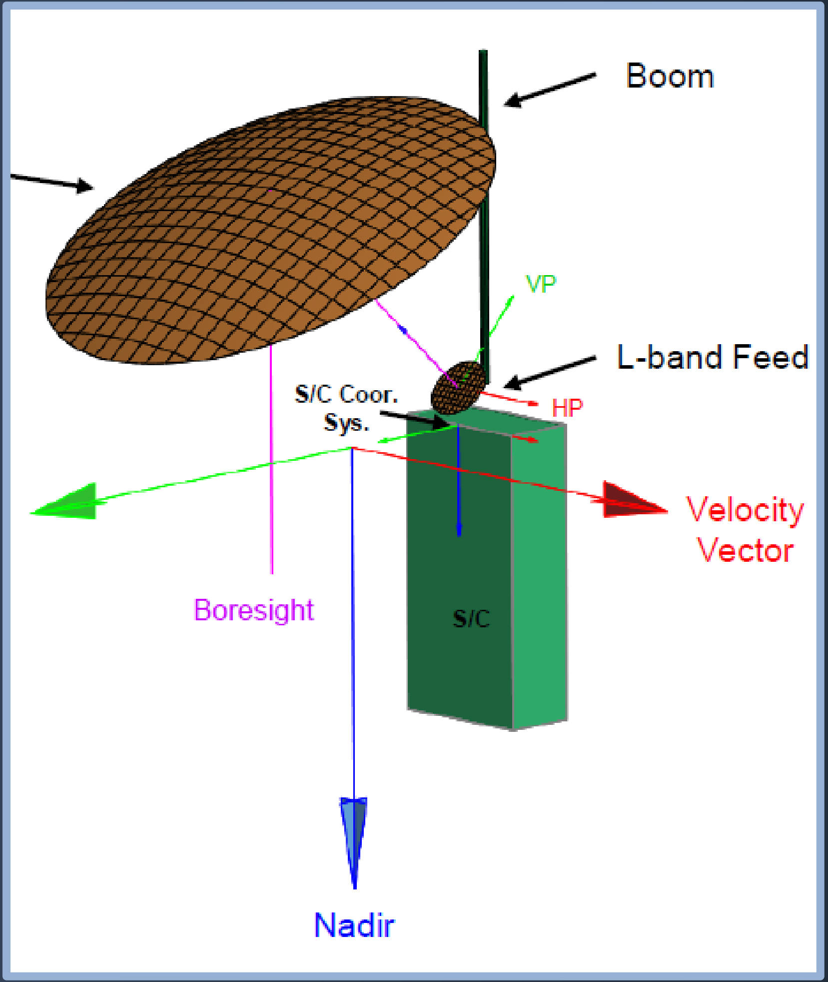
MARS SAR CONCEPT RECENT HISTORY

- 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



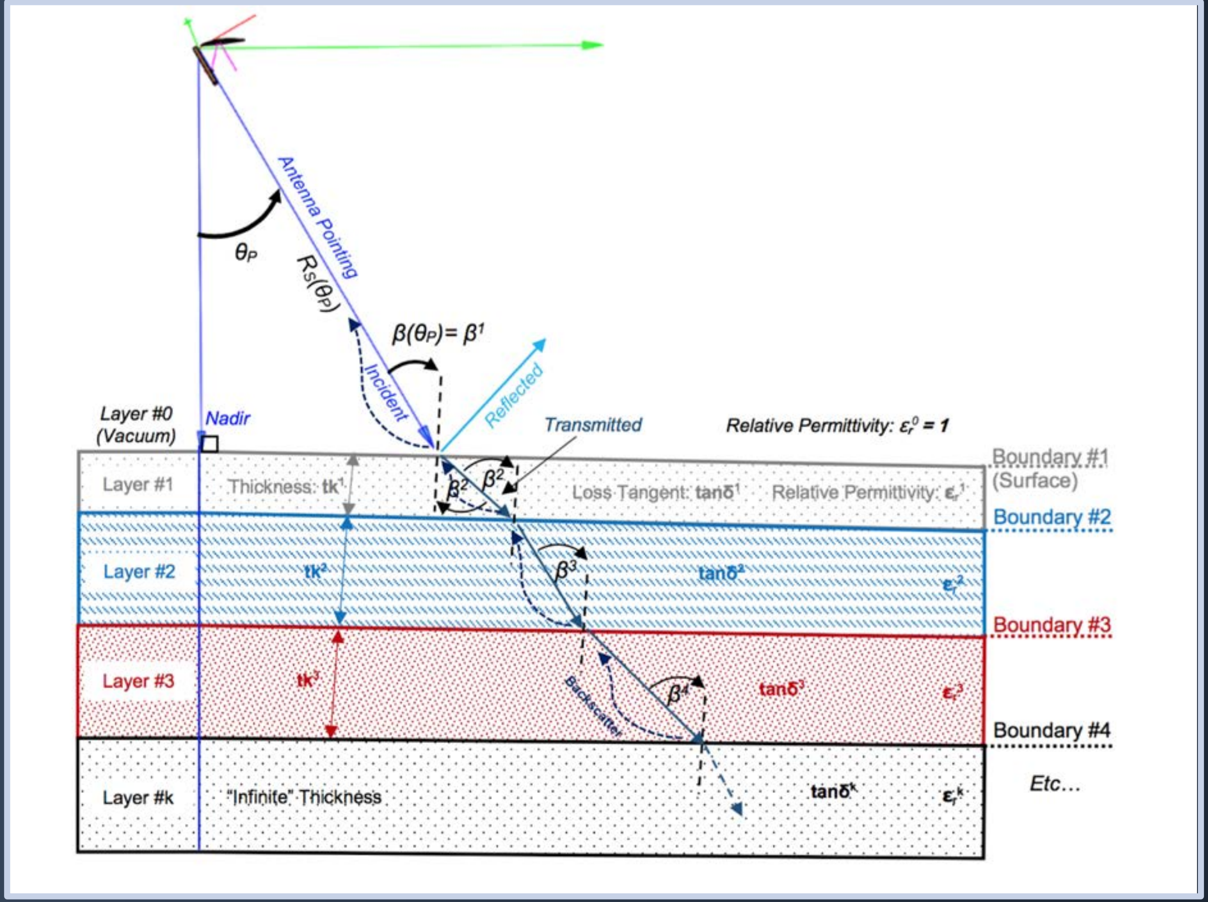


SAR Payload Concept



Property	Value
Center Frequency	930 MHz
Antenna	6 m deployable mesh
Sensitivity	-35 db as NESZ
Power	500-1000 W
Configuration	Multi-feed offset fed reflector
Operational Modes	SAR and Sounder
Polarization	Hybrid (circular transmit, dual linear reception)
SAR	
Swath Width	30 km
Incidence Angle	40-45°
Horizontal Resolution	5-30 m
Penetration Depth	> 6 m
Sounder	
Vertical Resolution	< 1 m
Along-track Resolution	30 m
Across-track Footprint	1.5 km

SAR Mode



Strip map swath width: 30 km

Incidence angle: 40-45°

Horizontal Resolution: 30 m

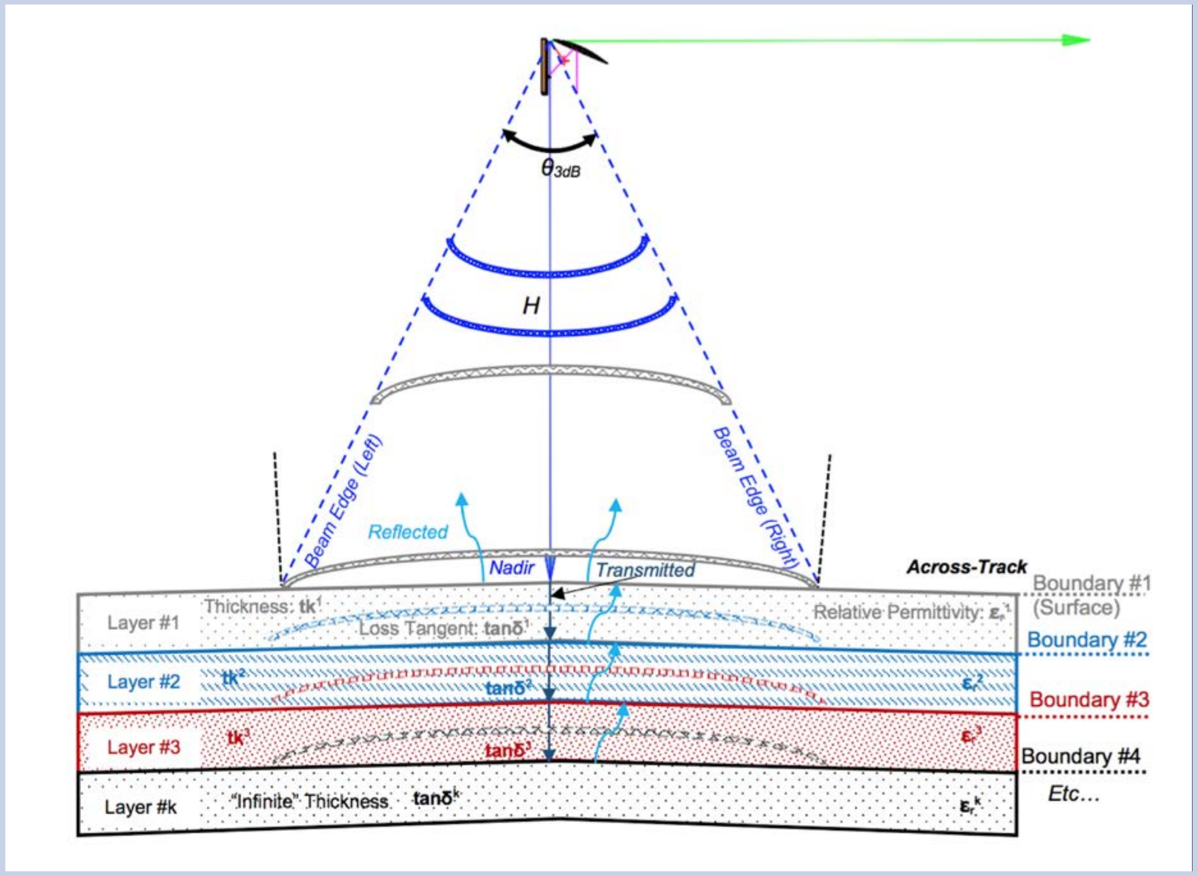
Highest Resolution: ~ 5 m

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

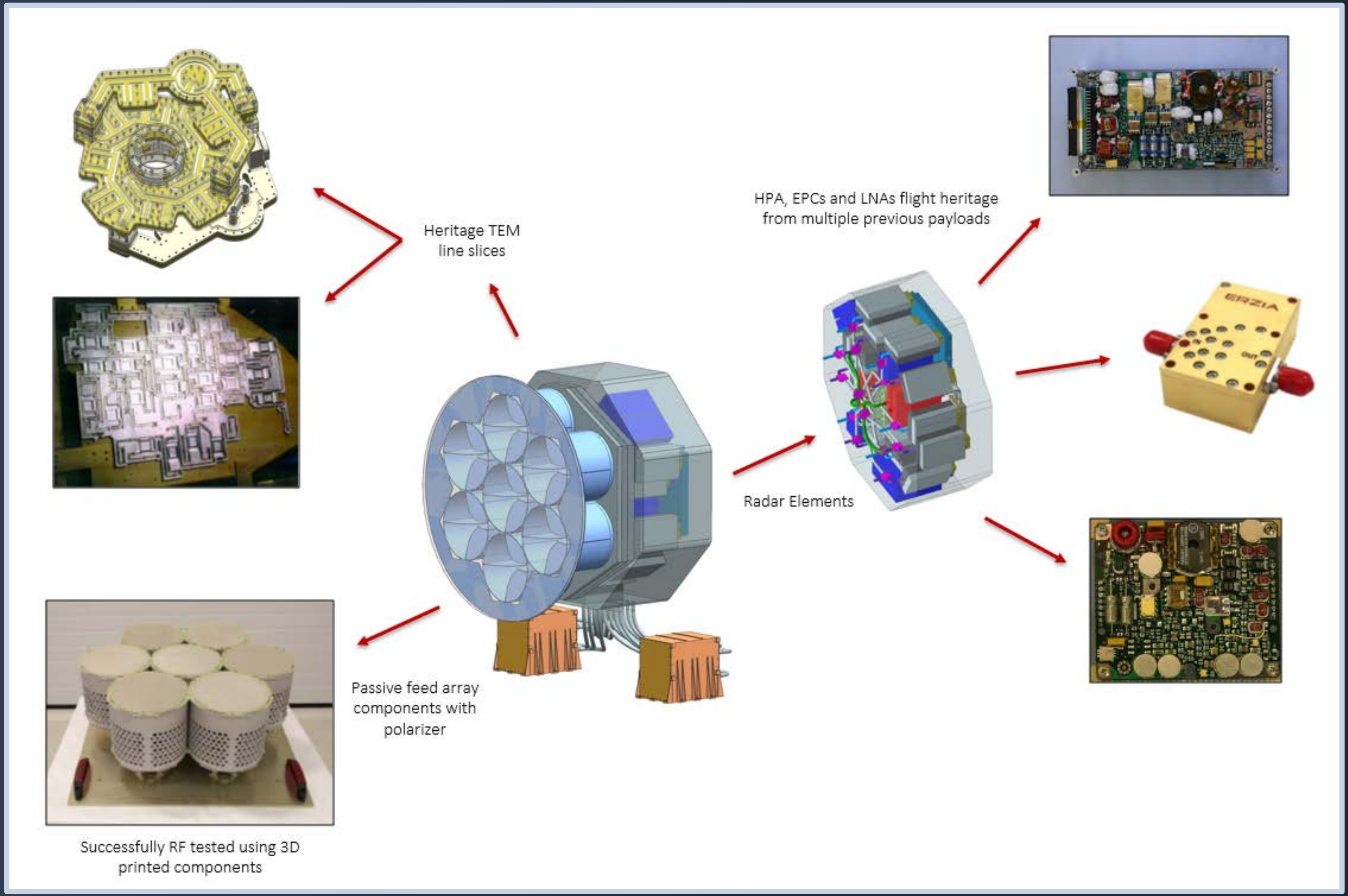
Vertical resolution: 1 m in free space

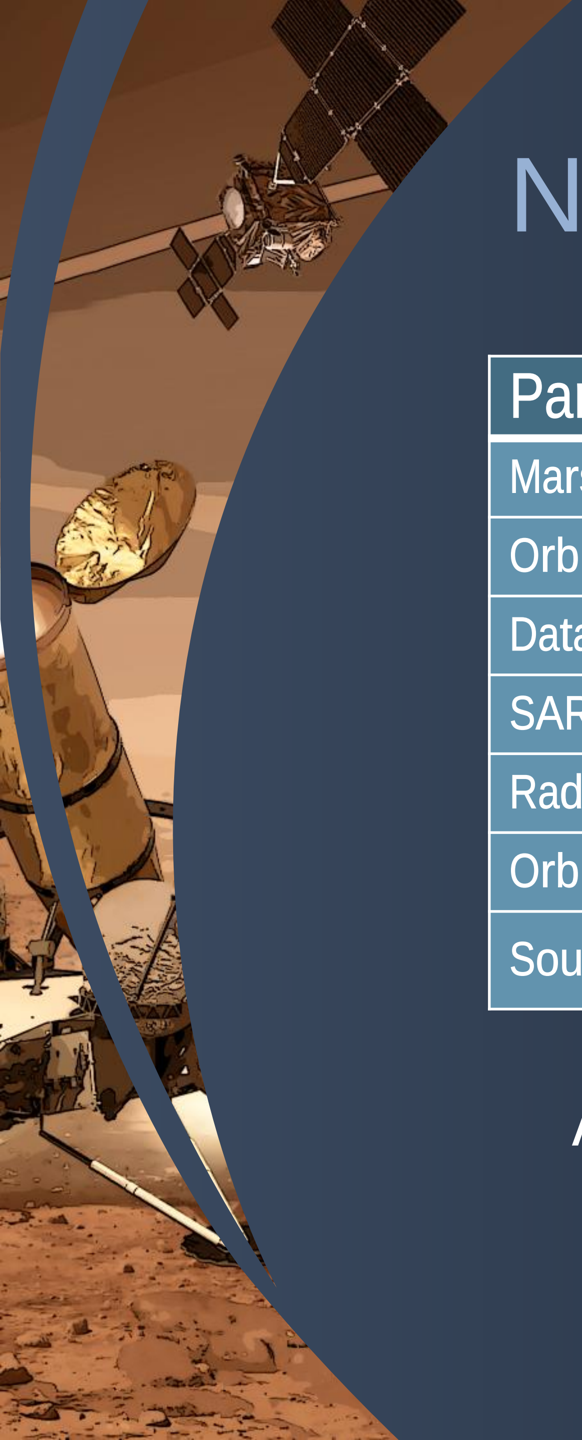
Along-track resolution: 30 m

Across-track footprint: 1.5 km

Modes: single track and repeat track

Mars SAR Technology Readiness



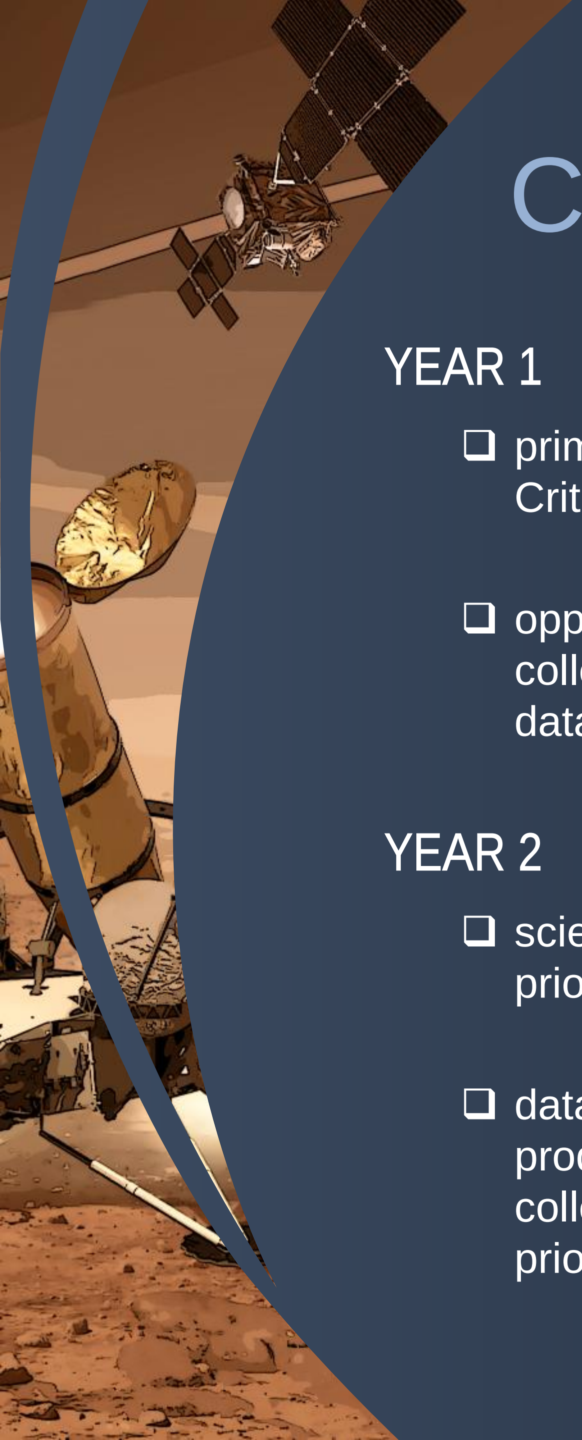


Nominal Mission Parameters

Parameter	Value	Unit
Mars Radius	3390	km
Orbital Altitude	250-320	km
Data Allocation	48000	Mbits/day
SAR Ground speed	~3	km/s
Radar Swath (side-looking)	32	km
Orbits	13	day^{-1}
Sounder Ground Track Spacing at equator	20	km

Assumptions

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



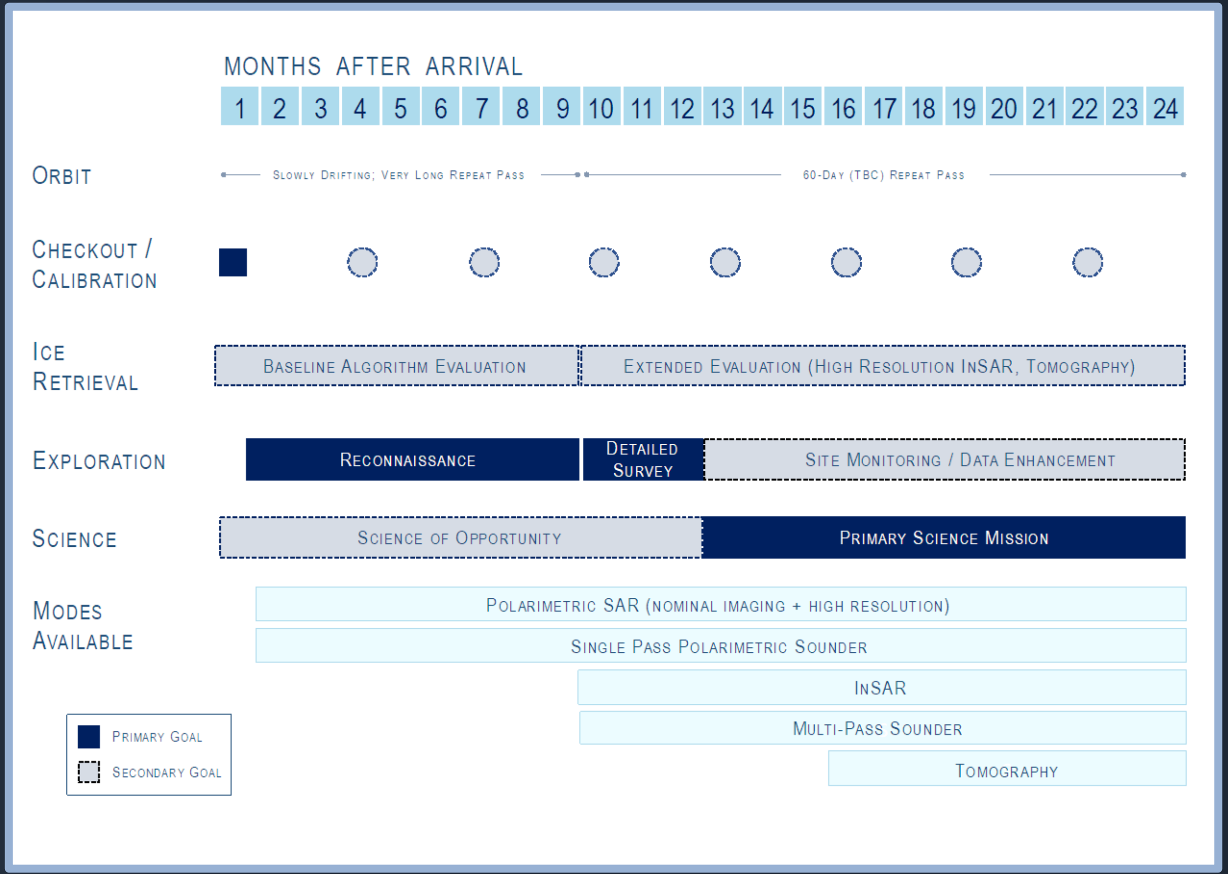
Concept of Operations

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)

HUMAN EXPLORATION OBJECTIVES							
Relation to NASA Goals	Human Exploration Objective	Investigation	Required Measurements	MEPAG Goals			
				Goal I: Life	Goal II: Climate	Goal III. Geology	Goal IV: Human
ISRU Water Resources & Civil Engineering. Properties	HE O1. Ground Ice as a Resource	Detection of Shallow Water Ice	Identification of Regions with Water Ice Present within 10 m of Surface				B4.2 C2.1 C2.2 D1.1
		Characterize Material Properties & Thickness of Dry Overburden	Identification of Regions where depth of Dry Overburden is < 2 m, and Estimation of Material Thickness & Consolidation				
	HE O2. Landing Site Geotechnical Properties	Surface Properties	Roughness; Slopes; Surface Texture, and Load-bearing Strength				A3.2 B4.1 B4.2

Relevance to MEPAG Goals (Science)

SCIENCE OBJECTIVES (Notional)							
Relation to NASA Goals	Science Objective	Investigation	Required Measurements	MEPAG Goals			
				Goal I: Life	Goal II: Climate	Goal III. Geology	Goal IV: Human
High Decadal Survey Priority	S O1. Distribution & Origin of Ice Reservoirs	Distribution of Buried Water & CO_2 ice plus Relationship to Surficial Polar Deposits	Extent and Volume of Water Ice in Non-polar Regions	A2.1 A2.5	A2.2 B1.1 B1.2 B1.3 B2.1 B2.2 B3.1 C1.2	A1.3 A1.4 A1.5 A4.3 B1.1	
			Extent & Volume of Buried CO_2 Ice in the Polar Caps				
			Shallow Subsurface Structure of Polar Cap & Layered Terrain				
New Discoveries / High MEPAG Priority	S O2. Dynamic Surface Processes on Mars	Role of Liquid Water in Recurring Slope Lineae (RSL)	Surface / Shallow Subsurface Hydration State as a Function of Season & Time of Day	A2.1		A1.1 A1.5 A4.3	
	S O3. Geologic Evidence for Environmental Transitions	Diversity of Ancient Aqueous Deposits	Fine-scale Composition & Morphology in Ancient Terrain	A1.2 A2.5 A3.2	C2.1	A1.2 A2.1 A3.1 A4.7	

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

Summary

- 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

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

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