

Science to Enable First Mars Human Missions

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Decadal Survey of Planetary Science Panel on Mars

National Academy of Sciences,
Engineering and Medicine

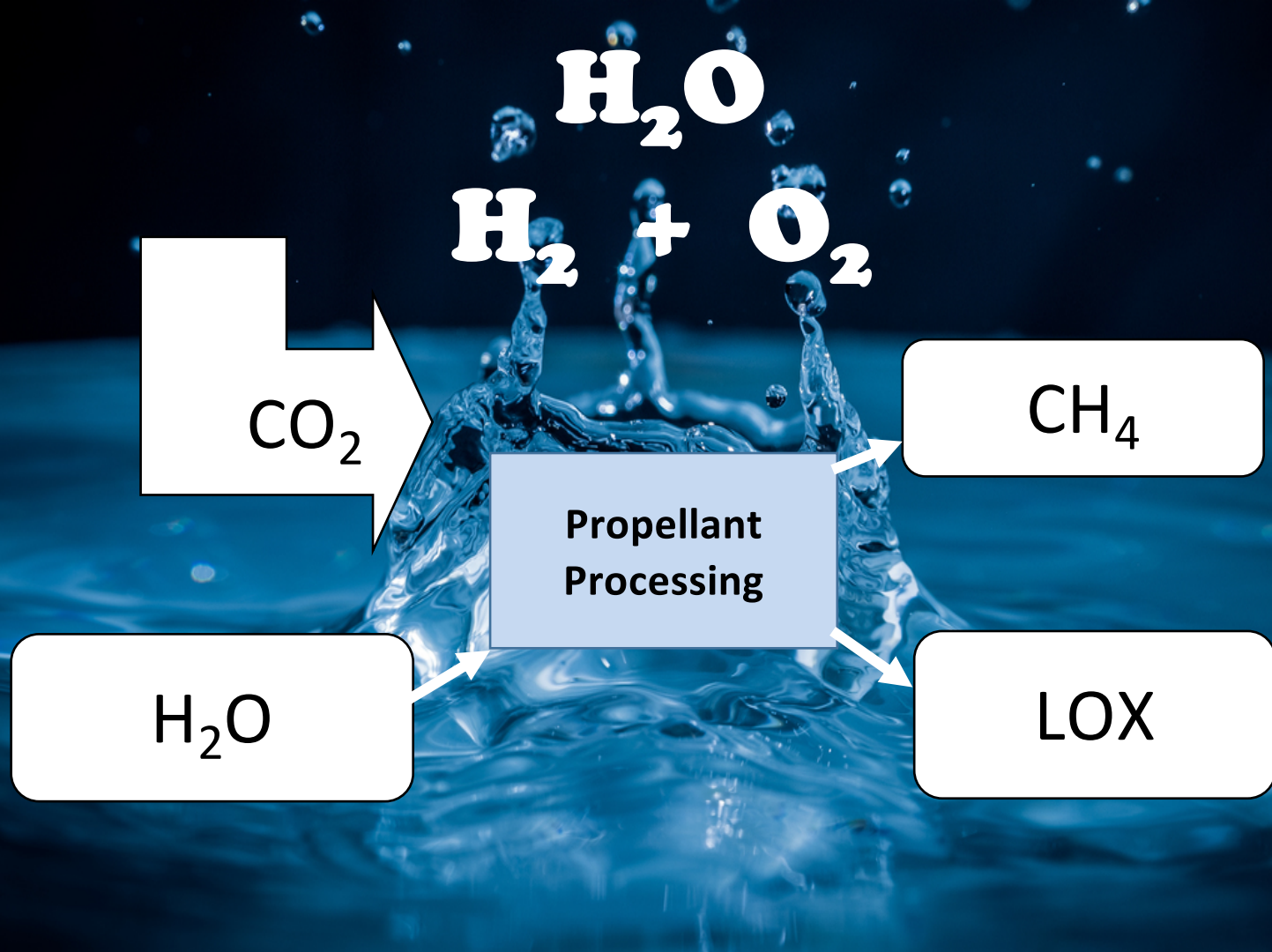
January 29, 2021

Potential resources:

- Minerals
- Metals
- Nonmetals (C, Si, P, S, Cl, Ge)
- Gases (atmosphere)
- Water (Ice, liquid)
- Regolith
- Location

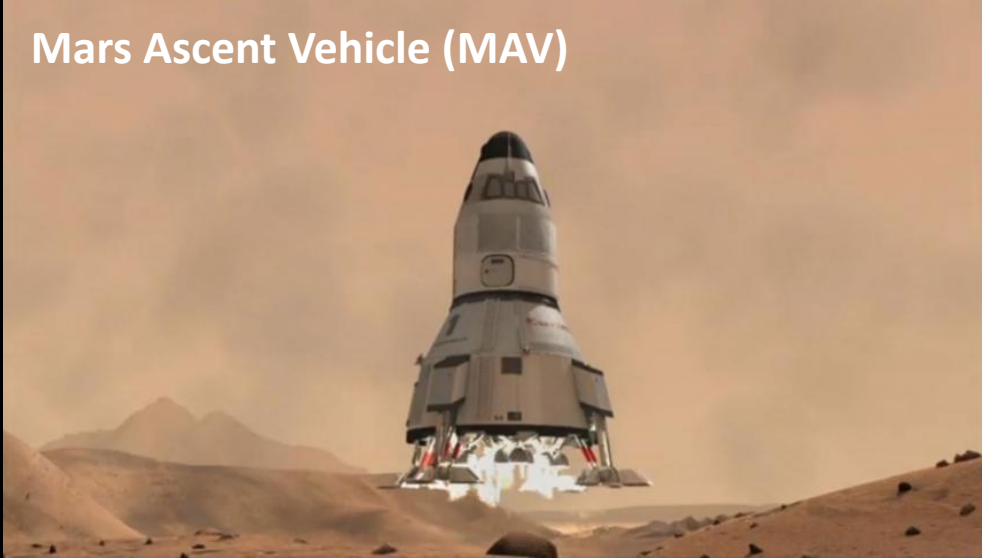


Which Mars resource is more valuable?



Mars Evolvable Campaign (2015)

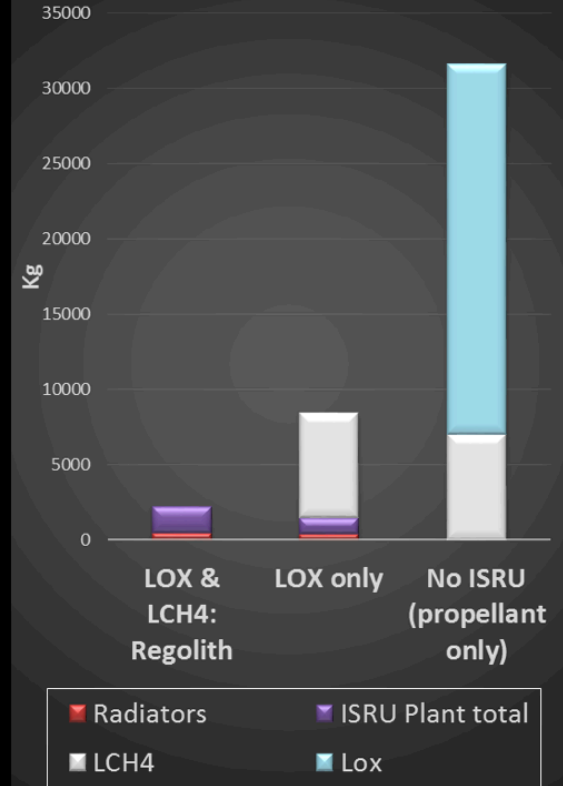
Mars Ascent Vehicle (MAV)



CH_4

LOX

Landed Mass Comparison



[illegible]



First Landing Site/Exploration Zone Workshop for Human Missions to the Surface of Mars

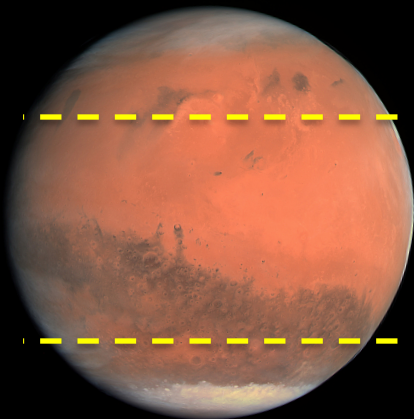
October, 2015

**Mars Water In-Situ Resource
Utilization (ISRU) Planning (M-WIP) Study**



Where, how much water, and when?

50° N



50° S

Parameters:

- WHERE? Between +/- 50 degrees latitude
- HOW MUCH? 16 MT tons of water per crew
- WHEN? ISRU production in 480 days

Improbable sources

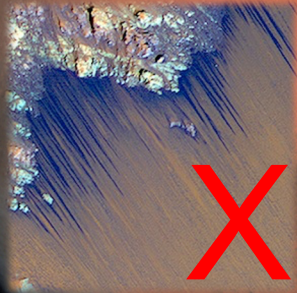
Polar caps

(too far away)

50° N

Atmosphere

(too little)



50° S

Recurring Slope Lineae

(not reliable and difficult access)

Mean Pressure ~0.6% of Earth

Carbon dioxide

96%

Argon

2%

Nitrogen

2%

Oxygen

0.15%

Carbon monoxide

0.06%

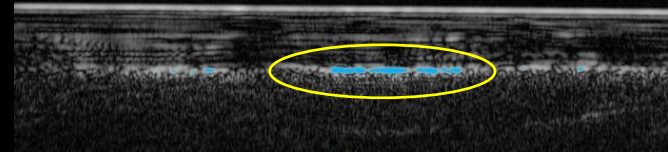
Water

0.03% (variable)

Liquid Water

(too deep)

Surface



} 1.5 km

Potential sources

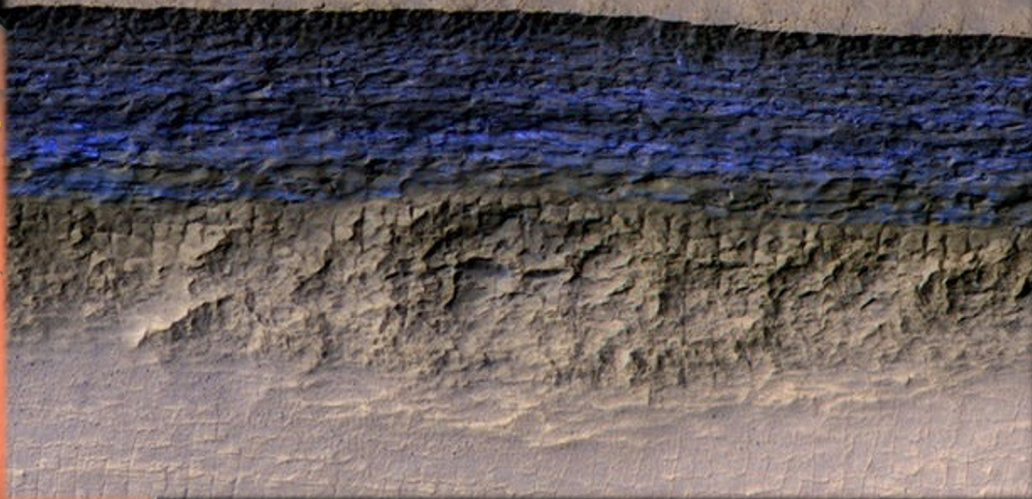
50° N



50° S



Subsurface ice

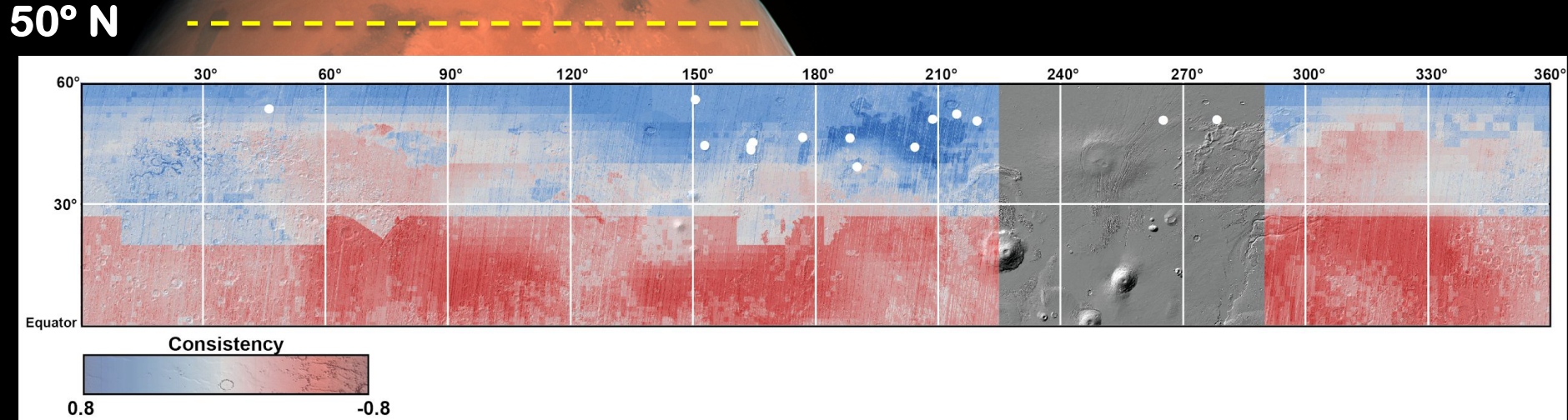


Debris Covered Glaciers (DCG)

(a few meters below surface)

Potential sources

Subsurface ice



50° S

Blue = ice likely

Red = ice unlikely

White dots: ice-exposing impacts craters



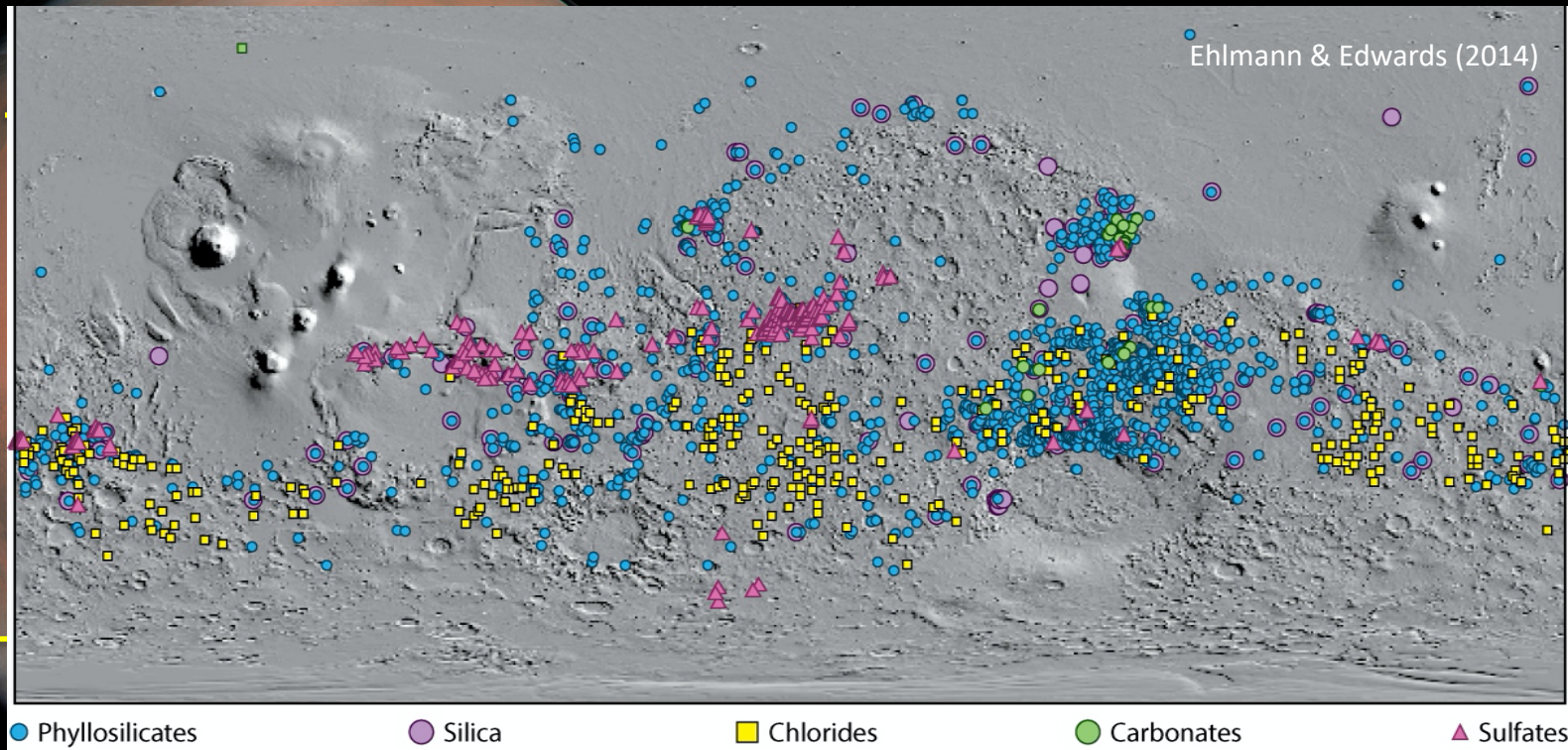
SWIM (Subsurface Water Ice Mapping)

Potential sources

Hydrated minerals

50° N

50° S



Regolith
(1-2% H₂O)

Phyllosilicates (4% H₂O)

Sulfates (20% H₂O)

Potential sources

50° N



50° S



What are the scientific contributions needed for resource identification?

#1 (The "Now")

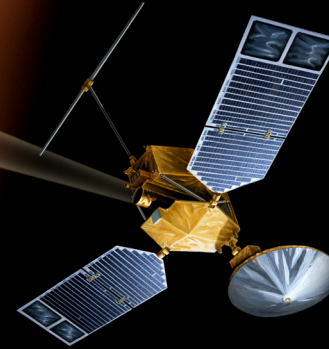


Mars Reconnaissance Orbiter (MRO)

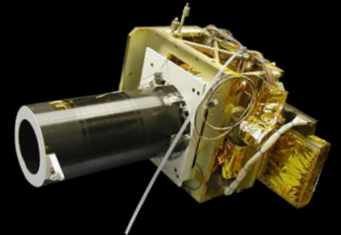
SHARAD
(Shallow Radar)



HiRISE, CTX Cameras



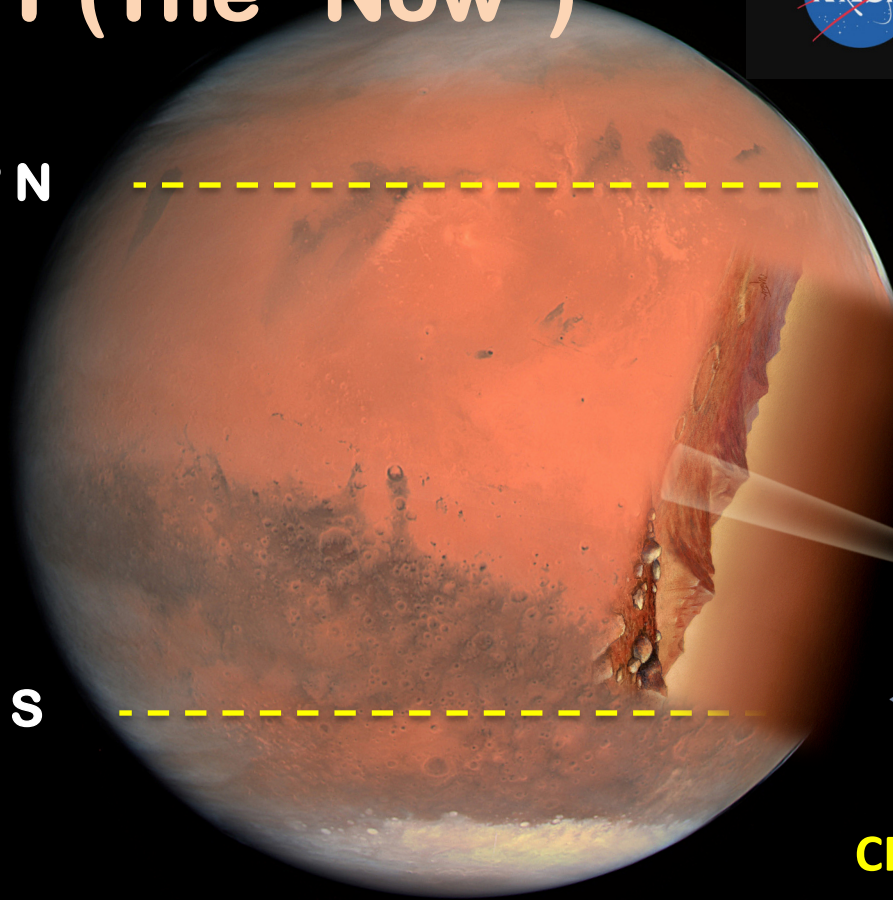
CRISM Spectrometer



50° N



50° S



#2 (The “Next”)

50° N



50° S

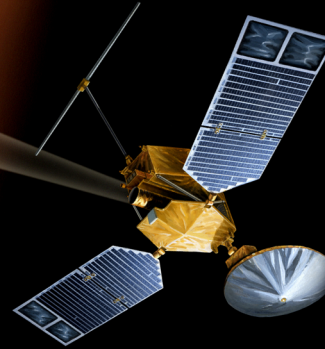


NEW ORBITER

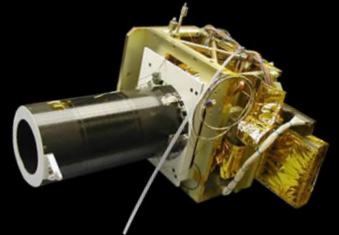
Next Radar – SAR
(High frequency,
<1m depth resolution)



Next Camera
(higher resolution)



Next Spectrometer
(Hydrated Minerals)



#3 (The “New”)

50° N

NASA

50° S

SURFACE EXPLORATION (Ground truth)

- 1) Depth, horizontal distribution, concentration, morphology of ice
- 2) Geotechnical properties of regolith
- 3) Topography: terrain slope, rocks
- 4) Mineral identification and composition
- 5) Increase resource certainty and determine extraction technology

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