STRATEGIES FOR PROSPECTING AND EXTRACTING WATER ON MARS FOR LONG-TERM HUMAN EXPLORATION

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Motivation

- Sending humans to the surface of Mars can greatly enhance scientific exploration
- Use of in-situ materials helps to reduce overall mission cost and risk
- Water is one of the most critical and versatile resources used by a crew

Resource Classification and Prospecting

Prospective Resources:

Play
- Context camera
- Thermal imaging
- Gamma ray spectrometer

Lead
- Context camera (1 km res.)
- High resolution camera (10 m res.)
- Thermal imaging spectrometer (100 m res.)
- Visible IR (100 m res.)
- Gamma ray spectrometer
- Shallow radar (100 m depth, 10 m res.)

Prospect
- Context camera (10 m res.)
- High resolution camera (< 1 m res.)
- Thermal imaging spectrometer (1 m res.)
- Visible IR (1 m res.)
- Gamma ray spectrometer
- Shallow radar (100 m depth, 1 m res.)

KDP 1: Sufficient data collected to justify investment in landed platform

Contingent Resources:
- Ground sampling over region of interest (100 m depth, 100 m spatial res.)
- Quantity and distribution of water constrained over region

KDP 2: Sufficient data collected to justify investment in additional prospecting time and conceptual extraction system design

Reserves:
- Ground sampling over region of interest (100 m depth, 10 m spatial res.)
- Quantity and distribution of water well constrained
- Resources are economically recoverable (less expensive than shipping from Earth)

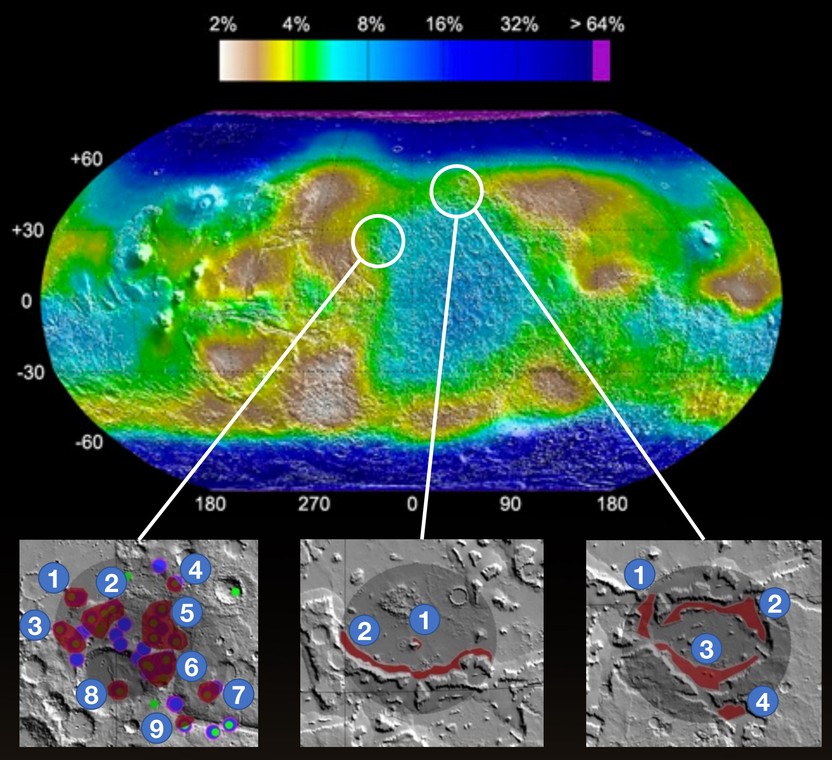
KDP 3: Sufficient data collected to justify design and production of extraction system to support human missions

Crew Water Demand

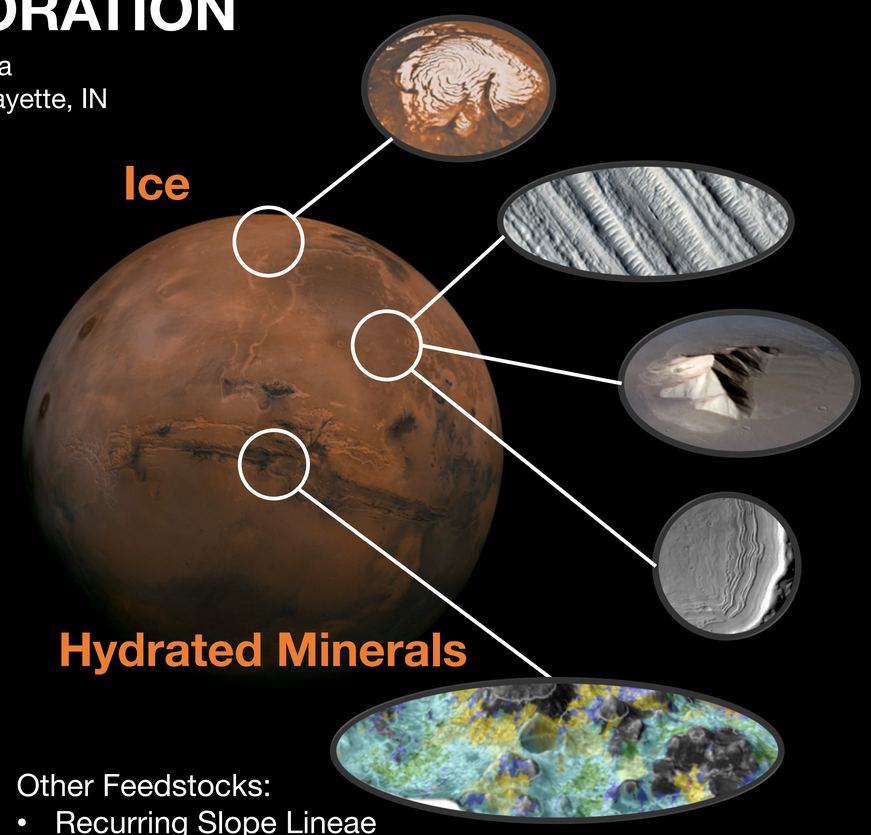
	Water Use	Minimum	Maximum
Enabling	Hydration*	115 kg	2.15 mt
	Food rehydration*	29 kg	539 kg
	Personal hygiene*	23 kg	432 kg
	Medical usage	34 kg	655 kg
	EVA	1.33 mt	10.39 mt
Enhancing	Oxygen production	0 kg	20.69 mt
	Radiation shielding	0 kg	13.2 mt
	Propellant production	0 kg	16.39 mt
	Total	1.53 mt	112.85 mt
	Rate	~3.2 kg/day (480 days)	~144.7 kg/day (780 days)

*Recyclable

Exploration Zone Analysis



Mawrth Vallis | Deuteronilus Mensae (North) | Deuteronilus Mensae (South)



Other Feedstocks:
- Recurring Slope Lineae
- Hydrated regolith
- Atmospheric water

Exploration Zone Resources

Site	Classification	Est. Water*
MV – Region 1	HM - Lead	665M mt
MV – Region 2	HM - Lead	1.7B mt
MV – Region 3	HM - Lead	1.2B mt
MV – Region 4	HM - Lead	301M mt
MV – Region 5	HM - Lead	2.6B mt
MV – Region 6	HM - Lead	1.7B mt
MV – Region 7	HM - Lead	623M mt
MV – Region 8	HM - Lead	557M mt
MV – Region 9	HM - Lead	315M mt
DM North – Region 1	Ice - Lead	822M mt
DM North – Region 2	Ice - Lead	19.4B mt
DM South – Region 1	Ice - Lead	6.6B mt
DM South – Region 2	Ice - Lead	16.1B mt
DM South – Region 3	Ice - Lead	18.2B mt
DM South – Region 4	Ice - Lead	4.3B mt

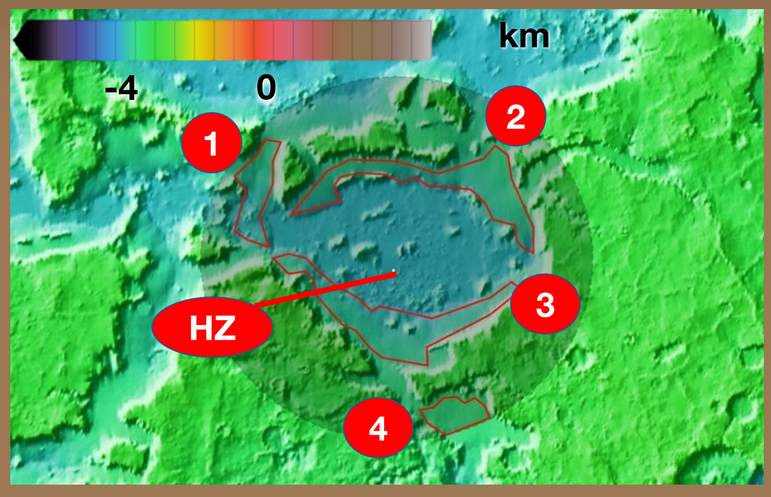
*Represents lower bound on expected water content

Deuteronilus Mensae South: Environmental Parameters

Parameter	Region 1	Region 2	Region 3	Region 4
Min. Distance to Hab. Zone	69 km	45 km	19 km	79 km
Max. Elevation Change to HZ	688 m	661 m	875 m	916 m
Max. Temperature	7.75° C	6.45° C	9.75° C	9.85° C
Min. Temperature	-125° C	-125° C	-125° C	-125° C
Avg. Dust Cover Index	0.950	0.953	0.957	0.966
Max. Nighttime Thermal Inertia	336	276	562	230
Estimated Max. Rock Size	< 0.001 m	< 0.001 m	0.03 – 0.1 m	< 0.001 m
Max. Slope	20.37°	15.88°	24.12°	7.23°

Water Extraction Techniques: Ice Feedstock

Metric	Weight	Remove Overburden		Keep Overburden	
		Chisel Ice	Drill Ice Cores	Melt Probe	Drill Ice Cores
Mass	0.15	High	High	Med	Low
Power	0.1	High	Med	Med	Low
Volume	0.15	High	High	Med	Low
Extraction Rate	0.1	Med	Med	High	Low
Technical Complexity	0.15	High	High	Med	Low
TRL	0.1	Med	Med	Med	High
Scalability	0.1	Low	Low	High	Med
Water Storage Density	0.05	Med	Med	High	Med
Level of Autonomy	0.1	High (initial setup) Low (operational)	High (initial setup) Low (operational)	Low (initial setup) Low (operational)	High (initial setup) High (operational)
Score		**1.35**	**1.45**	**2.15**	**2.65**



Results

- Water resources on Mars have the potential to far exceed crew needs
- Higher resolution orbital and in-situ data are needed to identify true water “reserves”
- Drilling ice cores through overburden is a viable option for early missions
- Melt probes have potential to sustain larger numbers of astronauts in permanent settlements

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