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Conducting Rock Mass Rating for Tunnel Construction on Mars

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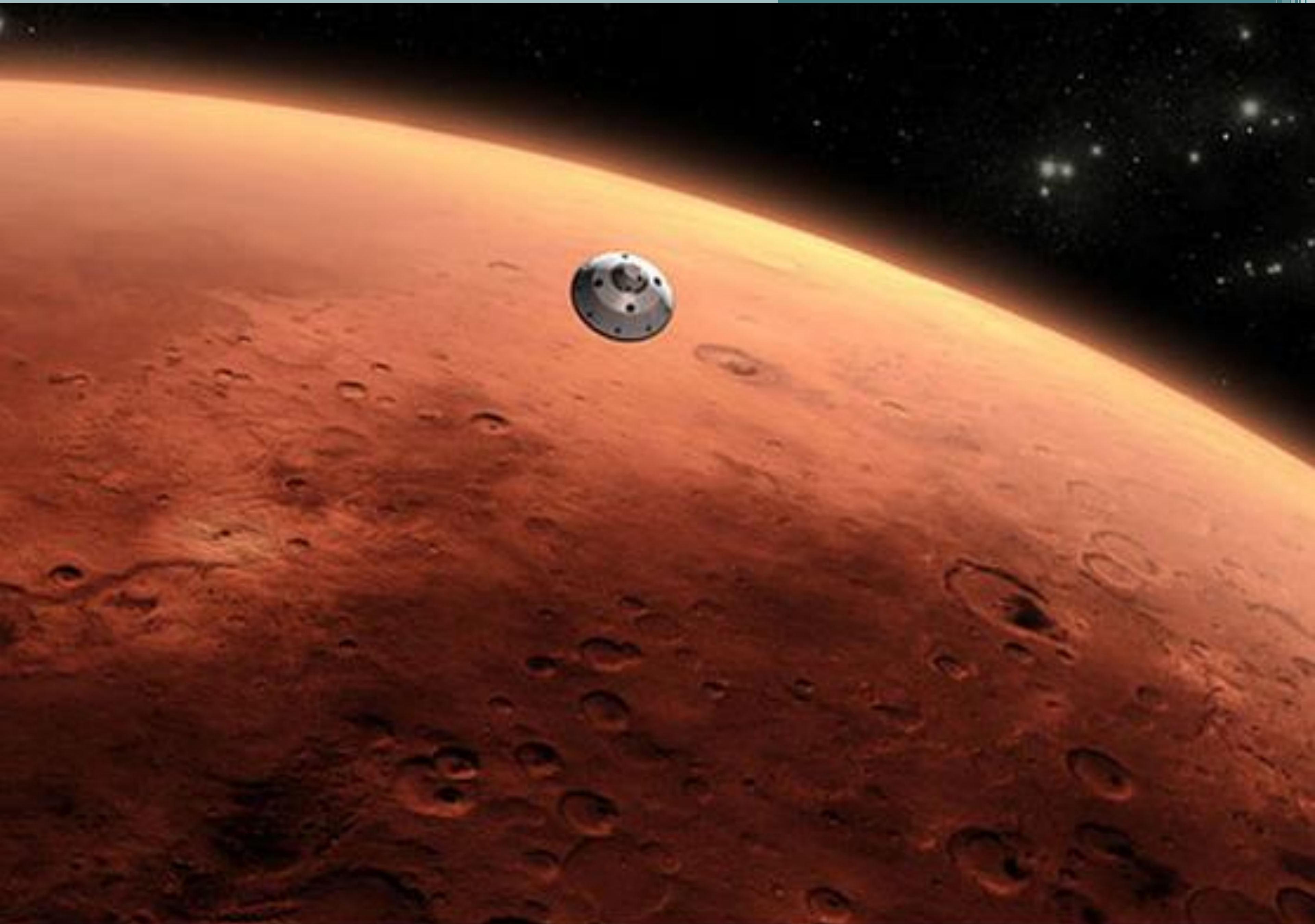
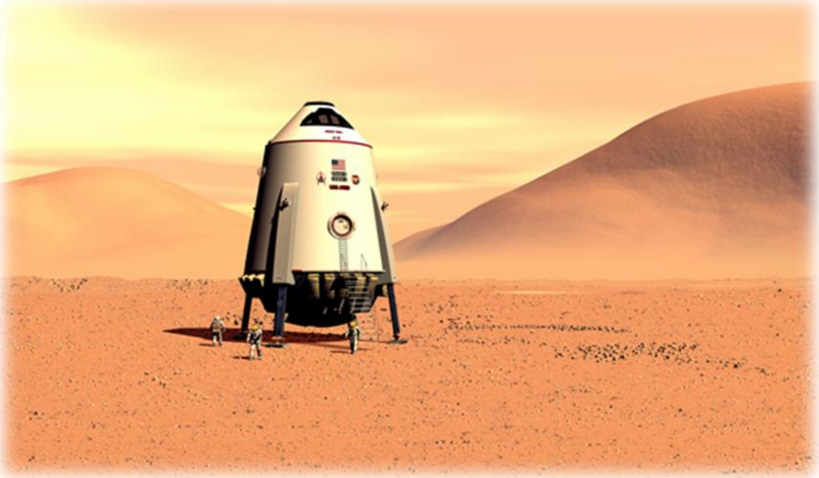


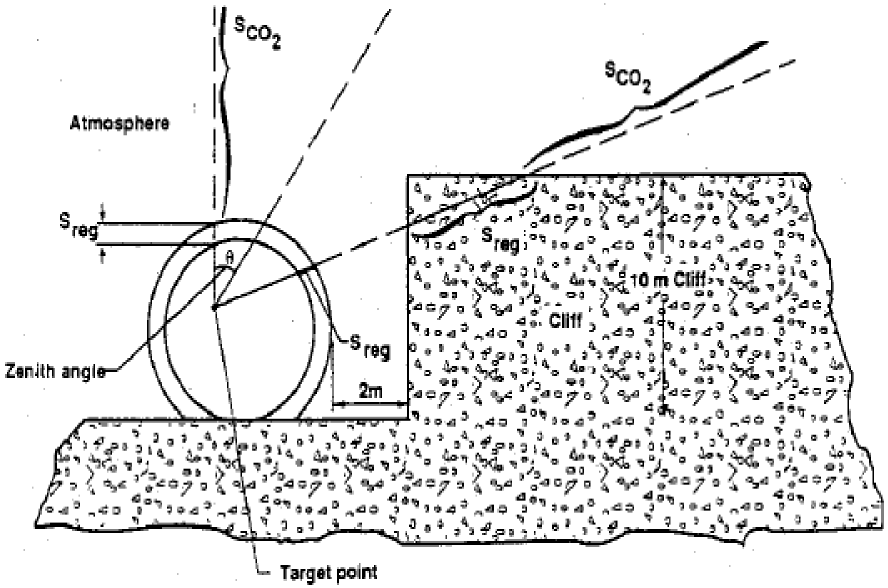
Radiation on Mars

- Radiation on Mars is a known obstacle for any mission to the red planet.
- Shielding will be the best way of mitigating its adverse effects.

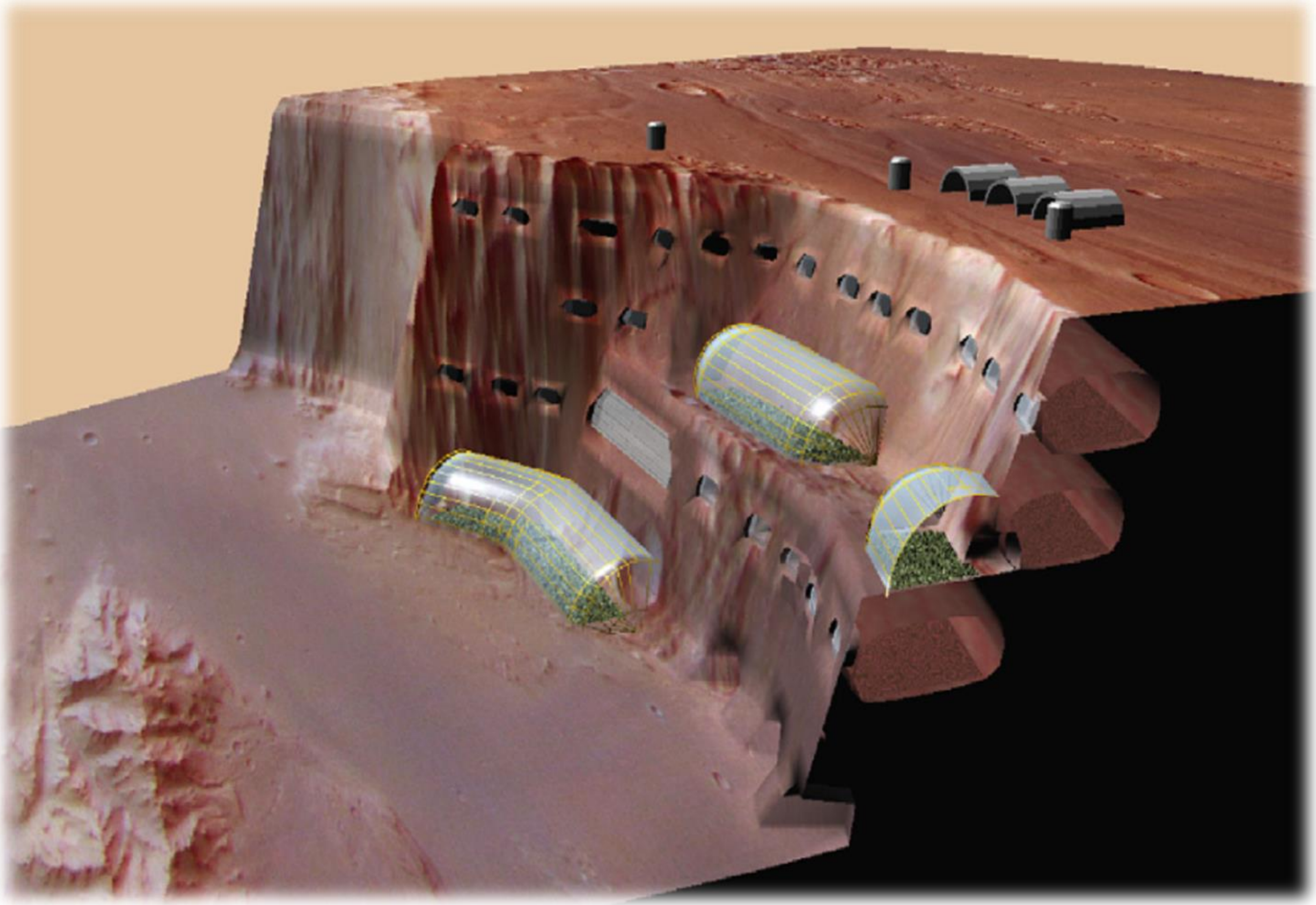
Year 1 (180 day transit, 180 days on Mars)		Year 2 (320 days on Mars, 40 days transit)		Year 3 (140 days transit to Earth)	
180 Transit (1.84± 0.30 mSv/day)	331 ± 54 mSv	320 days on Mars (0.64±0.12)	205 ± 38 mSv	140 Transit (1.84± 0.30 mSv/day)	258 ± 42 mSv
180 days on Mars (0.64±0.12)	169 ± 22 mSv	40 Transit (1.84± 0.30 mSv/day)	73.6 ± 12 mSv	220 days on Earth	negligible
Total mSv	500 ± 76 mSv/year	Total mSv	279 ± 50 mSv/year	Total mSv	258 ± 42 mSv/year
Total Rem	50.0 ± 7.6 Rem/year	Total Rem	27.9 ± 5.0 Rem/year	Total Rem	25.8 ± 4.2 Rem/year

Living in the Lander

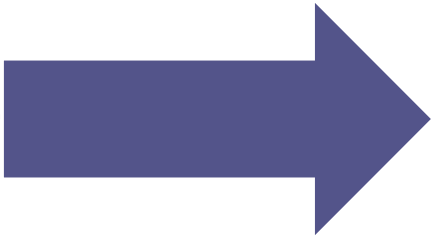


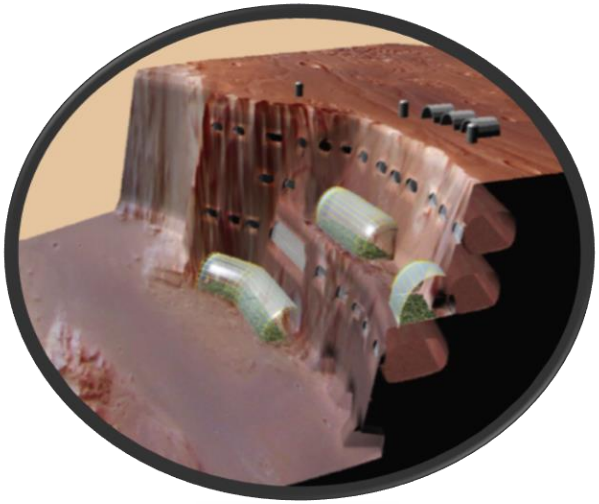


A More Permanent Solution

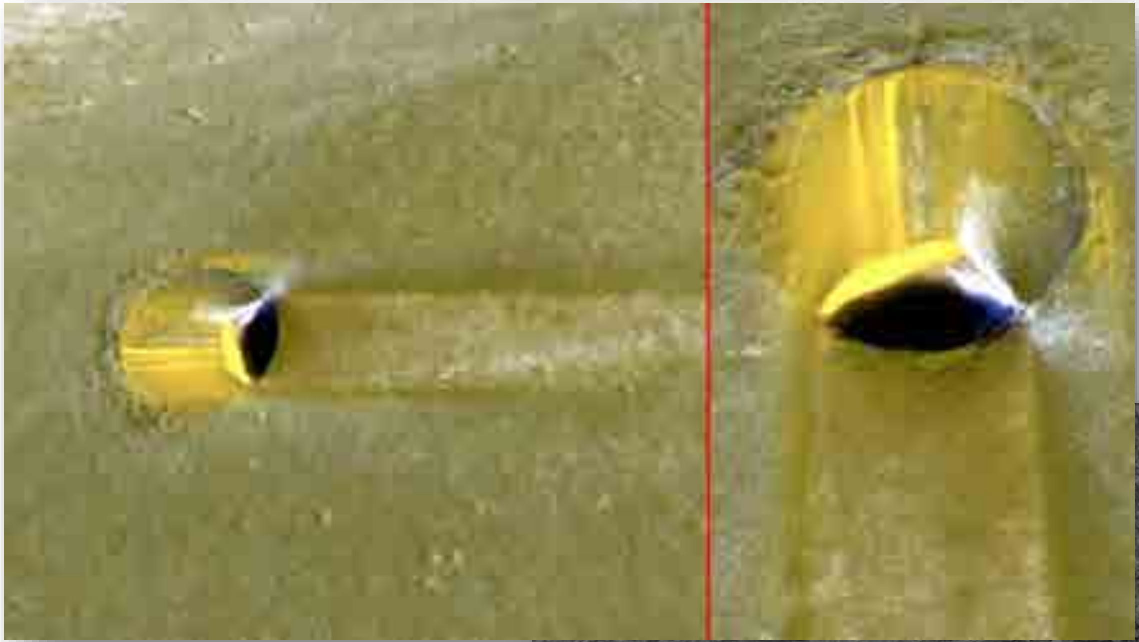


How do we get from landers to tunnels for long term colonization of Mars?

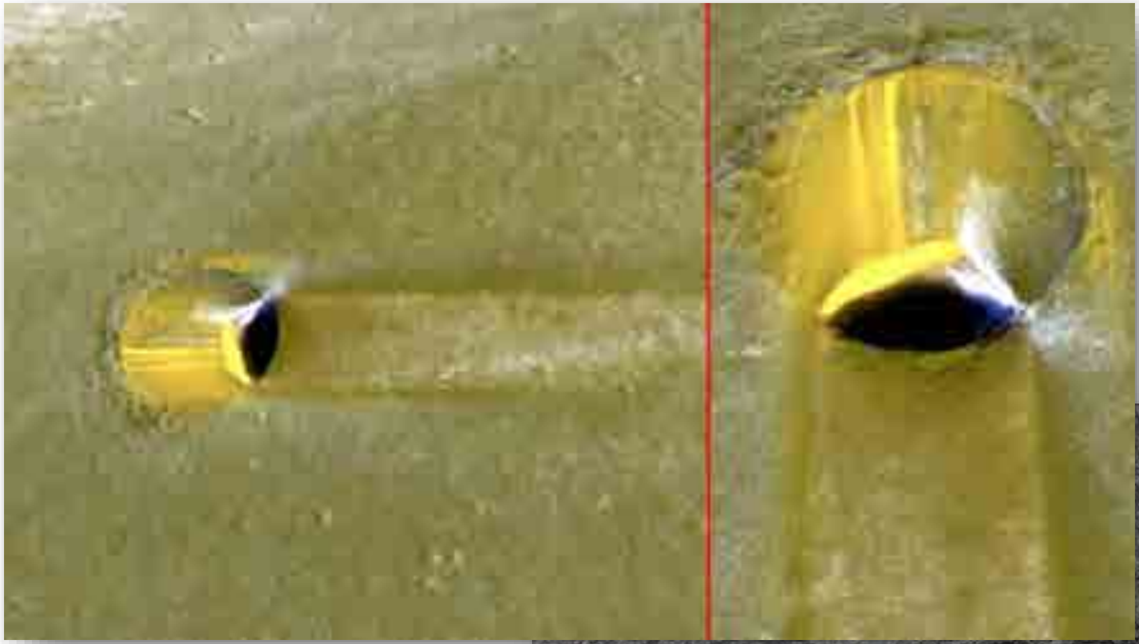




Caves?



Caves?



DIY

Rock Mass Rating

- According to Z.T. Bieniawski (1979) RMR is the easiest way to classify the geomechanics of a site.
  - Primarily used for tunneling projects, but can also be applied to slopes, foundations, and mines.

Rock Mass Rating

- Aims of the RMR System:

1. Identify the most significant parameters influencing the behavior of a rock mass.
2. Divide a particular rock mass formation into a number of rock mass classes of varying quality.
3. Provide a basis for understanding for engineering design
4. Derive quantitative design for engineering design
5. Provide a common basis for communication between engineers and geologists.

Rock Mass Rating cont.

- Rating uses six parameters to classify rock formations:
  - Uniaxial compressive strength of rock material
  - Rock Quality Designation (RQD)
  - Spacing of Discontinuities
  - Condition of Discontinuities
  - Ground Water Conditions
  - Orientation of Discontinuities

A. CLASSIFICATION PARAMLTERS AND THEIR RATINGS

	Parameter		Range of values						
1	Strength of intact rock material	Point-load strength index	>10 MPa	4-10 MPa	2-4 MPa	1-2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	>250 MPa	100-250 MPa	50-100 MPa	25-50 MPa	5-25 MPa	1-5 MPa	< 1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality *RQD*		90%-100%	75%-90%	50%-75%	25%-50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		> 2 m	0.6-2 . m	200-600 mm	60-200 mm	< 60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Ground water	Inflow per 10 m tunnel length (l/m)	None	< 10	10-25	25-125	> 125		
		(Joint water press)/ (Major principal σ)	0	< 0.1	0.1,-0.2	0.2-0.5	> 0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)

Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

Rock Mass Rating (cont)

- Each parameter is given a number rating based on present conditions.
- Final RMR is a number 1-100 totaling previous ratings.
- Rating allows the engineer to know the behavior of the rock.
  - Providing quantitative data for engineering design.

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS					
Rating	100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

How do we bring this Earth based engineering to Mars?

Identifying Rock Structures

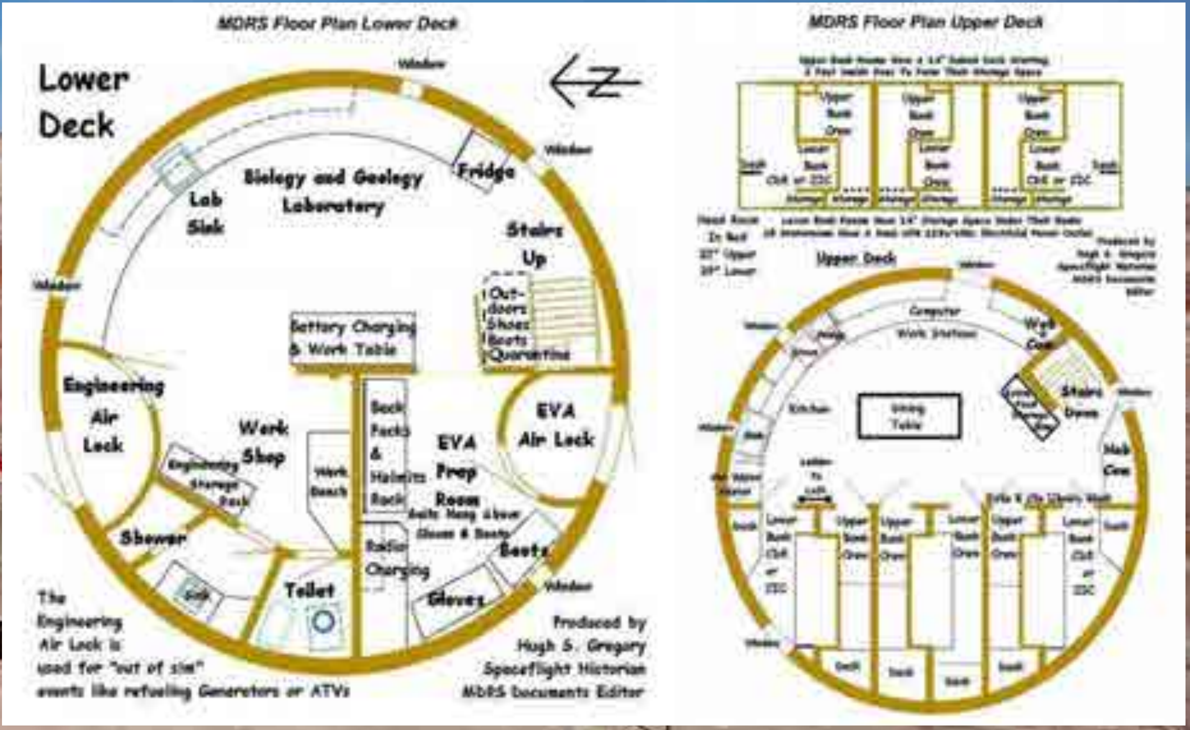
- Remote sensing techniques may be used to initially determine feasible sites for tunnel construction before committing a Martian colony to one site.
- Nahm and Schultz (2007) conducted a remote RMR for a Martian outcrop located within Vostok crater at Meridiani planum, Mars, using Remote sensing instruments
  - NASA's Mars Orbiter Camera (MOC)
  - Opportunity's navigation camera (NAVcam)

Identifying Rock Structures

- Once on the ground, Astronauts will be able to confirm RMR results remotely calculated.

Hyposis:
Simulation Astronauts can conduct RMR for a specified Rock Outcrop under simulated Mars conditions.

MARS DESERT RESEARCH STATION




ROCK MASS RATING TASK PACKET

DO NOT OPEN THIS PACKET UNTIL DAY THREE OF SIMULATION AND AS INSTRUCTED TO DO SO BY CAPCOM


Research Station

- Location: Longitude 38.402738
  and Latitude -110.792079
- RMR 63
- Classification: Good Rock

Geomechanics Classification	Result	# Rating
Drill Core Quality R.Q.D	Fair Quality 50-75%	13
Wall Rock of Discontinuities	Moderately weathered	20
Ground Water	Completely Dry	15
Strength of Intact Rock Material	Med High 50-100 MPa	7
Spacing of Discontinuities	Wide (200-600 mm)	10
Strike and Dip Orientations	Favorable	-2

Results

Task	Maximum Points per Task
The task was complete in less than three hours	20
The team was able to locate the rock outcrop	20
Rock Mass Rating Geologic Tasks	
1. Uniaxial compressive strength of rock material	5
2. Rock quality designation	5
3. Spacing discontinuities	5
4. Condition of discontinuities	5
5. Ground water conditions	5
6. Orientation of discontinuities	5
Completed the task safely	10
Correctly calculated RMR number using tables provided	20
Total Points	100

Note. Rock outcrop located at: Longitude 38.402738 and Latitude -110.792079


The 1st Team got lost- 85

2nd Team’s Geologist spoke very little English- 45

The 3rd team Nailed it!- 100

Results

Crew Number	Team Score
167	85
168	45
169	100

Task Performance

Mean	Standard Deviation	Range
76.67	24.62	45-100

Note. N= 9.


What have we learned?

Conclusions

- It can be concluded that the task of determining the Rock Mass Rating of a rock structure can be conducted by a Martian Simulation Astronaut.
- Without an engineering back ground, astronauts can collect the data needed for engineers back on earth to design a plan for a future Martian shelter.
  - The more knowledge and practice the team had on Geological survey techniques, the better the results.
- To replicate on Mars, teams would require additional core sample equipment.

Recommendations

- Reevaluating the task manual and include training prior to task performance
- Determine participants geological survey knowledge prior to task completion to determine effectiveness of training.
- Continue to analyze the human factors that effect performance
  - Team Efficacy
  - Stress
  - Feeling of isolation

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Photos credited to:

Space.com; Nat Geo; Mars Society; NASA

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  - Dr. Gary Rodgers, Virginia Military Institute
  - Shannon Rupert, Mars Society
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Questions?