Exolith Lab Martian Simulants

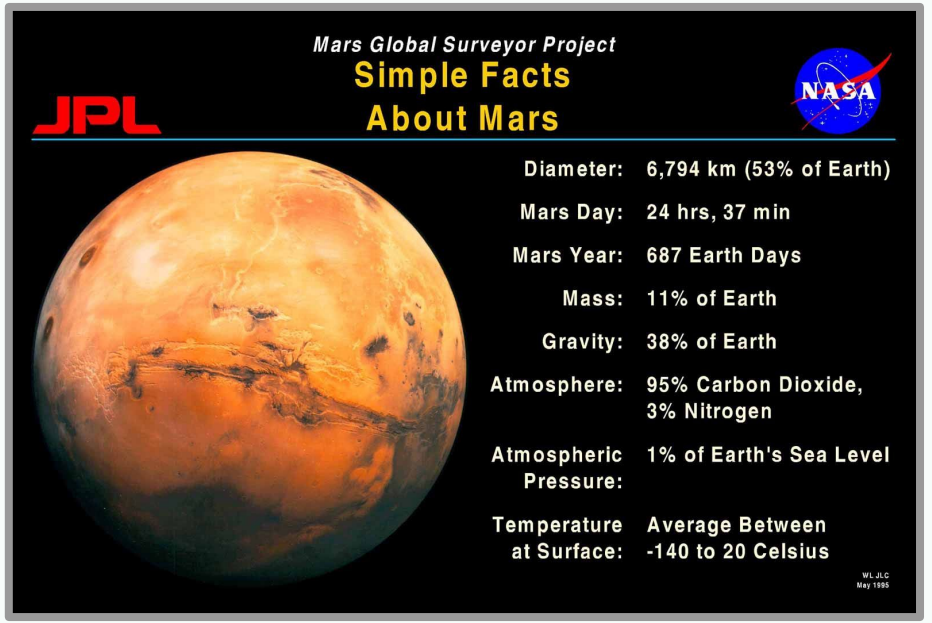
What is Exolith Lab?

- Exolith provides the space industry with Lunar, Martian, and Asteroid surface analogs
  - Also called “regolith simulants”
  - Working with companies like SpaceX, Blue Origin, NASA, ESA, and JAXA

- Part of the Florida Space Institute and CLASS
  - Under the University of Central Florida

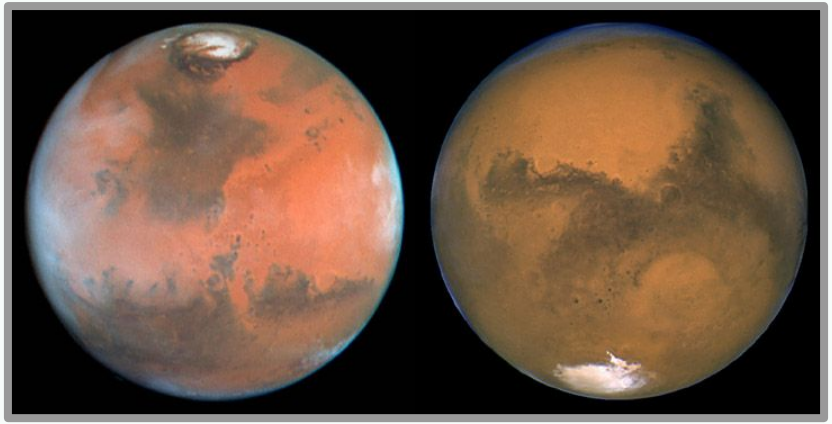
Mars

- 4th Planet from the Sun
  - Terrestrial planet
  - Second smallest in Solar System
- Very Thin atmosphere
  - 95% CO2
  - 2.7% Nitrogen
  - 1.6% Argon
  - 0.13% Oxygen
- “ The Red Planet”



“The Red Planet”

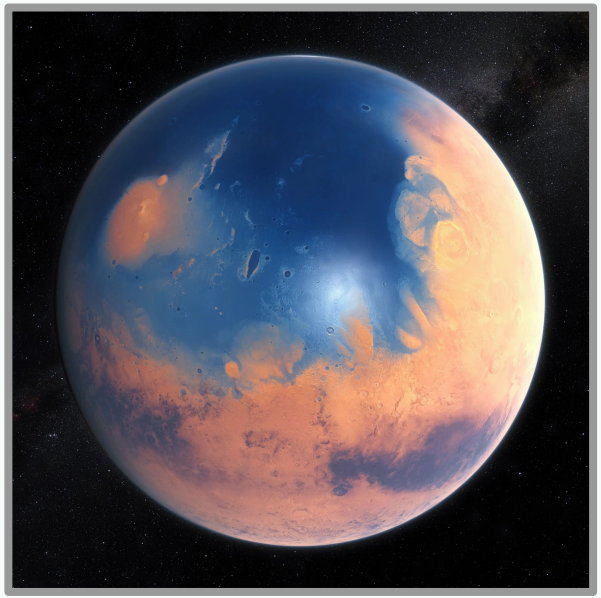
- Mars is red due to an abundance of Iron Oxide on its surface!
  - It is rusty
- Ice caps on the North and South pole
  - Water suspected to have once flowed on Mars
- Complex weather patterns and seismically active
  - A lot going on!!



North and South Poles of Mars

Geology of Mars

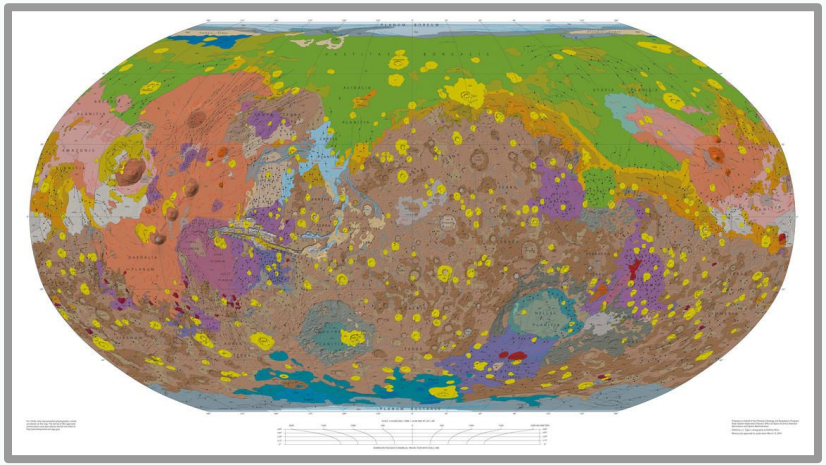
- Geologic History
  - Nochain (4.7-3.1 BY)
    - Heavy bombardment
    - Volcanic activity
    - Clay minerals formed
    - Water Bodies were common
  - Hesperian (3.7-2.9 BY)
    - Geological slow down
    - Sulphuric acid rain
    - Sulphate deposits formed
  - Amazonian (2.9 BY- Present)
    - dry and arid
    - Erosion and oxidation



Artistic Depiction of Water on Mars

Mineralogy of Mars

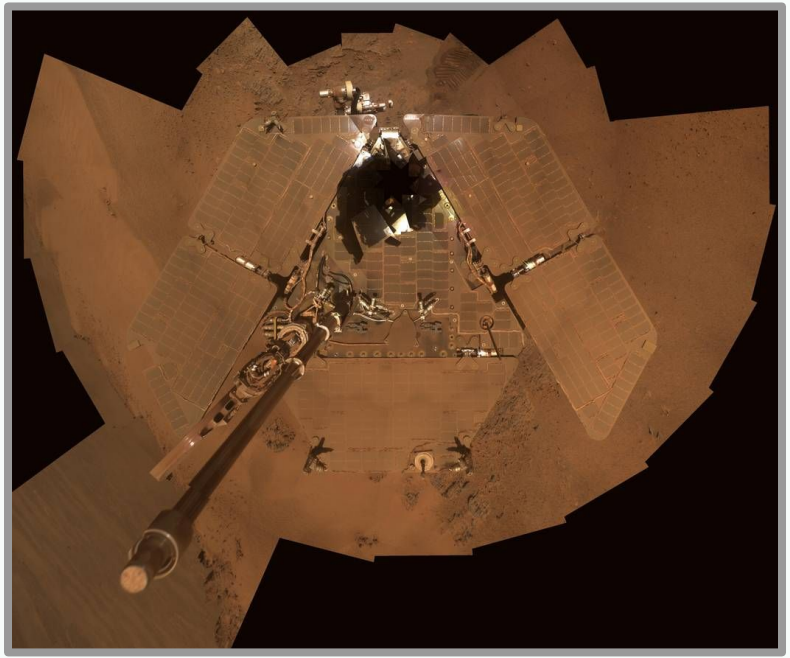
- Present Day Mineralogy
  - Phyllosilicates
    - Clays
  - Felsic Minerals
    - Silicate lacking Iron and Magnesium
  - Salts
  - Carbonates
  - Sulfates
  - Mafic Minerals
    - Silicate with Iron and Magnesium
  - Iron Oxide



Map of Martian Geology (USGS)

Martian Regolith

- Regolith is a blanket of unconsolidated, loose, heterogeneous superficial deposits covering solid rock
  - Problematic on Mars
  - Dust storms are frequent
- Regolith covers rover solar panels, ultimately killing them
  - Damages rover wheels



Opportunity Rover Covered in Regolith

Exolith Lab Martian Studies

- Regolith Simulant is used to test hardware and processes on Earth, before we go to Mars
  - Structural applications
  - Plant growth
  - Human health
  - Mineral extraction
  - Hardware deterioration
- High fidelity mixture of minerals found on Mars
- We do not simulate dangerous compounds (perchlorates, asbestos, etc.)

Plant Mars Challenge using Martian Simulants

General Simulant Mineralogy

- Phyllosilicates: Smectite
- Felsic Minerals: Plagioclase
- Salts: Gypsum/Anhydrite
- Carbonates: Fe Carbonate,
- Sulfates: Mg Sulfate,
- Mafic Minerals: Basalt, Pyroxene, Olivine
- Iron Oxide: Magnetite, Hematite, Ferrihydrite

Mineral	Wt.%
Olivine	32.0
Plagioclase	16.0
Glass-rich basalt	13.5
Pyroxene	12.0
Mg-carbonate	11.0
Smectite	6.0
Mg-sulfate	2.4
Ferrihydrite	2.1
Hydrated silica	1.8
Magnetite	1.1
Anhydrite	1.0
Fe-carbonate	0.8
Hematite	0.3

MGS-1 Mixture

Mineral	Wt.%
Plagioclase	27.1
Glass-rich basalt	22.9
Pyroxene	20.3
Olivine	13.7
Mg-sulfate	4.0
Ferrihydrite	3.5
Hydrated silica	3.0
Magnetite	1.9
Anhydrite	1.7
Fe-carbonate	1.4
Hematite	0.5

JEZ-1 Mixture

Simulant Creation

- Appropriate minerals are sourced
  - Come to us crushed or we crush them
  - XRD and XRF used to verify minerals
- Minerals are measured out using recipe sheet
- Mixture is put into cement mixer and mixed until homogenous
  - Oxidizes minerals and assures consistency

Outdoor Processing Area

Simulant Creation

- Data on the mineralogy of Mars has been gathered by different sources
  - Rovers
  - Mars Orbiters
- Goals of simulant
  - Accurate Mineralogy
  - Particle size range
  - Particle shape
  - Oxidation

Exolith Lab Mineral Mixture

Martian Global Simulant (MGS-1)

- Standard basaltic soil on Mars
  - Based on Rocknest soil analyzed by Curiosity
- Particle Size Range: .04-1000 microns
- Mean Particle Size: 90 Microns
- Bulk Density: 1.29 g/cm^3
  - Used to approximate martian regolith for any purpose

Mineral	Wt.%
Plagioclase	27.1
Glass-rich basalt	22.9
Pyroxene	20.3
Olivine	13.7
Mg-sulfate	4.0
Ferrihydrite	3.5
Hydrated silica	3.0
Magnetite	1.9
Anhydrite	1.7
Fe-carbonate	1.4
Hematite	0.5

Martian Global Simulant Clay (MGS-1C)

- Modified MGS-1 Simulant
  - Enhanced with Smectite for clay representation
- Used for In Situ Resource Utilization of water
- Mean Particle Size: 24 Microns

Mineralogy

Mineral	Wt.%
Smectite	40.0
Plagioclase	16.4
Glass-rich basalt	13.7
Pyroxene	12.2
Olivine	8.2
Mg-sulfate	2.4
Ferrihydrite	2.1
Hydrated silica	1.8
Magnetite	1.1
Anhydrite	1.0
Fe-carbonate	0.8
Hematite	0.3

Martian Global Simulant Sulfate (MGS-1S)

- Modified MGS-1 Simulant
  - Enhanced with Gypsum for sulfate representation
- Used for In Situ Resource Utilization of water
- Mean Particle Size: 119 Microns

Mineral	Wt.%
Gypsum	40.0
Plagioclase	16.4
Glass-rich basalt	13.7
Pyroxene	12.2
Olivine	8.2
Mg-sulfate	2.4
Ferrihydrite	2.1
Hydrated silica	1.8
Magnetite	1.1
Anhydrite	1.0
Fe-carbonate	0.8
Hematite	0.3

Jezero Delta Simulant (JEZ-1)

- Based on orbital data of Jezero Crater
  - Used for studies involving Perseverance
  - Additional Smectite, Mg-Carbonate, and Olivine
- Mean Particle Size: 70 Microns

Mineral	Wt.%
Olivine	32.0
Plagioclase	16.0
Glass-rich basalt	13.5
Pyroxene	12.0
Mg-carbonate	11.0
Smectite	6.0
Mg-sulfate	2.4
Ferrihydrite	2.1
Hydrated silica	1.8
Magnetite	1.1
Anhydrite	1.0
Fe-carbonate	0.8
Hematite	0.3

Phobos (PGI-1 and PCA-1)

- Two Phobos simulants were created for the JAXA Phobos mission
  - Phobos Giant Impact
  - Phobos Captured Asteroid
- Used to test sample return mechanisms

Phobos Simulant Creation

Uses of Simulant

- In Situ Resource Utilization
  - water extraction
  - construction processes
- Hardware Testing
  - Rover wheels
  - Sampling equipment
- Mechanical properties testing
- Plant growth
- Outreach

Student Plant Growth Studies

In Situ Resource Utilization

- Water extraction
  - Testing to see which types of regolith hold the most water
- Construction processes
  - Manufacturing using clay components
  - Utilizing Iron Oxides for sintering

Cup Created with MGS-1

Plant Growth

- Plant growth is one of the most common uses of MGS-1
  - Food production is essential on Mars
- Plant Mars challenge
  - Students all over world participate
  - Various methodologies and level of success

MGS-1 Plant Growth Experiment

Summary

- A good simulant will replicate:
  - Mineralogy
  - Physical Properties
    - Driven by mineralogy
- Exolith Lab creates mineralogically accurate simulants that mimic the expected chemical and physical properties of planetary regolith
  - Can create custom simulants
  - Free scientific consultations
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