



Analog Research on Earth and Moon for Mars Science and Exploration

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WHY Humans to Mars?

- Science?
- Exploration?
- Education?
- Jobs?
- National Prestige?
- Presidential Legacy?
- International Cooperation?
- Mars's Resources?
- Spin-offs?
- Migration/Colonization/Space Settlement?
- Start a New Branch of Human Civilization?
- Become a Multiplanet Species
- Human Destiny?
- *“Because we need the Challenge”?*
- *“Because we’ve already been to the Moon”*
- *“Because the Chinese are going”*
- *“Because it is there”?* (Mallory on Mt. Everest)
- *“Because it is clean”?* (Mawson on Antarctica)
- *“Because it’d be cool”?* (Anonymous School Kid)
- *“Why Not?”* (John F. Kennedy on going to the Moon and doing the other things)
- *“To Boldly go...”?* (Capt. James T. Kirk)
- **National Interest.**

Mars: Human Exploration Goals

- **Science and Exploration**
Search for + Investigation of **Life**
- **In-Situ Resource Utilization**
Search for + Utilization of **H₂O**
- **Strategic Settlement**
Establishment of long-term presence: **Base**

Analogy with Antarctic Exploration

Mars: Human Exploration Goals

Science and Exploration Drivers

- **Planetary Evolution**

- Planet Formation
- Geologic & Environmental Evolution

- **Astrobiology**

- H₂O and Habitability

- Life on Mars? 1) Yes or No?
 2) If Yes: What kind of Life?

- SETI Picture: $N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$

Earth-Moon-Mars:

Planetary Evolution

	Earth	Moon	Mars
Impact Cratering	Yes	Yes	Yes
Igneous (Volcanic+Plutonic)	Yes	Yes	Yes
Tectonics	Yes	Yes	Yes
Resurfacing, Physical	Yes	Yes	Yes
Resurfacing, Chemical	Yes	No	Yes
Aeolian (Wind)	Yes	No	Yes
Aqueous	Yes	No	Yes
Glacial	Yes	No	Yes
Periglacial	Yes	?	Yes

Earth-Moon-Mars:

Astrobiology

	Earth	Moon	Mars
H ₂ O	Yes	No ?	Yes
Habitability Past	Yes	No ?	Yes
Habitability Present	Yes	No ?	?
Life Past	Yes	No ?	?
Life Present	Yes	No ?	?
SETI $n_e =$	1	+ 0?	+ 1 ?
SETI $f_l =$	0.1	+ 0.1 ?	+ 0.1 ?
SETI $L =$	100 yrs +	x ?	x ?

Earth-Moon-Mars: Common Science Areas

- Moon Geology relevant to *Earth and Mars*.
 - Impact Cratering
 - Volcanism
- Moon Astrobiology has unfinished issues potentially relevant to *Earth and Mars*.
 - H₂O?
 - Habitability?
 - Life?
 - Planetary Protection?

Earth offers complex but diverse and accessible *science analogs* for Moon and Mars.

Earth-Moon-Mars:

Surface Operations Environments

	Earth	Moon	Mars
Gravity (g)	1.00	0.17	0.38
Atmospheric Pressure (mbar)	10^3	10^{-6}	10^1
Mean Solar Day / Synodic Spin Period	24 h	29.53 days	24h 39.6 min
Surface Temperature Range (K)	230 – 320	120 - 380	150 – 290
Diurnal ΔT (K)	20	160	80
1-way Light Travel Time (s)	1	1.3	240 – 1200
1-way Human Voyage Time (days)	2	5	180 - 330
Planetary Protection Requirements	Low	Low	High
Micrometeorites & Surface Radiation	OK	Lethal	?
Life Support System Failure	“OK”	Lethal	Lethal

Moon vs Mars Ops Challenges

- **Mars** in many ways **intermediate** between Earth and Moon:
 - 1) Moon can be more challenging than **Mars**.
 - 2) Earth *and* Moon ops experience will help plan **Mars** exploration.
- **Mars** is **more challenging** than Moon in specific areas:
 - 1) **distance** → long comms delays + exposure times
 - 2) chemical reactivity
 - 3) toxicity
 - 4) planetary protection

Earth Analog Program key complement to Return to the Moon
in Human Mars Exploration

Analog Program: Functions

Learning

from similarities *and* differences

- Comparative Planetary Science + Astrobiology
- Field Exploration Requirements Definition

Testing

Hardware + Software
Strategies

Training

Astronaut – Robot Systems

E / PO

Public Interest & Support
International Cooperation

Earth Analog Program

Desirable Attributes

- *Do on Earth what need not be done elsewhere.*
- Moon relevance first, but maximize Mars relevance.
- Engage students and general public.
- Engage global international community.

Results

- Safer Moon/Mars program
- Lower costs
- Increased Exploration Productivity
- Sustained public interest and support