From the Moon to Mars

Implications for Lunar Outpost Selection and the Nature of the Activity to be Carried Out There

Presented to the

LEAG Workshop on Enabling Exploration: Lunar outpost and Beyond

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Current concept for initial human exploration of Mars:

A program of three missions launched in consecutive opportunities

Draft Objectives, Initial Human Exploration

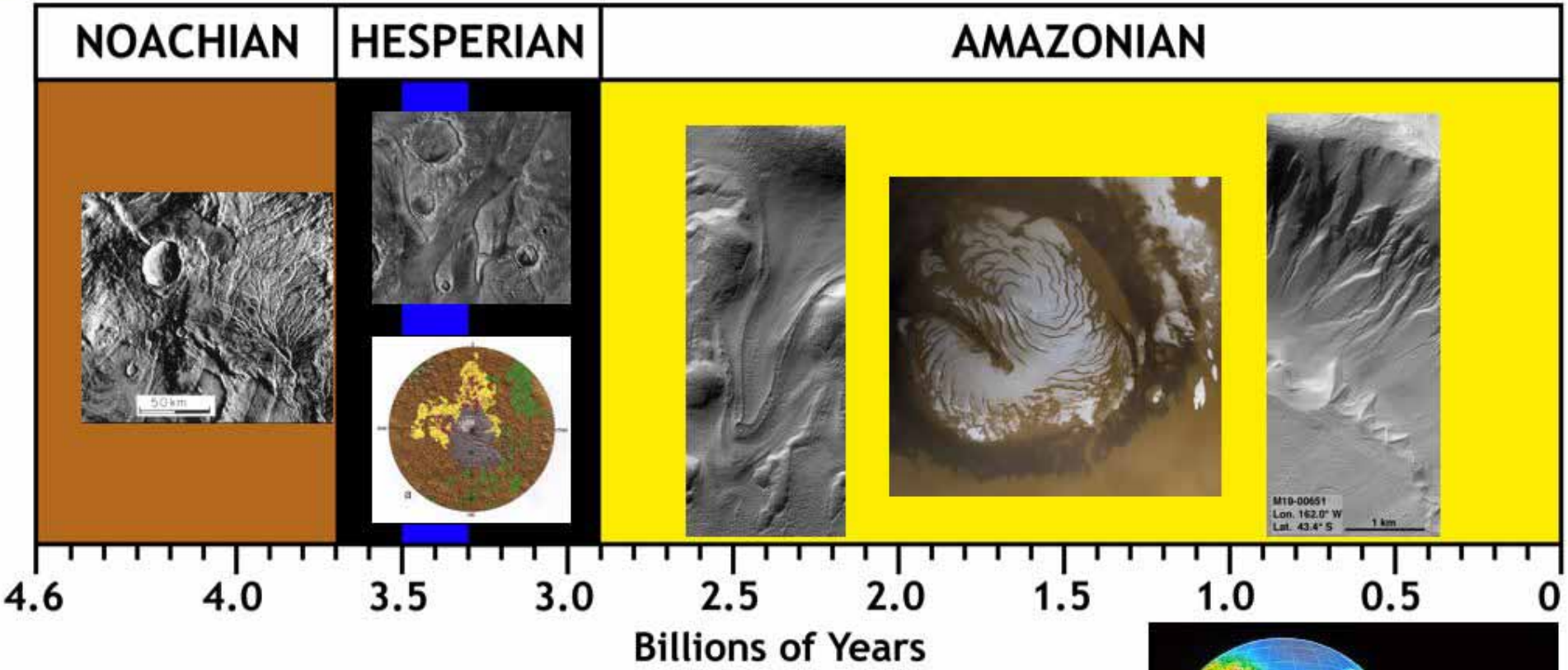
1. Quantitative characterization of the different components of the **martian geologic system** (at different parts of martian geologic history), and understand how these components relate to each other.
2. Search for **ancient life** on Mars
3. Make significant progress towards the goal of understanding whether or not **martian life** forms have persisted to the present.
4. Quantitative understanding of early Mars **habitability** and early Mars geochemical/biochemical/and possible **pre-biotic chemical processes**.
5. Characterize the structure, composition, dynamics, and evolution of the **Martian interior**

- Learn to make effective use of **martian resources**, including providing for crew needs, and if possible, power and propulsion consumables.
- Develop reliable and robust **exploration systems**; Increase the level of self-sufficiency of Mars operations
- Address **planetary protection** concerns regarding sustained presence
- Promote the development of **partnerships** (international, commercial, etc.) and sustain **public engagement**

Other Science: TBD

Not in priority order.

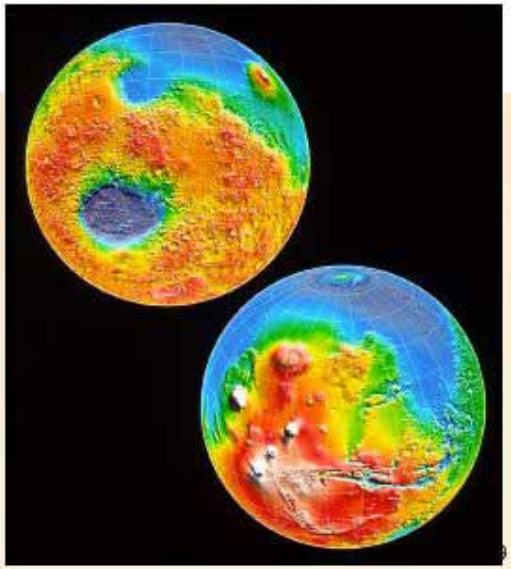
Why Multi-site diversity matters: Water on Mars: Relation to Geologic History



- Heavy impact bombardment.
- Valley networks.
- "Warm/Wet" early Mars?
- Dynamo Era

-Volcanism.
- Outflow channels.
- Oceans?
- South circumpolar deposits.

- Low impact rates.
- Tharsis volcanism continues.
- Outflow channels continue.
- Late-stage polar caps.
- "Cold/Dry" late Mars.
-Active "wet" gullies



Science Priorities

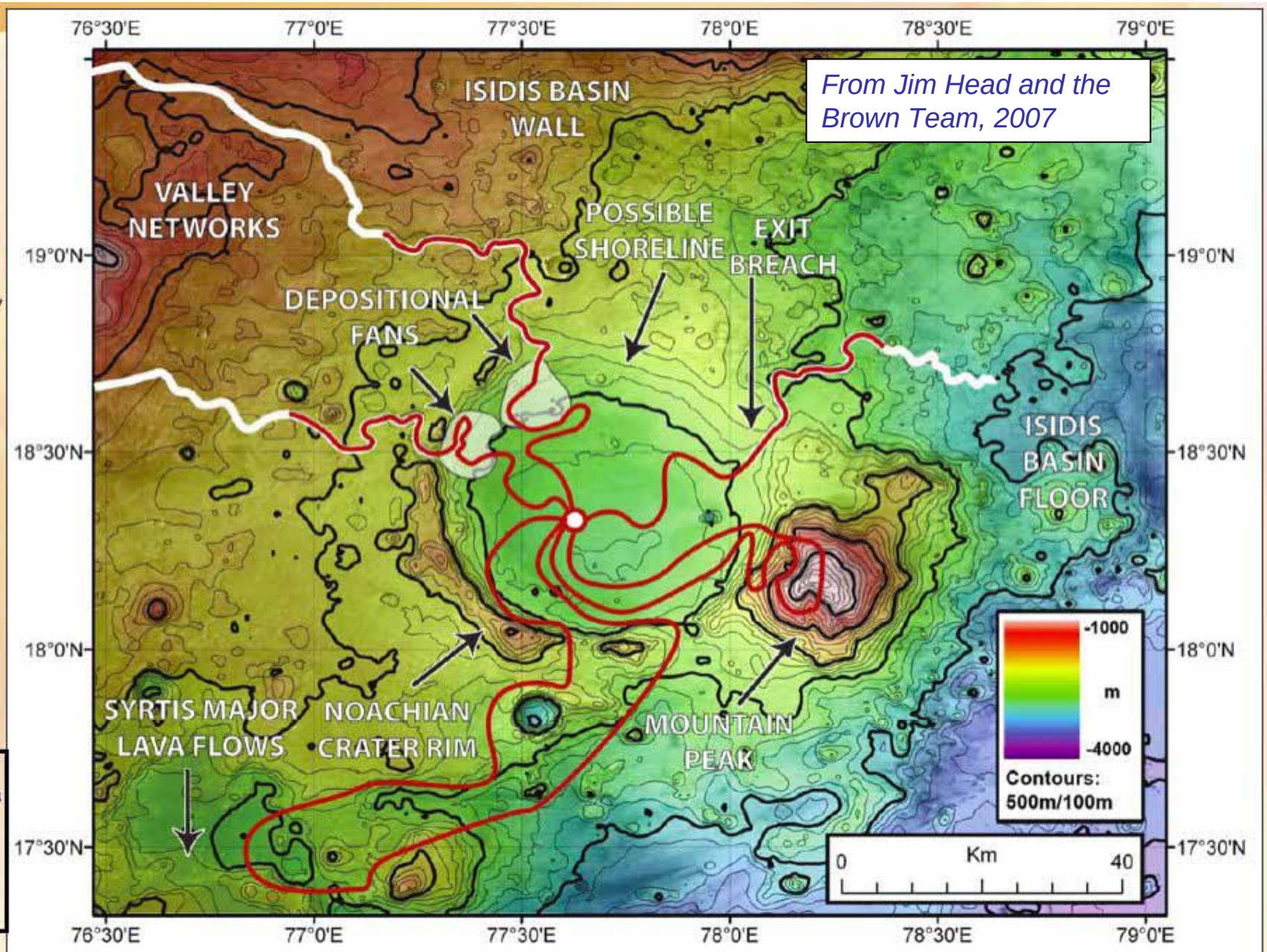
	Short Stay	Long-Stay
One Site	BELOW SCIENCE FLOOR	
Multiple Sites		

- Because of Mars' spatial diversity, this is critically important to science

- In order to make use of this time, significant mobility necessary
- Ideal for complex geological objectives
- Can achieve significant subsurface objectives; <u>key to life search</u>

Noachian

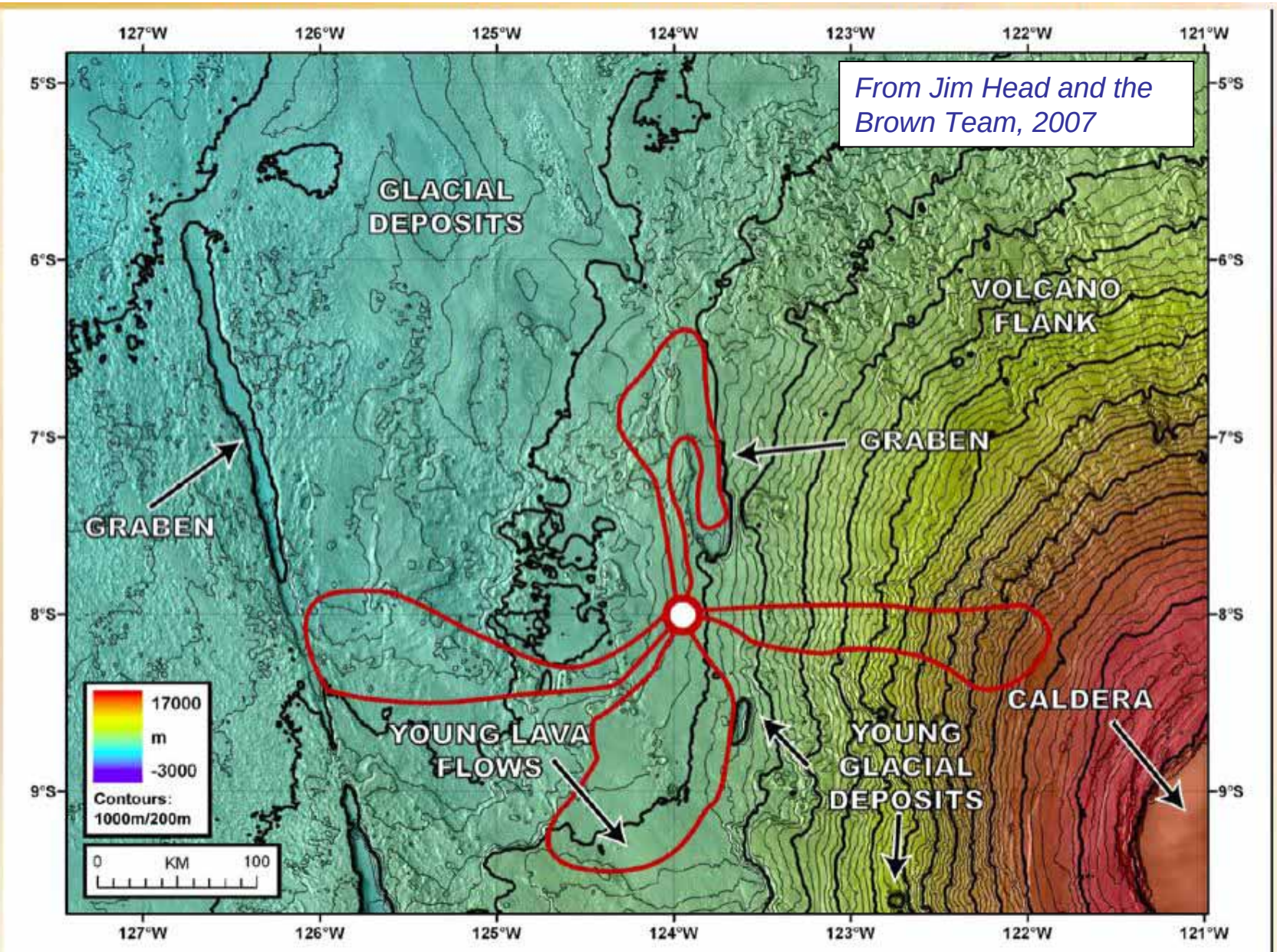
Ancient impact Basin and Early Crust HSRM Case Study Site



RED line indicates a set of science traverses (work in progress)

Hesperian

Tropical Mountain Glacier and Volcanism HSRM Case study site



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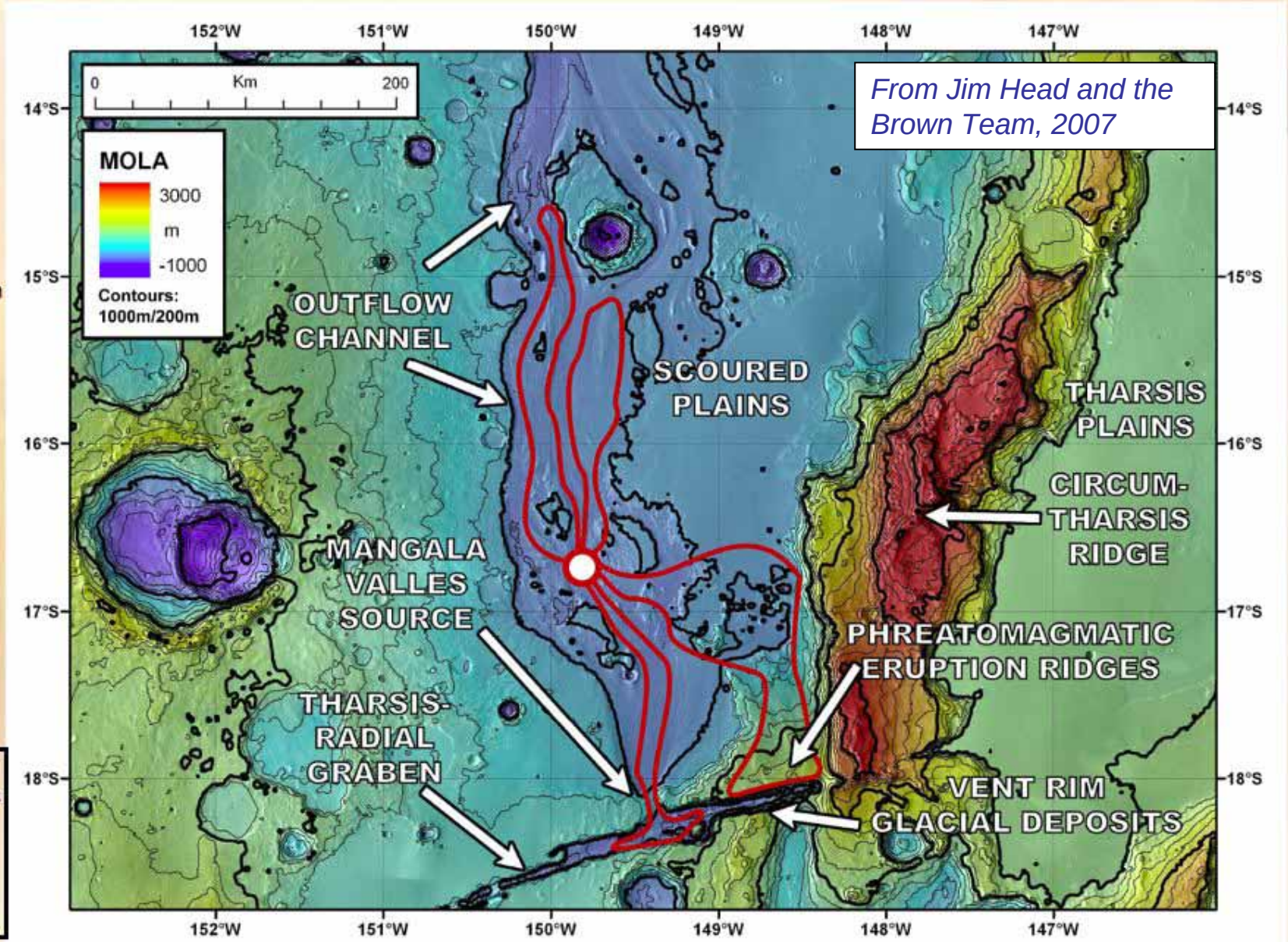
Amazonian

Channel History and water-related Volcanism HSRM Case Study Site



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Extent of Lab work on Mars?

There will be a need to do as much science as possible at Mars.

- restrictions of sample weight on return
- Portable lab devices will be well advanced in the next 30 years
- From a biological perspective, best to keep samples at ambient conditions which would be tough to do on sample return
- Makes good use of the humans
- Need to high-grade the best samples to return to Earth

Early Draft: On-Mars Laboratory

- **Analytic Instruments**
  - Mass spectrometer or gas chromatograph for volatile (and liquid?) analyses (elemental and molecular)
  - Mass spectrometer or other for elemental analyses of solids
  - XRD, petrographic scope and other for mineralogical/structural analysis of solids
  - Meso-scale and micro-scale imaging
  - Wet chemistry
  - Age-dating instrumentation
  - Thermal emission spectrometer, Raman spectrometer, Mossbauer spectrometer
  - Ice core analysis instrumentation
  - Oven for burning off volatiles
  - Subsurface sounding instrumentation
  - Seismic instrumentation
- **Sample Prep equipment**
  - Basic rock prep: Cutting, drilling, thin-sectioning, powdering
- **Carbon and life detecting instrumentation**

Scientific Equipment: In Rover

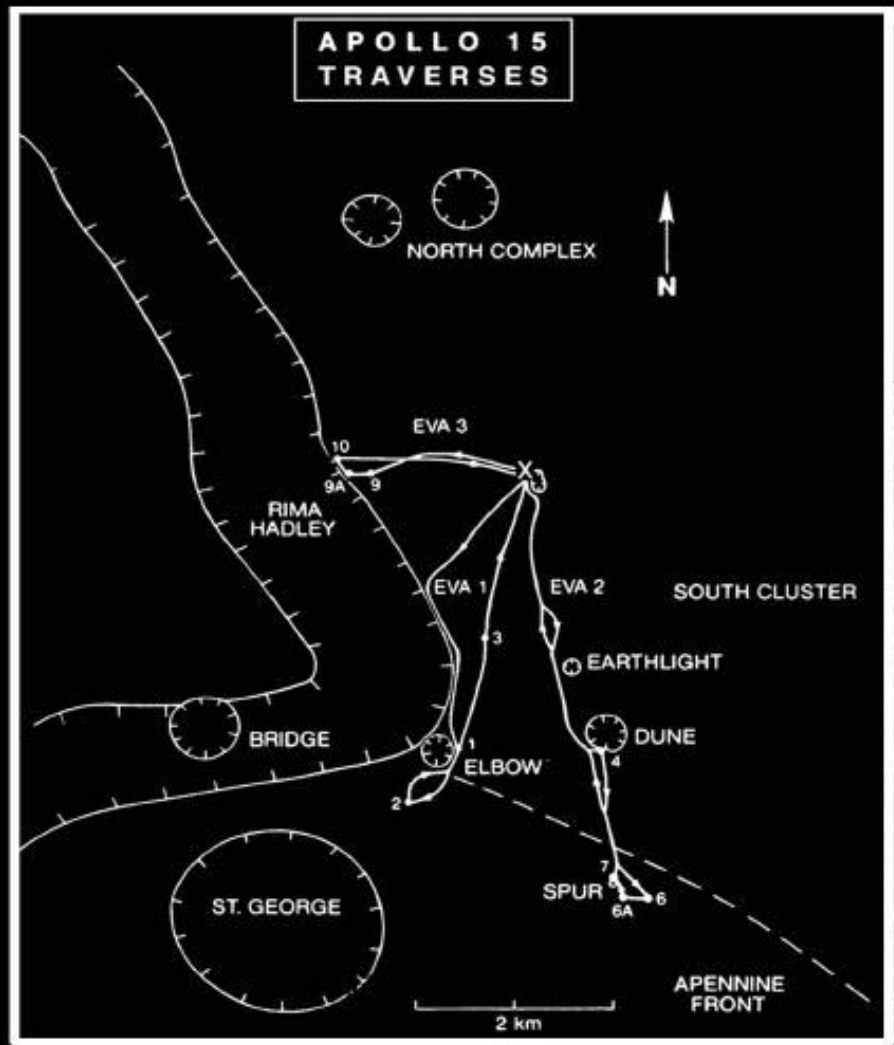
- **Analytic Instruments**
  - Thermal emission spectrometer
  - Elemental analysis instrumentation
- **Sample Prep equipment**
  - Digital cameras mounted on scopes to capture terrain and geological features
- **Other**
  - Meteorological sounding instrumentation
  - Remote sounders
  - Seismic instrumentation
  - Electromagnetic sounding instrumentation
  - Ground penetrating radar and neutron spectrometer

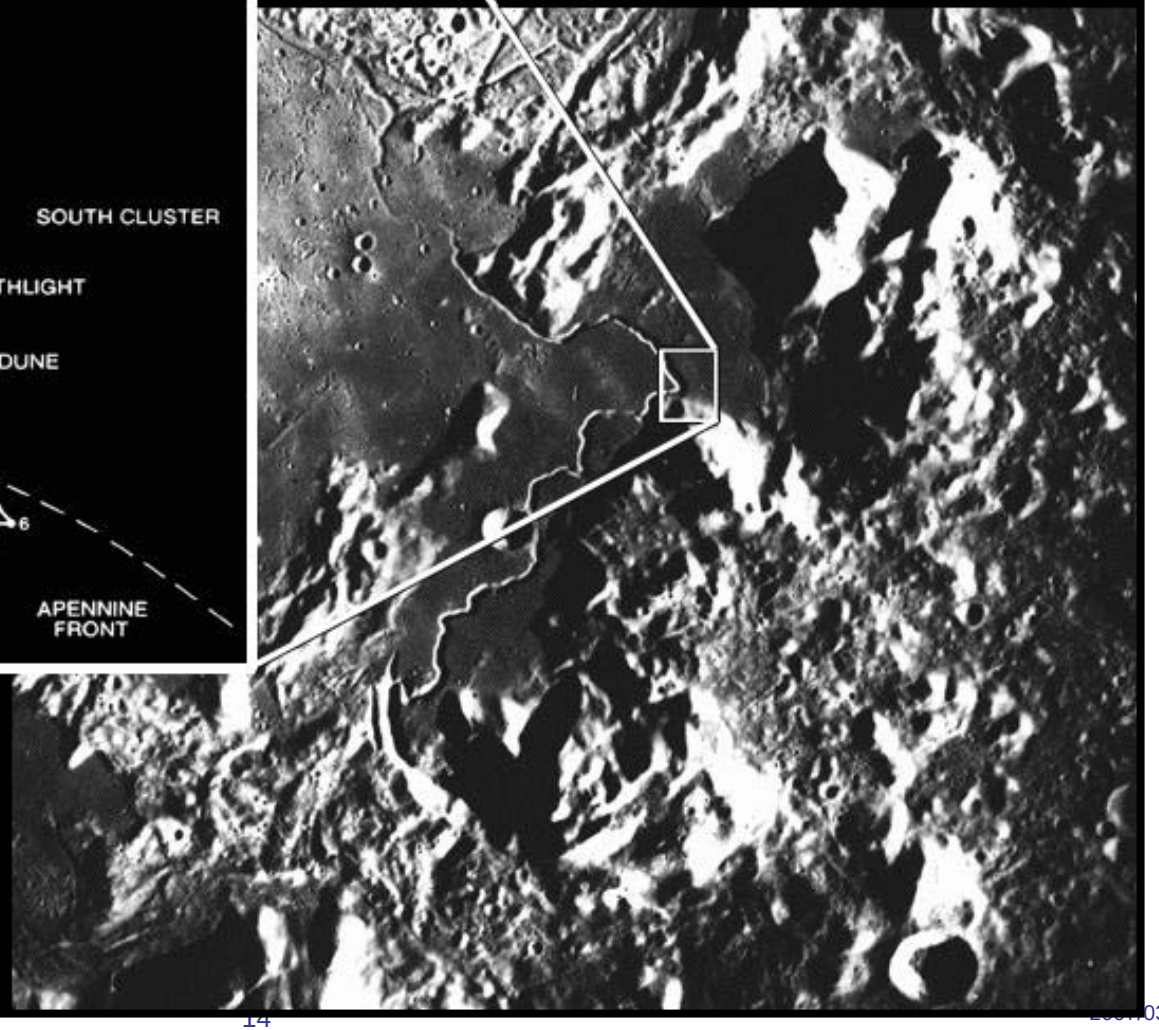
How about the Moon?

Mars Heritage: Lunar Surface Ops

- **Select sites that have significant interest w.r.t. planetary science**
  - Multi-site operations
- **Demonstrate primary and secondary mobility systems to maximize diversity of contact and contact time, demonstrate field procedure/hardware**
- **Sample acquisition, prep, and analysis equipment**
  - Drills (200 m)
  - Habitat laboratory
  - Rover-based instrumentation
- **ISRU, particularly anything related to hydrogen/water**
  - A lunar site located in proximity to an ice (or volatile-containing rocks) deposit from which samples would need to be specially "triaged" would provide an opportunity to explore most (if not all) collection, documentation, containment difficulties that might be required of a Martian sample of biological interest.

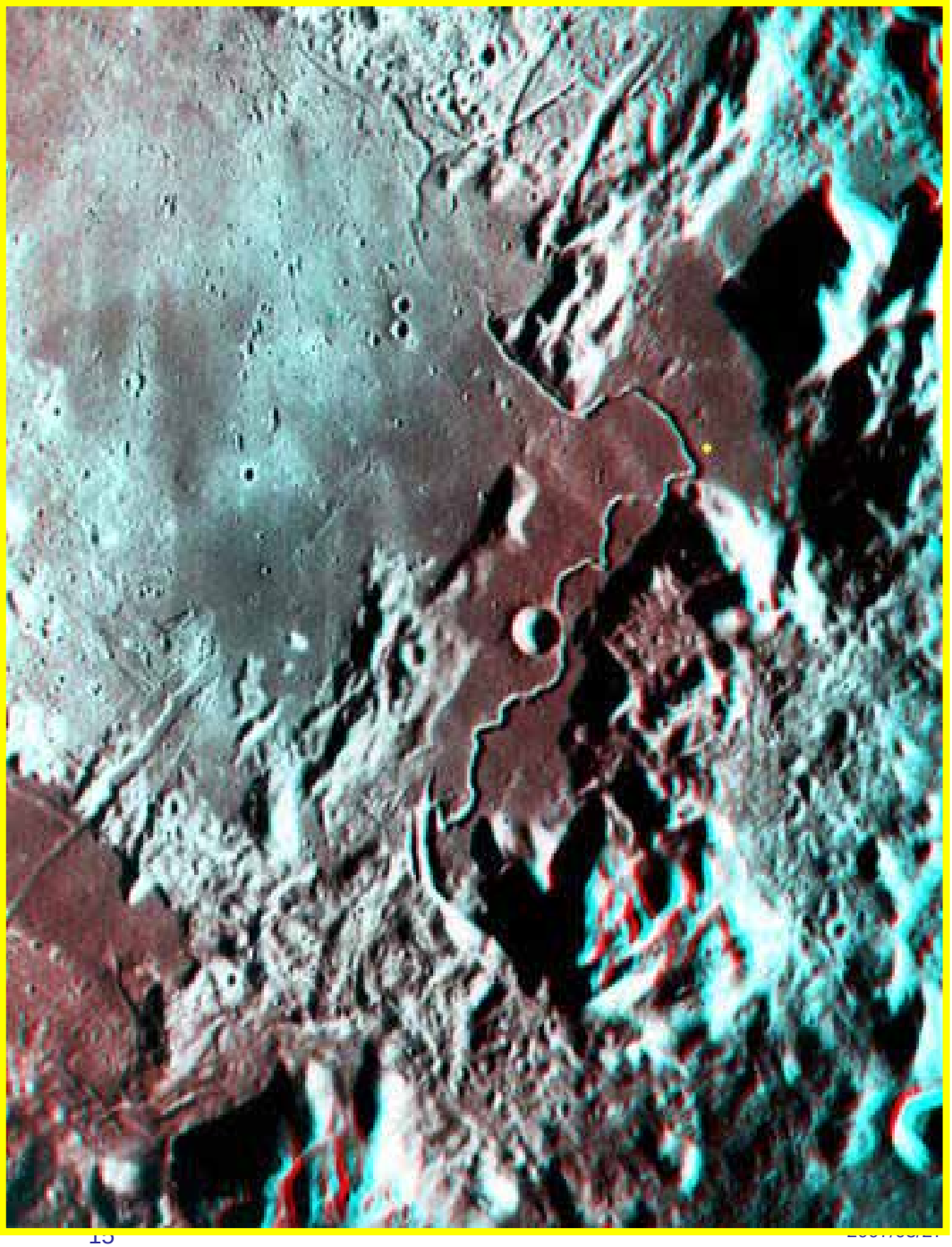
APOLLO 15 LANDING SITE





Apollo 15 500 Day Mission

1. Imbrium impact basin.
2. Sinuous rille origin.
3. Mare history.
4. Ejecta from far craters.
5. Regolith history.



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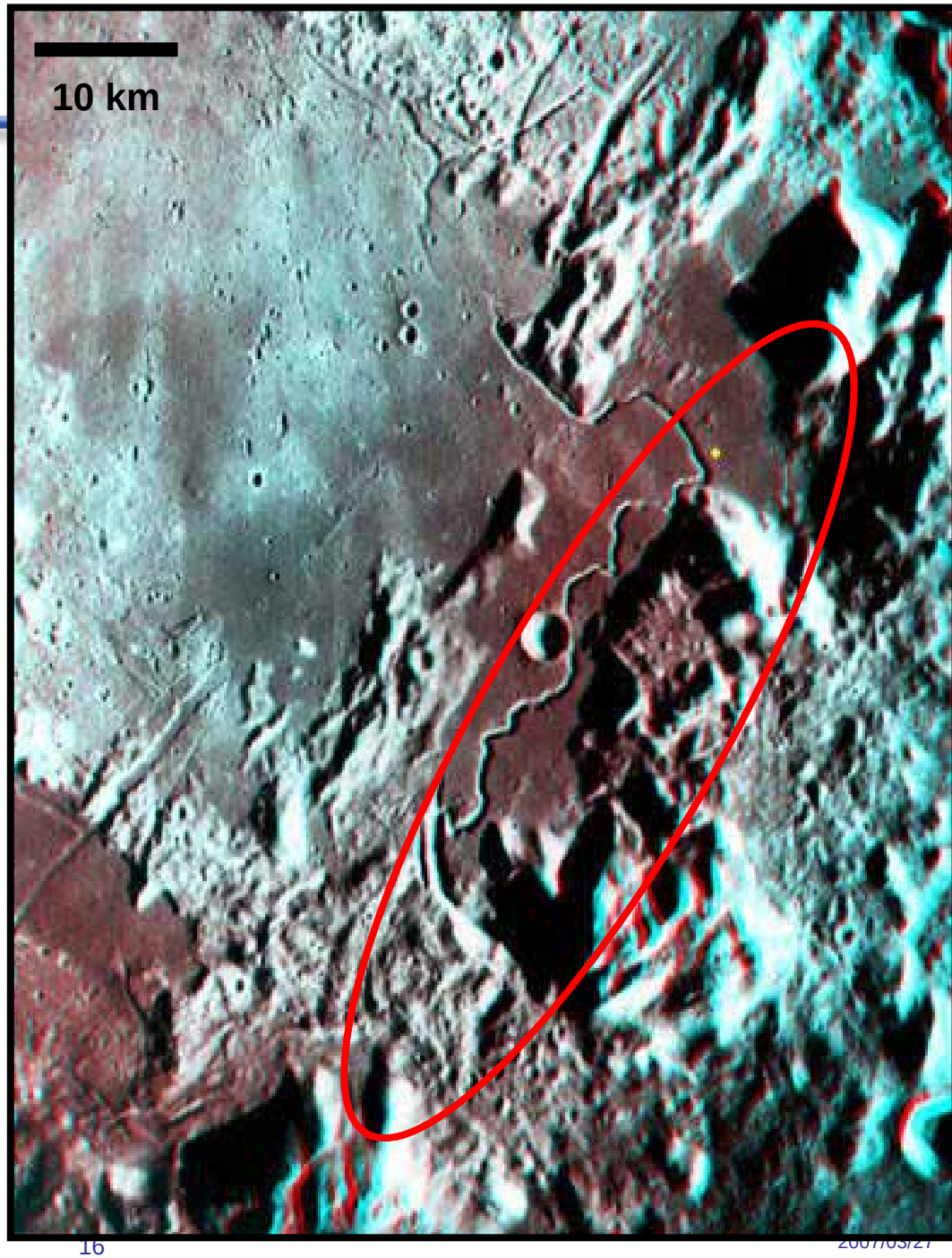

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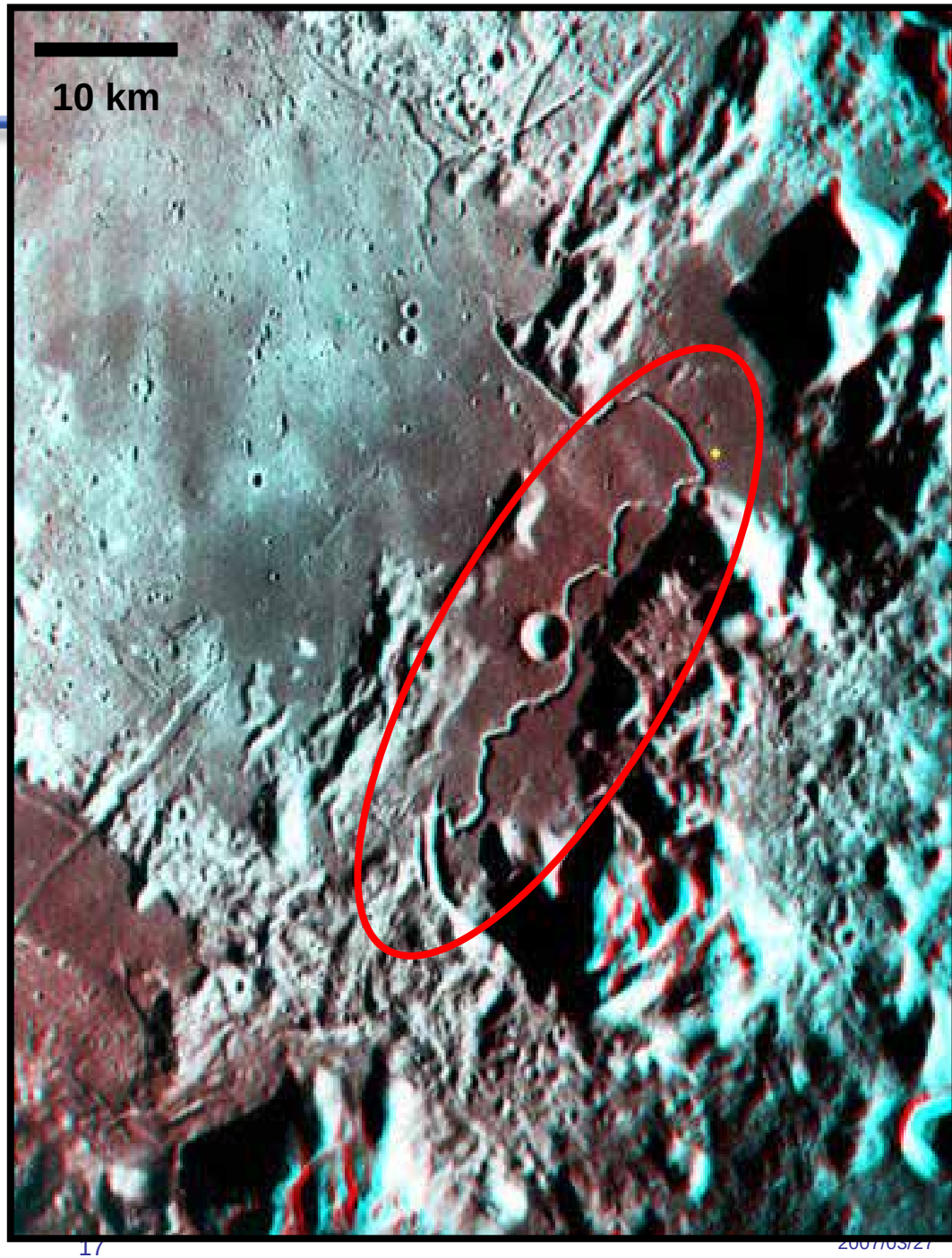

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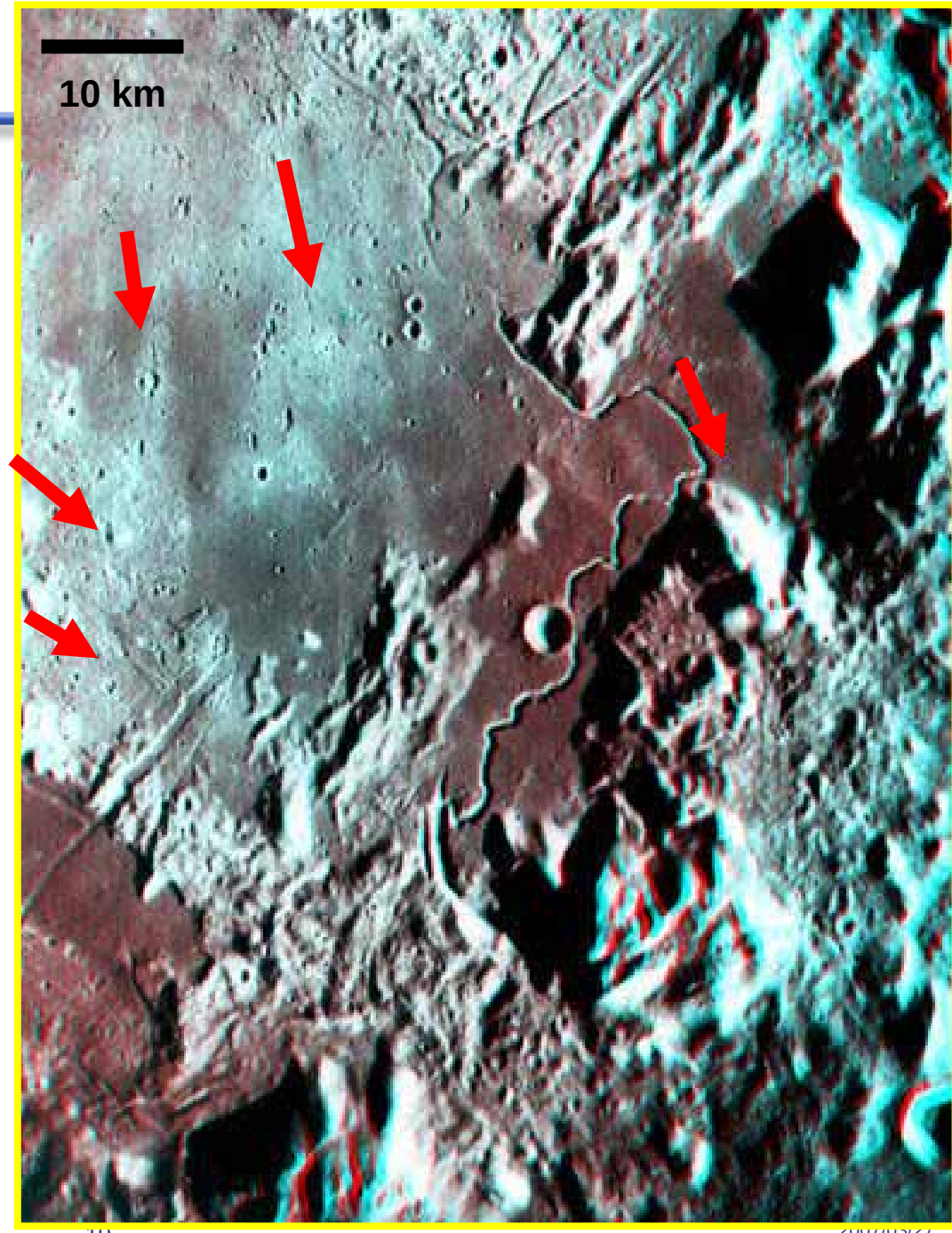

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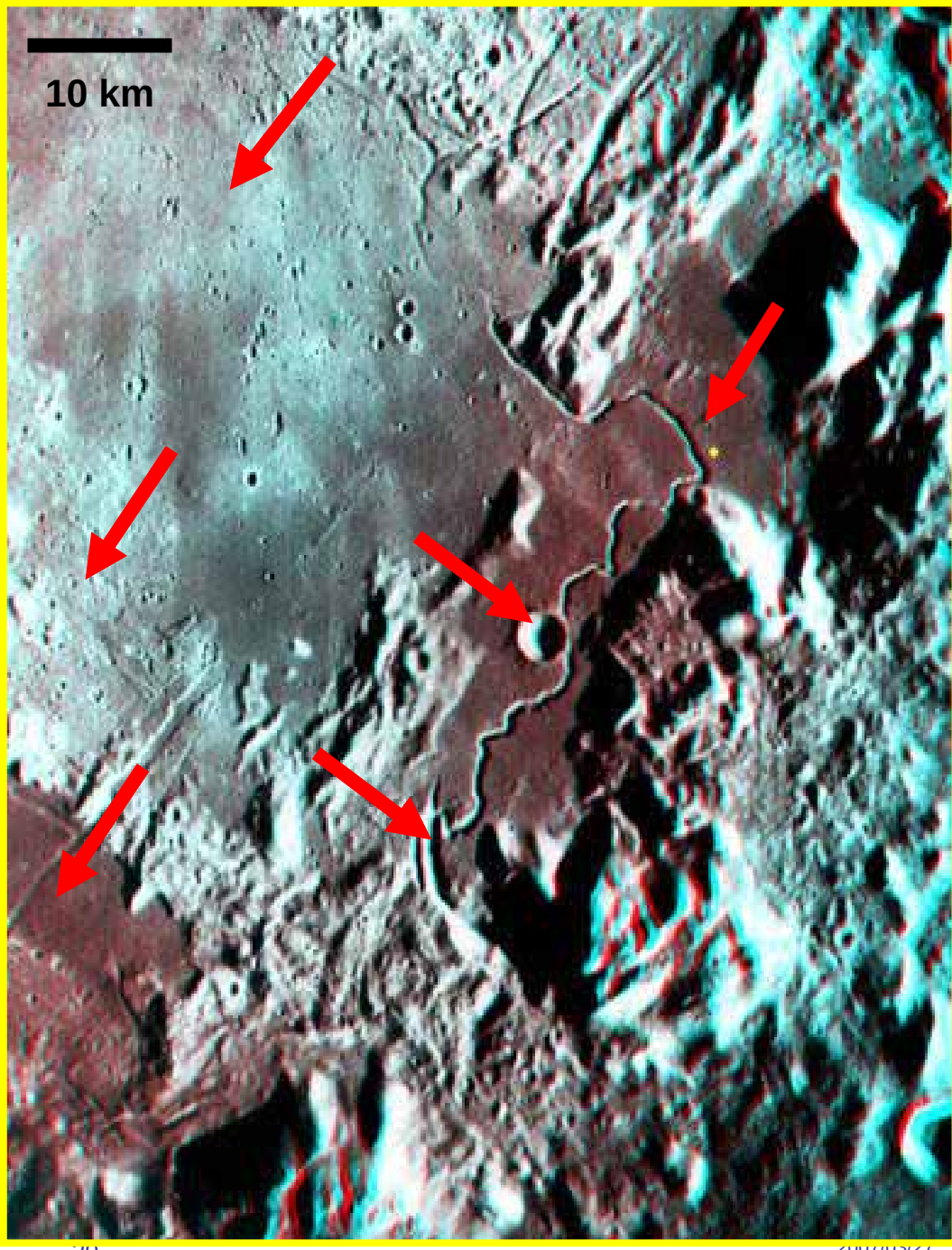
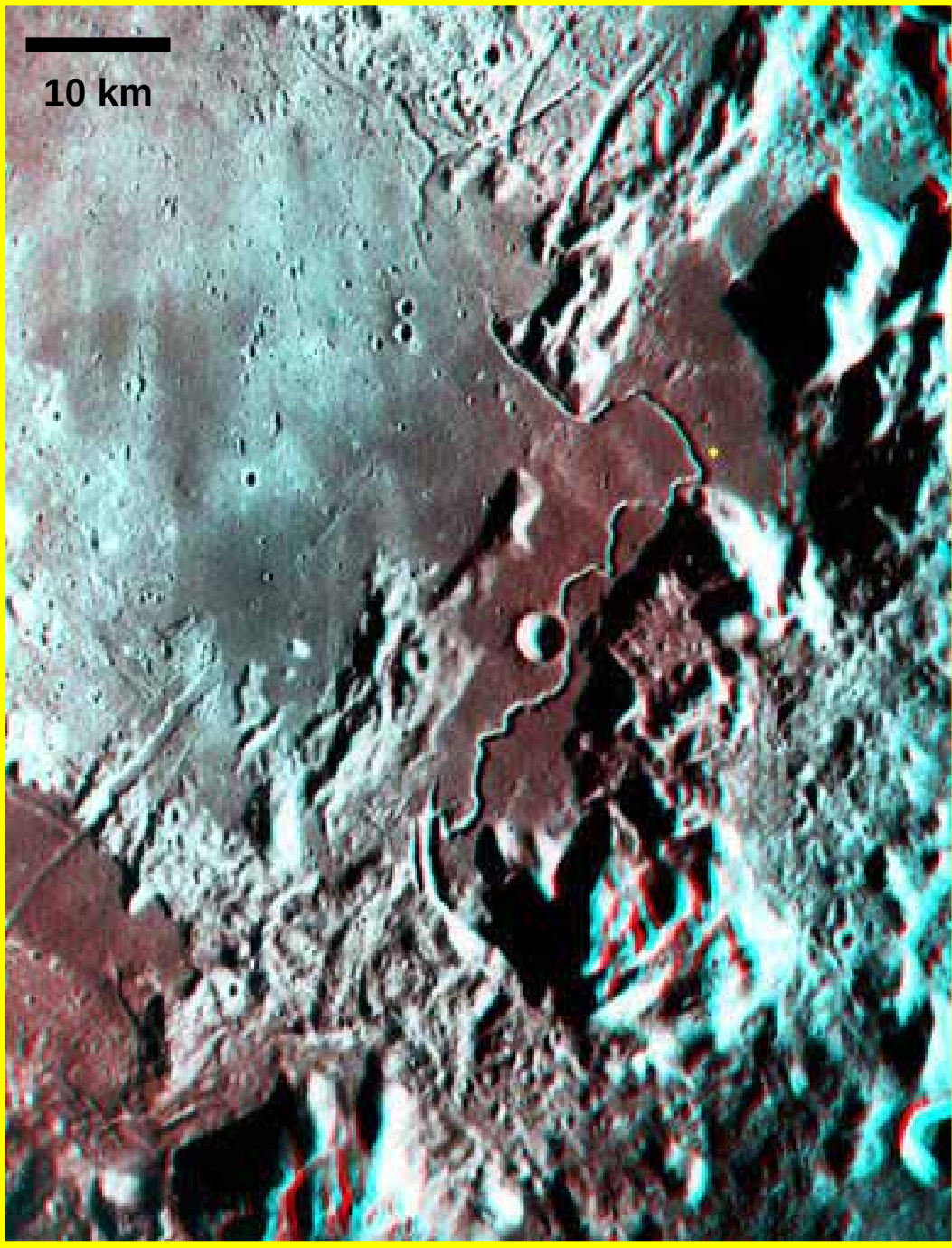


Preliminary Results

1. Stay Time: 500 days.
2. Range: >100 km.
3. Mobility: LRV+++; LFU.
4. In situ experiments.
5. Robotic Complements: Earth-controlled robotic rovers.
6. 3-D exploration: Depth.
7. In situ sample analysis.
8. Returned Payload: Many hundreds of kg!



Summary

- Pick multiple sites that are scientifically interesting in multiple ways
- Stay as long as possible
- Give the scientific system, mobility, and life support systems a good workout.

Backup

Site Selection: Implications for Telecommunications Infrastructure

- **Site selection has important implications for communications connectivity**
  - Surface to Earth
  - Surface to relay orbiter
- **Fundamental differences between Moon and Mars will influence the telecom architecture**
  - Tidally locked Moon: A given surface site can have permanent, or have no, direct-to-Earth visibility
  - Mars: Most sites will have daily periods of contact with Earth (largely overlapping the sunlit portion of the sol); however, high-latitude polar sites can be out of Earth view for months during Martian winter
  - Different relay orbit options exist at Moon and Mars (e.g., a Mars areostationary orbit provides an attractive relay option for a human Mars base; such orbits are not stable in the Earth-Moon system)
- **Exploration strategy will drive comm infrastructure evolution**
  - Does comm infrastructure need to support a single site, with successive build-up of surface capability, or successive globally-distributed sites?