Settling Mars:
Protecting Science and Exobiology

Kent Nebergall
Macroinvent.com

Mars Society Conference, 2018

Overview

- Lithopanspermia From Earth
  - Implications for Astrobiology
  - Implications for Space Settlement
- Working with Life in all its forms
- Preserving Science While Mining

Lithopanspermia from Earth

The Astrophysical Journal, 690:210–215, 2009 January 1 doi:10.1088/0004-637X/690/1/210

NATURAL TRANSFER OF VIABLE MICROBES IN SPACE FROM PLANETS IN EXTRA-SOLAR SYSTEMS TO A PLANET IN OUR SOLAR SYSTEM AND VICE VERSA

Mauri Valtonen[1], Pasi Nurmi[1], Jia-Qing Zheng[1], Francis A. Cucinotta[2], John W. Wilson[3], Gerda Horneck[4], Lennart Lindegren[5], Jay Melosh[6], Hans Rickman[7], and Curt Mileikowsky[8,9]
[1] Tuorla Observatory, Turku University, FIN-21500 Piikkiö, Finland; mvaltonen2001@yahoo.com
[2] NASA Johnson Space Center, 2101 NASA Road 1, Houston, TX 77058, USA
[3] NASA Langley Research Center, Mail Stop 111, Hampton, VA 23681–2199, USA
[4] Deutsches Zentrum für Luft- und Raumfahrt, Linder Höhe, D-51147 Köln, Germany
[5] Lund Observatory, Lund University, Box 43, SE-22100 Lund, Sweden
[6] Department of Planetary Sciences, Lunar and Planetary Laboratory, University of Arizona, 1629 East University Boulevard, Tucson, AZ 85721–0092, USA
[7] Department of Astronomy and Space Physics, Uppsala University, Box 515, SE-75120 Uppsala, Sweden
[8] Royal Institute of Technology (KTH), SE-10044 Stockholm, Sweden
Received 2008 July 8; accepted 2008 August 25; published 2008 December 1

ABSTRACT

We investigate whether it is possible that viable microbes could have been transported to the Earth from planets in extra-solar systems by means of natural vehicles such as ejecta expelled by comets or asteroid impacts on such planets. The probabilities of close encounters with other solar systems are taken into account as well as the limitations of bacterial survival times inside ejecta in space, caused by radiation and DNA decay. The conclusion is that no potentially DNA/RNA life-carrying ejecta from another solar system in the general Galactic star field landed on the Earth before life already existed on the Earth, even if the microbial survival time in space is as long as tens of millions of years. However, if the Sun formed initially as a part of a star cluster, as is commonly assumed, we cannot rule out the possibility of transfer of life from one of the sister systems to us. Likewise, there is a possibility that some extra-solar planets carry life that originated in our solar system. It will be of great interest to identify the members of the Sun's birth cluster of stars and study them for evidence of planets and life on the planets. The former step may be accomplished by the *GAIA* mission, the latter step by the *SIM* and *DARWIN* missions. Therefore it may not be too long until we have experimental knowledge to answer the question of whether the natural transfer of life from one solar system to another has actually taken place.

Key words: astrobiology – meteors, meteoroids – planetary systems – stellar dynamics

1. INTRODUCTION

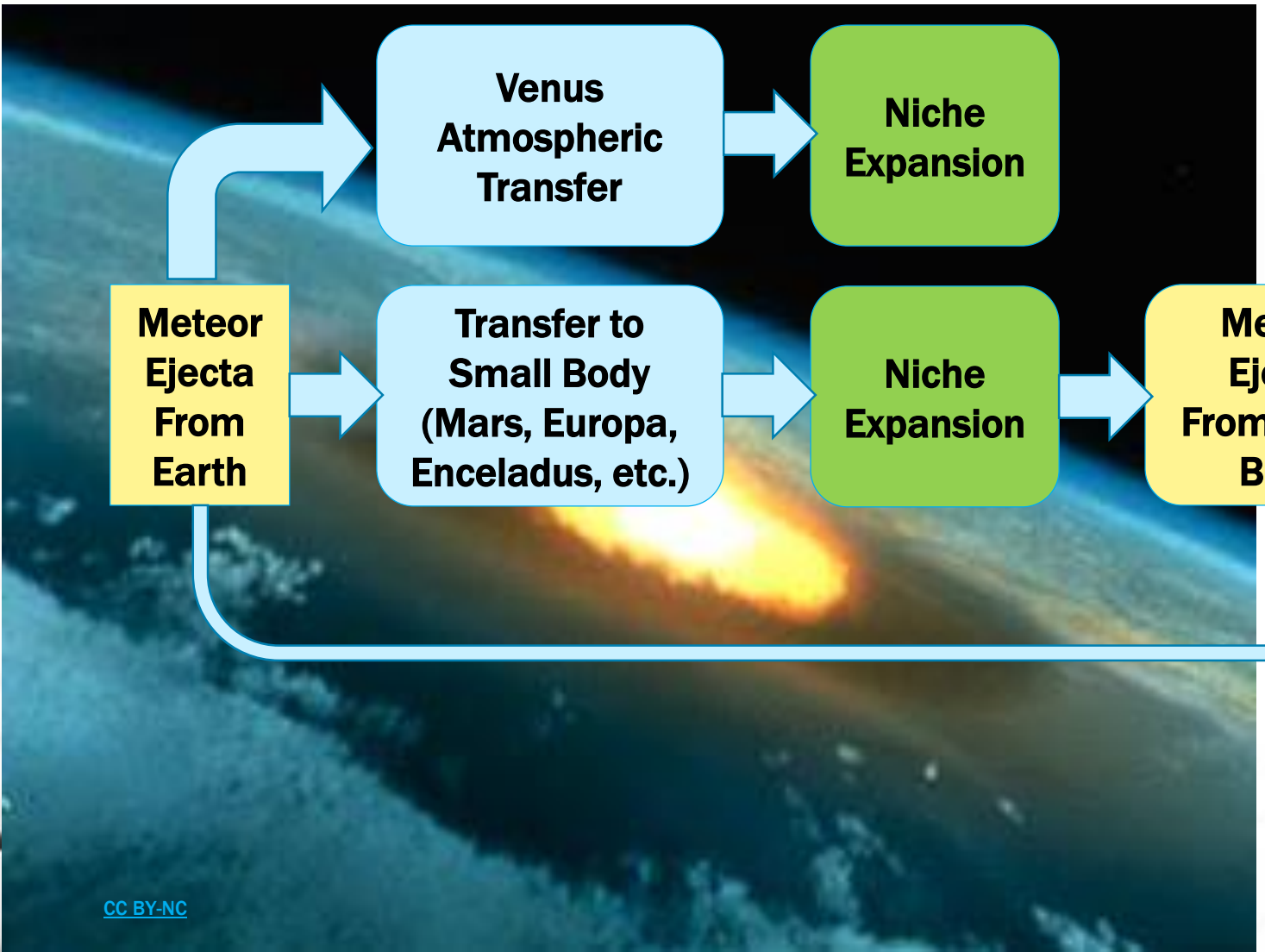
All presently known life on the Earth is controlled by DNA/RNA for information and replication, using the same code in a complicated manner, which gives a strong indication that all life on Earth has a common ancestor cell. This generally is the opinion of biologists today, and it is usually assumed that the ancestral cell originated on the Earth itself. Sometimes the question is raised, however, whether that cell, or one of

conditions during the journey and travel time of tens of millions of years.

2. EJECTA FROM PLANETS

When a comet or an asteroid impacts a planet, a crater is formed, the diameter of which is a known function of the diameter of the impactor and of its velocity. Part of the impactor and of the ground it hits is heated by a shock wave to melting point and it evaporates. Most of the ejecta resulting from the

Mechanisms



Meteor Ejecta From Earth

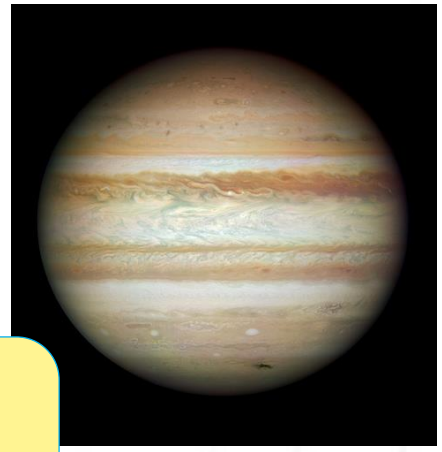
Venus Atmospheric Transfer

Niche Expansion

Transfer to Small Body (Mars, Europa, Enceladus, etc.)

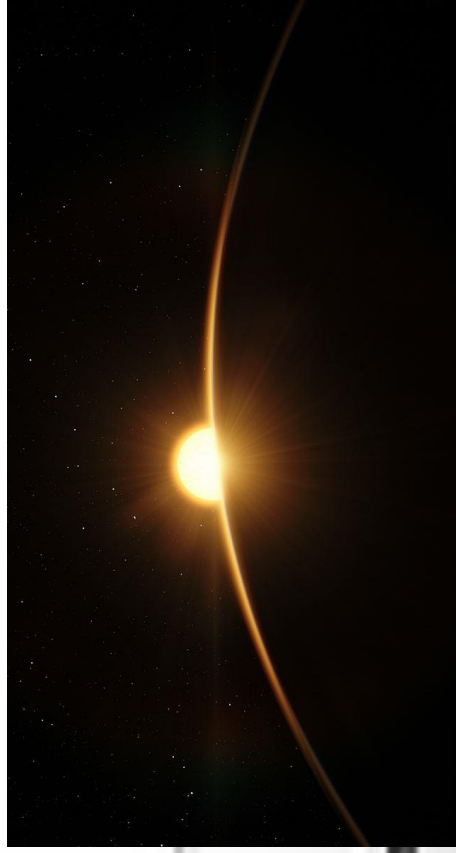
Niche Expansion

Meteor Ejecta From Small Body

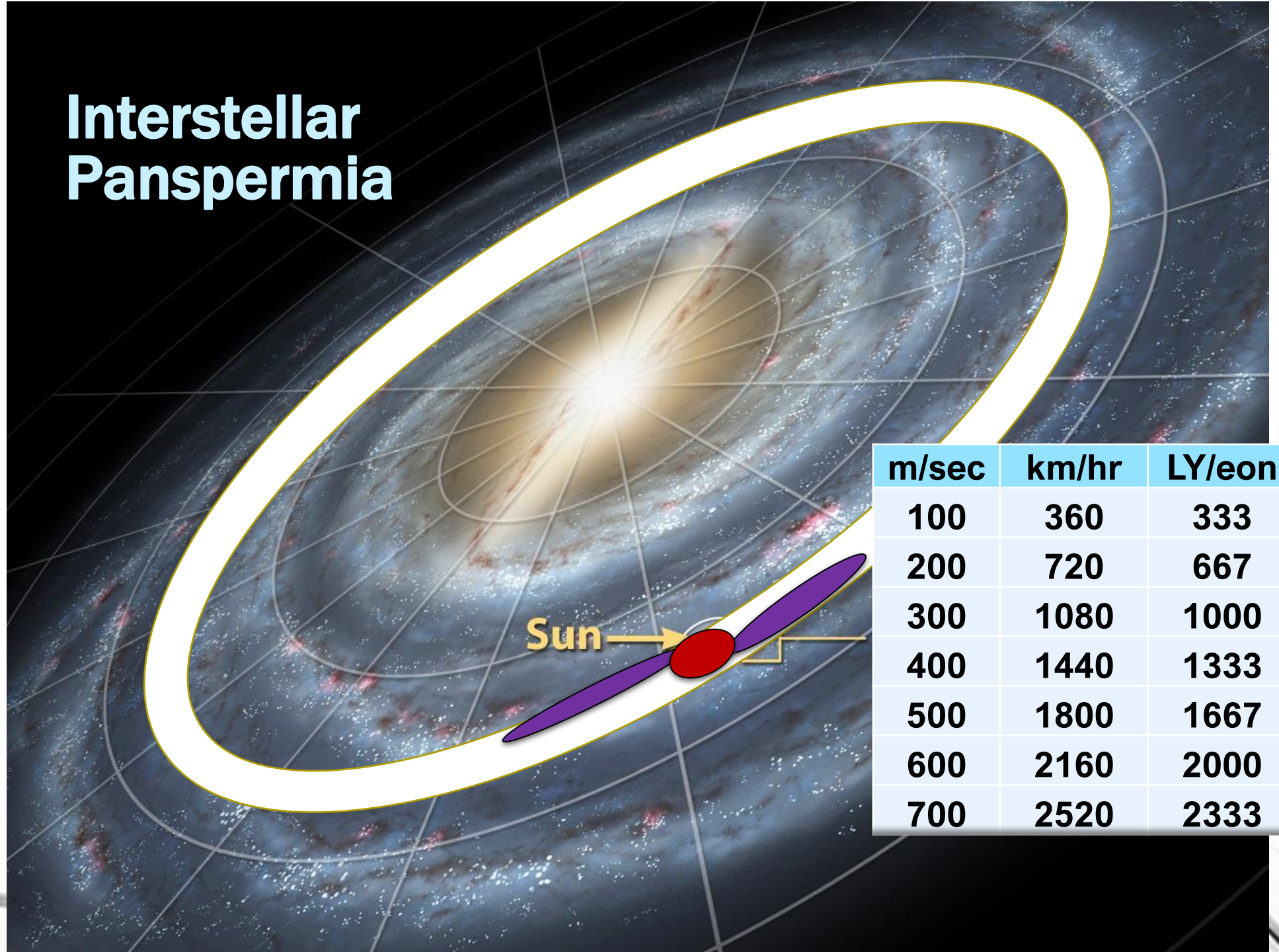


Gas Giant Gravity Ejection From Solar System

Interstellar Flight

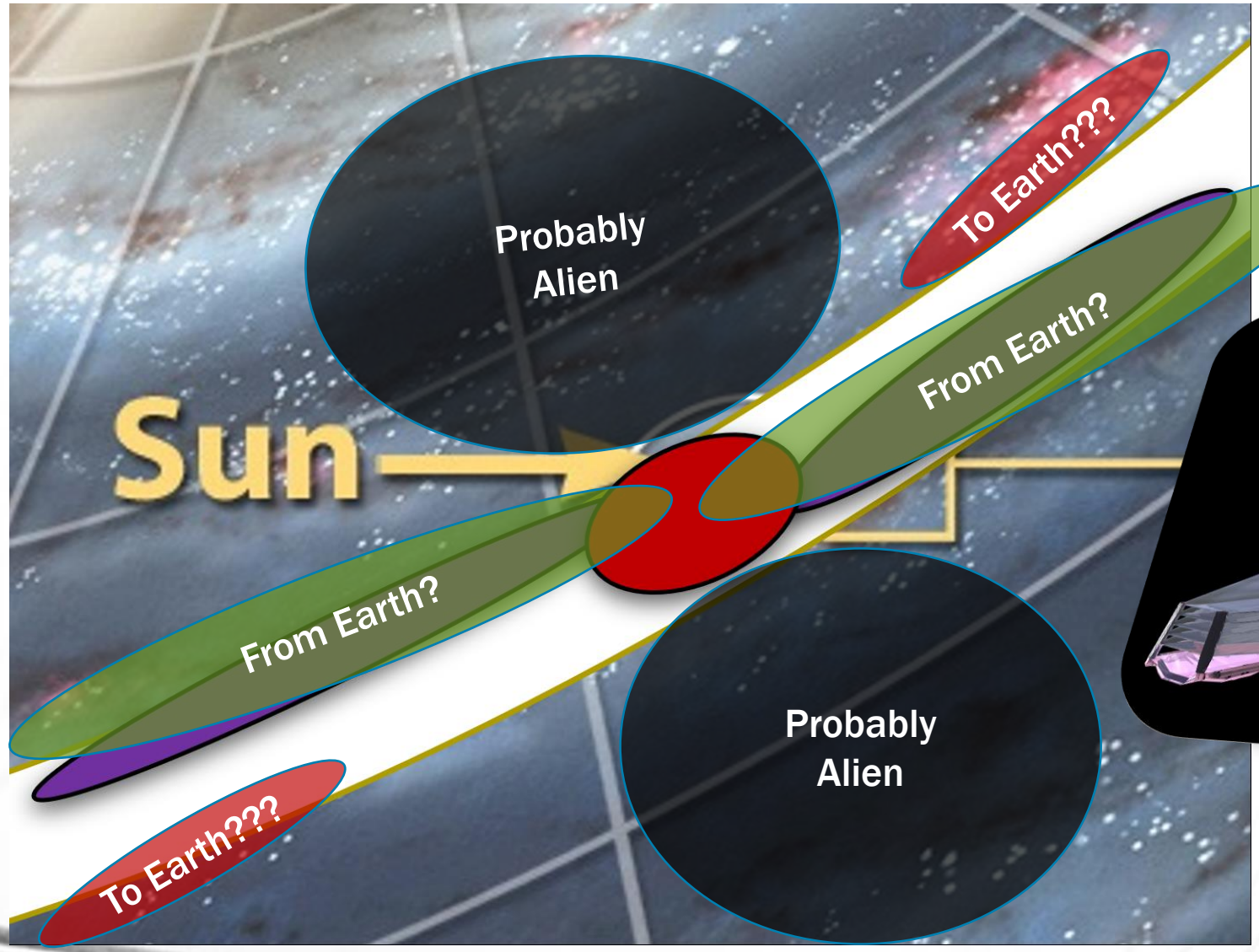


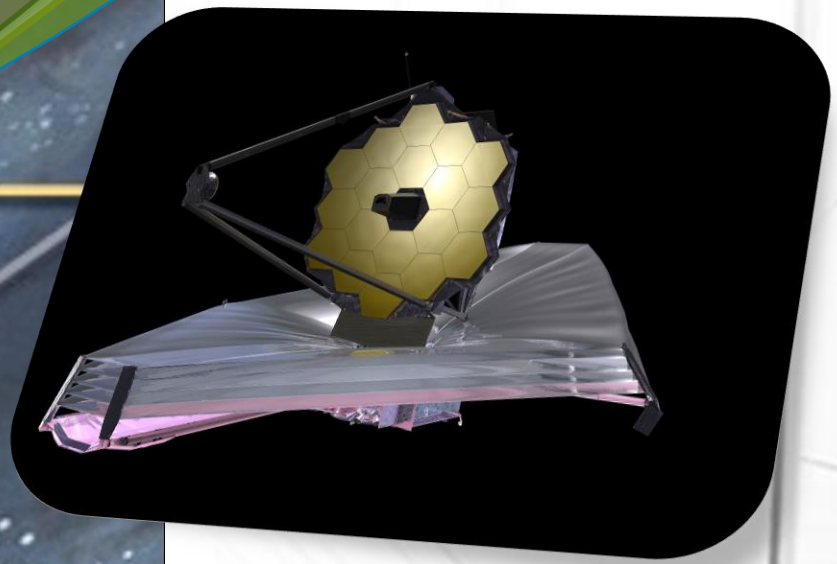
Interstellar Panspermia



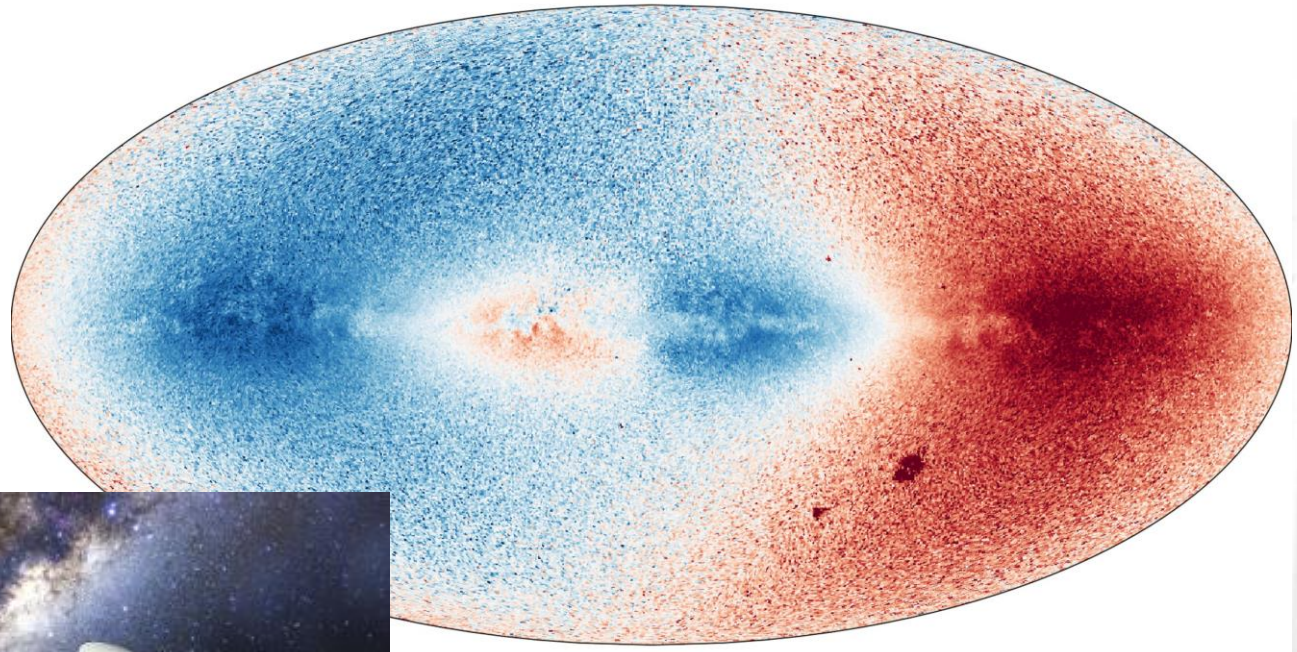
m/sec	km/hr	LY/eon
100	360	333
200	720	667
300	1080	1000
400	1440	1333
500	1800	1667
600	2160	2000
700	2520	2333

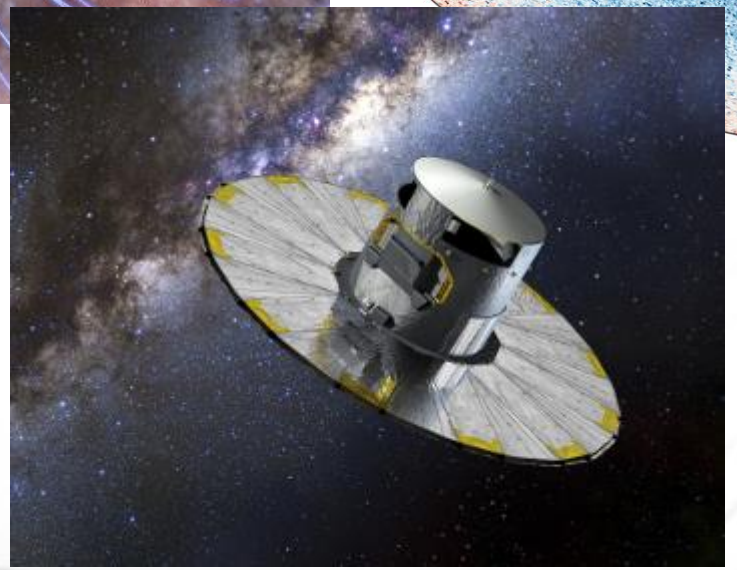
So if We see Life Signs in an Exoplanet Atmosphere...





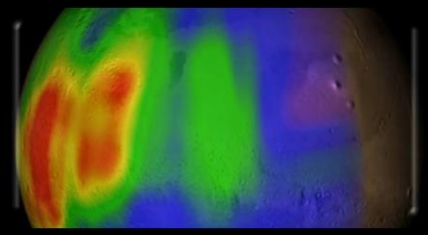
Not actually this simple, but…





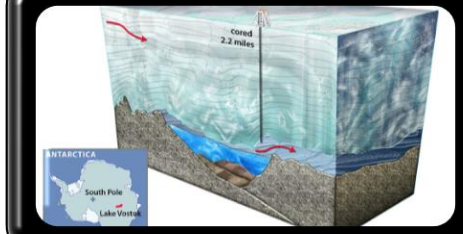
Credit: ESA.

Implications for Mars Settlement



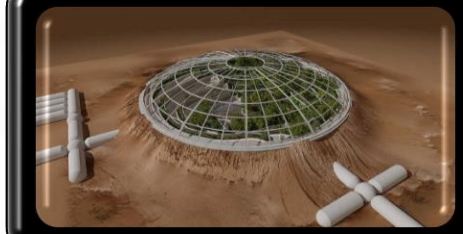
High probability of Earth Microbes on Mars

- Fossil Life at Surface
- Extant anaerobic biomes in niches



Should be Studied in Isolation

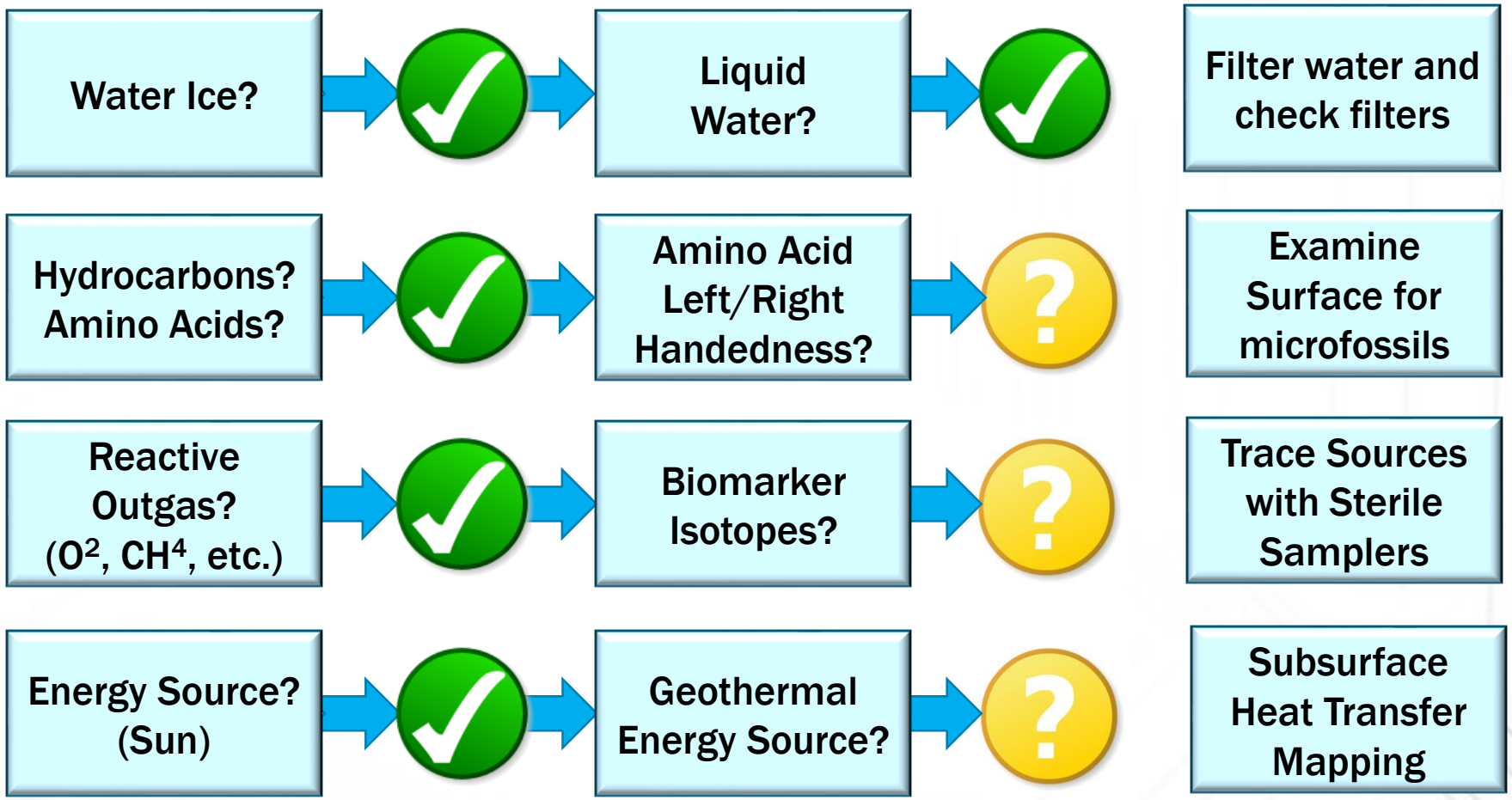
- Lake Vostok
- Use Sterilized Samplers. Treat like Plutonium.



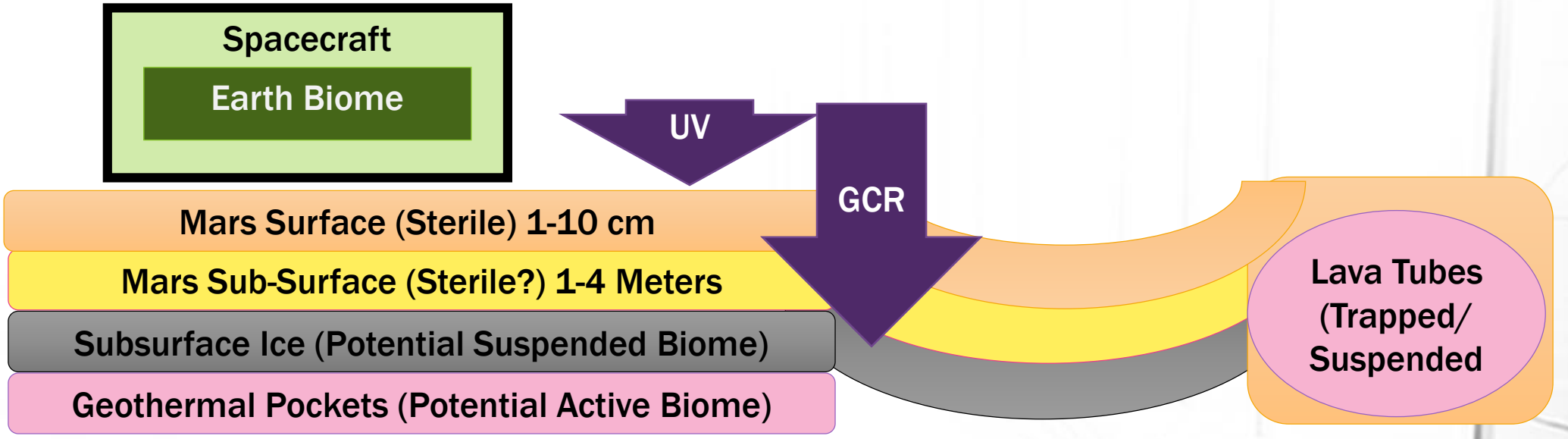
Surface 10 cm Still Open to Human Settlement

- Preference for Ice Covered Crater Domes
- Scrape surface for materials. Sterile instruments for deeper work.

Bio-Markers on Mars



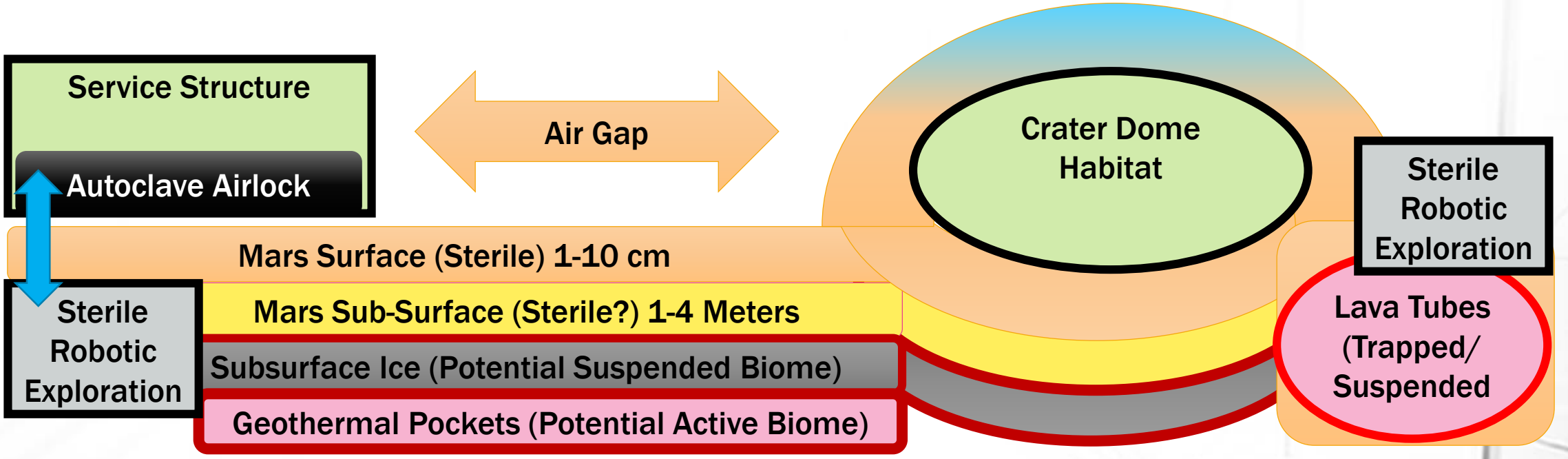
Basic Principles (Current)



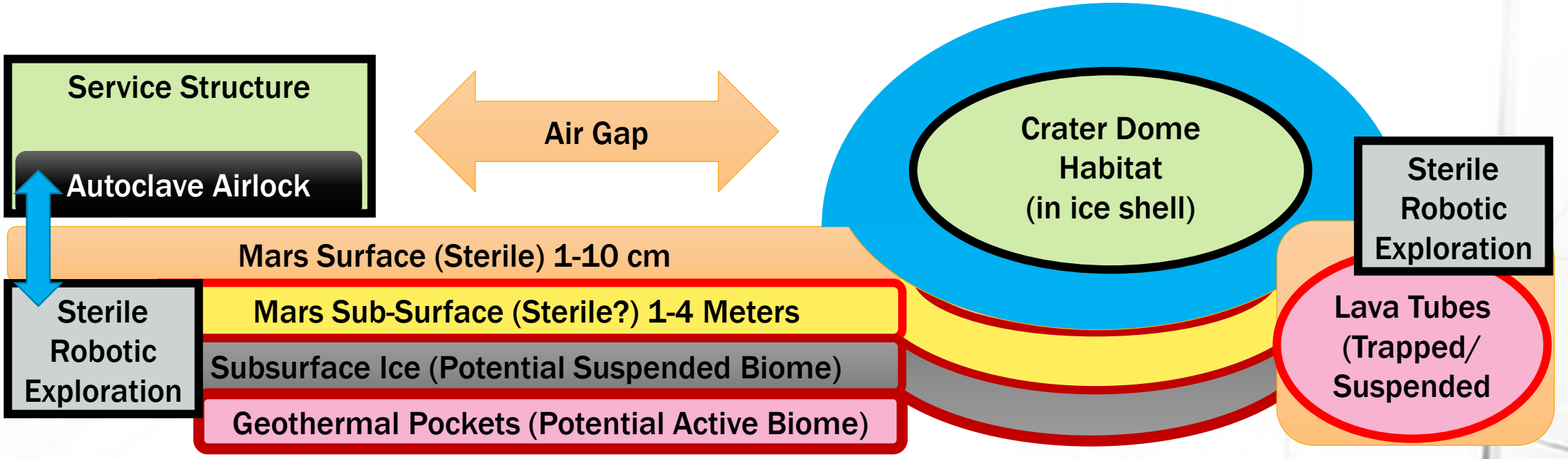
Sterile Depth Concerns

Rock Depth	Maximum Bacteria Survival Time, ISS Radiation Levels
3 cm	15 million years
70 cm	40 million years
1 meter	70 million years
1.67 meter	200 million years
2 meters	300 million years
2.33 meters	400 million years
2.67 meters	500 million years

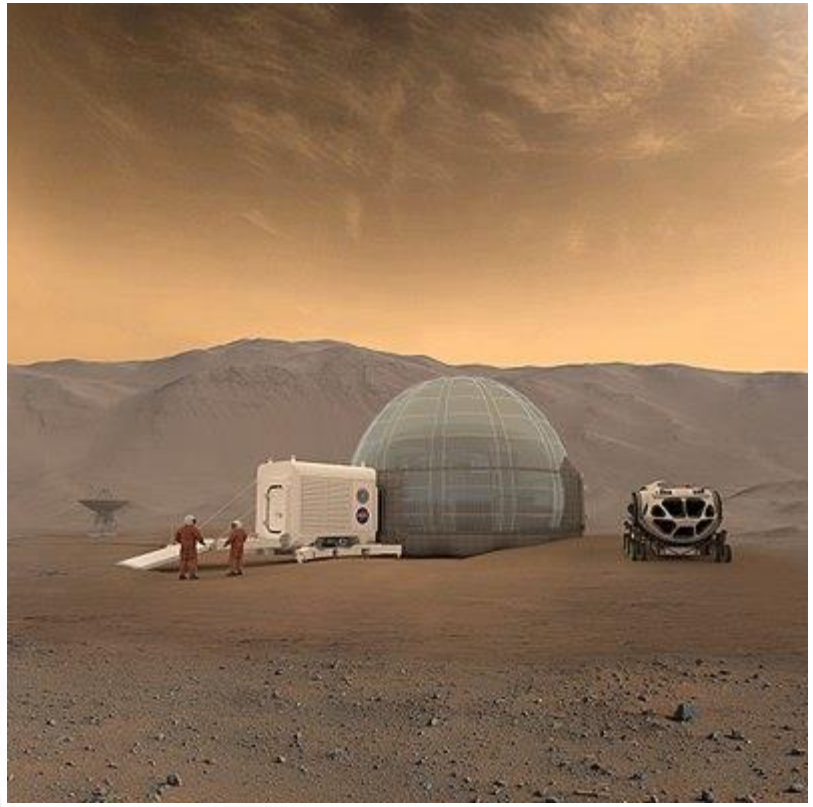
Basic Capacity and Limits (If Low Risk)

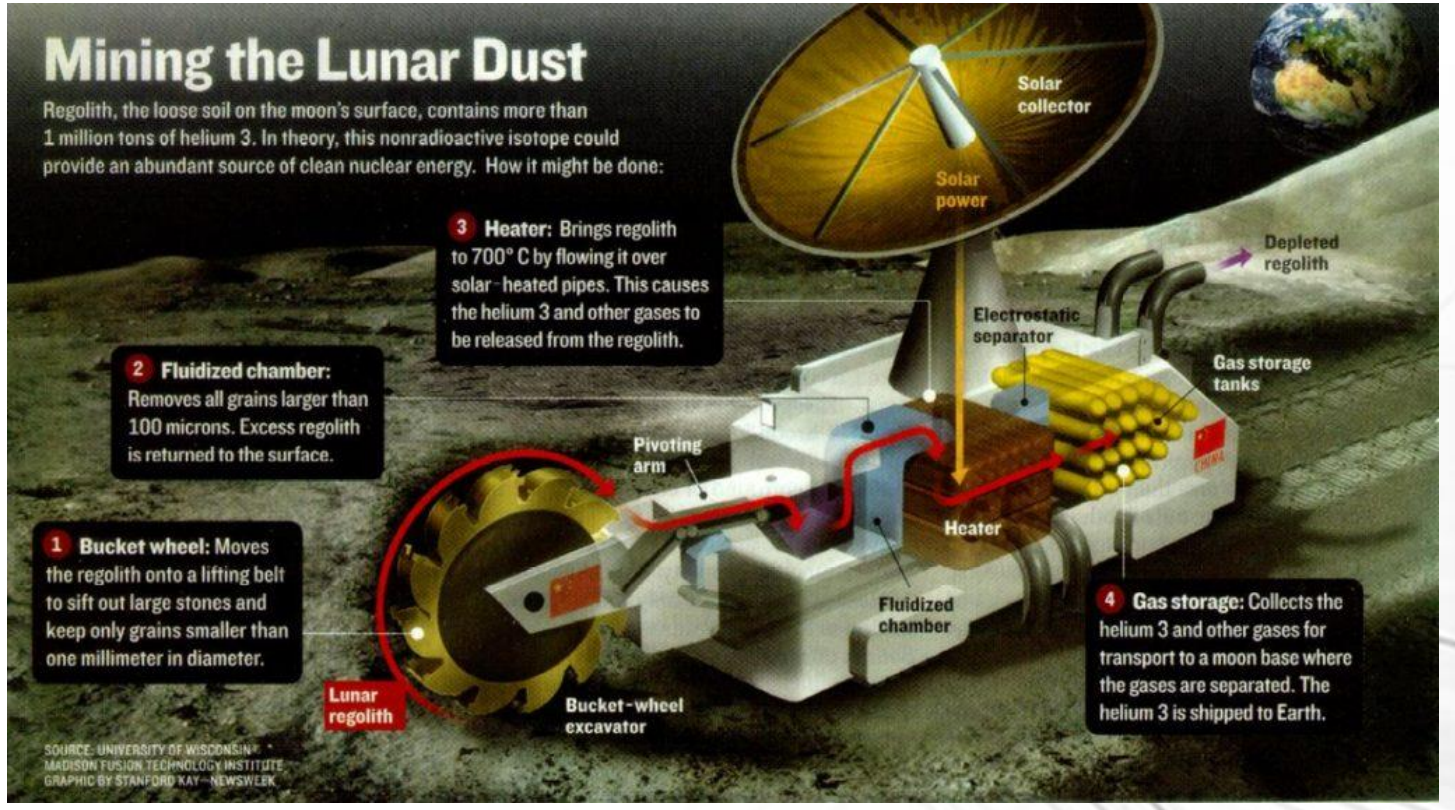


Basic Capacity and Limits (If High Risk)

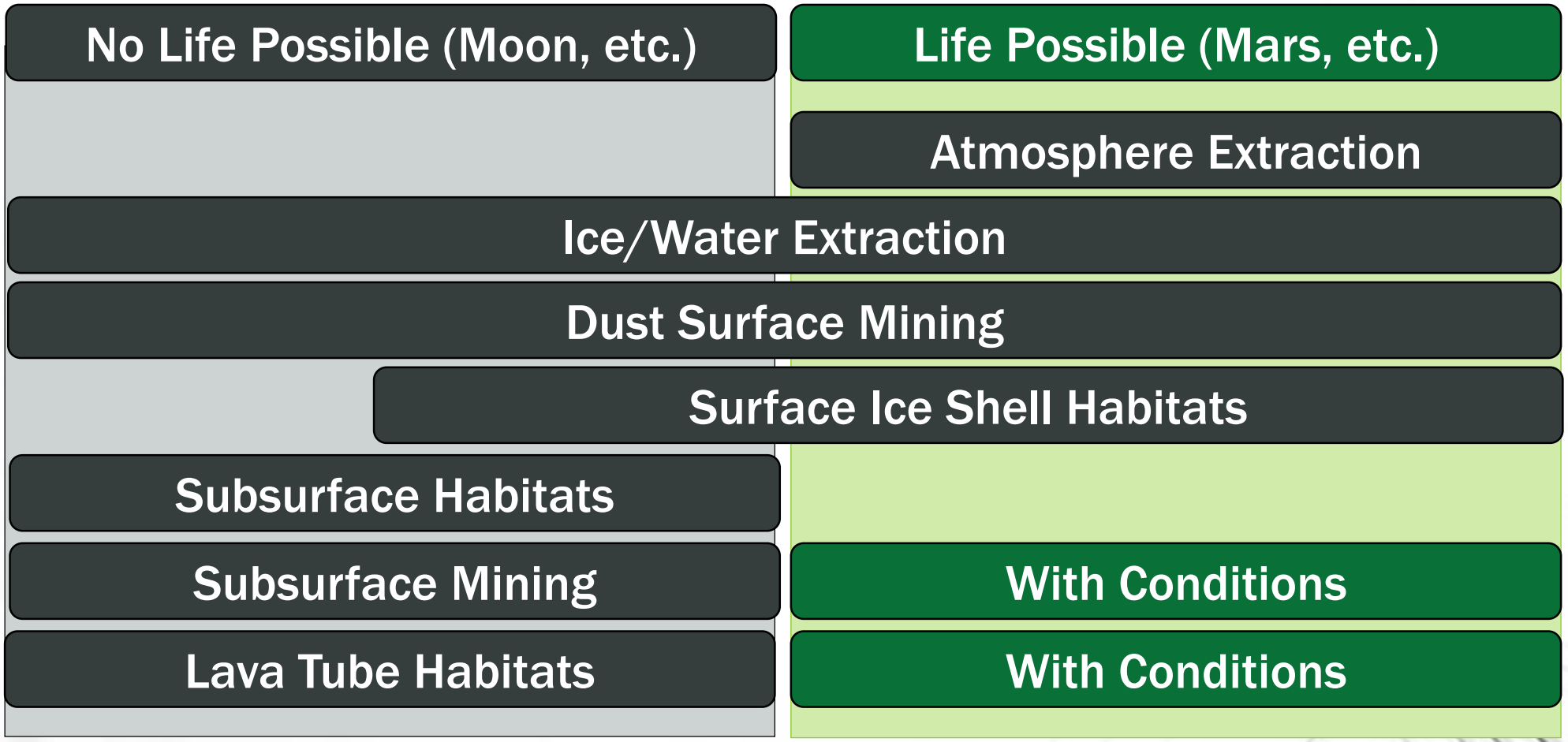


Focus of Near Term Settlement (Dual Use)





Settlement Methods



Mining Limitations if Life Found

Gas Mining (Atmospheric)

- OK, but sterilization in industrial process recommended

Liquid/Ice Mining

- Must be filtered to molecular level

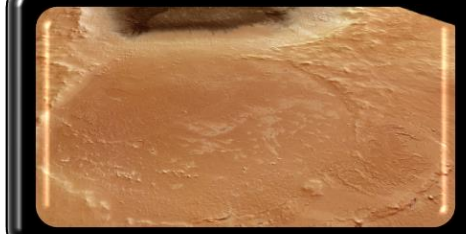
Dust Mining

- Able to separate easily, extract easily, and sterile from UV

Rock Mining

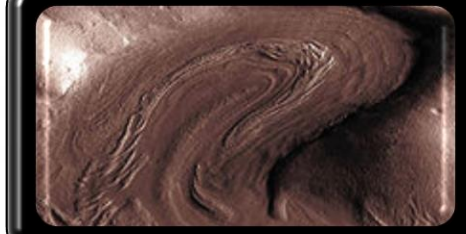
- Igneous and Metamorphic with conditions. Sedimentary with biology limited.
- Metal deposits in sedimentary OK if sterile robotic mining only

Human Settlements



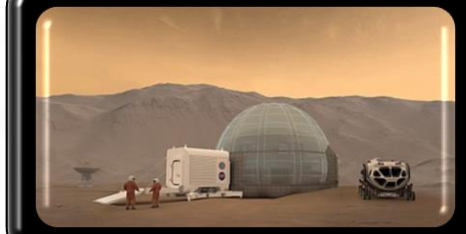
Site Location – Old Craters

- Older craters will be sterile to greater regolith depths than fresh craters
- The dust filling those craters is a sterile resource for construction



Water Resources – Mid-Latitude Underground Ice

- Drill for mid-latitude buried glaciers with sterile equipment
- Use superheated CO2 as a working fluid – avoid contamination

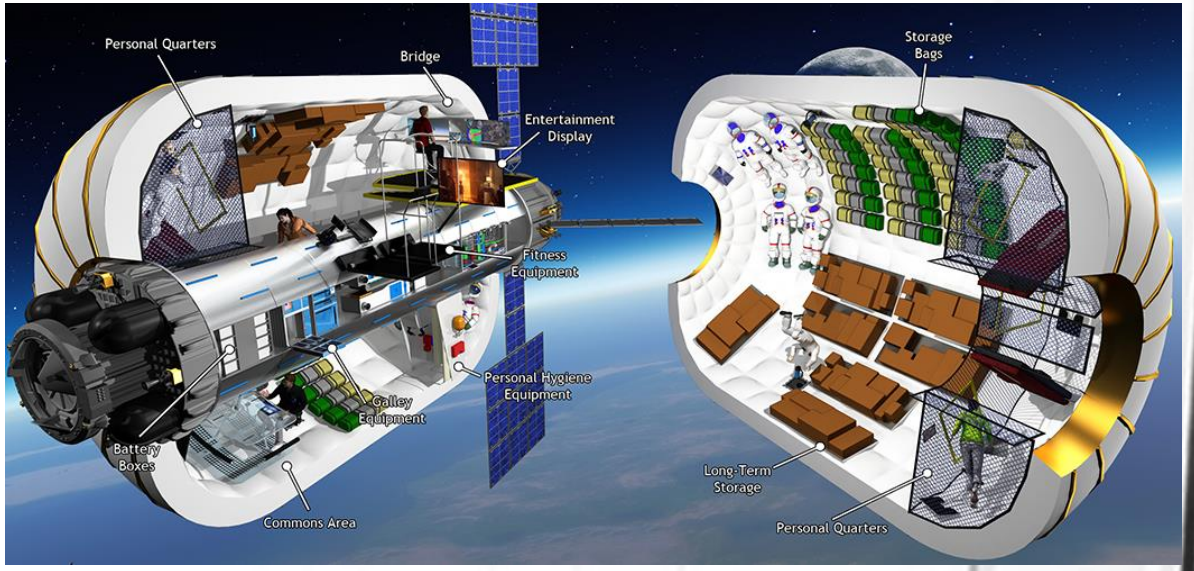


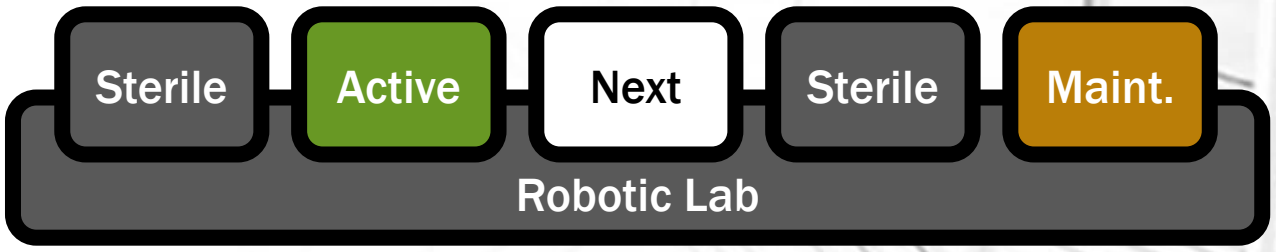
Habitat Construction – Ice Domes/Spheres

- Good for cosmic ray shielding and can be locally sourced eventually
- Simple construction, just add water

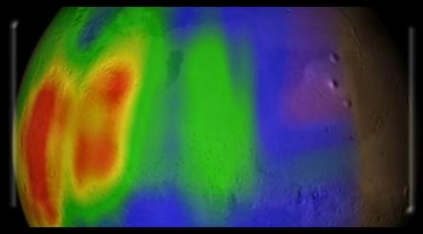
Working with Life

- Genome Mapping and Comparison
  - “Bacteri-Australia” – look for division in genomes due to isolation
  - Could GMO implications expand the ability of Earth life to inhabit more extreme environments?
- Centrifugal Labs
  - Revival Lab (Mars Jurassic Park, but in a Micro-Space Settlement)
- “Revolver Lab”
  - Move sample from lab to lab so each lab can be sterilized, maintained, sterilized again, and then reused.



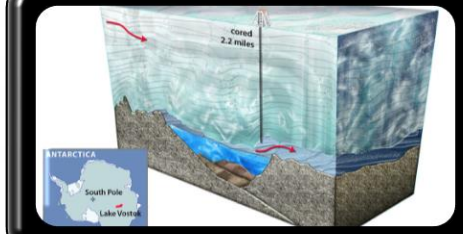


Preserving Other Science



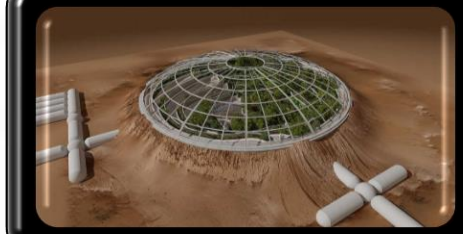
Gas Mining (Atmospheric)

- Extensive study during input (chromatograph, temperature, etc.)
- Occasional samples, extensive filtration



Liquid/Ice Mining

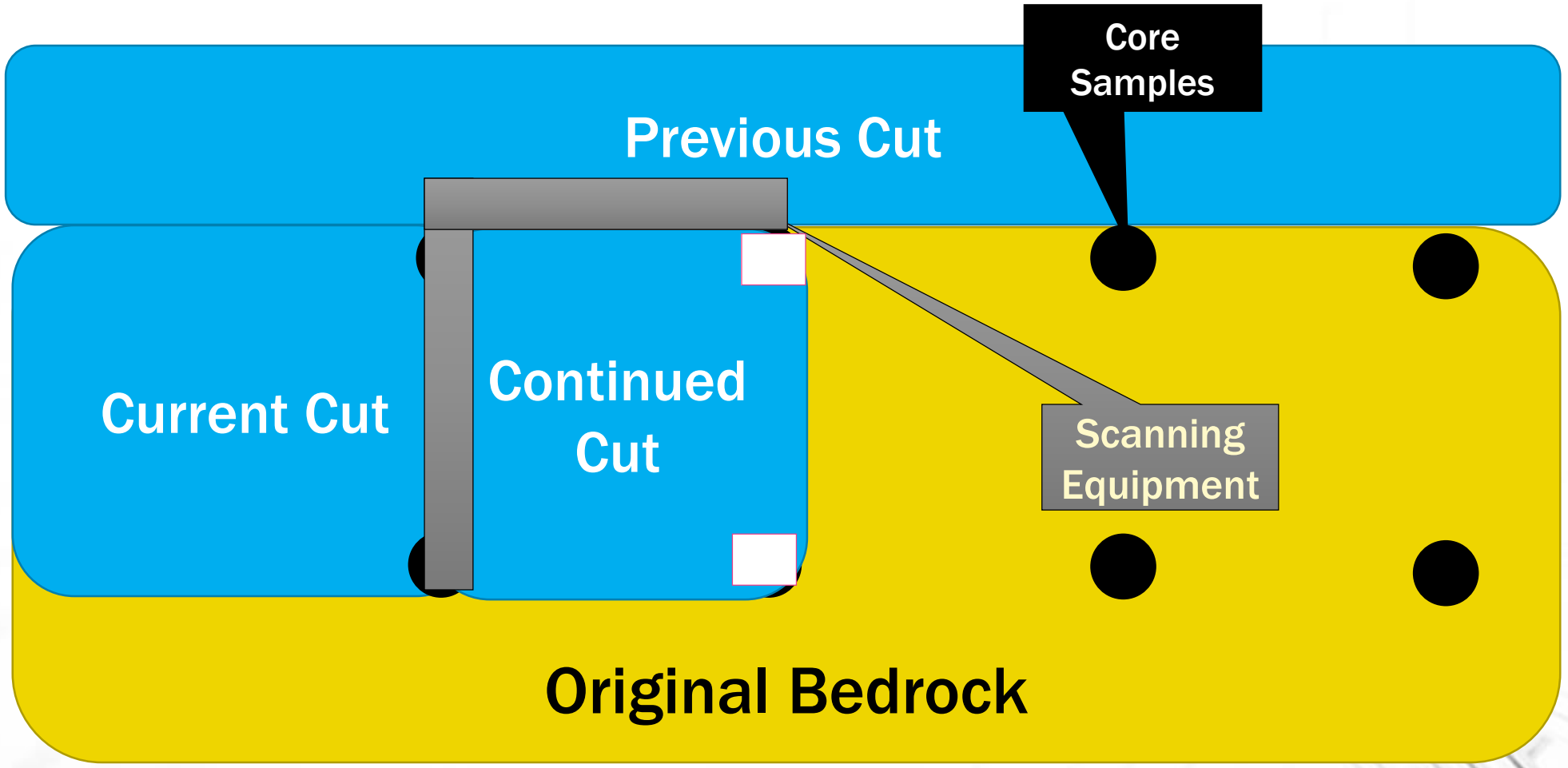
- Fully filtered (SWFI) before use
- Filtered/Precipitate/etc. kept for examination, possible resource



Mineral/Metals

- Scan and core sample sections
- Split “Libraries” of samples for future and remote examination

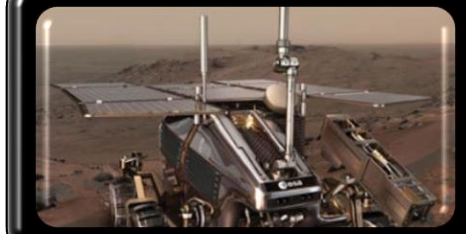
Mining (Bits and Atoms)



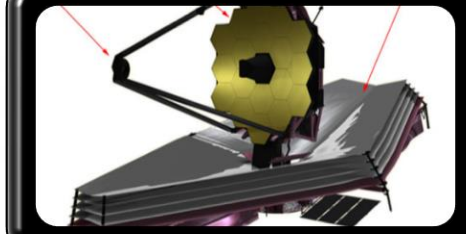
Open Questions for Mars Science

Question	Life Not Found	Life Found
How deep in the surface can life survive?	• Very difficult for lithopanspermia from Earth	• Can gauge probability of finding Earth life farther out due to survival depth. • Can decide how deep we can mine safely
Life found in polar ice? Lakes?	• Less likely on Europa, Titan, Enceladus, Ganymede, or Callisto	• More likely to be found on those moons, and possibly others. • Comparison to Antarctic bacteria in isolated lakes
Active life in Lava Tubes?	• Safe to move in with settlement	• Interesting options for cave life on other planets.
Natural wonders?	• Tourism	• Extraction? VR Tourism? Telepresence?

Timeline



2021: ExoMars Rover (1-2 meters)



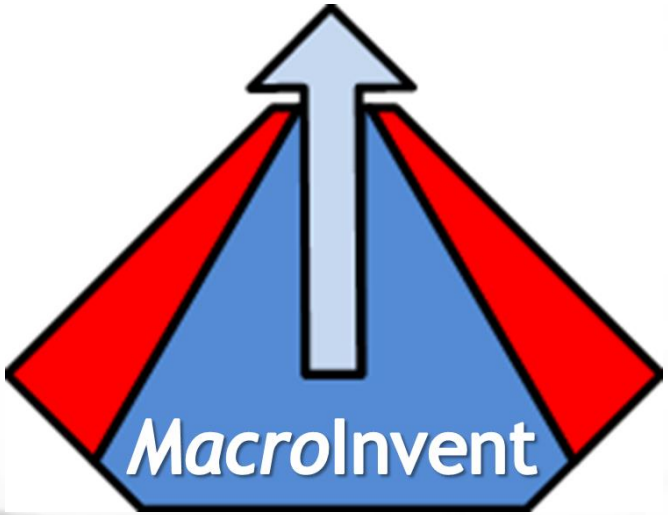
2022: James Webb Space Telescope
Exoplanet atmospheric studies

2030: BFS To Mars, First Flights

Questions?

Kent Nebergall

- Macroinvent.com
  - https://www.facebook.com/MacroInvent
- Kent@MacroInvent.com



Research Links

Interstellar, Earth Source Lithopanspermia

- http://iopscience.iop.org/article/10.1088/0004-637X/690/1/210/meta
- https://academic.oup.com/mnras/article/348/1/46/1415892
- Reverse - thousands of captured interstellar asteroids
- https://www.universal-sci.com/headlines/2018/2/8/the-solar-system-probably-has-thousands-of-captured-interstellar-asteroids