



Water and the Exploration of Space

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Evolving Science Strategies For Mars Exploration



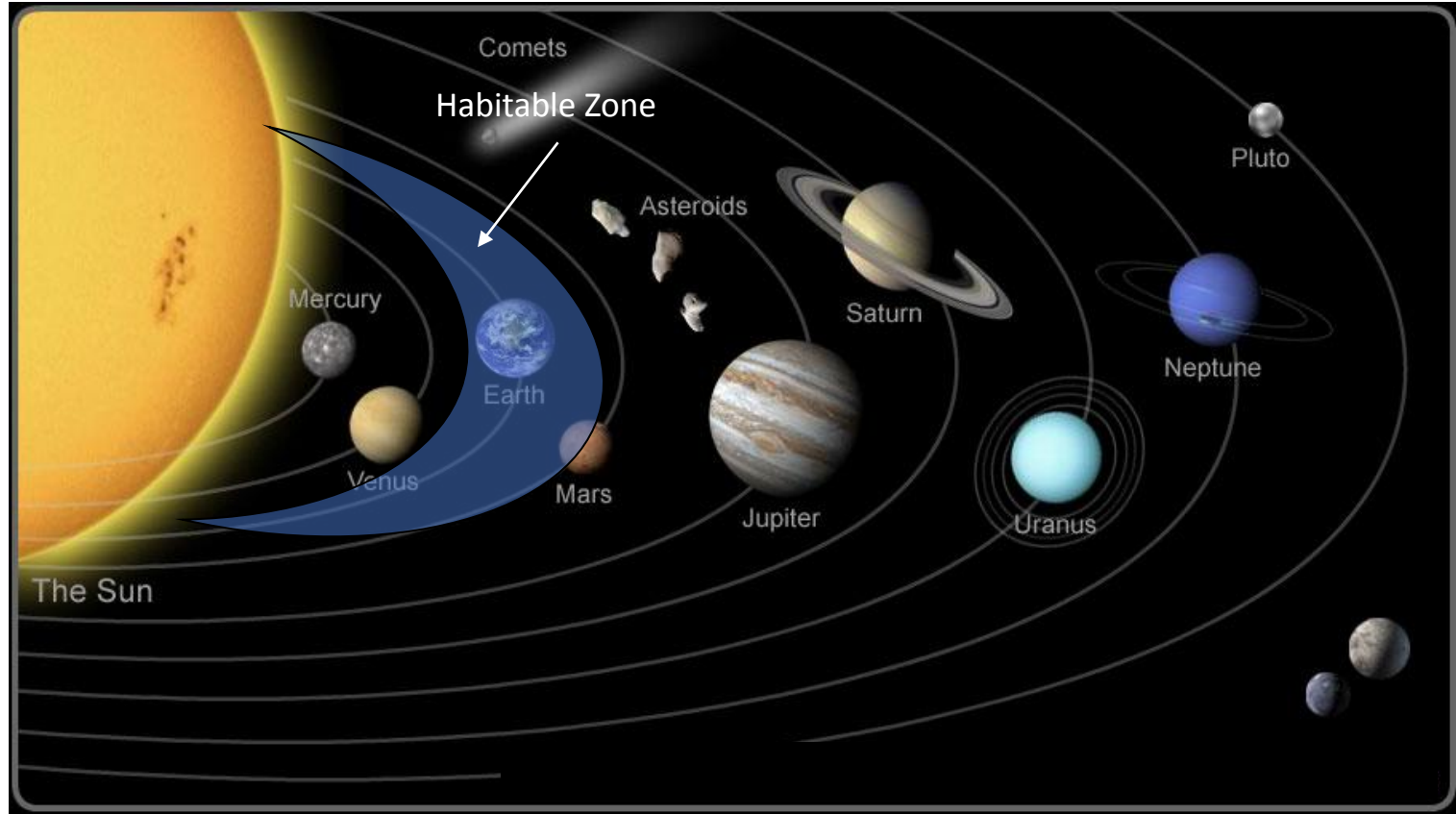
FOLLOW THE WATER

EXPLORE HABITABILITY

SEEK SIGNS OF LIFE

PREPARE FOR HUMAN EXPLORATION

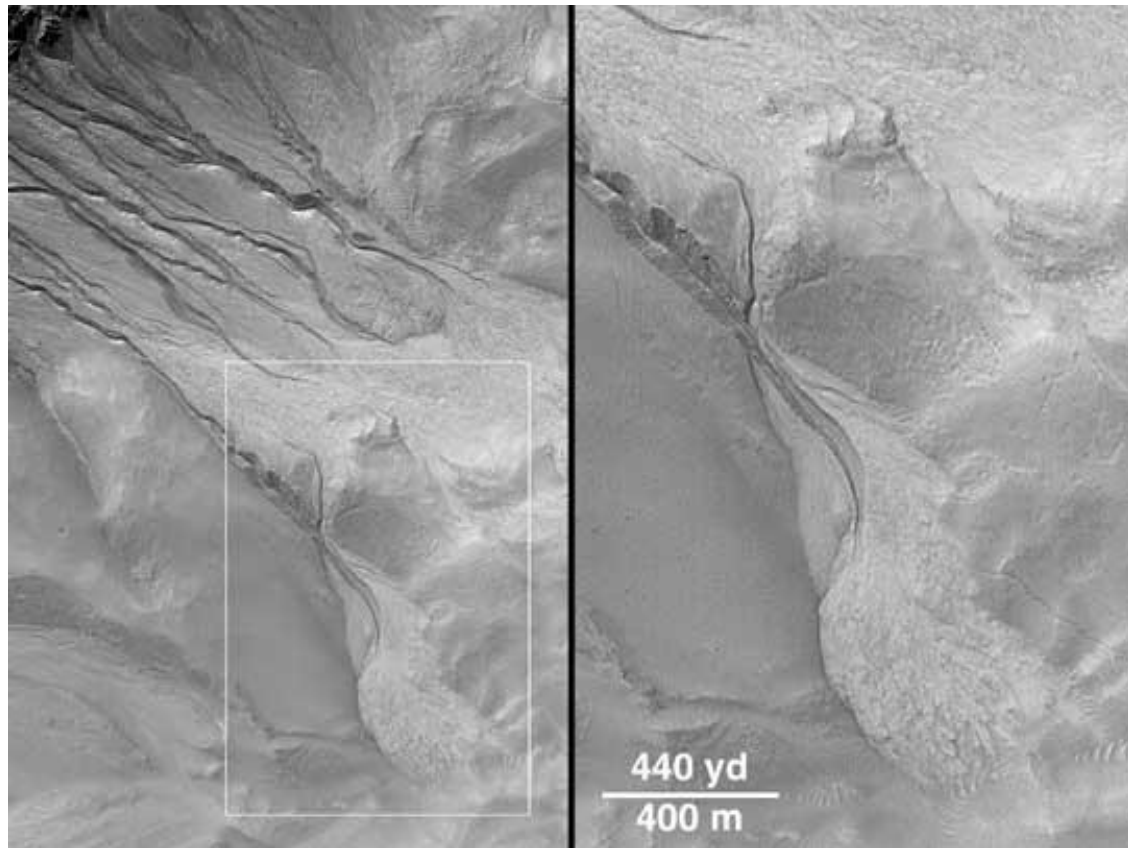
The habitable zone



Mars Phoenix Lander



East Gorgonum crater

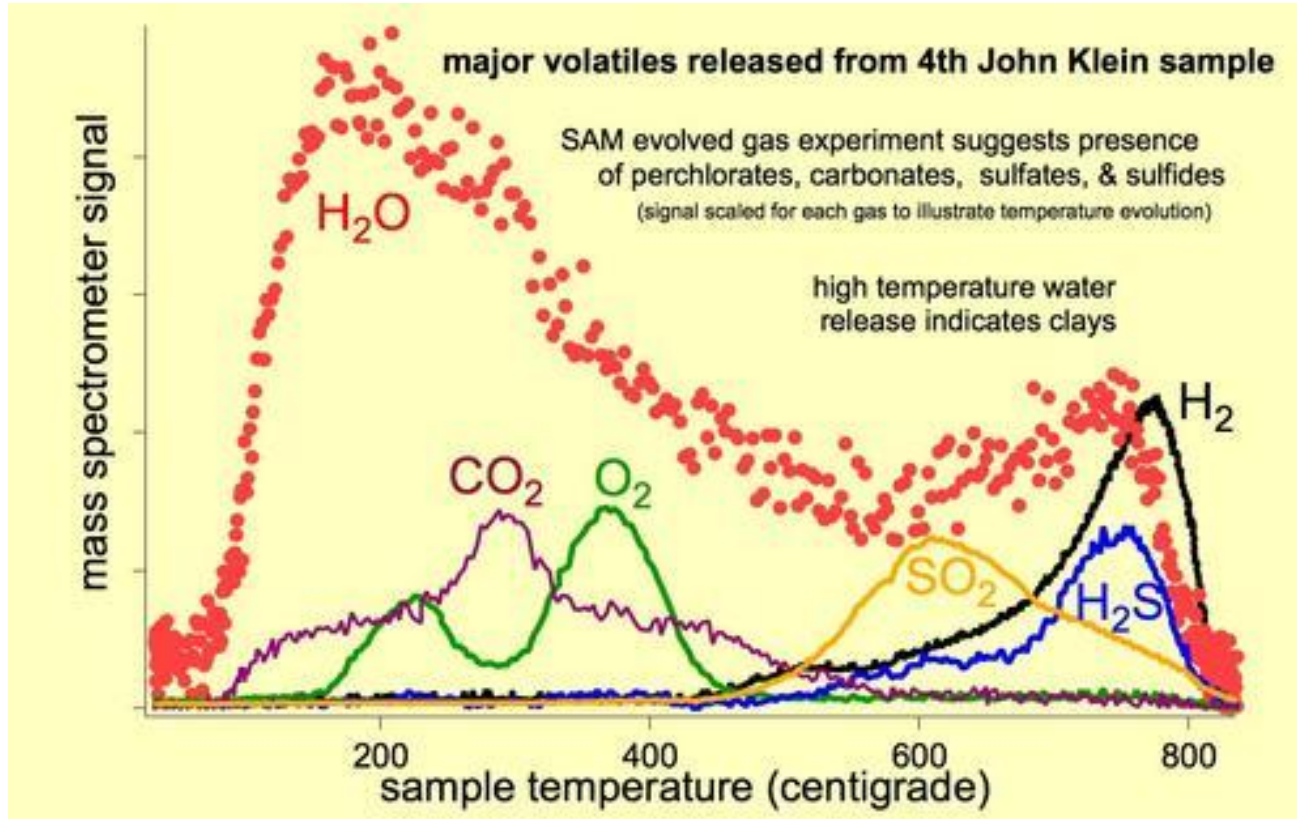


Mars Curiosity Rover

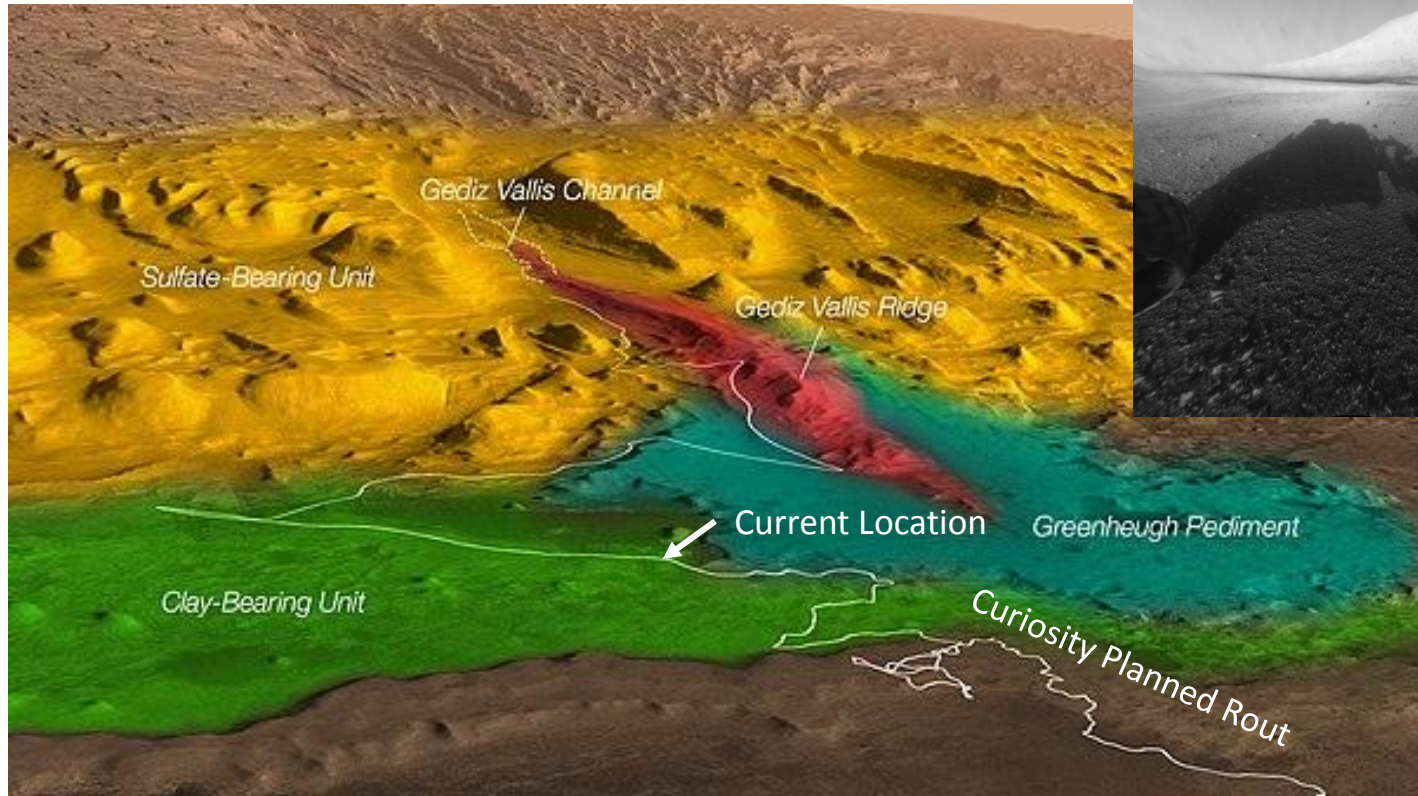


Curiosity on the Road to Hematite Ridge - Sol 1463 MAHI, Sol 1516 ML, Sol 1520 MR - NASA/JPL-Caltech/MSSS/Seán Doran

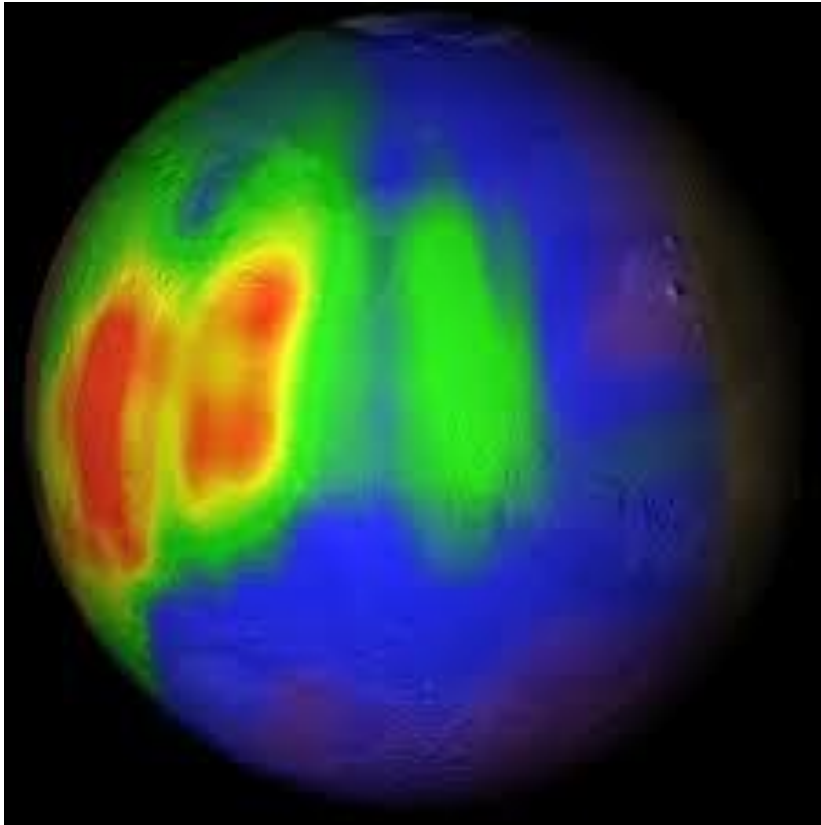
Mars Curiosity Rover



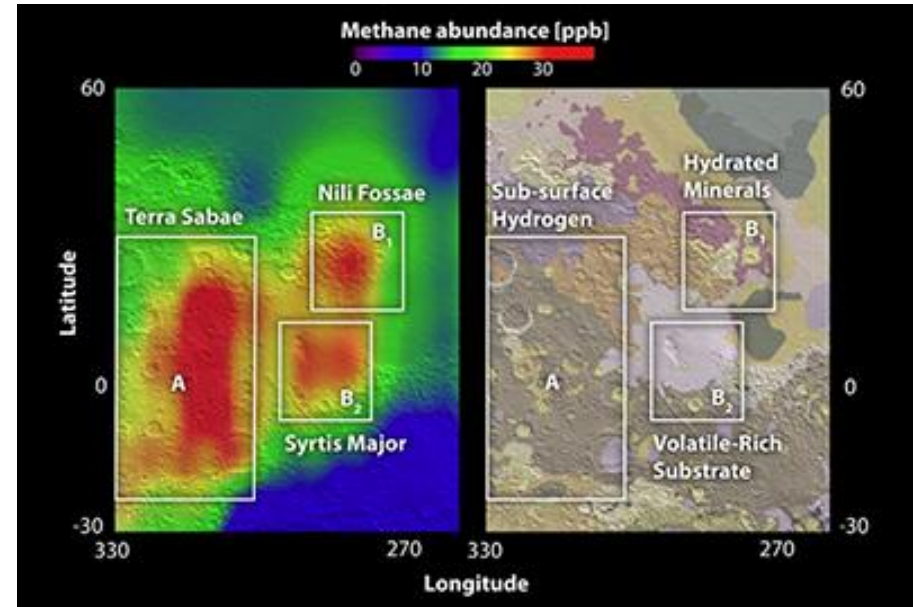
Curiosity Rover Current Location



Methane in the atmosphere of mars



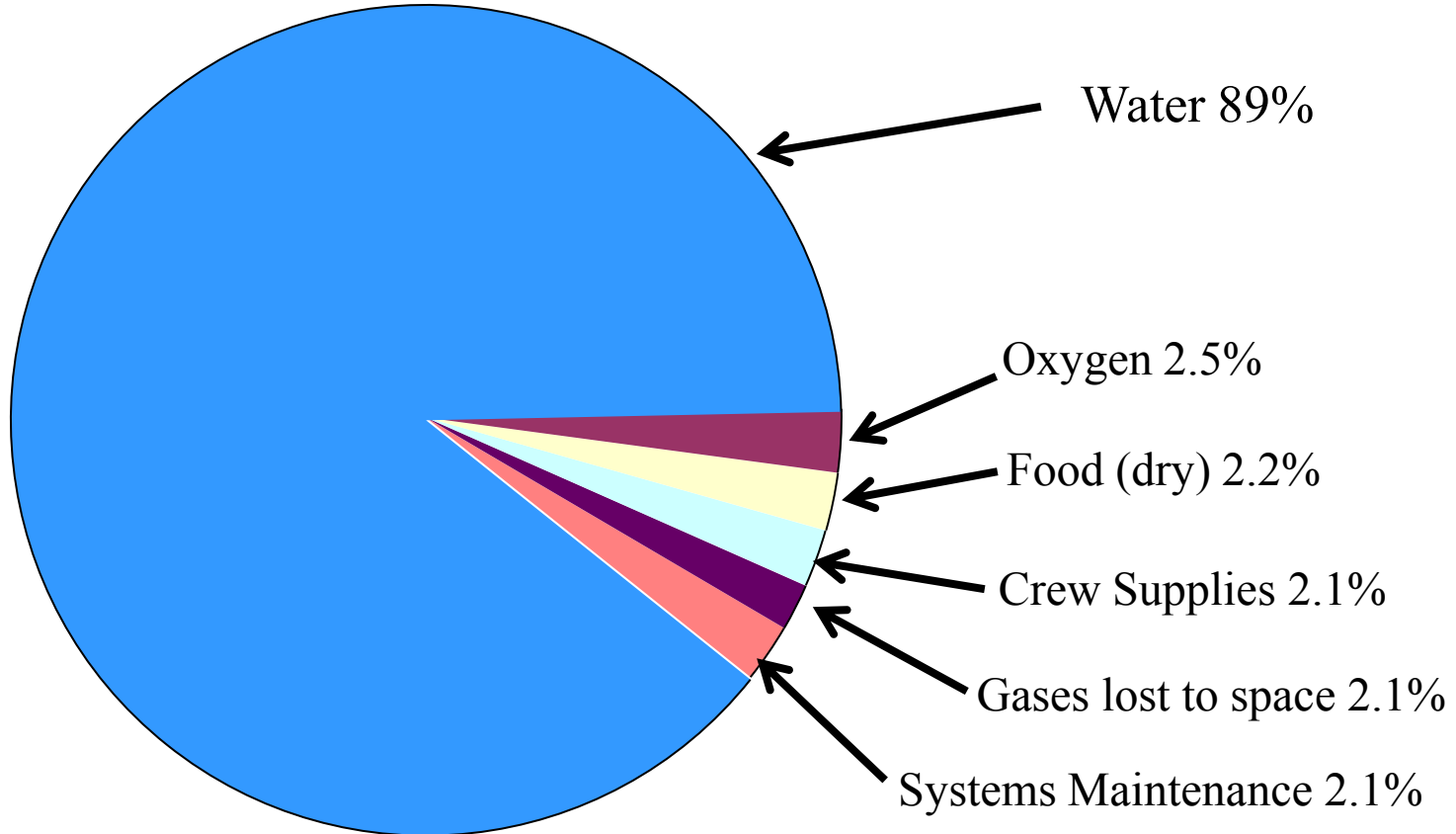
Mars Express Orbiter and ground based telescopes



To answer the question of when and if Mars ever had life we will need to send humans.



Human life support requirements

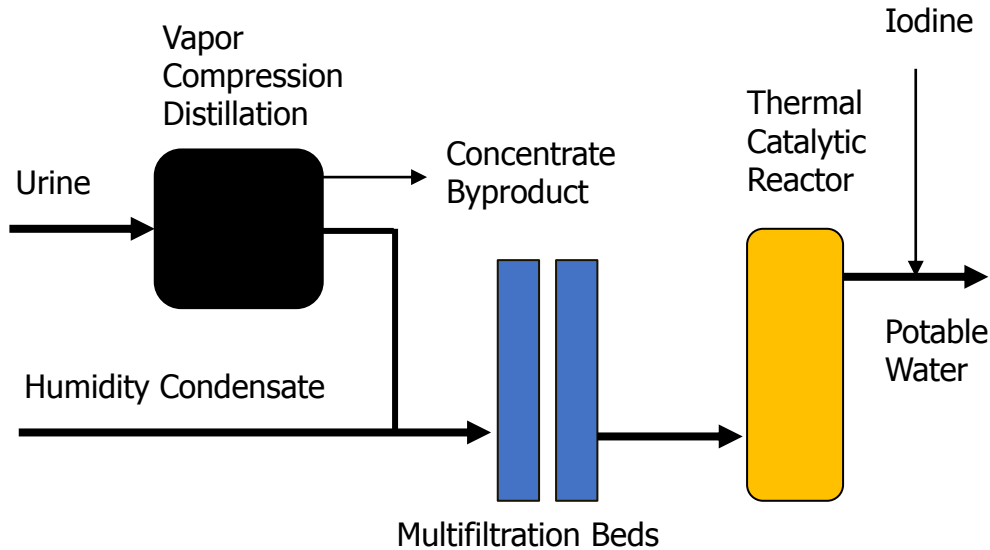


International Space Station (ISS)



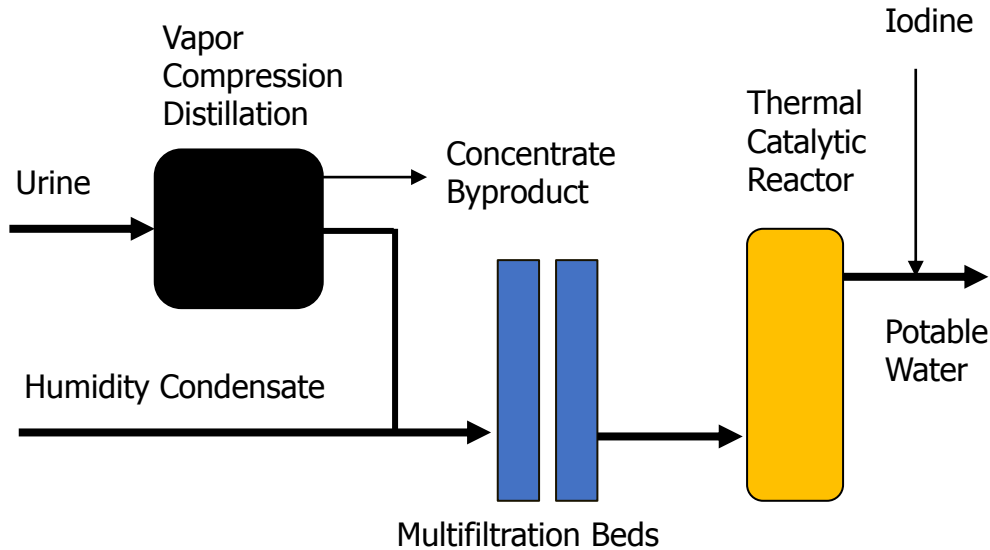
ISS Water processing assembly

Urine and humidity condensate are recycled into drinking water



ISS Water processing assembly

Urine and humidity condensate are recycled into drinking water



The Future: Planetary Water Recycling

- Future missions will establish 4 person outposts on the Moon and Mars that will evolve into the first human colonies and then future Mars communities.
- Major difference between International Space Station and planetary missions is gravity – this means terrestrial technology may be applicable
- NASA is currently conducting a planetary water recycling systems trade study.
- This study will evaluate commercial and space flight system and complete a down selection to 4 potential flight systems.
- All 4 systems will be constructed/procured and tested in a side by side test.
- Wastewater model is urine + condensate + hygiene.

Trade Study - Uses Quality Functional Deployment Methodology.

Inputs based on:

Equivalent System Mass

Mass

Power

Volume

Consumables

Technology Readiness Level

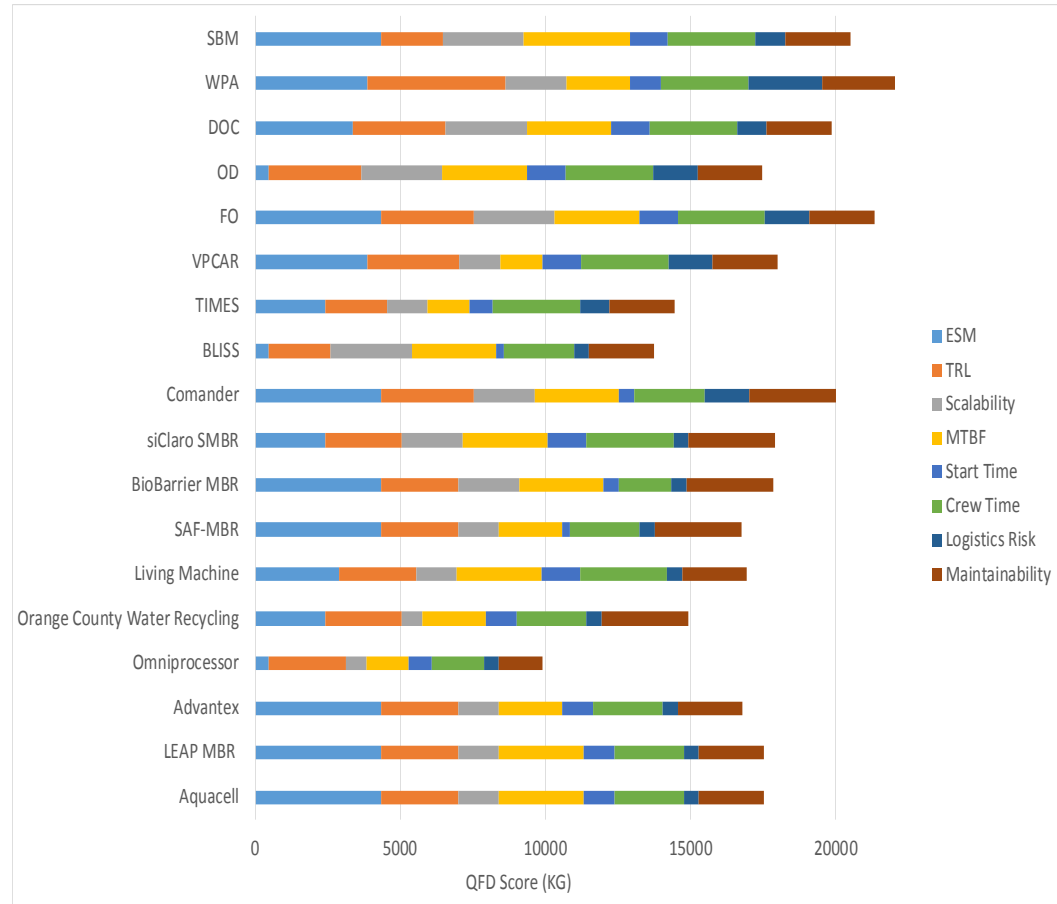
Scalability

Mean Time Between Failure

Crew Time Requirements

Logistics Risk

Maintainability



If you have a technology for inclusion to trade study send description and data to michael.flynn@nasa.gov

Technology Transfer: Gray Water Recycling at NASA Office Building

NASA's Sustainability Base building, Moffett Field, CA

- 250 person office building, system operating since 2014
- Recycles gray water to potable standards for toilet flushing.
- Uses forward osmosis membrane system



U.S Army Forward Operating Base Gray Water Recycling System



- Designed to support 150 soldier forward operating base.
- Delivered on December 10th 2015 to the U.S Army Tank Automotive Research Development Engineering Center (TARDEC), Selfridge ANGB.
- Operational test in July 2016 at Base Camp Integration Laboratory (BCIL), FT Devens, MA

Environmentally Sustainable Desalination (ESD)

ESD uses low water recovery ratio desalination to mitigate environmental impact by decoupling internal and external water recovery ratios.



Land based ESD system under test



Deployed ESD system under test

Addresses issues of:

- Generation of concentrated salt brine byproduct.
- Kill rate of entrained organisms.
- Generation of solid waste byproduct.

Black Water Recycling – Municipal Sewage

- Completed test at Codiga Resource Recovery Center using municipal sewage as feed.
- Operated for 3 months.
- Product water was appropriate for toilet flush water reuse according to all applicable standards.
- Designed zero discharge option.



Black Water Recycling - Winery Wastewater

Black-water recycling systems at winery in Napa & Sonoma

- Distillation
- Forward Osmosis



Conclusion

- **Water plays a key role in NASA's roadmap for the exploration of space.**
- **The search for life in the cosmos is a search for water.**
- **We have identified planets throughout our Galaxy and Solar System that could have water.**
- **To determine if these planets support life we will likely have to send people to them.**
- **The largest mass (cost) associated with human exploration of space is water.**
- **The International Space Station water recycling system has been operational since 2009.**
- **The next step is the development of Planetary Base water recycling systems.**
- **Currently conducting a planetary base water recycling trade study. Contact: michael.flynn@nasa.gov if you want your technology included.**
- **Technology transfer to terrestrial applications is also underway with the collaboration of commercial partners.**