# Beneficial Microbes in Spaceflight or: How I Learned to Stop Worrying and Love the Bugs


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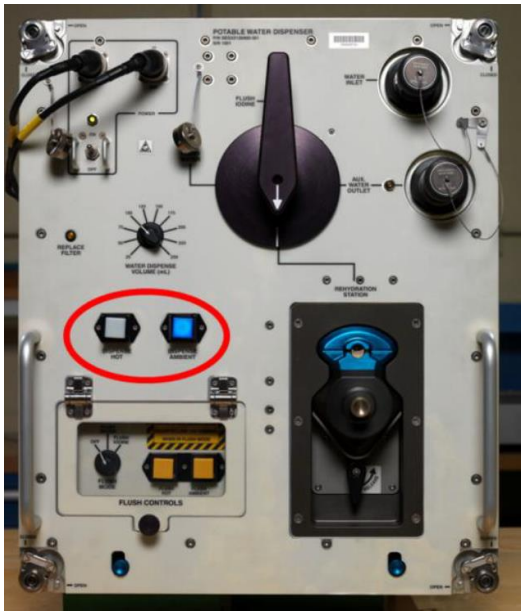
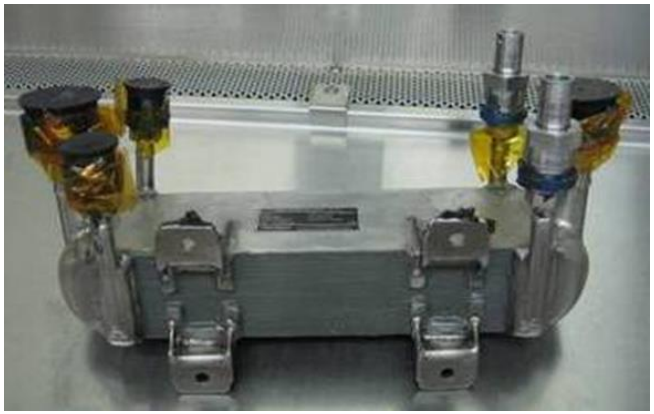
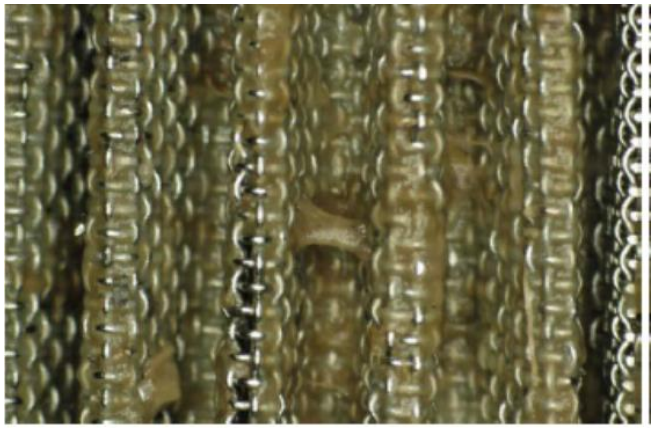
# Background

- Microorganisms have been hitchhiking their way into space since the beginning of manned spaceflight
  - Apollo
  - Space Shuttle
  - ISS
- Typically considered a nuisance

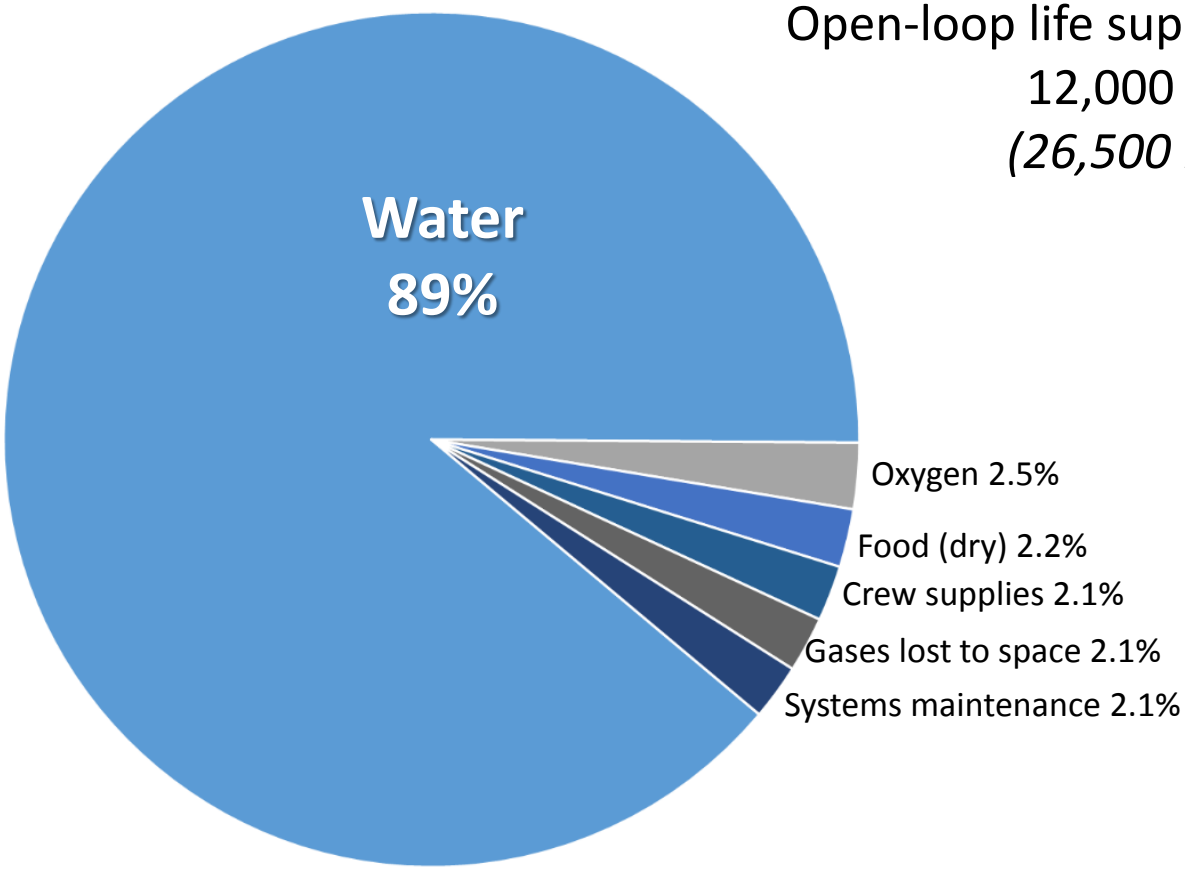




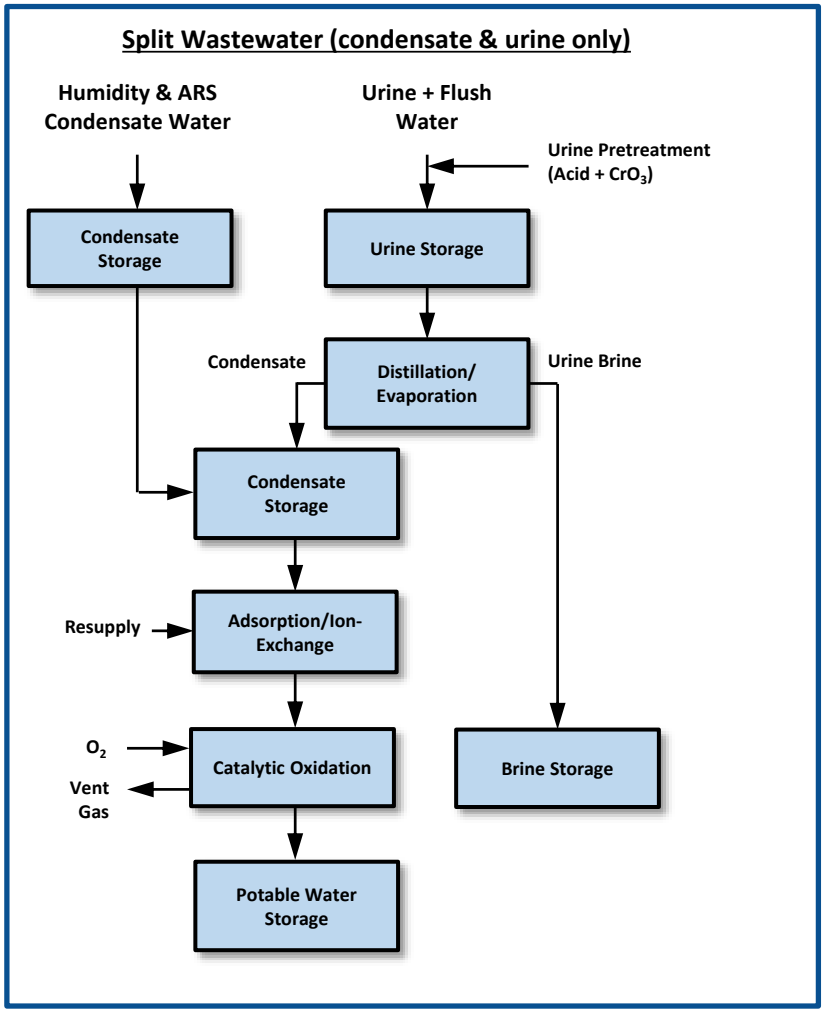
# Life Support Requirements

Open-loop life support system resupply mass
12,000 kg/person-year
*(26,500 lbs/person-year)*

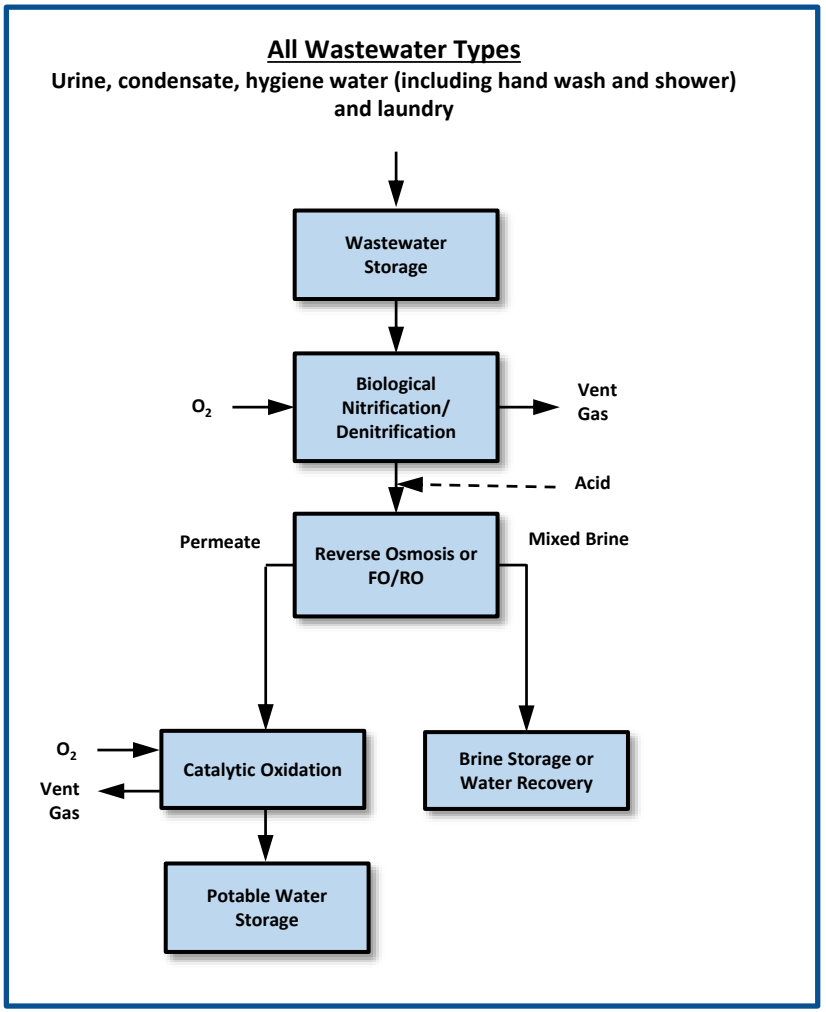


# Water Recovery Architectures

## Physiochemical Water Processor (ISS)




## Biological Water Processor

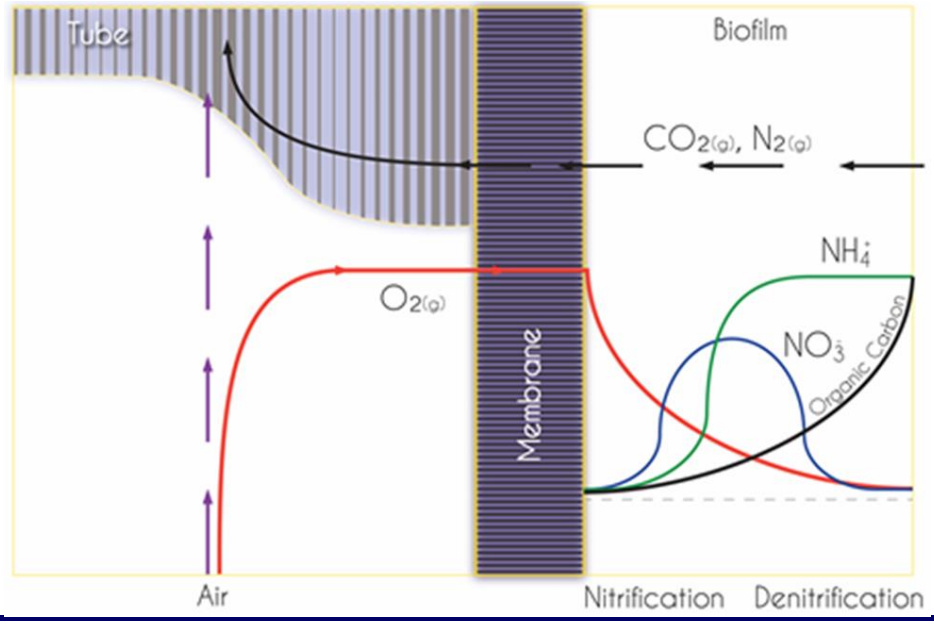



ARS = Atmosphere Revitalization System ($CO_2$ Reduction); FO/RO = Forward Osmosis/Reverse Osmosis

# Biological Water Processor (BWP)

- Comprised of four (4) membrane aerated bioreactors (MABR)
- Tube-in-tube design
  - Oxygen module: contained membranes where the biological activities take place
  - Water shell: Contained the fluid and provided structural support to oxygen module

# SND Process

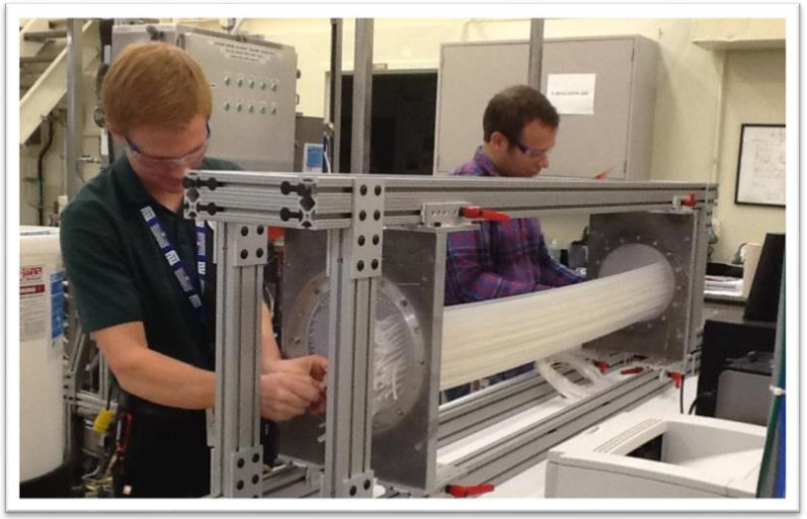

Tube
Biofilm
$CO_{2(g)}$, $N_{2(g)}$
$NH_4^+$
$O_{2(g)}$
$NO_3^-$
Organic Carbon
Membrane
Air
Nitrification
Denitrification

# Test Summary

- BWP operated for 286 days in a four reactor configuration
  - 84% TOC removal
  - 56% Ammonium conversion
- Took 71 days to go from inoculation to full operations (i.e. process all wastewater components
  - Could that duration reduced?

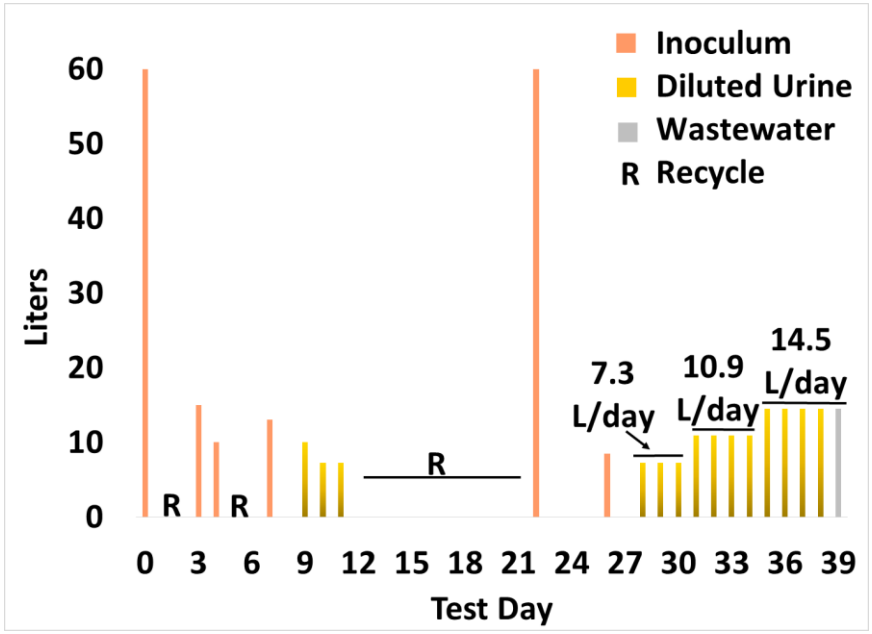
# Rapid Start Evaluation

- Goal: to reduce the time from inoculation to steady-state operations
- Two components to testing:
  - Membrane modification evaluation
    - Chemically etched tubing
    - Conditioned tubing
  - Inoculation protocol validation
    - Diluted vs non-diluted inoculum

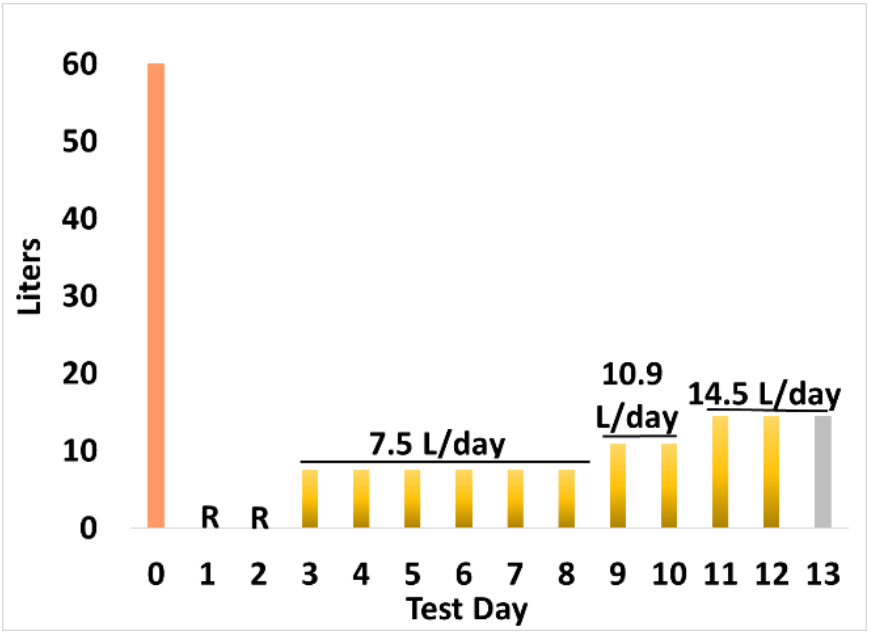


| Step | Volume fraction (% added of daily feed volume, 14.5L) | Influent composition | Volume | Feed Rate |
|---|---|---|---|---|
| | 100% | Filtered inoculum | 60 liters total | 0 (in recycle) |
| **First** | 50% | Urine in DI | 7.5 L total (1.14L urine) | 5.0 ml/min |
| **Second** | 75% | Urine in DI | 10.9L total: (1.7L urine) | 7.6 ml/min |
| **Third** | 100% | Urine in DI | 14.5L total: (2.275L urine) | 10.1 ml/min |
| **Fourth** | 100% | Full wastewater combined stream | 14.5L combined wastewater | 10.1 ml/min |

# Etched vs Conditioned Membranes

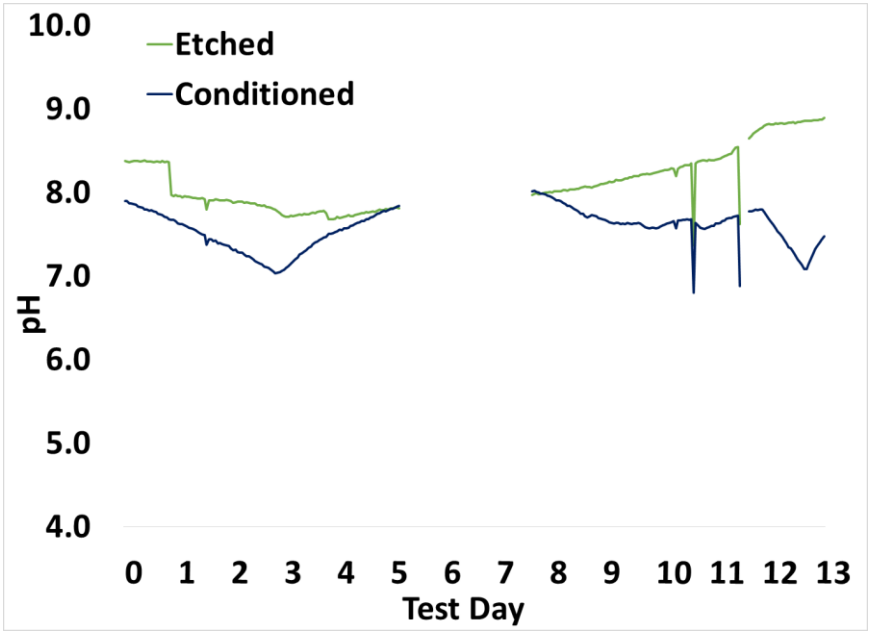



**Etched**

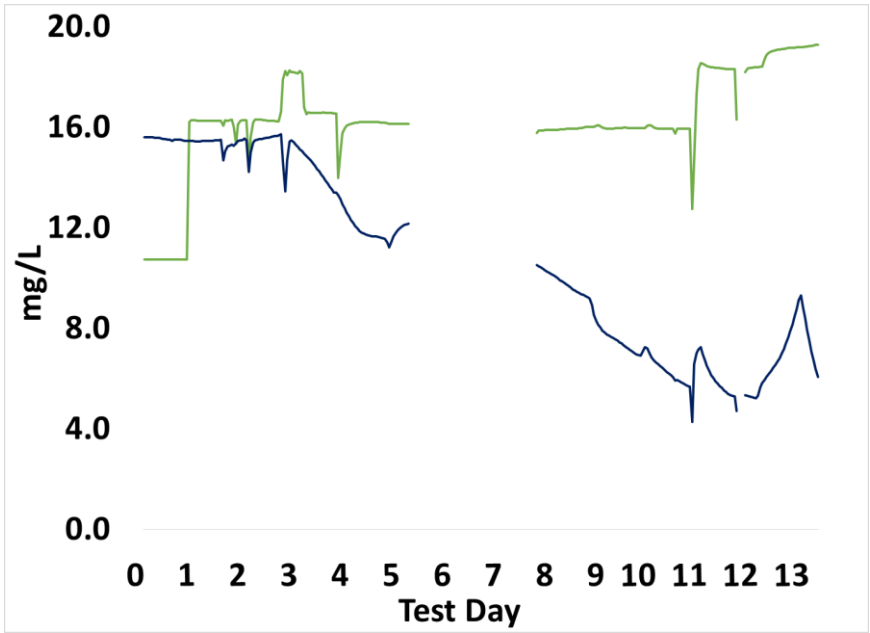



**Conditioned**

# pH and DO: Etched vs. Conditioned




pH




DO

# Summary and Next Steps

- Reduced duration of inoculation from 71 to 13 days
- Further work
  - Evaluate physical characteristics of membranes
  - Repeat rapid inoculation protocol in subsequent bioreactor tests for reproducibility
  - Evaluate surface area loading rates
  - Develop design specifications for an on-orbit MABR

# Physiological Changes in Spaceflight

- Bone loss
- Muscle atrophy
- Vision issues
- Depressed immunity
  - Virus reactivation

# Hosts and Microbes on ISS

- **<u>Microbiome</u> (Hernan Lorenzi, J Craig Venter Institute)** – Evaluating changes in the microbiome and immune status of nine astronauts during spaceflight missions.

# Impact of Long-term Space Travel on an Astronaut's Microbiome

- **Background:** Very limited information is available on potential changes in the astronaut microbiome. Current evidence suggests these changes could have major impact on crew health.
- **Research Questions:** What are the changes in the crew microbiome and could they have health implications?
- **Status:** This study designed to gather information on changes in the crew microbiome before during and after spaceflight missions. Samples include nasal, fecal, multiple skin, and environmental sites. Sample size is 9 astronauts. Samples continue to be batched and sent to the PI's institution for analysis. Sample collection is due to finish in August 2016.
- **Benefit:** While this study is a small overall sample size, these samples should provide a foundation from which (a) definition of any potential crew health problems can begin and (b) follow up studies can be solicited.

# Microbiome Experiment Design

| Pre-Flight | In-Flight** | Post-Flight |
|---|---|---|
| Subject Swabs<br>L-240, L-150, L-90, L-60 | Subject Swabs<br>FD7, FD90, R-14 | Subject Swabs<br>R+1/3, R+30, R+60 |
| Gastrointestinal Sampling<br>L-240, L-150, L-90, L-60 | Gastrointestinal Sampling (optional)<br>FD7, FD90, R-14 | Gastrointestinal Sampling<br>R+1/3, R+30, R+60 |
| Blood Draw*<br>L-60 | Blood Draw**<br>FD7, R-1 | Blood Draw*<br>R+0, R+180 |
| Saliva Collection***<br>L-240, L-150, L-90, L-60 | Saliva Collection***<br>FD7, FD90, R-14 | Saliva Collection***<br>R+1/3, R+30, R+60, R+180 |
| | Perspiration Swabs<br>FD7, R-14 | |
| | ISS Surface Swabs<br>FD7, R-14 | |
| | Potable Water Collection<br>R-14 (once per increment) | |

*Shared stick with Med Ops

**If possible, sessions will occur concurrently with existing medical/research activities

***Each session consists of a 7-day period with a sample collection performed every other day

# Thank you!