Overview of Microbial Monitoring Technologies Considered for Use Inside Long Duration Spaceflights and Planetary Habitats

Monsi C. Roman
NASA ECLSS Chief Microbiologist

C. Mark Ott, PhD
Microbiology Laboratory
NASA Johnson Space Center

Microbial Monitoring in Long Duration Missions

- **The purpose of this presentation is to start a conversation including the Crew Health, ECLSS, and Planetary Protection communities about the best approach for in-flight microbial monitoring as part of a risk mitigation strategy to prevent forward and back contamination while protecting the crew and vehicle.**
  - **Will help set future:**
    - **Resource allocations**
    - **Monitoring requirements**
    - **Minimize duplication of monitoring technologies for use in space**
    - **Foster complementary monitoring technologies**

Prevention is Important

Regular housekeeping/disinfection

Education of the crew

Minimize conditions that promote growth

Thorough ground disinfection

Prevention
Designed to Meet Current Requirements

So…Why Are We Currently Monitor Microorganisms?

Short-term Effects of Microbial Exposure (days to weeks)

***Air/Surfaces*:**

- Release of volatiles (e.g., odors)
- Allergies (e.g., skin, respiratory)
- Infectious diseases (e.g., Legionnaire's)

***Water*:**

- Objectionable taste/odor

Long-term Effects of Microbial Exposure (weeks to years)

***Air/Surfaces (same as short-term plus)*:**

- Release of toxins (e.g., mycotoxins)
- Sick building syndrome
- Environmental contamination
- Biodegradation of materials
- Systems performance

***Water (same as short-term plus)*:**

- System failure
  - Clogging, corrosion, pitting, antimicrobial resistance/regrowth potential (biofilm)

Microbial Monitoring Design Considerations*

"*Even in high quality water supplies protected by a residual bactericide, viable organisms can still persist. Therefore, the potential for microbial overgrowth is an ever-present hazard. Due to the long potential unmanned loiter time contributing to the duration of flights, routine microbiological monitoring of potable water coinciding with the re-ocupation by the crew to ensure that it meets the standards outlined in Table 7.2.3.2-1 and section 5, Natural and Induced Environments, for microbiological limits may be necessary.*"

The document also addresses the potential for BIOFILM formation

*__Reference__: NASA-STD-3000 Volume VIII- Human-Systems Integration Standards for the Crew Exploration Vehicle

Microbial Monitoring in Long Duration Missions

- Current in-flight microbial monitoring technology is good but it:
  - Provides only a partial assessment of the microbial population as it detects the fraction of microorganisms that will grow in the selected media
  - Is crew time intensive
  - Produces a biohazardous waste as microorganisms are grown in flight

Current US In-flight Microbial Monitoring Capabilities

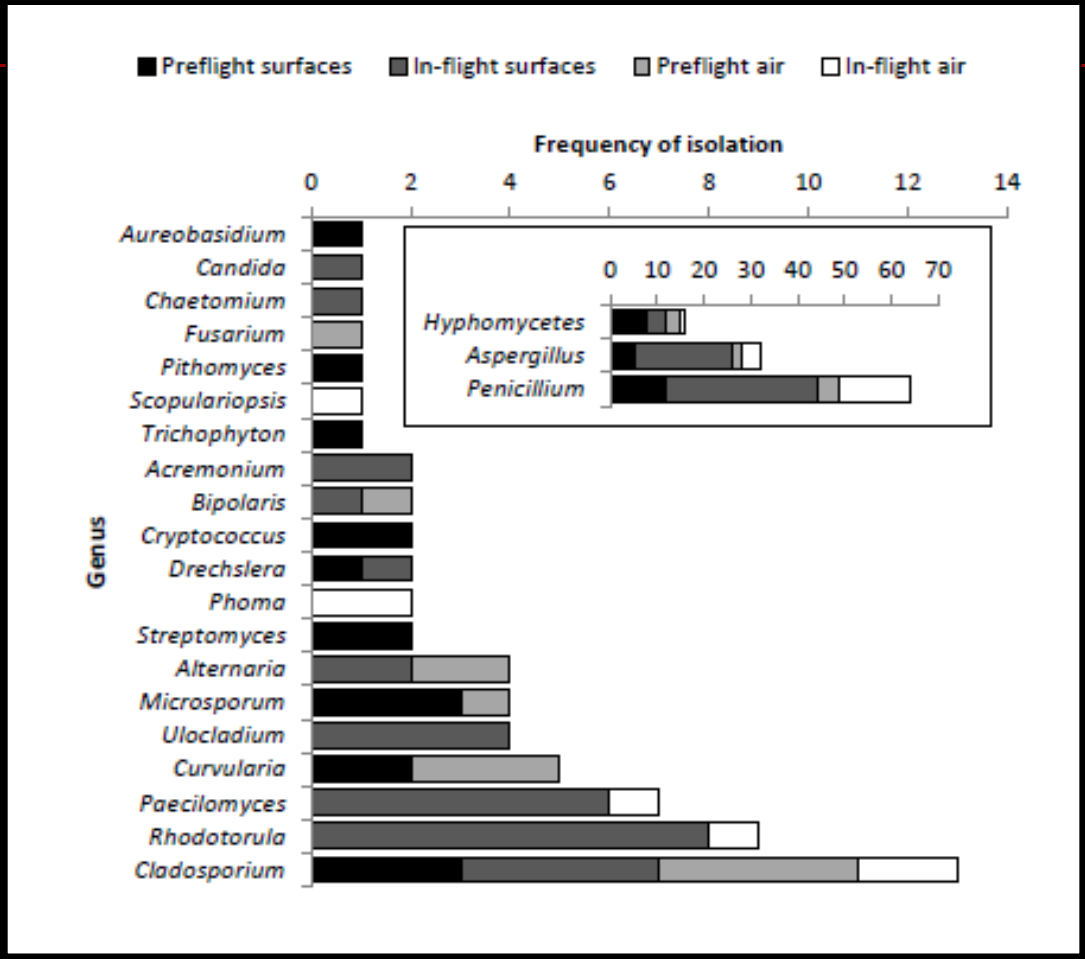
- Water Microbiology Kit (WMK)
  - Membrane filtration/ 48 hours incubation/ visual analysis
  - Sample collection/ processing: 122.5 min/ 62.5 min
- Water Microbiology Analysis Kit (WMAK)
  - Presence/absence analysis using Colisure
  - Final result reported in 24 to 48 hours
- Surface Sampler Kit (SSK)
  - Contact slide or swab/ 48 hohurs incubation/ visual analysis
  - Sample collection: 100 min; analysis: 220 min
- Microbial Air Sampler (MAS kit)
  - Impaction sampler/ incubation 5 days/ visual analysis
  - Sample collection: 135 min/ analysis: 220 min

Current Microbial In-Flight Analysis

coliform

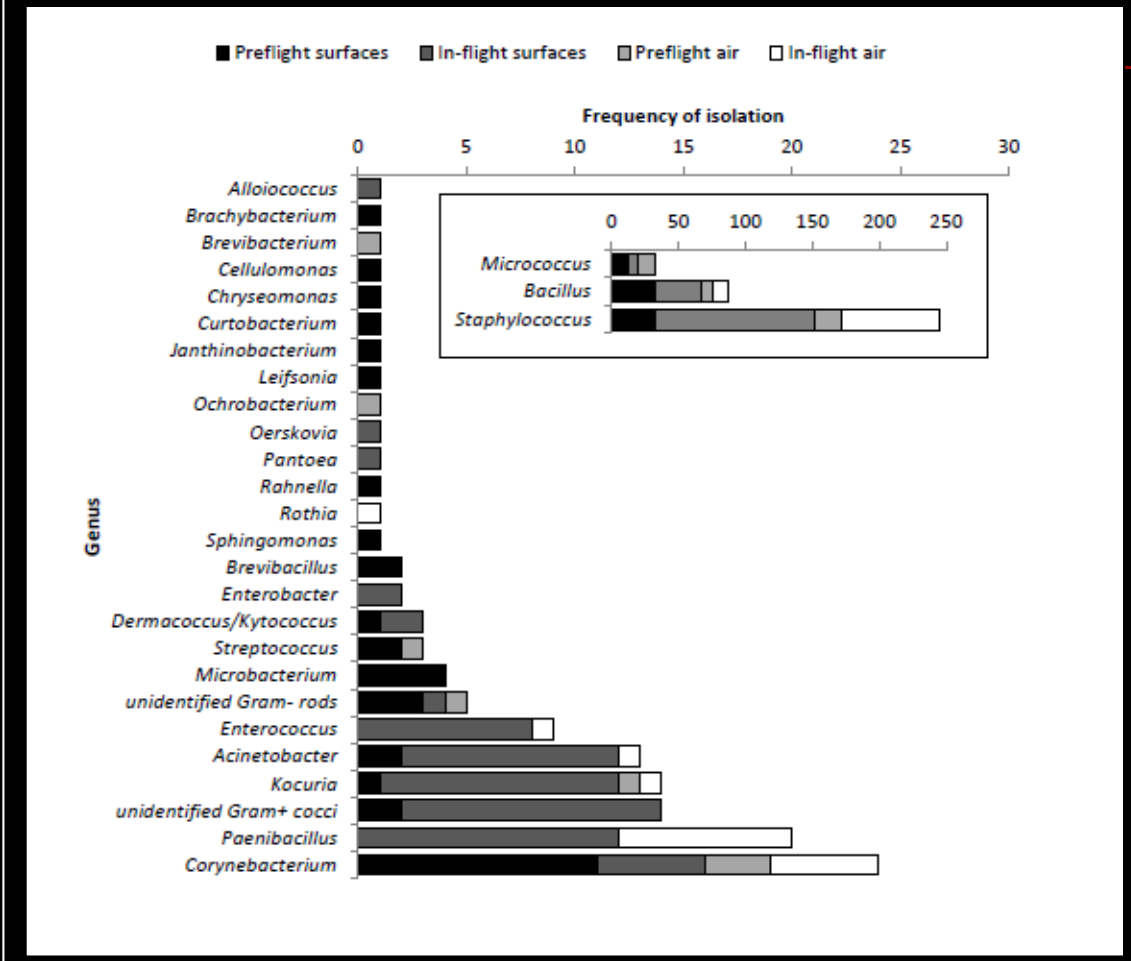
No coliform

ISS Air and Surface Monitoring
Fungal Isolates



Pierson, *et. al*. ***Environmental Monitoring: A Comprehensive Handbook*** 2012

ISS Air and Surface Monitoring
Bacterial Isolates



Pierson, *et. al*. ***Environmental Monitoring: A Comprehensive Handbook*** 2012

U. S. Potable Water Dispenser

- Provides “hot” and “ambient” potable water
- Processing includes:
  - Catalytic oxidizer
  - Iodine disinfection
  - In-line filter (0.2 micron)
- Common isolates
  - *Ralstonia pickettii*
  - *Burkholderia multivorans*
  - *Sphingomonas sanguinis*
  - *Cupriavidas metallidurans*

Stakeholders for In-Flight Microbial Monitoring Technology

- Crew Health
- Life Support Systems-system Health/Environmental
- Internal Coolant/Environmental
- Experiments/Payloads
- Astrobiology and Planetary Protection
- Spaceflight Food

Microbial Monitoring Capabilities
Crew Health and ECLSS

- To enable new technology that does not depend strictly on culture based systems, we have been investigating both hardware and requirements definition.
- Based upon feedback from multiple workshops:
  - Total counts reflect system performance (engineering requirement) and are not as important for health assessments
  - For crew health assessments, the monitor should target the identification of key organisms specific to a given mission architecture
  - For crew health assessments, the monitor must reflect viable organisms

Current Hardware Efforts

- Two DNA based microbiological monitoring systems are being evaluated under the ISS 2 x 2015 technology demonstration initiative
  - One effort is evaluating the RAZOR QPCR system developed by Biofire Diagnostics
  - One effort is evaluating the MinION system developed by Oxford Nanopore

Lessons Learned

- No single technology may provide the needed data (“a silver bullet solution”); combination of multiple technologies may provide the best approach. Two very small monitors may be more efficient than one very large monitor.
- Defining the requirements of all stakeholders is essential. For example, crew health requirements using non-culture based methodologies do not exist.
- Changes in mission architecture can cause changes in monitoring requirements.

Lessons Learned

- In the search for new technologies, in-flight sample collection and processing are often under emphasized.
- Chosen technologies need to be extensively validated in the proper environment with appropriate samples prior to use in long duration missions.