Microbial Monitoring and the Risk of Infectious Disease aboard the International Space Station

C. Mark Ott, NASA Johnson Space Center

ABSTRACT

The International Space Station (ISS) is a semi-closed habitat in low Earth orbit with environmental conditions provided by an advanced life support system that controls temperature and recycles air and most of the potable water. The crew's activities, such as eating, sleeping, hygiene, and laboratory research, are performed in relatively close proximity. Research in the laboratory includes a myriad of experiments, including those with rodents, plants, and pathogenic microorganisms. Despite these conditions, in-flight monitoring of ISS indicates that the microbial diversity is similar to homes on earth. Accordingly, the crew is generally very healthy, however infectious disease does occur and potential routes of infection by obligate and opportunistic pathogens cannot be completely prevented. Determining the extent of this risk is further complicated, as microorganisms can alter their characteristics in response to spaceflight culture, as exemplified by the increase in virulence of the enteric pathogen *Salmonella enterica* Typhimurium during spaceflight compared to otherwise identical cultures grown on Earth. Taken together, these factors suggest a need for continued microbiological monitoring and research to understand and mitigate the risk of infectious disease during long duration missions.

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Crewmembers enjoying a meal aboard the International Space Station (NASA S123E007231)

THE RISK OF ASTRONAUT INFECTION

Positives

- Preflight medical exams and medical consult throughout a mission
- Preflight crew quarantine
- Stringent microbiological monitoring of spacecraft and its cargo

Negatives

- Small enclosed environment with recycled air/water
- Limited medical diagnostics and treatment on board
- Limited environmental remediation capabilities
- Dysfunctional aspects of the crew immune system
- Unique alterations of microbial characteristics, including virulence

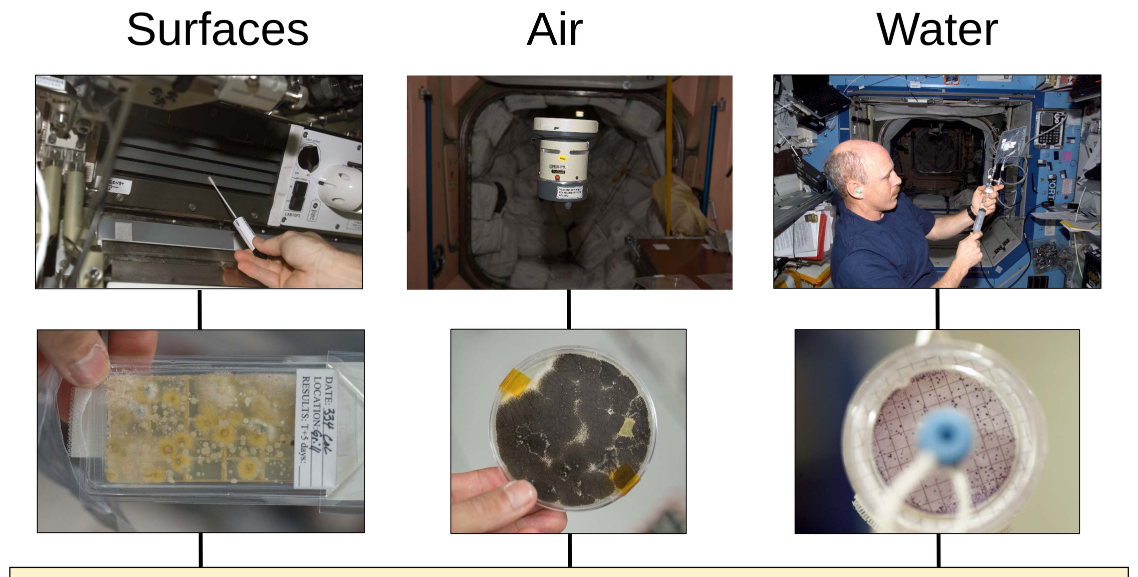
INFECTIOUS DISEASE DURING SPACEFLIGHT

Infectious disease rates are difficult to determine during spaceflight missions, as disease incidence is usually based on verbal communication of symptomology, such as "rash", "dry hacking cough", or "diarrhea."

Examples of diseases attributed to microorganisms during spaceflight missions

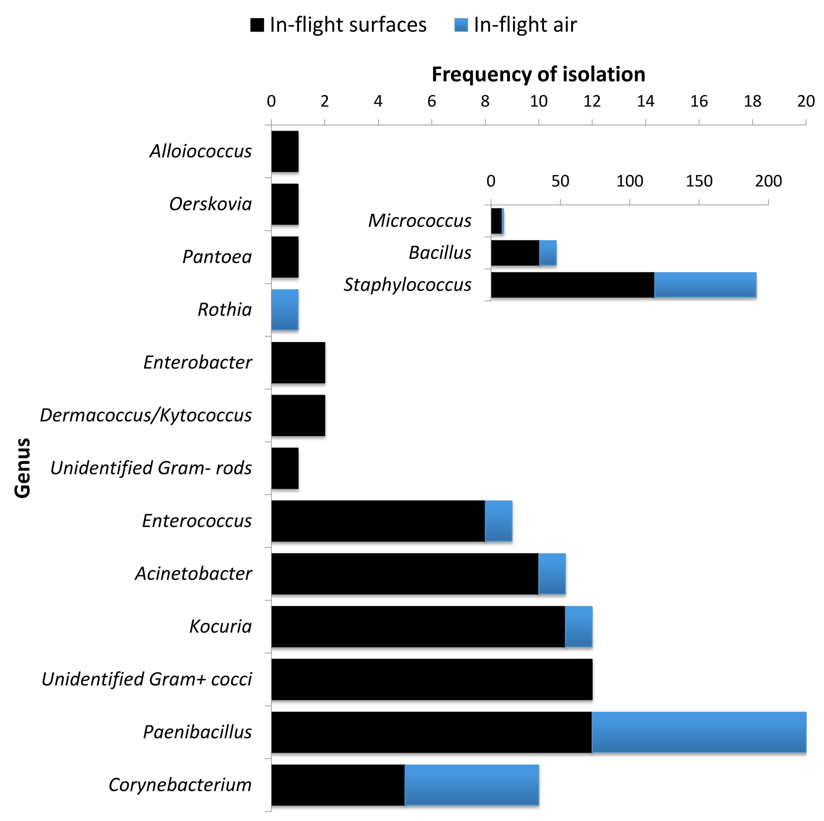
- Upper respiratory infections
- Urinary tract infections
- Ear infections
- Various fungal infections
- Herpes Zoster
- Stye
- Rashes & skin disorders
- Allergic reactions
- Gastroenteritis

MICROBIOLOGICAL MONITORING METHODS

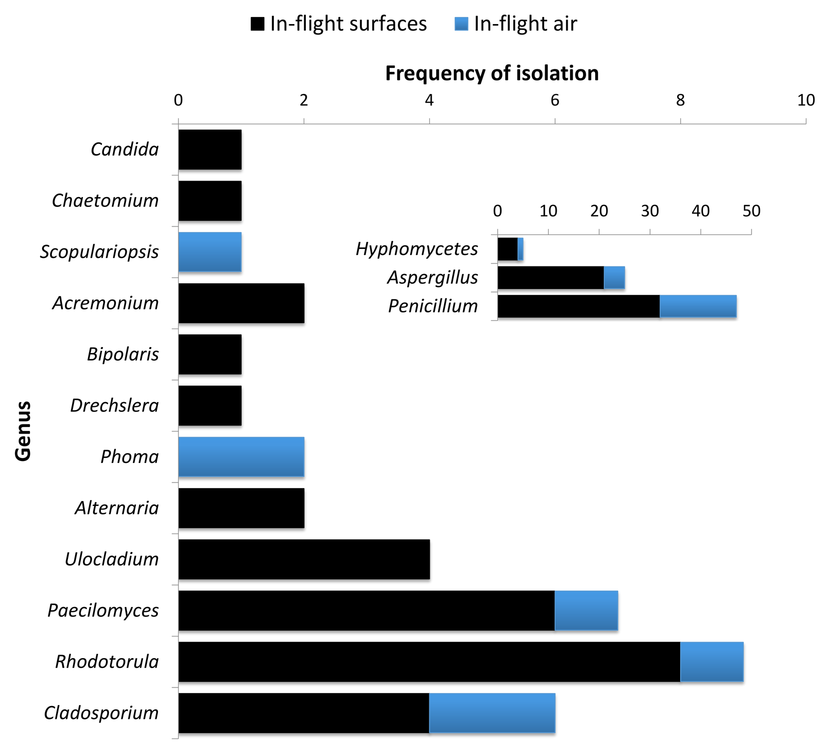


Quantified in-flight and returned to JSC for identification

Air and Surface Monitoring - Bacteria



Air and Surface Monitoring - Fungi



MONITORING SUMMARY

- Current vehicle design and operational activities generally maintain microorganisms at low levels.
- The microorganisms isolated from ISS are common environmental organisms similar to those found in terrestrial homes.
- Contamination events do occur, often from uncontrolled water sources, such as condensate formation and crew hygiene activities.
- Potable water is maintained below 50 CFU/ml. Bacterial isolates are primarily from the genera *Ralstonia*, *Burkholderia*, and *Sphingomonas*

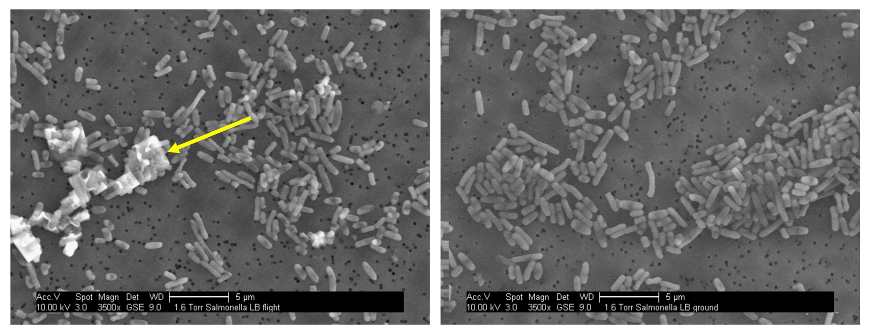
Fungal contamination on a panel in the Russian Functional Cargo Block module (NASA ISS009E28777)

ENHANCED VIRULENCE IN RESPONSE TO SPACEFLIGHT CULTURE

Multiple experiments over the past 50 years have indicated unique microbial responses when microorganisms are cultured during spaceflight, including changes in growth kinetics, antibiotic resistance, and biofilm formation.

The MICROBE Experiment (PI: Cheryl Nickerson, Arizona State University) investigated the response of the enteric pathogen *Salmonella enterica* serovar Typhimurium cultured during spaceflight compared to otherwise identical *S.* Typhimurium cultured on Earth (Wilson 2007).

- Spaceflight grown *S.* Typhimurium grown in LB broth **killed mice faster** and **killed mice at lower doses** than identical bacterial cultures grown on the ground. These findings were reproduced one year later on a separate spaceflight mission (Wilson 2008).
- *S.* Typhimurium grown in the spaceflight environment displayed an extracellular material not seen in ground controls.



Flight Sample　　Ground Control

- Proteomic profiling identified **73 differentially regulated proteins**, and microarray analysis identified **167 differentially regulated genes** compared to ground controls. The global regulatory protein, Hfq, was associated with 32% of the differentially regulated genes.
- Genes were globally distributed and associated with:
  - Protein secretion
  - Outer membrane proteins
  - Iron metabolism and storage
  - Ion response pathways
  - Plasmid transfer functions
  - Energy and metabolism
  - Ribosomal proteins
  - Small regulatory RNAs
  - Biofilm formation
  - Transcriptional regulators

Investigation of the response of other pathogenic microorganisms to spaceflight culture indicate alterations in virulence characteristics, including:

- Alterations in the architecture of *Pseudomonas aeruginosa* biofilms compared to ground controls (Kim 2013).
- Differential expression of 167 genes in spaceflight cultures of *P. aeruginosa* compared to ground controls, with Hfq again indicated as a mediator of this spaceflight-associated response (Crabbé, 2011).
- Differential regulation of 452 genes in spaceflight cultures of *Candida albicans* compared to ground controls. Spaceflight grown *C. albicans* also displayed random budding patterns as opposed to bipolar patterns on ground controls (Crabbe 2013).

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