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# Supportability for Mars: Risk, Logistics, and Crew Time


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# Supportability

**Supportability** describes the ease with which a system can be supported in a given mission context to enable safe, cost-effective operations

## Operational Impacts:

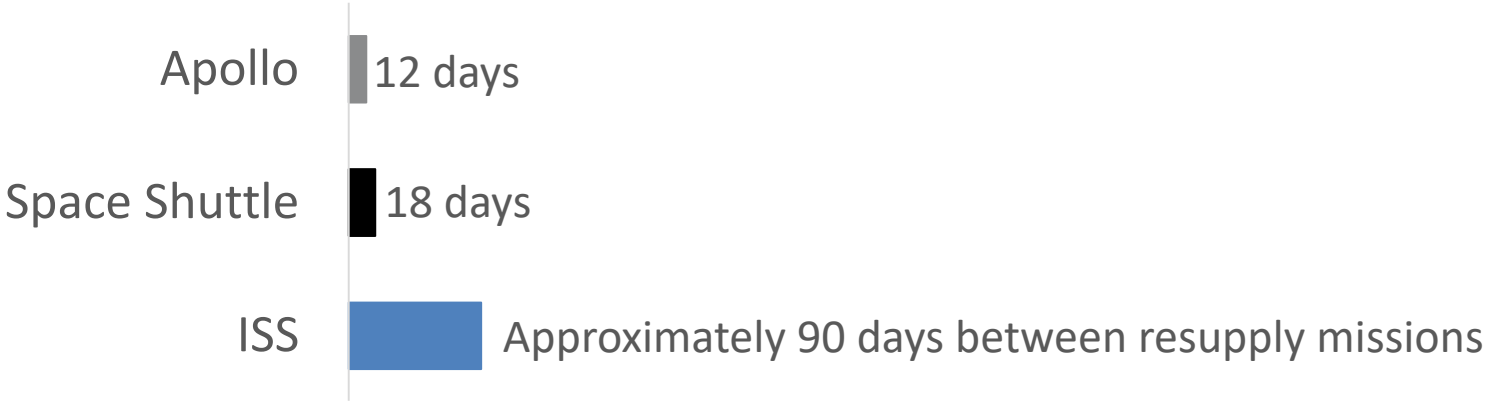
- **Mass/Volume**: logistics, spare parts, maintenance items, tools
- **Productivity**: crew time required for maintenance
- **Risk**: probability of having sufficient spares (POS)

**Decisions made early in system/mission development have a strong influence on supportability, which is a key driver of mass, crew time, and risk for missions beyond LEO**

# Mars is an Unprecedented Supportability Challenge

The **ISS** has provided extensive experience with long-duration human spaceflight. However, it relies on **regular resupply missions** and the ability to **abort to Earth** quickly in order to reduce risk.

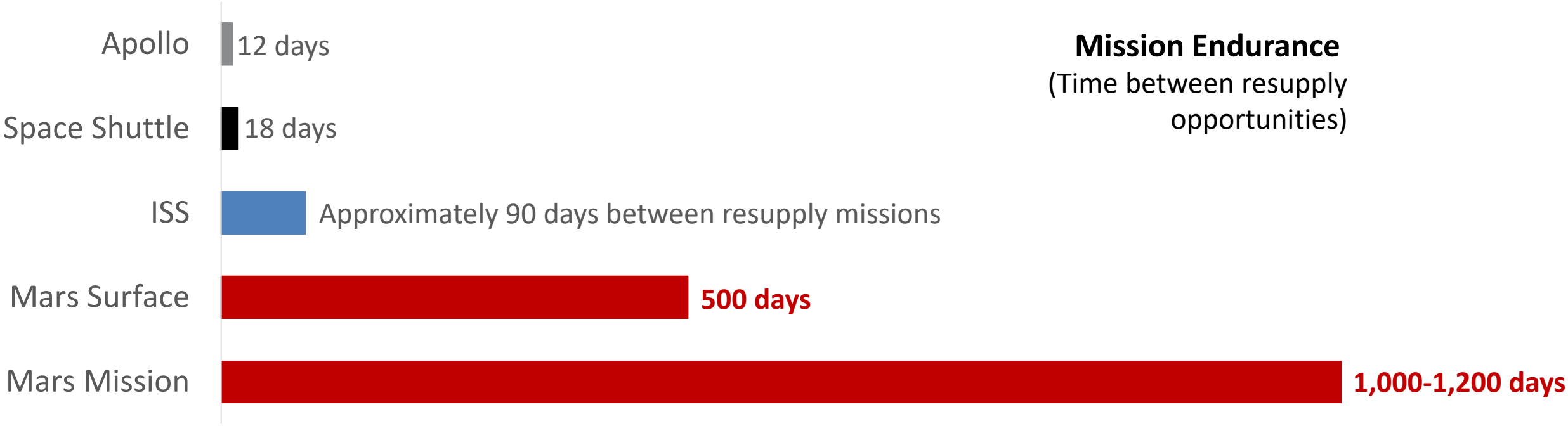
# Mars is an Unprecedented Supportability Challenge




**Mission Endurance**
(Time between resupply opportunities)

Driving factor for supportability is not mission duration, but rather **mission endurance**, defined as the amount of time that the system must sustain the crew independently, without resupply.

# Mars is an Unprecedented Supportability Challenge



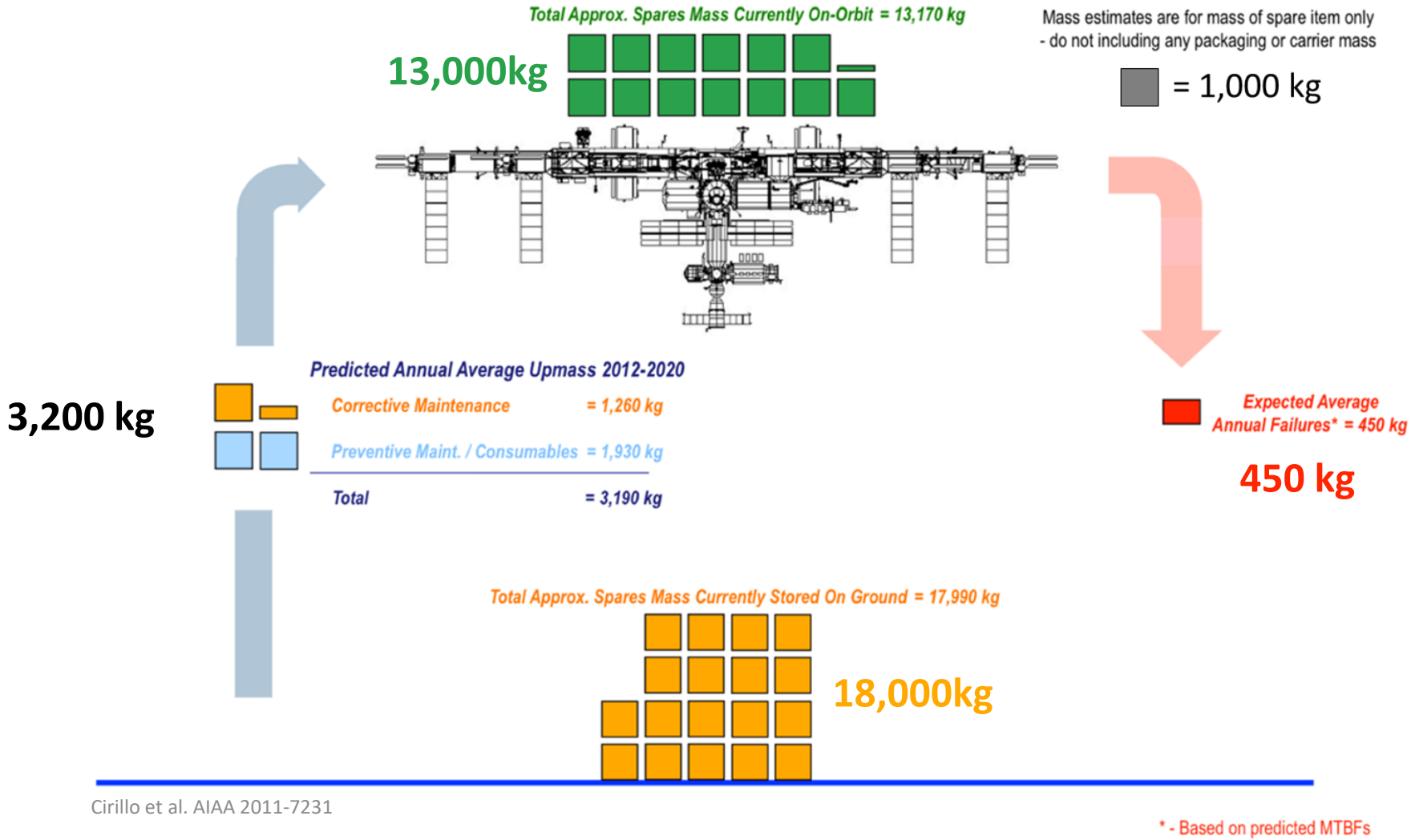

**Mission Endurance**
(Time between resupply opportunities)

Mars systems must support the crew independently, without resupply or quick abort options, for **much longer than ISS systems.**

Surface Stay → Over **5x** longer than ISS endurance

Total Mission → **11-13x** longer than ISS endurance

# ISS Logistics Are Already Challenging

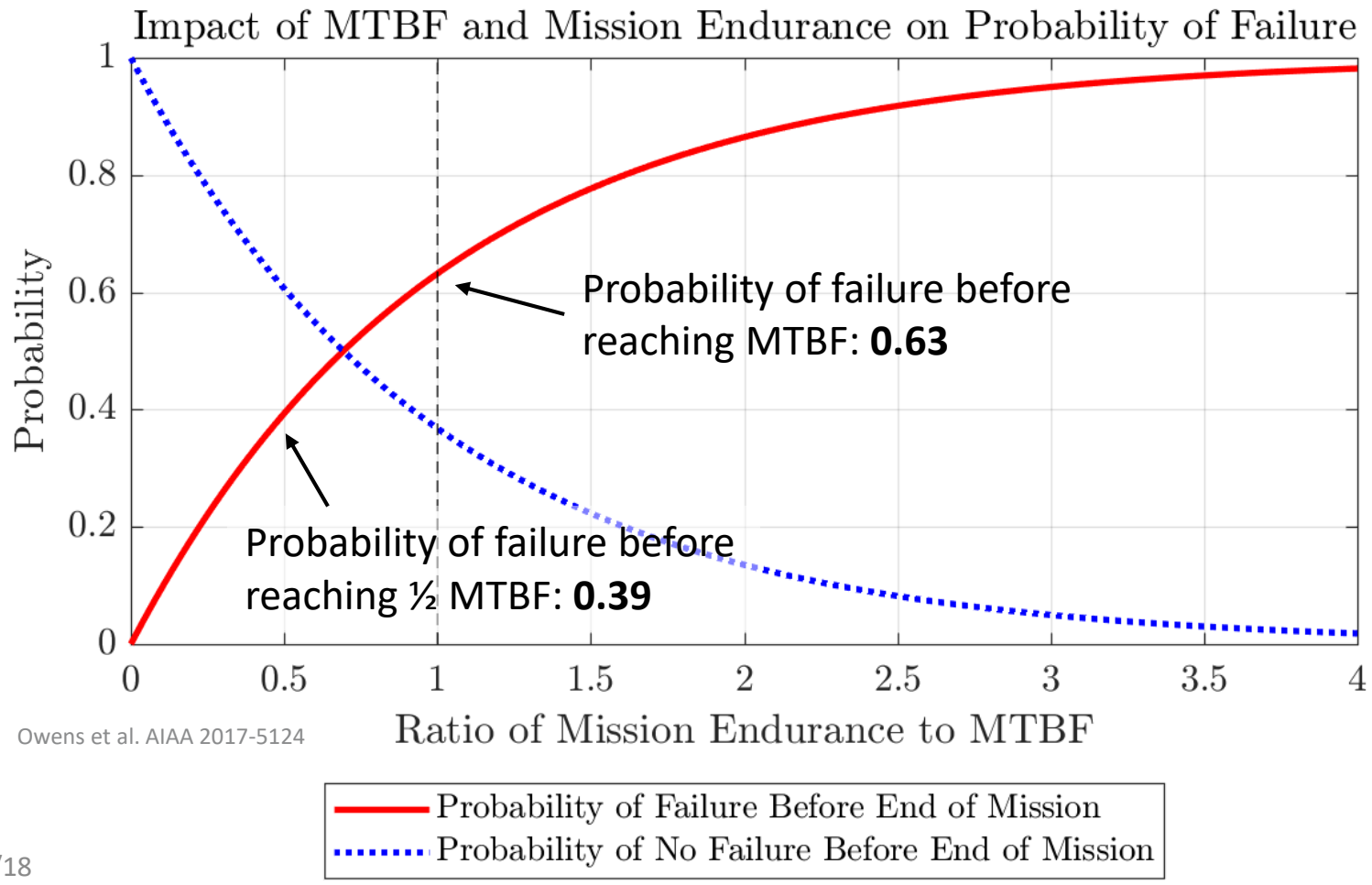



Cirillo et al. AIAA 2011-7231

* - Based on predicted MTBFs

# Longer Missions Require More Spares

Longer mission endurance increases the probability of failure, meaning more spares are required to reduce risk. A Mars mission may require **thousands of kilograms of spares** to reduce risk to acceptable levels.




Owens et al. AIAA 2017-5124

Random failures are characterized by **Mean Time Between Failures (MTBF)**, which is the inverse of failure rate. **MTBF is not a predicted lifetime**, but a parameter describing probability that a failure will occur in a given period of time.

Supportability is a holistic system characteristic driven by a wide range of decisions made during planning, development, and operations.

**Reliability Growth**

**Uncertainty Reduction**

**Higher/Lower Level of Repair**

**Commonality**

**In-Situ Resource Utilization**

**Redundancy**

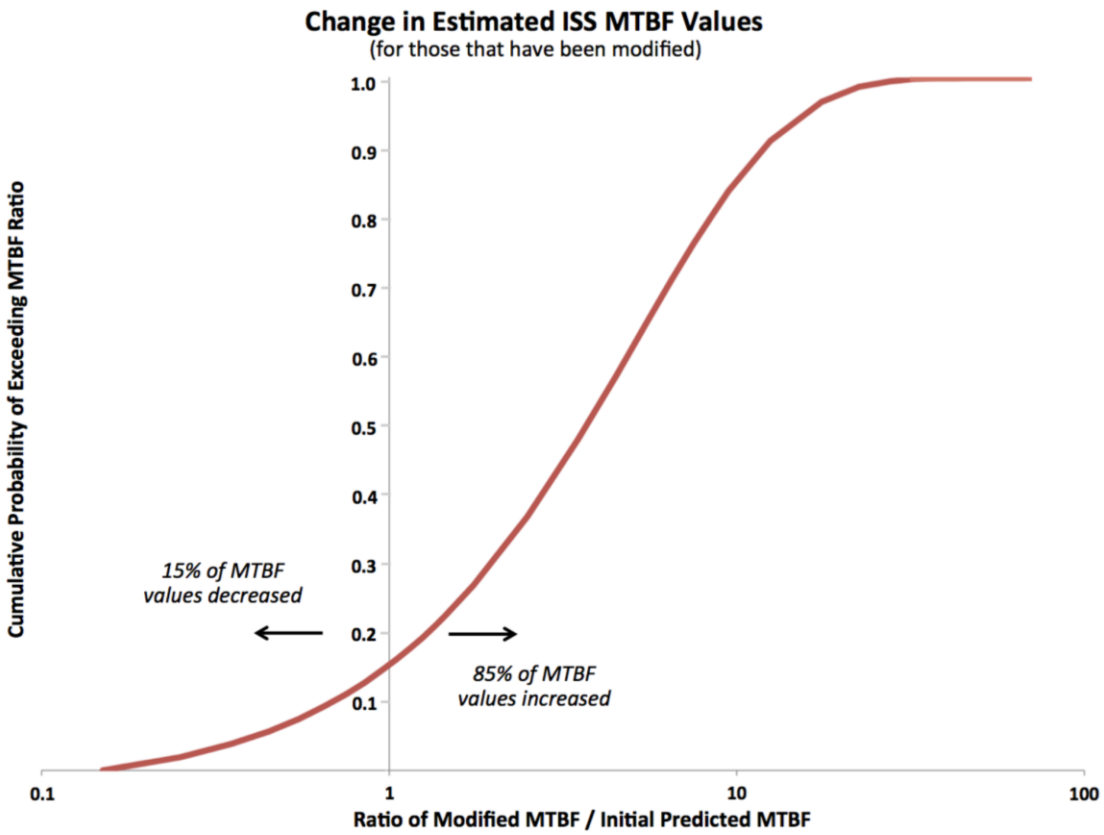
**Reduced Complexity**

**Pre-Deployed Spares**

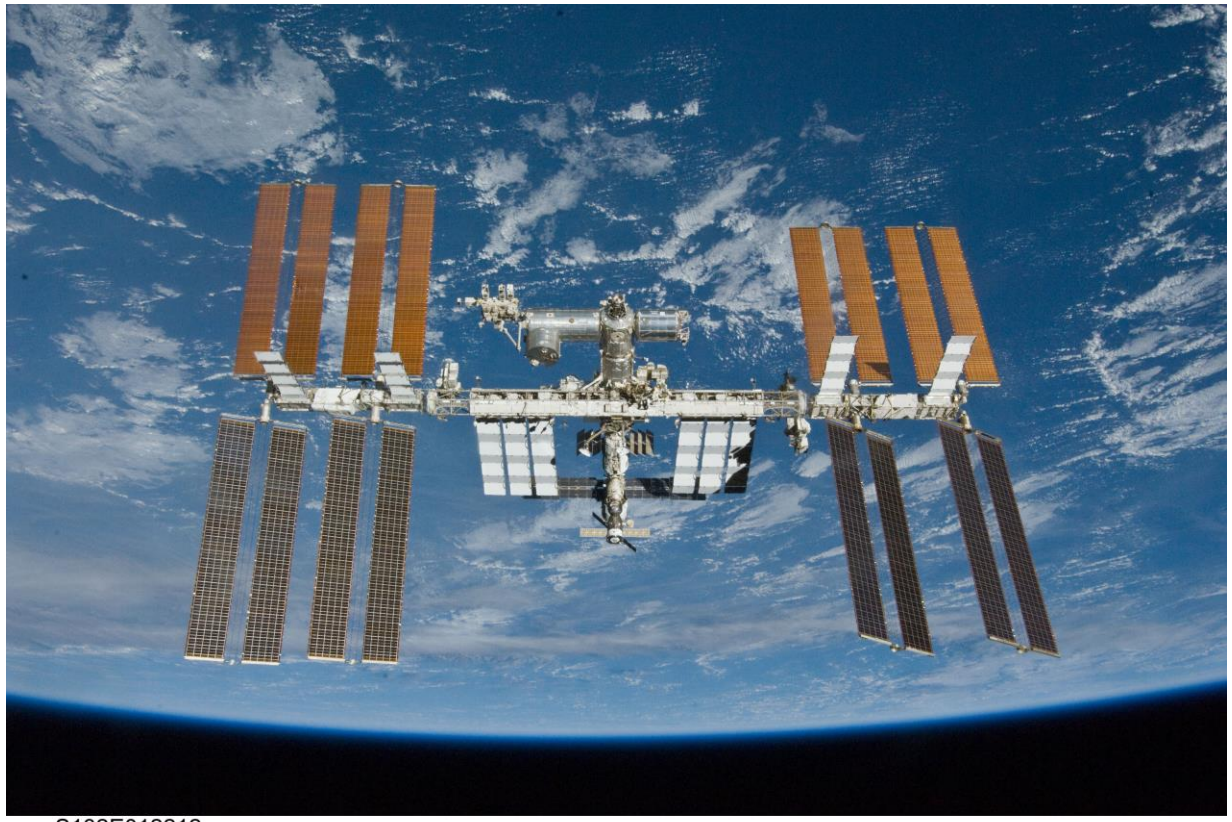
**In-Space Manufacturing**

**Material Recycling**

# Uncertainty Reduction




Stromgren et al. AIAA 2016-5307



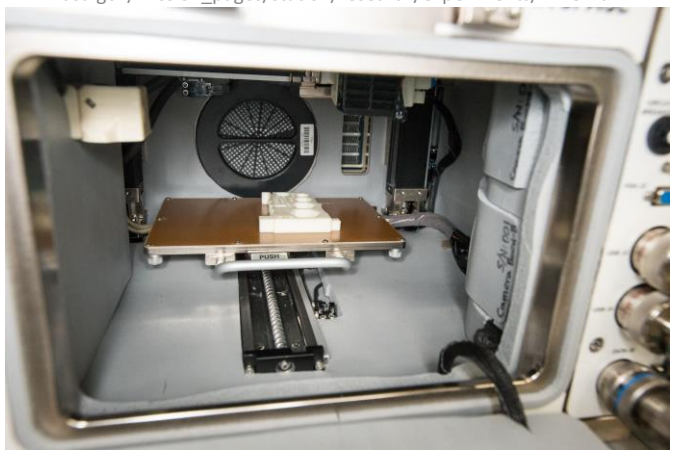
S132E012212

https://www.nasa.gov/mission_pages/station/images/station_post_construction/index.html

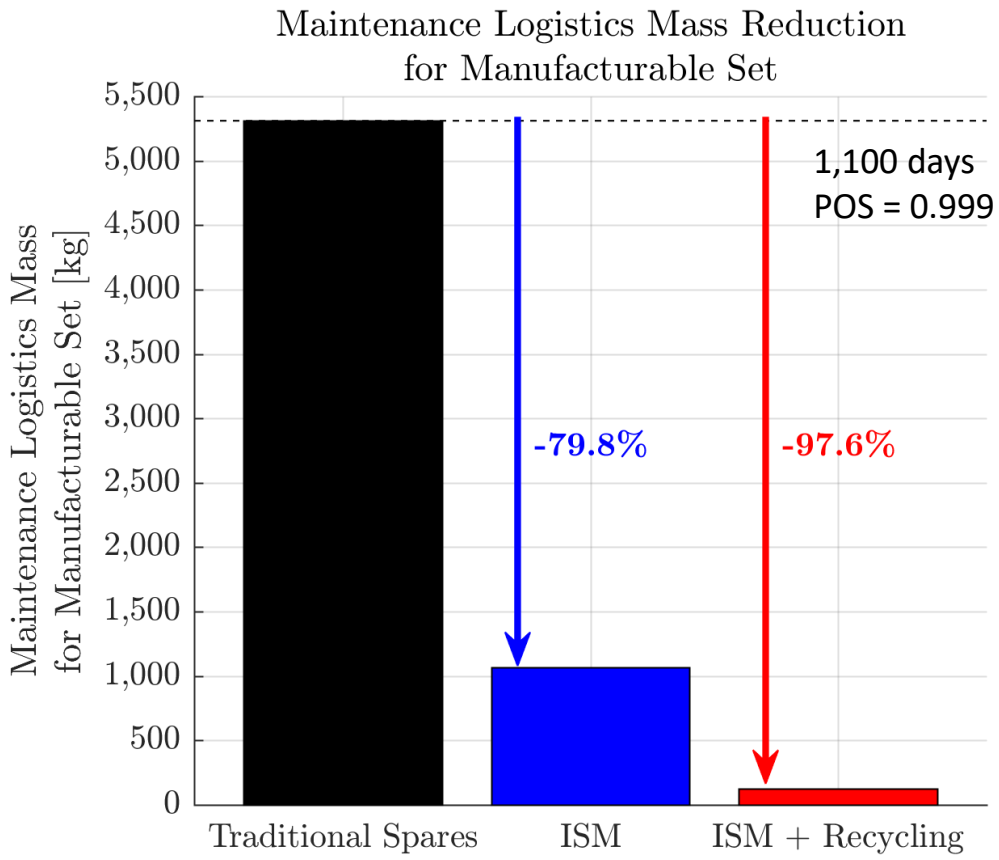
The ISS has been a valuable tool for understanding the failure behavior of space systems, **reducing uncertainty and increasing the accuracy of failure rate estimates**; this experience has revealed previously-unknown risks and enabled a significant reduction in spares mass.

# In-Space Manufacturing

https://www.nasa.gov/mission_pages/station/research/experiments/1115.html



https://www.nasa.gov/mission_pages/station/research/experiments/2542.html




Owens and de Weck AIAA 2016-5394

In-Space Manufacturing enables **adaptive spares logistics**: required items can be made on demand from common raw materials, reducing spares mass and risk.

# FAILURE IS NOT AN OPTION

# SYSTEM FAILURE IS NOT AN OPTION

## Component failure is likely

Good supportability characteristics allow the crew to perform maintenance and repair activities to mitigate risk without requiring excessive logistics or crew time.

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