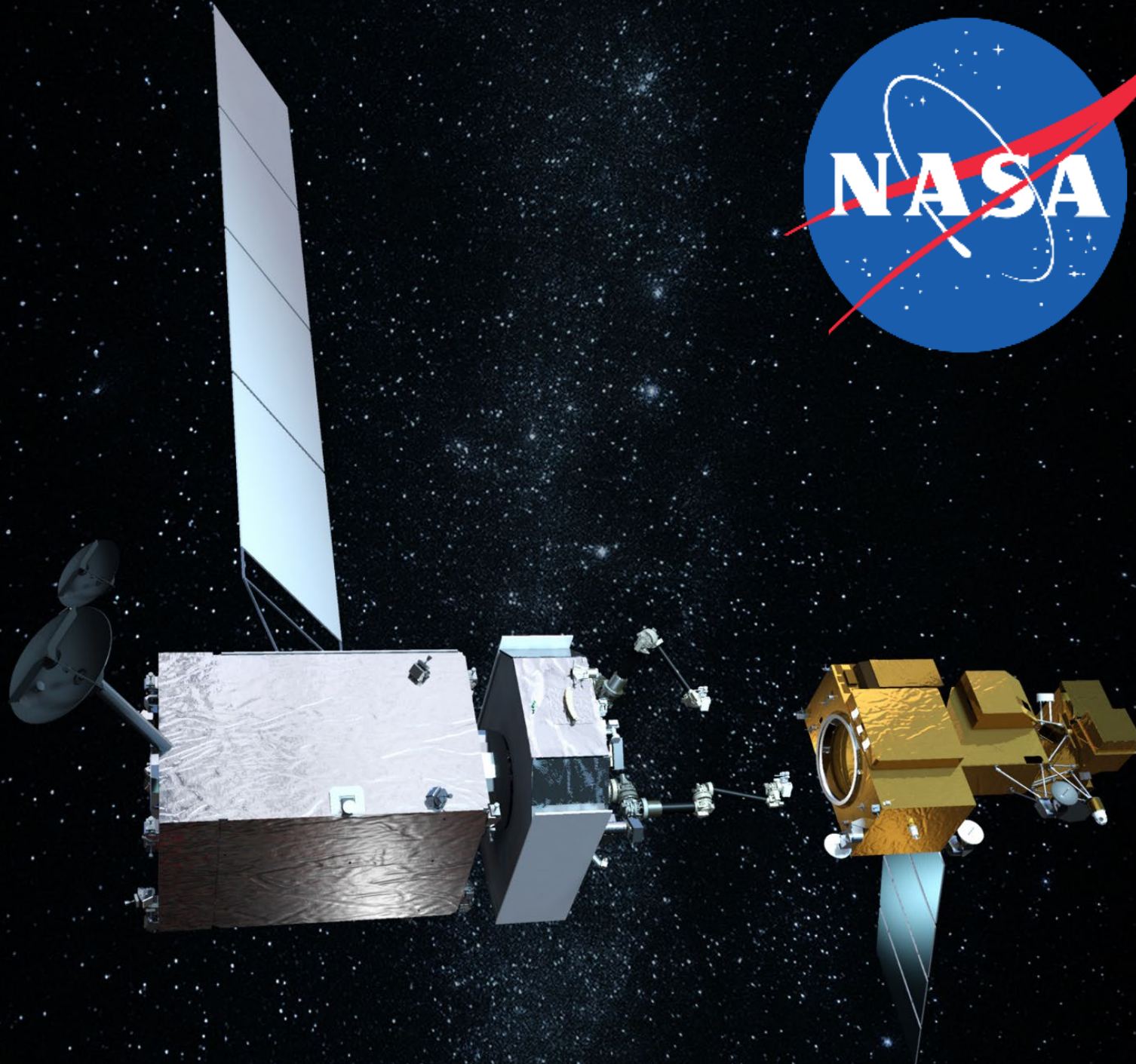


# **The Dawn of a New Era: Thinking Bigger, Living Longer, Journeying Farther**

*Conference on Small Satellites*

*August 5, 2019*

Benjamin Reed, Deputy Director  
Satellite Servicing Projects Division  
NASA's Goddard Space Flight Center







Thinking Bigger



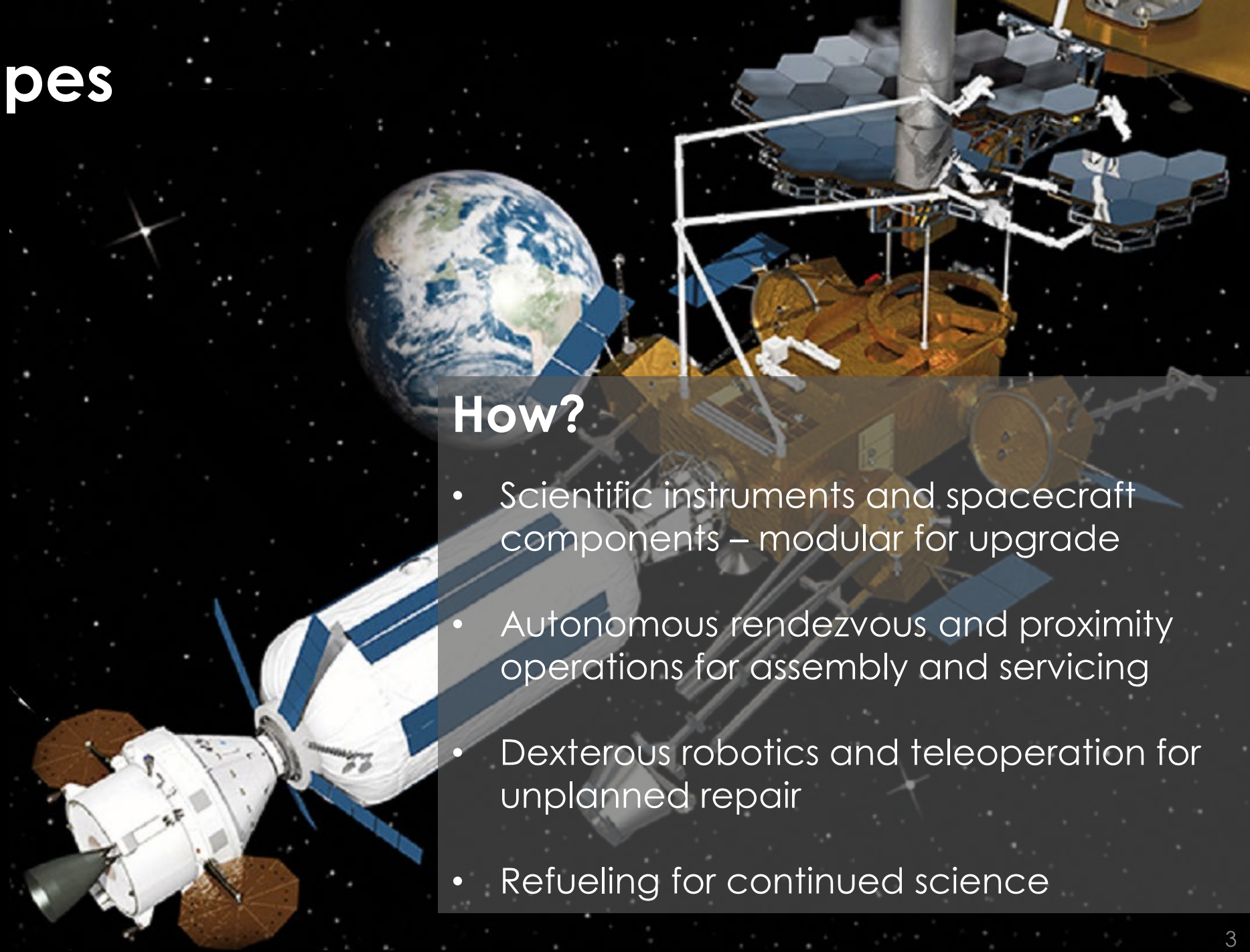
# Large Telescopes

## Why?

- Searching for the evidence of life outside of Earth
- Imaging and spectroscopy of photon starved targets
- Breaking the tyranny of the fairing

## How?

- Scientific instruments and spacecraft components – modular for upgrade
- Autonomous rendezvous and proximity operations for assembly and servicing
- Dexterous robotics and teleoperation for unplanned repair
- Refueling for continued science





# Starshades

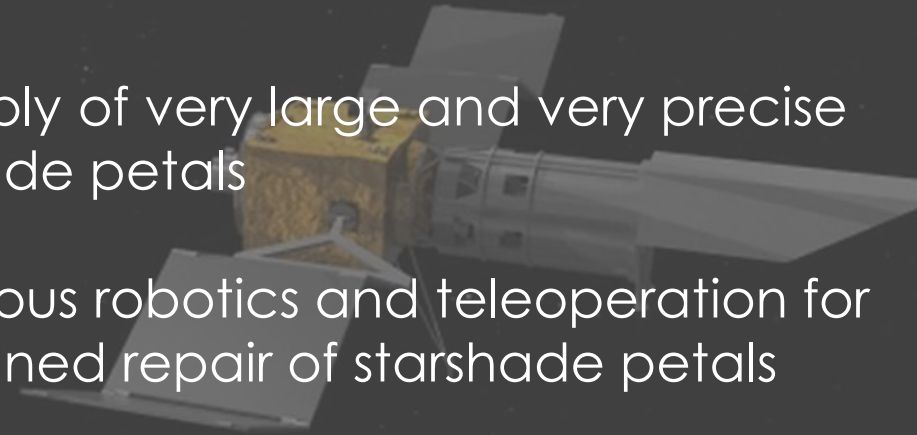
## Why?

- The exoplanets atmospheres can be interrogated for signs of life
- Earth-like planets orbiting a star are about 10 billion times fainter than their star, but starshades can precisely occult the star's light to allow imaging of the exoplanets



## How?

- Assembly of very large and very precise starshade petals
- Dexterous robotics and teleoperation for unplanned repair of starshade petals
- Cooperative refueling of both electric and chemical propellants for sustained formation flying and constant repositioning





A detailed view of the Space Shuttle Columbia's robotic arm, also known as the Shuttle Remote Manipulator System (SRMS). The arm is extended upwards, showing its two main segments with red and white thermal insulation. The base of the arm is attached to the orbiter, with various sensors and cameras visible. The background is the dark void of space.

# Living Longer

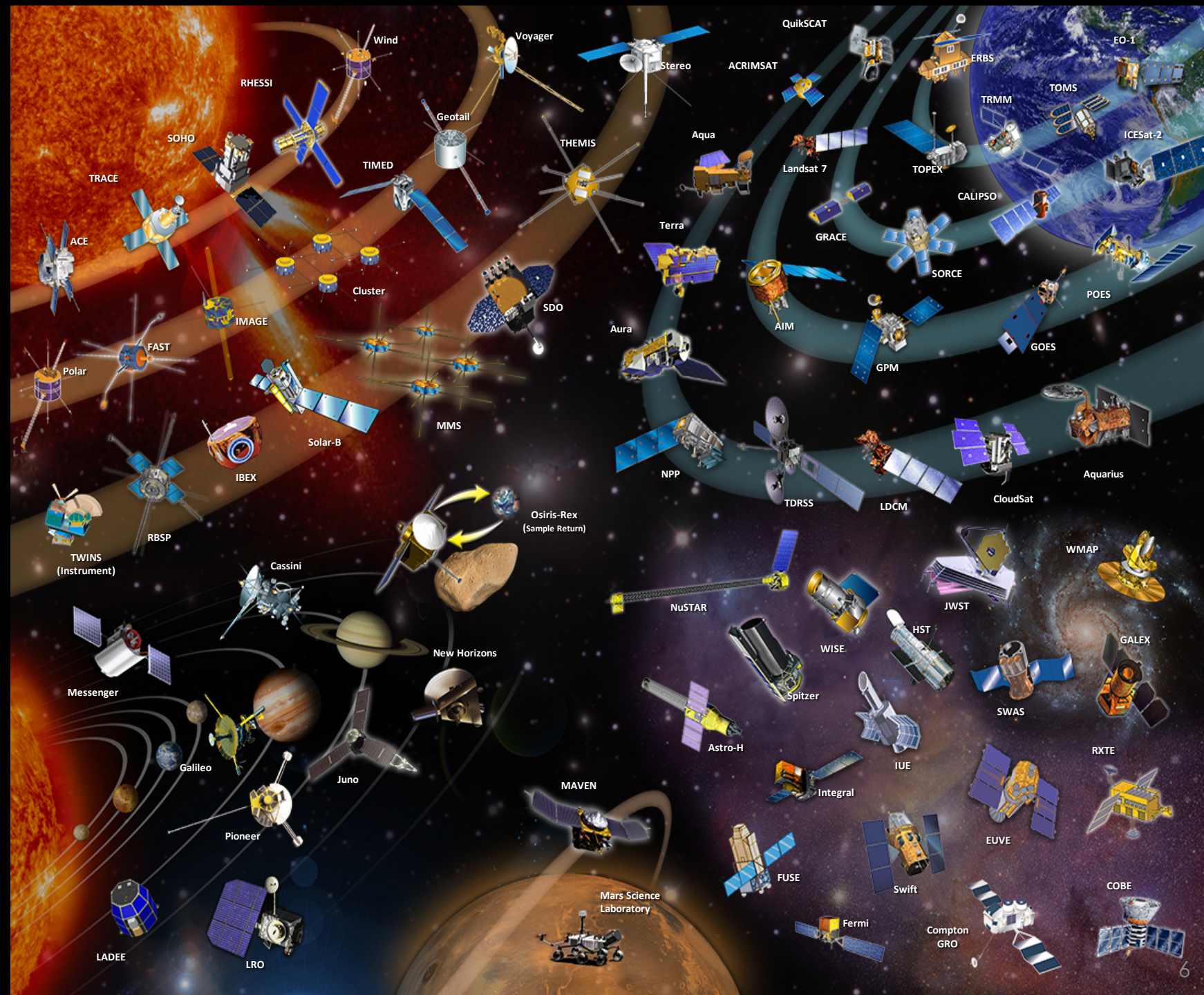


# The Existing Paradigm:

*The Era of One and Done*

- Fuel exhaustion
- Equipment anomaly
- Obsolete technology

*Satellites are decommissioned for many reasons*

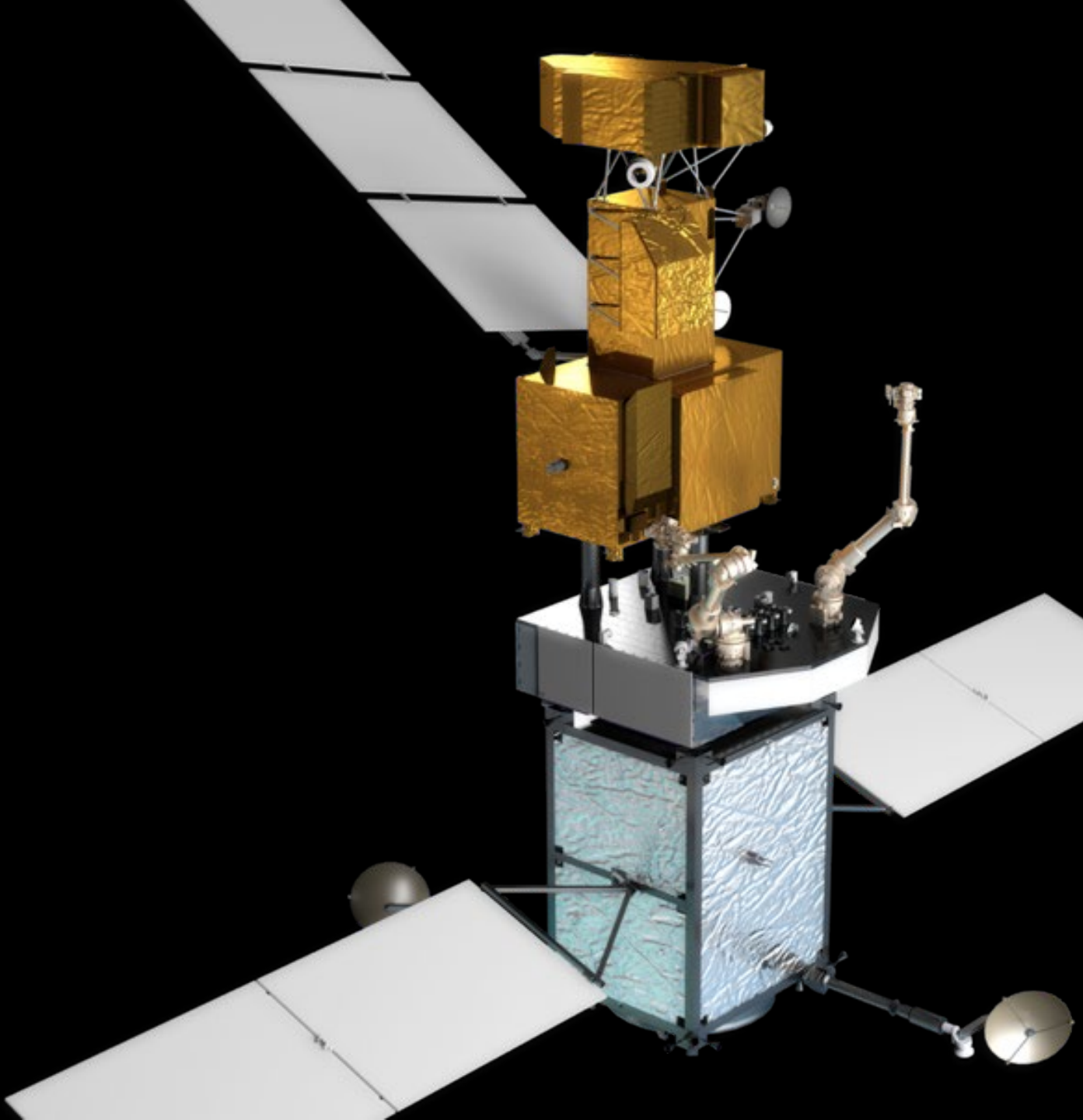




# The New Paradigm:

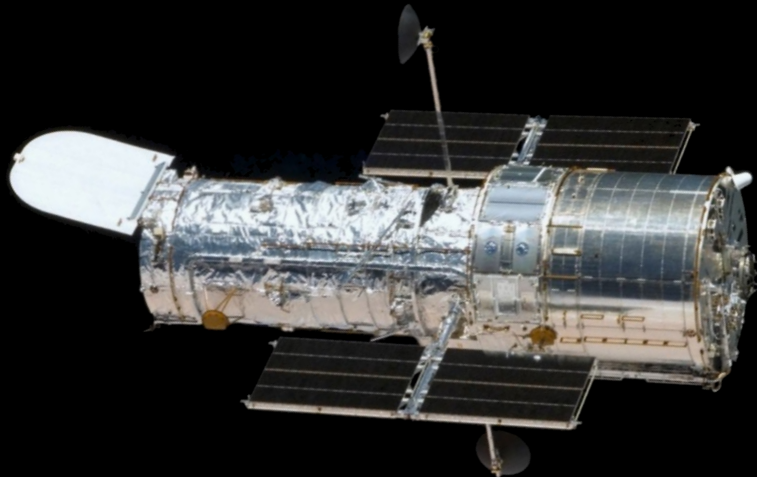
## *Resilience and Sustainability*

- Refueling
- Relocation
- Repair
- Replacement
- Upgrade
- Augmentation
- Aggregation
- Assembly
- Manufacturing





# Unplanned Repair



# Planned Upgrade





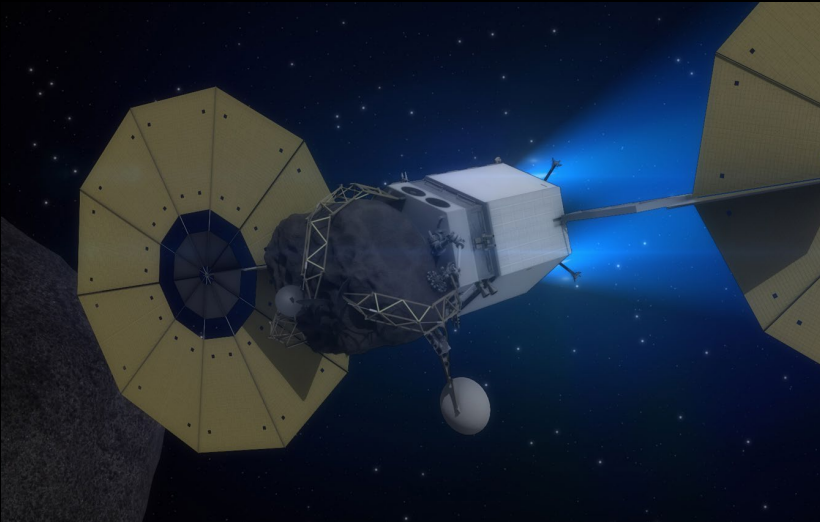
# Journeying Farther



# Long-Duration Space Travel

## Why?

To explore deeper into the solar system



## How?

- Departure vehicle aggregation and fueling
- Cryogen/xenon refueling
- Planned maintenance of subsystems
- Unplanned repair



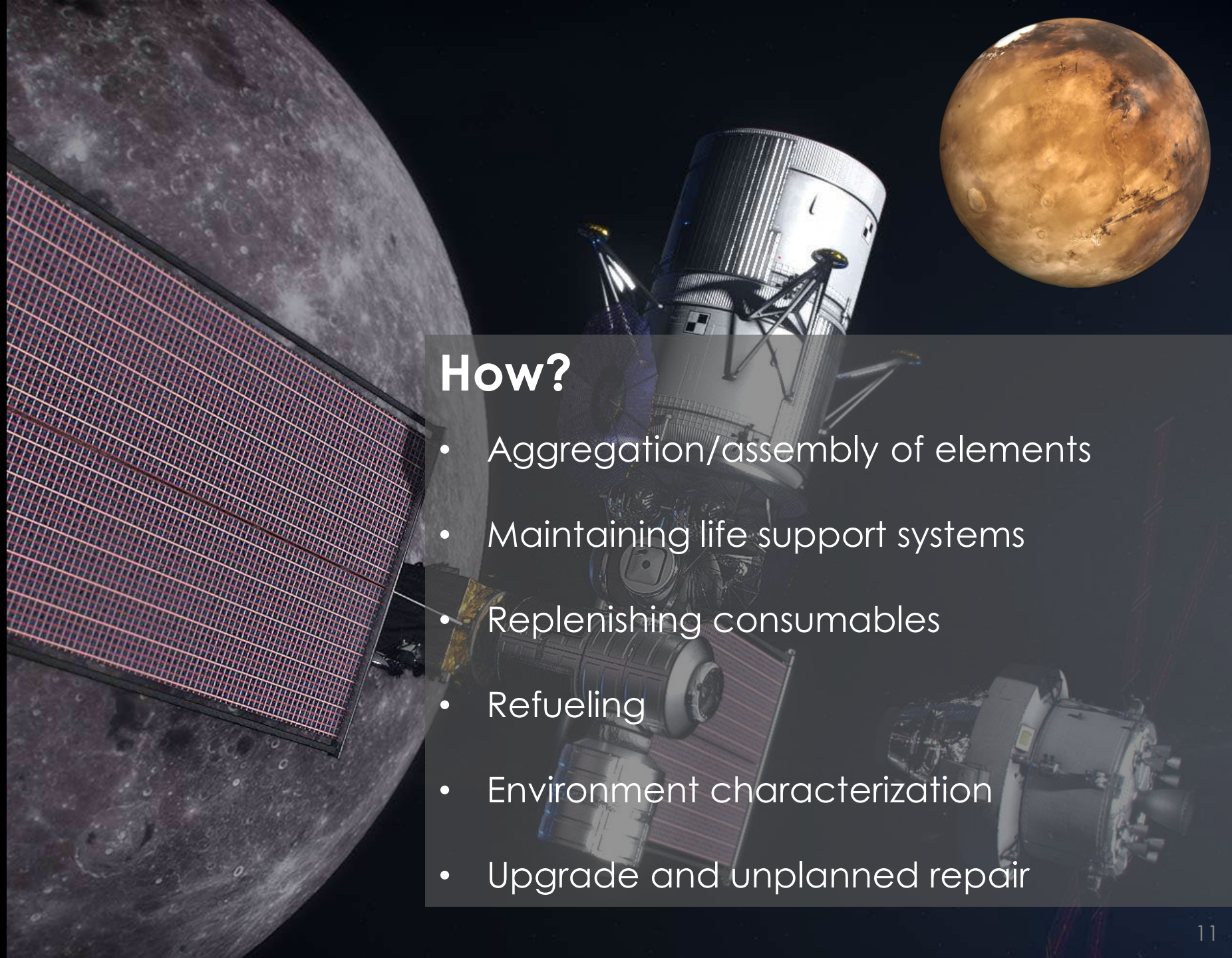
# Human Habitats

## Why?

- Enabling humans to safely live in space for extended periods of time

## How?

- Aggregation/assembly of elements
- Maintaining life support systems
- Replenishing consumables
- Refueling
- Environment characterization
- Upgrade and unplanned repair

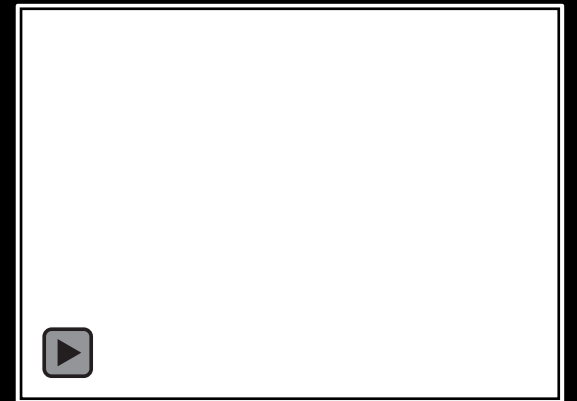
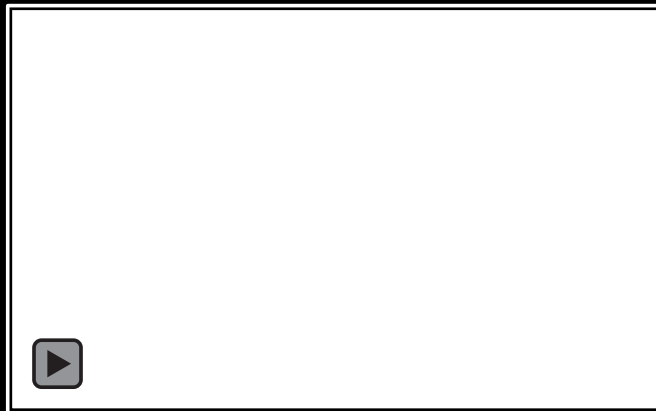
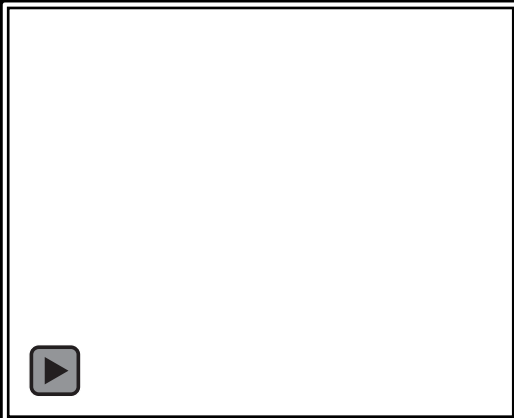
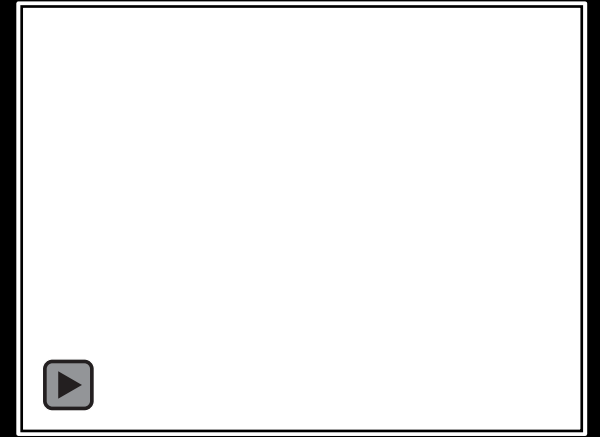
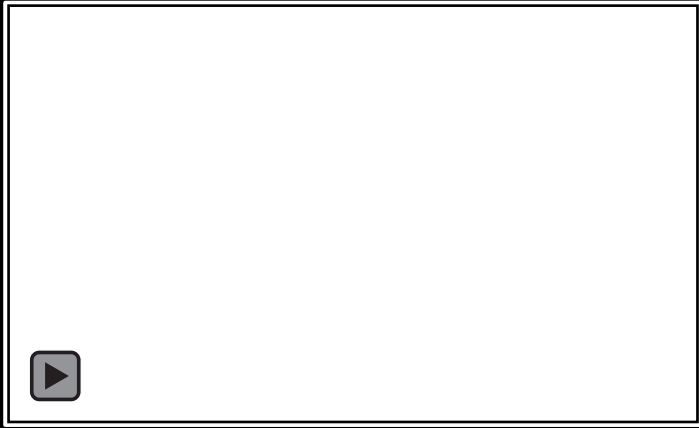
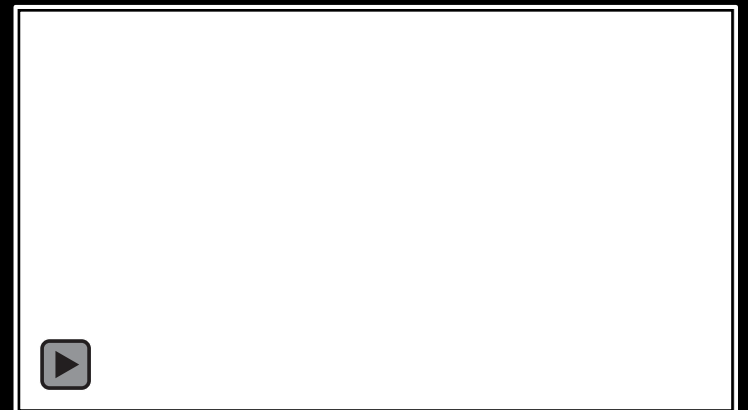
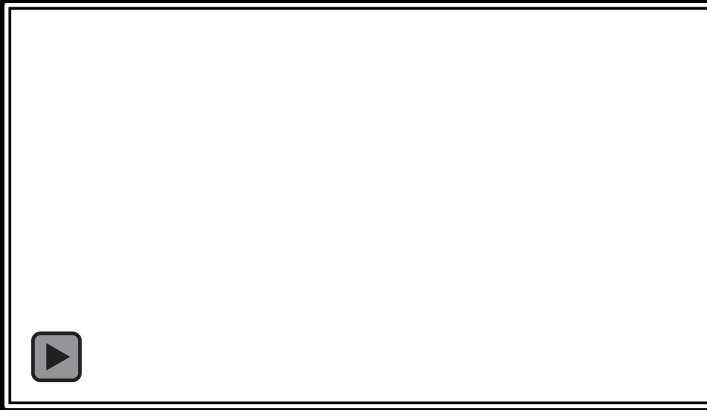






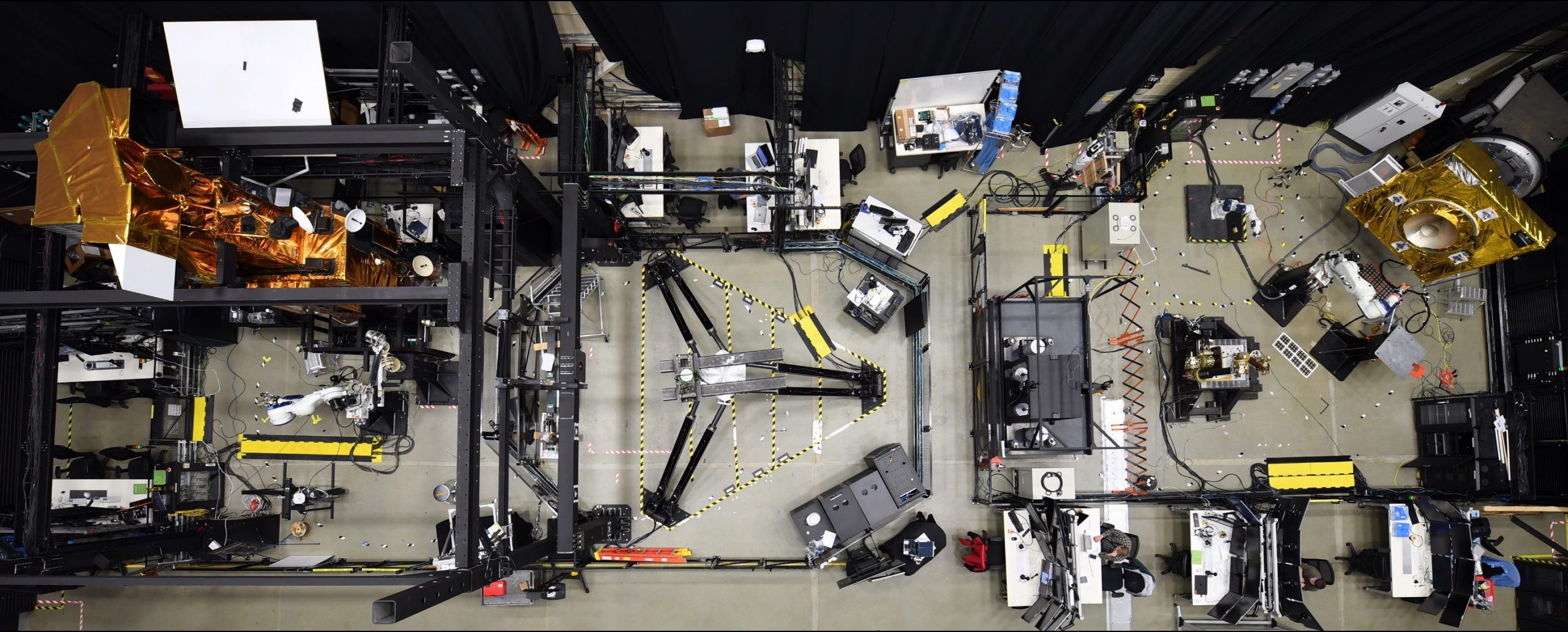
# Our Work

# SSPD Robotics





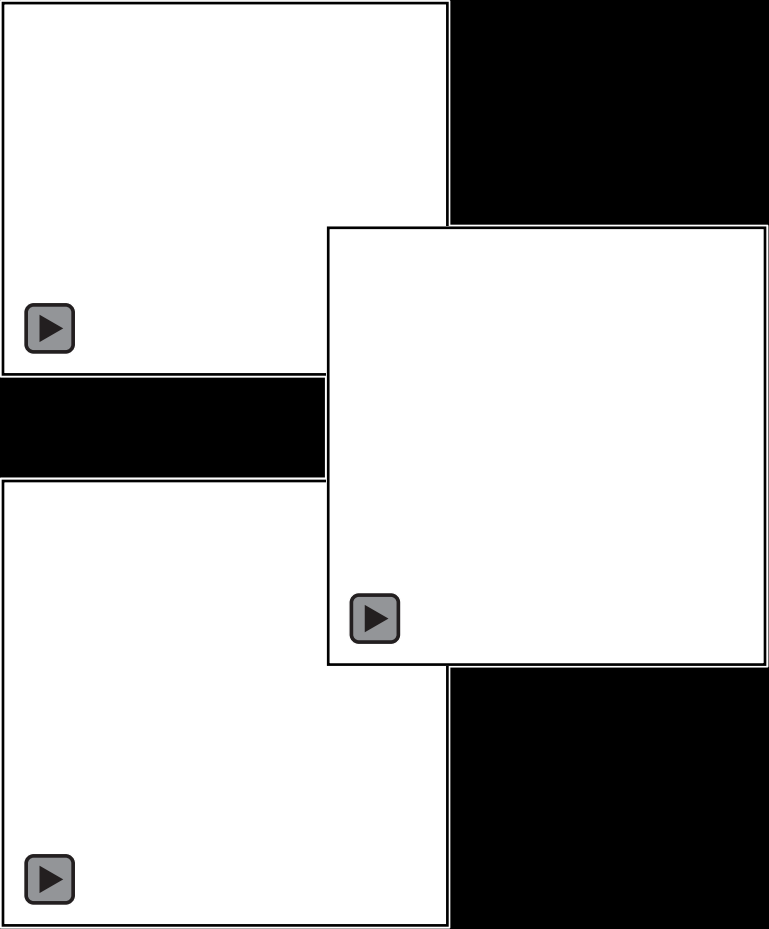
# SSPD's Robotic Operations Center (ROC)



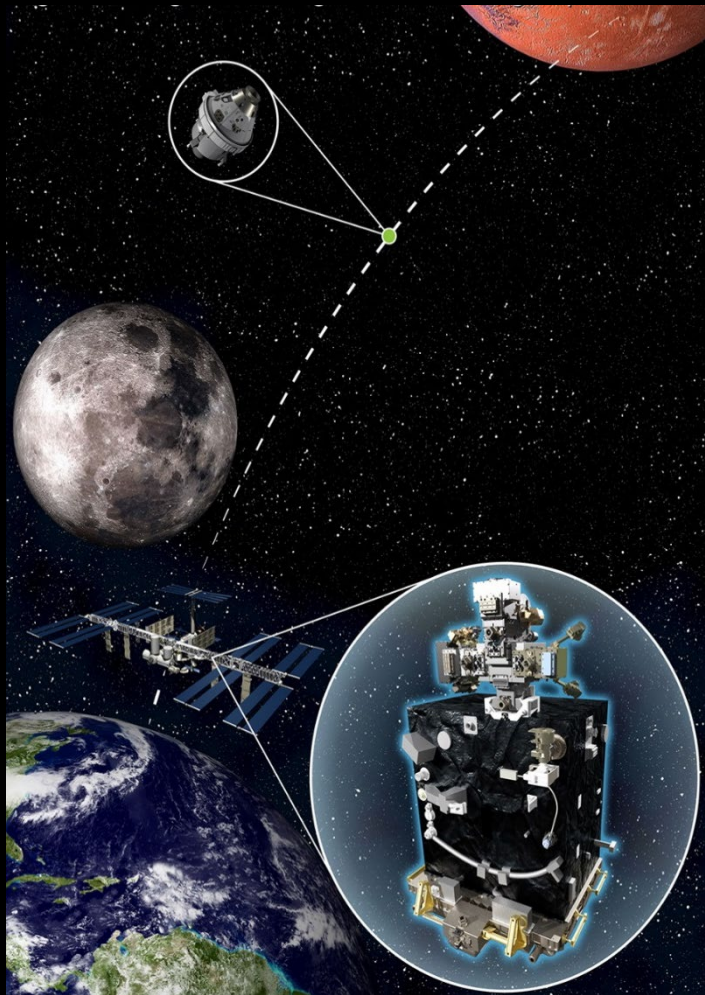


# International Space Station Projects

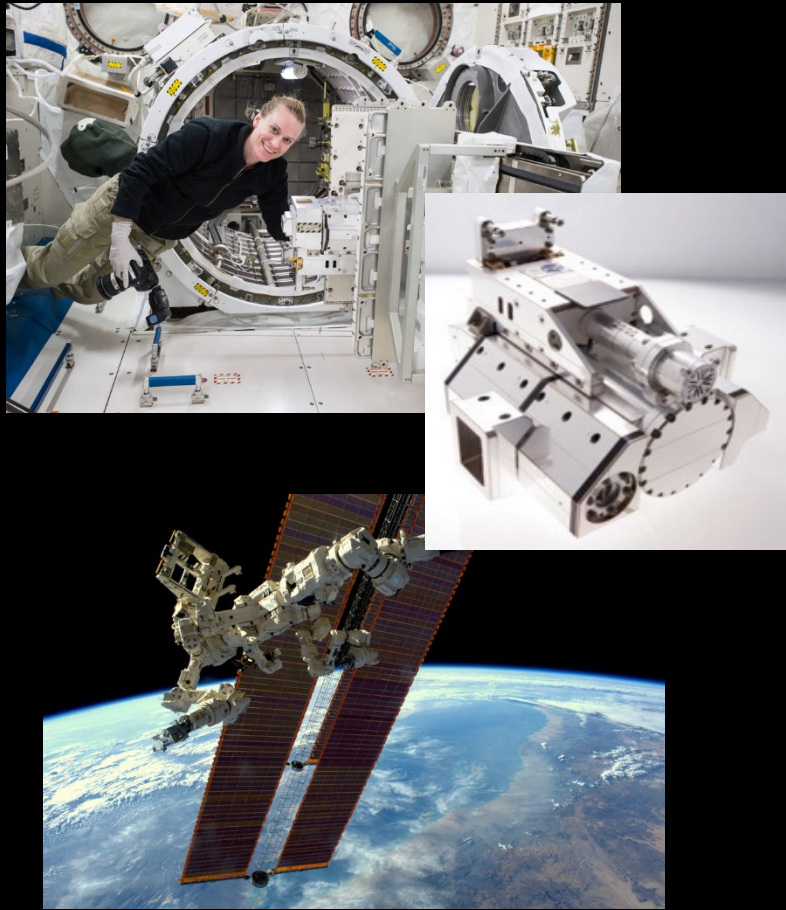
**Raven** - a technology-filled test module on that is helping NASA test key elements of a new spacecraft autopilot system, and bring NASA one step closer to having a relative navigation system.



**Robotic Refueling Mission 3 -** demonstrate the techniques needed to store and transfer cryogenic fluid in orbit, which is important for human exploration.

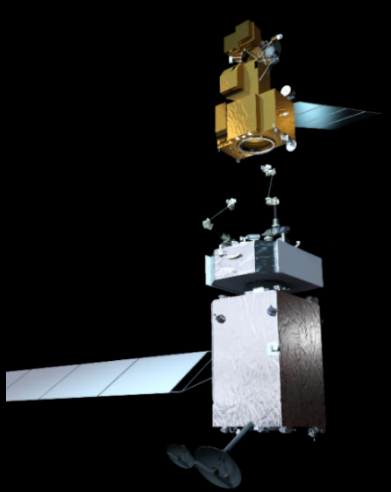


**Robotic External Leak Locator -** helps locate and precisely characterize leaks, eliminating the need for risky spacewalks. RELL can also be used in other contexts in-orbit to identify leaks.



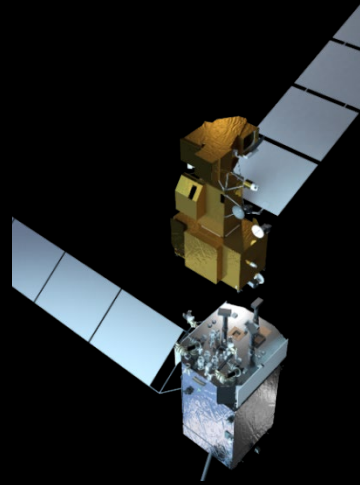
# Restore-L

1. Demonstrate national satellite servicing, assembly, and manufacturing capabilities in first-of-its-kind mission
2. Advance essential technologies for exploration, science, and national security
3. Kick-start a new U.S. commercial servicing industry, establishing best practices



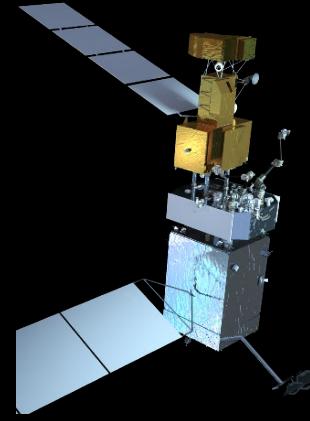
1

Autonomous  
Rendezvous,  
Inspection



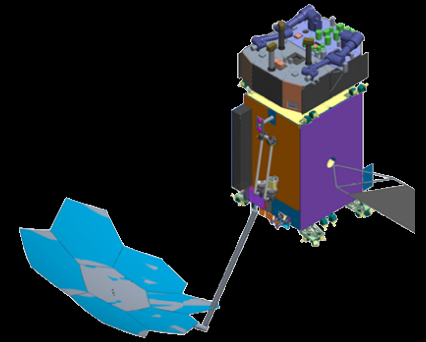
2

Autonomous  
Capture



3

Telerobotic  
Refuel  
& Relocate

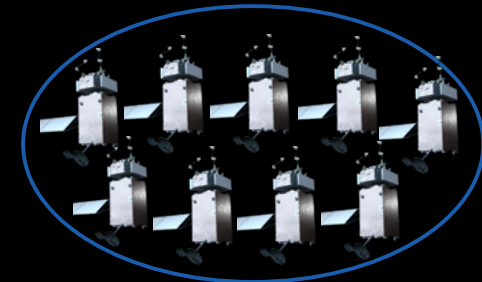
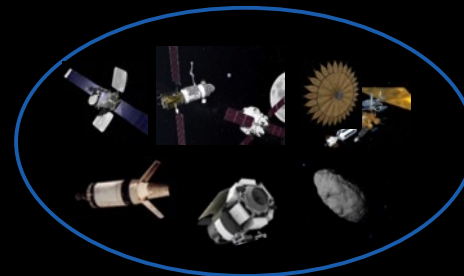


4

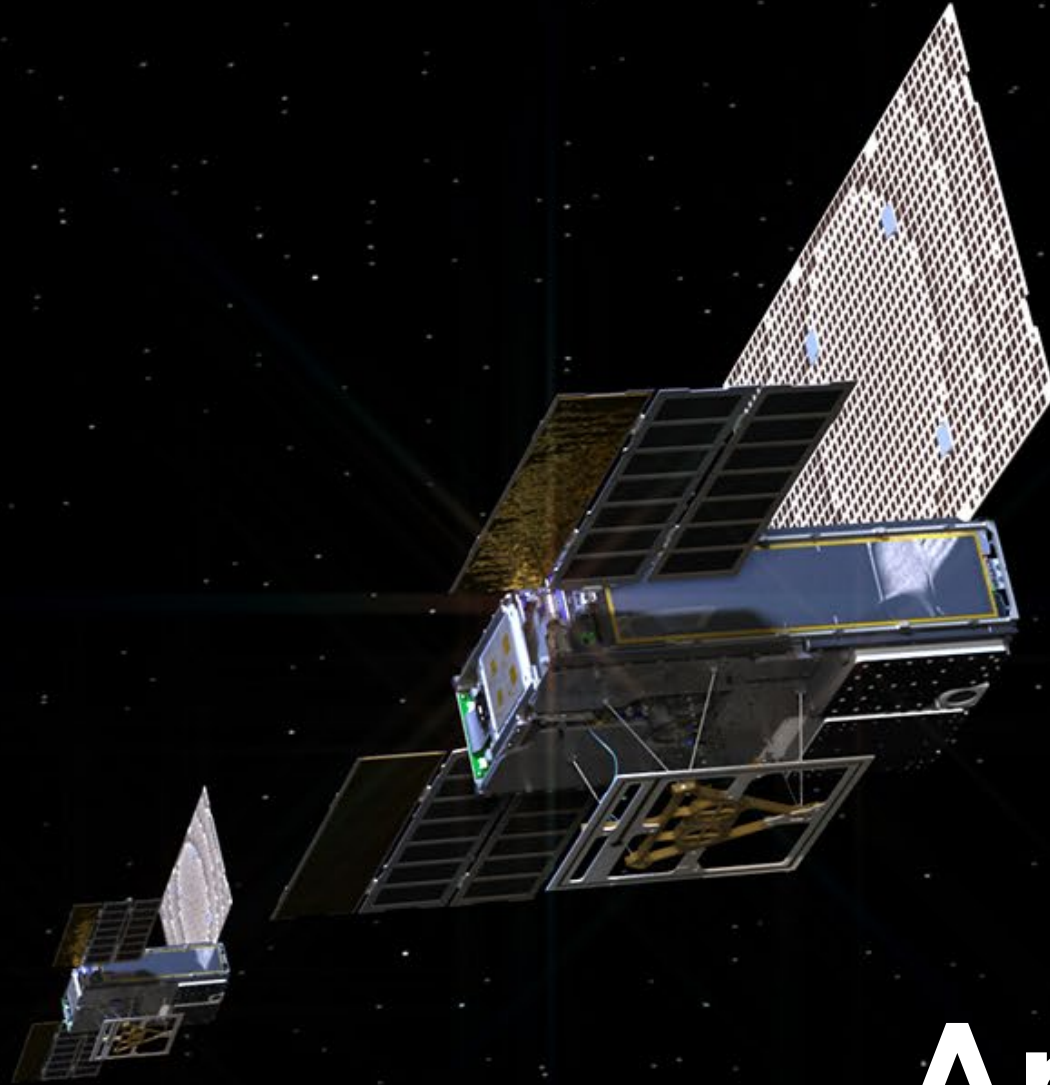
Telerobotic  
Assembly  
& Manufacture

Ongoing

Tech Transfer to U.S.  
Government and Industry







# Small Sat Applications?

# Buddy Sat

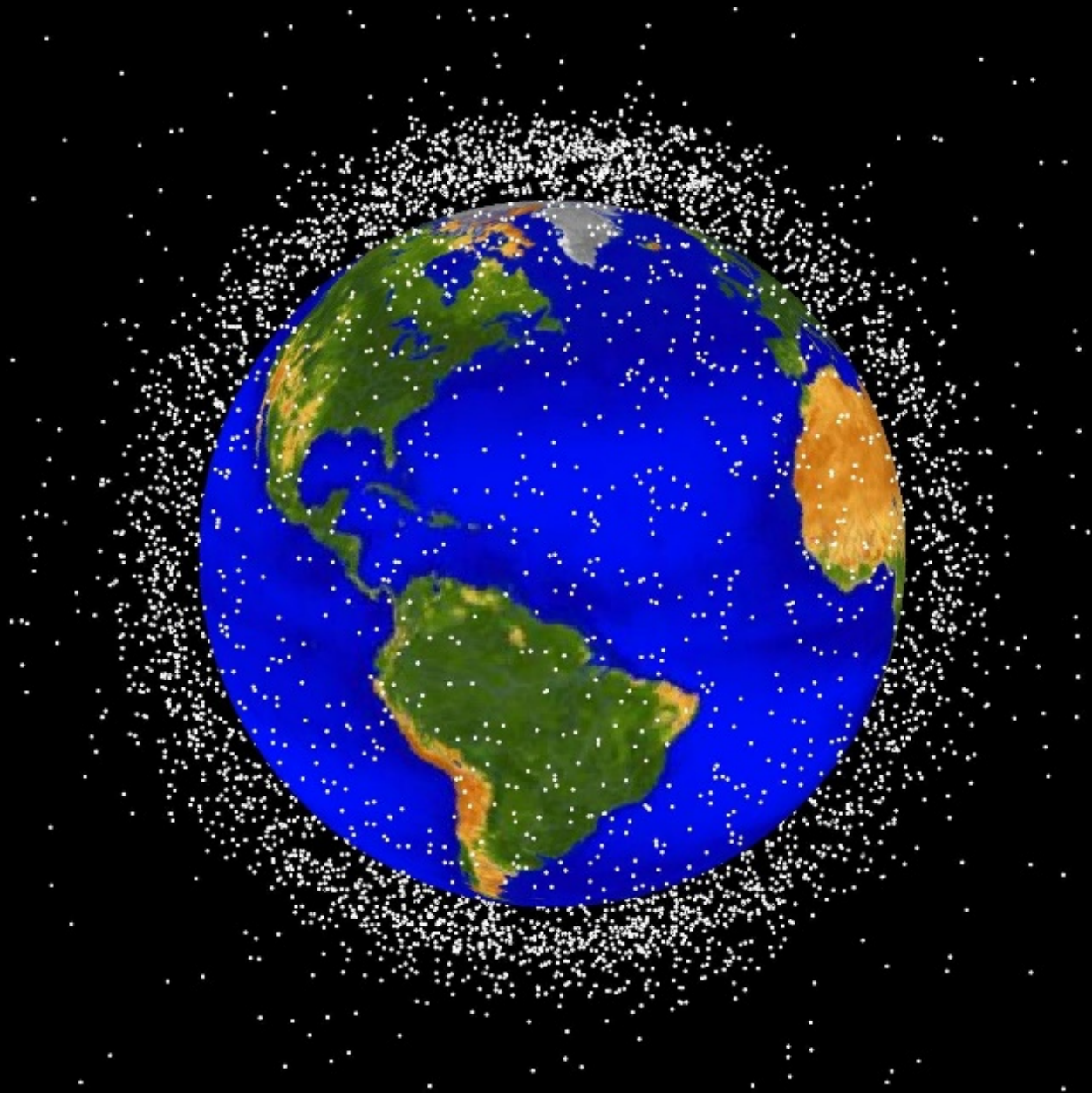
- Deployment(s) monitoring
- Inspection
- Situational awareness
- Servicing helper
- Publicity imaging





# Relocation

- Small sat servicer
- Small sat clients
- Delta-V intensive maneuvers: large plane changes or altitude raising/lowering
- Rapid maneuvering – chemical servicer with EP client
- Active orbital debris removal



# Persistent Platform

- Resupply of platform (ferry new payloads)
- Inspection of platform (buddy sat)
- Construction of small sats





