OSAM: Autonomy & Dexterous Robots

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NASEM DMMI Workshop
Logistics and Manufacturing Under Attack
04 June 2021

National Space Strategy

March 23, 2018

Space Policy Directive – 1

The National Aeronautics and Space Administration (NASA) to return American astronauts to the moon for long-term exploration and utilization, followed by human missions to Mars and other destinations.

National Space Strategy 2018

(U) **On-orbit Servicing and Manufacturing**. Explore new capabilities to **service, manufacture, and assemble space systems.** Develop and demonstrate satellite servicing technologies to support a nascent commercial satellite industry, as well as application by NASA, DOD, and Other government agencies. Enable an industry-led consortium to establish publicly available standards and operational safeguards for commercial satellite servicing using rendezvous and proximity operations.

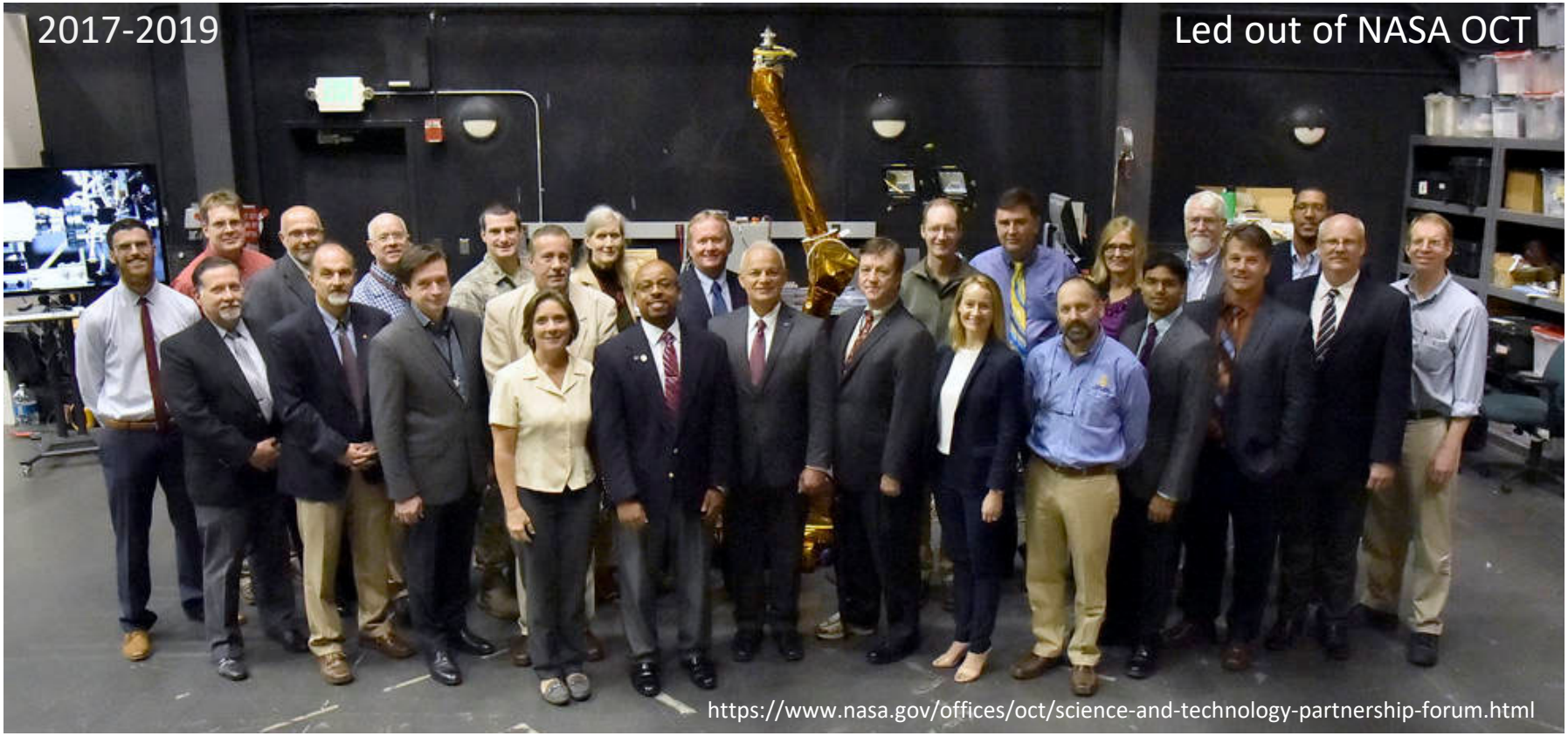
(U) **Lead: NASA** and DOD
(U) Supporting DOS and DOC
(U) Resources/Authorities required: NASA FY 2018 budget request of $74.0 million, **With outyear funding** / Covered under existing authorities in Title 51.
(U) Timeline: Continuous program
(U) Measure of Performance: Number of technologies developed and transferred between the government and industry; demonstration ff on-orbit mission extension, servicing, assembly, and manufacturing; and as appropriate, defined voluntary standards and operational practices for on-orbit servicing capabilities.

NASA CALLED TO LEAD IN TWO AREAS

1. Exploration

2. OSAM

OSAM ISA S&T Partnership Forum



- Opening the doors to assembling habitats away from the safe harbor of low-Earth orbit and building large telescopes
- Working together to identify common needs and capabilities for in-space assembly

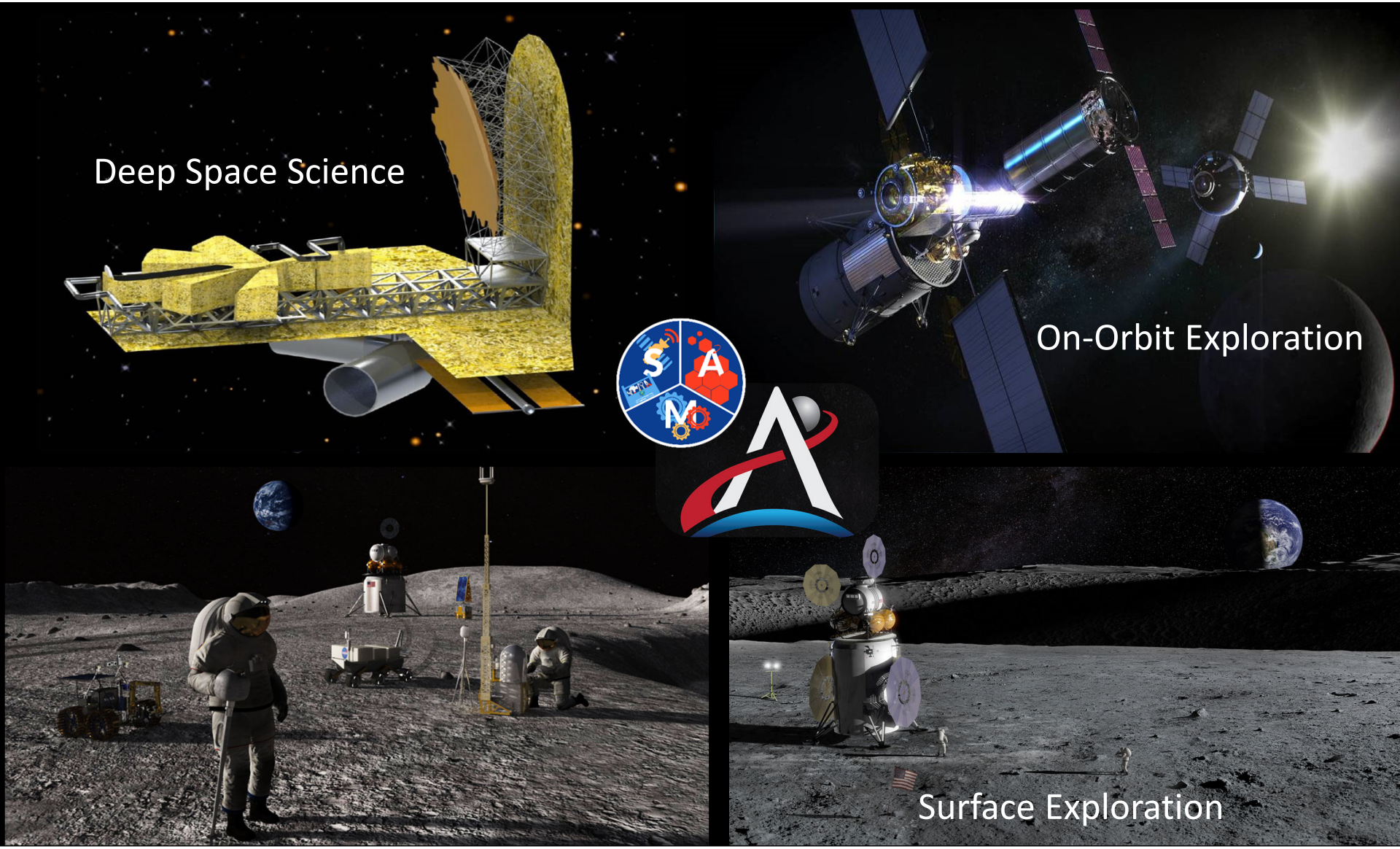
Why OSAM?

On-Orbit Servicing, Assembly, & Manufacturing

- High value satellites are isolated with few **servicing** opportunities to correct problems, refuel, etc. [DARPA].
- Gravity prevents manufacture of some structures (e.g. ultra-thin mirrors, gossamer structures). Reduce upmass. Why launch resources that can be harvested and/or **manufactured** in-situ?
- Launch fairings limit payload size and weight and therefore design. Modular **assembly** enables large and evolvable systems that can rapidly adapt to changes in mission needs or recover from induced damage.
  - A few modules types can be used to build a variety of systems (e.g., planar arrays, telescopes, fuel depots, platforms)
  - Pay as you go: many launches, instrument replacement/augmentation, etc.

- Automated/Autonomous dexterous robotics is the “glue” that enables these complex OSAM systems

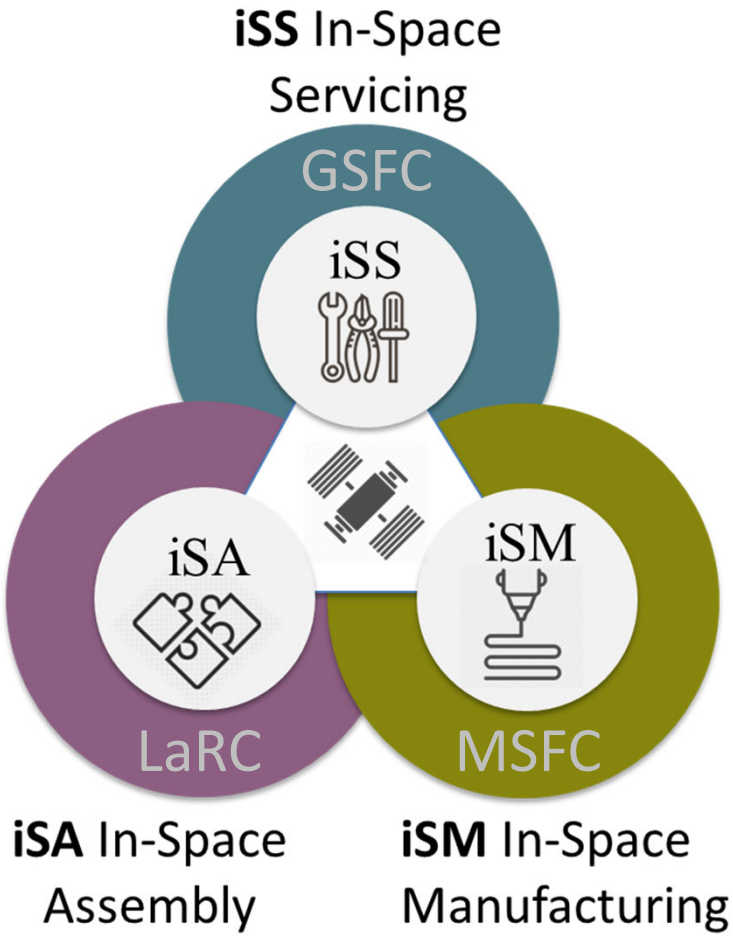
Performance, Pace, & Persistence



On-Orbit Servicing, Assembly, & Manufacturing

OSAM is an emerging set of capabilities that enables servicing, repair, upgrade, modular assembly, and inspection of space assets

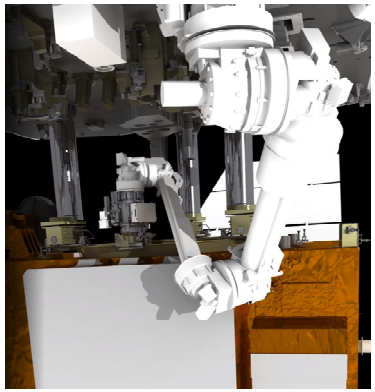
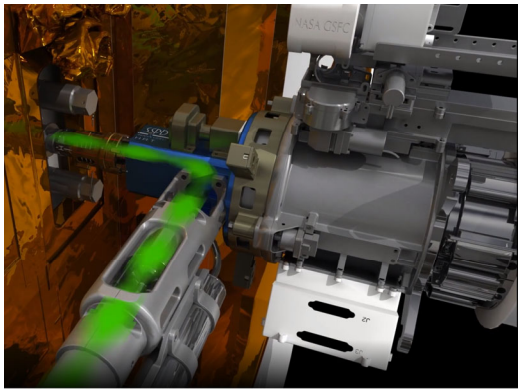
- ***Servicing* is the on-orbit alteration** of a satellite after its initial launch using another spacecraft
- ***Assembly* involves on-orbit aggregation of components** to constitute a spacecraft into a shape or configuration that cannot be achieved with traditional deployment methods and available launch vehicles
- ***Manufacturing* involves on-orbit transformation of raw materials** into usable spacecraft components



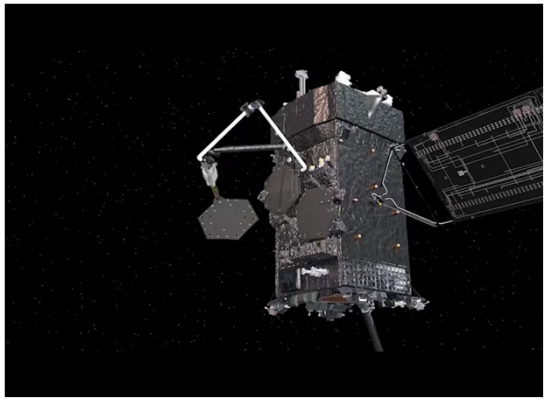
OSAM capabilities combine multiple technologies to enable new missions previously considered impossible…

OSAM-1 Servicing Mission

- Formerly known as Restore-L. Added SPIDER payload.
- RESTORE-L
  - Servicing mission for a government-owned satellite
  - Rendezvous with, grasp, and refuel

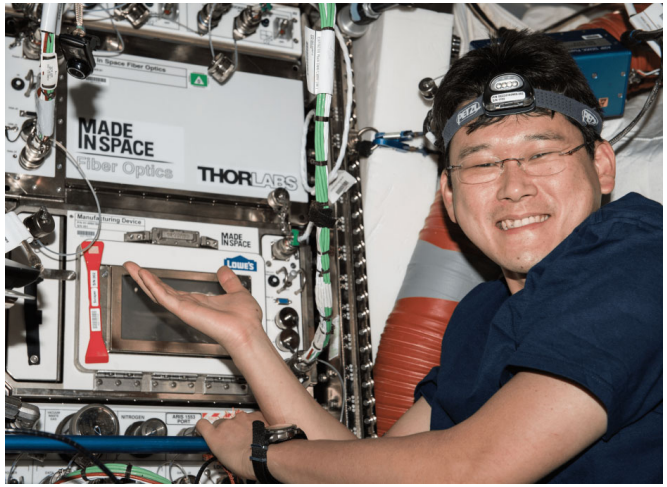




- SPIDER: Space Infrastructure Dexterous Robot (née Dragonfly)
  - A third lightweight 16-foot (5-meter) robotic arm
  - Assembly pathfinder to form a seven-element 9-foot (3-meter) Ka-band antenna
  - Manufacturing pathfinder for a 32-foot (10-meter) lightweight composite beam (Tethers Unlimited)
- Scheduled Launch: 2024 (TBC)
- Managed by GSFC



OSAM-2 Manufacturing Mission

- Formerly known as Archinaut
- PPP with Made in Space, Inc.
- Manufacturing Mission with Assembly Pathfinder
  - 3D print two beams that extend nearly 33 feet from each side of the spacecraft.
  - Unfurl solar arrays that can generate up to 5x more power than traditional (smaller) solar panels on similar-sized spacecraft.



- Scheduled launched: No Earlier Than 2022 (TBC)
- Managed by MSFC

OSAM: In-Space Assembly (ISA)

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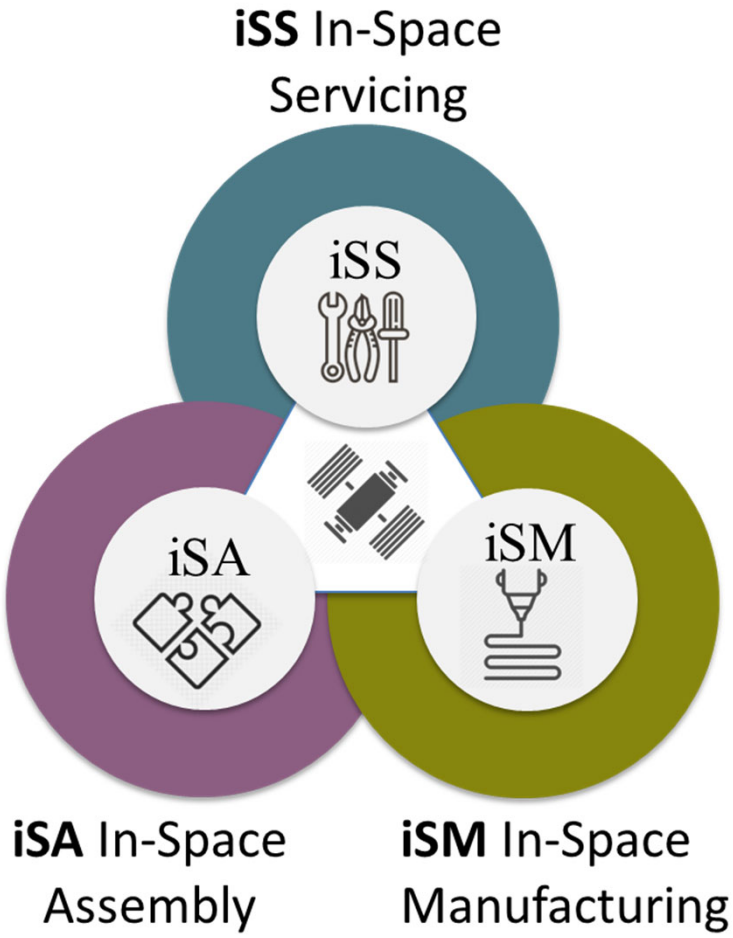
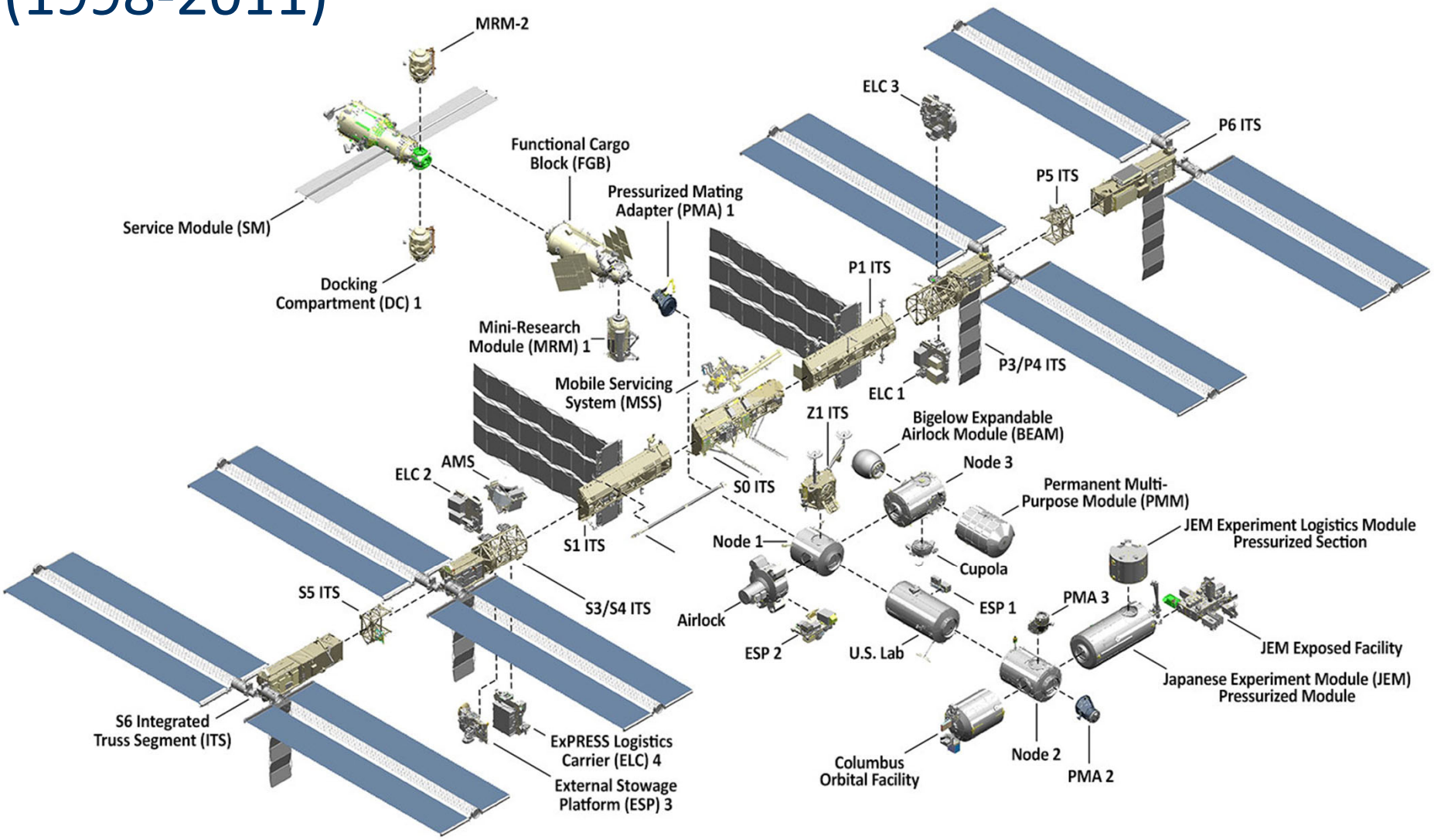


OSAM capabilities combine multiple technologies to enable new missions previously considered impossible…

ISS: In-Space Assembly

(1998-2011)



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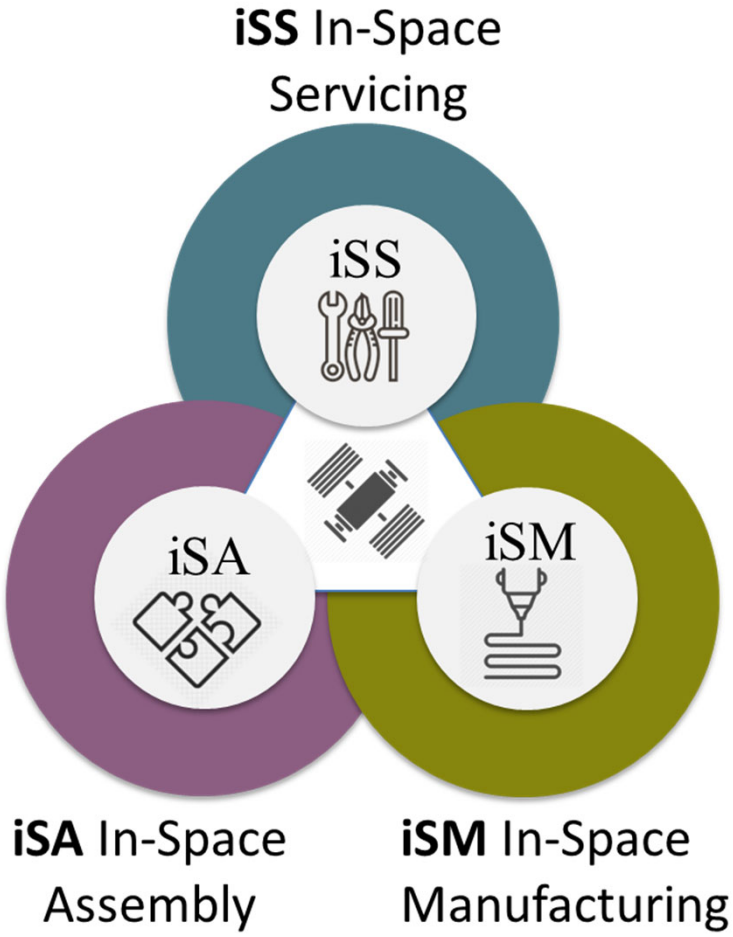

OSAM capabilities combine multiple technologies to enable new missions previously considered impossible… and demand autonomy!

OSAM: AUTONOMOUS In-Space Assembly

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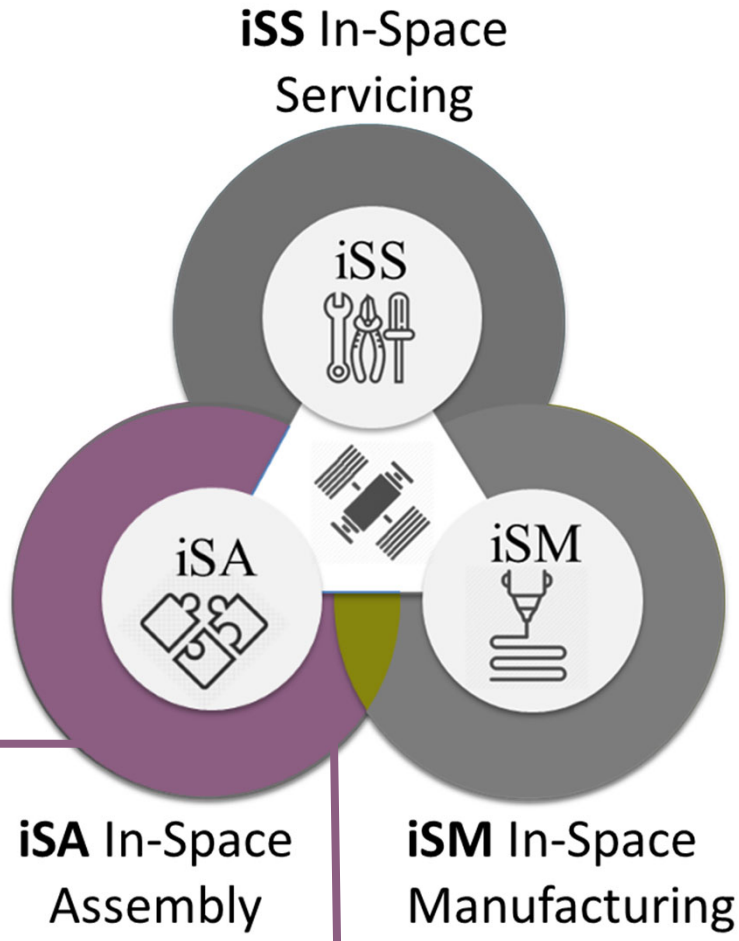
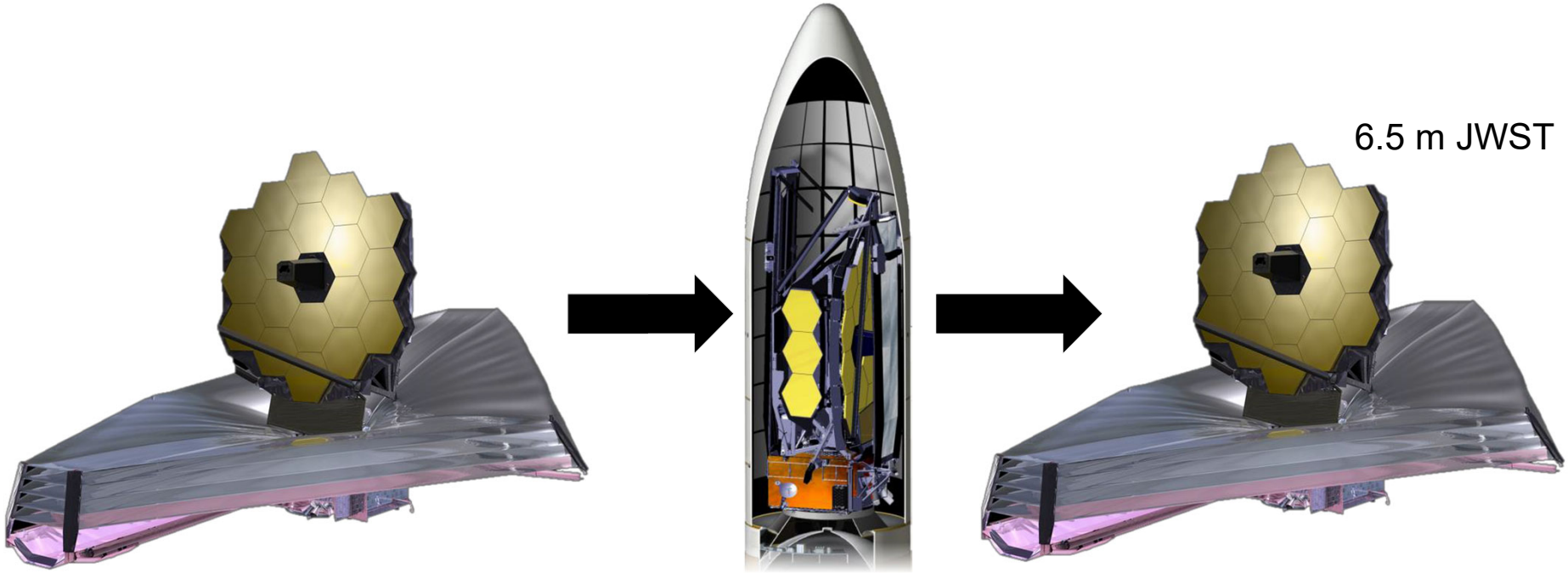


OSAM capabilities combine multiple technologies to enable new missions previously considered impossible… and demand autonomy!

The Current Fairing Paradigm

In-Space Deployment



volume and mass constraints

$$$  **Risk**

Currently, no existing LV to fly an 8 meter segmented telescope

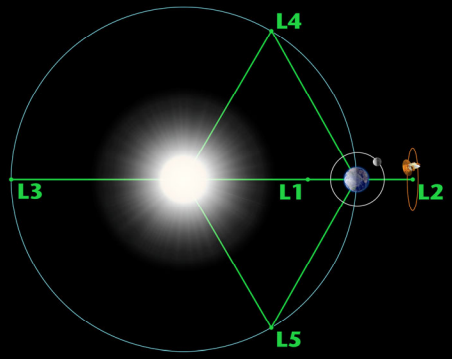
- **20 deployable events**
- **40 deployable structures**
- **178 release mechanisms**

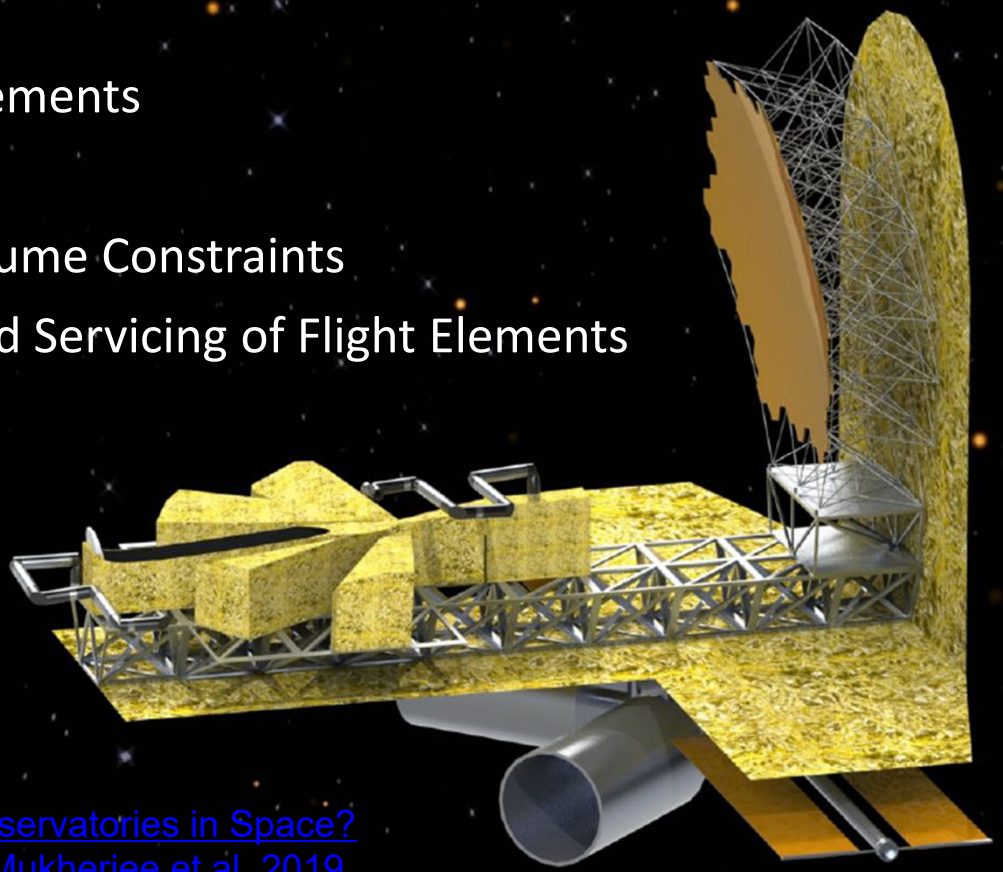
In-Space Assembled Telescope Study (iSAT)

20 m Segmented UV/V/NIR Telescope

Key Design Features

- Modularized Flight Elements
- Multiple Launches
- Relaxed Mass and Volume Constraints
- In-Space Assembly and Servicing of Flight Elements



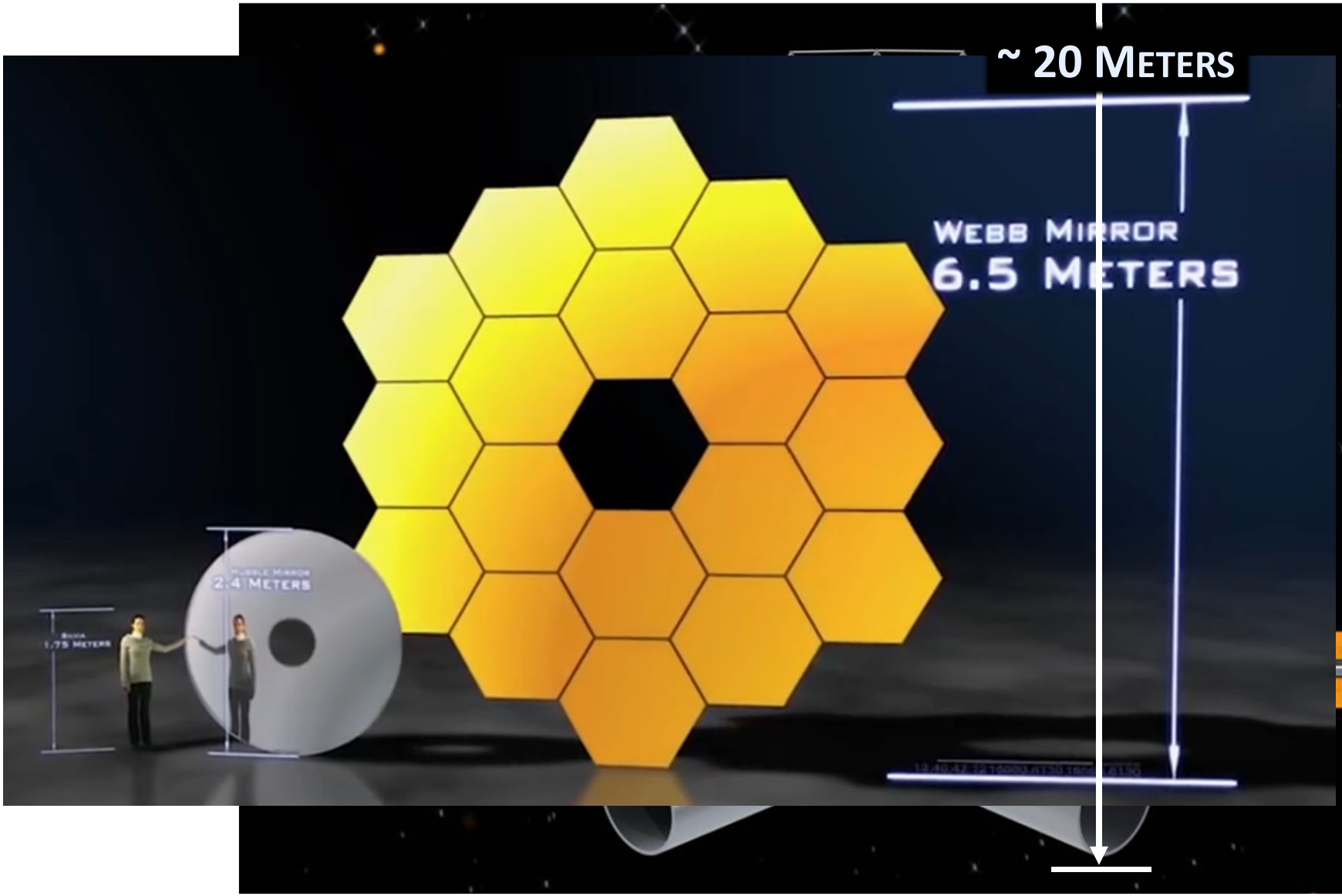


20 Meter Primary

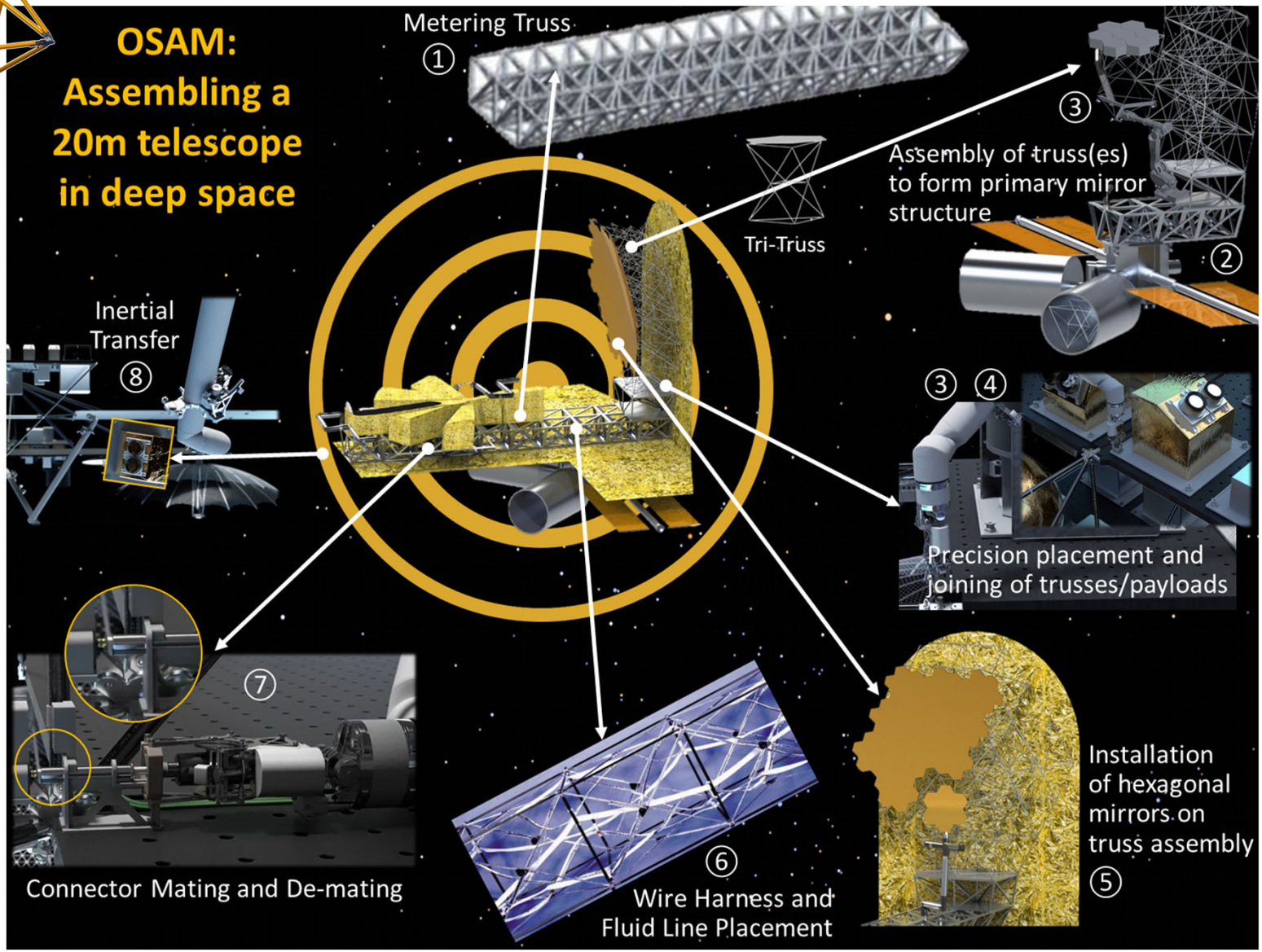
When is it Worth Assembling Observatories in Space? Astro 2020 APC Whitepaper, R Mukherjee et al. 2019

https://exoplanets.nasa.gov/exep/technology/in-space-assembly/iSAT_study/

Telescope Mirrors

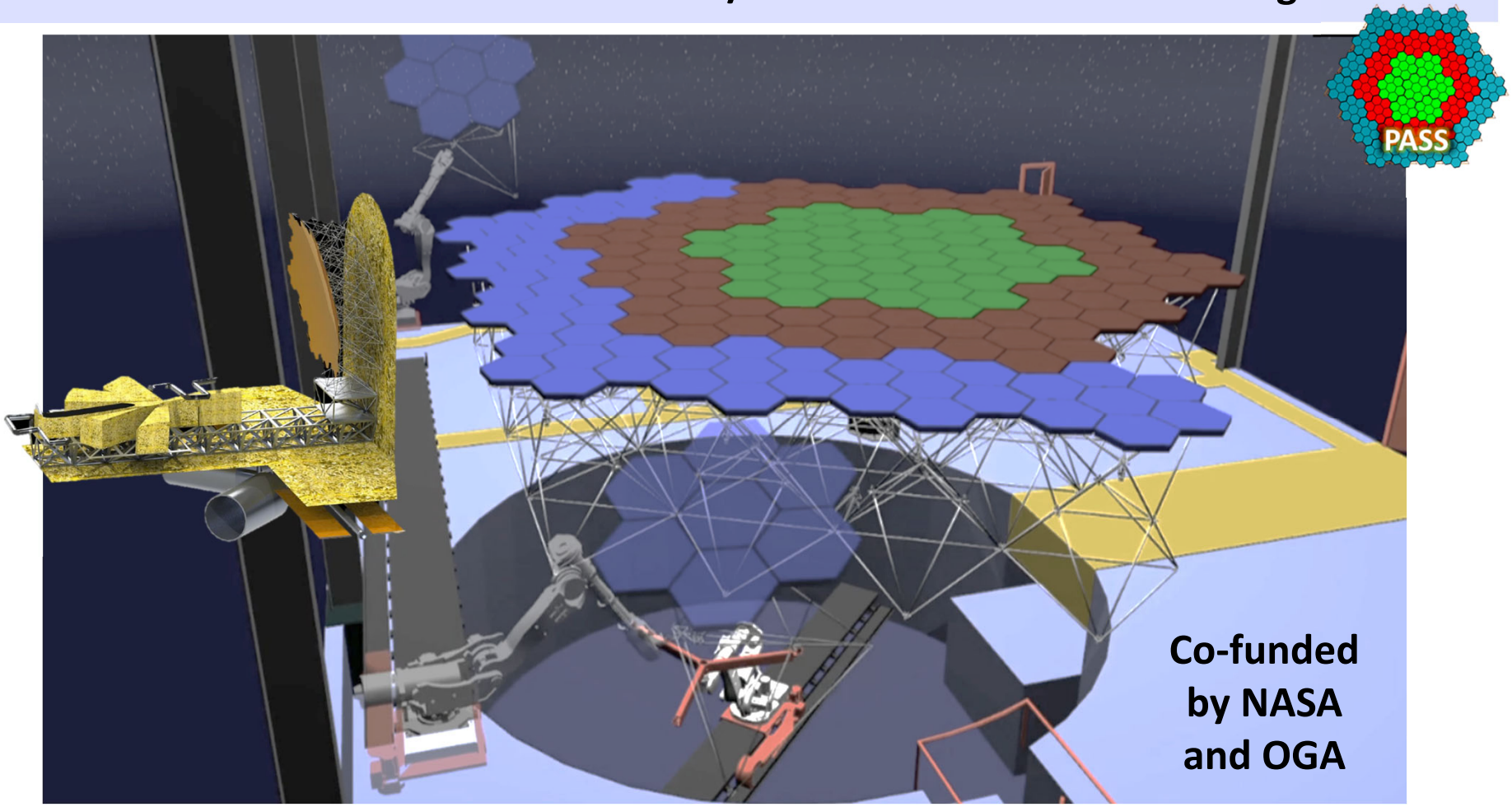


iSAT OV-1/Storyboard



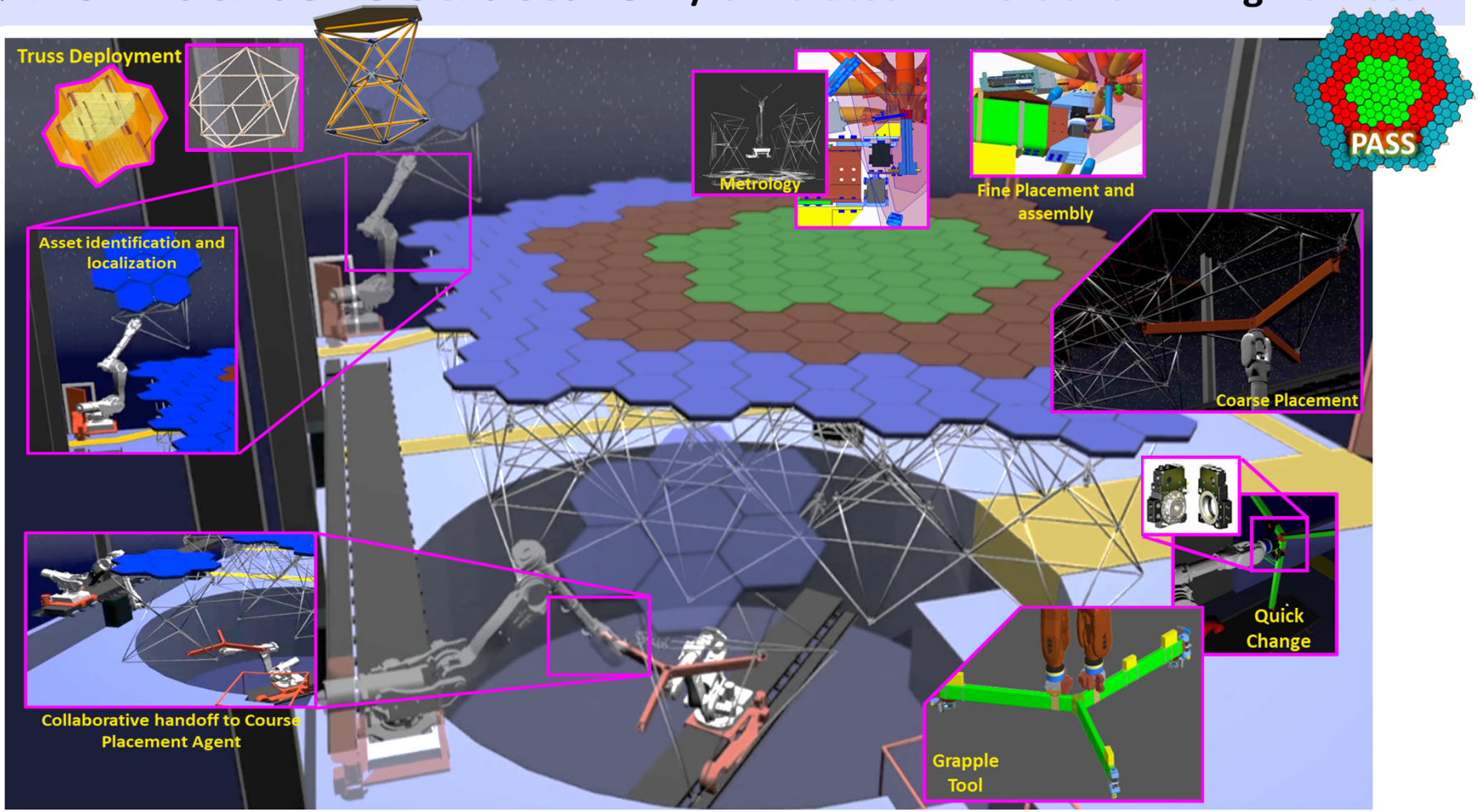
PASS: Precision Assembled Space Structure

Autonomous Modular Assembly of 20m-class Path-to-Flight Mirror Backbone Structure w/ Simulated Mirrors and Wiring Harness



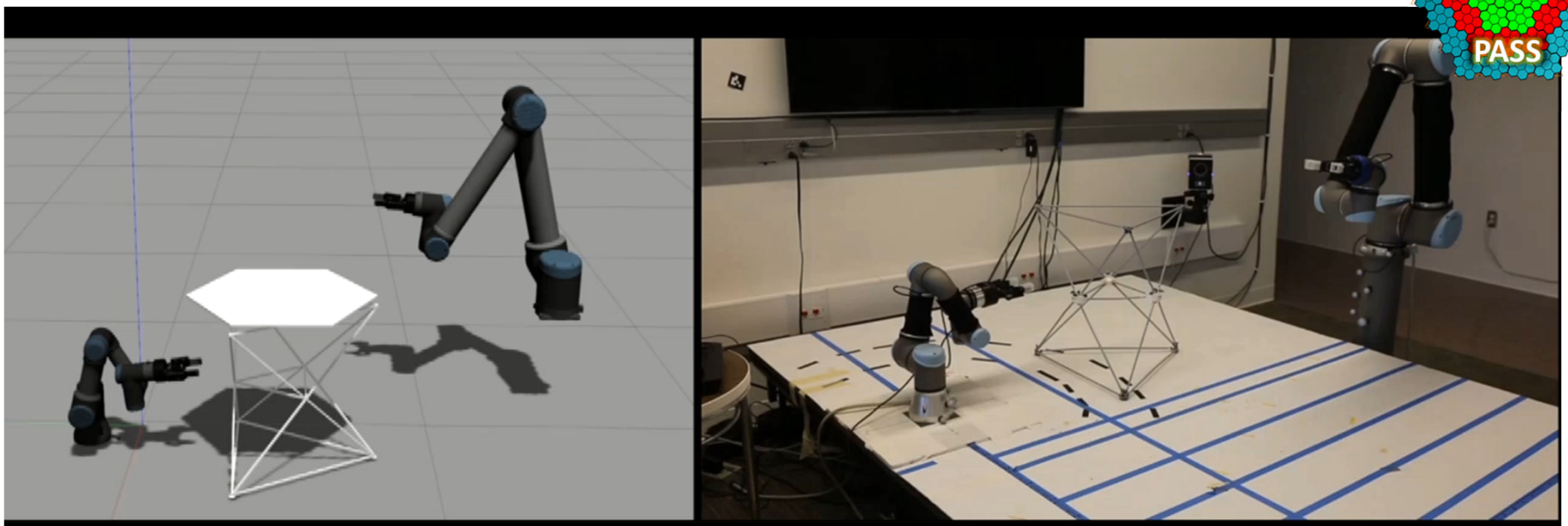
PASS: Dexterous Robots

Autonomous Modular Assembly of 20m-class Path-to-Flight Mirror Backbone Structure w/ Simulated Mirrors and Wiring Harness



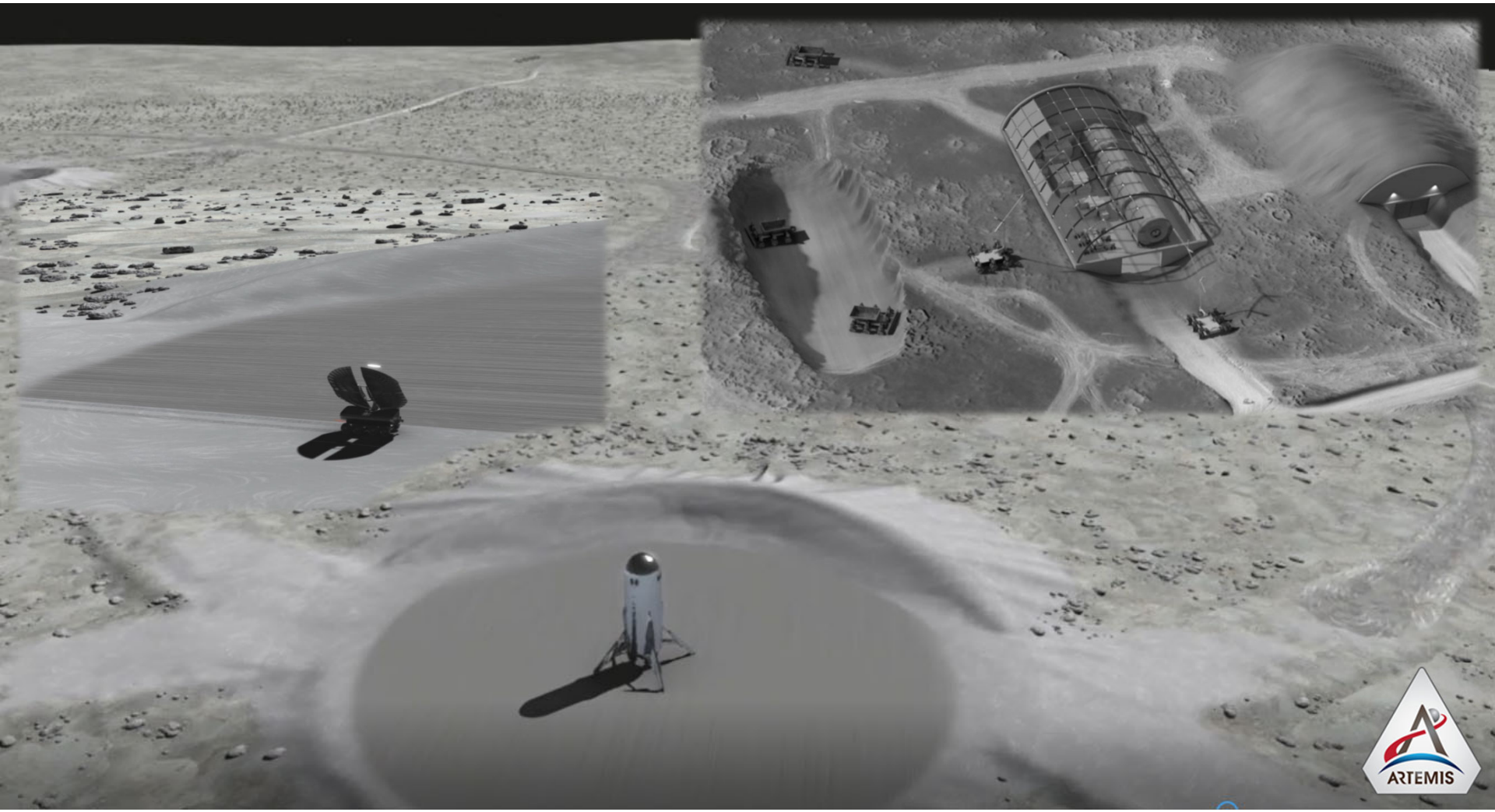
PASS: Collaborative Robotics

Autonomous Modular Assembly of 20m-class Path-to-Flight Mirror Backbone Structure w/ Simulated Mirrors and Wiring Harness



Autonomous Robotic Multi-Agent Collaborative Operations
Sim-To-Flight & Digital Twin

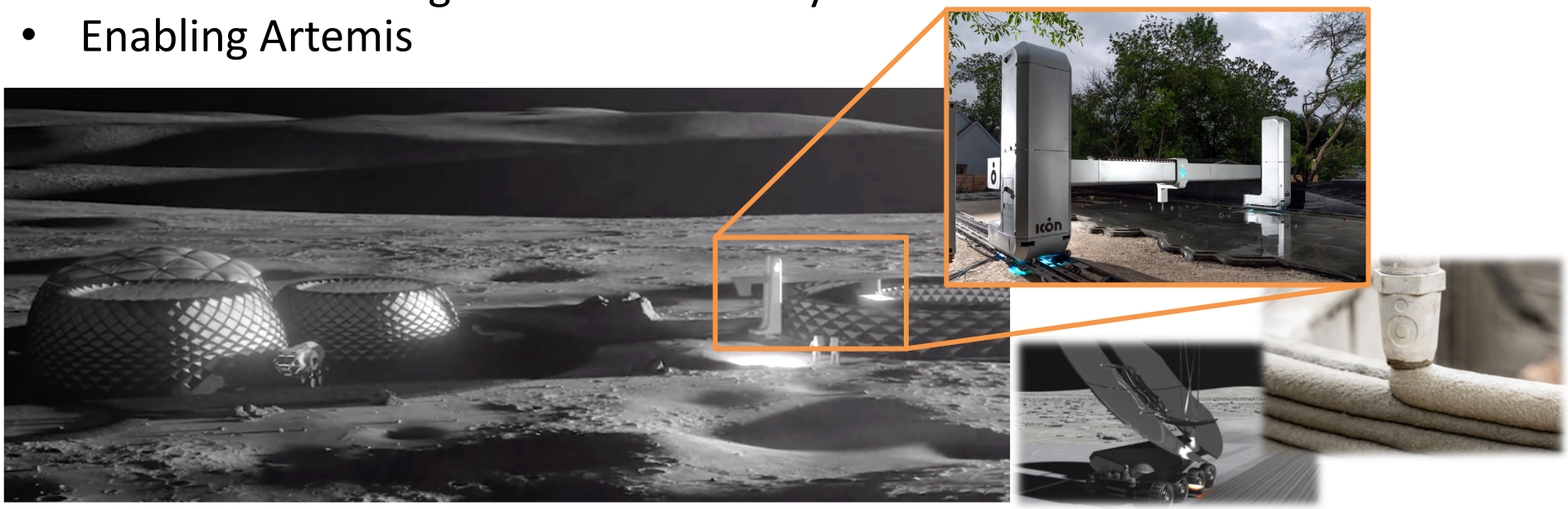
Sustainable Lunar Exploration



OSAM is the Foundation for Sustainable Lunar Exploration

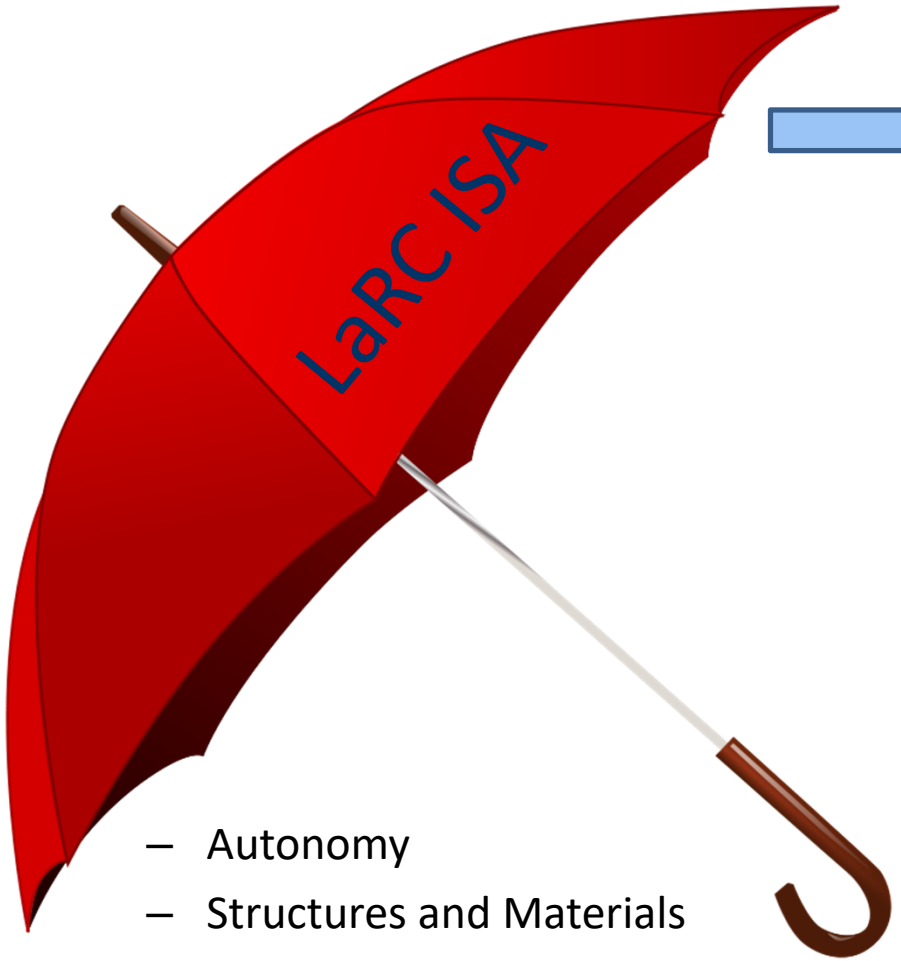
Moon-to-Mars
Planetary Autonomous Construction Technology

- Managed by MSFC
- IRSU+AM+ISA+Autonomy to build infrastructure on the Moon
- ICON working with MSFC to test lunar soil simulant with various processing and printing technologies. https://www.iconbuild.com/technology/space
- NASA LaRC leading ISA and Autonomy R&D
- Enabling Artemis



https://www.nasa.gov/centers/marshall/news/releases/2020/nasa-looks-to-advance-3d-printing-construction-systems-for-the-moon.html

OSAM/ISA is a Big Umbrella



- Autonomy
- Structures and Materials
- Modeling and Simulation
- System Architecture and Analysis

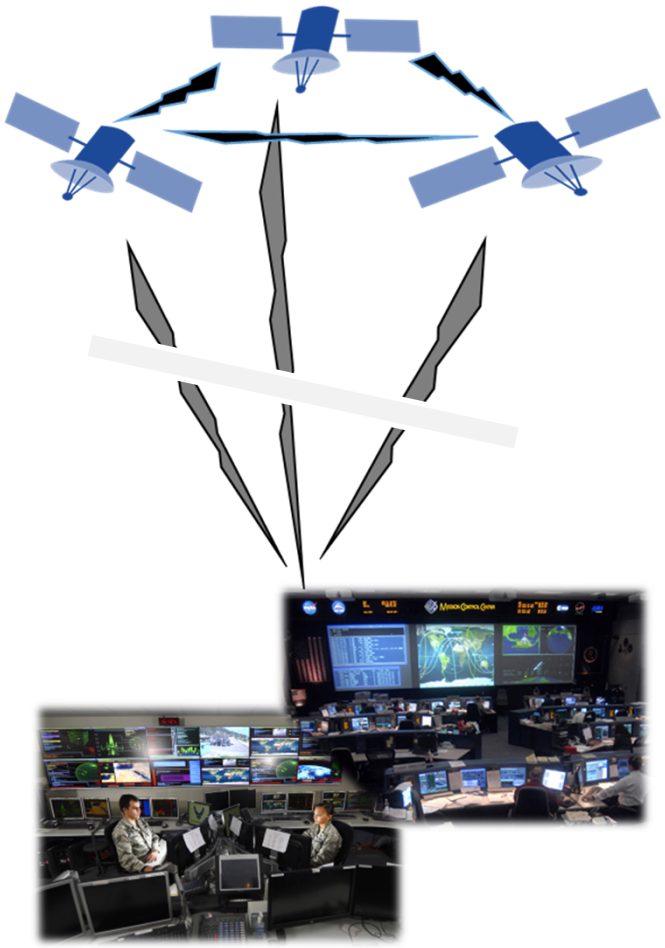
Broad Definition of "Assembly"

- Persistent Surface Infrastructure
  - Safe Haven
  - Autonomous Mobility
  - Launch and Landing
  - Power and Data Distribution
- Persistent Space Assets
  - Transport
  - Observatory
  - Platforms

MIRAAMOS

Mesh-based Intelligent Reconnaissance and Autonomous Assembly for Multi-agent Observations and Surveillance

- **MIRAAMOS = Formation Flight + Autonomous ISR**
- **External funding for SmallSat cluster formations:**
  - Develop and demonstrate
    - Autonomous formation flying
    - Autonomy capabilities for multi-agent persistent observation applications
  - Mature mesh network topology approach
  - Enable heterogeneous teams
- **Internal IRAD effort adds machine "intelligence"**
  - Data-driven ISR and earth science observations will increase detection pace, quality and improve SA
  - Human-machine teaming methods to maintain operator situational awareness for remote assets
  - Enabling NASA Science and DoD ISR needs
    - Earth Science: Cloud modeling, contamination, etc.
    - Planetary Science: Surface mapping, dynamic comms, grid management, etc.



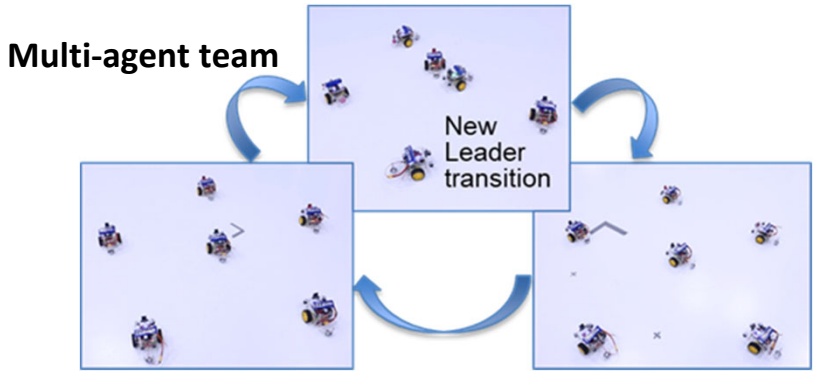
Multi-Agent Clusters for Persistent Observations from Space

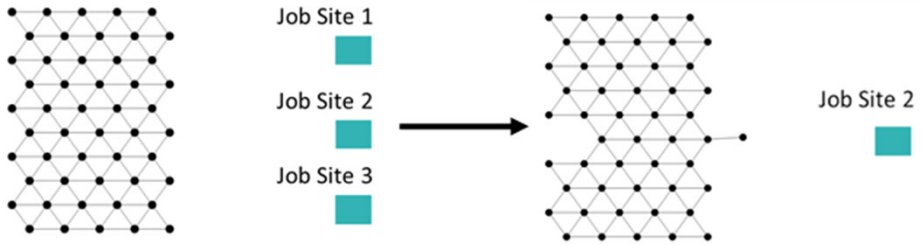
Objectives

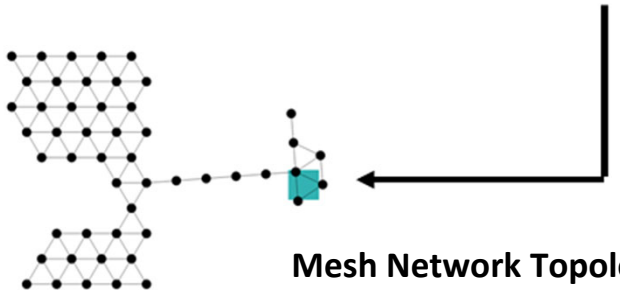
- Develop and demonstrate autonomy capabilities for multi-agent persistent observation applications
- Mature mesh network topology approach
- Enable heterogenous teams
- Develop human-machine teaming methods to maintain operator SA for remote assets

Impact

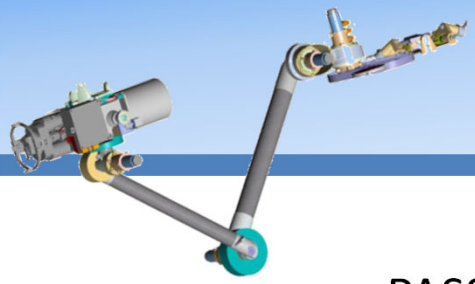
- Data-driven ISTR and earth science observations will increase detection pace, quality and improve situational awareness
- Enable planetary science surface mapping, dynamic communication, grid management, etc.
- Navigation aids
- Advance aviation safety and efficiency for advanced air mobility





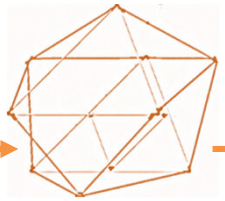


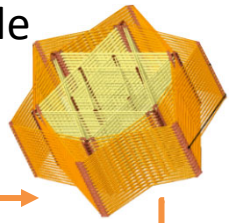
Dexterous Robots (+ Autonomy)



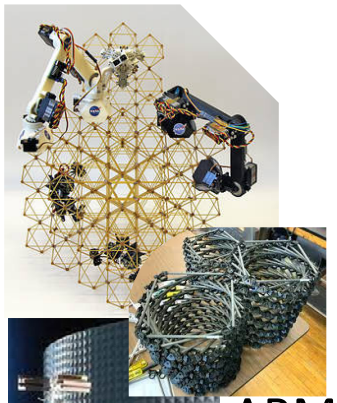
Collapsible

PASS
Tri-Truss Module

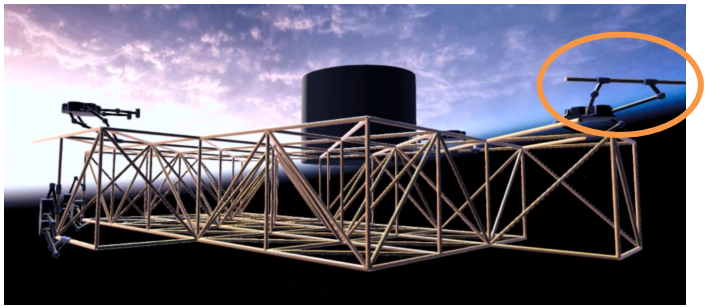




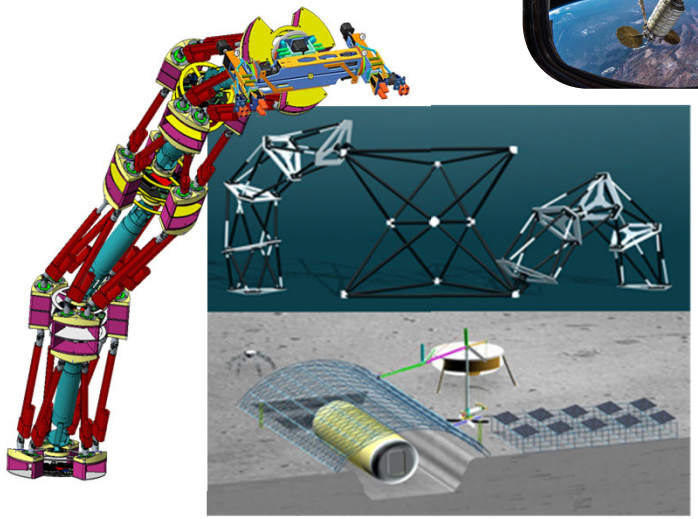
Deployable



ARMADAS
Voxel Module



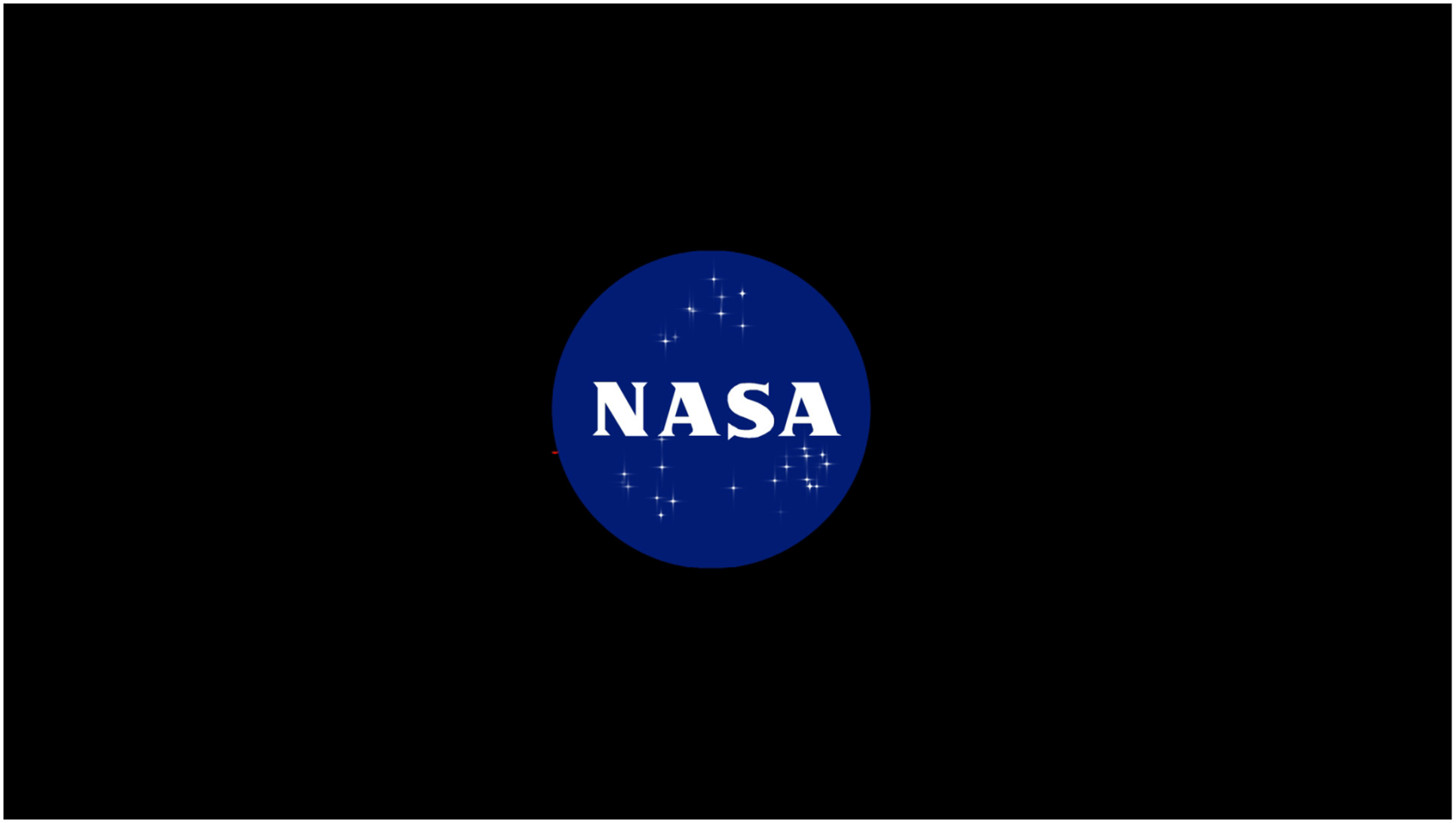
Strut Module
[Electrodynamic Technologies LLC]



ASSEMBLERS
Stewart Platform

Autonomous Dexterous Robotic Systems

The “glue” that enables OSAM



https://www.youtube.com/watch?v=FK8gD5PY-Ng

danette.allen@nasa.gov @DrDanetteAllen http://autonomyincubator.blogspot.com/

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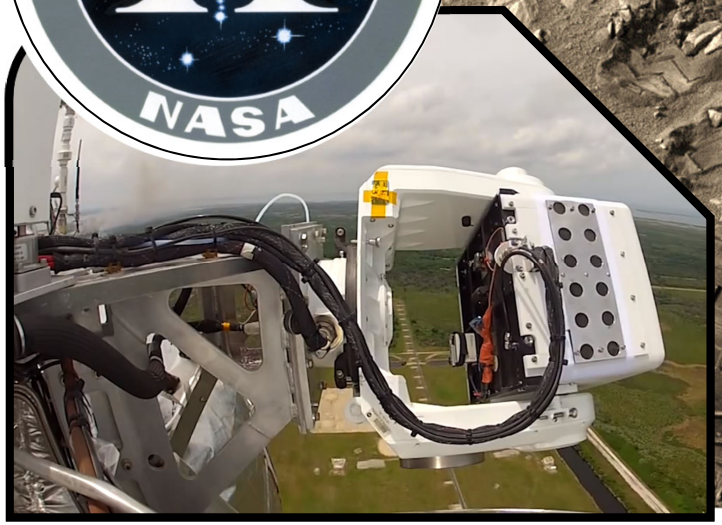

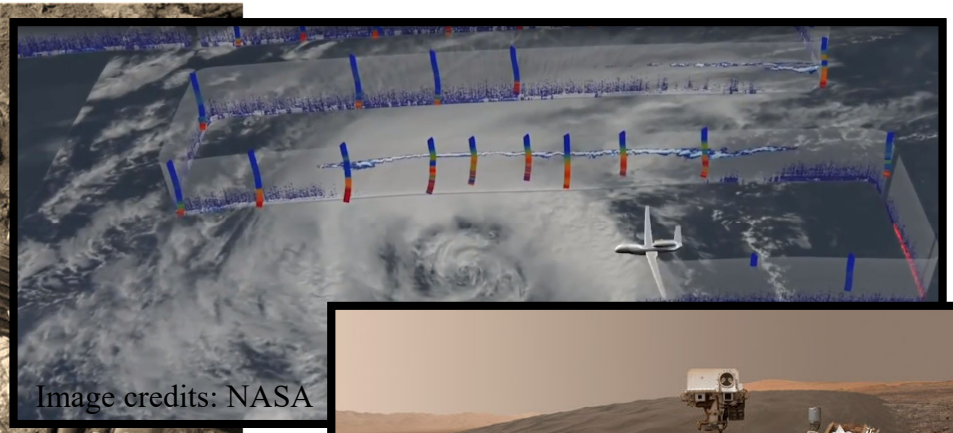

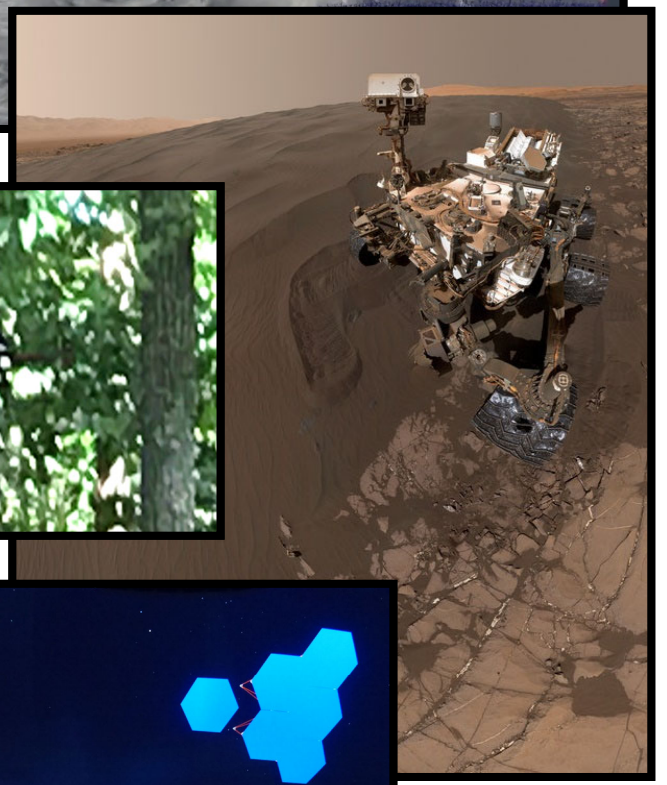

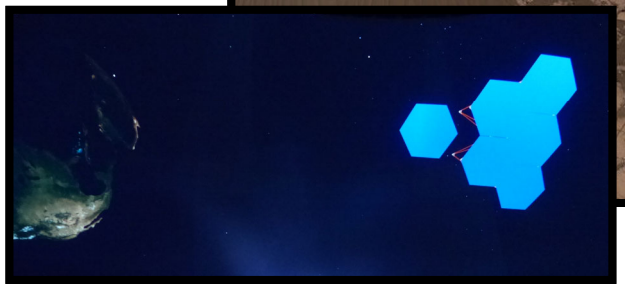

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