

OSAM: Autonomy & Dexterous Robots

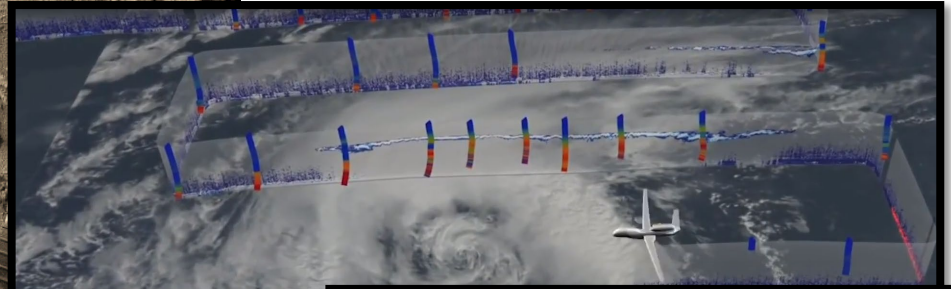
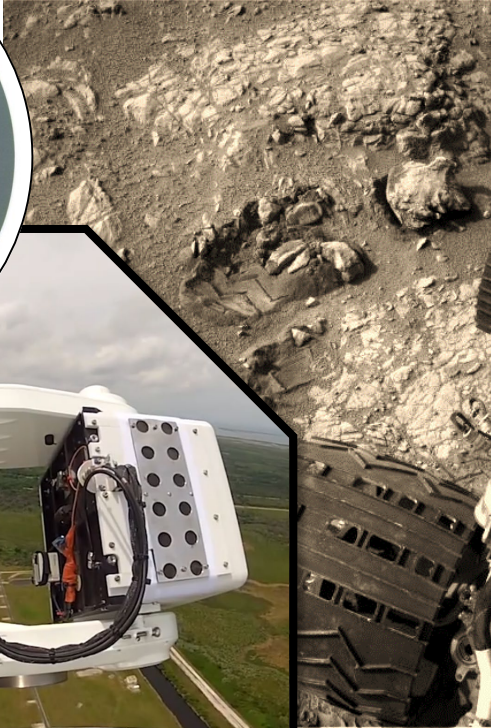
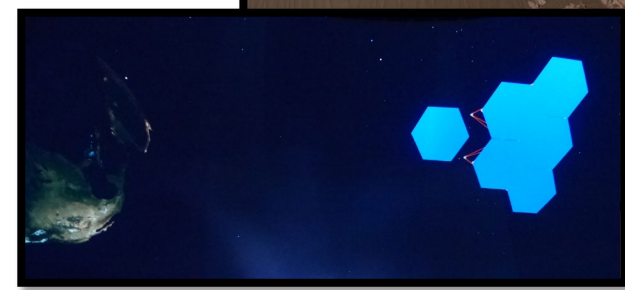
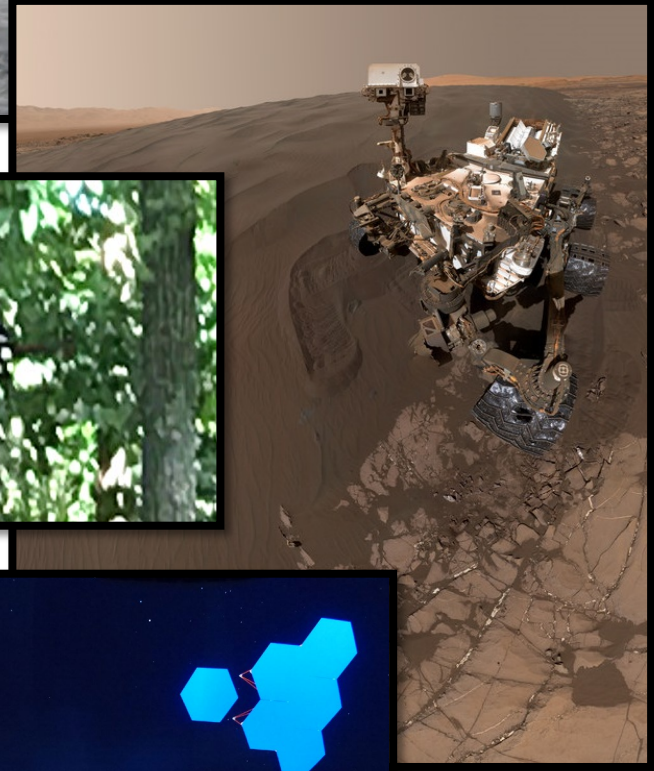
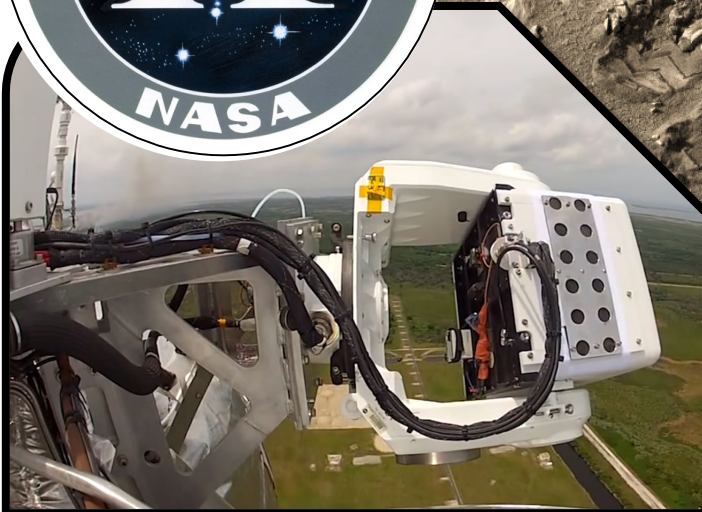


Image credits: NASA

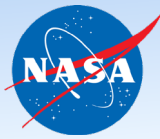


B. Danette Allen, PhD
ST for Intelligent Flight Systems
Deputy Lead for Autonomous Systems SCLT

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 of 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

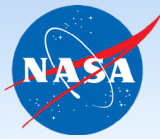
1. Exploration



2. OSAM



Why OSAM?

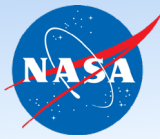


On-Orbit Servicing, Assembly, & Manufacturing

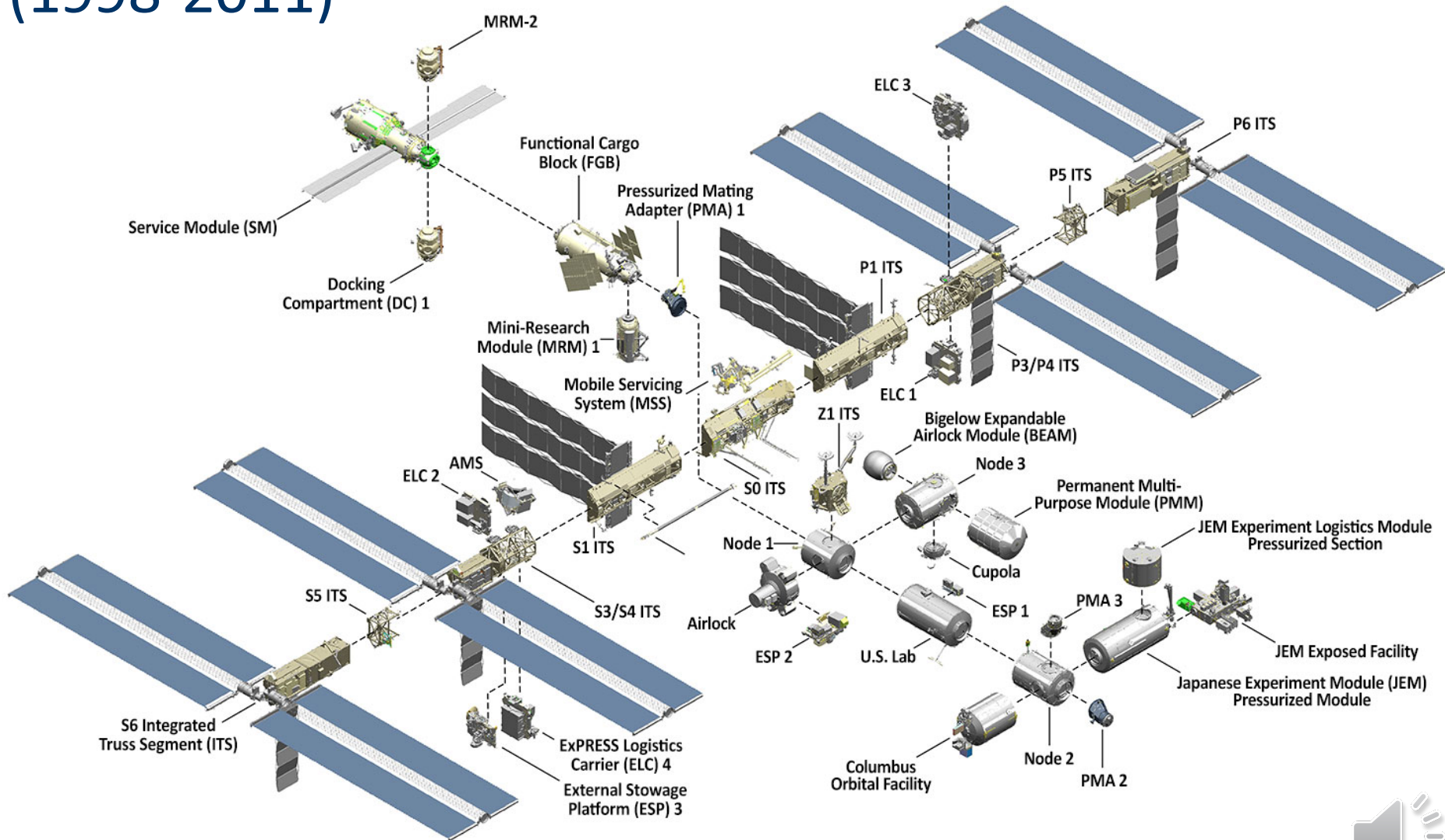
- High value satellites are isolated with few **servicing** opportunities to correct problems, refuel, etc. [DARPA].
- Gravity prevents manufacture of some structures (e.g. ultra-thin mirrors, gossamer structures). Reduce upmass. Why launch resources that can be harvested and/or **manufactured** in-situ?
- 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



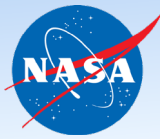
ISS: In-Space Assembly



(1998-2011)



OSAM ISA S&T Partnership Forum



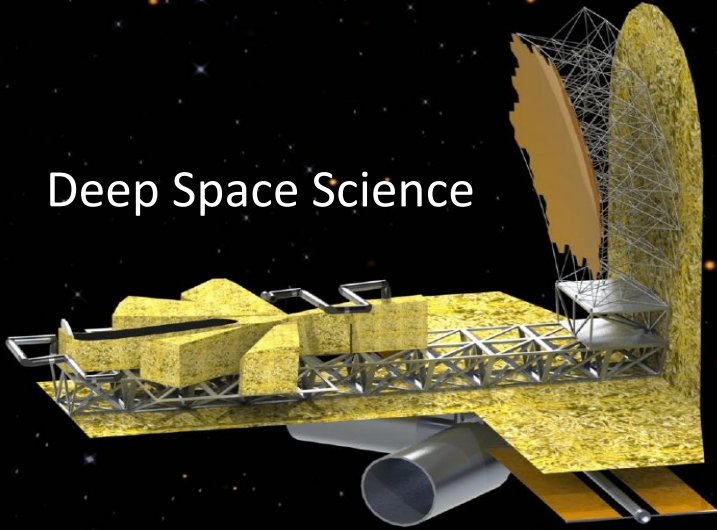
- Opening the doors to assembling habitats away from the safe harbor of low-Earth orbit and building large telescopes
- Working together to identify common needs and capabilities for in-space assembly



Performance, Pace, & Persistence



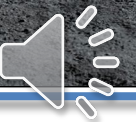
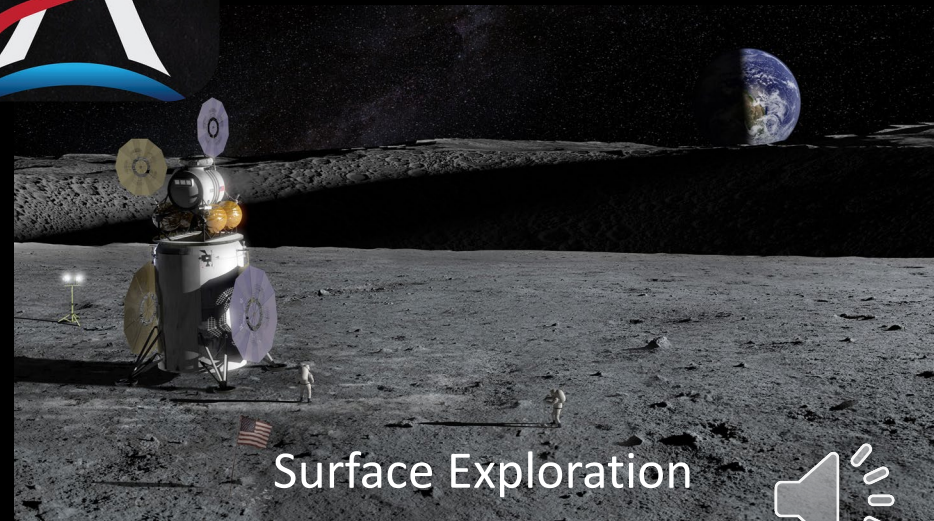
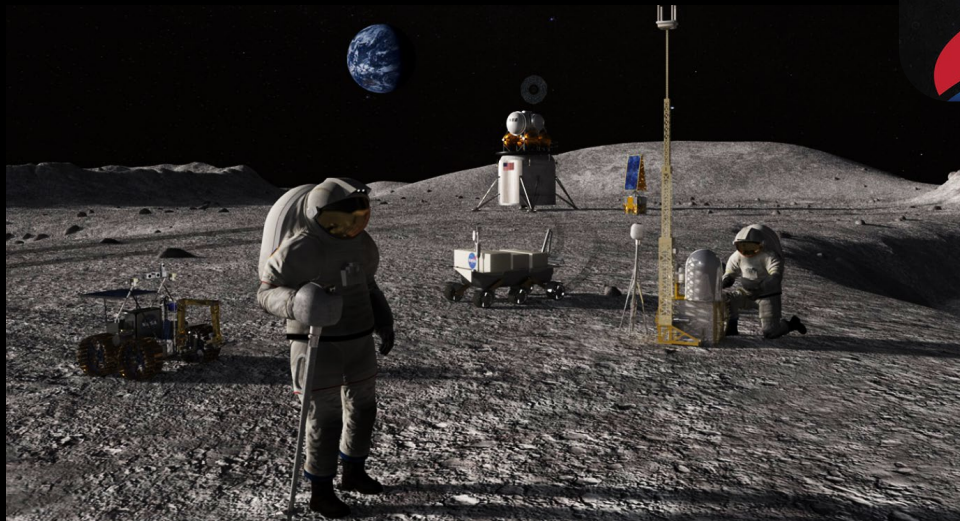
Deep Space Science



On-Orbit Exploration

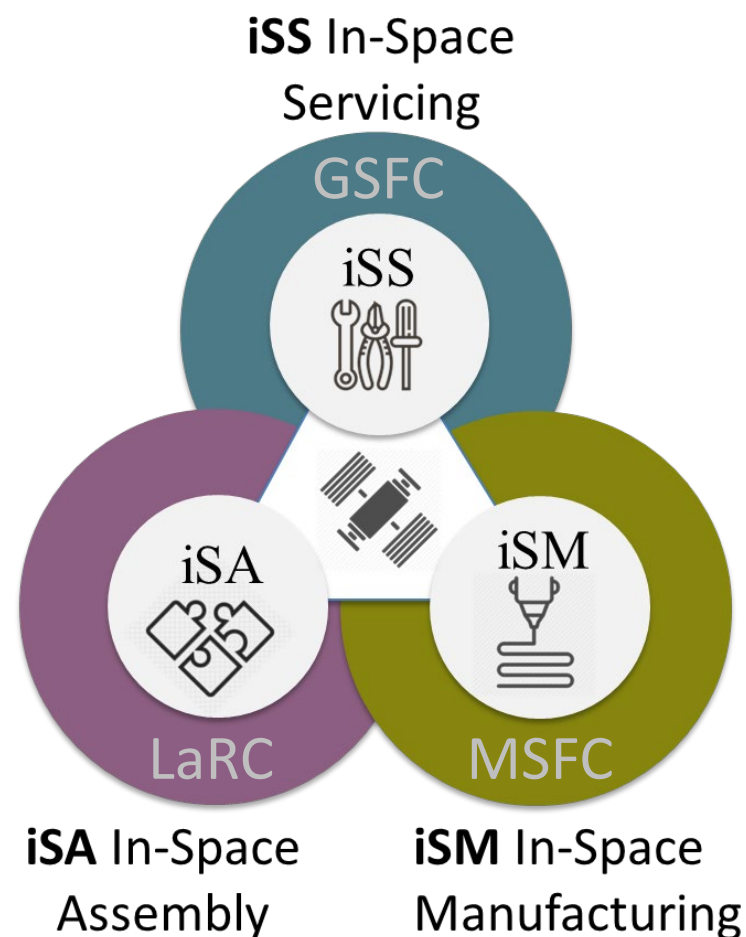


Surface Exploration



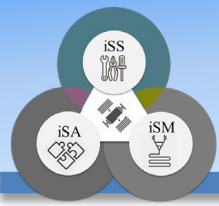
OSAM is an emerging set of capabilities that enables servicing, repair, upgrade, modular assembly, and inspection of space assets

- ***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...

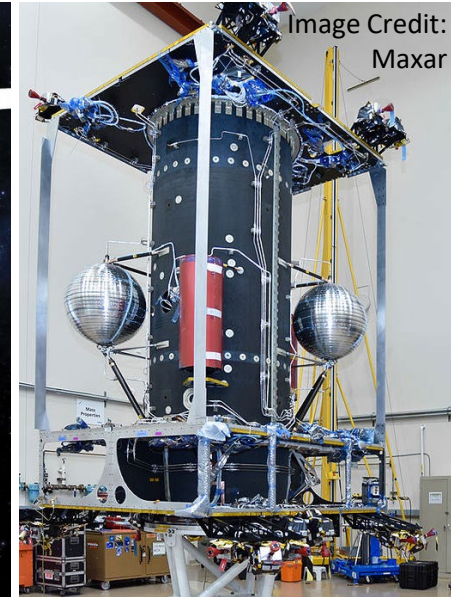
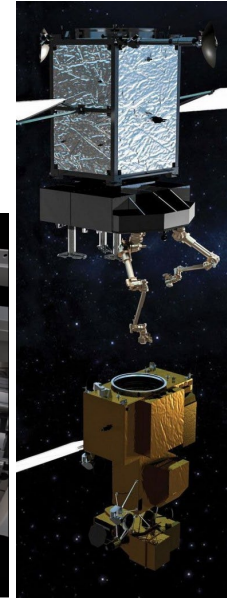
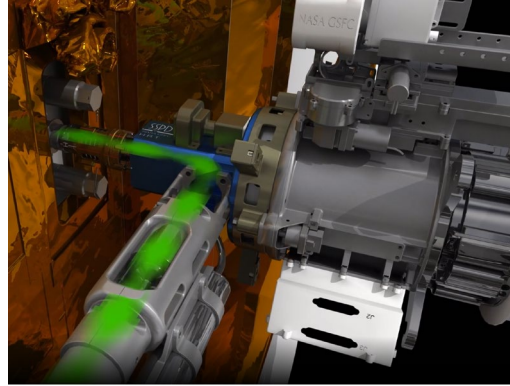
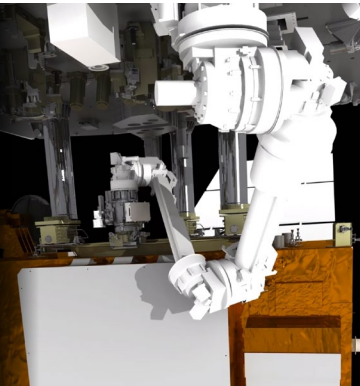
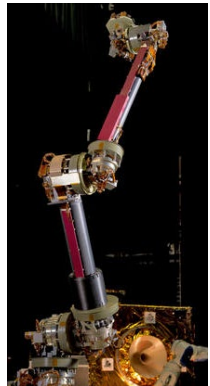




OSAM-1 Servicing Mission

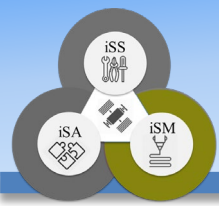


- Formerly known as Restore-L. Added SPIDER payload.
- RESTORE-L
 - Servicing mission for a government-owned satellite
 - Rendezvous with, grasp, and refuel

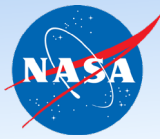


- SPIDER: Space Infrastructure Dexterous Robot (née Dragonfly)
 - A third lightweight 16-foot (5-meter) robotic arm
 - Assembly pathfinder to form a seven-element 9-foot (3-meter) Ka-band antenna
 - Manufacturing pathfinder for a 32-foot (10-meter) lightweight composite beam (Tethers Unlimited)
- Scheduled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

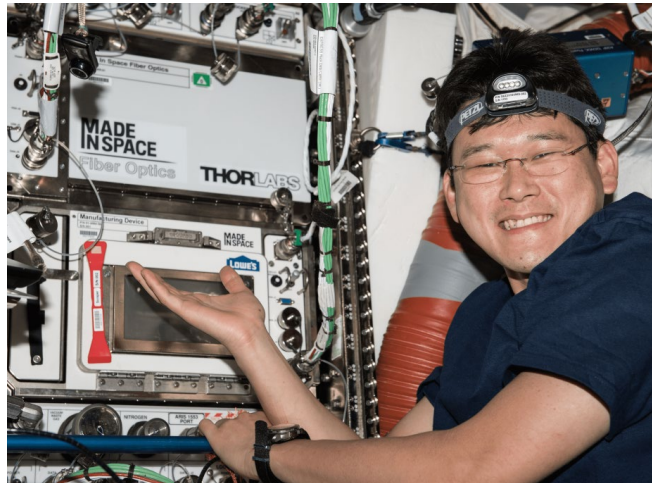
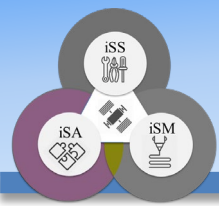


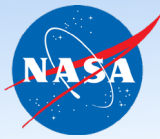
Image Credit:
Made In Space

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



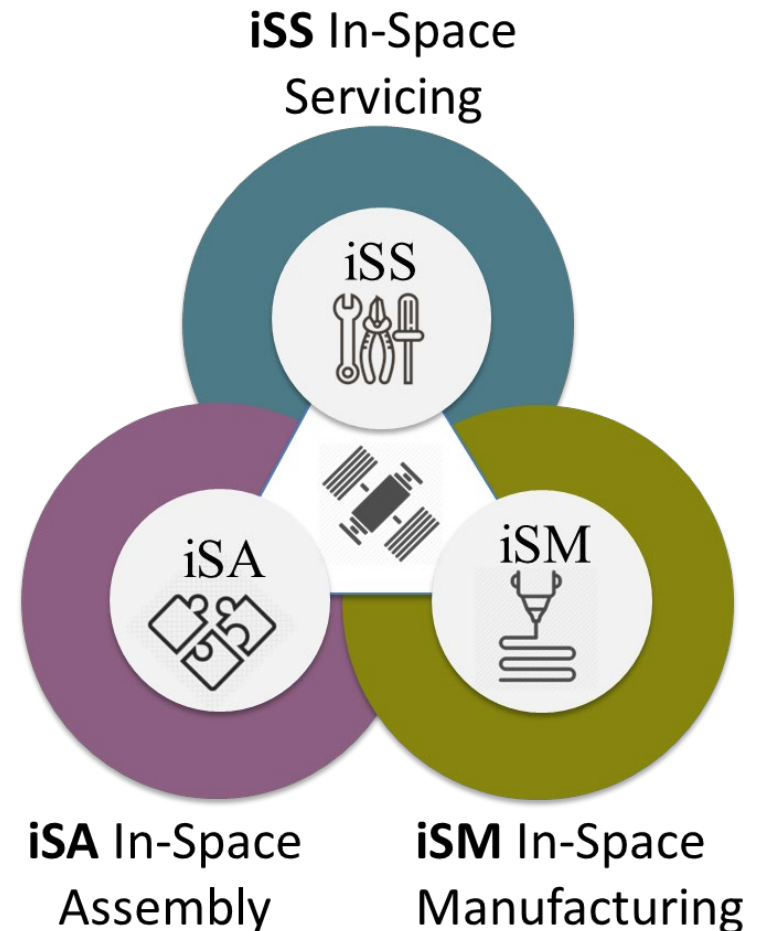


OSAM: In-Space Assembly (ISA)



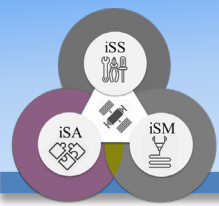
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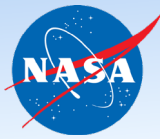


OSAM capabilities combine multiple technologies to enable new missions previously considered impossible...



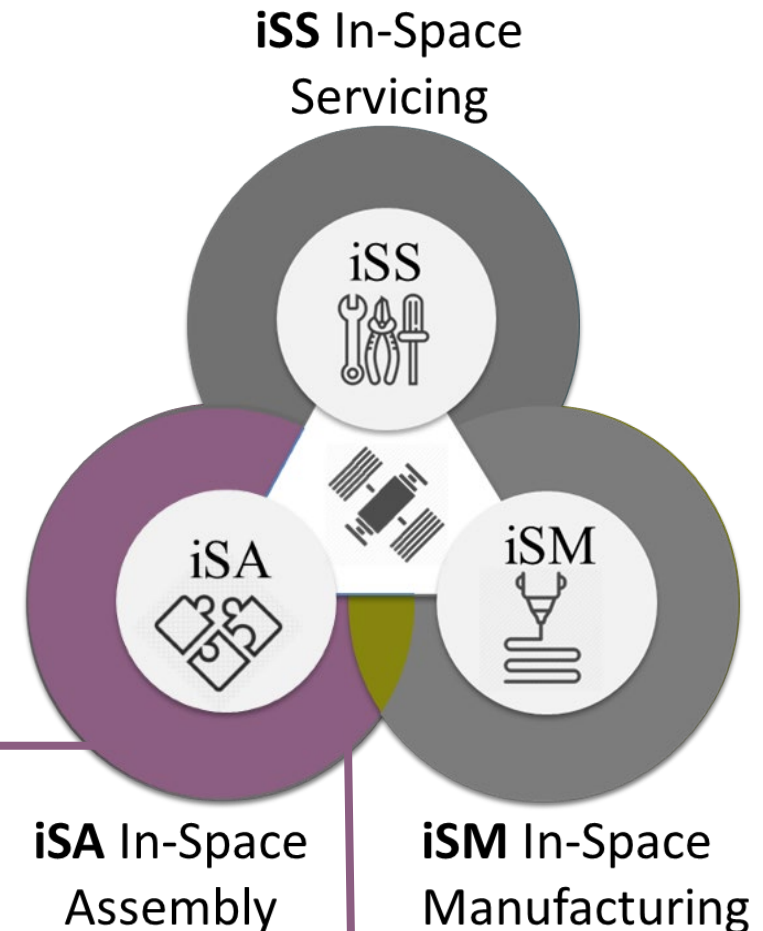


OSAM: **AUTONOMOUS** In-Space Assembly



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

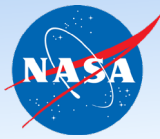
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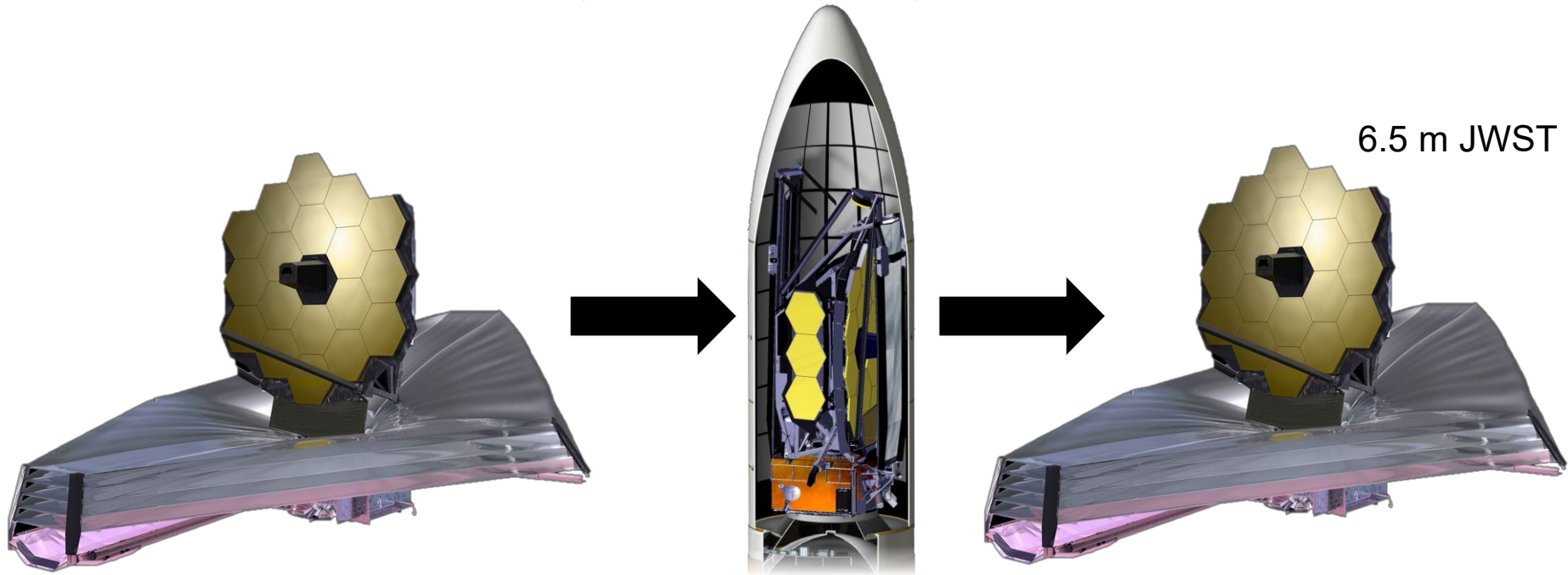
OSAM capabilities combine multiple technologies to enable new missions previously considered impossible... and demand autonomy!



The Current Fairing Paradigm



In-Space Deployment



**volume and mass
constraints**

\$\$\$  **Risk**

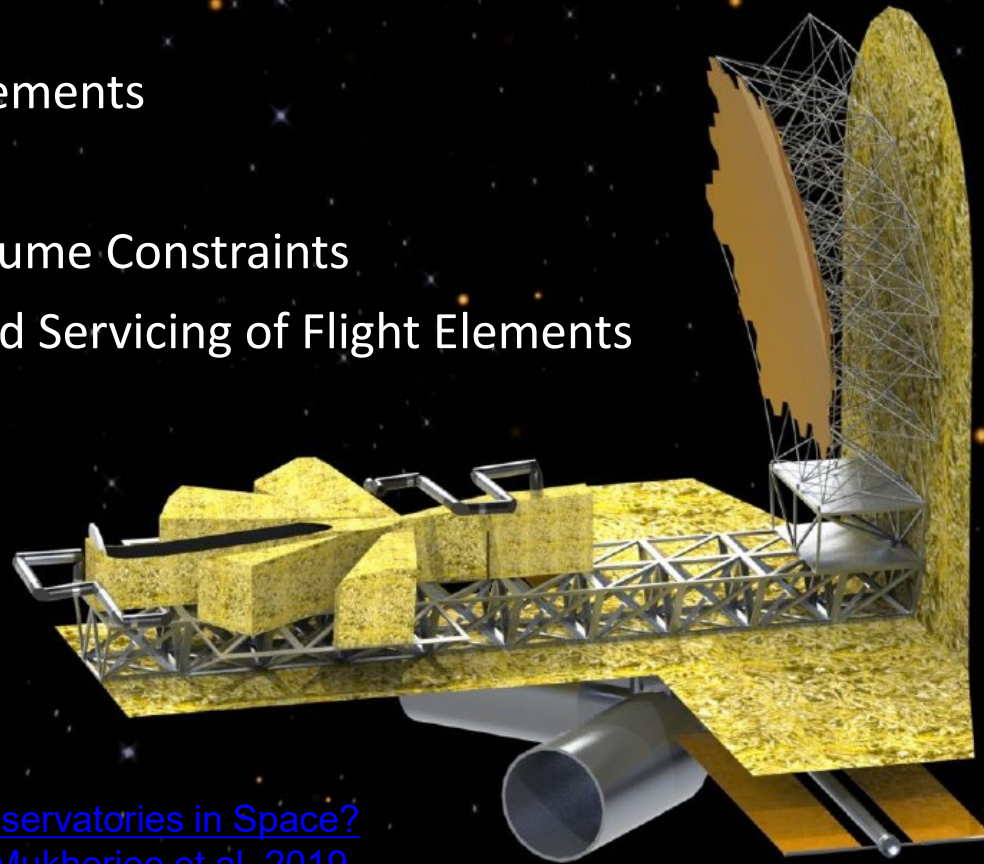
**Currently, no existing LV to fly
an 8 meter segmented telescope**

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

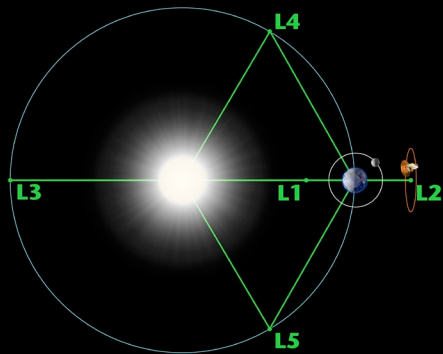
20 m Segmented UV/V/NIR Telescope

Key Design Features

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



20 Meter
Primary

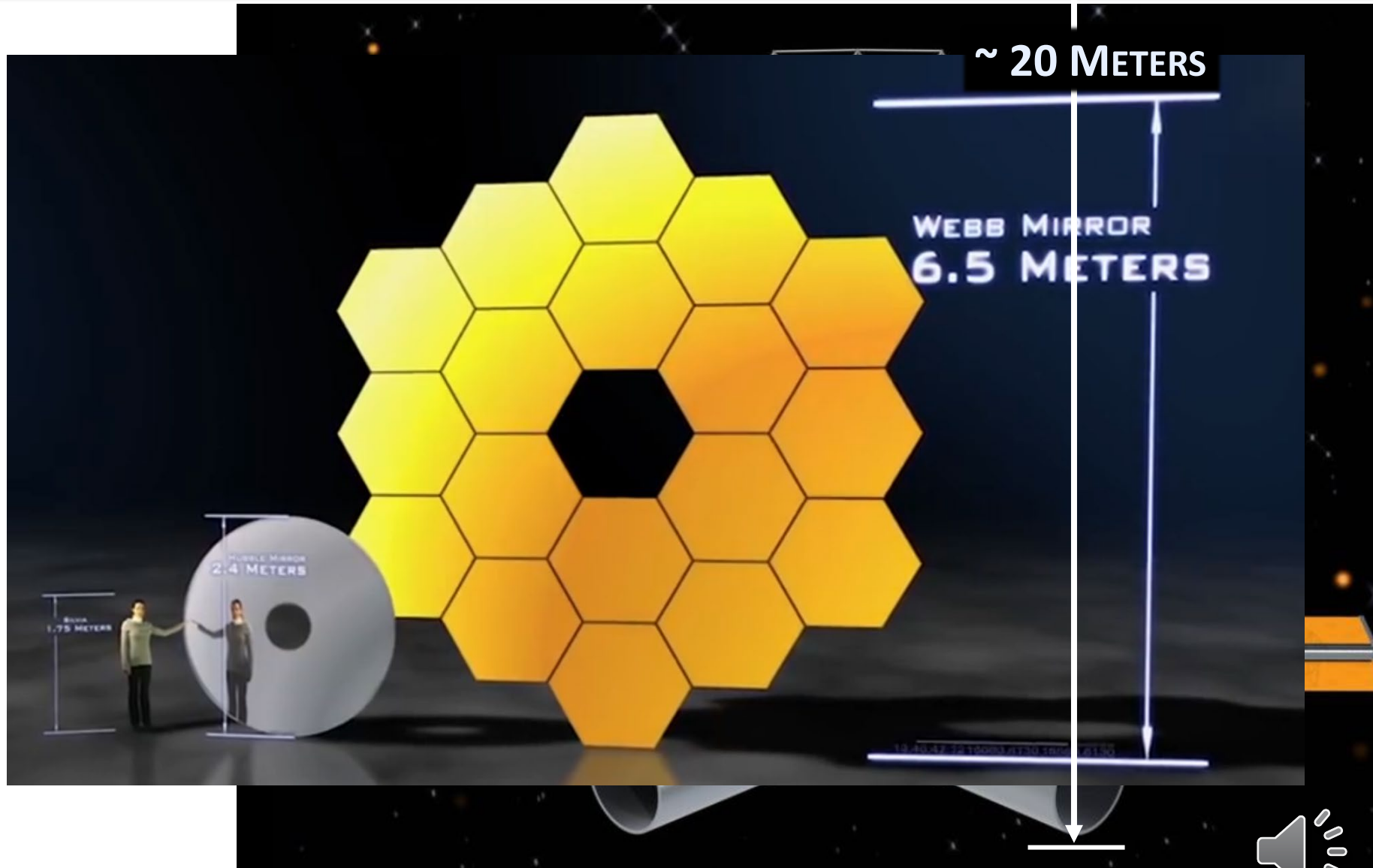


[When is it Worth Assembling Observatories in Space?](#)
[Astro 2020 APC Whitepaper, R Mukherjee et al. 2019](#)

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

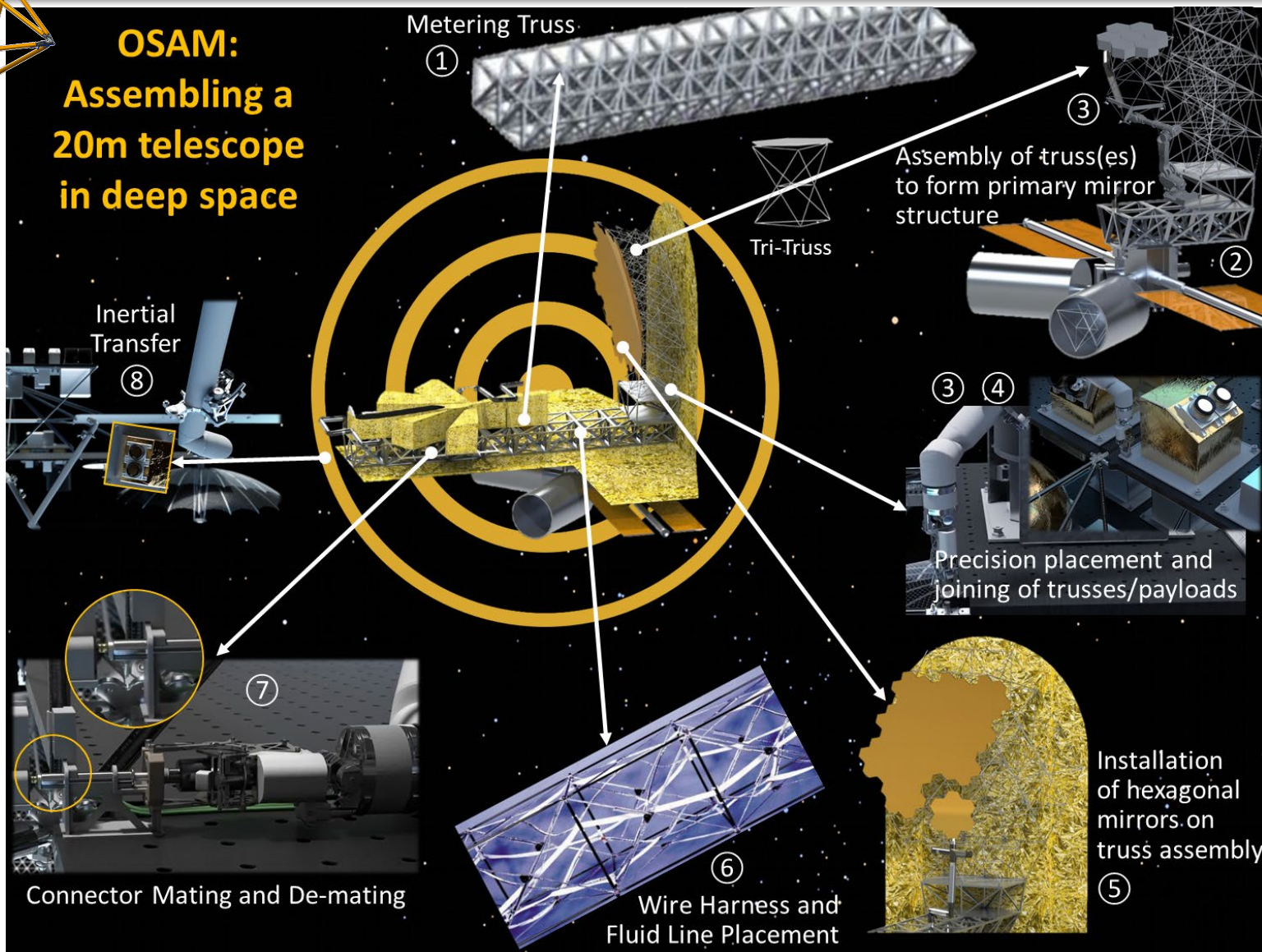


Telescope Mirrors

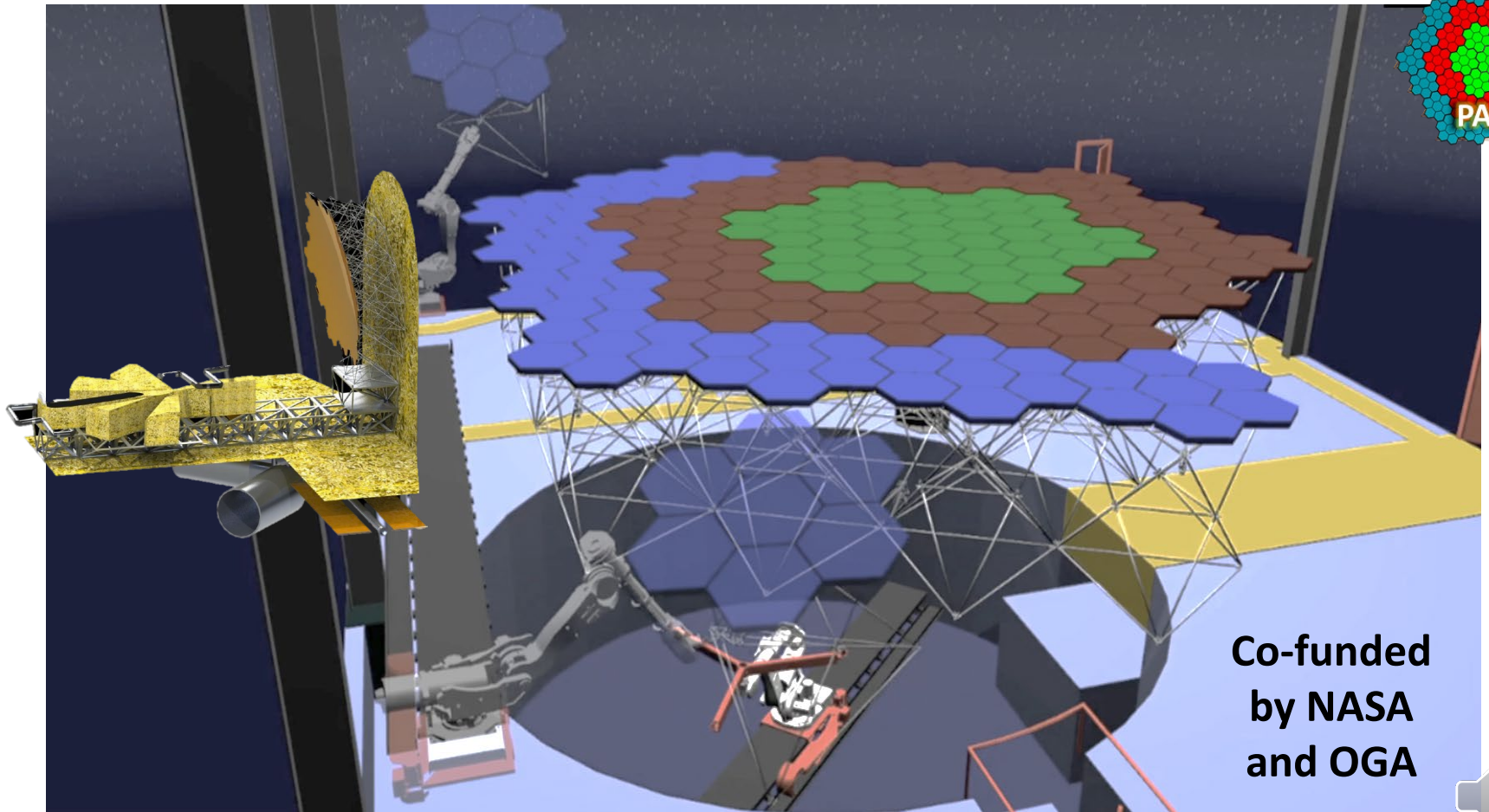


iSAT OV-1/Storyboard

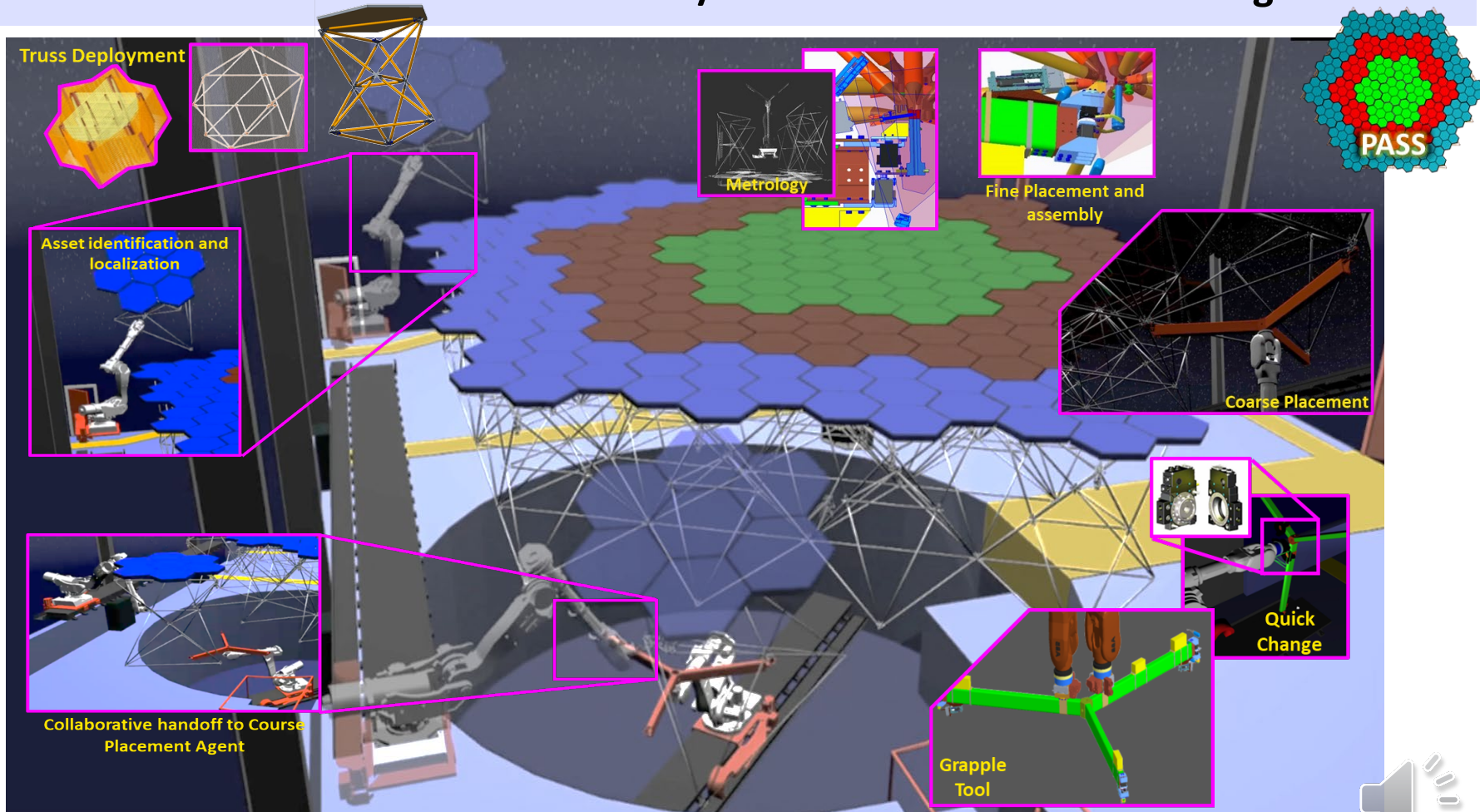
**OSAM:
Assembling a
20m telescope
in deep space**



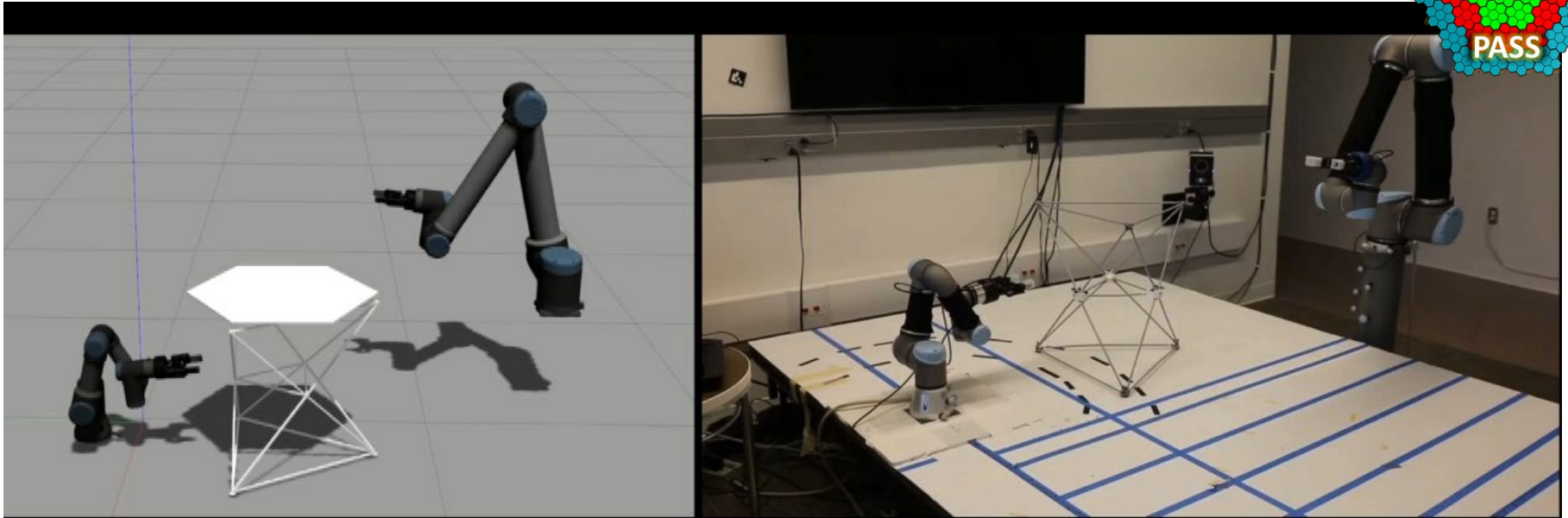
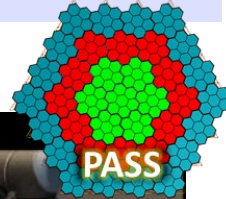
Autonomous Modular Assembly of 20m-class Path-to-Flight Mirror Backbone Structure w/ Simulated Mirrors and Wiring Harness



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



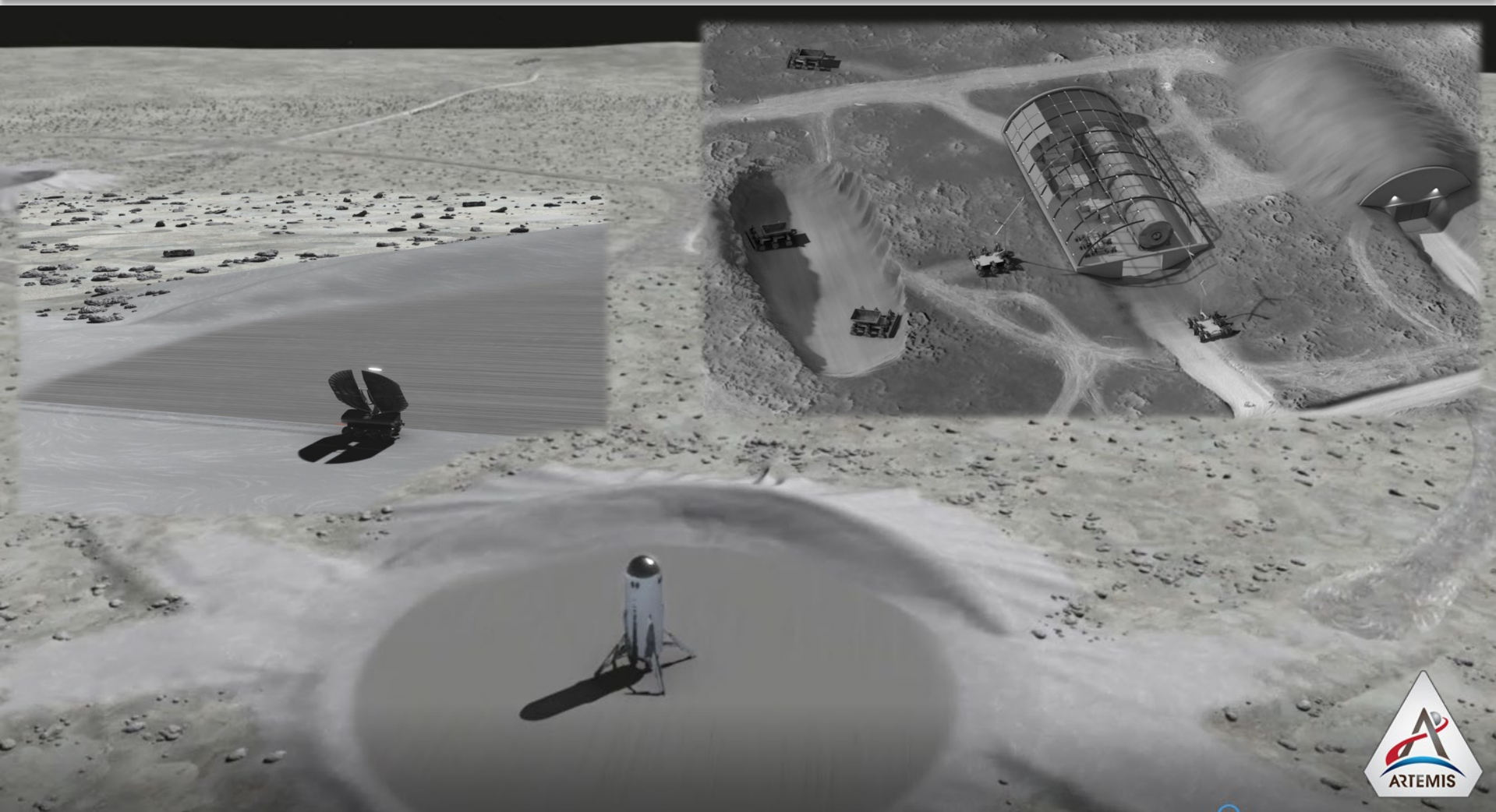
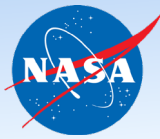
Autonomous Modular Assembly of 20m-class Path-to-Fight Mirror Backbone Structure w/ Simulated Mirrors and Wiring Harness



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



Sustainable Lunar Exploration

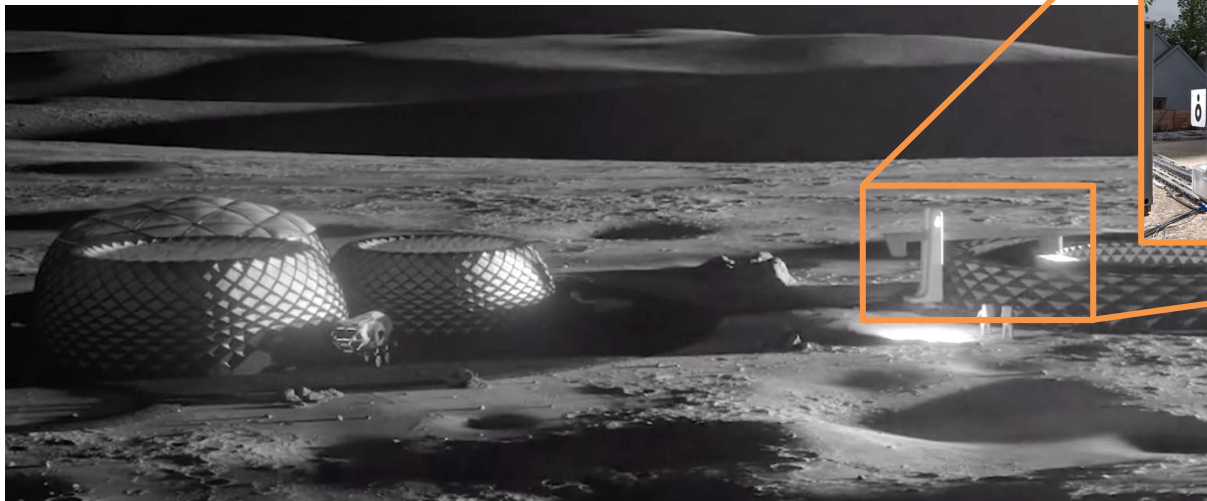


OSAM is the Foundation for Sustainable Lunar Exploration



Moon-to-Mars Planetary Autonomous Construction Technology

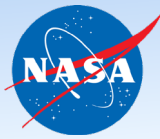
- Managed by MSFC
- ISRU+AM+ISA+Autonomy to build infrastructure on the Moon
- ICON working with MSFC to test lunar soil simulant with various processing and printing technologies. <https://www.iconbuild.com/technology/space>
- NASA LaRC leading ISA and Autonomy R&D
- Enabling Artemis



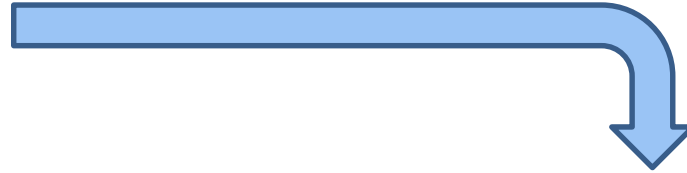
<https://www.nasa.gov/centers/marshall/news/releases/2020/nasa-looks-to-advance-3d-printing-construction-systems-for-the-moon.html>



OSAM/ISA is a Big Umbrella



Broad Definition of “Assembly”



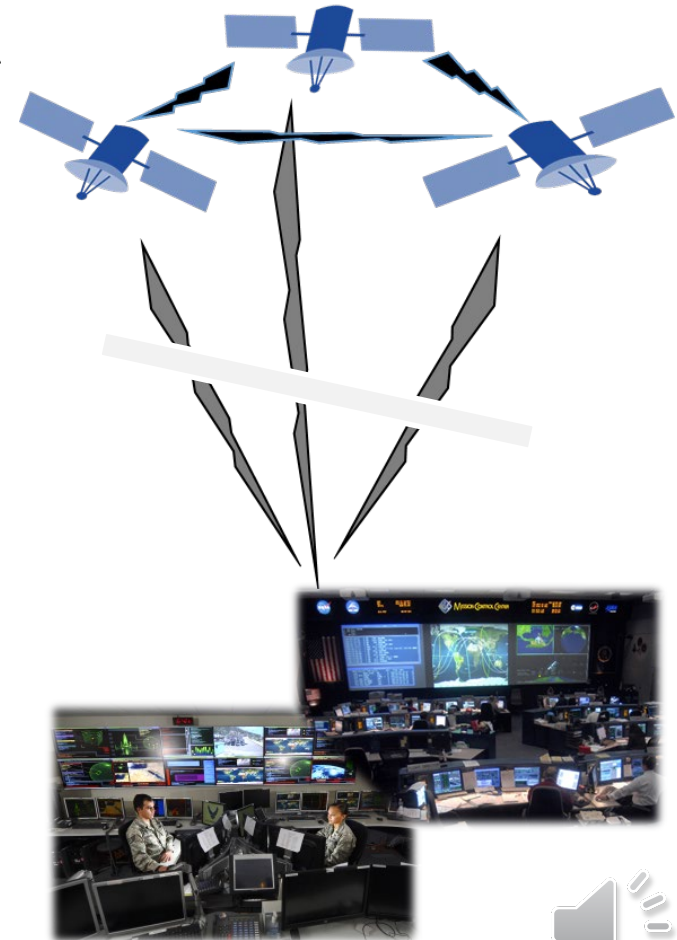
- Autonomy
- Structures and Materials
- Modeling and Simulation
- System Architecture and Analysis

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



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.



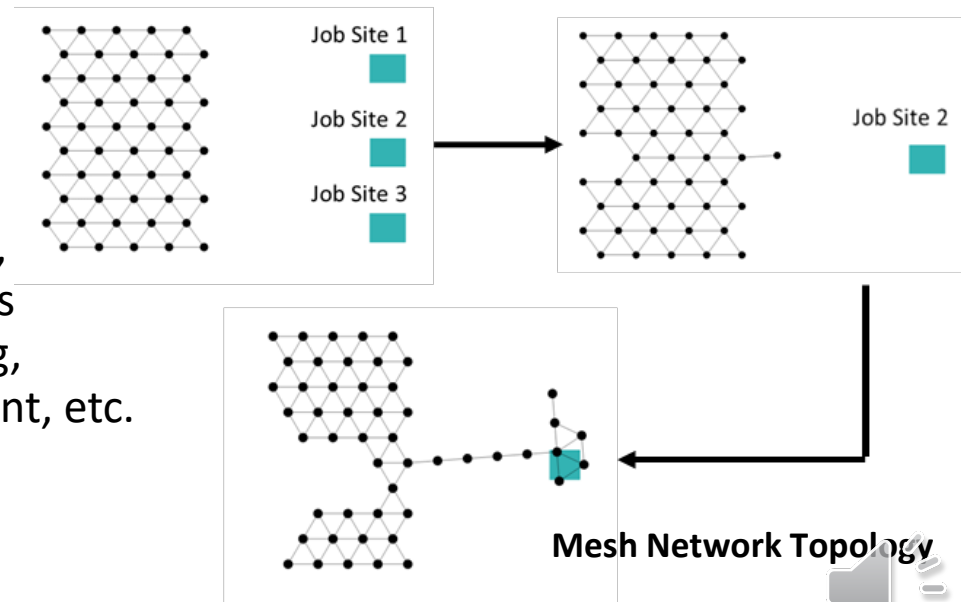
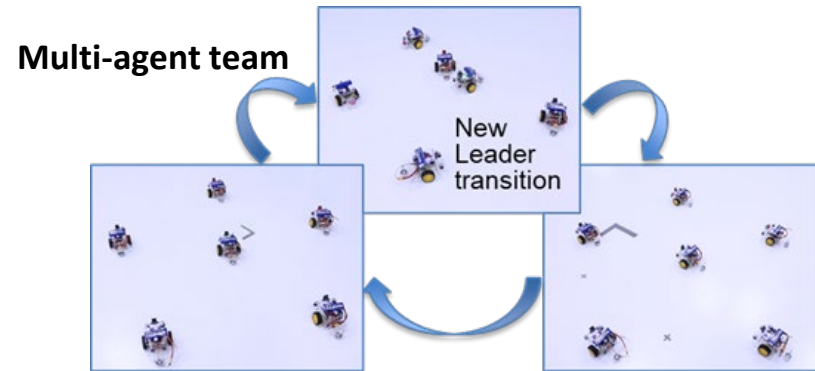
Multi-Agent Clusters for Persistent Observations from Space

Objectives

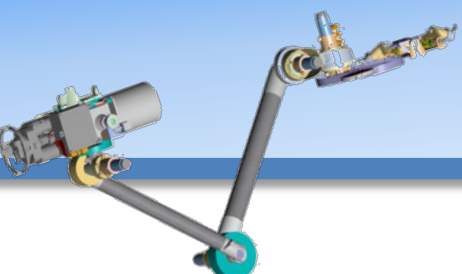
- Develop and demonstrate autonomy capabilities for multi-agent persistent observation applications
- Mature mesh network topology approach
- Enable heterogeneous teams
- Develop human-machine teaming methods to maintain operator SA for remote assets

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

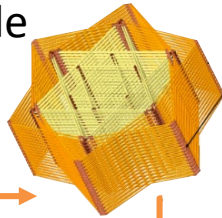
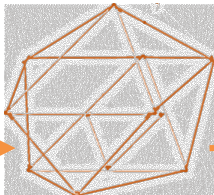


Dexterous Robots (+ Autonomy)

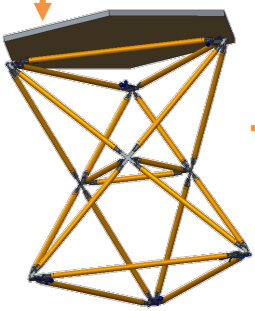


Collapsible

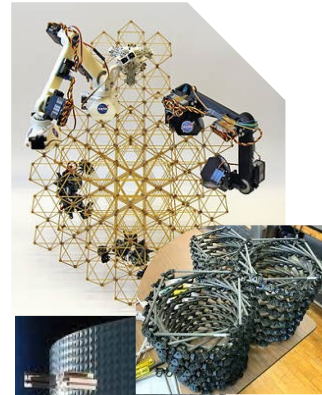
PASS
Tri-Truss Module



Deployable



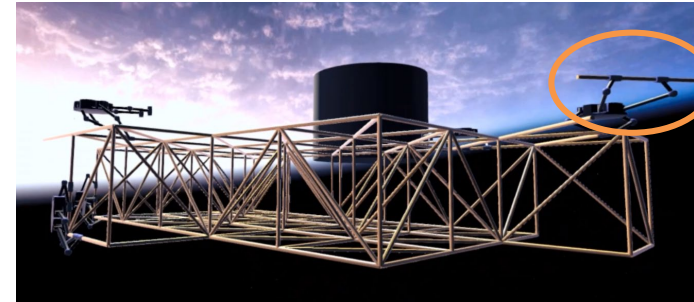
ISS



ARMADAS
Voxel Module



Space Port
Concept



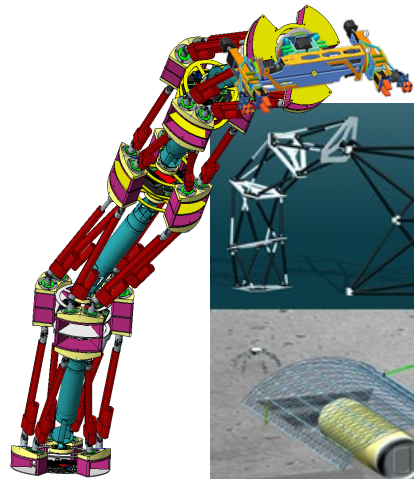
Strut Module

[Electrodynamic Technologies LLC]

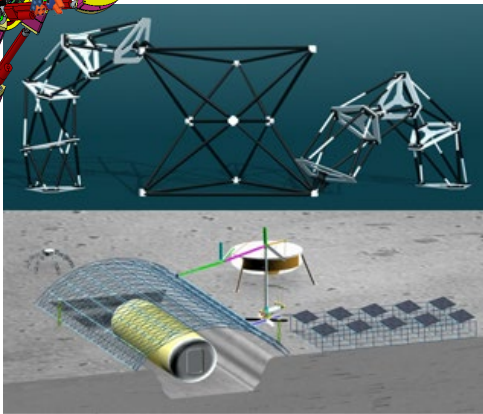
Credit: LM



SmallSats



ASSEMBLERS
Stewart Platform



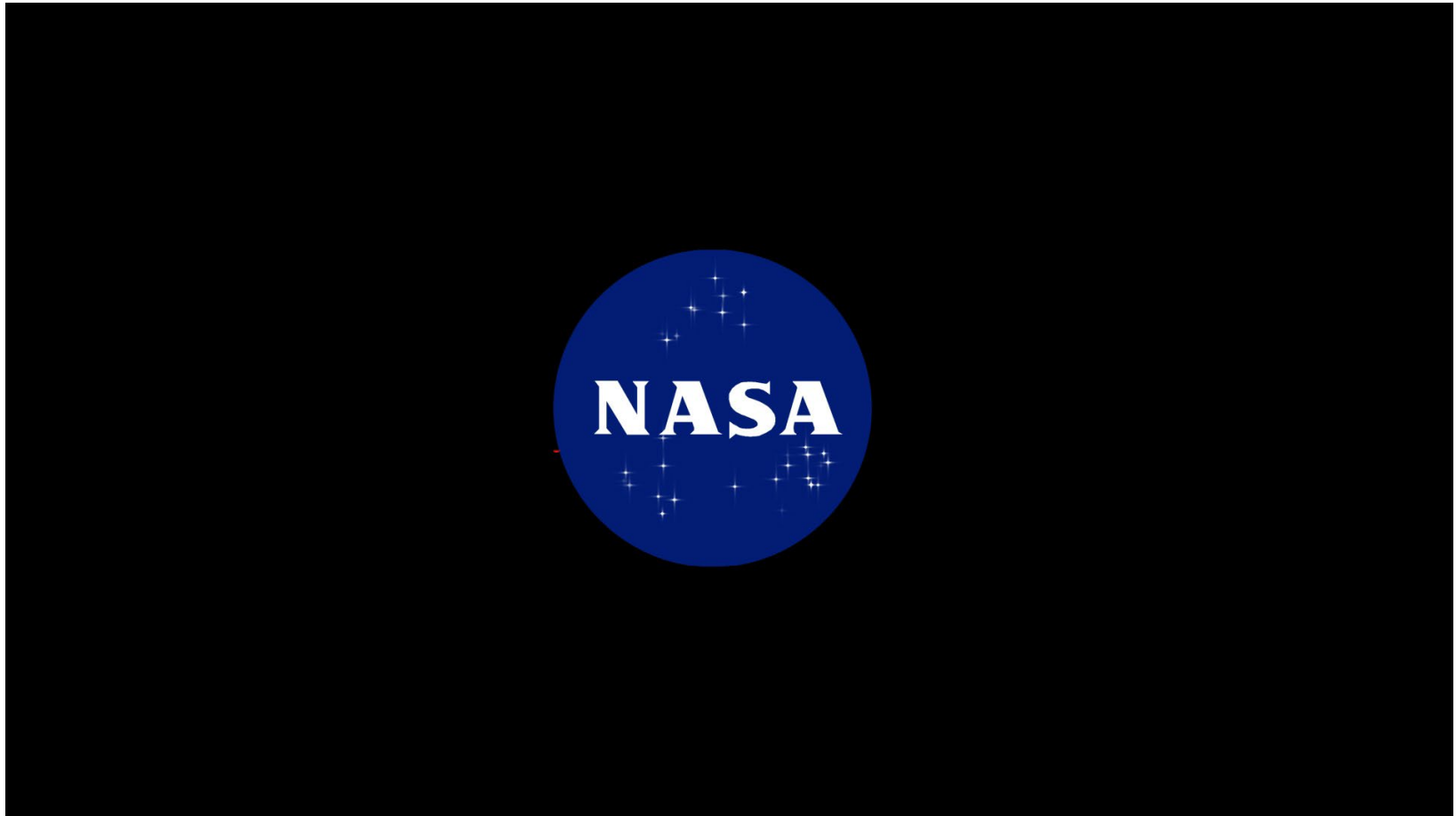
LSMS
Surface



TALISMAN
Long Reach



The “glue” that enables OSAM



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

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@DrDanetteAllen

<http://autonomyincubator.blogspot.com/>



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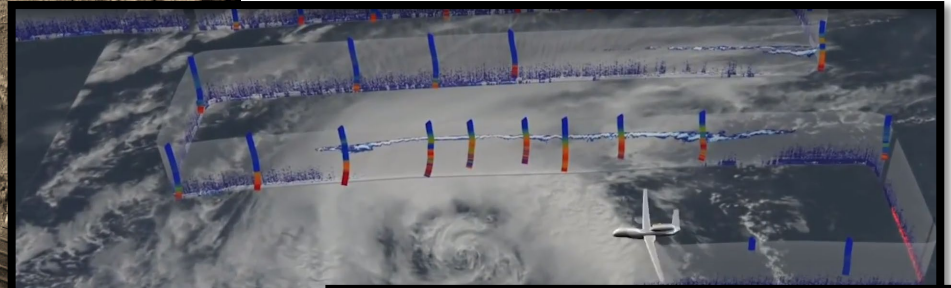
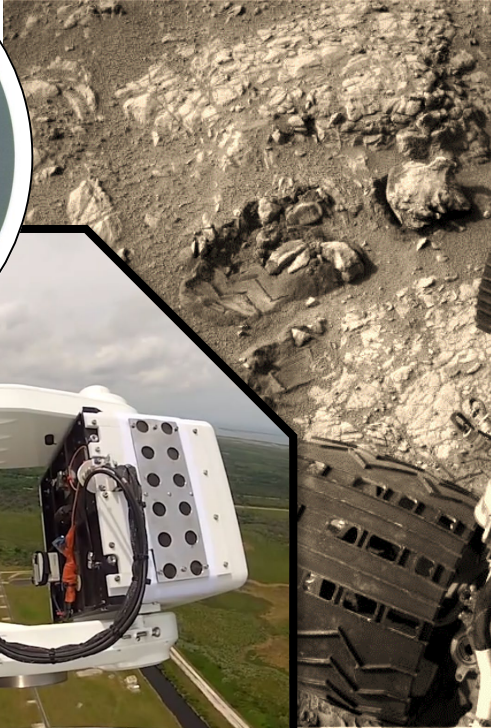
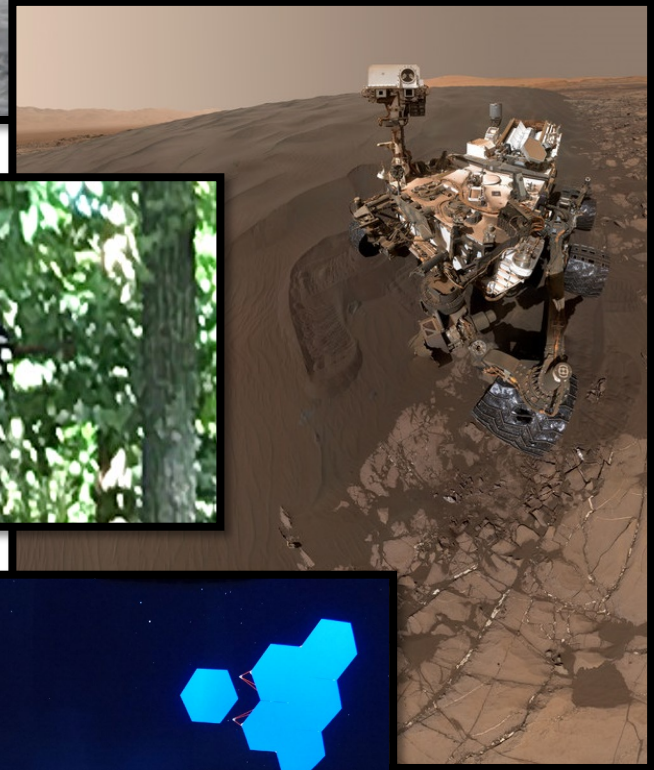


Image credits: NASA



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