National Aeronautics and Space Administration

OSAM-2: Plans and Progress for the First Demonstration of Structural Manufacturing in Space

Lawrence D. Huebner, NASA

Paul Shestople, Simon Patané, Daniel Hillsberry, Redwire Space

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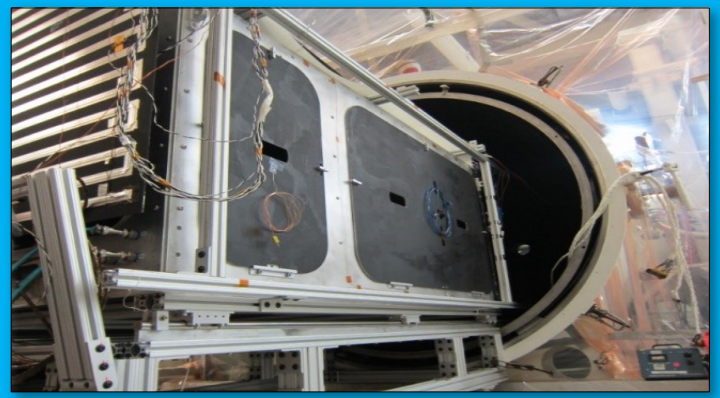
Background

- OSAM-2 began as a NASA Space Technology Mission Directorate Tipping Point project in 2016 in which an investment made in ground development and demonstration and/or flight demonstration will result in:
  - Significant advancement of technology's maturation
  - High likelihood for utilization of technology in commercially fielded space application
  - Significant improvement in ability to successfully bring space technology to market
- Topic area was "Robotic In-Space Manufacturing and Assembly of Spacecraft and Space Structures"
  - Made In Space, Inc. (now Redwire) proposed Archinaut One, an in-space robotic precision manufacturing and assembly system for larger-than-deployable structures
  - Manufacturing / assembly in the operational environment allows manufactured parts to be designed for that environment (and not for launch loads and need to deploy)
- In 2020 NASA budget language, NASA began using On-orbit Servicing, Assembly, and Manufacturing Mission 2 (OSAM-2) for Archinaut One
  - Restore-L + SPIDER (SPace Infrastructure DExterous Robot) became OSAM-1

OSAM-2 Technology Development Plan

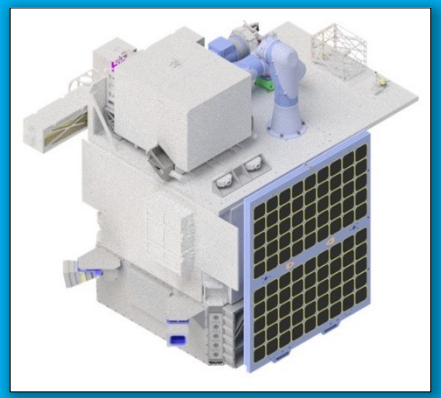
Phase I: Development

- Extended Structure Additive Manufacturing Machine (ESAMM) successfully tested in 2017
- Ground Based Manufacturing & Assembly System Hardware (GBMASH) successfully tested in 2018



Phase II: Demonstration

- OSAM-2 (Archinaut One): In-space demo of extended structure additive manufacturing, robotic manipulation, and part verification/validation
- Focus on demonstrating capabilities relevant to commercial and government (NASA/DoD) missions
- 5-Year, $74M flight demonstration mission funded by STMD



Phase III: Commercialization

- Deployment of commercial products in space
- Extended structure additive manufacturing, robotic assembly, and verification/validation capabilities applied to commercial and government missions
- Deployment funded by customers
- First generation space infrastructure

OSAM-2 Development Timeline

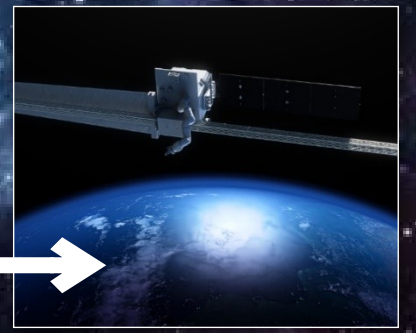
Archinaut Phase I ATP

GBMASH: Additive Manufacturing and Robotics in TVAC

Extruder Upgrades and Testing

TVAC Printing with flight-like Hardware

Flight Payload Integration at Redwire



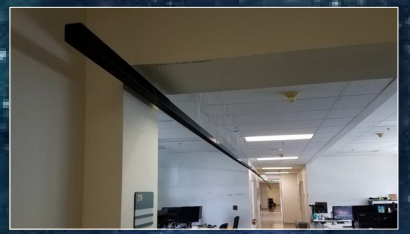
2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023

PDR 3/2020

CDR 12/2021

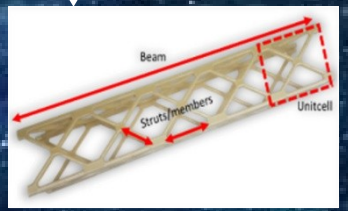
Launch

850 mm beam printed in TVAC

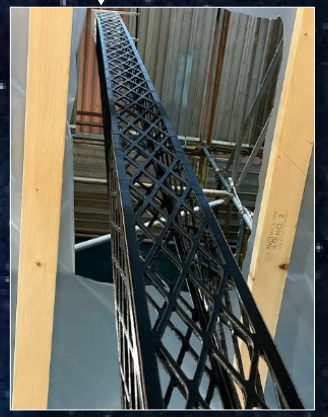


World's Longest AM Beam (37.5 m)

Archinaut Phase II ATP

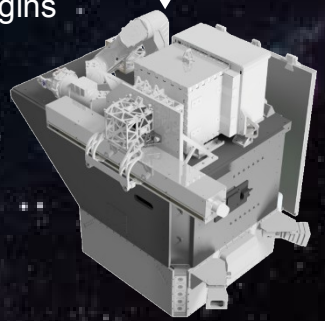


Flight Beam Design and Analysis



Vertical Beam Test: Flight-like hardware printing against flight loads

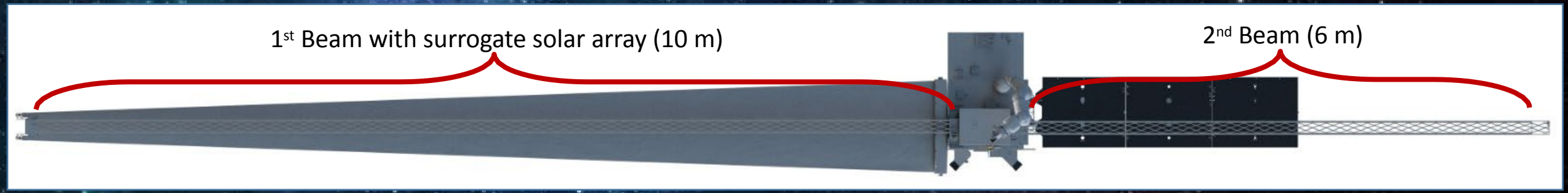
Payload End-to-End Test Begins



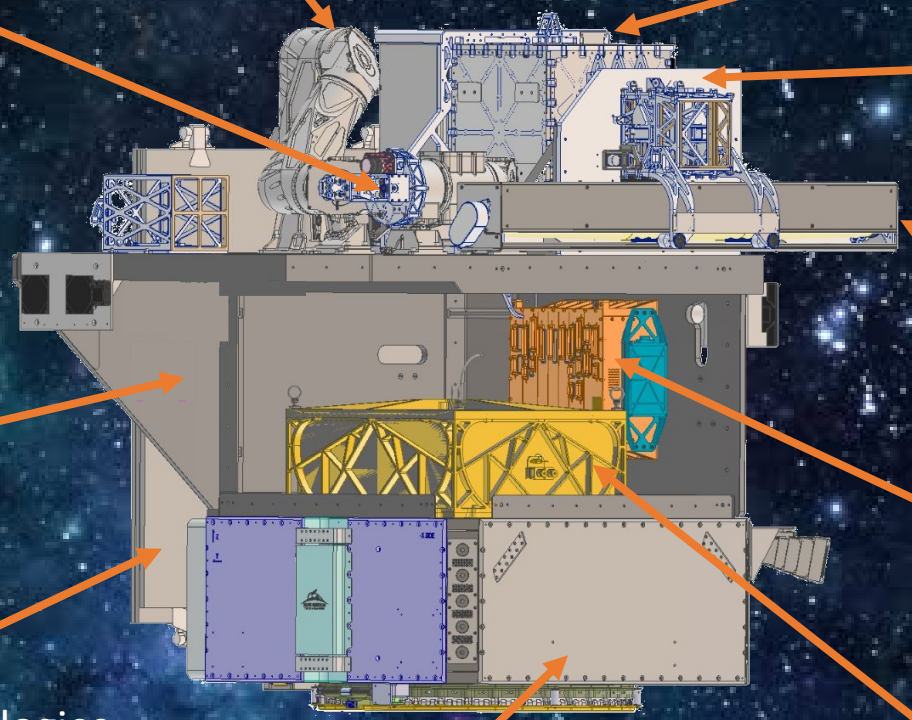
OSAM-2 AI&T Begins

Mission Overview

- NASA STMD Tipping Point project to demonstrate on-orbit additive manufacturing and robotic manipulation on an ESPA-class spacecraft
  - Inclination: 97.4° ± 0.1°
  - Orbit: 500 + 25 km (Sun Synchronous, dawn-dusk preferred)
- Led by Redwire (formerly Made In Space); managed by NASA's Technology Demonstration Missions Program Office
- Major Subsystems
  - Extended Structure Additive Manufacturing Machine (ESAMM)
  - Motiv Space Systems xLink 1.5 Robotic Arm
  - Northrop Grumman Payload Support Structure Assembly (PSSA)
  - Blue Canyon Technologies X-Sat Saturn Bus



Spacecraft and Subsystems



Motiv Space Systems
Robotic Arm

Extended Structure Additive
Manufacturing Machine (ESAMM)

Robotic Arm
End Effector

Beam Lockout
Assembly

Surrogate Solar
Array Assembly

Northrop Grumman
Payload Support
Structure Assembly

Payload Avionics

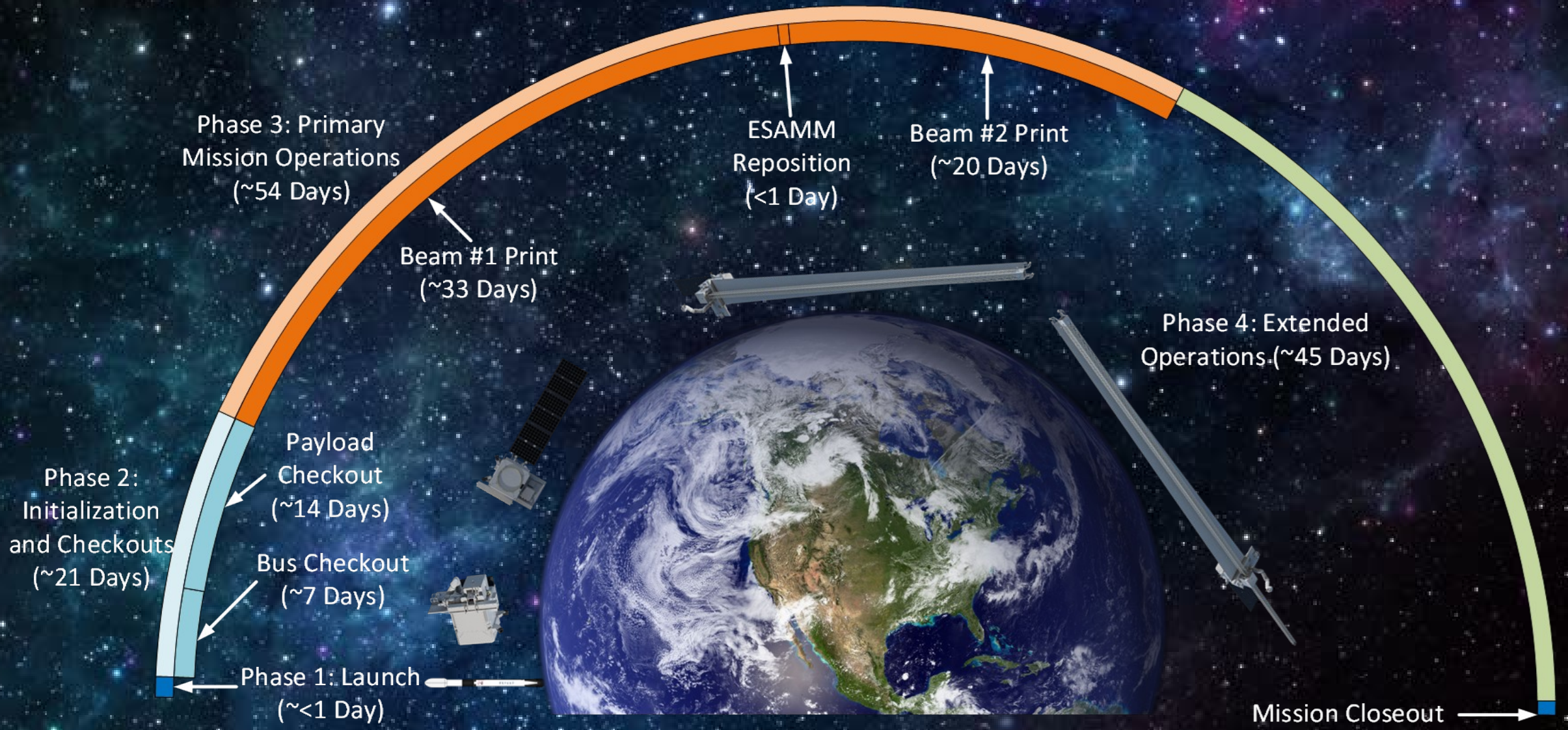
Blue Canyon Technologies
Hyperion Solar Array

Blue Canyon Technologies
X-Sat Saturn Bus

Feedstock Canister

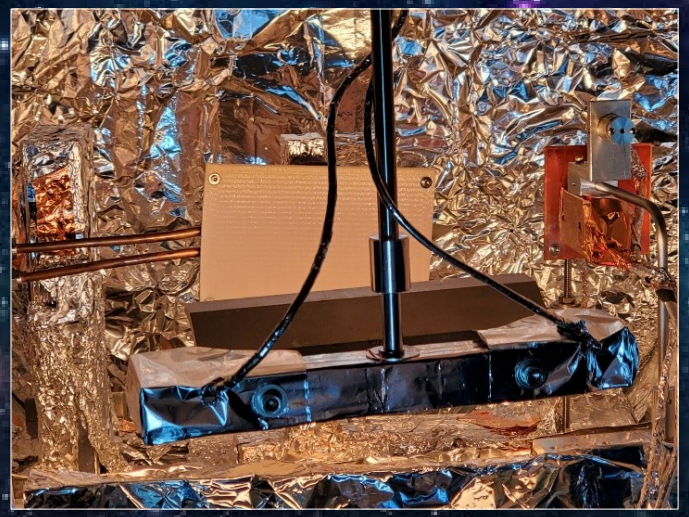
Concept of Operations Animation

Concept of Operations Timeline

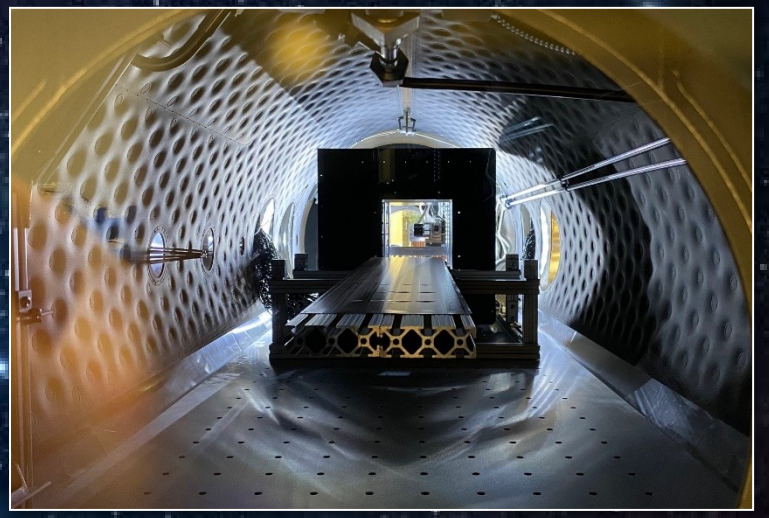


Recent Accomplishments, 1 of 2

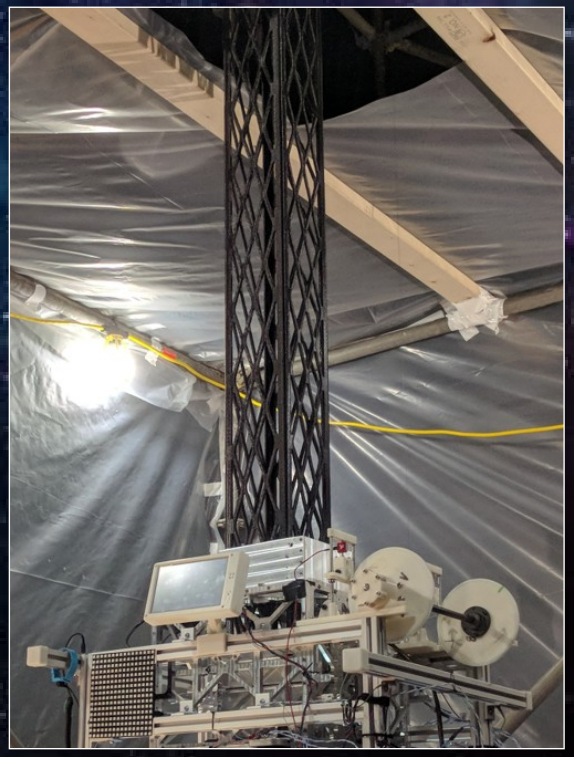
- Beam material electrostatic discharge (ESD) testing at MSFC
- Vertical print test
  - Test setup mimics relevant loading environment for on-orbit ESAMM operation
    - Off-load mass of beam during printing
    - Tension of deploying surrogate solar array
- Beam printing in relevant thermal vacuum (TVAC) space environment



Beam Material ESD Test Setup



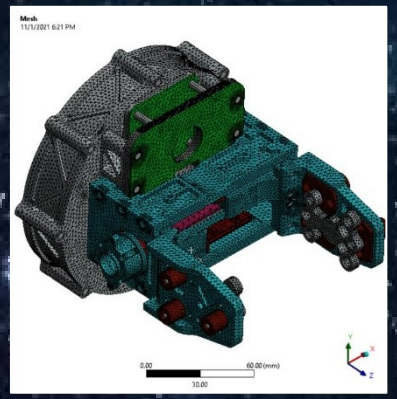
ESAMM Mk 10 in Redwire TVAC Chamber



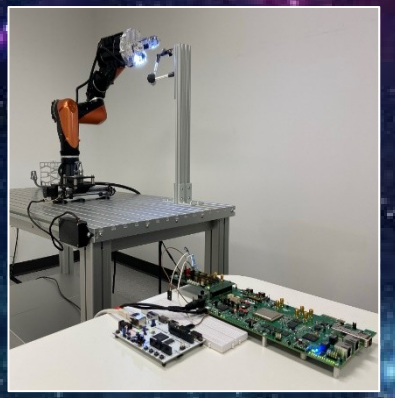
ESAMM Mk 9 Vertical Print Test

Recent Accomplishments, 2 of 2

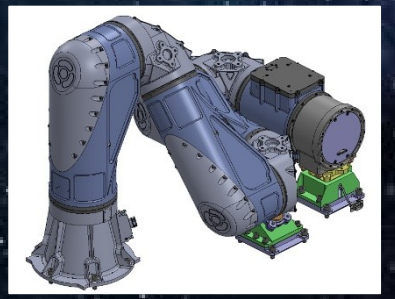
- Assembly / testing of Engineering Design Units
  - Feedstock Canister
  - Robotic Arm and Robotic Arm End Effector
  - ESAMM Mk 9: Ambient EDU primarily for software/flight avionics testbed
  - ESAMM Mk 10: TVAC testing of flight upgrades
- Incorporated key advances into ESAMM
- Completed flight avionics designs
- Simulations of hardware subsystems
- Robotic arm robustification
- Robotic arm commanding
- Software Improvements
- Reviews
  - Flight Avionics
  - Flight Material
  - Eight Subsystem Critical Design Reviews
  - Mission Critical Design Review



End Effector Simulation

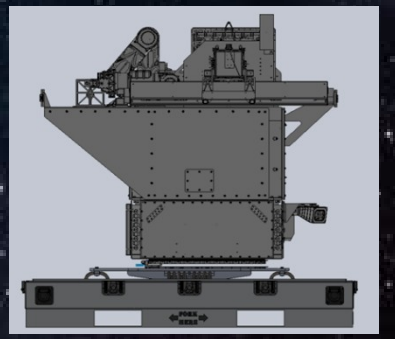


Robotic Arm Commanding

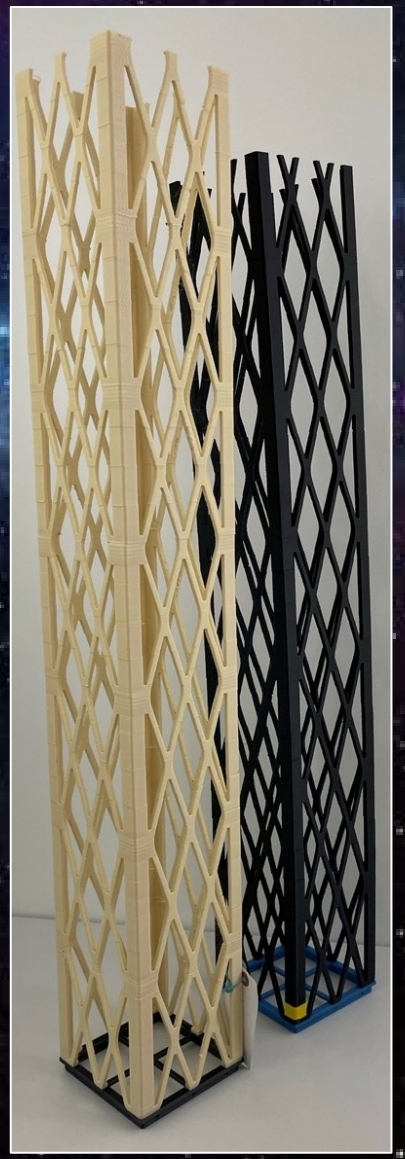


Robotic Arm 1.5

Hardware Assembly



AI&T Planning



Beams

Recent/Upcoming Accomplishments

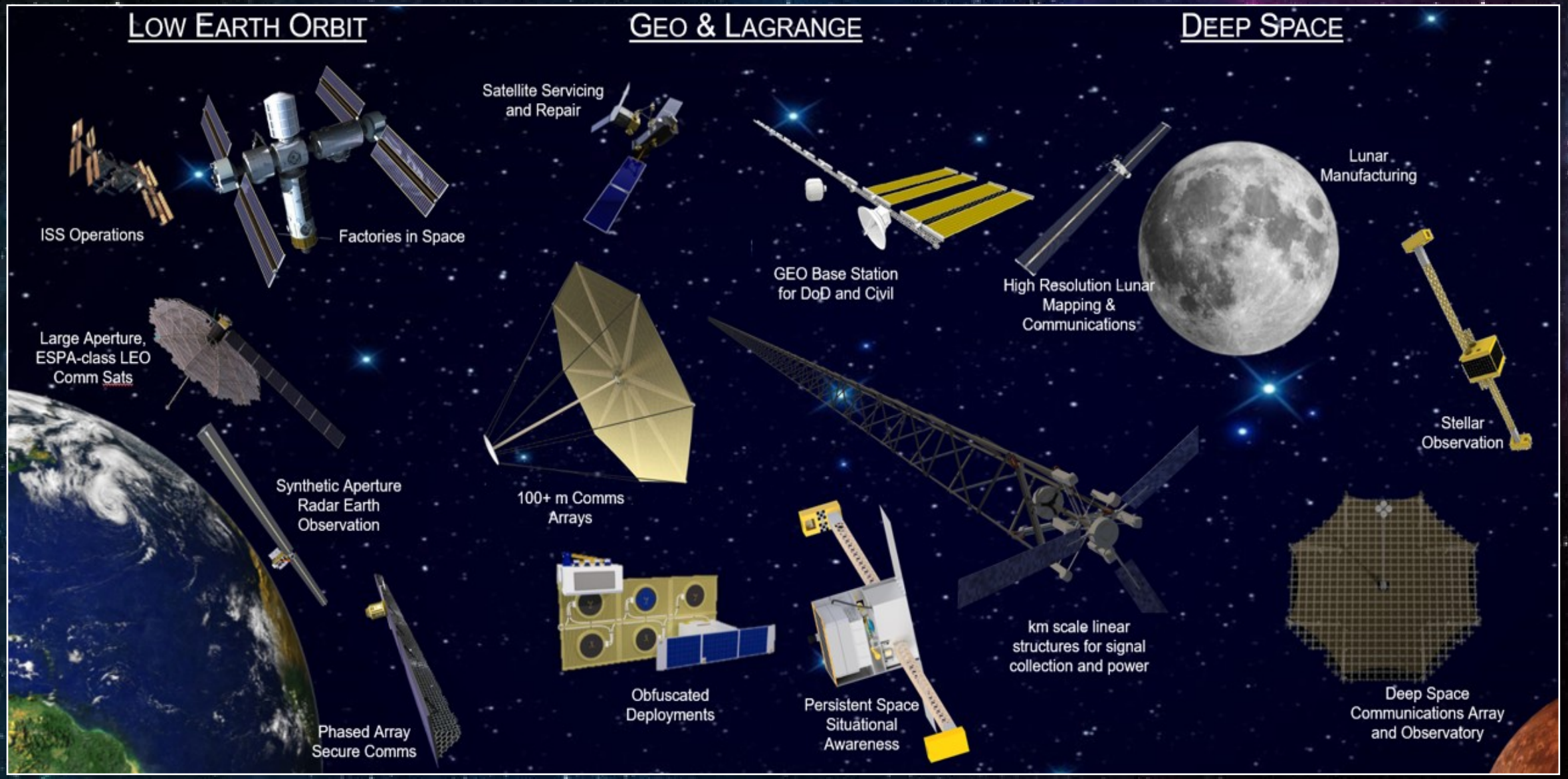
- Received PSSA from Northrop Grumman
- Harness routing checkout using mock space vehicle
- Bus component integration at Blue Canyon Technologies
- Feedstock Canister redesign
- Receive Robotic Arm from Motiv Space Systems
- ESAMM Mk 11 (flight unit) assembly and verification testing
- Begin Payload Integration
  - Robotic Arm, ESAMM Mk 11, and Feedstock Cannister onto Payload Support Structure Assembly
- Payload End-to-End Operations Test Readiness Review
  - Using flight-like EDUs, project will execute end to end test of payload operations
  - ESAMM Mk9R will print 10 m beam while deploying surrogate solar array
    - Mk9R is an upgraded, flight-like version of Mk9, used for ambient testing
  - Rotate Hyper-lite ESAMM 180^0 with Robotic Arm
  - Print 1 m beam
- Payload End-to-End Test completion report
- Subsystem environmental testing
- Receive bus from Blue Canyon Technologies
- System Integration Review

Payload End-to-End Test Facility Preparations

Technology Transition

- Big science from a small package
  - Core facets of OSAM-2 provide alternative design philosophies, unlocking next generation satellite architectures for future mission applications
    - Manufacturing: Utilize OSAM-2 manufacturing subsystems to deploy extended structures for long baseline interferometry missions
    - Assembly: Utilize OSAM-2 autonomous robotic assembly for persistent platform architectures that host multiple payloads over the mission life
    - Combination: Manufacture and assemble infrastructure on-orbit enabling enhanced capabilities such as large power generation, long baselines for optical benches, and persistent platforms
- Near Term Opportunities
  - Tipping Point Solicitation

Infusion Potential

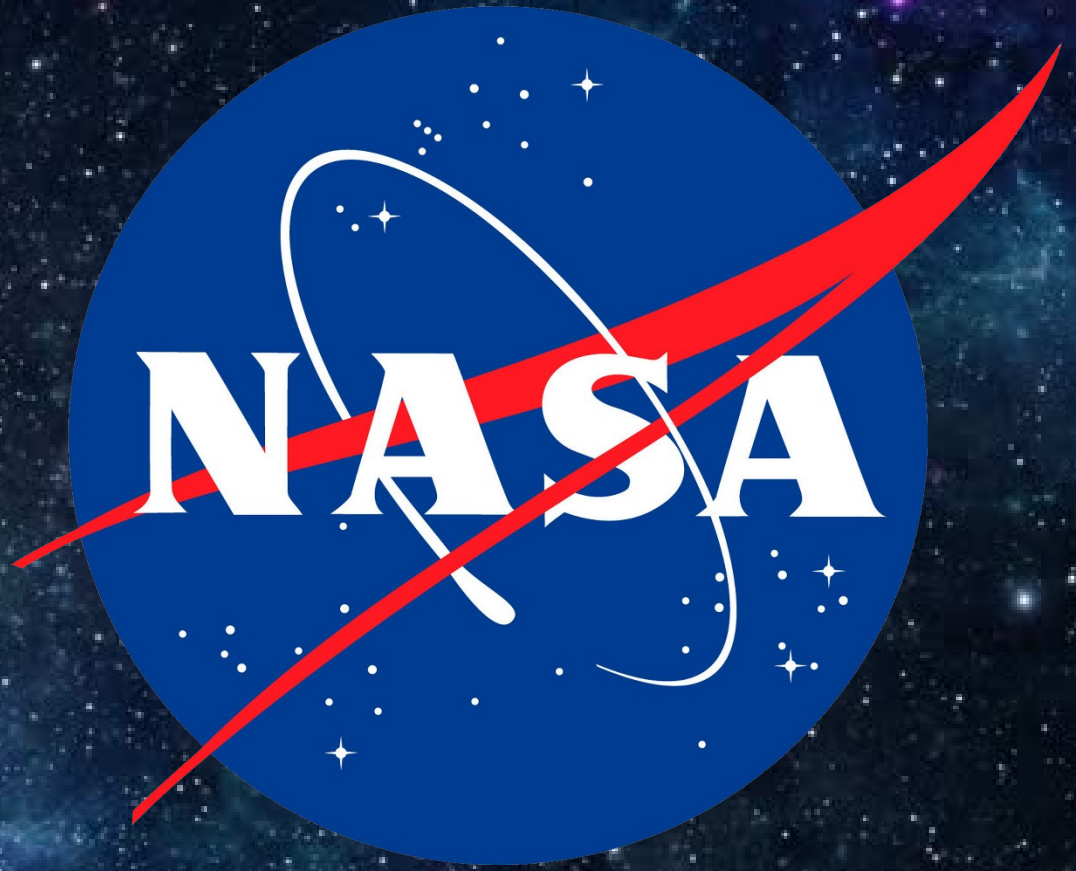


Summary

- OSAM-2 is poised to be the first flight demonstration of on-orbit structural manufacturing in an external space environment
- When successful, possibilities of technology infusion are rich
- Planned Phase II space vehicle milestones
  - Assembly and integration of space vehicle by May 2023
  - Space vehicle environmental testing by February 2024
  - Launch no earlier than April 2024
    - Initialization and checkout by L+21 days
    - First beam printed and SSA deployed by L+54 days
    - Second beam printed by L+75 days
    - Mission complete by L+120 days

Acknowledgments

- NASA STMD/TDM
- Redwire
- Northrop Grumman
- Blue Canyon Technologies
- Motiv Space Systems
- Design Review Team Members
- NASA Subject Matter Experts



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