In-Space Factories:
Building an Off-World Supply Chain

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Company Mission:

Develop Off-World Manufacturing Ecosystem to Support a Robust In-Space Economy

Tethers Unlimited, Inc.

Market 1

High-Performance SmallSat Components

Successful SBIR Commercialization

Establish our space hardware expertise, processes, revenue, and credibility

Growth Stage
LRIP => Full Production

Market 2

In-Space Manufacturing, & Assembly

Disrupt the Space Manufacturing Status Quo & Re-Invigorate the SATCOM Market

R&D Stage
Preparing Initial Flight Demos

Market 3

StarDock One

Hosted Payload Services, Propellant/Servicing Depot Orbital Manufacturing, Build Space Infrastructure, Conquer the Universe

Formulation Stage

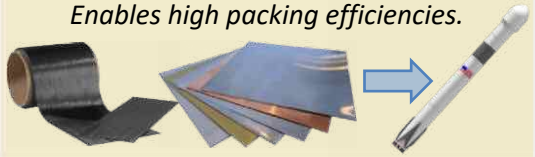
Building an In-Space Economy

OffWorld Manufacturing & Construction Supply Chain

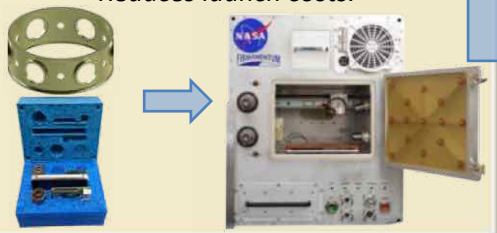
Sourcing Materials

Reduce Material Costs

Raw Material from Earth
Enables high packing efficiencies.



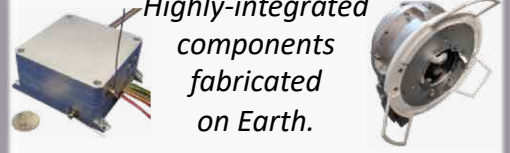
In-Space Recycling of "Space Waste"
Reduces launch costs.



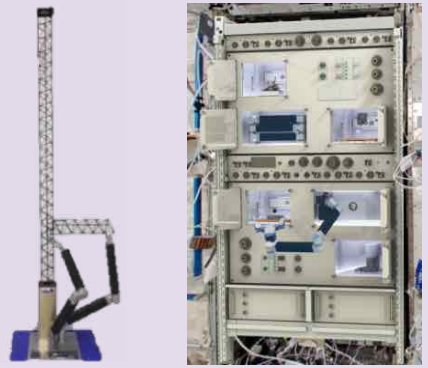
Harvesting Raw Materials In Space
Long-term development required.

Sourcing Components

Components Fabricated on Earth
Highly-integrated components fabricated on Earth.

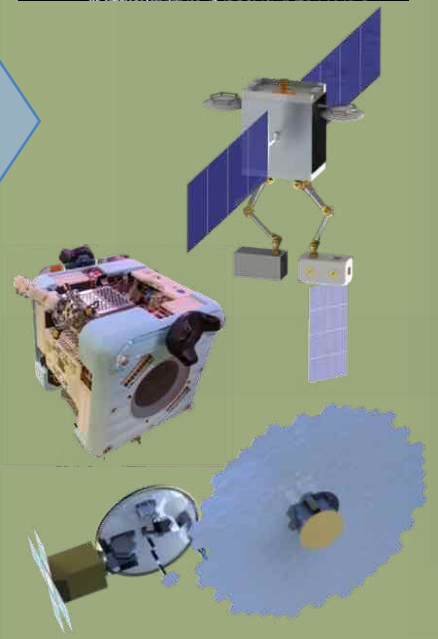


On-Orbit Fabrication
Components can be printed, extruded, cast, etc. on-orbit.



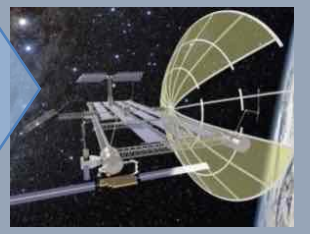
Reduce Logistics Cost & Time

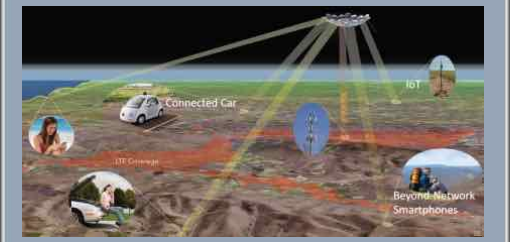
On-Orbit Assembly



Increase Performance-per-Cost

Orbital Services





Payload Hosting,
Orbital Construction,
Direct-to-Smartphone Broadband

Active, Funded Efforts Addressing All Stages of the OffWorld Supply Chain

Sourcing Material in Space:
Refabricator™

- SBIR
- Ph-III

Refabricator Recycling and 3D Printing System for ISS

- SBIR
- Ph-IIX

ERASMUS: Medical and Food-Safe Manufacturing on the ISS

CRISSP: Recyclable Launch Packaging Materials

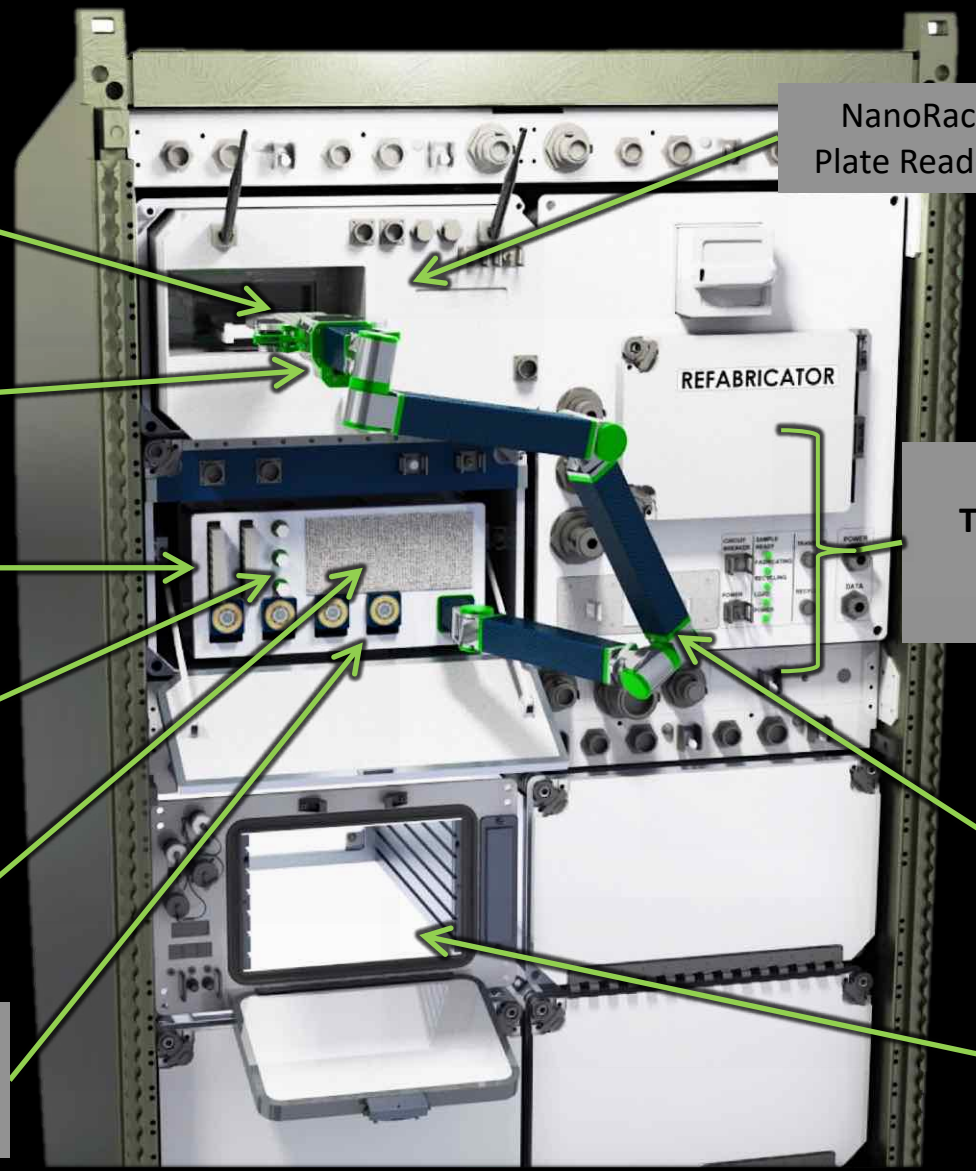
SBIR

NASA ISM TUI REFABRICATOR

TETHERS UNLIMITED

Enabling Remote Manufacturing:

MANTIS Teleoperation Manipulator



NanoRack Microplate

Gripper End-Effector

Microplate Holding Slot

MixStix Holding Slots

Work Surface with Hook-and-Loop

End-Effectors in End-Effector Swapping Area

NanoRacks Plate Reader 2

- SBIR

MANTIS Payload Transferring MicroPlate from Cold Storage to PlateReader

KRAKEN® Robotic Arm
(Stows when not in use)

MERLIN Cold Storage Locker

MANTIS Enables Teleoperation of ISS Experiments

KRAKEN Engineering Development Model

Manufacturing Mission-Critical Parts In Space:

FabLab

NextSTEP
Public/Private
Partnership

Challenges:

- In-line inspection
- Metal AM in zero-g
- Heat treatment in zero-g

Quality Assurance

Metal 3D Printer

Recycler

SBIR

Multi-Material 3D printer

SBIR

MANTIS Robotic Arm

SBIR

MAMBA Zero-G CNC

Metals Manufacturing On Orbit
MAMBA

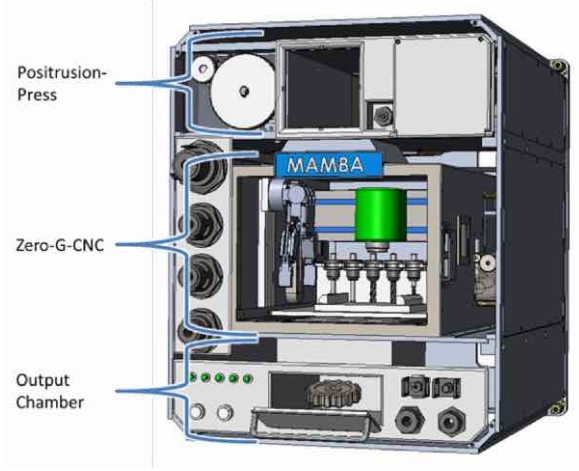
In-Space Manufacturing of Metals:

- Recycling and in-space manufacturing technologies are key to supporting manned space flight missions
- In-space manufacturing is currently limited to plastics
- Some long-distance, limited resupply mission applications will require the high-performance capabilities of metals

- Difficulties with in-space manufacturing of metals:
  - Standard metal additive manufacturing techniques are not well suited for ISS
    - **Powder-Based Metal Printing:** Powders pose safety risks
    - **Wire-Based Metal Printing**: Require high power levels

MAMBA: Metal Advanced Manufacturing Bot-Assisted Assembly:

- TUI's Phase II NASA SBIR
- Robotically-managed metal press and metal system for on-orbit precision metal part fabrication
- Closed-loop system enables metal recycling



Challenges:
- Chip collection in zero-g
- Cooling milling bits
- Heat treatment of parts

iSM Structures – Trusselator & MakerSat

- Demonstrate in-Space Manufacture of 10-50m structure, and characterize the structure
- Platform for long-baseline sensing - interferometric radioastronomy, geolocation, bistatic radar…

Trusselator

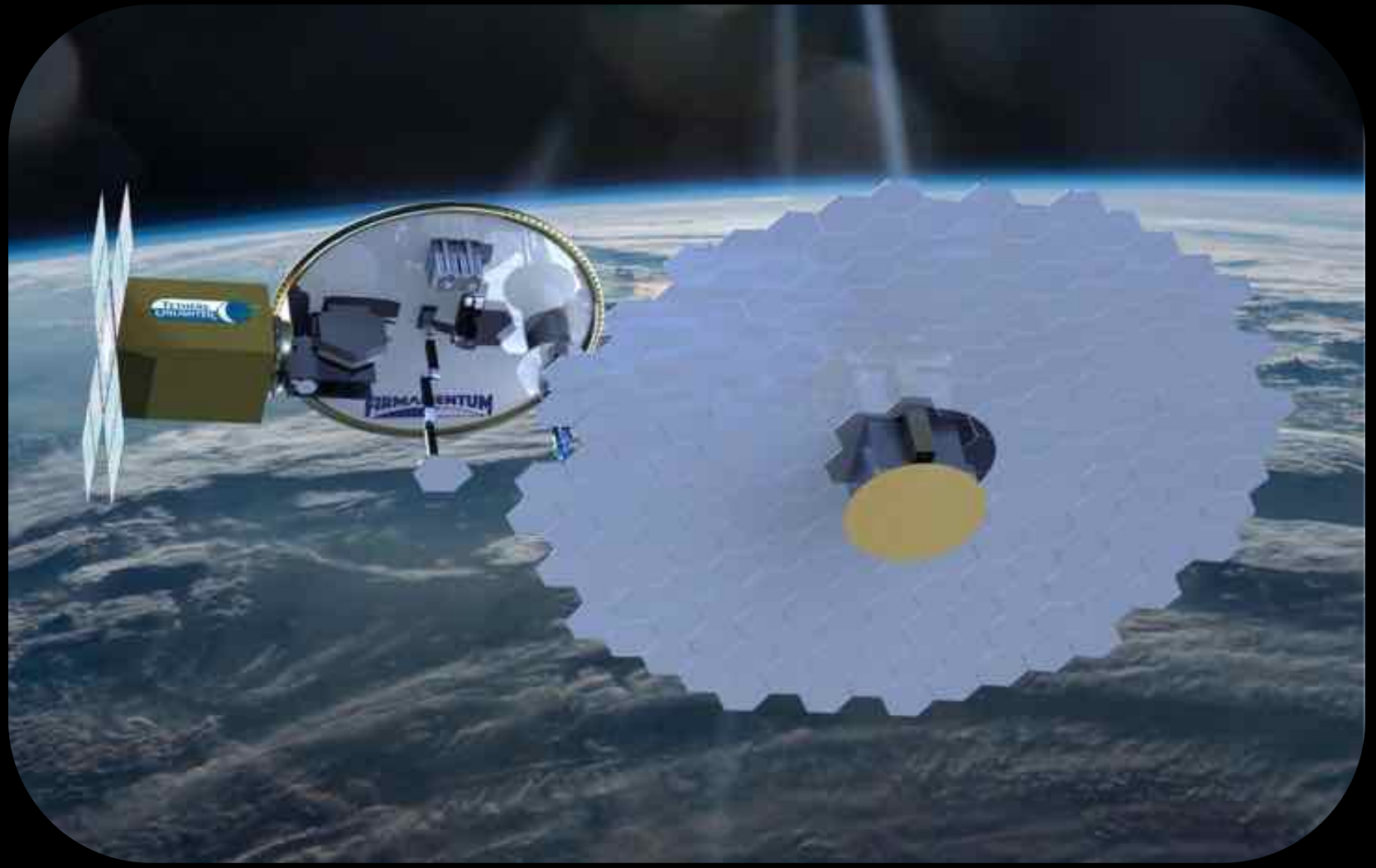
Challenges:

- Processing polymers in vacuum
- Process reliability
- Precise thermal control under orbital conditions

DragonFly/MakerSat

In-Space Manufacturing: OrbWeaver

- SBIR



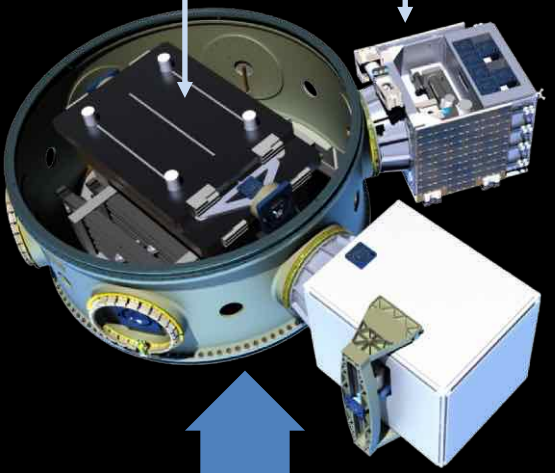
- In-space manufacture of high-throughput SATCOM smallsats
- In-space recycling of space debris

iSM + iSA: OrbWeaver

DARPA SBIR

Assembly/Servicer Robot Microsat

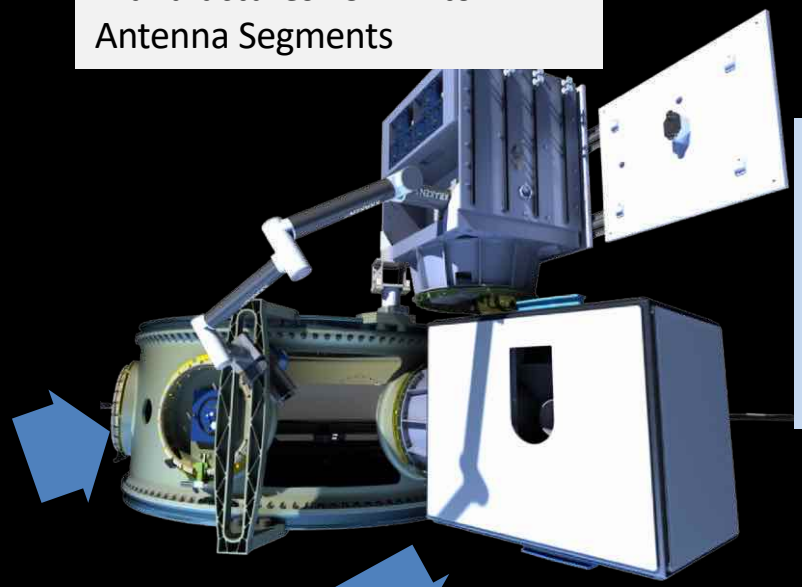
Power & RF Feed Components



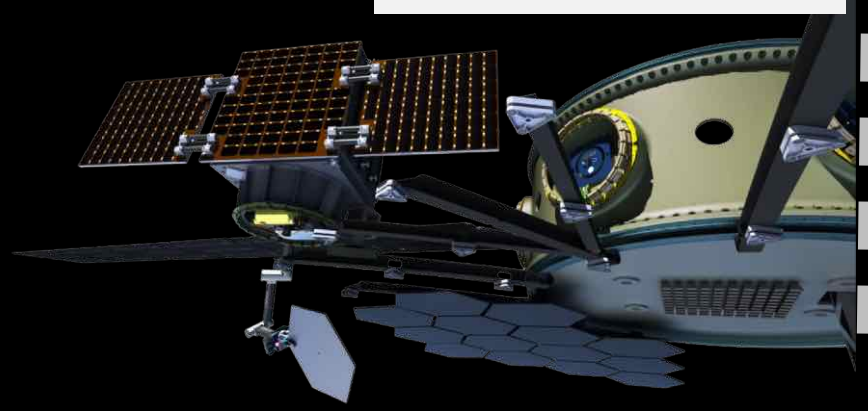
Nibbler & Hex-Caster

(1) OrbWeaver Launches as Secondary Payload on ESPA

(2) OrbWeaver Re-Manufactures ESPA Into Antenna Segments



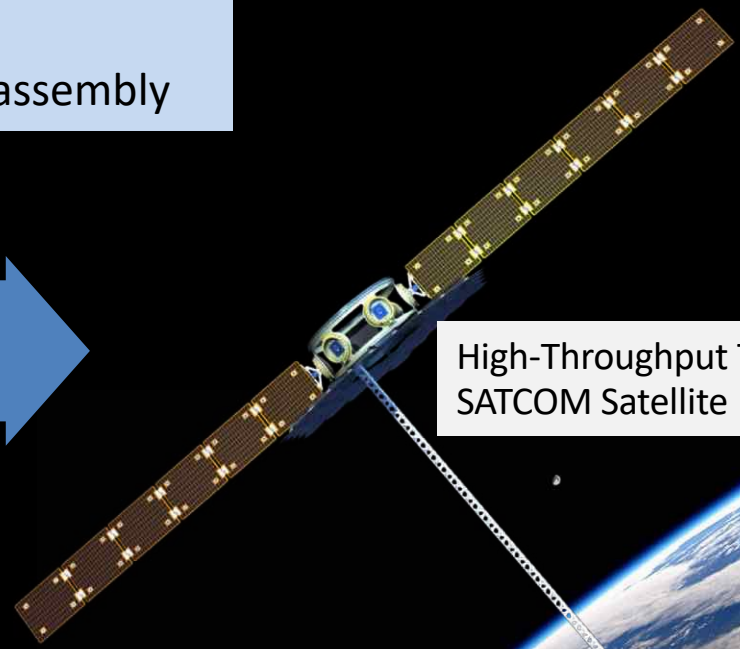
(3) OrbWeaver Assembles Antenna Reflector



Challenges:

- Casting in zero-g
- Heat-Treat metals in zero-g
- Precision assembly

Mobile Antenna Factory



High-Throughput Tactical SATCOM Satellite

Recycles Space Debris into Valueable Assets

Fiber Optic Manufacturing in Space

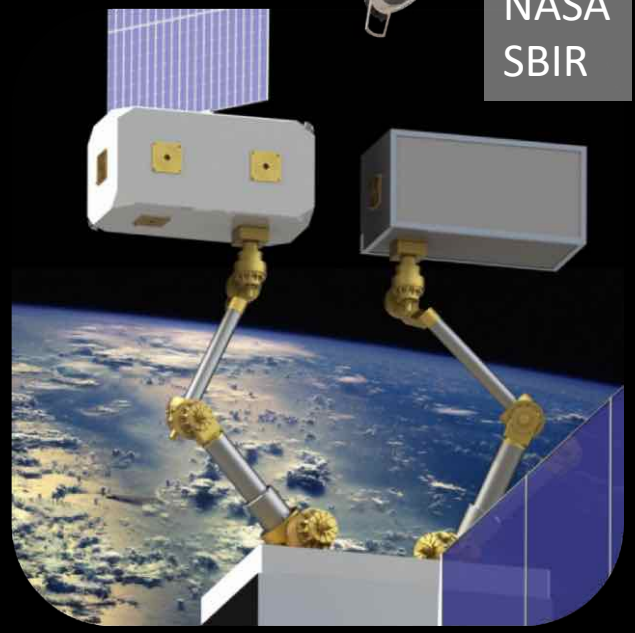
- Made In Space, FOMS, Inc., Physical Optics Inc.
  - M.I.S. 3rd Test on ISS now
- Microgravity manufacturing of ZBLAN fluoride optical fibers
- Preliminary testing indicates 10x to 100x reduction in signal attenuation
- Could enable trans-pacific optical links without repeaters
  - Does that raise value >> $10,000/kg?

Challenges:
- Controlling crystallization in zero-g
- Precise control of cooling in zero-g

In-Space Assembly of Persistent Space Platforms

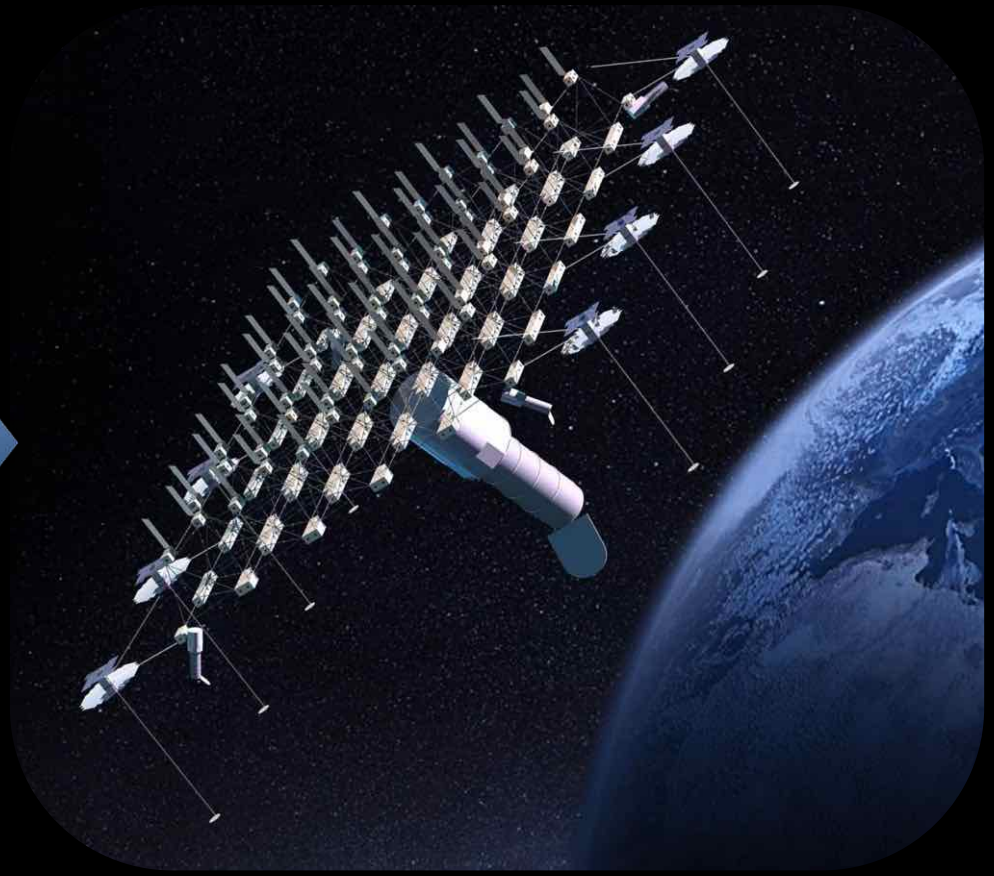
AXON™
Connectors

NASA
SBIR



Constructable™
Platforms

DARPA
SBIR

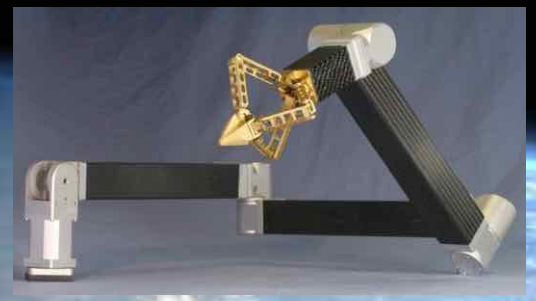


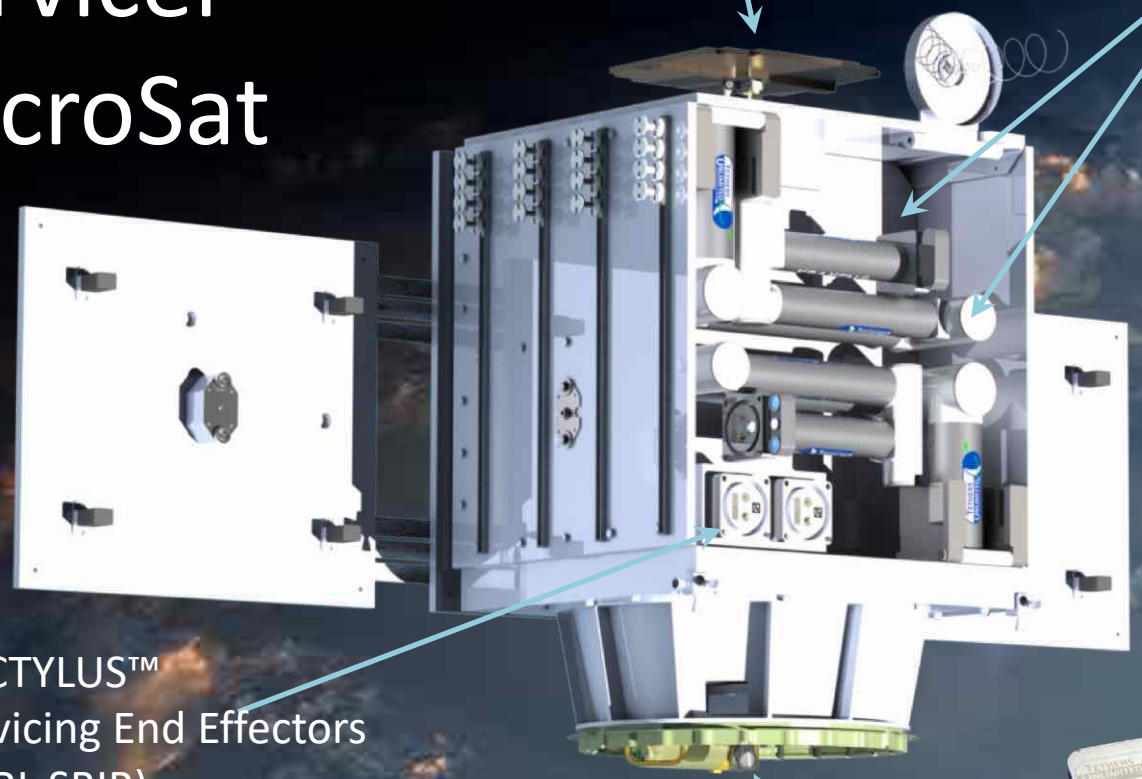
- Reduce Cost, Reduce Time-to-Market, and Improve ROI through Hosted Payload Services
- Modular Architectures Enable Economies of Scale in Building High-Reliability Platforms
- Distributed Control, distributed ADCS, distributed Power, distributed Comms
- Stop Making “Depreciating” Satellites, Instead Build “Appreciating” Space Real Estate

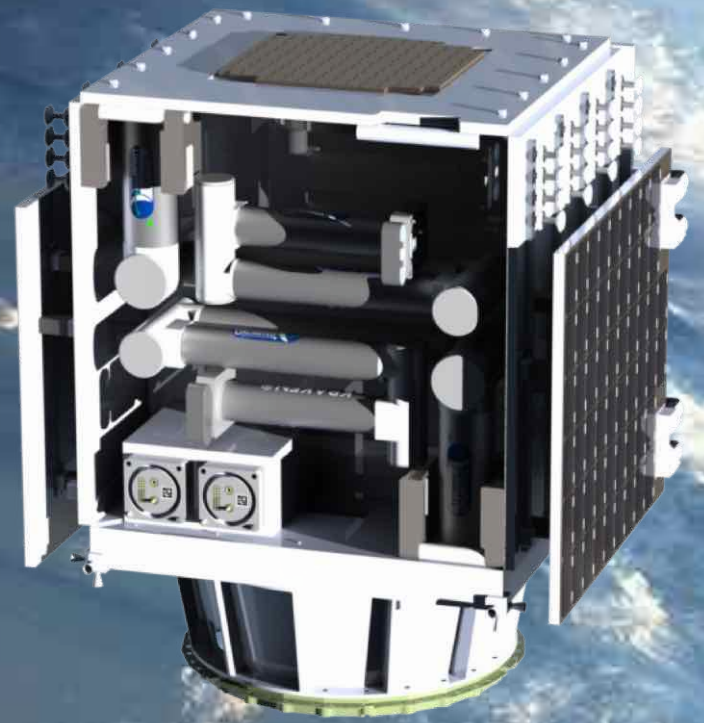
LEO Knight Assembly/ Servicer MicroSat

SWIFT® SDR Comms (AFRL SBIR)
TDRSS Backhaul TT&C

KRAKEN-X Robotic Arms (AFRL SBIR)







DACTYLUS™
Servicing End Effectors
(AFRL SBIR)

HYDROS-M
Thruster

Designed for Assembly & Servicing of Microsat-Class Systems

Oct 2018

Bootstrapping a Water-based In-Space Economy

- HYDROS-propelled SmallSat Servicer for platform module transport & integration
- Platform serves as ’gas station’ for servicers, tankers
  - Key to establishing a “water-based economy” in LEO