ISSRDC

Advancing Microgravity Manufacturing:
An Integrated System for On-Orbit Servicing and Resource Exchange

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Presenter: Ryan Elliott

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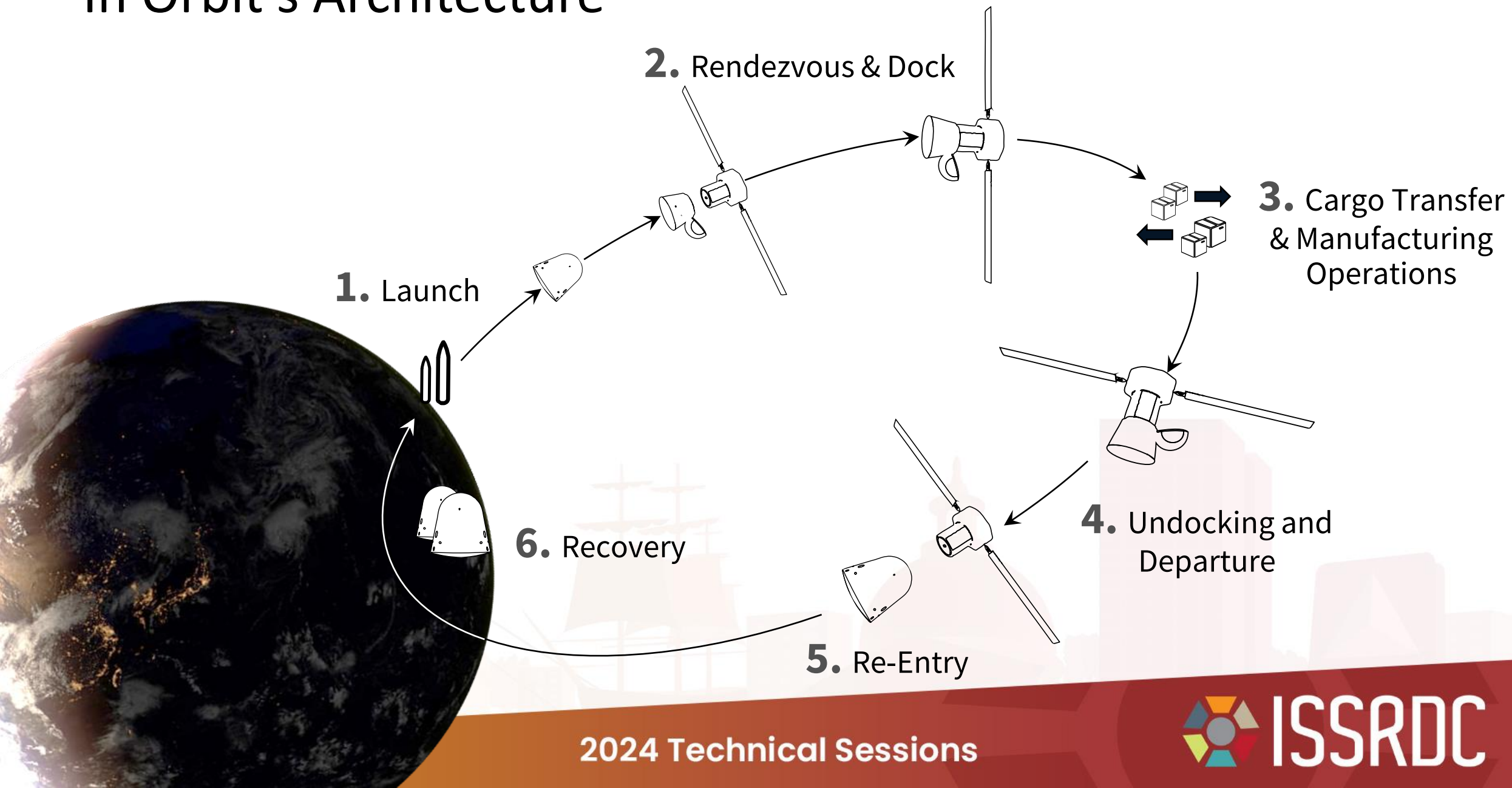
Overview: In Orbit

IN ORBIT aerospace

Founded in 2022. Based in Torrance, CA

In Orbit builds technologies to enable lower-cost and more frequent access from Space to Earth – supporting in-space manufacturing & research and precision cargo delivery for contested logistics.

In Orbit's Architecture



Automation

What is Automation?

- Methods for reducing human interaction
- It is extrapolative

Why Automate?

- Cost reduction
- Efficiency and speed
- Reliability and precision
- Safety

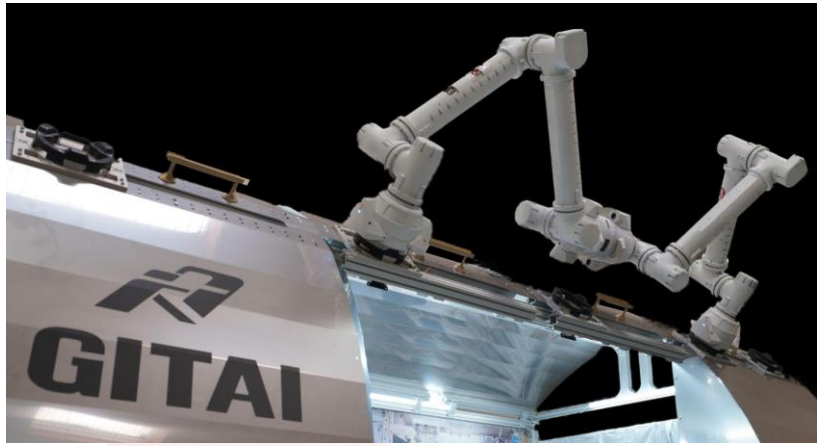
Photo Credit: Geoff Robinson, Amazon

State of Automation in Space

Automated Transfer Vehicle, Credit: ESA

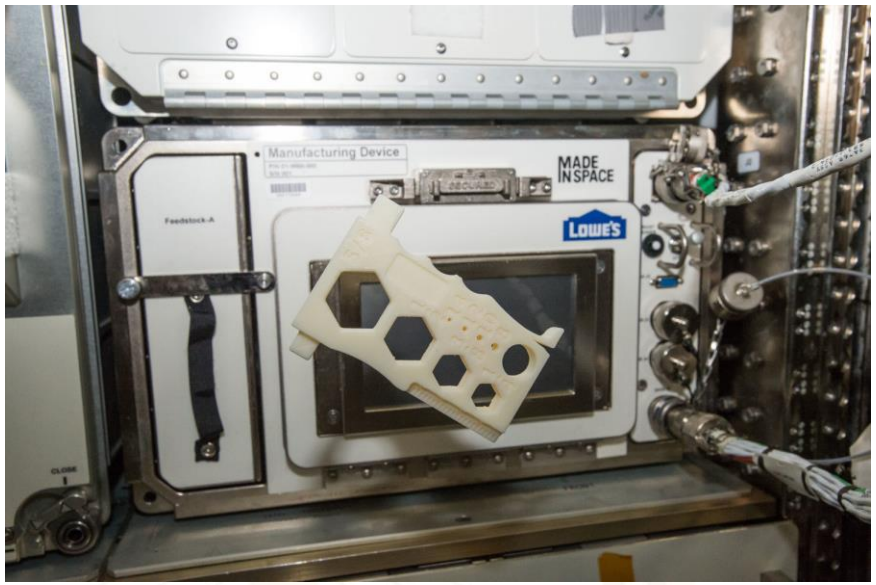
SpaceX Dragon 2, Credit: NASA

Astrobee, Credit: NASA

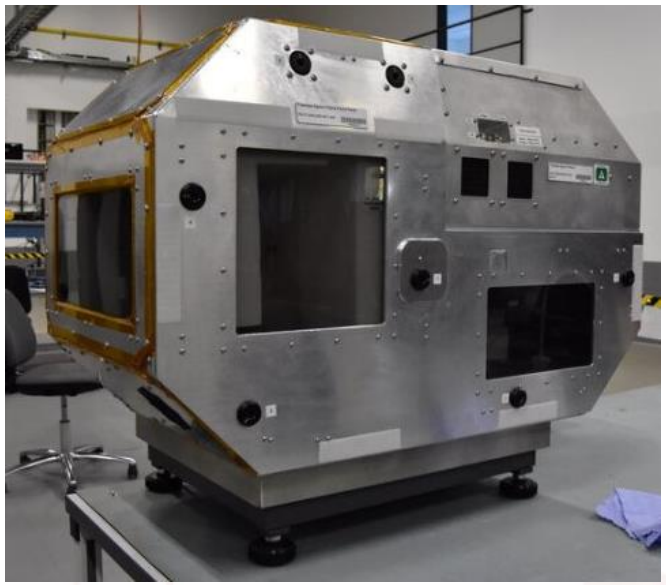


GITAI Robotic Arm, Credit: GITAI

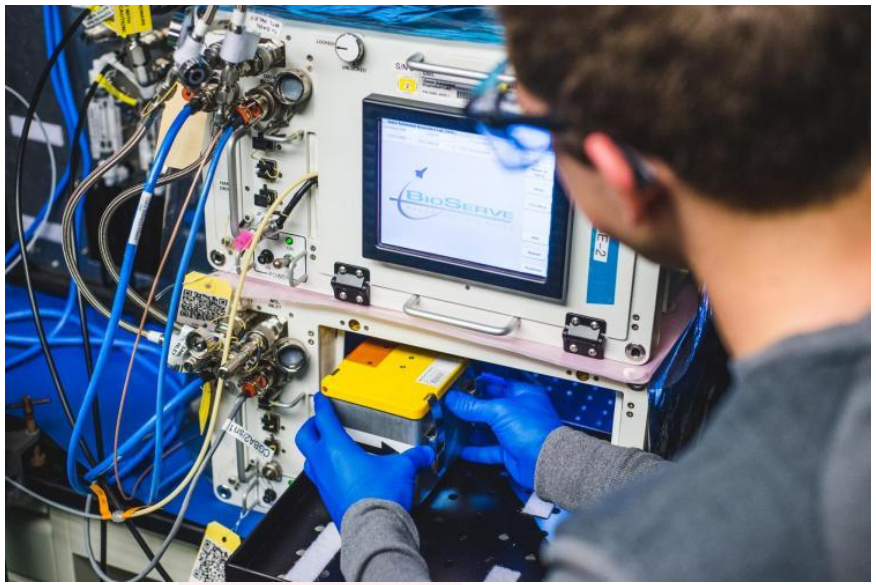
Automation on the ISS



Additive Manufacturing Facility and a 3D-printed tool.
Credit: NASA



Optical Fiber Manufacturing Machine.
Credit: Flawless Photonics



Space Automated Bioproduct Lab.
Credit: BioServe Space Technoogies

Problem Statement and Objectives

Problem:

We lack general purpose building blocks for automation in space

- Lack of automation requires crew intervention
- Lack of building blocks makes hardware development cumbersome
- Most terrestrial building blocks would not work

Objectives:

Create the foundation for space-based automation

- Obtain end-user feedback
- Receive insight into what efficiencies can be gained

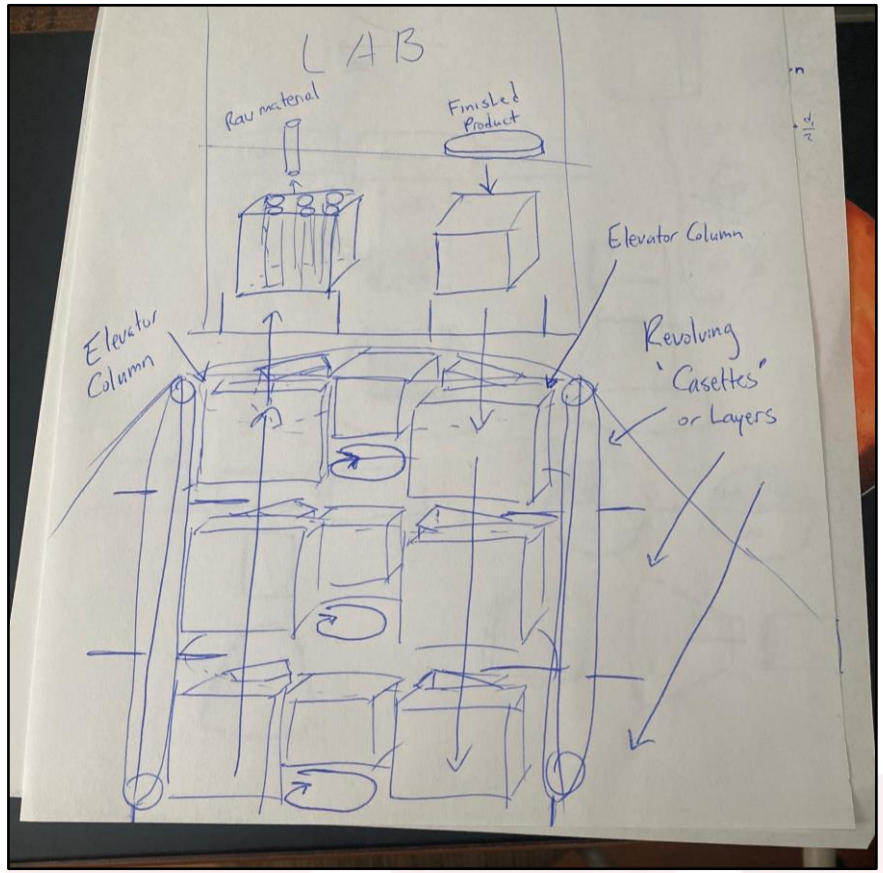
In Orbit defined principles for a building block of automation:

- **Automated cargo transfer**
- **Volumetric efficiency**
- **Low-complexity**
- **Upgradeable**

Resource **EX**change Module (REX)

How do we robotically manipulate and transfer cargo between vehicles in space?

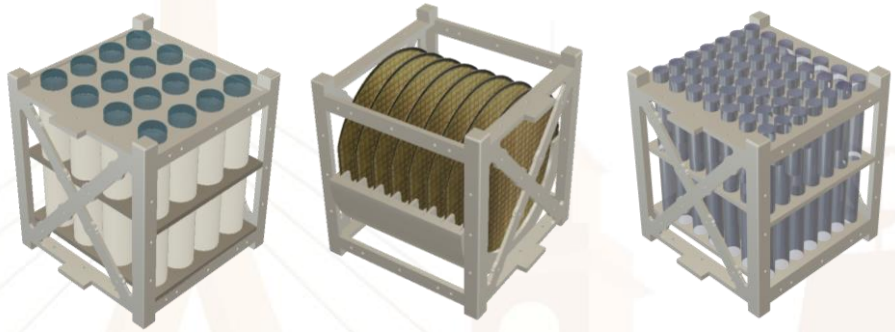
- Two symmetric REX modules would be docked with each other (*REX A*, *REX B*)
- Design features revolving layers and translation between the layers
- **REX A:** initially filled with raw materials
- **REX B:** contains customer research/mfg. laboratory
- Raw materials move from REX A to REX B
  - R&D occurs in the customer laboratory
  - Finished products move back from REX B to REX A



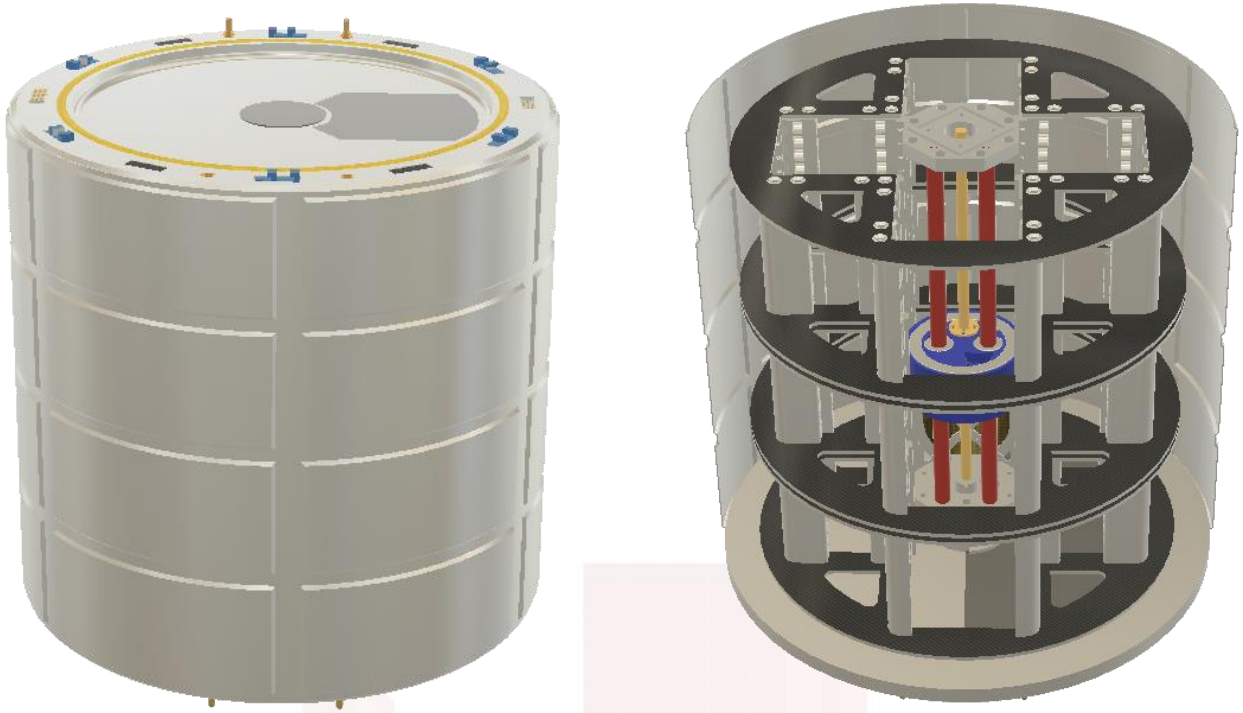
First Sketch of REX. Credit: In Orbit Aerospace Inc.

Resource Exchange Module – Early Model

- First iteration designed to be 80 cm in diameter and 80 cm in height
- Fits 12x 8U (2Ux2Ux2U) sized payloads
- Envisioned customer “payloads” are treated as black boxes

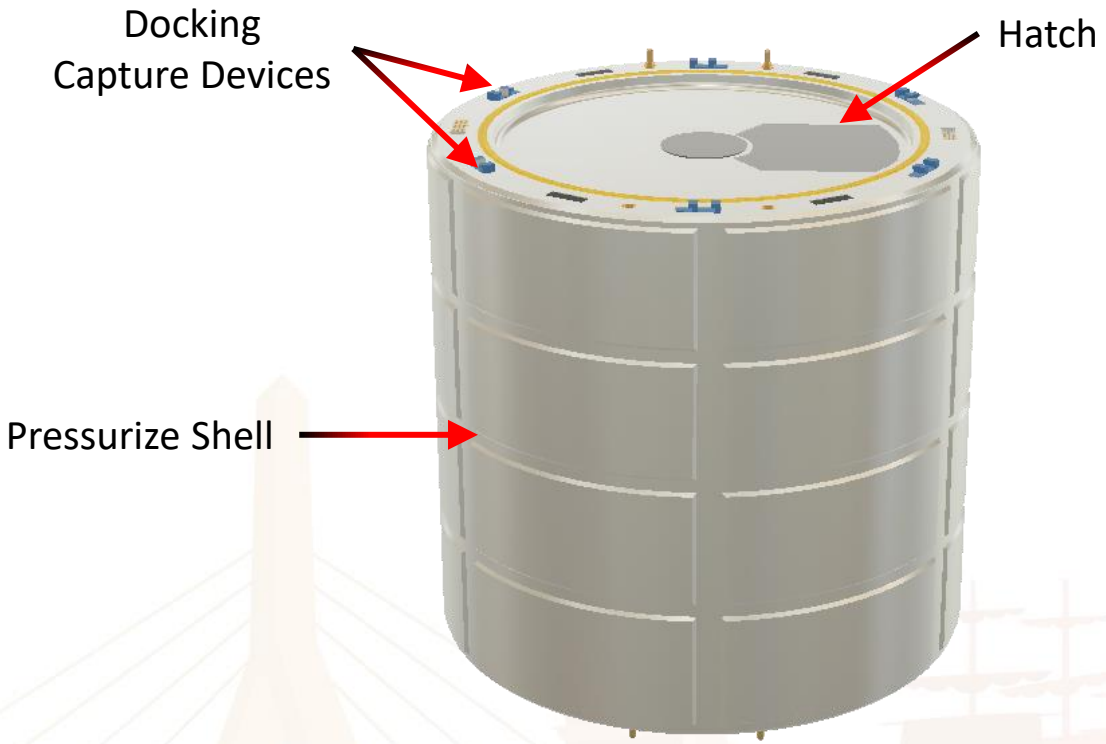


Common payloads container vials, semiconductor wafers, or glass rods.
Credit: In Orbit Aerospace Inc.

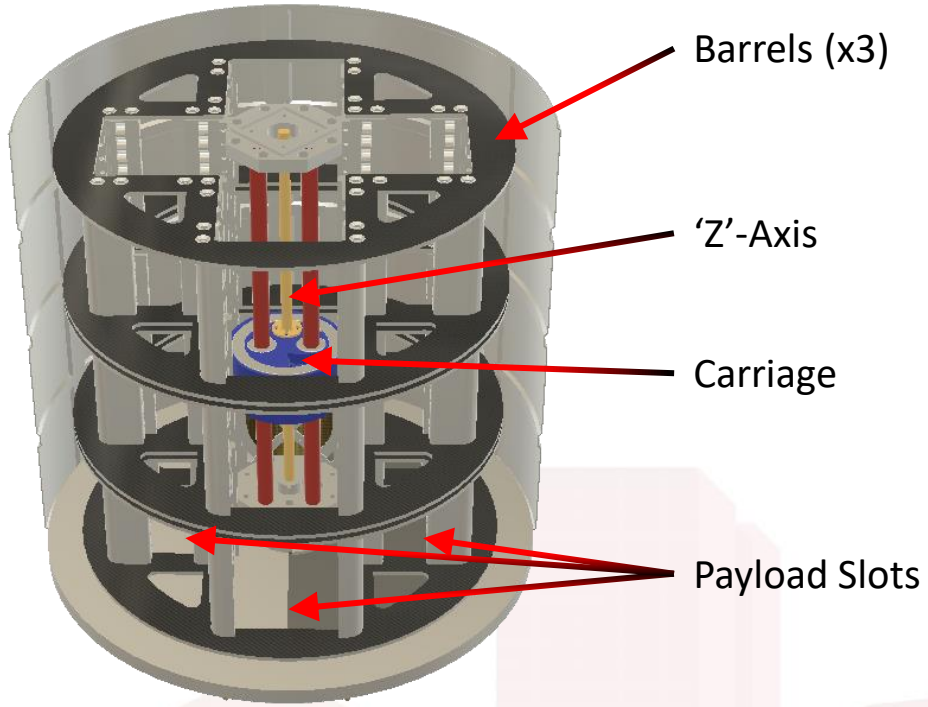


External (left) and Internal (right) View of a REX Module.
Credit: In Orbit Aerospace Inc.

Resource Exchange Module – Early Model

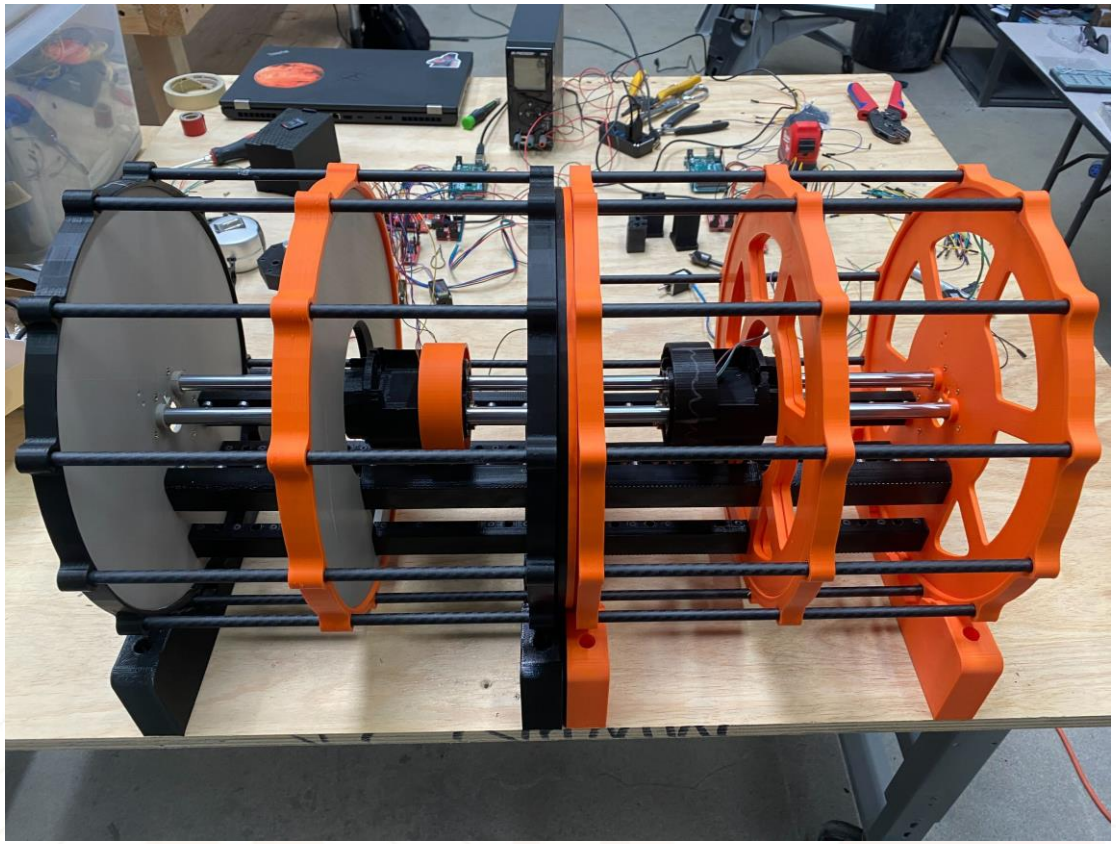


External View of a REX Module. Credit: In Orbit Aerospace Inc.



Internal View of a REX Module. Credit: In Orbit Aerospace Inc.

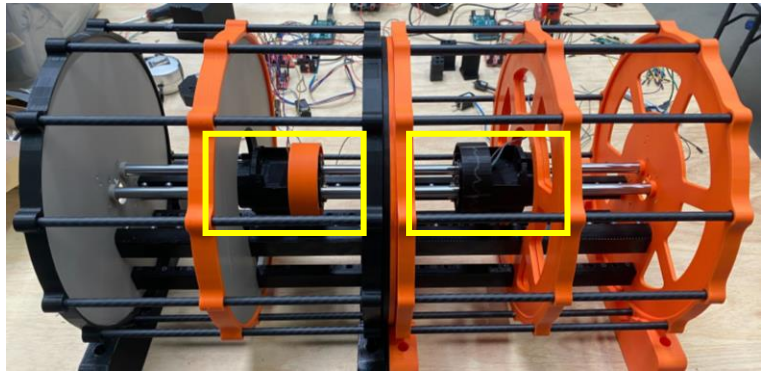
REX – First Prototype



Two Early Prototypes of the REX.
Credit: In Orbit Aerospace Inc.

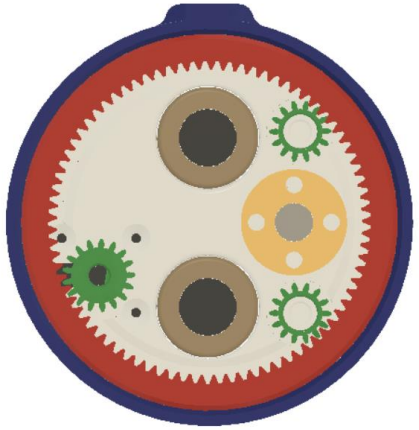
- First benchtop model built and tested in April 2023
- Consists of two connected REX modules
- Initial design focus on the carriage and Carriage
  - Translation-only
  - Two payload slots per REX

First Prototype – Carriage Focus



Two REX Modules with Carriages Highlighted.
Credit: In Orbit Aerospace Inc.

REX Carriage, Oblique View. Credit: In Orbit



REX Carriage, Top View. Credit: In Orbit

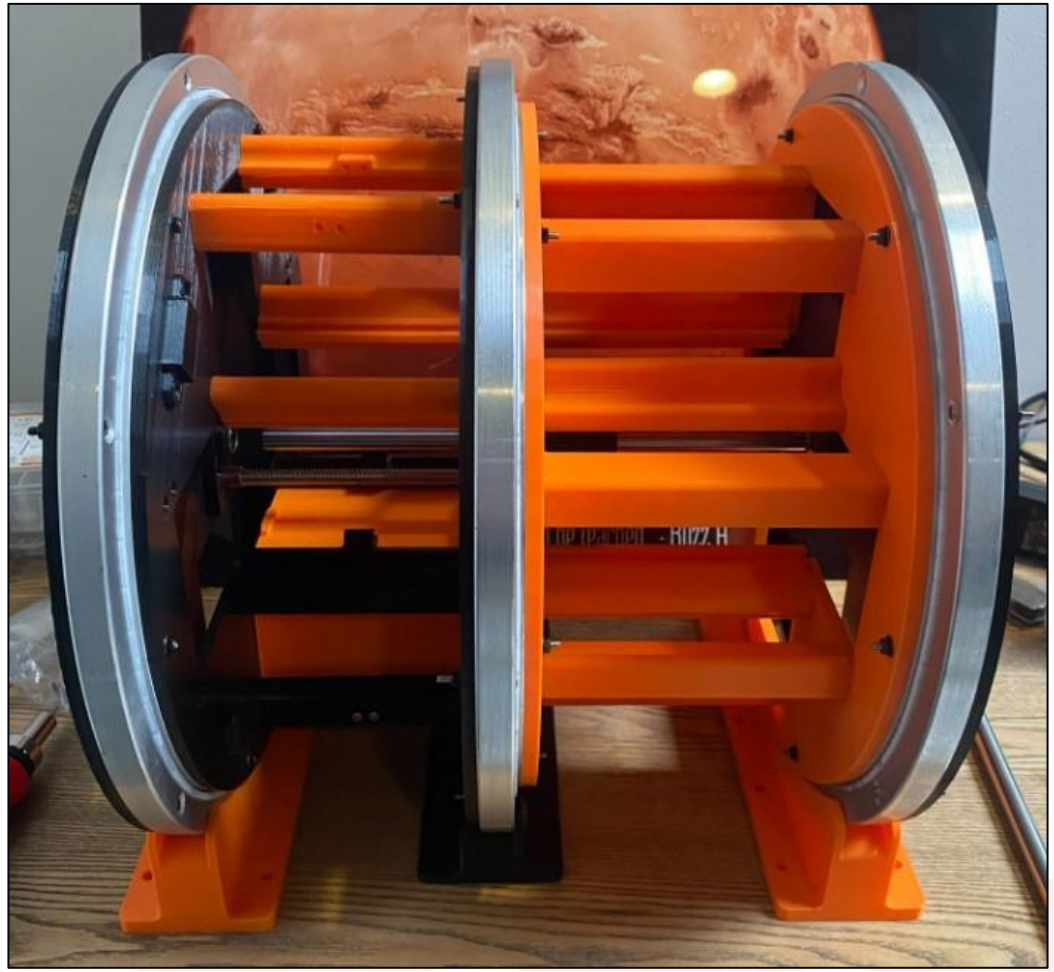
- ‘Carriage’ translates via lead screws and external motor
- ‘Sleeves’ are rotated around the Carriage via internal motors
- Tabs on the sleeves interface with the blocks
  - Length of the Carriage necessitated two sleeves

REX Carriage with sleeves removed. Credit: In Orbit

REX sleeve and gears. Credit: In Orbit

REX – Second Variation

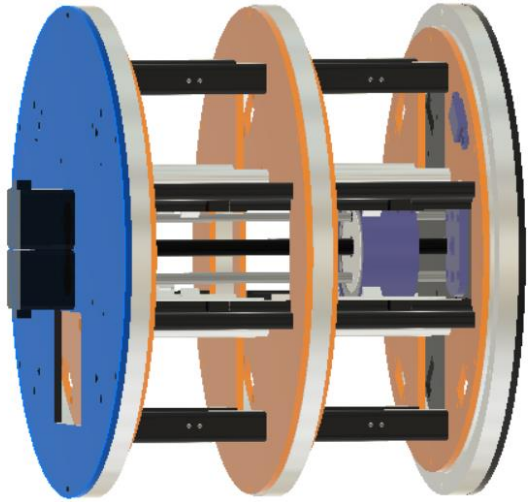
- Second variant built in early 2024
- Just a single REX with three main “updates”:
  - Inclusion of rotation mechanisms
  - Reduction of Carriage size
  - Include locks for payloads and barrels



Second iteration of REX, Side View. Credit: In Orbit

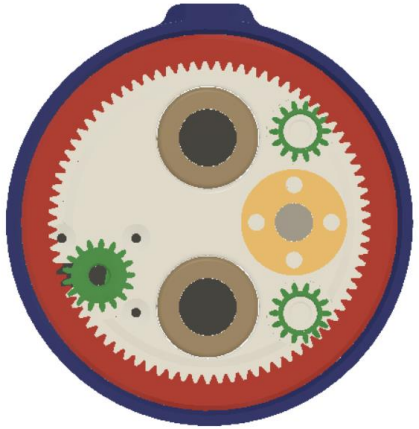
Second Variation – Carriage Focus

- Motors removed from the Carriage and placed at the end
- Reduction in volume allowed for just one sleeve, and therefore two total motors

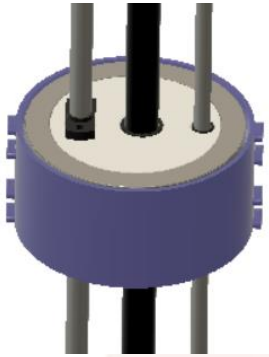


REX V2 CAD Model showing Motors on the Back Plate. Credit: In Orbit

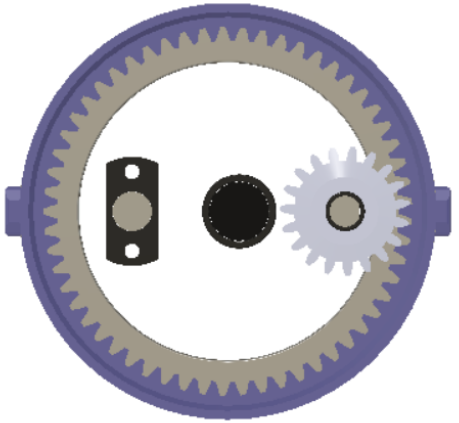
REX Carriage. Credit: In Orbit



REX Carriage, Top View. Credit: In Orbit



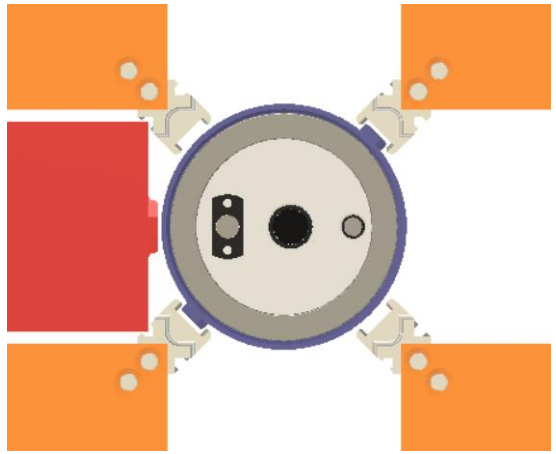
REX V2 Carriage. Credit: In Orbit



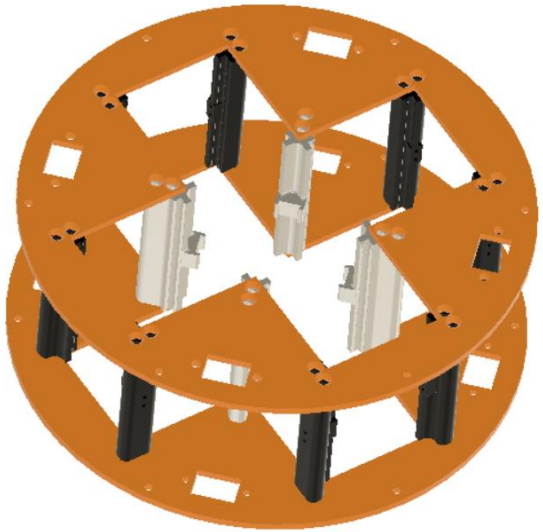
REX V2 Carriage, Top View with Housing Removed. Credit: In Orbit

Second Variation – Barrel Rotation

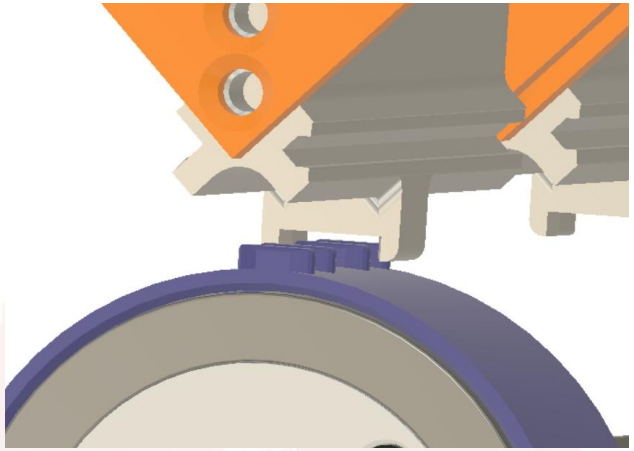
- Inner set of posts included a tab that interfaced with the Carriage
- The Carriage can then not only translate the payloads but rotate the barrels



Head on View showing Carriage Tabs Interfacing with the Posts to Enable Rotation. Credit: In Orbit



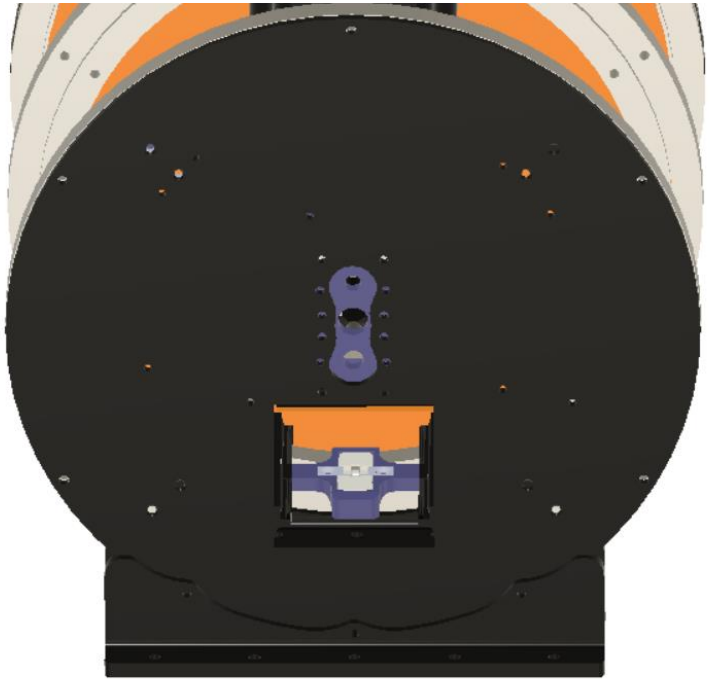
REX Barrel and Posts. Credit: In Orbit



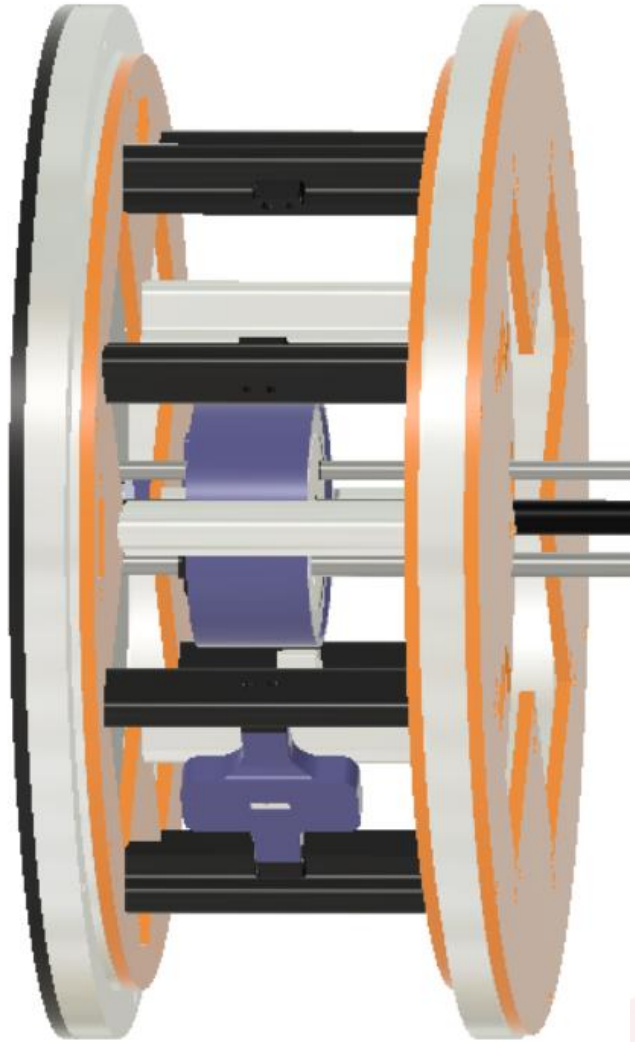
Close-up View of the Sleeve Tabs and Inner Post. Credit: In Orbit

REX – Latest Variations

- Included passive locking mechanisms for the payloads and for the barrels



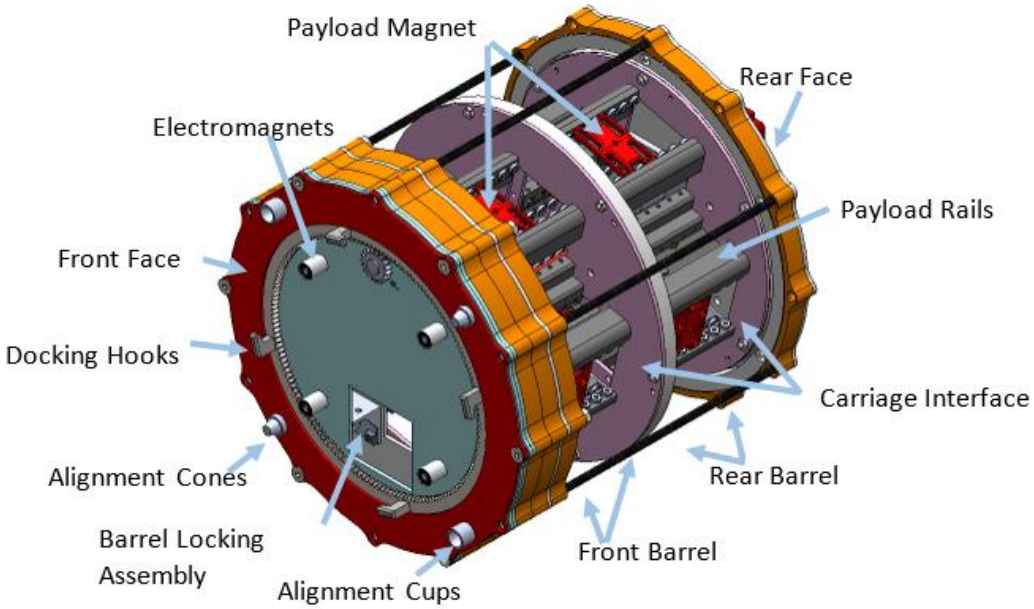
Rear View of REX showing a Passive Locking Mechanisms. Credit: In Orbit



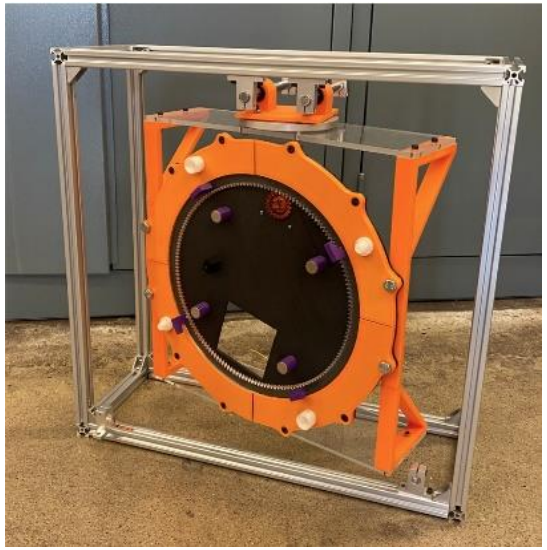
Side View of REX showing the location of a Block Locking Mechanism. Credit: In Orbit

Loyola-Marymount Variation

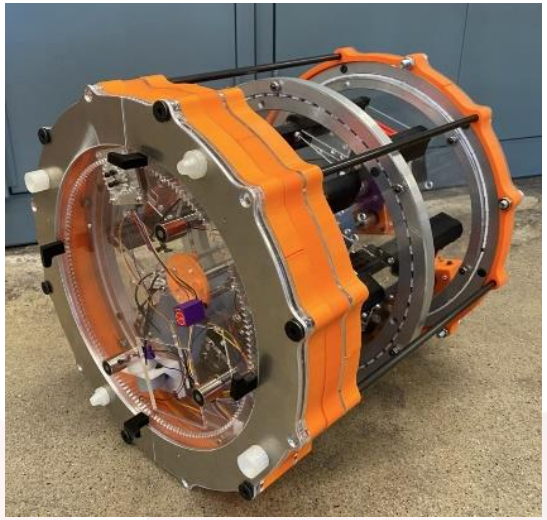
- Students from Loyola-Marymount elaborated on the second variation
- Incorporated a notional docking system utilizing electromagnets for soft capture



REX V2.1 Design by Loyola Marymount Students. Credit: In Orbit



REX Docking Demonstration Jig. Built by Loyola Marymount Students. Credit: In Orbit



REX V2.1 Built by Loyola Marymount Students. Credit: In Orbit

REX – Software Architecture

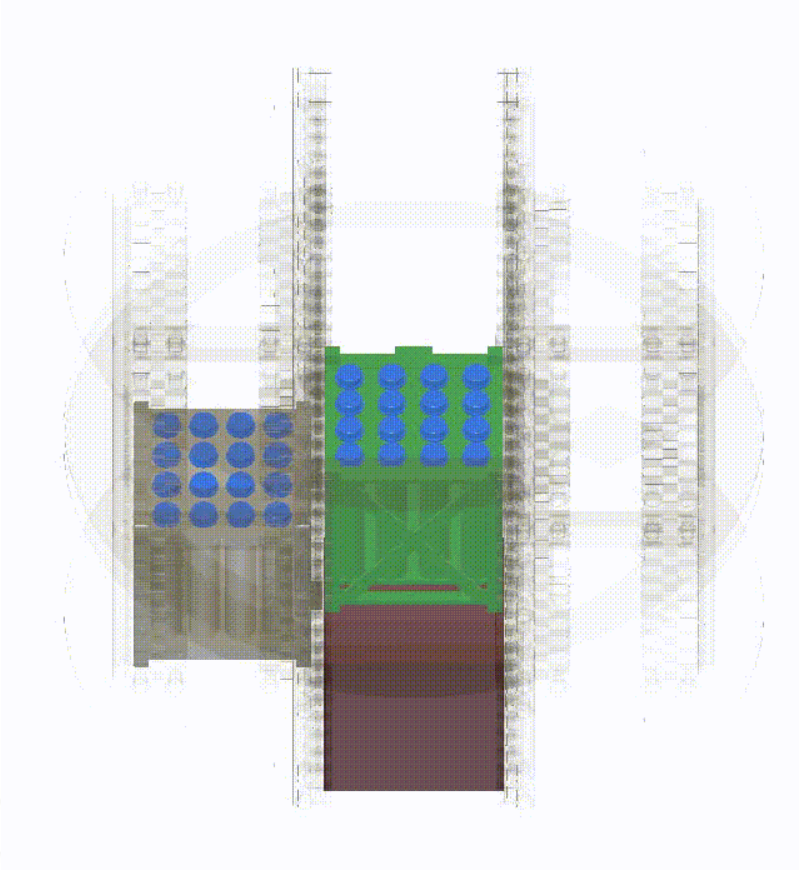
Objective:

- Move a block from one slot to another

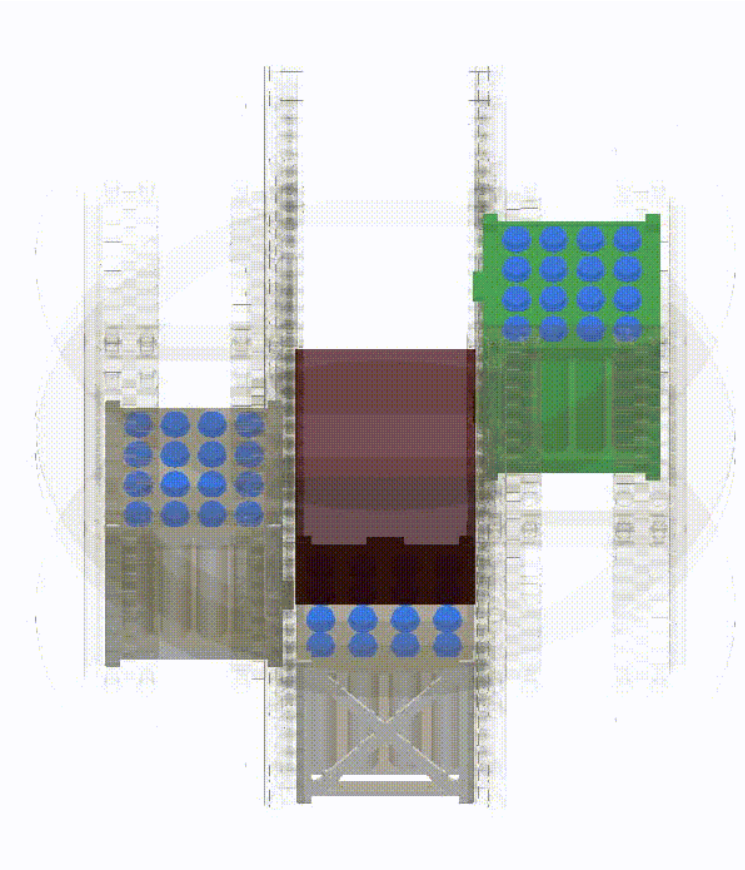
Operation:

- Write the software such that the path is automatically calculated
- Maintain a “map” of the system as you perform payload manipulation
- It’s an A* Algorithm, with blockages that can be moved
  - 7,112 combinations!
  - Reduces to 7 scenarios

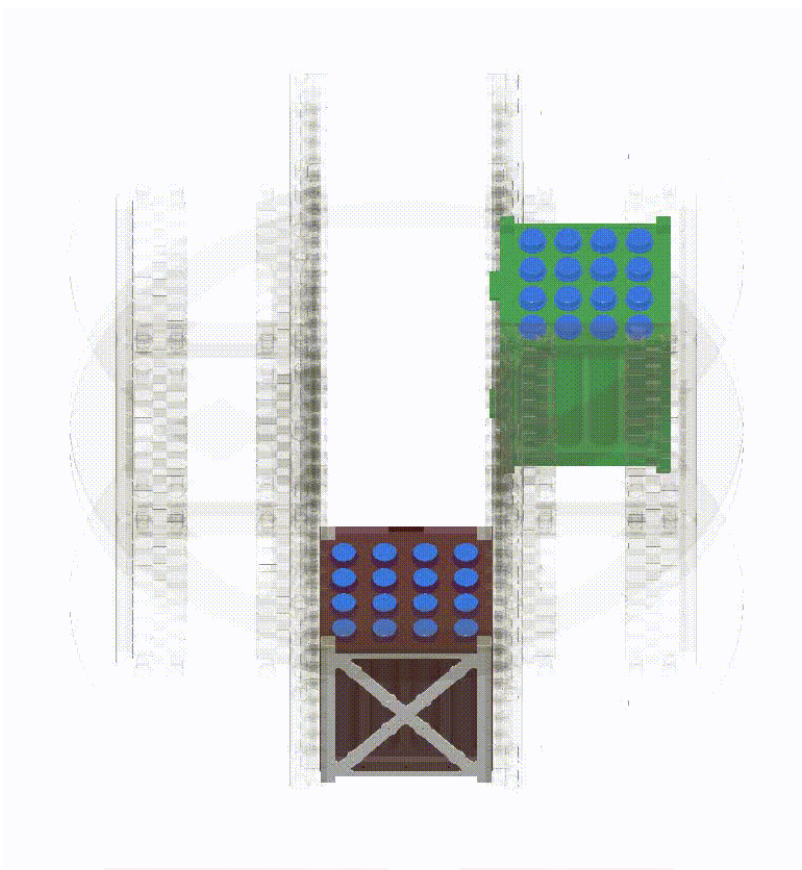
Manipulation Scenarios 1 – 3



Simple Translation

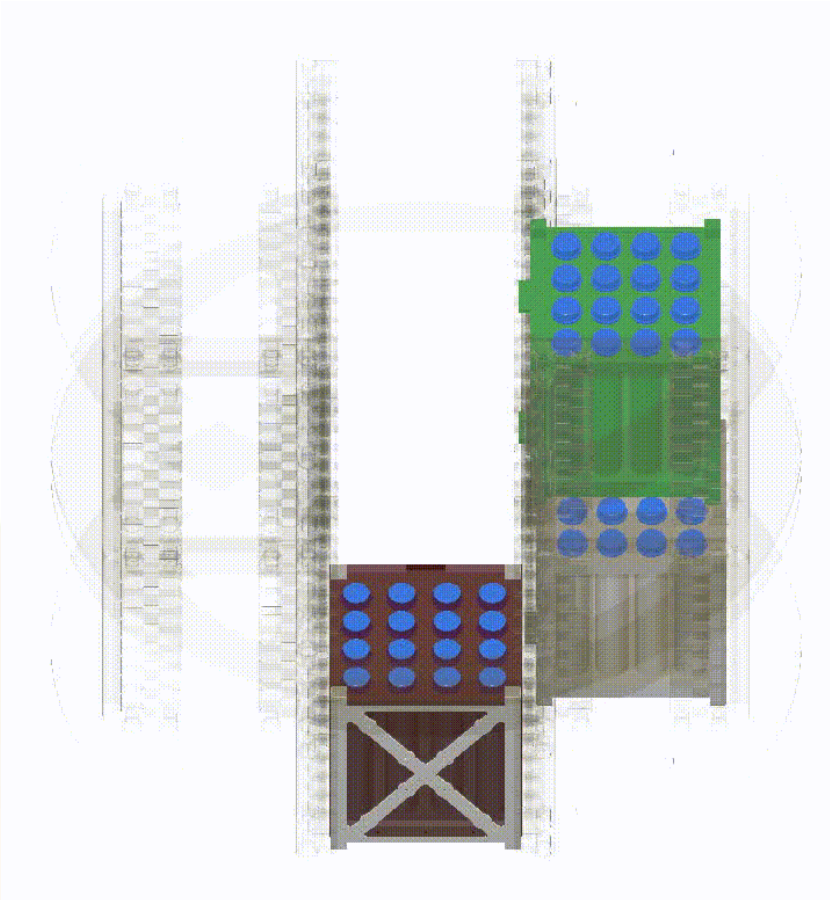


Simple Rotation

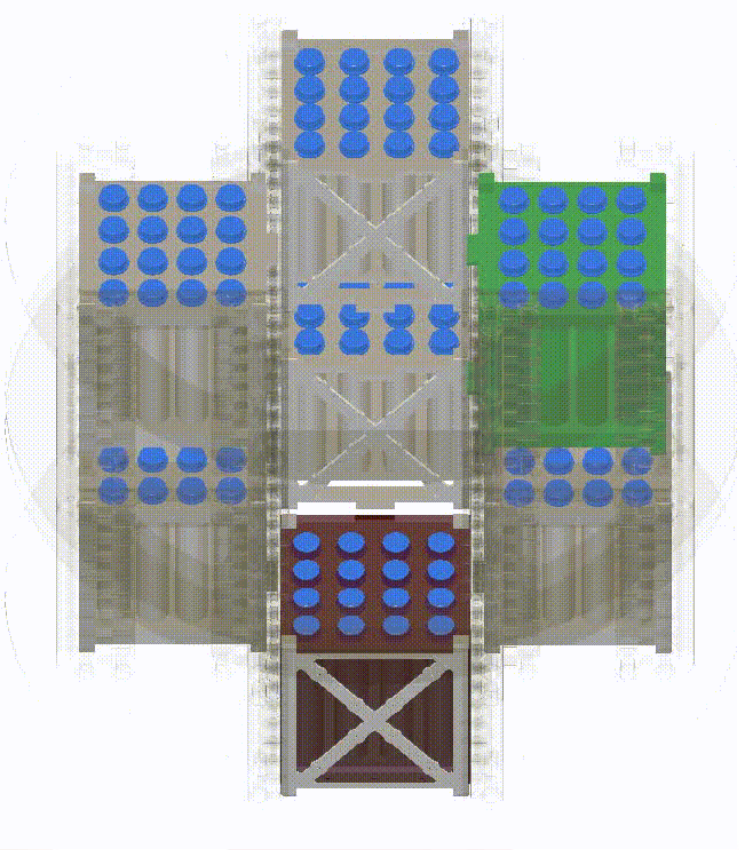


Translation + Rotation
Or vice versa

Manipulation Scenarios 4 – 5

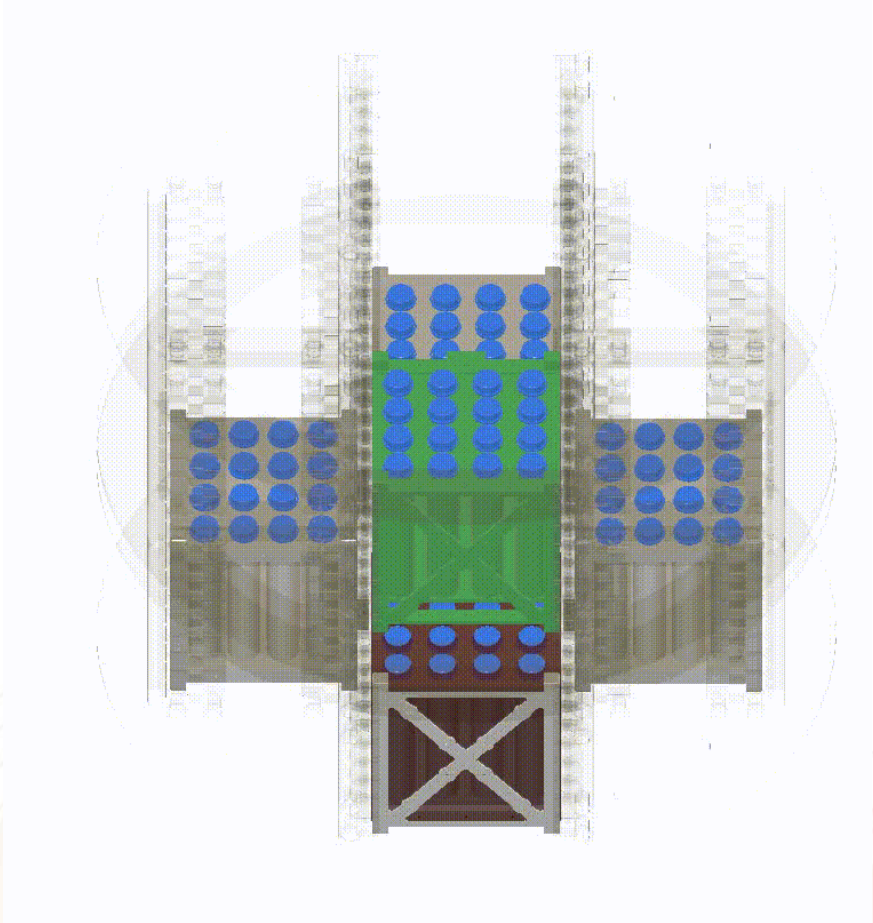


Rotation to clear blockage. Then
Rotation + Translation

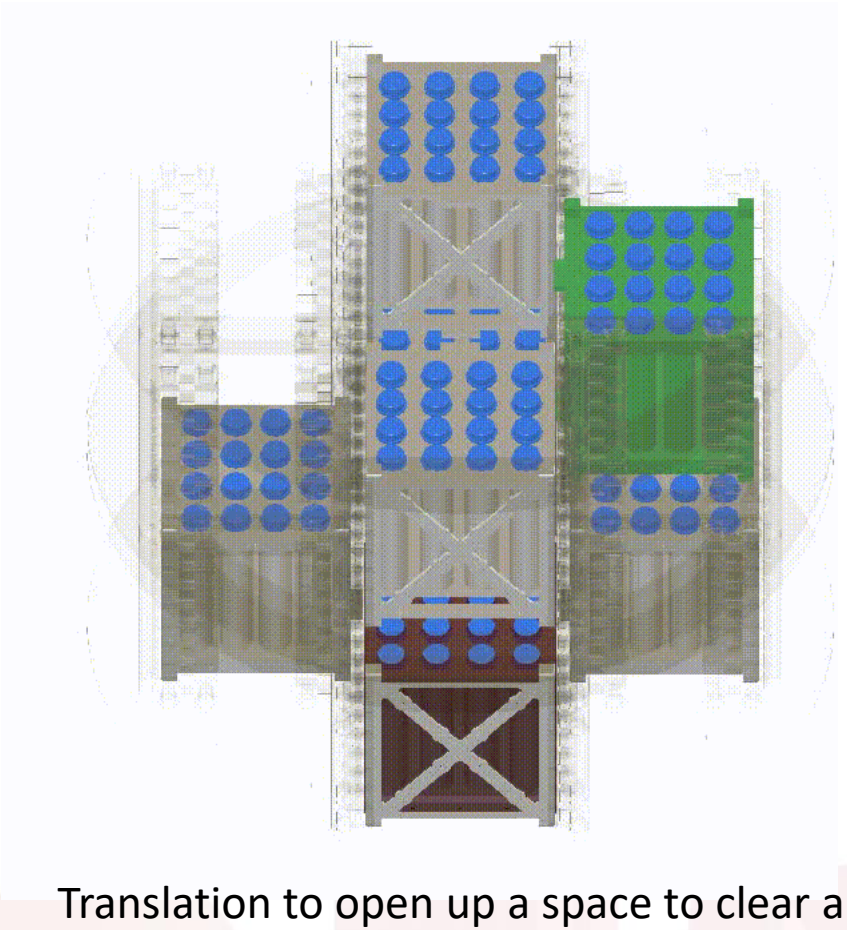


Translation to clear blockage. Then
Rotation + Translation

Manipulation Scenarios 6 – 7



Translation to open up a space to clear a blockage. Rotation to clear blockage. Then a translation



Translation to open up a space to clear a blockage. Rotation to line up the destination and block of interest, then a final translation

Economic Analysis

Cost Reduction and Efficiency

Operational Costs and Savings

Market Potential and Revenue Streams

Strategic Partnerships and Collaborations

Long-Term Economic Impact

REX on the International Space Station

In Orbit was awarded a contract from the ISS National Lab, with Nanoracks as the implementation partner, to demonstrate the REX in the microgravity environment (2026).

The project set out to perform the following goals:

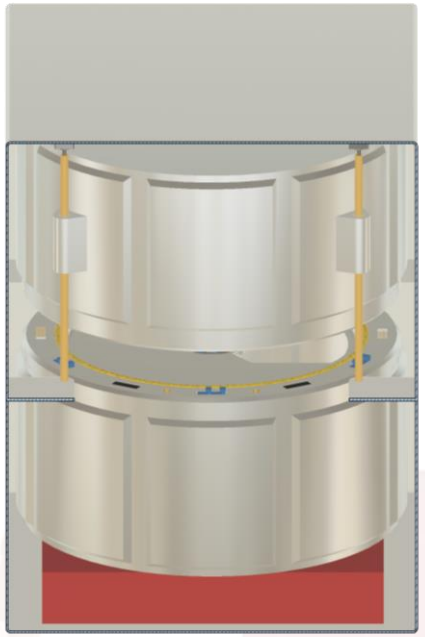
1. Sort payloads in preparation of transfer between two pressurized REX modules
2. Transfer payloads between two REX modules
3. Repeat the payload exchange, this time, from the secondary REX module back into the primary REX module in a different configuration from the initial (combines the sorting and transfer processes)

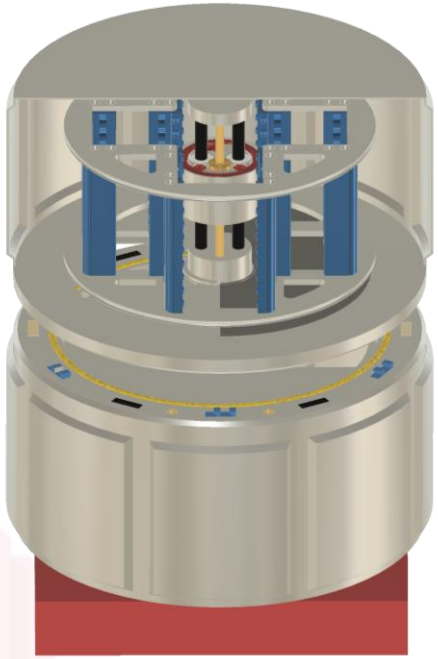
International Space Station. Credit: NASA

ISSREX

- This variation would include two REX's inside a sealed housing, jointly named the ISSREX
- The entire assembly would fit inside a CTM bag
- One REX would be stationary, and the second would be movable on 1-axis
- Would seek to repeatedly dock, pull a vacuum, and transfer payloads

The ISSREX External Housing. Credit: In Orbit


The ISSREX Showing Two REX Modules Inside. Credit: In Orbit


The ISSREX Showing Internals of One REX. Credit: In Orbit

Next Steps and Future Work

Focus on the ISSREX build:

- Shrink to fit in the CTB bag
- Upgrade mechanisms to active mechanisms
- Design to withstand the launch and space environment
- Design the individual REX modules to hold a pressure of 1 atm
- Stress Test and ensure this can operate for long periods of time without encountering a jam or other fault

Other REX Applications

The REX isn't just for manufacturing automation, but a general-purpose building block.

Thus, it can be used for a variety of applications:

- CubeSat deployer
- A multi-step manufacturing module
- Satellite servicing module
- A storage facility with automated package retrieval
- And more!

Conclusion

- **Building blocks for automation are heavily used on Earth**
  - Conveyer belts, robotic arms, etc.

- **Automation for space is of paramount importance** for scaling operations while maintaining quality and safety

- **The Resource Exchange Module allows for the sorting and transfer of materials**, and is one such example of an automation building block in the growing space economy

- **REX operationality in space will be demonstrated on the ISS in late 2025 – 2026**

Acknowledgements

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Scott Rodriguez and Mike Lewis at Nanoracks for their advice and serving as our implementation partner.

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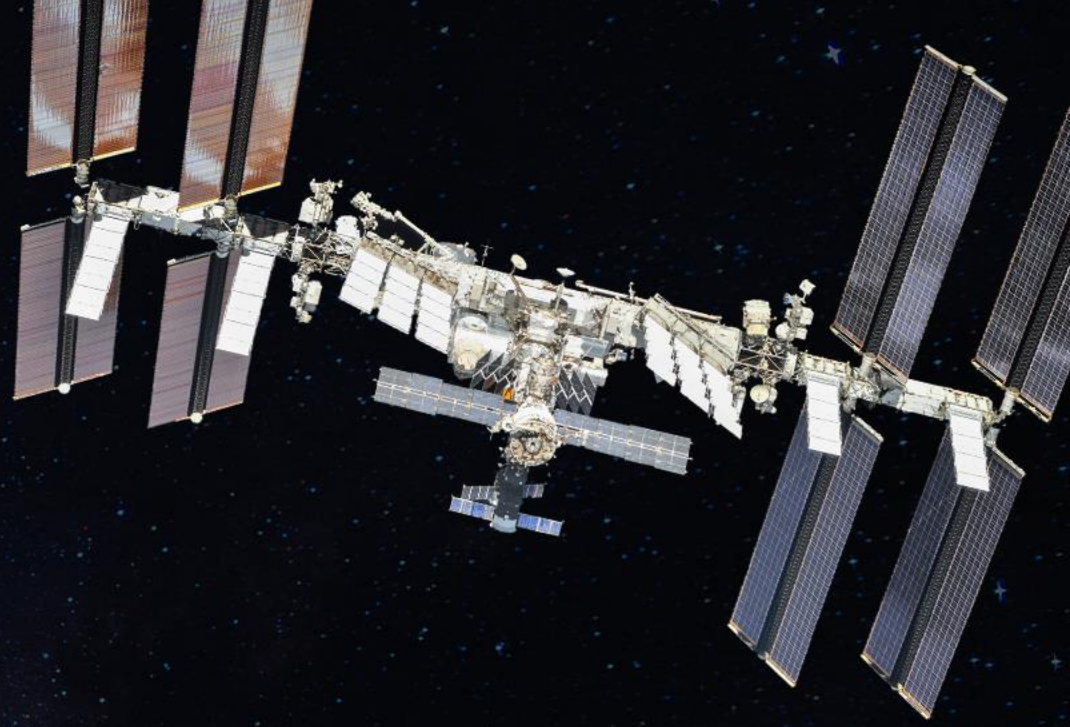

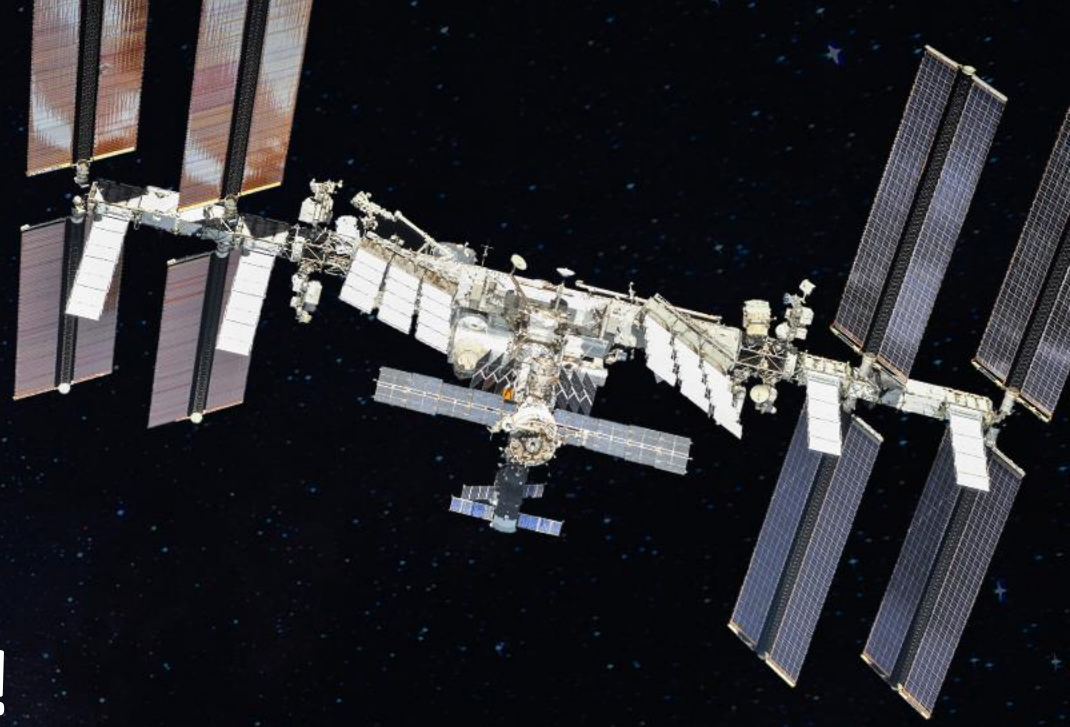

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