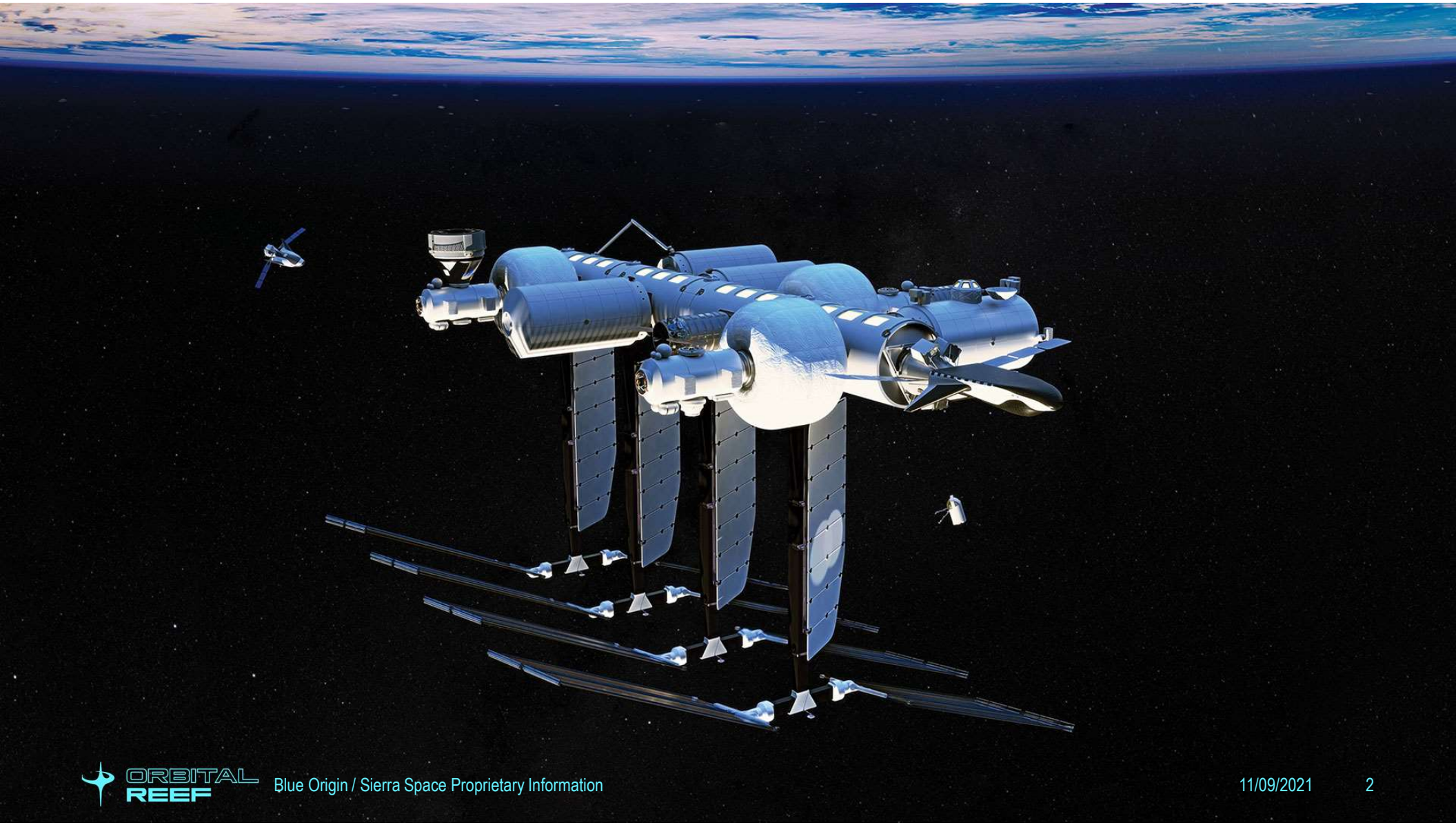
ORBITAL REEF

Orbital Reef

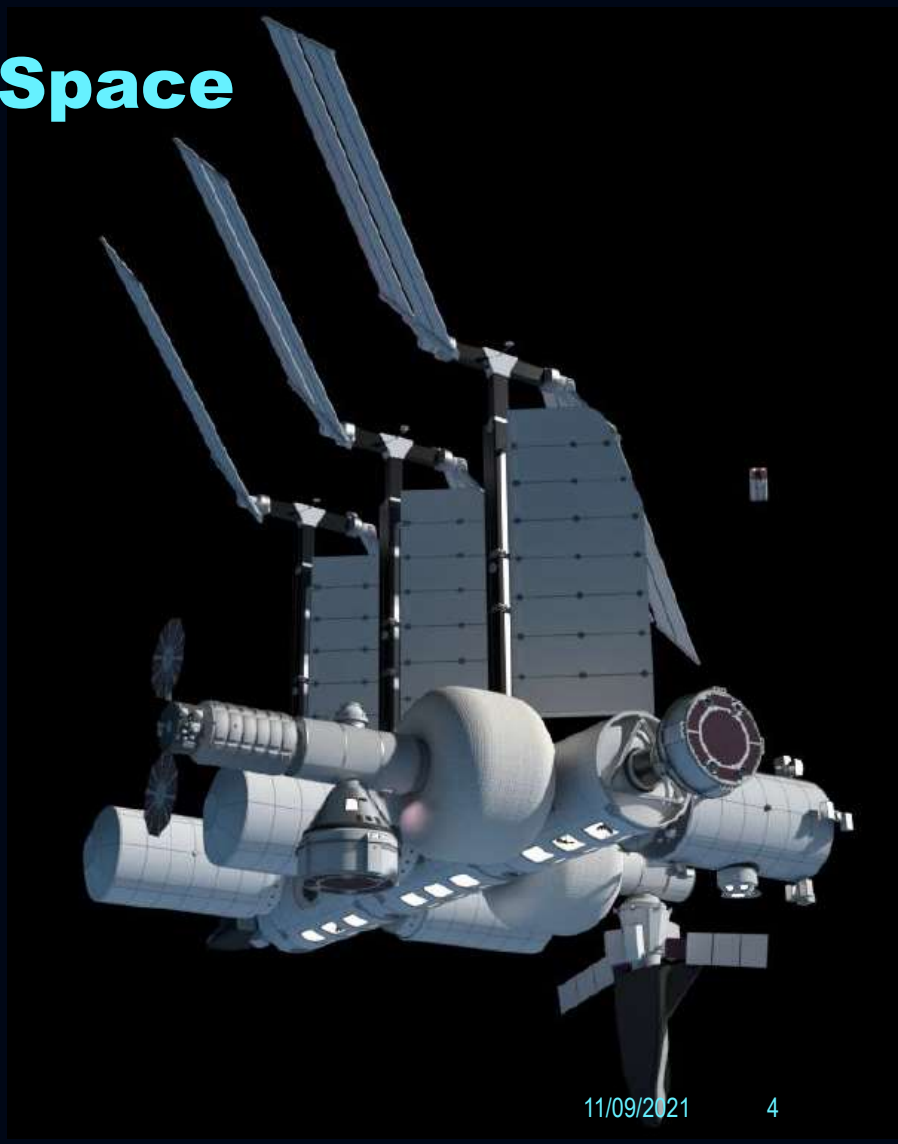
SSB
15 November 2021



Mixed Use Business Park in Space

- Commercially developed, owned, and operated station in low Earth orbit
- Shared long-term vision of developing and operating infrastructure and systems to enable humans to live and work in space in large numbers
- Modular and expandable architecture grows with market demand
- International collaborations to develop and utilize Orbital Reef for numerous commercial applications to create a thriving space economy

https://youtu.be/SC3ooNXfcGE



Diverse Team of Collaborators

BLUE ORIGIN	Utility systems, large-diameter core modules, reusable heavy-lift New Glenn launch system, and space tug vehicle	SIERRA SPACE	Expandable LIFE modules with docking nodes, and Dream Chaser reusable spaceplanes for crew and cargo delivery to runways worldwide
BOEING	Science module, station operations, maintenance engineering, and Starliner crew spacecraft	REDWIRE	Microgravity R&D and manufacturing; payload operations and deployable structures; digital engineering
GENESIS ENGINEERING	Single Person Spacecraft for routine operations and tourist excursions	ASU	Leads a consortium of global universities providing research advisory services and public outreach

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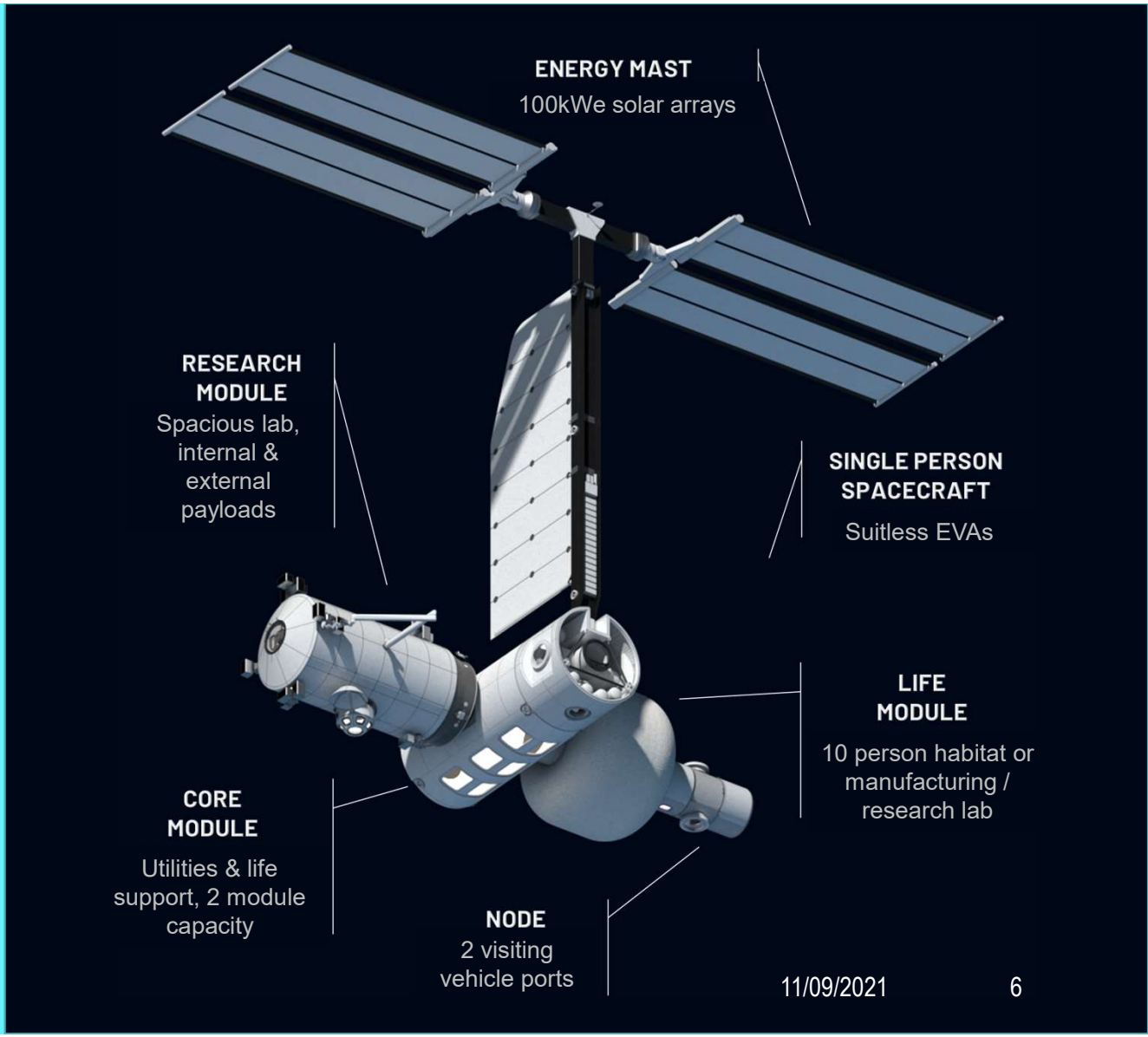
Ecosystem

The Orbital Reef initial architecture consists of **10 elements – <u>all in development today</u>**. This architecture is designed to be evolvable, and expands modularly to grow with demand.

Six destination elements comprise the in-space architecture (*pictured right*).

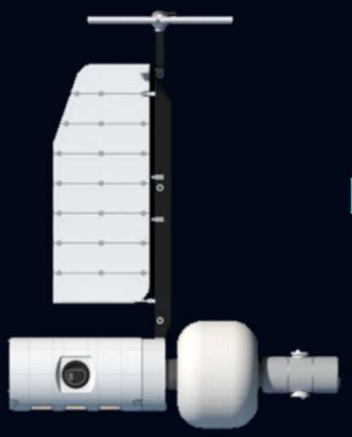
Four transportation elements – which will all start flying between 2022-2026 – keep Orbital Reef supplied, crewed, and safe in orbit, including:

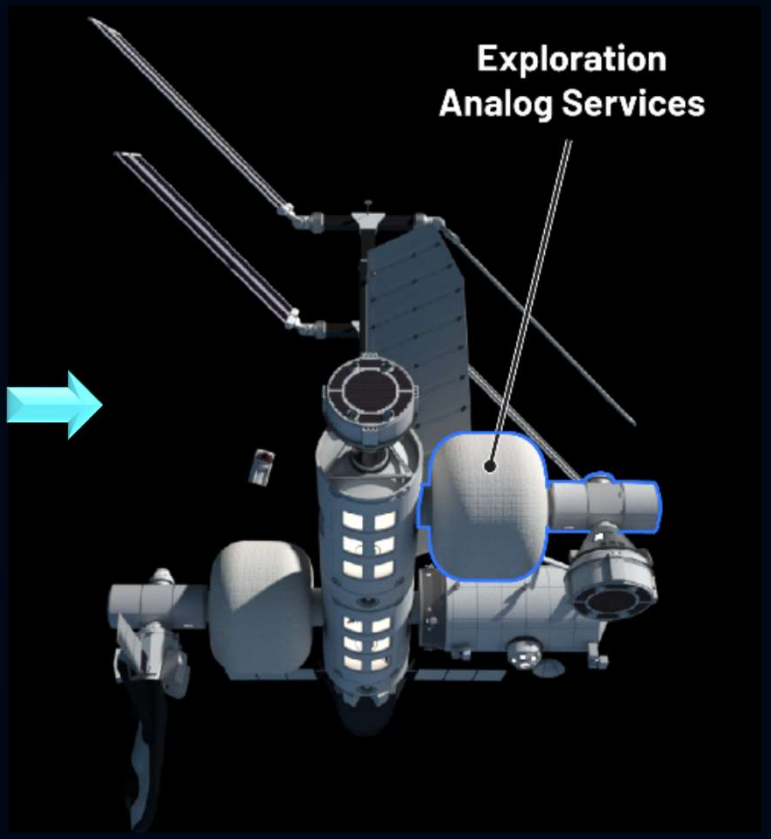
- Blue Origin's reusable New Glenn rocket and space tug vehicles
- Sierra Space's reusable Dream Chaser spaceplane for Crew and Cargo
- Boeing's Starliner



System Architecture Evolution

- System expands linearly with addition of each Core/Energy Mast, providing:
  - Berthing locations
  - Power generation
  - Thermal rejection
  - Orbit/attitude control
  - Expanded comms, data storage/processing
  - ECLSS
  - Storage
- Exploration analog services possible by isolating a module





Modular Expansion to meet increasing on-orbit demands

Hub for a Vibrant Commercial Space Market

Space Agency Destination

NASA & International Agencies forecast requirements for crew training, human exploration research, scientific research, and other missions beyond the life of ISS

Exploration Services

Integration point and base station for Lunar and beyond space exploration; providing a platform for astronaut training and exploration systems development

Satellites

In-orbit Support

In-orbit production/assembly, delivery, deployment, servicing, and decommission of LEO satellites for satellite owners and operators

Commercial

Research & Production

Companies pursuing microgravity benefits to develop and manufacture terrestrial products (e.g., ZBLAN fiber, semiconductors, protein crystals) and just-in-time parts and large space structures for use in orbit

Media

Entertainment & Advertising

Companies already pursuing advertising opportunities in space, with growing entertainment interest for space filming

Tourism

Private Astronauts

14 privately funded trips to ISS thus far, with industry demand signals ramping from high net worth individuals seeking adventure travel opportunities

Impacts of Commercialization on Research

- "NASA [Commercial LEO Destinations program] intends to stimulate demand, catalyze new markets, and transition to a long-term, sustainable, commercial human spaceflight economy in low-Earth orbit where NASA is one of many customers. "

- Significant reductions in development & operating costs
  - 2-10x reduction in program development, compared to traditional FAR-based acquisitions [1]
  - Anticipated annual savings of $1B over current ISS operations [2]
- Reduced barriers to entry for international, interdisciplinary, and non-traditional users
- Designed to be responsive to the speed of business, with turnkey services models designed to support a range of applications and communities

- Note: Facilities matter. Decadal inputs should insist on not just continuity of access to key resources, but thoughtful federal investment in the next generation of capabilities, with upgrades in data acquisition, processing power, analytics, and automation.

1. Zapata E (2017) An Assessment of Cost Improvements in the NASA COTS - CRS Program and Implications for Future NASA Missions. American Institute of Aeronautics and Astronautics. ntrs.nasa.gov/api/citations/20170008895/downloads/20170008895.pdf. Accessed 27 October 2021.
2. Sheetz M. "NASA reviews private space station proposals, expects to save over $1 billion annually after ISS retires". *CNBC,* 20 September 2021. www.cnbc.com/2021/09/20/nasa-evaluating-private-space-station-proposals-for-iss-replacement.html. Accessed 23 October 2021.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