

Opportunities and Practices to Enhance Space Safety and Sustainability

Note: This presentation represents the position of the speaker and does not necessarily reflect a USG position and does not necessarily reflect a USG position.



Presented by Professor Danielle Wood with contributions from Prof Richard Linares, Professor Moriba Jah, Miles Lifson, Maya Slavin, Riley Stienl, Scott Dorrington, Minoo Rathnasabapathy, Elena Cirkovic, Christine Joseph
Massachusetts Institute of Technology

- The demand for activity in space will continue to expand in Low Earth Orbit, in other orbital regimes around Earth and beyond.
- Countries from all regions and companies from many sizes and business areas are participating in the global space enterprise.
- Academic research by this team has explored the dynamics of increasing participation by new countries and companies in space.



Analysis of the Microgravity Research Ecosystem and Market Drivers of Accessibility

Joseph, Christine, and Danielle Wood. "Analysis of the Microgravity Research Ecosystem and Market Drivers of Accessibility." *New Space* (2021). <http://doi.org/10.3089/space.2020.0044>

May 12, 2021

- In this research paper in the journal *New Space*, our team analyzes the future plans for the use of Low Earth Orbit as a platform for research and scientific development
- The findings show that new models of collaboration are likely to emerge that could allow more countries and companies to participate in sending experiments, technology demonstrations and educational programs to orbital platforms such as new space stations

Citation: Joseph, Christine, and Danielle Wood. "Analysis of the Microgravity Research Ecosystem and Market Drivers of Accessibility." *New Space* 9, no. 2 (2021): 123-138.

Analysis of the Microgravity Research Ecosystem and Market Drivers of Accessibility

Christine Joseph and Danielle Wood

Space Enabled Research Group, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.

ABSTRACT

For decades, the International Space Station (ISS) has operated as a bastion of international cooperation and a unique testbed for microgravity research. In recent years, private industry has also been affiliating with NASA and international partners to offer transportation, logistics management, and payload demands. As the costs of flying projects to the ISS decrease, the barriers limiting nontraditional partners from accessing the ISS also decrease. However, the ISS in its current form cannot be sustained forever. As NASA looks toward commercialization of low Earth orbit (LEO) and the development of a cislunar station, concrete plans for shifting the public-private relationship of the ISS are unclear. With the consistent need to continue microgravity research—from governments and private industry—understanding the socio-technical and policy issues that affect the ecosystem for future microgravity platforms is essential to maintaining an accessible and sustainable space economy. Through this work, the authors seek to evaluate the accessibility of the evolving microgravity research ecosystem. To measure accessibility, the authors propose a new framework in which accessibility is defined along new metrics of economic and administrative openness. Through case study research, the authors conducted interviews with industry experts and organizational representatives and reviewed publicly available data about microgravity research platforms from the ground to LEO. This article then leverages Systems Architecture methods to examine the stakeholders, needs, objectives, system functions, and forms for the ISS and microgravity research platforms now and in the

future. Particular attention is paid toward the market dynamics affecting barriers to entry for emerging space nations and non-traditional spaceflight participants. Evaluations found that end users utilize a variety of fully public, mixed public/private, and fully private pathways to gain access to microgravity research platforms and that mixed public/private pathways fostered the highest levels of economic and administrative openness.

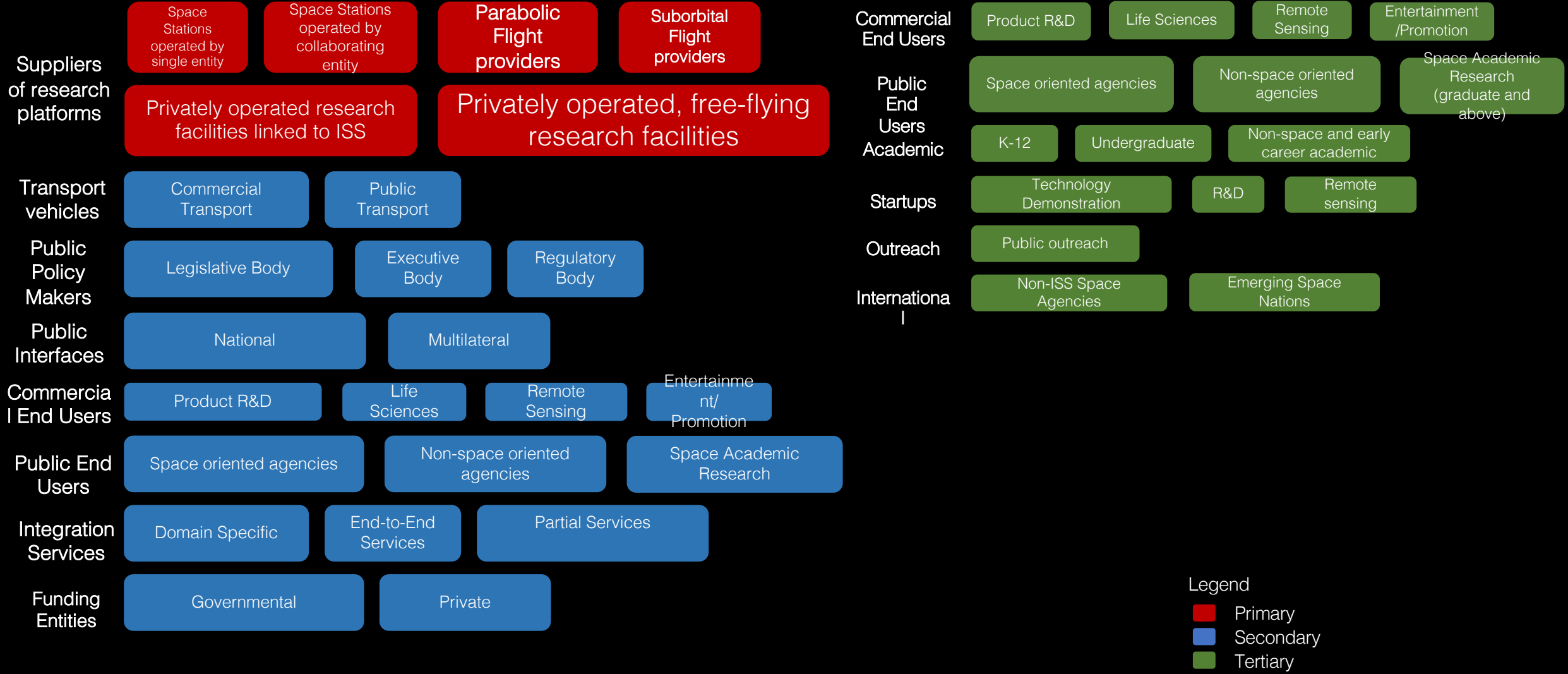
Keywords: microgravity, ISS, accessibility, space policy

INTRODUCTION

For decades, the International Space Station (ISS) has operated as a bastion of international cooperation and a unique testbed for microgravity research. Beyond enabling insights into human physiology in space, the ISS has served as a microgravity platform for numerous science experiments, technology demonstration projects, and outreach programs.¹ But just how “international” is the ISS? How accessible is it to different types of user groups around the world? The ISS is one of the largest and most expensive construction projects in human history. The development of the ISS took decades and is characterized by evolving priorities and socio-technical issues. Today, it is an immensely complex conglomeration of technical systems, public and commercial modules, and public-private partnerships. And yet it works, maintaining operations coordinated across the globe for the past 20 years. Because of the ISS and the efforts to develop it, humans have lived in space continuously since the year 2000.¹

In recent years, a combination of decreasing flight costs and the emergence of new models that invite participation of nontraditional actors have contributed to reducing the barriers of access to the ISS platform. As these nontraditional

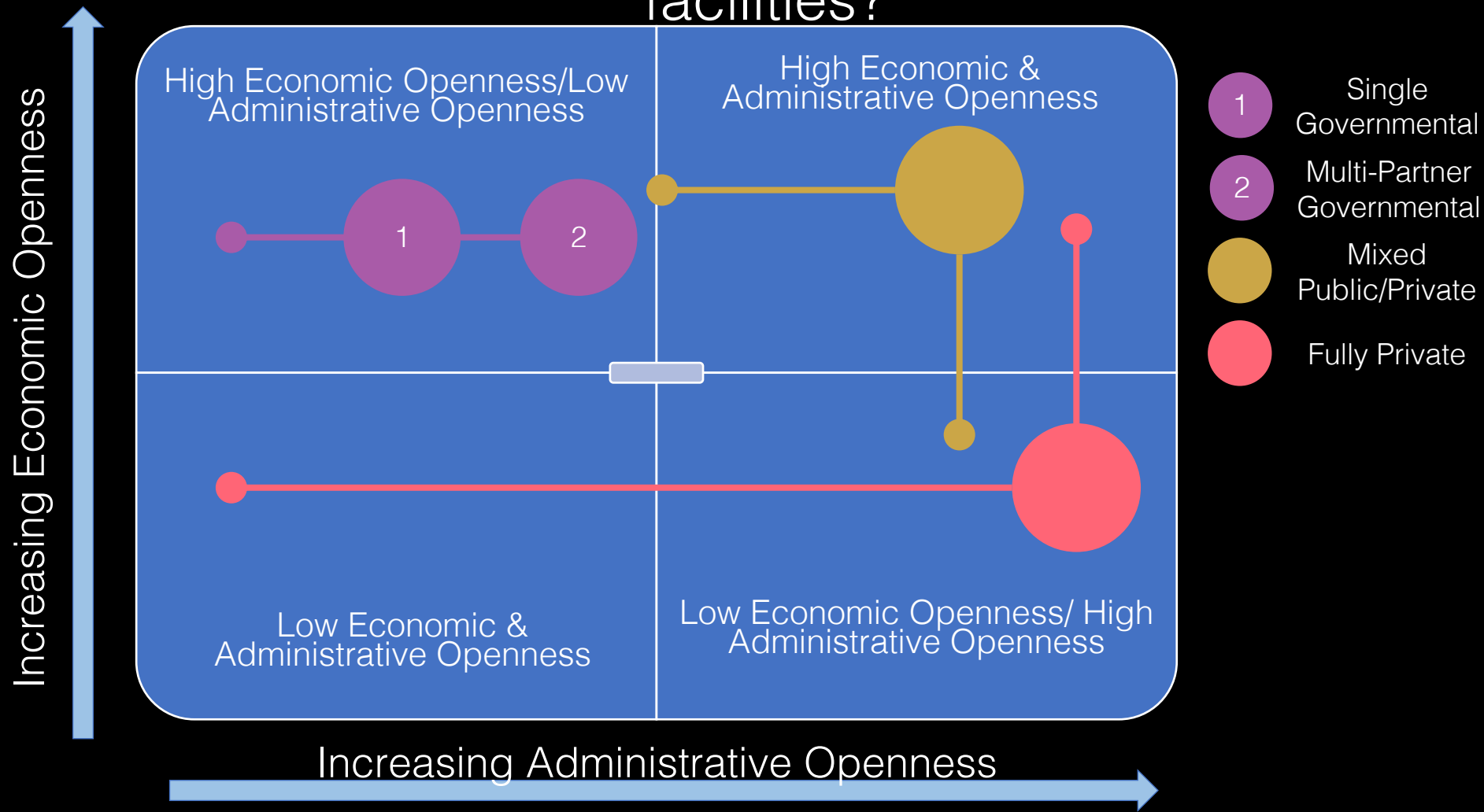
Future Microgravity Research Ecosystem



Legend
■ Primary
■ Secondary
■ Tertiary



What will influence who has access to future space research facilities?



- As noted in the previous paper, research shows an expected increase in interest by organizations from many nations and business sectors to participate in space activity, especially in Low Earth Orbit for research and operational services.
- In order to ensure that this opportunity is available in the long term, actions must be taken now to increase space safety and ensure space sustainability.
- In this discussion, “Sustainability” refers to the long term capability to avoid loss, disruption, or degradation of space services and activities
- This presentation builds on the concepts of Sustainability developed in the United Nations Committee on the Peaceful Uses of Outer Space in the **2019 Guidelines for the Long Term Sustainability of Outer Space**
- To move toward space safety and sustainability, actions can be taken now by governments, commercial and academic organizations



Space Sustainability Rating

Operated by the EPFL Space Center
in Switzerland

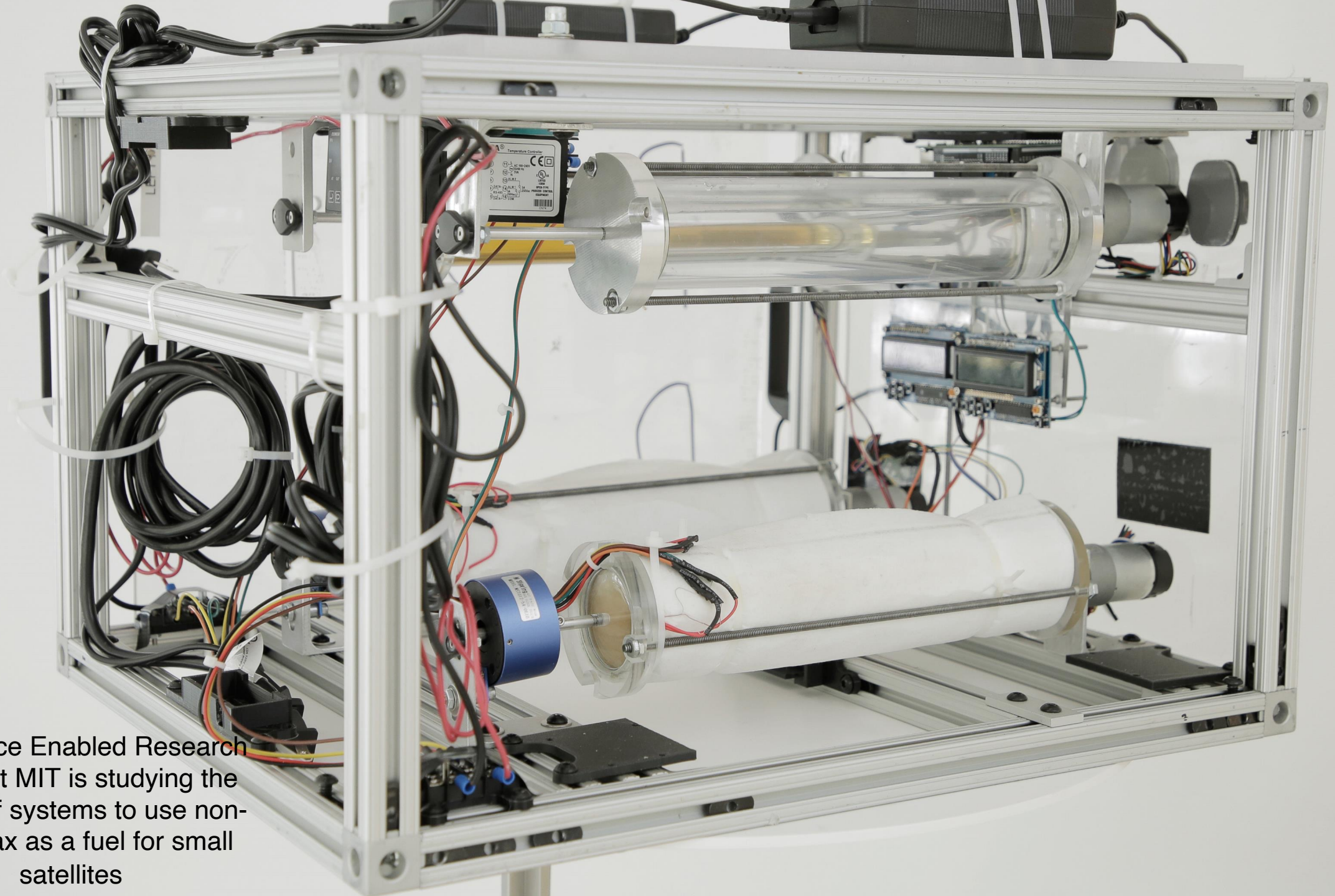
What actions can a satellite operator take during the **Design** of a space mission to increase space safety and sustainability?

- **Orbit selection & Mission Design**
 - Select an orbit that is not highly populated and allows for high probability of success with post mission disposal, for example, consider altitudes below the International Space Station
- **Design for Detectability, Identifiability and Trackability**
 - Selecting materials that balance trackability with protecting dark skies
 - Considering the orientation of the spacecraft for viewing by observers on earth
 - Apply active and passive systems to improve trackability such as beacons and reflectors
- **Design for Collision Avoidance**
 - Include on-orbit propulsion with capability for emergency avoidance and for post mission disposal
 - Design the mission and ground-control segment to have high confidence of mission location



Lower Cost
Design
Approaches

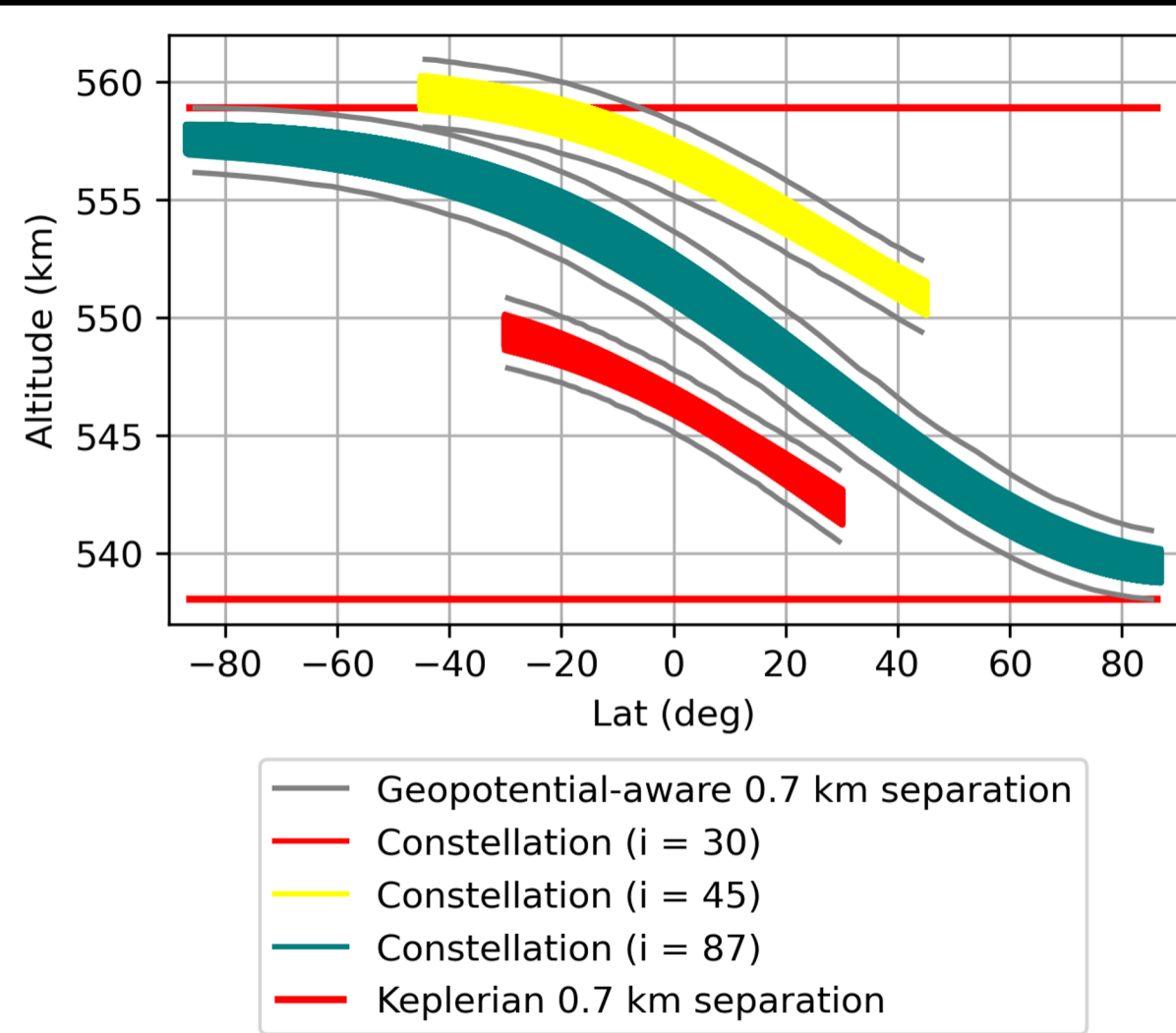
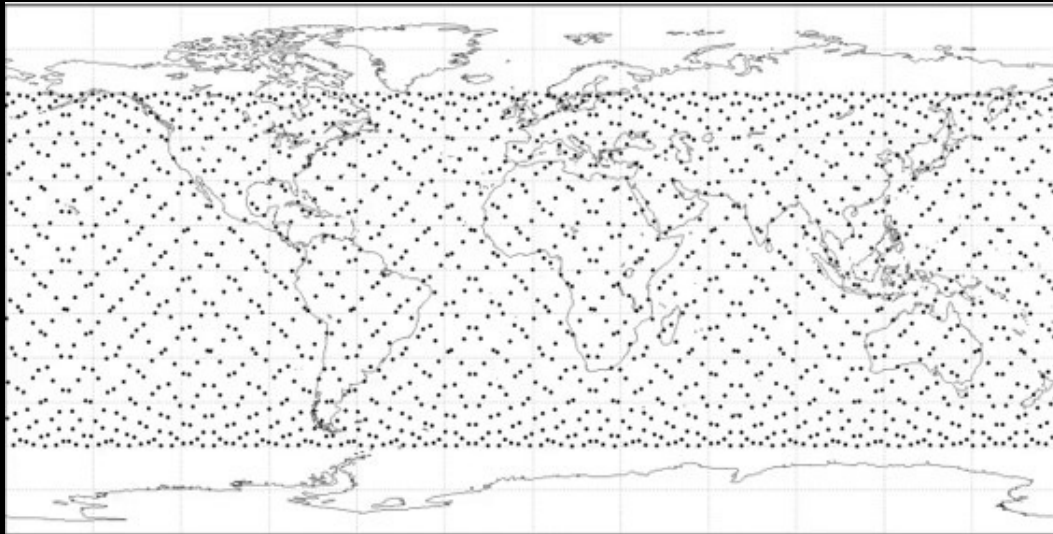
Higher Cost
Design
Approaches



The Space Enabled Research Group at MIT is studying the design of systems to use non-toxic wax as a fuel for small satellites

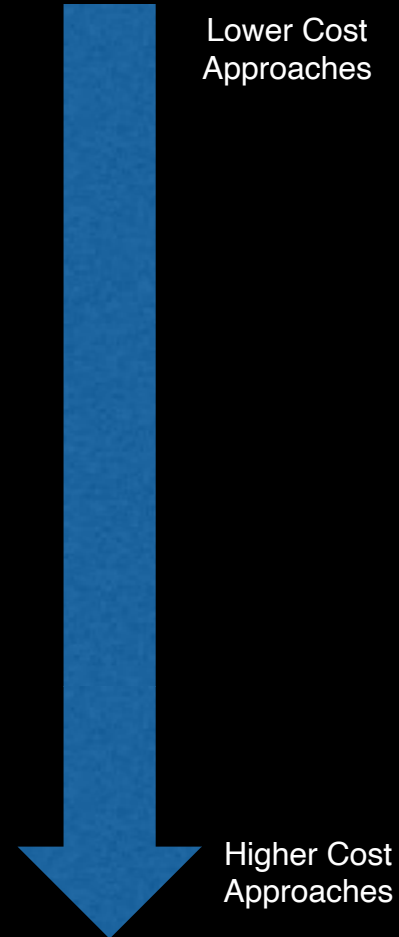
Intrinsic Capacity of Slotted Spacecraft

- How many spacecraft can we safely fit at a particular altitude?
- How to we arrange sets of spacecraft at different altitudes for maximum efficiency?
- How could operators safely share altitudes?



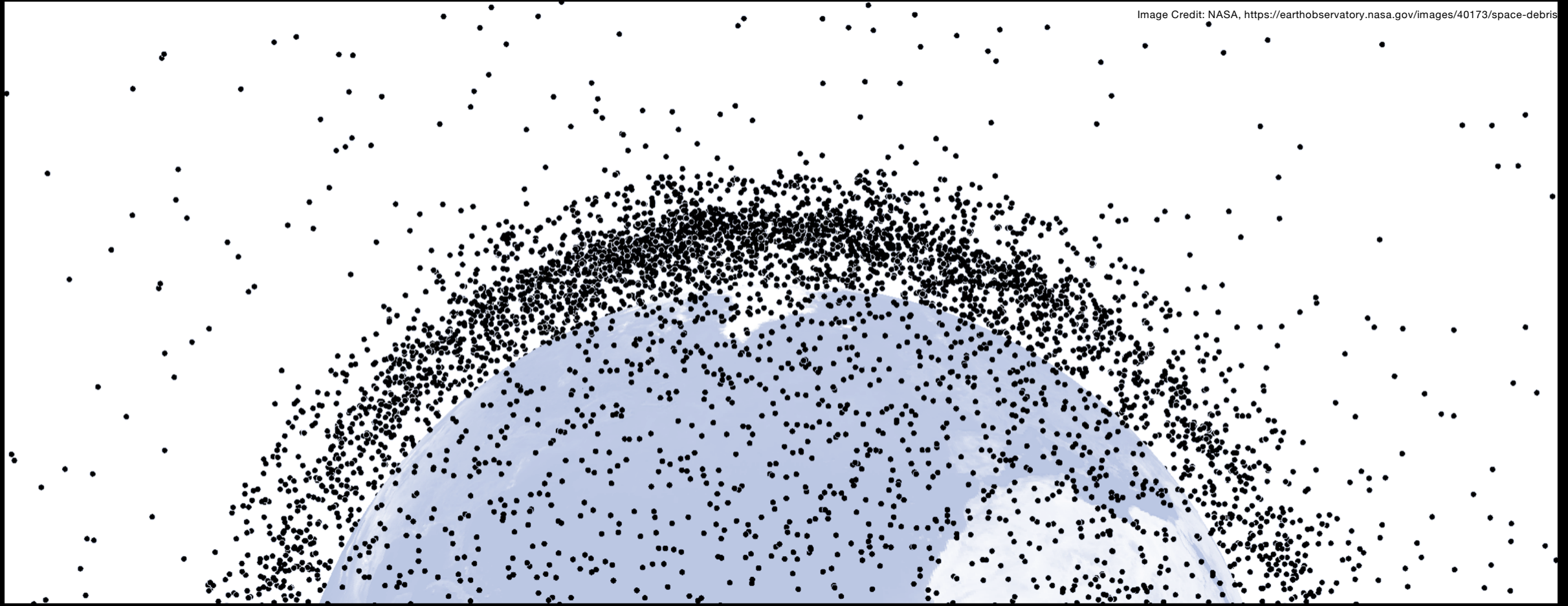
What actions can a satellite operator take during the **Operations** of a space mission to increase space safety and sustainability?

- **Data Sharing**
 - Share telemetry data about location and status of mission via a public website or provide to a public or private Space Situational Awareness service provider
 - Communicate publicly the plans for the mission to make orbital maneuvers, post mission disposal and changes in mission status
- **Collision Avoidance**
 - Share publicly the contact information and availability of people who can coordinate for potential collisions
 - Coordinate actively when contacted regarding potential collisions
- **Active Deorbiting and Servicing**
 - Consider the use of a service provider to enable active deorbiting or on-orbit servicing if that is likely to increase the safety of the mission



What preferences do space actors hold on the design process for a future Space Traffic Management System?

Miles Lifson, Danielle Wood

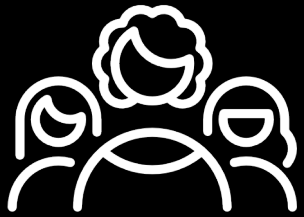


Miles Lifson
Research Assistant
Space Enabled research group

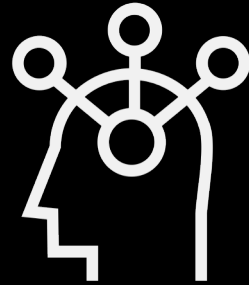
Danielle Wood, PhD
Assistant Professor, MIT Media Lab
Director, Space Enabled research group

Research Question

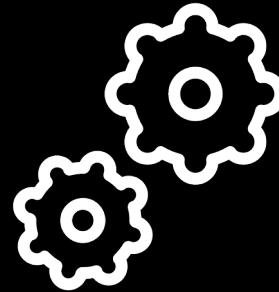
1. What are the **opinions** of representatives of space nations on the **design of a potential internationalized Space Traffic Management system**, and what shapes these opinions?
More specifically:



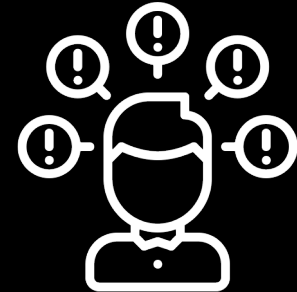
**Preferred Forms
Of Engagement**



**SSA/STM
Capability
Building**



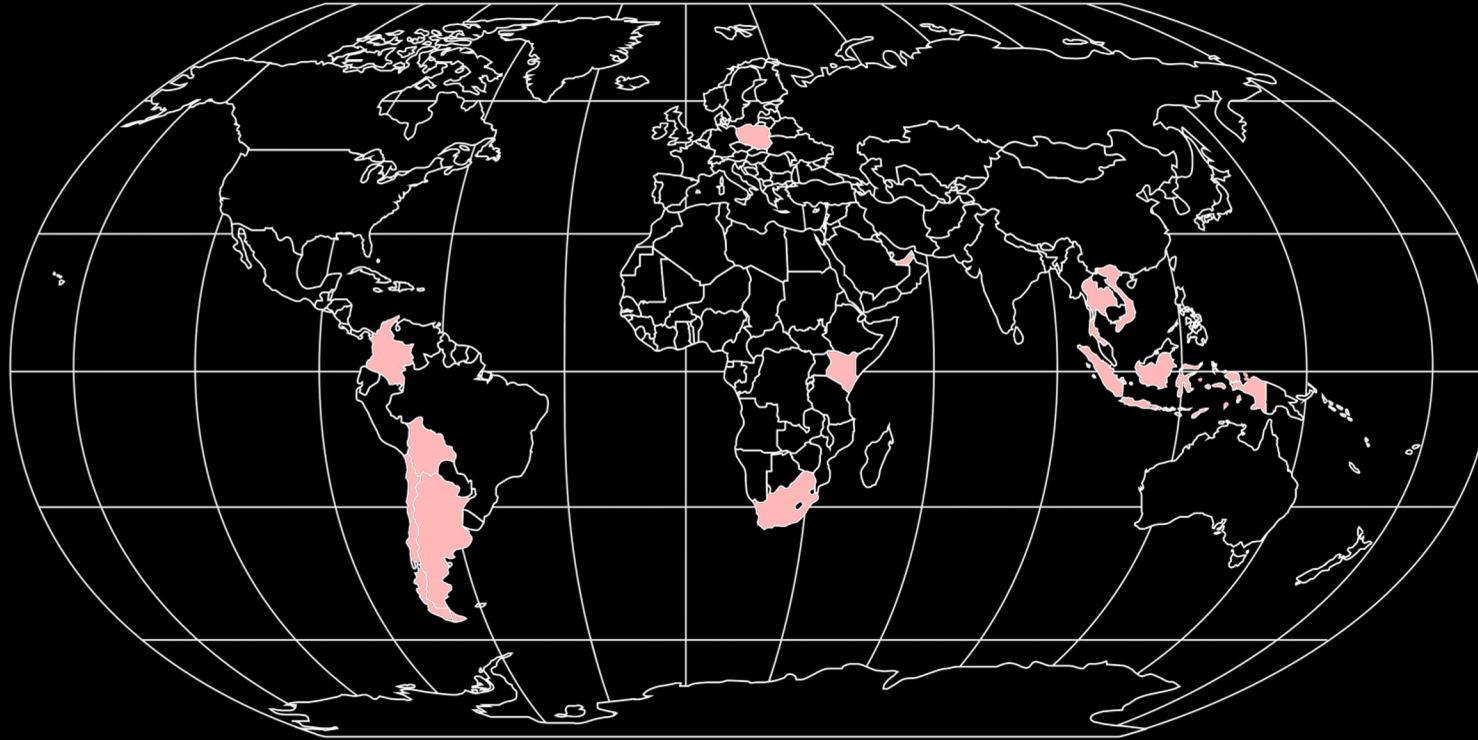
**System
Capabilities**



**Concerns
about System
Design**



Interview Sample



10 Interviews with SSA/STM Experts to Develop Interview Questions
3 Pilot Interviews with Space Nation young professionals
Sample of 13 Nations & 15 interviewees

- Anonymous Country
- Anonymous Country

Africa

- South Africa
- Kenya

Asia

- Indonesia
- Thailand
- UAE
- Viet Nam

Central and South America

- Argentina
- Bolivia
- Chile
- Colombia

Europe

- Poland



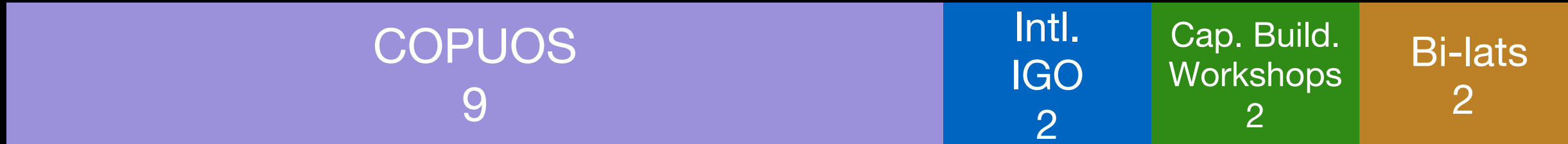
Results of Interviews with Stakeholders about STM

Every respondent believed...

- 1) Some form of STM system will be necessary in the future
- 2) Their country would want to participate in the development of that system
- 3) Their country would likely participate in the an international STM system once it was developed



What venues and methods do you think representatives of your country would prefer to provide input into the potential design of a future international SSA/STM system? (primary responses)



Do you have thoughts on whether STM should be organized from the top down by a few stakeholders, bottom up, or a mix?

