National Aeronautics and Space Administration

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NASA's Initial Assessment of Models For A Next Generation Microgravity National Laboratory

In September 2022, the National Space Council directed NASA to "develop a plan for the next generation microgravity national lab in a commercial space station world." NASA has been working to develop this strategy, with planning led by the Space Operations Mission Directorate (SOMD) and the Office of Technology, Policy, and Strategy (OTPS). The report below, titled "Models for Facilitating Government-Funded Activities in the Post-International Space Station (ISS) Low-Earth Orbit (LEO) Ecosystem" is one step in NASA's effort to define and develop a comprehensive strategy.

The ISS National Laboratory (ISSNL) was created by the NASA Authorization Act of 2005 and has become an essential tool for users to fly research, technology demonstrations, and Science, Technology, Engineering, and Math (STEM) activities to the space station. As directed by the NASA Authorization Act, 50% of U.S. ISS resources are allocated for non-NASA, National Lab use. Under a cooperative agreement with NASA, the Center for the Advancement of Science in Space (CASIS) in Melbourne, FL, manages all non-NASA research for users such as other U.S. government agencies, universities, and commercial entities, administered through the ISSNL. NASA maintains responsibility for integrating and manifesting all research on the ISS U.S. On-Orbit Segment (USOS) which includes NASA, ISSNL, the Japan Aerospace Exploration Agency (JAXA), the European Space Agency (ESA), and the Canadian Space Agency (CSA).

The ISSNL model has been successful in growing non-NASA interest in utilization of a platform for microgravity research and applications. To date, over 700 projects have flown, with over two-thirds developed by commercial users. In FY23, 35 publications were released bringing the total to 265 publications since the National Lab first began. As in previous years, many of these publications were made possible by research collaborations with other U.S. Government agencies including the National Science Foundation and the National Institutes of Health which funded research in space to address national research priorities in their portfolios. In FY23, 9 additional flight projects were funded by the National Science Foundation in collaboration with CASIS, and the National Center for Advancing Translational Sciences at the National Institutes of Health committed to fund and re-launch the Tissue Chips in Space collaboration with CASIS in FY25. CASIS, in partnership with NASA's Biological and Physical Sciences Division, announced the *Igniting Innovations* solicitation, seeking flight research to address the goals of the Cancer Moonshot^{SM} initiative and accelerating the translation of stem cell and organoid-based disease models and advanced technologies for biomanufacturing. In response to this new solicitation, over 50 concept white papers were submitted and are currently in review.

Given this successful trajectory, continuity of a national lab in LEO is an important objective and consideration in NASA's transition from the ISS to Commercial LEO Destinations (CLDs) at the end of the decade. Recognizing that the current ISSNL model needs to evolve as the infrastructure changes from a government-owned platform to commercially-owned platforms from which the government will purchase services, NASA's OTPS conducted a study of various candidate "models" of future operations between a National Laboratory and various Commercial LEO Destination (CLD), which is included and summarized below. The study answered two fundamental questions:

1. What are potential models for an ISS National Lab facilitating government-funded or subsidized activities on a commercial LEO platform after the transition of the ISS to one or more private platforms?
2. In light of these options, what modifications would be helpful to make in the current ISSNL-CASIS partnership and the NASA management processes as NASA plans for the transition of the ISS by 2030?

As described in the study report, six models were identified ranging from high levels of government oversight to a low levels of government oversight; each model was assessed across three potential future economy growth scenarios. The models are illustrative and hold positive attributes designed to inform strategy development for a future national laboratory. The report concludes that no one model on its own represents a complete strategy for a future national laboratory. With the report, along with responses from a December 2022 White House Office of Science and Technology Policy (OSTP) Request for Information as inputs, NASA's SOMD has been able to continually evaluate a combination of models that will best represent its recommended strategy. Some initial aspects of that strategy are included as follows.

As outlined in the National LEO R&D Strategy released in March 2023, a national laboratory in LEO should enable the accomplishment of the following goals:

1. Maintaining U.S. leadership in space for research, technology development and innovation;
2. Coalescing additional U.S. government efforts to utilize space to achieve national objectives, solve the world's greatest challenges, and improve lives;
3. Supporting additional government funded scientists and engineers with access to expertise and in-space research facilities;
4. Enabling international cooperation; and
5. Creating opportunities for STEM and diverse workforce development.

An ideal national lab will:

1. Represent all U.S. Government needs for space-based research;
2. Encourage collaboration;
3. Be scalable to demand;
4. Be platform agnostic, leveraging existing and new ground and space capabilities;
5. Provide equitable access for all and act as an honest broker; and
6. Foster workforce development.

By designing the future construct to represent all U.S. Government-sponsored research, collaboration between NASA and non-NASA users is increased and opportunities are consolidated into a single-entry portal for users. This approach will enhance the user experience, reduce overhead, encourage collaboration, and allow resource sharing between agencies.

As NASA continues to define the details of a post-ISS national lab strategy, the following issues remain in development:

1. Management structure of the national lab
2. Definition of roles and relationships including NASA, other U.S. government agencies, and commercial platform and service providers, ensuring a future national lab does not generate competition for, but rather supports and bolsters U. S. industry
3. Pathways for international cooperation
4. Proposed changes to NASA's national lab authorization legislation

5. Development of a stepwise transition strategy to enable continuity between the ISSNL and the post-ISS national lab, including evolution as the LEO ecosystem matures
6. Consideration of whether the name “national lab” is the best descriptor for the future construct, particularly since it would leverage multiple commercial platforms and capabilities

As NASA develops these details, the agency is actively engaging stakeholders including NASA, other U.S. government agencies, commercial industry, and the user community. NASA looks forward to sharing updates as this work progresses and is committed to developing a comprehensive strategy that is an improvement on the incredible infrastructure that exists today to ensure that U.S. government research and technology development in LEO continues to improve life on Earth.

Office of Technology, Policy, and Strategy

Models for Facilitating Government-Funded Activities in the Post-ISS LEO Ecosystem

November 2, 2023

Report ID: 20230005232

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Executive Summary

Models for Facilitating Government-Funded Activities in the Post-ISS LEO Ecosystem

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Purpose of the Study

This study helps elucidate NASA's future options for facilitating government-funded activities in the post-International Space Station (ISS) low-Earth orbit (LEO) ecosystem. NASA is preparing for the retirement of the ISS and transition of LEO activities to one or more Commercial LEO Destinations (CLDs) by 2030. This transition necessitates new models for connecting NASA and other users of the LEO environment to platforms and opportunities.

NASA's current model for facilitating non-exploration activities is embodied in the International Space Station National Lab (ISSNL). ISSNL was established through congressional authority in 2005 and has been managed by a nonprofit called the Center for the Advancement of Science in Space (CASIS) since 2011. CASIS was created with a mission to foster scientific discovery and technological innovation in space, expand U.S. leadership in commercial space, and inspire the next generation.

As the LEO ecosystem evolves through growth of the commercial space industry and as part of NASA's strategic goal to support development of a robust LEO economy in which many stakeholders on Earth can participate, so must the current ISSNL model, to ensure taxpayers realize the highest return on their investment in LEO.

The purpose of this study is to answer the following two questions:

1. **Potential Models**: *What are potential models for an ISS National Lab facilitating government-funded or subsidized activities on a commercial LEO platform after the transition of the ISS to one or more private platforms?*
2. **Near-Term Impact**: *In light of these options, what modifications would be helpful to make in the current ISSNL-CASIS partnership and the NASA management processes as NASA plans for the transition of the ISS by 2030?*

To address these questions, we conducted over 40 discussions with stakeholders internal and external to NASA and reviewed over 35 documents related to legislation, governance, LEO commercialization, potential models, and activities performed in microgravity and LEO.

Key Findings

Question 1: Potential Models

This report describes for consideration six models for facilitating government-funded activities in the post-ISS LEO ecosystem, as shown in Table 1. The ISSNL model is included as a baseline to identify near term opportunities to improve NASA's posture for success post-ISS.

Table 1. Six differentiated models for facilitating government-funded activities in the post-ISS LEO ecosystem

Model	Differentiator	Description
ISSNL	Reflection of current operations	Third party agreement to manage 50% of ISS U.S. segment activities for a broad range of academic, government, and commercial users.
1. Anchor Tenant	Long-term agreement for leasing space on a commercial platform	NASA as anchor tenant on CLD with dedicated destination for LEO activities. NASA program office is agent for all government-sponsored activities. Commercial users work directly with platform provider or respond to government proposal requests.
2. Government Research Broker	Customizable research using combinations of transport vehicles and CLDs	NASA program office guided by advisory committee brokers payloads to LEO, conducts mission planning, and negotiates end-to-end services. Flexible contract with CLDs based on short term needs. Crewed and uncrewed missions for flexible government research needs.
3. Innovation Campus	Modern terrestrial campus with workforce focus	Government-owned terrestrial campus operated by non-government entity. Dedicated to advancing research and development. Focused on innovation and building LEO workforce rather than connecting users to platforms.
4. Matchmaker	Neutral third party connecting users to platforms	Nonprofit funded by NASA to match specific users to LEO opportunities based on mission and technical requirements. Provides clear entry point for users and providers. Aggregates and communicates user demand to industry.
5. Institute Network	Network of separate but related efforts to enable commercial scaling and U.S. leadership	Government-sponsored consortia of distinct but related institutes within LEO and terrestrially. Institutes funded through public-private partnerships managed by nonprofits. CLD facilities leased from providers within institutes.
6. Fee for Service	Free market approach	Industry-driven model focused on transactions for services. Users purchase goods and services from providers. NASA is one user and leverages grants and data buys to meet needs.

These six models represent a wide trade space of potential options, each relying on unique mechanisms for facilitating activities on one or more commercial LEO platforms. The models as shown generally range from more to less government oversight, including options for facilitation of activities within a NASA program office—Anchor Tenant and Government

Research Broker—or through a non-governmental organization—Innovation Campus, Matchmaker, and Institute Network.

We assessed each model across three possible future scenarios varying in number and diversity of LEO activities and commercial offerings—*dynamic growth*, *steady growth*, and *limited growth*—and across five stakeholder-driven model evaluation criteria—*ability to meet NASA's needs; adaptability to infrastructure, service provider offerings, and user demands; opportunity for collaboration; market sustainability; and equity and accessibility*.

Model Insights

The Government Research Broker model performs best across all future scenarios, followed by Innovation Campus, Anchor Tenant, and Fee for Service, as shown in Table 2. While Matchmaker and Institute Network exhibit positive aspects, these models perform most favorably in future scenarios with well-established communities and markets and we do not preclude their viability for consideration. We list the key considerations for each of the models below, starting with the best performing.

Table 2. Evaluation criterion or criteria assessed as favorable across all future scenarios for each model

Model	Criterion or Criteria assessed as favorable across all scenarios
Government Research Broker	Ability to Meet NASA's Needs, Opportunity for Collaboration, Adaptability, Equity & Accessibility
Innovation Campus	Ability to Meet NASA's Needs, Opportunity for Collaboration
Anchor Tenant	Ability to Meet NASA's Needs, Opportunity for Collaboration
Fee for Service	Adaptability, Market Sustainability
Matchmaker	Adaptability
Institute Network	None
ISSNL	Equity & Accessibility, Market Sustainability

Government Research Broker

The Government Research Broker provides a reliable option for NASA to continue activities in LEO in any future scenario, meeting the needs of all but one of the stakeholder-driven performance criteria. The range of built-in flexibilities can buffer against changes in available infrastructure and against how capabilities across CLDs may develop. Shortcomings in market sustainability can be designed against by incentivizing port standardization and ensuring mutual government-industry benefits. The high level of government involvement, combined with the ability to optimize the government's research space as needed, make this model a viable option for consideration. If using this model, NASA will need to address the Commercial LEO Development Program's exclusion of sortie-style research options from CLD awards.

Innovation Campus

The Innovation Campus model is designed to augment efforts in LEO with ground-based resources and can best do so in a dynamic environment, where there are many stakeholders and enough funding to support activities. Assuming a separate model can connect users with commercial platforms, this model can help ensure the government maintains a skilled LEO workforce with the added benefit of scaling to account for mission needs beyond LEO. In future scenarios with less opportunity, however, resource limitations can hinder its benefit to some non-government users (and to government users in a very limited future scenario). The utility of this model could be enhanced by efforts to expand participation across the government, including adding other agencies as sponsors—similar to the Institute Network model—and by enabling pathways for industry to access campus resources.

Anchor Tenant

Anchor Tenant provides a long-term steady engagement with a CLD, which leads to reliable access for NASA to support a significant portion of its exploration needs. The model is best suited for a steady growth scenario, where markets and users may still rely on government involvement to advance interests. Reliable tenancy provides opportunities for collaboration, assuming they were identified when drafting the agreement. This model does not easily adapt to changing needs and can hinder long-term economic growth for some users. NASA can mitigate some of these weaknesses by leveraging flexible contracting pathways, establishing alternative pathways for international partners, expanding leased space to other platforms, and looking to the Government Research Broker model to conduct research in transient vehicles.

Fee for Service

The Fee for Service model embodies a flexible, free market and is particularly well suited to steady and dynamic growth scenarios in which the commercial potential of LEO is more fully realized. The model can generally adapt to activities, infrastructure, etc.; however, activities may skew towards those that generate the most revenue. NASA's demands are clearly communicated through grants and service/data buys, and users whose interests align well with NASA's interests may most benefit from these funding pathways. Barriers to entry may be prohibitive for some, including some international users. A free market approach somewhat limits NASA's ability to strengthen the model's limitations. However, economic policies may help channel commercial investment into areas that better meet NASA's needs, enable collaboration across the government, and ensure accessibility. The U.S. government can also encourage practices that promote equity and accessibility and provide incubation support to businesses (similar to current ISSNL-CASIS efforts) to steer economic development.

Matchmaker and Institute Network

The Matchmaker is a third-party nonprofit funded by NASA that connects user activities directly with platform providers based on mission and technical requirements. This model is adaptable across all future scenarios and generally performs well in a scenario with more opportunities but otherwise has limitations. Successful implementation of this model requires that the matchmaker understands the government's needs, which might be best accomplished through a close partnership with a government program office (such as in Anchor Tenant).

The Institute Network is a multi-user network that advances mutually beneficial areas of interest to enable commercial scaling and advance U.S. interests. Due to the reliance of the network on existing capabilities, users, and market potential, this model performs well only in a dynamic growth scenario, where these factors are demonstrated. This model's weakness can be mitigated through efforts to grow and diversify the LEO economy in preparation for future gains.

All models are illustrative and can be adjusted further to meet leadership priorities.

The models presented in this study are illustrative examples of continuing government-funded activities post-ISS and represent a potential trade space. Further, each of the six models requires change to current legislation. NASA leadership can adjust models as desired to align closer to their priorities, using combinations of the unique model mechanisms provided in our analysis. The best performing model that meets leadership priorities is likely a combination of features from multiple models.

Question 2: Near-Term Impact

To identify opportunities for modifying the current ISSNL-CASIS partnership in the near term, we leverage strengths from the ISSNL model and from the top-performing models to improve NASA's posture for success post-ISS. We identify four possible modifications to the ISSNL-CASIS partnership and NASA's management of these activities. NASA should engage Congress early to propose legislative changes necessary to pursue these modifications.

Create a pathway for ISSNL-CASIS to access commercial platforms as they come online prior to the ISS transition and determine NASA's role in brokering relationships.

Prior to the ISS transition, commercial platforms may include private modules attached to the ISS, or private transport vehicles traveling to and from the ISS, private orbital capsules, and spacecraft with no platform destination. Extending ISSNL activities to these additional volumes may provide more flexibility, diversification of research, and amount of research conducted, for instance, by enabling research throughout a mission rather than just on the ISS. This may entail exploring the contractual and legal feasibility of creating a pathway, the ability for NASA to purchase space on behalf of CASIS, and NASA's role in brokering relationships.

Elevate the ISSNL incubation role to support increased movement towards industrialization.

Focus on creating scalable and repeatable operations to support industrialization—on the path to commercialization—and sale of a product or service. An expanded incubation role, for example, might connect stakeholders and provide mentorship to address shared technological barriers related to in-space manufacturing. The incubator, possibly in partnership with NASA, might also explore ways to improve downmass capabilities. Building on this role may encourage market growth, improve processes and user experience, and mitigate risks to return on investment to platform providers.

Establish a terrestrial innovation campus for microgravity research and development.

A terrestrial campus provides a dedicated location for NASA to bring together LEO ecosystem stakeholders. This modification would allow NASA to prime the Innovation Campus model before the retirement of the ISS. Establishing a terrestrial campus now provides the additional opportunity for NASA to investigate the feasibility of using a Federally Funded Research and Development Center (FFRDC) or University Affiliated Research Center relationship in any of the models. For example, NASA may examine whether an FFRDC on a leased orbital commercial platform is possible and whether an FFRDC can have more than one government sponsor.

Formulate a strategy for buying data from commercial providers.

Buying data from commercial providers may provide an agile, alternative approach to meet research and development needs by augmenting or complementing NASA or other government agency (OGA) datasets. NASA can prepare now by investigating legal and regulatory concerns, such as navigating intellectual property and privacy protection and examining the ethics of selling human data. NASA can leverage lessons learned from the Science Mission Directorate's Commercial Smallsat Data Acquisition Program, such as establishing a pilot program to identify vendors and evaluate data and standardizing end-user license agreements across the government to facilitate collaboration.

Conclusion

The purpose of this study was to 1) identify potential models to continue government-funded activities in the post-ISS LEO ecosystem, and 2) determine near-term modifications to the ISSNL-CASIS partnership, given these models, to improve NASA's posture for success post-ISS. Working with experts across NASA and in discussion with stakeholders internal and external to NASA, we identified a wide trade space of unique models, evaluated their performance according to stakeholder-driven criteria, and presented six models for consideration. We then looked to strengths of the top-performing models to suggest four near-term modifications to apply to the current ISSNL-CASIS partnership, which if implemented, would help enable the transition to one or more commercial LEO platforms.

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Introduction

This report describes for National Aeronautics and Space Administration (NASA) senior-level consideration six potential models for facilitating government-funded activities in the post-International Space Station (ISS) low-Earth orbit (LEO) ecosystem. The current model for facilitating government-funded activities in LEO is included for comparison and analysis. To help guide decision-making, we score each model by its anticipated performance across three potential future scenarios—dynamic growth, steady growth, and limited growth—and across five model evaluation criteria derived from values echoed by the diverse stakeholder community: ability to meet NASA's needs, adaptability, opportunity for collaboration, market sustainability, and equity and accessibility.

After an introduction to the study background and objectives, limits in scope, and key terms, we describe the study methods and then present the main results of the study: descriptions and scoring highlights of each of the models. We then provide an aggregated view comparing all the models by their performance across the evaluation criteria and future scenarios. We conclude the main report with considerations to guide model selection, potential near-term opportunities to prepare for facilitating government-funded activities in the post-ISS LEO ecosystem, and insights gleaned from the study that will be key for future decision-making. Finally, a set of appendices provides summaries from stakeholder discussions, full future scenario narratives, a description of potential future LEO activities, full results of the model assessments, details on legislative considerations, and the list of stakeholder discussants.

Background

For almost two decades, the model for facilitating government-funded activities in LEO has been through the cooperatively managed International Space Station National Laboratory (ISSNL). Congress established a National Laboratory on the U.S. segment of the ISS in 2005, and in 2010, Congress directed NASA to enter a cooperative agreement with a nonprofit to manage the ISSNL.[1,2] The Center for the Advancement of Science in Space (CASIS) was created as a 501(c)(3) nonprofit with the mission to foster scientific discovery and technological innovation in space, expand U.S. leadership in commercial space, and inspire the next generation.[3]

However, over the years, the ISSNL-CASIS partnership model has faced challenges. In 2019, NASA commissioned an independent review team (IRT) to examine these challenges and propose recommendations to solve them, which the IRT released in 2020.[4] Though NASA and CASIS have adopted all of the IRT's recommendations, tensions remain between diverse user communities for limited resources. Some proposed solutions range from incremental (such as updating the cooperative agreement) to fundamentally changing the operation and management structure within NASA (for example, eliminating CASIS, creating a federally funded research and development center [FFRDC] to manage the National Laboratory, or eliminating the concept of a National Laboratory).

Ultimately, the primary mission of the ISSNL is not the same as it was in 2005. As the LEO user landscape evolved and NASA direction shifted in response, the ISSNL was functioning with an incongruent set of goals and priorities between peer-reviewed, decadal-driven science (including fundamental science, technology development, in-space manufacturing, and science, technology, engineering, and math [STEM]) and enabling commercial markets. Meanwhile, these growing commercial markets provide opportunities for new models for LEO activities after the retirement of the ISS in 2030.[5,6,7]

Commercial platforms after the ISS may provide a venue for NASA-driven, exploration-enabling research and technology development, as well as Earth-focused academic and commercial pursuits. Namely, four NASA-sponsored Commercial LEO Destinations (CLDs) are currently in development, including free flying stations by Blue Origin, Nanoracks, and Northrop Grumman and an ISS-attached station by Axiom Space that plans to eventually detach.[8,9] Assuming that one or more commercial platforms replaces the ISS in the 2030s, NASA leadership is considering next steps to continue government-driven activities in LEO, both in the near term and in the post-2030 timeframe. This study will help NASA leadership with those considerations.

Objectives

This study responds to two overarching challenges: 1) NASA and other LEO stakeholder communities need a plan for conducting and performing LEO activities after the retirement of the ISS in 2030, and 2) the current model for facilitating government-funded LEO activities, through the ISSNL, is specified and constrained by legislation and will need to evolve as utilization transitions from the ISS to CLDs. Given the need to reassess the current model due to the changing LEO ecosystem, NASA has an opportunity to optimize how it prepares for the post-ISS future. NASA leadership requested this study to guide considerations of NASA's next steps for LEO activities through and beyond the ISS-CLD transition.

Specifically, NASA senior leadership posed two questions:

1. **Potential Models**: What are potential models for an ISS National Lab facilitating government-funded or subsidized activities on a commercial LEO platform after the transition of the ISS to one or more private platforms?
2. **Near-Term Impact**: In light of these options, what modifications would be helpful to make in the current ISSNL-CASIS partnership and the NASA management processes as NASA plans for the transition of the ISS by 2030?

In answering these questions, the study team acknowledges important limitations in study scope. For Question 1, the study team recognizes the importance of identifying potential LEO activities of interest before assessing how the models can enable and facilitate these activities.

While the study includes an initial characterization of potential LEO activities, further decisions are needed to guide the overarching goals and objectives of the future model and to provide a clear list of activities that will and will not receive government funding or subsidy in the future. This is further discussed at the end of this report.

The team also acknowledges the limitation of referring to the future model as an "ISS National Laboratory." The team chose to examine the trade space using the generic term "model" to allow for a more comprehensive and creative set of options.

For Question 2, many previous reports, including the IRT and reviews from the Inspector General and Government Accountability Office (GAO), have detailed specific findings and recommendations for the ISSNL-CASIS management model.[4,10,11,12] Rather than repeating the results of these previous works, this study aims to answer Question 2 by identifying promising characteristics of potential future models and then applying these characteristics to strengthen the current ISSNL model in preparation for the transition of the ISS to CLDs.

We discuss additional limits in study scope in Methods.

Key Terms

We define the following key terms to clarify how we use them in this report, while acknowledging that these terms can carry different meanings in other contexts.

- **Model:** Collection of mechanisms and related organizational process and infrastructure that acts as a government touchpoint in the LEO ecosystem (the approach to connect users with providers).
- **Evaluation Criteria:** Representation of stakeholder-identified needs, which we used to score and compare model performance to guide decision-making.
- **Future Scenarios:** Representation of possible futures for the post-ISS LEO ecosystem used to frame the analysis and enable NASA leadership to compare models, their characteristics, and how they might differ with varying market dynamics.
- **LEO Activities:** Any action pursued by a user or provider in LEO, including for education, science and research, technology development and demonstration, human and robotic operations, and market stimulation.
- **Platform:** A facility that remains in orbit, providing space and equipment to enable different activities.
- **Commercial LEO Destination (CLD):** Commercially owned and operated LEO destinations supported by NASA's Commercial LEO Development Program.[13]
- **Spacecraft or Vehicle:** A volume that launches, returns, or enables LEO activities. Spacecraft and vehicles are defined as transitory, unlike the platforms that remain in orbit.
- **User:** An entity that seeks access to LEO for conducting a LEO activity, such as commercial, academic, or government users.

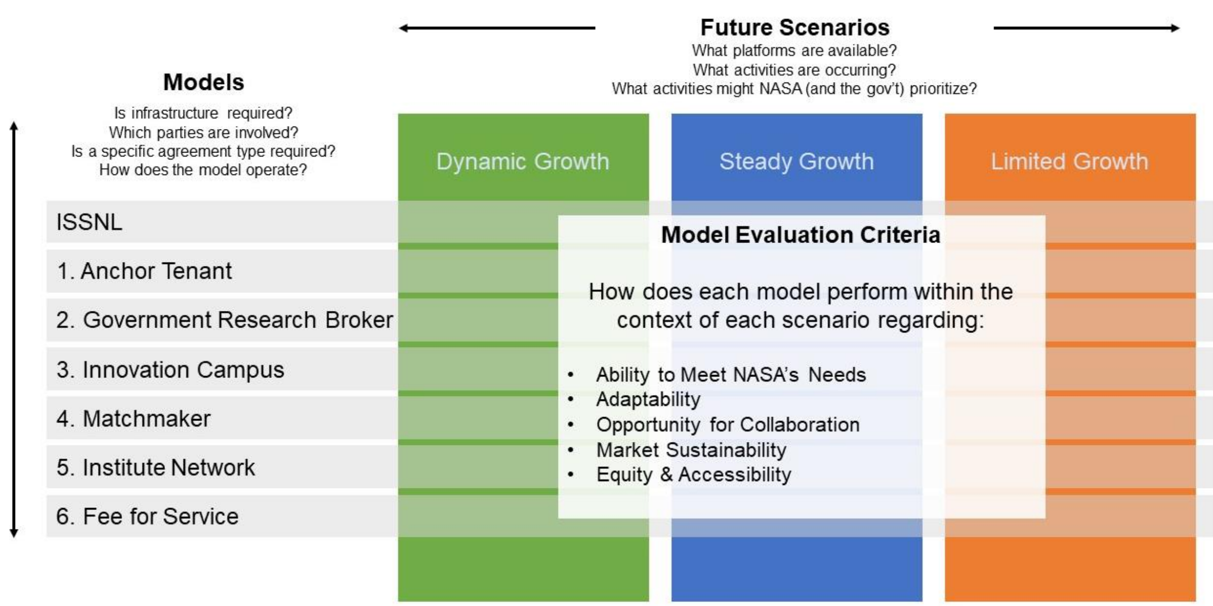
- **Provider:** An entity, usually commercial, that provides users with access to LEO platforms or spacecraft, which the provider owns and operates.
- **Stakeholder:** An entity with any stake in LEO activities, including users, providers, third-party operators, policymakers, students and educators, and beneficiaries of LEO activities, including the U.S. public at large.

Methods

To answer the two questions posed by leadership, we conducted an extensive literature review followed by a dual stakeholder-driven and scenario-driven analysis that relied heavily on an iterative process of gathering feedback from over 40 stakeholders. Stakeholders were selected to cover a diverse set of interests in LEO activities and provided iterative feedback from November 2021 to June 2022. We engaged with stakeholders through targeted conversations, discussions at national conferences, and during a dedicated meeting of experts hosted by the National Academies of Sciences, Engineering, and Medicine (NASEM). This approach allowed for a strong customer focus while also considering potential outcomes in a range of uncertain future possibilities. We assembled **six distinct models,** inspired by the literature and insight from stakeholders. Further, the stakeholder community helped inform **five model evaluation criteria** and **three future scenarios** to evaluate the models.

Once we developed these key analytical elements, a small study team independently scored (as Pro, Neutral, or Con) five model evaluation criteria for each of the six models and the existing ISSNL model. The team considered the evaluation criteria across the three scenarios as illustrated in Figure 1.

Figure 1. Study Approach



Generally, we used "Pro" to demonstrate the ability for the model to meet (or exceed) the criteria. We used "Neutral" to demonstrate that the model generally meets the criteria but with some limitations. Neutral was also used in situations where there was a mixture of favorable and unfavorable considerations. We used "Con" to note that the model did not perform well given the context of the future scenario. Because these scores are subjective, we then aggregated scores and met as a team to walk through any areas of disagreement. The scores were then presented to the larger study team, including members of OTPS, ISS Division, and ISSNL, for review and discussion. The final scores are provided in this report along with the justifications and considerations.

The Pro, Neutral, and Con scores were further aggregated across the future scenarios into overall model strengths and weaknesses, based on a model's ability to score favorably (Pro) across more than one future scenario. A model strength indicates a model evaluation criterion for which a model received at least two Pros across the three future scenarios. A model weakness, or area of possible improvement, indicates a model evaluation criterion for which a model received fewer than two Pros across the three future scenarios.

Model Development

To develop potential models, we first identified sixteen examples from the literature review and stakeholder discussions.[14,15,16] For example, we considered the National Science Foundation (NSF) FFRDC, the Department of Energy (DoE) FFRDC National Lab, and DoD Manufacturing Innovation Institute models, cited in the IRT, and the National Park and airport models, listed in the 2017 report by The Tauri Group.[4,17] Discussions with stakeholders also provided examples of models to include. To compare and consolidate the various examples, we identified four key characteristics to define a more cohesive and comprehensive set of models:

- **Infrastructure**: platforms, equipment, or systems required
- **Stakeholder roles**: users, providers, operators, NASA's role, other stakeholders involved
- **Process for accessing LEO**: how users get access to LEO, authorities needed, supply and demand considerations
- **Agreements between users and providers**: agreement types and lengths, level of NASA commitment

In the consolidation process, we also determined that the model should not entail any government-owned infrastructure (in space) and should not compete with commercial providers. Additionally, models should include some level of visible NASA presence, benefiting from the positive NASA brand. Taking these considerations into account and iterating based on feedback from stakeholder discussions resulted in the final six models (see descriptions listed in Table 3 along with the current ISSNL model). The model descriptions in terms of the four key model characteristics are further detailed in the Results section, along with the scores across the five model evaluation criteria and three future scenarios. The six models are meant to be illustrative and provide a broad trade-space of possible options. Model characteristics were specified for the purpose of making evaluations, however, options could be further adjusted and even mixed and matched.

Table 3. ISSNL and Six Differentiated Models for Facilitating Government-Funded Activities in LEO

Model	Differentiator	Description	Management & Oversight
ISSNL	Reflection of current operations	Third-party agreement to manage 50% of ISS U.S. segment activities for a broad range of academic, government, and commercial users.	Nonprofit (CASIS)
1. Anchor Tenant	Long-term agreement for leasing space on a commercial platform	NASA as anchor tenant on CLD with dedicated destination for LEO activities. NASA program office is agent for all government-sponsored activities. Commercial users work directly with platform provider or respond to government proposal requests.	Government (NASA Program Office)
2. Government Research Broker	Customizable research using combinations of transport vehicles and CLDs	NASA program office guided by advisory committee brokers payloads to LEO, conducts mission planning, and negotiates end-to-end services. Flexible contract with CLDs based on short-term needs. Crewed and uncrewed missions for flexible government research needs.	Government (NASA Program Office)
3. Innovation Campus	Modern terrestrial campus with workforce focus	Government-owned terrestrial campus operated by non-government entity. Dedicated to advancing research and development. Focused on innovation and building LEO workforce rather than connecting users to platforms.	3rd party with NASA as sponsor
4. Matchmaker	Neutral third party connecting users to platforms	Nonprofit funded by NASA to match specific users to LEO opportunities based on mission and technical requirements. Provides clear entry point for users and providers. Aggregates and communicates user demand to industry.	Nonprofit with NASA as sponsor
5. Institute Network	Network of separate but related efforts to enable commercial scaling and U.S. leadership	Government-sponsored consortia of distinct but related institutes within LEO and terrestrially. Institutes funded through public-private partnerships managed by nonprofits. CLD facilities leased from providers within institutes.	Nonprofit with NASA and OGAs as sponsors
6. Fee for Service	Free market approach	Industry-driven model focused on transactions for services. Users purchase goods and services from providers. NASA is one user and leverages grants and data buys to meet needs.	Industry; NASA management and oversight of grants and data buys

Stakeholder-Driven Analysis

Integrating perspectives from diverse stakeholders is imperative for the successful development of a future model to facilitate government-funded activities in LEO. We define a stakeholder as an entity with any stake in LEO activities, including users, providers, third-party operators, policymakers, students and educators, and beneficiaries of LEO activities, including the U.S. public at large.

We refined the models, model evaluation criteria, and future scenarios from 43 discussions with different stakeholder groups: 13 NASA, 10 other government agencies (OGAs), 10 commercial, and 10 academic and nonprofit. These targeted discussions at times included more than one stakeholder participant. The topics of conversation spanned multiple areas depending on the stakeholder but in general involved the future of the LEO ecosystem, NASA's future role, potential activities to be conducted, models or mechanisms to enable such activities, and areas for concern. At times, the study team engaged stakeholders in follow-up discussions as the study progressed or when clarification was needed. From these 43 discussions, we heard how different stakeholders valued LEO activities for outcomes like creating and sharing knowledge, demonstrating technology, serving as a springboard to the Moon and Mars, fostering economic growth, and maintaining and building relationships. Summaries from the stakeholder discussions are provided in Appendix A: Insights from Stakeholders. A list of stakeholder discussants is provided in Appendix G.

The study team also actively engaged the diverse LEO stakeholder community at multiple conferences, including the 2021 American Society for Gravitation and Space Research (ASGSR) meeting, the 2022 ASCENDx Texas summit, and the 2022 ISS R&D Conference. We also gained international perspectives, as members of the study team listened to the reflections of the ISS International Partner Working Group at approximately monthly virtual and in-person meetings. Additional insights came from reviewing literature following these engagements.[18,19,20]

Finally, the study included a NASEM Meeting of Experts on May 16, 2022, in which 11 experts with academic, policy, commercial, and international affiliations provided feedback on the primary study elements, including the models, model evaluation criteria, and future scenarios. Specifically, we posed two questions to the experts:

1. **Models**: What mechanisms, models, or combinations have you seen work well in supporting national objectives (research, exploration, economic growth, international cooperation)?
2. **Model Evaluation Criteria**: Do the model evaluation criteria appropriately characterize aspects that you find important? Are there additional criteria we should consider? What criteria is most relevant to your organization post-2030?

After briefly presenting our preliminary results, we asked each meeting participant to consider the two questions and provide five-minute responses for each question, with an additional three minutes of discussion among the participants. This resulted in a more refined analysis with clearer understandings of model strengths and weaknesses and other stakeholder considerations.

Model Evaluation Criteria

While we used stakeholder inputs to inform the development of the final six models and three future scenarios, their inputs were also directly applicable to the development and refinement of the five model evaluation criteria, listed in Table 4. These criteria are meant to represent the pertinent needs of the various communities and serve as a means to evaluate the effectiveness of models across future scenarios. As mentioned in the Introduction, the current model for facilitating activities in LEO is challenged by the incongruent set of goals and priorities of the diverse stakeholder community. A decision maker may view the following criteria as a set of priorities from various stakeholders and may look to assign values to each of the criteria to assist in decision-making. For example, we suggest that an academic researcher might highly value the equity and accessibility of a model over other criteria. If decision makers wish to optimize a model for the academic research community, they may value a model that performs well in terms of equity and accessibility. When comparing the different models, decision makers may consider not only overall scores, but also which models have the potential to benefit which stakeholder groups as needed.

Table 4. Five Model Evaluation Criteria

<table>
<tr><td colspan="2">Ability to Meet NASA's Needs: Provides for and prioritizes NASA s needs, including crew accommodation and training, human research, physical and biological research, technology demonstration, and science.</td></tr>
<tr><td>Sub-Criteria and Clarifying Questions:
Does the model help NASA meet its mission needs in LEO?</td><td>Interested Stakeholder(s):
NASA</td></tr>
<tr><td colspan="2">Adaptability: Involves priorities, processes, and parties that are easily adaptable to available infrastructure, offerings by the service providers, and user demands.</td></tr>
<tr><td>Sub-Criteria and Clarifying Questions:
Is the model restricted to an individual platform?
Does the model provide flexibility?
Does the model account for scalability?
Does the model enable diverse activities?
Does the model enable simultaneous activities?</td><td>Interested Stakeholder(s):
All users
All providers</td></tr>
<tr><td colspan="2">Opportunity for Collaboration: Allows and encourages interagency, international, and commercial partnerships through open communication, clear cost sharing mechanisms, or other means.</td></tr>
<tr><td>Sub-Criteria and Clarifying Questions:
Does the model facilitate coordination among NASA, OGAs, and international partners?
Does the model align with non-NASA user groups?</td><td>Interested Stakeholder(s):
NASA
OGAs
International</td></tr>
<tr><td colspan="2">Market Sustainability: Stimulates supply and demand by providing for the industrialization and commercialization of products and services, by buying down risk for commercial entities, and by ensuring a positive user experience.</td></tr>
<tr><td>Sub-Criteria and Clarifying Questions:
Does the model help encourage market growth?
Does the model result in a streamlined process and good user experience?
Does the model mitigate risks to return on investment for platform providers?</td><td>Interested Stakeholder(s):
CLD providers
U.S. industry
U.S. investors</td></tr>
<tr><td colspan="2">Equity & Accessibility: Enables and empowers underrepresented groups and nonprofit seeking ventures, such as fundamental research and education and outreach activities.</td></tr>
<tr><td>Sub-Criteria and Clarifying Questions:
Can user communities provide input into the activity selection process?
Does the model provide an easy-to-identify point of access?
Does the model include a low-cost pathway for research?
Does the model proactively seek input and participation from diverse stakeholder groups?</td><td>Interested Stakeholder(s):
U.S. academic institutions
U.S. students and educators
U.S. nonprofits
U.S. society
New entrants</td></tr>
</table>

Scenario-Driven Analysis

We used the scenario-driven analysis to consider model performance within a range of uncertain future possibilities. This approach enables NASA leadership to compare different models for the post-ISS LEO ecosystem by not only the models' characteristics but also by how those characteristics respond to different future possibilities. The future scenarios are used as a tool to frame the analysis for the models rather than serving as a prediction of the future LEO ecosystem. To develop this tool, we incorporated stakeholder insight and considered assumptions about the future ecosystem, including launch and transportation costs (see Limits in Study Scope below). These assumptions have been corroborated through studies on this issue.[21] With this in mind, we defined three future scenarios—limited growth, steady growth, and dynamic growth—that provide a broad range for considering the strengths and weaknesses of each model.

Future Scenarios

To characterize future scenarios, we used stakeholder input to answer four questions:

1. How might NASA's priorities change in different futures?
2. Which activities will be available?
3. How will NASA and other stakeholders prioritize the activities available?
4. What platforms and other resources will be available?

Answering these questions, we characterized three future scenarios, defined by the number of commercial offerings and by the amount and diversity of user activities in the LEO ecosystem:

- In dynamic growth, successful commercial markets spur innovation and capital investment, providing numerous and more diverse activities.
- In steady growth, one or more small commercial platforms are the center of LEO activity, but that activity is not diversified.
- In limited growth, low demand or market disruption leads to a lack of mature commercial platforms and few activities.

Overviews of the three future scenarios are provided below. The full scenario narratives are in Appendix B: Scenario Narratives.

To inform the future scenarios, we identified and characterized potential future LEO activities, including education, science and research, technology development and demonstration, operations, and market stimulation. To various extents, these activities are in or out of scope for NASA as specified in the Quantifying Demand White Paper.[22] Generally, activities in education, science and research, and technology development and demonstration, and operations are considered to be in scope for a future government-funded LEO model for all future scenarios. However, NASA's demand of these activities and ability to purchase them from commercial providers may vary based on available market supply across the future scenarios. Activities in market stimulation, such as private astronaut activities and commercial incubation and media, are considered to be in or out of scope depending on the future scenario. Further characterization of the anticipated future LEO activities is provided in Appendix C: Future LEO Activities.

We developed the future scenarios based on feedback from stakeholders and an objective to explore the most plausible range of future scenarios. This did exclude edge cases that are unlikely, but possible. For example, the limited growth scenario does not assume that most efforts fail resulting in a lack of LEO activities.

When developing the future scenarios, we had the following key factors in mind: number of available platforms; availability and diversity of activities; contributing factors to market dynamics; and impacts to user communities. We heard other factors in stakeholder discussion that might be important to readers but are outside the analysis. For example, geopolitical dynamics and how they might change in the 2030 timeframe are not directly incorporated into this analysis but may be useful insight for the decision-making process in combination with this analysis. We also heard that as market dynamics shift over time, the government may wish to consider how models may evolve to support changing needs.

Scenario 1: Dynamic Growth

Two or more CLDs in operation. NASA's investments in the CLD Space Act Agreement have ignited new LEO markets and investments. Early successes resulted in increased venture capital investment and accelerated interest in using and visiting LEO. Multiple, diversified services and activities span multiple providers. Possibly one single exquisite facility supports the activities, but more likely, several CLDs and reusable vehicles compete for user demand, which has expanded in both number of users and variety of demand. In addition to science, human exploration research, and technology demonstration, space tourism has grown significantly, and on-orbit manufacturing is an established market. Lower launch costs and greater accessibility enable new business models with new and improved offerings available every few years. These new business models increase flexibility and enable providers to tailor LEO platform services to specific users.

Scenario 2: Steady Growth

One or several small CLDs in operation. With moderate development of the LEO ecosystem, both users and providers continue to increase, though at a slow pace. Whether one platform or multiple small platforms are available, the range of services and activities is not diversified. NASA has sufficient access to LEO infrastructure to meet its primary needs. Other user communities are somewhat more limited, since commercial services remain generalized. Companies lack sufficient development and private investment to offer specialization. Despite these limitations, LEO continues to be a symbol of collaboration and an international environment.

Scenario 3: Limited Growth

One CLD in operation, though with limited capacity. Despite NASA's efforts to develop the U.S. LEO commercial market, commercial providers have not been able to survive the costs of entry, and expected markets failed to materialize. Investors have pulled out, leaving providers unable to buy down risks and mature technologies. One CLD is operational and can host research but in a much more limited capacity than on the ISS. Therefore, after the retirement of the ISS, the United States has limited access to a LEO platform. Users, including NASA, fly only their highest priority needs. Other users seek means of continuing activities in microgravity without using a LEO platform. Geopolitical dynamics are also shifting. Other nations likely have operational stations and are interested in new partnerships. As the United States shifts attention to the Moon and Mars, it cedes some geopolitical benefit of LEO to others.

Limits in Study Scope

In both stakeholder discussions and at the NASEM Meeting of Experts, at least three topics rose repeatedly as important considerations but ultimately fell outside the scope of this study.

Launch and Transportation Costs

This study was a scenario-driven analysis that built assumptions into each future scenario for the purpose of evaluating model performance within different contexts. As part of this approach, we considered launch costs an enabling factor for each future scenario. For example, we assumed launch costs were reduced when compared to today to enable the robust market dynamics in the dynamic growth scenario. If the reader does not agree with this assumption, we encourage the reader to consider model performance under the steady growth scenario, where transportation costs are not assumed to deviate much from today. For the limited growth scenario, launch costs are likely not the primary limitation, as in-space opportunities will be more limited than launch vehicles, which continue to benefit from the satellite launch market.

We heard from many stakeholders, including those at the NASEM Meeting of Experts, that if transportation costs don't reduce significantly, markets will not be able to materialize. Several stakeholders noted transportation was a major issue for consideration when identifying and selecting a model for the post-ISS ecosystem.

While we make assumptions on the cost of transportation in the 2030 timeframe, transportation itself was not a major focus of this study. Future potential models should consider transportation mechanisms as a major component, which will require further analysis. Overall, the effects of cost should not be underestimated. The likelihood of a future scenario could completely change based on launch and transportation costs.

Crewed Versus Uncrewed Activities

The scenario narratives do not differentiate between crewed and uncrewed platforms. Several stakeholders mentioned that future activities can be conducted on uncrewed platforms and recommended that future models take this into account in follow-on analyses. Additionally, certain activities in LEO (such as remote sensing and manufacturing) may be better suited to autonomous, robotic uncrewed operations.

International Partnerships

The scenario and model narratives do include sections on their impacts to international stakeholders' involvement, but the complexities of these relationships and future implications cannot be addressed in this study alone. Several stakeholders noted the importance of determining NASA's position towards international partnerships in a post-ISS ecosystem. Doing so requires additional analysis and thoughtful legal consideration, both for current ISS partners and for governments and agencies not in the current ISS partnership, such as emerging space agencies and Artemis Accords signatories. A separate working group led by NASA's Space Operations Mission Directorate has been established to begin discussions with the current ISS partners regarding the future LEO ecosystem.

In the context of our limited growth scenario, with just one operational CLD, we may assume that both U.S. and international users might use international providers for their LEO access needs. This could create a situation in which U.S. users, including NASA users, are more reliant on international partnerships, analogous to when after the retirement of the Shuttle program and prior to the Commercial Crew program, the U.S. relied on crew transportation to and from the ISS via the Russian Soyuz spacecraft.

Recent events in international policy, especially the U.S.-Russia integrated crew agreement that was reached in June 2022, will be important to consider in the post-ISS LEO ecosystem. The agreement specifies that U.S. astronauts and Russian cosmonauts can ride as integrated crews to and from the ISS on both U.S. crew spacecraft and the Russian Soyuz with a no-exchange-of-funds basis.[23] While not fully explored in this work, international partnerships and agreements, such as this example, are likely to impact a model's potential performance in the possible future scenarios, and their implications should be more intentionally assessed.

Levels of Fidelity for Models

We relied on literature reviews and stakeholder discussions to develop the models. Those we developed are largely notional and conceptual, representing a wide trade space of potential options. If decision makers select one or more models to iterate on, we suggest doing future work to address the other limits in study scope identified in this section, conducting follow-on analyses outlined at the end of this report, and giving more consideration to cost and legislative changes needed to specify the exact operations, management, and business details of each of the models we present.

Results

This section describes the six assembled models and the existing ISSNL model; highlights their scores; and provides an aggregate view of the model scores and considerations for senior leadership based on this aggregate view.

Six Models + ISSNL Model

Each model description includes the following information to guide senior leadership decisions:

1. An **overview** description of the model in practice, as envisioned in the post-ISS LEO ecosystem, including a "National Laboratory" characterization.
2. Assumptions about the physical **infrastructure** providing user access to LEO, including LEO platforms, facilities and equipment on platforms, spacecraft functioning as research vessels, and terrestrial facilities.
3. Assumptions about the **roles** of different stakeholders in this model, as users, providers, third-party operators or managers, or members of advisory committees or consortia.
4. Assumptions about the **process** in which providers provide access to LEO, users seek and acquire access, and other parties facilitate user-provider coordination, user-user partnership, or determination of supply and demand needs for LEO access. A flow diagram illustrates this process, which is defined by three major steps for connecting users (demand) with providers (supply):

   Step 1: "getting in the door" shows the path for users to follow if they wish to conduct an activity in LEO through the model, such as proposing to the identified stakeholder for activity selection. Users may engage with identified stakeholders regarding activity selection or to influence activity selection priorities.

   Step 2: "once in the door" refers to the stakeholder who allocates resources for the selected activities, such as integration, crew time, and mass to orbit, and facilitates the process for users to prepare flight-ready payloads.

   Step 3: "getting out the door" notes who then decides which flight-ready payloads will be manifested on a flight to the platform.

5. Assumptions about the types of **agreements** that users, providers, and other parties might use to receive, provide, or otherwise facilitate access to LEO.
6. A summary list of the anticipated **impacts** of this model on four non-NASA user communities: academic, international, OGA, and commercial.
7. Highlights of the model's **scores**, including a summary table of *Pros, Neutrals, and Cons* per future scenario, key takeaways, and lists of the model's main *strengths* and *weaknesses* in meeting the five evaluation criteria across multiple future scenarios.

ISS National Laboratory Model

The ISS National Laboratory (ISSNL) is a NASA-funded nonprofit National Laboratory established through the 2005 NASA Authorization Act. It is responsible for managing all non-NASA research. Investigations must utilize space for Earth benefits. These areas include but are not limited to physical sciences, life sciences, remote sensing, technology development, and education.

Key Discriminators

- The ISSNL is an honest broker for flying non-NASA science and provides significant support to the user community.

Infrastructure

By law, NASA is required to allocate 50% of the U.S. allocation of ISS utilization resources (upmass, downmass, crew time, etc.) for sole use of the ISSNL.

Stakeholder Roles

NASA maintains final responsibility for what is flown and operated. The ISS Program and CASIS integrate all hardware and investigations to fly and operate.

CASIS manages all investigations conducted under the ISSNL allocation. It is responsible for selection of these investigations through a peer review process designed to fly the highest rated proposals. CASIS creates and enables many partnerships between users, Implementation Partners (IPs), and Commercial Service Providers (CSPs). They provide some funding for investigations and integration costs but also encourage projects to be self-funded (CASIS provides on average 10% of project costs).

IPs support and facilitate investigations to be flown through the ISSNL. They may be selected by the users, but that is not required to successfully conduct science in space.

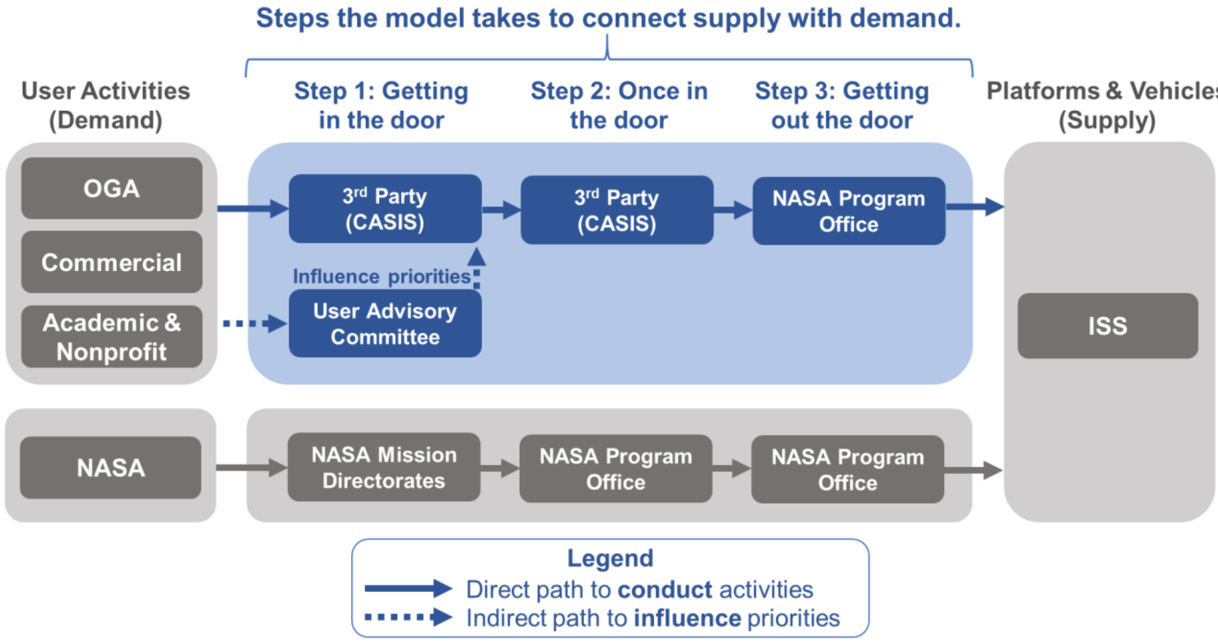
CSPs have flown and operated facilities on the platform and may sell services that their facilities provide to users they have brought to the ISSNL through their own business development. This can range from facilities in a rack to a commercially available airlock.

Users include anyone submitting investigations to be flown through the ISSNL. They include but are not limited to government agencies (other than NASA), academic institutions, and companies.

Process for Accessing LEO

Figure 2 illustrates the process this model takes for connecting user activities with platforms.

Figure 2. Process for Accessing LEO through the ISSNL Model



Step 1: There are many opportunities to apply and conduct research in space through the ISSNL that include but are not limited to: National Laboratory Research Announcements, public-private partnership challenges, solicitations, and CSPs who may request resources for their customers. Through a formal peer review process, the ISSNL and external reviewers read and rate all proposals. Only the best investigations are flown, and the ones that are not flown are given feedback to make their proposal better. Investigations can also be flown through CSPs, which are still evaluated by the ISSNL but in a less rigorous selection process, since other companies own their facilities.

Step 2: Once selected, ISSNL works with the user and any IP or CSP involved to prepare experiments for flight and translate ground-based experiments into flight-ready payloads. The ISSNL allocates resources such as integration, crew time, and mass to orbit.

Step 3: The ISSNL works with a NASA Program Office, the ISS Utilization Office, to provide payload manifestation priorities and to provide input to payload integration. The ISS Utilization Office integrates ISSNL selected payloads and NASA selected non-ISSNL payloads into missions on the ISS.

Agreements Between Users and Providers

CASIS manages the ISSNL through a cooperative agreement with NASA and with NASA funds. NASA provides ISS resources and transportation free of charge to ISSNL users. Users (including IPs and CSPs) operate under user agreements or a grant agreement.

Impacts to User Communities

This model is designed to benefit the user community and none of NASA's exploration goals, as designated by law. For the purpose of this analysis, we assume that the ISSNL model always maintains 50% of NASA's ISS utilization allocation, but future resources depend on how much access NASA has on a future platform.

- **Academic** users may fly science through the ISSNL through the processes described above or partner with NASA if the investigation meets the agency's exploration and research goals.
- **International** users may fly through the ISSNL only if flying through a U.S. company, like with a CSP, or they may fly with any other international partner using the platform.
- **OGA** users primarily fly science through the ISSNL through the processes described above but may also partner with NASA using NASA sponsorship if the investigation meets the agency's exploration and research goals.
- **Commercial** users fly through the ISSNL unless they are working through a NASA solicitation that meets the agency's exploration and research goals or have a commercial product that is not eligible for the ISSNL but can be flown through NASA Interim Directive 8600.121 on Use of ISS for Commercial and Marketing Activities and be willing to pay for all government services used (upmass, downmass, crew time, etc.).[24]

Scoring Highlights

When scoring the ISSNL model, we considered the current underlying model "as is," including existing legislation and use of one platform. Therefore, we recommend against directly comparing the ISSNL scores to the scores of the other six models. The scoring may provide insight into potential improvements to the existing model.

The current ISSNL model cannot be evaluated in reference to meeting NASA's needs given the split detailed in legislation, specifying the ISSNL focus on non-exploration (non-NASA) activities. However, we do assess the ISSNL model across the other evaluation criteria in the future scenarios, as it may be possible to extend all the current processes, parties involved, and agreement types characterizing the current ISSNL model to a leased portion of a CLD.

Table 5 summarizes the model's scores per future scenario, as evaluated by each of the five criteria. See Methods for definitions of the evaluation criteria, Appendix B for the full scenario narratives, and Appendix D for the full scoring results, including brief explanations for why each criteria receives a Pro, Neutral, or Con score per future scenario.

Table 5. ISSNL Scoring Summary

Model Evaluation Criteria		Future Scenario		
		Dynamic Growth	Steady Growth	Limited Growth
	Ability to Meet NASA's Needs	N/A	N/A	N/A
	Adaptability	Con	Con	Neutral
	Collaboration	Neutral	Neutral	Neutral
✓	Market Sustainability	Neutral	Pro	Pro
✓	Equity & Accessibility	Pro	Pro	Pro

✓ Overall strength = Criterion received at least two Pros across the three future scenarios

Key Takeaways

The ISSNL model provides equity and accessibility across all future scenarios as an honest broker to diverse users by engaging the private sector through research and cost-sharing arrangements while leveraging a network of IPs and CSPs, incubator partnerships, public-private sponsorships, and sponsored research. This model encourages market growth by covering costs for payload integration and by helping users in the form of grants and subsidies. The legislative authority implemented in the cooperative agreement limits NASA's flexibility in adjusting the relationship over time. The cooperative agreement also prevents CASIS from engaging in any non-ISSNL activities, constraining CASIS's business model. The cooperative agreement hinders the model's adaptability to offerings by providers and demands of users. Collaboration is a weakness because NASA, OGAs, and international users cannot easily collaborate among each other through ISSNL. This is because the 50% allocation is for non-NASA activities and international partners can fly only if going through a U.S. company.

Overall Strengths Across the Future Scenarios

The ISSNL model scores positively across **multiple** future scenarios, demonstrating robustness, in terms of:

- ✓ **Market Sustainability:** Encourages market growth by covering costs for payload integration and by helping users in the form of grants and subsidies. Concerns regarding limited visibility into planned resource allocations and changes to these allocations, as reported by the GAO, are actively being addressed and have improved with the continued input of the User Advisory Committee.[12] Accommodating further incubation and acceleration of technologies and startups is important but depends on updates to legislation.

✓ **Equity and Accessibility:** Enables outreach to new, diverse users through partnerships, challenges, and solicitations. Managed by a third-party nonprofit organization in a cooperative agreement with NASA, the ISSNL also acts as an honest broker and provides significant support to users, including matching with IPs, grant funding, introductions to an investor community, and customer service from proposal through flight and post-flight. Users are primarily responsible for bringing their research, but all other resources—launch, crew time, integration, etc.—are provided by NASA and ISSNL funding.

Overall Weaknesses Across the Future Scenarios

The ISSNL model does **not** score positively across **multiple** future scenarios, demonstrating a lack of robustness, in terms of:

- **Adaptability:** Hinders exchange of funds, constrained by the cooperative agreement in place and legislation in terms of exclusivity of operations, infrastructure, and allocation of platform resources. This reduces ability to leverage new opportunities and LEO activities.
- **Opportunity for Collaboration:** Enables civil government agency collaborations (such as NIH and NSF) but complicates options for DoD and international collaborations, due to intellectual property concerns and other competitive concerns.

Model 1: Anchor Tenant

NASA is an "anchor tenant" for one commercially available LEO platform. As an anchor customer, NASA provides a reliable source of revenue for a specified amount of time. NASA and other user communities have some degree of autonomy over activities conducted in dedicated areas or even individual segments of the platform. An estimated 30% to 90% of total activities on the platform are government-sponsored. The dedicated areas and individual segments or portions of these areas are designated a National Laboratory.

Key Discriminators

- NASA has a long-term, contracted relationship with the platform provider.
- NASA has direct input into platform requirements and a dedicated destination for conducting LEO activities.

Infrastructure

One platform is privately owned, with NASA as its main, and potentially only, long-term customer. As such, NASA might own specialized equipment or other facilities on the platform. However, NASA does not own competing platforms or have an ownership stake in the platform.

NASA has dedicated space and time on the platform. Other users might have dedicated space and time on the platform as well. A dedicated space can be an area within a segment of the platform or an entire segment itself.

Stakeholder Roles

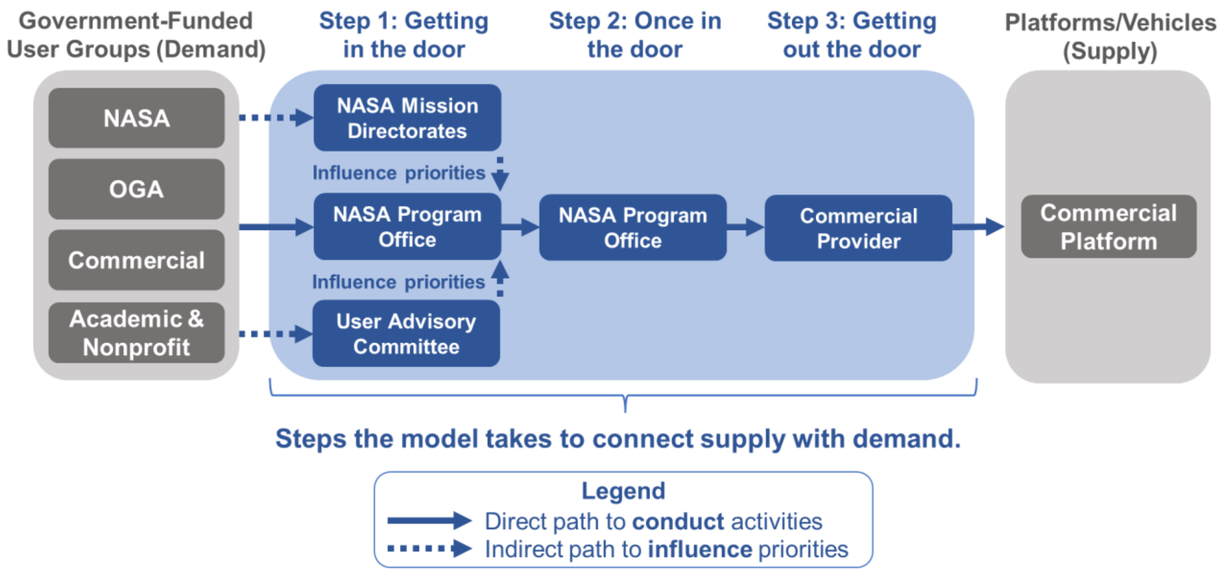
The CLD provider owns and operates the platform and leases space to the anchor tenant. The CLD provider has final authority over activities performed on the platform, including the authority to veto activities to ensure safety or avoid interoperation issues. However, as the anchor tenant, NASA has operational autonomy over its dedicated area of the platform, as stipulated in its contract. NASA can also provide input to help the CLD provider decide which activities to allow on the platform.

A dedicated NASA program office prioritizes, selects, and awards activities that use NASA's area of the platform. NASA acts as the agent and portal for all government-sponsored user activities. The program office can contract out some tasks for coordinating user community activities, but NASA maintains primary oversight of the activity selection process and execution. To offer their perspective on activity selection, user communities can provide input to the program office through a board of directors, user advisory committee, or decadal surveys.

Process for Accessing LEO

Figure 3 illustrates the process this model takes for connecting user activities with platforms.

Figure 3. Process for Accessing LEO through the Anchor Tenant Model



Step1: The dedicated NASA program office provides a clearly identified point of entry for users seeking to use NASA's area of the platform. In addition to submitting white papers proposing activities for the platform, users can respond to open calls for proposals, which the NASA program office uses to communicate NASA's priorities for activities. Through a formal review process, which includes input from a user advisory committee, the NASA program office selects activities among those proposed.

Step 2: After selecting an activity, the NASA program office (or contracted delegate) helps users define requirements and facilitates the process of ensuring flight-ready activities. The program office also allocates integration, crew time, and mass to orbit. In addition, the program office aggregates the demand of international partners and coordinates their involvement, as stipulated in NASA's overarching contract with the commercial platform provider (note that international partners may also seek other pathways with CLD providers).

Step 3: The NASA program office then works with the commercial provider, who decides which activities to allow on the platform.

Agreements Between Users and Providers

The agreement between NASA and the CLD provider is a long-term contract with a high level of commitment between parties. The contract details jointly identified requirements for NASA's area of the platform and lists potential activities. Although the contract might include options for built-in flexibility over the long period, and few options for scalability, these options will be for only preconceived activities and circumstances outlined in the contract. The contract authorizes NASA to perform safety certification/human rating.

For individual activities, the NASA program office can coordinate memoranda of understanding (MOUs), grants, barter agreements, government contracts, and other agreements with or between different stakeholders.

Impacts to User Communities

Although mostly NASA-focused, with activities frequently aligning with academic user needs, this model also provides support to international, OGA, and commercial users when excess capacity allows.

- **Academic** users can submit grant proposals through the NASA program office's formal review process, or potentially through a consortium that includes NASA and OGAs. The priorities of the NASA program office likely guide research activities.
- Assuming early identification of demand and priorities, **international** users might access the platform through bilateral agreements.
- **OGA** users coordinate directly with the NASA program office and might consolidate funding for academic grants or contracts with industry where interests align.
- **Commercial** users work directly through the CLD provider for most needs but can also respond to NASA or OGA requests for proposals.

Scoring Highlights

Table 6 summarizes the model's scores per future scenario, as evaluated by each of the five criteria. See Methods for definitions of the evaluation criteria, Appendix B for the full scenario narratives, and Appendix D for the full scoring results, including brief explanations for why each criteria receives a Pro, Neutral, or Con score per future scenario.

Table 6. Anchor Tenant Scoring Summary

	Model Evaluation Criteria	Future Scenario		
		Dynamic Growth	Steady Growth	Limited Growth
✓	Ability to Meet NASA's Needs	Pro	Pro	Neutral
	Adaptability	Con	Neutral	Neutral
✓	Opportunity for Collaboration	Pro	Pro	Neutral
	Market Sustainability	Neutral	Pro	Neutral
	Equity & Accessibility	Neutral	Neutral	Neutral

✓ Overall strength = Criterion received at least two Pros across the three future scenarios

Key Takeaways

The Anchor Tenant model provides a long-term steady engagement with a CLD. This leads to reliable access for NASA to support a significant portion of its exploration needs and for more collaborative opportunities, assuming they were identified when drafting the agreement. Substantially supporting a CLD also increases the probability of market sustainability. However, the model does not respond well to changing needs or to users with additional requirements that were not considered early in the process. Moreover, it may dampen long-term economic growth by reducing competition and increasing barriers to entry for non-NASA supported anchor tenants as well as users who are not well-established. NASA can try to mitigate some of these weaknesses by leveraging flexible contracting pathways, establishing alternative pathways for international partners, and increasing leased space to support future growth or support to underrepresented communities.

Overall Strengths Across the Future Scenarios

The Anchor Tenant model scores positively across **multiple** future scenarios, demonstrating robustness, in terms of:

- ✓ **Ability to Meet NASA's Needs:** Focuses largely on NASA's needs, although addressing changing NASA needs might be more difficult under an inflexible contract with the CLD provider. NASA has the ability to jointly (with the CLD provider) develop requirements and maintain some degree of autonomy over its area of the platform. NASA can continue its LEO activities without any gaps.
- ✓ **Opportunity for Collaboration:** Allows for a continuation of familiar ISS-era operations and relationships, given that entry through a NASA program office is familiar to OGA and international users. However, NASA likely continues to prioritize mission work over non-mission work, making areas of potential alignment between NASA, OGA, and international partner activities somewhat limited.

Overall Weaknesses Across the Future Scenarios

The Anchor Tenant model does **not** score positively across **multiple** future scenarios, demonstrating a lack of robustness, in terms of:

- **Adaptability:** Requires long-term agreements and large investments that lock NASA into a relationship with one CLD provider. These restrictions can hinder market dynamics in the dynamic growth scenario, but present less of a challenge in the steady growth scenario. If NASA were to expand its tenancy to more than one platform, it would improve diversity of activities, their simultaneous operations, and ability to scale.
- **Equity and Accessibility:** Enables NASA to engage underrepresented groups, although the focus remains largely on NASA's needs. Academic and educational activities that do not tie directly to NASA objectives must find funding elsewhere. Equity and accessibility is the only criterion that neither improves nor worsens by future scenario.

- **Market Sustainability:** Provides a reliable, consistent customer to the CLD provider, helping build their business case and mitigate risks to their return on investment, but if considered as is (on only one platform), might not support other operational CLDs. Anchor Tenant can help build the market in early stages and can help sustain the market in future scenarios with less opportunity but does not help the ecosystem become sustainable without NASA. Additionally, an early, significant investment by NASA might preclude interactions between platform providers and other potential customers, stifling a free market economy.

Model 2: Government Research Broker

Key Discriminators

- Building off the success of previous NASA programs for LEO access, all potential research platforms for the government become more flexible.
- The research space, or orbital transport spacecraft, offers shorter missions with reconfigurable sorties, tailored to user mission requirements.

Reconfigurable missions to CLD platforms maximize flexibility for government needs. The research space is an orbital transport spacecraft (like Dragon, Dream Chaser, or other) that docks at one or more CLDs. Users can conduct research on the orbital transport spacecraft itself or in combination with the CLD platform facilities. Each research space is designated a National Laboratory, or a collection of research spaces is named a National Laboratory.

A new NASA program, similar to the Launch Services Program, but with an expanded role, conducts mission planning and negotiates end-to-end services.[15,16] Acting as a broker bringing payloads to LEO, the program follows payload requirements, finds the launch provider and orbital transport spacecraft, and uses knowledge of the CLD platform (such as interfaces) to determine the best destination for payloads. This program may have evolved from earlier programs with similar capabilities, such as the Launch Services Program, Commercial Crew Program, and Commercial Resupply Services. In the limited growth scenario, where just one CLD is in development, the program office still acts as broker for the orbital transport spacecraft but to the one destination only.

NASA and other user communities identify priorities through a user advisory committee, but NASA has a guaranteed minimum amount of space per flight. This guarantee ensures NASA can prioritize mission needs, but because the guarantee is flexible, NASA can modify the terms of the guarantee over time. Funding for non-NASA activities can come from NASA or a consortium of departments and agencies that includes NASA.

Infrastructure

One or more orbital transport spacecraft, owned by a commercial provider, and at least one CLD platform are available. The reconfigurable missions of the Government Research Broker model may include a combination of owned and leased hardware and equipment hosted on the permanent platforms and spacecraft vehicles, as the specific missions require. Signature capabilities may necessitate NASA owning hardware, on the other hand, to meet sortie objectives. The LEO hardware on orbital transport spacecraft may change mission to mission and be owned by an entity other than NASA. The CLD platform might provide an exclusive port to government users to ensure availability.

Reconfigurable aspects of the orbital transport spacecraft provide flexibility to users. These aspects include the spacecraft itself (within limitations), instrumentation, and other equipment that changes between research-focused missions. Reconfigurable aspects of the spacecraft can work in tandem with the facilities or crew on the CLD platform.

Stakeholder Roles

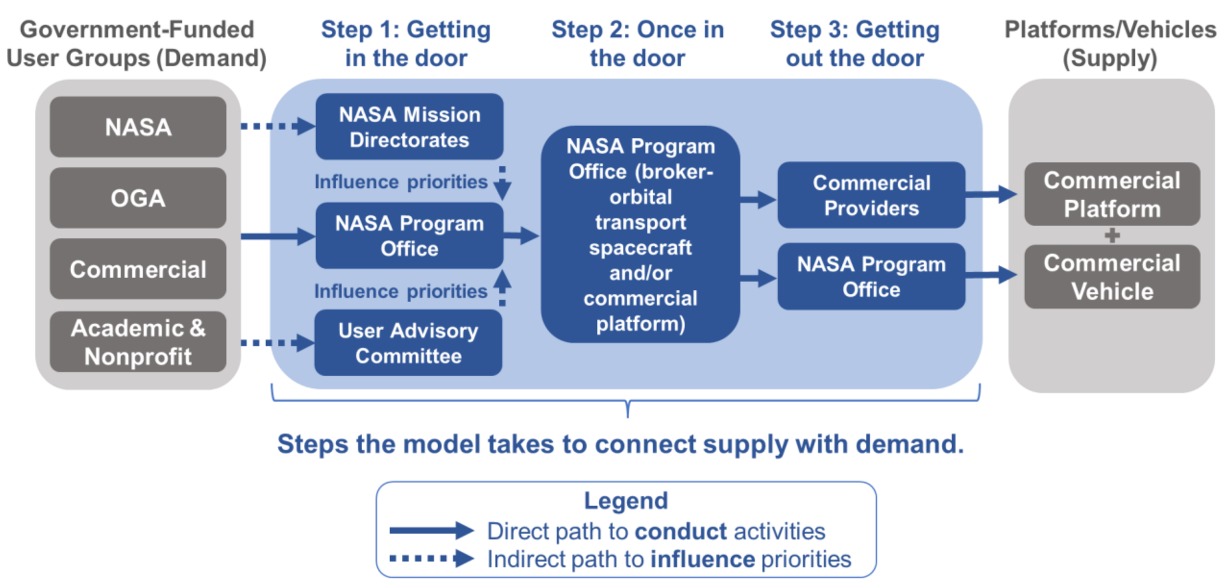
The NASA program office serving as the broker has final decision-making authority for selecting payloads and finding the best launch service provider and CLD platform to host the payloads. This is an expansion of previous NASA programs that includes a diverse set of stakeholders with varying priorities. The CLD provider has final authority over activities that use their platforms or ports.

NASA prioritizes activities through a user advisory committee, which includes both NASA and non-NASA users. Although NASA maintains control over the activity selection process, user communities can provide their input and perspective through the user advisory committee and through decadal surveys. The user advisory committee also sets research priorities, in a process similar to the decadal survey.

Process for Accessing LEO

Figure 4 illustrates the process this model takes for connecting user activities with platforms.

Figure 4. Process for Accessing LEO through the Government Research Broker Model



Step 1: The NASA program office leads the process for users' LEO access. A user advisory committee within the program office identifies user priorities. The program office uses grants and other funding mechanisms to enable LEO access for academic, OGA, and commercial users. The program office then selects which activities can be supported through the model.

Step 2: The program office facilitates the user process to achieve flight-ready payloads and also allocates integration, crew time, and mass to orbit. The program office determines payload priorities and, as broker, aggregates the payloads and finds the best launch provider, orbital transport spacecraft, and CLD platform for hosting the mission (if the mission will dock), given payload requirements.

Step 3: Finally, the program office guides the mission from pre-planning to post-launch if the mission does not dock to a CLD. If the mission docks to a CLD, then the commercial provider decides which missions are allowed to dock to the platform.

Agreements Between Users and Providers

The agreement between NASA and other orbital transport providers is a long-term contract, with built-in flexibilities. The agreement between the NASA program office and CLD providers is more flexible and based on shorter term mission needs. The NASA program office coordinates individual activities of user communities for various services. This includes transportation services to and from the CLD, which requires different contract terms and liability waivers.

Users who receive grant funding through the formal proposal and review process enter formal agreements with the granting agencies, whether NASA or others.

Impacts to User Communities

Although predominantly researched-focused, with activities frequently aligning with NASA, OGA, and academic user needs, this model provides some opportunity for international and commercial users. All user communities can have representation through a multi-user advisory committee. Users generally have research needs met, and NASA can prioritize mission-related research.

- **Academic** users can submit grant proposals to a formal review process by NASA or by a consortium that includes NASA and one or more OGAs.
- **International** users can interface directly with the NASA program office. When interests align, a bilateral agreement can enable activities on the research vessel.
- **OGA** users participate in the process through grants or contracts with NASA where interests align. NASA and OGAs can coordinate resources to fund research grants in areas of mutual interest.
- **Commercial** users work directly through the NASA program office. Companies may also partner with non-NASA researchers. NASA may provide a means to reduce costs for commercial users, particularly where interests align.

Scoring Highlights

Table 7 summarizes the model's scores per future scenario, as evaluated by each of the five criteria. See Methods for definitions of the evaluation criteria, Appendix B for the full scenario narratives, and Appendix D for the full scoring results, including brief explanations for why each criteria receives a Pro, Neutral, or Con score per future scenario.

Table 7. Government Research Broker Scoring Summary

	Model Evaluation Criteria	**Future Scenario**		
		Dynamic Growth	**Steady Growth**	**Limited Growth**
✓	Ability to Meet NASA's Needs	Pro	Pro	Neutral
✓	Adaptability	Pro	Pro	Neutral
✓	Opportunity for Collaboration	Pro	Pro	Neutral
	Market Sustainability	Neutral	Neutral	Neutral
✓	Equity & Accessibility	Pro	Pro	Neutral

✓ Overall strength = Criterion received at least two Pros across the three future scenarios

Key Takeaways

The Government Research Broker model provides a reliable option for NASA to continue activities in LEO in any future scenario, especially if the ecosystem does not develop as desired or expected. The range of built-in flexibilities can buffer against major changes in available infrastructure and against how capabilities within CLD platforms may develop. The Government Research Broker model meets the needs of all but one of the stakeholder-driven performance criteria. The model falls short in terms of market sustainability, as there is potential for competition to arise between the CLD platforms and the orbital transport spacecrafts. However, this can be designed against if considered early on by incentivizing port standardization and ensuring mutual government-industry benefits, for example. The high level of government involvement, combined with the ability to optimize the government's research space as needed, make this model a viable option for consideration. Note that NASA's Commercial LEO Program has precluded sortie-style research options from CLD awards. Should this model be considered, that should be taken into consideration.

Overall Strengths Across the Future Scenarios

The Government Research Broker model scores positively across **multiple** future scenarios, demonstrating robustness, in terms of:

- ✓ **Ability to Meet NASA's Needs:** Allows for NASA's exploration and research needs to be met, assuming the larger volume on a platform is available when the more confined volume on a research vessel is insufficient. NASA, and any users operating through NASA, benefit from the ability to optimize the research space in any future scenario. In a more limited future scenario, the model can account for NASA's needs, with some need to prioritize efforts due to platform limitations, however.
- ✓ **Adaptability:** Combines orbital transport vehicle capabilities with platform capabilities to optimize available infrastructure and to buffer against major uncertainties in the future ecosystem. With providers encouraged to build interoperability into ports, vehicles, and platforms, users can mix and match objectives over time and space. This model can provide flexibility in at least six ways: 1) the choice of crewed or uncrewed orbital transport spacecraft (Dragon, Crew Dragon, Starliner, Dream Chaser, or other); 2) ability to dock at one or more ports within a CLD platform; 3) ability to dock at multiple CLD platforms; 4) ability to conduct activities within the orbital transport spacecraft, within the CLD, or a combination of the two; 5) potential to undock from one port and move to a port on another CLD; and 6) tailorable contract durations for CLD port use. Ensuring access to an orbital transport vehicle capable of moving between commercial platforms (e.g., Dream Chaser) is a key component for flexibility in future scenarios where more than one commercial platform exists.
- ✓ **Opportunity for Collaboration:** Promotes collaboration by aggregating and brokering opportunities for themed missions, spanning different user bases. For example, payloads from government, international, academic, and commercial users may be strategically coalesced on a single mission to optimize resource and knowledge sharing. The user advisory committee helps to ensure collaboration among non-NASA partners. However, as opportunities on orbit decrease in the case of a limited growth future scenario, the user advisory committee may shift from championing collaboration to prioritizing research needs, as stronger ties to NASA's mission are needed in a more limited environment.
- ✓ **Equity and Accessibility:** Generally seeks input from a diversity of users, who are well-served in future scenarios with more opportunity. The NASA program office, user advisory committee, and grant opportunities promote widespread access. However, these benefits are more constrained in a more limited growth scenario, since opportunities may need higher alignment with NASA needs.

Overall Weaknesses Across the Future Scenarios

The Government Research Broker model does **not** score positively across **multiple** future scenarios, demonstrating a lack of robustness, in terms of:

- **Market Sustainability:** Has the potential to compete with industry, especially with CLD providers. Key aspects would help ensure that this model works with industry, benefitting both industry and NASA. Ensuring the orbital research vessel is designed to work in tandem with CLDs is one such consideration. Another is ensuring the orbital transport vehicle has NASA-specific hardware that will not be on the CLD. This aside, the model can accommodate some market growth either directly (i.e., ensuring access for industry) or indirectly (i.e., benefitting the orbital transport vehicle business). Some degree of access is also guaranteed to CLD providers, though this is intended to be flexible and would alter as market dynamics shift.

Model 3: Innovation Campus

A terrestrial innovation campus is the center for microgravity research, operations, and innovation, similar to a NASA concept called Sally Ride National Laboratory.[25] The concept details the creation of a new FFRDC or University Affiliated Research Center (UARC),[26] including a new government-owned campus (or center or lab) operated by a non-government entity. This campus is dedicated to conducting advanced science and R&D projects of benefit to the nation through the use of human spaceflight platforms. With participation open to all user communities, the campus promotes partnership, innovation, developmental R&D, and mission planning efforts for LEO. The campus attracts high-quality candidates, uses expertise from key sectors (academic, commercial, and others), facilitates academic exchanges, and promotes education and training in STEM and other disciplines. The campus is designated a National Laboratory.

Key Discriminators

- A terrestrial innovation campus focuses on spurring innovation, developing skillsets, and building the LEO workforce, rather than matching supply (platforms) to demand (payloads).
- While unique to this model, the innovation campus concept can work in concert with other models.

With NASA as the sponsor agency, a third party operates and maintains the government-owned campus using a standard FFRDC or UARC model.[14] The third party can be a nonprofit, an academic institution, or a commercial contractor.

As visualized in this model, the campus does not connect payloads to platform providers. It can, however, be used in combination with another model that does connect with platform providers. Similarly, the campus in this model is limited to LEO efforts, but the model can be expanded in scope to incorporate other human spaceflight efforts related to lunar and other domains.

Infrastructure

A terrestrial innovation campus attracts, aggregates, and develops a skilled workforce from academic institutions, industry, or other organizations. The campus hosts specialized facilities, equipment, and other infrastructure that various users can access for advanced research, development, testing, and evaluation.[27] NASA owns this physical infrastructure as a sponsor, but a third-party organization (nonprofit, academic institution, or commercial contractor) operates and maintains it.

Stakeholder Roles

NASA is the government sponsor that owns the campus and has final decision-making authority. As designated by NASA, a third-party operator conducts and manages day-to-day activities.

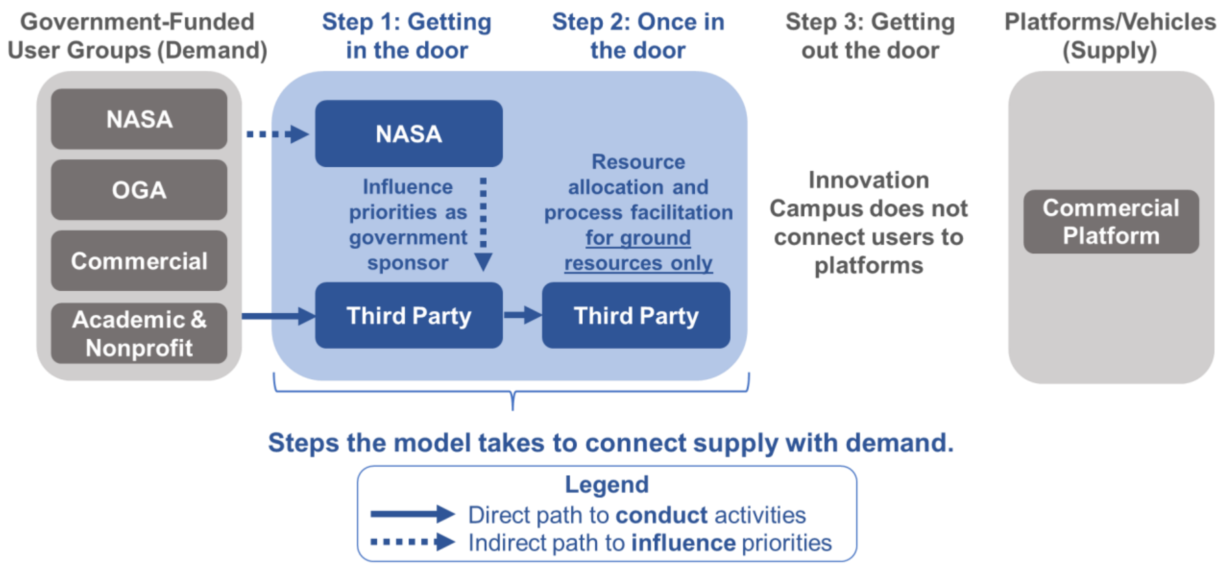
Other user communities contribute through academic exchanges, multi-user partnerships (including international partnerships), and other projects hosted at the campus as the NASA budget allows.

The campus provides a clearly identifiable point of entry for new users, which the third-party operator guides through the process.

Process for Accessing LEO

Figure 5 illustrates the process this model takes for connecting user activities with platforms.

Figure 5. Process for Accessing LEO through the Innovation Campus Model



Step 1: The campus maintains an open-door policy for OGA, commercial, international, and other users. The campus supports users through design and development of missions and projects. The campus may also conduct outreach to solicit partnership opportunities. NASA provides strategic priorities and funds specialized divisions. For new divisions or projects, NASA must approve additional funding requests, which likely require authorization by Congress as well. The third-party operator manages activities and day-to-day operations.

Step 2: For all approved activities, the third-party operator allocates resources and facilitates processes—for ground resources only, such as lab space and lab equipment. Ground resources can include use of facilities and pre- or post-flight operations.

Step 3: This model does not include a process to connect users to platform providers for LEO activities. The concept for the model emerged from stakeholder discussions and has been included in this list of models as a major differentiator. This model benefits from being able to work in concert with any of the other models presented in this report to connect users to LEO platforms.

Agreements Between Users and Providers

The agreement with the third-party operator is likely a long-term management and operations (M&O) contract. Agreements required for other campus activities, such as establishing partnerships or using specialized equipment and facilities, may involve other flexible types of agreements, such as SAAs, CRADAs, contracts, and grants. While the agreements for campus activities remain both targeted and flexible, the campus relies on long-term investments to build and maintain its workforce.

Impacts to User Communities

The campus's open-door policy in this model allows all users to participate.

- **Academic** users can lend faculty expertise, initiate or join in multi-user projects, and participate in student programs that promote STEM education and build workforce skills.
- **International** partners and firms can participate in exchanges, projects, and other activities at the campus. The campus invites countries with small or new space programs to participate in projects.
- **OGA** users can participate in exchanges, projects, and other activities at the campus. Their participation in the campus ensures OGAs have access to high-quality talent from industry and academic institutions.
- **Commercial** users can participate in exchanges, projects, and other activities at the campus. Close proximity to academic users may facilitate better technology transfer opportunities. Commercial users can also access specialized equipment and facilities for testing, evaluation, and demonstrations.

Scoring Highlights

Table 8 summarizes the model's scores per future scenario, as evaluated by each of the five criteria. See Methods for definitions of the evaluation criteria, Appendix B for the full scenario narratives, and Appendix D for the full scoring results, including brief explanations for why each criteria receives a Pro, Neutral, or Con score per future scenario.

Table 8. Innovation Campus Scoring Summary

Model Evaluation Criteria	Future Scenario		
	Dynamic Growth	Steady Growth	Limited Growth
✓ Ability to Meet NASA's Needs	Pro	Pro	Neutral
Adaptability	Pro	Neutral	Neutral
✓ Opportunity for Collaboration	Pro	Pro	Neutral
Market Sustainability	Neutral	Neutral	Neutral
Equity & Accessibility	Pro	Neutral	Neutral

✓ Overall strength = Criterion received at least two Pros across the three future scenarios

Key Takeaways

The Innovation Campus model is designed to augment efforts in LEO with ground-based resources and can best do so in a dynamic environment, where there are many stakeholders and enough funding to support activities. Assuming a separate model can connect users with CLDs, this model can help ensure the government maintains a skilled LEO workforce, with the added benefit of scaling to account for mission needs beyond LEO. These benefits significantly drop off however, as opportunities in LEO decrease. In future scenarios with less opportunity, the sponsoring agency typically must focus efforts on mission priorities. Tangential activities and non-government users or partners would most feel the effects of these prioritizations. The model can potentially support a steady growth scenario, but with limited resources. Considerations such as expanding the government sponsor to include multiple agencies may alleviate some resource-related restrictions seen in the steady and limited growth future scenarios. Additionally, creating a pathway for industry to access campus resources may augment some weaknesses in market growth seen in all future scenarios.

Overall Strengths Across the Future Scenarios

The Innovation Campus model scores positively across **multiple** future scenarios, demonstrating robustness, in terms of:

- ✓ **Ability to Meet NASA's Needs:** Supplements LEO-based activities with terrestrial activities focused on developing and testing technologies and building and maintaining skills for the LEO workforce. Assuming another mechanism to connect with CLDs, this model's ability to grow a LEO workforce positively contributes to meeting NASA's research and exploration needs. Built-in flexibilities to ensure that research focus areas can adjust to shifting needs will help ensure the model can meet NASA's needs in any future scenario.

- ✓ **Opportunity for Collaboration:** Generally supports a collaborative environment largely due to its open-door policy, allowing OGAs, international, and other users a physical space for collaboration. However, the activities and programs available for collaboration may be limited by NASA's budget and need for alignment with NASA's priorities. This becomes more evident in a more limited future scenario.

Overall Weaknesses Across the Future Scenarios

The Innovation Campus model does **not** score positively across **multiple** future scenarios, demonstrating a lack of robustness, in terms of:

- **Adaptability:** Might not move at the speed needed to adjust to shifts in the market. That said, the model's focus on NASA's mission and related activities may serve the government well. Activities identified as needing inclusion in the model can scale as needed. Activities can also scale beyond the LEO focus, adapting to NASA's mission needs as they evolve to Moon and Mars. Overall, activities can be limited across future scenarios, but their focus may serve the government well.
- **Market Sustainability:** Could be at odds with market growth given its heavy mission focus, unless there is a strong tie to identified mission needs. Generally, this model can provide some assurances to platform providers by developing and testing technologies terrestrially, increasing their probability for mission success. However, market growth related to companies wishing to purchase services in LEO may be strained if there are fewer opportunities to fly non-NASA payloads, as with the more limited future scenarios.
- **Equity and Accessibility:** Provides access to campus resources for many, with low-cost pathways for research (e.g., grants, exchanges, academic partnerships), but with lower impact in the limited and steady growth scenarios given fewer opportunities (and likely less funding). A focus on learning and on building skillsets within the NASA workforce while involving many non-NASA users promotes equity and accessibility.

Model 4: Matchmaker

A “matchmaker” connects user community activities directly with CLD providers based on mission and technical requirements. The matchmaker is a neutral third-party nonprofit organization funded by NASA. The matchmaker provides a clearly identified point of access to LEO for both users and providers.

Throughout the process, the matchmaker supports current and prospective users to ensure mission success. Meanwhile, CLD providers benefit from the dedicated marketplace made possible by the matchmaker, making their services accessible to customers. The suite of services provided by the matchmaker to coordinate, facilitate, foster, support, and aggregate is designated a National Laboratory.

Key Discriminators

- A neutral third party directly and objectively connects users to platform providers based on mission and technical requirements.
- The matchmaker aggregates and communicates user demand to industry to inform future services.

Infrastructure

Facilities, hardware, and other infrastructure are available from CLD providers.

The matchmaker has no direct connection to infrastructure but must remain knowledgeable of existing platform and infrastructure capabilities to offer effective matchmaking.

Stakeholder Roles

NASA is the sponsor agency for the matchmaker, which is a third-party nonprofit organization. The matchmaker oversees day-to-day matching of user activities to platform options.

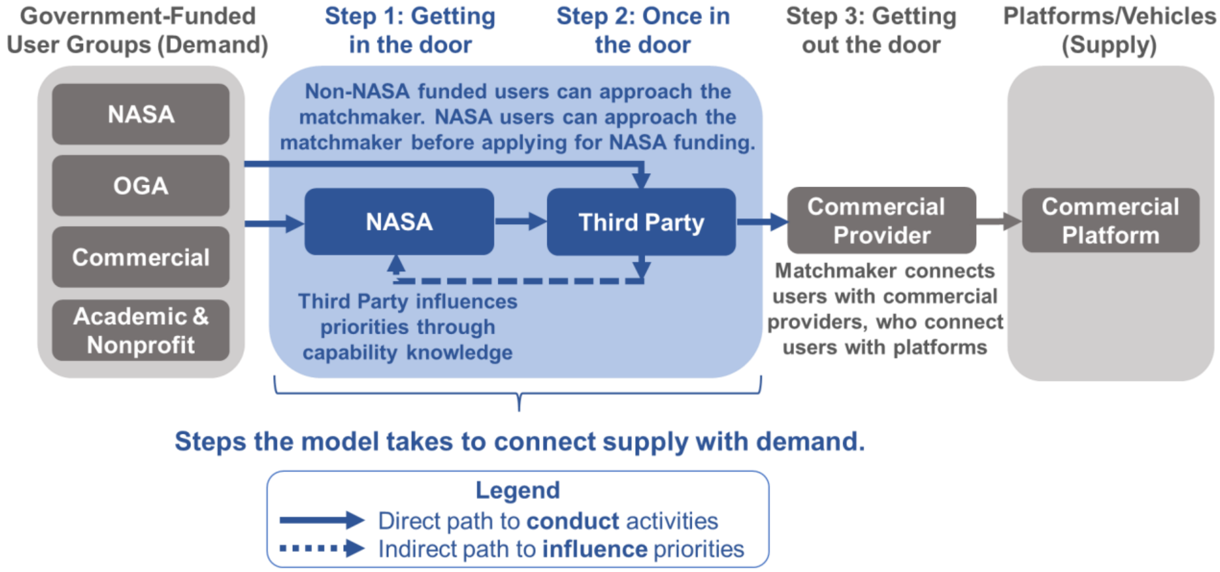
In addition to objective matchmaking and communicating user demand to industry, the matchmaker may coordinate research activities, facilitate technology transfer, foster emerging companies, and support multi-agency programs. NASA oversight and feedback is incorporated into matchmaking decisions and activities.

Both platform providers and users across all communities participate through the matchmaker. New users have a clearly identified point of access that assists them throughout the process, answers their questions, and provides guidance to ensure mission success.

Process for Accessing LEO

Figure 6 illustrates the process this model takes for connecting user activities with platforms.

Figure 6. Process for Accessing LEO through the Matchmaker Model



Step 1: NASA sponsored users approach NASA directly to seek funding for activities and may approach the matchmaker first to gain technical expertise. Non-NASA funded users can approach the matchmaker directly with an idea or a need.

Step 2: The matchmaker provides users with mission and technical expertise, analyzes available options, supports user-provider coordination based on available services and demand, and facilitates the process to prepare activities for flight. Providers can also approach the matchmaker with requests for support. The matchmaker can help providers enter the market or help make prospective customers aware of new goods and services. In some cases, the matchmaker can serve as a mechanism on behalf of government users to facilitate joint projects and accelerate technology transfer between labs and companies.

Step 3: The matchmaker connects selected user activities directly with the commercial provider, who then decides which flight-ready activities will go to a commercial platform.

Agreements Between Users and Providers

Typically involving flexible contracting mechanisms, agreements are based on need, customer affiliation, and service provided.

Impacts to User Communities

Despite the focus on meeting supply with demand, this model does not provide the means to ensure all user needs are met.

- **Academic** users can enter into agreements to gain access to platforms, systems, and other infrastructure, but at a significant cost. Participation may require grants from NASA or OGAs to cover the high cost.

- **International** users can continue partnering with NASA, but with activities coordinated through the matchmaker.
- **OGA** users can enter into agreements to gain access to platforms, systems, and other infrastructure, to have their needs met.
- **Commercial** platform providers can access the marketplace and communicate available goods and services through the matchmaker. Although commercial users can work directly with platform providers (business-to-business), going through the matchmaker might ensure a better match for their technical and mission needs.

Scoring Highlights

Table 9 summarizes the model's scores per future scenario, as evaluated by each of the five criteria. See Methods for definitions of the evaluation criteria, Appendix B for the full scenario narratives, and Appendix D for the full scoring results, including brief explanations for why each criteria receives a Pro, Neutral, or Con score per future scenario.

Table 9. Matchmaker Scoring Summary

	Model Evaluation Criteria	**Future Scenario**		
		Dynamic Growth	**Steady Growth**	**Limited Growth**
	Ability to Meet NASA's Needs	Pro	Neutral	Neutral
✓	Adaptability	Pro	Pro	Pro
	Opportunity for Collaboration	Pro	Neutral	Con
	Market Sustainability	Neutral	Neutral	Neutral
	Equity & Accessibility	Neutral	Neutral	Neutral

✓ Overall strength = Criterion received at least two Pros across the three future scenarios

Key Takeaways

The Matchmaker model generally is better served in future scenarios with an abundance of opportunities, allowing for NASA's needs to more easily be met and for more collaborative opportunities. The model's performance does not stand out in any evaluation criteria except for adaptability. Given this, the model's performance may be more dictated by limitations from the future scenario, rather than inherent limitations of the model itself. Given the adaptable nature of the matchmaker, this may mean that limitations can be designed against if considered early on.

Overall Strengths Across the Future Scenarios

The Matchmaker model scored positively across **multiple** future scenarios, demonstrating robustness, in terms of:

- ✓ **Adaptability:** Generally works within scenario-driven limitations and can therefore adapt to any of the future scenarios in terms of its ability to cater to different platforms and support activities in a number of ways. The matchmaker guides and optimizes the execution of activities, with full awareness of past, current, and upcoming missions, and can do so given the variety of ways the future scenarios may play out.

Overall Weaknesses Across the Future Scenarios

The Matchmaker model did **not** score positively across **multiple** future scenarios, demonstrating a lack of robustness, in terms of:

- **Ability to Meet NASA's Needs:** Steady growth and more restricted future scenarios may generally meet NASA's needs, but with a need to prioritize missions. Future scenarios with an abundance of opportunities, especially platform options, are best suited for NASA's needs. The matchmaker's incorporation of NASA oversight and feedback would increase NASA's ability to meet its needs in any future scenario.
- **Opportunity for Collaboration:** Furthers cooperation and collaboration through influence and by exhibiting trust as a third-party broker, but can lose that trust if a user receives a poor match. To form and maintain these trusted relationships, the matchmaker must use knowledge of and experience with the different players in the LEO ecosystem to match users with providers who meet mission and technical requirements. More options for connecting users and providers in a dynamic growth scenario may strengthen collaborations (though would increase the complexity of the matchmaker role), while having few users in a limited growth scenario reduces the opportunity for collaborations.
- **Market Sustainability:** Must prioritize objectivity to ensure it does not show favoritism, which could interfere with the market. The matchmaker can accommodate some market growth, boosted by the early communication of demand. It can reduce some risk for CLD providers but may need to proactively encourage this early on (e.g., by improving efficiencies and providing incentives). Assurances to CLD providers might decrease with less opportunity. Less opportunity combined with less overall support may also increase barriers to entry, affecting market development.
- **Equity and Accessibility:** Guides new entrants but lacks low-cost pathways for research (i.e., grants), and flights may still be cost-prohibitive to certain users. While the model does not feature a formal grants process, and instead seeks to match users to platform options as a neutral third party based on mission and technical requirements, low-cost pathways for research can be adopted to overcome this limitation. Similarly, ISSNL stakeholders noted that the model can replicate the ISSNL's approach of using a centralized LEO services

budget from NASA and allowing CLDs to bid on opportunities to accommodate user needs to avoid appearing to show favoritism and act as an honest broker.

Model 5: Institute Network

The Institute Network is a network of individual but related efforts with a focus on commercial scaling and maintaining U.S. leadership. Designed after the Manufacturing USA manufacturing innovation institutes (MIIs),[28,29] NASA and OGAs form a consortium to identify and jointly fund newly proposed institutes, which are considered public-private partnerships. Institutes can involve multiple user communities (commercial, academic, international) and include co-investment from commercial participants and potentially other participants. A third-party nonprofit organization manages each institute, coordinating the activities of its members and the use of infrastructure. The capabilities provided through the networked institutes are designated a National Laboratory.

Key Discriminators

- A multi-user network connects separate but related efforts to enable commercial scaling and advance U.S. interests.
- Individual or joint funding from government agencies funds the network, with co-investment from commercial participants and potentially others increasing over time.

NASA and OGAs benefit from cost-sharing and participant co-investment for new institutes while agreeing to fund new institutes that are designed to meet their needs. Other participants benefit from access to the network, infrastructure, and other capabilities to advance research and scalable commercialization activities.

Infrastructure

Participants in the network include CLD providers and other providers of platforms, hardware, and other infrastructure. The network enables collaborative use of these facilities among its various members for LEO activities.

Stakeholder Roles

NASA and OGAs fund new institutes designed to meet their needs as well as the needs of their stakeholders. A third-party nonprofit organization manages these institutes, but depending on the design, management of the institute can incorporate NASA oversight and feedback. The third-party nonprofit organization also coordinates the use of infrastructure.

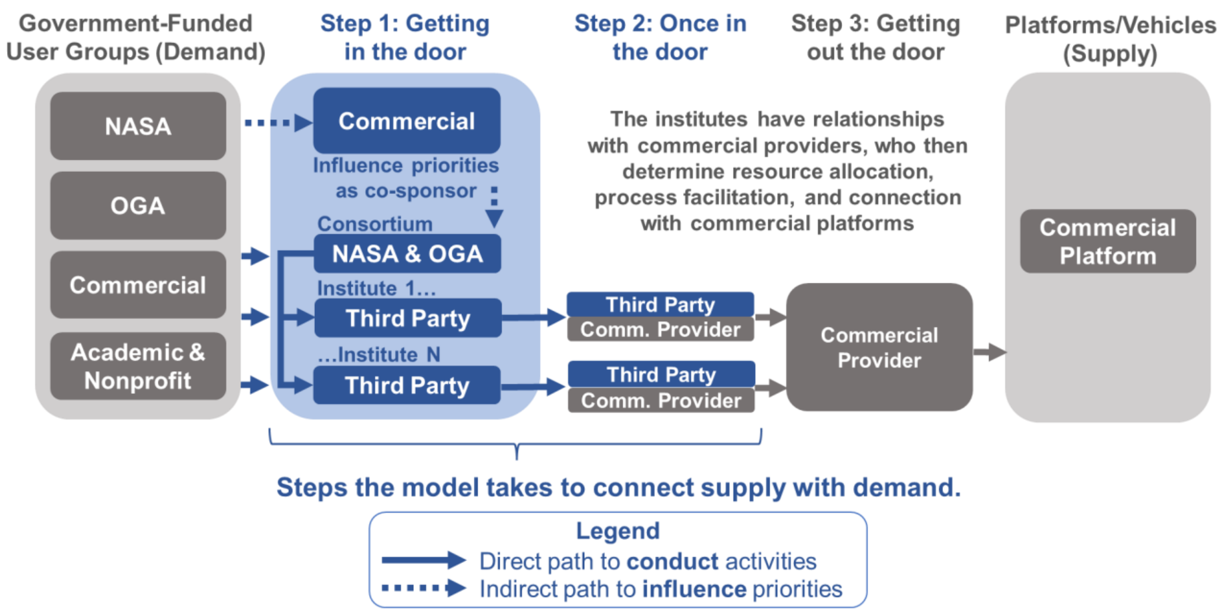
Companies co-invest in individual institutes, but other user communities can contribute to investment in an institute as well. The participating members in an institute can establish multi-user projects and use available infrastructure for project activities, as approved by the managing third-party nonprofit. New users can join pre-established institutes or form new ones with other potential participants.

Institutes can enter into a wider network with other established institutes to tackle larger challenges and wider focus areas. Similar to the MIIs, industry is expected to increase funding for individual institutes over time (potentially freeing up government funds for investment in other areas or in new institutes).

Process for Accessing LEO

Figure 7 illustrates the process this model takes for connecting user activities with platforms.

Figure 7. Process for Accessing LEO through the Institute Network Model



Step 1: NASA and OGAs guide the creation and selection of institutes. NASA and OGAs form a consortium to individually or jointly fund new institutes and receive Requests for Application from prospective networks. NASA and OGAs can also route interested participants to existing institutes that meet their needs. Users can lease platform facilities and other infrastructure from providers participating in the institutes. Users can either coordinate with the third-party nonprofit managing the institute or work directly with the provider, as directed by the institute.

Steps 2 and 3: Since commercial providers are part of the institutes, the providers are responsible for bringing selected activities to commercial platforms.

Agreements Between Users and Providers

NASA, or a consortium of government agencies that includes NASA, solicits new institutes through Requests for Application. Institutes are co-funded by the government consortium and industry, though the government decreases its funding over time. Applications for new institutes guarantee co-investment from commercial participants and potentially other participants.

Impacts to User Communities

Despite the model's primary focus on commercialization, which frequently aligns with commercial needs, opportunities do exist for other user communities.

- **Academic** users can participate in the institutes and enter into agreements to gain access to platforms, systems, and other infrastructure. NASA and OGAs may fund institutes that provide reduced costs for academic payloads or continue to support academic research through grants.
- Institutes can include **international** user participation. The institutes are responsible for legal considerations to protect intellectual property and other sensitive information.
- **OGA** users can form consortia with NASA and others to jointly select and fund institutes that meet their needs. Alternatively, OGAs can work directly with the nonprofit organization managing the institute as outlined in the cooperative agreement.
- **Commercial** users and providers can access partners, infrastructure, and services needed to advance and scale capabilities.

Scoring Highlights

Table 10 summarizes the model's scores per future scenario, as evaluated by each of the five criteria. See Methods for definitions of the evaluation criteria, Appendix B for the full scenario narratives, and Appendix D for the full scoring results, including brief explanations for why each criteria receives a Pro, Neutral, or Con score per future scenario.

Table 10. Institute Network Scoring Summary

Model Evaluation Criteria	Future Scenario		
	Dynamic Growth	**Steady Growth**	**Limited Growth**
Ability to Meet NASA's Needs	Pro	Neutral	Con
Adaptability	Pro	Neutral	Con
Opportunity for Collaboration	Pro	Neutral	Con
Market Sustainability	Pro	Neutral	Neutral
Equity & Accessibility	Neutral	Con	Con

✓ Overall strength = Criterion received at least two Pros across the three future scenarios

Key Takeaways

The benefits of the Institute Network generally scale across future scenarios. This model advances commercial capabilities in areas of interest to the government and is best positioned to do so in a dynamic growth scenario with many opportunities and players. The model's ability to bring many user communities together in support of government needs, with emphasis on advancing industry, is a unique way to advance the country's LEO capabilities. For this reason, NASA may want to consider this model after a successful transition to CLDs and demonstration of some success. NASA can also incorporate lessons learned from the MIIs (or similar programs) once the LEO ecosystem is more established.

Overall Strengths Across the Future Scenarios

This model has a high level of variability across all three future scenarios and no criterion receives at least two Pros across the three future scenarios. The model performs well in a dynamic growth scenario but struggles to provide the same benefit in steady and limited growth scenarios, since its ability to meet evaluation criteria relies on a large, more established network of participants.

Overall Weaknesses Across the Future Scenarios

The Institute Network model does **not** score positively across **multiple** future scenarios, demonstrating a lack of robustness, in terms of:

- **Ability to Meet NASA's Needs:** Best meets NASA's needs in the dynamic growth scenario, where focus areas can be as generalized or specific as needed, and a multitude of players can meet these needs. As opportunities reduce, focus areas may become more targeted. NASA also may need to ensure activities that do not have promising return on investment can still be advanced.
- **Adaptability:** Enables adaptability depending on the level of opportunity across future scenarios. Flexibility in research areas and scalability of activities is a major benefit of the networks, as well as available commercial platforms. Built-in flexibilities in focus areas would help the government adapt as mission needs change and as technologies mature. Overall, the institutes are more adaptable in a dynamic growth scenario.
- **Opportunity for Collaboration:** Allows flexibility in how users engage other users, encouraging information sharing and collaboration rather than competition for advancing a given capability. Although the institutes are designed for collaboration, implementing such collaboration across user groups could be a challenge, particularly in the areas of addressing competition and protecting intellectual property. Again, this criterion scales with more opportunity, making it most useful in a dynamic growth scenario, with some benefit in a future similar to today.
- **Market Sustainability:** Could drive the market in a positive direction given its emphasis on commercialization; however, the number of institutes decreases as opportunities decrease across future scenarios. This may be beneficial to prioritized focus areas but could exclude others. The distribution of responsibility allows for more time, energy, and money for individual institutes, delivering a high-quality experience to users. This again

applies to the dynamic growth scenario and becomes less useful with less growth and diversity.

- **Equity and Accessibility:** Prioritizes commercial interests in specific and potentially niche areas. New users might struggle to enter the process and network; participation may be limited to less diverse users already working in specific areas. With a focus on commercialization, academic participation might be limited to research that advances a capability or addresses a government-identified focus area that may not generate return on investment.

Model 6: Fee for Service

Key Discriminators

- A free market approach to accessing LEO, which ebbs and flows with supply and demand.

In a free market approach, users purchase goods and services from commercial providers. Users may purchase these goods and services directly from the providers, but users may also coordinate with other users to reduce costs, pool resources, and ensure needs are met in LEO. NASA awards grants for research and uses data buys to meet its central needs. NASA's grant announcements and requests for proposals (RFPs) communicate market demand to commercial providers. The collection of activities enabled by grants and data buys is designated a National Laboratory.

Infrastructure

All platforms, equipment, and other systems are commercially owned. NASA does not maintain any infrastructure in LEO.

Stakeholder Roles

CLD providers have authority over all decisions about their platforms and infrastructure. These providers coordinate with NASA and other user communities as customers only.

NASA, either independently or jointly with OGAs and international partners, funds grants in niche areas of research and development and purchases goods or services through NASA's commercial LEO services budget.

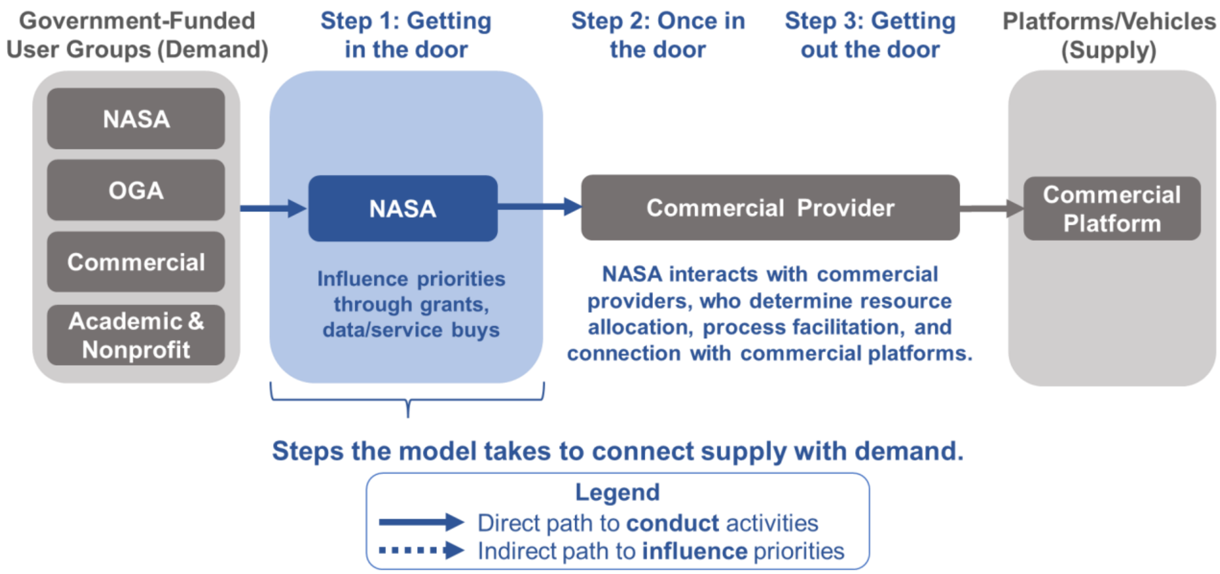
NASA can purchase goods and services in several ways, and NASA-funded users may use these as determined by NASA. Examples of how NASA can purchase goods and services include purchasing accommodations for crew; space to host a payload or other hardware; time to tend to a NASA-flown or CLD-owned payload; use of external space to host science payloads for a specified amount of time; and consumables or materials. NASA also contracts with commercial providers to purchase data with broad utility, such as for human research and technology performance.

Other government-sponsored user communities can contact platform providers directly for their needs. Some user communities may prefer to use NASA as an intermediary when working with providers. User communities can also provide input about critical research areas through decadal surveys and other means.

Process for Accessing LEO

Figure 8 illustrates the process this model takes for connecting user activities with platforms.

Figure 8. Process for Accessing LEO through the Fee for Service Model



Step 1: Commercial providers set prices for goods and services based on principles of supply and demand. NASA communicates demand for future goods and services to commercial providers. NASA gathers input from user communities on their needs. Agency priorities guide research topics and data needs, informing potential grants, services, and data buys. While commercial providers use this information to understand market demand, they have no obligation to fulfill these needs and may forgo service contract awards from NASA in favor of more profitable business-to-business transactions.

Steps 2 and 3: In this model, users can go through NASA (Step 1) to influence priorities; however, the commercial provider has the ultimate say on what activities are flown and, in the marketplace, which data and services can be purchased. Once the commercial provider determines what activities can be accommodated, they take the payloads through the steps to connect with a platform.

Agreements Between Users and Providers

Agreements are likely in the form of contracts between users and commercial providers. Contracts provide a low level of commitment for either short- or long-term services, as agreed upon by the user and provider. Follow-on contract options depend on the availability of the platform.

NASA maintains its grant review process and uses an RFP process for services and data buys. When NASA jointly sponsors a grant or service/data buy, a more complex interagency or international agreement might be necessary.

Impacts to User Communities

With this model, interacting with commercial platform providers offers users a straightforward process with a clear point of entry and customer-oriented service. Users are beholden to the prices for goods and services set by commercial companies, as driven by the market, though some forms of negotiation may exist.

- **Academic** users can continue to submit proposals for research grants and guide NASA research priorities through decadal surveys and other efforts. With research funding, awardees can coordinate directly with platform providers or indirectly through NASA. Recipient accommodations on a CLD would be purchased through NASA's commercial LEO services budget.
- **International** users can make arrangements to fly through NASA if strategic needs align. Otherwise, interfacing directly with CLDs may present challenges for some members of the international community if in conflict with their country's desire to purchase services from within their own country.
- **OGA** users may be able to jointly fund or benefit from grants and data buys, potentially with special data use agreements as required.
- **Commercial** users can interface directly with platform providers, develop partnerships, and participate in transactions in an open market. Commercial users can also submit responses to RFPs and receive data buy contract awards, although this option might be limited to large companies with richer datasets. NASA or OGAs may choose to continue to provide incubation subsidies to support emerging markets, such as in-space manufacturing.

Scoring Highlights

Table 11 summarizes the model's scores per future scenario, as evaluated by each of the five criteria. See Methods for definitions of the evaluation criteria, Appendix B for the full scenario narratives, and Appendix D for the full scoring results, including brief explanations for why each criteria receives a Pro, Neutral, or Con score per future scenario.

Table 11. Fee for Service Scoring Summary

	Model Evaluation Criteria	Future Scenario		
		Dynamic Growth	Steady Growth	Limited Growth
	Ability to Meet NASA's Needs	Neutral	Pro	Neutral
✓	Adaptability	Pro	Pro	Neutral
	Opportunity for Collaboration	Neutral	Neutral	Neutral
✓	Market Sustainability	Pro	Pro	Neutral
	Equity & Accessibility	Neutral	Neutral	Neutral

✓ Overall strength = Criterion received at least two Pros across the three future scenarios

Key Takeaways

The Fee for Service model embodies a flexible, free market and is particularly well-suited to steady and dynamic growth future scenarios in which the commercial potential of LEO is more fully realized. The model can generally adapt to activities, infrastructure, etc.; however, activities may skew towards those that generate the most revenue. To support market sustainability, NASA's demands are clearly communicated and financially supported through grants and service/data buys. However, the cost of conducting activities in LEO is primarily driven by supply and demand and set by the commercial providers. Users and providers whose interests align well with NASA's interests may seek funding through NASA grants and service/data buys, but others are largely left to fund and fend for themselves. Barriers to entry, including cost, expertise and know-how, and willingness to work directly with commercial providers, may prove prohibitive for new entrants, academic researchers, other government agencies, and the international community.

Overall Strengths Across the Future Scenarios

The Fee for Service model scores positively across **multiple** future scenarios, demonstrating robustness, in terms of:

- ✓ **Adaptability:** Provides flexibility and scalability of activities, and with available platforms and infrastructure options, can allow for multiple diverse activities to occur simultaneously. However, overall adaptability is contingent upon a thriving ecosystem with ample supply options in terms of platforms and services. While the model can generally adapt to what is available, we note that commercially supplied activities may skew towards those that generate the most revenue. NASA (and potentially international) users may still go through a singular NASA office to get projects to LEO. However, other users will need to work with the commercial providers directly to get their projects to orbit. This may encourage users to consider cheaper and more easily accessible flights in orbital, suborbital, and parabolic vehicles, in addition to permanent commercial space stations.

- ✓ **Market Sustainability:** Encourages market growth by allowing market-driven solutions and offerings to flourish; incentivizes businesses to provide a good user experience to gain repeat customers. The model may have a tendency to favor some markets over others.

Overall Weaknesses Across the Future Scenarios

The Fee for Service model does **not** score positively across **multiple** future scenarios, demonstrating a lack of robustness, in terms of:

- **Ability to Meet NASA's Needs:** Clearly communicates NASA's needs through grants and service/data buys but does not guarantee access to NASA researchers, who might struggle in a dynamic growth scenario where demand is high among commercial users. NASA might also struggle with access in a limited growth scenario, where it may face competition with other high-paying customers for few flight opportunities. In steady growth, NASA is likely not de-prioritized and can access platforms as needed. Offerings and prices set by the free market remain outside of NASA's control.
- **Opportunity for Collaboration:** Lacks a dedicated organization for helping new, inexperienced users enter the market. OGA and international users might prefer to work through NASA, given its experience, brand, and trust. OGAs may have opportunities for cost-sharing and mutual funding of grants and data buys but only in areas aligned with NASA's needs. International users might also participate in these efforts, if the right protections are in place, but might instead prefer to spend money within their own borders.
- **Equity and Accessibility:** Presents a barrier in cost, especially for academic and educational activities. Even with grants from the government, transactions and agreements have a "one-off" nature. Grants and some ability to provide input into activity selection processes do provide some buffer against free market dynamics; however, those dynamics are ultimately not in favor of prioritizing access for all.

Model Comparison

This section provides an aggregate view of the models by the five model evaluation criteria—*ability to meet NASA's needs; adaptability to infrastructure, service provider offerings, and user demands; opportunity for collaboration; market sustainability; and equity and accessibility*—across the three future scenarios—*dynamic growth*, *steady growth*, and *limited growth*—to enable comparison for senior leadership consideration. The Pro, Neutral, and Con scores that were previously detailed by the individual models were aggregated into overall model strengths and weaknesses, based on a model's ability to score favorably (Pro) across more than one future scenario. A model strength indicates a model evaluation criterion for which a model received at least two Pros across the three future scenarios. On the flip side, a model evaluation criterion is referred to as a weakness, or an area of possible improvement, if it does **not** score positively across multiple future scenarios, meaning the criterion primarily scored neutrally or negatively.

The Government Research Broker had the most model strengths across the future scenarios, followed by Innovation Campus, Anchor Tenant, and Fee for Service. While Matchmaker and Institute Network exhibited positive aspects, these models performed most favorably in future scenarios with well-established communities and markets.

It is important to note that these scores are specific to the six models as currently defined, and the scores could (and likely would) change if the model definitions were to change. We understand that different NASA decision makers may prioritize some model evaluation criteria over others. While each model has strengths and weaknesses, no single model (in its current form) performs well across all criteria in all three future scenarios. To this end, we intend for the model comparison to be a useful process in identifying relative strengths of models to inform future decisions.

A decision maker may seek a model that exhibits robustness to a set of unknown future scenarios, meaning the model is able to perform well in a variety of environments and ecosystems. In this case, the overall model strengths in Table 12 provide a good starting point. The Government Research Broker, with four model strengths, rises as a relatively robust option for the future, particularly in regard to meeting NASA's needs, allowing for adaptability, providing opportunities for collaboration, and providing equity and accessibility.

Table 12. Model Strengths Summary

Model	Model Evaluation Criteria				
	Ability to Meet NASA's Needs	**Adaptability**	**Opportunity for Collaboration**	**Market Sustainability**	**Equity & Accessibility**
Current Model					
ISSNL	N/A			✓	✓
Future Model Trade Space					
1. Anchor Tenant	✓		✓		
2. Government Research Broker	✓	✓	✓		✓
3. Innovation Campus	✓		✓		
4. Matchmaker		✓			
5. Institute Network					
6. Fee for Service		✓		✓	

✓ Marks an overall model strength across the future scenarios, meaning the model evaluation criteria received a Pro in at least two future scenarios.

Mixing and Matching Models

The models presented in this study are illustrative examples of means to pursue government-funded research, representing a wide trade space of options. No single model represents the path forward — the best performing model that meets leadership priorities is likely a combination of features from multiple models. NASA leadership can adjust models as desired to align closer to their priorities. As examples, the Anchor Tenant model can be expanded to include other agencies in prominent tenancy roles; the Government Research Broker model can use a contracted third party to serve as broker, rather than a NASA program office; and the Institute Network model can operate in a limited capacity until the LEO ecosystem is more fully established.

The relative strengths and weakness of the example models evaluated in this study may help illustrate pathways for NASA leadership to tailor a future approach. The following are examples of ways models can be combined by mixing and matching different model aspects to account for scenario-driven or model-intrinsic shortfalls.

Anchor Tenant

Strengthen by combining with aspects from Government Research Broker.

The Anchor Tenant model has potential weaknesses in adaptability, market sustainability, and equity and accessibility. These weaknesses and possible concerns can be addressed through a blended approach that supports a primary CLD with options for tenancy on other platforms or by using orbital transport vehicles to augment activities, such as the concept in the Government Research Broker model. These modifications may increase cost, but they provide an opportunity to support a broader commercial market and to facilitate research from additional communities. Ultimately, a hybrid Anchor Tenant-Government Research Broker model could strike the appropriate balance in commitments (e.g., length of time, percentage of space, access to crew) among various persistent and transient platforms. In this optimization, the benefit to both industry and government is important to consider.

Innovation Campus

Strengthen by combining with aspects from Anchor Tenant, Government Research Broker, and Matchmaker.

The challenges the Innovation Campus model has with adaptability, market sustainability, and accessibility are largely due to the model's partial alignment with stakeholder needs. The utility of the campus could be enhanced by efforts to expand participation across the government and to enable pathways for industry to access campus resources.

Additionally, the model needs to be combined with access to space and in-space platforms. An Innovation Campus can increase the utility of research through an Anchor Tenant model or ensure a robust pipeline for research within transport vehicles, like in the Government Research Broker model. The campus could also support a Matchmaker model, providing a terrestrial center of gravity for LEO activities. As appropriate, matchmaking functions provided through the Innovation Campus could be extended to orbital and microgravity platforms.

Strengthen by combining with aspects from Institute Network.

The Innovation Campus model was defined and evaluated with NASA as the sole government sponsor. However, like the Institute Network model, in which NASA and OGAs can jointly fund new institutes designed to meet their needs as well as the needs of their stakeholders, we note that the Innovation Campus model could benefit from interagency sponsorship. Adding other agency sponsors to the FFRDC or UARC-like model could not only amplify opportunity for interagency collaboration and enable whole-of-government coordination but could also broaden access for commercial and academic users seeking funding. By tapping into the interagency science and technology community and the "for the benefit of Earth" mission sets of federal agencies such as NSF, NIH, etc., a wider set of potential users may be reached and supported, furthering innovation. We encourage exploration of the feasibility of this interagency concept as a means to reduce the financial burden of this model on NASA, provide greater access to diverse users, and stimulate interest from commercial users.

Matchmaker

Strengthen by combining with aspects from Anchor Tenant.

In the Matchmaker model, a neutral third party directly and objectively connects users to platform providers based on mission and technical requirements. This matchmaker is designed to act on behalf of the government; however, successful implementation of this model requires the matchmaker to closely understand the government's needs. A government program office, like the one in the Anchor Tenant model, working as a close partner to the matchmaker would help mitigate any disconnects.

Institute Network

Strengthen by combining with aspects from other institutes and related initiatives.

The Institute Network model was defined in this work as a network of individual but related efforts specially focusing on commercial scaling and maintaining U.S. leadership. That said, we acknowledge that NASA and the broader government currently make many investments in diverse institutes and initiatives with unique focuses, including the Space Technology Research Institutes (STRIs), the Translational Research Institute for Space Health (TRISH), and Lunar Surface Innovation Initiative (LSII), to name a few. The Institute Network model would be best suited to consider how it fits in, builds upon, or adds something new to the current, established network of institutes that span LEO, lunar, and terrestrial topics.

Fee for Service

Strengthen by combining with aspects from ISSNL.

Adopting a Fee for Service model reduces NASA's, or any agency's, ability to direct and strengthen a commercially driven model. However, economic policies may help channel commercial investment into areas that better meet NASA's needs, enable collaboration across the government, and ensure accessibility. A focus on an incubation role as the Fee for Service model develops, similar to the current ISSNL-CASIS efforts with incubation, could help steer economic development towards capabilities needed for future missions. The U.S. government can also act as a "smart buyer" encouraging practices that promote equity and accessibility.

Considerations to Guide Model Selection

Cost Considerations

Although cost considerations are a critical driver for model selection, this analysis was not designed to provide definitive information on a cost comparison between models. To facilitate this cross-model comparison, separate detailed cost models and analysis will be necessary—potentially one tailored for each considered model. In addition, discussions with stakeholders indicated that many of the primary cost drivers (such as transportation, platform use, and novel systems) are largely driven by the nature of the ecosystem, as exemplified in the future scenarios. That said, several observations on potential cost drivers were identified for each model, which may help facilitate follow-on studies and discussions of model cost.

Anchor Tenant: The cost of the Anchor Tenant model is largely dependent on the degree to which a CLD provider requires support from NASA. If NASA accounts for the bulk of the CLD revenue, it would represent a substantial, long-term investment to maintain the model. To the degree that other users grow in activity, increasing revenue for the CLD, the reliance on NASA to cover ancillary costs associated with this model are reduced.

Government Research Broker: Cost drivers for the Government Research Broker model include support for activities conducted on a CLD, similar to Anchor Tenant model costs, in addition to the unique research platform in the form of the transportation vehicle. The mechanism for funding the vehicle (e.g., long-term lease, pay-per-flight, retainer) is a unique factor when considering cost for this model. In addition, this model requires a government investment in a program office.

Innovation Campus: A cost analysis for the Innovation Campus model will differ from the other models as the direct costs support a terrestrial campus. This investment may have a long-term impact on the cost to conduct activities in LEO through the transfer of knowledge and capabilities, but in the near term, this investment is likely additive to other costs associated with launching and conducting activities in the LEO ecosystem.

Matchmaker: The Matchmaker model includes two factors that contribute to cost: funding to support the third-party matchmaker and the costs associated with conducting activities. Multiple potential mechanisms for supporting the third-party matchmaker exist, ranging from a direct contract with the nonprofit organization to a fee structure based on the transactions that occur. In developing the cost analysis, consideration should be given to the resulting incentives for the third-party matchmaker and alignment to NASA's priorities for each potential funding mechanism.

Institute Network: The cost of the Institute Network model is largely dependent on the scope and types of institutes within the network. To be successful, investment must come from commercial stakeholders in addition to public funding. As with terrestrial public-private partnerships considered in the development of this model, the blend and nature of this investment varies.

Fee for Service: Costs in the Fee for Service model represent a direct transition between the users and service or platform providers. However, NASA's approach to data buys within this market might not be simplistic. The current commercial satellite data buy programs for Earth science have shown challenges negotiating with multiple companies on a bilateral basis and the premium associated with these contracts given NASA's needs. Additional conversations with potential performers will be necessary to help characterize these data buy costs.

Although we can't provide a direct comparison of costs, this study does shed some light on the complexity of estimating costs for a model. Once the trade space of potential models is narrowed to a few explicit alternatives, a detailed cost assessment will be necessary to provide an accurate comparison.

Legislative Considerations

Congress routinely passes about two or three NASA Authorization Acts each decade, which partially guide the agency's activities until the next act is passed. These acts contain directives regarding NASA's efforts, including those in space exploration, scientific research, space technology development, and agency security. The acts reveal congressional opinion of what NASA's priorities should be in the near future. The five most recent Authorization Acts—from 2005, 2008, 2010, 2017, and 2022—provide an understanding of Congress's vision for NASA in recent years. All five acts include goals related to NASA's role in LEO activities, namely the ISS.

We summarize current ISS-related requirements in the most recent five Authorization Acts by four themes: *ISSNL Management*, *Science and Technology Goals*, *Documentation and Reporting*, and *Creation of an ISSNL Advisory Committee*. Each of the six assembled models require change to current legislation in two of the four grouped theme areas: *ISSNL Management* and *Creation of an ISSNL Advisory Committee*. The type and level of change required varies for each potential model. We recommend that NASA engage Congress early to propose the legislative changes necessary to enable a particular model.

ISSNL Management

Establishment and Operation of ISSNL

The 2005 NASA Authorization Act designates the ISSNL on the U.S. segment of the ISS. This requirement is a significant consideration for the six assembled models regarding both language and intent. Legislative changes are required to enable any model because there will no longer be a National Laboratory on the ISS when the ISS retires and activities are transitioned to CLDs. The National Laboratory nomenclature may be completely removed from legislation, or the intent of a National Laboratory may transition to a new model in a post-ISS LEO ecosystem that lacks a government-owned platform.

Different aspects of each model could be designated as a National Laboratory in the post-ISS ecosystem if the National Laboratory nomenclature is deemed an appropriate name that reflects and reinforces the goals and objectives of the chosen model. Regulation around these determinations would need to be clarified in an upcoming Authorization Act. For example, in the Anchor Tenant model, the dedicated areas and individual segments or portions of these areas within the tenancy are designated a National Laboratory. In the Government Research Broker model, each research space is designated a National Laboratory or a collection of research spaces are designated a National Laboratory within orbital transport vehicles. In the Innovation Campus model, the terrestrial innovation campus is designated a National Laboratory. In the Matchmaker model, the suite of services provided to coordinate, facilitate, foster, support and aggregate is designated a National Laboratory. In the Institute Network model, the capabilities provided through the networked institutes are designated a National Laboratory. In the Fee for Service model, the collection of activities enabled by research grants and purchased data is designated a National Laboratory.

Resource Split Between NASA and ISSNL

The 2010 NASA Authorization Act allocates at least half of U.S. research resources on the ISS to ISSNL-managed experiments. The resource split equally between NASA- and ISSNL-managed activities is a concern for all six models. This requirement is overly restrictive and will become more so as NASA is no longer the sole overseer of U.S. LEO platforms. Legislative changes are required to enable any model.

Cooperative Agreement

The 2010 NASA Authorization Act designates that NASA enter into a cooperative agreement with a nonprofit, which is prohibited from engaging in any non-ISSNL activities. A cooperative agreement may be restrictive for all models by limiting the government's ability to specify contracts that leverage the strengths and potential opportunities for any model. Additionally, prohibiting the ISSNL management entity from engaging in non-ISSNL activities may be problematic for the Institute Network model; this model relies on the ability of commercial companies to compete for contracts, so this particular attribute of congressional language would have to be rethought to ensure that this model could function as intended. If Congress applies the intent of a National Laboratory to CLDs, then legislative changes are required to fully enable any model. If Congress does not confer this intent, then this language should be removed completely.

Creation of an ISSNL Advisory Committee

The 2008 NASA Authorization Act establishes the ISSNL Advisory Committee to advise utilization on the ISSNL. The ISSNL Advisory Committee was never established, but the User Advisory Committee was established following the IRT recommendations. Depending on the selected model of a National Laboratory in the post-ISS LEO ecosystem, this language regarding the ISSNL Advisory Committee should be revised or removed in alignment to government-sponsored user community recommendations.

See Appendix E: Legislative Changes to Enable Models for a detailed discussion of the status quo legislation, changes necessary to enable any of the models, and recently proposed changes to legislation from NASA's Office of Legislative and Intergovernmental Affairs.

Preparing for the ISS Transition

To identify opportunities for modifying the current ISSNL-CASIS partnership in the near term, we leverage strengths from the ISSNL model and from the top-performing models. We identify four possible modifications to the ISSNL-CASIS partnership and NASA's management of these activities. By implementing these modifications early, NASA increases the return from ISSNL-CASIS in preparation for future models as one or more CLD replaces the ISS by 2030. NASA should engage Congress early to propose legislative changes necessary to pursue these modifications.

1. Create a pathway for ISSNL-CASIS to access commercial platforms as they come online prior to the ISS transition and determine NASA's role in brokering these relationships.

Prior to the ISS transition, commercial platforms may include private modules attached to the ISS, private transport vehicles traveling to and from the ISS, and private orbital capsules or spacecraft with no platform destination. Expanding the list of possible LEO platforms available to ISSNL users could provide more flexibility, diversification of research, and amount of research conducted, by enabling research throughout a mission rather than just on the ISS, for example (similarly to how research vessels in Antarctica conduct research during all phases of travel). For users, this maximizes the use of time in the LEO environment, including during transit, and could exploit the unique environments of launch and reentry (e.g., g-loads, high-altitude access). Current non-NASA stakeholders may benefit from integrating research onto these platforms as they become available. For example, Axiom's platform will become available prior to the transition. CASIS may consider identifying which of its users may benefit from either transitioning access to these platforms or expanding access to encompass both. Exploring this pathway may also drive standardization for interfaces among vehicles and help spur a market of ancillary services first for ISSNL-CASIS and then future CLDs.

The contractual and legal feasibility of creating this pathway may need to be further explored. In implementing this modification, NASA may wish to consider mechanisms to purchase space on these commercial platforms on behalf of CASIS. Depending on the level of government oversight desired, NASA could be included in the pathway as a broker of relationships. The exact role of NASA, ranging from a more active facilitator to more passive stakeholder, may be guided by whichever longer-term model of facilitating activities is chosen.

2. Elevate the ISSNL incubation role to support increased movement towards industrialization.

The model analysis suggests pathways to grow the ISSNL incubation role to create scalable and repeatable operations that support industrialization—on the path to commercialization—and sale of products or services. Incubation of potential commercial markets has been part of the ISSNL mission, and CASIS has seen growing demand from commercial research, technology demonstration, and in-space production applications. An even more expanded incubation role may contribute to market sustainability and to the adaptability of future models by increasing the diversity and quality of future services. It can also mitigate uncertainties in how platforms may evolve to support commercial needs.

Providing additional support to advance early-stage technology developments—of mutual benefit to companies wishing to sell products and to CLD providers—may address barriers relevant to all parties. For example, in-space manufacturing has widespread interest within industry and as a use for CLDs, and therefore may benefit from more government backing prior to 2030 as well as beyond the ISS transition to CLDs.

An expanded incubation role to support movement towards industrialization for manufacturing markets of interest may entail increased support to address relevant barriers to growth for the LEO economy, as identified in a previous report submitted under NASA's NextSTEP-2 Appendix J.[30] This will contribute to the ability of the government to ensure that CLD providers are set up for success, that the market will be better able to support diversity in activities, and that users will be able to focus on their R&D activities and secure financial backing needed to move towards industrialization.

3. Establish a terrestrial innovation campus for microgravity research and development.

A terrestrial campus provides a dedicated location for NASA to bring together stakeholders in the LEO ecosystem. For example, this campus could enable collaboration, connecting users with providers to drive market growth, increasing OGA participation in space research (e.g., NIH tissue-on-a-chip research), and providing a physical, virtual, or hybrid space for workforce development and academic exchange. This campus may be a co-located set of physical facilities and offices or an associated set of physical facilities and offices across the country. Visions for terrestrial labs are already in development within the commercial and academic sectors, such as the planned terrestrial analog of the George Washington Carver Science Park recently announced by Voyager Space to be located at The Ohio State University in Columbus, Ohio.[31]

As described, the innovation campus can provide support for a wide range of LEO activities that government agencies may want to pursue (see Appendix C). The campus helps prepare for maximizing quality microgravity R&D on future platforms by identifying research areas that can be prioritized in the near term. Some of these research areas have specific requirements—precision manufacturing, for example—and would benefit from early identification during the development of future LEO platforms.

By sponsoring an innovation campus before the retirement of the ISS, NASA will be able to establish processes and leverage existing expertise that support the nascent CLD ecosystem.

Specifically, this modification seeks to build upon, learn from, and coalesce the current successful pre- and post-flight activities on the ground, such as those conducted at CASIS's facilities in Florida, the sites of the ISSNL IPs and CSPs, universities nationwide, and NASA Johnson Space Center, giving the nation a "center of gravity" for orbital and microgravity R&D and innovation. Establishing a terrestrial campus also provides the additional opportunity for NASA to investigate the feasibility of using an FFRDC or UARC type of relationship in any of the models. For example, NASA may learn whether an FFRDC on a leased commercial platform in orbit is possible and whether an FFRDC can have more than one government sponsor.

4. Formulate a strategy for buying data from commercial providers.

As more commercial offerings become available in the post-ISS LEO ecosystem, NASA, OGAs, and other users may look to purchase data products from companies to augment or complement their own datasets. These data products may come from sensors, experiments, technology maturation, or human subjects. Buying data from commercial providers could provide an agile, alternative approach to meet R&D needs. NASA's Science Mission Directorate established the Commercial Smallsat Data Acquisition (CSDA) Program to identify, evaluate, and acquire data from commercial sources that support NASA's Earth science research and application goals.[32] The CSDA began when companies started to amass Earth observation data relevant to NASA's science goals. Similarly, CLDs and companies that perform activities on CLDs may amass data relevant to NASA's exploration goals.

To prepare for when exploration data may be purchased from companies to augment or complement NASA or OGA datasets, a strategy and an implementation plan are necessary. NASA and OGAs will need to continuously monitor the development of companies and acquire relevant data. Data that is favorably evaluated may be purchased for broad sustained use and disseminated among the U.S. government and to government-funded researchers. NASA can prepare now for purchases in an entirely new market by investigating legal and regulatory concerns, such as navigating intellectual property, privacy protection, and ethics of selling human data. NASA can continue to prepare now by leveraging lessons learned from the CSDA Program, such as establishing a pilot program to identify vendors and evaluate data, and standardizing end-user license agreements across the government to facilitate collaboration.

Additional Insights

This section provides additional study insights identified during discussions with stakeholders and suggestions for follow-on studies. The insights and suggested studies are tangential to the scope of this effort; however, they further explore and refine some of the concepts reported in the previous sections.

Consider the transportation ecosystem

Launch costs were identified by several stakeholders as a critical barrier to the successful development of the identified models. As noted above we made assumptions about launch costs generally trending down, and without these trends the dynamic and possibly steady growth future scenarios may not be possible. In addition to costs, stakeholders noted the reliability of launch schedules and manifests, and the underrealized demand for downmass is impeding transition to a commercially driven ecosystem. The role of the government to continue to support this critical facet of the LEO infrastructure should be part of the post-ISS national lab strategy.

Provide clear goals

Several stakeholders noted that the success of NASA's role in the future LEO ecosystem will depend, in part, on the agency's ability to clearly define and communicate goals for LEO activities. It is necessary to understand how these goals integrate with the broader commercial, research, and exploration activities both on Earth and beyond LEO. If NASA's Artemis Campaign and Moon to Mars initiative are blueprints for space exploration, should LEO be the blueprint for space commercialization?

Consider the name

The current ISS model uses the name "National Lab," which immediately draws comparison to the DoE National Lab model. This connotation is confusing, given that the ISSNL varies significantly from the DoE National Lab model. When selecting a model, consider a name that reflects and reinforces the goals and objectives of the model.

Consider level of government oversight as the LEO ecosystem grows

Several stakeholders, both inside and outside NASA, recommended that NASA consider models that provide more near-term oversight to nurture the LEO ecosystem through its early stages. Stakeholders also acknowledged that as the LEO ecosystem grows over time, models with more government oversight may stifle growth; therefore, more flexible and scalable models may be needed to keep pace with demand.

Consider how platforms may evolve to support fewer, specialized activities

Several stakeholders mentioned the uncertainty in how platforms may evolve to support differing activities, which may impact NASA's ability to carry out research. When selecting a model, ensuring it can adapt as needed to major changes such as these can buffer against their uncertainties.

Consider conducting follow-on studies

Several more detailed studies were suggested by stakeholders and considered during this analysis. Ultimately, these studies were beyond the scope of this effort, but they would benefit NASA decision makers as they plan for the transition to one or more CLDs by 2030. These studies may be performed by NASA or any member of the stakeholder community. Specifically, suggested studies include:

- Detailed cost assessments of considered models
- Roadmaps for recommended models to adapt and evolve as the LEO ecosystem continues to grow beyond 2030
- Interagency and international impact analyses
- Legal and regulatory assessment of selected model(s)
- Sensitivity analysis of model assumptions and their applicability to future scenarios outside the trade space we considered

Summary

NASA is preparing for the retirement of the ISS and transition of LEO activities to one or more CLDs by 2030. NASA's Commercial LEO Development Program has already awarded contracts to four primary commercial entities to work towards this transition.[8,9] As NASA and other user communities continue to prepare for this transition, NASA and these communities need a plan for how to carry out government-funded activities in LEO post-ISS. Addressing this challenge also raises the question of how the current model of the ISSNL can evolve to support this transition.

In light of these challenges, NASA senior leadership tasked OTPS with answering two questions: 1) what are potential models for an ISS National Lab facilitating government-funded or subsidized activities on a commercial LEO platform after the transition of the ISS to one or more private platforms, and 2) in light of these options, what modifications would be helpful to make in the current ISSNL-CASIS partnership and the NASA management processes as NASA plans for the transition of the ISS by 2030?

To answer the first question, we conducted a stakeholder-driven analysis to identify a trade space of six differentiated model options. We then evaluated their performance in three potential future scenarios, according to evaluation criteria deemed important to stakeholders. The six models are illustrative and representational of a potential trade space. Additionally, each model requires change to current legislation related to the following: establishment and operation of the ISSNL, resource allocation split between NASA and the ISSNL, NASA-CASIS cooperative agreement, ISS longevity, and creation of an ISSNL advisory committee. To further aid in leadership decision-making, we provided considerations for how to strengthen each model by mixing and matching different model aspects.

To answer the second question, we looked to strengths of the top-performing models to evolve the current ISSNL-CASIS relationship and improve NASA's posture for success post-ISS. We identified four possible modifications to the ISSNL-CASIS partnership and NASA's management of these activities.

- Create a pathway for ISSNL-CASIS to access commercial platforms as they come online prior to the ISS transition and determine NASA's role in brokering these relationships.
- Elevate the ISSNL incubation role to support increased movement towards industrialization.
- Establish a terrestrial innovation campus for microgravity research and development.
- Formulate a strategy for buying data from commercial providers.

By implementing these modifications early, NASA can increase the return from ISSNL-CASIS and help prepare for future models as one or more CLD replaces the ISS by 2030.

Appendix A: Insights from Stakeholders

To better understand how the study results reflect the needs and experiences of the different stakeholders for LEO activities, this appendix highlights specific insights from conversations with members from four stakeholder groups: NASA, other government agencies (OGA), commercial, and academic and nonprofit. We talked to at least 10 representatives in each of the four stakeholder groups for broad representation of thought, on the topics of:

- Views on the Future LEO Ecosystem
- LEO Platform Activities and Priorities
- Thoughts on NASA's Role
- Potential Models and Mechanisms to Connect Users to Platform Providers
- Model Evaluation Criteria
- Challenges, Risks, and Concerns

There was no consensus on the views around these topics even within stakeholder groups. In order to give the most comprehensive summary for each stakeholder group, similar comments were merged while conflicting comments were preserved into a final list of *themes*. Each of the *themes* is clarified with *context* and illustrated with paraphrased *quotes* from the stakeholders. Note that all included quotes are paraphrased for brevity and content.

Insights from NASA Stakeholders

The NASA stakeholders we spoke to possessed expertise in commercial spaceflight, economics, and biological sciences, among other areas. Their perspectives ranged from research-oriented needs to those with a focus on growing the LEO ecosystem. Discussions covered views that spanned operations-related needs to strategic needs for the agency.

We held discussions with 13 individuals within this stakeholder group.

Views on the Future LEO Ecosystem

Themes	Context
Some LEO studies have already been completed and are driving this community's understanding of LEO's future.	Industry studies have already partially shaped opinions on future activities.
The future of the LEO ecosystem will change as thinking develops with time.	New decadal reports, arising market trends, and new technology capabilities in the near future will provide more guidance.
Suborbital activities will continue to be a steppingstone for LEO, and LEO activities a steppingstone for longer duration missions beyond LEO.	LEO activities can test crews for long-duration missions without a relatively complex logistical component.

Quotes

- *"The decadal will drive future activities and represents a change in mentality regarding requesting resources necessary to do the most compelling science."*
- *"There are several gaps that might be included in LEO activities: long missions, gravity transition missions, partial gravity simulators."*
- *"We have the narrative of competition now, but there are trends toward monopolies."*

LEO Platform Activities and Priorities Mentioned	
Themes	**Context**
Regular and reliable access to resources for research, chiefly money, is necessary.	This allows for multi-year-long research, rather than the current short-term time scales on the ISS, and for more research initiatives.
The market should be demand-driven and should have demand met at a reasonable level.	Customers' needs should be the motivation behind market-based planning and decisions.
A significant focus on in-space manufacturing is important.	Future in-space manufacturing is building on the success of NASA's In Space Production Applications and other efforts.
Tourism could provide new opportunities.	Once more established, tourism can be leveraged for additional datasets and platforms.

Quotes

- *"For years, the Space Station was always a limiting resource for research. In a robust ecosystem, there will be lots of different opportunities and we can start thinking about research campaigns that span years; regular, reliable access is critical."*
- *"Private money is opening opportunities. Having private astronaut data will significantly increase the size of datasets."*
- *"If there is demand to fly a payload one should be able to find an opportunity to do so."*

Thoughts on NASA's Role	
Themes	**Context**
NASA may have to be the only customer for CLDs at the beginning of the commercialization of LEO.	While demand for LEO activities may fluctuate in the near future, NASA may temporarily be the sole customer for CLDs.
NASA must maintain the opportunity for international engagement and diplomacy in LEO.	Other space agencies should continue to have the opportunity to participate in LEO activities.
NASA should adopt a role of "convener."	NASA could reduce barriers to entry and be a facilitator in convening different groups with similar interests.
NASA should adopt the role of "protector."	NASA could be responsible for balancing and protecting the needs of customers.
NASA should conduct knowledge transfer to industry players.	Tools like the Commercial Crew and Cargo program and the CLD program help enable this transfer.

Quotes

- *"We should be a facilitator and customer. If we lead, we will shackle commercial development."*
- *"NASA has a strong brand and can be seen as a credible neutral party, which could lead to a 'convener' role."*
- *"Our job is to knock down barriers and let people run in."*

Potential Models and Mechanisms to Connect Users to Platform Providers	
Themes	**Context**
The nonprofit component of the National Lab model is generally ideal.	Science and technology objectives can be achieved that the market would not be able to support, and this model has helped define demand for commercial groups for the ISS.
NASA needs an alternative to the restrictions of the ISSNL cooperative agreement.	Other types of contracts or grants may provide NASA with more flexibility.
CLDs should offer variable services.	To be profitable, each CLD will have its own business model and thus will go after different customers.
A government platform would generally be counterproductive.	Developing such a platform would hinder the development of commercial LEO and introduce the government as a competitor.

Quotes

- *"In-space manufacturing is not a NASA requirement or goal; it needs a National Lab model like we have with CASIS."*
- *"The National Lab model feels contrary to the desired 'one of many' approach. The National Lab is too top-down driven."*
- *"Give commercial a hand to get going and have a clear handoff until they take over."*

Model Evaluation Criteria	
Themes	**Context**
Opportunities for international consumers are necessary for a sizeable market.	Models need to consider how to satisfy international demand, either directly through NASA's selected model or indirectly through the ecosystem.
Non-NASA science needs must be addressed.	Non-NASA research is crucial and could be addressed through a National Lab-type model.
A model needs to have the ability to transition to multiple CLD customers, given that it originates with NASA as the only customer.	Some of NASA's past behavior demonstrates a lack of follow-through when planning on creating a multi-customer marketplace.

Quotes

- *"There might not be a one-size-fits-all mechanism."*
- *"Everyone knows that NASA will be the anchor customer in the first few years."*
- *"Companies need to understand the demand function. They need a consolidated demand signal, but that might not be NASA—maybe a nonprofit?"*

Challenges, Risks, and Concerns	
Themes	**Context**
A lack of collaboration and communication between the NASA, OGA, and commercial groups and their respective architectures is a concern.	Currently, there is not much known about these architectures.
Costs of maintaining a sustained crew and vehicle launch and return must be reduced.	Having multiple launch and return providers and new capabilities, including rideshare opportunities, is critical to creating a robust LEO environment.
The needs of CLD customers are as of yet unknown, so flexibility in NASA's services will be a necessity.	NASA should focus on creating baseline LEO capabilities to adapt to different commercial needs when they are realized.
There is a lack of support for microgravity research.	Current support is insufficient to maintain a campaign of research.
Commercial flight companies may not have a demand for space stations in the long run.	Alternatives, like SpaceX's Starship, could undermine the usefulness of space stations.

Quotes

- *"The pipeline of research and technology will be overflowing but limited by transportation and cost."*
- *"What you need may change in three years, but if you have a foundational capability that provides a standard for anything you want to do, you will be prepared."*
- *"The workforce and support of the microgravity research community will be missing. I can see something like JPL with a cool campus and NASA funding microgravity problems."*

Insights from OGA Stakeholders

Several government agencies and other federal entities beyond NASA have a strong stake in the future of LEO. Discussions with this stakeholder group included discussions with NIH, NRL, AFRL, SDA (DoD), DOE, FAA, and NSF. Individuals at these organizations serve to accomplish their respective missions, but all have overlapping interest in the success of LEO commercialization.

We held discussions with 10 individuals within this stakeholder group.

Views on the Future LEO Ecosystem	
Themes	**Context**
OSAM will be necessary for the success of LEO activities.	In-space assembly will be required for certain satellites currently in development.
LEO can serve as a testbed for further exploration, like for future trips to the Moon and Mars.	N/A
LEO should be run by the commercial sector, while GEO is run by the government.	The majority of efforts in some agencies lies specifically in GEO, leaving LEO to be developed by private groups.
One main goal of the LEO ecosystem should be to improve conditions on Earth.	LEO activities should have a partial objective of finding new discoveries in research, manufacturing, etc. that have Earth, not just space, applications.

Quotes

- *"Test platforms and even transfer vehicles in LEO can provide easier access to experimentation for exploration beyond LEO."*
- *"LEO should be a robust and competitive commercial sphere, with megaconstellations and multiple players invested in technological development."*
- *"When we look at LEO, whatever occurs there has to benefit Earth. We have to make sure to have that focus."*

LEO Platform Activities and Priorities Mentioned	
Themes	**Context**
Platforms should contain a broad range of experimental equipment and laboratory technology.	Skilled scientists should have access to these resources at a justifiable cost.
LEO should provide opportunities for new technology to be tested in space.	LEO could be a test platform for many types of technology, including GEO electronics and experiments.
Casual tourism should be considered for the far future.	Likely would not be achievable in the 2030 timeframe.
Certain current abilities that the ISS provides to OGAs need to be maintained by commercialized LEO.	OGAs rely on services currently provided by the ISS that should persist beyond 2030.
Transparent data publication of LEO laboratory activities should be provided.	Increasing access to LEO data fosters innovation and development within the LEO ecosystem.

Quotes

- *"Space activities are so rare that even showing that a technology works for a few hours is an accomplishment that LEO has a unique ability to prove."*
- *"There should be something like the 'iPhone development cycle' where you're frequently replacing devices to always have the best ones in operation."*
- *"We currently have a good relationship with the ISS, as we routinely put payloads up there. We would need some way to maintain that ability in a post-ISS world, maybe with free flyers to get costs down."*

Thoughts on NASA's Role	
Themes	**Context**
NASA should encourage and facilitate international collaboration.	Other departments may not have the opportunities for international collaboration that NASA has, so NASA must be responsible for these partnerships.
NASA should incorporate some aspect of diplomacy in LEO.	Diplomacy on the ISS is something to be replicated.
NASA should be involved with every facet of LEO, adopting the roles of "customer," "leader," and "facilitator."	This structure would provide confidence in LEO and a common set of goals.
NASA should adopt the role of "communicator."	NASA should renew a public interest in space.
NASA should adopt the role of "coordinator."	NASA should help get experiments to space and provide guidance in the process of running an experiment.

Quotes

- *"Continue the diplomacy in space necessitated by the ISS, even when it doesn't correlate with maximum efficiency."*
- *"International cooperation is a strength of NASA and is necessary to prevent 'bad actors' from targeting the platform."*
- *"NASA's role is to reinvigorate interest in space, like with JWST, which is something that other agencies can't do."*

Potential Models and Mechanisms to Connect Users to Platform Providers	
Themes	**Context**
A model like the ISS National Lab is necessary.	The ISSNL model provides opportunities to government agencies outside of NASA and strengthens national capability.
The ideal model is an infrastructure that is not owned by a single entity but that multiple parties rely on for operation.	A cell phone tower is an analogy to this model, and NASA would need to compel companies to get payloads up to this "tower" and maintain them.
There should be services offered by the government as well as private companies.	A mix of services provided by government and companies enables differentiation within the ecosystem.

Quotes

- *"Continuation of an intergovernmental laboratory such as ISSNL in the future of LEO is critical, as its independence from NASA has provided unique resources and access."*
- *"Think of postal services—there's USPS, a government-run option, but also FedEx and UPS that provide different services. There's room for more than one entity."*
- *"We need to create a mechanism for connecting agencies and reducing the administrative hurdles."*

Model Evaluation Criteria	
Themes	**Context**
LEO needs to provide a diversity of suppliers.	Having multiple suppliers of multiple services is necessary.
Opportunities on multiple commercial platforms must be centralized and screened for redundancy.	Having platforms run by several smaller companies yields productivity but could be inefficient for government users.
The cost of using LEO facilities should not be prohibitive.	Ensuring that the barriers to entry for LEO opportunities are relatively low is essential.
The new model should make getting to space easier and more accessible.	LEO should become a universal payload-citizen science environment, similar to CubeSat "revolution."

Quotes

- *"We work with FFRDCs and UARCs. The structure isn't bad but it's very personality dependent. To be productive, organizations can't be too big."*
- *"Opportunities for facility use that are accessible outside of the space community are important and cannot be prohibitively expensive."*
- *"A centralized model for proliferated platforms should ensure efficiencies and make sure that the value across the enterprise is not reduced."*

Challenges, Risks, and Concerns	
Themes	**Context**
Reliable access to information on launches and returns is necessary.	Launch and return information can affect a scientist's work, producing samples and subsequent timing.
Not every LEO activity should be classified.	Excessive bureaucracy and secrecy are concerns.
There is a risk of a negative image of LEO if investments go wrong or do not produce results.	Concern about the image of “wasting taxpayer dollars.”
There is confusion over regulation and burdensome documentation requirements.	Rules should be clarified, and documentation kept to a minimum.
Ground-based astronomy could become obsolete due to light pollution and debris in LEO.	NASA should explore ways to mitigate effects of these circumstances.

Quotes

- *“Access to launch and to the lab are important as well; changing launch details causes upsets for experiments because it can take up to a year to have the right amount of [biological] cells to send into space. Ideally, we would always know the actual date in advance with a very low chance of that date shifting.”*
- *“Integration and launch capabilities should be simple, like getting on a train, instead of fraught with red tape, like getting on an airplane.”*
- *“There are burdens of the ‘extreme documentation’ needed for human space flight. There’s confusion about what the requirements are and how to go about proposing cross-agency collaboration.”*

Insights from Commercial Stakeholders

Companies will be both providers and users of services in LEO. They will establish platforms to provide habitation, research, and manufacturing services, among other activities, and be customers of these services, depending on the company function.

We held discussions with 10 individuals in this stakeholder group.

Views on the Future LEO Ecosystem	
Themes	**Context**
The decommissioning of the ISS is a major inflection point for LEO.	2030 is the timeframe when the ISS becomes politically and financially irrelevant.
LEO commercialization will yield the emergence of new business models.	There will be a new type of economy, similar to what occurred after the internet became widespread
The new LEO economy will be much more similar to a terrestrial economy than a space economy.	Terrestrial markets will move to space to increase profits, especially when related to space exploration or applications.
The decommissioning of the ISS provides opportunities for ISS-related technology to be adapted to different or broader uses.	The future market provides opportunities for technology currently only used for specific ISS-related tasks.

Quotes

- *"From a LEO economy perspective, 2030 is an inflection point where there's a change from government platforms to commercial platforms."*
- *"Our plan is to continue to offer [what we currently offer], but with the demise of the ISS, we can be more than just that. We're seeing what we can provide and what the market is looking for."*
- *"We're betting on the need for human space stations. Others are also banking on expanded operations in LEO. We're seeing commercial needs."*

LEO Platform Activities and Priorities Mentioned	
Themes	**Context**
There should be a focus on manufacturing and consumer-based services.	Increasing manufacturing and consumer-based economies in LEO is an enabler for other activities.
Tourism is a big market right now.	Some activities may be more profitable in the future, but tourism is currently a profitable activity.
Individual platforms will not be able to provide all types of services.	CLDs will need to specialize to some degree.
Activities should not need to have a human presence.	Astronauts greatly increase expenses and do not add to the functioning of the ecosystem.
Immediate focus should be on building infrastructure to support future needs.	Doing so removes the need to try to predict what the LEO market will look like in the future.

Quotes

- *"We see commercial needs. Things like tourism now, but also research-based and commercial-based operation, manufacturing, and more."*
- *"Do you build your station for tourism or for science? People are seeking all of the above, but CLDs won't be one-size-fits-all."*
- *"...want to do research, manufacturing, film, commercials, etc. We see the need to be diverse because there's so much uncertainty."*

Thoughts on NASA's Role	
Themes	**Context**
NASA should be one of many customers.	The LEO market should span business to government, business to business, and business to consumer.
NASA's role must fall between a provider and a user.	NASA has a role as a customer of LEO services and facilitator of other users accessing those services.
NASA has an opportunity to show confidence in U.S. CLDs, which would encourage international partners to invest in them.	NASA should do so as soon as possible.
NASA should maintain international partnerships to maintain U.S. leadership in space.	NASA can do so through agreements and buying seats on U.S. commercial flights to encourage other countries to buy seats as well.
NASA should find a way to share existing knowledge with industry groups engaging with LEO for the first time.	The lessons learned and data that NASA has collected should be offered to companies.
Funding from NASA provides confidence in commercial projects.	With NASA's approval, companies may be less nervous about their ability to attract investors and customers.

Thoughts on NASA's Role

Quotes

- *"NASA can't use the resources of commercial companies and still exercise ownership over the equipment. If NASA is a partial owner, there needs to be a clear standard regarding what NASA pays for."*
- *"Without intentional leadership from NASA, international engagement and investment decreases."*
- *"The NASA seal of approval is huge."*

Potential Models and Mechanisms to Connect Users to Platform Providers	
Themes	**Context**
NASA should employ an anchor tenant model.	This model is flexible enough to be able to meet the needs of many customers.
NASA should not employ the anchor tenant model.	Using an anchor tenant model would not allow for the necessary shift from R&D to a full ecosystem.
A business park model is the best option for customers.	The business park model would allow customers to experiment with activities while remaining stable.
There are many questions with a "space hotel" model.	Logistical questions arise, like would the CLD provide astronauts with lunch, or just give them access to the kitchen? Is NASA co-creating the experience or just receiving services?

Quotes

- *"NASA continuing to act like an anchor tenant for maintenance is more important than the percentage of business that they provide, for the sake of consistency."*
- *"The anchor tenant model is essential to kicking off a business park model for a CLD."*
- *"The model of the business park is fundamental to success."*
- *"Commercial entities have gone through CASIS for access, but we hope to have channels where they can come directly to us. However, setting up independent relations with all agencies becomes cumbersome."*

Model Evaluation Criteria	
Themes	**Context**
Ecosystem architecture should be flexible enough to sustain varied commercial demand.	Diversity of capabilities could combat uncertainty.
NASA should be "buying time."	Contracts with NASA should be based on time periods, not deliverables.
It should be easy for customers to switch between service providers.	Companies should not have to set up independent relationships with every provider.
Other government agencies should have opportunities to participate in LEO activities.	Agencies like NSF and NIH as customers will make LEO a broader market.
If NASA wants to be a customer in the long term, the chosen model should be flexible enough to allow a transition from NASA to the Department of Commerce.	If the government wants to be one of many customers, the Department of Commerce needs to take lead on the customer and economic development components.

Quotes

- *"The single most important thing is flexibility of the architecture."*
- *"Commerce will need to have the resources to take over NASA's position as customer, which it doesn't right now. For NASA to try to recreate Commerce's role would be an inefficient use of the government's efforts and of NASA's expertise."*
- *"Consider cost-sharing and substantiating the market for certain areas. Flexibility is key."*

Challenges, Risks, and Concerns	
Themes	**Context**
It will be difficult for customers to understand what CLD features will be available when.	Early, publicized capabilities for the post-ISS transition could solve this problem.
Providing robust data services to customers will be critical.	To be successful, LEO needs to address logistical delays. There is an expectation in the broader economy that users can get their data on demand.
There should be consideration for an astronaut crew dedicated to maintenance.	Astronauts would have more time for experiments if there were a crew on board for maintenance, which is a current burden on the ISS.
There is confusion about insurance logistics for CLDs.	It is unclear if the government needs to be involved and if government astronauts need to be insured.
There is a growing worry over not having a specific point of contact in the government for mission authorization.	The government needs to be specific about what requirements providers are working towards and who can sign off on them.
NASA's small business and university programs are slow to provide funding.	The funding cycle doesn't align with small business or a growing economy.
Time between the retirement of the ISS and the start of use of CLDs needs to be minimized.	Opportunities scientifically and commercially will be lost without a continued presence in LEO.

Challenges, Risks, and Concerns

Quotes

- *"There's uncertainty about what the transition model will look like. Will the ISS coexist with a CLD for a period, and will someone be allowed to choose to put a payload on a CLD at that point, or does the ISS take priority?"*
- *"There is no shortage of programs to support universities, institutions, and small businesses. All of them are very slow. SBIR takes years. NIAC is great but things are 10 years down the road."*
- *"We cannot have a space station gap. We need to make sure there's a continual presence in LEO. A single year gap in a space station could have a decades long impact in the research pipelines we're seeing."*
- *"I worry about the timeframes of NASA moving in these directions. An ISS replacement would take years to develop, realistically. We must find a way to replace those critical items—whether crew capsules, facilities within ISS—and finding temporary fixes to overcome gaps now."*

Insights from Academic and Nonprofit Stakeholders

This research community includes both universities and research-focused nonprofits. Those with an academic interest in LEO research determine the ways in which science priorities are tangibly realized on LEO platforms and thus are significant users and facilitators of CLD platforms.

We held discussions with 10 individuals in this stakeholder group.

Views on the Future LEO Ecosystem

Themes	**Context**
There will be multiple platforms that are a mix of commercial- and government-run.	Even if the U.S. government does not have a strong LEO presence, foreign governments likely will.
By 2030, the LEO ecosystem will be dominated by industry.	Current private sector investments are growing, and the ecosystem will be driven by the private sector after the retirement of the ISS.
The two major stakeholders in LEO will be commercial and research.	The commercial sector is driven by profit and the research sector is driven by discovery.
The LEO ecosystem will fill the role of the current ISSNL, providing opportunities in R&D for technology.	The activities currently provided by the ISSNL will be available across the LEO ecosystem.

Quotes

- *"There are several other governments that have expressed interest in having a presence in LEO, whether that's flying astronauts or doing science."*
- *"We're seeing a proliferation of the private sector, which I see continuing. By 2030, I think that transition will be complete, leading to an ecosystem that's run by the private sector."*
- *"The days of NASA being the primary driver in LEO are gone. NASA doesn't have to be primary driver and can focus resources elsewhere, like the Moon."*

LEO Platform Activities and Priorities Mentioned	
Themes	**Context**
Academic LEO science needs to remain a priority in LEO.	Science needs funding from NASA because commercial business models won't fund it.
Tourism alone will not provide enough customers for businesses to invest in LEO.	Regardless, LEO tourism should be pursued.
Platforms for science should have specific focuses.	Research in LEO should move away from multipurpose to single-purpose facilities to enable specialization and reduce redundancy
CLDs should have a diversity of capabilities.	One question is how to ensure this variety in capabilities.

Quotes

- *"If there aren't low-cost opportunities, there will be no opportunity for academia to participate."*
- *"As we move closer to 2030, I think there's going to be a renewed focus on science facilities that are more purpose-built and less multipurpose, which tend to not satisfy anyone completely."*
- *"There's an opportunity for industry and research partners to develop larger instrumentation techniques to see how things like additive manufacturing in microgravity would work in LEO."*

Thoughts on NASA's Role	
Themes	**Context**
NASA should be a customer and provide other means of making profit in LEO.	NASA will need to bolster commercial efforts to maintain industry investment in LEO.
NASA should provide microgravity environment training to private astronauts.	Doing so will be cheaper than current training practices.
NASA needs to provide funding to academic users for LEO science or subsidize it.	Grants currently supporting academic research do not account for launch costs, and NASA will need to continue or transfer this subsidy cost.
NASA should adopt the role of "convener."	NASA could bring multiple, less funded organizations together to bolster U.S. presence in LEO science.
NASA should adopt the responsibility of space environment management.	There is not a single entity with this responsibility right now, and the danger of a lack of regulation will increase.

Quotes

- *"NASA could be a funding agency driving the research interests, especially in the academic community, as they understand the realistic costs of sending a payload to a platform."*
- *"NASA could drive the market, but I don't think they're going to control it."*
- *"The LEO environment is only going to get more complicated with more satellites and debris. That could and should be a role for NASA to step in."*
- *"NASA can't move at the pace that a private sector wants to innovate."*

Potential Models and Mechanisms to Connect Users to Platform Providers	
Themes	**Context**
A single body to vet and choose experiments from the research community is necessary.	This could be CASIS or something similar.
A body needs to coordinate launch schedules and logistics.	N/A
NASA could provide mission requirements and accept bids.	This is similar to DoD's Space Enterprise Consortium and bandwidth auctions.
DoE's Management and Operations contract model could provide a good blueprint.	This model includes metrics to evaluate work.
An anchor tenant model should be considered.	NASA can use an anchor tenant model to transfer best practices to industry.

Quotes

- *"NASA is not universally sold on the idea of handing things off to industry."*
- *"I hope the government will continue to take a role in research, because when we turn that over to the private sector, it tends to languish."*
- *"An anchor tenant model comes with NASA best practices that can help lead industry to develop their own best practices."*

Model Evaluation Criteria	
Themes	**Context**
The research community needs adequate access to all sizes of payloads.	There are currently not many opportunities for academic users to run large experiments.
The first model should serve as an incubator for industry.	The government should provide an incubator function to encourage industrialization.
Nonprofit entities should not compete with the government in any model.	The current split of CASIS and NASA work creates an artificial divide in research areas that both NASA and other stakeholders need.
Any agreements between the government and nonprofits should be less restrictive than the current cooperative agreement.	The current agreement obstructs what both NASA and CASIS can do.
Research groups should be able to pick between platforms for their research.	There needs to be enough differentiation for platform selection to be driven by science needs.

Quotes

- *"Having a single managing organization like CASIS is not sustainable."*
- *"The thing that's missing is industrialization, which is how we take technology from the laboratory to something we can do at scale where we can make product and make money."*
- *"You might have heard the idea that ISSNL competes with the BPS division of SMD, and that's a problem. Why would a national laboratory that works through NASA be competing with its parent sponsor?"*

Challenges, Risks, and Concerns	
Themes	**Context**
There is a desire for consistent and thorough safety inspections.	A single entity is needed to be responsible for safety; this could be made up of NASA and FAA.
Launch costs are a constraint.	Regardless of the model, launches are expensive and may not be worth pursuing if potential for profit is not large enough.
Human presence on research platforms can be harmful.	Human interaction with a platform could disrupt research processes.
Academic users will need guidance on how to successfully run an experiment on LEO platforms.	Industry will have more resources than nonprofits or universities to figure out logistics.
Current congressional authorization language allows for only ISSNL work on the ISS.	Language needs to be updated to include platforms beyond the ISS.
Workforce development is crucial for a sustainable CLD environment.	Rotational internship programs or something similar could be a good means to do so.
CLDs will not be able to provide the necessary large scale of manufacturing.	One solution could be to have a platform dedicated to only manufacturing, with no research component.

Challenges, Risks, and Concerns

Quotes

- *"Having humans on the platform creates all kinds of vibrations and noise that may not be conducive to good experimental results."*
- *"NASA has to make equitable opportunities for research interests. Principal Investigators won't be able to figure out which platforms are available or how to use them. How can they figure these things out?"*
- *"Scientific communities should have conversations with CLD providers to make sure their needs are met."*

Appendix B: Scenario Narratives

This section describes three future scenarios that inform the scoring of the models and the model recommendations:

- Dynamic Growth
- Steady Growth
- Limited Growth

These scenarios represent the three possible futures that we anticipate for the LEO ecosystem in the 2030s after the retirement of the ISS. The future scenarios are used as a tool to frame the analysis for model performance rather than serving as a prediction of the future LEO ecosystem. For each future scenario, we list its defining characteristics, provide a summary overview, describe the primary limitations and opportunities of the future scenario, and describe the anticipated outlook for each user community in the LEO ecosystem: science and academic users, OGAs, international partners, commercial organizations, and NASA.

Note that rather than representing distinct futures only, the future of the LEO ecosystem may see more than one of these future scenarios occur over time, or any number of other potential scenarios, as the ecosystem evolves. The future trajectory of the ecosystem may also expand or contract resulting in multiple platforms or smaller, reconfigurable sorties.

Dynamic Growth Scenario

Key Characteristics

- Flexible
- Diverse
- Accessible
- Affordable
- Robust
- Tailored
- Exciting

Dynamic Growth

Successful commercial markets spur innovation and capital investment. Characterized by:

- Multiple platforms
- Diversified commercial services with niche offerings
- Influx of venture capital
- Complex, difficult to navigate unaided

Overview

NASA's investments in the CLD Space Act Agreement have ignited new LEO markets and investments. Early successes resulted in increased venture capital investment and accelerated interest in using and visiting LEO.

Multiple, diversified services and activities span multiple providers. Possibly one single exquisite facility supports the activities, but more likely, several CLDs and reusable vehicles compete for user demand, which has expanded in both number of users and variety of demand. In addition to science, human exploration research, and technology demonstration, space tourism has grown significantly, and on-orbit manufacturing is an established market.

Lower launch costs and greater accessibility enable new business models, with new and improved offerings available every few years. These new business models increase flexibility and enable providers to tailor LEO platform services to specific users.

Limitations

Some activities, such as partial gravity or testing of nuclear technologies, may not be available through commercial services. Overall, NASA can meet its mission needs and, depending on which model it adopts, can maintain a strong presence in LEO.

The rapid growth and diversity of services and activities create challenges for regulating LEO activities. Debris is a growing problem. A lack of internationally recognized standards or "rules of the road" increase the risk to LEO assets and human life. The rapid growth of manufacturing and pharmaceutical production in LEO raises concerns about ensuring quality and certifying authentic products.

Opportunities

The co-development of transportation for LEO entry and return has reduced launch costs and increased the number and variety of LEO access options. Users can choose among multiple options for returning payloads, including specialized services for cryogenically cooled or low-vibration payloads. Although space tourism remains limited to a wealthy elite, newly available on-orbit habitats increase tourism options and the growing market aspires to lower costs and thereby increase access for future tourists. In addition to physical access, providers have expanded virtual networks in LEO, enabling realistic virtual access to users across the planet. This democratization of LEO ensures continued societal interest in space and promises continued growth.

Outlook for User Communities

Science and Academic Users: Scientists have more opportunities to directly access their experiments. Moreover, results and payloads can rapidly be sent and returned from LEO, which increases returns from scientific projects and enables campaigns of scientific investment rather than one-off experiments. Applied science with commercial value dominates due to private investment. Researchers may have multiple platforms and providers to choose from or may seek to use a dedicated premier laboratory, depending on the models adopted by NASA, OGAs, or other nation's space agencies.

Other Government Agencies: LEO is an important technology test bed for DoD. However, security restrictions, as well as security concerns rising from the increased number of LEO users, limit activities on commercial platforms to early technology demonstrations. DoD may use a separate, mission-focused platform. Other research agencies like NSF, NIH, and Department of Agriculture follow NASA's lead and leverage the mechanisms that NASA sets up. The degree of activity for these agencies varies by the ease and cost of these mechanisms.

International Partners: Although NASA's investment resulted in a favorable position for U.S. commercial companies, other nations are active in LEO. Foreign LEO platforms are in development and reusable spacecraft have been proposed. However, a U.S. competitive advantage exists, and many space agencies are interested in working with the United States through NASA or with the companies directly. Avenues to accessing U.S. capabilities in LEO are highly dependent on the model NASA adopts but include a range from government-to-government, government-to-industry, and industry-to-industry agreements.

Commercial: Industry uses LEO for a range of activities, from manufacturing to satellite servicing to tourism. The success of prior ventures and an influx of venture capital allow commercial companies to experiment with different business models and services.

NASA: The level of activity in LEO benefits NASA greatly, with low-cost services covering most of the agency's research and technology demonstration needs. However, no longer the primary customer for LEO access and services, NASA must adapt to commercial timetables and accept less control over launches. Opportunities for a dedicated long-term platform are fewer and significantly more expensive than payloads on a shared platform.[21] Some activities, such as partial gravity or testing of nuclear technologies, may not be available through commercial services. Overall, NASA can meet its mission needs and, depending on which model it adopts, can maintain a strong presence in LEO.

Steady Growth Scenario

Key Characteristics

- Stable
- Quasi-flexible
- Enabling
- Inspirational
- Hopeful
- Attainable

Steady Growth

Moderate market growth akin to the status quo—slow but steady. Characterized by:

- One platform, or multiple small similar platforms
- Lack of diversity in activities
- Prioritization of limited space
- Some organic commercial market developments
- Common focus across stakeholder groups

Overview

This post-ISS scenario is akin to the status quo. With moderate development of the LEO ecosystem, both users and providers continue to increase, though at a slow pace. Whether one platform or multiple small platforms are available, the range of services and activities is not diversified.

NASA has sufficient access to LEO and LEO infrastructure to meet its primary needs. Other user communities are somewhat more limited, because commercial services remain generalized. Commercial companies lack sufficient development and private investment to offer specialization. Despite these limitations, LEO continues to be a symbol of collaboration and an international playing ground.

Limitations

Although cost to access space is lower than today's standards, the cost is still high enough to hinder market development, leaving providers to rely more heavily on government customers. Partnerships with government agencies might lower cost to access for some commercial customers.

The top-priority commercial markets are those with the greatest likelihood for generating the highest revenue, so most scientific research accesses space through NASA mechanisms only.

Due to volume and mass restrictions on launches and platforms, technology development is limited to the highest priority activities.

Opportunities

LEO remains a destination of geopolitical benefit to the United States. With steady, gradual growth in LEO activities, customers across domains and nations continue pursuing synergies and partnerships with the U.S. government and any active U.S. commercial providers. The current pace of technology development continues.

Having enabled at least one commercial platform, early risk reduction activities, especially in financial risk, have given some confidence to investors, suggesting a potential for unanticipated market growth.

Outlook for User Communities

Science and Academic Users: Similar to today, LEO is a destination for scientific research across disciplines. Engagement from academia remains strong, especially in support of research for human exploration missions. The design of the LEO platform(s) is flexible enough to incorporate most instruments identified as high priority, including state-of-the-art sensing and observation instruments. With real-time data downlinks and high-speed video transmission, scientists can adjust experiments in real time, achieving greater efficiencies and outputs. Continued opportunities for involvement in scientific research in LEO inspires students of all levels across the United States.

Other Government Agencies: Because costs to access LEO are not much lower than costs today, government agencies limit their participation to top-priority activities, as determined by National strategies and NASA's research needs.

International Partners: Nations who partnered with NASA on ISS may continue to work directly with NASA on commercial LEO platform(s). Less volume is available than on ISS, so nations may partner with other government platforms or develop plans to access LEO themselves to maintain momentum. Barter agreements between partnering nations are possible if the agreement benefits both parties. As such, major space-faring nations might re-balance bartering tools between governments involved in LEO. Depending on the model, NASA may benefit from maintaining accessibility and flexibility for international partners. Emerging space-faring nations may view partnering opportunities with NASA differently than nations who previously partnered on ISS. Emerging international partners might prioritize accessibility and strategic value when considering different partnership opportunities with NASA.

Commercial: From the early efforts to commercialize LEO to the 2030s, industry experiences rises and falls in demand and investment. Services such as orbital tourism and flying commercial or government astronauts have enough demand to be a reliable revenue stream. Activities with less demand, such as advanced and additive manufacturing, vary in terms of progress and profitability. Rather than catering to diverse services and activities, commercial companies might dedicate individual platforms to one type of service or activity, which then develops that market area further.

NASA: Though NASA might have to prioritize some needs, it can accomplish its goals in LEO for exploration missions. NASA uses insights from the Commercial Crew Program to adjust to unexpected outcomes in services or activities. Efforts to provide dissimilar redundancy for cases where NASA's mission cannot be accomplished without access to LEO remain an option for any major unmet needs.

Limited Growth Scenario

Key Characteristics

- Restricted
- Inflexible
- Focused
- NASA-centric
- Needs-based
- Undeveloped

Limited Growth

Lack of mature commercial platforms and limited opportunities. Characterized by:

- Single CLD in development with NASA monopsony
- High cost to close NASA gaps
- Focus on prioritized, strategic activities

Overview

Despite NASA's efforts to develop the U.S. LEO commercial market, commercial providers have not been able to survive the costs of entry, and expected markets failed to materialize. Investors have pulled out, leaving providers unable to buy down risks and mature technologies.

Therefore, after the recent retirement of the ISS, the U.S. has limited access to LEO. One CLD is operational and can host research but in a much more limited capacity than on the ISS. Users, including NASA, fly only their highest priority needs. Other users seek means of continuing activities in microgravity without using a LEO platform.

Geopolitical dynamics are shifting. China likely continues to operate its station and expresses interest in attracting new partnerships, including with other spacefaring nations. As the U.S. shifts attention to the Moon and Mars, it cedes some geopolitical benefit of LEO to China and others.

Limitations

NASA has low flexibility for activities in LEO. Only the most strategic technology development can continue. NASA may consider other means to ensure that mission-critical work can continue for Moon and Mars exploration missions. Ensuring dissimilar redundancy may allow for more needs to be met, such as pursuing a crewed or uncrewed orbital vehicle such as Dragon or Dream Chaser.

Opportunities

Some residual momentum from the commercial LEO market is transferred to new partnerships, potentially with other nations.

NASA can redirect resources from sustaining a laboratory and testbed in LEO toward other research activities and exploration missions.

Outlook for User Communities

Science and Academic Users: Academic institutions in the United States have significantly fewer opportunities to access LEO. Where possible, academic users will largely shift to suborbital research, ground analogs, and drop towers. Science in support of human research (e.g., for long-duration missions) is prioritized due to the limited volume and accessibility of LEO platforms.

OGAs: Most government agencies cannot justify the cost unless specifically tied in through a partnership with NASA in support of joint programmatic goals. DoD may consider pursuing its own platform.

International Partners: International partnerships with NASA in LEO have shifted to either those in support of Artemis or those reserved for diplomatic reasons. The Chinese space station has enough volume to host experiments and astronauts; other nations therefore look to China to continue research in LEO. With NASA's efforts in cis-lunar space and only one CLD in development, dynamics have shifted with respect to nations' roles in LEO.

Commercial: Commercial activities are limited, though the range of activities that can be prioritized is high. The inability to mature many technologies leaves more to be done. Some commercial research critical for Moon and Mars exploration is prioritized, but a lack of private investors leads to a heavier reliance on government.

NASA: Though the agency planned for a prioritization of activities critical for Moon and Mars exploration, these goals suffer schedule impacts due to limited opportunities in LEO. Specifically, crewed missions to Mars are pushed back significantly. Long-duration lunar surface missions also have some delay, as constraints in LEO have slowed the development of technologies needed for safe operations outside Earth's safety net. Schedule impacts to Moon and Mars can potentially be buffered by planning for dissimilar redundancy (e.g., uncrewed or crewed orbital vehicles to continue mission-critical research in addition to the CLD in development). NASA can carry only its highest priority needs.

Appendix C: Future LEO Activities

To inform the future scenarios, we looked at what activities may be available in the post-ISS LEO ecosystem and how they might vary across future scenarios. This assessment is based on existing literature, including the NASA Quantifying Demand[22] white paper, and discussions with stakeholders, which are summarized in Appendix A: Insights from Stakeholders.

For each future scenario, we assume that some activities are covered by non-NASA entities, primarily by commercial partners. Activities that are not covered by non-NASA entities are identified as having potential for government funding. These activities cover a wide range and some may necessitate or be better suited to human presence and tending, while others may be performed on autonomous, robotic uncrewed platforms.

From the future scenarios, several key factors drive what activities are available.

- In the dynamic growth scenario, there is a proliferation of users, activities, and services in LEO. Activities are not restricted by platform volume and opportunities exist for most conceivable activities.
- In the limited growth scenario, commercial services have not fully materialized, and a single permanent platform still in development comes with volume restrictions.

Generally, the number of services increases as the LEO ecosystem grows. In the dynamic growth future scenario, markets can sufficiently sustain activities and industry is less reliant on the government. The government may purchase any of the listed activities as a service. In the steady growth future scenario, available activities center around platform operations and more generalized services. In the limited growth future scenario, there are fewer options available to purchase. With limited market growth, industry focuses on generalized services.

After identifying what may be available for the government to purchase, we looked at how the government may prioritize the activities.

As seen in Table 13 below, the types of activities and their focus shift across future scenarios. Each future scenario contains details that impact the importance of activities to NASA and other government stakeholders. For example, when markets are not mature, as in the limited growth future scenario, the government has more opportunity to stimulate various markets. As markets mature, however, increased commercial services allow the government to invest in more niche applications and buy mature systems and technologies from the market. Some activities (e.g., crew training or systems demonstration) remain split between commercial services and government investment. We considered the mixture of activities within each future scenario when evaluating the models.

See Table 13 for the summarized listing and characterization of future LEO activities. We assembled this information from the extensive literature review and stakeholder discussions. The table includes check marks (✓) for demanded activities that are in scope for government support and a cross (×) to denote activities that are out of scope for government support. In future scenarios where there is significantly more (✓+) or less (✓-), demand for government support modified which checkmarks are used. Finally, shading indicates commercial services can likely satisfy some or all demand for these activities. For the latest estimates on quantified demand (that is the number of projects or crew trips per year) that may be considered for the steady growth future scenario, we refer the reader to the 2019 white paper on *Forecasting Future NASA Demand in Low-Earth Orbit: Revision Two – Quantifying Demand*, the 2022 *ISS Transition Report*, the 2022 In-Space Production (InSPA) plans, and the 2023 *Request for Information for future Commercial LEO Destinations – Concept Operations and Utilization*.[22,5,33,4,34] The various documents provide estimates for future LEO activities by considering historical needs from the NASA Mission Directorates, NASA programs such as the NASA Human Research Program, and the ISSNL.

The key takeaway remains that government priorities shift across future scenarios, since what is readily available also shifts. These shifts are not linear, and they can impact model performance across future scenarios. We took this into account in our model assessment.

Table 13. NASA and National Priorities for Future LEO Activities.

Government demand and commercial supply are expected to vary across future scenarios. Expected government demand is indicated by ✓. Expected change in government demand as compared to the steady growth scenario is indicated by more (+) or less (-). No expected government demand is indicated by ✗. Commercial supply is indicated by shading.

LEO Activity	Description	Future Growth Scenario		
		Dynamic	**Steady**	**Limited**
Education				
STEM Engagement	Science, Technology, Engineering, and Math (STEM) Engagement	✓+	✓	✓-
Science & Research				
Human Research	Addressing radiation, isolation and confinement, distance from Earth, altered gravity, and extreme environments	✓+	✓	✓-
Biological (Life) and Physical Science	Biological (including plants, model organisms such as rodents, microorganisms) and physical (including quantum)	✓+	✓	✓-
Other Science and Remote Sensing	Including astrophysics, heliophysics, planetary science, and Earth Science	✓+	✓	✓
Technology Demonstration & Development				
Production and Manufacturing	In-Space Production Applications (InSPA) including advanced materials and bio-manufacturing	✓-	✓	✓
Human Exploration Systems	Including food system, exercise equipment, medical equipment, Environmental Control and Life Support Systems (ECLSSs), plant growth facilities	✓+	✓	✓
Other Systems	Including (quantum) communications, power and	✓+	✓	✓

LEO Activity	Description	Future Growth Scenario		
		Dynamic	Steady	Limited
	energy storage, robotics, and autonomous systems			
Operations				
Cargo Transportation	Utilizing Commercial Crew and Cargo	✓	✓	✓
NASA Crew Training, Transportation, and Accommodation	Utilizing Commercial LEO Destinations (CLDs)	✓	✓	✓
Debris Mitigation and Remediation		✓+	✓	×
Other Operations	Including extravehicular activity (EVA), small satellite deployment	✓	✓	✓
Market Stimulation				
Private Crew Training, Transportation, and Accommodation	Utilizing Private Astronaut Missions (PAMs)	×	✓	✓
Tourism	Private crew not serving a NASA or National Lab mission or objective	×	×	×
Commercial Incubation	Including industrial and commercial development	×	✓	✓
Commercial Media	Including games, movies, advertising, and branding	×	×	✓

Appendix D: Full Evaluation Criteria and Scores

For an in-depth comparison of the models, this section provides the full scoring results and evaluation criteria for each model, per future scenario. Each highlight is a summary of the study team's scores for each criterion.

Full Score for ISSNL

Dynamic Growth

Table 14. ISSNL model in the dynamic growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	N/A
Adaptability	Constraints related to legislation, including the cooperative agreement, resource allocation, and contractual limitations, prevent ISSNL from being an adaptable model. This especially holds in this future scenario, which is heavily dependent on flexibility and scalability.
Opportunity for Collaboration	The model still provides a means to collaborate between NASA, OGAs, and international partners, but the dynamic growth scenario may force non-NASA entities to pursue other options that better suit their needs or possess better capabilities.
Market Sustainability	The cooperative agreement in place may limit ISSNL's ability to encourage market growth and provide a good user experience compared to other potential options in a dynamic growth scenario. While it can potentially help mitigate some risks to return on investment (ROI), this will not be needed in a dynamic growth scenario with many customers. Incubation and acceleration functions are needed to enable small companies.
Equity & Accessibility	The model still allows input into the activity selection process, provides low-cost pathways for research, and proactively seeks input from diverse stakeholder groups.

Steady Growth

Table 15. ISSNL model in the steady growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	N/A
Adaptability	Constraints related to legislation and the cooperative agreement prevent ISSNL from being an adaptable model. In a steady growth scenario, flexibility and scalability are required for platforms and activities to flourish.
Opportunity for Collaboration	The model still provides a means to collaborate between NASA, OGAs, and international partners, but the steady growth scenario may force non-NASA entities to pursue other options that better suit their needs or possess better capabilities.
Market Sustainability	This model encourages market growth and could potentially mitigate risks to ROI for platform providers by covering costs for payload integration and by helping users in the form of grants and subsidies. Incubation and acceleration functions are needed to enable small companies.
Equity & Accessibility	The model still allows input into the activity selection process, provides low-cost pathways for research, and proactively seeks input from diverse stakeholder groups.

Limited Growth

Table 16. ISSNL model in the limited growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	N/A
Adaptability	Constraints related to legislation, including the cooperative agreement prevent ISSNL from being an adaptable model. In a limited growth

Model Evaluation Criteria	Future Scenario Highlights
	scenario, flexibility and scalability are required for platforms to succeed.
Opportunity for Collaboration	The model still provides a means to collaborate between NASA, OGAs, and international partners in a way that current parties are familiar.
Market Sustainability	This model encourages market growth and could potentially mitigate risks to ROI for platform providers by covering costs for payload integration and by helping users in the form of grants and subsidies. Incubation and acceleration functions are needed to enable small companies.
Equity & Accessibility	The model still allows input into the activity selection process, provides low-cost pathways for research, and proactively seeks input from diverse stakeholder groups.

Full Score for Anchor Tenant

Dynamic Growth

Table 17. Anchor Tenant model in the dynamic growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	Overall NASA's needs are fulfilled.
Adaptability	Restriction to one platform and inflexible contracts hinder the dynamics of the market. Expanding to multiple platforms (though not considered here) would improve diversity of activities, their simultaneous operations, and ability to scale.
Opportunity for Collaboration	Opportunities and experiences vary across OGAs and international. The NASA-centric role may hinder some, prompting them to pursue non-NASA options.
Market Sustainability	Processes could hinder the speed needed for growth but would provide stability to a CLD. The ability to span across multiple platforms was not

	considered here, but the anchor tenant role would mitigate risks for other CLDs, if considered.
Equity & Accessibility	Diverse groups can be sought and can provide input on activities, though with some difficulty. Grants open up opportunities with many applicants competing.

Steady Growth

Table 18. Anchor Tenant model in the steady growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	Overall, NASA's needs are fulfilled.
Adaptability	This model works well catering to the level of activities in this future scenario, with some limitations due to volume restrictions.
Opportunity for Collaboration	Overall OGAs and international partners are satisfied, though some international partners may pursue other options.
Market Sustainability	The model may show preference towards some activities, but nevertheless provides some market stability. Overall, this is beneficial to the CLD provider.
Equity & Accessibility	The diversity of stakeholder groups can be limited, but opportunities are available for many.

Limited Growth

Table 19. Anchor Tenant model in the limited growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to NASA's Needs	NASA's needs are mostly met, with some need to prioritize due to constraints.

Adaptability	Flexibility and ability to cater to activities are limited. Prioritized activities can be carried out within platform constraints.
Opportunity for Collaboration	Collaboration is more limited and must have stronger alignment with NASA's needs. International users may have less opportunity than OGAs.
Market Sustainability	Growth is limited, but the model can cater to available opportunities. Overall, the model is beneficial to CLD providers. User experience can be cumbersome.
Equity & Accessibility	Diverse groups can be sought, but opportunities are very competitive and must have strong alignment to NASA's priorities.

Full Score for Government Research Broker

Dynamic Growth

Table 20. Government Research Broker model in the dynamic growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA's needs can be met. Activities aside from basic research (e.g., tech demo, crew training) will need to use the CLD platform more heavily.
Adaptability	Highly adaptable to platforms, activities, users, and transport vehicle options. Noted ability to move from platform to platform. Scalability of activities is limited by the volume of the orbital transport vehicle and by platform volume.
Opportunity for Collaboration	The model promotes collaboration by aggregating and brokering opportunities for themed missions, spanning different user bases. A user advisory committee helps ensure collaboration among non-NASA partners. There may be some competition for grants, but opportunities for partners are abundant.
Market Sustainability	The model can accommodate some market growth. The broker must ensure NASA-funded research does not compete with industry (through

Model Evaluation Criteria	Future Scenario Highlights
	NASA-aligned grants or other means). CLD providers also have some level of guaranteed business, but NASA may wish to consider ways to ensure the research space utilizes both the orbital vehicle and the platform to give more assurance and avoid competition with CLDs.
Equity & Accessibility	The model seeks input from many and grants ensure users are connected with opportunities. The user advisory committee allows for input, but competition may dilute that input. More resources (i.e., more flights) may increase equity and accessibility in this future scenario, given the plethora of supply and demand.

Steady Growth

Table 21. Government Research Broker model in the steady growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA's needs are mostly met.
Adaptability	Highly flexible, especially given differing ways platforms can exist in this future scenario (one or multiple small platforms). Enables diverse activities. Scalability of activities has some dependency on usable CLD volume, abundance of orbital vehicles, or ability to dedicate flights to scale activities as needed.
Opportunity for Collaboration	The model promotes collaboration by aggregating and brokering opportunities for themed missions, spanning different user bases. A user advisory committee helps ensure collaboration among non-NASA partners. There may be some competition for grants, but opportunities for partners are regular.
Market Sustainability	The model can accommodate some market growth. The broker must ensure NASA-funded research does not compete with industry (through NASA-aligned grants or other means). CLD providers also have some level of

Model Evaluation Criteria	Future Scenario Highlights
	guaranteed business, but NASA may wish to consider ways to ensure the research space utilizes both the orbital vehicle and the platform to give more assurance and avoid competition with CLDs.
Equity & Accessibility	The model seeks input from many, grants ensure users are connected with opportunities, and the user advisory committee allows for input. NASA may need to more proactively seek input to ensure identified users can be connected to supply. The broker may also need to ensure it's not hindering competition.

Limited Growth

Table 22. Government Research Broker model in the limited growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA's needs are mostly met, though some prioritization is necessary.
Adaptability	Overall, the model can adapt to the restrictions of the future scenario, with some volume limitations from the platform and vehicle. The broker role is more applied to matching users and activities to the orbital transport vehicle.
Opportunity for Collaboration	Overall, the model is effective for collaboration, but alignment to NASA's needs may be required in a limited growth future scenario, especially for non-research-oriented activities.
Market Sustainability	The model can accommodate some market growth but may be more limited. The model may provide assurance to the CLD provider but might not do enough to sustain the platform if activities do not utilize both the orbital vehicle and the platform.
Equity & Accessibility	The ability to be equitable and provide accessibility (aside from those with high alignment to NASA's needs) is low.

Full Score for Innovation Campus

Dynamic Growth

Table 23. Innovation Campus model in the dynamic growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	The model meets NASA's needs, assuming there's an additional method of connecting supply to demand. There is an abundance of opportunities and users, and NASA has final authority on the campus' focus.
Adaptability	Overall, the model is adaptable to the dynamics of this future scenario. Built-in flexible agreement types and opportunities to reach beyond NASA's priorities (if desired) may increase diversity of activities.
Opportunity for Collaboration	The model has a noted ability for collaboration in this future scenario but may favor those with more alignment to NASA's needs.
Market Sustainability	Overall, the model has the ability to drive some market growth. Developing and testing technologies terrestrially first may provide a higher mission success probability, which helps reduce risk to ROI for CLD providers.
Equity & Accessibility	Overall, the model has a strong ability to seek input from many groups, but this may be limited to ground-based needs. There's a low-cost pathway for research, but activities need to overlap with NASA's needs.

Steady Growth

Table 24. Innovation Campus model in the steady growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	The model meets NASA's needs, assuming there's an additional method of connecting supply to demand. Built in flexibility may help ensure the campus activities can adjust to CLD capabilities.

Model Evaluation Criteria	Future Scenario Highlights
Adaptability	The model has some restrictions on its ability to adjust to differing outcomes and expand activities, but it can prioritize many activities at once.
Opportunity for Collaboration	The model has strong potential for collaboration, with some preference to those with more alignment to NASA's needs.
Market Sustainability	Overall, the model has the ability to drive some market growth. Developing and testing technologies terrestrially first may provide a higher mission success probability, which helps reduce risk to ROI for CLD providers.
Equity & Accessibility	The model has some ability to seek diverse groups, but user needs must overlap with NASA's priorities.

Limited Growth

Table 25. Innovation Campus model in the limited growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	The model may present some difficulty in meeting NASA's needs due to limited resources (assuming there's an additional method of connecting supply to demand). The focus of campus activity may be narrower. Due to the need to prioritize mission-critical research for the LEO platform, a narrow focus and the ability to partner where needed may be beneficial.
Adaptability	Limited opportunities in this future scenario may present difficulties in justifying resource needs. NASA may need to explore ways of limiting the activity focus or otherwise reducing financial ties.
Opportunity for Collaboration	Collaboration is possible, but alignment to NASA's needs is necessary.
Market Sustainability	The model can allow for market growth, but opportunities are more limited. Developing and testing technologies terrestrially first may

Model Evaluation Criteria	Future Scenario Highlights
	provide a higher mission success probability, which helps reduce risk to ROI for CLD providers.
Equity & Accessibility	The model can seek out diverse users, but alignment with NASA priorities is needed. A low-cost pathway for research may provide opportunities, but in a limited capacity.

Full Score for Matchmaker

Dynamic Growth

Table 26. Matchmaker model in the dynamic growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	Overall, the model can meet NASA's needs and can be designed to incorporate more NASA oversight to ensure this, especially in a robust market with many users.
Adaptability	The model is capable of enabling diverse activities and optimizing as needed. The model does well with high supply and demand.
Opportunity for Collaboration	The model enables collaboration, though collaboration may need to be considered up front to be most effective.
Market Sustainability	The model somewhat enables market growth and communicates demand well. The model reduces some risk for CLD providers but may need to proactively encourage this early (e.g., by improving efficiencies and providing incentives).
Equity & Accessibility	The model doesn't proactively seek out users, but this can be designed for early on. This would be especially useful for a robust supply and demand future scenario. Users can provide input into activities but aren't guaranteed selection. The model can be designed to include low-cost pathways for research if that is desired.

Steady Growth

Table 27. Matchmaker model in the steady growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA has the ability to meet its needs but will need to be proactive to ensure prioritization.
Adaptability	The model is capable of enabling diverse activities and optimizing as needed. Some attention may be needed to ensure activities and their potential to scale are not constrained.
Collaboration	Collaboration is enabled but with some limitations.
Market Sustainability	The model provides some market growth and communicates demand well. The model reduces some risk for CLD providers, but may need to proactively encourage this early on (e.g., improving efficiencies and providing incentives).
Equity & Accessibility	The model doesn't proactively seek out users, but this can be designed for early on. Users can provide input into activities but aren't guaranteed selection and may have to work within limitations. Low-cost pathways for research can be included as an add-on to this model.

Limited Growth

Table 28. Matchmaker model in the limited growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA's needs may be met if the agency has some oversight over the nonprofit. The role of the nonprofit may be reduced in a limited growth scenario.
Adaptability	The model is adaptable. Any limitations are driven more by the restrictions of the future scenario rather than the model (i.e., limited volume and opportunities).

Model Evaluation Criteria	Future Scenario Highlights
Opportunity for Collaboration	Collaboration is limited. Partners need strong alignment to NASA's needs.
Market Sustainability	The model has some limitations but can operate within the future scenario. The model might not provide enough assurances to CLD providers.
Equity & Accessibility	The model doesn't actively seek input from others, but this can be designed for early on. The matchmaker may face competition for opportunities with just one platform in development. Non-NASA users have much less opportunity and ability to provide input. Low-cost pathways for research can be included as an add-on to this model but would need strong alignment to NASA's priorities.

Full Score for Institute Network

Dynamic Growth

Table 29. Institute Network model in the dynamic growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	The institutes funded by NASA, OGAs, and industry can help NASA meet most of its needs if enough institutes are formed and can advance focus areas sufficiently. The government consortium may need to regularly assess performance to ensure progress on all targeted areas.
Adaptability	The dynamic ecosystem includes participation from different stakeholders in the various institutes. This network can help provide flexibility and scalability and can accommodate both diverse and simultaneous activities.
Opportunity for Collaboration	With a high number of participants, NASA, OGAs, and international partners have numerous avenues for collaboration, though implementing this collaboration may remain a challenge.

Model Evaluation Criteria	Future Scenario Highlights
Market Sustainability	The institutes rely on participation from platform providers, who have some level of guaranteed business from other members of the institute. Pairing this with a focus on commercialization can result in market growth.
Equity & Accessibility	There are some low-cost pathways to research for academic and research organizations, but these are limited to areas with opportunities for commercialization. It may be difficult for prospective users to identify and join the right institutes if there are several in existence, and overall participation is limited to those with direct expertise in specific areas.

Steady Growth

Table 30. Institute Network model in the steady growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA may need to ensure focus areas more strongly align with prioritized mission needs. The focus on commercialization may mean that NASA also has to incentivize focus areas that might not generate as much ROI as other areas.
Adaptability	The institutes can remain somewhat flexible and activities can scale to some extent, but activities are largely focused on a small subset of areas and do not encourage other diverse activities. Conducting simultaneous activities will be limited by platform availability.
Opportunity for Collaboration	There remains some degree of coordination in standing up and participating in new institutes, but there are fewer institutes in existence, less participation from stakeholders, and fewer areas of overlapping needs between NASA, OGAs, and international partners.
Market Sustainability	Market sustainability exists but only for specific areas of focus, resulting in a limited amount of market growth and mitigation of risks to ROI for platform providers. Users will continue to have a positive experience but only for the outlined areas of focus.

Model Evaluation Criteria	Future Scenario Highlights
Equity & Accessibility	It is difficult to provide equity with a limited number of institutes and only niche areas to develop. Participation is limited to known players with capabilities in those areas.

Limited Growth

Table 31. Institute Network model in the limited growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA's needs will not be met in LEO as there are limited to no opportunities for participation in the institutes in a limited growth scenario. As such, NASA will not be able to meet needs outside of commercialization in very specific and niche areas.
Adaptability	There may be some degree of flexibility and scalability related to very specific and niche areas, but having limited platform and infrastructure options prevents diverse and simultaneous activities.
Opportunity for Collaboration	Areas of focus for the institutes will be extremely specific. It will be very difficult for NASA, OGAs, and international partners to identify potential areas of overlapping interest.
Market Sustainability	In a limited growth scenario with only very specific areas to explore, this model can still provide some degree of market growth and a satisfactory user experience. However, limiting activity to niche areas does not help mitigate risk to ROI for platform providers, which require a wide customer base.
Equity & Accessibility	Equity and accessibility will not be provided due to a very limited number of institutes in only niche areas. Participation is limited to the well-known players with capabilities in those areas.

Full Score for Fee for Service

Dynamic Growth

Table 32. Fee for Service model in the dynamic growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA can mostly meet its needs, but potentially with some watchouts. Being one of many customers, NASA may experience some prioritization effects. Grants and data buys help ensure needs are met.
Adaptability	The model is overall very adaptable to this future scenario. Model platforms enable more and more diverse activities, which can be conducted simultaneously and at scale. Niche services may also thrive. Being a true free market model in a robust supply and demand future scenario, companies may have the upper hand in selecting users and prices. This may lead to preference in users and activities generating the most ROI.
Opportunity for Collaboration	Opportunities for collaboration with OGAs and international partners may vary in nature and by user experience. OGAs may pool funding, including funding for their own data buys, or may mostly participate through grants. Some international partners may find the process simple, and some may be hesitant to purchase directly from CLD providers.
Market Sustainability	This model is very well-suited for this future scenario; the dynamic LEO ecosystem supports the low level of government control inherent in the model. The model must encourage market growth to thrive. CLD providers may have some risk early on (i.e., may need some government assurances while the market is beginning to grow), but the ROI is high.
Equity & Accessibility	Proactively seeking input from diverse users is likely not a priority of a free market model, but grants help increase participation. Customers with the most to spend may again be preferred, limiting participation of others.

Steady Growth

Table 33. Fee for Service model in the steady growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA can meet its needs, though aside from grants and data buys, services might come at a price.
Adaptability	The model can mostly adapt to this future scenario, where activities are not diverse and platforms can exist in different ways (i.e., one platform or several small). Activities may skew towards those that generate the most revenue, limiting a diversity of activities from panning out.
Opportunity for Collaboration	This model presents varied opportunities for collaboration with OGAs and international partners. OGAs may need more alignment with NASA needs, and international partners may have less opportunity for collaboration due to competing priorities.
Market Sustainability	This model helps encourage market growth. A demand signal is communicated through grants. Again, there may be some preference toward higher cost services. CLD providers may have some risk early on and may need some government assurances while the market is beginning to grow.
Equity & Accessibility	Users with less to spend may be de-prioritized. Users can provide input into activity selection processes but might not always be selected. Grants provide a low-cost pathway for research, but in a lesser capacity.

Limited Growth

Table 34. Fee for Service model in the limited growth future scenario scoring and highlights

Model Evaluation Criteria	Future Scenario Highlights
Ability to Meet NASA's Needs	NASA can mostly meet its needs but with significant limitations. Priority may be placed on mission-critical activities, and grants and data buys need strong alignment with NASA priorities. NASA may also be de-prioritized at times due to competition from other users.

Model Evaluation Criteria	Future Scenario Highlights
Adaptability	Most limitations are due to the lack of dynamics of the future scenario (e.g., low number of platforms, less diverse activities). The model can work within these, but it is not designed for a limited ecosystem.
Opportunity for Collaboration	Collaboration among OGAs is limited and likely must align strongly to NASA's needs. International partners have less opportunity to participate and may be de-prioritized at times.
Market Sustainability	The model can enable some growth, but at slow speeds. The CLD provider may see some benefit in being the sole provider and can set costs to their preference. However, the CLD provider might need more commitment from a dedicated partner.
Equity & Accessibility	The model is limited in diversity of stakeholder groups. Users with the most commitment and most revenue-generating purchases will be prioritized. Grants and data buys however, help ensure others can participate and provide a low-cost pathway for research.

Appendix E: Legislative Changes to Enable Models

To supplement the considerations involving legislative changes (briefly described in the "Considerations to Guide Model Selection" section of the main report), this appendix further details the legislative changes that we anticipate being necessary when planning for particular models. Table 35 summarizes these changes.

Table 35. Summary of Legislative Considerations and Necessary Degree of Change Per Model

Model	**Legislative Consideration and Necessary Degree of Related Changes**									
	ISSNL	**Management**		**Science and Technology Goals**			**Documentation and Reporting**			**Creation of an ISSNL Advisory Committee**
	1.1	*1.2*	*1.3*	*2.1*	*2.2*	*2.3*	*3.1*	*3.2*	*3.3*	*4*
ISSNL	N/A	N/A	Minor	N/A	Minor	N/A	N/A	N/A	N/A	Minor
1. Anchor Tenant	Major	Major	Minor	N/A	Minor	N/A	N/A	N/A	N/A	Minor
2. Government Research Broker	Major	Major	Minor	N/A	Minor	N/A	N/A	N/A	N/A	Minor
3. Innovation Campus	Minor	Minor	Minor	N/A	Minor	N/A	N/A	N/A	N/A	Minor
4. Matchmaker	Minor	Minor	Minor	N/A	Minor	N/A	N/A	N/A	N/A	Minor
5. Institute Network	Minor	Minor	Major	N/A	Minor	N/A	N/A	N/A	N/A	Minor
6. Fee for Service	Major	Major	Major	N/A	Minor	N/A	N/A	N/A	N/A	Minor

Congressional Requirements for NASA's Role in U.S. LEO Activities

Congress routinely passes about two or three NASA Authorization Acts each decade, which partially guide the agency's activities until the next act is passed. These acts contain directives regarding NASA's efforts, including those in space exploration, scientific research, space technology development, and agency security. The acts reveal congressional opinion of what

NASA's priorities should be in the near future. The five most recent Authorization Acts—from 2005, 2008, 2010, 2017, and 2022—provide an understanding of Congress's vision for NASA in recent years. All five acts include goals related to NASA's role in LEO activities, namely the ISS.

The next section summarizes the current congressional requirements regarding the ISS by theme, followed by a section describing anticipated changes to these requirements in future iterations of the acts.

Current Requirements by Theme

We have summarized the current ISS-related requirements in the most recent five Authorization Acts by four themes related to ISSNL management, science and technology goals, documentation and reporting, and creation of an ISSNL advisory committee. These requirements are paraphrased and simplified. (See the congress.gov legislation database for exact wording.)

1. ISSNL Management

1.1. Establishment and Operation of ISSNL

- Establish the U.S. portion of the ISS as the ISSNL and contract a non-governmental entity to operate it, also creating a plan for ISSNL operation (2005)
- Establish a process to help ISSNL users develop a transportation plan to and from the ISS (2008)
- Use the Space Life Sciences Laboratory at Kennedy Space Center to support ISSNL capabilities when appropriate (2008)
- Allow other federal agencies to use the ISSNL for educational activities when appropriate (2008)

1.2. Resource Split Between NASA and ISSNL

- Allocate at least half of U.S. research resources on the ISS to ISSNL-managed experiments (2010)

1.3. Cooperative Agreement

- Enter into a cooperative agreement with a nonprofit, which is prohibited from engaging in any non-ISSNL activities, for the management of the ISSNL (2010)
- Designate a NASA Space Operations Mission Directorate employee as the liaison between NASA and the cooperative agreement organization (2010)
- Assist the cooperative agreement organization financially while it initiates research activities (2010)

2. Science and Technology Goals

2.1. Scientific Research

- Run a microgravity research program that includes research on the ISS into how the human body is affected by long periods of time spent in space (2005)

- Allocate >15% of ISS research funds to studies that do not directly support NASA's human exploration programs (2005)
- Maximize scientific research and development (2010)
- Plan and manage research facilities on the ISS (2010)
- Consider the National Academies Biological and Physical Sciences in Space Decadal Survey when prioritizing research and enhancing ISSNL capabilities and opportunities (2010)
- Advance knowledge to the nation through a research program on the ISS (2017)
- Use the ISS for SMD missions in LEO (2017)

2.2. Spaceflight Technology

- Support the development of automated docking and rendezvous capabilities to be used by the ISS (2005)
- Maintain ISS capabilities such that existing activities can be continued if the Space Shuttle is unavailable for cargo resupply (2005, 2008)
- Support technology and capability development on the ISS when appropriate (2010)
- Maximize technology research and development (2010)
- Use the ISS to further human presence in space beyond near-Earth orbits (2010)
- Develop new means of flying instrument-level payloads for early demonstration, using the ISS as a platform from which to do so if possible (2010)
- Use the ISS in the development of capabilities and technology for upcoming human space exploration beyond LEO (2017)
- Develop an advanced space suit for ISS use (2017)

2.3. Commercial Technology Development

- Provide access to ISS technology, such as docking adaptors, to selected ISS commercial crew providers (2008)
- Enter into a contract with any commercial provider that can adequately provide crew transfer and crew rescue services (2008, 2017)
- Use commercially developed private launch and delivery systems for crew missions to the ISS (2017)
- Assist in development and certification of commercial transportation of U.S. government astronauts to and from the ISS via the Commercial Crew Program (2017)
- Run an open competition for a contract for federal government access and return services to and from the ISS (2017)

3. Documentation and Reporting

3.1. Science and Technology Plans

- Create a plan for research on the ISS by NASA and propose a final configuration of the ISS (2005)
- Create a plan for any changes in the sequence of ISS assembly if they are to occur (2005)
- Create a plan to address the role of the ISS in exploration risk mitigation (2008)
- Write a report containing a list of necessary hardware, maintenance, and upmass and downmass requirements to keep the ISS functional through 2020 (2008)
- Write a review of scientific equipment, vehicles, and other components on the ISS that are critical (2010)
- Write a report on Orion's ability to delivery crew and cargo to the ISS (2017)

3.2. Independent Review Teams

- Establish an independent task force to assess vulnerabilities of the ISS (2005)
- Establish an independent commission to review any future events that cause the loss of the ISS or its viability (2005)

3.3. ISS Organizational and Budgetary Reports

- Write a report on expected development costs of the ISS and changes to costs incurred because of Space Shuttle events (2005)
- Write semiannual reports containing details of any Russian work to complete the ISS (2005)
- Submit a plan for the operation and use of the ISS until at least fiscal year 2020, including information about expansion of the operation of the ISSNL (2008)
- Submit a plan for the management of the ISS, including a description of the selection process for research, use of crew time, and other facets of on-board research (2008)
- Submit a budget plan for upcoming ISS-related activities through 2020 (2008)
- Write a report on the ways in which NASA encourages international collaboration on the ISS (2010)
- Write a report on means of return of research samples and equipment from the ISS that have been commercially developed (2010)
- Write a report summarizing lessons learned from contracts for commercial resupply services that should be applied to crew transfer services to and from the ISS going forward (2017)
- Write biennial reports through 2023 on achievements on the ISS furthering deep space human exploration, future research goals for LEO platforms, LEO commercialization, ISS cost estimates, and evaluations of feasibility and impact of the ISS's lifetime through 2028 and beyond (2017)

4. Creation of an ISSNL Advisory Committee

- Establish the ISSNL Advisory Committee to advise on the utilization of the ISSNL (2008)

Anticipated Future Requirements

Revisions to past Authorization Acts can be established by adopting new language in upcoming Acts. Given the frequency of the passing of Authorization Acts, NASA's Office of Legislative and Intergovernmental Affairs (OLIA) predicts that two Acts will be sanctioned this decade: one passed in August of 2022, and the other will likely pass toward the end of the 2020s. Congress publishes calls for proposed legislative changes to government agencies yearly, and as such, OLIA submitted the following four proposed changes for the 2022 NASA Authorization Act based on the IRT recommendations delivered to NASA in February 2020.[4,7,35]

1. **Replacement of "cooperative agreement" language when referring to the arrangement between NASA and the ISSNL nonprofit**
    - Confining the contract to existing as a cooperative agreement only limits NASA's flexibility in adjusting this relationship with time
    - Given the congressional definition of the cooperative agreement, the nonprofit role is somewhat unclear and redundant, and thus OLIA suggests replacing "cooperative agreement" with "arrangement," a less stringent phrasing, when citing the contract between NASA and the non-governmental ISSNL manager
2. **Clarification of NASA and nonprofit responsibilities**
    - NASA science and exploration research will fly under NASA allocation, rather than ISSNL allocation
3. **Removal of the prohibition on the ISSNL management nonprofit conducting activities unrelated to the ISSNL**
    - This prohibition limits the options of entities that can be considered for ISSNL management and constrains the business models of said entities
    - Instead of this prohibition, OLIA suggests a requirement that the nonprofit create a conflict-of-interest plan
4. **Removal of the requirement to establish a ISSNL Advisory Committee (INLAC)**
    - An INLAC has never been seated, but many of its responsibilities have been taken on by an established ISSNL User Advisory Committee, established based on IRT recommendations

This new act did not address the four updates suggested by OLIA, nor did it contain any other changes relevant to this study. That is, the current congressional requirements still stand, noting that OLIA will continue to propose yearly changes likely similar to those outlined above to anticipate future requirements.

Impact of Authorization Acts on this Study

The Authorization Acts are potentially a major limiting factor for NASA moving forward, for some models more than others. Considering the decommissioning of the ISS and the subsequent future of LEO, we see that many requirements set by the Authorization Acts will no longer be applicable. Congressional requirements for NASA will have to undergo some changes, particularly with regards to how the future LEO ecosystem will be established. NASA has an opportunity now to consider what updates to suggest for the expected second Authorization Act of the decade.

The following statements summarize whether a theme warrants concern with respect to the six LEO ecosystem models and, if so, how future NASA Authorization Acts need updates to maintain legality and congruence between NASA's plans and congressional requirements. Note that all direct references to the ISS will instead use language similar to "CLDs" or "LEO platforms," to reflect the transition from ISS usage to one of the new LEO models; this change will not affect intent of past acts.

1. ISSNL Management

1.1. Establishment and Operation of ISSNL

- This requirement is a significant consideration for the six models, both regarding language and intent.
- The language of a National Laboratory as it currently exists for the ISS is fairly flexible, with the 2005 Authorization Act stating, "the United States segment of the ISS is hereby designated a national laboratory."[1]
- A National Laboratory is undefined with reference to the ISS, and definitions that exist for other agencies are agency-specific.[1]
- With this flexibility, different components of each model could serve as a National Laboratory and the regulation around these determinations would need to be clarified in an upcoming Authorization Act.
- A National Laboratory could be space- or ground-based, depending on the LEO model.
- In the Anchor Tenant and Government Research Broker models, NASA could lease a space on a platform or conduct research on an orbital transport vehicle and dedicate some of that space to a National Laboratory.
- In the Matchmaker, Innovation Campus, and Institute Network models, the overseeing nonprofit could be the National Laboratory.
- In the Fee for Service model, NASA could coordinate research grants and data buys to serve as a National Laboratory.
- Regarding intent, Congress should evaluate if a National Laboratory is necessary to accomplishing national goals, or if activities currently conducted by the ISSNL could be more effectively completed through other means.[4]

1.2. Resource Split Between NASA and ISSNL

- The split of ISS resources equally between NASA- and ISSNL-run activities is a concern for all six models.
- Depending on whether a National Laboratory will be created and, if so, who will operate it, an even split of resources may not be possible or necessary.
- This requirement as it currently stands is overly restrictive and will become more so if NASA is no longer the sole overseer of U.S. LEO platforms, as would be the case in all six models.
- Congress should evaluate this intent and language and update Acts accordingly if there is a continued intent for such stringent resource sharing.

1.3. Cooperative Agreement

- The language used for describing the arrangement between the ISSNL operator and NASA is specifically a "cooperative agreement," but this phrase is restrictive and thus is a concern for all six models.
- If Congress decides to apply the intent of establishing a National Laboratory to future LEO ecosystems, this language should be updated to be more general, such as "arrangement," as is included in OLIA's recently proposed Authorization Act updates.
- In addition, OLIA's suggestion to remove the prohibition on the ISSNL management entity of non-ISSNL activities and replace it with a conflict-of-interest plan requirement could be problematic for the Institute Network model. This model relies on the ability of commercial companies to compete for contracts, so this particular attribute of congressional language would have to be rethought to ensure that this model could function as intended.
- If Congress does not confer this intent, then this language should be removed completely.

2. Science and Technology Goals

2.1. Scientific Research

- Future scientific priorities will be driven by the National Academies' decadal surveys, regardless of which model is adopted.
- As such, Congress should update language regularly in accordance with decadal findings.

2.2. Spaceflight Technology

- Requirements set by the Authorization Acts related to spaceflight technology are general and can be accomplished within the ecosystems of all six models.
- The only desired change in language is a clarification on past requirements regarding the Space Shuttle given its retirement in 2011.

2.3. Commercial Technology Development

- Past acts require that NASA take certain efforts toward commercial technology development and a commercial future in LEO, which will be realized within any of the six models.
- No updates are needed with respect to this theme.

3. ISS Documentation and Reporting

3.1. Science and Technology Plans

- Regardless of the model selected, science and technology plans mandated by Congress can be written and submitted.
- No updates are needed with respect to this theme.

3.2. Independent Review Teams

- All six models allow for independent review teams mandated by Congress to be established and produce a report.
- No updates are needed with respect to this theme.

3.3. ISS Organizational and Budgetary Reports

- None of the six models would hinder the writing or submission of organizational or budgetary reports.
- No updates are needed with respect to this theme.

4. Creation of an ISSNL Advisory Committee

- Though Congress instructed that an INLAC be established in the 2008 Authorization Act, it never was.
- Congress should reevaluate intent of requirements that fall under this topic.
- If the intent of establishing a National Laboratory remains post-ISS, the concept of an Advisory Committee should be replaced with a User Advisory Committee, as has occurred with the current ISSNL.[4]
- If a National Laboratory will not be established, language regarding the INLAC should be removed.

Conclusion

With the current legislation, the only viable model for the post-ISS LEO ecosystem is a reflection of the current ISSNL model, assuming the definition of the ISSNL merely transfers to a CLD or other designated platform. If NASA leadership prefers a different model or combination of models for future activities in LEO, NASA must propose legislative changes to Congress for consideration before the retirement of the ISS.

Appendix F: Acronyms

AFRL	Air Force Research Laboratory
ASGSR	American Society for Gravitation and Space Research
BPS	Biological and Physical Sciences
CASIS	Center for the Advancement of Science in Space
CLD	Commercial LEO Destination
CSDA	Commercial Smallsat Data Acquisition
CSP	Commercial Service Provider
DoD	Department of Defense
DOE	Department of Energy
EVA	extravehicular activity
FAA	Federal Aviation Administration
FFRDC	Federally Funded Research and Development Center
GAO	Government Accountability Office
GEO	geosynchronous orbit
INLAC	ISSNL Advisory Committee
IP	Implementation Partner
IRT	Independent Review Team
ISS	International Space Station
ISSNL	International Space Station National Laboratory
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope

LEO	low-Earth orbit
LSII	Lunar Surface Innovation Initiative
MII	Manufacturing Innovation Institute
MOU	memorandum of understanding
NASEM	National Academies of Sciences, Engineering, and Medicine
NIAC	NASA Innovative Advanced Concepts
NIH	National Institutes of Health
NRL	Naval Research Laboratory
NSF	National Science Foundation
OGA	other Government agency
OLIA	Office of Legislative and Intergovernmental Affairs
OSAM	on-orbit servicing, assembly, and manufacturing
OTPS	Office of Technology, Policy, and Strategy
RFP	request for proposals
ROI	return on investment
SBIR	Small Business Innovation Research
SDA	Space Development Agency
SMD	Science Mission Directorate
STEM	science, technology, engineering, mathematics
STRI	Space Technology Research Institute
TRISH	Translational Research Institute for Space Health
UARC	University Affiliated Research Center

Appendix G: Stakeholder Discussants

NASA

Name	Title, Affiliation
Camille Alleyne	Deputy Manager, Commercial LEO Development Program
Kevin Engelbert	Manager, In Space Production Applications (InSPA) Portfolio OZ/ISS Business & Economic Development Office
Jenn Gustetic	Director, Early-Stage Innovations and Partnerships
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Jacob Keaton	Senior Policy Advisor, ISS Division
John Kelly	Flight Opportunities Program Manager
Joe Kroener	Director, Partnership Office
Craig Kundrot	Director, SMD Biological and Physical Sciences Division
Alex MacDonald	Chief Economist
Phil McAlister	Director, Commercial Space Division
Elaina McGhee	Quality Engineer, Launch Services Program
Joel Montalbano	Program Manager, ISS
Julie A. Robinson	Deputy Director, SMD Earth Science Division

OGA

Name	Title, Affiliation
Brad Chedister	Chief Technology & Innovation Officer, Defensewerx

Name	Title, Affiliation
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Ronald Joslin	Program Director, Fluid Dynamics Program - Chemical, Bioengineering, Environmental and Transport System - NSF
Bernard Kelm	Superintendent, Spacecraft Engineering Division, NRL
Barry Kirkendall	Technical Director, Space - Defense Innovation Unit
John Labarge	Director, Office of Laboratory Policy, Office of Science - DOE
Lucie Low	Translational Partnerships Scientist, National Center for Advancing Translational Sciences - NIH
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Anonymous	FAA Office of Commercial Space Transportation
Jaime Stearns	Director, Space Vehicles Directorate, AFRL
Karl Stolleis	Program Manager, Autonomous Robotics - AFRL Space Vehicles Directorate
Paula Trimble	Policy Chief and Legislative Affairs Director, SDA
J.F. Turner	Technical Director, SDA, U.S. Space Force

Commercial

Name	Title, Affiliation
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Tejpaul Bhatia	Chief Revenue Officer, Axiom Space
Mary Lynne Dittmar	Chief Government & External Relations Officer, Axiom Space
Robbie Harris	Director of Advanced Concepts, Nanoracks

Name	Title, Affiliation
Christian Maender	Executive Vice President, In-Space Solutions, Axiom Space
David Marsh	Acting Director, George Washington Carver Science Park; Strategy Lead, Nanoracks
Rick Mastracchio	Director Of Business Development, Northrop Grumman Space Systems
Todd Mosher	Customer Experience Leader, Space Destinations - Blue Origin
Elizabeth Reynolds	Managing Director, Starburst Aerospace
Janice Starzyk	Vice President, Government Operations - Virgin Orbit
Erika Wagner	Senior Director, Emerging Space Markets - Blue Origin

Academic and Nonprofit Community

Name	Title, Affiliation
Matthew Bernards	Associate Professor of Chemical Engineering and Director of NASA Idaho Space Grant Consortium & Idaho NASA EPSCoR, University of Idaho
Elizabeth Cantwell	Chairperson of the Board, CASIS ISSNL
Keith Crane	Economist, Science and Technology Policy Institute - Institute of Defense Analyses
Pascale Ehrenfreund	President, International Space University; Research Professor, Space Policy & International Affairs at Space Policy Institute, George Washington University; President, Committee on Space Research
Rob Ferl	Distinguished Professor and Assistant Vice President for Research, University of Florida
Ray Lugo	Chief Executive Officer and Principal Investigator, CASIS

Name	Title, Affiliation
Douglas Matson	Chair of the ISSNL User Advisory Committee
Ian Miller	Chief Science and Innovation Officer, National Geographic Society
Alexander Moen	Chief Explorer Engagement Officer, National Geographic Society
Jim Pawelczyk	Associate Professor, Penn State; Board of Directors, CASIS ISSNL
Michael Roberts	Chief Scientist, CASIS ISSNL
Victoria Samson	Washington Office Director, Secure World Foundation
Steve Swanson	Distinguished Educator in Residence, Boise State University
Krystyn Van Vliet	Associate Provost and Associate Vice President for Research, Massachusetts Institute of Technology
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Appendix H: Acknowledgements

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Appendix I: Endnotes

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