

NASA's Plan for Commercial LEO Development

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Abstract—A robust and competitive low-Earth orbit (LEO) economy is vital to continued progress in space. The United States is committed to encouraging and facilitating the growth of the U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the next generation of new markets and innovation-driven entrepreneurship.

NASA has developed a long-term vision to achieve this goal where, one day, NASA will become one of many customers in low-Earth orbit. The plan was publicly unveiled on June 7, 2019 at Nasdaq in New York. This plan builds on, uses the capabilities of, and applies the lessons learned from over a decade of work and experience with commercial companies. This plan, entitled NASA's Plan for Commercial LEO Development [1], addresses how NASA will partner with industry to bolster supply of commercial LEO destinations, stimulate demand for new and emerging markets in LEO, and lays out near-term steps to achieve a robust economy in LEO.

In the near term, NASA developed and is implementing a five-point plan building on the work of the last two decades.

- 1) NASA established a commercial use and pricing policy for the International Space Station (ISS) that will enable companies to reduce uncertainty and build business plans as they seek to perform commercial activities, including marketing;
- 2) NASA has announced the intent to enable flight of private astronauts to the ISS with the first mission as early as 2020, including a solicitation as a mechanism to enable the assessment and approval of these missions;

- 3) NASA has initiated a process for developing commercial low-Earth orbit destinations, including the overall strategy, timeline, and solicitations for developing commercial destinations using the ISS Node 2 Forward Port, and free-flyer destinations;
- 4) NASA has laid out a plan to pursue opportunities to stimulate scalable and sustainable demand for LEO destinations including solicitations with calls for in-space manufacturing and regenerative medicine flight demonstrations, as well efforts to expand the pipeline of potential users and seeking innovative approaches to broadly stimulate demand;
- 5) NASA has updated a white paper quantifying the agency's long-term needs in LEO.

This paper provides an overview of NASA's plan and long-term vision for development of the LEO economy, and provides a summary of progress being made in each of the five areas of the plan.

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1. INTRODUCTION

NASA is opening the [International Space Station](#) [2] for commercial business, unleashing U.S. industry on the path to a commercial economy in low-Earth orbit. NASA will partner with industry to achieve this commercial economy as the agency moves full speed ahead toward its goal of landing the first woman and next man on the Moon by 2024. Commercial companies will play an essential role in establishing a sustainable presence in low-Earth orbit as well as on and around the Moon, working with NASA to test technologies, train astronauts and strengthen the burgeoning space economy.

A robust and competitive low-Earth orbit (LEO) economy is vital to continued progress in space. The United States is committed to encouraging and facilitating the growth of the U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the next generation of new markets and innovation-driven entrepreneurship. NASA has developed a long-term vision to achieve this goal where, one day, NASA will become one of many customers in LEO. This plan builds on, uses the capabilities of, and applies the lessons learned from over a

decade of work and experience with commercial companies.

This plan, entitled [NASA's Plan for Commercial LEO Development](#) [3], addresses supply, demand, and lays out steps to date that have been taken. It also includes detailed steps that will be taken in the near-term, mid-term, and long-term (see Figure 1 below). NASA utilized the recommendations provided by 12 companies from recent [market studies](#) [4] while developing this plan. The companies assessed the potential growth of a LEO economy and how to best stimulate private demand for commercial human spaceflight and other commercial and marketing activities in LEO.

NASA developed a five-part plan of near-term actions that will build on the work of the last two decades. These plans have all developed opportunities, policies and information that can be found on the NASA LEO Economy website at www.nasa.gov/leo-economy.

First, NASA established a commercial use and pricing policy (<https://www.nasa.gov/leo-economy/commercial-use-policy>) [5] for the International Space Station (ISS) that will enable companies to purchase ISS resources for commercial activities, thereby reducing uncertainty and allowing them to build business plans;

Second, NASA has announced the intent to allow companies to fly private astronauts to the ISS (<https://www.nasa.gov/leo-economy/private-astronaut->

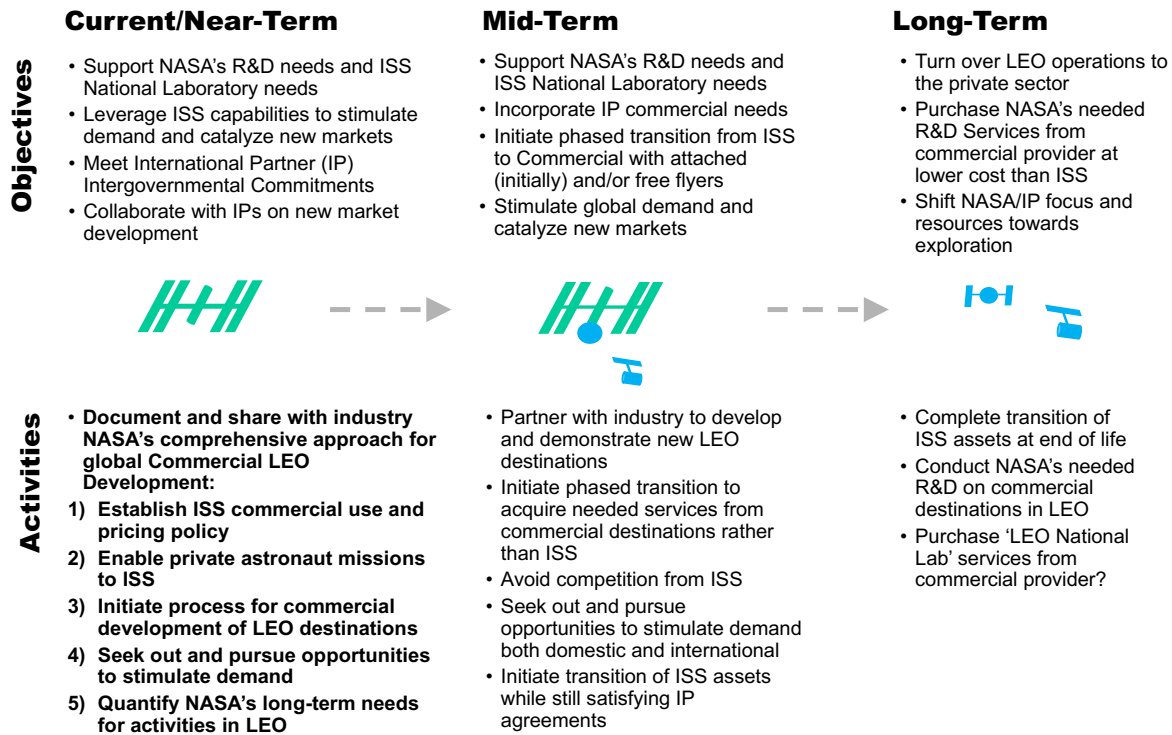


Figure 1. NASA's framework for commercial development of low-Earth orbit moves towards a robust economy in which NASA purchases services as one of many customers

[missions](#)) [6] with the first mission as early as 2020;

Third, NASA has initiated a process for developing commercial LEO destinations, including the overall strategy, timeline, and solicitation releases in 2019 of the ISS Node 2 Forward Port to be followed by a solicitation for a free flying platform;

Fourth, NASA has laid out a plan to pursue opportunities to stimulate demand (<https://www.nasa.gov/leo-economy/opportunities-to-stimulate-demand>) [7], including two ISS Utilization NRAs with calls for demand stimulation ideas as well as a call in the NextSTEP2 BAA Appendix J;

And Fifth, NASA has updated a [white paper providing quantification of the agency's long term needs in LEO](#) [8].

The overall framework for NASA's commercial LEO development plan is shown in Figure 1, with the five-part near term plan highlighted in the bottom left of the figure.

2. BACKGROUND

A robust and competitive commercial space sector is vital to continued progress in space. The United States is committed to encouraging and facilitating the growth of the U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship. NASA recognizes that to financially sustain a commercial platform in low-Earth orbit (LEO), developing new markets beyond the traditional research and technology development market will be required. While NASA will always have a requirement to train crews, perform fundamental and applied research, and develop technology in LEO, if NASA is to achieve its goal of becoming one of many customers of a platform after ISS end of life, a targeted strategy for enabling the development of a robust, sustainable commercially-driven economy in LEO is required.

More than 50 companies already are conducting commercial research and development on the space station via the [International Space Station U.S. National Laboratory](#) [9], and their results are yielding great promise. In addition, NASA has worked with 11 different companies to install 14 commercial facilities on the station supporting research and development projects for NASA and the ISS National Lab. Opportunity exists to move projects beyond research and development into manufacturing and production. A new [NASA directive](#) [10] enables commercial manufacturing and production, allows both NASA and private astronauts to conduct new commercial activities aboard the orbiting laboratory, and sets commercial prices for use of U.S. government resources in pursuit of commercial and marketing activities aboard the International Space Station.

In addition to its primary mission to enable exploration and research, the space station is uniquely poised as a testbed and proving ground for new markets, innovative new technologies and systems that will enable the development of a robust economy in low-Earth orbit.

As the Agency pursues its mission to move beyond low-Earth Orbit (LEO) to deep space exploration, we must find new ways to maintain access to LEO to fulfill NASA's needs to conduct research, advance new technologies, and train astronauts. As the International Space Station is planned to be the last U.S. government-led crewed LEO platform, the Agency has developed a comprehensive strategy to ensure that a commercially-driven access to LEO is enabled. The 2018 NASA Strategic Plan defines NASA's vision for LEO as a self-sustaining, space-based marketplace that provides economic benefits to the nation and societal benefits to all people. The vision is one where NASA is one of many customers of privately-owned, human-tended or permanently-crewed platforms supported by U.S. crew and cargo transportation capabilities that enable a variety of activities in LEO.

The President's 2020 Budget:

- Drives toward a vibrant, U.S.-led economy in earth orbit. The budget provides funding for the International Space Station as well as for new commercial space capabilities that will facilitate a transition to a more robust and cost-effective approach to human space activities near the Earth. By 2025, the budget envisions commercial capabilities on the International Space Station as well as new commercial facilities and platforms to continue the American presence in Earth orbit.

It is the sense of Congress that “an orderly transition for United States human space flight activities in low-Earth orbit from the current regime, that relies heavily on NASA sponsorship, to a regime where NASA is one of many customers of a low-Earth orbit commercial human space flight enterprise may be necessary.”

- P.L. 115-10, NASA Transition Authorization Act of 2017

Over the past several years, numerous pieces of legislation have enumerated LEO commercialization goals and direction for the Agency. Congress provided guidance in the NASA Transition Authorization Act of 2017, reaffirming that commercial use of the ISS supports NASA's mandate to “seek and encourage, to the maximum extent possible, the fullest commercial use of space,” as stated in Title 51 United States Code (U.S.C). § 20112(a)(4). The following excerpts relate directly to commercial utilization of the ISS:

- Title III, Section 301 (a)(4) - “utilization of the ISS will sustain United States leadership and progress in human space exploration by” – (A) “facilitating the

commercialization and economic development of low-Earth orbit"; and

- Title III Section 303 (b)(1) - "an orderly transition for United States human space flight activities in LEO from the current regime, that relies heavily on NASA sponsorship, to a regime where NASA is one of many customers of a LEO commercial human space flight enterprise..."

The FY20 President's Budget Request further promotes NASA's efforts to assist commercial space industry in developing a long-term, sustained commercial LEO presence. The Budget Request recommends that NASA's efforts focus on enabling industry to develop and deploy commercial platforms in LEO.

NASA awarded 12 companies a [contract to conduct a 4-month study](#) [11] on the commercialization of LEO and ISS transition. Companies spanned a broad range from independent market consulting firms, transportation providers, future habitat suppliers, and market demand service providers. The study objectives were to evaluate business plans, review market data and concepts for commercial habitable platforms in LEO, using ISS or that are free-flying. ISS transition concepts were also requested as well as recommendations for the government.

The results varied extensively on the configuration of a commercial habitable platform, the commercial offering, timing and schedule, the government funding or contribution of infrastructure required and the minimum government purchase of services. The key findings included the following points.

- Commercial LEO human spaceflight destinations are only viable with significant U.S. government investment and purchase of services. NASA is expected to be a primary tenant at least initially.
- NASA astronaut habitation and government research and development is the largest near-term market for revenue with foreign country astronaut habitation being the next largest market.
- It was not clear from the studies if the market is strong enough to support more than one LEO destination at this time. Some studies did not find a business case for even one destination. There was a risk identified that the commercial LEO destination may eventually need more NASA investment or service purchases than initially anticipated if the demand does not develop as expected.
- Crew and cargo transportation costs are the major barrier to economic development of LEO and if not reduced, affect both the commercial LEO destination costs and market demand.
- Future NASA costs for LEO include crew and cargo transportation, rent to a landlord station, research costs and government funding for habitat development.

- High crew and cargo transportation costs to/from LEO negatively affect both station costs and commercial market demand
 - Transportation costs make up a very large portion of the cost of a space station over time – on the order of 2/3 of annual costs are spent on crew and cargo missions
 - A reduction in the seat cost to transport tourists to orbit from 10's of millions of dollars down to a few million dollars could significantly increase the number of potential tourists that can afford a trip
 - The cost is very high to transport raw materials into space, convert them into something else (such as fiber optics) and return them to the ground – so the end product must sell at a very high price
- Continuing ISS use over the next few years supports commercial industry growth
- Businesses want to use ISS directly, for example by attaching a commercial module to an ISS port, or if free-flying, they prefer to be co-located in orbit near ISS

The studies identified key market areas that are anticipated to generate revenue for commercial destinations, as summarized below.

- Accommodations – sleep stations, toilet, galley, etc. for tourists or foreign/US governments
- Research & Development – use of facilities or space and power/utilities for customer facilities, and possibly commercial crewmember time to conduct experiments
- In-space manufacturing of unique materials or products – use of facilities or space and power/utilities
 - Items made in space and then sold on the ground: For example, fiber optics
 - Items made in space for on-orbit use: For example, parts for maintaining or assembling spacecraft
- Entertainment – films, documentaries, sporting events
- Sponsorship and Advertising
- Transportation of people and cargo to/from Low Earth Orbit
- Large Structure and Satellite Assembly

Some additional observations from the studies are summarized below.

- Commercial market predictions vary, making forecast difficult
 - The markets are emerging – some might 'take off' and some might fail
 - Competition for revenue includes terrestrial, parabolic/sub-orbital flights, and other space stations (commercial or non-U.S.)
- Early on, NASA's use of and payment to destinations will be a key enabler for the emerging commercial market
- Studies generally assumed some number of NASA crew in Low Earth Orbit at all times, and NASA would

pay ‘rent’ to a landlord Destination to accommodate them

- Because NASA has a need for microgravity research and exploration testing in Low Earth Orbit in the future, many studies assumed their destinations housed U.S. government research

These studies were critical to helped shape this strategy for commercial LEO development. Summaries of the 12 studies are available online, including each of the 12 [one-page summary charts](#) [12], as well as the [executive summary](#) [13] for each study.

For nearly two decades, as summarized in Figure 2, NASA has been moving from purchase of hardware and vehicles to purchase of services to support the government’s needs. Initially, NASA experimented with acquisition strategies through the purchase of non-essential services for ISS, such as the acquisition of water production capabilities through United Technologies Corporation.

NASA moved on to stimulate the development of critical cargo delivery systems through the Commercial Orbital Transportation Systems Program which led to the development and purchase of commercial capabilities to provide Cargo Resupply Services for the International Space Station. This highly successful program resulted in the development of two U.S. cargo delivery capabilities which

have provided over 70 tons of cargo to ISS over the past 7 years.

A little more than two years after the end of the Space Shuttle Program, SpaceX and Northrop Grumman (formerly Orbital ATK) began successfully resupplying the space station with cargo launched from the United States. The companies developed the rockets and spacecraft through public-private partnerships under the agency’s Commercial Orbital Transportation Services (COTS) program, an initiative that aimed to achieve safe, reliable and cost-effective commercial transportation to and from the space station and low-Earth orbit. The companies are successfully resupplying the space station, and more missions to deliver scientific investigations and cargo are planned. This partnership changed the way NASA does business and strengthened the American commercial space industry while restoring American capability to deliver and return ISS cargo.

NASA continued along this path by purchasing research capabilities as they became commercially available from over 10 commercial companies with their own hardware on the ISS. These research capabilities provided NASA a cost-effective means to expand on the research pipeline at reduced costs. Additional companies continue to develop hardware and provide state of the art research capabilities on the ISS today.

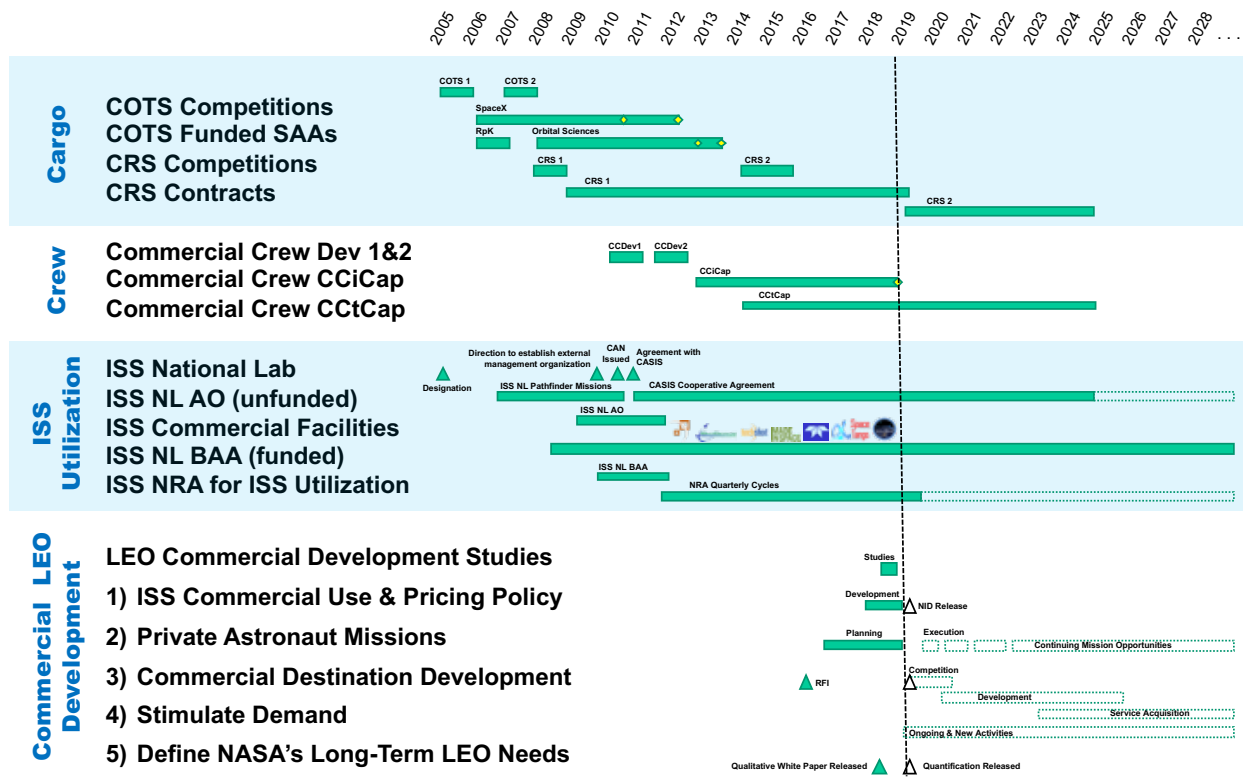


Figure 2. For nearly two decades NASA been laying the groundwork to enable the commercial development of low-Earth orbit

When NASA retired the space shuttle, not only was its cargo capability lost, America lost the ability to provide humans routine access to space. NASA's Commercial Crew Program (CCP) was formed to facilitate the development of a U.S. commercial crew space transportation capability with the goal of achieving safe, reliable and cost-effective access to and from the International Space Station and low-Earth orbit. CCP has invested billions of dollars in multiple American companies that are designing and developing these transportation capabilities. In 2010, NASA invested a total of nearly \$50 million of the American Recovery and Reinvestment Act (ARRA) funds for Commercial Crew Development to stimulate efforts within the private sector to aid in the development and demonstration of safe, reliable and cost-effective crew transportation capabilities. It included the development and maturation of systems and subsystems, such as a spacecraft, launch vehicle, launch abort systems, environmental control and life support system, launch vehicle emergency detection systems and more. By supporting the development of these human spaceflight capabilities, NASA laid the foundation for future commercial transportation capabilities.

The United States is committed to encouraging and facilitating the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship. NASA is preparing to secure the nation's long-term presence in LEO by partnering with industry to develop commercial enterprises and capabilities for this transition that will stimulate and utilize private demand while supporting NASA's long-term needs in LEO.

Commercial LEO Development builds on, uses the capabilities of, and applies the lessons learned over the last nearly two decades of working towards a commercial LEO ecosystem.

3. ISS COMMERCIAL USE AND PRICING POLICY

The International Space Station (ISS) is a unique orbiting platform that enables researchers from all over the world to put their talents to work on innovative experiments that could not be done anywhere else. Having proven its value as a platform for a broad array of research disciplines as well as technology development, the ISS also provides an ideal opportunity to test new business relationships. This allows an opportunity to shift from a paradigm of government funded, contractor-provided goods and services to a commercially provided, government-as-a-customer approach. To help enable commercial markets and future commercial destinations in low-Earth orbit (LEO), the ISS provides a unique opportunity to test and nurture emerging markets. However, the scope of commercial activities undertaken on ISS in the past has been primarily limited to commercial R&D through the ISS National Laboratory. To

go beyond R&D and open new opportunities in areas such as manufacturing for-profit, marketing and tourism, NASA needs to open the aperture of allowable activities aboard the ISS.

NASA has addressed this need by the development of the [NASA Interim Directive on Use of International Space Station for Commercial and Marketing Activities](#) [10].

NASA seeks to achieve a continuous U.S. human presence in low-Earth orbit (LEO) – both with government astronauts and with private citizens – in order to support the utilization of space by U.S. citizens, companies, academia, and international partners and to maintain a permanent American foothold on the nearest part of the space frontier. This document supports this goal by establishing NASA International Space Station (ISS) Program policies governing Commercial and Marketing Activities using the U.S. Government (USG) Modules with the intent of catalyzing and nurturing new emerging markets leading to a commercial economy in LEO.

It outlines NASA's plans to enable commercial and marketing activities by including:

- Policies and requirements that must be followed for commercial and marketing activities,
- Pricing of NASA resources in order to stimulate an emerging market, thus not reflective of NASA's full costs,
- Regular review (at least semi-annually) of stated prices and amount of allocated resources,
- A supply of resources committed by NASA for commercial for-profit and marketing activities, and a limit on resources any one commercial entity can acquire annually, to enable market competition, and
- Initially, NASA is making available five percent of its allocation of utilization resources (as illustrated in Figure 3) to stimulate the commercial for-profit market, in the following categories:

<u>Resource</u>	<u>Annual Available</u>	<u>Annual limit per entity</u>
Cargo up*	175 kg	50 kg
Trash disposal*	175 kg	50 kg
Cargo returned*	125 kg	35 kg
Crew time	90 hrs	25 hrs

** Only passive cargo is available for purchase; no cold stowage or late load accommodations are available at this time.*

For activities other than research and development, those activities must comply with the following:

1. Shall be consistent with all U.S. laws and regulations;

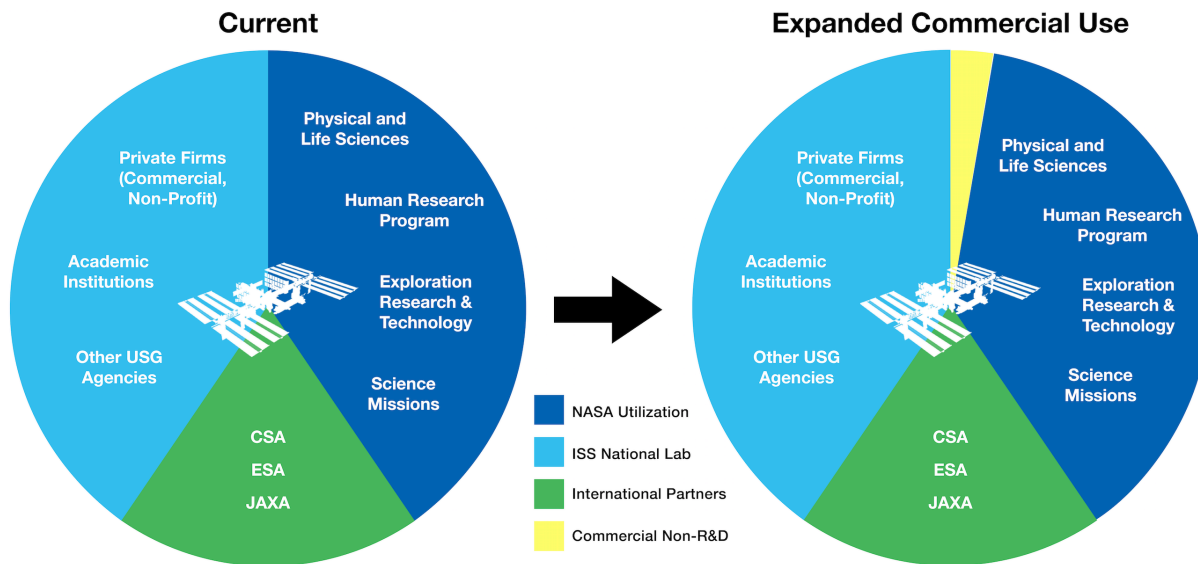


Figure 3. NASA will make available 5% of the NASA utilization.

2. Shall not compromise the safety of NASA civil servant or contractor personnel, NASA facilities, ISS Crew Members, ISS Modules, or on-orbit vehicles;
3. Shall not reflect unfavorably on NASA, any ISS Partner, or related entity;
4. Shall be subject to the IGA, MOUs and implementing arrangements, and related obligations to the ISS Partners;
5. Shall respect the intellectual property rights (including rights of publicity) of NASA, U.S. Entities, ISS Crew Members, ISS Partners, or any of their related entities;
6. Shall only task USG Astronauts and other USG personnel with duties consistent with the Standards of Ethical Conduct for Employees of the Executive Branch, 5 C.F.R. Part 2635, and all other applicable USG ethics requirements;
7. Shall be executed through an arrangement with a U.S. Entity or NASA;
8. Shall adhere to the Code of Conduct for International Space Station Crew;¹
9. Shall not imply or suggest NASA or USG endorsement for any Commercial Activity;
10. Shall not use any image(s) of the NASA insignia or emblem, or other material(s) that could imply that the Commercial Activity is endorsed or supported by NASA;
11. Shall not use any corporate name(s), logo(s), or trademark(s) depicted in marketing activities without permission.

AND one of the of the following must apply:

1. Require the unique microgravity environment to enable manufacturing or production or development of a commercial application; or
2. Have a nexus to the NASA mission;² or
3. Support the development of a sustainable low-Earth orbit economy.

4. PRIVATE ASTRONAUT MISSIONS

NASA has outlined a broad strategy to facilitate the commercialization of low-Earth orbit (LEO) by United States (U.S.) companies. As part of that strategy, NASA plans to enable private astronaut missions to the ISS. NASA defines a private astronaut mission as a commercial mission consisting of activities to be conducted on the ISS (or in a commercial segment attached to the ISS) by private astronauts, transported on a commercial launch vehicle dedicated to this private mission.

Building a robust economy in low-Earth orbit will depend on routine and affordable access to space for humans and cargo. NASA has partnered with Boeing and SpaceX through the commercial crew program to develop the capability for human access to space. The current market for these vehicles is limited to transporting NASA's astronauts to the ISS. NASA's accommodation of private astronaut missions to the ISS enables an expanded market opportunity for these commercial service providers. Such missions also expand the scope and amount of commercial activities that can be done at the ISS while the passengers from the private astronaut missions are at the ISS.

¹ Code of Conduct for International Space Station Crew, 14 Code of Federal Regulations (C.F.R.) § 1214.4 [14]

² See 51 U.S.C. § 20102. Congressional declaration of policy and purpose; can be accessed online at <http://uscode.house.gov/statviewer.htm?volume=124&page=3330> [15]

NASA is enabling private astronaut missions to the International Space Station, with the first as early as 2020. Those missions will be privately funded, dedicated commercial spaceflights allowing approved commercial activities to be conducted in space. Private astronaut missions will use a U.S. spacecraft developed under NASA's [Commercial Crew Program](#)³ [16]. Meeting any regulatory requirements for flying private astronauts to space will be the responsibility of the commercial company conducting the mission.

Market studies identified private astronaut missions to low-Earth orbit as a key element to demonstrate demand and reduce risk for future commercial destinations in low-Earth orbit. NASA can accommodate up to two short-duration private astronaut missions per year to the International Space Station, if supported by the market.

The commercial entity developing the mission will determine the crew composition and ensure private astronauts meet NASA's medical standards and training and certification procedures for International Space Station crew. A private astronaut assigned to a mission on the space station will have the ability to fulfill duties that fall into the approved commercial and marketing activities outlined in the directive released today. A new private astronaut missions focus area issued to the [NASA Research Announcement](#)⁴ [17] is providing the path for those future missions.

Additionally, NASA will encourage foreign governments to work through U.S. companies.

NASA achieves many benefits for development of the LEO economy through private astronaut missions, including:

- Allows commercial industry to purchase commercial services and gain insight into the costs associated with owning and operating own platform in the future,
- Reduces market risk to commercial LEO destination developers by demonstrating market,
 - Non-government human missions to LEO were identified by LEO Development studies as a key market element for future commercial LEO destinations,
- Expands range of commercial activities that can be performed on ISS,
 - New commercial use policy in development identifies activities that can be performed by private astronauts but not by NASA astronauts,
- Potential to increase flight rate and strengthen market for commercial crew launch service providers, and
- Potential to increase available crew time on orbit for NASA, commercial, and other R&D activities.

³ <http://www.nasa.gov/commercialcrew>

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<https://nspires.nasaprs.com/external/solicitations/summary.do?solId=%7b21E0270C-BC1F-EFC4-3D87-30713B5FF373%7d&path=&method=init>

5. COMMERCIAL LEO DESTINATIONS

In order to cost-effectively meet NASA's long-term research and technology development needs in low-Earth orbit (LEO), a robust commercial human spaceflight economy must be established including commercial destinations and new markets such that NASA can be one of many customers of a broad portfolio of commercial products and services. Development and operation of a commercial destination to provide those services will require significant private investment over many years and significant non-NASA demand to ensure long-term financial viability. NASA will partner with industry to help enable industry to develop one or more commercial destinations that can meet NASA's long-term needs in LEO.

One of the consistent themes that came through from the recent industry studies on commercial development of LEO (section A.3) was that development of commercial destinations is unlikely without NASA playing a significant role due to the high uncertainty of markets, and the high cost of developing and operating such systems. NASA's plan for commercial LEO development is intended to catalyze and nurture new commercial markets, thereby significantly reducing uncertainty and risk for commercial development. Furthermore, NASA is seeking to make full use of ISS to provide a foothold for these nascent markets, and partner with industry to develop commercial destinations in LEO.

In the long-term, NASA's goal is to become just one of many customers purchasing services from independent, commercial free-flying habitable destinations in low-Earth orbit. A robust low-Earth orbit economy will need multiple commercial destinations, and NASA is partnering with industry to pursue dual paths to that objective that either go through the space station or directly to a free-flying destination. To help reduce risk and uncertainty for development of commercial destinations, NASA is seeking to partner with industry by providing access to NASA resources, a forecast of NASA demand for future services, and funding towards capability development.

As a first step, NASA is making one space station port available for industry to attach a commercial module to support commercial activities, and released a solicitation as Appendix I in NASA's Next Space Technologies for Exploration Partnerships (NextSTEP) 2 Broad Agency Announcement (BAA). NASA received proposals in September, 2019. The forward port of the station's Harmony module will be available to industry for a finite period of time. International Space Station utilities will be made available along with the port. NASA seeks to consider approaches that will enable one or more partners with sequenced access to the port if desired.

To partner with industry for the development of future free-flying commercial stations in low-Earth orbit, NASA followed up with a solicitation for NextSTEP 2 Appendix K that was released in draft form in October, 2019. NASA

also plans to make available other resources that industry may request, potentially including use of existing hardware on ground or in space (transitioned from ISS). NASA is making available long-term demand projections for future services that can reduce uncertainty as to the types and amount of services NASA intends to acquire in the future. This forecast is discussed in section 7 of this paper. Finally, NASA plans to provide funding towards demonstration of commercial services and capabilities in partnership with industry.

The attributes that NASA is seeking for these partnerships with industry include the following:

- NASA is not taking delivery of hardware or services at this time,
- NASA intends to continue to let providers maintain as much ownership of their data and invention rights as possible,
- NASA intends to treat the commercial destination developers as partners and not suppliers,
- Minimize industry and investor uncertainty and reduce risk of commercial failure, and
- Performance-based milestones in order to obtain NASA funding.

Continued NASA involvement in LEO will continue to foster expansion of knowledge of human physiology implications of spaceflight while continuing to stimulate STEM. Fostering commercialization of LEO will lead to more jobs as new industry is created along with new technology development to benefit life on earth. Creation of commercial destinations is intended to decrease NASA's costs for activities in LEO, freeing up dollars for exploration objectives.

6. STIMULATE SUSTAINABLE DEMAND

In order to financially sustain a commercial platform in low-Earth orbit (LEO), NASA is interested in developing new markets beyond the traditional research and technology development market and reducing the cost and technical barriers for access to LEO. If NASA is to achieve its goal of becoming one of many customers of a research platform post-ISS, a targeted strategy for enabling the development of a sustainable, scalable, and profitable non-NASA demand for LEO services must be implemented.

The traditional grant-funded research demand for LEO services has proven over many years to require substantial subsidies from NASA, including fully-subsidized up mass, crew time, on-orbit accommodations, power, data, etc. It is highly unlikely that future NASA budgets will be sufficient to pay virtually all of the operating costs of a commercial platform. Therefore, NASA must enable the development of high-value capabilities during the remaining life of the ISS, using its subsidized resources. Additionally, transportation costs have been identified as the limiting factor in fostering the long-term growth of new and emerging markets for commercial activities in LEO,

particularly for human-rated commercial destinations. By reducing cost and technical barriers for access, industry can reach profitability sooner.

To help stimulate sustainable demand, NASA has expanded the [International Space Station Utilization NASA Research Announcement \(NRA\)](#) [17] to request proposals from U.S. industry for commercial concepts with a focus on the areas of in-space manufacturing and regenerative medicine/bioengineering, and will also consider other fields that may lead to a scalable, financially self-sustaining demand for LEO capabilities.

Successful ventures will further mature concepts with potential for scalability, such as returning high-value items for terrestrial use, capturing sizeable markets or creating new markets, and disrupting existing technologies by taking advantage of the International Space Station (ISS), and eventually follow-on human-rated destinations in LEO. NASA seeks concepts that, if successful, will utilize a breadth of LEO capabilities: they will benefit from the scalability that commercial platform(s) can provide; their transportation needs will support the growing U.S. crew and cargo launch industry; and their presence on commercial platforms will strengthen the LEO ecosystem that NASA seeks, as one of many customer(s) of the commercial platform(s).

NASA also released Appendix J to the Next Space Technologies for Exploration Partnerships (NextSTEP-2) Broad Agency Announcement (BAA) to request proposals from U.S. entities that have innovative approaches to broadly stimulating demand. Such approaches could focus on: reducing transportation costs to and from LEO destinations; understanding the transportation-driven price elasticity of demand for existing and potential LEO commercial markets; opportunities to broaden the base of industry, academia, and government researchers seeking to utilize LEO capabilities (e.g. through reducing real or perceived barriers to entry, and broadening the pipeline of researchers by realizing synergies with feeder capabilities including drop-towers, parabolic flights, sounding rockets, suborbital flights, etc.); or other approaches that identify innovative opportunities to foster long-term market growth.

Successful proposals will define the path by which the identified solutions broadly foster market growth, provide data-driven rationale to support the defined path to reducing transportation costs, and lead to recommendations on which NASA, industry or other organizations could act. NASA seeks proposals that, if successful, will: strengthen NASA's insights into opportunities for reducing cost and technical barriers to enable space market growth; identify actionable recommendations, and lead to a strong LEO ecosystem with NASA as one of many customers of commercial transportation and destination(s) in LEO. Proposals must include an identification and assessment of specific cost and technical barriers and potential markets they intend to foster.

Successful flight demonstrations of in-space manufacturing will allow companies to develop their “minimally viable product”, allowing them to raise private capital necessary to scale their on-orbit production capabilities. This allows them to become a customer of a LEO platform, sharing the operating costs of the platform with NASA and other customers, driving down the costs to NASA for using the platform. It also creates revenue, leading to job growth and adds fuel to the U.S. economy.

7. QUANTIFY NASA’S LONG-TERM NEEDS

In order for commercial platform and services providers to define capabilities and project viable business cases, they need to understand what capabilities and services that NASA intends to purchase in LEO as one of many customers.

NASA provided a [forecast of its minimum long-term, low-Earth orbit requirements](#) [8], representing the type and amount of services that NASA intends to purchase in the future when those services become commercially available. The goal is to reduce uncertainty for commercial destination providers about NASA as a customer, and to help them make business case decisions about which parts of the NASA demand they are interested in pursuing. NASA provided details and estimated quantities for NASA crew accommodation, human research, biological and physical science research, technology demonstrations, and hosted science instruments. In addition, NASA intends to continue to purchase services for a national laboratory capability in low-Earth orbit.

Publishing this forecast allows NASA long-term LEO requirements needed for exploration missions to be met by commercial platforms. It signals to U.S. industry and commercial partners the likely sources of NASA LEO human spaceflight demand in the future. It also ensures an ongoing LEO National Lab capability for use by other government agencies, academia, and to incubate promising commercial applications that could enable new markets and U.S. competitive industry as well as benefits to humanity. Without defining NASA’s ongoing needs, the capabilities and services offered by commercial providers may be limited such that NASA will not be able to fully transition off the ISS, or put its ongoing exploration missions at risk.

8. SUMMARY

NASA has prepared, released, and initiated the execution of a comprehensive plan to achieve the goal of a robust economy in low-Earth orbit in which NASA will be one of many customers. Since rolling out the plan in June of 2018, the Agency has made good progress in its execution of the plan including multiple solicitations that lay the foundation for key industry partnerships going forward. NASA is setting the table to enable the LEO economy, but achieving the vision will be dependent on the innovation and entrepreneurship of the private sector.

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BIOGRAPHIES



Douglas A. Comstock is leading NASA's efforts for development of the low-Earth orbit economy in the Human Exploration and Operations Mission Directorate. He previously served as the Agency's Deputy Chief Financial Officer for Integration, and as Director of Cost Analysis in NASA's Office of Evaluation. His previous roles also included directing NASA's Innovative Partnerships Program, he served as the NASA comptroller for two years, and he was the founding director of the Strategic Investments Division. Before coming to NASA, Doug was a program examiner for NASA's Human Spaceflight, Biological and Physical research, and personnel activities at the Office of Management and Budget, serving two years in the Clinton administration and two years in the George W. Bush administration. His fifteen years of industry experience prior to entering government service includes leading the engineering & program management division at Futron Corporation, and advanced concepts and preliminary design at General Dynamics Space Systems. He holds undergraduate degrees in Mechanical Engineering and Architecture from the University of Washington, and graduate degrees in Aeronautics & Astronautics as well as Technology & Policy from MIT.



Robyn Gatens is the Deputy Director of the International Space Station Division in the Human Exploration and Operations Mission Directorate at NASA Headquarters. In addition, she is the agency's Systems Capability Lead for Environmental Control and Life Support Systems and Crew Health Systems, leading a team of system-specific subject matter experts from across the agency. Ms. Gatens has more than 30 years of experience in development and management of the systems and processes that support human life in space, everything from water recycling and reuse to the air astronauts breathe. At Headquarters, Ms. Gatens has led agency strategic and budget planning to mature the life support and environmental monitoring technologies needed for future deep space exploration missions, using the ISS as a demonstration testbed. As part of her role as ISS Deputy Director, Ms. Gatens is engaged in NASA's strategic planning to enable a successful, long-term private sector space economy in Low Earth Orbit by leveraging the ISS. She began her NASA career in 1985 at the Marshall Space Flight Center in Huntsville, Alabama. She held various leadership positions at Marshall, including Manager for the Orion Crew Support and Thermal Systems before transferring to NASA Headquarters in

2012. Ms. Gatens is the recipient of NASA's Outstanding Leadership and Exceptional Achievement Medals, and holds a Bachelor of Chemical Engineering degree from the Georgia Institute of Technology.



Christie Cox works for the International Space Station (ISS) Division in Human Explorations and Operations (HEO) Mission Directorate as the Utilization and Commercial Use Manager at NASA Headquarters in Washington DC. She supports ongoing research as well as commercialization of low-Earth orbit strategic planning. Christie has worked for the ISS program for over 10 years, including working as an Environmental Control and Life Support Systems (ECLSS) project manager, subsystem manager for the Oxygen Generation System (OGS) and most recently, the Strategic Flight Planning Lead at the Johnson Space Center. She received her B.S. in Aerospace Engineering from the University of California at San Diego.



Jacob L. Keaton is a Senior Policy Advisor in the International Space Station Division in the Human Exploration and Operations Mission Directorate at NASA Headquarters. He conducts strategic planning and provides policy analysis for the International Space Station Program, including in areas such as ISS transition, low-Earth orbit commercialization and use policies, science mission development, and commercial resupply, including coordination and execution with the Executive and Legislative branches.



Marybeth Edeen is the Manager of the Research Integration Office in the International Space Station (ISS) Program which is responsible for enabling all research and technology development on the ISS. This includes research sponsored by NASA and other government agencies as well as commercial and non-profit use which takes advantage of the ISS being a National Lab. After joining NASA in 1989, she worked on Advanced Life Support System development and ISS Environmental Control and Life Support Systems. Ms. Edeen holds a BS in Chemical Engineering from the University of Texas and a Masters in Chemical Engineering from Rice University.



Mike Read is the Manager of Commercial Space Utilization in the International Space Station (ISS) Program. He is Responsible for enabling a broad commercial participation in low-Earth orbit leveraging the assets and infrastructure of the International Space Station. Leads

the effort to develop new research capabilities onboard the ISS via commercial (not traditional government-contractor) relationships. Assists new participants in seeing possibilities and performing feasibility assessments in order to fully exploit the ISS as a platform not only for research and technology development, but also as a proving ground for new business partnerships. He holds a BS in Business Administration from Kansas State University and a Master of Public Administration degree from Wichita State University.



David H. Korth is currently the Deputy Manager of the ISS Systems Engineering and Integration Office at Johnson Space Center. Previously, Mr. Korth served as an ISS Flight Director (“Odyssey Flight”) for 8 years leading ISS Expeditions 21, 22, and 37 and several visiting vehicle missions and US EVAs including

USOS EVA 23 (water in the helmet). Previously, Mr. Korth spent 14 years as a flight planner for both Space Shuttle and ISS. Mr. Korth holds a BS in aerospace engineering from Texas A&M University (1990) and an MS in Statistics from University of Houston – Clear Lake (2017).