An Emerging Marketplace: Low Earth Orbit and the International Space Station

Mr. Sam Scimemi[*]

Low Earth orbit, as seen from the International Space Station in July 2014.

The United States has announced plans to continue supporting the International Space Station (ISS) through at least the year 2024. NASA, working with the other ISS International Partners, will continue to foster greater use of the ISS platform, for both research and commercial activities, while using the ISS as a base for expanding the commercial use of low Earth orbit (LEO). In the United States, NASA remains the primary supplier of capabilities and

[*] Director, International Space Station, National Aeronautics and Space Administration, Washington, D.C., USA, sam.scimemi@nasa.gov

services in LEO, such as habitation systems, power, cooling, crew health equipment, upmass and sample return, research facilities, cold stowage, crew time, and data transmission. Access to LEO for ISS cargo has already been transitioned from a primary government activity to a commercially supplied capability through the development and operations of the Commercial Cargo Services providers. NASA is in the process of developing commercial crew transportation system capabilities also in support to the ISS. It is the goal of NASA to evolve these systems and capabilities through the ISS Program in such a way that they will support market driven commercial research, as well as NASA's long-term exploration plans. NASA will continue to make investments in these areas through at least 2024 to ensure continue access to LEO. This paper will examine the intersection of the growing commercial transportation and research markets, as well as the ways in which the transition from government to commercial activity in LEO might unfold.

The International Space Station: a Government Outpost Ready for Transition

The International Space Station (ISS) is humanity's outpost in low Earth orbit. Possessing more electrical power, crew time, data transfer capabilities, and experiment and research housing than any space vehicle in human history, the ISS is the anchor tenant of this most accessible region of space. Occupied continuously from November 2, 2000, through today, the ISS has hosted more than 200 people from 15 countries, and represents the largest and most complicated international engineering effort ever attempted. The pressurized crew modules, built in the United States, Japan, Europe, and Russia, launched onboard the U.S. Space Shuttle and Russia's Proton vehicle, were assembled on-orbit by spacewalking crews using a Canadian robot arm; most of the modules had never met on the ground, and every one connected successfully in space. The amount of crew time available for research aboard the ISS is already equal to every other human spaceflight program in history, worldwide, combined, and will more than double that amount over the next decade, with operations continuing through at least 2024. However, until now, the ISS has been a primarily government undertaking. This is beginning to change dramatically.
NASA's mission on the ISS encompasses four main areas:

- Research many science disciplines aboard this space laboratory
- Establish a global partnership for future exploration beyond Earth
- Serve as a technology development testbed for deep space exploration
- Grow a commercial marketplace in space

This paper will primarily address the fourth area: the ways in which the International Space Station is facilitating the growth of a robust commercial market in low Earth orbit for scientific research, technology development, and human and cargo transportation. The ISS will show that LEO is an emerging marketplace, ripe for commercial development and utilization.

Recent Activities in the Commercialization of Low Earth Orbit

While launch vehicles have traditionally been the realm of governments, or at least government-sponsored providers, actual users of Earth orbit have included many commercial players, from Telstar-1 in 1962, built by AT&T, through the commercial radio, satellite internet and phone service, and Earth observations satellites on-orbit today. NASA has, at various points, attempted to encourage commercialization; much of the justification for building the Space Shuttle was the promise of a cheap, easy way to quickly and reliably launch commercial satellites.

Onboard the ISS, commercial companies have been playing an increasingly important role in many different areas. NASA sponsored the Commercial Orbital Transportation System (COTS) program, which resulted in the development of two new launch vehicles and two new cargo capsules. Today, SpaceX's Falcon 9 launch vehicle and Dragon capsule are three flights into a 12-flight Commercial Resupply Services (CRS) contract, delivering 20 metric tons of pressurized and unpressurized cargo to the ISS, as well as returning science samples to the ground; Orbital Science Corporation's Antares launch vehicle and Cygnus capsule are two flights into an eight flight contract, also delivering 20 metric tons of cargo to ISS and providing much-needed refuse disposal upon reentry. With the proven and ongoing success of these services, a CRS-2 contract is in work to continue essential cargo delivery to ISS for the duration of its life on-orbit.

NASA, using lessons learned from the COTS development effort, is also providing funding and expertise for a new round of vehicle development, this time to take crew to and from the ISS. Crew transportation, using Russia's historically reliable Soyuz vehicle, stands as the only mission-critical single-fault-tolerant link in the entire Space Station chain. For both mission and national needs, NASA is helping several different private companies develop human-rated vehicles under the Commercial Crew Program. While development is ongoing, first flights are expected in 2017.

Cargo and crew transportation, however, are only the most obvious and visible ways in which the ISS is contributing to the inevitable commercialization of low Earth orbit. With the ISS, NASA has built the runways, radios, and beacons of the 1920s airmail system. It has helped develop the private craft necessary to fly between Earth and space. Now, through the NASA National Laboratory initiative and the Center for the Advancement of Science in Space (CASIS), the market is open for new, commercial developments in nearly every area of research and technology, including communications, biotechnology, human health, habitats, material sciences, Earth and Space science and observations, and other uses that may not even be hinted at yet.

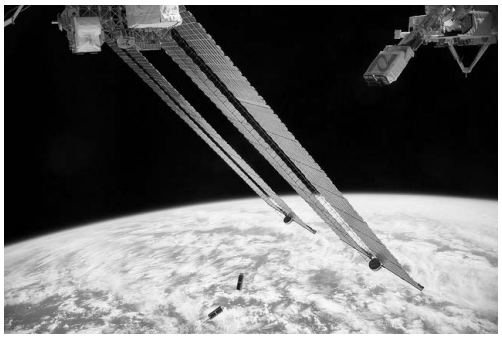

Figure 1 - The Japanese robotic arm, using a Nanoracks deployer, releases a pair of commercial CubeSats on 20 August 2014.

For example, through an arrangement with CASIS, the Nanoracks company of Webster, Texas, has developed a suite of facilities that are now onboard ISS. Other interested parties, from biotech development firms to elementary schools, can contract with Nanoracks and CASIS to use these facilities for whatever purposes they require, from vaccine development to Cubesat launches. Because transportation to ISS is still in a relatively early stage of maturation, NASA provides launch services and on-orbit accommodations for all U.S. National Lab and CASIS payloads, eliminating this not-insignificant risk for smaller developmental organizations.

Also under development and slated for launch in 2015 is the Bigelow Expandable Activity Module (BEAM). Developed by Bigelow Aerospace, the BEAM will be a demonstration of the feasibility of using lower-cost, lower-weight inflatable modules for human habitation in low Earth orbit. By utilizing the ISS, Bigelow is able to save on development costs of independent power, data, and environmental control systems, while getting experience with actual humans moving around and working in an inflatable structure- something that has never before been demonstrated in space. If BEAM is successfully demonstrated on ISS, it will open the door to large-scale, lower-cost inflatable habitats that can be deployed in low Earth orbit as an eventual commercial successor to the ISS.

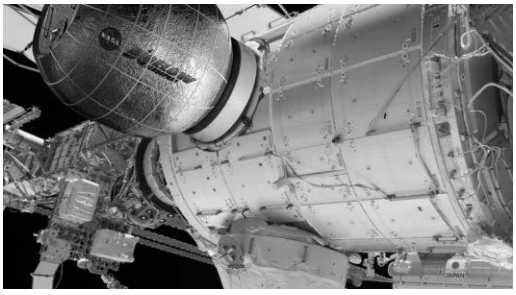

Figure 2 - An artist's conception of BEAM attached to ISS (Photo: Bigelow Aerospace)

Nanoracks and Bigelow are only two examples of the many companies currently pursuing research using the capabilities of the ISS. In order to fully understand the potential of the commercial marketplace that is developing in space, we must examine the constraints- financial, technical, and political- to opening up this final frontier.

Creating an Economic Development zone in LEO

Commercial activity in low Earth orbit, for industries besides communications and remote sensing, has always faced a chicken-and-the-egg problem; supply of transportation and resources cannot exist without demand for these capabilities, but demand for services in LEO cannot develop without a consistent supply chain. Economically viable supply and demand is just one of the barriers or constraints to developing a commercial market in LEO.

NASA, along with its international partners, hopes to help show that LEO is a viable economic development zone, with unique resources that are available to anyone with the ability to exploit them. Similar to emerging markets around the world, LEO is a geographic area with its own benefits and challenges; as with any market, those that can maximize the benefits while mitigating the challenges will profit the most. As the scope and breadth of the activities at the ISS show, this profit can take many forms- economic, research results, technology development, new operational models, and so on. However, like traditional emerging markets, there are barriers to commerce and development in LEO. Unlike traditional emerging markets, however, they are not simply matters of culture and regulatory differences (though these also factor as well).

Despite NASA's efforts to serve as a pathfinder in utilization of LEO, significant barriers still exist outside NASA's control. These include economically viable transportation for cargo and crew; intellectual property rights derived from government activity; and investment and tax incentives to encourage private industry to risk their own capital in LEO. By committing to operating the ISS through at least 2024, NASA has at a minimum another decade to continue to work with stakeholders through the technical, financial, and policy barriers that inhibit the development of a commercial market in LEO.

Another significant barrier is that of demand for LEO, which is still primarily NASA-driven. Going forward, NASA can guarantee at least 10 more years of operations in low Earth orbit, with the crew and cargo transportation this will require (approximately five cargo and two crew flights per year, at a minimum). NASA can also define areas of operations that are open to commercially-provided services for which NASA can be a customer; for example, the Sabatier carbon dioxide reduction system that is on-orbit was originally a commercial model where NASA purchased the water it produced rather than the hardware that generates it. NASA is in the process of determining what capabilities and/or services that are required for NASA's mission that are also applicable to the transition and development of a LEO commercial market. It is hoped that a commer-

cial demand for services like this will flow out of the proof-of-concept demand that NASA is providing. Until such time, industry is likely to remain dependent on government to provide demand for services in LEO.

Through examples like Nanoracks and BEAM, it is becoming apparent that there is demand for space station-type capabilities in LEO. While many communications and Earth-observation satellites can justify the expense of a free-flying satellite bus, many smaller, experimental or developmental payloads cannot afford that type of investment. However, by using the power, data, crew time, attitude and control, and transportation resources provided by the ISS, experiments and technology development activities can be undertaken that would never before have been economical on their own. As profitable commercial endeavors become routine, it can be expected that other commercial providers will enter the market to provide ISS-like resources in LEO, offering services to allow continued development or production that can only be accomplished in this environment. For some activities, reliable and economically feasible crew transportation will also be a key factor; by 2024, ISS will have proven this capability as well.

For the NASA side of this emerging market, there are steps the government can take to continue the positive path that industry is on. NASA, with input from industry, can begin creating a strategic plan for the gradual transition of being a supplier of many services in LEO- data transmission, environmental control and life support, research facilities- to being a consumer of and customer for these services, and can forecast its own need for continued LEO services post-ISS. As a pathfinder, NASA is able to take the types of risks for new types of operational models that industry cannot. Working with industry, NASA can help identify the areas of ISS operations that can be privatized, in order to provide operational experience for the commercial successors to ISS.

However, NASA still needs help from industry to create the kind of effective strategic plan necessary for this marketplace to flourish. New avenues to create demand need to be identified, especially in areas where government does not or cannot operate, such as space tourism. Methods for protecting intellectual property (IP) created in an international environment by non-employees of the IP creators need to be strengthened. Government and industry need to work together to find ways to create investment incentives for microgravity research and applications. Fortunately, much of this will be accomplished in due course as the full research potential of the ISS becomes apparent. "Mission success" for ISS will be defined as the day when a private space station is launched because there is no room to do more research onboard ISS.

Conclusions

Spaceflight is an entirely different endeavor than computer development, commercial air transportation, or standard economic emerging markets. It is unrealistic to draw straight-line comparisons between development

timeframes for these or any other industries. However, the historical model of government development followed by a transition to commercial utilization and further development is sound. NASA and the space industry are quickly reaching this tipping point, and are beginning to show that low Earth orbit is an emerging commercial marketplace, similar to any other. The next few years will be a critical time for commercial transportation to low Earth orbit. The next decade will also be a critical time for NASA, along with industry partners, to show that research and development in low Earth orbit need not be confined only to the launch and communication industries. Biomedical firms, educational institutions, and technology development efforts need help in realizing the full potential of the amazing facilities and capabilities offered by the ISS. Full utilization of all sectors of low Earth orbit will be required to ensure a vibrant and viable marketplace. Working together, we can achieve new heights.

The constellation Orion rises in this view from the International Space Station, taken in June 2014.