Meeting Notes
SSB/ASEB Low Earth Orbit Commercialization Panel
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Panel Discussion on LEO Commercialization

By Marc S. Allen, Principal, Odonata Research
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The Space Studies Board (SSB) and the Aeronautics and Space Engineering Board (ASEB) of the National Academies of Sciences, Engineering and Medicine held a joint session on April 26, 2016 to discuss the commercialization of Low Earth Orbit (LEO).

The two boards first heard a presentation by NASA Director for International Space Station (ISS) Sam Scimemi on "NASA's Vision for LEO: 2017-2024 and Beyond." His presentation was followed by a panel discussion with prominent experts in that field:

- Carissa Christensen, Managing Partner of the Tauri Group;
- John Elbon, Boeing's Vice President and General Manager of Space Exploration;
- Mike Gold, Director of Washington Operations for Bigelow Aerospace and Chair of the FAA's Commercial Space Transportation Advisory Committee (COMSTAC);
- George Nield, FAA Associate Administrator for Commercial Space Transportation (AST);
- Greg Johnson, Executive Director of NASA's Center for the Advancement of Science in Space (CASIS); and
- Ben Roberts, Assistant Director for Civil and Commercial Space in the White House Office of Science and Technology Policy.

The panel was moderated by Betsy Cantwell, Deputy Vice President in the Office of Knowledge Enterprise Development at Arizona State University and co-chair of the NAS Committee on Biological and Physical Sciences in Space.

Scimemi explained that the idea of commercial development of LEO began in the early days of the space shuttle program, but was interrupted by the 1986 Challenger accident. Subsequently, there was little emphasis on commercialization's "demand side" during the build-up of what is now known as the ISS, but this changed when the ISS was designated by Congress as a "national laboratory" in the 2005 NASA Authorization Act.

He offered a definition of "commercialization of LEO" – "sustained economic activity in LEO enabled by human spaceflight, driven by private and public investment, creating value and benefiting Earth through private industry supply and private and public demand."

NASA's perspective on LEO as an economic development zone is that NASA would buy needed services there, but the majority of demand would be from the private sector. It is NASA's intention that its own focus will be beyond LEO, in deep space.

The commercialization definition can be broken down into four goal areas. First, demonstrate the value of LEO using private sector-friendly acquisition models right now with ISS. Second, address the policy and regulatory environment for an economic activity zone, including issues of intellectual property (IP) retention, liability, etc. Third, stimulate the supply side, for example through the NASA Next Space Technologies for Exploration Partnerships (NextSTEP) Broad Agency Announcements, and explore synergies with NASA's programs to go beyond LEO. Fourth, stimulate the demand side by encouraging the private sector via the National Lab concept and the Center for the Advancement of Science in Space (CASIS).

NASA is currently discussing its commercialization objectives and policies with the ISS international partners, which in some cases do not share them. Other U.S. policies in place include no exchange of funds (barter instead) and the value of government investment in reducing sustainability risk.

There are two ends of the spectrum. At one end, there are government-driven capabilities and services. At the other are market-driven capabilities and services. Along this spectrum lie different risks, policies, leveraging strategies (partnerships of various types), and sustainability issues. It is important to realize that LEO commercialization is not just about flight hardware. It also includes ground infrastructure and other elements such as operations, training, and planning. All of these must be transitioned to the private sector.

Following Scimemi's introductory remarks, panel moderator Betsy Cantwell introduced the panel members.

The first panelist to speak was Carissa Christensen. The emerging LEO economy is characterized by the elements of investment, supply, and demand, she said, and listed three segments or destinations of the LEO economy: suborbital, orbital, and platforms.

With respect to investments, Christensen stated that 2015 saw $2 billion of startup-scale new ventures – a record. Investments fall into several categories. First, there are "advocacy investments," such as Elon Musk and SpaceX. Second, there are "strategic investments," which align with companies' existing business areas. Third, there is the more typical "financial investment," putting money into the best money-making opportunities. The latter is still a rarity in human spaceflight.

Likewise, the destinations break out into three categories. For suborbital activities, supply is lagging, but demand is robust: for example, 1,000 deposits for passenger flights on suborbital vehicles. In the orbital domain, there is a robust supply side, with NASA being the major investor and customer. For platforms, the demand is "very uncertain."

NASA views its engagement with the private sector's space economy from a vantage point of self-interest, which Christensen feels leads to better decision-making. The overall market dynamics are that the necessary systems are technically feasible, but the investments are large and the technology complex so the "business cases are generally not yet proven."

Boeing's John Elbon spoke next. As a major aerospace company, Boeing is involved in all three investment segments. Transportation and supply are in a chicken-and-egg dynamic. As a rough order of magnitude business case, ISS transportation operations are annually a $3 billion enterprise for the United States and perhaps $1 billion for other players, a total of $4 billion. Development of a commercial space station would cost about $5 billion, and the business would need to deliver stockholders about 15%, or $750 million, in annual revenue. Cut the annual operating costs of a smaller station system to half of ISS, or about $2 billion annually, and the revenue needed for a stand-alone commercial station would be in "single digit billions" to operate on-orbit as a purely commercial entity. It would appear to need a mix of private and government participation to support that and stimulate the demand side.

The next speaker was Mike Gold. COMSTAC, the Commercial Space Transportation Advisory Committee, is the federal advisory committee to the FAA Office of Commercial Space Transportation (AST), with four specialized working groups. He asserted that "LEO *has* been commercialized," with a multi-billion dollar industry in telecommunications satellites, but in this panel discussion the context is human spaceflight. It is essential to have the transportation first and in his view "we still have a long way to go with commercial crew."

Gold noted that FAA/AST is an important element in space commercialization, but congressional funding levels for that office are inadequate for its tasks. In addition, there is a regulatory gap in implementing Article VI of the 1967 Outer Space Treaty, which requires governments to authorize and continually supervise activities of non-government entities, like companies. No U.S. agency has been assigned that role for most commercial space activities, but potential investors want to know what the regulatory environment will be. There also are export control issues. Even though there have been great strides in this area, more is needed. He added that a key to success is public-private partnerships, exemplified by the Bigelow Expandable Activity Module (BEAM) project, a partnership between Bigelow, Boeing, and NASA.

The next remarks were delivered by FAA/AST director George Nield. Government and industry have different things to bring to the table and there is a wide range of potential markets. He enumerated policy issues such as compliance with the Outer Space Treaty, safety of the general public, and utilization of space resources. "We need to resolve these

if we want to have an environment where we have regulatory certainty for private investment and commercial operations." The government can help incentivize private investment with, for example, research projects, tax incentives, loan guarantees, help with funding for needed capabilities, or purchase of commercial services. NASA's Commercial Orbital Transportation Services (COTS) program, also known as the commercial cargo program, is an excellent example of what can be done. He expressed confidence in future commercial activity in LEO, but added that the government can accelerate this.

CASIS Director Johnson was next. He began by reflecting on past progress and plans for the future. NASA is building the "supply side" for LEO. CASIS, on the other hand, is building the "demand side." He cited as examples recent developments in rodent research, discoveries relating to human health, and commercial product development. As of the last fiscal year, CASIS has attracted non-NASA cost sharing of $25 million, some in-kind, but some cash. In the area of human disease, there is CASIS research using rodents as models, plus projects by pharmaceutical companies Novartis and Eli Lilly. The National Institutes of Health (NIH) BioMed program is involved in research and Procter and Gamble is researching complex fluids. There is also work in 3D printing by Made in Space and multiple projects in remote sensing.

The last panelist to speak was OSTP's Ben Roberts. He began by observing that the next presidential administration will have to make critical decisions in the next 2-3 years about a future on-orbit platform – "one of the most pressing issues for them to face." Without some other platform, it will be very hard for the United States to go beyond LEO. He stressed that the cost of building a space station should not be taken as a "given." More economical concepts than the ISS are emerging. The first step might be to reuse existing hardware or experiment with cheaper, more basic systems (compared to the ISS). It is exciting that advances in artificial intelligence (AI) suggest that more can be done without expensive and highly constrained crew time, making LEO research much less expensive, he said.

Following those presentations, SSB chair David Spergel began the discussion by noting that there are more "spacefaring" nations now, perhaps 90 that see themselves that way. As with telescopes, big players will want to move on and new players may want to come in, as well as adding other governments as users. Scimemi agreed, saying that some other entities have entered into utilizing ISS not through NASA, but through other conduits, such as NanoRacks, LLC, which arranges for very small satellites (cubesats) to be launched to and ejected into orbit from ISS. New participants in utilizing ISS might not be full partners like those countries that are signatories to the existing ISS Intergovernmental Agreement, but make other arrangements.

Gold felt that new opportunities will be opening up, e.g., the United Arab Emirates (UAE), which recently created a space agency. Transitioning to private entities building the next LEO space stations opens up new opportunities, he argued. Moreover, China is building a space station that it is advocating energetically and offering for free. Elbon

added that partners in international space stations typically want to spend their money in their own countries, and this needs to be taken into account.

Board member Eileen Collins, a former astronaut, was surprised that there are still concerns about the availability of ISS crew time and asked what can be done. There are now six astronauts on board ISS instead of two as in the early 2000s. What are they doing? Scimemi responded that there is a requirement for 35 hours of crew research time per week, and that is being exceeded (usually more than 40). Once commercial crew flights begin, ISS crew size will increase to seven and the additional crew member's time will be largely devoted to research, doubling the amount of research crew time available.

Cantwell asked how long it will be before a commercial capability exists to increase ISS research capacity. CASIS's Johnson said that it was difficult to estimate a time requirement for innovation, but there is currently a marked increase in commercial demand and new companies are getting interested. He thinks it will continue to develop, but OSTP's Roberts noted that if humans are required to perform the research (instead of automated experiments), it might take some time. He instead foresees dedicated orbital research facilities on a commercial orbital vehicle, operated telerobotically. Board member John Olson observed that price is the key driver, especially for transportation and insurance. The platform is a third factor, far behind these.

Board member Tom Gavin commented that the six-person ISS crew is preoccupied with maintenance of the space station, and asked how that will change. Scimemi replied that there is a misconception about this aspect. Research is going on all the time without crew intervention, so crew time is only one consideration.

Christensen returned to her earlier point about the next platform. Her concern was that NASA might divest in the ISS before a replacement is available. Scimemi reflected that the research partnerships established by CASIS (and NASA) will require a follow-on capability overlapping with ISS, but not every user will need a full-blown space station the size of ISS. He believes the supply side will be there once commercial crew systems are operating. Five nations now know how to build a space station, the key is to move to a point where the use of such stations are for commercial rather than government purposes.

Christensen felt that it was reasonable to ask the government what LEO facilities will exist in 2024 or 2028, but not to ask that of a new industry. It would be better to ask them what might there be and what are the factors? Three-quarters of venture capital initiatives fail, she asserted. Some of the new satellite companies will fail, but that does not mean LEO commercialization is not viable.

Board member Tony Janetos cited a report from last year that said satellites are a $200 billion industry today even though satellites did not exist 50 years ago. Could this LEO industry be half as big? Christensen stated that big industries like GPS applications or direct-to-home television services did not exist even 15 years ago. Gold said that similar developments could occur, but only when commercial entities can develop those systems

themselves. The difference today is that the environment is more international, so it will happen, even if not in America.

Board member Sherrie Zacharius said she believed that military spending supported a lot of satellite activity growth, and Christensen concurred, pointing to GPS, for example. But this is less true now. Roberts said that growing demand, perhaps from finding a way to cross-subsidize a small research program with other services, will be needed to field bigger platforms.

Elbon got the last word by urging continued use of the ISS (which Boeing operates for NASA). ISS research will lead to serendipitous discoveries, he asserted.