

# The Next Step in Low Orbit Space Commercialization



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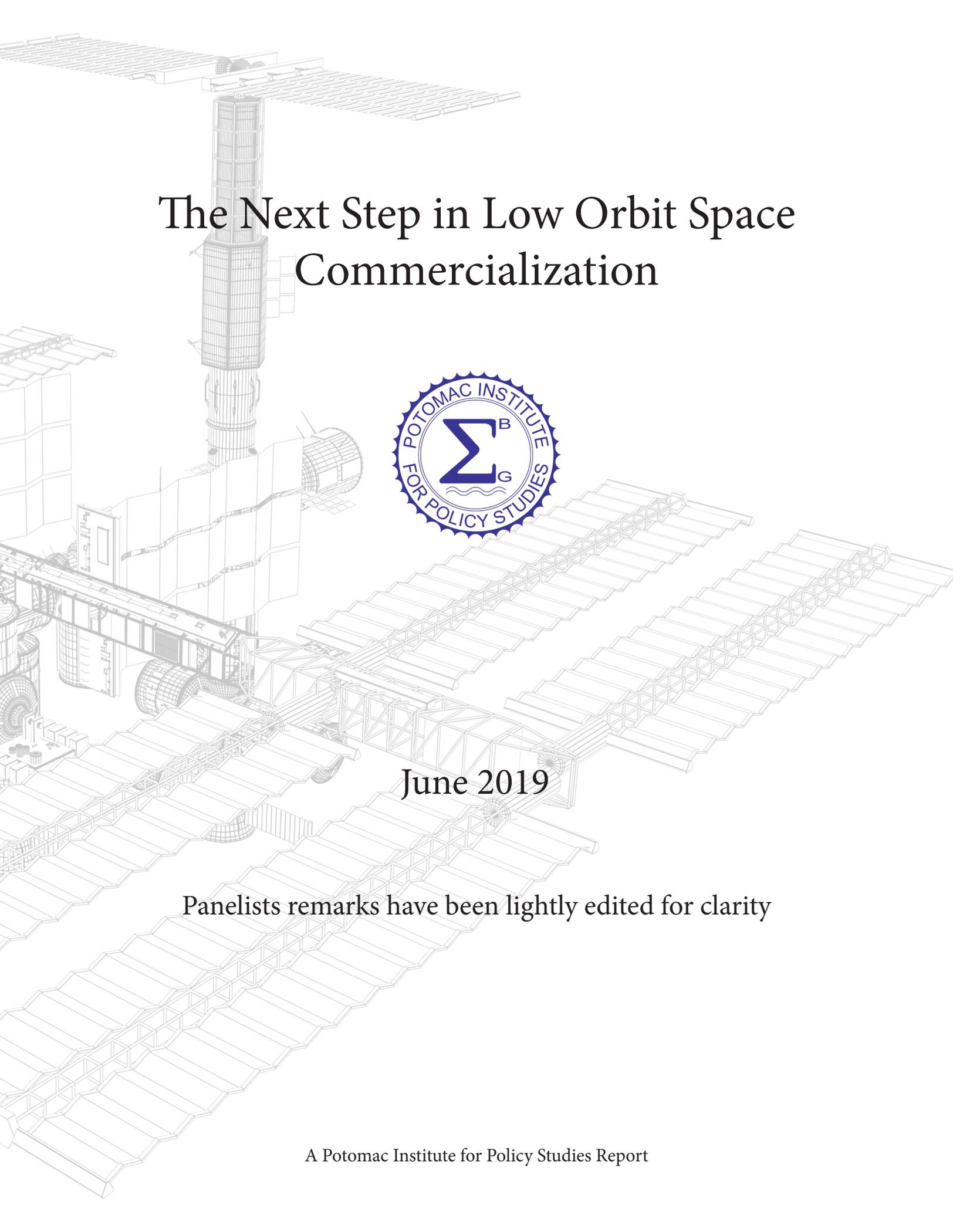
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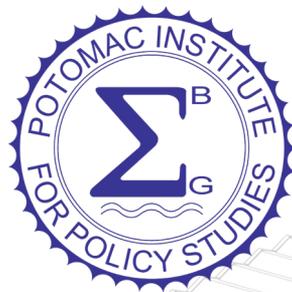
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# The Next Step in Low Orbit Space Commercialization



June 2019

Panelists remarks have been lightly edited for clarity

# Table of Contents

Executive Summary.....1

Welcome from Jennifer Buss.....4

Opening Remarks by Michael Beavin.....5

Panelist Remarks.....8

    Kerry Timmons.....8

    Jeffrey Manber.....9

    Doug Comstock.....11

Panel Discussion

Moderated by MajGen Charles F. Bolden Jr. ....14

Summary.....26



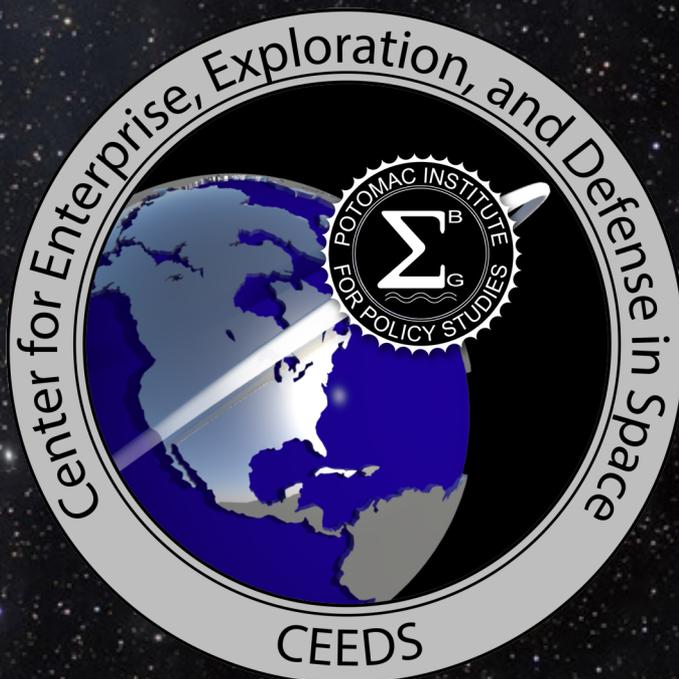
**Appendix A: Panelist Bios.....28**  
MajGen Charlie F. Bolden Jr. ....28  
Michael Beavin.....28  
Jeffrey Manber.....29  
Doug Comstock.....29  
Kerry Timmons.....30

**Appendix B: Participant Slide Presentations.....31**  
Jeffrey Manber Presentation.....31  
Doug Comstock Presentation.....34



# Executive Summary

On June 21, 2019, the Potomac Institute for Policy Studies' Center for Enterprise, Exploration, and Defense in Space (CEEDS) held a seminar titled: "The Next Space Industry: Low Earth Orbit Commercialization" to examine and discuss issues related to low Earth orbit (LEO) commercialization.



The commercialization of LEO is a multidecadal process that has resulted in many successes, most notably the development and operation of the commercial Dragon and Cygnus capsules for cargo delivery to the International Space Station (ISS) and the advancement of commercial crew transport options. The definition of “commercial” varies drastically among audiences. Meanings range from “the government as the sole customer that shares heavy cost burden,” to “the government is one customer of many within a large marketplace.” For companies striving to create a sustainable marketplace in LEO, commercialization means “the realization of sustainable, profitable business models without complete reliance on government funding.” This is a critical point. As the ISS begins to reach the end of its operational lifetime, the United States needs a plan of action and a firm sense of purpose to maintain a presence in LEO. Otherwise, we will repeat the capability losses we experienced with the 2011 decommissioning of the Space Shuttle. Moreover, we will lose leverage within the commercial marketplace of tomorrow, ceding our commercial hegemony to other countries and companies, and in this way, handicap our future space exploration efforts.

The goal is to have commercial destinations in LEO where NASA can purchase commercial services and be one of many customers. This process should include a transitional period ensuring that the ISS is deorbited only after the replacement ecosystem is in place. To work towards that goal, NASA has developed and sustained a number of programs and public-private partnerships. NASA’s Commercial Orbital Transportation Services (COTS) program has demonstrated successful performance. The ISS—as a national lab—ushered in an era of commercial activity and the Commercial Crew Program is almost ready for deployment. The success of these programs and partnerships will open up previously impossible new market opportunities. However, continuation of this trend and discovery of new markets will require continued government investment and industry partnerships.

NASA recently released a five-point plan for near-term commercial LEO development. Their goal is to reduce uncertainty in commercial partners’ business models; to open opportunities for commercial modules, free-flying stations, and astronauts; to encourage more corporate business opportunities; and to articulate future NASA needs to commercial providers. As NASA increasingly turns to private industry for less expensive and more efficient LEO operations, NASA can redirect excess funds to additional plans for exploration. This pathway also creates jobs in private companies and incentivizes economic development.

Large and small commercial companies, like Lockheed Martin and NanoRacks—that were represented at the June 21st event—are already working directly in partnership with NASA toward LEO commercialization. Lockheed Martin aims to leverage a wide array of emerging and maturing technologies like autonomy, robotics, and machine learning to enable new applications and markets in a future space infrastructure. NanoRacks has proposed the development of a set of commercial ecosystems consisting of space stations crafted from parts of multiple providers’ previous launch vehicles. Their products include multiple outposts, multiple orbits, crewed and uncrewed spacecraft,

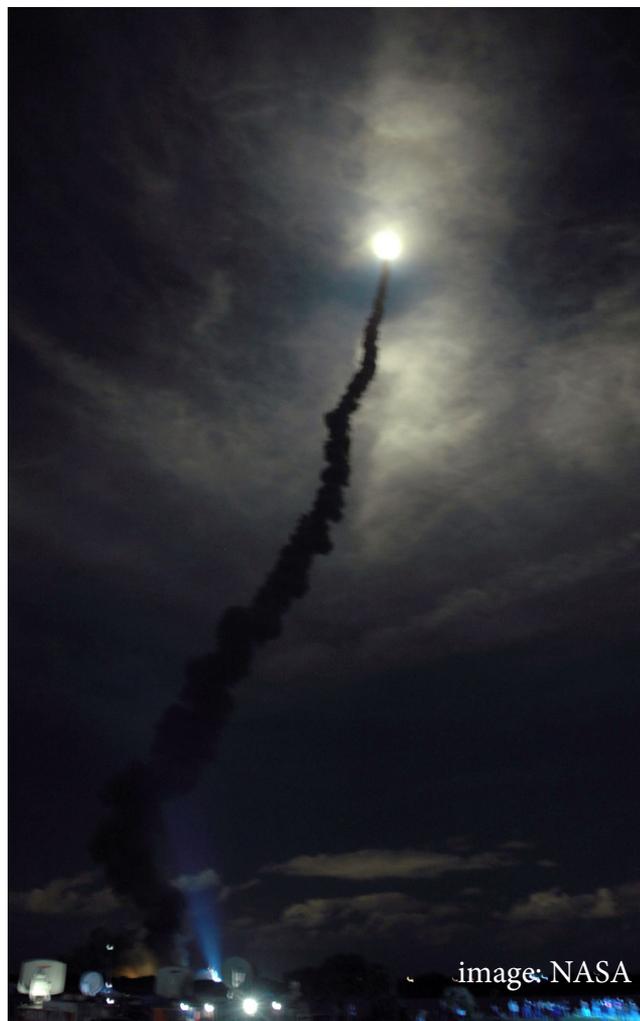


and attached and detached ISS structures. Both companies enumerated the importance of a sustainable, profitable ecosystem and infrastructure that will greatly expand LEO access for more actors. Increased infrastructure reduces risk for commercial partners and encourages investors to bring applications, products, and goods into orbit.

While it may be difficult to project the next “killer app” that will generate massive revenue from LEO, there are exciting applications on the horizon, such as ZBLAN manufacturing (critical for optical fiber) and an artificial retina (that has the potential to cure blindness). History leads us to believe that the development of such a revenue-generating application is certain. It is also apparent that increased LEO access will accelerate development of increasingly impactful applications, expand the number of destinations, and afford easier access for smaller companies and researchers.

These plans currently require continued engagement, funding, and support from the federal government through NASA and other agency partners. The maturation of public-private partnerships over the last ten years, increased understanding of commercial business needs, and legislation supporting a favorable private industry business climate have all contributed to improving and easing these interactions. However, more can still be done. There is continued public and congressional hesitancy to allow private companies to profit from NASA-provided infrastructure and funding, including in LEO commercialization efforts. This hesitation is misguided, and there are numerous historical analogies that illustrate the traditional, critical role of the federal government within industry development. The aviation industry received large-scale subsidies and functioned, while retaining profits, through government-operated airports using a government-owned and operated air traffic control system. The railroad industry offers another example with a slightly different twist, as many of the buildings, facilities, and land were corporate-owned. Nearly every industry engages to some degree with the federal government, even mature, profitable enterprises like oil and natural gas manufacturing and processing. The position of engagement on the public-private partnership support spectrum varies by industry, but space-related commercialization is not unique in its reliance on the federal government.

Commercial companies are charging ahead, but more can be done to ensure that the United States remains at the forefront of LEO commercialization efforts. A burgeoning marketplace in LEO will create jobs, spark new industries, reduce costs for NASA, enable even greater expansion in orbit, and serve as a stepping stone for exploration and development of the rest of the solar system.



# Welcome from Jennifer Buss

Good afternoon everyone, my name is Jennifer Buss, and I'm the President of the Potomac Institute for Policy Studies. On behalf of our Center for Enterprise, Exploration, and Defense in Space, I would like to welcome our panelists and thank everyone for joining us here today.

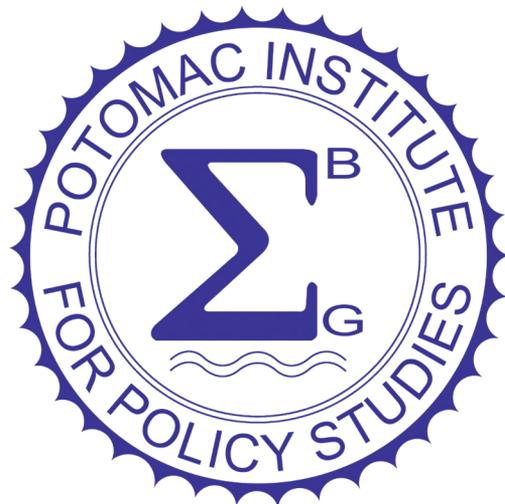
The Potomac Institute for Policy Studies was formed in the early 1990s to carry on the mission of the Office of Technology Assessment. Since that time, we have provided timely recommendations to senior policymakers across a wide range of science and technology issues, including on many occasions, questions on space commercialization.

Commercialization of the space domain has long been the dream of space policy makers. Over the years, many attempts have been made through

legislation, policy directives, and NASA programs to accomplish this goal. So, why are efforts today any different? Several factors are working in concert to change the status quo, including focus from the administration through the reconstituted National Space Council, plummeting launch costs, record-level investment in space startups, and a robust new NASA policy.

Today, the Institute has brought together three leading experts from government and industry to help unpack this exciting topic. Led by our esteemed Senior Fellow, former NASA Administrator MajGen Charlie Bolden, they will help answer some important questions, such as:

- 1) what does the term "commercial space" really mean?
- 2) what LEO commercialization efforts are underway today?
- 3) what more can be done to accelerate the process of creating a robust marketplace in low Earth orbit? Specifically, a marketplace in which the government can be one customer of many that will enable private industry to secure a foothold for humanity among the stars.



# Opening Remarks by Michael Beavin

I'd like to thank the Potomac Institute for hosting this event and for inviting me to come speak on this important topic. We are here to talk about LEO commercialization and how it will facilitate the successful efforts of NASA and our international partners in exploration—not just in LEO, but to the Moon and then on to Mars. Before we get into some of the details, I'd like to address one policy conundrum that I've been wrestling with in space policy for over 20 years. There always seems to be this debate over what is truly commercial. The reality is that there is a very wide spectrum of commercialization. There is no pristine formula etched in a stone tablet somewhere. It takes many forms in all sectors of our economy, and in space, it's no different.



In space, we've actually been at this for a while. We currently enjoy enormous benefits from both our commercial and international partners in space, and we know how to do this. Commercial Dragon and Cygnus capsules already transport cargo to the ISS, and soon Dragon and Starliner capsules will do the same for astronauts. NASA has just released a new commercial use policy for the ISS and has plans for free flyers, port selection, microgravity R&D, commercial cargo and logistic support to the Gateway, commercial landers on the Moon, etc. This is the right thing to do. The cold, hard fact is that the ISS is going to end at some point, and we need to continue this transition—that we've been doing for a while now—onto what's next. All these initial steps are important bricks in the wall. But we are not building a wall, we are building a cathedral. We can't lose sight of the bigger picture. It's an economy that supports and enables sustainable exploration from the Earth, to the surface of the Moon, and then on to Mars. That's really what we are talking about.

The time is now. The president knows that Americans are not satisfied with the status quo and that the future is open only to those brave enough to seize it. The great explorers of the past did not stop after a few expeditions never to return. This requires both bold leadership and tough decisions. While NASA directed almost every element of the Apollo program, today we have a diverse array of space-capable entities across both commercial and international domains. We have to tap every resource to fully realize the future with American leadership and values of space. As Bill Gerstenmaier, NASA's Associate Administrator for Human Exploration and Operations (HEO) recently said, "we need to think of a different way of doing business." This is true not just in HEO but across NASA and the rest of the U.S. government. All of our efforts must build a continuum that sustains exploration out from LEO to the surface of the Moon and on to Mars. A great example in the near term is the Commercial Lunar Payload Services Program. The NASA Science Mission Directorate recently announced three commercial partners that could send payloads to the Moon, which could start as early as next year. Another example is the Gateway's power and propulsion element (PPE). NASA is not procuring the PPE but rather is supporting the construction and launch of the module, followed by a year of in-space testing. At the end of testing, NASA has the option to acquire the PPE for the gateway, but a similar approach could be used

for free flyers in LEO with additional PPEs and modules offered as a commercial service.

So how do we proceed? NASA is poised to lead with commercial international partners in the design and development of a lunar field station at the Moon's south pole. But what are the capabilities that the commercial sector could provide beyond landers for cargo and crew? Could commercial services provide crew habitation, solar and nuclear power generations, surface mobility, resource extraction, and the like? Some concepts for building a planetary field station come from NASA's current plans for human missions to Mars. Building on that foundation, we should design the lunar architecture in such a way that it feeds commercial services forward to enable exploration beyond the Moon. So, if you will permit me, I'd like to come back to the bricks and wall analogy and reiterate that all these pieces are interlinked—from LEO, out to the Moon, on the surface of the Moon, and on to Mars. The idea here is that each individual brick builds up the wall and then ultimately, the cathedral. A robust economy will develop. Not overnight, but in the fullness of time. In doing so, we will be better equipped to sustainably expand human presence beyond LEO to the surface of the Moon, and to lay the foundations to Mars. With that, I'd like to thank the Potomac Institute for organizing this event. I believe this particular topic is what is key to sustainable space exploration. Thank you.

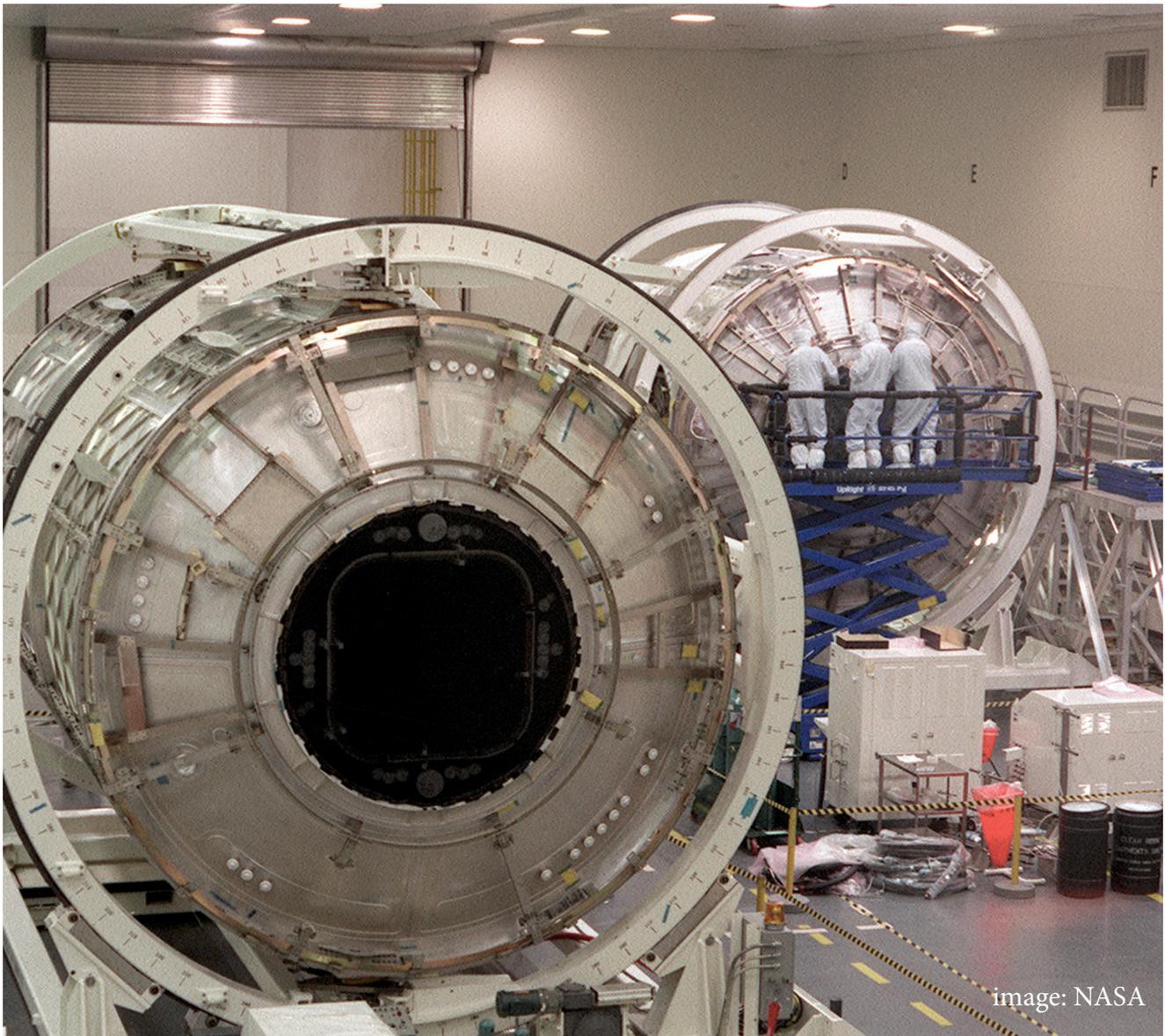


image: NASA

## Panelist Remarks



### Kerry Timmons

I really got involved in this in middle-to-late last year when we supported NASA’s LEO commercialization study. It was such a cool experience. It was significantly different than the things we normally do where we are told, “Here’s your requirement set—go build this.” Instead, it was, “What’s your vision of the future? How do you want space to look 5, 10, 15 years from now?” And we approached it with this mindset from three angles 1) What does it look like now, how much does it cost, what’s the business model we’re using, and then how does that evolve? 2) What does ISS, a future space station, or even a future free flyer look like, and then 3) How do we energize the commercial market—companies and partners—to really get engaged to bring their money and their ideas to space. The last part is especially exciting for Lockheed because we’re maturing a lot of in-space manufacturing and assembly technologies. We are a tech company with a lot of experience in robotics and autonomy, and we’re learning more every day about artificial intelligence and machine learning. These things are going to be the infrastructure that enable commercialization in the future, so we’re really excited about supporting that aspect of commercial space, by figuring out how to build up the infrastructure that buys down the risk and enables commercial partners and investors to bring more applications, products, and goods to commercial space.



## Jeffrey Manber

First off, let me say that we're at a beautiful place now policy-wise. For those of us who have been struggling for many years to get NASA and the government to behave as a customer, this is exciting, because increasingly, the government is doing just that. Kerry was talking about technology, but it's also of course about the policy and where we are economically because it's still a market in its infancy.

When Charlie challenged me on what to talk about, I decided I'd like to begin with our proudest accomplishment at NanoRacks: our customers. We are the largest commercial user of the ISS. We have customers in over 30 countries, and as Mike was saying earlier, there's this endless battle in this town as to what is commercial. For me, we have NASA as a customer, we have European Space Agency as a customer. It's commercial because we designed the hardware, it was our capital at risk, and if we don't produce, we're in trouble. NanoRacks still lives from launch to launch; it's not an easy business. However, we're growing very rapidly thanks to the customers and the policy changes on the station.

I also wanted to just take a moment and say one of the most interesting things happening is the maturing of the public/private partnership. When we started NanoRacks 10 years ago—as Charlie said, using the technical terms “stuff”—we were the first company to own and market our own “stuff” on the space station and NASA didn't really know what to do with that. They initially did not understand why they should let the commercial companies set a price for their services and keep all the money they earned. There were fierce battles in 2009 as to how a private company could be on a taxpayer platform, charge their own prices, and keep the revenue. Since then, we've had I think four or five Space Act agreements, and each one is growing in maturity. It will probably change soon with the commercial platforms coming out and other policy changes, but as of today, NanoRacks has the most capital committed on the station. In terms of private capital, we have \$40 to \$50 million invested, and we're building a commercial airlock called Bishop, entirely funded by private capital. We've matured as NASA has matured, and it's due in large part to those of you here in Congress that have wanted to see the private sector unleashed in LEO.

In the future, we are looking at commercial platforms both attached to the ISS and free flying, and we're looking at different ways to have cost efficiencies in these. As Mike said, the station will not be there forever. As I like to remind my congressional friends and colleagues, it's not up to them; the ISS is a living thing and it's getting older. I lived through an aging space station called the Mir, and they age as they wish. It's wonderful we have bipartisan support for the station to continue for the next decade, but it's

not up to us. It's up to the machinery, which means we should be prepared for the worst-case scenario so that we never have a gap like we did with the Shuttle. I welcome us taking the first baby steps here today and figuring out how to work with NASA and how to work with foreign competitors and space agencies. I also worry about much of what my competitors are doing in town as I do what JAXA, ESA, and other non-ISS space agencies are doing. Today is the time for us to figure this all out, and it's a very exciting time. If we get this right, we'll have American leadership far into the next few decades, and the way we do it best is with the private sector leading the way.



*A set of NanoRacks CubeSats is photographed by an Expedition 38 crew member after the deployment by the NanoRacks Launcher attached to the end of the Japanese robotic arm. The CubeSats program contains a variety of experiments such as Earth observations and advanced electronics testing. International Space Station solar array panels are at left. Earth's horizon and the blackness of space provide the backdrop for the scene.*



## Doug Comstock

Thanks to the Potomac Institute for hosting this event. I want to share a little bit about what NASA is doing. We just released a strategy for developing the LEO economy a couple of weeks ago.

First, just a thought on the definition of commercial; it's not a black-and-white definition. It's a continuum and at one end you have the traditional government contract, where it's a cost-plus contract and all the risk is on the government. There the government is the only customer. At the other end, space products and services become commoditized. That could be something like communication satellites, where you can buy bandwidth or buy access to a transponder and you just have a fixed price and buy it as a commodity. There are a whole lot of variations and steps in between those two points, but it really is a continuum, and for different sorts of services we're at very different points along the continuum. I think we are trying to move towards the direction that's more commercial, where you're purchasing commodities. In some cases, we've got a long way to go, but we're working to get there.

We have built a framework for how we envision LEO, particularly with regard to the ISS, and how that transition can happen over the next decade or so. Right now, the station is an amazing capability that's been up there for 20 years. As Jeff said, we've got commercial activities up there now. NanoRacks was the first one, and we've now got 14 different commercial facilities that have been built by 11 different companies that are operational on the ISS. So, there has been great work in paving the path, and we've got a lot of others following with some robust activities, now. But, as we've talked about also, at some point the station is going to be aged and we are not going to have a station anymore. We want to position the agency and the country to avoid a gap in capability for human access to LEO and this strategy talks about how we get there. We want to have commercial destinations in LEO where NASA can purchase services as one of many customers. We want to make sure that we have a transition period with a handoff where we manage the risk and only deorbit the space station when it's time to do so. Then we have confidence that the commercial capabilities are going to be there; they've been proven out and the markets are beginning to mature. The framework is sort of laid out here<sup>1</sup> and I'll talk about the activities we have in the lower-left—the near-term activities—in some detail.

I just wanted to talk a little bit about the context for this, historically. The whole transition to commercial activities in LEO is really a multi-decade transition that we're a couple of decades into. If you look back

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1: See Appendix for reference slides.

at the beginning of the commercial cargo activities, we started with the COTS competition in 2005. We now have robust capabilities for routine delivery of cargo from two commercial providers and we've got a third one in development. We started the Commercial Crew Program after that, and Charlie's tenure at NASA made a lot of progress in developing these capabilities. In 2005, the ISS was also designated as a national lab by Congress, and we began having commercial activities, as Jeff mentioned. Today, you can see a lot of commercial facilities up there. All these things are beginning to come together, and it's an exciting time because we'll soon have the ability to deliver commercial cargo and commercial astronauts to the space station. This will allow us to try out some new markets that really haven't been possible to pursue before.

We have put together a five-point plan that is available at [www.nasa.gov/leoconomy](http://www.nasa.gov/leoconomy). In this plan are the details to really help develop these markets in the near term. We talked about business plans and, at the root of it, all these activities are intended to reduce uncertainty in those plans. The worst thing you can have in a business plan is uncertainty. You want to know what your market is, you want to know who the customers are, and you want to know how much things are going to cost.

One of the first things we did is establish a commercial use policy. Christie Cox, who's here with us today, was a key enabler in getting that through NASA and getting it in place. Through it we have expanded the types of commercial activities that we can do on the ISS, and we can move into manufacturing, which is beyond the current role of the ISS National Lab. We can also now do things like allow companies to shoot commercials on the space station, have trinkets manufactured, and all sorts of other new things. Each of these also has an associated price, which functions as an experiment where NASA sets initial prices and then can analyze how the market reacts. We're going to share this information with industry so they can begin to have insights into how the market reacts to different prices—informing their business plans for developing these commercial destinations. As the market responds, we'll adjust those prices and that will further inform industry. I think that will also reduce the uncertainty that industry has had in putting together their business cases for these commercial destinations.

We've also announced that we're going to enable private astronaut missions to the ISS and we'll soon have capabilities from both Boeing and SpaceX to deliver NASA astronauts. Those capabilities will be available for purchase on a private basis for commercial missions to the space station with private astronauts. We've already begun to plan the accommodation of those missions with planning for the space station. We can accommodate up to two missions per year for about 30 days each, and the first one could potentially be as early as October of 2020 if Boeing and SpaceX are ready. So it's exciting to open the opportunity for that market segment.

Another thing that we're doing is working on the supply side. We want to have commercial destinations for use after the space station. NASA wants to work with industry in a partnership, much the way we have with the commercial cargo and commercial crew programs, to develop these commercial destinations. We're going to have two paths to do that: 1) using the Node 2 port on the space station to have a commercial module dock and begin to test out and demonstrate some of the markets, and 2) we're going to pursue a path that would go directly to a free flyer. We're expecting to release the solicitation for the node use today. We will also be releasing the solicitation for the free flyer in a month or so after that. We're building on the experience that we've had already with commercial crew and cargo and applying a similar approach to developing these commercial destinations. Our aim in the future is to be able to purchase services for crew and for all the research activities and technology demonstrations that we do in LEO, just as we're now purchasing services for cargo delivery.

The fourth element of the plan is to work with industry to try to stimulate demand. This was identified by all the studies as a huge area of uncertainty. There are a wide range of estimates on what these new markets may be, and because they are new markets, there are a lot of uncertainties. We want to work with industry to make the space station available to begin demonstrating these new markets to reduce that uncertainty and help build the business case that industry needs to develop these commercial destinations.

Finally, NASA is going to be a customer in the future. We want to buy services for our R&D needs and for our technology demonstration needs. Toward this end, we put forward a white paper that quantified what NASA is going to need as a customer from these commercial destinations once they are available. All those activities are really focused on helping industry build a business case: reducing uncertainty from markets with NASA as a customer and helping them develop the systems that are going to be needed in a post-ISS world. This also ties into our exploration plans because we anticipate that industry will be able to provide the sort of R&D services and technology demonstration services in LEO that the agency needs at a much more efficient cost than NASA currently does with the ISS. We anticipate that we'll be able to free up resources that we can put towards the Moon, then Mars, while continuing to help industry in the process of developing this LEO economy, which will create new jobs and new industries in space. So that's what NASA is hoping to achieve with our vision for the LEO economy and these plan that we just announced. Thank you.



# Panel Discussion

Moderated by MajGen Charles F. Bolden Jr.

## **MajGen Bolden**

Let me kick off the discussion by asking about a major concern for entrepreneurs, which is barriers to entry. Everything has barriers. Jeffery, let me ask you to start out. You've already mentioned one thing that I suspect you're going to talk about, which is regulation. Can you talk a little bit about some of the common barriers to entry that almost every company will run into, whether large or small?

## **Mr. Manber**

Well Charlie, I may disappoint you right from the outset. I don't want to focus just on regulatory—a gradual transition over the last several decades has been policies resulting in regulatory shift. Twenty-five years ago, NASA was the sole voice in the government for civilian space. That was just plain wrong. During the Reagan administration, folks could get the FAA involved in regulating launch vehicles, which is the proper role of the FAA. Why should NASA be in charge of launch vehicles and policy? Then I helped set up the Office of Space Commerce, which in the past has been sort of dormant, but now seems to be rising up with Kevin O'Connell.

So, it's not only the regulatory, it's the entire framework of how we are doing the transition. If you were an entrepreneur five, seven, eight years ago, you at least knew what the launch vehicle was and where you should go in the agencies. Before that, you didn't even know. The first launch vehicle was the Conestoga rocket with Deke Slayton in the 1980s, and they said it took months and months and months—just like Moon Express and figuring out the process of getting the first license to go to the Moon. Charlie's right in that we face a lot of regulatory hurdles. If you have anything today that has a camera, even if it's not germane to your mission, you have to obtain a license from the FCC, and they can be backed up for quite some time.

So, regulations are one part of it, but it's changing, and the regulations are not the determining factor. It's more market, as Doug is saying. Do we have a glut of launch vehicles? That is another problem.

## **MajGen Bolden**

Kerry, another issue is that we must have a community. If you are serious about commercialization of LEO, you know that just one or two companies does not enable the real, sustainable infrastructure needed. Noticing that you are working with in-space manufacturing and things like that, what is Lockheed's approach, or Kerry's approach, to try to build this community? How do you represent Lockheed while recognizing the fact that you have to go out and get some partners or some competitors in order to get the right mass to make anything happen?

## **Ms. Timmons**

Sure. Absolutely. This is definitely going to require collaboration. It will be old space—or established space, as I like to say, instead—and new space working in partnership with the government. I think NASA has done a lot of things through their Next Step program with the public-private partnership and expecting commercialization and some in-kind contributions. It is really making those expectations clear, and generally leveling the playing field.

I have also been working on the Gateway program and our Next Step studies associated with that. We have been working with several partners – including NanoRacks – at Kennedy Space Center, figuring out what we need to put in place so that it works for both of us, so that we can each make our business case close. Because it needs to be a win-win situation all around the board. Us reaching out to the commercial companies and them not turning us away like, “You are old space and we do not want to work with you,”—just continuing to be openminded in this new world.

**Mr. Manber**

And it works both ways. Thank you for being openminded about working with little companies.

**MajGen Bolden**

Doug, you have been around this for a while. I mentioned the fact that you were in cost analysis for a startup out here. What kind of things were you looking at in terms of trying to help them build their business case and help them understand what a business case really is? What are the factors that go into it? What do you tell them to do?

**Audience Member**

Can I ask a question? Just to modify yours a bit so as not to repeat it later. When discussing a business case for Doug, the difference between new space and old space is all based on money and the timelines expected to pay back, and the vision that is articulated to weigh the risk so that you can have your money people—whether it is Congress or investors, or stockholders—do that. Could each of you talk about that aspect? NASA, as a governmental organization, does not typically have to worry about building a business case, but since they are building a policy and a program to enable industry, what lessons have you learned that help you understand what these business cases could be?

**Mr. Comstock**

After having spent 15 years in the private sector, I think the cost analysis is similar to what industry does when they are building a business case in that it is all related to uncertainty. When you talk about a cost estimate for something you know there is a tendency to identify that as a point estimate; yet the only thing you know is that point estimate is wrong. There are uncertainties associated with that. There are risks associated with all sorts of things. The way you really develop a robust cost estimate is to understand all of those risks and accommodate those risks in your analysis. It is the same kind of thing with a business plan. The objective is to identify markets, customers, and sell things for more than it costs you to produce them. But there are uncertainties associated with what it will cost you to produce those things. There is uncertainty over who the customers are, what you will charge, and so on. Part of what NASA is trying to do is not tell industry how to do their business plans but identify where there are uncertainties that NASA can help reduce. That is part of what we are trying to do with a number of elements in these five-point plans. It is up to industry to go and develop those markets. What NASA is trying to do is set the table and turn industry loose on these challenges, but it is up to industry to make it happen.

**Mr. Manber**

I just wanted to say that a few months ago we looked into the history of aviation. I was struck with how much of what we are struggling to do here is not unique—it is sort of the American way. I found that there really was a Mr. Boeing, and a Mr. Northrop, and a Mr. Grumman. Yes, they were all misters. But they needed Congress. They had ten-year exclusive monopolies on aviation but they were not making

enough money, so Congress gave them more money. Then I found out—I did not know any of this—that Boeing owned United and got so successful that it was split apart. So, I just want to make the point that all of you are involved in this—everything that Doug and NASA are trying to do, and what we are trying to do in industry—space is not the first frontier.

### **Ms. Timmons**

We also recently looked into the railroad industry, which is another similar parallel. What is different about the railroad industry is that it owned a lot of the buildings, facilities, and locations that they were trying to get to. So, they had incentives for keeping that going. That may be a potential model in advancing space exploration and commercial space.

### **MajGen Bolden**

I asked Kerry earlier about how you build communities? Kerry just alluded to something when she talked about the railroads. And you [Jeff] talked about the glut of launch providers. I share that concern with you that everybody wants to get into, at least early on, everybody wanted to have a launch vehicle. That was the thing—to be a launch vehicle provider. Well, we need places for the launch provider to go. Can you talk a little bit about the risk that you took with providing places to take people? Because you had to go through some pretty extraordinary efforts.

### **Mr. Manber**

You are exactly right. We call ourselves at NanoRacks a destination company. For the past seven, eight, nine years I think, we helped the CubeSat market develop. We helped deploy some of the first satellites at Planet, at Spire, and at GOMspace. We helped that market take place, and then people saw the demand and the capital flowed into launch vehicles. Now we have this extraordinary liquidity and capital for launch vehicles. We have this robustness that we have never had, which is wonderful.

I do have some fear of the fallout. I mean, just do the math. If all these folks are flying the once a month that they say, or they are flying 40, 50, or 60 times a year, they are not all going to make it. Then throw in international service providers, as well.

We have struggled to raise capital in the past. People say, “Jeff, if only you were a launch vehicle,” or “Jeff, if only you were a constellation.” You know, we are not. We are a destination. What is so important about what NASA has announced is that it shows folks new to the community that it is the position of the United States government that destinations are important as well, and that they will be treated in much the same way. But we have had a difficult time. We are self-financed at NanoRacks and part of that is because everybody was putting money into launch vehicles. Now, that is changing.

But I do worry about two things. One, what are the repercussions of all of these launch vehicles coming onto the market? It is good because it lowers prices, but there will be commercial failures. And secondly, I worry that now NASA believes in commercial too much. They think it will be billions of dollars of revenue in LEO. Newsflash: it will not. I worry that there is this belief in the LEO market. Given that the ISS is controlled by so many people: Japanese, Europeans, Canadians, the private sector, and NASA, and with so many different things to do like the commercialization of media and branding, it will be difficult to extract optimal revenue. So, we must be realistic.

### **Audience Member**

Is the chokepoint the shortfall of spaceports? When you talk about too many launch vehicles, is there just a need for more launch locations dedicated to commercial only?

### **Mr. Manber**

Right now most of these are dedicated to CubeSat and SmallSat. And I just don't see, this is just me speaking, but I just don't see the constellations coming along. SpaceX is self-launching and you have OneWeb—they are even doing a lot of non-U.S. work. But I do not think it is the spaceports. We just need to see enough demand for constellations or destinations. I would like to see ten space stations in the next ten years. That would help.

### **Audience Member**

One of my favorite movies is *Wall-E*, which showed the contamination of LEO. One of the key components of your business case is how to commercialize LEO without messing it up? What are commercial companies or NASA doing to consider orbital debris? There is going to be a cost for it, whether it is for us or for our grandchildren.

### **Mr. Manber**

At NanoRacks, most of our satellites deploy low enough that they come back in on their own after about nine months to a year. I am concerned by the higher LEO orbits and major constellations, but we (NanoRacks) are not in that zone yet.

### **Ms. Timmons**

The hard part is you cannot make the business case close. The reality is that there is not someone paying to clean up low Earth orbit. That could be where regulation and policy come in to help keep us all honest.

### **MajGen Bolden**

One thing that was done well was a convention put in place that if you launch something then you have to provide enough propellant to either safely deorbit it into a nice safe place in the ocean somewhere, or kick it up to a parking orbit where it stays for several hundred years. For the most part, I think people comply with that. But your question is one that I can remember discussing while sitting around the table with the Secretary of the Air Force and someone representing the national security arena. We all agreed that low Earth orbital debris is our most critical problem. We said, "Okay and who is going to take the lead?" Then everybody looked at their checkbook and said, "Let's defer this to the next meeting." That is just a fact of life and that is not sustainable. So that is a critical question that we have. The encouraging thing to see is kids start to think of really innovative ways to build a spacecraft that can go out and do a "James Bond" eat-it-up, or drag a big magnet in space, or something. Those are probably not near-term solutions, but people are thinking about them for the future.

### **Audience Member**

What do you think of our current framework of adjudication of sovereign territorial jurisdiction for the future regarding deorbiting of debris and claims over extraterrestrial territories?

### **Mr. Manber**

One of the exciting things for me personally is seeing the emergence of space nodes, or regulatory nodes. Of course, you have it in Luxembourg now and you have it in other places. You have a similar analogy in shipping where it can be a convenience of flag, and I think we are going to see that in space, where Luxembourg, the UK, and UAE are all trying very hard. The emergence of UAE such that in the next few years, they are going to be a major player in commercial and civil space with their Mars program. For me, it is encouraging, as long as we get it right. Like the question on orbital debris, there isn't any player that can operate and not worry about orbital debris. In theory it is a good thing that there are emerging and different locations of expertise.

### **Audience Member**

First, is a specific question for Mr. Manber. Do you have any plans on making your company publicly traded? And second, how does one actually make a profit from being in LEO as a private company?

### **Mr. Manber**

It is an interesting question. There is such excitement towards commercial space now and we have watched as some of our colleagues have gone public. GOM space is a good example. We also watch how their senior management then spends 80% of their time dealing with regulatory issues. I will answer candidly. If folks here start to go public and it becomes a means of raising capital, then it may be a way for us to grow. Right now, it is happening in Europe, it is happening in Australia, and I've watch as my friends are spending all their time with lawyers. Nothing against lawyers.

Secondly, in the early days, NASA was not sure philosophically if they should allow a company to be able to make a profit using the taxpayers' hardware, and I would argue by saying that it is the American way. Now I go back to my friends at NASA and say, "I'm still trying to make that profit." However, NanoRacks has been profitable because we are not existing on venture capital. We have been profitable for the last seven years. Doug mentioned the correct way to do it earlier—you keep your expenses lower than your revenue. We haven't been able to grow or go into all the things we want to go into. Right now, the Bishop airlock is taking up most of the available resources, but that method is how you stay profitable.

### **MajGen Bolden**

A question for the audience. Jeff has kind of hinted at this a couple of times. All of you taxpayers—how would you respond to your fellow taxpayer who says, "Why should my tax dollars go to supporting a private entity that is going make money and I'm not going to see any of it in return"? For those of you who are enthusiasts, does anyone have an answer?

### **Audience Member**

I would say it is a valid question. I think being protective of your tax dollars and being reminded that while the government may seem to have an "unlimited pool of money" that they can grab, it is not really theirs. So, I think that is a valid point.

However, I would say that innovation—moving further, going beyond, and discovering new things—pays dividends, and there are just so many resources in space. I just think innovation pays dividends, and at the end of the day someone has got to make that investment. And if we are all doing it then it is going to cost us a hell of a lot less in the long run.

**Mr. Manber**

We spend a lot of time here on the Hill, and one of the charts that we show is how many jobs our customers have now in commercial space—and those are just the NanoRacks customers. It is wonderful to see.

**Mr. Comstock**

I was just going to say that with the strategy we have laid out, NASA has sort of taken the long view on this. We expect that when we have the commercial infrastructure that we hope to in a decade or so, we will be saving money for doing the things that we want in LEO so we can place more of NASA's focus on exploration further out. Sort of turn over LEO operations to the private sector who can do it much more efficiently. In addition, by creating this economy in LEO, you are also creating jobs. The people in those companies pay taxes and it comes back to the taxpayer that way, as well.

**Ms. Timmons**

This may be to altruistic or cliché, but there's something about space that inspires people and it motivates future generations. When I do public outreach events at local schools or museums, the crowds are huge and the kids are just so engaged and so excited to hear about what we're doing. Mostly they want to know about the bathrooms, but they love it.

**Audience Member**

NASA recently released results from those 12 commercialization studies, but they consisted of one-page overviews. I wanted to ask Kerry especially—if you were heading up that study—was there enough of a market to be profitable given what your costs were expected to be, and can you talk a little bit more about those details. What markets are you looking at? What are some of the big ones, and are you making a profit?

**Ms. Timmons**

We did study that. We looked at several different business cases for different products. In-space manufacturing and assembly was where we were really focusing. I'll talk a little bit about some things that are more publicly known like ZBLAN. That's a fiber optical cable that you can gain a lot of advantages from being manufactured in space. We used that as an example to show how you could close a business case. We're working on our own internal concepts for building up the infrastructure that supports those kinds of products. We want to buy down the risk for the companies that are doing those things to help them be profitable.

**Mr. Comstock**

Let me just add one other thing, we've also released the executive summaries for all 12 of those studies and they're available on the resources page if you go to the LEO economy website.

**Audience Member**

Jeff made the argument that this is just another critical infrastructure and used the example of our current interstate system. You have to put it in terms that the people you're presenting to can understand. If it's people that are accustomed to cruise ships, think of the port authorities. It's the same critical infrastructure. You're not paying for it, but you redeemed benefit over a period of time. You have to acknowledge that as you gain more benefit from a government infrastructure project, you will start to pay some sort of tax.

### **Mr. Manber**

As I said earlier, I agree exactly. This is not the first frontier; it's just our frontier. Just look at aviation. No one questions the fact that it is a mature industry where the U.S. government, by means of the taxpayer, pays for the airports. And the government workers oversee regulation and safety—what would the ticket price be if United and Southwest had to pay for the airport? There's a negative part about space, and it is that people say, "Wait a second ... this is somehow different because its space." But every industry that's come along, even mature ones like oil and gas, has that public-private partnership to various degrees.

### **Mr. Comstock**

Another example is GPS satellites. Lots of people make money off of GPS and those are all funded by the federal government.

### **Audience Member**

I have an observation and that is that there actually is a business model that's been demonstrated in LEO. It's the business around commercial satellite imagery and the entire business that's spawned from that. For those that were at the GEOINT conference in San Antonio a couple of weeks ago, you were among 4,000 of your closest friends at what I've described as kind of a combination of Woodstock and SeaCom, and it was all for satellite imagery and location-based services. That all started with subsidies and a set of policies—national space policies and presidential directives, essentially—that talked about commercial satellite imagery. Then there were some critical government investments and now that market is fully self-supporting even though the government remains a customer. It's an international marketplace of very traditional regards, a lot of ongoing investment, and a lot of energy.

### **MajGen Bolden**

I see an old friend in the back that I'm going to put on the spot, and that's Admiral Latenbacher who was at one time with NOAA. Can you comment on how you have seen NOAA and other government agencies sort of migrate to utilization of commercially-available data?

### **Adm Latenbacher**

Yes, I'm working with a company right now in trying to commercialize data and sell to government as well as to the private sector. We believe there are values for the government as well as for private sector. There are industries that need the information that we are going to gather. The problem is the change from the models that we have today of building the very large satellites because we can't afford more than one \$5 billion satellite every few years. So, if you can do this much more inexpensively with instruments the size of your cell phone and if you have enough of them, you can do things much more efficiently and you can keep the cost down. From our view there are customers on both sides. This is like any other business that's going to develop from new information, inventions, and all of the creativity that people can bring to the future. Just look at the changes we have today with the miniaturization of technical components and their reliability.

### **Audience Member**

Thank you to all the panelists, you all have been really insightful. I'm curious about how you safeguard national security and an enterprise where more private corporations are getting involved? What happens in cases where there is espionage, where there could potentially be a "private entity" that says I'm just making a new company. They could be on the ISS, but they're actually being used to survey the U.S. How do you safeguard against that and other similar situations?

### **Mr. Manber**

Early on at NanoRacks—as you’ve heard we were the first company to own our own stuff on the station—there was some concern from Homeland Security that we were marketing to the public. One of our products offered access to a relatively small NanoLab, and there was concern that when marketing to the public you don’t know who you’re marketing to. We actually had some very tense discussions until we explained that it’s harder to hide something in something small than in a huge hundreds of millions of dollar payload that goes up. That’s one clever answer. But in general, I can say that there is an extremely rigorous and robust procedure within NASA that NanoRacks works with to ensure our payloads, which we know to the centimeter, and everything that’s in our stuff. We work closely with the folks at NASA and we work with the State Department. From an outside perspective it may look haphazard, but it’s not.

### **MajGen Bolden**

Can you tell the story of your journey to Houston when you took on the first Chinese customer?

### **Mr. Manber**

As you may know there’s a prohibition that was put on by Congressman Wolf, who is now retired, to prohibit NASA and other U.S. government agencies from dealing with China in civil space activities. About four years ago, I realized that this irked me. The reason it irked me is because our friends in Europe were working with the Chinese in space. And again, space should be a normal place to do business and we were artificially tying our hands behind our backs. The Germans are working with the Chinese in microgravity research, the French and the Italians are working with them, but I couldn’t be in the room. I read the Wolf Amendment and it actually didn’t say anything about commercial. We went to the Obama Administration and they allowed us to try to find an opportunity. We found Beijing Institute of Technology doing a synthetic DNA project. It had flown before so it was not opening the door and Charlie Bolden was willing to write to a republican, Chairman Culberson. His letter stated that NanoRacks was a commercial entity, the Chinese were paying NanoRacks, there was involvement with the PLA, there was no technology transfer and that under the Wolf Amendment, NASA saw it as being allowed. And then NanoRacks did something unusual in this town. We did two things: We sought out representative Wolf who was retired, we told him what we were doing, and we asked permission. And the message came back, “I don’t like it, I don’t like working with China, I have human rights concerns, but your project satisfies my amendment.” Then we went to representative Culberson and we said the same thing. He said, “I appreciate what you are doing,” and so that’s how we got it through. So, you don’t give up. You understand the policy, you stay within the law, and you respect everybody on both sides of the aisle. We did that and we were very fortunate in how folks treated us.

### **Audience Member**

I’m studying international relations at American University. I can’t help but think that there is a sense of urgency in this area. People may not be aware, but the reality with new frontiers, regardless whether it’s nuclear energy, rocketry, AI, or whatever else, whoever gets there first and gets there the most gets to set the rules. That’s just how international relations works. And that’s how private industry works. And the reality is, it is in our security interest to encourage private sector development in space. Because if we’re not doing it, the Chinese are going to do it, the Russians are going to do it, and the Europeans are going to do it.

### **Mr. Comstock**

Let me address just one aspect of that. The ISS is an international partnership. We work very closely with our international partners in development and operation of the ISS and we have also coordinated this new policy with them. They're trying to develop commercial activities using the ISS as well, so while there is certainly the aspect of competition with regards to commercial activities, its underscored by great collaboration and cooperation between many nations with the ISS.

### **Mr. Manber**

I've always been motivated by the Louisiana effect. To this day, Louisiana has the Napoleonic Code because of who got there first in terms of Western society. It was the French, and to this day their legal system is different. That motivates me to make sure some of our principal values go into space.

### **Audience Member**

I'm curious about what you have to say about what taxpayers can expect to see from this. My mind goes to the Hubble Telescope where one of the spinoff technologies we see today thanks to that is in your cell phone camera. So, I'm wondering, maybe if American taxpayers won't see immediate dividends from LEO commercialization, they'll see some spin off technologies come out of this. Do you have anything in mind when you think of that, or what might we expect to see?

### **Ms. Timmons**

It's a difficult question because you're almost asking us to predict the future. We are not so focused on what that next killer app is, but rather how do we get there from here. How do we buy down the risk so that other companies can do that? If you have to build your whole satellite with propulsion and comms, and power before you can even put your payload on it, then the barrier and the hurdle is so high. With all of the commercialization we have on the ISS, it is important to realize that Orion is also a NASA platform. It even has a different available environment in deep space, and we are looking right now at how we can put different payloads on that. We have a solicitation on our website requesting ideas from companies and the public. So, I think the more you get the message out, the more ideas you have coming in, the sooner you get to those "killer apps."

### **Mr. Comstock**

Currently on the ISS, half of the U.S. capacity goes to the ISS national lab, which is focused on research and development in a number of areas. There's academic research, there's government research—not only NASA but also NIH and NSF—and there's a lot of commercial research going on for R&D through the ISS national lab. There are a number of the things that are being worked on there, ZBLAN, a very efficient fiber optic, was already mentioned. There's also a very interesting concept that develops an artificial retina that can only be developed in space, which if successful could restore vision to blind people. That is one example that is being worked on now. Organs on a chip are being tested in space right now. There are a host of things that are already in the pipeline, but the thing that is really exciting is that we have no idea what the killer app could be or what things may come in the future. But given NASA's history of 60 years of spin-offs that are part of our everyday life, we know that there will be more in the future.

### **MajGen Bolden**

How do you envision the future of research in LEO given that the machinery of the ISS will inevitably age out? Say 10-15 years?

### **Ms. Timmons**

I envision it continuing, but with even more commercial partnerships. As we look to go beyond LEO, to the Moon and to Mars, there are still a lot of things that we need to understand better. I think that the LEO platforms—the ISS and whatever follows it—are already great national labs and they'll continue that work to advance our knowledge of the environmental effect on humans, biological sciences, and technologies that we need to go farther into space.

### **Mr. Manber**

I'm excited about us evolving into dedicated platforms for dedicated markets. The last 50-60 years have shown us that a guy on a bicycle does indeed disrupt the microgravity environment. I'm looking forward over the next ten years to the potential for Lockheed to do a platform dedicated to in-space manufacturing of ZBLAN. NanoRacks may be doing something in biopharma, and then there will be hotels, and then there will be professional astronauts. Each linked by an ecosystem, but not physically linked. That's the exciting part to me.

### **Mr. Comstock**

I envision in the future that doing research and development in the microgravity or space environment is going to be something that not just a small community of researchers do, but that the entire research enterprise across universities and industry and governments is actively thinking about the opportunities in microgravity. Part of what we want to do through this commercial enterprise is to make it available to all.

### **MajGen Bolden**

NASA has this organization mandated by Congress called the Aerospace Safety Advisory Panel and it works for Congress and they report out every year to Congress. One of its former leaders was Vice Admiral Joe Dyer, and he had a saying every time he came over to the Hill to talk about safety. He said NASA and the nation needs to have constancy of purpose. We can't keep changing and going back and forth. So, my final question to all of you is how do we ensure continuity of interest and support? How do we do something that we found so difficult to do in the past? How do we ensure continuity of interest and support?

### **Ms. Timmons**

Common purpose. Common goals are always a way to unite people. So, whether it's exploration and what's over that next hill, the excitement of what is out there and human eyes witnessing it—not through a lens, not through a camera, but just in person. I think there's a lot of interest and excitement in the human race as explorers.

### **Mr. Manber**

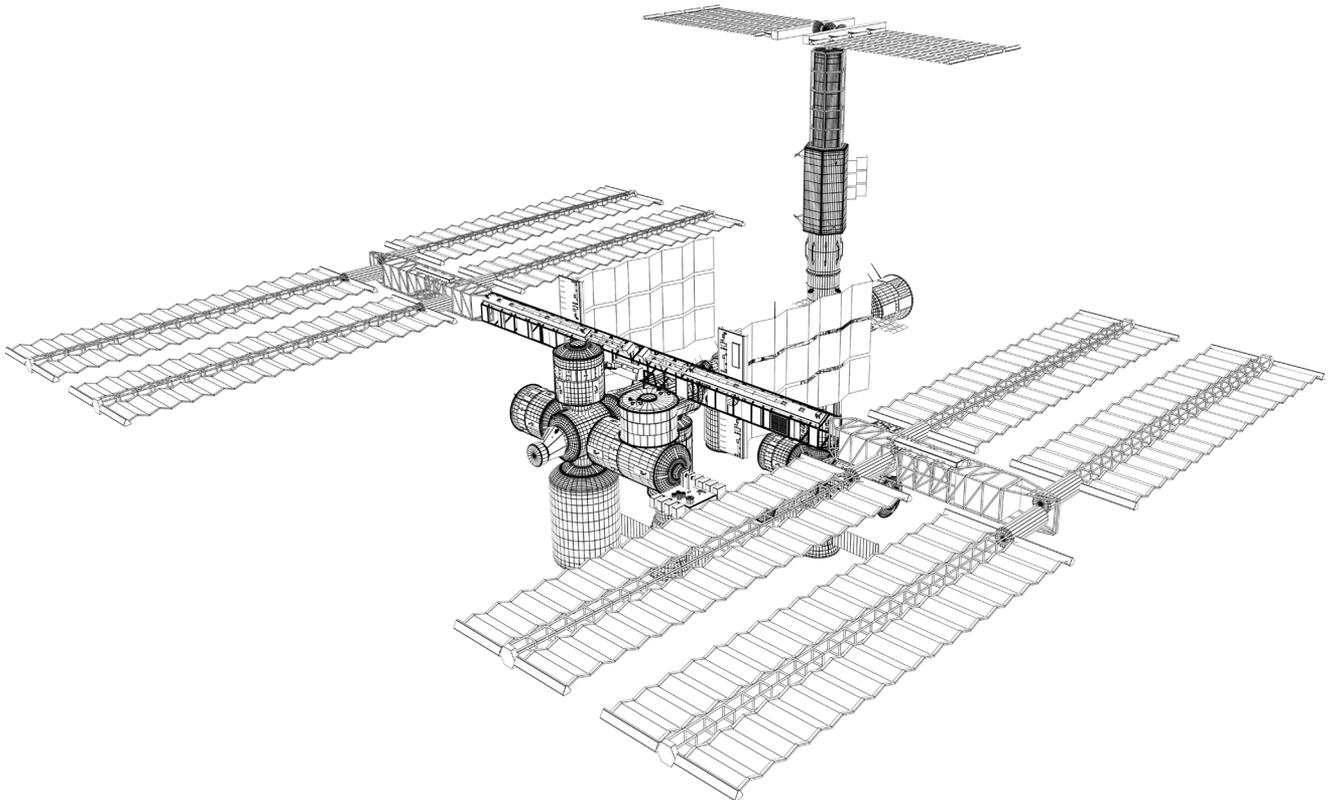
I'm a little more pessimistic, but I'm optimistic in this sense: we always figure it out. It's messy, it's sloppy, we had a spike at the beginning in the NASA funding because we were fearful of a very powerful foe and I don't want to see that again for that reason. But we'll figure it out, we always seem to. I just have this belief in America that it'll happen through open markets and competition and ingenuity. Everyone has a different reason. Some people are motivated by national interest, some people are motivated to make a buck, and some people are motivated to find a cure for an illness. I just have this belief that as long as we unleash the ingenuity of everybody in our society, that in the end we get there.

## Mr. Comstock

I think communication and letting people know what we are doing and how it is benefiting them, and that may be different for every person. Sometimes I'll take a cab ride and while talking to the cab driver, I'll ask, "Have you seen the space station and did you know there are six astronauts up there now and it goes by seventeen and a half thousand miles an hour?" and he says, "What? I thought you guys were shut down." You can never communicate too much, so we need to just keep communicating and the stories that we can't communicate are just going to keep getting better and better.

## MajGen Bolden

You all have been great, and I want to thank the Potomac Institute for allowing me to be a part of this and thank everyone for coming out. I will close with a demand. I do a lot of traveling around the world and I am still amazed at how many people outside this country still look at us as the shining city on the hill. Don't ever, ever, ever forget that. Things come, things go, policies change, policies go; we still represent the one last hope for humanity for a lot of people who don't have the privilege of living in this country. So, remember that. Talk about today, whether you're a space junkie or whatever you call it, tell people why you enjoyed it or why you didn't like it. Your homework is to go out and tell people what you saw and heard here today and to bring someone the next time Potomac Institute holds an event like this.



# Summary

Efforts to commercialize LEO are currently underway, but more can and should be done to help the process. The ISS is currently the only manned space capability, and it has a finite lifespan. It is critical that the U.S. avoid a gap in on-orbit capabilities like it experienced after the Space Shuttle. This will involve multiple companies working in concert with continued government support to create a profitable, privately-owned and operated infrastructure, where government can purchase the services it requires as one customer among many.

These efforts to build out a new infrastructure in concert with private industry is not a novel concept—space is not the first frontier. It has been the historical role of the federal government to stimulate new commercial marketplaces around critical infrastructure, and to provide services that allow for profitable ventures. The federal government should continue to provide funding and administrative, technical, and regulatory support for the private space industry and allow private companies to profit from the resulting infrastructure. This includes helping industry buy down the risks that would otherwise prove insurmountable from an economic standpoint.

There are regulatory hurdles for commercial space companies, but government regulations are not the only issue. For a long time, the entire administrative framework of the government space enterprise was nebulous, difficult to navigate, and inefficient. Various congressional space acts and presidential directives have improved the problem over time. Congress and the Executive branch should continue to refine the regulatory and administrative framework of the government space enterprise. Goals should be clearly defined and roles and responsibilities of disparate government agencies and offices assigned and communicated to support a regulatory system sustains profitable business models.

The discussion yielded a far-reaching vision for the continued growth of the LEO economy. With continued support from Congress and the Executive branch and sustained enthusiasm from industry, a future containing a burgeoning marketplace of commercial space stations will be just around the corner.

image: NASA





# Appendix A: Panelist Bios

## MajGen Charlie F. Bolden Jr.

During the first half of 1998, MajGen Bolden served as Commanding General of the 1st Marine Expeditionary Force Forward in support of *Operation Desert Thunder* in Kuwait. He was promoted to his final rank of major general in July 1998 and named Deputy Commander of U.S. forces in Japan. He later served as the Commanding General of the 3rd Marine Aircraft Wing at Marine Corps Air Station Miramar in San Diego, CA from 2000-2002. He retired from the Marine Corps in 2003. Bolden's many military decorations include the Defense Superior Service Medal and the Distinguished Flying Cross. He was inducted into the U.S. Astronaut Hall of Fame in May 2006 and enshrined in the National Aviation Hall of Fame in October 2017.

Bolden was nominated by President Barack Obama and confirmed by the U.S. Senate as the 12th Administrator of the National Aeronautics and Space Administration (NASA). He began his duties as head of the Agency on July 17, 2009. As Administrator, Bolden led a nationwide NASA team to advance the missions and goals of the U.S. space program.

Bolden's 34-year career with the Marine Corps also included 14 years as a member of NASA's Astronaut Office. After joining the office in 1980, he traveled to orbit four times aboard the Space Shuttle between 1986 and 1994, commanding two of the missions and piloting two others. His flights included deployment of the Hubble Space Telescope and the first joint U.S.-Russian shuttle mission, which featured a cosmonaut as a member of his crew.

Bolden received an appointment to the U.S. Naval Academy, where he earned a Bachelor of Science degree in electrical science in 1968 and was commissioned as a second lieutenant in the Marine Corps. After completing flight training in 1970, he became a Naval Aviator. Bolden flew more than 100 combat missions in North and South Vietnam, Laos, and Cambodia while stationed in Namphong, Thailand between 1972-1973. Bolden earned a Master of Science degree in systems management from the University of Southern California in 1977. In 1978, he was assigned to the Naval Test Pilot School at Patuxent River, MD, and completed his training in 1979. While working at the Naval Air Test Center's Systems Engineering and Strike Aircraft Test Directorates, he tested a variety of ground attack aircraft until his selection as an astronaut candidate in 1980.

## Michael Beavin

Mike Beavin is the Director of Commercial Space Policy at the National Space Council. Before joining the National Space Council at the White House, Mike held various senior policy positions on congressional committees, at federal departments, and industry associations, including the U.S. House of Representatives Committee on Science, Space, and Technology, the Senate Committee on Commerce, Science, and Transportation, the Department of Commerce, the Federal Aviation Administration, NASA, the Satellite Industry Association and the American Institute of Aeronautics and Astronautics.

Mike lives in Del Ray, VA with his lovely wife and four children.

## Jeffrey Manber

Jeffrey is regarded as a pioneer in bringing about a robust commercial space exploration program, one where the private sector contributes as much as the government. His goal has long been to make space just another place to do business.

As the CEO of NanoRacks, LLC from 2009, Jeffrey has steered the growth of NanoRacks from a garage space to where NanoRacks is today—a leader in the commercial use of the International Space Station and other privately-owned space platforms.

As the first company to own and market its own hardware on the space station, NanoRacks has deployed over 200 satellites from the space station for companies as well as for NASA, the European Union, and universities. Researchers and students from a dozen countries use the NanoRacks' research hardware on a commercial basis, including the first customer onboard the space station from China. The strong educational customer base caused Jeffrey to co-found DreamUp in order to maximize the ability to make space a learning tool world-wide.

Earlier, as CEO of MirCorp, which leased the Russian space station Mir, he oversaw the first ever (and still only) commercially funded manned mission, of over 70 days, to the Mir space station and signed with Mark Burnett of Survivor and NBC to do a game show where the winner goes to space. He is the only American to work for the Russian space program, and carried over to Russia the first contract between NASA and the Russian space effort. More recently, he and NanoRacks were able to bring the first commercial Chinese customer (Beijing Institute of Technology) to perform research on the ISS.

Jeffrey has served as an adviser to numerous companies and governments and speaks to industry and university organizations on a regular basis. The author of multiple books, his second (*Selling Peace*) chronicles his time working with the Russian space program. In 2012, Jeffrey was awarded the NASA Exceptional Public Achievement Medal and the 2017 the Pioneer of New Space Award from the Space Frontier Foundation, and most recently the 2019 Space Pioneer Award from the National Space Society.

## Doug Comstock

Douglas A. Comstock is on a detail assignment as the NASA Human Exploration and Operations Mission Directorate (HEOMD) Commercial Low Earth Orbit Liaison. In this role he is the focal point within NASA HEOMD for developing and communicating an integrated strategy for maximizing the potential for growth of commercial activities in low Earth orbit.

Doug Comstock is the Deputy Chief Financial Officer for Integration, reporting to the CFO.

Comstock was previously Director of the Cost Analysis Division in the Office of Evaluation at NASA HQ, as part of the Office of the Administrator. He was responsible for cost estimating policy, providing cost analysis capabilities and tools for NASA, developing new and improved methods for cost analysis through research, as well as cost analysis consulting to programs and projects and cost analysis for agency studies.

Comstock was previously the Director of NASA's Innovative Partnerships Program (IPP), responsible for directing the IPP portfolio of technology investments and partnering mechanisms including Small Business Innovative Research, Small Business Technology Transfer Research, the Centennial Challenges, and the Innovative Partnerships Seed Fund. Additionally, he was responsible for intellectual property management and technology transfer, and for encouraging and facilitating partnerships with the emerging commercial space sector including the agency's purchase of emerging commercial services.

Comstock previously served as the NASA comptroller, responsible for the preparation, tracking, presentation and defense of NASA's budget to the White House Office of Management and Budget (OMB) and the Congress. As the founding director of NASA's Strategic Investments Division, he was responsible for integrating NASA's strategic planning and program analysis supporting budget decisions into a single organization.

Before coming to NASA, Comstock spent four years as a program examiner in OMB, with responsibility for NASA's human space flight activities, biological and physical research, and personnel. Prior to his government service, he was Director of Engineering with the Futron Corporation, a Bethesda, MD-based technology consulting firm, and began his career with General Dynamics Space Systems Division, conducting preliminary design and systems analysis for numerous aerospace systems, from strategic defense to advanced space transportation.

Comstock has undergraduate degrees from the University of Washington in both mechanical engineering and architecture. He completed graduate studies at the Massachusetts Institute of Technology and received masters degrees in both aeronautics and astronautics, and technology and policy.

He resides in Ashburn, VA and is married to the former Susan Louk. They have two children.

## Kerry Timmons

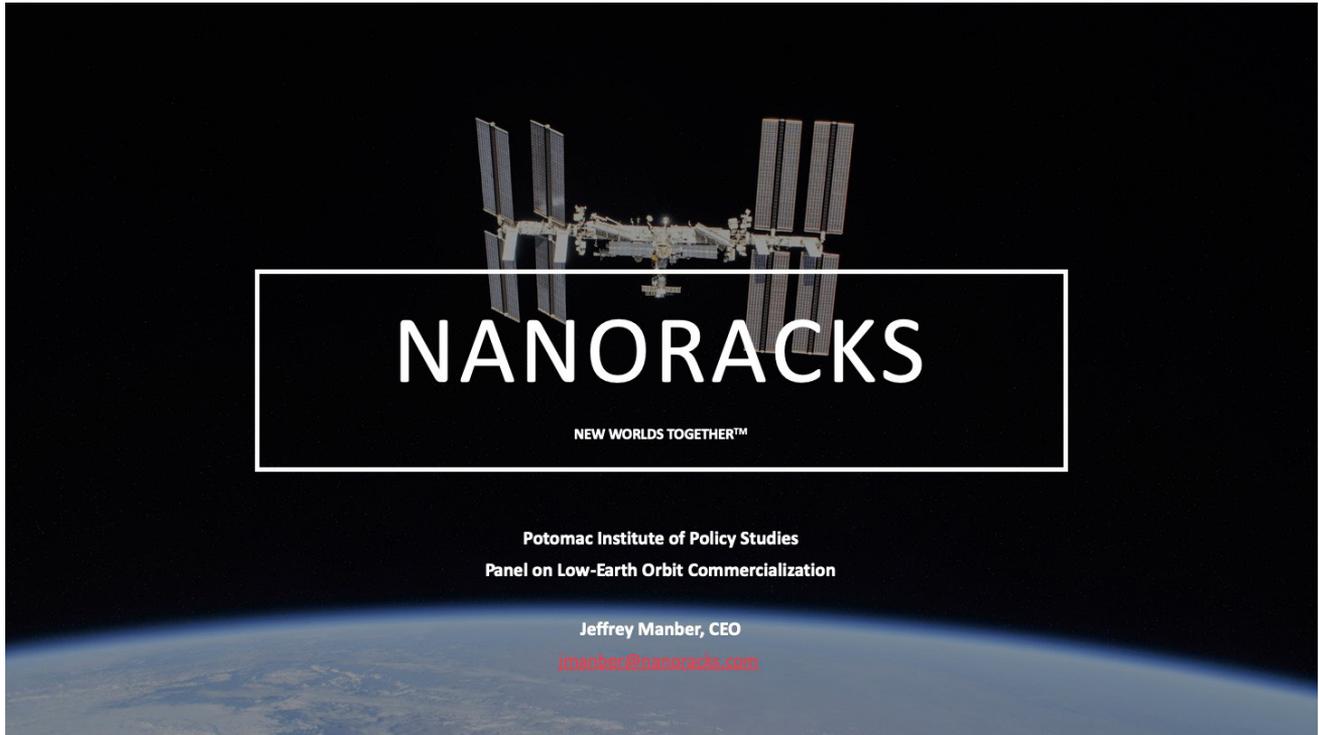
**K**erry Timmons is Lockheed Martin's Program Management Lead for NASA's LEO Commercialization Study and activities related to In-Space Manufacturing and Assembly. She is also the Avionics and Power Lead for Advanced Programs where she leads a team of engineers working towards solutions that will support deep space exploration missions to the Moon and beyond.

She joined Lockheed Martin in 2004 and her previous job experience includes systems engineering tasks in support of design, development, and testing of the Orion Avionics, Power and Wiring systems.

Timmons has a B.S. in Mechanical Engineering from the University of Colorado and an M.S. in Mechatronics from the University of Denver.

# Appendix B: Participant Slide Presentations

## Jeffrey Manber Presentation



### NANORACKS CUSTOMERS AROUND THE WORLD

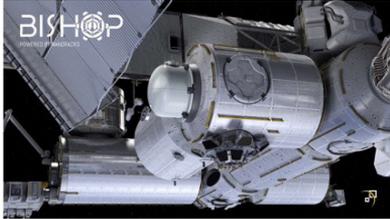


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## PUBLIC-PRIVATE PARTNERSHIPS: THE RIGHT BALANCE



- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>• <b>US Government/NASA</b> <ul style="list-style-type: none"> <li>• Real estate (Node &amp; LEO)</li> <li>• Operations</li> <li>• Customer support</li> <li>• Subsidized transportation</li> </ul> </li> </ul>  | <ul style="list-style-type: none"> <li>• <b>NanoRacks</b> <ul style="list-style-type: none"> <li>• Concept</li> <li>• Funding</li> <li>• Customer base</li> <li>• Bringing marketing efficiencies</li> </ul> </li> </ul>   |
| <ul style="list-style-type: none"> <li>• <b>US Government/NASA</b> <ul style="list-style-type: none"> <li>• Real estate (Node &amp; LEO)</li> <li>• Station resources</li> <li>• Operations</li> <li>• Subsidized transportation</li> </ul> </li> </ul> | <ul style="list-style-type: none"> <li>• <b>NanoRacks Space Outpost Program</b> <ul style="list-style-type: none"> <li>• Real Estate (Commercial Platform)</li> <li>• Funding</li> <li>• Customer base</li> <li>• Bringing marketing efficiencies</li> </ul> </li> </ul> |

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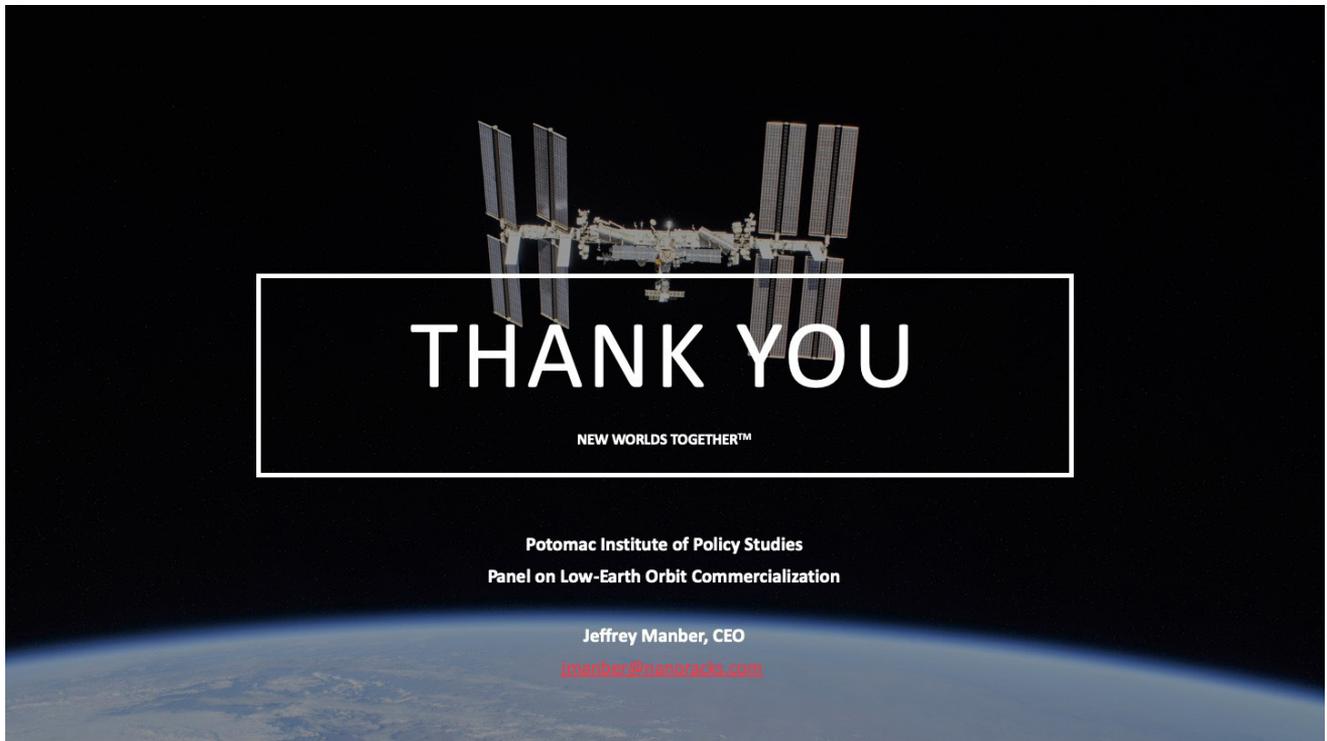


### NANORACKS SPACE OUTPOST PROGRAM

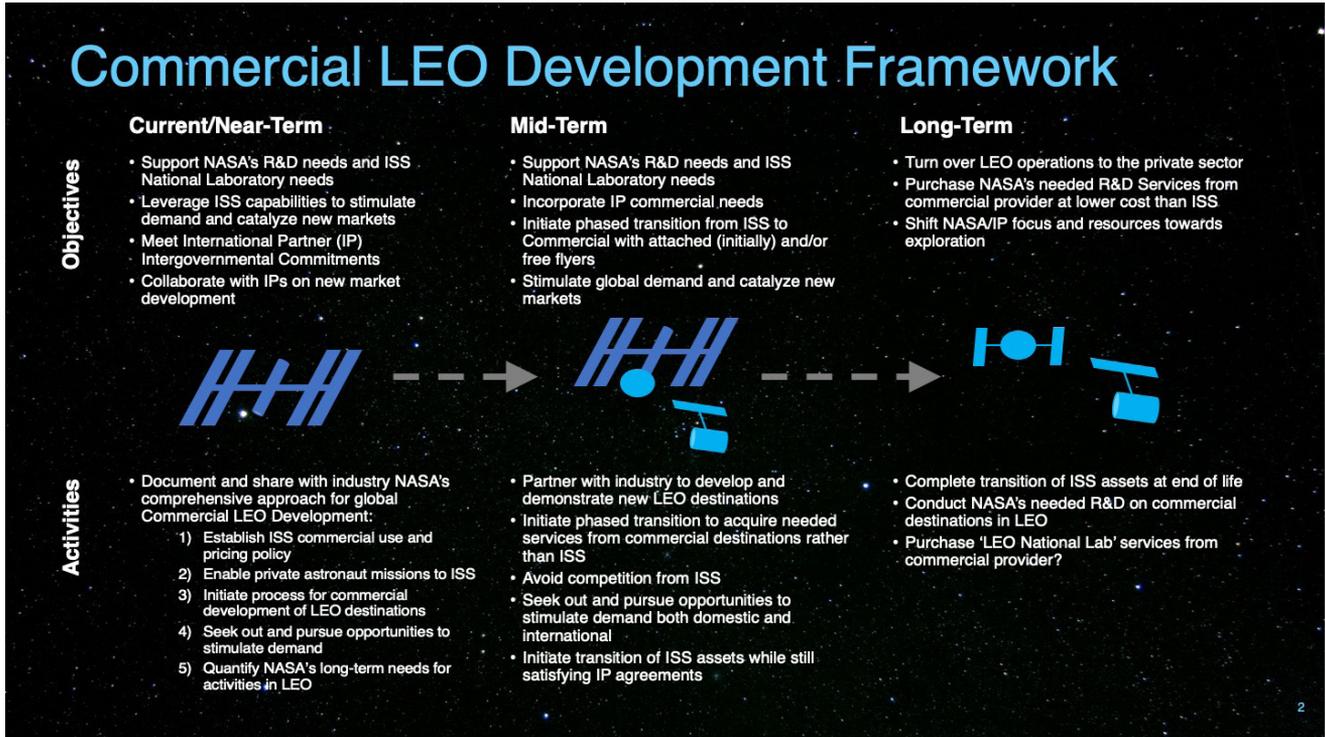
- To realize our vision, we are building commercial space stations to become the factories, warehouses, medical centers and more in space.
- We plan to be the leading company on the day that space hotels and factories come to life over the next 10 years.
- Let's take advantage of the booming launch vehicle market around the world to reach multiple destinations in space for users all over the world.

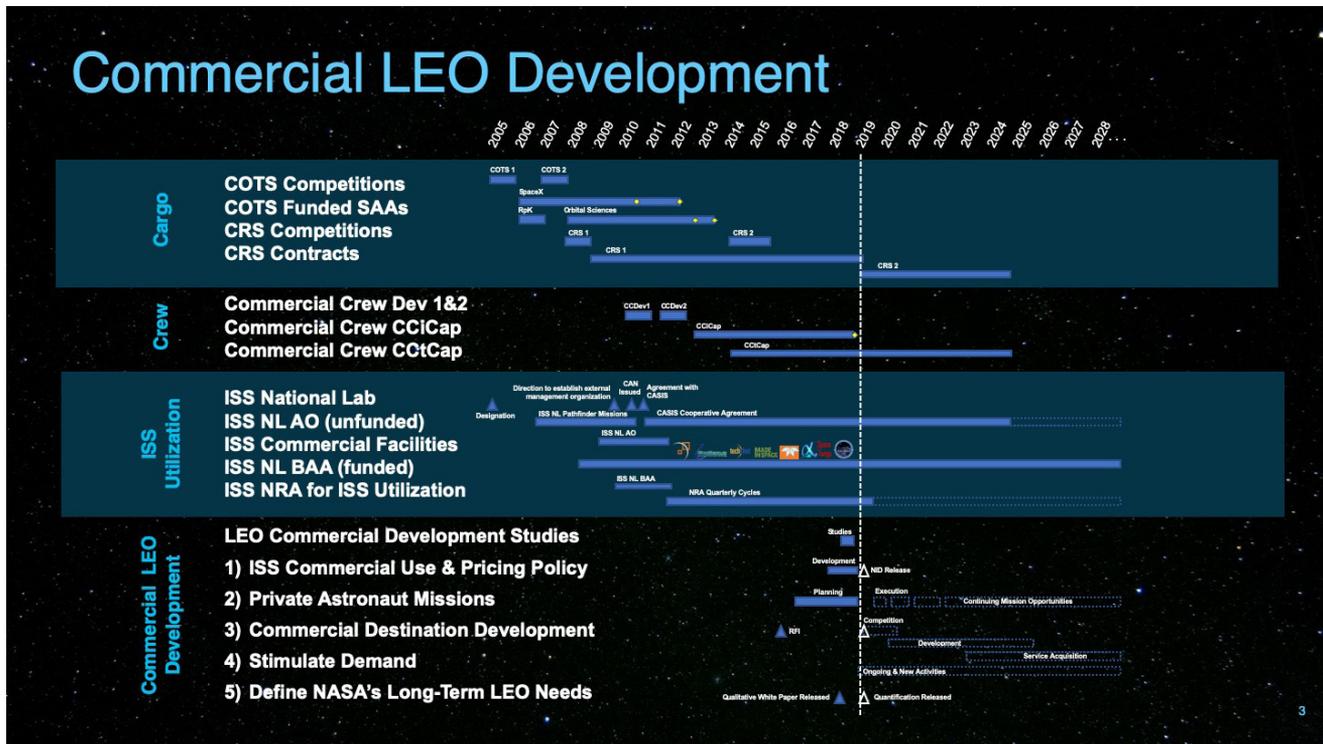
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# Doug Comstock Presentation





# NASA Plan for Commercial LEO Development

In the near term, NASA developed a five-point plan building on the work of the last two decades. This plan includes new policies, multiple solicitations, and new information that can be found on the Leo Economy website.

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 two paths including use of the ISS Node 2 Forward Port, and direct to a free-flyer destination;
4. NASA has laid out a plan to pursue opportunities to stimulate scalable and sustainable demand for LEO destinations including solicitations with targeted calls for in-space manufacturing and regenerative medicine flight demonstrations, as well as ideas to broadly stimulate demand growth;
5. NASA has updated a white paper quantifying the agency's long term needs in LEO.

**NASA Plan for Commercial LEO Development**  
 to achieve a robust low-Earth orbit economy from which NASA can purchase services as one of many customers

**Summary and Near-Term Implementation Plans**

June 7, 2019





Major General  
Charles F. Bolden







