Leveraging the Academic–Commercial Partnership for NewSpace

Moderator: James F. Bell III[1]

Participants: Cheryl Nickerson,[2] Michael Lopez-Alegria,[3] Thomas D. Jones,[4] and William Pomerantz[5]

[1]School of Earth and Space Exploration and [2]Biodesign Institute, Arizona State University, Tempe, Arizona.
[3]Commercial Spaceflight Federation, Washington, District of Columbia.
[4]Florida Institute for Human and Machine Cognition, Pensacola, Florida.
[5]Virgin Galactic, Pasadena, California.

INTRODUCTION AND PANELISTS

When thinking about the interrelationships among the various stakeholders in the space industry, one can imagine a Venn diagram with at least four distinct realms: one called commercial, another called government, another called academia, and a final one called the public. These realms intersect in sometimes-simple, sometimes-complex ways, and often dynamically as new strategies, interests, and capabilities come and go. In the past few years, we have seen significant discussion, some here in this journal, about the interactions between the government and the commercial space sector (and their overlap with the public), but not as much discussion and strategizing about the most effective ways for academia to interact with the commercial space sector.

In order to spur this discussion, we have begun a new campus-wide Space Technology and Science ("NewSpace") Initiative at Arizona State University (ASU), with the specific goal of establishing and fostering partnerships between academic institutions like ASU and next-generation nongovernmental space exploration science and technology companies (often called the NewSpace sector). We aim to enable the discovery of new research avenues, new partnerships, and new opportunities for student, faculty, and staff engagement in NewSpace. We believe that focused bottom-line-oriented collaborations among space savvy academics and industry partners can substantially advance the aims of everybody involved.

In the spirit of the roundtable discussions promoted by *New Space* journal editor Scott Hubbard on topics of interest to a wide spectrum of the NewSpace community, on April 1, 2014, the ASU/NewSpace initiative sponsored a special panel discussion at the recent Space-Tech Expo 2014 at the Long Beach Convention Center in Long Beach, CA. The topic of that discussion was on leveraging the academic–commercial partnership for NewSpace. What follows is a transcript of that hour-long panel discussion, edited for length by moderator and ASU NewSpace Initiative director Prof. James F. Bell III. Panelists were Dr. Cheryl Nickerson (ASU), Michael Lopez-Alegria (former NASA astronaut, now with the Commercial Spaceflight Federation), Dr. Thomas D. Jones (former NASA astronaut, now with the Florida Institute for Human and Machine Cognition), and Will Pomerantz (Virgin Galactic).

Our first panelist was my ASU colleague, Dr. Cheryl Nickerson. She's a professor in the School of Life Sciences in the Center for Infectious Diseases and Vaccinology at the Biodesign Institute at Arizona State. She's internationally recognized for her pioneering research in utilizing the microgravity environment of spaceflight as a unique research platform to provide novel insight into how physical forces dictate the outcome of host–pathogen interactions that lead to infectious disease. Her landmark spaceflight experiments aboard the Space Shuttle and International Space Station (ISS) and soon SpaceX launch vehicles along with the use of NASA-designed ground-based microgravity analogs have placed her work at the forefront of the field of cellular biomechanics. She's received several prestigious awards, including the Presidential Early Career Award for Scientists and Engineers (PECASE) and NASA's Exceptional Scientific Achievement medal, and she was an astronaut candidate finalist.

Next was Michael Lopez-Alegria, president of the Commercial Space Flight Federation. Michael comes from a distinguished background in aerospace, which includes positions as a naval aviator and test pilot and NASA astronaut. He's flown on STS73, 92, and 113 and was the commander of ISS Expedition 14. He got his BS from the Naval Academy, and his masters in aeronautical engineering from the Naval Post Graduate School. He's also a graduate of Harvard's Kennedy School of Government for senior executives in national and international security. He holds three NASA records: longest spaceflight, 215 days; largest number of extra-vehicular activities (EVAs), 10; and greatest cumulative EVA time, more than 67 hours. He was most recently the assistant director for ISS in the Flight Crew Operations Directorate at Johnson Space Center in Houston.

Our third panelist was Dr. Thomas D. Jones. Tom is a planetary scientist, former NASA astronaut, and currently a senior research scientist at the Florida Institute for Human and Machine Cognition, where he focuses on the future direction of human space exploration, uses of asteroid and space resources, and planetary defense. He has a PhD in planetary science (asteroid studies), and in more than 11 years with NASA flew on four Space Shuttle missions to Earth orbit. On his last flight, he led three space walks to install the U.S. Destiny Laboratory at the ISS. He's been on the NASA Advisory Council and serves on the Board of the Association of Space Explorers and the

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Astronauts Memorial Foundation. Tom has written several space and aviation books, and he writes frequently for space-related magazines. He's received the NASA Distinguished Service Medal, four NASA Space Flight medals, and NASA's Exceptional Service Award, Outstanding Leadership Medal, and Exceptional Public Service Award.

Our final panelist member was William Pomerantz, who is vice president for special projects at Sir Richard Branson's Virgin Galactic. A graduate of Harvard, the NASA Academy, and the International Space University, with a degree in earth and planetary sciences, Will works to help extend Virgin Galactic's efforts beyond space tourism, developing efforts such as the *LauncherOne* orbital launch vehicle for small satellites as well as suborbital research campaigns on *SpaceShipTwo*. Will also serves as a trustee and the chair of the Board of Advisors for the Students for the Exploration and Development of Space. Before joining Virgin Galactic, he worked on the X Prize Foundation, where he served as the primary author and manager of the $30 million Google Lunar X Prize and the $2 million Northrop Grumman Lunar Lander X Challenge.

DISCUSSION

Jim Bell: **I'm delighted to welcome you all to Space Tech Expo 2014 and to our ASU-sponsored panel discussion on leveraging the academic–commercial partnership for NewSpace. I'm looking forward to some very lively discussion about the interrelationships of various important stakeholders in this rapidly evolving area of space travel, space technology, space science, and space exploration. These stakeholders are, of course, the companies that are working in this business—government agencies like NASA, the Federal Aviation Administration, the Department of Defense, the National Science Foundation, and others, as well as the academic space science exploration and engineering community working on a wide range of space-related fields at leading technological institutions like ASU.**

Cheryl, we'll start the questioning with you. You're an outstanding role model for academic and commercial space industry collaborations. It's exciting to see your space station research extending into the realm of close cooperation with this NewSpace industry. Can you briefly tell us about how you developed your collaboration with SpaceX and what opportunities and challenges you've encountered in that process?

Cheryl Nickerson: Our spaceflight research has all been funded by NASA. That includes our upcoming experiment that's going to fly on SpaceX, which will be the first time we have had the privilege since the Shuttle has been retired to fly with a commercial carrier to the ISS.

One thing I'd like to mention is how critical it is to pair NASA and the commercial spaceflight sector together. I think that when the ISS was built, at least in terms of the potential for its science, NASA thought, "If you build it, they will come." That's not the way it works for scientists, though. Scientists don't individually fund their own research. Our research is funded mainly by government, but also increasingly by commercial funders. For example, I work all the time with big pharma and biotech. I'm in the trenches with them every day because we work to translate our spaceflight research into advances that can help us down here on Earth.

I will guarantee you that we have the interest of potential commercial research funders. They're paying attention. To date, though, for the biological sciences, they're not throwing fistfuls of money around. You don't have millions of dollars that they're wanting to pay for the platform right now, but they're interested; they realize the potential, and I think that's because the true homerun hasn't been hit yet.

What we need to do is to have government step up—and NASA's doing this now, and they're stepping up and funding this kind of research that will be carried to the ISS on different commercial craft such as SpaceX. You can't ask the commercial industry to put the money up to hit the homerun unless they just really want to be philanthropic. That's not what they do.

By way of example, I don't know if people are aware but the National Institutes of Health (NIH) and the United States Department of Agriculture (USDA) signed a memorandum of understanding to fund research on the ISS. Only the NIH came through with that, but the NIH is the world's leading funder of biomedical research in the world. They see the value and potential of putting money behind this. They stood down a couple of years ago because there's a lack right now of consistent access to get the researchers that they've funded up there. But they are ready, I believe, to start the funding up again once access becomes more consistent. We now have SpaceX and others coming onboard to make that happen.

I don't think that the research mission of the ISS will succeed without the commercial spaceflight industry, and I don't think that the commercial spaceflight industry will succeed without the ISS. We have to work together to make that happen. It's not an "us versus them." We both integrally need each other to work to really bring these kinds of translational advances back that we promised the American public when we invested $150 billion or so in this semipermanent biomedical research platform. We promised it. We can do it.

Just one more quick point: I just want everyone to know that the value of the ISS for the potential discovery of major causes of human morbidity and mortality doesn't just stop with infectious diseases. Researchers, not only my team at ASU for infectious diseases but also many others, have shown incredibly intriguing results, novel results, with immunological disorders such as cancer, bone and muscle wasting loss diseases, neurovestibular disorders, and aging. These are the leading sources of human suffering and death that we don't have answers to, despite spending billions of dollars on the ground. There's something about flying biological living systems in orbit where you greatly reduce that force of gravity and they reveal some of these answers to you about how they're behaving normally, or transitioning to disease, that you cannot get anywhere else.

Jim Bell: **Thanks, Cheryl. Exciting times. Next is a short question for you, Michael Lopez-Alegria. You have a very distinguished record within the government aviation and space worlds**

with the Navy and NASA. Recently, your focus and energy has been on helping to promote the commercial, often more entrepreneurial sectors of the space business, as president of the Commercial Space Flight Federation (CSF). There must have been some aspect of the future of this industry that compelled you to take on the leadership of the CSF. What do you see as the role of academic institutions, like ASU, in the future of the CSF?

Michael Lopez-Alegria: I'll tell you the story about how all this happened. I flew to the ISS on *Soyuz TMA-9* with Russian crewmate Mikhail Tyurin and a third person, a tourist or "spaceflight participant," named Anousheh Ansari. When I was training for the couple of years leading up to that, I wasn't all that keen on this idea of commercial and entrepreneurial space. I thought, "ISS is still under construction. It's for professionals sort of wearing hard hats up there." As a steely-eyed test pilot, I just didn't think that it was appropriate for others outside of NASA to be integral to it. But as I got to know not only Anousheh, but also some other folks of her ilk who were training for spaceflights in Star City, I became aware that these are very obviously accomplished professionals who had done things in different worlds and made a fair amount of money doing them, meaning that they were pretty good at them.

When I flew with Anousheh back in 2006, I was struck by a couple of things. Blogs were sort of new. She was keeping in touch with folks on the ground by posting a blog about what her experience was like on orbit. The reach that she had was unbelievable. One of our other duties as an astronaut is to go on the road and tout the benefits of human spaceflight. She was so much more effective at communicating that message to so many more people that I thought, "This is really important."

At the end of the day, NASA exists because Congress funds it. If Congress is doing their job right, they fund it because their constituents want them to fund it. To the extent that you can convince the constituents that it's worthwhile, you can promote human spaceflight. Understanding that closed-loop system—that's when the light came on for me.

Fast-forward to a few years later when I became very involved in the crew ops side of ISS, not paying very much attention to what was just then starting as the commercial cargo and commercial crew initiatives at NASA. The opportunity at CSF came to me, and I really leaped at it because I really thought that commercial human spaceflight is the key to the future human exploration of space, period. If you think you can influence things and make a difference, then what better job is there? I took the chance. I left NASA a couple years ago and came to Washington to work with the CSF.

To answer the second part about the nexus between academia and commercial space, Cheryl's work has been almost all through the government, as she described, on ISS or on the Space Shuttle mostly. ISS has a platform for that sort of thing now through CASIS, the Center for the Advancement of Science in Space, but it's still a very expensive proposition. The threshold, or I should say the barrier, for companies or academic institutions or anybody who wants to do research is the price. It's very expensive to go to space. What we're seeing in the commercial side is that they're able to, through economies of scale, through spreading the cost out, and through a broader number of launches, drive the cost down. I want to address two different pieces of that: orbital and suborbital.

On the orbital side, it's still very expensive to get a payload to orbit. In the future, I think that we'll see some commercial space stations coming up. We have a couple of companies that are actually interested in doing such a thing. We now have commercial transportation that is on the threshold of becoming a reality with at least one, if not two, maybe even three companies able to do that. As those things become possible and the cost comes down, you'll see a greater investment in space research through government funding, with the end users often being academia.

On the suborbital side, I think the picture is even more optimistic, because instead of tens of thousands of dollars per pound to orbit, it's going to be in the order of hundreds of dollars per pound. You can fly repeatedly on a suborbital aircraft like Virgin Galactic's *SpaceShipTwo*, like XCOR's *Lynx*, and others. When the thing lands, you can go get your payload, you can analyze it, and you can launch it again the next day. The repeatability and the frequency of access in addition to the price are going to make those venues very attractive to academia.

Jim Bell: **Thanks, Michael, for those exciting predictions. Next is a question for Thomas Jones. Among your many achievements, Tom, your experience as an active planetary scientist and an astronaut gives you a unique perspective on the potential interactions between the academic and commercial space sectors. What do you think are the most compelling opportunities for space science or exploration collaborations between academia and commercial space?**

Thomas D. Jones: Thanks, Jim. It's a pleasure to be with all my panelists, to talk about a new generation of exploration where not just the government, but a lot of academic and commercial contributions can really make things go more quickly and more productively. I think that we are embarking on an era where we hope that humans will be visiting deep space for the first time since the early 1970s. I think there's an essential role to play there for commercial and academic contributors—innovators who can really enliven the government's approach to conducting these large programs that must span decades.

I came to this realization—like Mike, very slowly—that there was a world of space exploration opportunity outside the government, because that's of course what I experienced at NASA as a Shuttle crew member and an ISS builder. I started out working on asteroids, as Jim mentioned. I was, even 25 years ago, 30 years ago, thinking about how we could use those native resources of space on the asteroids to further our ventures to Mars one day.

Then I got into the human exploration business for about 11 years at NASA down in Houston. We did some planetary science from the Space Shuttle. We helped build this research facility—the ISS—that Cheryl's getting to use now. After my flying career, through the NASA Advisory Council, I became acquainted with some of the

advanced exploration concepts coming down the road. And for about 6 years now I've been working for the Florida Institute for Human and Machine Cognition, where we apply robotic concepts to further human aspirations in deep space, and to try to help NASA formulate a clear, logical, and saleable plan for getting humans eventually out to Mars.

I'm very interested in this next chapter of human, deep space exploration. Let me discuss, very briefly, some areas where I think there's opportunity for commercial as well as academic contributions. We've got a number of aspirations in deep space for humans. We can return to the Moon. We could snare an asteroid and send an astronaut crew out to visit this captured asteroid, as NASA proposes with its Asteroid Redirect Mission. That might lead to further deep space expeditions to asteroids by human explorers, paving the way to the Martian moons and then eventually to the Martian surface.

In the next 10 years I see lunar exploration reviving on the robotic front, with prizes for getting lunar landers and rovers down to the surface and commercial launchers playing a low-cost role in delivering these landers and their payloads. And not just public relations payloads or marketing payloads, but real scientific payloads that NASA wants to deliver to the lunar surface. I think that reestablishment of lunar access is going to be a great step forward in the near term for commercial folks, enabling resource development on the Moon, scientific exploration of the Moon, and public participation in activities on the Moon's surface.

If NASA manages to get their Asteroid Redirect Mission off the ground and a 500- or 1000-ton asteroid is nudged into translunar space, I believe that this opportunity won't end with astronauts sampling that asteroid on just one mission. I think we must plan a whole decade of exploitation beyond that to make that mission concept fly. That's going to involve exploitation by international partners, but also commercial launchers bringing small payloads up to place on that asteroid. Those would do further scientific investigations while astronauts are not there, which will be most of the time. They'll also deliver, I believe, processing equipment on this captured asteroid to, for example, extract the first water from an extraterrestrial object. That's going to be a commercial or NASA–commercial development, not solely a NASA experiment. That's so important for the future of human exploration—to sample extraterrestrial material, extract useful quantities of water or metals or radiation shielding from that, and go on to use that to enable further expeditions. These new companies—Planetary Resources (I'm an advisor to that company) and Deep Space Industries—are the kinds of partners that NASA should be actively pursuing to exploit a captured asteroid.

Those ventures over the next 10 years might enable deep space expeditions to larger asteroids. We'd continue learning how to operate on low-gravity bodies, continue the process of scaling up resource extraction so that we can make propellant in space that can enable us to escape the Earth–Moon system for good. I really think that's a key. It's going to be a breakthrough if we can use space-derived propellants to lower the cost of future exploration and reduce the risk of Mars missions.

You might think of commercial companies furnishing the launcher power to help NASA assemble a deep space craft being assembled in translunar space. That vehicle, a combination of conventional government contracting and, for example, habitats furnished by commercial suppliers like Bigelow Aerospace, might enable us to move beyond the Earth–Moon system more quickly than government alone could do it.

I think, ultimately, we can take that example of translunar space activity by commercial and academic partners all the way out to the Mars system. It's a really big technical challenge to get people and equipment down on the surface of Mars; we don't really know how to get big landers down to Mars yet. Getting to a perch in the Mars system on Phobos or Deimos, for example, can be enabled by habitat developers and commercial launchers that can help load a solar electric propulsion system in Earth–Moon space and then start hauling cargo under contract to Mars. These kinds of systems will be a big scale-up from the kinds of activities we're talking about from suborbital to space station activities to maybe this lunar playground that we're talking about opening up. Ultimately, I think there's going to be a chance for commercial and academic innovation to really pave the way for the first human expeditions to Mars.

Jim Bell: **Fascinating—thank you, Tom! Now, here's an initial question for our final panelist, Will Pomerantz. Will, you're on the front lines of this veritable revolution in the way that suborbital transportation is going to evolve over the coming years. Part of that is due to your own personal interests and advocacy of suborbital science and engineering research. What new opportunities do you envision that your efforts at Virgin or those of others will enable for suborbital researchers, especially via academic–industrial partnerships, and what challenges do you think will need to be overcome to realize those opportunities?**

William Pomerantz: Excellent question, and thanks for the invitation. While I have a degree in earth and planetary sciences, I do not work in that field anymore. There are a variety of reasons for that, but the most important one is that as a young person fresh out of school and just entering the field, I very quickly got extremely frustrated by how infrequent the research opportunities were. For most of the planets and other bodies of study, you're really lucky if you get a new data set once a generation. If one rocket has a bad day, or if one technician tightening a bolt on an antenna has a bad day, maybe that data you were counting on for your thesis or your tenure or your next grant never arrive. That was really frustrating to me. To be honest, I didn't have the patience to stick it out and hope that I would be lucky and get the data set that I was counting on.

As I am involved now in organizations like the Students for the Exploration and Development of Space (SEDS), I see that the next generation is used to a different time scale of getting feedback on things. They don't deal in decades anymore. They deal in seconds now. They are never going to get results quickly enough in classical spaceflight. It just takes too long to get to Pluto; it doesn't matter whether you're commercial or government, you just can't go faster than a certain speed.

I think it's really important that we get more opportunities to conduct space research, because it's going to keep more people involved and is also going to allow them to try the crazier, riskier things that their faculty members and other mentors may tell them is a silly idea. But let's face it, we experienced mentors that are occasionally incorrect about things! We'll never know for sure if a new idea is going to work unless someone goes out and tries it.

I think that's really parallel to a phenomenon I see not just in the science community, but also in the industry as a whole. I had the great pleasure 7 or 8 years ago now of serving on a federal advisory board through the national academies that was looking at the national aerospace workforce. At the time, this was looking at the workforce to meet President Bush's Vision for Space Exploration. We had the chance to meet with a number of executives—CEOs at the big aerospace primes, at smaller companies, as well as NASA leaders. One hundred percent of them were all pulling out their hair about the problem of not having enough young people in the industry. Everyone has seen the graph of age distribution of aerospace professionals, and it's really skewed to one side. They would all say, "All those people are about to retire as soon as the Shuttle retires. What are we going to do? We don't have any young people in the industry. We're not making enough young engineers, not making enough young scientists." As the token young person on the panel, I would always say, "That's really interesting. I sympathize with your point. I'd like to ask you, though: how many openings do you have right now for people with fewer than five years' experience?" None of them knew the answer to that question.

When I went and checked, it was almost always zero. I said, "That's a real disconnect. How can you be saying out of one side of your mouth, 'We don't have enough young people' and out of the other side say, 'I sure don't want to hire any young people'?" But now that I'm on the other side, and I'm the one doing the hiring, I can understand why they don't want to hire any young people; when you're building something that human lives depend on and that your investors or your taxpayers have spent hundreds of millions of dollars on, you don't want to trust someone who's never done it before. You're never going to want to. It doesn't matter whether you're Elon Musk or you're Charley Bolden.

The only way we're going to get those young people coming in—the ones that I want to hire and that are going to be ready to do great things—is if they gain experience. They're never going to gain experience when experience comes with a $10 million price tag. We need cheap, easy ways for them to fail. When I hire new people at Virgin Galactic, I'm looking for them to have run a project—probably to have failed, and to have figured out why that failure happened. If they've already gone through that painful experience, I know that's one mistake they are never going to make again. That's a really valuable experience to have. But they are going to get that only if opportunities are frequent and cheap.

I think suborbital spaceflight is one of many great platforms for those frequent and cheap learning opportunities, in addition to things like Cubesats. You can now put something in space as a result of a Kickstarter campaign, and that's a fundamental game changer, because it means that a 21-year-old engineer who has gone to a great program like the one at Arizona State and learnt how to do all these things academically now also has on his or her resume, "And I built a Cubesat and it flew in space, and it worked for this long, and it broke for this reason." That really is very different.

And we're seeing that now on the suborbital side. For some people, suborbital flight is a means to an end. We have many scientists who are doing publishable, groundbreaking research on suborbital flights, but we have even more that are like Dr. Nickerson who ultimately want to fly their experiments to the Space Station, but who need to try it out before they are willing to invest all the time it takes to get it to ISS. It's really nice to be able to do that fast and, like Michael said, with suborbital, you can fly today and fly again tomorrow and figure out what broke and fix it. That's a real game changer.

Jim Bell: **Agreed, Will—great points. All right, now I want to open this up for some general panel discussion and interactions on a couple of broader topics. We'll start with a very general question. Some of you had touched on this, but I really think this would be valuable for those of us on the academic side. It's the question that is the crux of our job in the ASU NewSpace office, and that is: How can large leading research and teaching academic institutions best partner with commercial space enterprises to most effectively advance the goals of both?**

Michael Lopez-Alegria: I think Will touched on one of the fundamental ways, and that is that by creating curricula and having research that is relevant to spaceflight of any kind, you grow a job force that is much more employable and that obviously serves the needs of growing companies that need that kind of skill set. I think the way that feeds back is that people graduate from an institution, then they go work for a SpaceX or a Virgin Galactic or other companies like that and they start blazing trails. The network connections are established. It becomes a little ecosystem of flow from academic institutions to industry. There'll be a feedback loop as well.

Jim Bell: **Cheryl, maybe you come at it from the other way as well. You're on the inside of the academic side.**

Cheryl Nickerson: I think we're each going to come at it from parallel ways and have similarities and interesting differences. From the biotech side of things, I think that the current trend for pharma and biotech is to invest in academia to do the research because it's cheaper and faster for them in the long run. The major discoveries are being driven by academia. That's no different than what would be envisioned to happen with spaceflight. There are very few pharmaceutical or biotech companies that are doing anything related to spaceflight research. Many of us are interfacing with pharma and biotech to get the message out about the value of this platform, because at the end of the day, if they see something that will give them a competitive advantage, they're willing to take the risk. They'll put the money into it as long as the outcome has an equal or better chance to really drive a product or an application forward. They will invest in us. They will invest in academic research for spaceflight. But as I said earlier, I do not believe that they will invest heavily until government steps in to put up more seed funding to help make this happen.

I really like what Will said about the Cubesats, because that's a phenomenally great way to get something up cheap and fast. But you have to think very carefully about the type of research you're doing. In the biomedical field, Cubesats are great for many things but not so great for other things. No one kind of platform will do everything for you. For example, if you're growing cells for a long duration to ultimately find out gene expression and metabolomics and immunological responses, you might need larger volumes for experiments beyond what you can get in smaller platforms. I wanted to bring this up because, as we are defining the types and sets and scope of research that needs to be done in flight, particularly in the biological sciences, that is what's driving the development and the engineering of new hardware that can actually do more things on orbit. Sometimes we need experiments to be more automated, but sometimes we need the crew to be able to give the human touch for hands-on work.

My research group has had multiple spaceflight opportunities. Most people don't get the chance to do that. Science is driven by independently validating your results. Science is driven by being in the lab 24/7. How can you do that if you get to fly an experiment once a year, or in our case, if we've been lucky, six? We're fortunate in the biological sciences because we've made discoveries up there and have been able to do iterative research. We bring experiments back down on the ground and can simulate some of the aspects of microgravity. We can use those kinds of iterative back-and-forth approaches, make the *Discovery* on orbit, bring it back down, and tweak the experiment to try and mimic as much as we see up there. Drive it. Do it again. I think that an understanding of the science and exploration goes hand in hand—the science dictates what the hardware should look like, and the engineering helps dictate what the science will look like.

Jim Bell: **Will, let me specifically ask you something about this question. When you gave me, Scott Smas, and Craig Hardgrove from the ASU/NewSpace office that wonderful tour of Virgin's Mojave, California, facility recently, we met some young engineers who were running into thorny problems with materials and structures. In order to do what they needed to do, they and others that you work with had to go and literally invent new materials and processes. This made me wonder: How can the kinds of basic research that is done all the time at universities, fundamental research on materials or orbital properties or structures or thermal behavior—all of that kind of basic research work and more—best make its way into the world of relatively small, lean, cutting-edge, bottom-line-oriented commercial space enterprises like yours?**

William Pomerantz: Great question. I was sort of preparing a list of requests that I would like to formally make of the academy while I'm up here. That's certainly one of them. Universities do have this incredibly important function of advancing fundamental research in a way where, going into a program, the return on investment is not necessarily self-evident. Commercial space companies aren't necessarily going to invest in research in the way that the federal government and academia will. But the research universities get real benefits, not just from the patents. Another important return on that investment is improving the quality of the young men and women who are coming through the program, because they're going to go on and do great things and represent your university. Keep doing that.

There are a few other things that I would love to see, and these all exist to an extent but could exist even more coming out of the academy. One is ensuring that we are fully tapping into the talent pool of all of humanity. I've seen too many jobs in the aerospace industry where the applicant pool looks too much like this panel does: five Caucasians, four men, one woman. That tells me we're not necessarily drawing on all the talented people on Earth. We need all the talented people on Earth to do the really amazing things like everyone up here wants to do.

Another thing I'd like to see for every young woman and young man who graduates with a technical degree from every one of these universities is to make it impossible to graduate if they've never spent time at a lab bench or similar setting working on a hands-on project, whether that's science or engineering. Preferably, it's something where you're not following instructions because you're the one making up the instructions. That is the best way to learn.

I personally think that there is no time where you are better cushioned from failure than when you're a student. Most people I've met agree with that. People are going to be so generous with their time, I've found, telling you which way you might want to go, helping you find resources, and helping you pick back up after your experiment hasn't done what you wanted it to do. I think it seems like in the past 10 or 15 years universities have swung the pendulum in the direction of having everything be computer-aided design (CAD), and it's all on the computer and it's all in the virtual world. You can gain great knowledge that way, but that isn't a substitute. It's a compliment for, not a substitute for, the experience that you get in the real world.

Jim Bell: **Let me also ask Tom to chime in on this one, just thinking about the human space exploration program. You've talked a little bit about the role of science at academic institutions and helping to put that together. What about new technologies? Maybe you can expand on that.**

Thomas D. Jones: Just pulling together the thoughts we've already heard from our friends here, it seems to me that NewSpace companies are very lean. They have to stay lean and keep their costs low. They don't have standing laboratory space. Universities have that. Thus, there's an opportunity here for NewSpace companies to commission directed research, maybe to fulfill some NASA requirement or call for capability. The research can get done at the universities. You can tap the great graduate student workforce to keep the costs low there.

Say you've got a concept that needs to be tested in flight. Now the commercial sector can turn right around and give those researchers the opportunity to see their experiment fly, and that might lead to some practical development that's of value to NASA and their potential commercial supplier. I think there's a great opportunity for utilizing all these great materials-handling labs around the country, for example, to investigate the behavior of solid materials, granular materials in low-gravity fields—like you'll find on asteroids where we don't know the answers. We don't know what human explorers are

going to encounter on an asteroid surface. We've got to start on the lab bench; fly suborbital flights in low-gravity conditions; go to a Space Station bench, if you will, in nanoracks, whatever volumes can be procured from NASA or others; and then take those experiments to the point where you're actually processing meteorites in space to extract water, metals, and shielding material like you will from their parent asteroids.

Jim Bell: **Those were some great specific responses from all of you—thank you. Now, general question number two. I'll ask this question as an educator at ASU and also as president of the Planetary Society. My university colleagues and I think a lot about ways that educating and training students and their teachers or informing or entertaining the general public can trickle down to benefit not only our specific fields, but also our society as a whole. So the question is, how can and should the general public be most effectively engaged, educated, inspired, entertained—whatever your favorite verb is—by new collaborations between universities and commercial space-related partners who are attempting to define different ways for future-based science and exploration?**

Thomas D. Jones: I'll continue with my theme of asteroid exploration. We capture an asteroid. It's orbiting around the Moon. Astronauts visit it. They bring back 50 kilograms of asteroid samples. What next? Now you've got an opportunity to emplace industry-developed experiments and resource experiments. Those can be commercially driven. Those can be from the asteroid mining companies. This opens up untilled ground where you might invite the public to come up with concepts for anchoring, for coring, and for handling the materials that we actually encounter on the surface of a small asteroid.

NASA has these grand challenges—one example of engaging the public with some brainstorming and pulling in the best ideas. You've got 10 years now to work on this alien body and find a way to digest 500 or 1,000 tons of asteroidal material and make something useful out of it. Somebody suggested to me just last week that NASA should turn over the asteroid to a commercial consortium to explore ways to exploit this body. We'll have to talk to the lawyers about whether that's actually allowable, but there are a million asteroids—plenty to go around. A million asteroids, 30 or 40 meters in size; that's plenty of fresh material to deal with.

That kind of opportunity to throw open the exploitation of a new body to public engagement and public brainstorming is a wise option, I think. There's also the chance to invite people to participate in exploring the Moon with these remotely controlled rovers, teleoperated from Earth, where one might actually drive a lunar rover. Maybe a commercial company will have the marketing savvy to sell minutes of driving time to a commercial sponsor or run a lottery so that you can actually get to experience that in a school environment. You might extend that to exploration of deep space objects with a commercial supplier providing public high-definition television coverage of the arrival of an astronaut expedition at that body. You get there in advance. You set up your camera views. You get to sell that air time for marketing purposes while you're recording the arrival of a human expedition to an asteroid or to Phobos or Deimos.

Cheryl Nickerson: From my biomedical research background, I think you have to make it personal. Why should the general public care? Why do I care that the 18th U.S. National Laboratory isn't on terra firma? The gravity of that, if you will pardon the pun, should set in immediately. Designating the ISS as a U.S. National Laboratory speaks volumes to the tremendous potential that Congress and the public think that this platform has for next-generation breakthroughs to globally advance human health and the quality of life, period. I'll have colleagues in my field come to me and say, "Cheryl, why would you pair microgravity with your infectious disease research? Why would you think you could find these cool things you're finding?" I think, "Why would you not?" You have got to get out of your comfort zone. Paradigm-changing science doesn't happen by staying in your comfort zone. You've got to get out of it. Throughout the course of biological history, every single time we have pushed living systems to adapt and survive and thrive in extreme environments, not only have we learned paradigm-changing information fundamentally about life itself, but also we've been able to take that same information and translate it into products we use on a daily basis. Fly it. Discover it. Bring it back here. Translate it. Get the IP on it and get it to the world and help make people's lives better.

Jim Bell: **Way to go, sister Cheryl. Bring it! Let's also hear from Will on this, as Virgin Galactic, of course, has lots of interaction with the general public, right?**

William Pomerantz: It's only about 95% of our business or something like that! I think you asked both the why and the how of public outreach. For me, the why is easy. Helping the general public is the only reason why we in the space industry do what we do, both in the near term and the long-term. In the near term, that's who's paying the bills, whether it's space tourists buying tickets or it's taxpayers funding everything the government does. We couldn't do what we're doing if the general public didn't care enough to at least allow Congress and NASA to support it or to spend their hard-earned money buying products directly from companies like ours.

In the long-term, I'm a believer that everything you do in space ultimately is for the public. It's to protect them from threats like asteroids coming in. It's to open up new economic opportunities. It's to allow us to back up the biosphere. It's all those wonderful long-term lofty things as well as the near-term lofty things. That, to me, is the "why." We gotta do it. It's the reason we're in the business.

As for the "how," I totally agree with Cheryl that it's all about personal experiences. I was so happy that Michael made the comments that he did about Anousheh and their ISS flight together. Astronauts historically haven't been picked to be in the astronaut corps because of education and outreach. That was maybe on the application, but it wasn't question number one, I don't think. So if we want to really leverage the educational or inspirational capability of space travelers, we need some people in that group who have been to space and have that as their number one talent. We need the storytellers, the filmmakers, the artists, the communicators, the politicians, and even those who can come back and tell us about what they experienced and open up our eyes to those capabilities in many new

ways. As of last week, as a species, we just sent our 543rd person into space. The estimate I've seen is that there've probably been about 110 or 115 billion human beings throughout all of history, and 543 out of 110 billion is a pretty small percentage. We need to get that percentage up, and we need them to have a more diverse set of skills and backgrounds.

Jim Bell: **Michael, we'll give you the last word on this. You're representing an organization, the Commercial Spaceflight Federation, that is interacting with the representatives of the general public all the time in Washington, DC. Do you have a perspective from "inside the bubble" on this?**

Michael Lopez-Alegria: I was listening to what my colleagues said, and I really like the "how," Will. I want to address the "why" a little bit differently, however, from your fairly practical approach, which I admit is accurate and absolutely required. You're right that we were not necessarily picked for our ability to communicate the experience. I'd count myself among the worst of those people. But I'm going to give it a shot here so hang on because this could be interesting.

First of all, when people say, "Why do we explore space and why do we spend the money that we do?" there is the practical answer about spinoffs and all of those things, which are absolutely valid. Then there's the sort of soft answer, which is because humans have an innate desire to explore. If you've ever been to a Space Shuttle launch where the audience is massive and in total rapt attention, or if you look at the *Curiosity* landing on Mars and the number of people who were watching that live on the Internet, people are absolutely fascinated by the experience of going to space, whether robotically or with humans.

This is a little bit of a stretch so bear with me. There is something that has been dubbed the "Overview Effect," which is attributed to people who have flown in space and who now somehow have a different view of life. That, because of the experience, because of seeing the planet from that vantage point, because of the serenity of floating weightlessly—whatever it is—people come back slightly changed. When I came back, I felt like I was really changed for about a week or two, and then I had to pay bills, I got stuck in traffic, and it turns out that I was pretty much the same as when I left.

But still there is a slight change. I think people's perspective is a little bit more global, no pun intended. It's also a little bit more tolerant. From space, you don't see famine. You don't see disease. You don't see wars. You don't see a lot of things that are bad on Earth. You see a beautiful thing that you want to protect. I think the degree to which we can extend that experience to more than 542 people is going to result in a better place for all of us to live. That's really why.

SUMMARY

I would like to extend my thanks to Cheryl Nickerson, Michael Lopez-Alegria, Tom Jones, and Will Pomerantz for being on our panel; to SpaceTech Expo 2014 for hosting our event; and to Arizona State University and the ASU/NewSpace Initiative office for sponsoring our panel. Our hour-long conversation revealed interesting and diverse ideas and perspectives on the potential of the academic–commercial relationship in the future of space science, engineering, and exploration. It's an exciting and evolving conversation that is only just beginning within many sectors of the NewSpace industry. I welcome comments and feedback from others out there who are also exploring and innovating within this realm. The full video from our panel discussion by expert scientists, astronauts, and space business leaders can be found on the ASU/NewSpace website.

AUTHOR DISCLOSURE STATEMENT

None of the participants of this roundtable have any financial conflicts to disclose.