THE BROOKINGS INSTITUTION

WEBINAR

EXPLORING MARS AND THE MOON

THURSDAY, MAY 2, 2024

MODERATOR: DARREL WEST
Senior Fellow, Center for Technology Innovation, Douglas Dillon Chair in Governmental Studies, Brookings

JENN GUSTETIC
Director of Early Stage Innovations and Partnerships, NASA

JOHN M. LOGSDON
Professor Emeritus of Political Science and International Affairs, George Washington University

CURT NIEBUR
Lead Scientist for Flight Programs, Planetary Science Division, NASA

* * * * *

WEST: Good afternoon. I am Darrell West, senior fellow in the center for Technology Innovation at the Brookings Institution, and I would like to welcome you to our 15th annual A Alfred Taubman Forum. Mr. Taubman was a visionary who had the idea to set up a forum that would cover different topics each year as a way to inform public discussion of the issue. So we are grateful for the support of the Taubman family over that period, and we also appreciate all the public interest that has been expressed in this forum, as well as the other ones that we have held. This year we have a very hot topic, the topic of space exploration, a topic that excites many people both in the United States as well as around the world. With the recent landings on the moon and plans for new explorations elsewhere, US space missions are accelerating rapidly. NASA, in conjunction with a number of private companies, are paving the way for new missions which will expand our knowledge of the solar system and beyond. To help us understand these and other issues. We're delighted to have three distinguished experts with us. Jenn Gustetic is director of early stage innovations and partnerships at NASA, where she works on the agency's connections with universities and small businesses in order to increase space related innovation. Curt Niebur is the lead scientist for flight programs at NASA. He is spearheading robotic missions to the Jupiter moon of Europa as well as other places. And John Logsdon is professor emeritus of political science and international affairs at George Washington University. He's the author of a number of books about space and the policy issues associated with them. If you have questions for our panelists, you can email them to us at events@brookings.edu. That's events@brookings.edu or tweet @BrookingsGov using the #SpaceExploration. So I'd like to start with Jenn. So you work on early stage innovations and partnerships at NASA. Could you describe your portfolio and how it advances space related innovation?

GUSTETIC: Absolutely. And, thank you for having me, here with all of the other panelists to have this important and exciting conversation. It's certainly an exciting time, in space and aeronautics. So, as was mentioned, I'm Jenn Gustetic, I'm the director for early stage innovations and partnerships in the Space Technology Mission Directorate at NASA headquarters. And my portfolio of programs makes investments in universities, small businesses, large businesses, as well as individual members of the public, folks working in makerspaces or kind of out of their garages that have good ideas related to technology development, for space exploration. So we fund roughly, 700 projects a year, to the, to the tune of about $300 million to feed a pipeline of early stage technology, opportunities into, the rest of the agency, ranging from robotics to institute resource utilization to future sensor detectors and instrument systems, to some aeronautics, investments as well. So one of the, the major, things that we make available at the agency is to be a friendly front door, for folks looking to work at kind of early stages with early stage ideas. Again, ranging from small businesses to

universities to individual members of the public. Happy to be here today to talk more about that work and technology at NASA.

WEST: Sounds like you have 3 or 4 different jobs there at NASA. Amazed you can keep track of all those things. Curt, you handled NASA's robotic missions other than Mars. Mars has its own, team. But NASA has had extraordinary success with flybys, satellite imaging, and then actual landing pf things on other entities. Can you talk a little bit about your objectives with the robotic missions and how they advanced our space knowledge?

NIEBUR: Absolutely, it's a very diverse portfolio. We we set the bar very high for ourselves with what our missions accomplish. And we try to meet that expectation of every mission. But broadly speaking, every mission we do, no matter the destination, is well aligned with NASA's overarching goal of exploring the universe. And the excitement of all this is that despite decades and decades of exploration, the amount we don't know still far exceeds what we do know. And every time we send a spacecraft out there, it not only answers the questions we've posed, but it generates so many new ones, which is, you know, how science is supposed to work. So we are pushing back the boundary not only on exploration, but on our scientific understanding of each of those destinations. But more importantly, and I think more interestingly to to people on Earth, it is the fact that we're not just learning about Jupiter, Europa, Mars. We're learning about the differences and the similarities between all of them. And when you learn something about Pluto, one of the most amazing things we've discovered is that tells you a lot about Mars. When you learn something about Mars that tells you a lot about Earth. When you learn something about Earth that tells you something about Venus. Everything. Everything is interrelated and touches upon one another.

WEST: Okay. Terrific. So, John, you are the dean of academic researchers who focus on space exploration and have many important writings on this topic. What do you think about current NASA priorities, and what knowledge can we gain as a result of some of the upcoming missions?

LOGSDON: Well, we're really in a different stage in space exploration in 2024. For the first 40 years or so, it was purely a government undertaking. Now we have the private sector involved working in partnerships with NASA. With respect to robotic science, there is an established process called decadal surveys, where the community, the scientific community, comes together and sets priorities for the next ten years. And NASA's supposed to, implement those priorities unless they have good reason to otherwise. So there's a process for

setting goals. That's well established, has worked pretty well and has produced ambition. Lots of ambitious missions. Curt is not dealing with Mars, but there's a very important issue with the mission called Mars Sample Return, which is on the precipice of, finding a way to, lower its cost in order to go forward. There's a new, ambitious mission called Dragonfly that's supposed to send a spacecraft to orbit Saturn's moon Titan, which is a very interesting place. And there's an issue of whether we can afford both of them. So there are tough choices in going forward in robotic exploration. And then we have the Artemis program that's supposed to return Americans and Japanese right now, to the moon sometime in the next few years. And that's a multibillion-dollar kind of enterprise that that's a challenge to exploration.

WEST: So it sounds like we are on the cusp of exciting new developments. There are so many different missions of the sort that you just mentioned, and soon we will be starting to get the payoff from those new explorations. So, Jenn, among the different things that you cited, I know you also work on technology transfer between NASA and other entities, including universities. And of course, there have been many commercial spinoffs over the years from the US space program. So I'm just curious, how does this tech transfer work and how do you encourage spinoffs?

GUSTETIC: So it's a really, really good question. NASA, by its very nature is a research and development organization. We invent things. We invent things, every day, not just in our research centers with the scientists, technologists and engineers that are working kind of at our centers. But also we encourage invention through the awards of contracts and grants with some of our partners in industry and academia. And when it comes to the inventions that we make within our own laboratories, we have a very robust technology transfer program where we seek to, encourage the disclosure of those inventions, actively at each NASA center, an active marketing campaign to get inventors to tell us what they're inventing so that we can identify which of those inventions, are high potential public value to go through the process of patenting those inventions. Once they are patented, then the real fun part of the tech transfer program starts in that we've come up with a lot of really kind of creative, cutting edge ways to try to encourage licensing of those technologies with startups, with companies with all sorts of different, sources of potential, entrepreneurs and commercialization of those technologies in the future. I could talk about some of those, exciting, experiments that we're doing. But essentially, the purpose of those experiments are to encourage folks to license, those technologies in order to create applications of those, technologies, not only for space, but right here on Earth. And that's where you see a number of the examples of spin offs, that are published every year in our, I think many, many years, I mean, decades running, spin offs, publication now, where we have hundreds and

hundreds and hundreds of examples of where NASA technology, where we invested in it for a space purpose or an aeronautics purpose has been adapted that, that that kind of exquisite cutting edge technology has been adapted, for some, commercial benefit here on Earth, ranging from medical devices to health products to, one of the recent stories that I really loved was a robot, kind of an adaptable, flexible robot that can help in emergency response, type of activities that are being used by emergency responders across the country. Pick an industry. We probably have examples of spin offs where NASA technology is affecting everybody's daily life.

WEST: So I know I grew up watching Star Trek on television, and I'm amazed how many of the products that appeared on that TV series we actually have now. It's really been extraordinary innovation in so many different areas. Curt, I know one of your upcoming launches is the Europa Clipper. And of course, Europa is a Jupiter moon, and it is thought to have a large body of liquid water, oceans, I believe beneath it's, deep layer of ice on the surface. What is this mission seeking to accomplish? And how could it advance human knowledge?

NIEBUR: Well, let me say this is a mission that we've been working toward for over 20 years. It's been a long time coming. And to be this close to launch, you know, October 10th of this year is tremendously exciting and and also tremendously nerve wracking. But what we're going after with Europa Clipper is, as you alluded to it, it's a moon orbiting Jupiter, distant in the solar system, very cold. But what surprised us is we discovered that there is a vast liquid water ocean underneath the icy surface of Europa. And it is right now the place in the solar system that we think is most likely to have life today. And not a billion years ago, not 2 billion years ago. Not fossils. It could have life swimming in that ocean right now, today. So what we're sending Europa Clipper to do is to go characterize that ocean and determine, does it have the the necessary ingredients for that possibility of life to exist there? Because if it doesn't have those ingredients and the life can't be present. So Europa Clipper will fly by about 40, 50 times, take some very complex measurements and send us back the data to Earth so that scientists can assess, you know, does it have those four main ingredients? And if the answer is yes, then the question becomes, well, should we go back and check if there's actual life in that ocean today?

WEST: And of course, that would be completely dramatic if we actually check those four boxes and then at some point down the road, discover even microbial life on these oceans, like if you have, two places in the

solar system, where a life, exists, the probability of life, being abundant, perhaps throughout the universe, seems to arise pretty.

NIEBUR: Oh. Absolutely. The implications are huge. And even if we just figure out that Europa's habitable. And let me be clear, by habitable, it's it would be habitable for people as well. To have two habitable places in one solar system also has big implications for how common habitable worlds are in the galaxy and in the universe.

WEST: Yeah, exactly. So, John, I know that private companies such as SpaceX, Blue Origin, and a number of other firms are playing a substantial role in NASA activities these days. What is your sense of these public private partnerships and how they operate?

LOGSDON: Well, there are really two kinds of relationships. One is the traditional one where a private sector company under contract to NASA carries out particular tasks, sub-missions. That's not what you're talking about. For the past 20 years or so. NASA has entered into formal partnerships with profit-seeking private organizations to work together on a particular challenging task, whether it's landing robotic missions on the surface of the moon. There's a program called Clips, now commercial lunar something or provide, even some, private sector firm and particularly SpaceX. Say we're going to do that on our own. Elon Musk wants to establish a million person city on the surface of Mars, using his own resources. He says he's making money now selling rockets to the government and to the private sector in order to have the resources to do his own exploration, and work towards, humans living, being born, live, die on other places than Earth.

WEST: So, Jenn, I know you talk a little bit about a public engagement at NASA. And of course, there are a number of different ways the public can both follow what NASA is doing and even get involved a little more directly. I'm just wondering if you could describe some of those opportunities. How can the public both follow and engage with NASA?

GUSTETIC: Yeah. So, within within the portfolio that I lead, I think, and I'm a little biased on the use of prizes and challenges, and that I think that a really cool mechanism to engage the public. They are within my portfolio. So I'll talk a little bit about that particular mechanism to engage the public. But there's a tool that's been around for a couple decades. That allows us to, kind of, put out prize purses with a problem that we would like to be solved, but we don't specify how that problem is to be solved. That allows us to attract out of,

discipline perspectives where a breakthrough solution might come from. It also allows us to attract participants that don't work at a particular entity. Right. You don't have to have a Duns number and work for a company, or be employed at a university to kind of get like the business official endorsement for a proposal to come in. You can be any person in their garage and participate in a prize competition or a crowdsourcing activity. And, NASA is the agency that is by far the most active agency in the federal government and perhaps the most, active entity in the world using these kinds of tools. Each year we run more than, 60 or 70 of these public competitions and prizes range from, you know, $5,000 to several million dollars for technologies being demonstrated in a relevant environment on the higher order of, of kind of the cost or the prize bounty spectrum to, like designs on paper being submitted through, a web-based platform on kind of the lower end of the spectrum. But we routinely engage thousands of people, each year, many hundreds of thousands of people each year, not only in kind of watching NASA and watching what NASA does or being communicated about what NASA does, but actively participating in what we do by helping us to, address particular problems that we pose to the public and also, pay for it, for the winning solutions that come out of that. So, you can find out more for folks that are interested in that on the NASA website, on the engage with us page, we list all of our challenges there in addition to on challenge.gov, which is the government wide platform for, accessing, challenges that are posted and, and hosted by the, by the entire federal government.

WEST: And I would definitely encourage people to look at the NASA website, not just for this particular program, but there is just a wealth of information, there, you know, videos, scientific, information, so even amateurs can kind of peruse, the information and occasionally, people actually come up with good ideas. So, Curt, I know one of the things that you focus on is not just kind of the Europa Clipper as a, launch that is coming up soon, but thinking about what the priorities for various space missions should be in the future, kind of on a longer term basis. And of course, there are so many different options of going to various planets, various moons of those planets, asteroids and other, passing, bodies. So I'm just curious how you think about the way in which space missions should be prioritized. Like, what are the criteria that you're thinking about? I, I know you get, many more proposals than you, possibly can fund. So how do you think about this issue of priority setting?

NIEBUR: So it's a it's a critical issue because, as you mentioned, there are so many places to go, and each planet you want to go to has dozens of things you want to do there. And and we can't do them all. We don't have the resources. So we do have to prioritize. And we use a three-tiered system to prioritize, for our biggest missions, what we call flagships, ones that cost multiple millions of dollars. We really rely on the

decadal survey that John mentioned, which is a document that takes about two years for 50 scientists to come up with the lays out scientific priorities and says, a mission to this planet doing this science is a higher priority than a mission to this other planet doing this other science. We use that to help set the priority for those largest flagship missions, for the smallest missions. We really rely on the scientific community, to come up with those ideas and go through a competition and very intense competition where they can, they can bring forward ideas they have for mission to whichever destination with whatever science. And then in that competitive process, we evaluated how good is the science, how good is the engineering, what's it going to cost? And then we pick the best of the best. And again, I can't stress enough how intense those competitions are. And then we have our medium class missions, which are, you know, somewhere in the middle. And for that we do a hybrid mixture where it's partly what the decadal survey is saying, our priorities and partly ideas from the broader scientific community. And then they again step forward and share those ideas with us and go through that competitive process. And we pick what are believed to be the the best ideas that are scientifically, technically, and we call programmatically, you know, schedule and budget, which are the best in those areas. And those are the missions that we go forward with. But it is a grueling process and and very, very stressful.

WEST: Sounds like a great process for making friends and making enemies at the same time, just based on the decisions that you make, because everybody wants their idea to get funded. So, John, I know you've been studying NASA for a very long time. I'm just curious about your sense of priority setting within NASA. How do you think the process works, the possible role of Congress in this, because, they are funding a lot of these programs. Are we seeing, much engagement on the Congress side in terms of priority setting?

LOGSDON: Well, Congress is always interesting where money is going. So they get engaged. Let's go back to these flagship missions and how they're chosen. Which is a process called decadal surveys. Do you think about that? These are billions of dollars being spent on these missions. Current estimate for Mars sample return, which Administrator Nelson says is too expensive. Is it $11 billion? That's public money. Being spent on the basis of priorities set by a very few people in the scientific community. These decadal surveys are very powerful, and it's a, you know, as a as a policy person, I think it's very interesting to see that a small community can command that much government resources to do what it has defined as the highest priority missions. Mars, the moons of Jupiter and Saturn, etc.. So the process is, is established and not very subject to congressional or broader public influence, except when a congressman gets interested. It was a Texas congressman named John Culberson, who was fascinated with going to, Europa. And he put money in the

Commented [AP1]: If you Google "john culbertson texas" you get results for John Culberson (no t) who was a congressman from TX.

NASA budget for it. He's no longer there, but the program is there. So there is politics. And this is, again, millions and billions of dollars of public money being spent. So the fact that there is some political interest in house, that is not very surprising. In a sense, it's appropriate. Then, and we haven't talked about it at all. There's human spaceflight. And it was a fair question of why we are doing it. And particularly why we're on a path to once again, after 60 years, send people beyond Earth orbit. What are the reasons for human spaceflight, and are they consistent with, in conflict with, compatible with robotic spaceflight, that that process is it is a rather messy process of setting targets.

WEST: So, Jenn, one of the interesting, relatively new developments is the role of private sector companies in space exploration. And I'm just curious, your sense of these public private partnerships, how they operate. How does NASA coordinate kind of both on the small business side, which I know you are particularly interested in, but also with the larger firms?

GUSTETIC: Yeah, I'm glad you asked. I almost wanted to. When you asked John about public private partnerships earlier, I was a little chomping at the bit to offer a little perspective from the technology perspective as well. So thanks for asking. Certainly a lot of the the portfolio that I lead does a lot of small business, investing. But, you know, small businesses of today oftentimes become sometimes not oftentimes, but sometimes become the big businesses of the future. And we've seen actually a lot of that activity in the commercial, aerospace sector recently, with a whole host of mergers and acquisitions that have led to some kind of more, medium, medium size companies that are starting to, enter the kind of more competitive landscape, with some of the, more established, larger firms, that have been, working in the aerospace industry for some time. So some examples of those are like Red Wire and Voyager Space Holdings. They're kind of bringing together, small company capabilities, into firms that are now competing against some of the, the other companies that you might, for a longer period of time have associated with working in and space exploration. In the Space Technology Mission Directorate. We actually partner with all kinds of private sector companies, from small to large, in order to develop the technologies that our customers both in the Science Mission Directorate, speaking of robotic exploration and, our ESMDM exploration systems. And SOMD space operations colleagues on the human exploration side of things are prioritizing as technology needs to enable their future missions. So we have a variety of tools that we we use to do that to partner with industry. In my portfolio, we make a lot of kind of SBIR or small business innovation research awards that kind of seed ideas and small businesses that lower technology readiness levels and try to help get them up the development spectrum so that they're, ready as viable solutions, for systems in, in the future. But we also

have some activities, that engage in much larger dollar value, public private partnerships with industry to help, develop capabilities that are not only of interest to NASA as a customer, but the broader space, commercial space industry as a customer. So the tipping point, solicitation and announcement of collaborative opportunities, ACO are two, ways that we have invested hundreds of millions of dollars in firms, ranging from SpaceX to, Nokia, who's developing a 4G, communication system for the use on the moon through a tipping point award, to some of the smaller companies, that we've, that we've engaged through those tipping points as well. And those awards can be quite large, and they require the companies to bring some resources to the table as well. So John had mentioned, the utilization of kind of Space Act agreements, kind of these, these, these kind of cost sharing partnerships that are a little different than pure play contracts. That's how we run those tipping points and those ACO solicitations where it's it's truly a joint effort, to develop something that not only is on the company's business plan trajectory, but is something that we know is, a need of, our customers, who we consider to be the Science Mission Directorate, the, the human exploration directorates within NASA, other government agencies and the commercial space sector.

WEST: So, Curt, I'd like to get your perspective on these, public private partnerships as well. So I know you focus more on the robotic missions aspect of that. How what role are private companies playing, in that area? And how does NASA coordinate with these private firms?

NIEBUR: Well, there's two roles that that I think John alluded to before and Jenn as well. And there's the traditional role of providing the technology and the components that the missions NASA's doing needs, you know, engines, propellant tanks, things like that. And then there's the newer role where they're actually exploring on their own, often with NASA funding. And I just want to say not to sound flippant. Space is big. You know, there's a lot to do out there. So the more organizations, national or private that are out there doing that exploration, the more we all benefit. But more pursuant to to my role as as Jenn mentioned, the missions that I do are really, you know, in many cases, the end users of the technologies that that Jenn and her group, the Space Technology Mission Directorate, are using. But it's in a different framework when you're developing those technologies. You expect failures. You need failures. That's that's how you learn. That's how you advance. But when we use those technologies on a mission that I'm doing that where you've spent 10 or 15 years getting the mission ready, choose destination. Those technologies, absolutely, 100% need to work. We need to have extraordinarily high confidence that they're going to work as intended. So there's that maturation process. And NASA is, I think, a very valuable and forthright and open partner, and investor and all of these companies that have all these technology ideas that we may one day use on our missions, and

Commented [AP2]: Any time you see the same speaker name credited twice in a row, that's almost certainly an error. And you can see that Darrell has indicated who he's talking to (Curt), so that means the second speaker should be Niebur.

it's in our best interest to invest in them, help them along, and make sure that they are developing technologies that we can use. And as Jenn mentioned, that a lot of other end users can benefit as well. And John may have something to say about this, but Jenn mentioned spin offs. You know, there are estimates that that for every dollar that is spent on NASA, that society as a whole reaps a benefit of, you know, $10, $15, $20 worth of spin offs. And people debate which number is it? I don't care what the actual number is. Come up with one other thing the government does that generates that kind of return on investment. That's what NASA does. And that's just our side gig. Our main gig is exploration and science.

GUSTETIC: Darrell, can I provide a quick example to just build off of what Curt just said in terms of the partnership between technology development and kind of science and users, is just an example. So, many years ago it was almost 20 years ago. We started investing through SBIR, as in this concept for how you might develop solar arrays that actually roll out, right, that aren't, rigid solar arrays that have to the concept of the consequence of rigidity is how you pack it, how fragile they are. You know, how much volume it takes to actually get up, up in space, right? So that the technology seed idea was, can you actually come up with materials and a mechanism for deployment where you could roll these things out right where you could deploy them differently? And that, I mean, we started working on maybe 20 years ago through SBIR with a company called Deployable Space Systems. Fast forward almost ten years. We got our first ground demo, of, larger scale example of that working. AFRL and then the International Space Station invested in a, in a in space demo a couple of years later from that on the International Space Station to say, hey, would this concept work in space? That's the amount of testing and time that the court was talking about making sure it works. Because if you're putting that amount of money into a mission, that's a that's not that cost to the taxpayer. You want to make sure it works. That technology development process can take some time and it can take many partners, right? Not just at NASA, but many government, other government agencies and commercial partners in order to make that happen. Fast forward to today. The International Space Station now has six new, deployable solar arrays that we call iROSA, roll out solar arrays, that have improved the efficiency of the power generation on the International Space Station. And they were actually, proven out enough that us SMD was willing to pick the DART mission, the double asteroid redirect test mission, which you all may have heard about in the last year. That kind of nudged an asteroid. That that ROSA technology was actually used to power DART. And it is what that ROSA technology is now baseline on the gateway. The gateway, element of the moon architecture. And so point being that technology is supporting many customers, right? It took a while to get there, but now it's, you know, it's gangbusters. Right? Folks are using

seeing that the, the efficiency of this technology and using it for a variety of different applications for both, science and human exploration purposes.

WEST: Great. Thank you very much for that. So, John, I have one more question for you. Then we're going to open the floor to questions from our audience. And I'd like to remind our viewers that they can submit questions through emailing us at events@brookings.edu, that's events@brookings.edu. And we will get to as many of those questions as possible. So, John, I just have one more follow up on this public private partnership issue. Are there any risks or the things that you worry about in terms of the growing role of private companies in space exploration? Does it affect the way priorities are setting, are the things we among the viewing public should be worried about there?

LOGSDON: Well, I mean, fundamentally, the private sector has different priorities than government. That's why they exist. And that will begin to penetrate permeate activity in space. Differences in point of view between the private sector and the public sector. I said in passing, why do we explore? Why does the private sector explore? Eventually to make money, if that's what they're in business for. That's why they exist. And that's not what government is supposed to be doing in exploration. It's supposed to doing be doing discovery. So how you meld those two into a coherent national effort? I think there's a real challenge for current policy makers. And it's gonna be interesting to see how it evolves in the NASA of 2024 is very different than the NASA of 1969, when we landed on the moon and its evolution into a different kind of organization with government and the private sector partner together. Is a process. It's a process that's far from complete.

WEST: Okay. We're starting to get some questions from our audience. So I'm going to ask that and any of our panelists who want to jump in and address it and feel free to do so. So we have a question from Leonard who's a reporter with Inside Outer Space, and he asks, basically, how do you gauge the post-Sputnik space race of decades ago that we had with the then Soviet Union, with today's US China space initiatives? Basically, are we in a new space race with China?

LOGSDON: Well, let me take that first. I'm on record. I've written that there is no space, new space race. It's a competition. I mean, we go back to two post Sputnik and the bipolar US, Soviet competition in space. It was a race, and there were only two participants in that race, and there was a finish line. So you could say there was a winner and a loser. We got to the moon first. We won. Now we have multiple countries doing

things in space. And then the United States and China are the most active out there. Europe. Japan, India, also have very active space programs. So there's there's competition. And as Americans, we should think that competition is good. And so I think the competition drives. The willingness of governments to spend money on space. We didn't talk at all about national security space and probably shouldn't. But that's an important activity.

WEST: Curt or Jenn, have any thoughts on the international aspects in terms of, like just the sheer number of countries that are engaging in space exploration now?

NIEBUR: Well, on on the science side. We have from the beginning been more proponents of cooperation than competition, of doing missions together, of sharing the information from those those missions, the data from those missions. More recently, in the past 10 to 15 years, we've been actively building partnerships with, with, with the quote unquote newcomers that that John mentioned, India and Japan and others, so that we can not only partner with them, but that we can share our experience and in some cases, our expertise with them, as well as have mutually beneficial partnerships where we can have our instruments flying on their spacecraft or vice versa. And that just provides a synergy and a force multiplier for the amount of science and exploration that we can get done. And even when it comes to China, where there are significant limits that are that are placed on on what NASA can do. We recently brokered an agreement where US scientists could get access to some of this extraterrestrial samples that they have returned. So from the science perspective, we are always focused on cooperation and partnership in the international sphere.

WEST: So we have a question from Sarah of Moog Incorporated. And she asks, "we are seeing a lower appetite in Congress to fund NASA exploration efforts as budgetary pressures come from other areas. What trends are you seeing in support? What trends are you seeing in congressional support for moon and Mars exploration? And what kind of arguments, and or discussions, are you having with Congress concerning NASA funding?"

LOGSDON: Everybody is quiet. I'll have a reaction to that. What we're seeing is that Congress prefers to put its money on human exploration of the moon and eventually Mars. Somewhat at the cost of adequate funding for the robotic science part of the NASA portfolio. The Artemis Program, our program go back to the moon and, to Mars is being funded, multiple billions of dollars at a relatively adequate level. The science portfolio is under pressure for funding. It certainly can't do all the good things it could do. So there is a

tension and a political intervention. It's biased in favor of human spaceflight because that produces contrast for various congressional districts. It keeps major NASA centers fully occupied and as a political support base, stronger than the robotic support base. And that plays out. Things still happen. After all, NASA's getting, what, 26 billion, maybe 1 billion or 2 of this year and a lot of money, to put know in one area of activity. So, we're not starving our space program.

GUSTETIC: I would only add that. In the president's budget request, for 25, that was for 25.4 billion, I believe. We've got, you know, a lot of stuff. We've got a lot of responsibilities at NASA that we do beyond even the conversation about the, robotic exploration and human exploration. You know, with those dollars we, invest in not only the, Artemis campaign for lunar exploration, but also, we study our own planet, our own home planet, with our science and climate science and information for the Science Mission Directorate as well. We look down back at ourselves to understand our home planet. We develop technology, stuff that the organization, that, that I am in, leads for the agency as well as our aeronautics efforts for efficient and greener commercial airliners. The transition for commercial to commercial space stations and also the STEM investments that we make, in building future workforce, in the aerospace sector. So there's quite a bit that NASA, balances, in that, that budget, process every year.

WEST: Thank you.

NIEBUR: And, Darrell, if I could just I take John's point, but let me add the enviable role of jumping to Congress's defense, I will say, for speaking only for planetary, which is my area of NASA. We've actually, over the past five, eight years, enjoyed extraordinary support from the White House and from Congress. You know, our budget has actually been growing substantially over the past five to eight years. And that's that's fantastic. I think part of the problem has been. The blessing and the curse for planetary exploration has been how much everybody is supportive of it and loves it, because that's fantastic. But when we get that kind of support attached with and we'd like you to spend the money on this idea we have, because as we've talked about, we have our own process for setting priorities and picking missions. But when external stakeholders come in and say, here's our idea, here's what we want you to do, it makes it much more complicated as well. And I think that's where a lot of the stress comes in, where our reach starts going beyond our grasp. And but in turn, just in terms of budget support and overall support, the government as a whole has been very supportive of science, and particularly planetary science mission over the past five to eight years.

WEST: Well, speaking of more complications in your life, Abby Cohen has a question about a possible change in administration and how that could affect NASA. The question is, "what dangers could the proposed Schedule F under a new Trump administration mean for science agencies such as NASA? Under this proposal, she says, subject matter experts could be reclassified as political employees and could be replaced by political appointments rather than experts. How should we think about that? Any comments or reactions? I know it's kind of a hot topic, but.

LOGSDON: I have a reaction.

WEST: John. Go ahead.

LOGSDON: Whatever else one thinks about Mr. Trump's first term in office, it was good for the space program. There's organization in the executive office of the president called the National Space Council, happened to be run by my successor at George Washington, Scott Pace. That I think in all areas of space activity, put forth a very coherent set of policies and priorities that were well conceived. They did not intervene with, markedly political agendas in the space program. What will happen if Mr. Trump is reelected? That's a fair question given, given his blueprint for what he's going to do in his second term. And I don't want to get very political in this forum. But it's something that people need to ask if they choose their future leadership.

WEST: Okay. Great. Thank you. We have another question from Iman, from an organization called Icon, who asks, "what is the private sector activity that is most likely to take hold on the moon first? Is it going to be space tourism? Is it going to be space mining? Is it going to be in-situ resource utilization, which is harnessing local resources at the space destinations?" Like what do you put your crystal balls, in front of you? What are you seeing as, possible activities that could move to the forefront?

GUSTETIC: I can start with that one. So, there's a lot of exciting, activity, technology development activity that we are investing in, leading towards kind of a more sustainable presence on the moon, both from a robotic perspective and from a human exploration perspective. And it's it's I mean, those are things ranging from in-situ resource utilization. So using what you've got on the moon, in order to fabricate, items and structures that you need as opposed to having to bring everything with you, the power, the surface power that's going to be required to power activities not only like excavation and mining and, and ISRU, but, to

power habitats and all sorts of other elements of the infrastructure, surface mobility and, logistics, how you kind of transport around once you get there and, grappling with some things that are particularly tough on the lunar surface, including lunar dust, that stuff is pretty nasty. And dealing with technologies that can act actively or passively, resist, damage to equipment, and, and equipment, spacesuits, all of that with lunar dust. Is, is a is a key area of research. So I say that to say you kind of have to invest, you have to take a portfolio approach to investing across all of those areas because they all work together in order to lead to a sustainable presence on the moon. If we take Mars as any pointer, you know, the robotic aspects happened before the human exploration aspects. So you might expect to see more robotic activity on the surface of the moon before you see active tourism to the surface of the moon. Now, that doesn't mean that there couldn't be tourism, to other aspects, orbital aspects. But, it's an exciting ecosystem at this time. And we're investing not only in the technologies to help enable that future, but also through programs like the eclipse program, which is one that's actually managed, by our our colleagues in the Science Mission Directorate, to try to get services that, able to, work with the private sector to help us get more routine access, to the lunar surface as well. So, as we can start to get more and more routine access, we'll see more and more technology development, experimentation. And, it's like a flywheel. It just begets each other that that work just begets each other. So excited to see which of those capabilities become, available first.

WEST: Okay. Curt, I have a, science-oriented question for you. And even though it deals with Mars and I know that's outside your official portfolio, you probably have some opinions on this. It's a question from William of Dartmouth College. Who wants to know, "Is it currently feasible to shield astronauts from interstellar radiation on a trip to Mars?"

NIEBUR: Oh, absolutely it is. It's it's really just a question of mass, of keeping the spacecraft light enough that you can get it off the ground. Because if you simply put 8 or 10ft of liquid water between the astronaut in space, that's a great shield from radiation. Fantastic. Or, you know, eight feet of of thick lead would do it as well. The challenge is getting all that shielding off the surface of Earth because it's really, really heavy. So there have been people that have looked into more exotic solutions for that as well, including, you know, generating very strong magnetic fields that would protect what's inside. So there are solutions. Are there viable economically and technically viable solutions? That's a tougher question to answer, but I think it's it's a technical problem that we can resolve. Yes.

WEST: And I also know just in terms of people actually being on Mars, like there are these huge lava tubes, which has many advantages. And one of them actually is shielding people from, radiation. So, when people are thinking about colonies, it may be less likely that there's a colony on surface and more likely there could be colonies within these lava tubes.

NIEBUR: Absolutely true. True for the moon as well. You're not going to have a lunar settlement just on the surface of the moon. You're going to want to be buried beneath regolith, beneath the dirt, or in a lava tube for that shielding.

WEST: We have we have another call -- oh, John. Go ahead.

LOGSDON: Just a quick political correction. Don't use the word colonies. Say settlement.

WEST: Okay, I stand corrected.

LOGSDON: Colonies has a rather negative connotation to it.

WEST: Yep. No, you're exactly right on that. We have a question from Douglas. Who wants to know why does support for the Mars sample return seem thin when it has been a priority of the past three-decade old surveys, and its costs are not really out of family with the James Webb Space Telescope or Dragonfly.

NIEBUR: Well, I would say, first of all, I wouldn't say it is thin, for the for the very reason that the, the question posed, which is that it's been --

WEST: Okay. I think we lost curt there for a minute. I don't know if either one of you, have other thoughts on the Mars return sample program and congressional funding levels. curt is now back with us. We lost you there for a minute, but --

NIEBUR: So it has been a high priority of the challenge we're facing, though, is the priority it's been given has been alongside another priority of make sure the overall program is balanced. In other words, you can't spend all the money on one thing, whether it's Mars sample return or another mission. And our best analyzes have showed that the Mars sample return program is going to be a lot more expensive than we thought. And

while it's less than JWST, which was around $20 billion, it is definitely going to be the most expensive planetary mission we've ever undertaken by about a factor of two with its current current, architecture. So that is the basic struggle. It's not so much. Is the science worthwhile? Does the science have support? Absolutely the science is worthwhile. The question is, can we do this and keep a balanced program of exploration to the solar system as a whole, rather than focusing too much, too many resources just on returning samples from Mars? There are a lot of places we want to go to, not just Mars.

WEST: And of course, just to add a quick footnote to what you said, the scientific value of being able to return Mars stuff back to planet Earth is we can subject that material to much more refined and more sophisticated exploration, like the techniques and the examination tools that we have here are going to be far superior to whatever is out of space.

NIEBUR: It's mind-boggling what scientists can learn from a something the size of a grain of sand. And we're seeing that for the samples from the OSIRIS-REx mission that are from an asteroid, asteroid Bennu that are currently being analyzed right now, the the huge things you can learn from small amount of material is mind boggling.

WEST: Yeah. No, it is very impressive. We have a question from Jacob, who's with the interstellar lab, who wants to know "how can teams that are interested in leading infrastructure efforts on the moon and or Mars partner with NASA?" Jenn, this is a partnership question, so maybe we can direct that to you.

GUSTETIC: Yeah. Well I'd say the first place to look is in the the moon to Mars blueprint architecture that has actually been released, that's been released publicly, that lists the types of objectives that we're looking as an agency and capabilities we're looking to develop in that realm of infrastructure. There's actually a whole aspect of that strategy that is about infrastructure. So it kind of lays out what are the components of an infrastructure that we're trying to build, so folks can get a view of kind of what the vision is, and understand how they might be, a part of that. There are solicitations that come out kind of routinely across the agency on different aspects of the Moon to Mars Initiative. Things coming out of the Science Mission Directorate, for example, with the eclipse, delivery services, out of ESDMD with many of their BAA activities, as well as the technology development role, leadership role, for the interest for infrastructure development pieces that the Space Technology Mission Directorate has, that I represent. And so, getting familiar with the different funding opportunities, that are coming out that are both traditional contracts, but also grants to universities.

We engage our grant, our, university partners, as well as, through, less traditional public private partnerships. There are opportunities kind of across the agency, that are coming up. But familiarize yourself with the strategy first. The other thing that I wanted to make sure to say, before we ended today was that, you know, there's been some discussion about the process that the Science Mission Directorate uses in order to prioritize, science objectives, through these decadal surveys. I wanted to let folks know that the Space Technology Mission Directorate, actually, for the first time, is going through a public process to get inputs from, the public and all of our stakeholders and customers on how technology capability, technology capabilities should be prioritized. Technology organizations never have enough budget to address every single technology objective. Just like Curt was saying, that Science Mission Directorate doesn't have all of the budget to address every science objective. And so we're trying to figure out how we might, prioritize, publicly and transparently the technology objectives that are most important to our, our end users and to our stakeholder community. So we're looking for public input, that is open until May 13th. And you can find those, opportunities for all of those technology gaps. There's about 187 of them that we've identified, on spacetechpriorities.org. So again, before May 13th, we're looking for inputs about the technical priorities, that NASA should be looking at in order to support that wide range of customers that I had mentioned earlier. I would be remiss if I didn't mention that before, before, ending today.

WEST: No, thanks for mentioning that. I'm sure that our, people are watching who have their own ideas. So it sounds like they should, check out that website. We just have a few minutes left. I want to close with a general question for each of the three of you, which is I'm going to name you the space czar. Give you an opportunity to make a pitch to policymakers. What do you want to tell them? What do you think they need to know?

GUSTETIC: I'll go first. It's that, you know, an investment. Every dollar that we invest in space has, significant multiplier ROI here on Earth. We talked about a number of different reasons. Today, an investment in space as an investment in our own economy, and our own future. So it's dollars well spent.

WEST: Curt. Your advice?

NIEBUR: I would say the message would be these aren't science missions. They're they're everyone's missions. Come with us.

WEST: Okay, John.

LOGSDON: Well that the space program of 2024 is not your father's old space program. There's a lot of change, a lot of dynamism in what's going on in space. And I think we're just learning how to adapt to that, how to work together across, business sectors, across government, across countries. So that the space program that results for the Earth is the most productive one possible.

WEST: But we will make that the conclusion of this event. And I want to thank Jenn, Curt and John for sharing your insights. All of you have been terrific. Very, thought provoking ideas, from each of you and those in our viewing audience. So we at Brookings write on space policy as well as technology innovation in general. We have a tech tank, blog located @brookings.edu. We also have a tech tank, a podcast, where we discuss space and other technology issues as well. So feel free to look at those sites for further information. So thank you very much for tuning in today.