NASA COST AND SCHEDULE OVERRUNS: ACQUISITION AND PROGRAM MANAGEMENT CHALLENGES

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

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CONTENTS

June 14, 2018

NASA COST AND SCHEDULE OVERRUNS: ACQUISITION AND PROGRAM MANAGEMENT CHALLENGES

THURSDAY, JUNE 14, 2018

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:04 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Babin [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

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House of Representatives
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NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges

Thursday, June 14, 2018
10:00 a.m.
2318 Rayburn House Office Building

Witnesses

Ms. Cristina T. Chaplain, Director, Contracting and National Security Acquisitions, GAO

Mr. Stephen Jurczyk, Associate Administrator, NASA

Mr. Paul K. Martin, Inspector General, NASA

Mr. Daniel L. Dumbacher, Executive Director, American Institute of Aeronautics and Astronautics

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

Charter

TO:	Members, Committee on Science, Space, and Technology
FROM:	Majority Staff, Committee on Science, Space, and Technology
DATE:	June 7, 2018
SUBJECT:	Space Subcommittee Hearing: "NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

On Thursday, June 14 at 10:00 a.m. in Room 2318 of the Rayburn House Office Building, the Subcommittee on Space will hold a hearing titled, "NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges."

Hearing Purpose

The purpose of the hearing is to focus discussion on the Government Accountability Office's (GAO) 2018 Quick Look report (published on May 1, 2018), this report's assessments of major National Aeronautics and Space Administration (NASA) projects, and a comparison of this 2018 assessment to cost control and program management trends that GAO and the NASA Inspector General (IG) assessed in previous years. Additional cost control and program management discussion will be gleaned from NASA's response to the 2018 GAO report and the updated WFIRST space telescope cost estimate required by the FY18 Omnibus and due to the appropriate committees by May 22, 2018. Furthermore, the NASA IG will provide related testimony drawn from prior year audits and reports on the Joint Confidence Level (JCL) process and the management of major projects and programs. This hearing is not intended to restrict discussion to just observed problems. Identifying recommendations for improvement is necessary, especially for assessing the sufficiency of existing appropriation funding authorities, existing cost-estimating methodologies, contracting and other acquisition mechanisms, program management, and incentivizing/disincentivizing good contractor and program management performance.

Witnesses

- **Ms. Cristina Chaplain**, Director, GAO: Contracting and National Security Acquisitions
- **Mr. Steve Jurczyk**, Associate Administrator, NASA
- **Mr. Paul Martin**, Inspector General, NASA
- **Mr. Daniel L. Dumbacher**, Executive Director, American Institute of Aeronautics and Astronautics (AIAA)

Staff Contact

For questions related to the hearing, please contact Dr. Michael Mineiro, Staff Director, Space Subcommittee, Dr. Samuel Amber, Professional Staff Member, Space Subcommittee, or Ms. Sara Ratliff, Policy Assistant, Space Subcommittee, at 202-225-6371.

Chairman BABIN. Good morning. The Subcommittee on Space will come to order.

Without objection, the Chair is authorized to declare recesses of the Subcommittee at any time.

Welcome to today's hearing titled, "NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges."

I will now recognize myself for five minutes for an opening statement.

NASA is at a critical juncture as it lays out the details of its roadmap for human exploration missions while determining the best business approach to success. However, human exploration doesn't encompass the breadth of NASA's total work. They are also launching interplanetary spacecraft systems, advancing science and aeronautics research, and developing critical technologies to enable U.S. leadership in space. Strategic acquisition planning, utilization of new contracting mechanisms, and improving management and oversight will be a crucial part of effective, affordable, and sustainable mission success for NASA.

As Chairman of the Space Subcommittee and a proud representative of Johnson Space Center in Houston, I am a tireless advocate for NASA. However, as Members of this Committee, we have a responsibility to every taxpayer to ensure that NASA is being a good steward, managing the resources with which we have been entrusted. Today's hearing will touch upon a number of important oversight topics, including acquisition mechanisms, cost-estimation methodologies, and NASA program management.

Procurements represent over 90 percent of NASA's annual budget. In fiscal year 2016, NASA procured over $18.6 billion through nearly 41,000 active procurements. That's a tremendous amount of work. Unfortunately, NASA has been plagued for years with contract management issues, which have resulted in substantial cost overruns and schedule slips. Generally, it's the high-profile, major programs which get the most scrutiny because of the funding and time associated with these procurements. However, there are other well-documented issues, many of which could constitute and possibly warrant a dedicated hearing.

In May of this year, the Government Accountability Office released its annual Assessment of Major NASA Projects, those exceeding $250 million in appropriations. This assessment covered 26 major projects. I'd like to note the Subcommittee will have a dedicated hearing about the James Webb Space Telescope next month, but this project's long history of cost and schedule overruns is relevant to today's discussion as well.

GAO reported an overall deterioration in the major program portfolio, primarily due to the fact that 9 out of 17 projects in development are experiencing cost and schedule performance growth as a result of risky program management decisions, significant technical challenges, and issues beyond the control of the projects.

Last year, GAO assessed that NASA projects were "continuing a generally positive trend of limiting cost and schedule growth, maturing technologies, and stabilizing designs." However, GAO also noted that many of the more expensive projects were "approaching the phase of their life—their lifecycles when cost and schedule growth is most likely."

The Subcommittee will also investigate specific NASA cost-estimating methodologies such as the Joint Cost and Schedule Confidence Level, the JCL process, and NASA management techniques related to project schedule determination and the use of headquarters reserve funding. We are particularly interested in the NASA Inspector General's recommendations on improvements with NASA's cost estimating methodologies, especially if there is a need to continue using the JCL process or adopt another cost-estimating technique.

Furthermore, the Subcommittee will investigate these and other questions: What acquisition mechanisms—cost plus, fixed price, award fee, Space Act Agreements, et cetera—are most appropriate for various types of procurements?

Next, how do these acquisition tools incentivize the provider to perform safely and efficiently? What are the pros and cons?

And then, are existing appropriation funding authorities sufficient for Congressional oversight of major NASA projects?

And lastly, do current agency approaches hold both the agency and provider accountable for overall performance?

And this is a very timely hearing today. In their report last month, GAO noted that NASA is planning to invest about $61 billion over the lifecycle of its current portfolio of 26 major programs, and that doesn't even account for thousands of other procurements and a significant portion of NASA's spending authority. Whether large or small, all of NASA's business decisions matter. Decisions made now have long-lasting implications on NASA's mission success and leadership.

I want to thank the witnesses for being here. I'm sorry I was a little bit late, didn't get a chance to shake each of your hands, but we're looking forward to your testimony on the challenges that NASA is facing in controlling program cost and schedule.

[The prepared statement of Chairman Babin follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
June 14, 2018

Media Contacts: Thea McDonald, Bridget Dunn
(202) 225-6371

Statement by Chairman Brian Babin (R-Texas)

NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges

Chairman Babin: NASA is at a critical juncture as it lays out the details of its roadmap for human exploration missions, while determining the best business approach to success. However, human exploration doesn't encompass the breadth of NASA's work. They are also launching interplanetary spacecraft systems, advancing science and aeronautics research and developing critical technologies to enable U.S. leadership in space.

Strategic acquisition planning, utilization of new contracting mechanisms and improving management and oversight will be a crucial part of effective, affordable and sustainable mission success for NASA.

As the chairman of the Space Subcommittee and a proud representative of Johnson Space Center, I am a tireless advocate for NASA. However, as members of this committee, we have a responsibility to every tax-payer to ensure that NASA is being a good steward, managing the resources with which they are entrusted. Today's hearing will touch upon a number of important oversight topics, including acquisition mechanisms, cost-estimation methodologies and NASA program management.

Procurements represent over 90 percent of NASA's annual budget. In FY16, NASA procured over $18.6 billion through nearly 41 thousand (40,914) active procurements—that's a tremendous amount of work.

Unfortunately, NASA has been plagued for years with contract management issues which have resulted in substantial cost overruns and schedule slips. Generally, it's the high-profile, major programs which get the most scrutiny because of the funding and time associated with these procurements. However, there are other well-documented issues many of which could constitute and possibly warrant a dedicated hearing.

In May of this year, the Government Accountability Office (GAO) released its annual Assessment of Major NASA Projects, those exceeding $250 million in appropriations; this assessment covered 26 major projects.

I'd like to note the subcommittee will have a dedicated hearing about the James Webb Space Telescope next month, but this project's long history of cost and schedule overruns is relevant to today's discussion.

GAO reported an overall deterioration in the major program portfolio—primarily due to the fact that 9 of 17 projects in development are experiencing cost and schedule performance growth as a result of risky program management decisions, significant technical challenges and issues beyond the control of the projects.

Last year, GAO assessed that NASA projects were "continuing a generally positive trend of limiting cost and schedule growth, maturing technologies and stabilizing designs." However, GAO also noted that many of the more expensive projects were "approaching the phase in their life cycles when cost and schedule growth is most likely."

The subcommittee will also investigate specific NASA cost estimating methodologies such as the Joint Cost and Schedule Confidence Level (JCL) process and NASA management techniques related to project schedule determination and the use of headquarters reserve funding.

We are particularly interested in the NASA Inspector General's (IG) recommendations on improvements with NASA's cost estimating methodologies, especially if there is a need to continue using the JCL process or adopt another cost estimating technique.

Furthermore, the subcommittee will investigate these and other questions:

- What acquisition mechanisms (cost plus, fixed price, award fee, space act agreements, etc.) are most appropriate for various types of procurements?
- How do these acquisition tools incentivize the provider to perform safely and efficiently? What are the pros and cons?
- Are existing appropriation funding authorities sufficient for congressional oversight of major NASA projects?
- Do current agency approaches hold both the agency and provider accountable for overall performance?

This is a very timely hearing. In their report last month, GAO noted that NASA is planning to invest about $61 billion over the life-cycle of its current portfolio of 26 major programs—and that doesn't even account for thousands of other procurements and a significant portion of NASA's spending authority. Whether large or small, all of NASA's business decisions matter. Decisions made now have long lasting implications on NASA's mission success and leadership.

I thank the witnesses for appearing and look forward to their testimony on the challenges NASA faces in controlling program cost and schedule.

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Chairman BABIN. So now, I'd like to recognize the Ranking Member of the Subcommittee from California, Mr. Bera.

Mr. BERA. Thank you, Mr. Chairman. Thank you for having this timely hearing, and welcome to the witnesses. I do look forward to your testimony.

When you think about NASA, NASA is a unique agency. It's a source of national pride for us, but it also is a cutting-edge agency that serves to inspire. Those of us who grew up during the space race certainly understood that inspiration and it motivated many of us to go into the sciences.

I want to also acknowledge it's not that often we walk into a hearing room and we see a line of folks waiting to get in here, and I think we're joined by NASA's interns and that next generation that hopefully is going to inspire, discover, and move us forward. So, thank you to the interns that are here. You are the future.

In terms of thinking about Congress' role here, we clearly have a role, a fiscal responsibility and oversight, and those at NASA don't have an easy job. I mean, you are trying to think about what that future looks like. You are trying to put those projects together and I appreciate that check and balance. As you're doing things that we've never done before, you often encounter the unexpected. And I think that's why this is an important hearing.

Resolving cost and scheduling issues are hard, and there really is no simple fix for these types of situations. That said I have no doubt that NASA's talented workforce is looking to find those improvements of how it conducts project management, oversees its contractors, collaborates with international partners, provides greater funding certainty, and applies cost estimation tools and techniques.

But today's discussion of schedule delays and cost increases and the search for corrective actions cannot take away from the accomplishments and discoveries made by programs like Hubble, the International Space Station, and Mars Curiosity. These accomplishments and discoveries would not have happened had the nation not made the hard decisions that enable these projects to carry through in spite of scheduling delays and cost growth.

And we've been well-rewarded with countless innovations thanks to the dedicated and inspired work by NASA, its supporting contractors, and the nation's colleges and universities. One area for improvement is a better agreement on the baseline from which cost growth and schedule delay are determined.

The inconsistent measurement of cost growth across programs was noted in the National Academies' review of NASA Earth Science and Space Missions in 2010. For example, some people characterize the cost growth of the Webb Space Telescope using an initial baseline project cost of $1 billion to $3.5 billion. While this was the initial range cost estimated in 1996, that estimate was not based on a detailed analysis. A detailed analysis is needed to establish a baseline from which NASA makes a commitment to Congress that it can design, develop, and build a project at the cost specified. The initial baseline was established in the fiscal year of 2009, and according to that baseline, JWST was estimated to have a lifecycle cost of about $5 billion. That is a pretty different number than $1 billion.

So, in closing, Mr. Chairman, this topic is timely. NASA's need to effectively manage its programs will gain even more importance as the agency seeks to manage its wide-ranging portfolio in an increasingly constrained fiscal environment while pursuing ambitious goals such as exploring Europa and sending humans far away from Earth.

I look forward to a robust discussion at today's hearing, and with that, I'll yield back.

[The prepared statement of Mr. Bera follows:]

OPENING STATEMENT
Ranking Member Ami Bera (D-CA)
of the Subcommittee on Space

Committee on Science, Space, and Technology
Subcommittee on Space
"NASA's Cost and Schedule Overruns:
Acquisitions and Program Management Challenges"
June 14, 2018

Good morning, and thank you, Mr. Chairman, for holding this hearing on *"NASA's Cost and Schedule Overruns: Acquisitions and Program Management Challenges"*. Welcome to our witnesses, and I look forward to your testimony.

One of the most important responsibilities Congress has is to ensure that agencies, such as NASA, have the resources and tools necessary to carry out their mission. However, we have the added responsibility for making sure that agencies are being good stewards of taxpayer dollars. As we will hear today, NASA is encountering schedule delays, and in some cases, cost increases in a number of projects and programs. I appreciate the good work by the Government Accountability Office and NASA's Inspector General in bringing these cases to our attention as we can learn from those cases in order to minimize issues in the future.

Resolving cost and schedule issues is *hard*, and there's no simple fix or the situation would have been resolved long ago. But I have no doubt that NASA's talented workforce can find improvements in how it conducts program management; oversees its contractors; collaborates with its international partners; provides greater funding certainty; and applies cost estimation tools and techniques. However, today's discussion of schedule delays and cost increases, and the search for corrective actions, cannot take away from the accomplishments and discoveries made possible by programs and projects such as Hubble, the International Space Station, and Mars Curiosity. These accomplishments and discoveries would not have happened had the Nation not made the hard decisions that enabled these projects to carry through, in spite of schedule delays and cost growth. And we have been well rewarded with countless innovations, thanks to the dedicated and inspired work by NASA, its supporting contractors, and the Nation's colleges and universities.

One area for improvement is a better agreement on the baseline from which cost growth and schedule delay are determined. The inconsistent measurement of cost growth across programs was noted in a National Academies review of NASA Earth Science and Space Science Missions in 2010. For example, some people characterize the cost growth of the James Webb Space Telescope using an initial baseline project costs of $1 billion to $3.5 billion. While this was the initial range of cost estimated in 1996, that estimate was not based on a detailed analysis. A detailed analysis is needed to establish a baseline from which NASA makes a commitment to Congress that it can design, develop, and build the project at the cost and schedule specified. That initial baseline was established in Fiscal Year 2009. According to that baseline, JWST was estimated to have a life cycle cost of about $5 billion. That is a far cry from $1 billion.

In closing, Mr. Chairman, this topic is timely. NASA's need to effectively manage its programs will gain even more importance as the agency seeks to manage its wide-ranging portfolio in an increasingly constrained fiscal environment while pursuing ambitious goals, such as exploring Europa and sending humans far away from Earth.

I look forward to a robust discussion at today's hearing. With that, I yield back.

Chairman BABIN. Thank you very much.

And now I'd like to—in fact, before I recognize our next speaker, I also want to reiterate—thank you for saying this, Congressman Bera. I met some of you outside in the hall when I walked up, and I wanted to tell you that we're elated that we've have got all of these NASA interns in here, and we really appreciate the good work you're doing and just want to pat you all on the back. You're our future in the space program. Thank you for being here.

Now, I'd like to introduce our—the Chairman of the full Committee, the gentleman from Texas, Chairman Lamar Smith.

Chairman SMITH. Thank you, Mr. Chairman.

This Committee has demonstrated time and again that U.S. leadership in space is a bipartisan priority. Our vote on the 2018 NASA Authorization Act in April was a clear demonstration of that.

Congress and the Administration support a consistent, focused space program, and the current NASA budget demonstrates that resolve. NASA once again received one of the most favorable authorizations and appropriations of any agency.

Healthy budgets are a good start, but they must be followed up with solid management and oversight to make certain taxpayers' funds are spent well. However, excessive costs and missed deadlines may undermine the very NASA projects Congress and the American people support.

We recently held hearings discussing four of NASA's highest profile programs: SLS, Orion, Commercial Crew, and the James Webb Space Telescope. The Subcommittee will have a hearing next month about the JWST program breach, and Northrop Grumman's CEO has agreed to testify.

The GAO's report identified significant cost and deadline problems with all four of these high-interest programs. SLS and JWST are identified as having deteriorating cost and schedule performance due to risky decisions involving technology. GAO found that the commercial crew contractors continue to have significant delays in the test flight schedules. And NASA expects the Orion program to exceed its cost baseline.

GAO assessed other NASA major projects this year as well. For example, the Wide Field Infrared Survey Telescope remains a serious concern for Congress. This Committee has requested but not received the WFIRST lifecycle cost estimate that was required by the fiscal year 2018 omnibus.

Congress has a responsibility to authorize and appropriate funding necessary to accomplish the tasks it directs NASA to carry out. But Congress also has a responsibility to not let cost overruns detract from other NASA priorities, such as research and small- and medium-class missions.

It is time for NASA's contractors to deliver. The 2018 NASA Authorization Act takes important steps to impose a contractor responsibility watchlist. This watchlist would penalize poor performing contractors by restricting them from competing for further NASA work.

Beyond contractor watchlists, NASA should continue to explore additional options to reduce the costs of these large programs, such as leveraging program surpluses, early-stage cost caps, firm fixed-price contracts, and public-private partnerships that benefit tax-

payers. Anything short of that will undermine Congressional confidence in the contractors' ability to deliver on their promises at a reasonable cost.

If space exploration is going to continue to earn the public's trust, then contractors will have to deliver on time and on budget. If they cannot, then they should face sanctions.

Mr. Chairman, again, I look forward to our witnesses' testimony today and yield back the balance of my time.

[The prepared statement of Chairman Smith follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
June 14, 2018

Media Contacts: Thea McDonald, Bridget Dunn
(202) 225-6371

Statement by Chairman Lamar Smith (R-Texas)

NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges

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GAO found the commercial crew contractors continue to have significant delays in the test flight schedules. And, NASA expects the Orion program to exceed its cost baseline.

GAO assessed other NASA major projects this year as well. For example, the Wide Field Infrared Survey Telescope (WFIRST) remains a serious concern for Congress. This committee has requested but not received the WFIRST life cycle cost estimate that was required by the FY18 Omnibus.

Congress has a responsibility to authorize and appropriate funding necessary to accomplish the tasks it directs NASA to carry out. But Congress also has a responsibility to not let cost overruns detract from other NASA priorities, such as research and small—and medium—class missions.

It is time for NASA's contractors to deliver. The 2018 NASA Authorization Act takes important steps to impose a contractor responsibility watch list. This watch list would penalize poor performing contractors by restricting them from competing for further NASA work.

Beyond contractor watch lists, NASA should continue to explore additional options to reduce the costs of these large programs, such as leveraging program surpluses, early-stage cost-caps, firm fixed-price contracts and public-private partnerships that benefit taxpayers.

Anything short of that will undermine congressional confidence in the contractors' ability to deliver on their promises at a reasonable cost. If space exploration is going to continue to earn the public's trust, then contractors will have to deliver on time and on budget. If they cannot, then they could face suspension and debarment.

I look forward to our witnesses' testimony today. Thank you, Mr. Chairman.

###

Chairman BABIN. Thank you very much.

Now, I'd like to introduce the gentlewoman from Texas, the Ranking Member of the full Committee, Ms. Johnson.

Ms. JOHNSON. Thank you very much, Mr. Chairman, and thank you for holding this hearing and thanks to our witnesses for being here.

This morning, we hope we're going to get a status update on NASA's management and its programs, particularly cost and schedule status on its large missions. To that end, I hope the hearing will provide answers to some of our key questions. Is NASA's ability to manage cost and schedule on its programs improving or is it getting worse, as the Government Accountability Office seems to indicate in its recent report on NASA's major projects?

If it is getting worse, what should be done, particularly by this Committee? Cost and schedule can be expected to be difficult on projects that push the state-of-the-art in science and engineering. Challenging missions and transformational science are what we expect of space programs worthy of this great nation.

That said, Mr. Chairman, we can do better. In particular, we need to improve our ability to identify early on when we can still make design decisions whether a project runs the risk of exceeding budget constraints and, if so, what options we have at our disposal to make sure the program meets those budget constraints.

The Wide Field Infrared Survey Telescope is a good example. After stakeholders, including the National Academies, expressed concerns that the WFIRST could run into potential cost and schedule growth, NASA established expert groups to rigorously review the cost, engineering, and science objectives for the mission. I commend NASA for taking this action. These steps are being taken before a final WFIRST mission design is established and while there is still time to reconsider the scope and approach of the mission to preclude the possibility of exceeding costs, schedule expectations as it starts its development.

Mr. Chairman, I look forward to discussing learning opportunities such as this one in determining whether future NASA missions would benefit from incorporating similar processes to minimize the possibility of future schedule delay and/or cost increases.

One thing I learned early on while serving on this Committee is that NASA is a unique engine of innovation, a force for pushing new advances in space technology and operations. That is why I'm anxious to hear from our witnesses on whether the costs and schedule models that are based on the past, traditional approaches to national project development are being updated to reflect the changes in today's manufacturing, operations, and technology environment. Is R&D on cost and schedule models needed? Are there other tools that could help NASA improve the management of cost and schedule in its acquisition of space systems?

We do have a lot to discuss this morning, and I look forward to hearing from our witnesses. Thank you, and I yield back.

[The prepared statement of Ms. Johnson follows:]

OPENING STATEMENT
Ranking Member Eddie Bernice Johnson (D-TX)

Committee on Science, Space, and Technology
Subcommittee on Space
"NASA's Cost and Schedule Overruns:
Acquisitions and Program Management Challenges"
June 14, 2018

Good morning, Mr. Chairman, and thank you for holding this hearing on "*NASA's Cost and Schedule Overruns: Acquisitions and Program Management Challenges.*" I'd like to welcome our witnesses, and I look forward to your testimony. This morning, we are going get a status update on NASA's management of its programs, particularly cost and schedule status on its large missions. To that end, I hope the hearing will provide answers to some key questions. Is NASA's ability to manage cost and schedule on its programs improving, or is it getting worse as the Government Accountability Office seems to indicate in its recent report on NASA's major projects? If it is getting worse, what should be done, particularly by this Committee?

Cost and schedule can be expected to be difficult on projects that push the state-of-the-art in science and engineering. Challenging missions and transformational science are what we expect of a space program worthy of a great nation. That said, Mr. Chairman, we can do better. In particular, we need to improve our ability to identify early on--when we can still make design decisions--whether a project runs the risk of exceeding budget constraints and, if so, what options we have at our disposal to make sure the program meets those budget constraints.

The Wide-Field Infrared Survey Telescope (WFIRST) is a good example. After stakeholders, including the National Academies, expressed concerns that WFIRST could run into potential cost and schedule growth, NASA established expert groups to rigorously review the cost, engineering, and science objectives for the mission. I commend NASA for taking this action. These steps are being taken before a final WFIRST mission design is established and while there is still time to reconsider the scope and approach for the mission to preclude the possibility of exceeding cost and schedule expectations as it starts development.

Mr. Chairman, I look forward to discussing learning opportunities such as this one and determining whether future NASA missions would benefit from incorporating similar processes to minimize the possibility of future schedule delay and/or cost increases. One thing I learned early on while serving on this Committee is that NASA is a unique engine of innovation, a force for pushing new advances in space technology and operations. That is why I am anxious to hear from our witnesses on whether cost and schedule models that were based on past, traditional approaches to NASA's project development are being updated to reflect the changes in today's manufacturing, operations, and technology environment. Is R&D on cost and schedule models needed? Are there other tools that could help NASA improve the management of cost and schedule in its acquisition of space systems?

Well, we have a lot to discuss this morning, and I look forward to a good discussion at today's hearing.

Thank you and I yield back.

Chairman BABIN. Thank you very much.

Now, I'd like to introduce our witnesses. Our first witness today is Ms. Cristina Chaplain, Director of Contracting and National Security Acquisitions at the U.S. Government Accountability Office. Among other topics, Ms. Chaplain has led reviews on the ISS, the SLS, and Orion crew capsule, as well as commercial cargo and crew projects at NASA.

Ms. Chaplain received her bachelor's degree in international relations from Boston University and a master's degree in journalism from Columbia University. We welcome you.

Our second witness today is Mr. Stephen Jurczyk, serving as the Associate Administrator of NASA, the agency's highest-ranking career civil service position. Prior to this appointment, Mr. Jurczyk served as Associate Administrator of the Space Technology Mission Directorate where he formulated and executed the agency's space technology programs.

Mr. Jurczyk is a graduate of the University of Virginia where he received a Bachelor of Science and a Master of Science in electrical engineering. Thank you for being here.

Our third witness today is Hon. Paul Martin, Inspector General of NASA. Prior to this appointment, Mr. Martin served as the Deputy Inspector General of the U.S. Department of Justice in the Office of Inspector General. Mr. Martin holds a Bachelor of Arts in journalism from Pennsylvania State University and a Juris Doctor from Georgetown University Law Center. Thank you for being here.

Our final witness today is Mr. Daniel Dumbacher, the Executive Director of the American Institute of Aeronautics and Astronautics, or AIAA. Mr. Dumbacher—is it Bacher or Bacher?

Mr. DUMBACHER. Bacher.

Chairman BABIN. Bacher, I thought so. I served three years in Germany, so I thought so. Mr. Dumbacher has previously served as the Deputy Associate Administrator of the Exploration Systems Development Division of NASA's Human Exploration and Operations Mission Directorate.

Mr. Dumbacher earned his bachelor's degree in mechanical engineering from Purdue University and a master's degree in business administration from the University of Alabama in Huntsville. He has also completed the Senior Managers in Government program at Harvard University.

So I'd like to recognize Ms. Chaplain for five minutes to present her testimony.

TESTIMONY OF MS. CRISTINA CHAPLAIN, DIRECTOR, GAO: CONTRACTING AND NATIONAL SECURITY ACQUISITIONS

Ms. CHAPLAIN. Chairman Babin and Ranking Member Bera, Chairman Smith and Ranking Member Johnson, thank you for inviting me today to discuss the cost and schedule performance of NASA's largest projects.

Since we began our assessments of major projects ten years ago, we have seen NASA make progress in reducing acquisition risk, but our most recent review found that performance has worsened after several years of following a general positive trend.

[Slide.]

Ms. CHAPLAIN. Specifically, as shown in this graph, the average launch delay, which is the yellow line with dots, increased from 7 months in our 2017 report to 12 months in this year's report. This was the first year we could not determine the extent of cost growth because NASA does not have a current estimate for the Orion program. Orion accounts for 22 percent of about $30 billion of development costs for major projects.

Even without including Orion, however, the overall development cost growth increased to 18.8 percent, up from 15.6 percent in 2017. We expect this number to increase further once Orion is factored in and probably even more as large projects, including James Webb, Space Launch System, and Exploration Ground Systems are in their riskiest phases of development.

In regard to this graph, I'd also like to point out that when we started our assessments in 2009, cost and schedule growth was more problematic than depicted. Many baselines had been set just a couple years prior in response to a statutory requirement aimed at enabling more consistent reporting from NASA. So, as you can see, it's been a struggle for Congress to hold them accountable for years. Also in 2012, you can see the impact that James Webb had on the overall cost growth when its estimate increased from 4.9 billion to $8.8 billion.

[Slide.]

Ms. CHAPLAIN. This next graph depicts some of the reasons why projects experience cost and schedule growth. They're not so different than what we've seen in the past at NASA and across government space programs. Cost and schedule growth is sometimes due to issues beyond a project's control—the light blue circles—which might include a delivery—a late delivery and a delay of the launch vehicle.

In other times the dark blue circles, it was due to risky management decisions. For instance, human spaceflight programs have been operating with very low cost and schedule reserves, which has limited their ability to address unforeseen technical challenges. In other cases, projects encounter technical problems that can sometimes be avoided and sometimes not. The James Webb program is reporting delays, for example, due to workmanship errors that delayed the delivery of the spacecraft propulsion system and also because of unanticipated complexities involved with unfurling the sunshield, which is unique to the telescope. We're looking at whether more could have been done to avoid the workmanship issues.

Since the mid-2000s, NASA has made strides in developing tools and approaches to reduce costs and schedule growth.

[Slide.]

Ms. CHAPLAIN. As shown in this graph, for example, projects are increasingly building more knowledge about critical technologies early so that they do not discover problems when they're more expensive and time-consuming to fix. Similarly, they're building more knowledge about design before proceeding into integration. NASA has also improved cost and schedule estimating processes and its oversight processes.

While we recognize NASA's progress, we believe more can be done to put programs on a sounder footing. For example, as men-

tioned earlier, the human spaceflight projects should not be operating with low cost and schedule reserves. Projects should also regularly update cost and schedule estimates, but they are more often reluctant to do so. For James Webb, an updated estimate may have forecasted the current schedule delays if it were done a few years ago.

We also still find that some projects do not manage contractors well and react only after problems become overwhelming. This year, we saw that workmanship errors on even the smallest of components can sometimes have dramatic impacts.

Lastly, NASA should take steps needed to ensure cost growth from a large project does not overwhelm a portfolio. NASA did this recently for its astrophysics portfolio when it undertook an independent review of the WFIRST telescope before the more costly phases of the acquisition process began. This type of assessment should continue.

In conclusion, we recognize NASA projects are complex, they face inherent technical challenges. Some cost and schedule growth is inevitable when you push the state of technology, but more can be done to limit management risks that often exasperates problems.

Chairman Babin, Ranking Member Bera, this concludes my statement, and I'm happy to answer any questions you have.

[The prepared statement of Ms. Chaplain follows:]

United States Government Accountability Office

GAO

Testimony

Before the Subcommittee on Space, Committee on Science, Space, and Technology, House of Representatives

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NASA MAJOR PROJECTS

Portfolio Is at Risk for Continued Cost Growth and Schedule Delays

Statement of Cristina T. Chaplain, Director,
Contracting and National Security Acquisitions

GAO Highlights

Highlights of GAO-18-576T, a testimony before the Subcommittee on Space, Committee on Science, Space, and Technology, House of Representatives

June 14, 2018

NASA MAJOR PROJECTS

Portfolio Is at Risk for Continued Cost Growth and Schedule Delays

Why GAO Did This Study

GAO designated NASA's acquisition management as a high-risk area in 1990 after a history of persistent cost growth and schedule slippage in many of NASA's major projects. In more recent years, GAO found that NASA had taken some steps to improve its management, and, in May 2017, GAO found that projects were continuing a generally positive trend of limiting cost and schedule growth. But at the same time, GAO noted that many of these projects, including some of the most expensive ones, were approaching the phase in their life cycles when cost and schedule growth is most likely.

This statement summarizes GAO's 2018 findings from its 10th annual snapshot of how well NASA is planning and executing its major acquisition projects, and describes (1) the cost and schedule performance of NASA's portfolio of major projects and (2) the extent to which NASA faces risks for further cost increases and schedule delays. To conduct its review for the 2018 report, GAO-18-280SP, GAO analyzed cost, schedule, and other data for NASA's 26 major projects, each with a life-cycle cost of over $250 million; reviewed monthly project status reports; and interviewed NASA officials.

What GAO Recommends

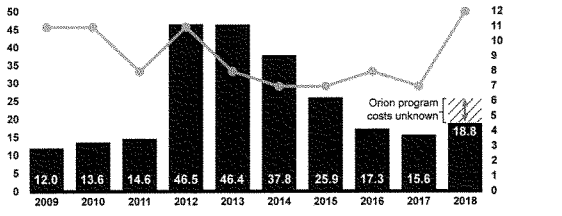
GAO is not making any new recommendations in this statement. GAO has made recommendations in prior reports to strengthen NASA's acquisition management of its major projects. NASA generally agreed with these recommendations, but has not fully addressed some of them. GAO continues to believe they should be fully addressed.

View GAO-18-576T. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

The cost and schedule performance of the National Aeronautics and Space Administration's (NASA) portfolio of major projects has deteriorated, but the extent of cost performance deterioration is unknown. NASA expects cost growth for the Orion crew capsule—one of the largest projects in the portfolio—but does not have a current cost estimate. In addition, the average launch delay for the portfolio was 12 months, the highest delay GAO has reported in its 10 years of assessing major NASA projects (see figure below).

NASA's Major Project Portfolio Cost and Schedule Performance Deteriorated in 2018



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

The deterioration in portfolio performance was the result of 9 of the 17 projects in development experiencing cost or schedule growth.

- Four projects encountered technical issues that were compounded by risky program management decisions. For example, the Space Launch System and Exploration Ground Systems programs are large-scale, technically complex human spaceflight programs, and NASA managed them to aggressive schedules and with insufficient levels of cost and schedule reserves. This made it more difficult for the programs to operate within their committed baseline cost and schedule estimates.
- Two projects ran into technical challenges that resulted in delays in the integration and test phase. For example, in December 2017, GAO found that the James Webb Space Telescope project encountered delays primarily due to the integration of the various spacecraft elements taking longer than expected, as well as the need to resolve technical issues during testing. GAO has previously found that integration and testing is when projects are most at risk of incurring cost and schedule growth.
- Three projects experienced cost growth or schedule delays due to factors outside of the projects' control, such as delays related to their launch vehicles.

NASA continues to face increased risk of cost and schedule growth in future years due to new, large and complex projects that will enter the portfolio and expensive projects remaining in the portfolio longer than expected.

Chairman Babin, Ranking Member Bera, and Members of the Subcommittee:

Thank you for inviting me to discuss the cost and schedule performance of the National Aeronautics and Space Administration's (NASA) portfolio of major acquisition projects. NASA's major projects are the key enablers for the agency to achieve its vision and its mission. They include NASA's Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle (Orion), which are the centerpieces of NASA's human exploration plans; Mars 2020 and Europa Clipper, which will further our understanding of the habitability of other planets; and the Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2), which will provide better data on changes in the Earth. In its fiscal year 2019 budget request, NASA requested $19.9 billion, which included about $4.5 billion for its deep space exploration programs and research and about $6 billion for science programs and research. As these projects are complex and specialized, and often push the state of the art in space technology, NASA manages a portfolio that will always have inherent technical, design, and integration risks.

We have been assessing the cost and schedule performance of NASA's major projects—those that have a life-cycle cost over $250 million—annually for 10 years. Over this time, we have seen NASA make progress in reducing acquisition risks, such as by improving cost and schedule estimating tools, and establishing design metrics and tracking projects against the metrics. But our most recent assessment in May 2018 found that the cost and schedule performance of the portfolio deteriorated after several years of following a generally positive trend of limiting cost and schedule growth.[1]

My statement today is based primarily upon our May 2018 report. Specifically, I will discuss (1) the cost and schedule performance of NASA's portfolio of major projects and (2) the extent to which NASA faces risks for continued cost increases and schedule delays. To conduct this work, we collected cost and schedule information from NASA's major projects using a data collection instrument, analyzed projects' monthly status reports, interviewed NASA project and headquarters officials, and reviewed project documentation. At the time of our review, there were 26 major projects in total, but the information available depended on where a

[1]GAO, *NASA: Assessments of Major Projects*, GAO-18-280SP (Washington, D.C.: May 1, 2018).

project was in its life cycle.[2] For the 17 projects that were in the implementation phase, we compared current cost and schedule estimates to their original cost and schedule baselines. We reviewed historical data on cost and schedule performance for major projects from our prior reports and compared them to the performance of NASA's current portfolio of major projects. More detailed information on our objectives, scope, and methodology for that work can be found in our May 2018 report. In addition, we requested and received an update from NASA in early June 2018 on whether the agency had completed a new life-cycle cost estimate for the Orion program. We also updated the actual launch date for the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) project and updated information on the launch date for the Ionospheric Connection Explorer (ICON) project.

We conducted the work on which this statement is based in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

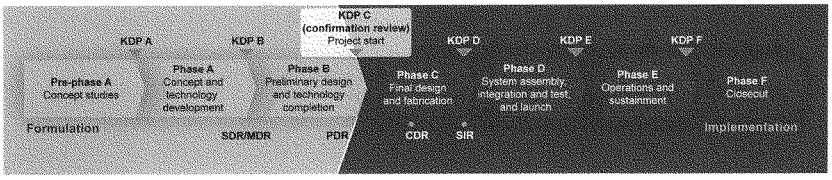
Background

NASA Acquisition Life Cycle for Space Flight Projects

The life cycle for NASA space flight projects consists of two phases—formulation, which takes a project from concept to preliminary design, and implementation, which includes building, launching, and operating the system, among other activities. NASA further divides formulation and implementation into phases, phase A through phase F. Major projects must get approval from senior NASA officials at key decision points before they can enter each new phase. Formulation culminates in a review at key decision point C, known as project confirmation, where cost and schedule baselines are established and documented in a decision memorandum. Figure 1 depicts NASA's life cycle for space flight projects.

[2]Eight projects were in an early stage of development, called formulation, when there are still unknowns about requirements, technology, and design. For those projects, we reported preliminary cost ranges and schedule estimates. The Commercial Crew Program has a tailored project life cycle and project management requirements. As a result, it was excluded from our cost and schedule performance analysis.

Figure 1: NASA's Life Cycle for Space Flight Projects



Management decision reviews

KDP = key decision point

Technical reviews

SDR/MDR = system definition review/mission definition review

PDR = preliminary design review

CDR = critical design review

SIR = system integration review

Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

At the time of our review in May 2018, NASA had a portfolio of 26 major projects (see table 1). See appendix I for a brief description of each project.

Table 1: Major NASA Projects Reviewed in GAO's 2018 Assessment by Phase

Projects in formulation	Double Asteroid Redirection Test (DART)
	Europa Clipper
	Low Boom Flight Demonstrator (LBFD)
	Lucy
	Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)
	Psyche
	Restore-L
	Wide-Field Infrared Survey Telescope (WFIRST)
Projects in implementation	Commercial Crew Program (CCP)
	Exploration Ground Systems (EGS)
	Gravity Recovery and Climate Experiment Follow-On (GRACE-FO)
	Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)
	Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight)
	Ionospheric Connection Explorer (ICON)
	James Webb Space Telescope (JWST)
	Landsat 9 (L9)
	Laser Communications Relay Demonstration (LCRD)
	Mars 2020
	NASA ISRO Synthetic Aperture Radar (NISAR)
	Orion Multi-Purpose Crew Vehicle (Orion)
	Parker Solar Probe (PSP) (formerly Solar Probe Plus)
	Radiation Budget Instrument (RBI)
	Space Launch System (SLS)
	Space Network Ground Segment Sustainment (SGSS)
	Surface Water and Ocean Topography (SWOT)
	Transiting Exoplanet Survey Satellite (TESS)

Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

NASA Acquisition Management as a High-Risk Area

NASA acquisition management is an area that we monitor on our high-risk list.[3] Our high-risk series is a biennial report that keeps focused attention on government operations with greater vulnerabilities to fraud, waste, abuse, and mismanagement or that are in need of transformation

[3]GAO, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others*, GAO-17-317 (Washington, D.C.: Feb. 15, 2017). We first designated NASA contract management as a high-risk area in 1990. In 2009, we updated the title of the area to NASA acquisition management because of the scope of issues that needed to be resolved to address persistent cost growth and schedule delays.

to address economy, efficiency, or effectiveness challenges. In 1990, we first designated the area as high risk because there was little emphasis on end results, product performance, and cost control; the acquisition process itself was cumbersome and time-consuming; and NASA found itself procuring expensive hardware that did not work properly. For example, in April 1990, NASA deployed the $1.5 billion Hubble Space Telescope and soon after, the agency discovered that the primary mirror had been manufactured in the wrong shape, severely degrading some of the telescope's scientific capabilities.

Subsequently, we and other organizations, including the National Academy of Sciences and NASA's Office of the Inspector General, found that NASA's cost estimates were overly optimistic.[4] Our reviews also found that NASA continued to experience significant cost and schedule growth due, in part, to not having a disciplined cost estimating process.

- In 1992, we reviewed the cost and schedule performance of 29 NASA programs and found that 25 of those programs experienced cost growth that ranged from 14 to 426 percent above their initial estimates.[5] Further, the median estimate change for all programs was an increase of 77 percent. General reasons that NASA provided for the cost growth included insufficient definition studies, program and funding instability, overly optimistic assumptions by program officials, and unrealistic contractor estimates. The more specific reasons for the cost growth we found included program redesigns, technical complexities, budget constraints, and incomplete cost estimates.
- In 2004, we reviewed the cost and schedule performance of 27 NASA programs and found that 17 of the programs experienced cost growth.[6] Cost growth for 10 of the 17 programs was over 25 percent.

[4]GAO, *Space Programs: NASA's Independent Cost Estimating Capability Needs Improvement,* GAO/NSIAD-93-73 (Washington, D.C.: Nov. 5, 1992); *NASA Program Costs: Space Missions Require Substantially more Funding Than Initially Estimated,* GAO/NSIAD-93-97 (Washington, D.C.: Dec. 31, 1992); National Research Council of the National Academies, *Controlling Cost Growth of NASA Earth and Space Science Missions* (Washington, D.C.: National Academies Press, 2010); and NASA Office of Inspector General, *Inspector General Assessment of NASA's Most Serious Management and Performance Challenges,* (Washington, D.C.: Feb. 4, 2002) and *NASA's Independent Cost Estimating Capability,* IG-00-045 (Washington, D.C.: Sept. 20, 2000).

[5]GAO/NSIAD-93-97.

[6]GAO, *NASA: Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management,* GAO-04-642 (Washington, D.C.: May 28, 2004).

We found that considerable change in NASA's program cost estimates—both increases and decreases—indicated that NASA lacked a clear understanding of how much its programs cost and how long they will take to achieve their objectives. Further, we found that NASA's basic cost-estimating processes—an important tool for managing programs—lacked the discipline needed to ensure that program estimates are reasonable.

In more recent years we have found that NASA's leadership was focused on improving acquisition outcomes and had taken some steps to improve its management.

- In 2006, NASA established a management review process to enable NASA's senior management to more effectively monitor a project's performance, including cost, schedule, and cross-cutting technical and nontechnical issues.
- In 2009, NASA began requiring that NASA major programs and projects develop a joint cost and schedule confidence level (JCL) prior to project confirmation in order to ensure that cost and schedule estimates were realistic and projects thoroughly planned for anticipated risks. The JCL is a point-in-time estimate that, among other things, includes all cost and schedule elements, incorporates and quantifies known risks, assesses the impacts of cost and schedule to date, and addresses available annual resources. NASA policy generally requires that projects be baselined and budgeted at the 70 percent confidence level.
- In 2012, the agency established metrics to more consistently measure a project's design progress and, in 2014, we found that most major projects in the portfolio were tracking and reporting those metrics. In addition, experts with whom we met confirmed that NASA's metrics are valid measures to assess design maturity in space systems.
- Since 2015, we have observed a positive trend of higher numbers of projects maturing technologies prior to preliminary design review.[7] Demonstrating that technologies will work as intended in a relevant environment serves as a fundamental element of a sound business case, and projects falling short of this standard often experience subsequent technical problems. Our best practices work has shown

[7]A technology is considered mature when it reaches a technology readiness level 6, which is achieved after demonstrating a representative prototype of the technology in a relevant environment that simulates the harsh conditions of space.

that maturing technologies prior to preliminary design review can minimize risks for projects entering development, which lowers the risk of subsequent cost growth and schedule delays.

We believe that many of these steps NASA has taken contributed to the largely positive trend of cost and schedule performance for NASA's portfolio of major projects between 2013 and 2017. In our May 2017 assessment of major projects, we found that out of 16 projects in development, 5 experienced cost growth and 4 experienced schedule delays over their development cost and schedule baselines.[8] Both of these measures were at or near the lowest levels we have reported since we began our annual assessments in 2009.

However, we also found in our February 2017 high risk update that NASA needed to do more with respect to anticipating and mitigating risks—especially with regard to large programs, estimating and forecasting costs for its largest projects, and implementing management tools.[9] We highlighted several actions that would be critical to improving NASA's acquisition outcomes, including the following:

- Ensuring that NASA conducted adequate and ongoing assessments of risks for larger programs because the impacts of any potential miscalculations will be felt across NASA's portfolio.
- Ensuring that NASA understood long-term human exploration program costs. While the three major human exploration programs—Orion, SLS, and the Exploration Ground Systems (EGS)—have been baselined, none of the three programs has a baseline that covers activities beyond the second planned flight. Long-term estimates, which could be revised as potential mission paths are narrowed and selected, would provide decision makers with a more informed understanding of costs and schedules associated with potential agency development paths.
- Ensuring that program offices regularly and consistently updated their JCL across the portfolio. As a project reaches the later stages of development, especially integration and testing, its risk posture may change. An updated project JCL would provide both project and

[8]GAO, *NASA: Assessments of Major Projects*, GAO-17-303SP (Washington, D.C.: May 16, 2017).

[9]GAO-17-317.

agency management with data on relevant risks that can guide project decisions.

- Ensuring that NASA continued its efforts to build capacity in areas such as cost and schedule estimating and measuring contractor performance.

Further, in our 2016 and 2017 assessments of major projects, we found that while the cost and schedule performance of NASA's portfolio was improving, a number of large, complex projects were in or would soon be entering the integration and test phase—the phase in development that often reveals unforeseen challenges that can lead to cost and schedule growth.[10] In May 2017, projects in this phase included all three human spaceflight programs and the James Webb Space Telescope (JWST).[11] Subsequently, we found that these programs experienced delays during this phase of development. For example, in December 2017, NASA announced a 13- to 19-month delay for the first integrated mission of Orion, SLS, and EGS. This mission is referred to as Exploration Mission 1 (EM-1) and will not have crew. In addition, in December 2017, we found that the JWST project continued to make progress towards launch, but the program was encountering technical challenges that required both time and money to fix and may lead to additional delays.[12] Subsequently, the JWST project delayed its launch readiness date by at least 19 months from October 2018 to May 2020.

Portfolio Cost and Schedule Deteriorated but Extent of Cost Growth Is Unknown

The cost and schedule performance of NASA's portfolio of major projects deteriorated between May 2017 and May 2018, but the extent of cost growth is unknown. NASA lacks a current cost estimate for its Orion crew capsule—one of the largest programs in the portfolio—but expects the program will exceed its cost baseline when NASA updates the program's life-cycle cost estimate. Because the Orion program accounts for about 22 percent of all development costs, even a small percentage of cost growth for the Orion program could significantly affect portfolio cost performance. The known negative cost and schedule performance is

[10]GAO, *NASA: Assessments of Major Projects*, GAO-16-309SP (Washington, D.C.: Mar. 30, 2016); and GAO-17-303SP.

[11]GAO-17-303SP.

[12]GAO, *NASA: Preliminary Observations on the Management of Space Telescopes*, GAO-18-277T (Washington, D.C.: Dec. 6, 2017).

largely driven by the cost and schedule growth of four projects—SLS, EGS, Space Network Ground Segment Sustainment (SGSS) and Mars 2020—that experienced technical problems compounded by programmatic challenges. Together, these projects experienced $638 million in cost growth and 59 months in aggregate schedule delays. Two projects—JWST and ICESat-2—experienced schedule delays due to technical challenges identified during integration and test. Another 3 projects—NASA Indian Space Research Organisation Synthetic Aperture Radar (NISAR), ICON, and GRACE-FO—experienced cost growth or delays largely due to factors outside of the projects' control, such as launch vehicle delays.

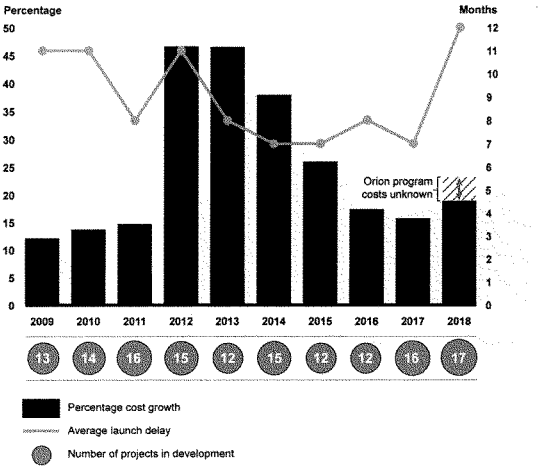
Portfolio Average Launch Delays Increased, but NASA Lacks a Current Orion Program Cost Estimate to Determine Extent of Cost Growth

The average launch delay increased from 7 months in our May 2017 report to 12 months in our May 2018 report—the highest schedule delay we have reported to date.[13] We were not able to determine the extent of portfolio cost growth this year because NASA does not have a current cost estimate for the Orion program—one of the largest programs in its portfolio—and officials expect the cost to increase. As of June 2017, the Orion program's development cost was about $6.6 billion; based on that estimate, it accounts for 22 percent of the portfolio's estimated $30.1 billion of development costs. As a result, a small percentage of cost growth for the Orion program could significantly affect cost performance. Even without including Orion cost growth, the overall development cost growth for the portfolio of 17 development projects increased to 18.8 percent, up from 15.6 percent in 2017 (see figure 2).[14]

[13]GAO-17-303SP.

[14]We have historically presented cost and schedule performance including and excluding the James Webb Space Telescope (JWST) because, prior to 2015, it had a development cost baseline significantly larger than other projects and the magnitude of its cost growth masked the performance of the remainder of the portfolio. Now that other projects in the portfolio, such as Orion and the Space Launch System, have large development cost baselines, we no longer present cost performance trends excluding JWST.

Figure 2: Development Cost Performance and Average Launch Delay for Major NASA Projects from 2009 to 2018



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

Note: The years given in the figure refer to the year we issued each of our annual assessments of NASA major projects reports. Cost and schedule performance is compared across each report period.

Senior-level NASA officials told us they expect that the Human Exploration and Operations Mission Directorate and the Orion program will complete an updated life-cycle cost estimate in June 2018. This would be approximately 10 months after the program raised to senior-level officials' attention that the program expects cost growth over its cost baseline during an August 2017 briefing concerning potential cost increases related to the launch delay for EM-1.[15] In early June 2018,

[15]The Orion program is baselined to the second combined mission of Orion, SLS, and EGS. This mission is known as Exploration Mission 2 (EM-2) and will have crew.

NASA officials said that they had not yet completed the updated life-cycle cost estimate.

In our May 2018 report, we found that 7 of 17 NASA major projects had stayed within cost and schedule estimates since our 2017 annual assessment of major projects, but 9 projects experienced cost growth or schedule delays and cost growth is expected for the Orion program. Table 2 provides data on the cost and schedule performance between our May 2017 and 2018 reports for the 17 major projects in development that have cost and schedule baselines.[16]

[16]GAO-17-303SP.

Table 2: Development Cost and Schedule Performance of Selected Major NASA Projects in Development as of May 2018 Assessment

Overall performance	Project	Confirmation date	Changes between May 2017 and May 2018		Cumulative performance	
		Year	Cost (millions)	Schedule (months)	Cost (millions)	Schedule (months)
Lower than expected cost	PSP	2014	$0.0	0	-$5.4	0
	GRACE-FO	2014	-$1.6	3	-$2.2	3
	TESS	2014	-$13.1	-2	-$39.9	-2
Within baseline	ICON	2014	$0.0	8	$0.0	8
	SWOT	2016	$0.0	0	$0.0	0
	LCRD	2017	$0.0	0	$0.0	0
	Landsat 9	2017	$0.0	0	$0.0	0
Higher than expected cost	Mars 2020[a]	2016	$12.9	0	$10.7	0
	NISAR	2016	$22.0	0	$22.0	0
Replan[c]	InSight	2014	$0.0	0	$131.7	26
	EGS (EM-1)	2014	$417.8	19	$421.4	19
	SLS (EM-1)	2014	$147.8	19	$147.8	19
Rebaseline[c]	JWST	2008	$0.0	19	$3,607.7	71
	ICESat-2	2012	$1.4	4	$206.3	17
	SGSS[b]	2013	$59.5	21	$421.6	48
Canceled	RBI	2016	$0.0	0	$0.0	0
Under revision	Orion (EM-2)[d]	2015	$0.0	0	-$151.7	0
Total:			**$646.7**	**91**	**$4,770.0**	**209**

Legend: PSP: Parker Solar Probe; GRACE-FO: Gravity Recovery and Climate Experiment Follow-On; TESS: Transiting Exoplanet Survey Satellite; ICON: Ionospheric Connection Explorer; SWOT: Surface Water and Ocean Topography; NISAR: NASA Indian Space Research Organisation – Synthetic Aperture Radar; LCRD: Laser Communications Relay Demonstration; InSight: Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport; EGS: Exploration Ground Systems; SLS: Space Launch System; EM-1: Exploration Mission 1; JWST: James Webb Space Telescope; ICESat-2: Ice, Cloud, and Land Elevation Satellite-2; SGSS: Space Network Ground Segment Sustainment; RBI: Radiation Budget Instrument; Orion: Orion Multi-Purpose Crew Vehicle; EM-2: Exploration Mission 2.

Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

Note: The confirmation date is the year NASA established and documented a cost and schedule baseline for each project. Positive values indicate cost growth or launch delays. Negative values indicate cost decreases or earlier than planned launch dates.

[a]The Mars 2020 project used $2.2 million in funds originally budgeted for development for formulation activities. This partially offsets an increase of $12.9 million in development cost growth primarily due to increased costs associated with a technology demonstration instrument and entry, descent, and landing instrument.

[b]The SGSS project reported cost growth up through its first operational readiness review, which is currently planned for the end of fiscal year 2019. However, the project expects that there could be additional cost and schedule growth beyond what is reported here.

[c]A replan process is initiated if development costs increase by 15 percent or more. NASA replanned the SLS program even though development costs did not increase by 15 percent or more. A replan does not require a new project baseline to be established. A rebaseline is a process initiated if development costs increase by 30 percent or more. When development cost growth is likely to

exceed the development cost estimate by 15 percent or more, NASA must submit a report to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate. In addition, if a project or program milestone is likely to be delayed by 6 months or more, this report is also required.

[4]NASA officials said they are revising the Orion program's life-cycle cost estimate and expect to complete a new estimate in June 2018. The new cost is expected to exceed the program's development cost baseline. The current costs in the table reflect the estimate provided in June 2017. The cumulative cost change reflects the program shifting $151.7 million of funding previously budgeted for the development phase to the formulation phase.

The deteriorating cost and schedule performance of the portfolio in 2018 is the result of

- four projects—SLS, EGS, SGSS, and Mars 2020—addressing technical challenges that were compounded by risky programmatic decisions;
- two projects—JWST and ICESat-2—experiencing delays due to technical challenges identified during integration and test; and
- three projects—NISAR, ICON, and GRACE-FO—experiencing cost growth or delays largely due to factors outside of the projects' control.

We elaborate on these three scenarios below.

Technical challenges compounded by risky programmatic decisions. Together, SLS, EGS, SGSS, and Mars 2020 experienced $638 million in cost growth and 59 months in aggregate schedule delays due to technical problems that were compounded by programmatic challenges since our May 2017 report.[17] The SLS and EGS programs experienced cost growth and schedule delays associated with EM-1, their first combined mission along with the Orion program. We have found for several years that the human spaceflight programs—Orion, SLS, and EGS—are making progress maturing designs and building hardware, but also are experiencing some significant engineering and manufacturing challenges. For example, the SLS program ran into numerous challenges completing the welding of its core stage element in 2017. The program stopped welding on the core stage for months to identify and resolve low weld strength in the liquid oxygen and liquid hydrogen tanks due to low weld strength measurements found in the liquid oxygen tanks caused by a program and contractor decision to change the weld tool configuration during fabrication. The EGS program also experienced technical challenges, including with the design and installation of the ground

[17]GAO-17-303SP.

support equipment and the 10 umbilicals that connect SLS and Orion to the Mobile Launcher—which supports the assembly, testing, and servicing of SLS and provides the platform on which SLS and Orion will launch.

Finally, although the Orion program has not yet reported cost growth, it also experienced technical challenges. These challenges included software and hardware delays, and at least 14 months of delays with the European Service Module—which provides air, water, power, and propulsion to Orion during in-space flight—since the element's critical design review in June 2016. In April 2017, we found that, according to program officials, the delays with the service module were largely due to NASA, the European Space Agency, and the European Space Agency contractor underestimating the time and effort necessary to address design issues for the first production service module and the availability of parts from suppliers and subcontractors. NASA expects the Orion program to experience cost growth over its cost baseline to the second combined mission, Exploration Mission 2 (EM-2). However, the extent of the growth is unknown because, as noted above, NASA is currently revising the program's life-cycle cost estimate.

Technical challenges such as these are not unusual for large-scale programs, especially human exploration programs that are inherently complex and difficult. However, we have found that NASA has made programmatic decisions—including establishing low cost and schedule reserves, managing to aggressive schedules, and not following best practices for earned value management or creating reliable cost and schedule baselines—that have compounded the technical challenges (see table 3).[18] As a result, the three human spaceflight programs have been at risk of cost and schedule growth since NASA approved their baselines.

[18]GAO, *Space Launch System: Management Tools Should Better Track to Cost and Schedule Commitments to Adequately Monitor Increasing Risk*, GAO-15-596 (Washington, D.C.: July 16, 2015); *NASA Human Space Exploration: Opportunity Nears to Reassess Launch Vehicle and Ground Systems Cost and Schedule*, GAO-16-612 (Washington, D.C.: July 27, 2016); *Orion Multi-Purpose Crew Vehicle: Action Needed to Improve Visibility into Cost, Schedule, and Capacity to Resolve Technical Challenges*, GAO-16-620 (Washington, D.C.: July 27, 2016); and *NASA Human Space Exploration: Delay Likely for First Exploration Mission*, GAO-17-414 (Washington, D.C.: Apr. 27, 2017). Cost reserves are for costs that are expected to be incurred—for instance, to address project risks—but are not yet allocated to a specific part of the project. Schedule reserves are extra time in project schedules that can be allocated to specific activities, elements, and major subsystems to mitigate delays or address unforeseen risks.

Table 3: Examples of Risky Programmatic Decisions Made by National Aeronautics and Space Administration's (NASA) Human Spaceflight Programs

Programmatic decision	Example(s)	Negative effect	GAO report(s)
NASA baselined the Exploration Ground Systems (EGS), Orion Multi-Purpose Crew Vehicle (Orion), and Space Launch System (SLS) programs with low cost and schedule reserves.	In July 2016, we found that NASA baselined the SLS program with cost reserves of less than 2 percent, even though guidance for Marshall Space Flight Center—the NASA center with responsibility for the SLS program—established standard cost reserve for launch vehicle programs of 20 percent when the baseline is approved.	Operating with low cost and schedule reserves limits a program's ability to address risks and unforeseen technical challenges.	GAO-17-414 and GAO-16-612
NASA managed the EGS, Orion, and SLS programs to an internal schedule for completing development production that was aggressive and could exacerbate delays and lead to cost overruns.	In July 2016, we found that the EGS program planned to conduct the mobile launcher's verification and validation concurrent with ground support equipment systems and umbilicals installation to support the program's internal schedule goal. We found this to be a risky practice because of uncertainties regarding how systems not yet installed may affect the systems already installed.	Working towards a more aggressive internal goal is not a bad practice; however, increasing cost and schedule risk to the program in order to pursue such a goal is not beneficial to programs in the long term.	GAO-16-620 and GAO-16-612
The SLS program did not follow best practices for using earned value management, which integrates the project scope of work with cost, schedule, and performance elements for optimum project planning and control.	In July 2016, we found that the SLS program had not positioned itself well to provide accurate assessments of progress with the core stage because it operated for several years without a performance measurement baseline that is necessary to support full earned value management reporting. The use of earned value management is advocated by both GAO's best practices for cost estimating and NASA's own guidance.	Programs that do not use earned value data are limited in their ability to have accurate assessments of project progress, produce early warning signs of impending schedule delays and cost overruns, and provide unbiased estimates of anticipated costs at completion.	GAO-16-612
The Orion and SLS programs established baselines that were not fully reliable.[a]	In July 2016, we found that the Orion program did not generally follow best practices in preparing its cost and schedule estimates, which were key inputs into the program's joint cost and schedule confidence level processes and baseline. In July 2015, we found that cost and schedule estimates for the SLS program substantially met five of six characteristics that GAO considers best practices for preparing reliable estimates, but could not be deemed fully reliable because they only partially met the sixth characteristic—credibility.	Without sound cost and schedule estimates, decision makers do not have a clear understanding of the cost and schedule risk inherent in the program or important information needed to make programmatic decisions.	GAO-16-620 and GAO-15-596

Source: GAO analysis of prior GAO reports. | GAO-18-576T

[a]We did not assess EGS's cost and schedule estimates compared to best practices.

In December 2017, NASA announced the new internal launch readiness date for EM-1 is now December 2019, and has allocated 6 months of schedule reserve available to extend the date to June 2020 for possible manufacturing and production schedule risks. This represents a delay of

13-19 months for EM-1. It is too soon to know if NASA has addressed the programmatic challenges identified above. We will continue to follow up through future reviews.

Similarly, the SGSS project experienced new cost growth of $59.5 million and delayed its completion by 21 months. Project officials attributed the cost growth and delays to the contractor's incomplete understanding of its requirements, which led to poor contractor plans and late design changes. But project management has been a challenge as well.[19] The project has historically struggled to manage contractor performance and has faced both contractor and project staffing shortfalls, as we found in our prior reports starting in 2013.[20] For example, NASA managers noted concerns with contractor plans and staffing estimates in 2013 during project confirmation. In March 2015, we found that the project was being rebaselined due to the contractor's poor cost and schedule performance and in order to conform with limitations that NASA placed on the funding available to the contractor in fiscal years 2014 and 2015. The contractor was also operating with a limited number of staff at that time. In May 2017, we found that the project continued to experience contractor performance problems and had experienced cost growth and schedule delays over the 2015 rebaseline even as the project decreased its scope. In addition, the project experienced staff shortfalls in key areas, such as systems engineering and business management.

The Mars 2020 project experienced $12.9 million in development cost growth, but no schedule delays. The cost growth was primarily due to technical challenges on a technology demonstration instrument and higher than anticipated integration costs for an entry, descent, and landing instrument. Both instruments are funded by the Human Exploration and Operations and Space Technology Mission Directorates. NASA officials attributed the cost growth of the technology demonstration instrument—which is designed to convert carbon dioxide to oxygen—to

[19]In 2016, NASA announced it was reclassifying SGSS as a hybrid sustainment project for the Space Network. A hybrid sustainment effort is a sustainment effort that still includes development work. The SGSS project expects to experience additional cost growth and schedule delays, but the exact magnitude is unknown. The project was reevaluating its cost and schedules through its final acceptance review at the time of our review.

[20]GAO, *NASA: Assessments of Selected Large-Scale Projects*, GAO-13-276SP (Washington, D.C.: Apr. 17, 2013); *NASA: Assessments of Selected Large-Scale Projects*, GAO-14-338SP (Washington, D.C.: Apr. 15, 2014); *NASA: Assessments of Selected Large-Scale Projects*, GAO-15-320SP (Washington, D.C.: Mar. 24, 2015); GAO-16-309SP; and GAO-17-303SP.

the complexity of the technology development for the effort. At the project's preliminary design review in February 2016, a critical technology for the technology demonstration instrument did not meet the recommended level of maturity, which we have found can increase risk for systems entering product development. The project had matured the technology to this recommended level by its critical design review in February 2017. However, as a result of the focus on maturing this particular technology, other components of the instrument fell behind the planned schedule. Project costs for Mars 2020 also increased for an entry, descent, and landing instrument, due, in part, to cost increases for integration and to add additional staff to the instrument team to maintain schedule.

Finally, the Radiation Budget Instrument project would have likely exceeded its cost baseline if NASA had not decided to cancel the project in January 2018. According to NASA's cancellation memorandum, the project was canceled because of continued cost growth, technical issues, and poor contractor performance. In 2017, we found that the project was working to an aggressive schedule, and the prime contractor continued to experience cost overruns even after NASA added a deputy project manager and increased site visits and meetings with the contractor.[21] Subsequently, the project—which was developing an instrument to be hosted on a National Oceanic and Atmospheric Administration satellite—determined that it would not be able to meet its delivery date for integration with the satellite without requiring additional funding in excess of the project's cost baseline if other technical issues arose. In its cancellation memorandum, NASA stated continuing to fund the project from within the Earth Science Division budget would slow other important activities.

Technical challenges identified during integration and test. The JWST and ICESat-2 projects experienced technical challenges during integration and test that delayed their schedules. Both projects were previously rebaselined before entering system-level integration and testing, and the current schedule delays are beyond the new schedules that NASA set for the projects in 2011 for JWST and in 2014 for ICESat-2.

[21]GAO-17-303SP.

- The JWST project delayed its launch readiness date by at least 19 months from October 2018 to May 2020. NASA announced two delays for the project since our portfolio-wide review in May 2017.[22] First, as we found in February 2018, the project delayed its launch readiness date by up to 8 months primarily due to the integration of the various spacecraft elements taking longer than expected.[23] Specifically, execution of spacecraft integration and test tasks, due to complexity of work and cautious handling given the sensitivity of flight hardware, was slower than planned. In addition, before the delay, the project used all of its schedule reserves to its prior launch readiness date. This was the result of various contractor workmanship errors, particularly with respect to the spacecraft propulsion systems, as well as the resolution of various technical issues, including a test anomaly on the telescope and sunshield hardware challenges. Second, in March 2018, NASA announced that it had delayed the project's launch readiness date by an additional 11 months to approximately May 2020 and planned to establish an external independent review board to analyze the project's organizational and technical issues to inform a more specific launch time frame.

  The announcement also stated that after a new launch date is established, NASA would provide a new cost estimate that may exceed the $8 billion congressional cost cap that was established in 2011. NASA plans to finalize the project's cost and schedule estimate by the end of June 2018. Because the additional delays were announced while a draft of our May 2018 report was with NASA for comment, we plan to follow up on the reasons for the additional delays and the results of the analysis in a future review.

  In our prior assessments of JWST, we have made recommendations with regard to improving cost and schedule estimating, updating risk assessments, and strengthening management oversight. NASA has generally agreed and taken steps to implement a number of our recommendations. For example, in December 2015, we recommended that the JWST project require contractors to identify, explain, and document anomalies in contractor-delivered monthly

[22]GAO-17-303SP.

[23]GAO, *James Webb Space Telescope: Integration and Test Challenges Have Delayed Launch and Threaten to Push Costs Over Cap*, GAO-18-273 (Washington, D.C.: Feb. 28, 2018).

earned value management reports.[24] NASA concurred with this recommendation and, in February 2016, directed the contractors to implement the actions stated in the recommendation. However, NASA did not implement some recommendations, which if implemented, may have provided insight into the challenges it now faces. For example, in December 2012, we recommended the JWST project update its JCL.[25] Although NASA concurred with this recommendation, it did not take steps to implement it. An updated JCL may have portended the current schedule delays, which could have been proactively addressed by the project.

- The ICESat-2 project delayed its launch readiness date by 4 months from June to October 2018 due to technical issues with its only instrument, the Advanced Topographic Laser Altimeter System. A key part in the instrument's lasers failed during instrument environmental testing, which delayed the project's system integration review—the start of system-level integration and test. The manufacturer determined the primary cause of the anomaly was a flaw in the design of the mount that ensures a component of the optical module remains in a specific, precise position. The spare flight laser encountered the same problem during earlier testing, which indicated a systemic problem. The project redesigned and repaired the lasers and is proceeding through integration and test.

External factors. External factors—including responding to requests for additional data collection and delays due to launch-vehicle related issues—contributed to cost increases or schedule delays for the NISAR, ICON, and GRACE-FO projects.

- The NISAR project experienced cost growth as the result of an increase in the scope of data collection in response to additional data needs being identified by an interagency working group. The additional data include soil moisture and natural hazard data that would be of value for other federal agencies and the science community. NASA officials said the additional funding for development would be used to upgrade the ground stations so that they can receive the additional data at a higher downlink data rate and volume.

[24]GAO, James Webb Space Telescope: Project on Track but May Benefit from Improved Contractor Data to Better Understand Costs, GAO-16-112 (Washington, D.C.: Dec. 17, 2015).

[25]GAO, James Webb Space Telescope: Actions Needed to Improve Cost Estimate and Oversight of Test and Integration, GAO-13-4 (Washington, D.C.: Dec. 3, 2012).

- The ICON project missed its committed launch readiness date because of an accident involving its launch vehicle. In January 2017, two of the Pegasus launch vehicle's three stages were involved in a transport accident. The stages were subsequently returned to the launch vehicle contractor facility for inspection and testing, and no damage was found. The project had been on track to launch early. Subsequently, in September 2017, an anomaly found in testing of the launch vehicle bolt cutter assemblies resulted in additional delays. NASA had planned to launch ICON in mid-June 2018, but recently announced a delay after off-nominal data was observed from the rocket during transit to the launch site. NASA announced a new launch date would be determined at a later date.
- The GRACE-FO project delayed its launch readiness date from February to May 2018 due to issues with its planned launch vehicle and launch site. The launch vehicle is the responsibility of NASA's partner on the project—German Research Centre for Geosciences (GFZ). GRACE-FO had planned to launch at a Russian launch site. In February 2016, GFZ reported that it was notified by the Russian Federal Space Agency that the Dnepr launch vehicle was no longer available for GRACE-FO. GFZ, in June 2016, arranged to launch the two GRACE-FO spacecraft, along with commercial satellites, on a SpaceX Falcon 9. On May 22, 2018, GRACE-FO launched from Vandenberg Air Force Base in California.

In addition, the Commercial Crew Program also experienced delays, which are not included above because the program does not have a schedule baseline. Since the award of the current Commercial Crew contracts in September 2014, the program, Boeing, SpaceX, and multiple independent review bodies have all identified the contractors' delivery schedules as aggressive. In February 2017, we found that Boeing and SpaceX had determined that neither could meet their original 2017 dates for NASA to certify their systems for human spaceflight.[26] In January 2018, we found that both contractors had notified NASA that final certification dates have slipped again and are now in the first quarter of calendar year 2019.[27] The Commercial Crew Program's schedule

[26]GAO, *NASA Commercial Crew Program: Schedule Pressure Increases as Contractors Delay Key Events*, GAO-17-137 (Washington, D.C.: Feb. 16, 2017).

[27]GAO, *NASA Commercial Crew Program: Continued Delays Pose Risks for Uninterrupted Access to the International Space Station*, GAO-18-317T (Washington, D.C.: Jan. 17, 2018).

analysis indicates that certification may be further delayed to December 2019 for SpaceX and February 2020 for Boeing.

NASA Is Likely to Encounter Additional Cost Growth and Schedule Delays

The composition of the portfolio in the coming years is expected to include large and complex projects, putting NASA at risk of continued cost increases and schedule delays. Specifically, NASA plans to have complex projects enter the development portfolio in the next few years as it holds confirmation reviews and set cost and schedule baselines. This includes the Europa Clipper project and potentially the Wide-Field Infrared Survey Telescope (WFIRST) project. In February 2018, the President's 2019 Budget Request proposed canceling the WFIRST project due to the project's significant costs and higher priorities in the agency. However, the project may continue if funding is received. Together, preliminary estimates indicate that these two projects could cost as much as $7.8 billion. In addition, NASA expects to begin other large, complex projects like the Lunar Orbital Platform-Gateway—currently being discussed as a space station or outpost in lunar orbit—and a Europa Lander project in the coming years. A December 2017 space policy directive also instructed NASA to return astronauts to the moon for long-term exploration and to pursue human exploration of Mars and the broader solar system.

To its credit, NASA recently took steps to put a process in place to control the costs of two projects while in formulation, which may prove useful if properly executed.

- The Europa Clipper project implemented a process whereby cost growth threats would be offset by descoping instruments in whole or in part. For example, if an instrument exceeds its development cost by 20 percent, the project would propose a descope option to NASA that brings instrument cost below that threshold. NASA had not descoped any instruments as of our May 2018 report.
- The WFIRST project is responding to findings from an independent review that was conducted to ensure the mission's scope and required resources are well understood and executable. The review found that the mission scope is understood, but not aligned with the resources provided and concluded that the mission is not executable without adjustments and/or additional resources. For example, the study team found that NASA's current forecasted funding profile for the WFIRST project would require the project to slow down activities starting in fiscal year 2020, which would result in an increase in development cost and schedule. NASA agreed with the study team's

results and directed the project to reduce the cost and complexity of the design in order to maintain costs within the $3.2 billion preliminary cost target.

But even with these efforts, NASA's cost and schedule performance may be further tested in upcoming years as some expensive, complex projects linger in the portfolio longer than expected.

- As previously discussed, the Orion program expects cost growth and faces other schedule and technical risks as it moves through the integration and test phase for EM-1 into at least 2019 and then through 2023 for EM-2. As of August 2017, NASA officials expected that new hardware and addressing development challenges would be the factors contributing to increased cost for the program. For example, there was a cost impact when the program moved from a single-piece, or monolithic, heatshield design to one that employs blocks in order to improve its structural strength. Program officials said they are also assessing schedule delays for EM-2, and noted that the EM-2 launch date depends on the outcome of the EM-1 launch date.
- The SLS and EGS programs continue to face cost, schedule, and technical risks as they move through the integration and test phase into at least 2019. For example, SLS will have to complete a "green run" test which requires multiple first-time efforts. Specifically, the test is the culmination of the development effort and includes the core stage integration with its four main engines, fully fueling with cryogenic hydrogen and oxygen, and then firing all four engines for about 500 seconds. NASA currently has no schedule reserve to its target December 2019 launch readiness date for two key areas in the core stage schedule. First, there is no reserve between the end of core stage production and the delivery of the core stage to the test facility. Second, there is no reserve between the end of the testing and delivery to Kennedy Space Center for final integration and testing prior to launch.
- As previously discussed, the JWST project is at risk of exceeding its congressional cost cap, and faces schedule risks as it completes its remaining integration and test work. These activities have taken considerably longer than planned due to a variety of challenges, including reach and access limitations on the flight hardware. Additionally, the project faces significant work ahead. For example, the project must complete integration of spacecraft element hardware and conduct deployment and environmental tests of the integrated sunshield and spacecraft. Further, it must integrate the telescope

element with the spacecraft element to form the JWST observatory, and complete another set of challenging environmental tests on the full integrated observatory. At the same time, the project will need to mitigate dozens of remaining hardware and software risks to acceptable levels and address the project's many potential single point failures to the extent possible.

- The SGSS project expects to experience additional cost growth through the final acceptance review because the full scope of the effort has not been included in the cost. NASA only approved its new cost estimate through the initial operational readiness review, currently planned for September 2019. A project official said NASA headquarters asked the project to determine if there are ways to reduce the cost between the operational readiness review and the final acceptance review. NASA plans to conduct an independent review of the project in mid-2018 to inform a decision on whether to continue the project past the operational readiness review. If NASA decides to continue the project past this review, additional cost growth is expected for SGSS when NASA revisits project costs through future budget cycles.

In closing, NASA continues to make improvements to the acquisition management of its portfolio of major projects. However, the deterioration of the cost and schedule performance of NASA's portfolio this year and the likelihood of additional cost growth and schedule delays demonstrate the need for NASA to continue to take actions to further reduce acquisition risk as we and others have recommended. Continuing to improve cost and schedule estimating tools and practices—such as by providing projects with sufficient cost and schedule reserves to address risks and unforeseen technical challenges and ensuring that program offices regularly and consistently update their JCLs across the portfolio—could help to better position NASA for improved outcomes. We look forward to continuing to work with NASA and this subcommittee in addressing these issues.

Chairman Babin, Ranking Member Bera, and Members of the Subcommittee, this completes my prepared statement. I would be pleased to respond to any questions that you may have at this time.

GAO Contact and Staff Acknowledgments

If you or your staff have any questions about this testimony, please contact Cristina T. Chaplain, Director, Contracting and National Security Acquisitions at (202) 512-4841 or chaplainc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this statement. GAO staff who made key contributions to this statement include Molly Traci, Assistant Director; Laura Greifner; Erin Kennedy; Miranda Riemer; Roxanna T. Sun; and Alyssa Weir.

Appendix I: Descriptions of National Aeronautics and Space Administration Major Projects Reviewed in GAO's 2018 Assessment

Table 4: Descriptions of the 26 National Aeronautics and Space Administration (NASA) Major Projects Reviewed in GAO's 2018 Assessment

Project name	Project description
Commercial Crew Program	The Commercial Crew Program facilitates and oversees the development of safe, reliable, and cost-effective crew transportation systems by commercial companies to carry NASA astronauts to and from the International Space Station. The program is a multi-phase effort that started in 2010. During the current phase, the program is working with two contractors—Boeing and SpaceX—that will design, develop, test, and operate the crew transportation systems. Once NASA determines the systems meet its standards for human spaceflight—a process called certification—the companies will fly up to six crewed missions to the space station.
Double Asteroid Redirection Test (DART)	The DART project plans to travel to the near-Earth asteroid Didymos, a binary system, and impact the smaller of the two bodies. NASA will assess the deflection result of the impact for potential future use on other potentially hazardous near-Earth objects. The project responds to near-Earth object guidance by the Office of Science and Technology Policy to better understand our impact mitigation posture, and to recommendations by the National Research Council Committee to conduct a test of a kinetic impactor. The DART mission is part of the Asteroid Impact and Deflection Assessment, which is an international collaboration with the European Space Agency.
Europa Clipper	The Europa Clipper mission aims to investigate whether the Jupiter moon could harbor conditions suitable for life. The project plans to launch a spacecraft in the 2020s, place it in orbit around Jupiter, and conduct a series of investigatory flybys of Europa. The mission's planned objectives include characterizing Europa's ice shell and any subsurface water, analyzing the composition and chemistry of its surface and ionosphere, understanding the formation of its surface features, and surveying sites for a potential landed mission.
Exploration Ground Systems (EGS)	The EGS program is modernizing and upgrading infrastructure at the Kennedy Space Center and developing software needed to integrate, process, and launch the Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle (Orion). The EGS program consists of several major construction and facilities projects including the Mobile Launcher, Crawler Transporter, Vehicle Assembly Building, and launch pad, all of which need to be complete before the first uncrewed exploration mission using the SLS and Orion vehicles.
Gravity Recovery and Climate Experiment Follow-On (GRACE-FO)	The GRACE-FO mission will continue and expand upon the 2002 GRACE mission, which ended science operations in October 2017. The system, which consists of two spacecraft working together to obtain scientific measurements, will provide high-resolution models of Earth's gravity field and insight into water movement on and beneath the Earth's surface for up to 5 years. These models will provide rates of ground water depletion and polar ice melt and enable improved planning for droughts and floods. GRACE-FO is a collaborative effort with the German Research Centre for Geosciences.
Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)	The ICESat-2 mission is a follow-on mission to ICESat that will measure changes in polar ice-sheet mass and elevation. The measurements will provide researchers a better understanding of the mechanisms that drive polar ice changes and their effect on global sea level. ICESat-2's upgraded laser instrument will allow the satellite to make more frequent measurements and provide better elevation estimates over certain types of terrain than ICESat.
Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight)	InSight is a Mars lander with two primary objectives. It is intended to further understanding of the formation and evolution of terrestrial planets by determining Mars's size, its composition, and the physical state of the core; the thickness of the crust; and the composition and structure of the mantle, as well as the thermal state of the interior. It will also determine the present level of tectonic activity and the meteorite impact rate on Mars. InSight is based on the Phoenix lander design. Phoenix successfully landed on Mars in 2008.

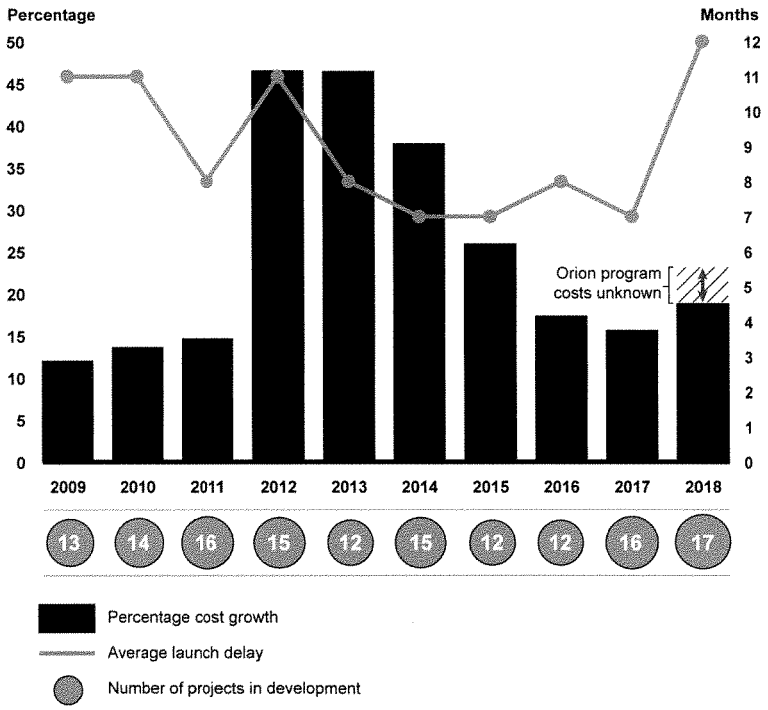
Project name	Project description
Ionospheric Connection Explorer (ICON)	The ICON observatory will orbit Earth to explore its ionosphere—the boundary region between Earth and space where ionized plasma and neutral gas collide and react. Its four instruments will make direct measurements and use remote sensing to further researchers' understanding of Earth's upper atmosphere, the Earth-Sun connection, and the ways in which Earth weather drives space weather.
James Webb Space Telescope (JWST)	JWST is a large, infrared-optimized space telescope designed to help understand the origin and destiny of the universe, the creation and evolution of the first stars and galaxies, and the formation of stars and planetary systems. It will also help further the search for Earth-like planets. JWST will have a large primary mirror composed of 18 smaller mirrors and a sunshield the size of a tennis court. Both the mirror and sunshield are folded for launch and open once JWST is in space. JWST will reside in an orbit about 1 million miles from the Earth.
Landsat 9	Landsat 9 is the next satellite in the Landsat series Program, which provides a continuous space-based record of land surface observations to study, predict, and understand the consequences of land surface dynamics, such as deforestation. The program is a collaborative, joint mission between NASA and the U.S. Geological Survey. The Landsat data archive constitutes the longest continuous moderate-resolution record of the global land surface as viewed from space and is used by many fields, such as agriculture, mapping, forestry, and geology.
Laser Communications Relay Demonstration (LCRD)	LCRD is a technology demonstration mission with the goal of advancing optical communication technology for use in deep space and near-Earth systems. LCRD will demonstrate bidirectional laser communications between a satellite and ground stations, develop operational procedures, and transfer the technology to industry for future use on commercial and government satellites. NASA anticipates using the technology as a next generation Earth relay as well as to support near-Earth and deep space science, such as the International Space Station and human spaceflight missions. The project is a mission partner and will be a payload on a U.S. Air Force Space Test Program satellite.
Low Boom Flight Demonstrator (LBFD)	LBFD is a flight demonstration project planned to demonstrate that noise from supersonic flight—sonic boom—can be reduced to acceptable levels, allowing for eventual commercial use of overland supersonic flight paths. Plans include multiple flights beyond fiscal year 2022 to gather community responses to the flights and to create a database to support development of international noise rules for supersonic flight.
Lucy	Lucy will be the first mission to investigate the Trojans, which are a population of never-explored asteroids orbiting in tandem with Jupiter. The project aims to understand the formation and evolution of planetary systems by conducting flybys of these remnants of giant planet formation. The Lucy spacecraft will first encounter a main belt asteroid—located between the orbits of Mars and Jupiter—and then will travel to the outer solar system where the spacecraft will encounter six Trojans over an 11-year mission. The mission's planned measurements include asteroid surface color and composition, interior composition, and surface geology.
Mars 2020	Mars 2020 is part of the Mars Exploration Program, which seeks to further understand whether Mars was, is, or can be a habitable planet. Its rover and science instruments will explore Mars and conduct geological assessments, search for signs of ancient life, determine potential environmental habitability, and prepare soil and rock samples for potential future return to Earth. The rover will include a technology demonstration instrument designed to convert carbon dioxide into oxygen. Mars 2020 is based heavily on the Mars Science Laboratory, or Curiosity, which landed on Mars in 2012 and remains in operation.

Project name	Project description
NASA ISRO Synthetic Aperture Radar (NISAR)	NISAR is a joint project between NASA and Indian Space Research Organisation (ISRO) that will study the solid Earth, ice masses, and ecosystems. It aims to address questions related to global environmental change, Earth's carbon cycle, and natural hazards, such as earthquakes and volcanoes. The project will include the first dual frequency synthetic aperture radar instrument, which will use advanced radar imaging to construct large-scale data sets of the Earth's movements. NISAR represents the first major aerospace science partnership between NASA and ISRO.
Orion Multi-Purpose Crew Vehicle (Orion)	Orion is being developed to transport and support astronauts beyond low-Earth orbit, including traveling to Mars or an asteroid. The Orion program is continuing to advance development of the human safety features, designs, and systems started under the Constellation program, which was canceled in 2010. Orion is planned to launch atop NASA's Space Launch System. The current design of Orion consists of a crew module, service module, and launch abort system.
Parker Solar Probe (PSP)	PSP will be the first NASA mission to visit a star. Using the gravity of Venus, the spacecraft will orbit the Sun 24 times and gather information to increase knowledge about the solar wind, including its origin, acceleration, and how it is heated. PSP instruments will observe the generation and flow of solar winds from very close range and sample and take measurements of the Sun's outer atmosphere, where solar particles are energized. To achieve its mission, parts of the spacecraft must be able to withstand temperatures exceeding 2,500 degrees Fahrenheit and endure blasts of extreme radiation. The project was formerly named Solar Probe Plus, or SPP, and was renamed in May 2017.
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)	PACE is a polar-orbiting mission that will use advanced global remote sensing instruments to improve scientists' understanding of ocean biology, biogeochemistry, ecology, aerosols, and cloud properties. PACE will extend climate-related observations begun under earlier NASA missions, which will enable researchers to study long-term trends on Earth's oceans and atmosphere, and ocean-atmosphere interactions. PACE will also enable assessments of air and coastal water quality, such as the locations of harmful algae blooms.
Psyche	Psyche will be the first mission to visit a metal asteroid and aims to understand a previously unexplored component of the early building blocks of planets: iron cores. The project plans to orbit the Psyche asteroid to determine if it is a planetary core, characterize its topography, assess the elemental composition, and determine the relative ages of its surface regions.
Radiation Budget Instrument (RBI)	RBI is a scanning radiometer that NASA planned to launch on the National Oceanic and Atmospheric Administration's (NOAA) Joint Polar Satellite System 2. RBI's planned mission was to support global climate monitoring by continuing measurements of the Earth's reflected sunlight and emitted thermal radiation made by NASA and NOAA satellites over the past 30 years. This data was intended to represent one of two key sets of measurements needed to determine whether the Earth is warming or cooling.
Restore-L	The Restore-L project will demonstrate the capability to refuel on-orbit satellites for eventual use by commercial entities. Specifically, Restore-L plans to autonomously rendezvous with, inspect, capture, refuel, adjust the orbit of, safely release, and depart from the U.S. Geological Survey's Landsat 7 satellite. Landsat 7 can extend operations if successfully refueled, but it is planned for retirement if the technology demonstration is unsuccessful.
Space Launch System (SLS)	SLS is intended to be NASA's first human-rated heavy-lift launch vehicle since the Saturn V was developed for the Apollo program. SLS is planned to launch NASA's Orion spacecraft and other systems on missions between the Earth and Moon and to enable deep space missions, including Mars. NASA is designing SLS to provide an initial lift capacity of 70 metric tons to low-Earth orbit, and be evolvable to 130 metric tons, enabling deep space missions. The 70-metric-ton capability will include a core stage, powered by four RS-25 engines, and two five-segment boosters. The 130-metric-ton capability will use a new upper stage and evolved boosters.

Project name	Project description
Space Network Ground Segment Sustainment (SGSS)	The SGSS project plans to develop and deliver a new ground system for one Space Network site. The Space Network provides essential communications and tracking services to NASA and non-NASA missions. Existing systems, based on 1980s technology, are increasingly obsolete and unsustainable. The new ground system will include updated systems, software, and equipment that will allow the Space Network to continue to provide critical communications services for the next several decades. The Space Network is managed by the Space Communication and Navigation program.
Surface Water and Ocean Topography (SWOT)	The SWOT mission will use its wide-swath radar altimetry technology to take repeated high-resolution measurements of the world's oceans and freshwater bodies to develop a global survey. This survey will make it possible to estimate water discharge into rivers more accurately, and help improve flood prediction. It will also provide global measurements of ocean surface topography and variations in ocean currents, which will help improve weather and climate predictions. SWOT is a joint project between NASA and the French Space Agency—the Centre National d'Etudes Spatiales.
Transiting Exoplanet Survey Satellite (TESS)	TESS will use four identical, wide field-of-view cameras to conduct the first extensive survey of the sky from space for transiting exoplanets—or planets in other solar systems. The mission's goal is to discover these exoplanets during transit, the time when the planet's orbit carries it in front of its star as viewed from Earth. The project plans to discover rocky and potentially habitable Earth-sized and super-Earth planets orbiting nearby bright stars for further evaluation through ground- and space-based observations by other missions, such as JWST.
Wide-Field Infrared Survey Telescope (WFIRST)	WFIRST is an observatory designed to perform wide-field imaging and survey of the near-infrared sky to answer questions about the structure and evolution of the universe, and expand our knowledge of planets beyond our solar system. The project will use a telescope that was originally built and qualified by another federal agency. The project plans to launch WFIRST in the mid-2020s to an orbit about 1 million miles from the Earth. The project is also planning a guest observer program, in which the project may provide observation time to academic and other institutions.

Source: GAO. | GAO-18-576T

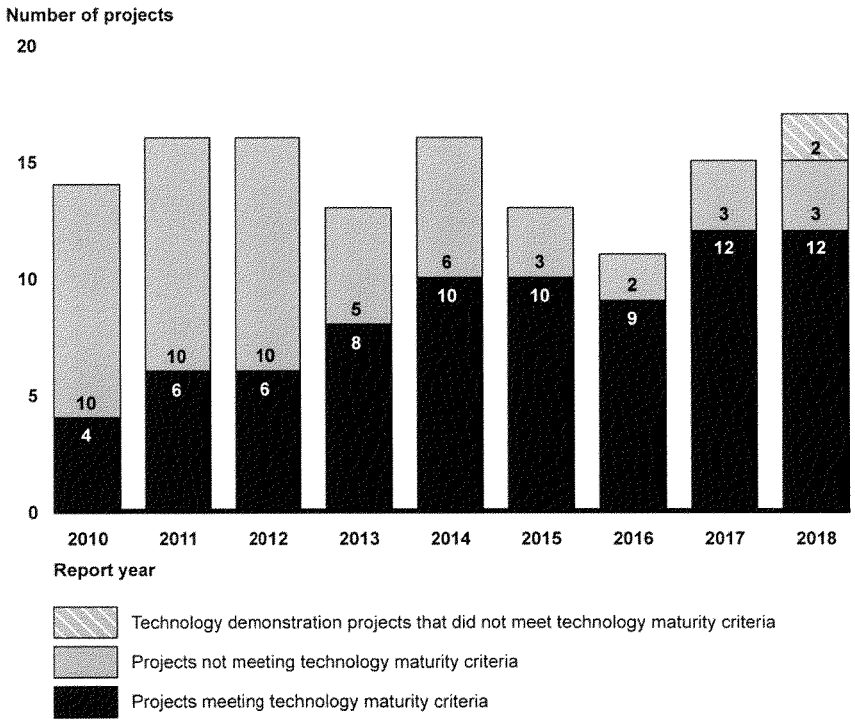
Development Cost Performance and Average Launch Delay for Major NASA Projects from 2009 to 2018



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-18-576T

Reasons Why NASA Major Projects Experience Cost and Schedule Growth

Number of NASA's Major Projects Attaining Technology Maturity by Preliminary Design Review from 2010 to 2018



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-18-280SP

Cristina T. Chaplain

Ms. Chaplain currently serves as a Director, Contracting and National Security Acquisitions, at the U.S. Government Accountability Office. She has responsibility for GAO assessments of military space acquisitions, NASA, and the Missile Defense Agency. Among other topics, she has led reviews on the International Space Station, the Space Launch System and the Orion crew capsule, acquisition progress for major NASA projects, the James Webb telescope, commercial cargo and crew, NASA contract management, contract terminations, weather satellites, and the Global Positioning System. In addition to her work on space and missile system development, Ms. Chaplain has led a variety of DOD-wide contracting-related and best practice evaluations for the GAO. Before her current position, Ms. Chaplain worked with GAO's financial management and information technology teams. Ms. Chaplain has been with the GAO for 26 years. She received a bachelor's degree, magna cum laude, in International Relations from Boston University and a Masters Degree in Journalism from Columbia University.

Chairman BABIN. Thank you, ma'am.

I now recognize Mr. Jurczyk for five minutes to present his testimony.

TESTIMONY OF MR. STEVE JURCZYK,
ASSOCIATE ADMINISTRATOR, NASA

Mr. JURCZYK. Mr. Chairman and Members of the Committee, I am pleased to have the opportunity to discuss NASA's program management accomplishments and challenges.

NASA is focused on its mission of science and exploration. In support of this mission, the agency has developed a rigorous process for program formulation, approval, implementation, and evaluation. NASA's challenge is to develop and improve our program project management capabilities to ensure both efficiency and accountability. We must execute and deliver missions on cost and on schedule. We have to execute in an environment that includes some significant risk, and we are focused on identifying and characterizing risks as quickly as possible. We must take corrective actions promptly, whether mitigating, accepting, evaluating, or monitoring an identified risk.

NASA implements a rigorous process for project formulation, development, and execution. Projects proceed through a series of key decision gates. At Key Decision Point C, which we refer to as KDP–C, the agency commits to deliver a project within an established baseline cost and schedule. This agency baseline commitment is the baseline against we which we evaluate performance.

Beginning in 2009, NASA adopted a joint confidence level—or JCL—approach to producing estimates, and this approach has resulted in improved performance. The JCL employs probabilistic risk assessment to establish a confidence level for an estimate. Typical NASA—typically, NASA establishes baselines for major projects around a 70 percent confidence level. Since the agency established its JCL policy, programmatic performance has significantly improved as NASA has launched more projects at or near their original cost and schedule baselines.

NASA is committed to applying a robust set of available authorities to accomplish our mission efficiently and effectively. NASA's strategic acquisition process utilizes multiple authorities to meet agency objectives, including, though not limited to, federal acquisition regulation or FAR-based contracts, grants, cooperative agreements, international agreements, and Space Act Agreements. NASA has expanded its use of fixed-price contracts where appropriate with the percentage of funds NASA spends on firm fixed-price contracts increasing from 26 percent in 2013 to 35 percent in 2016.

The JCL approach has certainly improved our performance, and we look forward to building on this success to address our ongoing challenges with major projects. NASA is working to strengthen program planning and control through a series of initiatives, including the application of industry-standard earned value management processes. NASA began the process of applying an in-house EVM capability in 2013 and has broadened its use in a stepwise fashion over time. NASA is leading an effort through the scheduling initia-

tive to strengthen schedule management by building a community to identify and reinforce schedule management best practices.

Our decision to conduct independent reviews of both WFIRST and JWST missions, along with our continued support for regular GAO reviews and audits, illustrate our commitment to transparency and our determination to identify risks as early as possible and immediately take action to mitigate them.

Finally, Mr. Chairman, NASA will continue to accept the big challenges that the Committee and the nation place before us. Our missions will continue to incorporate cutting-edge technologies and to pursue the challenging goals that can only be accomplished in the hostile environment of space. NASA missions do things that have never been done before. The Parker Solar Probe will dive into the sun's corona. The James Webb Space Telescope will unfold itself almost a million miles from Earth and operate at minus 380 degrees Fahrenheit. The Space Launch System or SLS will enable humans to travel deeper into space than ever before. These missions will employ technologies that must be developed and tested on Earth but can only be demonstrated in space.

All this is to say that NASA must accept the risk, but we are committed to managing that risk and executing within our cost and schedule commitments.

Thank you for the invitation to testify before you today, and I look forward to answering any questions you may have.

[The prepared statement of Mr. Jurczyk follows:]

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UNTIL PRESENTED BY WITNESS
June 14, 2018

Statement of

Stephen Jurczyk
Associate Administrator
National Aeronautics and Space Administration

before the

Subcommittee on Space
Committee on Science, Space, and Technology
United States House of Representatives

Mr. Chairman and Members of the Committee, I am pleased to have this opportunity to discuss NASA program management accomplishments and challenges.

NASA is focused on its mission of science and exploration. With consistent support from Congress, we look forward to extending human presence beyond low Earth orbit, exploring potentially habitable environments around the solar system, deepening our understanding of our home planet, pushing our observations of the universe back to the time when the first stars were forming, and opening the space frontier. In support of this mission, the Agency has developed a rigorous process for program formulation, approval, implementation and evaluation. We see excellence in program management as a core capability, and critical for enabling exploration. NASA's program management expertise brings together the people, resources and processes necessary to execute the most challenging and complex programs as we explore our world and our universe.

We take our responsibilities as stewards of limited federal resources very seriously and we will apply a robust set of available authorities to accomplish our mission efficiently and effectively. At the same time, the nation expects NASA to embrace big challenges. NASA must continue to manage risk to acceptable levels. Our missions will continue to incorporate cutting-edge technologies and to pursue the challenging goals that can only be accomplished in the hostile environment of space. NASA missions do things that have never been done before. The Parker Solar Probe will dive into the Sun's corona. The James Webb Space Telescope (JWST) will unfold itself almost a million miles from Earth and operate at extremely cold temperatures -- approximately -380 degrees Fahrenheit or -228 degrees Celsius. The Space Launch System (SLS) will enable humans to travel deep into space. These missions will employ technologies that must be developed and tested on Earth, but can only be demonstrated in space. Innovation is

the foundation of everything NASA does, and we cannot encourage innovation and discovery without accepting some level of risk and uncertainty.

NASA's challenge is to develop and improve our program/project management capabilities necessary to ensure both efficiency and accountability in what is, inevitably, a dynamic and challenging development environment. We appreciate that, in order to retain the confidence of Congress and the American people, we must execute and deliver missions on cost and on schedule. At the same time, we must identify and characterize risks as quickly as possible so we can promptly take the appropriate corrective action, whether that is mitigating, accepting, evaluating, or monitoring.

NASA Procedural Requirement 7120.5E establishes NASA's rigorous process for project formulation, development, and execution. Projects proceed through a series of key decision gates and generate cost and schedule estimates with increasing levels of fidelity as they transition through the project development lifecycle. The Agency makes the decision on whether a project should proceed out of its formulation phase and into its development phase, and establishes the cost and schedule baselines, at Key Decision Point C (KDP-C). At KDP-C, projects with a life cycle cost of $250 million or more must generate a resource-loaded schedule and produce a Joint Confidence Level (JCL) estimate for cost and schedule. A JCL calculates the probability that cost will be equal or less than the targeted cost *and* schedule will be equal or less then the targeted schedule date. The JCL estimate is risk-informed and executable within the available annual resources and launch constraints. For each major project, NASA establishes an independent review board. NASA's selection and vetting process ensures the necessary technical and programmatic areas are covered expertly and adequately, while simultaneously satisfying the Agency-level need to have an informed, independent assessment and recommendation to the convening authorities and decision authority at KDPs. The review board functions independently of the program or project, with members selected from outside the program or project management chain, free of any organizational or personal conflicts of interest (or have approved mitigation plans in place where necessary). The review board evaluates the inputs to the project-generated estimates and produces its own JCL results for management that considers the independently-informed risks.

With a decision to proceed at KDP-C, the Agency commits externally to deliver the project within the established baseline cost and schedule. This "Agency Baseline Commitment" (ABC) is the appropriate baseline against which to evaluate performance. Typically, the ABC is established around a 70 percent confidence level based on the JCL estimate, meaning that a degree of programmatic risk exposure remains as the project is implemented. Because some programmatic uncertainty remains following KDP-C, projects continue to generate estimates, and independent review boards continue to evaluate the project as it enters the next phases of the development life cycle. Specifically, these reviews evaluate the project's cost and schedule performance and provide forewarning should any project begin to significantly deviate from its ABC.

NASA policy does not require a program or project to continue to recalculate the JCL through the balance of the program/project development, but uses a variety of performance metrics,

including Earned Value Management, to assess how well the program or project is performing against its plan. NASA appreciates the open dialog we have had over the past several years with the Government Accountability Office (GAO) as we have refined our project management requirements and discussed best practices that might apply to our projects at different stages in their lifecycles.

NASA first established its JCL policy in 2009 by requiring a JCL of major projects coming to confirmation. This requirement was subsequently expanded to include cost and schedule ranges for projects going through Key Decision Points during the Formulation Phase. Since the Agency established its JCL policy, programmatic performance has improved as NASA has launched more projects at or nearer their original cost and schedule baselines. NASA's approach to conducting JCLs has evolved as we have gained more experience, and the Agency continues to improve the process.

NASA is currently undergoing critical development activities on several major space flight systems. These larger projects typically involve the development of a greater number of new technologies and a significantly higher degree of system complexity, which present greater risk and are more difficult to estimate and assess at the outset. Other challenges commonly found in larger projects may include extensive and critical interagency or international partnerships, high fixed labor costs, a large multi-state distributed workforce, multi-build/production projects, among others that are difficult to capture in the baseline plan estimates feeding JCL and similar analysis.

In 2015, NASA made a decision to reorganize and realign the Agency's independent assessment function toward the goals of ensuring mission success and clarifying management accountability. Programmatic Analysis Capability, which consists of resource analysis, schedule management, cost estimation, program/project performance progress and forecasting, and independent assessment activities, faced particular examination. The most significant action in support of this intent was the dissolution of the Independent Program Assessment Office (IPAO), as well as that of its umbrella organization, the Office of Evaluation (OoE). The other functioning office, the Cost Analysis Division (CAD), transitioned to the Office of the Chief Financial Officer (OCFO). Again, the intent of this action was not about eliminating independent assessment of programs and projects; that function remains vital to NASA's long-term success. Rather it is about the need to clarify accountability of the Mission Directorates and the performing Centers, as well as about enabling more of our skilled workforce toward in-line program/project work. In addition, in alignment with the Program Management Improvement and Accountability Act (PMIAA), NASA has designated a Program Management Improvement Officer reporting directly to the Associate Administrator (Chief Operating Officer), who will ensure proper fulfillment of requirements set forth in the soon-to-be-released OMB PMIAA implementation guidance.

NASA is working to strengthen Program Planning and Control (PP&C) through a series of initiatives, including the application of industry standard Earned Value Management (EVM) processes. NASA began the process of applying an in-house EVM capability in 2013, and has broadened its use in steps over time. EVM is a powerful project management tool that ensures good upfront planning and supports reliable cost and schedule performance data, including accurate Estimate-At-Completion (EAC) forecasts, and has already begun to pay dividends by

helping the Agency improve performance in both cost and schedule commitments. NASA recognizes that tailoring and honing processes to meet a project's unique risk posture and environment is key to effective management. As such, NASA continues to employ EVM policy with the goal of maximizing efficiencies.

NASA is leading an effort, through the Schedule Initiative, to strengthen schedule management by building a community to identify and reinforce schedule management best practices. NASA is updating its schedule management handbook to formally capture best practices proven to be successful within the Agency, which will enhance continuous improvements to schedule processes and capabilities. A centralized, formal PP&C training curriculum, including schedule management, is being defined to cultivate the development and grow proficiency levels within the schedule management workforce.

Contractor Accountability and Acquisition Strategy

NASA's strategic acquisition process supports obtaining or advancing the development of science, aeronautics, space technology and human exploration to fulfill the Agency's mission. NASA utilizes multiple authorities to meet these objectives. NASA's acquisition authorities include, but are not limited to: Federal Acquisition Regulation (FAR)-based contracts, grants, cooperative agreements, international agreements, and Space Act Agreements (SAA). In deciding on the best acquisition strategy for a program or project, NASA considers such factors as: resource availability; impact on the Agency workforce; maintaining core capabilities; make-or-buy planning; potential for partnerships; and the availability of the industrial base capability and supply chain needed to design, develop, produce, and support the program or project. Another important element in the development of the acquisition strategy for a program or project is the selection of contract type and associated contractor incentive structures. NASA weighs the use of various contract types and incentive structures to motivate optimal contractor performance and achieve mission success while at the same time, controlling costs and meeting schedule milestones.

Given the nature of NASA's mission, many of our procurements are for complicated research and development efforts that involve complex requirements, where the likelihood of changes makes it difficult to estimate performance costs in advance. Consequently, in many cases, a cost-plus type contract is appropriate due to these complex requirements, significant technical risk, and cost uncertainty. In order to mitigate the cost risk associated with cost type contracts, NASA utilizes the full range of contract incentives afforded in the FAR in order to properly incentivize the contractor to control costs while performing at an optimal level and delivering the products or services that meet the agency's requirements on schedule. NASA has expanded its use of fixed-price contracts where appropriate. The agency has utilized fixed price contracts when industry products are mature and flight proven, and when we are purchasing a service. The percentage of funds NASA spends on firm fixed-price contracts has increased from 26 percent in 2013 to 35 percent in 2016. These contracts can be more advantageous to the government by shifting a substantial portion of the cost risk to the contractor, thus significantly incentivizing the contractor to control costs.

Additionally, NASA has employed an innovative partnership approach to developing some needed capabilities while encouraging commercial innovation. NASA's Commercial Orbital Transportation Services (COTS) and Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) initiatives both represent examples of NASA using Space Act Agreements to provide support to industry partners developing commercial space capabilities that could eventually support both government and commercial users. The particular approaches to be employed in future partnerships will depend on a variety of factors and on applicable lessons learned from previous partnerships.

NASA's commitment to responsible stewardship of federal resources is also reflected in the Agency's policy to detect and correct instances of fraud and corruption. This policy is important in order to maintain operational readiness, recoup lost financial resources, maintain public confidence in NASA procurement and non-procurement activities, and to prevent future fraudulent conduct. For over a decade, NASA has instituted and maintained the Office of the General Counsel Acquisition Integrity Program, a comprehensive coordination of fraud remedies program to: (1) promote transparency, accountability, and integrity throughout the acquisition process; (2) improve effectiveness of Agency operations and enhance the Agency mission by combating fraud, waste, and abuse on NASA contracts, other funding instruments, and other commitments of NASA resources; and (3) monitor and ensure the coordination of criminal, civil, contractual, and administrative (suspension and debarment) remedies. Throughout the duration of the program, the Acquisition Integrity Program has helped the federal government recover over $365 million and handled over 270 suspension and debarment related actions to protect the government's interest and ensure the integrity of the acquisition process.

GAO's most recent assessment of major NASA projects "NASA: Assessments of Major Projects" (GAO-18-280SP), provides NASA with a valued independent perspective on our major acquisitions. The report includes assessments of our 26 major projects in development. NASA recognizes some development challenges exist in these projects that have resulted in recently revised cost and schedule plans. We value the insights and recommendations provided to us in this report as an independent source of information that we use internally to inform and make new policy decisions toward programmatic improvement.

Space Launch System (SLS)/Orion Deep Space Missions

SLS, Orion, and the Exploration Ground Systems (EGS) that support them are critical capabilities for maintaining and extending U.S. human spaceflight leadership beyond low-Earth orbit (LEO) to the Moon and eventually, to Mars and beyond.. NASA plans to launch an initial, uncrewed deep space test flight of the new heavy-lift SLS and Orion spacecraft to lunar orbit on Exploration Mission-1 (EM-1), in FY 2020, in preparation for the first crewed mission, EM-2. The FY 2019 budget fully funds the Agency baseline commitment schedule to fly the Orion spacecraft on EM-2 no later than FY 2023 while enabling NASA to begin work on post EM-2 missions. FY 2018 appropriations (including direction to develop a second Mobile Launcher [ML] at the Kennedy Space Center specifically for the SLS Block 1B and a decision to use a Block 1 SLS for EM-2 for roughly $600 million), provide an opportunity to potentially accelerate the EM-2 crewed mission by 6-months relative to a currently estimated launch in mid-2023. Missions on the SLS and Orion in the 2020s will reaffirm and sustain U.S. leadership in

orbit around and on the surface of the Moon, and establish the capability to operate safely and productively in deep space for decades to come.

NASA's new deep space exploration system is seeing specific areas of targeted challenges consistent with first-time production and testing of a complex human spacecraft system for deep space. Most recently, SLS has been managing a slower-than-expected ramp up in core stage production, due in part to contamination recently seen in some of the propellant lines installed in the engine section. These issues be resolved through a continued focus on managing processes and resources at the Michoud Assembly Facility in Louisiana. NASA is also closely managing the development and testing of hardware and software to support integration at KSC, and working well with the European Space Agency to ensure delivery of the Orion service module this summer.

Some flight hardware is already in production for EM-2, including the crew module pressure vessel and European Service Module for Orion, and the boosters and early work on core stage for SLS. In addition, the direction in the FY 2018 appropriations act to build a second ML allows NASA the technical and scheduling flexibility to use the SLS Block 1 configuration for the first crewed flight on EM-2, rather than Block 1B, thereby relieving a significant technical and schedule dependency between the two. This allows NASA to extend work on the more powerful Block 1B variant to a first flight in the 2024 timeframe. NASA (as well as the General Accountability Office) is reviewing the integrated schedules for EM-1 and EM-2 and will provide an updated assessment when this review is complete. With NASA's multi-mission approach to deep space exploration, we have hardware in production for the first three missions. As teams complete hardware for one flight, they move on to the next set of flights. Extreme focus on early flights can be harmful to future missions in a multi-flight program, and focusing solely on the first flights of EM-1 for SLS and EM-2 for Orion can impact the ability to deliver a human deep space exploration system for use in the decades to come. The flight test data we will collect on EM-1 and EM-2 will ensure the success of the exploration campaign in the years to come.

James Webb Space Telescope

Webb's flight hardware is comprised of two elements. One half of the observatory – the optical telescope and science payload – is complete and has been tested successfully. The other half of the observatory – the sunshield and the spacecraft bus – is complete and ready for testing. Earlier this year, the Webb Standing Review Board (SRB) assessed the project's plans for the time and cost necessary to complete development, in light of challenges encountered during spacecraft and sunshield integration, and additional time needed to integrate these two elements into final flight configuration and complete testing. The SRB estimated that, at a 70 percent joint cost and schedule confidence level, launch readiness will be approximately May 2020, instead of the baseline launch readiness estimate of October 2018. We also implemented leadership changes and revised oversight strategy to mitigate issues identified by the SRB and recommendations by the upcoming Independent Review Board report.

Subsequent to the SRB's assessment, NASA established an external Webb Independent Review Board (IRB), chaired by Thomas Young, a highly respected NASA and industry veteran who is often called on to chair advisory committees and analyze organizational and technical issues. The

Webb IRB is evaluating all factors, including those identified by the SRB as influencing JWST's success, to ensure that NASA's approach to completing Integration and Test (I&T), the launch campaign, and the commissioning of the Webb Telescope is appropriate for the Agency's next flagship observatory.

The Webb IRB, convened by NASA's Science Mission Directorate, includes individuals with extensive experience in program and project management, schedule and cost management, systems engineering, risk management, and the integration and testing of large and complex space systems, including systems with science instrumentation, unique flight hardware, and science objectives similar to Webb.

The Webb IRB review process will take approximately two months. Once the review concludes, the board members will deliver a presentation and final report to NASA providing their observations, concerns, findings, and recommendations. NASA will review that feedback along with other inputs to determine updates to the remaining JWST development schedule and cost, which NASA plans to provide to Congress in a report this summer.

Conclusion

We take our responsibilities as stewards of limited federal resources very seriously and we recognize that executing our projects consistent with our baseline cost and schedule commitments is critical to the continued support of Congress and our continued success on behalf of the American people. Excellence in program and project management is a requirement if we are to successfully develop and operate technologies and systems for the human exploration of deep space; encourage the creation of a thriving commercial space economy in LEO and beyond; execute robust programs of robotic missions to monitor the Sun and Earth, explore the planets of our solar system, and observe the universe beyond; and continue to make aviation safer, more efficient, and more environmentally friendly.

Thank you for the invitation to testify before you today, and I look forward to answering any questions you may have.

Mr. Stephen Jurczyk became NASA's associate administrator, the agency's highest-ranking civil servant position, effective May, 2018. Prior to this assignment he was the associate administrator of the Space Technology Mission Directorate, effective since June, 2015. In this position he formulated and executed the agency's Space Technology programs, focusing on developing and demonstrating transformative technologies for human and robotic exploration of the solar system in partnership with industry and academia.

He previously was Director at NASA's Langley Research Center in Hampton, VA. Named to this position in May 2014, he headed NASA's first field Center, which plays a critical role in NASA's aeronautics research, exploration and science missions. Jurczyk served as Langley's Deputy Center Director from August 2006 until his appointment as director.

Jurczyk began his NASA career in 1988 at Langley in the Electronic Systems Branch as a design and integration & test engineer developing several space-based Earth remote sensing systems. From 2002 to 2004 Jurczyk was director of engineering, and from 2004 to 2006 he was director of research and technology at Langley where he led the organizations' contributions to a broad range of research, technology and engineering disciplines contributing to all NASA mission areas.

Jurczyk is a graduate of the University of Virginia where he received Bachelor of Science and Master of Science degrees in Electrical Engineering in 1984 and 1986. He currently lives in Fredericksburg, Va. with his wife Ann. They have two adult daughters.

Chairman BABIN. Thank you, Mr. Jurczyk.

I would like to now recognize Mr. Martin for five minutes to present his testimony.

TESTIMONY OF MR. PAUL MARTIN,
INSPECTOR GENERAL, NASA

Mr. MARTIN. Thank you, sir.

Chairman BABIN. Yes, sir.

Mr. MARTIN. Members of the Subcommittee, over its 60-year history, NASA has been responsible for numerous scientific discoveries and technological innovations. However, many of NASA's largest projects cost significantly more to complete and take much longer to launch than originally planned.

Our office has examined NASA's successes and failures in project management by examining the long-standing challenges the agency has faced in meeting cost, schedule, and performance objectives, as well as the tools it has developed to address these shortcomings. We identified four factors that present the greatest challenges to successful project outcomes: one, NASA's culture of optimism; two, underestimating technical complexity; three, funding instability; and four, development of new project managers. My remarks this morning address the first two of these challenges, optimism.

Optimism exemplified by the agency's greatest achievement, landing humans on the Moon and safely returning them to Earth, NASA's ability to overcome obstacles has become part of its can-do culture. However, our work has shown that this attitude contributes to development of unrealistic plans and performance baselines, particularly with respect to its largest projects.

And technological success, often at a significantly greater cost than originally estimated, tends to reaffirm a mindset that project cost and adherence to schedule are secondary concerns. In fact, several people offered a name for this phenomenon, calling it the "Hubble psychology" or an expectation that projects that fail to meet initial cost and schedule goals will receive additional funding and that subsequent scientific success will overshadow budget and schedule problems.

The Hubble Space Telescope was two years late and about $1 billion more than initial estimates, but most people don't remember that. Instead, they rightfully remember its stupendous images of the universe. While a few projects in NASA's recent past have been canceled because of poor cost and schedule performance, a too-big-to-fail mentality pervades agency thinking when it comes to NASA's larger and most important missions. While understandable given the investment of agency resources, cost overruns in these projects can result in delays to other missions as funding is reprioritized.

Technical complexity: The technical complexity inherent in NASA projects remains a major challenge to achieving cost and schedule goals, with project managers attempting to predict the amount of time and the amount of money needed to develop one-of-a-kind and first-of-their-kind technologies. We found that NASA historically has underestimated the level of effort needed to develop, mature, and integrate such technologies.

To help project managers avoid cost and schedule overruns, NASA has implemented a number of initiatives. I highlight two this morning. JCL: Required since 2009 for all NASA projects with lifecycle costs exceeding $250 million, a JCL analysis calculates the likelihood a project will achieve its objectives within budget and on time. The process uses software models that combine cost, schedule, risk, and uncertainty to evaluate how expected threats and unexpected events may affect a project's cost and schedule. Our examination of NASA's use of JCL found mixed success with the tool unevenly applied across agency projects.

Contracting: NASA makes use of multiple procurement vehicles for its projects, including fixed-price and cost-reimbursement contracts, as well as funded Space Act Agreements used to spur development of commercial cargo and crew capabilities. As NASA looks increasingly to the private sector to leverage its resources, it must ensure that the contracting mechanisms it chooses are best suited to maximize the agency's significant investments.

In sum, to meet cost and schedule goals, agency leaders must temper NASA's historic culture of optimism by demanding more realistic cost and schedule estimates, well-defined and stable requirements, and mature technologies early in project development. In addition, Congress and NASA managers must ensure that funding is adequate and properly phased.

Finally, the agency must be willing to take remedial action up to and including termination when these critical project elements are not present. In our judgment, meeting these project-related challenges can only be accomplished through leadership that articulates a clear, unified, and sustaining vision for NASA and provides the necessary resources to execute that vision. Thank you, sir.

[The prepared statement of Mr. Martin follows:]

NASA
National Aeronautics and Space Administration

Office of Inspector General

Testimony before the House of Representatives
Subcommittee on Space, Committee on Science,
Space, and Technology

NASA COST AND SCHEDULE OVERRUNS: ACQUISITIONS AND PROGRAM MANAGEMENT CHALLENGES

Statement of Paul K. Martin
Inspector General
National Aeronautics and Space Administration

For Release on Delivery (expected at 10:00 a.m.)
June 14, 2018

Chairman Babin, Ranking Member Bera, and Members of the Subcommittee:

The Office of Inspector General (OIG) is committed to providing independent, aggressive, and objective oversight of NASA programs and projects, and we welcome this opportunity to discuss the Agency's challenges in meeting project cost, schedule, and performance goals.

Throughout its 60-year history, NASA has been at the forefront of aeronautics, science, and space exploration, responsible for numerous scientific discoveries and technological innovations. However, many of NASA's largest projects cost significantly more to complete and take much longer to launch than originally planned. Finding ways to better manage its projects – many of which are one-of-a-kind and first-of-their-kind – remains an ongoing challenge for the Agency.

Over the past 8 years, our office has examined NASA's successes and failures in project management on two levels: first, by examining the historic challenges the Agency faces in meeting cost, schedule, and performance objectives and the processes it has developed to address these shortcomings. Second, by assessing the effectiveness of NASA's use of these project management tools through dozens of audits of discrete projects, including development of science satellites such as the Surface Water and Ocean Topography (SWOT) mission, rover missions to Mars, construction of rocket test facilities, human space flight vehicles such as the Space Launch System (SLS) rocket and Orion crew capsule, and aeronautics research to integrate unmanned aerial vehicles in the national airspace. My testimony today is informed by the findings and recommendations of these OIG reports.

NASA's Historic Challenges to Meeting Cost, Schedule, and Performance Goals

NASA's storied history evidences a unique agency with spectacular accomplishments. For example, since its launch in 1990 the Hubble Space Telescope (Hubble) has helped scientists determine the age of the universe, identify quasars, and prove the existence of dark energy. Hubble's successor, the James Webb Space Telescope (JWST), will study the birth and evolution of galaxies while the Mars Science Laboratory (MSL), which successfully landed its Curiosity rover in August 2012, produced last week's blockbuster announcement of the presence of organic molecules and methane – important clues into whether the Red Planet is or has ever been able to support life.

Unfortunately, in addition to their scientific accomplishments these projects and many others at NASA share another less positive trait – significant cost and schedule overruns. For example, in 1977 NASA estimated that it would complete development of Hubble by 1983 at a total cost of $200 million; however, the telescope was not completed until 2 years later at a cost of approximately $1.2 billion. And even when launched, a flaw in its mirror required multiple repair and servicing missions that, while successful, added billions of dollars to the project's overall cost. MSL also launched 2 years behind schedule with development costs that increased 83 percent from $969 million to $1.77 billion. In 2009, NASA estimated JWST would cost $2.6 billion to develop and launch in 2014; however, its price tag now exceeds $8 billion and its launch date has slipped to approximately May 2020.

Our office's foundational examination of NASA's project management challenges identified four factors that present the greatest challenges to successful project outcomes: NASA's culture of optimism,

underestimating technical complexity, funding instability, and development and retention of new and experienced project managers.[1]

Culture of Optimism. Exemplified by the Agency's greatest achievement – landing humans on the moon and safely returning them to Earth – NASA's ability to overcome technological and scientific obstacles to accomplish a given objective has become part of the Agency's culture and has helped foster a belief that NASA can accomplish anything. Indeed, it was this "can-do attitude" that enabled NASA to bring the ailing Apollo 13 safely back to Earth, find a way to fix Hubble's flawed mirror in orbit, and land the Curiosity rover on Mars using a supersonic parachute/sky crane combination. However, our past work has found that this outlook causes NASA to view the success of projects primarily in technical rather than cost and schedule terms. More specifically, NASA's at times overly optimistic culture contributes to development of unrealistic plans and performance baselines, particularly with respect to its largest programs and projects. Subsequent technological success – at a significantly greater cost than originally estimated – reaffirms a mindset that project costs and adherence to schedule are secondary considerations to achieving operational success. In fact, many people we interviewed raised the "Hubble Psychology" – an expectation among Agency personnel that projects that fail to meet initial cost and schedule goals will receive additional funding and subsequent scientific and technological success will overshadow budgetary and schedule problems.

Our work over the past 8 years has identified three related ways excessive optimism can create cost and schedule challenges:

1. measures of project success do not include cost and schedule factors,
2. establishment of unrealistic cost and schedule baselines, and
3. an expectation that additional funding will be made available if a project runs "short."

In addition, NASA project managers are often overly optimistic about the effort required to mature critical technologies and frequently underestimate the cost and schedule reserves needed to address known and unknown risks, optimistically assuming that most risks will not materialize. However, when they do they result in significant cost, schedule, and performance problems.

Lastly, many project managers admitted to an expectation that projects that fail to meet initial cost and schedule goals, especially the larger projects, will receive additional funding and that subsequent scientific and technological success will overshadow budgetary and schedule problems. Past examples of this phenomena include Hubble, while current examples include JWST, the Orion crew capsule, and the SLS rocket. Although a few projects in NASA's recent past were cancelled because of poor cost and schedule performance, a "too big to fail" mentality pervades Agency thinking when it comes to NASA's larger and most important missions. While understandable given the heavy investment of Agency resources, these cost overruns can result in delays to other NASA missions as funding is reprioritized.

Underestimating Technical Complexity. The technical complexity inherent in NASA projects remains a major challenge to achieving cost and schedule goals, with project managers attempting to predict the amount of time and money needed to develop one-of-a-kind, first-of-their-kind technologies, instruments, and spacecraft. NASA historically has underestimated the level of effort needed to

[1] NASA OIG, "NASA's Challenges to Meeting Cost, Schedule, and Performance Goals" (IG-12-021, September 27, 2012). For this review, we interviewed 85 individuals including the NASA Administrator, Deputy Administrator, Associate Administrators, Center Directors, project managers, project staff, former NASA Administrators and staff, and external parties.

develop, mature, and integrate these technologies, as well as account for the extensive pre-launch testing required to reduce risk and increase the likelihood that the technologies will operate as designed in space.

Our work has shown that NASA can take several actions to mitigate this challenge. First, projects need to mature critical technologies early in the project life cycle, preferably before establishing their baseline cost and schedule. Establishing the level of effort needed to incorporate the technology in an operational system reduces risk and provides greater transparency at the project's "buy-in" point for decision makers.[2] Second, the amount and availability of reserves needs to be commensurate with a project's technical risk to cover expenses associated with work managers did not plan for at the beginning of the project but almost inevitably will need due to the complexities inherent in developing space flight projects. Lastly, managers need to control project scope and requirements "creep" that can occur when engineers, scientists, or other advocates suggest functionalities greater than the instrument's original requirements to increase its technical capabilities.

Funding Instability. Funding instability includes situations in which a project receives less money than planned or when funds are disbursed on a schedule different than planned. Such instability results from congressional or Agency-directed actions and can require deferring critical tasks to later phases of development or de-scoping or discontinuing lower priority tasks to keep project costs within a revised budget profile, leading to cost increases and schedule delays. To this point, since 1959 NASA has received its annual appropriation at the start of a fiscal year only seven times, often resulting in weeks- or months-long continuing resolutions (CR) that generally set funding at the prior year's level. The current fiscal year is a striking illustration of this phenomena: five CRs were required before NASA (and the rest of the Federal Government) received its annual appropriation – at the half-year mark.

Development and Retention of Experienced Project Managers. We also identified a number of issues related to developing project managers' experience that could affect NASA's ability to manage its projects effectively in the future. First, most project managers and senior officials we spoke with said that experience and on-the-job training were keys to a project manager's ability to manage cost, schedule, and performance goals. In that regard, managers described NASA's small projects as invaluable for developing management skills and learning the key elements of project management, including making appropriate trade-offs among cost, schedule, and performance goals when necessary. To that end, they said it was vital that NASA maintain a balanced portfolio that continues to provide these learning opportunities.

Interviewees also expressed concern about a lack of in-house development opportunities, with some expressing the view that as NASA has increasingly relied on contractors to support project development, the Agency's in-house capabilities have declined. Moreover, they expressed concern that because NASA contracts the majority of its hardware and software development efforts to private industry, Agency engineers spend most of their time overseeing contractor efforts rather than building spaceflight components, thereby limiting opportunities for NASA engineers to gain practical "hands-on" experience. Finally, interviewees raised concerns that NASA will not be able to attract and retain recent graduates or experienced engineers seeking opportunities to design and build spaceflight systems. Instead, these

[2] In an address to the American Astronautical Society Goddard Symposium in March 2008, former NASA Administrator Michael Griffin described the problem this way: "[T]here have been many instances where proponents of individual missions have downplayed the technical difficulty and risk of their individual mission, or grossly underestimated the cost and effort involved to solve the problems, in order to gain 'new start' funds for [a] particular project. Everyone knows that, once started, any given mission is nearly impossible to cancel, so the goal becomes that of getting started, no matter what has to be said or done to accomplish it."

individuals may choose positions in private industry and as a result, NASA will lose core competencies as experienced Agency engineers retire.

Efforts to Address Project Cost and Schedule Growth

NASA has implemented a number of initiatives over the years with mixed success to help project managers avoid cost and schedule overruns.

Joint Cost and Schedule Confidence Level (JCL). Beginning in 2006, NASA incorporated progressively more sophisticated cost and schedule estimating techniques into Agency policy, culminating in 2009 with formal adoption of a JCL requirement for projects with life-cycle costs greater than $250 million. A JCL analysis, completed during the final portion of the project's formulation phase and required as part of the Agency's decision to move the project into the implementation phase, calculates the likelihood a project will achieve its objectives within budget and on time. A properly executed JCL not only provides a percentage likelihood the project will be developed at a particular cost and on a particular schedule, but also identifies associated cost and schedule reserves needed to back-up the plan. Unless senior management approves an exception, projects are funded at a minimum of the 50 percent confidence level (the Management Agreement) and budgeted at the 70 percent confidence level (the Agency Baseline Commitment or external commitment) – the difference between the two figures being the reserves.

The JCL process uses software models that combine cost, schedule, risk, and uncertainty to evaluate how expected threats and unexpected events may affect a project's cost and schedule and help managers' assess whether a project has an executable plan moving forward. To generate this data, project managers develop comprehensive project plans, inputs, and priorities that integrate costs, schedules, risks, and uncertainties. NASA officials believe gathering this data encourages better communication among project personnel; improves cost, schedule, risk, and uncertainty analyses; and fosters an understanding of how different project elements impact one another.

However, as we wrote in a September 2015 report, the JCL is not a one-stop solution for ending cost overruns and schedule delays.[3] Rather, we found the process was unevenly applied across various projects and has inherent limitations in that it does not fully address the issue of predicting "unknown/unknowns" or other root causes of NASA's project management challenges such as funding instability and underestimation of technical complexity. Moreover, we found that while success when using this process relies on the expertise of risk managers, cost estimators, and schedulers, NASA had a shortage of people with this experience. Furthermore, although NASA policy requires JCL calculations to include consideration of all risks whether or not funded by the project, we found that NASA routinely leaves out risks "external" to the project such as involvement of international partners and risks associated with selection and timely delivery of launch vehicles. While NASA has embraced JCL and implemented it across its space flight project portfolio, applying lessons learned from successful projects and enhancing training on its use will increase its value as a project management tool.

Contracting. NASA has multiple contracting mechanisms available for acquiring goods and services, including fixed-price and cost-reimbursement contracts. In a fixed-price contract, the contractor agrees to deliver a product or service at a price not to exceed an agreed-upon amount. Fixed-price contracts are generally used when costs and risks can be clearly defined – for example, when purchasing commercially available items such as laptop computers. In contrast, under cost-reimbursement

[3] NASA OIG, "Audit of NASA's Joint Cost and Schedule Confidence Level Process" (IG-15-024, September 29, 2015).

contracts NASA agrees to pay all allowable costs the contractor incurs in delivering the service or product. Cost-reimbursement contracts involve increased risk for the Government and are generally more appropriate when it is difficult to accurately estimate specific costs in advance. Given the nature of the projects developed at NASA, cost-reimbursement contracts are very common at the Agency.

Contracts may also include incentives in which a predetermined amount of money is set aside for the contractor to earn above the contract's base price based on performance. Properly structured and executed, incentive contracts can reduce the risk of cost overruns, delays, and performance failures by providing a well-performing contractor the opportunity to earn additional money.

NASA has also used its "other transactions" authority provided by the National Aeronautics and Space Act of 1958 for large-scale development projects, most significantly to encourage development of commercial cargo and crew delivery capabilities to resupply the International Space Station (ISS or Station).[4] Under these Space Act Agreements, NASA agrees to provide funding, goods, services, facilities, or equipment that the partner uses to accomplish stated objectives. In return, the partner may advance technologies that support NASA's mission, share information, or reimburse NASA for the support provided. With respect to the development of commercial cargo and crew services, contractors were required to commit significant amounts of their own funds while NASA paid the companies when they met predetermined milestones. While providing financial benefits to the Agency, the use of funded Space Act Agreements decreases the level of NASA oversight and control compared to traditional procurement contracts.

Regardless of approach, our work has highlighted multiple examples of contracting costs, benefits, and challenges at NASA. Since 2011, we have issued eight reports examining acquisition strategies used by NASA for commercial cargo and crew transportation services to access the ISS. While NASA's costs to develop these services using Space Act Agreements are generally perceived as significantly less than if the Agency had used traditional contracting mechanisms, cargo services still were not provided until 3 years later than planned and crew services have yet to be demonstrated and are 3 years beyond initial expectations. Furthermore, several of our reports identify specific issues in NASA's commercial cargo contracts where it could save money by modifying contract terms and agreements.

Likewise, a November 2013 OIG report examined NASA's use of award-fee incentive contracts and questioned its methodology for motivating and incentivizing contractors' performance.[5] In particular, we found that overly complex award-fee formulas and a contract clause designed to hold contractors accountable for the quality of the final product that disregards interim performance evaluations have diminished the effectiveness of the Agency's award-fee contracts. For example, if JWST produces the science expected after its eventual launch, the Agency has the ability under the contract to award the contractor all of the award fees it could have earned over the past 15 years – even though NASA previously denied payment of some of those fees due to poor contractor performance.

Finally, a May 2017 report detailed how fixed-price contract costs increased on NASA's construction of two test stands at Marshall Space Flight Center that will be used to test SLS components.[6] Because the stand designs were based on preliminary specifications from the SLS program, the requirements and capabilities needed were not fully understood when the construction contract was awarded.

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[4] 51 U.S.C. § 20113(e), "National Aeronautics and Space Act of 1958" (2010).

[5] NASA OIG, "NASA's Use of Award-fee Contracts" (IG-14-003, November 19, 2013).

[6] NASA OIG, "Construction of Test Stands 4693 and 4697 at Marshall Space Flight Center" (IG-17-021, May 17, 2017).

Subsequently, NASA was required to modify the contract to meet changing requirements, added extra features, and made other modifications that raised the contract price by $20.3 million. Further, NASA did not establish adequate funding reserves to cover these changes and therefore had to secure $35.5 million in additional funding over the planned budget.

As NASA increasingly relies on the private sector to leverage its capacity, innovation, and competitiveness, the Agency must ensure that the contracting mechanisms it chooses are best suited to maximize its significant investments.

Partnerships. Partnerships, both domestic and international, are playing an increasingly important role in NASA's programs and projects. These collaborations can reduce NASA's required investment through sharing of capabilities, expertise, and scientific research while cultivating positive working relations among nations. As NASA missions become more complex and costly, it will be difficult for the Agency to achieve its ambitious goals at current funding levels without leveraging such partnerships, particularly for human exploration beyond low Earth orbit.

While NASA currently manages more than 750 international agreements with 125 different countries, it faces challenges in maintaining or expanding its use of such partnerships. For example, a May 2016 OIG audit found NASA sometimes experienced difficulty gaining agreement approval from the Department of State, as well as overcoming cumbersome U.S. export control regulations, restrictions on NASA employees' attendance at international conferences, and geopolitical realities that limit expansion of such partnerships, particularly with the Russian and Chinese space agencies.[7]

That said, international partnerships come with their own challenges. For example, in September 2016 we reported on likely launch schedule delays for Orion due to the European Space Agency's late delivery of the European Service Module needed for Exploration Mission 1.[8] More recently, our work in January of this year noted that the SWOT mission is dependent on about $400 million in instruments and other contributions from the French and Canadian space agencies – contributions critical to mission success.[9] Unfortunately, the French contribution is late and has forced project management to delay completion of a major life-cycle review that could potentially impact the launch schedule.

Looking toward the future, NASA hopes to leverage the emerging commercial spaceflight industry by forming public-private partnerships to further its space exploration and science research goals, particularly with respect to operation of the Station. According to NASA, such public-private partnerships will enable it to share the financial risk with private industry to better leverage Government investments.

Conclusion

NASA should rightly be proud of its six decades of significant achievements exploring space, helping understand the Earth and other planets' evolution and environment, and conducting fundamental research in aeronautics. However, consistently managing the Agency's largest science and space exploration projects to meet cost, schedule, and performance goals remains elusive.

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[7] NASA OIG, "NASA's International Partnerships: Capabilities, Benefits, and Challenges" (IG-16-020, May 5, 2016).

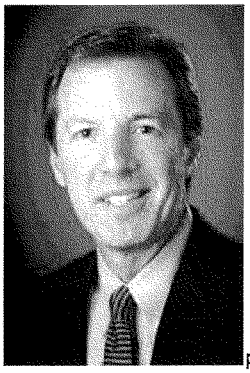
[8] NASA OIG, "NASA's Management of the Orion Multi-Purpose Crew Vehicle Program" (IG-16-029, September 6, 2016).

[9] NASA OIG, "NASA's Surface Water and Ocean Topography Mission" (IG-18-011, January 17, 2018).

Our work has shown that Agency leaders and stakeholders must temper NASA's historic culture of optimism by demanding realistic cost and schedule estimates, well-defined and stable requirements, and mature technologies early in project development. In addition, they must ensure that funding is adequate and properly phased and that known funding risks are identified and accounted for in mitigation strategies. Finally, they must be willing to take remedial action – up to and including termination – when these critical project elements are not present.

In our judgment, meeting these challenges can only be accomplished through a "unity of effort" that includes strong, consistent, and sustained leadership by the President, Congress, and NASA management. Articulating a clear, unified, and sustaining vision for the Agency and providing the necessary resources to execute that vision is critical to ensuring that project managers are best positioned to complete projects within cost and on schedule.

Paul K. Martin
NASA Inspector General



Paul K. Martin was confirmed by the United States Senate as NASA Inspector General on Nov. 20, 2009.

Prior to his NASA appointment, Martin served as the Deputy Inspector General at the U.S. Department of Justice, Office of the Inspector General (OIG). In that capacity, he assisted the Inspector General in managing the audit, inspection and investigative activities of the office's 425 employees. From 2001 to 2003, he served as Counselor to the Inspector General, and from 1998 to 2001 he served as Special Counsel to the Inspector General.

Before joining the Department of Justice OIG, Martin spent 13 years at the U.S. Sentencing Commission in a variety of positions, including 6 years as the Commission's Deputy Staff Director. Martin was one of the Sentencing Commission's first employees when the agency was created in 1985, and helped develop the first set of federal sentencing guidelines.

Martin began his professional career as a reporter with The Greenville News, a daily newspaper in Greenville, SC. He holds a B.A. in Journalism from The Pennsylvania State University and a Juris Doctor from The Georgetown University Law Center.

Martin is married to Rebekah Liu, an attorney working in Washington, DC. A native of Pittsburgh, PA, he and his wife have three daughters.

Chairman BABIN. Thank you very much, Mr. Martin.

Now, I'd like to recognize Mr. Dumbacher for five minutes to present his testimony.

TESTIMONY OF MR. DANIEL L. DUMBACHER,
EXECUTIVE DIRECTOR,
AMERICAN INSTITUTE OF AERONAUTICS
AND ASTRONAUTICS (AIAA)

Mr. DUMBACHER. Chairman Babin, Ranking Member Bera, and distinguished Members of the Committee and Subcommittee——

Chairman BABIN. You may want to push your button there. I'm sorry. Yes.

Mr. DUMBACHER. Chairman Babin, Ranking Member Bera, and distinguished Members of the Subcommittee, thank you for this opportunity to address you today. Your support for the nation's space program is to be commended.

I sit before you as a former NASA Program Manager, former educator, and as the current Executive Director of the world's largest aerospace professional society.

Let me first say that the work NASA employees and its industry partners do is purposely challenging. The NASA industry teams should be commended for their accomplishments under such tight constraints. Programs are complex, and a great deal of planning and commitment is necessary to execute a successful mission.

Every program has its unique challenges. The NASA industry team works hard to address these issues, develop solutions, and incrementally make progress towards the respective missions. No matter how much planning takes place or how well-thought-out the plan, it's difficult to estimate the cost and schedules of these complex one-of-a-kind projects.

All federal government departments and agencies are operating in a time of heightened fiscal responsibility and accountability. Accordingly, NASA has updated policies and guidance to focus on formulation and implementation with robust cost-estimating; well-defined baselines, designs, and risk postures at key decision points; and formal requirements and guidance.

Especially during the implementation phases of its projects, NASA has processes to ensure that rigorous cost assessment is performed. Program progress is tracked through the periodic performance review process. Since NASA instituted its joint confidence level policy nearly a decade ago, NASA's cost and schedule performance has improved.

From my perspective, the issues experienced in the NASA projects can be assessed in two categories: one, the need for stable, predictable, and consistent funding; and workforce development. Simply stated, project management has three basic knobs: content, schedule, and cost. A change in any one of these three variables directly affects the other two.

Cost and schedule issues do arise when there are unanticipated changes to a program or when development challenges arise, particularly during first-time production and when technical capability is being pushed. Disruptions to the budget process and funding stream, along with major policy and priority shifts, affect schedules and contracts and ultimately lead to additional cost. It is also quite

difficult for NASA to plan and implement programs without sufficient resources or reserves.

A key issue is projects developed under a flatline budget. A flatline budget requires project managers to realign the work as they go to stay under the budget cap, resulting in hard priority decisions and inefficiencies that explicitly break the program linkages across schedule and budget. These circumstances can and do add to program cost to move schedules to the right. We learned this lesson with the International Space Station and yet now we're repeating it with SLS and Orion.

The current budgeting process, including the regular use of continuing resolutions, late-year appropriations, and threats of government shutdowns result in endless multiple planning scenarios. As stated in October 2015 testimony before this Subcommittee, the need to constantly have backup plans for various potential appropriations outcomes, different budget planning levels, along with flexible workforce blueprints invites confusion and miscommunication.

A related issue is the inability of NASA to include appropriate budget and schedule margin in its program planning due to externally imposed constraints. Planned margin is difficult to include because it becomes the first target for budget reduction in the budget and appropriations process.

A separate but related issue that must be addressed is the workforce challenge impacting the aerospace community as a whole. There remains a nationwide shortage of workers for jobs requiring science, technology, engineering, arts, and mathematics. According to Aviation Week's 2017 workforce study, nearly 30 percent of the nation's aerospace and defense workforce are over the age of 55, and 22 percent are younger than 35.

More concerning is the lack of development program experience. The vast majority of the NASA human spaceflight workforce has been hired and trained after space shuttle development. Space station development has provided on-orbit expertise. However, launch system development experience is minimal. NASA expertise that developed the space shuttle has mostly retired or passed away.

For the United States to continue its long-held space exploration leadership, significant investments must be made in addressing the workforce development via hands-on real-world hardware programs and research. Key technical challenges for the future of space exploration such as new propulsion, on-orbit assembly, and human survival in microgravity should be addressed. Such investments would meet key research and engineering needs, while providing valuable experience. A well-developed leadership bench is also necessary for a program's mission success. This ensures the appropriate expertise to assess and balance risk and priorities.

In conclusion, I thank this Committee for the opportunity to talk today and look forward to your questions.

[The prepared statement of Mr. Dumbacher follows:]

Written Statement of

Mr. Daniel L. Dumbacher
Executive Director
American Institute of Aeronautics and Astronautics

Subcommittee on Space
Committee on Science, Space, and Technology
United States House of Representatives

"NASA's Cost and Schedule Overruns: Acquisitions and Program Management Challenges"

June 14, 2018

Chairman Babin, Ranking Member Bera, and distinguished members of the Subcommittee, I want to thank you for the opportunity to address you today as you consider recommendations to help minimize challenges that lead to increased costs and schedule on NASA programs. I sit before you as a former NASA program manager, a former educator, and as the current executive director of the world's largest aerospace professional society, the American Institute of Aeronautics and Astronautics. Over the span of my career I have led several of these major NASA programs and I have helped educate and prepare our nation's future aerospace workforce.

Let me first say that the work NASA employees and its industry partners do is challenging. The NASA/Industry team should be commended for their accomplishments under tight constraints.

The programs are complex, and a great deal of planning and commitment are necessary to execute a successful mission. Every program has its unique challenges and setbacks, but NASA works hard to address these issues, develop solutions, and incrementally make progress toward achieving the respective missions. No matter how much planning takes place, or how well thought out the plan, it is difficult to estimate the costs and schedules of these complex projects. This is especially the case for the larger projects such as the Space Launch System (SLS), the Orion spacecraft, and the James Webb Space Telescope. For these programs, even when using the soundest estimating tools based on applicable past experience, it is extremely challenging, in part because each first-time development is unique.

All federal government departments and agencies are operating in a time of heightened fiscal responsibility and accountability. Accordingly, NASA has updated policies and guidance to focus on (1) program formulation and implementation with robust cost estimating, including cost estimates and the approach, (2) well-defined baselines, designs, and risk postures at key decision points, and (3) authoritative requirements and guidance with emphasis on formal (decision) documentation. Especially during the implementation phases of its projects, NASA has processes to ensure that rigorous cost assessment is performed and program progress is well understood by enhancing the periodic performance review process and by providing support to projects when cost, schedule, and/or technical performance is in question. NASA has shifted its operational paradigm to better balance technical requirements with the establishment of adequate cost, schedule, and technical baselines, and during execution by addressing poor performance to avoid collateral impact to other missions. Since NASA instituted its Joint Cost and Schedule Confidence Level, or JCL, policy nearly a decade ago to understand and assess program risks impacting cost and schedule, NASA's cost and schedule performance has improved... *significantly.* NASA should be lauded for moving cost growth against established baselines from 45 percent on average, pre-JCL, to less than 2 percent since instituting the JCL process.

From my perspective, the issues experienced in the NASA projects can be assessed in basically two categories. These categories are (1) the need for stable and consistent funding, and (2) workforce development. I will address these below.

Stable and Consistent Funding

In a simplified perspective, project management has three basic "knobs"—content, schedule, and cost. A change in any one of these variables directly affects the other two variables. Cost and schedule issues do arise when there are unanticipated changes to a program or when development challenges arise, particularly during first-time production and when technical capability is being pushed. Disruptions to the budget process and funding stream, along with major policy and priority shifts, affect schedules and contracts and ultimately lead to additional costs. This is especially problematic for large projects that require long-term investments and long-term life cycles. It is also quite difficult for NASA to plan and implement programs without sufficient resources or reserves. While the agency receives approximately 5/10ths of a penny for every tax dollar, the number, breadth, and complexity of programs continues to increase. NASA also operates within the confines of administration policy shifts and the economic market conditions. Overall, aerospace, and increasingly commercial supply chains, are affected by external policy and economic conditions.

A key issue is how certain projects are developed under a flat-line budget that does not account for the needed project life-cycle growth for detailed design and test. Perhaps even more important, a flat-line budget does not provide program managers with the ability to address design and operational changes required both before and after testing and also with system integration. In fact, a flat-line budget requires project managers to realign the work as they go to stay under the budget cap, resulting in hard priority decisions and inefficiencies that explicitly break the linkages across schedules and budget allocations within a program. These circumstances can, and do, add to program costs and move schedules to the right.

We learned this lesson with the International Space Station (ISS) and yet, now we are repeating it with the SLS and Orion. Moreover, at various points these fiscal limitations have also led to contractor layoffs, which negatively impact the base of knowledge and experience available to draw from in future programs.

The current budgeting process, including the regular use of continuing resolutions, late year appropriations, and threats of government shutdowns, results in endless, multiple planning scenarios. Such irregularities lead to inefficiencies in planning and technical execution. It is extremely challenging for NASA and its industry partners to resolve complex technical issues, hold schedules, and predict accurate flight dates when the budget is constantly in flux. Although budget increases in recent years have helped to increase margin in the programs, additional funding, outside of the normal planning cycle, can create inefficient spending profiles because there is little time to integrate a changed funding profile – even when the change is a

positive one – into program planning. As I stated in my October 2015 testimony before this subcommittee, the need to constantly have backup plans for each potential appropriations outcome, different budget planning levels, along with flexible workforce blueprints, all but invites confusion and miscommunication. In a program such as SLS these inefficiencies can and do result in significant cost to the taxpayer that occurs simply because of disruptions to the planning process caused by external factors such as the ones I have described.

A related issue is the inability of NASA to include appropriate budget and schedule margins in its program planning because of externally imposed constraints. Like the imposed flat- line budgets, planned margin is difficult to include because it becomes the first target for budget reduction in the Executive Branch budget and congressional appropriations processes. The May 2018 Government Accountability Office (GAO) report discusses the Goddard Space Flight Center margin requirements. This is done for the small missions; however, in the large-scale, higher visibility programs, planned margin becomes the victim of the budget negotiation process. I must point out that even the smaller missions have difficulty in protecting the schedule and cost margins in the budget process.

Workforce Development

A separate, but related, issue that must be addressed is the workforce challenges impacting not only NASA but the aerospace community as a whole. There remains a nationwide shortage of workers for jobs requiring skills in science, technology, engineering, arts, and mathematics (STEAM). These workers form the backbone of an aerospace and defense (A&D) industrial base that the United States and its allies count on to ensure and sustain innovation, economic growth, global competitiveness, and security. According to Aviation Week & Space Technology's 2017 Aerospace & Defense Workforce Study, nearly 30 percent of the nation's A&D workforce is over the age of 55, and 22 percent are younger than 35. The percentages of ethnic minorities and women working in A&D, at less than 25 percent, have not changed significantly in four decades despite a major shift in the demographics of the United States. Additionally, only 16 percent of 12th graders are proficient in math and have expressed interest in a STEAM-related career.

More specific to NASA, the GAO cites that 56 percent of NASA's workforce is 50 years of age or older. More experienced employees have retired, passed away, or moved on to other endeavors. Others have stayed several years past their initial retirement eligibility date. Unfortunately, there is a shortage of highly trained technical graduates to fill the skills gap, and many young professionals are inadequately prepared in cross-functional skills. More concerning, they lack development program experience. The vast majority of the NASA human

spaceflight workforce has been hired and trained after Space Shuttle development. ISS development has provided on-orbit expertise; however, launch system development experience is minimal. NASA expertise that developed the Space Shuttle has retired or passed away.

Many young professionals are also electing to leave NASA or the sector altogether for other high-tech jobs. This is sometimes the result of program layoffs, but, according to Aviation Week, it really comes down to job satisfaction, which includes challenging work; access to tools, learning, and technology; and being part of an organization that encourages innovation in technology, processes, and business.

For the United States to continue its long-held space exploration leadership in the world, significant investments need to be made in addressing the workforce development via hands-on real hardware programs and research. Key technical challenges for the future of space exploration such as nuclear propulsion, on-orbit assembly, human survival in microgravity, and propellant depots need to be addressed. Such investments would meet key research and engineering needs while providing valuable experience for the future workforce.

NASA should proactively, with administration and congressional support, establish key metrics for doing in-house work and assess use of its capabilities as space privatization continues to grow. The Goddard Space Flight Center model of 10 percent in-house effort is a prime example. Use of the unique NASA test facilities and workforce expertise for common testing and assessment of commercial space systems and products will ensure standard program performance, safety and reliability, and, if done right, will save private industry from the large investments.

Workforce diversity is absolutely essential as well. The future complex problems demand the inclusion of all perspectives for innovative AND relevant solutions. Moreover, we must continue to welcome highly skilled, non-U.S. citizens who wish to be educated and trained at our top institutions and retain those talented individuals who want to work alongside U.S.-born colleagues to contribute to the advancement of our sector. Collectively this workforce drives economic growth, innovation, and the entrepreneurial spirit that has continually pushed the aerospace community to accomplish the seemingly impossible. A well-developed "leadership bench" is also necessary for a program or mission's success. This ensures the availability of appropriate expertise to assess and balance risk and priorities—all in a timely manner. Developing the workforce through hands-on real hardware programs will provide the needed bench strength.

The tightly constrained and constantly changing fiscal environment also leaves little maneuvering room or forgiveness for the ability to predict outcomes during a development process. Since the Challenger accident in 1986, and particularly following the Columbia accident, NASA's program and project managers have become increasingly conservative, sometimes losing sight of opportunities that present themselves by pushing the envelope of design, technology, and testing.

I must be crystal clear on this point: Safety remains the utmost priority in space exploration. This nation must always protect the safety of the astronauts, their families, and the workforce. I am suggesting that there is a better balance in terms of accepting risk. NASA must be allowed, like in the Apollo era, to recognize the opportunities, be bold in pursuing them, assess the risks, and consciously and continuously manage the risk for these challenging endeavors – without facing punitive outcomes. By its very nature, exploration requires the ability to understand the situation and make intelligent judgments to move forward.

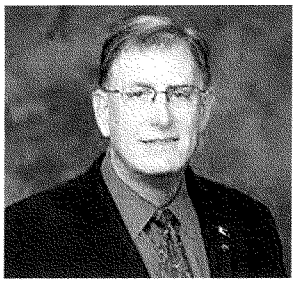
Conclusion

The keys to a well-executed program are stable and adequate funding and a sufficiently experienced workforce. Plain and simple. I commend NASA for doing such a great job operating under the current unpredictable budget environment and funding constraints. The agency is working to integrate the latest technologies to reduce costs while maintaining or improving performance and safety. The programs in development are advancing steadily, and they will continue to encounter technical, management, and operational challenges. Keeping programs on schedule is essential to maintain our global leadership in space and minimize the overall program costs. A return to a regular appropriations process coupled with a long-term perspective will help address these issues and will help accomplish the administration's goal of returning to the moon and furthering the human neighborhood to Mars and beyond.

At the same time, Congress must continue to pass legislation that enhances the pipeline of STEAM-competent workers into the U.S. economy; this includes initiatives aimed at underrepresented demographics. Congress should also craft legislation that will bolster economic competitiveness and job opportunities in the sector and encourage education and training programs required for both the existing workforce and new entrants. Federal incentives and/or grants need to be readily available to support industry, government, and academic partnerships that tailor training for high-level skills and that provide professional education opportunities and research-focused collaborations. And Congress should pass visa legislation that encourages the retention of foreign professional workers in U.S. industry.

Again, thank you for the opportunity to address this body and thank you for your continued support of our nation's space program. I look forward to answering any questions you may have for me in this regard.

Daniel L. Dumbacher



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Before joining the AIAA staff in January 2018, Dumbacher was a Professor of Engineering Practice in the School of Aeronautics and Astronautics at Purdue University, where he taught courses in systems thinking, systems engineering, and space policy.

Prior to Purdue, Dumbacher served as the Deputy Associate Administrator, Exploration Systems Development Division, Human Exploration and Operations Mission Directorate at NASA Headquarters. In that capacity, he provided leadership and management as the Program Director for Exploration Systems Development, which included: the Space Launch System, Orion, and Ground Systems Development and Operations development and integration efforts. He led a national team of over 5,000, spanning all NASA centers and industry, and was responsible for a $3 billion annual budget.

During his career, he has received numerous awards and honors including the coveted Silver Snoopy Award and the NASA Distinguished Service Medal. In 2015, Purdue recognized him with the Gustafson Teaching Award.

Dumbacher earned his bachelor's degree in mechanical engineering from Purdue University and a master's degree in business administration from the University of Alabama in Huntsville. He has also completed the Senior Managers in Government program at Harvard University.

Dumbacher is a native of Indianapolis, Indiana. He and his wife Lee have three grown children.

Chairman BABIN. Thank you, Mr. Dumbacher. We appreciate it.

Now, I would like to recognize myself for five minutes for questioning. And I have a bunch of questions, and I'm sure everybody else does, too, so if you could just get right to the point, answer these things, we want to cover as much of this part of ground as we possibly can.

NASA has a storied history with overrunning costs and schedules for space systems development. Some of these programs have even suffered cancelation as a result, and this has simply got to stop. We need performance, not excuses from the agency, as well as providers. And with that in mind, of NASA's options, what acquisition mechanisms such as cost-plus, fixed-price, or Space Act Agreements are most useful in promoting performance and holding the provider as well as the agency management accountable for meeting the acquisition requirements? And I'd ask you first, Mr. Dumbacher.

Mr. DUMBACHER. Congressman, I think the appropriate acquisition tool depends on the objectives of the program and the scientific engineering issues and risks associated with that.

Typically, we have a lot of experience with cost-plus contracts in this country. NASA uses that a lot for its major programs. There is the discussion of public-private partnerships, which can also be valuable and have been tried in the past, some successful, some not. When we consider all of this, we need to consider the objectives that are for the program, what are the incentives and the motives that are necessary for success both in terms of how it would apply in a public-private partnership, as well as a cost-plus arena? And we need to sort through those and make valid, conscious, objective decisions.

Chairman BABIN. Thank you. And now that same question, Ms. Chaplain, if you would answer that. I don't need to repeat it, right?

Ms. CHAPLAIN. Right.

Chairman BABIN. Okay.

Chairman BABIN. So with fixed-price contracts, the contractor bears the most risk for meeting cost and schedule goals, so that's your main aim. That's a contract, but it's not really appropriate when you're facing a lot of unknowns at the beginning. If you're really stretching technology, don't know how long it's going to take, how much it's going to cost, in that case the government does need to bear the risk of the contract, and that's where cost-plus comes in.

Chairman BABIN. Okay. Thank you. And then we're talking about cost-plus, so I'm just going to—the second part of my question to you two, do cost-plus contracts provide any incentive for the provider to complete the project on time and on schedule?

Ms. CHAPLAIN. There are typically incentives built into the contract, and they come through the award fees. So some may be tied to performance and quality and things like that, but others could definitely be tied to cost and schedule.

Chairman BABIN. Okay. All right. Thank you. And, Mr. Dumbacher?

Mr. DUMBACHER. Just to add a little bit to that, when we have done award fee, cost-plus award fee, and incentive fee in the past, we do and can make schedule performance and cost performance part of the evaluation criteria, and that is typically included.

Chairman BABIN. Okay. Thank you. And then to Mr. Martin and Ms. Chaplain as well, acquisition encompasses a great deal, including strategic planning, procurement processes, and the development of clear requirements. For many years, the DOD has employed a robust training and certification program for defense acquisition professionals. What institutional improvements such as training, certification, and career progression are necessary or perhaps missing from NASA's acquisition processes?

Ms. CHAPLAIN. I know NASA has invested pretty heavily in training cost estimators and project management. They have conferences every year, for example. But I still think maybe more could be done in that area in certain techniques and especially more program management issues related to managing contracts.

Chairman BABIN. Okay. And then Mr. Martin?

Mr. MARTIN. Attracting and retaining the project managers is a real challenge for the agency. As Mr. Dumbacher suggested, within NASA, 50 percent of the workforce is over 50 years old, and with a diminishing number of small projects for these project managers to really get the experience and cut their teeth on, it's a real concern.

Chairman BABIN. Okay. And then do you think NASA can gain from DOD's experiences?

Mr. MARTIN. I'm not as familiar with DOD's experiences.

Chairman BABIN. Okay. Ms. Chaplain?

Ms. CHAPLAIN. I think that Defense Acquisition University is a very good model for training programs and all kinds of issues. It's something NASA could look toward.

Chairman BABIN. Okay. Thank you.

Mr. Jurczyk, NASA recently took steps to control the costs of the Europa Clipper and WFIRST missions while in formulation. Have these steps proven helpful, and can similar measures be implemented on other major projects to control the cost?

Mr. JURCZYK. Yes. On WFIRST we did an independent—had an independent review board come in and look at the project early in phase A, in formulation, and they confirmed that the project scope had grown and they were not going to be able to execute the mission within the $3.2 billion budget that we had for their—for them for the management agreement. They made some recommendations. The project took those recommendations and adjusted the scope and re-planned the cost and schedule estimates and they came in and presented their baseline to the agency program management council, which I chair. And we have confidence, based on their estimate given the re-plan, that they have a solid estimate going into phase B. I think that—and similarly for Europa Clipper. So I think that is a way to try to minimize cost and schedule risk early in the program.

Chairman BABIN. Okay. I'm out of time. I had several more questions, but thank you very much.

I'd like to recognize the gentleman from California, the Ranking Member, Mr. Bera.

Mr. BERA. Thank you, Mr. Chairman. Each of you in your opening statements obviously touch on the complexity of budgeting and scheduling when you're trying to do something that you may never have done before. And I have to imagine when we started on the

Apollo missions, lots of cost overruns, lots of scheduling delays, but as you got further down the road, understood what we had to do, that started to reduce and there was more predictability.

As we think about future missions, let's put it in the context of something we talk a lot about, Mars by 2033. We don't know how we're going to do that. We don't know the technology and the science and everything else. As we go into deeper space, we are encountering more complicated projects. As we look at the balance of the commercial sector, the entrepreneurial sector, more reliance on external entities. When we did Apollo, NASA was the launch vehicle, the landing vehicle, the science mission, maybe a little bit more control as you think about working with outside contractors and new startup companies that may be—a little bit more unpredictability, I think that adds another variable. As the international community becomes much more engaged, as you see countries like India, Japan, the European Space Agency start to do some of the science, another complicated variable.

So, as opposed to budgeting and scheduling getting easier, my sense is budgeting and scheduling is going to get more difficult. Is that a reasonable—reasonably accurate thought? I guess, Ms. Chaplain.

Ms. CHAPLAIN. Well, I would like to note in the Apollo era, a lot of things had never been done before, so they were very difficult to estimate. I think now we have the benefit of time and history that there are a lot of things we can estimate even if we haven't done that particular mission.

And I also know that in the past decade the three space agencies, DOD, NRO, and NASA have been working very closely together to kind of gain that historical perspective in costs and build databases so there is more knowledge there that gives you an advantage. But yes, those other complexities do make it hard.

Mr. BERA. Right. And as we think about that, learning from what we've done in the past, trying to create more predictable models of budgeting and scheduling, I think to Chairman Babin's question, you know, I'll put it in the context of my profession as a doctor. We'll often—and—as we're caring for populations of patients, we'll have a shared risk pool that says, okay for a certain fee, we're going to take care of this population of patients. If we do really well, we improve health, et cetera, there's a reward on that end. If, on the other hand, we do a bad job taking care of these patients, we share some of that risk.

And I don't know if in contracting—I think you touched on the shared risk award fees, et cetera. Have you noticed in that type of contracting that you actually get better predictability when not doing something that we know how to do and is pretty predictable but something where there is some risk involved? And Ms. Chaplain, if you want to answer that or, Mr. Martin, if you want to take that.

Mr. MARTIN. Let me just toss in that over the last ten years, NASA has moved to a new procurement mechanism, the funded Space Act Agreements, particularly to spur development of transportation capabilities for cargo and crew services to the International Space Station. Now, NASA contributes significant—billions of dollars—to the funded Space Act Agreements, but the com-

mercial companies also have a significant financial stake in the game. So having them have their skin in the game as well to develop these private capabilities of which NASA will be procuring as a service, I think is interesting and has been relatively successful.

Has it increased cost schedule and timing? Not particularly.

Mr. BERA. Mr. Jurczyk?

Mr. JURCZYK. Yes, as I said before, we choose kind of—either a FAR-based, you know, contract, either cost reimbursement or fixed price or a public-private partnership where it makes sense. Particularly public-private partnerships where there's shared strategic common interests between ourselves and an industry partner or partners, that makes a lot of sense, and therefore, there—we also share the risk there in that partnership.

We did do a reimbursable Space Act Agreement, a funded Space Act Agreement for cargo. We've kind of moved away from that approach because of our ability to have insight and manage. And our latest public-private partnerships have actually been through fixed-price contracts with cost-sharing where we use the FAR rules to manage the relationship and allow the contractor to contribute resources and share the risk.

Mr. BERA. All right I'm out of time, so——

Chairman BABIN. Thank you very much.

And now, I'd like to recognize the Chairman of the full committee, Mr. Smith from Texas.

Chairman SMITH. Thank you, Mr. Chairman.

Ms. Chaplain and Mr. Martin, a lot of NASA contractors seem to not be able to stay on schedule, they fall behind, and they end up with cost overruns and fail to perform as we expect them to do. In the 2018 NASA Authorization Act, we have a watchlist for contractors who don't perform well.

And let me—before I get to my specific question, let me just say that I think the American people are rightfully sometimes frustrated by the Federal Government when things go wrong, when projects end up not being performed as they should, when there are cost overruns, when the deadlines are missed. And somehow no one is held accountable; no one is responsible. It just happened. And I think that is frustrating to the American people when they see projects that cost millions if not billions of dollars more than expected.

So I'd like to ask you all who you think would be good candidates for that watchlist. The watchlist is just that, these are contractors who need to be watched more closely, who need to be reminded of their contractual obligations and perhaps sanctioned if they don't improve their performance. But, given your investigations, who are some of the contractors that we might consider putting on such a watchlist? And, Ms. Chaplain, start with you if we could.

Ms. CHAPLAIN. It's a difficult question because in some cases there's a shared responsibility between NASA and the contractor, so it's hard to parse out who's really responsible for that overrun. Even when it comes to like a workmanship issue, there could be some shared responsibility there.

If you look at the provision you were talking about, there are a couple projects in our list where performance has been bad consist-

ently over time, and NASA has actually canceled or proposed canceling a project or is looking at whether to do that because—

Chairman SMITH. Okay.

Ms. CHAPLAIN. —contractor performance. In those cases—

Chairman SMITH. And who were those contractors?

Ms. CHAPLAIN. One is—for the SGSS project, that would be General Dynamics, so that project is being looked at. Performance has been a long-standing issue on that.

Chairman SMITH. Okay.

Ms. CHAPLAIN. The other one was the RBI Instrument, which is a weather satellite sensor. That one was proposed for termination. That was Harris Corporation and formerly Exelis. That—those are the more extreme cases—

Chairman SMITH. Okay.

Ms. CHAPLAIN. —that could possibly—but it's ultimately like NASA's decision, and they have to—

Chairman SMITH. I understand.

Ms. CHAPLAIN. —really investigate the situation.

Chairman SMITH. Okay. Thank you. Mr. Martin, in your testimony, you made a couple of really good suggestions I thought to try to avoid the to-big-to-fail syndrome. What are some other ways we can hold contractors accountable? We have the watchlist. What are some other things that we can do to keep projects on time and on budget?

Mr. MARTIN. I think one of them is what you are doing here today is an oversight hearing and the proposed hearing several weeks from now to focus on the issues specific to JWST.

Chairman SMITH. Right.

Mr. MARTIN. I think aggressive oversight by GAO and the IG's Office is important, and I think just a general sense that folks need to be held accountable for—you know, there's human failure, we all fail, but there are avoidable human mistakes on some of these projects. For instance, the improper use of a solvent on the JWST by Northrop Grumman, inadequate welding on the SLS core stage by Boeing, as the prime contractor. So we have individual avoidable mistakes.

We have issues with our international partnerships, which are key to the future of NASA. But when the European Service Module is 14 months behind schedule, that impacts Orion.

Chairman SMITH. Right. Final question for you and also I think for Ms. Chaplain, and it is this, that it is very unlikely that NASA's budget is going to see a significant increase, say 25 percent, anytime soon. It's just not the nature of our spending, and various constraints are going to prohibit I think any agency from getting a significant increase. We're fortunate, I believe, to have—NASA had sort of a flatline budget. So many agencies—other agencies have been cut. Yet there are a lot of people and pundits who expect us to keep the International Space Station as-is, go back to the moon, and then on to Mars, and seem to be able to think we're going to do everything all the time.

I think that in my opinion is not being willing to make some difficult decisions. Realistically, I don't think it's possible. I think it's very naive to think we can do everything all the time. Do you agree with that assessment or is—am I missing—is there some magic so-

lution that will enable us to do everything all the time? Or are we going to have to take a hard look at some of these big missions like—either ones that we already have like the space station or others to come like the Moon and Mars?

Mr. MARTIN. No, you're not missing anything. I think it's all about choices. There's a finite amount of resources, and you're right, NASA has been very fortunate in the budgets it's received over the years. But that's why cost and schedule estimation is so important, to come up with realistic cost and schedule so you can put it before the decision-makers at NASA and in Congress.

Had NASA been able to say that the James Webb Space Telescope was going to cost $8 billion ten years ago when it was proposed, then it's a decision. You do James Webb—and I'm not suggesting it should or shouldn't have been done. It's going to do amazing things when it's up there—but you make a decision based on that. But if you say yes to James Webb, you're saying no to a lot of other things.

Chairman SMITH. Right. And that's what we have to appreciate and recognize and understand.

My time is up but, Ms. Chaplain, can you give us a really brief response to that as well?

Ms. CHAPLAIN. I think NASA is at risk of having too many programs to pay for at one time. Even if you look at what we've been looking at over the years, we started out with 15 to 16 projects. That helped them reduce cost overall.

Chairman SMITH. Okay.

Ms. CHAPLAIN. Now, we're looking at 26.

Chairman SMITH. Okay. Thank you. Thank you, Mr. Chairman.

Chairman BABIN. Great questions. Thank you.

I now recognize the gentlelady from Texas, Ms. Johnson.

Ms. JOHNSON. Thank you very much.

Ms. Chaplain, in your 2017 assessment of NASA's major projects, you indicated that in October 2015, NASA decided to decentralize its independent assessment function and deploy the staff to the agency centers in part to better use its workforce to meet program needs in areas such as program management and cost estimating.

GAO had previously reported on the potential risk that this change could pose for project oversight but stated that it was too early in the transition to assess its effect on areas such as independence, the robustness of the reviews, and information-sharing. So now one year later, are you able to tell us whether that decentralization was successful?

Ms. CHAPLAIN. We haven't seen a real visible impact either way yet. We're still very concerned about that move. I think it's beneficial to the agency to have centralized expertise in those areas. They really can leverage each other a lot.

Ms. JOHNSON. Mr. Jurczyk, do you have any comment?

Mr. JURCZYK. Yes, I think we've moved to a model where we're putting the responsibility and accountability of the mission directorate to manage the programs to do that independent assessment, and so far, they've stepped up to the job, and I think they're doing an effective job in implementing our spaceflight project management processes, including reviews.

We do still have a cadre of experts in the Office of the Chief Financial Officer that have schedule and cost assessment expertise that the review boards can draw on. And we've also given stewardship of project planning and control to the Office of the Chief Financial Officer, and that's been very beneficial, and not only this cadre of people for schedule and cost estimating but improving our skills and processes and capabilities in cost and schedule estimating and management.

Ms. JOHNSON. Okay. Let me ask you this. What are the most important things that NASA can do to minimize cost and schedule growth? And when NASA is faced with an unexpected cost growth and schedule delay, what are the tradeoffs that NASA can make? And give me some examples of successful tradeoffs.

Mr. JURCZYK. Yes, so, you know, I think we continue to mature and effectively apply the joint confidence level process is going to be really important. And I've seen—since 2009, I've seen the value of that in budgeting projects at the agency based on coming in at the 70 percent confidence level, and I think we can do even better there in maturing that process. And I've seen success, and I think we need to continue to have success there.

I think we can—we need to continue to focus on development of the project management workforce and the program planning and control workforce has been noted, including, you know, hiring and developing the talent through hands-on project management and project experience and training.

About 15 years ago, we identified a shortage of skills in project planning and control, and we've really taken on an effort to hire and train people in that area, cost estimating and schedule estimating and management, and I think that's paid off. We need to continue to do that.

We talked about independent assessments, and we can continue to strengthen independent assessments.

And then we have capturing and communicating lessons learned and looking for systemic issues and challenges across programs and putting corrective action plans in place to deal with those like the shortage of program planning and control staff. We need to continue to do that. And I think all those things can lead to improved program project—continued improved program project performance.

Ms. JOHNSON. Thank you very much. My time is about out, but would any other witness like to comment on any of the questions?

Ms. CHAPLAIN. I would just add a couple more things to his list. One would be to update cost estimates and schedule estimates as risks change over time. We see programs reluctant to do that. And then focusing more on quality management because these workmanship issues come up all the time. There has been efforts to focus on that, but I think more can be done.

Mr. DUMBACHER. Congressman, I would like to add also there's also—there is a need to recognize that you need appropriate skills for the portion of the program lifecycle you are in. So development skills are needed upfront in a development program, operational skills at the end, and we need to make sure that we're working for the right skills at the right time.

Ms. JOHNSON. Thank you very much. Thank you, Mr. Chairman.

Chairman BABIN. Yes, ma'am. Thank you.

I'd like to recognize the gentleman from Oklahoma now, Mr. Lucas.

Mr. LUCAS. Thank you, Mr. Chairman.

And thinking about the questions that my colleagues have had, Mr. Jurczyk, let's discuss for a moment in January of 2018 GAO found that the commercial crew program contractors Boeing and SpaceX experienced additional schedule delays for their demonstration missions and their certification of the vehicles for human spaceflight, and these delays could jeopardize the ability of NASA to maintain access to the International Space Station. Will there be a gap in U.S. access to the International Space Station?

Mr. JURCZYK. No, there will not be a gap in access. We've taken actions and we have other actions we can take to minimize the risk of a gap, so the first action we have taken is to buy three more seats on Soyuz, and that extends the ability to access station by that capability and minimizes the risk of any gap between our Soyuz contracted seats ending and commercial crew coming online.

There's a couple other things that we're looking at. One is adding a third crewmember to the first Boeing crewed flight. That will be important. The other is extending missions from approximately 140 days to 190 days and being able to space the launches—the Soyuz launches out, and these are other actions we can take to further mitigate any risk of a gap.

Mr. LUCAS. But you're confident that the direction the contractors are going, that we won't have to use those measures?

Mr. JURCZYK. We—this summer, we're engaging in an assessment of the schedules for both SpaceX and Boeing, and we'll have a better handle on whether we need to take those initial measures at the end of the summer. We'd be glad to report back to you on that.

Mr. LUCAS. Fair enough. Mr. Chairman, that answers my question. I yield back.

Chairman BABIN. Yes, sir. Thank you.

And now, I'd like to recognize the gentleman from Virginia, Mr. Beyer.

Mr. BEYER. Mr. Chairman, thank you very much, and thank you all for being here.

Ms. Chaplain, you mentioned that it would be helpful to have much more frequent updates of cost and timelines, that these come very sporadically. I know in the family business we update the projections at least once a month. Here in the Federal Government we're getting all kinds of monthly reports on new-home sales and unemployment claims and new jobs created. Why are NASA and the contractors reluctant to update on a regular basis when it would be probably a lot easier to tolerate?

Ms. CHAPLAIN. Yes, it would be easier if they continually did it because then it wouldn't be such a chore to do it after a couple years. But right now, they set the baselines when they really start their program, and they don't revisit. And in some cases I think they don't want to revisit. They don't want to really show to the world like what the cost truly is at that point. But you'd really have to ask the programs. I think it's a healthy thing to do when you see conditions change.

In the James Webb program there were a lot of things that had changed in a few years. The cryocooler, for example, took way longer to manufacture than anticipated. That would have been a good time to reassess where the project stood, but they didn't do it.

Mr. BEYER. This may be one of the things as we move forward is looking at requiring much more frequent updates on both cost and timeline.

Mr. Dumbacher, this may be more of a rhetorical editorial comment, but you write, "The current budgeting process, including the regular use of continuing resolutions, late-year appropriations, threats of government shutdowns, result in endless, multiple planning scenarios." Resolving complex technical issues, hold schedules, and predicting accurate flight dates is difficult when the budget is constantly in flux. Is it then credible to say that Congress plays a role in the problems that NASA has with budget and timeline?

Mr. DUMBACHER. Yes, sir, I would say that.

Mr. BEYER. You don't need to say anymore. But thank you for making that so clear.

Mr. Jurczyk, why not under-promise and overperform? I know that's what my children do with me.

Mr. JURCZYK. Yes. So, you know, our job on—in any given program area is to optimize the portfolio and deliver the most science or exploration missions that we can for the budget given. So we have, you know, taken an approach of having a portfolio of small, medium, and large missions and an approach where we budget these missions at the 70 percent confidence level. We think that balances the risk of projects in formulation and implementation against the opportunity cost of budgeting more than at the 70 percent confidence level and delaying starting new missions. So it's a matter of optimizing the portfolios and delivering the most science and exploration content we can for the budget that we have been given.

Mr. BEYER. I would suggest to you that part of optimizing that is managing the expectations of the people whose expectations you have to——

Mr. JURCZYK. Yes, we can definitely do a better job at managing expectations.

Mr. BEYER. Mr. Martin?

Mr. MARTIN. I think one of the other realistic things is if you under-promise, you're in greater danger of not getting your project started in the first place, of attracting enough excitement and attention to get the project funded. So I think what NASA's problem is often is they overpromise, obviously overpromise the maturity of the technology.

I was struck in the—like a lawyer going over the footnote on page 3 of our written statement, there's a quote from former Administrator Griffin. I think he was current Administrator at that time talking about projects, proponents of individual missions, downplay the technical difficulty and risk, grossly at times, in order to gain new start funds. I think that has been a historic problem for NASA.

Mr. BEYER. You raised two interesting pieces in your testimony, Mr. Martin. One was that there's this culture of optimism that was

too optimistic, and, number two, that we needed far more accountability. But at the same time, the dilemma with the accountability is we also have a shortage of the talent that we need, you know, more than half are over 50 years old, the challenge with getting the STEM kids. How do you ratchet up accountability and not depress, you know, the enthusiasm, the sense of worth? And also how do you dampen out the optimism in an agency that has to be so optimistic?

Mr. MARTIN. It's an incredibly difficult—you're dancing on the edge of a knife when you do that because, as you point out, you have to have that optimism, that freethinking to really think of things that have never been built before, to conceptualize them and then actually put—to start bending metal on them. So it's an incredibly difficult balance.

If it was easy, NASA would be doing it. I mean, it is rocket science after all, and so it is very difficult. And I just think—and, like I said, NASA has brought in a lot of its cost-estimating techniques and its JCLs and other processes—they just need to force adherence to it, to those requirements.

Mr. BEYER. Great. Thank you. Mr. Chair, I'll yield back.

Chairman BABIN. Yes, sir. Thank you.

Now, I'd like to recognize the gentleman from Alabama, Mr. Brooks.

Mr. BROOKS. Thank you, Mr. Chairman.

I am concerned by the perceived transition process away from the current operational format of the International Space Station. There have not been, in my judgment, enough substantive public debate on what this transition involves.

And with that as a backdrop, I have a question directed at Ms. Chaplain, Director, Contracting and National Security Acquisitions, GAO; and NASA Associate Administrator Stephen Jurczyk. First, has NASA come up with a definition of what commercialization of the International Space Station means?

Ms. CHAPLAIN. We have not been doing work in that area, and I don't believe they have yet, but I'll let Steve——

Mr. JURCZYK. Yes, so let me tell you where we are with I would say the more detailed planning of the station transition. So we released a solicitation not too long ago for studies, industry studies on transitioning space station to some sort of collaborative or commercial enterprise. We're getting the proposals back in this week, and we'll evaluate those.

And what we asked for in those studies is the capabilities that commercial thinks they can provide us as compared to what we need and what we have and we need in the future. The second is their technical approach to achieving those capabilities. And then third is their business plan. You know, what is their business plan? Because, although we don't have a rigorous definition, NASA should be a maybe 20, 30 percent user of the capability and other government entities and commercial entities should also use that capability. We should not be the 80 or 90 percent, you know, kind of anchor tenant of a capability. To me—personally to me, it's not—I would not define it as commercial.

So we're going to get those studies back in December, and that will inform a more detailed transition plan. And I think we'd be

ready to come to you all and present that plan and get your feedback and input on it.

Mr. BROOKS. When do you anticipate having that more detailed plan that you can present to us that we have a better understanding of what this commercialization means?

Mr. JURCZYK. Yes, we'll get the results from the studies in December of this year, so we'll probably need some number of months, so probably, you know, first half of next calendar year we'll definitely be able to come back to you and lay that out informed by that—those industry studies and industry input of what looks feasible in the mid-'20s time frame.

Mr. BROOKS. So you would be in a position to answer the question in the first 6 months of 2019? Is that correct?

Mr. JURCZYK. Yes. And I can take a question to get back to you on a more exact date if you'd like.

Mr. BROOKS. All right. Thank you.

Mr. Martin, your audit of commercial resupply services to the International Space Station report dated April 26, 2018, notes that, quote, "SpaceX's average pricing per kilogram will increase approximately 50 percent under CRS–2 while Orbital ATK's average per-kilogram pricing will decrease by roughly 15 percent." The major difference between those contracts is SpaceX's introduction of reusability. SpaceX has noted multiple times that customer should not expect substantial discounts on reused hardware.

My question is this: Are you concerned about whether taxpayers will save money with reusable rockets? And second follow-up question is, is it possible reuse may end up costing NASA and the United States taxpayer more overall?

Mr. MARTIN. Steve could probably answer this more specifically, but I believe there is a slight reduction in the area of 3 to 7 percent for use of a reused SpaceX rocket. I think it's happened once if not twice so far for commercial cargo, so there is a slight reduction.

And am I concerned? I mean, it's a safety issue, and so the launch services people need to assess the specific rocket, and they have access to the rocket, before they authorize them for launch.

Mr. BROOKS. Well, Mr. Jurczyk, since Mr. Martin pointed the finger at you——

Mr. JURCZYK. Yes.

Mr. BROOKS. —with your insight, can you——

Mr. JURCZYK. Yes, I think——

Mr. BROOKS. —share what insights you may have on that question?

Mr. JURCZYK. Yes, I think Mr. Martin is right with respect to the marginal cost reduction, with the introduction of the reusability of the first stage of the Falcon 9, and they're also working towards reusing the fairing and they recently are—announced that they're looking at approach to reuse the upper stage also.

I think as we—as they gain experience and as anybody gains experience operationally with the system and they gain experience with reuse, I think there is opportunity to further reduce the risk and reduce the cost, my understanding what the condition of the hardware is when it comes back and how much effort it takes to recondition it, to re-fly it, so there's opportunity there. I'm not able

to predict what additional savings they might achieve through reuse at this point.

Mr. BROOKS. Is there any chance you could expound on increased risk factor of using a novel approach, i.e., reusable rockets?

Mr. JURCZYK. Yes, we're—like Mr. Martin said, we're—the Launch Services Program is in the process of assessing that risk for all missions, and I can take a question for the record on that to get back with you when that assessment will be done.

Mr. BROOKS. Please. Thank you, Mr. Chairman.

Chairman BABIN. Thank you. I now recognize the gentleman from Pennsylvania, Mr. Lamb.

Mr. LAMB. Thank you, Mr. Chairman.

Everyone, I appreciate you highlighting the difficult position that you're in when it comes to unpredictable funding streams, threats to shut down the government, funding by CRs, that kind of thing. I'm trying to learn a little bit more about how that actually affects you on the ground day-to-day. This is a question for anyone. Can you share some more specific examples of how that might have affected a particular project?

Mr. DUMBACHER. Well, I'll be happy to take that because I lived it for a while. And what happens, Congressman, is when you're working on a program and you're trying to put the plan together for the future and what's my workplan for this year, what's my workplan over a five-year budget horizon? And as I'm working through the appropriations budgeting process, every time I'm—I have to plan to a different number, that means I've got to go back through that planning iteration process.

So at a time when the President's budget request was significantly different from what was typically coming from the appropriations process, it was necessary to—A, to do the plan that was supportive and was inclusive in the President's budget request, and I had to be ready as a program manager that if additional appropriations did come in, I at least had an ability to plan and be able to react to that.

Mr. LAMB. And what type of program were you managing that you're talking about right now?

Mr. DUMBACHER. At the time I was doing this, this was the beginning of the SLS and Orion programs.

Mr. LAMB. Okay. And so that was a program that was supposed to take how long kind of from start to finish?

Mr. DUMBACHER. At the time I was there, we were looking at first launch in the 2017, 2018 time frame, and in the—while I—during my tenure as the Program Director for SLS and Orion, we had to deal with a government shutdown, continual negotiations on both ends of Pennsylvania Avenue, and then in addition to that, while I'm doing all that planning, my—the team's focus is pulled away from the day-to-day management of these technically complex jobs. So we were working through all of that and actually had to deal with a government shutdown and work through that and then all the multiple planning cycles.

Mr. LAMB. Thank you. And, Ms. Chaplain, it seemed like you had something to add.

Ms. CHAPLAIN. I think I've heard very similar things from other agencies that I oversee like Missile Defense, that kind of constant

re-planning and the chaos and time that it consumes. But another real example of like the impact of a shutdown can have is a cryocooler—or cryo test at the end of a program like James Webb, it might take a couple weeks to get the facility ready for this test and then two weeks to cool down, and the shutdown—I think there was a shutdown threat while there were doing that test this time, and they were really worried, like if we had to shut down, we're going to lose a whole month of time.

Mr. LAMB. Okay. Thank you very much.

And, again, a question for really anyone because I think it's pressing, but some of you have highlighted the workforce development issues that you have within NASA, and I think it was Mr. Dumbacher that talked about young people especially leaving NASA for higher-paying jobs in the private sector, which is a challenge obviously across the government. It happens in the military, too. But if there was one reform you could suggest or one thing that we can improve or strengthen to retain some of this talent and to attract new talent, what would it be?

Mr. DUMBACHER. Well, as I stated in my testimony, the one thing I would recommend is good real hardware programs that—to go address those technical needs that we need for space exploration and for the NASA mission but to go give these students, give these young professionals real hands-on hardware experience because that informs their capability and informs their experience throughout their career.

Mr. JURCZYK. Yes, I would just like to second that. The first project I worked on after I got out of college was a spaceflight instrument development project in-house at NASA Langley Research Center, so I was able to design, build, integrate, test all the way through environmental test flight hardware, and that experience was critical throughout my entire career as I moved to a Subsystem Manager and Systems Engineer and Project Manager and then Line Manager. So I would just second that. I—it—without that experience, I don't know how I would have been able to be as effective as I was as I moved through my career at NASA.

Mr. DUMBACHER. And if I may just give you a little bit of a story, too, if you stand back and look at—there are a group of people of which I was one, Robert Lightfoot was one, where we had the ability and we were asked and required by our mentors to actually test shuttle main engines in-house, and we tested the new technology that ultimately became the final flight configuration for shuttle. And that hands-on experience—they—our mentors, our leaders forced us into that because they knew that it fit into the long-term career.

Mr. MARTIN. Just echoing the same thing, we've heard from a number of Project Managers that we've spoke with, their frustrations about their spending—agency engineers are spending most of their time overseeing contractors' effort, and that's frustrating.

Mr. LAMB. Thank you. Thank you, Mr. Chairman.

Chairman BABIN. Yes, sir. Thank you.

I'd like to recognize the gentleman from Louisiana, Mr. Higgins.

Mr. HIGGINS. Thank you, Mr. Chairman. Mr. Chairman, it's uplifting to see these young Americans here today, these NASA interns, and I hope you young men and women are paying attention

to these budget discussions. We are a nation that's $20 trillion in debt. And should this body ever manage to produce a surplus, say, $1 billion, it would require 20,000 years of $1 billion surplus to address a $20 trillion debt.

So I'm prayerful that NASA has a spirit of doing more with less because not only are individual projects at risk, but certainly anyone can recognize that a $20 trillion debt puts the entire stability of all programs at risk in every government agency. I'm very hopeful that you young Americans are paying close attention to this conversation.

Mr. Martin, I'm concerned about the culture of optimism that you referred to and the too-big-to-fail attitude amongst Project Managers. But I understand their perception that their projects are too big to fail because in every case a tremendous amount of American treasure has been invested in that project, and therefore, it's quite logical for these Project Managers to have this cavalier attitude of too big to fail. What can this Committee do, what can Congress do to ensure projects are developed and managed within their budget constraints, including—I'd like your thoughts, sir, regarding accountability for our contractors within these projects.

Mr. MARTIN. Again, I think more frequent conversations with Members of Congress about the status of individual projects is important, more fidelity to the cost estimating that NASA does right now, and then the occasional example that projects large or small are going to be terminated if they go too far over cost and schedule. And in preparation for this hearing, I think the last project that I remember being canceled was something called GEMS. It was a telescope that was supposed to look for evidence of black holes, and it was a smaller program from NASA. It was capped at $105 million. And then partway through formulation, they realized in an independent cost assessment that it was going to be 20 or 30 percent over that $105 million cap, and NASA canceled it. And it got people's attention.

Mr. HIGGINS. Generally speaking, the contractors that are involved in cost overruns for NASA projects, large projects, these are for-profit companies, are they not?

Mr. MARTIN. They are, sir.

Mr. HIGGINS. And has that ever been addressed within the leadership at NASA, that, you know, most Americans, if we receive a bid from a professional contractor to perform a particular service, then we expect that service performed for the price that was bid. And they're held accountable legally by civil law, and there's a certain expectation of performance when you're giving a bid. And yet within the Federal Government and certainly within NASA's large projects there seems to be an attitude of well, we're not really accountable for the actual bid that we presented, and we won't be forced to perform.

Mr. MARTIN. He's NASA leadership.

Mr. JURCZYK. Okay. So, yes, the—most—a lot of the time we're doing things—building—designing and building systems for the first time that no one else has ever built before, and so in those cases we use a cost reimbursement contractor. And the incentives—and we use incentives to hold the contract accountable through a performance evaluation plan. And those incentives are tied to fee,

usually award fee, and that is their profit. So if they do not perform and—they should get a low score against their performance evaluation plan and either receive much less profit or no profit depending on how we weight the incentives in the plan and how they're scored.

So given the high-risk nature and—the nature of what we do, very complex systems, very high-risk with new technology, we take that approach, and then we hold them accountable. And the ultimate price to pay for them if they don't perform is loss of—complete loss of profit.

Mr. HIGGINS. Gentlemen, thank you for your response.

Mr. Chairman, my time has expired. If there's a second round, I have a question for Ms. Chaplain.

Chairman BABIN. Yes, sir. Thank you very much.

Now, the—Mr. Foster.

Mr. FOSTER. Yes. Thank you. And I guess I'd like to start just by making an observation about the—you know, the amount of funding that you can think about having in the next decades. Last week, the Federal Reserve made the historic announcement that household net worth in the United States, the wealth of Americans, just went over $100 trillion. This is up $45 trillion since President Obama signed the stimulus, reversed the economic collapse, and triggers the economic growth that's going on today. So when people tell you there is not enough money to do this or that, the scale for that is what fraction of $100 trillion might we think about, you know, using to travel to Mars or wherever—whatever your dream is.

I also want to say that I resonated—as a former Project Manager and someone doing technical components for large federal projects, I very much resonated with your desire to retain in-house expertise. It is very, very difficult to manage a project if you've never done it yourself. And so when I decided that I had to manage a group doing a large number of integrated circuits, I learned all the integrated circuit design control tools and made integrated circuits myself before I decided that now I could sit at the top and emit specifications for other engineers.

And this is crucial, and we have to look very carefully when we—this rush to privatization runs the risk of losing the in-house expertise that will ultimately cost more money because you'll have projects that are not managed as well as they could be. So I just—we ought to be very cognizant of that as we contemplate this transition.

Now, you know, when I think about cost overruns, you know they're sort of two big general classes. The first ones are in enthusiast cost estimates, you know, in the initial scoping of a project, the initial scoping is always done by people who are advocates for the project, and then you have to get adults in the room with experience to actually pull back and say, okay, how does this compare to actual cost?

The other one is legitimate technical risk. And I would just like to say that I would hope that my colleagues in Congress would be much more tolerant of technical risk. You know, it is okay to take significant technical risk. And if you assemble a group of experts that say success is not assured but this looks like a good bet and

then it turns out you lose the bet, then Congress should be, you know, very understanding and tolerant but much less tolerant when projects are approved when everyone in the room knows the—you know, I don't want to point fingers, but I'm sure in your minds you know several projects that have been approved where a large number of the people knew that you weren't really going to get the project done for that cost. And it's not just NASA. This happens everywhere in the government.

And so I just was wondering, are there ways that you can identify retrospectively the times when you've had enthusiast cost estimates? Are there any sociological red flags that would allow you to say, okay, I'm suspicious that this is not a real cost estimate? Yes.

Ms. CHAPLAIN. I always—I can tell like when I'm suspicious. It's usually when there are very grand statements made about the program and the achievements that it's going to get seem overly exaggerated. And that's when you start wondering, are these estimates real?

What I would say in the case of NASA, I kind of trust the process that they have because they do review those estimates pretty carefully. They have standing review boards that look at them before they make their decisions. They could have more independent estimating to kind of compare. That's one thing. But I do believe that their processes now, as opposed to a few years ago, are pretty rigorous in ensuring those estimates are complete.

I would just add, one thing you said about taking risks, you know, that's—you need to still do that. I think there is a concern within NASA and other places in the government that we're not taking enough technical risk, that we're too afraid to do that.

Mr. FOSTER. Yes, I concur.

Mr. MARTIN. With respect to science missions, NASA relies extensively on the findings of the National Research Council and their decadal surveys that identify specific projects, so I think that's another check as opposed to——

Mr. FOSTER. No, they don't do cost estimates. They're sort of given external estimates is my understanding.

Mr. MARTIN. I think they do cost—they don't do very good cost estimates, but they do cost estimates.

Mr. FOSTER. Yes. That's where you need the expertise and judgment, at that stage. Yes.

Mr. DUMBACHER. And if I may, Congressman, is when I think back on my career and some of the places where I've seen this problem occur the most, one key thing stands out, and that is have the people doing the cost estimate be the ones that will be held accountable for the program execution. I have seen a couple of instances where the people making the initial estimate putting the plan together knew that they were going to be moving on to something else and then they brought the new person and the new person was what's this?

I think if you—if there is an air of accountability and they know that they're ultimately accountable for that cost—for executing to their cost estimate, that starts to get the behavior where I think you want it sociologically.

Mr. FOSTER. Thank you. And it's—well, there's a whole set of questions when you go to an external contractor model, who does the cost estimate and who takes the responsibility in that model?

I guess I'm out of time here.

Mr. BROOKS. [Presiding] Thank you. The Chair recognizes Congressman Dunn from Florida.

Mr. DUNN. Thank you very much, Mr. Chairman. Jump right in here.

Mr. Jurczyk, the Canadian Space Agency last month canceled its participation in WFIRST project for budgetary reasons. In your assessment what will the impact be to the technology development and the cost which results from CSA's decision to pull out of the WFIRST?

Mr. JURCZYK. Yes, so that decision was factored into the projects re-planning after the independent review of WFIRST and was factored into the plan they brought forward to move from phase A to phase B. So they've been able to adjust scope and adjust their cost and schedule estimates to stay within the $3.2 billion and still without the Canadian contribution, so that——

Mr. DUNN. How does that affect the technology development?

Mr. JURCZYK. I don't think it significantly affects the technology development. I think that the project has a really good plan to early on develop prototype hardware——

Mr. DUNN. All right.

Mr. JURCZYK. —to reduce the risk of that element, as well as other elements of high risk——

Mr. DUNN. How about the mission itself? Does the capability—the mission goals, do they change because——

Mr. JURCZYK. No. No, the level-one science goals do not change, and they will meet the requirements of the mission as defined in the NRC decadal survey for astrophysics.

Mr. DUNN. That's great news. So the '18 omnibus bill required a lifecycle cost estimate by May 22. That's behind us. When will that be submitted to Congress?

Mr. JURCZYK. We will get you that within the next couple of weeks. It's been done, and they're just wrapping up the documentation, and it will be here hopefully within the next 2 or so weeks. That's our plan.

Mr. DUNN. Great. So many people here on the panel have called the assessment—many assessments, that you need stable, predictable funding to plan. So let's close our eyes just for a minute and imagine that Congress might provide multiyear funding authority. It's a pleasant fiction, I know, but let's imagine that. In that scenario, how would that—how would this authority change your planning for your programs?

Mr. JURCZYK. Well, I think it would allow us to only plan once and execute to that plan and deal with the challenges that Mr. Dumbacher had articulated before.

The one example that we have of getting multiyear funding was OV–105, which is the replacement orbiter after the Challenger accident where Congress appropriated multiyear funding for that project. And they were very successful in executing on schedule and on budget with the profile that ramped up, peaked, and ramped down like any project—rational project plan should, and having the

money—the adequate money when they needed it, so that's just an example of what you're talking about.

Mr. DUNN. So that might actually be good for a lot of different agencies in the government?

Mr. JURCZYK. For any large complex program that's going to take multiple years to execute, I would think so.

Mr. DUNN. I'm thinking Ms. Chaplain would love that, right?

So let me—in our limited time, so again for—well, actually, Mr. Jurczyk, you may be under constraints, unable to answer this. I think we're all disappointed that the James Webb Space Telescope cost overruns missed—and missed deadlines. What programmatic changes would you make to that program to prevent that in light of that failure? Can you answer that?

Mr. JURCZYK. I can tell you what we have done——

Mr. DUNN. Okay, good.

Mr. JURCZYK. —to date, and so the first is a series of actions that we worked on with Northrup Grumman. So, first of all, we completely restructured the I&T organization in Northrup to flatten it and be able to more clearly hold people accountable for getting through the integration and test program. That also has allowed them to identify and resolve issues in a more timely manner to minimize the impact of those issues.

We've also added staffing to the I&T team out at Northrup, and we've really strengthened the mission assurance function and personnel out there to deal with some of the workmanship and quality issues that were mentioned by Ms. Chaplain and others to try to avoid these human errors that have caused schedule delays. Like was mentioned, a small error or problem has a very large effect on a program like JWST.

Mr. DUNN. I can well imagine. In the 30 seconds remaining, Mr. Martin, do you have anything to add to Mr. Jurczyk's comments on that?

Mr. MARTIN. Yes, we have not done significant oversight of JWST. Congress directed——

Mr. DUNN. How about you, Ms. Chaplain?

Ms. CHAPLAIN. Yes, I believe the actions they've taken have been reasonable. I would note they were—already had some onsite presence over at NGAS, but we'll be looking to see how effective those actions are as we do our next review.

Mr. DUNN. Well, here's wishing you multiyear funding authority. And with that, Mr. Chairman, I yield back.

Mr. BROOKS. The gentleman yields back.

The Chair recognizes Representative Lofgren from California.

Ms. LOFGREN. Thank you, Mr. Chairman. I think this is an important hearing, and most of the questions have been asked, but I would like to think about what further Congress could do in addition to avoiding the kind of situations Mr. Lamb addressed, the shutdowns issue, the inconsistency between the President's requested budget and what's appropriated that lends uncertainty to the planning process. What could Congress do to limit the uncertainty in funding other than those two issues? The idea of a multiyear funding program for large projects is valuable, but can you give us further guidance to stem losses through our own actions?

Ms. CHAPLAIN. I'd—I'll start. I would say avoid over-specifying what your expectations are, avoid setting dates for a program, avoid choosing, you know, how they're going to do it because that limits their choices even more in what they can do.

Mr. JURCZYK. Yes, I would just echo that. We seem to be getting more and more direction through the appropriations process, particularly through the report, and we're—the expectation is we will follow that direction. And that constrains the solution space and our ability to manage effectively sometimes, so I'd say just to echo what Ms. Chaplain said. I think that's one additional thing I could think of.

Mr. MARTIN. With respect to the funding issues, not only the actual dollar amount, it's when that dollar amount comes, the proper phasing——

Ms. LOFGREN. Right.

Mr. MARTIN. —of the appropriation has impacted NASA programs.

Mr. DUMBACHER. I would add work to make sure that the environment in which we have these discussions is less punitive and more objective and more willing to hear the risks and understand the issues. I think we have to be careful that a lot of the—that we can be—you've inadvertently set up a vicious cycle of oversight leads to conservativism leads to more oversight, and it just keeps going around in a circle. And I think what Congress can do and this Subcommittee can do because of its oversight activities is to help establish an environment that allows more open communication on these kinds of issues.

Ms. LOFGREN. Well, I think the point that Mr. Foster made all scientists know, which is failure is a learning experience. I mean, science is testing and not knowing the answer before you start. And we need to foster that sense of discovery and willingness to take risks if we're going to be successful.

Let me just close with sort of a parochial question. I represent part of Santa Clara County. NASA Ames is located in Santa Clara County. And thinking about the demographic issues we face in NASA with so much of the workforce being over 50 years of age, the NASA Ames facility is located in a key part of the country. It's in Silicon Valley, and there's a lot of synergy between what's going on in the tech community and NASA Ames. And although it's very expensive to live in Santa Clara County, actually, they just built some housing for NASA employees so that it's possible to maintain their—that synergy.

I'm just wondering in terms of that facility as well as others that are co-located with technology centers, what further we can do to move top scientists away from really better-paying jobs into the agency to make young people who are smart and who are good scientists want to work in NASA? If anybody has an answer to that.

Mr. DUMBACHER. I'll take a try at it. I think what the young people want now is similar to what the young people wanted when I got out of school. They want exciting work, they want to know that they have an opportunity to make a difference, and they want to help solve today and future problems. And I think providing those and then in addition to the infrastructure kind of options that you have described would be extremely beneficial.

I think they want to—from my experience teaching at Purdue for a few years is if you hit those first three bullet, then the students will come. That's why they go to SpaceX and Blue Origin. They see exciting work. That's why they still want to come to NASA because NASA still has that cachet that it's always had. So exciting work, help make a difference, and do something quick, and I think you'll be a long way down the road.

Ms. LOFGREN. Thank you very much. I see my time is expired, Mr. Chairman, so I yield back.

Mr. BROOKS. Thank you for your questions and participation.

The Chair next recognizes Representative Rohrabacher of California.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. I apologize for being late to the hearing. Obviously, two important hearings have to happen at exactly the same time, which perhaps leads me to the first point, which is we need to make sure we hold NASA accountable, but I have to assume that the Congress isn't doing its job all that well either. And when we're talking about continuing resolutions and omnibus bills, I mean, that's a reflection on the fact that we aren't doing our job here as well. So please don't think if there's any criticism here coming from this end that we don't realize—or at least some of us don't realize that there is justified criticism of the way Congress is doing its job.

Let me ask a couple of questions here about these cost overruns and—that seem to be around. They've been around as long as I've been around. And let me ask you this. Is a lot of this intentional low bidding on the part of companies in order to achieve a contract? Is this part of that? And to whoever can answer that question.

Mr. JURCZYK. You know, we have a pretty rigorous request for proposal and proposal evaluation process, including independent cost and schedule estimates by the government to ensure that what's being proposed is actually executable. What's being proposed in that contract is executable.

Mr. ROHRABACHER. So it's not to say you don't see this as a scheme by some big corporation to intentionally bid low, get the contract, and then realize we're going to have to pay for it later on?

Mr. JURCZYK. I do not.

Mr. ROHRABACHER. Okay. Anybody believe that at all? Good. Thank you. That helps our understanding of this.

And a lot of these companies that do have the cost overruns are companies that are worth billions and billions of dollars themselves. If—what penalty does a company have that goes through a major cost overrun and doesn't meet its commitments through a contract? What's the punishment?

Ms. CHAPLAIN. So, as we discussed earlier, you can take actions to punish companies just through award and incentive fees, but often, they're tied to multiple objectives so you're limited in terms of what you can do. So the ultimate thing is just to cancel a program if you really feel like——

Mr. ROHRABACHER. Well, what about the next program? Can a company that did not meet its contract be denied the next contract or a contract down the road because they have not met their obligation?

Ms. CHAPLAIN. Yes, I think that's possible. And the proposal that's in your bill about a contractor watchlist, they could go on that list if they're not performing well and that NASA will not deal with them in the future for a period of time. That is one option. I didn't know if you want to comment.

Mr. ROHRABACHER. Yes, maybe you could expand on that for me.

Mr. JURCZYK. Yes, so what we do now—first of all, we have a very robust acquisition integrity program within the agency that's run by our Office of Procurement and our Office of the General Counsel and so, you know, they, along with the programs, look at contract performance and we'll use the FAR process for suspension and debarment for lack of performance or for waste and abuse, you know, so we use the existing process.

The other thing we do is we have the contractor performance assessment reporting system, so when we evaluate a contractor on a regular basis, that assessment goes into that system, as well as the assessments of all of the departments and agencies within the Federal Government, and then not only NASA but other departments and agencies can draw on that to use in assessing past performance of the contract to determine whether to award them anything in the future.

Mr. ROHRABACHER. Well, it seems to me that we have to be much more diligent on—in that area and—if—unless we have accountability and responsibility for these things, we can expect to have more problems. And I have to assume that we did not have the amount of discipline in our system and the accountability that will deter companies—perhaps maybe companies that make bids should be held responsibility for that bid, meaning that the money that's lost perhaps should be absorbed by the company. As I say, these are multibillion-dollar companies, and if they're going to be taking the taxpayer money and failing in what they're claiming to do, why should the taxpayer pick it up?

We have—we just mentioned a—we have $20 trillion debt, and the gentleman mentioned how that is—if there's anything that's going to keep us from going into space, it's going to be the total disintegration of our economic system so that we can't afford any of this stuff.

I would—also, let me just note that we're also going to have to—we have a $20 billion budget for NASA, $20 billion. We should be able to do a lot with $20 billion. And let me just note that when I first got involved that I realized that the budget wasn't enough to accomplish the missions, and that's why I dramatically—I tried to focus totally on international cooperation and private sector investment. So let's hope that we—that's one avenue of making more revenue come in, but we also have to make sure we pay attention to what this hearing is all about is making sure that we're managing the actual projects themselves in a way to minimize the loss of very scarce dollars.

So thank you very much, Mr. Chairman.

Mr. BROOKS. Certainly. The Chair thanks the gentleman for his participation.

We're nearing the noon hour and we're going to finish by noon, but from what I understand, there may be a member who wishes to ask a second set of questions, and as long as we are able to do

so within that time frame, the Chair is most comfortable in doing so.

Mr. Higgins, did you want to do follow-up?

Mr. HIGGINS. Thank you, Mr. Chairman. I have one question.

Mr. BROOKS. Well, one second. The Chair recognizes Representative Higgins of Louisiana for that follow-up.

Mr. HIGGINS. Thank you, Mr. Chairman, for recognizing me and allowing me to ask one question to Ms. Chaplain.

Ms. Chaplain, NASA has received multiple recommendations on ways to better develop cost and schedule estimates, as well as perform joint cost and schedule confidence level analysis during the beginning stages of the implementation phase of large projects. In December 2012, it was recommended that the JWST project update its JCL. According to the report, NASA concurred with this recommendation, and yet no steps were taken to implement it. Further analysis indicates that, if implemented, an updated JCL may have prevented schedule delays.

Among the many known and unknown challenges that NASA encounters regarding cost and schedule continuity, can you elaborate on why this recommendation was purposefully overlooked?

Ms. CHAPLAIN. At the time they did concur, as you said, so I didn't ever have an official reason why it was overlooked. I think they just were reluctant to relook at their costs. A couple years later, we recommended that they at least do something similar to do a cost schedule risk analysis and really take a deep look at their risks, and we even were going to do that ourselves, working with the contractor, but that was rejected by the contractor. And then it wasn't until they were getting ready to work with the launch agency on setting the date that they actually did a schedule risk analysis themselves and realized how far behind they really were.

Mr. HIGGINS. Ms. Chaplain, thank you for your candid answer.

Mr. Chairman, thank you for allowing me to ask a second question.

Mr. BROOKS. Certainly.

Any other member wish to ask any other follow-up questions?

Seeing none, I thank the witnesses for their valuable testimony and the Members for their questions. The record will remain open for two weeks for additional comments and written questions from Members.

This hearing is adjourned.

[Whereupon, at 11:57 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ms. Cristina Chaplain

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Ms. Cristina Chaplain, Director, Contracting and National Security Acquisitions, U.S. Government Accountability Office

Questions submitted by Ranking Member Ami Bera, House Committee on Science, Space, and Technology

1. Are there any similarities with cost growth and schedule delays experienced by the Department of Defense and other federal agencies in their acquisition of space systems? How has DOD dealt with changing design requirements, such as those caused by shifting Administration priorities, and how effective have DOD's actions been?

   Answer: While the purpose and characteristics of the Department of Defense's (DOD) and National Aeronautics and Space Administration's (NASA) space programs are often different, both agencies have struggled with cost growth and schedule delays on their programs. One primary reason that both DOD and NASA have experienced challenges has been the absence of a solid match between the system's requirements and the resources available to develop and potentially produce the system—mature technologies, time, funding, and management capacity—at the start of space development programs. In recent years, both agencies have sought to reduce acquisition risk and even cooperated in some efforts to do so, such as improving cost estimating for space systems and being better able to anticipate and mitigate parts quality problems. At this time, cost and schedule growth for space programs appear to be more pronounced at DOD. For example, DOD has four major satellite programs in production. Their cost growth ranges from 36 to 258 percent and their schedule growth ranges from 3.7 years to nearly nine years.

   There are some factors that make it difficult to directly compare NASA with DOD or other agencies. For example, most NASA projects are comprised of a single spacecraft while most DOD projects are comprised of multiple satellites. The DOD projects, as a result, tend to span many more years in acquisition than NASA's projects. Three of the four satellite programs mentioned above, in fact, started more than a decade ago and most of their cost and schedule growth occurred during product development and before reforms were instituted, including from the 2009 Weapon Systems Acquisition Reform Act that Congress passed to improve the organization and procedures of the Department

of Defense for the acquisition of major weapons systems, among other things.[1] Most NASA projects tend to be considerably smaller than DOD projects and they tend to focus on a specific line of scientific research. DOD projects, by contrast, usually need to meet requirements of multiple agencies and missions, including those of civil and intelligence agencies. DOD currently has a fairly stringent requirements setting process that has helped to minimize top-level requirements churn on its major weapon systems. But that process is also increasingly viewed as cumbersome and time consuming.

2. GAO has found that contractor performance is a key contributor to many of the instances of cost growth and schedule delay. The identification of contractor performance as a key contributor begs the question as to the sufficiency of NASA's oversight of its contractors.

    a. What are your observations on the level of contractor oversight exercised by NASA?

    b. In your opinion, is NASA doing enough upfront thinking and communication about the project and its requirements in order to clearly lay out to the contractor what work needs to be accomplished and the resources available to get there?

Answer: NASA has taken steps in the past to improve contractor oversight, but we continue to see instances of poor contractor performance in our work that highlight the importance of NASA continuing to improve in this area. For example, in May 2018[2] we found that:

- The Space Network Ground Segment Sustainment project exceeded its original cost baseline by at least $461.2 million and had been delayed by at least 48 months, even as the scope decreased. The SGSS project attributes most of its cost and schedule growth to the contractor underestimating the scope of the development effort. Project officials stated the contractor did not fully understand the requirements, technical planning was inadequate, and the contractor's planning did not account for resolving software defects. In response to the issues the project has faced, the SGSS project has taken some actions to try to address contractor performance problems, such as working with the contractor to develop new, more reliable cost and schedule estimates both for 2017 and beyond. NASA plans to conduct an independent review of the project in mid-2018 to inform a decision on whether to continue the project past the operational readiness review.

[1]See Weapons Systems Acquisition Reform Act of 2009, Pub. L. No. 111-23 (May 22, 2009). The Act has been modified numerous times over the years. See, e.g., Ike Skelton National Defense Authorization Act for Fiscal Year 2011, Pub. L. No. 111-383 §813 (Jan. 7, 2011); National Defense Authorization Act for Fiscal Year 2012, Pub. L. No. 112-81 §819 (Dec. 31, 2011).
[2]GAO, *NASA: Assessments of Major Projects*, GAO-18-280SP (Washington, D.C.: May 1, 2018).

- NASA canceled the RBI project because, according to NASA's cancellation memorandum, the project experienced continued cost growth, technical issues, and poor contractor performance. The project identified the following specific issues that contributed to poor project cost and schedule performance: schedule planning that did not realistically account for contractor past performance, insufficient oversight of the contractor and its subcontractors, and poor integration of government and contractor teams with limited transparency concerning risks and issues.

NASA has done a better job of establishing a business case for its projects in recent years, but the agency could improve in assessing contractor capabilities prior to awarding contracts. With respect to establishing better business cases, since 2015, we have observed that NASA has continued its trend of higher numbers of projects maturing technologies prior to preliminary design review.[3] Demonstrating that technologies will work as intended in a relevant environment serves as a fundamental element of a sound business case, and projects falling short of this standard often experience subsequent technical problems.

In addition, we found in May 2018 that nine of the 17 projects in development experienced cost or schedule growth.[4] As a result of this growth, expensive projects are going to remain in the portfolio longer than expected. We also found that NASA is likely to encounter additional cost growth and schedule delays for projects in the portfolio. Because the cost growth experienced on current projects will limit the remaining wedge of funding available for new projects, NASA will need to take additional steps to ensure that projects are affordable before committing to them. This includes better assessing the resources needed to complete a project and then ensuring that the agency has those resources available in the years the project would need them.

3. It is not surprising that teams want to put their best foot forward while being faced with the competitive pressure of initiating a mission at the lowest cost. Unfortunately, in some cases, content or complexity is often underestimated. How can NASA incentivize its teams to be realistic in identifying both their requirements and resource needs?

   Answer: We have found in recent years that NASA's leadership was focused on improving acquisition outcomes and had taken some steps to improve its management. This includes requiring that NASA major programs and projects develop a joint cost and

[3]GAO-18-280SP.

[4]GAO-18-280SP.

schedule confidence level prior to project confirmation in order to ensure that cost and schedule estimates were realistic and projects thoroughly planned for anticipated risks. We believe that many of these steps NASA has taken contributed to the largely positive trend of cost and schedule performance for NASA's portfolio of major projects between 2013 and 2017.

However, the deterioration of the cost and schedule performance of NASA's portfolio identified in our May 2018 assessment of NASA major projects means that expensive projects are going to remain in the portfolio longer than expected and NASA will have to find a way to absorb this growth.[5] Further, we found that NASA is likely to encounter additional cost growth and schedule delays for projects currently in the portfolio. This means that NASA may not be able to start as many projects and will need to add additional scrutiny to new project proposals to assure that they have a good understanding of resources needed to meet mission requirements.

In our February 2017 high risk update, we found that NASA needed to do more with respect to anticipating and mitigating risks—especially with regard to large programs, estimating and forecasting costs for its largest projects, and implementing management tools.[6] We highlighted several actions that would be critical to improving NASA's acquisition outcomes, including 1) ensuring that NASA conducted adequate and ongoing assessments of risks for larger programs because the impacts of any potential miscalculations will be felt across NASA's portfolio and 2) ensuring that program offices regularly and consistently updated their joint cost and schedule confidence levels across the portfolio. An updated project joint cost and schedule confidence level would provide both project and agency management with data on relevant risks that can guide project decisions. These actions are especially important because projects that encounter cost and schedule growth may have an incentive to not disclose problems early or the full extent of a problem for fear of being canceled.

Our broader program management best practice reports have found that organizations can create positive incentives for producing realistic estimates and requirements.[7] To ensure there is a good foundation for starting new programs, leading organizations will conduct high-level strategic planning and investment decisions and concerted efforts to make sure that any new initiative the company undertook is achievable within the time and money

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[5]GAO-18-280SP.

[6]GAO, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others,* GAO-17-317 (Washington, D.C.: Feb. 15, 2017).

[7]GAO, *Best Practices: Better Support of Weapon System Program Managers Needed to Improve Outcomes,* GAO-06-110 (Washington, D.C.: Nov. 30, 2005).

and other resources the company had available. Technology development and program advocacy are also generally kept out of a program manager's domain. Once new efforts get off the ground, program managers are empowered to manage resources, encouraged to bring up problems and propose solutions, and consult with senior leaders without fear of losing their support. At the same time, however, they are expected to base their decisions on hard data and to ensure the right knowledge is in-hand before proceeding into the next phases of development. They are also held accountable for their choices, though companies generally find that with good pre-program decisions, a good launch, a sound, disciplined process for execution, and continued support, there is little need to punish or remove their program managers. Ultimately, as long as a program manager can deliver the right product at the right time for the right cost, he or she is incentivized to do so without interference from above. Recognizing that government programs face a variety of barriers in creating such an environment, we have recommended that agencies complement their improvement efforts with more strategic planning, portfolio management, program manager support, and accountability.

4. GAO has reviewed the use of award fees at several federal agencies, including NASA. Has NASA's use of the award fee tool instilled better contractor performance? What are some examples where that was the case?

   Answer: The last time we conducted a comprehensive review of NASA's use of award fees was in January 2007.[8] In this report, we made three recommendations to increase the likelihood that the award fees NASA pays incentivize high performance from its suppliers:

   - Reemphasize to the NASA centers the importance of tying award-fee criteria to desired outcomes and limiting the number of subfactors used in evaluations;

   - Direct the centers to consider costs and benefits in choosing this contract type by requiring documentation explaining how the perceived benefits will offset the additional cost associated with its administration as required by the Federal Acquisition Regulation;

   - Require the development of metrics for measuring the effectiveness of award fees, establish a system for collecting data on the use of award-fee contracts, and regularly examine the effectiveness of award fees in achieving desired acquisition outcomes.

[8]GAO, *NASA Procurement: Use of Award Fees for Achieving Program Outcomes Should Be Improved,* GAO-07-58 (Washington, D.C.: Jan. 17, 2007).

NASA concurred with all three recommendations and took steps to implement them, including reemphasizing its award fee guidance to the centers through letters and training; revising NASA's Federal Acquisition Regulation supplement to require written documentation of the cost benefit analysis; and establishing a regular review to monitor program and project performance and to identify the root cause factors for performance issues.

We have also reviewed NASA's use of award fees for the James Webb Space Telescope in December 2014 and December 2015:

- In December 2014, we found that the project used NASA's award fee structure to implement incentives that align with cost and schedule priorities and contractors have been responsive to these incentives, but the evaluation criteria were not specified for the final evaluation of total contract performance in the project's performance evaluation plans.[9] In order to ensure JWST's award fee contracts' final evaluations thoroughly and fairly evaluate contractor performance over the life of the contract and to provide clarity to the process that will be used for the final evaluation, we recommended that the NASA Administrator direct JWST project officials, in conjunction with the performance evaluation board for JWST and the Goddard Space Flight Center fee determining official, to modify performance evaluation plans for its award fee contracts to ensure they (a) specify evaluation criteria that reflects total contract performance in advance of the final evaluation, and (b) clearly describe the process the performance evaluation board and fee determining official will use to evaluate contractor performance in the final evaluation. NASA concurred with the recommendation and revised the performance evaluation plans for its two major contractors.

- In December 2015, we found that although project officials evaluated workforce management as part of NASA's appraisal of Northrop Grumman's performance in its award fee determinations to incentivize the contractor to lower its workforce, the award fee the contractor has received was not reduced as a result of workforce size issues because it had worked within its budget in fiscal years 2014 and 2015.[10]

[9]GAO, *James Webb Space Telescope: Project Facing Increased Schedule Risk with Significant Work Remaining*, GAO-15-100 (Washington, D.C.: Dec. 15, 2014).

[10]GAO, *James Webb Space Telescope: Project on Track but May Benefit from Improved Contractor Data to Better Understand Costs*, GAO-16-112 (Washington, D.C.: Dec. 17, 2015).

In June 2017, we also reviewed the use of on-orbit incentives—incentives based on successful performance in space—for satellites developed by DOD, NASA, and the Department of Commerce's National Oceanic and Atmospheric Administration.[11] Program officials said that award fee determinations can be effective in changing contractor behavior. For example, one NASA program official stated that during a particular award fee period, they informed the contractor that it needed to address planning for a complicated spacecraft thermal vacuum test that was behind schedule. The official said that after program officials documented their concerns in award fee letters, contractor performance improved, resolving the issue.

5. Technology changes at a rapid pace and often leads to new concepts for NASA missions and spacecraft operations. Yet, current cost models used to develop cost estimates rely heavily on historical experience. To what extent are cost and schedule models keeping pace with new concepts?

   Answer: We have not conducted a review to determine the extent to which NASA's cost and schedule models are keeping pace with new concepts. However, in March 2012, we found that the Joint Space Cost Council, of which NASA is a part, was actively working to improve cost credibility and realism in estimates, budgets, schedules, data, proposals, and program execution.[12] The organizations on the council have worked together with the goal of developing and enhancing cost methods. For example, at that time, one initiative developed a standard work breakdown structure that was being vetted through industry and government. In addition, NASA holds an annual symposium on cost estimating and scheduling that brings together the experts in the cost and scheduling communities within NASA and externally, including industry and other federal agencies, to share information on improving cost estimating and scheduling.

6. Do other federal agencies use cost and schedule reserves in their development activities? What has been their experience? Are there any best practices NASA can apply?

   Answer: GAO's Cost Estimating and Assessment Guide states that developing a good cost estimate requires stable program requirements, access to detailed documentation and historical data, well-trained and experienced cost analysts, a risk and uncertainty analysis, the identification of a range of confidence levels, and adequate contingency and

[11]GAO, *Satellite Acquisitions: Agencies May Recover a Limited Portion of Contract Value When Satellites Fail*, GAO-17-490 (Washington, D.C.: June 9, 2017).

[12]GAO, *Space Acquisitions: DOD Faces Challenges in Fully Realizing Benefits of Satellite Acquisition Improvements*, GAO-12-563T (Washington, D.C.: Mar. 21, 2018). The council was formed in 2007 with membership across industry and military and civil government agencies, including DOD, National Reconnaissance Office, United States Air Force, Aerospace Industries Association, and NASA.

management reserves as defined in the guide.[13] The cost guide also states that while no specific confidence level is considered a best practice, experts agreed that program cost estimates should be budgeted to at least the 50 percent confidence level, but budgeting to a higher level (for example, 70 percent to 80 percent, or the mean) is now common practice. Moreover, the experts stressed that contingency reserves are necessary to cover increased costs resulting from unexpected design complexity, incomplete requirements, technology uncertainty, and industrial base concerns, to name a few uncertainties that can affect programs.

We have not conducted a government-wide review of how agencies use cost or schedule reserves for development activities. Other federal agencies, including DOD, the Department of Homeland Security (DHS), and the Department of Energy (DOE), use cost and schedule reserves, but not always consistently.

- At DOD, programs and contractors may or may not hold cost and schedule reserves. In our 2017 review of the Amphibious Combat Vehicle's cost estimate, program officials told us that they interviewed subject matter experts to develop risk inputs for their cost estimate and then added a 30 percent contingency to those figures because a DOD risk and uncertainty handbook suggests that subject matter experts typically capture only 70 percent of risk due to optimism.[14] Conversely, in June 2017 we found that the second Ford-Class Aircraft Carrier (CVN 79) program's budget is set at a confidence level well below typical risk-adjusted funding levels based on GAO's best practices and Navy guidance.[15] As a result, the current budget for CVN 79 construction is unlikely to cover the program costs even if there are no issues or schedule delays, and therefore leaves no margin for program risk or uncertainty. In addition, DOD contractors may hold some management reserve. DOD's earned value management guidance states that an allowance is made for a portion of the contract budget base to be withheld outside of the performance measurement baseline for internal management control purposes.[16] Management reserve is intended to provide the contractor with a budget to manage risk—

[13]GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: Mar. 2, 2009).

[14]GAO, *Amphibious Combat Vehicle Acquisition: Cost Estimate Meets Best Practices, but Concurrency between Testing and Production Increases Risk*, GAO-17-402 (Washington, D.C.: Apr. 2017) and Department of Defense and National Aeronautics and Space Administration, *Joint Agency Cost Schedule Risk and Uncertainty Handbook*, Mar. 12, 2014.

[15]GAO, *Ford-Class Aircraft Carrier: Follow-On Ships Need More Frequent and Accurate Cost Estimates to Avoid Pitfalls of Lead Ship*, GAO-17-575 (Washington, D.C.: June 13, 2017).

[16]*Department of Defense Earned Value Management System Interpretation Guide*, Feb, 1, 2018.

including to react to unforeseen situations that arise during the life of a program—within the established contract scope.

- At DHS, programs also may or may not hold cost and schedule reserves. Program acquisition cost and schedule baselines are defined in terms of an objective and minimum threshold value, and programs are measured against the threshold value. According to the DHS acquisition policy on establishing cost parameters, qualifying major acquisition programs that are funded at the objective level below the 50 percent confidence level require program rationale and justification, and the threshold value is to be set no more than 15 percent above the objective cost parameter. The DHS acquisition policy on establishing schedule parameters states that threshold values exceeding the objective value by more than three months for qualifying major acquisition programs lasting less than three years between the first acquisition decision event and full operational capability—and threshold values exceeding the objective value by more than six months for qualifying major acquisition programs lasting more than three years between the first acquisition decision event and full operational capability—require rationale and justification by the program. We plan to look at cost and schedule reserve use at DHS in a future review.

- At DOE, capital asset projects, such as construction projects, are to include contingencies in the performance baseline. In addition, for capital asset projects, the contractor may hold management reserve to address risks. However, a November 2014 DOE Contract and Project Management Working Group report on improving project management states that based on its observations of previous and ongoing DOE projects, underestimating contingency and planning problems have been and continue to be an issue.[17] For nuclear waste disposal operations activities, contingency funding is not included in the project's baseline. In August 2016, we reviewed one nuclear waste disposal operations activity—DOE's Waste Isolation Pilot Plant project. We found that DOE did not follow all best practices for developing the cost and schedule estimates for restarting waste disposal operations at the plant.[18] In particular, the project's schedule did not include extra time, or contingency, to account for known project risks.

[17]U.S. Department of Energy Contract and Project Management Working Group, *Improving Project Management*, Nov. 2014.

[18]GAO, *Nuclear Waste: Waste Isolation Pilot Plant Recovery Demonstrates Cost and Schedule Requirements Needed for DOE Cleanup Operations,* GAO-16-608 (Washington, D.C.: Aug. 4, 2016).

7. At the hearing, reference was made to the "watch list" provision included in the Majority's H.R. 5503, the National Aeronautics and Space Administration Authorization Act of 2018. Will the watch list provide NASA the ability to restrict contractors beyond what is already available in the Federal Acquisition Regulation (FAR)?

   Answer: Federal agencies currently have a number of tools they can use to deal with poor performing contractors. Some of these tools are:

   - Agencies are generally required under Part 42 of the Federal Acquisition Regulation to evaluate the performance of their contractors and to enter their assessments into the Contractor Performance Assessment Reporting System (CPARS).

   - Agencies generally must use this information, which is available to them through the Past Performance Information Retrieval System (PPIRS), in conducting evaluations leading to the award of new contracts. FAR § 15.304 generally requires that past performance be an evaluation factor for all negotiated contracts.

   - Before awarding any new contract, agencies generally must determine that the prospective contractor is responsible, meaning that the contractor has the resources needed to perform the contract and has a satisfactory performance record, among other things.

   - Agencies faced with poorly performing contractors may completely or partially terminate contracts for default under Subpart FAR 49.4.

   - Agencies may suspend or debar contractors as appropriate. Debarment may last for up to three years under Subpart FAR 9.4. The names of suspended or debarred contractors are listed in a database maintained by the General Services Administration. Such contractors are generally ineligible for the award of new contracts.

   In prior work, we have found that use of systems that track contractor performance can serve as a motivating factor for contractors. For example, in our review of satellite contract incentives, program officials we interviewed stated that contractors react strongly to negative performance evaluations, as this could affect their ability to win future contracts.[19]

[19]GAO-17-490.

Responses by Mr. Steve Jurczyk

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Stephen Jurczyk, Associate Administrator, NASA

Questions submitted by Chairman Brian Babin, House Committee on Science, Space, and Technology

1. During Rep. Dunn's questioning during the hearing, you stated that you would provide the Wide Field Infrared Survey Telescope (WFIRST) cost estimate in the next couple of weeks. You also stated that NASA has been able to adjust scope, cost, and schedule estimates to stay within $3.2 billion.

    a. Regarding the WFIRST mission scope review, what originally planned scientific instrument and spacecraft bus capabilities will no longer be included in order to stay within $3.2 billion?

    Answer: The 2019 Budget proposes to terminate the WFIRST mission given its significant cost and higher priorities within NASA. If the mission continues to be funded, $3.2B is the target cost estimate for the Science Mission Directorate's (SMD's) contribution to the mission's estimated lifecycle cost, at a 50 percent confidence level. This cost estimate includes SMD's contribution to the associated coronagraph technology demonstration, but not what the Space Technology Mission Directorate would have contributed to the project.

    A high level summary of the rescopes taken to reduce the estimated cost to SMD of WFIRST to $3.2B includes:

    - Changes in the Widefield Instrument (WFI) requirements to reduce cost and cost risk, including (i) specifying performance at the focal plane level, rather than at the individual detector level, which reduces cost by decreasing the time required to manufacture a full set of flight detectors; (ii) utilizing WFI radiator thermal margin to decrease focal plane operating temperature from 100K to 95K, which reduces noise, thereby increasing detector yield and reducing cost; and (iii) descoping the interface for a contributed integral field channel (IFC), which reduces cost, given that the Canadian Space Agency was not able to make a commitment in a timely manner.
    - Changes in the Coronagraph Instrument (CGI) resulting from treating it as a technology demonstration instrument to reduce cost and cost risk, including (i) removing all mission-level CGI science requirements; (ii) relaxing mission-level CGI performance requirements to ensure healthy performance margins, informed by laboratory testing to date; (iii) reducing the coronagraph science team to level needed for technology demonstration

support; (iv) replacing the CGI science operations center pipeline with a coronagraph data analysis team to meet technology demonstration requirements; (v) eliminating CGI general observer program and replaced it with a participating scientist program; (vi) eliminating several coronagraph modes which reduce the schedule by an estimated 10 weeks; (vii) deleting two mask orientations, two observing modes, and two spectral bands; (viii) reducing CGI operations to that necessary to demonstrate technology, i.e. from 12 months to 3 months; and (ix) assuming contributions of CGI hardware from international partners.

- Consolidations in the science operations center to reduce cost, including (i) reduced funding for science teams; (ii) only developing observing modes required by the dark energy and exoplanet surveys; (iii) reductions in widefield instrument science operations capability; (iv) consolidation of science center operations from Goddard Space Flight Center to Space Telescope Science Institute; and (v) assuming contribution of a pipeline from an international partner.
- Engineering trades have been made that reduce costs without significant reductions in science, including (i) payload integration flow changed to eliminate need for second instrument carrier; (ii) simplified telescope door mechanism; (iii) eliminated dedicated payload command and data handling box; (iv) eliminated high gain antenna damper; and (v) adjusted or reduced WFI, spacecraft, and observatory integration and testing timelines.

b. What is the total amount of headquarters reserve required for WFIRST?

Answer: The 2019 Budget proposes to terminate WFIRST. If the mission were to continue to be funded, standard NASA practice is to estimate joint cost and schedule confidence levels (JCL) based on the integrated master schedule and multiple independent cost estimates developed for the preliminary design review (PDR) prior to approval to begin Phase C (Key Decision Point C).

- Once the JCL has been estimated, adequate Headquarters reserve will be identified to bring the total WFIRST budget up to a 70 percent confidence level.
- At this time (the beginning of Phase B), the mission design is not mature enough to estimate a JCL. However, based on the independent cost assessments which took place following the system requirements review (SRR) prior to approval to begin Phase B (Key Decision Point B), a range of cost for WFIRST was estimated.
- The range of costs for WFIRST is $3.2B to $3.8B (SMD only).
- The current estimate of the Headquarters reserves required for WFIRST is up to $605M.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Stephen Jurczyk, Associate Administrator, NASA

Questions submitted by Ranking Member Ami Bera, House Committee on Science, Space, and Technology

1. After years of reporting that conditions at NASA were improving, GAO recently found that schedule delays and cost growth are now on the upswing. Were you surprised by the upswing in schedule delays and cost growth that GAO brought to light? Are both short-term and long-term changes being considered by NASA to address the problem? If so, what are some examples?

   Answer: When NASA establishes a cost and schedule baseline, an associated joint cost and schedule confidence level (JCL) is provided alongside the cost and schedule figures. This confidence level is the product of a probabilistic analysis of the coupled cost and schedule to measure the likelihood of completing all remaining work at or below the budgeted levels and on or before the planned completion of the development phase. Although the JCL process quantitatively incorporates risks and threats, it does not account for two key facets that have the ability to drive cost and schedule.

   - Unknown-unknowns-- although NASA's Continuous Risk Management (CRM) process aims to create as comprehensive a risk register as possible, it is not feasible to predict all events that could possibly increase cost or schedule;
   - Uncertainty in the baseline estimate-- disregarding risks altogether, it is impossible to precisely predict the time or budget required to complete various segments of space vehicle research, development, and production.

   As a result, there is an inherent uncertainty present in the decision to proceed with development budgeted at a 70 percent confidence level, and it must be accepted that cost and schedule overruns will occur in some projects some of the time. NASA continues to work to strengthen implementation of the JCL process and the CRM process to ensure highly informed baseline decisions. Other items underway to bolster cost and schedule improvement include:

   - Looking at ways to more effectively utilize Earned Value Management (EVM) performance data in estimating the final costs of our major acquisitions;
   - Evaluating procurement approaches and contract incentives;
   - Communicating with our key stakeholders on inherent uncertainties and challenges, and our efforts to mitigate them; and,

- Strengthening and expanding various programmatic assessment training curricula including electronics learning, detail/transfer opportunities among Centers, and partnership with other U.S. Government organizations.

NASA utilizes Knowledge Officers, and a Chief Knowledge Officer, to ensure that all Centers operate as learning organizations. The NASA APPEL (Academy of Program/Project & Engineering Leadership) program is a resource for project management training. NASA schedules regular Virtual Project Management Challenges to train personnel and share best practices. The most recent session was held on June 21 with the topic, "Big Lessons from Small(er) NASA Projects."

NASA has enhanced the Cost Analysis Data Requirement (CADRe) to more formally capture projects' risk lists for each milestone. The goal of this enhancement is to have an established dataset for analysts to utilize. For example, to better inform the programmatic and risk management communities during JCL analysis.

NASA is in the process of renewing its Corrective Action Plan associated with our high risk designation in GAO's biennial High Risk Report. As part of this plan, NASA is evaluating a range of enhancements and improvements for programmatic stewardship, including but not limited to: training curriculum implementation, contract consolidation, modernizing decision memoranda process, automating cost and schedule reporting, greater rigor on cost and schedule estimating practices, and generating clarified guidelines for forecast-driven and data-informed development phase programmatic assessment on major projects. The current target for drafting, circulating, and finalizing the new Corrective Action Plan is through the end of calendar year 2018.

2. Recent instances have occurred where avoidable mistakes were committed by contractor personnel during fabrication, assembly, testing, and integration of spacecraft. Is there an underlying cause for these unforced errors and how can they be minimized?

Answer: While progress on NASA's human spaceflight programs has been substantial, NASA and its contractors have faced challenges with first-time design and assembly. Many of these challenges involved unforeseen technical issues associated with the building of cutting-edge, large, complex aerospace systems. This critical hardware has to operate in the extreme environment of space, requiring the development and implementation of state-of-the-art processes. However, other mistakes should not be expected or acceptable and have been the result of failures in execution. The learning curve has been steep, however the long-term benefits of challenging the national industrial base to produce these kinds of systems is significant. NASA's focus is on ways to further strengthen the technical rigor within Agency and prime contractors systems such that those mistakes, when they happen, are promptly detected and corrected before

they substantively impact cost and/or schedule. Specific areas of recent systemic focus include:

- processes that produce predictable, repeatable results, that are not subject to interpretation, and that represent the collective learning experience of the organization, including from preventive/corrective action from past failures and anomalies;
- individuals who are properly trained in the processes, follow them in a disciplined way, and are authorized to call a halt if something in the process doesn't seem right;
- accountable individuals in functions who ensure that procedures have been properly followed prior to sign-off; and
- verification and validation testing to ensure system requirements are met.

In the case of the heavy-lift Space Launch System (SLS), NASA and core stage prime contractor Boeing are working methodically through issues that are not unexpected during the first-time production of such a large and complex piece of aerospace hardware. The team has overcome initial challenges in using advanced friction stir welding to produce the core stage liquid oxygen and liquid hydrogen tanks. Along the way, engineers working on the rocket have learned a great deal from meeting challenges (ranging from the precise alignment of weld machines to addressing the fact that tiny threads on welding pins affect weld strength) that have pushed the state-of-the-art for self-reacting friction stir welding of thicker materials. Most recently, NASA has been managing a slower than expected ramp up in outfitting the core stage, due in part to contamination recently seen in some of the propellant lines in the engine section. This contamination issue came from the subcontractor tubing supply chain. Investigation has shown this issue to be broader than SLS and involve several suppliers. It appears that the tubing suppliers do not have effective cleaning processes or processes that adequately verify cleanliness.

NASA and Boeing have implemented a number of changes that are already having a positive impact on SLS core stage production. For example, senior Boeing management is very engaged in monitoring program progress and quickly addressing challenges as soon as they occur. NASA has moved additional engineering staff to Michoud to reduce the cycle time for solving manufacturing problems in real time. Boeing has increased on-site production labor working three shifts during the week and two shifts on weekends. Boeing has also set up a dedicated core stage production operations center with integration managers coordinating daily operations, as well as a dedicated green run manager to ready the first core stage for testing at the Stennis Space Center in Mississippi starting approximately one year prior to launch.

NASA also recognizes that the lessons learned from its recent experience with the James Webb Space Telescope have similarities to other issues we are seeing around NASA's development programs, including our interaction with contractors, and it is imperative for NASA to not only internalize these messages to lasting effect on Webb, but also across all of NASA's programs. Results concerning development, management and industrial base have been discussed among Agency leaders, and NASA will be setting up an all-hands meeting with Agency development personnel so these lessons can be spread and discussed.

The successful completion of the James Webb Space Telescope is critical to advancing our understanding of the Universe. Webb will conduct world-class science, answering questions about our place in the universe – Where did we come from? Are we alone? The data acquired with Webb will underpin many future projects. The superb performance of Webb's telescope and instruments during testing have made us eager to put them to use in space toward addressing fundamental science questions. The Independent Review Board (IRB) noted that Webb has "awesome scientific potential." Despite the challenges encountered during its integration and testing, NASA is confident that Webb will achieve mission success. That confidence is increased with the implementation of the IRB's recommendations, and mission success must be NASA's driving consideration moving forward. Along with the scientific community and the public, NASA is disappointed that completing Webb is taking longer than expected, but NASA is absolutely committed to successfully completing, launching, and commissioning Webb, and to carrying out its important scientific mission.

3. How can NASA balance accountability and enforcement of contract provisions with the need to maintain a trusting, team-oriented relationship with its contractors and partners? Has the use of contract incentives such as award fees led to positive outcomes at NASA? If so, please provide some examples. What leverage does NASA have on a contractor when award fees are no longer available?

Answer: NASA values the strong professional relationships that we have built with our contractors and partners over the years. It is through these strong relationships that we are able to accomplish NASA's challenging mission. It is NASA's goal to enter into contractual arrangements that contain fair and balanced terms and conditions that ensure that the contractor is incentivized to perform in an exemplary fashion in the areas of cost, schedule, and technical performance. We believe that such contractual arrangements can actually be a catalyst to building a trusting and team-oriented relationship with our contractors and partners. For example, NASA award fee procedures require interim award fee evaluations before the final award fee evaluation determination. These interim evaluations encourage continual communications between government and contractor personnel during contract performance which promotes the building of professional,

team-oriented relationships. Many NASA flight programs and projects are high risk, and require special hardware or design, as well as contracting mechanisms that manage various risks. Every new concept for a space craft, a satellite, or rover comes to life through high-risk contracting. High-risk missions are always a challenge and award fee contracts, when used effectively, can assist in meeting the challenge of these high risk contracts. NASA has successfully used award fee incentives to motivate contractors to enhance contractor performance in the areas of cost, schedule, and technical performance. For example, on an award fee type contract, NASA managers made complaints regarding inconsistent support from the contractor. The award fee evaluation board for this contract was able to evaluate this performance weakness through the award fee process which incentivized the contractor to implement corrective actions. In another example, under an award fee contract, the contractor's required plan reviews were not providing the accuracy required by the government. The award fee evaluation board negatively impacted the contractor's technical score in their award fee evaluation for that period. This action got the contractor's attention and noticeable improvements were made. Beyond award fee incentives, NASA has other contractual leverage to motivate contractor performance ranging from partial payment withholdings for poor performance to recording poor contractor performance in the Contractor Performance Assessment Reporting System (CPARs). CPARs data is utilized by Federal Agencies in competitive procurements to determine a contractor's past performance record.

4. In a 2012 report, the NASA OIG stated that funding instability can lead to inefficient management practices and encouraged NASA to both increase its efforts to determine the extent to which funding instability impacts NASA projects and to clarify the cause and effect relationship between funding instability and project increases, schedule delays, and performance problems. Has NASA implemented actions responsive to the NASA OIG's concern? What are examples of actions NASA has taken or is taking?

   Answer: As noted in the NASA response to the OIG findings, NASA had previously implemented many changes to mitigate the effects of funding instability. Formulation Agreements, Program Plans, Project Plans, and Decision Memoranda were implemented that document the agreements and expectations between the Agency and the program or project manager. In the Decision Memoranda, the Management Agreement (MA) defines the parameters and authorities over which the program or project manager has management control, and should be viewed as a contract between the Agency and the program or project manager. Any divergence from the MA that any party identifies, including changes in funding profiles, is to be accompanied by an amendment to the Decision Memorandum. These changes to internal practices facilitate identification of impacts, encourage discussion regarding resolution path, and document changes to the agreements. With regard to incremental funding, funds availability is continuously tracked at the project level. Any emergent issues associated with incremental funding are

communicated via routine channels and quickly resolved. The specific implementation of incremental funding varies across Mission Directorates to allow for the most efficient and effective means by which to fund different types of projects balanced with fiscal control at the Mission Directorate level.

Also as noted in the NASA response to the OIG findings, external funding instability drivers are more difficult to control or influence. United States Government policies and priorities may change over time, and Continuing Resolutions may be in place for long periods of time. Instability brought on from constant Continuing Resolutions is often cited as a primary challenge in terms of project and program planning. NASA continues to seek to keep external stakeholders informed when external decisions impact a project's ability to deliver on NASA's Agency Baseline Commitment. NASA also continues to advise projects to consider the probability of a Continuing Resolution when developing and refining plans at the beginning of a fiscal year.

5. Technology changes at a rapid pace and often leads to new concepts for NASA missions and spacecraft operations. Yet, current cost models used to develop cost estimates rely heavily on historical experience.

    a. To what extent are cost and schedule models keeping pace with new concepts?

    b. Is NASA supporting research and development in cost and schedule modeling? If so, provide examples of existing efforts.

Answer: NASA supports the research and development of cost and schedule modeling in three specific ways.

Firstly, NASA robustly collects historical cost, schedule, and technical data. Every NASA spaceflight project is required to produce a Cost Analysis Data Requirement (CADRe). Specifically, CADRe is a three-part document that describes a NASA project at each milestone, contains key technical parameters, and captures the estimated and actual cost for each element in a project. The CADRe provides historical record of cost, schedule, and technical project attributes so that estimators can better estimate future analogous projects. The first part of CADRe (Part A) describes the NASA project at each milestone and describes significant changes that have occurred since the last milestone. The second part (Part B) contains standardized templates to capture key technical parameters that are considered to drive cost and schedule (e.g., mass, power, data rates, etc.). Lastly, the third part (Part C), captures the project's cost estimate and actual life cycle costs. Each project produces a CADRe five times during its lifecycle (System Requirements Review, Preliminary Design Review, Critical Design Review, System Integration Review, Launch, and End of Mission) which creates a temporal look at how

projects change, augment, or descope during their development. The primary purpose of the CADRe effort is to have the data available to improve NASA cost and schedule modeling capabilities.

Secondly, NASA devotes resources annually to improve its models. These efforts include populating existing models with new CADRe data, updating methodologies based on community best practices, and updating cost drivers based on community best practices and research. Recently launched missions are incorporated in each model as quickly as possible to support ongoing model improvements. Cost models are used not to perfectly reflect the future actual cost, but to instead provide a deeper understanding of risks and scenarios for planning and management.

Thirdly, NASA's cost and schedule community utilizes NASA CADRe to conduct research to: a) Develop new models that aim to improve estimating capability, b) Understand what drives cost and schedule performance, and/or c) Collect additional data that is not currently captured in CADRe to see if it better informs NASA cost and schedule forecasting. CADRe data capture has been improved over the years based on previously mentioned research (e.g., schedule and risk data). NASA conducts this research at various levels (e.g., project, Center, Agency). Recent Agency budget for cost and schedule research has been effectively cut.

Examples of research conducted are numerous. Some examples of research from 2013-2015 can be accessed at: https://www.nasa.gov/offices/ocfo/functions/research_analysis .

Good examples of research conducted in 2016 are:

- NICM Instrument Class: https://www.nasa.gov/sites/default/files/atoms/files/13_nicm_missionclass_2016nasacost_symposiumfinal_rev3_tagged.pdf
- CubeSat Or Microsat Probabilistic + Analogies Cost Tool: https://www.nasa.gov/sites/default/files/atoms/files/25_compact_nasa_cost_symposium_2016final2_tagged.pdf

Good examples of research conducted in 2017 are:

- Schedule Estimating Relationships: https://www.nasa.gov/sites/default/files/atoms/files/17_2017_nasa_symposium_ser_presentation_v5_14_august_2017_tagged.pdf
- Cryocooler Modeling: https://www.nasa.gov/sites/default/files/atoms/files/14_nicmcryocooler_costsymposium_2017_urs_final_tagged.pdf

NASA shares community research during the annual Cost and Schedule Analysis Symposium. A more complete list of research over the years, including model improvements, can be accessed via: https://www.nasa.gov/offices/ocfo/cost_symposium.

6. GAO identified workforce challenges, including workforce skills and sufficiency of staffing, as an issue in its assessment of major projects. How does NASA factor workforce capabilities into its decisions on choosing whether to place mission development and management responsibilities at a Center or with a contractor?

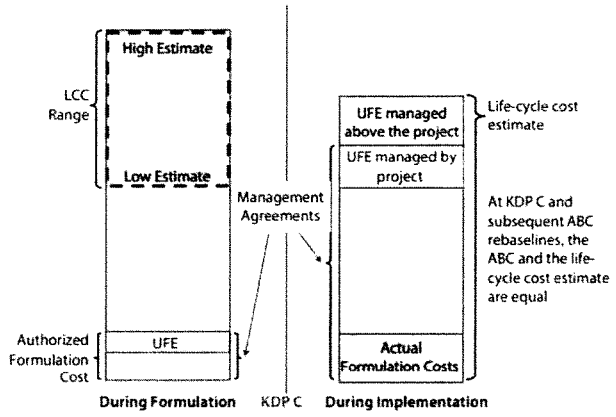
   Answer: NASA's Office of Strategy and Plans provides leadership in the development and application of NASA's acquisition policy. This NASA Policy provides the overall policy framework for NASA's strategic acquisition process, augments the Agency governance structure for decision making, and supports obtaining or advancing the development of the systems, research, services, construction, and supplies to fulfill the Agency's mission and other activities which advance the Agency's statutory objectives. Among many considerations, this Policy requires Agency leaders to consider, when developing an acquisition strategy, the full spectrum of acquisition approaches, as appropriate, to advance the Agency's objectives, taking into consideration providing best value, maximizing competition, and preserving the Agency's core capabilities. In addition, it requires that NASA capabilities, as required by senior Agency management to efficiently and effectively implement the NASA Strategic Plan, are maintained, including workforce and infrastructure, over both the short term and long term.

7. How does NASA determine the level of cost and schedule reserves to be included in the estimated cost of a program and how does NASA determine how much of these reserves are allocated to the project and program?

   Answer: For projects with a lifecycle cost greater than $250M, NASA uses probabilistic cost-loaded schedules, or Joint Cost and Schedule Confidence Level (JCL) analysis, so the program/project and the independent review entity can focus on the program/project plan. This improves program or project planning by systematically integrating cost, schedule, and risk products and processes. It also facilitates transparency with stakeholders on expectations and the probabilities of meeting those expectations. Lastly, it provides a cohesive and holistic picture of the program or project's ability to achieve cost and schedule goals and enables the determination of Unallocated Future Expenses (UFE) and funded schedule margins required by the program or project. UFE (i.e., reserves) are the portion of estimated cost required to meet the specific confidence level that cannot yet be allocated to the specific Work Breakdown Structure (WBS) sub-elements because the estimate includes probabilistic risks and specific needs that are not known until these risks are realized. For programs and projects that are not required to perform probabilistic analysis, the UFE should be informed by the program or project's unique risk posture in accordance with Mission Directorate and Center guidance and

requirements. The rationale for the UFE, if not conducted via a probabilistic analysis, should be appropriately documented and be traceable, repeatable, and defendable. Otherwise, UFE is determined by the confidence level provided by the joint cost and schedule calculations. For projects with a lifecycle cost greater than $250M, the goal is to provide sufficient understanding of the risks and associated impacts on cost and schedule to allow determination of a cost estimate and its associated confidence levels with the estimate NASA commits to external stakeholders.

The Management Agreement cost figure contains sufficient UFE to meet the 50 percent confidence level as determined by the supporting probabilistic analysis. This UFE is under the control of the Project Manager. Additional UFE is held above the project level at the Program or Mission Directorate level sufficient to meet 70 percent confidence as determined by the supporting probabilistic analysis. Use of this Program or Mission Directorate UFE requires a change to the project's Management Agreement via the project's decision authority since responsibility has transferred to the project's control.



Note: Figure is notional and not drawn to scale.

8. Although NASA's collaboration with international partners has been critical to the success of many missions, some of these partnerships have encountered schedule delays. What are the lessons learned from instances of schedule delay with international partners? What, if any, steps can NASA take to mitigate the risks associated with international collaboration?

   Answer: Complications and delays can arise for an organization in any nation working on complex systems such as those that NASA and its international partners develops. In

many cases, the instruments or technologies are the first of their kind and international collaboration, with appropriate export controls, helps leverage expertise from more than one nation to advance science and resolve significant technological challenges. International partnerships also leverage capabilities and resources that might otherwise be out of reach if not for the participation of other nations on science and exploration missions. Finally, international partnerships promote broader U.S. national goals.

All NASA missions follow a rigorous development and design review cycle, regardless of whether the mission involves international partners. In cases where delays occur, NASA has instituted a variety of measures to improve performance including but not limited to increasing technical oversight, instituting independent reviews, and establishing more robust programmatic reporting requirements. These measures have been detailed in NASA policy guidance related to partnerships, such as NASA Policy Directive 1360.2, "Initiation and Development of International Cooperation in Space and Aeronautics Programs," and the NASA Space Act Agreements and Partnership Guides.

Several of these best practices are designed to minimize the inherent risks – schedule and others – associated with such partnerships. Specifically, NASA takes care to ensure that international contributions fall within the known scientific and technical capabilities as well as available funding of its cooperative partners. Further, international projects involving a commitment of NASA resources are documented in legally binding agreements intended to protect NASA's investment. To minimize complexity and misunderstandings, the division of responsibilities between NASA and its cooperating partners is clearly defined in our cooperative agreements. Finally, NASA strives to include performance milestones in our international agreements with sufficient clarity to support preparation of cost estimates, sound management planning, and efficient agreement administration.

9. What lessons learned from other NASA human spaceflight programs such as Shuttle, ISS, SLS, and Orion can be applied to the Lunar Outpost Gateway to ensure that it is developed and operated within cost estimates and on schedule?

Answer: From a technical perspective, the groundwork for Gateway's capabilities is already being laid aboard the International Space Station (ISS), which provides heritage and operating experience for critical systems in areas such as environmental control and life support. Additionally, ISS is currently serving as a microgravity testbed to mature technologies for cislunar and deep space missions: a national capability that was not available during the design of the ISS. This critical work will continue throughout the operating life of the Station. The Orion crew vehicle's modern avionics, crew systems, and long-duration capability are all features that will also inform Gateway development. In addition, the Next Space Technologies for Exploration Partnerships (NextSTEP) contractors are currently developing Gateway ground prototypes and revealing new

approaches to Gateway design, operations, and technology application to lower overall operational costs. All of these technology maturation activities serve to reduce risk and bring finer resolution to the Gateway functional requirements.

A number of lessons from NASA's experience with the commercial crew and cargo programs were employed to inform the acquisition strategy for the Gateway. For example, the Power and Propulsion Element (PPE), Habitation Element modules, and Logistics Elements, all will leverage commercial capabilities and plans including an extensive effort to develop a minimum set of NASA unique requirements and a common set of global interoperability standards. PPE released a draft solicitation in June, and inputs from industry will inform the final solicitation. Maximum use of mature technologies (e.g., commercial satellite technology, existing and advanced life support technologies) coupled with fixed-price, milestone-based contracts will serve to focus development efforts and minimize potential for cost, schedule, and requirements growth. This approach preserves program affordability by maintaining NASA costs targets, sharing of benefits and risks with industry, and executing development strategies that incorporate cost and schedule controls and incentives while adapting technical systems with high reliability for human spaceflight applications.

By utilizing ongoing NextSTEP studies and prototyping activities, NASA has established a robust commercial engagement campaign and integrated cost of analysis and feedback activities to keep the aerospace industrial base informed and participating in NASA's strategic planning and technology drivers for cislunar and deep space exploration capabilities. The Gateway team has issued multiple Requests For Information to the domestic aerospace community seeking insights on Gateway plans supporting cislunar economic development, technology maturation, and science utilization. These inputs are under review by the Gateway systems engineering teams to identify potential design options that meet Government, partner and commercial needs.

The Gateway acquisition strategy considers all available NASA contracting authorities to encourage responsiveness and efficiency in acquisition, including commercial service acquisitions, public-private partnerships, and traditional competitive procurements. The Gateway acquisition will benefit from lessons learned and best practices identified and refined through the successful award of the 32 NextSTEP contracts to date. Further, NASA is also proactively developing interoperability standards with domestic industry and international agencies to ensure broader opportunities are available for Gateway participation which also encourages a competitive environment to lower overall costs while enhancing cislunar capabilities for Government and commercial goals.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Stephen Jurczyk, Associate Administrator, NASA

Questions submitted by Ranking Member Eddie Bernice Johnson, House Committee on Science, Space, and Technology

1. During the hearing, I inquired about key things NASA could do to minimize cost and schedule growth. As part of my question, I also asked what trade-offs NASA makes when the agency is faced with unexpected cost growth and schedule delay. While I appreciate your addressing the first part of my question on what NASA was doing to minimize cost and schedule growth, you did not cover the issue of trade-offs, nor provide examples of successful trade-offs NASA has made. Please provide a more complete response to my question.

   Answer: NASA policy requires that for all applicable programs and projects required to have Key Decision Point Decision Memoranda, there be consistency between cost estimates, commitments, and budget account projections (by fiscal year) to ensure overall alignment with expected resources. During the budget formulation process, NASA assigns responsibility for managing budget accounts at the Mission Directorate level. These Control Account Managers (CAMs) strive to align resources to their top line budget control levels, even when realizing cost and schedule growth against commitments. When cost and schedule growth does occur, a Mission Directorate may elect to exercise de-scope options to stay within program commitments. If this is not a suitable option, the CAMs must propose trades within their accounts to cover the growth. In the rare scenario where the Agency believes the impacts are too severe to accept, it may explore alternatives to fund the growth outside of the account. One recent example where the trade was contained within the account occurred in reference to the InSight Mars Lander mission. The mission's cost increased from $675.1M to $828.9M when the mission's launch was delayed from March of 2016 to May of 2018. In this instance, Planetary Science was able to accommodate this growth within their existing budget level and the growth did not impact any other Themes within the Science Mission Directorate, or accounts across the Agency. NASA has not had to make trades across accounts due to cost and schedule growth on missions since the last James Webb re-baseline in 2011.

Responses by Mr. Paul Martin

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Paul Martin, Inspector General, NASA

Questions submitted by Ranking Member Ami Bera, House Committee on Science, Space, and Technology

1. In a 2012 report, the NASA OIG stated that funding instability can lead to inefficient management practices and the report encouraged NASA to both increase its efforts to determine the extent to which funding instability impacts NASA projects and to clarify the cause and effect relationship between funding instability and project increases, schedule delays, and performance problems. Has NASA implemented actions responsive to your concern? What are examples of actions taken by NASA in response to your concern?

   Answer: NASA has taken some actions in response to concerns we raised about the impact of funding instability on project performance and costs. For example, NASA has described in various publications and guidance the importance of planning for unexpected funding changes and concomitant impacts on a project's cost and schedule performance. In January 2013, the Goddard Space Flight Center Director completed a study, "Cost and Schedule Growth in NASA Missions: Findings and Recommendations from the Explanation of Change Study and Flagship Mission Assessment," that discussed the importance and impact of establishing and maintaining an appropriate funding profile over the life of a project. Also, in 2014 NASA published the "NASA Space Flight Program and Project Management Handbook," that contains a section on the Federal budgeting process and warns of the impacts when funding is less than expected or delayed.

2. Your office has found that contractor performance is a key contributor to many of the instances of cost growth and schedule delay. The identification of contractor performance as a key contributor begs the question as to the sufficiency of NASA's oversight of its contractors.

   a. What are your observations on the level of contractor oversight exercised by NASA?

      Answer: In general, we have found the level of NASA's oversight of contractors varies considerably by project. For example, the Agency intentionally provides somewhat less oversight in the development of commercial cargo and crew projects, instead entering into an arrangement where the contractor demonstrates that its spaceflight configuration meets NASA standards. We have also found that

NASA is inconsistent in its application of controls designed to incentivize contractor performance, particularly in the area of award-fee incentive contracts.

b. In your opinion, is NASA doing enough upfront thinking and communication about a project and its requirements in order to clearly lay out to the contractor what work needs to be accomplished and the resources available to get there?

Answer: For the most part, we believe NASA communicates well with its contractors to establish requirements and budget expectations. However, we have found that the Agency, at times, has awarded contracts for work prior to finalizing requirements for a project's end-state. This has been noted in the Orion/Space Launch System (SLS)/Ground Systems programs as well as the facilities needed to test SLS components at the Marshall Space Flight Center. Determining and communicating end-state requirements to contractors prior to establishing a contract is beneficial in both establishing expectations for initial costs as well as cutting down on unexpected costs when and if requirements change. However, projects expected to take multiple years to complete have experienced challenges in this area due to the need for contractors to begin working on "long-lead items" that take significant time to build prior to when they are actually required for integration and testing.

3. The NASA OIG has looked at NASA's workforce over the years. Have you seen any workforce issues that are contributing to cost and schedule growth? In your view, what should NASA do to ensure that it has an experienced workforce capable of mounting a sustained exploration campaign?

Answer: The extent to which NASA can successfully address the challenges it faces in developing and retaining experienced project managers and engineers will not only affect the agency's ability to better manage project cost, schedule, and performance but ultimately its ability to sustain a long-term exploration campaign. For example, it is important that NASA maintain a balanced portfolio of large and small projects so that managers can receive on-the-job training, including making appropriate tradeoffs among cost, schedule, and performance goals. Likewise, to the extent that Agency engineers spend more time overseeing contractors rather than building spaceflight components limits their opportunities to gain hands-on experience and may make it more difficult for NASA to recruit and retain recent graduates or experienced engineers.

4. It is not surprising that teams want to put their best foot forward while being faced with the competitive pressure of initiating a mission at the lowest cost. Unfortunately, in some cases, content or complexity is often underestimated. How can NASA incentivize its teams to be realistic in identifying both their requirements and resource needs?

   Answer: Incentivizing teams to develop more realistic plans and performance baselines will likely continue to be a challenge for NASA given that an overly optimistic culture, an expectation that additional funding will be made available for a major project if needed, and a "too big to fail" mentality pervades Agency thinking when it comes to larger missions. However, NASA can more consistently apply tools at its disposal such as the Joint Cost and Schedule Confidence Level (JCL) process across projects to help mitigate these issues and hold officials more accountable for managing project costs and performance.

Responses by Mr. Daniel L. Dumbacher

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Daniel L. Dumbacher, Executive Director, American Institute of Aeronautics and Astronautics (AIAA)

Questions submitted by Ranking Member Ami Bera, House Committee on Science, Space, and Technology

1. Parts not meeting specifications and mishandling of components during fabrication were identified this year as reasons for rework. Rework in turn contributes to launch date delays. During your tenure at NASA, how common a problem was the need for rework? In addition to enhancing quality control, what can NASA and industry do to ensure that such instances do not become the norm?

   Answer: It is essential to have good quality control and supply chain management throughout the program life cycle. The biggest challenges are accountability and continuously increasing oversight that results in unclear accountability. Clear accountability can be achieved with less oversight and less bureaucracy. Within the aerospace sector, from my perspective, the commercial manufacturing of business and civil aircraft have moved in a very positive direction with regards to this kind of accountability. These practices should be evaluated for use in the space sector.

   In addition, it is imperative that the quality control and mission assurance functions be staffed by high quality and experienced staff. These professionals should have design, development, and testing experience, and be included from the earliest stages of a program and concept development.

2. How important is mentoring to retaining experience in the workforce, and do we need to change the way we train our future aerospace workforce so that roles, responsibilities, and accountability are better understood?

   Answer: It is absolutely essential for the next generation to learn lessons from those of us in the workforce. This is how I learned and developed my skill set as a young professional. Lessons need to be internalized and the best way to do that is through human interaction, working on real hardware activities on a team, and mentoring. Programs such as AIAA's Design/Build/Fly competition in which 800 college students from across the country participate each year and the Team America Rocketry Challenge offer hands-on experience that proves invaluable to aerospace employers. Similarly, professional societies also play an important role with the future aerospace workforce by providing networking opportunities and other interactions with employers and

professionals in their field. This is apparent when thousands of students participate in AIAA forums and take courses from professors of practice.

As young professionals progress from their university studies to the workplace, employers need to consider the use of in-house, hands-on projects to build the skills and capabilities for the future. Development skills necessary for the large-scale, complex aerospace programs are fostered and refined through involvement with hardware developments at the smaller scales. This needs to be a focus for NASA's and other government agencies' complex aerospace systems.

3. It is not surprising that teams want to put their best foot forward while being faced with the competitive pressure of initiating a mission at the lowest cost. Unfortunately, in some cases, content or complexity is often underestimated. How can NASA incentivize its teams to be realistic in identifying both their requirements and resource needs?

   Answer: The problem is the contentious environment and the challenging constraints that are placed on the teams. These are complex, challenging programs that have never been developed before. Teams must be allowed the opportunity to objectively discuss and address risks associated with these complex programs. NASA teams do not need incentives; rather, they need a proper environment to address the issues and communicate the cost requirements for those issues. And, to be frank, the best way to incentivize NASA teams is to provide sufficient budgets with appropriate cost and schedule margins. Project teams need to be able to communicate risks and needed margins and reserves. The Office of Management and Budget (OMB) and Congress should assure that the margins are commensurate with the risks, and once agreed upon, fully support the needed budget.

4. Your statement indicates concern about cost reserves becoming the first target for budget reduction in the Executive Branch budget and congressional appropriations processes. Have you seen that happen during your time at NASA? How can we avoid that from happening?

   Answer: Yes, I have seen this happen. From personal experience, SLS and Orion had to plan to a flat-line budget that skewed the natural program phasing in cost and in schedule. Inflation was explicitly not addressed at the direction of OMB, and it was made clear that the cost-cap was established in such a manner that it would not allow sufficient reserves. Per the written testimony, natural program development life cycles do not work well under flat-line budgets. Providing funding for the necessary program phasing is essential and must account for expected inflation. We have learned this lesson on the International Space Station development, but OMB and Congress continue to allow this to occur.

5. Technology changes at a rapid pace and often leads to new concepts for NASA missions and spacecraft operations. Yet, current cost models used to develop cost estimates rely heavily on historical experience. To what extent are cost and schedule models keeping pace with new concepts? What role can colleges and universities play in enhancing student familiarity with the application of cost and schedule models and developing cost and schedule models that reflect new concepts?

   Answer: First, cost and schedule models try to keep pace with new concepts, but the collection of proper data and then factoring that new data into the new model must be addressed. This process will always lag (to some degree) behind the planning of new projects and programs. Efforts to update the cost models are essential for future program planning as technology and approaches change.

   Second, colleges and universities should require more engineering economics courses, which would give students the foundation and understanding of the economics associated with large engineering projects. Cost estimating and budgeting should also be included in Capstone design courses. Students will then be provided exposure to the language, approaches, and the important need of economic and policy analysis surrounding complex aerospace programs.

6. In your prepared statement, you urge NASA to establish key metrics for doing in-house work and assess use of its capabilities as space privatization continues to grow. Please elaborate on the need for in-house work at NASA Centers, including options on how NASA could address that need.

   Answer: The agency's success stems from having technical capabilities within the agency. NASA's mission requires extending the boundary of human knowledge and experience. To accomplish goals and objectives never before achieved, the workforce must have knowledge of what can be done and what are the risks, and be able to develop the needed creative solutions. This can only come on the foundation of previous accomplishments and failures.

   In spite of all the commercial activity that is currently underway, continued in-house work at NASA is as important as ever. NASA continues to push the boundaries of knowledge in science, space exploration, and aeronautics. The workforce to address these challenges must be properly prepared with technical knowledge and real-world experience to conquer the unknown.

   NASA should use the Goddard Space Flight Center model of 10 percent of the effort being performed in-house. This could be applied at an agency level for workforce development and to assure cross Center collaboration.

   Well-planned and executed public–private partnerships can make good use of government-developed technology and capabilities for application to the private sector.

For example, government test facilities can be available to assist private industry and utilize previous taxpayer investment.

Appendix II

Additional Material for the Record

DOCUMENTS SUBMITTED BY NASA

Project Management Institute

June 14, 2018

The Honorable Brian Babin
Chairman, Subcommittee on Space
U.S. House Committee on Science,
Space, and Technology
2321 Rayburn House Office Building
Washington, DC 20515

The Honorable Ami Bera
Ranking Member, Subcommittee on Space
U.S. House Committee on Science,
Space, and Technology
394 Ford House Office Building
Washington, DC 20515

Dear Chairman Babin and Ranking Member Bera:

On behalf of our half million members and certification holders in the United States, the Project Management Institute (PMI) thanks you both for the opportunity to contribute to the U.S. House Committee on Science, Space, and Technology Subcommittee on Space hearing entitled "NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges."

As the world's leading not-for-profit professional association for the project, program and portfolio management profession, PMI works with Congress to improve the federal government's ability to effectively manage its portfolios of projects and programs. The importance of adopting leading project management practices is difficult to overstate. PMI's *Pulse of the Profession*® 2018 survey reveals that 9.9% of every dollar is wasted due to poor project performance—that's $99 million for every $1 billion invested! The data further shows that when proven project, program and portfolio management practices are implemented, projects and programs meet their original goals and business intent far more often than those without.

As your Subcommittee continues to work with NASA to enhance our nation's leadership in space, PMI is pleased to share its perspective on how project, program and portfolio management standards and workforce development lead to greater organizational success and less wasteful federal government spending.

Standards
Coast to coast, thousands of organizations—from small businesses and Fortune 500 companies to state and federal government agencies—across all industries, manage their portfolios of projects and programs using the widely-accepted American National Standards Institute (ANSI) standards for project, program and portfolio management.

Within federal agencies, ANSI standards and frameworks allow for better performance tracking, promote flexibility and agility, foster transparency and accountability, and

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ensure compliance with existing statutes and Office of Management and Budget (OMB) guidance (including Public Law 104-113, the "National Technology Transfer and Advancement Act of 1995;" Public Law 114-264, "The Program Management Improvement and Accountability Act," and OMB Circular No. A-119 Revised). Further, the U.S. Government Accountability Office (GAO) uses the ANSI standards as benchmarks in its project and program evaluations, including those focused on NASA.

PMI's *Pulse of the Profession*® 2018 survey confirms that when organizations have mature value delivery capabilities, including the incorporation of ANSI-accredited standardized practices, project and program performance improves significantly:

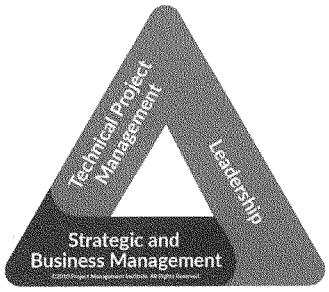
- 23% more projects and programs are completed on time
- 20% fewer projects and programs are deemed as failures
- 18% more projects and programs are completed within budget
- 14% fewer projects and programs suffer from scope creep
- 13% more projects and programs meet their goals and strategic intent

Effectively leveraging standards is even more critical for organizations engaging in highly-complex and highly-technical projects and programs, such as the development of interplanetary spacecraft systems and other critical technologies currently being undertaken by NASA. To date, NASA has worked to align their project, program and portfolio management practices with the relevant ANSI standards, and PMI encourages NASA leadership to ensure that standardized practices are leveraged across the agency to better support the on-time, on-budget delivery of its projects and programs.

Workforce development

In today's environment of constant disruption, project, program and portfolio managers are the bridges that connect organizational strategy to implementation. As a result, there is a widening gap between employers' need for these skilled workers and the availability of qualified professionals to fill those roles. This gap is particularly acute within federal agencies, where there has been a dramatic increase in the number of jobs requiring project-oriented skills taking place at the same time many professionals are retiring from the workforce.

To deliver their portfolios of projects and programs more effectively and efficiently, federal agencies, including NASA, need skilled, certified project, program and portfolio managers. These important stewards of taxpayer dollars require a unique set of technical competencies, detailed in the PMI *Project Manager Competency Development Framework—Third Edition*, combined with leadership skills and strategic and business management expertise, as embodied in the PMI Talent Triangle.



The NASA Academy of Program/Project & Engineering Leadership (APPEL) has a strong track record of integrating project, program and portfolio management competencies into its workforce development activities and aligning its efforts with marketplace best practices and certifications. PMI strongly supports efforts by the Chief Knowledge Officer and NASA leadership to ensure the retention and continuous development of its workforce to achieve future success and address the opportunities GAO outlined in its recent *NASA: Assessments of Major Projects* report.

Conclusion
In closing, thank you again for the opportunity to highlight the importance of project, program and portfolio management leading practices to delivering on the Subcommittee's goal of sustaining U.S. leadership in space. PMI stands ready to work with both of you, your staffs, GAO, and NASA to ensure that NASA achieves its important mission. If you have any questions, or if we can provide further information, please contact Jordon Sims (202-772-3598 | jordon.sims@pmi.org) or Tommy Goodwin (202-772-3592 | tommy.goodwin@pmi.org) from PMI's Washington, DC office.

Sincerely,

Mark A. Langley
President and Chief Executive Officer

Material requested for the record by Representative Brooks during the June 14, 2018 hearing at which Mr. Jurczyk testified.

Answer:

NASA will be able to provide the Committee with a more specific ISS Transition Report delivery timeframe after the receipt of industry studies on ISS transition, which is slated for December 2018. The content of the studies will provide the Agency with a better understanding of industry's views about potential transition options, and this information will help inform the development of the second edition of the report.

Material requested for the record by Representative Brooks during the June 14, 2018 hearing at which Mr. Jurczyk testified.

Answer:

[Jurczyk: Yes, we're--like Mr. Martin said, we're--the launch services program is in the process of assessing that risk for all missions, and I can take a question for the record on that to get back with you when that assessment will be done.]

NASA's Launch Services Program (LSP) was asked in Spring 2017 by the International Space Station (ISS) program to assess a 2nd flight of a Falcon 9 Block 3 or Block 4 1st stage booster. LSP briefed the ISS program and NASA HQ on their findings and recommendations in October 2017. The summary from the LSP assessment was there was no discernable increase in risk for a Commercial Resupply Services (CRS) flight carrying cargo to the ISS through the reuse of a Falcon 9 1st stage booster as long as that booster has had only one prior flight; the trajectory was a "benign" trajectory flying to low-Earth orbit; the booster returned to a land landing; and SpaceX performed its post-flight inspection, repair and replace process. The SpaceX CRS-13 flight successfully flew on December 6th, 2017 using a previously flown 1st stage booster that met the LSP provided criteria. (LSP also conducted an assessment at the request of ISS for the SpaceX CRS-15 flight that flew successfully on June 29th, 2018.) LSP will continue to evaluate Falcon 9 reusability as necessary for appropriate future NASA missions.