JAMES WEBB SPACE TELESCOPE: PROGRAM BREACH AND ITS IMPLICATIONS

HEARING

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

JULY 25, 2018 AND JULY 26, 2018

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July 25, 2018

JAMES WEBB SPACE TELESCOPE: PROGRAM BREACH AND ITS IMPLICATIONS

2018

AND THURSDAY, JULY 26, 2018

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

The Committee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Lamar Smith [Chairman of the Committee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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James Webb Space Telescope: Program Breach and its Implications

Wednesday, July 25, 2018
10:00 a.m.
2318 Rayburn House Office Building

Witnesses

Panel 1, June 25:

Hon. Jim Bridenstine, Administrator, NASA

Mr. Tom Young, Chairman, JWST Independent Review Board

Panel 2, July 26:

Mr. Wesley Bush, Chief Executive Officer, Northrop Grumman

Mr. Tom Young, Chairman, JWST Independent Review Board

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: July 25, 2018
SUBJECT: Full Committee Hearing: "James Webb Space Telescope: Program Breach and its Implications"

On Wednesday, July 25, at 10:00 a.m., and Thursday, July 26, at 9:00 a.m., in Room 2318 of the Rayburn House Office Building, the Committee on Science, Space, and Technology will hold a two-part hearing titled, "James Webb Space Telescope: Program Breach and its Implications."

Hearing Purpose

The purpose of this hearing is to focus discussion on the James Webb Space Telescope (JWST) Independent Review Board (IRB) report and NASA's response, as well as the implications of the ongoing JWST program breach, especially to other NASA programs. Since the JWST program has now breached under 51 USC 30104 notification conditions, the hearing discussion on July 25 will explore NASA program management effectiveness, program continuation and reauthorization, and budgetary implications across NASA's entire science portfolio, to include the WFIRST program. The second part on July 26 will explore contractor issues and recommended improvements regarding contractor accountability.

Witnesses

Panel 1, June 25:

- **Hon. Jim Bridenstine**, Administrator, NASA[1]
- **Mr. Tom Young**, Chairman, JWST Independent Review Board

Panel 2, July 26:

- **Mr. Wesley Bush**, Chief Executive Officer, Northrop Grumman[2]
- **Mr. Tom Young**, Chairman, JWST Independent Review Board

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.

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[1] Mr. Bridenstine may have an assistant with him at the witness table to assist with technical questions, but a single statement will be submitted on behalf of NASA.
[2] Mr. Bush may have an assistant with him at the witness table to assist with technical questions, but a single statement will be submitted on behalf of Northrop Grumman.

Chairman SMITH. The Committee on Space, Science, and Technology will come to order. Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Good morning, and welcome to today's hearing entitled "James Webb Space Telescope: Program Breach and its Implications." I'll recognize myself for an opening statement.

Today, we will hear from Administrator Bridenstine on NASA's plans to ensure that the James Webb Space Telescope is a success. We will also hear from Tom Young on the findings and recommendations of the JWST Independent Review Board.

Tomorrow, at the second part of the hearing, Northrop Grumman's CEO, Mr. Wes Bush, will testify. We will learn more about why Northrop failed to deliver JWST on budget and on schedule and what can be done about it.

Welcome to Jim Bridenstine, who is testifying for the first time since leaving the Committee to become NASA's Administrator. He began his job with our high expectations, and he has already exceeded them. Jim, that's the highest compliment I can pay you.

Mr. BRIDENSTINE. Why, thank you.

Chairman SMITH. We can be confident that he is striving to tackle the program management issues NASA faces, specifically those associated with the James Webb Space Telescope.

Starting on March 26, 2018, NASA began notifying this committee about the James Webb Space Telescope's cost and schedule breaches. Now that the Independent Review Board has completed its work, we should review the decades-long JWST cost overruns and schedule delays. And if Members will take a look at this chart that's on the screen in front of us.

[Slide.]

Chairman SMITH. This chart chronicles JWST's substantial cost growth and launch schedule delays starting with the 1996 initial projections in the lower-left-hand corner all the way to the IRB's 2018 projection in the upper-right corner. It is truly staggering to behold how this space telescope's cost and schedule projections went from costing the same as a space shuttle mission—around half-a-billion dollars with an original launch date in 2007—to now becoming an expenditure exceeding $9 billion with a new launch goal in March 2021. This is 19 times the original cost and a delay of 14 years. It doesn't get much worse than that.

The cost of delaying the launch again will add almost another billion dollars to the total program cost. The $8 billion development cost cap set in 2012 will be exceeded by $803 million. With other program costs added in, the IRB now estimates the total cost at over $9.6 billion.

The IRB also stated that technical complications and unclear reporting roles, responsibilities, and lines of communications greatly impacted the development schedule and its associated cost increases. Mr. Young will provide details during his testimony. We will discuss options going forward, such as the contractor watch list designation contained in the bipartisan NASA Authorization Act of 2018.

I support the continuation of JWST to mission completion and appreciate Administrator Bridenstine's efforts to improve contractor performance. Going forward, Congress needs to have the

necessary confidence in NASA's contractors to put us on the right path at a reasonable cost. Anything short of that will undermine Congressional confidence in contractors' ability to deliver on their promises.

Usually, when government contractors make mistakes, no one is held accountable. The mistakes "just happened" or "were unavoidable" or "won't happen again." But in every case, the American people pick up the bill. We often forget there is no such thing as federal dollars. It's the American taxpayers' hard-earned money. If space exploration is going to continue to earn the public's support, then contractors will have to deliver on time and on budget. If they cannot, they should be penalized.

[The prepared statement of Chairman Smith follows:]

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

For Immediate Release
July 25, 2018

Media Contacts: Heather Vaughan, Bridget Dunn
(202) 225-6371

Statement by Chairman Lamar Smith (R-Texas)

James Webb Space Telescope: Program Breach and its Implications

Chairman Smith: Today, we will hear from Administrator Bridenstine on NASA's plans to ensure that the James Webb Space Telescope (JWST) is a success. We will also hear from Tom Young on the findings and recommendations of the JWST Independent Review Board (IRB).

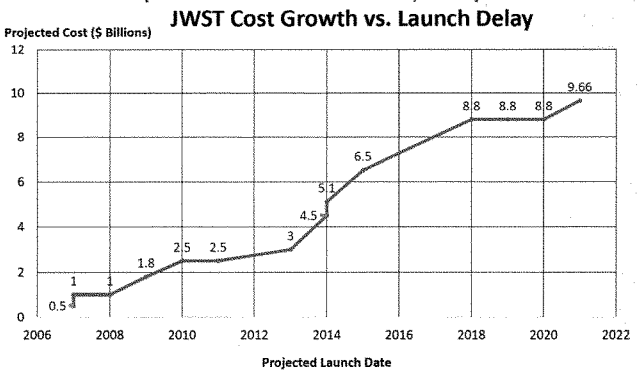
Tomorrow, at the second part of the hearing, Northrop Grumman's CEO, Mr. Wes Bush, will testify. We will learn more about why Northrop failed to deliver JWST on budget and on schedule and what can be done about it.

Welcome to Jim Bridenstine who is testifying for the first time since leaving the committee to become the NASA Administrator. He began his job with our high expectations, and he has already exceeded them. We can be confident that he is striving to tackle the program management issues NASA faces, specifically those associated with the James Webb Space Telescope.

Starting on March 26, 2018, NASA began notifying this committee about the JWST cost and schedule breaches.

Now that the IRB has completed its work, we should review the decades-long JWST cost overruns and schedule delays. Take a look at the chart on display.

[JWST cost and schedule delay chart]



This chart chronicles JWST's substantial cost growth and launch schedule delays starting with the 1996 initial projections in the lower-left corner all the way to the IRB's 2018 projection in the upper-right corner.

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The cost of delaying the launch again will add almost another billion dollars to the total program cost. The $8 billion development cost cap set in 2012 will be exceeded by $803 million. With other program costs added in, the IRB now estimates the total cost at $9.6 billion.

The IRB also stated that technical complications and unclear reporting roles, responsibilities, and lines of communications greatly impacted the development schedule and its associated cost increases. Mr. Young will provide details during his testimony.

We will discuss options going forward, such as the contractor watch list designation contained in the bipartisan NASA Authorization Act of 2018.

I support the continuation of JWST to mission completion and appreciate Administrator Bridenstine's efforts to improve contractor performance.

Going forward, Congress needs to have the necessary confidence in NASA's contractors to put us on the right path at a reasonable cost. Anything short of that will undermine congressional confidence in contractors' ability to deliver on their promises.

Usually, when government contractors make mistakes, no one is held accountable. The mistakes "just happened" or "were unavoidable" or "won't happen again." But in every case, the American people pick up the bill. We often forget there is no such thing as federal dollars. It's the American taxpayers' hard-earned money.

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

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Chairman SMITH. That concludes my opening statement, and the Ranking Member, the gentlewoman from Texas, is recognized for hers.

Ms. JOHNSON. Thank you very much. Good morning to everyone and, Mr. Chairman, I thank you for holding this hearing on the James Webb Space Telescope program breach and its implications. Excuse me.

Welcome to our witnesses, to the Administrator Bridenstine and Mr. Young. We appreciate your commitment to this high-priority science mission.

As a powerful observatory that will be 100 times more sensitive than the Hubble Space Telescope, the James Webb Space Telescope will be a gateway to unlocking the origins of the universe. Further, like Hubble, it will also be an inspiration for our next generation of scientists, engineers, and citizens and a symbol of American—America's leadership in space, science, and exploration.

I appreciate the tireless commitment and dedication of NASA to its industry, international, and academic partners, also for their work on this project.

The hardware for the mission is now complete, and the observatory is undergoing integration and testing. Getting to this point has not been easy. A 2010 review of the project identified significant costs in growth—schedule growth while subsequent re-baseline plans help keep the program on track for many years. Today, we will discuss another series of setbacks.

I want to commend NASA for establishing the Independent Review Board. The Independent Review Board and I want to recognize the members for contributing their time and expertise and Mr. Young for his leadership in chairing the effort.

The message is clear. Mission success for the James Webb Space Telescope needs to be the priority, and finding potential embedded problems and minimizing the impact of human errors must be a focus going forward.

That said, the Independent Review Board was also clear on the fact that both NASA and the prime contractor for the mission, Northrop Grumman, have contributed to the 29-month schedule delay and the $1 billion cost increase to the project. In particular, the review board found complex and confusing management reporting on the project and inconsistent, uncoordinated communications on the James Webb Space Telescope within NASA and with external stakeholders, including Congress. This is not good news, especially since some of these problems were identified in the 2010 review.

I hope that today's hearing will inform us on how NASA plans to ensure that these and the other findings and recommendations of the Independent Review Board are successfully implemented and how lasting processes are being put in place to prevent these problems from occurring on other NASA projects.

I am also concerned about the potential collateral damage. I'm eager to hear from the Administrator on how NASA plans to ensure the health and balance of the astrophysics program, including small missions research and analysis and the next high-priority decadal survey mission—excuse me—the WFIRST, given the additional resources that will be needed to complete the James Webb Space Telescope.

And as I've said on many occasions before, inspiring and challenging projects such as the James Webb Space Telescope are an investment in our future, and the review board found that it is an observatory with incredible capacity and awesome scientific potential. And while it is up to this committee to carry out the oversight of the taxpayers' significant investment in this project, we must not lose sight of the importance of bringing the James Webb Space Telescope to a successful outcome.

And, Mr. Chairman, I have a letter I'd like to submit for the record.

Chairman SMITH. Okay.

Ms. JOHNSON. This is a letter of support of the project from the American Astronomical Society.

Chairman SMITH. Without objection, the letter from the American Astronomical Society will be made a part of the record.

[The information follows:]

AMERICAN ASTRONOMICAL SOCIETY

Office of the President

July 24, 2018

The Honorable Lamar Smith
Chairman, Committee on Science,
Space, and Technology
316 Cannon House Office Building
Washington, DC 20515

The Honorable Eddie Bernice Johnson
Ranking Member, Committee on Science,
Space, and Technology
1431 Longworth House Office Building
Washington, DC 20515

Dear Chairman Smith and Ranking Member Johnson,

I am writing as the President of the American Astronomical Society (AAS)—the major North American organization of professional scientists, engineers, and educators advancing astrophysics, planetary science, and heliophysics—to thank you for your oversight over the development of the James Webb Space Telescope (JWST) and for convening a hearing to review the Independent Review Board (IRB) finding that the project would breach its development cost and schedule constraints.

As you know, JWST will be the most ambitious, capable space telescope humanity has ever built. It will transform scientific understanding of our place in the universe. The astronomical community is eager to realize the extraordinary potential of this observatory, and we share your frustration at the news of this breach. Significant cost and schedule overruns driven by preventable human errors are unacceptable, particularly on such an incredibly high profile mission. I am pleased with NASA's commitment to completing JWST. We agree that mission success is paramount, even if that unfortunately requires further launch delay and an increase in development costs. I am confident that NASA has learned, and will continue to learn, from this experience. Carrying those lessons forward to the next generation of ambitious NASA missions is essential to ensuring a balanced, world-leading space-science program.

I encourage you to reauthorize JWST at the updated cost and schedule estimate, and continue to conduct rigorous oversight of the project, its prime contractor, and NASA. Congressional oversight is a key component in maximizing the scientific return from public investment in the astronomical sciences.

Thank you for your strong past support and thank you in advance for considering this feedback. We look forward to working with you and your Congressional colleagues to ensure that the U.S. space science program continues to be world leading. Please feel free to contact me with any questions or concerns, or Joel Parriott, AAS Director of Public Policy, at joel.parriott@aas.org.

Sincerely,

Megan Donahue, Ph.D.
President, American Astronomical Society
Professor of Physics and Astronomy, Michigan State University

cc: Senator John Thune, Chairman, Senate Committee on Commerce, Space, and Technology
Senator Bill Nelson, Ranking Member, Senate Committee on Commerce, Space, and Technology

1667 K St. NW, Suite 800 • Washington, DC 20006 • 202-328-2010 • F 202-234-2560 • megan.donahue@aas.org

Ms. JOHNSON. Thank you very much. I yield back.
[The prepared statement of Ms. Johnson follows:]

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

House Committee on Science, Space, and Technology
"James Webb Space Telescope: Program Breach and its Implications"
July 25, 2018

Good morning. Thank you, Mr. Chairman, for holding this hearing on the "*James Webb Space Telescope: Program Breach and its Implications*," and welcome to our witnesses, Administrator Bridenstine and Mr. Young. We appreciate your commitment to this high-priority science mission.

As a powerful observatory that will be 100 times more sensitive than the Hubble Space Telescope, the James Webb Space Telescope will be a gateway to unlocking the origins of the universe. Further, like Hubble, JWST will be an inspiration for our next generation of scientists, engineers, and citizens, and a symbol of America's leadership in space science and exploration.

I appreciate the tireless commitment and dedication of NASA and its industry, international, and academic partners for their work on JWST. The hardware for the mission is now complete, and the observatory is undergoing integration and testing.

Getting to this point has not been easy. A 2010 review of the project identified significant cost and schedule growth. While the subsequent rebaseline plan helped keep the program on track for many years, today, we will discuss another series of setbacks to JWST.

I want to commend NASA for establishing the JWST Independent Review Board—the IRB—and I want to recognize the IRB Members for contributing their time and expertise, and Mr. Young for his leadership in chairing this effort. The IRB's message is clear. Mission success for JWST needs to be the priority and finding potential embedded problems and minimizing the impact of human errors must be the focus going forward.

That said, the IRB was also clear on the fact that both NASA and the prime contractor for the mission, Northrop Grumman, have contributed to the 29-month schedule delay and $1 billion cost increase to the project. In particular, the IRB found complex and confusing management reporting on the project, and inconsistent, uncoordinated communications on JWST within NASA and with external stakeholders, including Congress.

This is not good news, especially since some of these problems were identified in the 2010 review. I hope that today's hearing will inform us of how NASA plans to ensure that these and the other IRB findings and recommendations are successfully implemented and how lasting processes are being put in place to prevent JWST's problems from occurring on other NASA projects.

I am also concerned about potential "collateral" damage. I am eager to hear from Administrator Bridenstine on how NASA plans to ensure the health and balance of the astrophysics program, including small missions, research and analysis, and the next high-priority decadal survey mission, WFIRST, given the additional resources that will be needed to complete JWST.

As I've said on many occasions before, inspiring and challenging projects such as JWST are an investment in our future. The IRB found that "*JWST is an observatory with incredible capability and awesome scientific potential.*" And while it is up to this Committee to carry out the oversight of the taxpayer's significant investment in the project, we must not lose sight of the importance of bringing JWST to a successful outcome.

Thank you, Mr. Chairman, and I yield back.

Chairman SMITH. Thank you, Ms. Johnson.

And the gentleman from Texas, the Chairman of the Space Subcommittee, is recognized for his opening statement.

Mr. BABIN. Thank you very much, Mr. Chairman. And thank you witnesses, expert witnesses, for being here as well.

As Chairman of the Space Subcommittee and proud representative of Johnson Space Center, I'm a very tireless advocate for NASA. I strongly believe in the mission of NASA, and I commend the tremendous dedication of the NASA and industry team under Mr. Bridenstine and the rest of the team. However, as Members of this Committee, we have a responsibility to every taxpayer to ensure that government agencies, including NASA, are being good stewards and effective at managing our resources with which they are entrusted.

Today's hearing will focus on the serious issues associated with the James Webb Space Telescope program breach and its implications, the Independent Review Board's analysis and recommendations, and the coming debate over Congressional reauthorization of JWST. Chairman Smith summarized the IRB's findings and recommendations, so I want to use this opportunity to discuss NASA's lost opportunities due to flagship program cost overruns.

As the Space Subcommittee Chairman, I focus on the NASA budget in its entirety and every project and program in the agency's portfolio, particularly those where budget limitations force difficult decisions on reducing specific project budgets or whether we can even fund them at all. Please give your attention to the chart on display.

[Slide.]

Mr. BABIN. The Committee surveyed NASA's science portfolio over the last few fiscal years to identify project budget reductions and unfunded requests due to limitations. These projects are listed by fiscal year starting on the left there with fiscal year 2013 all the way up through fiscal year 2019. You can see those.

Now, with the fiscal year 2018 coming to a close shortly and the IRB's announced JWST cap breach of $803 million in development costs, this chart reflects the reality of the breach going into fiscal year 2019 budget planning. In terms of lost opportunities and NASA's budgetary trade space, it is important to know the full impact of JWST breach on NASA and the American public as a whole.

So we'll bring up the next one.

[Slide.]

Mr. BABIN. The $803 million needed to fund the JWST cost breach could fund nearly every one of NASA's science funding shortfalls from fiscal year 2013 all the way up through fiscal year 2016. These projects include earth science and education projects greatly promoted by our Democratic colleagues on the Committee.

And looking forward to fiscal year 2019 and NASA's future flagship program plans, the cost issues with the Wide Field Infrared Survey Telescope, or WFIRST, will become a subject of debate right alongside the JWST Congressional reauthorization. The fiscal year 2018 omnibus required an updated lifecycle cost estimate for WFIRST, and NASA's report concludes the estimated cost range is $3.3 billion to $3.9 billion. This lifecycle cost estimate exceeds the

NASA-imposed cost cap of $3.2 billion included in the bipartisan NASA Authorization Act of 2018.

To give perspective to the funding dilemma presented by JWST and WFIRST cost issues, NASA's WFIRST estimate includes a request for $371 million, which is now reflected on the fiscal year 2019 chart.

Thank you.

[Slide.]

Mr. BABIN. The bipartisan NASA Authorization Act of 2018 seeks to limit flagship program overlap to reduce NASA's risk of becoming overwhelmed by WFIRST development before JWST is operational in space. Thus, it is my hope the IRB report and our witness panel testimony will shed some light on lessons learned with JWST and lead to a successful flight and operations in March 2021. We do not want these mistakes repeated during the development of WFIRST.

Congress needs to understand the unvarnished truth of the status of these programs today, as well as the plan going forward. Decisions made now can have long-lasting implications on future missions. We need to know that there is not a systemic or a fundamental management problem with how NASA plans and executes these larger strategic missions.

And I want to thank the witnesses here today, helping us to better understand where we are and how we plan to move forward, and I look forward to your testimony.

I yield back.

[The prepared statement of Mr. Babin follows:]

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

For Immediate Release
July 25, 2018

Media Contact: Heather Vaughan, Bridget Dunn
(202) 225-6371

Statement by Chairman Brian Babin (R-Texas)

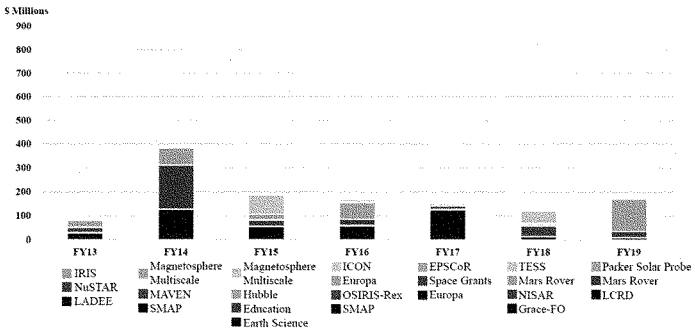
James Webb Space Telescope: Program Breach and its Implications

Chairman Babin: As the Chairman of the Space Subcommittee and proud representative of Johnson Space Center, I am a tireless advocate for NASA. I strongly believe in the mission of NASA and commend the tremendous dedication of the NASA and industry team.

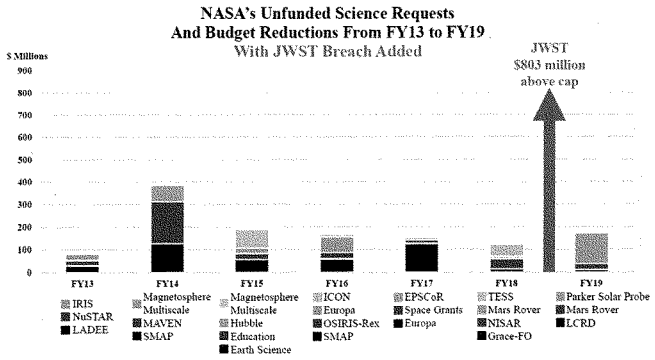
However, as members of this committee, we have a responsibility to every tax-payer to ensure that government agencies, including NASA, are being good stewards and effectively managing the resources with which they are entrusted.

Today's hearing will focus on the serious issues associated with the James Webb Space Telescope (JWST) program breach and its implications, the Independent Review Board's (IRB) analysis and recommendations, and the coming debate over congressional reauthorization of the JWST.

Chairman Smith summarized the IRB's findings and recommendations, so I want to use this opportunity to discuss NASA's lost opportunities due to flagship program cost overruns. As the Space Subcommittee chairman, I focus on the NASA budget in its entirety and every project and program in agency's portfolio, particularly those where budget limitations force difficult decisions on reducing specific project budgets or whether we can fund them at all. Please give your attention to the chart on display.

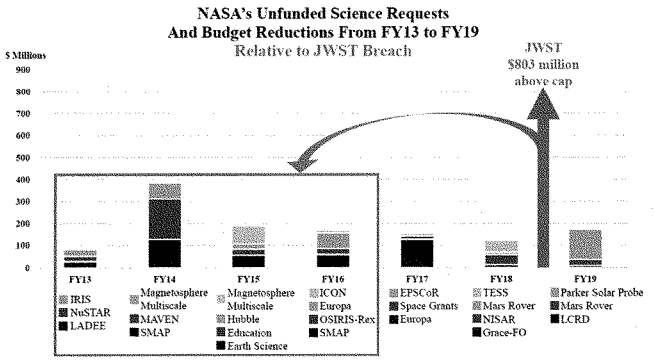


The committee surveyed NASA's science portfolio over the last few fiscal years to identify project budget reductions and unfunded requests due to limitations. Those projects are listed by fiscal year starting with FY13 and going through projections for FY19.



With FY18 coming to a close shortly and the IRB's announced JWST cap breach of $803 million in development costs, this chart reflects the reality of the breach going into FY19 budget planning.

In terms of lost opportunities and NASA's budgetary trade space, it is important to know the full impact the JWST breach caused for NASA and the American public as a whole.

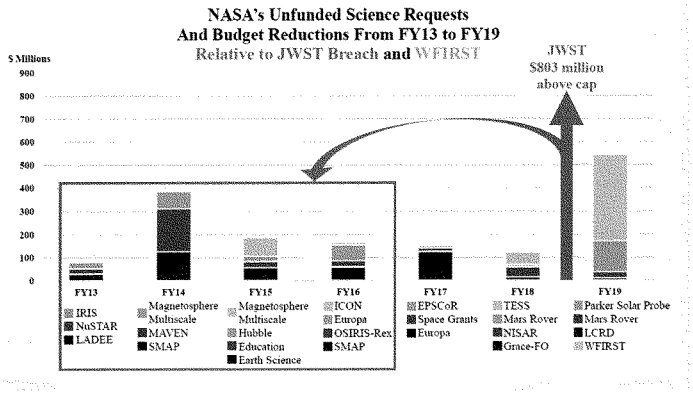


The $803 million needed to fund the JWST cost breach could fund nearly every one of NASA's science funding shortfalls from FY13 to FY16. These projects include Earth science and education projects greatly promoted by our Democratic colleagues on the committee.

Looking forward to FY19 and NASA's future flagship program plans, the cost issues with the Wide Field Infrared Survey Telescope (W-FIRST) will become a subject of debate alongside the JWST congressional reauthorization. The FY18 Omnibus required an updated life-cycle cost estimate for W-FIRST and NASA's report concludes the estimated cost range is $3.3 billion to $3.9 billion.

This life-cycle cost estimate exceeds the NASA-imposed cost cap of $3.2 billion included in the bipartisan NASA Authorization Act of 2018.

To give perspective to the funding dilemma presented by the JWST and W-FIRST cost issues, NASA's W-FIRST estimate includes a request for $371 million which is now reflected on this FY19 chart.



The bipartisan NASA Authorization Act of 2018 seeks to limit flagship program overlap to reduce the NASA's risk of becoming overwhelmed by W-FIRST development before JWST is operational in space. Thus, it is my hope the IRB report and our witness panel testimony will shed light on lessons learned with JWST, leading to a successful flight and operations in March 2021. We DO NOT want these mistakes repeated during the development of W-FIRST. Congress needs to understand the "unvarnished" status of these programs today, as well as the plan going forward. Decisions made now can have long lasting implications on future missions. We need to know that there is not a systematic or fundamental management problem with how NASA plans and executes these larger strategic missions.

I thank our witnesses here today, helping us to better understand where we are and how we plan to move forward, and look forward to your testimony.

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Chairman SMITH. Thank you, Mr. Babin.

Mr. BABIN. Yes, sir.

Chairman SMITH. The gentleman from California, Mr. Bera, the Ranking Member of the Space Subcommittee, is recognized for his opening statement.

Mr. BERA. Thank you, Mr. Chairman, and thank you to the Ranking Member for holding this hearing.

In many ways, these hearings are a continuation of hearings that the Space Subcommittee had last month on NASA costs and schedule overruns, and it's always good to see our former colleague, Administrator Bridenstine, on that side of the podium.

I won't reiterate what both the Chairman and Ranking Member and the Chairman of the Subcommittee have gone through, but I do think what the cost overruns suggest and remind us is the complexity of mentioning when you're thinking about doing something that you've never done, the scientific and technologic complexity. And, you know—and it also highlights the important role that Congress has in our oversight role in making sure that, as we're budgeting and thinking about those future priorities, we're doing so with the most accurate information.

As we think about— I'm someone—I think along with a lot of my colleagues—that puts a lot of faith in the decadal survey and in an objective way kind of laying out what our priorities are. And in that decadal survey when we think about WFIRST and think about future projects, in that context I'm going to be curious to hear both today and tomorrow what we can learn in terms of if we look backwards on Webb in terms of budgeting, in terms of timeline, that will help inform us going forward.

I do think there will be robust dialogue and discussion as we look at future missions, future budgets and allocations knowing that this is a pretty significant cost overrun. One billion dollars is a lot of money. So it is what can we learn.

At that Space Subcommittee hearing, we also started to talk about, as NASA contracts out with other commercial vendors and others to do a lot of the important and necessary work, what are newer types of contracts that do share some of the risk there and—on deliverables. You use them in many other industries. Are those even viable in this context when you're trying to do something that you've never done before and what does that look like? And I do think, over this Congress but then also into future Congresses it will be important for us to have that conversation as we think about prioritizing.

And then just one last statement. I think it is worth noting that, despite the headline-grabbing finding of schedule and cost growth, the IRB's concluded that James Webb should continue based on its extraordinary scientific potential and critical role in maintaining U.S. leadership in astronomy and astrophysics. And, you already have a lot of the sunk costs in there, so it would be shortsighted on our part not to say, you know, let's finish this incredibly important project.

But again, as we go forward, it'll be interesting to hear from NASA, as well as the contractors and subcontractors what can we learn from the Webb experience that helps better inform us going forward as Members of Congress.

So thank you. 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

House Committee on Science, Space, and Technology
"James Webb Space Telescope: Program Breach and its Implications"
July 25, 2018

Good morning, and thank you, Mr. Chairman, for holding these hearings on *"James Webb Space Telescope: Program Breach and its Implications* ". I am pleased to see Administrator Jim Bridenstine make his first appearance before the full Committee. As most know, the Administrator sat on this side of the dais for several years. I look forward to working with him in his new capacity in the months ahead. I also want to thank Mr. Young who will be joining us on both panels today and tomorrow. Mr. Young, thank you for your willingness, time and time again over the years, to chair the many assessments you have been asked to undertake in reviewing space programs in difficulty.

Mr. Chairman, in many respects, these hearings are a continuation of the hearing the Space Subcommittee held just last month on NASA cost and schedule overruns. As we will hear today, JWST has encountered a significant schedule delay. This will translate into a new projected launch date of March 2021 and a program cost increase of about $1 billion.

In terms of what we should focus on today, I hope that Mr. Young and the Administrator will address:

- How much confidence Congress can have in the March 2021 launch date in light of the IRB's acknowledgment that some risks are not included in projecting that date;
- How Congress can measure NASA's progress in implementing the findings and recommendations of the IRB report;
- The impacts of the JWST delay and cost increase, both on the Science Mission Directorate and agency-wide;
- Why issues identified in the 2010 JWST independent review regarding communications and program reporting appear to have been unaddressed; and
- When additional funding will be requested for JWST, and how much will be needed.

It is worth noting that despite the headline-grabbing finding of schedule and cost growth, the IRB concluded that "*JWST should continue based on its extraordinary scientific potential and critical role in maintaining U.S. leadership in astronomy and astrophysics.*" That is why I look forward, over the course of the next two days, to having frank discussions with the people most involved in moving us forward towards commissioning this tremendous observatory.

With that, I yield back.

Chairman SMITH. All right. Thank you, Mr. Bera.

Our first witness today is Mr. Jim Bridenstine, Administrator of NASA. A former colleague and Member of the Science Committee and its Space Subcommittee, Mr. Bridenstine now serves as a Senior Space Science Advisor to the President and oversees agency operations.

Prior to his election to Congress, Mr. Bridenstine was the Director of Tulsa's Air and Space Museum. He completed a triple major at Rice University and earned his Master's of Business Administration at Cornell University.

Our second witness is Mr. Tom Young, Chairman of the Independent Review Board. In this role, Mr. Young led a team of 11 members to conduct a review of the JWST program. Mr. Young is the former Director of NASA's Goddard Space Flight Center, as well as the former President and Chief Operating Officer of Martin Marietta Corporation.

He earned both a bachelor's degree in aeronautical engineering and a bachelor's degree in mechanical engineering from the University of Virginia and a Master's of Management degree from MIT.

We welcome you both, look forward to your testimony. And, Mr. Bridenstine, if you'll begin.

TESTIMONY OF HON. JIM BRIDENSTINE, ADMINISTRATOR, NASA

Mr. BRIDENSTINE. Thank you, Chairman Smith. It's an honor to be here. Chairman Smith, Chairman Babin, Ranking Member Johnson, Ranking Member Bera, thank you all for your leadership on this Committee. Thank you for your leadership with the James Webb Space Telescope quite frankly. And, when I was on your side there back in March, NASA came to Congress and let everybody know that we're up against a cost overrun and of course an increase in schedule. And at that moment I knew that I would be sitting on this side coming back and testifying before the Committee that I used to serve on.

So here we are, and I want to share with you some of the things that I've learned in my time here at NASA. First of all, the Independent Review Board was called for by NASA at a time when we were having trouble with the spacecraft element of the James Webb Space Telescope. When I say the spacecraft element, there's really two elements. One is the optical telescope element, which includes all the scientific capabilities, and then really the bus.

And if you go back in time, we really believed at NASA that the most difficult part of the James Webb Space Telescope would, no kidding, be all of the scientific instruments and the capabilities on that side of the spacecraft. The spacecraft element seemed to be a little bit more routine.

There's one big difference in this spacecraft element than every other spacecraft that we've ever developed, and that is that we need a sunshield. On one side of the spacecraft we need to be down around 7 degrees Kelvin, which is near absolute zero. That's an incredibly cold temperature and necessary in order to use the infrared side of this telescope, which is really just—it's detecting heat signatures from galaxies that go back to the very dawn of time if

you will, the very beginning of the universe. So in order to do that, it has to be extremely cold.

So that—we need a heat shield. And that heat shield is a very complex, very dynamic piece of equipment that is unique in this particular spacecraft. And it has five layers, and the—in order to deploy it, think of five sheets the size of a tennis court stacked on top of each other, and on one side of this heat shield the temperatures are going to be almost, you know, 300 degrees Fahrenheit and on the other side minus 390 degrees Fahrenheit separated by maybe just a couple of feet. That's a very impressive scientific achievement once it's complete.

But to deploy that heat shield is very complex and very challenging, and there's a whole lot of single points of failure. And we have to test it. And NASA was going through a process of deploying that heat shield and then folding it back for the purpose of testing. And in that process we discovered—NASA discovered—I wasn't there at the time, but NASA discovered that this is going to take a lot longer. We were very optimistic in the amount of time that we believed that it would take to test this. Ultimately, that proved to be incorrect.

And during the course of this, NASA said we need to have an Independent Review Board to—and I want to be really clear. Nobody likes Independent Review Boards. They are not fun. They are not fun for NASA, they are not fun for the contractor. But NASA called for an Independent Review Board on itself because of the delays and the cost overruns that we got on James Webb.

During the Independent Review Board, there was more testing being conducted and embedded problems were found in some human errors were found that once again delayed it during the course of the Independent Review Board. So that's how we came to the conclusion that we needed to really do a re-planning, and that re-planning has been done and we're looking now at a launch date of March 30 of 2021 and a cost overrun of about $800 million. So it's gone from a development cost of $8 billion to $8.8 billion and a total lifecycle cost of $8.8 billion up to $9.6 billion. These are massive increases, and I understand that.

It's also true—and I want to be really clear about what we're doing here. And Ranking Member Bera I think hit the nail on the head. We are doing things that have never been done before, and we are doing things that nobody on the face of the planet other than the United States and our European, you know, supporters, the European Space Agency has instruments on this telescope. This has never been done before in the history of the world, and it really sets the stage for who in the world is the leader in astrophysics and these kind of capabilities. And only the United States of America could accomplish this. That's where we are.

I also want to be clear that we are going to change how we understand the universe. We're going to see very—all the way back to the very beginning of the universe, what we call cosmic dawn, the very first light from the beginning of the universe. And the reason that this telescope is an infrared is because the universe is expanding, all the time expanding. In fact, it's expanding at an accelerating rate, and we're trying to understand, why is that happening?

But when you see back to the very beginning, cosmic dawn, you're talking about, as the universe expands, those wavelengths lengthen, so instead of being able to detect optical light, we're going to be looking at infrared light. And that gives us a requirement to have this extremely cold cryocooled antenna that can see back that far basically detecting heat signatures from light from the very beginning of dawn.

We're also going to be able to see inside of other galaxies in ways that we've never seen before. We're going to be able to look at the atmospheres of exoplanets. This is also I think an important point. If you go back in time when we started this project, we did not even know that exoplanets existed. Now, we know that there are thousands of exoplanets, planets maybe even like Earth orbiting other stars in our galaxy. We're going to be able to use this telescope with a spectrometer to understand, what are the atmospheres of this planet like, and are they capable of hosting life? So this is a tremendous capability that we're bringing to bear that, again, nobody else on the planet can do.

So I want to reemphasize how important this mission is, and the work that this committee has done helping us get to this point has been amazing. It's not comfortable to come back and have to testify on cost overruns and of course schedule delays, but at the end, my testimony to you is that I really believe that this will be worth it.

And I look forward to answering your questions, and I appreciate all of you having me here today.

[The prepared statement of Mr. Bridenstine follows:]

Statement of

James F. Bridenstine
Administrator
National Aeronautics and Space Administration

before the

Committee on Science, Space and Technology
U. S. House of Representatives

July 25, 2018

In March, NASA informed Congress about a schedule delay and potential cost increase for the James Webb Space Telescope, NASA's next great observatory. Since then, the agency has been working to understand the causes of the delay, determine steps necessary to ensure mission success and improve our estimates of the time and cost necessary to complete development, launch, and commissioning. NASA is committed to successfully completing Webb, an international program with partners from Europe and Canada, and sharing its unprecedented and certainly incredible view of the early Universe and observations of exoplanets with the scientific community, U.S. taxpayers, and the world.

Successfully implementing the Webb mission is a high priority and critical to maintaining national leadership in the space sciences. Webb was the highest priority major initiative of the National Academy of Sciences' 2001 decadal survey, *Astronomy and Astrophysics in the New Millennium*. Webb is designed to see the Universe's first stars and galaxies, to reveal how the familiar night sky of galaxies and stars came to be, and to take the next giant leap in characterizing planets orbiting other stars (exoplanets) and searching for Earth-like planets. Webb plays a significant role in the Astrophysics program. For example, the Transiting Exoplanet Survey Satellite that launched in April 2018 is designed to provide a pipeline of target exoplanets that are well-suited for characterization using Webb.

While Webb will transform our understanding of the Universe, to achieve its objectives it must necessarily be sophisticated. In fact, it is the most challenging science mission and the largest observatory that NASA has ever developed. Webb's mission requires a very large telescope optimized to make observations in the infrared portion of the spectrum. The telescope and its instruments need to be extremely cold to limit the amount of infrared light emitted by the telescope itself. Both the primary mirror and the sunshield it uses to keep cool are larger than the fairing of any rocket yet flown. The mirror and sunshield will be folded to fit inside the fairing, and they will deploy after launch into their final mission configurations while Webb is maneuvering to its operational location in space over 1 million miles from Earth. There is significant risk associated with these deployments, and every effort must be made to ensure they occur as planned. Developing the observatory required the maturation of new technologies to enable Webb's next-generation instruments, mirrors and mirror system, telescope structure, sunshield, and thermal-control systems. Each of these technology advancements is required to

provide the Webb observatory with the capabilities needed to see the first stars, to characterize exoplanets, and to achieve Webb's other science objectives.

Webb is in the final stages of its development. All of its hardware has been fabricated, and the flight hardware and software are undergoing the last major steps of its integration and testing (I&T) phase. The observatory is currently integrated into two elements. One element is the Optical Telescope Element / Integrated Science Instrument Module, called OTIS. OTIS is comprised of the Optical Telescope Array, itself made from 18 precision mirror segments aligned to achieve the sensitivity of a single large mirror, and four state-of-the-art infrared science instruments. The other element is the Spacecraft Element, which is composed of the spacecraft (solar arrays, communications, propulsion, power, command and data handling, etc.) and the five-layer, tennis-court-sized sunshield. Both elements now reside in a single clean room at the observatory contractor, Northrop Grumman Aerospace Systems (NGAS), in Redondo Beach, California. OTIS has completed testing that simulates the conditions of launch and of space with excellent results. The Spacecraft Element has been completely assembled and is currently undergoing similar testing. Once testing of the Spacecraft Element is complete, the two elements will be joined together into the full observatory and put through a series of tests as an integrated system. The observatory will be shipped by sea to French Guiana where it will be launched on an Ariane 5 rocket. In space, Webb will undergo six months of commissioning, including deployments of the observatory's mirrors, sunshield, and a number of smaller systems, as well as powering-up, testing, and calibrating the observatory's five instruments and multiple observing modes.

Early this year, NASA recognized that it would take longer to complete the Spacecraft Element I&T than previously estimated. Problems during I&T caused significant delays, and the team discovered that certain tasks—in particular deploying and re-folding the sunshield—would take significantly more time and possibly more funding than previously estimated.

Due to the schedule delays and possible cost increase, NASA formed an Independent Review Board (IRB) chaired by A. Thomas Young, a distinguished leader of the aerospace community, member of the National Academy of Engineering, former director of NASA's Goddard Space Flight Center, and former president of Martin Marietta. The IRB's charge was to evaluate all factors influencing Webb's success, to ensure that NASA's approach to completing I&T, the launch campaign, and commissioning would maximize the likelihood of mission success. NASA also requested the IRB to provide an independent assessment of the schedule and cost necessary to complete Webb's development including launch and commissioning. The IRB was asked to conduct its review quickly since the project was at a critical stage. The IRB members are an impressive set of well-known experts across engineering, science and management fields, and NASA appreciates the hard work they put into the task. In spite of the disruption to their lives, they accepted the challenge of conducting a thorough review on a relatively short timeline, recognizing the importance of Webb's success to NASA and the Nation.

While the IRB was meeting, a new issue was discovered. During acoustic testing of the Spacecraft Element—a test that subjects the hardware to the intense sound levels that it will experience during launch—a number of fasteners for covers that protect the sunshield membranes until deployment in space loosened and detached, falling onto or near the sunshield

and spacecraft. Determining the cause and solution to the problem took time and significantly extended the schedule necessary to complete I&T. This additional work added six months beyond the delays already evident when the IRB convened. The Webb project team is currently correcting the problem, searching for any potential related issues that might be present, and preparing the Spacecraft Element to repeat acoustic testing and complete the remaining Spacecraft Element testing in preparation for integration with the OTIS.

Mr. Young's testimony will discuss the IRB Report, and I recommend reading this thoughtful and useful report to obtain a full understanding of their findings and recommendations. The IRB submitted their report to NASA on May 31. The IRB made 32 recommendations, all aimed at maximizing the likelihood of Webb's success. In their report, they found that issues including human errors, embedded problems (lurking undetected problems, like the fastener issue revealed by the acoustic test), excessive optimism in I&T planning, the lack of sunshield experience, and system complexity significantly impacted the development schedule. Two examples of human errors highlighted by the IRB were damage to propellant valves caused by cleaning with an improper solvent and damage to pressure transducers due to application of excessive voltage during testing. A fundamental observation was that due to the scale and complexity of Webb's development, small mistakes often lead to large impacts on schedule and cost. A central focus of the IRB recommendations was the reinforcement of figurative safety nets to catch human errors that happen during I&T. In addition, the IRB focused on enhancing efforts to reveal embedded problems that may be hidden in the observatory, and to mitigate the impacts of any embedded problems on the schedule and cost of completing observatory development. The IRB also reaffirmed Webb's incredible scientific potential and its critical role in maintaining U.S. leadership in astronomy and astrophysics. Thanks to the IRB members' extensive experience and independent perspective, their findings and recommendations provide NASA with a clear and actionable roadmap of the areas where we should focus as the Webb team works to complete development.

In June, NASA provided a report to the Committee on Science, Space and Technology as well as other Congressional Committees describing the actions we are taking in response to the IRB's recommendations. NASA accepts all of the IRB's recommendations. NASA already is fully implementing all of the recommendations except two, with plans to respond to those as well.

Some select IRB recommendations are: 1) due to the complexity of Webb's commissioning, especially the deployment of the telescope and sunshield, NASA should name a world-class system engineer as "Commissioning Manager," with total end-to-end responsibility for commissioning success; 2) Northrop Grumman Aerospace Systems (NGAS) and NASA should take a number of actions to address human errors during I&T and embedded problems, to prevent them or, if that fails, to catch them before they arise in a context in which they would affect schedule, cost, or mission success; and 3) NGAS should take steps to ensure that certain important engineers are present at critical stages through the rest of development.

As part of the review, the IRB requested the Webb teams at each of the major organizations developing Webb (NASA's Goddard Space Flight Center, Northrop Grumman Aerospace Systems, and the Space Telescope Science Institute) identify additional activities that would enhance mission success if implemented, without regard to any impact on cost and schedule.

One of the IRB's recommendations was that NASA evaluate those mission success enhancing activities and implement them as appropriate. NASA used a cost versus benefit analysis to decide which of those mission enhancements could be implemented. The small set of exceptions are items that would either take too long to implement or would not provide a net benefit to mission success after taking all considerations into account.

The IRB's analysis of the schedule found that the Webb project's scheduling process was robust. However, the IRB's schedule estimate included some differences from the previous Webb schedule estimates, including uncertainty in the durations of tasks, and likelihoods of risks and threats. The largest contribution to the shift in the IRB's schedule from previous NASA estimates was due to the fastener issue that occurred during the IRB's deliberations and after NASA's schedule announcement in March.

The IRB's cost estimate accounted for the continued workforce needed to complete development throughout the duration of the delay, which is characterstic given the mature stage of development for the project.

NASA greatly appreciates the IRB's thorough and thoughtful analysis and the care they put into developing their recommendations and explaining their results. Their efforts will be invaluable to ensuring Webb's success as it progresses through development to become an operational scientific observatory. We have made the IRB's report available to this Committee and the public.

NASA has incorporated the IRB's schedule analysis along with other inputs to determine a revised estimate of Webb's launch date and the cost necessary to complete the mission. NASA has established March 30, 2021, as Webb's new launch date with 80 percent confidence. This new date is consistent with the findings of the IRB. It includes time to accommodate the technical issues and over-optimism identified by the IRB, addresses the fastener issue encountered during acoustic testing, and reestablishes appropriate schedule reserves.

While both the IRB's schedule analysis and NASA's revised launch date include significant margin for problems that may arise while completing development, neither accommodates the time required to recover from unknowable future events such as another several-month delay due to human errors or embedded problems of the sort that have cost so much time recently. The estimates assume that the corrective actions taken based on the IRB's recommendations will significantly reduce or eliminate the likelihood of such events, and we must ensure that they do. Additionally, they do not accommodate the time required to recover from a significant spacecraft subsystem or instrument problem where the element needs to be removed from the observatory for corrective action. Removing an embedded element could add several months to the schedule, or, in the case of an instrument, potentially more than a year. It should be noted that no program typically adds schedule margin for such significant hardware anomalies because such anomalies are very rare.

As a result of the additional time needed to complete development of Webb, additional funding is required. To support the March 30, 2021 launch date and five years of science operations, we

estimate that Webb's new life-cycle cost will be $9.663 billion. The estimated development cost, including launch and commissioning, to support the new launch date is $8.803 billion, up from the $7.998 billion development-cost estimate established in 2011. Over Webb's lifetime, about $837 million in new funding will be necessary beyond previous requests, including $813.8 million in development funding and $23.5 million in additional funding for Phase E (operations and closeout). The increase in cost accommodates the additional time required to complete development of Webb, implement the IRB's recommendations, incorporate additional activities to enhance mission success identified by project in response to the IRB, and replenish reserves at all levels of the project (NASA Headquarters, Goddard, and Northrop Grumman). The revised estimates do not require a change to the budget request for Fiscal Year (FY) 2019.

We anticipate that the cost growth on Webb will have implications for other missions and programs. We expect the most serious repercussions to occur in FY 2020 and FY 2021, due to the estimated $490 million of additional funding required for Webb in those years above the prior planning budget. We have not yet determined what the impacts will be on other NASA programs and projects, but our plan will be informed by the priorities established through the National Academy's decadal surveys. We look forward to providing our plan for successful completion of Webb to this Committee as part of the FY 2020 budget request.

NASA also recognizes that the lessons learned here have similarities to other issues we are seeing around NASA's development programs for large, complex space systems 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. We have talked about these results concerning development, management and the U.S. industrial base with all of our agency leaders. I have asked my team to communicate these lessons directly to NASA development personnel in an appropriate forum. This is an important opportunity for us to get better, an opportunity we do not want to miss.

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 and rewriting textbooks for years. The data acquired with Webb will underpin many future projects. Notwithstanding the issues encountered during integration and testing of the Spacecraft Element, the superb performance of Webb's telescope and instruments during testing have made us eager to put them to use in space to address fundamental science questions. The IRB put it succinctly—Webb has "awesome scientific potential." Despite the recent challenges, 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, we are disappointed that completing Webb is taking longer and costing more than expected, but NASA is absolutely committed to successfully completing, launching, and commissioning Webb, and to carrying out its important scientific mission.

We ask this Committee, Congress, the scientific community, and the public for their continued support as we work to do everything necessary to make Webb successful. We appreciate your understanding of the complexity of what is required to ensure Webb's success, and we will continue to do everything possible to be good stewards of the resources with which you have entrusted us. I assure you that, in the end, Webb will be worth the wait.

NASA Administrator Jim Bridenstine

James Frederick "Jim" Bridenstine was nominated by President Donald Trump, confirmed by the U.S. Senate, and sworn in as NASA's 13th administrator on April 23, 2018.

Bridenstine was elected in 2012 to represent Oklahoma's First Congressional District in the U.S. House of Representatives, where he served on the Armed Services Committee and the Science, Space and Technology Committee.

Bridenstine's career in federal service began in the U.S. Navy, flying the E-2C Hawkeye off the USS Abraham Lincoln aircraft carrier. It was there that he flew combat missions in Iraq and Afghanistan and accrued most of his 1,900 flight hours and 333 carrier-arrested landings. He later moved to the F-18 Hornet and flew at the Naval Strike and Air Warfare Center, the parent command to TOPGUN.

After transitioning from active duty to the U.S. Navy Reserve, Bridenstine returned to Tulsa, Oklahoma, to be the Executive Director of the Tulsa Air and Space Museum & Planetarium.

Bridenstine was promoted to the rank of Lieutenant Commander in 2012 while flying missions in Central and South America in support of America's war on drugs. Most recently, he transitioned to the 137th Special Operations Wing of the Oklahoma Air National Guard.

Bridenstine completed a triple major at Rice University, and earned his MBA at Cornell University. He has three children with his wife, Michelle.

Chairman SMITH. Thank you, Mr. Bridenstine.
Mr. Young?

TESTIMONY OF MR. TOM YOUNG, CHAIRMAN, JWST INDEPENDENT REVIEW BOARD

Mr. YOUNG. Chairman Smith and Ranking Member Johnson and Committee Members, I'm pleased to present the results of the Independent Review Board evaluation of the James Webb Space Telescope mission.

The IRB charter established by NASA require that we evaluate all factors influencing JWST success. Our report is complete. We believe we have satisfied our charter. Our report contains 32 recommendations. We believe the implementation of all—underline in all—32 recommendations is required to maximize the probability of JWST success.

Our initial observation is that JWST is an observatory with incredible capability, awesome scientific potential, and significant complexity, risk, and first-time events. An overarching recommendation of the IRB is that mission success be the top priority in all future JWST activities. JWST is at a point in its development that every appropriate thing that can be done to maximize mission success should be done.

There are a large number of JWST accomplishments that require recognition. All flight hardware has been delivered. All science instruments have been integrated into the science module, which has been combined with the telescope to form the optical telescope and science instrument model called OTIS. OTIS has been successfully tested. The science instruments have met their requirements, and it has been delivered to Northrop Grumman for integration with the spacecraft and sunshield. This is but a few of the positive JWST accomplishments.

In our report, we cite seven noteworthy JWST firsts, the most noteworthy being the sunshield, which is mandatory for success, and it has no significant legacy. There are two yet-to-be-completed phases of the JWST project that represent significant risk. The first is integration and test. To date, there have been human errors and embedded problems that have caused significant delays in integration tests, resulting in large schedule delays.

The IRB has been very—has very specific recommendations focused upon human errors and embedded problems. The success in implementing the IRB recommended corrective actions will determine the success of completing JWST development.

Human errors are mistakes made by people working on the flight hardware or developing procedures that dictate how work on the flight hardware is to be conducted. Three examples of human errors that have had a major impact on JWST schedule and cost are: wrong solvent used to clean propulsion valves, test wiring erroneously connected to flight hardware without adequate inspection, sunshield cover fasteners improperly installed. The capability of the integration and test workforce and the quality of procedures must be such that human errors are minimized, and when they occur, their impact is negligible.

Embedded problems or problems in the as-built hardware that are undetected until a major test many months in the future after

the problem is introduced or, even worse, not detected until the observatory is in space. The valve solvent problem and sunshield fastener problem are examples of embedded problems that have had a major impact on scheduling. An in-depth audit by NASA and Northrop Grumman of the flight hardware, including drawings, procedures, et cetera, is required to identify any additional embedded problems that may exist.

The second JWST phase with high risk is spacecraft and sunshield deployments that occur during observatory commissioning. Approximately 307 single-point failure items must work to success—have these deployments be successful. This phase of JWST is similar to the entry-descent-landing phase of a Mars science laboratory mission which, for comparison, had 72 single-point failures when it landed on Mars in 2012. Both are high-risk missions with no ability to test as you fly. A world-class systems engineer established as EDL manager has been critical to the success of Mars landers. The IRB recommends the position of commissioning manager staff by a world-class engineer be established for JWST.

There are several additional technical and management recommendations from the IRB. If fully implemented, such recommendations as NASA certification launch vehicle and management reporting and communication increase the probability of mission success.

The IRB recommended launch date for JWST is March 2021. This is a 29-month delay from the October 2018 date established in 2011 with a cost of approximately $1 billion. Five factors have caused this delay: human errors, embedded problems, lack of experience in areas such as the sunshield, excessive optimism, and systems complexity. The JWST complexity and risk cannot be overstated. The IRB recommends—recommending March 2021 launch date assumes the successful implementation of the recommendations in our report. No allowance has been made for additional INT errors or embedded problems with multi-month impacts. Additional sunshield deployments during INT beyond the currently planned two or removal of the spacecraft sun system or science estimate.

With all factors considered, the members of the IRB are unanimous in recommending that JWST continue based on its extraordinary scientific potential and critical role in maintaining U.S. leadership in astronomy and astrophysics. Thank you.

[The prepared statement of Mr. Young follows:]

TESTIMONY TO THE COMMITTEE

ON

SCIENCE, SPACE AND TECHNOLOGY

JULY 25, 2018

A. THOMAS YOUNG
CHAIR, JWST INDEPENDENT REVIEW BOARD

Chairman Smith, Ranking Member Bernice Johnson and Committee members, I am pleased to present the results of the Independent Review Board (IRB) evaluation of the James Webb Space Telescope (JWST) mission.

The IRB charter established by NASA required that we evaluate all factors influencing JWST success. Our report is complete. We believe we have satisfied our charter. Our report contains 32 recommendations. We believe the implementation of all 32 recommendations is required to maximize the probability of JWST success.

Our initial observation is that JWST is an observatory with incredible capability, awesome scientific potential and significant complexity, risk and first-time events.

An overarching recommendation of the IRB is that mission success be the top priority in all future JWST activities. JWST is at the point in its development that every appropriate thing that can be done to maximize mission success should be done.

There are a large number of JWST accomplishments that require recognition. All flight hardware has been delivered. All science instruments have been integrated into the science module which has been combined with the telescope to form the optical telescope and science instrument module (OTIS). OTIS has been successfully tested, the science instruments have met their requirements and it has been delivered to Northrop Grumman for integration with the spacecraft and sunshield. This is but a few of the positive JWST accomplishments.

In our report we cite seven noteworthy JWST Firsts. The most noteworthy being the sunshield which is mandatory for success and has no significant legacy. Two yet to be completed phases of the JWST project represent significant risk. The first is Integration and Test (I & T). To date, there have been human errors and embedded problems that have caused significant problems in I & T resulting in large schedule delays. The IRB has very specific recommendations focused upon human errors and embedded problems. The success in implementing the IRB recommended corrective actions will determine the success of completing JWST development.

Human errors are mistakes made by people working on the flight hardware or developing procedures that dictate how work on the flight hardware is to be conducted. Three examples of human errors that have had a major impact on JWST schedule and cost are:

- Wrong solvent used to clean propulsion valves.
- Test wiring erroneously connected to flight hardware without adequate inspection.
- Sunshield cover fasteners improperly installed.

The capability of the I & T workforce and the quality of procedures must be such that human errors are minimized and when they occur their impact is negligible.

Embedded problems are problems in the as-built hardware that are undetected until a major test many months in the future after the problem is introduced or even worse not detected until the Observatory is in space. The valve solvent problem and sunshield fastener problem are examples of embedded problems that have had a major impact on schedule.

An in-depth audit by NASA and Northrop Grumman of the flight hardware including drawings, procedures, etc. is required to identify any additional embedded problems that may exist.

The second JWST phase with high risk is spacecraft and sunshield deployments that occur during Observatory Commissioning. Approximately 307 single point failure items must work to have successful deployments. This phase of JWST is similar to the entry-decent-landing (EDL) phase of a Mars Science Laboratory mission, which for comparison had 75 single point failures when it landed on Mars in 2012. Both are high risk missions with no ability to test-as-you-fly. A "World Class" systems engineer assigned as EDL manager has been critical to the success of Mars landers. The IRB recommends the position of Commissioning Manager staffed by a "World Class" engineer be established for JWST.

There are several additional important technical and management recommendations from the IRB. If fully implemented, such recommendations as NASA certification of the launch vehicle and management reporting and communication increase the probability of mission success.

The IRB recommended launch date for JWST is March, 2021. This is a 29-month delay from the October, 2018 date established in 2011 with a cost of approximately 1B$. Five factors have caused this delay:

- Human errors.
- Embedded problems.
- Lack of experience in areas such as the sunshield.
- Excessive optimism.
- Systems complexity.

The JWST complexity and risk cannot be overstated. The IRB recommended March, 2021 launch date assumes the successful implementation of the recommendations in our report. No allowance has been made for:

- Additional I & T errors or imbedded problems with multi-month impacts.
- Additional sunshield deployments during I & T beyond the currently planned two.
- Removal of a spacecraft subsystem or science instrument.

With all factors considered, the members of the IRB are unanimous in recommending that JWST continue based on its extraordinary scientific potential and critical role in maintaining U.S. leadership in astronomy and astrophysics.

Thank you, I will be pleased to respond to any questions you may have.

A. Thomas Young

A. Thomas Young is the former Director of NASA's Goddard Space Flight Center, President and COO of Martin Marietta and Chairman of SAIC. He retired from Lockheed Martin in July, 1995 and the SAIC Board in 2013. Mr. Young is involved in various advisory and review activities associated with the U.S. Space Program.

Mr. Young began his career with NASA at the Langley Research Center in 1961. He was a member of the Lunar Orbiter Project Team and was Mission Director for Project Viking, which resulted in the successful landing of two spacecraft on the surface of Mars. He became director of the Planetary Program at NASA Headquarters in 1976 and was appointed Deputy Director of the Ames Research Center in 1978. Mr. Young was Director of the Goddard Space Flight Center from 1979 to 1982. He joined the Martin Marietta Corporation in 1982 and was subsequently President of Baltimore Aerospace and the Electronics and Missiles Group. Mr. Young was President and COO of Martin Marietta from 1990 to 1995.

Mr. Young is an Honorary Fellow of the American Institute of Aeronautics and Astronautics, a Fellow of the American Astronautical Society, a Fellow of the Royal Astronautical Society and a Fellow of the International Academy of Astronautics. He is a member of the National Academy of Engineering and the University of Virginia Raven Society. Mr. Young is a former member of the NASA Advisory Council.

Mr. Young earned a Bachelor of Aeronautical Engineering degree and a Bachelor of Mechanical Engineering degree in 1961 from the University of Virginia. In 1971 he received a Masters of Management degree from MIT which he attended as a Sloan Fellow. He also holds an honorary doctor of science degree from Salisbury University.

Chairman SMITH. Thank you, Mr. Young. And I'll recognize myself for questions. Let me address the first one to Administrator Bridenstine. When we take a look at the cost overruns, when we take a look at the missed deadlines in regard to JWST, what are your options when it comes to contractor accountability for this particular mission, as well as for others?

Mr. BRIDENSTINE. So for this particular contract it's cost-plus and award fee, and the award fee is the profit because, other than that, the contractor is working at cost. The award fee is based on a set of metrics that NASA determines. Technical capability is included in that; cost, schedule, business administration is included in that. And during the course of evaluating the contractor, we're making determinations as to what their award fee will be.

So a couple of things here. Number one, their award fee has not been as good as it otherwise would have been, so that has in essence hurts their bottom line. And number two, when there's a cost overrun or a schedule delay, as we have right now, there is no award fee, so they are in essence working right now at cost.

Chairman SMITH. Okay.

Mr. BRIDENSTINE. Now, ultimately, as has been identified, there's going to be a commissioning process of the satellite once it's in space, and there are potential award fees in that. Those potential award fees add up to—if they were to maximize it, it would add up to about $60 million. We have already taken off the table $28 million of the $60 million, which again is not helpful to the contractor and hurts their bottom line. It is also true that the remainder $30 million-plus available they're going to have to perform in order to accomplish and achieve that award fee, which is again there only profit.

Chairman SMITH. Okay.

Mr. BRIDENSTINE. It is also true that there are provisions in the contracts to actually claw back previously earned award fees. And I want to be really clear, Mr. Chairman. We don't want any of that to happen going forward. We want success going forward, which means that the punishment they've already received would be the punishment they will receive. That doesn't guarantee that's how it's going to be going forward——

Chairman SMITH. Right.

Mr. BRIDENSTINE. —but, ultimately, we want them to be successful because if they're successful, then we are successful. And so those are some of the tools that we have in our belt.

Chairman SMITH. Okay. That is really helpful, all those options that you just mentioned, and I appreciate that.

Next question, is there any legislation that Congress can pass that will help you enforce contractor accountability? Do you need any more authority than you already have?

Mr. BRIDENSTINE. We have really good authorities that we utilize right now. We have what's called an Acquisition Integrity Program that's administered by the Office of the General Counsel at NASA. The Acquisition Integrity Program ultimately has provisions by which a contractor can be suspended or can be debarred. Again, we don't like exercising those authorities, but under the federal acquisition regulations, those are tools available to us.

If there's a law that Congress could pass, one of the things we're doing right now is we are taking some of our best talent and we are embedding them with Northrop Grumman in this process. You know, NASA—we like to count ourselves a smart buyer. When I say that, we have—and this is absolutely true. We have really intelligent and capable and qualified people that we can take off of other projects and put on to this project, for example, and we are doing that right now and embedding them with the contractor. That's——

Chairman SMITH. Okay.

Mr. BRIDENSTINE. —smart buying. One of the challenges we have going forward is a lot of the talent is going other places because of the way we hire. So if we could—if you could pass one law, maybe direct-hire authority could help us ultimately keep our smart buyer capabilities.

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

Mr. Young, how do you think the program management for JWST compares to other programs that you've analyzed?

Mr. YOUNG. It depends on how far back you—excuse me. It depends on how far back you're going back in the program, I mean, looking at the charts that you had this morning. If you go back to, say, the first confirmation that I'm familiar with where I think JWST was confirmed by NASA at $2.75 billion with a 2011 launch, you know, we—the costs have increased roughly a factor of three since that time period——

Chairman SMITH. I was primarily talking just about the program management itself in isolation. Do you consider it to be one of the worst, one of the average? How does it compare to others?

Mr. YOUNG. Well, I'm kind of sneaking up on that answer.

Chairman SMITH. Okay. All right. I've got limited time, so I hope you'll sneak up quickly.

Mr. YOUNG. Okay. And I'll sneak fast. Okay. So if you look at the program, it's grown a factor of three in a decade. It is hard to take a program with those characteristics and conclude it's anything other than a not-well-managed program and by comparison not a well-managed program.

Chairman SMITH. Okay. Any description as to what you think of a program that costs 19 times what was anticipated and is 14 years delayed?

Mr. YOUNG. My description would be the same, poorly managed.

Chairman SMITH. Okay. And what about recommendations, Jim Bridenstine mentioned a couple of the options that he had, like sanctions. Do you have any recommendations going forward for what we might do with some of those fees and some of the profit and how that can be used to encourage Northrop Grumman to perform better?

Mr. YOUNG. I think his comments were very good. I would really underline the fact that at this stage in the program all of us—emphasize all of us—need to be focused on maximize the probability of JWST being successful. So if I—I'm speaking only as an individual, but if I had this problem, I would take all of the available fees that currently exist, be they the fee on work to be done, the award fees that have not been awarded, the future award fees, I'd put them altogether and I'd put them in one lump sum and I would

have the criteria for getting them the quantity and quality of data returned by JWST after it's on orbit. So I would turn every dollar yet to be awarded into an award fee based on mission success.

Chairman SMITH. That is a very good suggestion, which I endorse, and I thank you for mentioning it today.

The gentlewoman from Texas, the Ranking Member, is recognized for her questions.

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

Mr. Administrator, you mentioned in your last statement that we're moving people and unable to control some of that movement. Could you expand a little bit on that?

Mr. BRIDENSTINE. So there's a number of things that we are already putting into place ultimately to ensure success, so we have taken some NASA talent and put it on this project that—and it's not just people and bodies. It's capability, it's people with history and—that are highly qualified on this project embedded with Northrop Grumman. We are also instituting more oversight from the Goddard Space Flight Center and from NASA headquarters, and in fact we have created an even stronger mission assurance capability so that every screw that goes on to this spacecraft ultimately is being quality assured so we get immediate feedback if something is—if anybody believes something is not right.

We want everybody to be empowered to say stop because one of the challenges that we've had is that there are embedded problems. Some of these problems are screws that were put in the sunshield covers going back years, and we don't discover it until the integration and tests.

I also want to—and I think it's important for me to testify that—and I heard it from Mr. Young as well. We're at the integration and test phase. All of the hardware is built. The software is ready to go. In fact, the scientific instruments have already been tested. What we're doing now is we're integrating the scientific instruments ultimately with the spacecraft and then testing that. And that's where we're having the challenge.

So I think it's important to note, if I can give an analogy, we're on the five yard line we're trying to punch it into the end zone. And I know that, you know, a cost overrun and a delay is not what Congress wants to hear, but at this point, given the scientific return, I think it's critical that we continue to put all of our resources here to get it complete.

Ms. JOHNSON. Do you think you have the proper tools to hold Northrop Grumman accountable?

Mr. BRIDENSTINE. I do at this point. It is my assessment that we have a contract that gives us flexibility ultimately to hold them accountable.

Ms. JOHNSON. Mr. Young, would you like to comment?

Mr. YOUNG. My comments would be similar. I think we do make some observations in our report of areas that we think it really be strengthened. One I think was in one of your opening statements. I think it's very clear that NASA have clear lines of authority and accountability for managing this project, and an observation was that they did not exist when we were looking at them. We made a very strong recommendation in this regard that the Center Director of Goddard have a clear responsibility for the success of the pro-

gram and the Associate Administrator of SMD have a clear responsibility for the success of this program.

Our observation is that's not been the practice to date. That's our recommendation. I don't know what NASA's response to that is, but accountability, clear-lines responsibility, and authority to proceed are critical to managing a program such as JWST.

Mr. BRIDENSTINE. I would just piggyback on that and say we are in fact implementing that recommendation of the IRB and certainly it will make a difference.

And by the way, Tom Young used to be the Director of the Goddard Space Flight Center, so he knows a thing or two about the organizational structure so—

Ms. JOHNSON. Well, let me thank you both and kind of review that this is the first time we've ever done something like this. It's a big project, and it's an important project, and I would hope and I believe that both of you will continue to—well, your responsibility, Mr. Young, is over, but I hope you keep a little eye going, too. And thanks to both of you.

I yield back.

Chairman SMITH. Thank you, Ms. Johnson.

The gentleman from Texas, Mr. Babin, is recognized for his questions.

Mr. BABIN. Yes, sir. Thank you, Mr. Chairman.

My first question is for Administrator Bridenstine. The JWST program cost issues pose a budgetary threat to the other NASA science mission programs, especially the WFIRST program. What is your assessment of the budget planning challenges for NASA science mission programs in light of the latest JWST cost overruns?

Mr. BRIDENSTINE. That's a wonderful question, Chairman, and it's something that we think about and we worry about because you're absolutely right. This cost overrun is going to be a challenge going forward. So I'd like to start by saying that, right now, we have a very balanced portfolio for astrophysics that includes small missions that are not very expensive, medium missions that are a little more expensive, and that we have these, as you mentioned, flagship missions that are strategic in nature, take a long time, and very expensive but ultimately make the United States of America the premier country when it comes to these kind of scientific capabilities, which we all like and believe in. When we do these massive flagship missions, as you just identified, and there are overruns and there are delays, it absolutely makes us in essence cannibalize some of the other missions in the future.

You mentioned WFIRST. The idea of WFIRST presumed that JWST would be on orbit and delivering science, and so it is my recommendation that, you know, we move forward with WFIRST after we move forward with JWST. I think that's—now, it is true that we can do some development now. I'm not saying that we need to shut down WFIRST and we shouldn't do it.

Mr. BABIN. Right.

Mr. BRIDENSTINE. What I'm saying is there's opportunity here because it presumes JWST would be on orbit. It is also true that, as we go forward with this balanced portfolio to make sure that we are getting the best science that we can get in astrophysics and throughout the entire Science Mission Directorate, we want to fol-

low what Ranking Member Bera mentioned, which is the decadal surveys that come from the National Academies of Sciences. So that gives us kind of our guidance if you will to make sure that we're not damaging our total portfolio to deliver the absolute best science.

So I will—this is important, too, Mr. Chairman. The goal—when you think about 2019, we have—there is some money that is left over from last year, plus the—you know, the—at this point JWST was intended to be in operation, so we have the operational money that we can apply to the development of JWST, so for 2019 it doesn't look like we're going to need any more money. The first time that we're going to need any more money is going to be 2020——

Mr. BABIN. Right.

Mr. BRIDENSTINE. —and that's when we're going to have to look at ultimately how do we balance this portfolio to make sure we get the mix right.

Mr. BABIN. And our reauthorization bill actually specifies that before WFIRST is complete, we've got to have JWST on orbit.

Mr. BRIDENSTINE. Yes, sir.

Mr. BABIN. Yes. Also, for both of you gentlemen, the Trump Administration has included space as part of the national security strategy. Do you think the JWST development issues signal an erosion in the quality of the American space industrial base to our near-peer adversaries, thus negatively affecting our national security strategy? Are JWST problems signs of more serious problems with our space industrial base?

Mr. BRIDENSTINE. So we—there is a study underway right now that is considering that as an issue. I don't want to prejudge that study, but I will tell you the industrial base is something that is critically important to the national security interests of this country, and NASA plays a role there. Our scientific capabilities ultimately are for peaceful purposes. I mean, that's just the reality. We do discovery, we do exploration, we do science. That's what NASA is, that's what NASA does. We inspire and we educate. And so we don't get involved in national security directly.

It is absolutely true, though, that what we do does help the industrial base, and the technologies in many cases can be used both for science and for national security. So I don't want to prejudge the study, but certainly NASA plays a role here.

Mr. BABIN. Okay. And Mr. Young?

Mr. YOUNG. My general observation is that the industrial base is strong. I think that the problems that we're talking about on JWST are problems that we know how to solve. I mean, they're not failures of F equals MA or what have you. So it is—space is a one-strike-and-you're-out business. You don't get two swings at it. And what that really says is it takes extraordinary discipline, it takes extraordinary training of the people, and it takes a safety net that prevents a problem when it occurs because humans are going to make errors from that problem becoming mission catastrophic. We know how to do that. The disappointing thing in what we're talking about here to be honest is these are problems we know how to prevent.

So my observation would be, yes, we should learn from JWST the—every day in a one-strike-and-you're-out business you've got to renew your focus on discipline, but it's certainly that we know how to do, can do, and it will be a positive factor not only for the civil space program but also for national security space.

Mr. BABIN. Thank you very much. I wish I had 10 more minutes, Mr. Chairman, but I don't. And I yield back.

Chairman SMITH. Thank you, Mr. Babin.

The gentleman from California, Mr. Bera, is recognized.

Mr. BERA. Thank you, Mr. Chairman.

As I said in my opening statement, when you're looking at budgeting, et cetera, it's complicated, particularly when you're doing budgeting for something that you haven't done. I'm a simple person. I think about it in the context of my daughter going off to college and she's going to start her senior year. And we made a contract saying you're going to finish in four years, and she assures me she is going to finish in four years, but I don't—we won't have this conversation in the committee hearing if she comes back at the end of that fourth year and says I've got a couple units that I it won't be a comfortable conversation. And, Administrator Bridenstine, I know this isn't a comfortable conversation.

And I think everyone understands that, given the scientific importance of JWST, given the sunk costs that we already have in this and the additional costs, it doesn't make any sense not to complete this mission and, you know—and do it in a way that optimizes success. I mean, it would be a real shame if we stopped this mission. It would be an even bigger shame if we continued. And I think, Mr. Young, you said 307 single-point failure areas, which suggests how complicated this is, that we went through you to finish and we got 306 right but we didn't get the 307th right.

So, I don't sense that Congress or the committee will say put a halt on this, but it doesn't mitigate what we think about going forward, right? I mean, I think a lot of us understand the scientific importance of WFIRST, et cetera. It does make it harder for this body in fiscally austere times when we're thinking about a lot of budget considerations, not just in the area of NASA but obviously throughout the entire federal budget as we authorize and allocate funds going forward.

And I think in that context—and, Mr. Young, through the IRB process, I'd be curious about hearing some of what we've learned looking backwards that will help this body in its oversight role make better decisions going forward. Does that make sense?

Mr. YOUNG. Sure, good question. I think that you can certainly look at JWST but you can also look at WFIRST. I think what NASA did recently with WFIRST was they did an in-depth review of the WFIRST program to look at requirements, cost, budget, all the factors. And they did it at a time where there's total flexibility. In other words, for WFIRST today everything is controllable that you can make every decision that you want on the program. You can adjust the requirements to go with the cost, to go with the schedule, to go with the technical risk. And that's—now, what it also requires is after you got all those data, if you'll allow me to say so, it requires leadership to utilize those data to turn them into a credible program.

But I think that it should become common practice for programs, flagship missions, not only for astronomy and astrophysics but across the board to—prior to entering into real development to take the time to really look at all the trade space and to make intelligent decisions as to how far you want to push the technology, how far you want to push the requirements, and what's affordable and what is a reasonable schedule in the process. I actually think that's an extraordinarily powerful tool that can eliminate some of the issues that we're talking about now with future programs, starting with WFIRST.

Mr. BERA. So as—I guess maybe this is for Administrator Bridenstine. As we start to look forward certainly within JWST but within future programs, I think it'll be incredibly important to think about what we've learned, to think about there's obviously scientific and technological risks that are unexpected, but also, if I listen to Mr. Young, there's the organizational, decision-making, human error side of things that we ought to have a lot more control over and put the systems and processes in place, the redundancy, et cetera, that helps prevent these types of issues happening in the future.

So, you know, it looks like I'm out of time, but again, we can't undo the past. Let's just make sure we learn from the past and we don't repeat the same failures in the future.

Chairman SMITH. Thank you, Mr. Bera.

The gentleman from California, Mr. Rohrabacher, is recognized for his questions.

Mr. ROHRABACHER. This, of course, is very disturbing when a large amount of wealth has just evaporated that we thought we had and we had planned on. And when you talk about the real difficulty of the mission—you have to come to the point where this type of mission where every screw has to have its quality tested, and that's part of this. Well, I can tell you this is about the biggest screw job I've ever seen, and it's the taxpayers getting screwed here.

And, however, let us note when we say that and understand that and we expect more, that this is not inconsistent with other things that we have witnessed from NASA and from the aerospace industry. I remember the C–17 project, and the C–17 was $1 billion over budget and they were going to close down the whole line, and I remember—it was one of the first things when I came here—I remember calling my father, who was a DC–3 pilot in World War II, saying "should I vote for the money to put this C–17 back in production? Because they have already gone almost $1 billion overrun and they're going to have to start all over in building the line."

And my dad said, "well, let me ask you this. Do you think the C–17 is going to be needed by people who are defending our country in the future?" And I said, "well, yes, because we're going to have to project power." And thank God I thought of that because I said in the future we're going to have to project our power to areas on the other side of the world rather than having bases everywhere.

And he said, "well, then you just answered your question. You need the airplane." And he said every single plane I know—my dad was a career pilot—every single plane had cost overruns, every sin-

gle plane, he says, because they're trying to do what they haven't done before. And that's what goes with that territory, when you're doing something that you've never done before.

I would hope that we can be more realistic, and we can hope that Mr. Bridenstine in his new job here can be more realistic in the assessments. Let's note that in 2002 we awarded, what, $824 million to TRW for this telescope project, and it was supposed to be launched eight years later. And now, it's twice as long as what was expected, and the cost is 12 times more than expected for the James Webb Space Telescope. But when you look back, the Hubble Space Telescope was 12 times the cost and twice as long as expected as well. I think I see a trend there somewhere. And I think that we need to be very serious about that. I mean, I remember we had trouble with the space station as well in cost overruns, and we certainly had trouble with the Hubble and the C–17.

Let me ask you, Mr. Young, is one of the problems of these professionals that we rely on in the aerospace industry, are they bidding and saying they can do something before they know they can do it or—it's one thing to say "we believe we can do this," but are they basing a lot of their bids on maybe something that they don't know they can do but they think they can? Is that one of the problems?

Mr. YOUNG. If you take JWST, the bidding was a long time ago, as you point out, it was in '02. And NASA, we've come a long way since '02 in our understanding as to how to cost these projects and to establish schedule for these projects. But I think it is fair to recognize that on—with cost-plus programs this is not—you're not going to enjoy this answer, but with cost-plus programs, contractors fundamentally bid lowest credible cost, and it's really up to the evaluators to have a competent capability such that lowest credible doesn't win. So there is a situation that exists, but that's the status that existed then and probably, you know, still to a degree exists today. But as long as lowest credible cost wins, lowest credible cost will be bid.

Mr. ROHRABACHER. And can we change that? Is there an alternative to that?

Mr. YOUNG. Sure, there's an alternative, and that is the—how smart the buyer is to be able to establish what the realistic costs are and to punish in the bidding process bidding unrealistically low cost.

Mr. ROHRABACHER. Well, when we try to analyze what the cost of the screw job is going to be, I hope that we understand that that's what the cost is to the American people if we aren't handling that in a professional way. Thank you very much.

Chairman SMITH. Thank you, Mr. Rohrabacher.

The gentleman from Illinois, Mr. Lipinski, is recognized.

Mr. LIPINSKI. Thank you, Mr. Chairman.

It's good to have you back, Mr. Bridenstine. Thank you for your work there at NASA. This is obviously a critical program. The impact that this is going to have on astrophysics and for, you know—we talked a little bit about what that means in terms of searching for life, seeing the beginning of the universe, the impact is very hard for everyone to understand.

I think one of the issues that we have here in this Committee and Congress in general is trying to understand the technology, understand how we can do the best job we can do to get the best science at the—you know, without the cost overruns, without the delays. But lacking the expertise, we have a difficult time with that.

We've discussed a lot of things. You and Mr. Young have discussed a lot of things that went wrong with the JWST and some things that could be changed going forward. So I wanted to ask you, Mr. Bridenstine, do you believe that, going forward, that lessons learned really can be applied here? Because it seems there's a lot of things that we're talking about, and some of them taking more time, I mean, that's going to be more time and more cost, you know, figuring these things out, making sure that everything's covered, making sure that everything is checked. Are you confident that there are lessons learned? And how are those lessons learned going to be, you know, implemented going forward?

And Mr. Rohrabacher brought up, you know, well—and Mr. Young said that everyone—everyone who's bidding always underbids. Well, do you have the ability at NASA to really get these things better under control so that you can deliver better for the American people going forward?

Mr. BRIDENSTINE. All wonderful points, and certainly the answer is I really believe that there are a whole host of learning points here and that these learning points ultimately need to be distributed not only across NASA but across government at large. And so one of the first things we're doing is we're taking the lessons learned, when you think about all of the 32 recommendations from the Independent Review Board, we're compiling those and we're going to have a roadshow and go to all 10 of the NASA centers and other facilities that NASA has and we're going to go around and we're going to talk about ultimately what the failure was here. This is an opportunity, quite frankly, to learn and to prevent this kind of thing from happening in other missions.

A couple of things I think are important to address on the chart we saw, you know, the $500 million original cost figure. One of the challenges NASA had going back all the way to then, the early 2000s, was what are the requirements? What are we building here? And at the time the telescope was going to be a 4 meter—it's going to have a four meter mirror. The primary meter—or the primary mirror was only going to be four meters large. Then it was determined, well, hold on a second, we want to see all the way back to the very beginning of the universe, the very first light. Well, that means we have to be able to detect even more trace infrared signatures that we've never been able to do before.

So how do we accomplish that? Well, we have to have, you know, almost absolute zero temperatures, we have to have this massive heat shield that is very intricate with five different layers of Kapton sheets, so on one——

Mr. LIPINSKI. But——

Mr. BRIDENSTINE. Yes.

Mr. LIPINSKI. Excuse me because I'm running out of time here.

Mr. BRIDENSTINE. Yes.

Mr. LIPINSKI. Is there—going forward, though——

Mr. BRIDENSTINE. Yes.

Mr. LIPINSKI. —I understand the complexity and the added complexity as looking for something that could do more. Is there a way that we can be confident here that this is not going to happen in the future? It wasn't just the added complexity.

Mr. BRIDENSTINE. Right.

Mr. LIPINSKI. The complexity was added, but then how much it was going to cost, how long it's going to take——

Mr. BRIDENSTINE. Yes.

Mr. LIPINSKI. —there was not a—it doesn't seem to maybe have been realistic, you know——

Mr. BRIDENSTINE. That is absolutely true, and that was the recommendation from the Independent Review Board is that we were excessively optimistic.

Mr. LIPINSKI. Well, let me ask Mr. Young. Are you—how much confidence do you have that we're not going to be back here with another, you know, WFIRST or any other major NASA projects, that we're not going to be talking about the same issues again after we've gone through this?

Mr. YOUNG. If you could narrow your question, if—and do I believe that for JWST we know the lessons learned in order to successfully complete this program. I believe my answer to that is yes. And what I really mean is that if the recommendations that we have made, if NASA implements them as we intended in the depth that we intended them to, then I believe we will maximize the probability of success of JWST.

A few fundamentals: We have got to—when human errors occur, we have got to have the processes in place that keep them from having any significant impact on schedule, and we know how to do that. The other item, which is harder, is the embedded problems. There have been two. Are there any more embedded problems? And if they are, we have got to find them before we get to the test so that we can eliminate them.

Now, that is a hard item. That will take tens of people months to go through. Fundamentally, what you're doing is you are reestablishing the pedigree for each piece of hardware that you are——

Mr. LIPINSKI. So it's more time is going to take?

Mr. YOUNG. Yes. Yes, it could—it possibly could——

Mr. LIPINSKI. And we have to understand that.

Mr. YOUNG. It's possible it could take more time.

Mr. LIPINSKI. We have to be accepting of that.

Mr. YOUNG. It's possible. That's possible. I actually think that the schedule has been established with the reservations that I—or with the footnotes that I put on in my comments is a realistic schedule, but the program is really at a point right now that you—there's really—the control parameters are small, and that is you really have a choice between cost and schedule and risk. I mean, that's what your—that's what the program is managing from this day forward. And if you try to go too fast with too little cost, then you're probably going to add risk. And it doesn't mean that you don't have to be prudent in how you manage the risk, but you're really trading risk, schedule, and cost every day is what the project people would be doing from this day forward in JWST.

Mr. LIPINSKI. Well, I think the science is so important that we—no question that we need to move forward. Thank you.

Chairman SMITH. Thank you, Mr. Lipinski.

The gentleman from Alabama, Mr. Brooks, is recognized.

Mr. BROOKS. Good to see you here, Mr. Bridenstine.

Mr. BRIDENSTINE. Thank you.

Mr. BROOKS. I miss some of our witty conversations during votes on the House Floor.

Mr. BRIDENSTINE. You bet.

Mr. BROOKS. You have not been replaced, but we're looking.

Mr. BRIDENSTINE. All right.

Mr. BROOKS. Per the testimony, the James Webb Space Telescope delay cost taxpayers roughly $800 million. With the limited resources of the NASA budget, I'm concerned that other space priorities will have their funding impacted by these cost overruns, and that concern has been heightened by your testimony that these cost overruns may force NASA to, quote, "cannibalize other missions," end quote.

With that as a backdrop, will you commit here today that these James Webb Space Telescope cost overruns will not come from the space and human exploration or, more specifically, the space launch system portions of the budget?

Mr. BRIDENSTINE. So there—at this point, that hasn't even been discussed, so this is relevant to the Science Mission Directorate exclusively, and that's where at this point we've had discussions about, you know, what are the options going forward.

Mr. BROOKS. What is the timetable for NASA's determination of what programs will be cannibalized to come up with that now $800 million shortfall?

Mr. BRIDENSTINE. So maybe the word cannibalized isn't the right word, but the idea is there is an opportunity cost going forward, what missions maybe we—do we not start and that kind of thing. So the answer is by the 2021—or, actually, by the 2020 time frame is when we're going to need to have additional funds, and so between now and then we're going to have to make determinations. And, you know, that process is right now. It's underway. And in this process what we're trying to do is, again, evaluate where we are with respect to the decadal surveys for each of the divisions of the Science Mission Directorate, make sure that we're in compliance with that, and ultimately, do it in a way that people can agree on. And I'd love to have your feedback on that.

Mr. BROOKS. Well, as a member of the Space Subcommittee and also as a member of the Science, Space, and Technology Committee, you can imagine how each of us on this Committee focus on different parts of what NASA does for our country. And I suspect that each of us has some concern about whether things that we believe are most important may be delayed as a result of these James Webb Space Telescope cost overruns. So if you could please keep us informed as you engage in your decision-making process, I would very much appreciate it, and I'd submit that the Committee as a whole would also do so.

Mr. BRIDENSTINE. You can count on it.

Mr. BROOKS. With that, Mr. Chairman, I yield back the balance of my time.

Chairman SMITH. Thank you, Mr. Brooks.

And the gentleman from Virginia, Mr. Beyer, is recognized.

Mr. BEYER. Thank you, Mr. Chairman, very much.

Mr. Bridenstine, welcome back.

Mr. BRIDENSTINE. Thank you.

Mr. BEYER. You know, how much has changed since 1996——

Mr. BRIDENSTINE. Oh, my goodness.

Mr. BEYER. —when this was first put out there at half-a-billion dollars? And I was just thinking about so many projects that we've seen over the years, whether there's been actually evolution in design, what we expected the project to do, the kind of instruments that were on board. I love that you brought up the search for the cosmic dawn and looking back into that. Can you even talk about how much cosmology has changed, the science itself in those 22 years, and what impact has that had on the delays and the cost?

Mr. BRIDENSTINE. It's a wonderful question, and when you think of the universe at large, we're—NASA is learning new things every single day—how the universe is expanding and not just expanding but expanding at an ever-increasing rate; it's actually accelerating—and what is causing that, and can James Webb help us understand that—you know, at the edge of the universe there are galaxies in essence disappearing because they're accelerating faster than the speed of light. So those galaxies, the light from them if they're faster than the speed of light, that light can't get back to Earth, which means there's a lot of things we don't understand about the physics, astrophysics that this particular spacecraft is going to help us learn.

Going back to the very beginning of cosmic dawn, we're going to learn how did the very first galaxies form, what did that first light look like, what was its shape, what was its pattern? And we have models at NASA that we believe could be accurate, but I'm telling you they're not because we don't know.

We talk about things like dark matter and dark energy, things that we have very little understanding of. We cannot interact with it in any way. We cannot sense it, we cannot detect it, but we—there's evidence of it based on how objects move in space. There's evidence of gravitational effects of it.

And so—and all of these things—talk about gravitational waves, things that, you know, just recently we have been able to detect, you know, so all these kind of, you know, new things that didn't exist, you know, even a few years ago—and earlier, I mentioned the exoplanets. The idea that exoplanets existed is a—I mean, the idea that they existed is not new, but we had no evidence of it until, you know, within the last ten years, and now every day we're detecting new exoplanets. And now there's thousands of exoplanets right near our own star, and the question is, you know, can this help us understand the atmospheric composition of those planets that are around other stars and help us understand whether or not life could exist there? So——

Mr. BEYER. Well, I really want to thank you for the comprehensiveness of that answer because I think you point out very clearly that this isn't simply mismanagement or cost overruns or delay. It's the fact that the world and science itself is changing——

Mr. BRIDENSTINE. Yes.

Mr. BEYER. —in ways that impact the project that we have completely different expectations for in 2018 than we had in 1996.

Mr. BRIDENSTINE. That——

Mr. BEYER. So let me ask you another completely speculative question, but you did so well on that one. Nine-point-six billion dollars is what we're going to spend. What would be the value of the knowledge that we get compared to that $9.6 billion?

Mr. BRIDENSTINE. So, again, we don't know what we don't know until this spacecraft is operational. I want to be clear; we are doing everything we can to make it operational. But when it becomes operational, it's going to change our understanding really of astrophysics, change our understanding of the universe and even galaxies and their formation and the formation of planets. So all of this is going to add tremendous value.

But I would also argue—and I really believe this—that the United States of America may have lost some ground when it comes to science and astrophysics on the international scene. What this spacecraft represents is the reestablishment of the United States of America is the preeminent Nation when it comes to astrophysics and science. And I think that's an important part of our leadership in the world, and ultimately, other countries all around the world are coming up with ideas on how to use this spacecraft, and they want access to it, countries that you wouldn't normally think of that—and universities that have great astrophysicists that want to have access to this. And they're sending NASA ideas all the time on how to use this, so there's a whole host of capabilities that we can't even predict yet until it's on orbit, and we're doing everything we can to get there.

Mr. BEYER. Mr. Chairman, I just wish we had a head of NASA that was excited about this project.

Chairman SMITH. Well, when you asked your first question, I could see that answer going on for a couple of hours, but I thought it was a good answer.

And thank you, Mr. Beyer.

We'll now go to the gentleman from California, I believe, Mr. Knight. He's recognized for questions.

Mr. KNIGHT. Thank you, Mr. Chairman.

I had the honor of having the new Administrator at our new NASA caucus last night, and he spoke about all of the great things that NASA is doing. And we brought up what New Horizons did and how that was kind of a mankind-changing event. It was on every newspaper across the globe. This wasn't a national issue; this was a total-globe issue when we went by Pluto and we were able to go within 10,000 miles of Pluto's surface and do all of the things that New Horizons brought to us.

But I'd like to kind of look at what we've done in progression with Hubble and even closer to home with SOFIA and some of the other telescopes that we use and what we see and what we get. Give me an idea—and I think you've expanded on this quite a bit—but how much of a game-changing event is James Webb going to be——

Mr. BRIDENSTINE. Yes.

Mr. KNIGHT. —compared to what Hubble gives us that's 350 miles away from us and James Webb being almost a million miles away from us and cruising?

Mr. BRIDENSTINE. It's a wonderful question, and I've heard Chairman Smith talk about Hubble a lot in my days on this Committee and his excitement for it. And I'll tell you the story he tells and how Hubble absolutely changed the game of what we understand about our universe. The way Chairman Smith describes it, if you hold a penny up at arm's length and you look at the eye of Abraham Lincoln, when Hubble looks through that eye, which is a very small piece of sky, just—that's all the piece of sky that it's looking at, but in an area of space where there's not a lot of stars in our own galaxy so we could see beyond our galaxy, Hubble started taking pictures in areas like that.

And instead of seeing stars, Hubble saw thousands and thousands of galaxies. So we now believe that there are potentially 400 billion-plus galaxies, each with 400 billion-plus stars, and I'm just throwing out round numbers here. Every galaxy is very different.

Mr. KNIGHT. We won't hold you to those numbers.

Mr. BRIDENSTINE. Right, okay. But it changed the way we understand our place in the cosmos and ultimately how complex our cosmos is. And Hubble changed the game. It changed textbooks. You know, the—we didn't grow up with that knowledge. Now, we have that knowledge, and it's in the textbooks that my kids are reading.

James Webb is going to do the same thing for our understanding of how, you know, physics in the early universe worked because there's a lot of things we don't know. And so it will change textbooks. It will be generational just like Hubble was, and it's a whole new level of understanding that we're going to have to have as a Nation and as humanity.

Mr. KNIGHT. Absolutely. And I appreciate the Chairman doing this. This is very important. It's important for us as Representatives for us to know what is a cost overrun, what is a time overrun, what are the difficulties, and is this something that we saw when we started out on this.

A lot of times government asks for something that we might not know how to do, but over a period of time we're going to learn that, something that maybe we've got a get a little better at, too. This is an extremely difficult issue, and this is something that is going in a different direction. But as I like to say, America takes giant leaps where others thought was impossible, and that's exactly what we're doing with James Webb.

So I think that everyone has said keep it on time now, move forward, let's get this in the air so that our academics, our kids who are going to learn from this and scientists around the world are going to learn. That is who we are going to impact. This is a humankind event. This is not something that's easy, and this is not something that we're going to have more problems. But when this happens, this will be a humankind event.

So I appreciate your leadership. I appreciate the enthusiasm. That's what NASA is about. It's achieving. It's making sure that that seven-year-old that wants to be an aeronautical engineer or an astronaut or whatever looks at NASA and says, "look at all they're

achieving." That's what I want to do. And it changes the globe for the better, so thank you.

Mr. BRIDENSTINE. Mr. Knight, I would add that we're making great progress on the low-boom flight demonstrator.

Chairman SMITH. Thank you, Mr. Knight.

And thank you, Mr. Bridenstine, for that great description of the deep-field view taken by the——

Mr. BRIDENSTINE. There you go.

Chairman SMITH. —Hubble Space Telescope. I've actually passed out over a thousand 8 x 11 glossies of that deep-field view, that——

Mr. BRIDENSTINE. Is that right?

Chairman SMITH. —speck of sky where you describe where nothing was thought to exist. The film was exposed for 24 hours, and in that speck, there were 3,000 points of light, each not a star but each a galaxy consisting of an average of 100 million stars. If anyone wants to know why we explore, take a look at that deep-field view.

The gentleman from Pennsylvania, Mr. Lamb, is recognized for his questions.

Mr. LAMB. Thank you, Mr. Chairman.

Mr. Bridenstine, you used the term reestablishment of the United States as the leader in astrophysics. Could you just go a little further with that? Do you feel that we've lost ground in recent times? And what would be the reason for that?

Mr. BRIDENSTINE. I don't know that I would say—well, I would say that others have gained ground, how about that? And there are other countries around the world that are developing capabilities all the time. The European Space Agency is doing wonderful work. China is in fact establishing a pretty impressive astrophysics capability. And so I wouldn't say we've lost ground. I would say others have gained ground.

We welcome that. Knowledge is knowledge, and we want them to be successful. In this particular case, this is going to gain new ground for the United States of America, and I think it's important that we always strive to do more because when we do more, then they're going to do more, and ultimately, our knowledge, especially from James Webb, from Hubble, these capabilities, the data that we get from it, the information, the scientific—it's available to the world. And scientists can actually use the data to make discoveries that NASA doesn't have the capacity to make on its own. And so when we make it available, a lot of people find new things that we didn't ourselves even discover, and so it's good for the entire world.

Mr. LAMB. Absolutely. Do you—so I think that's an important point that the funding discussion behind this both for James Webb and for NASA overall isn't taking place in a vacuum. China, you mentioned, is making significant investments in astrophysics, and I think we know that in their space program they're going it alone in some areas, you know, suggesting that there is a bit of competition going on. Is that something that you think should influence the discussion of the NASA budget and the decisions we make in 2020 when there is, you know, a projected shortfall because of these overruns?

Mr. BRIDENSTINE. Absolutely. I mean, I do believe that, you know, NASA is an agency that can establish American leadership,

that ultimately the NASA budget always returns far more than the investment. And I can give example after example. We actually promote the fact that we—we have a spinoff Twitter feed, NASA spinoff, so go to "at NASA spinoff" and you'll find all kinds of capabilities that have been developed. What NASA does we make available to the world, and then people use it for all sorts of things that are good.

But humanity itself, the way we communicate, the way we navigate, you probably may have had DirecTV or dish network, maybe internet broadband from space, the—you know, using GPS, the way we predict weather, the way we understand the climate, certainly the way we do national security and defense, disaster relief, simple things that we don't normally think about like banking requires the GPS signal. Banking is fundamental to the United States of America. Every transaction requires that timing signal from GPS.

So when you think about what space represents, it represents a fundamental increase in the standard of living not only for all Americans but for the entire world. And all of those capabilities are available because of a trail that was blazed by NASA, these investments if you will.

And so the answer is yes, when the United States Congress makes determinations to invest in NASA, it always strengthens the United States of America, and it always lifts not just our citizens but citizens around the world in ways that we never even imagined when we make the investments. So I do fundamentally believe that NASA is a great investment for the United States.

Mr. LAMB. Thank you. Just one more question. We have talked in this Committee before about developing the future workforce in aerospace and astrophysics, and one of the pieces of feedback we heard was that NASA's sort of comparative advantage when they're competing I guess against private-sector employers is the ability of NASA to give its workers really hands-on experience on one-of-a-kind projects, especially earlier in their career. Do you know if that's happening on James Webb? Is there a younger workforce that's able to take part in this and able to get the kind of experience that they wouldn't be getting anywhere else?

Mr. BRIDENSTINE. So that's a wonderful question. NASA is, as you can imagine—it has for seven years in a row been the number-one federal agency as far as workforce. When I see number one, the best place to work as determined by the workers themselves. So that's really an amazing capability. What that means is that NASA's workforce, we don't have a lot of turnover. In fact, it's about 4.5 percent per year, which means our workforce is aging, and that's just the reality.

So we are using authorities right now to attract a younger workforce, a program called the Pathways Program that helps us get interns and ultimately recent college graduates, recent graduates from master's programs. We're doing what we can to get a younger workforce, and we are engaging them absolutely in projects. In fact, right now this summer, we have over 1,600 students interning at NASA, and a lot of those interns, you know, they're—I'll tell you, most of them want to work for NASA. There's not going to be spots for all of them to work at NASA, but they're probably going to work in the—in a related field or for a contractor or something like that.

So the answer is yes, we're doing what we can. The workforce is in fact aging. There is a bow wave that I am very concerned about because eventually there's going to be a lot of retirements coming. We've got to be very cognizant of that and preparing for it today. And of course—and it's my belief that NASA's doing what it can to make sure that we're prepared for that bow wave. But the workforce is aging. You're making a great point. We're doing what we can to make it younger.

Mr. LAMB. Thank you. Mr. Chairman, I yield. Thank you.

Chairman SMITH. Thank you, Mr. Lamb.

The gentleman from Illinois, Mr. Hultgren, is recognized for his questions.

Mr. HULTGREN. Thank you, Chairman, and thank you both for being here. This is an important hearing as we continue our oversight of the James Webb Space Telescope and review recent problems that we've had.

Back in a hearing in 2011 on the issues with the telescope, I talked about my thoughts of the importance of American leadership in these fields and how this really is part of who we are as a Nation and the fact that we continue to be an exceptional Nation. It's important to acknowledge that we've had some very serious issues with project management over the life of this program, but we also have to remind ourselves that we're almost over the finish line, and this is truly where we all do want to be. Many people looked at the 2011 re-plan as the last chance. It's obviously not what we want to see.

Administrator Bridenstine, thank you for your work. It's so good to see you back here and especially in the role that you're in, so congratulations and thanks for your work. Also, it was good to see you last night and again want to commend you on the vision that you're bringing to NASA and the direction that the President and the Administration has charged you with and NASA with. It's exciting, and you can just feel the excitement that so many are sharing with that.

You know about my views on these world-leading projects. I've always been so proud of NASA's ability to inspire and bring others along, certainly from young children that you inspire in STEM to also our foreign partners on ISS or other ESA projects.

I wondered if you could discuss some other projects that NASA is working on or planning and how the capabilities of James Webb are necessary for them to get the best science. In short, how many other investments are we making that rely on this initial investment, and what else do we have to lose if this does not go up?

Mr. BRIDENSTINE. So James Webb, when you think of it, the astrophysics division of the Science Mission Directorate, James Webb is one piece, and there are other missions out there that can help us ultimately that are less expensive, less capable but ultimately can help us determine how to best use James Webb as a force multiplier if you will. So it is absolutely true that we think of it as a system of systems and that some of the smaller missions inform how we want to use the flagship missions.

That being said, we have to get this right. As Tom Young mentioned, there's over 300 parts that are single points of failure, which is why we are testing it and retesting it and testing it some

more to make sure that it works in every single one of these—I want to be clear about this, too. Single—300 single points of failure is a lot. That's not what NASA normally does. NASA does normally have projects that have a lot of single points of failure. The Curiosity rover that landed on Mars had over 70 single points of failure.

It's a successful mission, overwhelmingly successful. We are discovering right now that, you know, there are complex organic compounds on Mars, which has never been determined before, and now we're finding them, which increases the probability of life. Methane, of course, cycles are now—we now know that methane cycles are commensurate with the seasons on Mars and in fact, you know, today, you are probably going to see reports that we have found what appears to be liquid water about 1.5 kilometers below the surface of Mars, amazing—that wasn't from Curiosity. That's from another satellite mission around Mars that has, you know, radar.

So—but these are capabilities that we make investments in. They have single points of failure. This one's more complex. There's more single points of failure. We have to be more diligent about every aspect. That's why we're putting so much effort into mission assurance and other things. But it is a force multiplier, as you're acknowledging——

Mr. HULTGREN. Yes.

Mr. BRIDENSTINE. —that the other missions that we do are excellent. This actually makes them even better. It makes those investments even better.

Mr. HULTGREN. It's really helpful. Let me go down to one last quick question——

Mr. BRIDENSTINE. Yes, sir.

Mr. HULTGREN. —in my last minute here. Administrator, you brought up this little bit last night, but I think it would be good to get it on record. And this is also something I had asked former NASA Administrator Griffin and it's something that worries me as we work with other nations on world-leading science experiments. What is the first question you get from our foreign partners when you come to them and see how we can collaborate? I'm always worried about our budgetary process and especially CRs, but your comments last night did give me hope. I wondered if you could talk about what you're hearing from——

Mr. BRIDENSTINE. Yes.

Mr. HULTGREN. —collaborators?

Mr. BRIDENSTINE. Thank you for bringing that up. I just got back from the Farnborough Air Show. The heads of space agencies from throughout the world were there, and we had great collaborations. I was going with the mindset that I'm going to have to make a sales pitch, that our—you know, we're going forward to the moon with a sustainable architecture so that this time we can stay and then we're going to go on to Mars. We need all of our international partners involved and more, and we need not just our international partners but commercial partners. And I was going there to make a sales pitch.

And overwhelmingly what I heard from our international partners, which we've established strong partnerships with I think it's over 90 different countries at this point, although they weren't all of this one event, what I heard overwhelmingly is tell us what we

need to do. It wasn't me trying to make a sales pitch. They're ready to go.

Mr. HULTGREN. That's great.

Mr. BRIDENSTINE. They want direction and then they can sell their governments and we can move forward as a body. Space represents, in my view, a very strong soft-power tool for the United States of America to establish leadership. James Webb is a perfect example of that. The European Space Agency is providing two scientific instruments. They're providing scientists that are going to be integrated with our scientists on James Webb, and they're providing a launch capability.

So the European Space Agency has really stepped up to the plate on James Webb. They're making sacrifices the same as we're making sacrifices because they, like us, believe it will be worth it.

Mr. HULTGREN. Great. Thank you.

Mr. LUCAS. [Presiding] The gentleman's time has expired.

Mr. HULTGREN. I yield back.

Mr. LUCAS. The Chair now recognizes the gentleman from Florida, Mr. Crist, for five minutes.

Mr. CRIST. Thank you, Mr. Chairman. And thank you, Administrator Bridenstine and Mr. Young, for being with us today. I appreciate your time.

It's a concern of mine that the repeated schedule delays and cost overruns are putting increasing pressure on both NASA, as well as Northrop Grumman to prevent any further slippage. While it's important to keep schedule and cost under control, it's even more important in my opinion to make sure that we get this done right and that we don't cut any corners that could negatively impact mission success. So, Administrator Bridenstine, how will NASA be able to guarantee that the remaining integration and test work is not affected by this schedule pressure?

Mr. BRIDENSTINE. That's a wonderful question. The Independent Review Board made an assessment on both schedule and costs. NASA ran independently an assessment on schedule and costs through our agency program management council and our directorate program management council. We came to in essence the same conclusion. We wanted to make sure that there was adequate margin for both cost and schedule so that we weren't putting ourselves up against the wall. So we do believe there's adequate margin in there.

At the same time we are incorporating all of the recommendations from the Independent Review Board. There are, you know, two recommendations that we haven't implemented yet but we're making progress on, and so I really believe that we're going to be able to accomplish the task. We've—again, we have taken NASA workforce and put that—put them on this task, highly qualified NASA workforce. We have strengthened the mission assurance piece, which is immediate feedback in response to every—you know, every item that goes on or off the spacecraft is being overseen by somebody who can stop the entire program immediately. We are providing direct oversight from the Goddard Space Flight Center, and we're providing, you know, direct oversight from NASA headquarters as well.

So I do believe that we've taken all the tools that we have and we're using them to the best of our ability. And if we continue to execute how we're executing right now, we will be on cost, we will be on schedule, and we will have mission success.

Mr. CRIST. Okay. Thank you, sir.

Mr. Young, would you add anything to that?

Mr. YOUNG. I thought that the description was really quite good that was just given. I think that the only thing I would underline is that when we do hit the hard spots—and there will be some—that mission success has got to be the defining criteria as to how we go forward. So I think your question is really excellent, and the idea is that while schedule and cost are important, they're not more important than mission success.

Mr. CRIST. Right.

Mr. YOUNG. And as long as we have that culture and philosophy, which I actually see existing, then I think that, you know, we'll proceed well, but that's got to be the hallmark as to how we go forward. And that's got to be communicated down to the lower—to working levels of the organization because right today, while we're having this hearing, my guess would be that at some—at a working level somebody made a decision that probably can have a real influence on the success of JWST, and we want to be sure that the criteria that they're making that decision gains us mission success and not schedule and cost.

Mr. CRIST. Great. Thank you, sir. Back to you, Administrator. What do you believe is NASA's responsibility when human error by contractors occurs, and what changes do you think might need to be made, if any, for contractor oversight.

Mr. BRIDENSTINE. So specifications and requirements that come from NASA ultimately need to be very crystal-clear. There can be no mistakes as NASA generates specifications and requirements. One of the challenges we saw during acoustic testing when you think about the sunshield covers, you know, the sunshields have to be folded up and then flown and—within a rocket faring and then deployed once in space.

The sunshield covers had fasteners that kept them—and kept the sunshield covered. Those fasteners ultimately were held together by screws and bolts, and NASA did not specify what the torque specification requirements were. That's a failure of NASA. Should Northrop Grumman have maybe done things differently? Maybe, but NASA has responsibility here as well. And so it's on us to—mission success is on NASA. We can blame the contractor, but the reality is it's on us to have mission success.

So accountability is critical. We have tools in place for accountability. We are at this point at the integration and testing phase. We are on the—again, I've said it before, I'm going to say it again. We're on the 5-yard line trying to punch it into the end zone. We're almost there. I believe we're going to get there, but going forward, we have to be—and this is one of the takeaways that we're going to take on a roadshow. When we generate specifications and requirements, we can't miss anything because ultimately mission success is on NASA.

Mr. CRIST. Thank you, sir.

Mr. Chairman, I yield back my time.

Chairman SMITH. Thank you, Mr. Crist.

The gentlewoman from Arizona, Mrs. Lesko, is recognized.

Mrs. LESKO. Thank you, Mr. Chair. You know, I'm the second-newest member to Congress, and I don't know if some of my fellow Congressmen are more used to these budget overruns or not, but when I read this, I thought it was outrageous that it's 19 times over the budget that was estimated and so far behind. And I really think this is just a perfect example of why the American public doesn't trust the Federal Government in spending its tax dollars. I really do. I just thought it was outrageous.

So I guess my question, since I'm new, is what has been done since—in 2007 this was expected to be finished. Has Congress or NASA done anything in between besides what's just happening now with this IRB? And if they did do something, obviously, it didn't work. So I want to know if anything has been done in the past 11 years, and if so, why should we believe it's going to change in the future?

Mr. BRIDENSTINE. So in 2011 there was an Independent Review Board, and at the time the—all of this was still in development. Going back even further, one of the big challenges we had is changing requirements, changing specifications. What do we want the telescope to do, how far do we want to see? And if you go from—I mentioned this earlier. If you go from a four meter telescope to a 6.5 meter telescope—when I say telescope, I'm talking about the size of the mirror that actually reflects onto another mirror and then the sensors—you—when you change something that is this precise this much, it really has an impact on cost and schedule.

In 2011, we had an independent review. We set a new baseline, and that new baseline actually had its launching in 2019. And we got—again, we got all the way to the 5-yard line. And when we integrated the spacecraft element with the optical telescope element and did testing, we made all kinds of discoveries that were unfortunate, and not just unfortunate, problematic. And that's where we are today.

So what we have to do now is, as Mr. Young has noted, we are going back and we're going to make sure because the way this telescope is going to be launched, you know, it's going to be a million miles away from Earth. We don't have any human spacecraft capability that can get up there to service it, and if we could, this telescope is too delicate to even service.

That being said, we have to get it right the first time. So that's why we go through such extensive testing. Some of the testing, ultimately, we discovered things that are routine, which is why you test. Some of the testing demonstrated that we in fact have some embedded errors and some human errors, embedded problems and human errors, some embedded problems going back a number of years. Mr. Young mentioned that the thrusters were washed with the wrong solvent, and that corroded some seals. That was done years ago, and we only discovered in testing that that had happened. Again, this is why we test. We want to make these mistakes here on Earth because that mistake, if it was in space, it would be too late. It can't be fixed.

So some of it is routine testing that ultimately we're making discoveries that we need to make discoveries on, and others, we're

finding errors that occurred years ago, and some of those errors include, you know, the—using the wrong solvent to wash the thrusters, which is why we're going through right now and we are starting from a baseline and saying if we have to find every embedded error, that we have to go back to the very beginning of every component on this spacecraft and make sure we haven't made any errors, which is what we're doing because there's no room for failure once it's in space. And that's what we're doing. Mission success is the primary objective. I believe that we're there, and here we are requesting an extra $800 million and a few more years, and I think we can get it done.

Mrs. LESKO. Thank you, Mr. Chair. Yes, I appreciate that we're under a new Administration and that you're new and so you have to take what was given you. I just again want to express my frustration that we're talking about taxpayer dollars, and it's very frustrating to me and other taxpayers that this is so much of a cost overrun, and although I've heard testimony how important it is, I understand that, it's very frustrating. I think we need to do a better job of making sure that we are not so far off the mark. Thank you——

Mr. BRIDENSTINE. Yes, ma'am.

Mrs. LESKO. —and I yield back my time.

Chairman SMITH. Thank you, Mrs. Lesko.

And the gentleman from California, Mr. Takano, is recognized.

Mr. TAKANO. Welcome back, Administrator Bridenstine.

Mr. BRIDENSTINE. Thank you, sir.

Mr. TAKANO. It's good to see you. And congratulations. I didn't get to say that to you earlier.

Mr. BRIDENSTINE. Thank you.

Mr. TAKANO. And thank you, Mr. Young, for being here.

Administrator, you just mentioned an $800 million figure. Is that for fiscal year 2020 and fiscal year 2021?

Mr. BRIDENSTINE. It gets us through launch, which would be through March 30 of 2021, which is the new launch date.

Mr. TAKANO. So March—so you have enough money for fiscal year 2019——

Mr. BRIDENSTINE. We do.

Mr. TAKANO. —correct?

Mr. BRIDENSTINE. That's correct.

Mr. TAKANO. And so this supplemental that you're asking for is for the year 2021?

Mr. BRIDENSTINE. It's really—we're not really asking for a supplemental, although if you'd like to give it to us, we'll take it.

Mr. TAKANO. Okay.

Mr. BRIDENSTINE. The—what the law requires is that if we hit $800 billion—or $8 billion—gosh, dang——

Mr. TAKANO. Eight hundred million.

Mr. BRIDENSTINE. Eight hundred. But if we hit $8 billion, the program is no longer authorized. And so, ultimately in the development we haven't hit it yet, but we will soon hit $8 billion and we'll need Congress to reauthorize it if we're going to continue.

Mr. TAKANO. So you're asking for an authorization——

Mr. BRIDENSTINE. That's correct.

Mr. TAKANO. —of an additional $800 million——

Mr. BRIDENSTINE. Yes.

Mr. TAKANO. —for the program?

Mr. BRIDENSTINE. Yes. And that money could come from NASA or if you want to appropriate additional, it could come from there as well.

Mr. TAKANO. You know, we may have to do that. I might prefer not having to choose between our children.

Mr. BRIDENSTINE. I know.

Mr. TAKANO. Right? But we have hard choices to make here. So $800 million. Let's see. The question I wanted to ask. Administrator, given that we're moving the launch date, have you hired graduate students and plan for graduate student work based on the October 18 launch date?

Mr. BRIDENSTINE. The March 30 launch date of 2021, have we hired graduate——

Mr. TAKANO. Well, no, because given that you——

Mr. BRIDENSTINE. Oh, oh, oh, I see——

Mr. TAKANO. I'm wondering if you did hire graduate students based on the old——

Mr. BRIDENSTINE. The old launch date.

Mr. TAKANO. —launch date——

Mr. BRIDENSTINE. So——

Mr. TAKANO. Can you tell me what's going on with that?

Mr. BRIDENSTINE. So the launch is actually being provided by the European Space Agency on an Ariane 5, so they are our international partner on this particular project. And so to my knowledge we haven't hired any graduate students to help us with the launch. It's being provided by the European Space Agency.

Mr. TAKANO. All right. You might just want to check up——

Mr. BRIDENSTINE. I will.

Mr. TAKANO. —on that detail because if we've hired graduate students——

Mr. BRIDENSTINE. Right.

Mr. TAKANO. —based on the launch date—but maybe you've delayed doing that because you were uncertain about when you are going to be able to launch.

Mr. BRIDENSTINE. Right.

Mr. TAKANO. How many cost overrun proposals has Northrop submitted to NASA since the original JWST re-plan agreement in 2011? Do you know that?

Mr. BRIDENSTINE. I don't know offhand, but——

Mr. TAKANO. If you could get that——

Mr. BRIDENSTINE. Yes, I will. I will get that.

Mr. TAKANO. If you could get that to my office——

Mr. BRIDENSTINE. I'll take that for the record.

Mr. TAKANO. And if you could also get me a total on the value of the cost overrun proposals and whether they included any award fees.

Mr. BRIDENSTINE. I will.

Mr. TAKANO. That'd be helpful for me to know.

You know, I want to go back to the workforce training issues that were kind of gone over by I think Mr. Hultgren and Mr. Lamb. You spoke about the unique workforce that you have and the in-

terns and the programs, and you're worried about the aging out of the current workforce.

Mr. BRIDENSTINE. Yes.

Mr. TAKANO. And it's a pretty specialized workforce. What can Congress do to support opportunities for relevant workforce training and experience beyond what it has now?

Mr. BRIDENSTINE. That's a——

Mr. TAKANO. Can we do more?

Mr. BRIDENSTINE. Absolutely. Thank you for asking because I'll be sure to let you know the—one thing that we have been talking about a lot at NASA is the competition that exists today that might not have existed for NASA centers even maybe, you know, 20 or 30 years ago. So if you're a young person in Houston, Texas, there's, you know, an amazing energy industry down there that is trying to gobble up all of the electrical engineers, mechanical engineers, chemical engineers. If you're a young person out in the San Francisco Bay area where Ames Research Center is, there's all of the tech companies that are gobbling up those types of talents.

And so it's—the challenge that NASA has is ultimately the way a young person can get a job with NASA is to apply online. And in the six months that follow, you may or may not get a response, let alone get a job. And this is a challenge that we need to—there is a challenge in the way——

Mr. TAKANO. So there's a personnel office problem, inefficiencies there. The applications are kind of stuck is what you're telling me?

Mr. BRIDENSTINE. Well, that's a piece of it, but there's also a piece of it that there's a body of law that we have to follow in order to hire somebody. And a lot of our competitors for that talent, private companies, they can go to a job fair and hire somebody on the spot. And it's not—you know, when I say we're competing, we're not competing against the people that supply services to us necessarily. We're competing against entire other industries for that talent. And so when they can hire on the spot and when we hire, we have to go through this elaborate process, we lose. We lose a lot of talent. So direct-hire authority is something that we would love to have.

Mr. TAKANO. Mr. Chairman, I'm sorry for going over, but I think this is a rich topic and I hope we can maybe explore this topic more with more hearings about——

Chairman SMITH. We will.

Mr. TAKANO. I know we've done some stuff on workforce development, but I've heard a statistic that Mexico is producing more mechanical engineers than we are in the United States, and so I think—this is a broader topic and I hope we can devote more time to it later.

Chairman SMITH. Okay.

Mr. TAKANO. Thanks.

Chairman SMITH. Thank you, Mr. Takano.

The gentleman from Texas, Mr. Weber, is recognized for questions.

Mr. WEBER. Thank you, Mr. Chairman.

To paraphrase JFK, we choose to take risks not because they're known or easy but because they're unknown and they're hard. So

you just answered the question I had Administrator Bridenstine. And welcome back, by the way.

Mr. BRIDENSTINE. Thank you.

Mr. WEBER. We kind of miss the days you sat up here and make snide remarks about some of the other Members.

Mr. BRIDENSTINE. Now you're making them about me.

Mr. WEBER. I know. Did I say that out loud? I'm encouraged to hear that it's important that we lead in space. Dr. Babin had a conversation—I forget with which one of you it was with—about the fact that we were cost overrun and behind schedule, and that washurting us with a national security and with the industrial base. And I would argue exactly the opposite, that it's actually helping us. And when you said there's 90 countries who are ready to help with this, I was so encouraged by that because it shows the world that we are determined to be the space leader, and we're going to do it come hell or high water, if that applies to the amount of water we found here the other day. So thank you for saying that. I'm encouraged by that, Jim.

Mr. Young, in the IGR report you made was it 32 recommendations?

Mr. YOUNG. Yes, sir.

Mr. WEBER. Three hundred and seven failure areas, is that what I understand? And then you said all, and I'm quoting, "All of us need to focus on maximizing the program," okay, end quote. Who does that for those 32 recommendations and 307 failure areas? Do you make recommendations about who actually takes that responsibility?

Mr. YOUNG. I think it's pretty clear for each of those who has the responsibility. We—the—our particular activity was chaired by the—was—excuse me, was established by the Associate Administrator of Space Science. And so that in essence is where our report went, but we did report directly to the Administrator. And we did highlight some areas where we want to get special attention, so some are aimed towards Northrop Grumman, some are aimed towards NASA Goddard, and some are aimed towards NASA headquarters. So the answer is there are very specific indicators as to who should be responsible for each and who should be necessarily responding.

Mr. WEBER. Well, that's what I want to hear. The famous example about Edison and the lightbulb and when somebody said you failed a thousand times, doesn't that discourage you? And he said, what are you talking about? We're a thousand times closer.

Mr. BRIDENSTINE. Yes.

Mr. WEBER. So if we're learning from this, if we're going to use this to our benefit and show the world that we can do this, I think it's a good thing.

Administrator Bridenstine, I want to come back to you. You named categories of missions in earlier comments. You said strategic, flagship, and——

Mr. BRIDENSTINE. Just different sizes of missions.

Mr. WEBER. There's different sizes of missions, okay.

Mr. BRIDENSTINE. So the idea being that for smaller missions there's a lot less risk because there's a lot less—it's not as complicated, we don't spend as much money, and if there's a failure,

it's one failure of, say, eight different small missions. But for a flagship mission or a strategic mission——

Mr. WEBER. It's huge.

Mr. BRIDENSTINE. —it's—yes, it's a big impact.

Mr. WEBER. Right. Are you able to give us a percentage of those three categories and how much is in each category?

Mr. BRIDENSTINE. Well, given where we are with James Webb, that's by far the largest category at this point.

Mr. WEBER. Sure.

Mr. BRIDENSTINE. So——

Mr. WEBER. I've been there to see it by the way.

Mr. BRIDENSTINE. That's good. That's good.

Mr. WEBER. Yes.

Mr. BRIDENSTINE. It's impressive. So the—but I can get you a breakdown, a very specific breakdown of missions and costs.

Mr. WEBER. Right. And then, Mr. Young, back to you. You made a comment earlier about the contractors who bid the lowest. What did you call it? Lowest—there was a——

Mr. YOUNG. Lowest credible cost.

Mr. WEBER. Lowest credible cost. How do we fix that?

Mr. YOUNG. Well, you know, contractors are going to do, you know, what you would expect, and that is they're going to bid in accordance to what they think will be the determining factor in winning the contract so——

Mr. WEBER. So do you need authorization or change in the law from Congress on how the bidding process works?

Mr. YOUNG. I personally don't think so. I mean, I think it is much more the contracting organization establishing criteria for who wins a contract to be consistent with the—what the particular contracting organization wants to get from the contractors. But people—the contractors, you know, are very capable in figuring out what is the criteria that will maximize their chance of winning, and they're going to—they're going to perform in that particular manner. And the contracting organization has to change it such that the criteria are such that it gets the performance that that one in the bids that they get. And my personal belief is that there is adequate law and legislation to allow that to happen today.

Mr. WEBER. Okay. Mr. Bridenstine, you want to weigh in on that?

Mr. BRIDENSTINE. Well, just that it is important for NASA, when you think about the way we do contracting and we have, you know, contracting officer representatives, we have contractors, and then we have program managers and project managers, when we go through a contract, it is critically important that NASA be every bit as smart on the capabilities and the requirements and—as the contractor that we are buying from. We have to be smarter than the people we are buying from to know whether or not what they are telling us is accurate and can be accomplished.

Mr. WEBER. There's a Latin term for that. Caveat——

Mr. BRIDENSTINE. Okay.

Mr. WEBER. —emptor.

Mr. BRIDENSTINE. Okay.

Mr. WEBER. Okay? Buyer beware I think it is. But look——

Mr. BRIDENSTINE. Sure.

Mr. WEBER. —thank you. You guys are doing great, and we appreciate your commitment. And short of sounding a little hokay, I think you're helping to continue to make America great again, always have. We appreciate NASA.

Mr. BRIDENSTINE. Thank you.

Mr. WEBER. Thank you.

Mr. LUCAS. [Presiding] The gentleman's time is expired.

The Chair now turns to the gentleman from Colorado, Mr. Perlmutter, for five minutes.

Mr. PERLMUTTER. Thank you.

Mr. BRIDENSTINE. Twenty thirty-three.

Mr. PERLMUTTER. Gentlemen, thank you for your testimony. Obviously—what did I—everybody's leaving. Oh, my gosh.

Anyway, just—no, obviously, thank you for your testimony. I have confidence in both of you and in your review of something that really is, you know, disappointing in a lot of respects, but obviously this is new territory that's being broken. There are some contractual things. And, Mr. Young, I want to talk to you about them in a second. But if you have confidence—and I think there—a specific question came form Mr. Lipinski to you, Tom, that, you know, can this get done in this time frame that's been set for $800 million? And you have confidence that it can. That's good enough for me honestly.

Let me just ask you some basic questions because there is some contractual stuff in here that I think really are good learning tools for you at NASA, for the industry generally. And, Mr. Bridenstine, you talked about it. So my dad was in the construction business, all right? He said it was always easiest to fix a problem at the blueprint stage before you built the building. And in yours you've got an added complexity, which is the design phase, the construction phase, and then it's a million-miles-out-there phase. So we're in the—sort of the construction phase where you can fix it here and not a million miles away and it's a much better use of our money to do it here.

In this process, Mr. Young, in this next two or three years, is there—see, I think one of the things that happened here, there was a critical path of some sort that was used. And you had vendors. Northrop Grumman was the general contractor, had vendors to it, and then—and now we're at the integration stage. Could there have been something different in terms of the critical path that would have allowed us to see these mistakes, which we know can happen when people are putting the screws in? Is there a different way to do this critical path? Could we have integrated this thing earlier? That's my first question.

Mr. YOUNG. It's a good question. Let me touch on two aspects of it. Relative to embedded problems, you know, that are discovered later, you know, the technique that we utilize to make sure that they don't happen is to really go through a progressive test program. And so what it really says is that if you have a piece of hardware and you start out with it, you test it as a standalone item, and so you know the—I'll call it the pedigree again or the quality of that hardware all the way through. And so if you get to the particular point that you've installed out on the spacecraft before you have gone through each of these steps, you have made yourself vul-

nerable to an embedded problem being there that has a much larger implication.

I've got to really say that we did not go back through and trace the history, you know, of each of these items because what we were trying to do is assess where we are today and what do we have to do to get to a successful completion.

Mr. PERLMUTTER. I guess what I'd like you to do, though, is when you guys are doing sort of an after, you know, project kind of analysis, look at the critical-path piece of this.

Mr. YOUNG. It needs to be done. And, typically, if you walk through that process that you're asking about, which is probably no different than the construction process, by the way, I would argue, if each step of the way you know the quality of that particular hardware, then you are pretty confident that you have not moved too far to the right of an embedded problem without discovering it. So that's the process of doing it.

And I do think you raise a really good point. As a lesson learned, it would probably be a good thing to take all of these and go back and look at how the step-by-step test program was implemented.

Mr. PERLMUTTER. I'm going to change the subject just a little bit. So I feel like we have three opportunity costs kind of lost here. One is the billion dollars or $800 million, which, you know, I'm reading something today says that the majority party, the Republicans are thinking of another $600 billion tax cut on top of the 1.5 or $1,500 billion tax cut. We could fix this problem a lot with that revenue that we are foregoing.

But I think the two issues that I'm particularly concerned about are the lost science and the reallocation of assets away from other projects that NASA may have. If we were to authorize and appropriate another $800 million, could you keep those other projects on time or keep them going?

Mr. LUCAS. The gentleman's time is expired. The witness may answer the question, though.

Mr. BRIDENSTINE. The answer is yes, sir, we absolutely could. I would also argue that some of those projects haven't even started yet, so we would in essence start new projects that otherwise wouldn't get started if we didn't have the additional money.

Mr. PERLMUTTER. Okay. Thank you.

Mr. LUCAS. The—

Mr. PERLMUTTER. And I yield back. Thanks, Mr. Chairman.

Mr. LUCAS. The gentleman yields back.

The Chair now turns to the gentleman from Louisiana, Mr. Higgins, for 5 minutes.

Mr. HIGGINS. Thank you, Mr. Chairman. Mr. Chairman, I support this program and the completion of this crucial project. I believe the money should come from offsets in other areas.

Like my colleagues, I voice my concern regarding the cost overruns and schedule delays, but these guys are doing something that has never been done before. And although all Americans recall the infamous "Bridge to Nowhere," the endeavor we're speaking of today, Mr. Chairman, is a bridge to everywhere. So I concur with my colleagues. I believe that the United States should be number one on Earth, and thus, we must be number one in space. As a Christian-principled man, it's fascinating to me to observe as

science begins to come to grips with "Let there be light." And this is the mission that could bring us to a new level of understanding never dreamed of before.

Mr. Bridenstine, thank you for your service, sir. The Independent Review Board recommends that NASA and Northrop Grumman Aerospace Systems should take a number of actions to address human errors during the integration and testing phase to prevent, or at the very least detect, embedded problems before they affect a project's schedule. Please elaborate on what actions NASA has taken to ensure that Northrop Grumman is properly implementing the recommendations that the Independent Review Board suggested to ensure that human error and embedded problems will not continue.

Mr. BRIDENSTINE. So one of the reasons that we have extended the time of the program is ultimately to go back and look at all of the components that go into the entire spacecraft from the beginning and ultimately to determine whether or not there are other embedded problems like the issue we had with the fasteners, like the issue we had with using the wrong solvent to clean the thrusters. Are there any other of those issues that might have been accomplished years ago that ultimately could end up revealing themselves in space? And what we want to do is make sure—

Mr. HIGGINS. And fix that on the ground.

Mr. BRIDENSTINE. And fix it on the ground.

Mr. HIGGINS. Understood. So you're very focused on the 32 recommendations that have been concluded by the review board?

Mr. BRIDENSTINE. Yes, sir. Absolutely.

Mr. HIGGINS. And for the record, Mr. Young, in regard to NASA and Northrop Grumman's plan for implementing your board's recommendations, how soon do you recommend a review of those implementation plans?

Mr. YOUNG. That's really a good question. I actually—and it's a decision for NASA to decide, you know, when they want that to be done. My personal judgment is that in the next couple of months the course is going to be set for JWST and hopefully the success—

Mr. HIGGINS. Mr. Bridenstine seems to be very animated and sincere about following your recommendations. Can you provide for this Committee, sir, in writing a recommendation what you believe should be a time frame for a review of those implementations, say, 90 days or whatever you believe it would be? Mr. Young, can you provide that?

Mr. YOUNG. Yes. Yes, sir, I can.

Mr. HIGGINS. And, Mr. Bridenstine, will you provide that as well, that you'll concur with that?

Mr. BRIDENSTINE. Absolutely. In fact——

Mr. HIGGINS. Okay. Let me jump forward. These cost overruns, they predate my service at the Congressional level. They predate your service for NASA, sir, so we're just living with what we have. But we have to finish this thing. And it's fascinating, as you pointed out, that the largest issue you're dealing with is a never-before-designed spaceship. Now, had that spaceship been designed prior, would we have eliminated a lot of the problems that we've encountered with cost overruns?

Mr. BRIDENSTINE. Absolutely.

Mr. HIGGINS. So is it not reasonable to conclude that future NASA projects and future space exploration projects will certainly draw upon the knowledge that you all are frontiering right now and pioneering, engineering, regarding heat shields in this particular type of spacecraft? Is it not reasonable to conclude that the work you're doing now and the treasure we're investing now will benefit future projects and future generations of all mankind?

Mr. BRIDENSTINE. Absolutely. We have bought down a ton of risk through this process.

Mr. HIGGINS. Thank you, Mr. Chairman. I yield.

Mr. LUCAS. The gentleman's time is expired.

The Chair now recognizes the gentleman from Illinois, Mr. Foster, for five minutes.

Mr. FOSTER. Thank you, Mr. Chairman. Thank you to our witnesses.

As someone who's actually managed not multibillion but multimillion dollar technical projects for the government, you know, I probably stayed up way too late last night reading the, I guess, 69 pages of your independent review report. And I was quite impressed with the top-line recommendations you made. And I have a couple of concerns with NASA's plan for dealing with some of them.

But let's see. First, Mr. Bridenstine, you emphasized that there is now the ability for more people to say stop when they see a technical thing. Did anyone for the two major difficulties you've had, either the thrusters solving problem or the sunshield covers, did anyone at any point say stop and was shouted down?

Mr. BRIDENSTINE. As far as the thrusters go, the—my understanding is the technician—and this was years ago. The technician ultimately did ask for permission to use a specific solvent and was given the go-ahead by mission assurance. Now, that was a mistake that was made a couple years ago and in testing—

Mr. FOSTER. Right, but it was not an instance, you know, like the shuttle O-ring situation——

Mr. BRIDENSTINE. No.

Mr. FOSTER. —where engineers got overruled—and now on the other one, the—which was I think a secondary problem with the redesign of the fastener attachment plate with concerns about snagging, and so a redesign of which nuts and bolts would be used, and so was that—I guess this is for Mr. Young. Was that under configuration control when someone changed the design of how those attachments would be made? And was there a traceable signature authority when that design change was made or was this something where a technician sort of said, okay, maybe we should use a different kind of nut and bolt on this?

Mr. YOUNG. We did not go through all the paper, so I want to be clear about that, but my assumption is it was under configuration control and there was a procedure that was written and established by Northrop Grumman that was implemented by the subcontractor in installing them, so there was a change process. The change was documented. The change was incorporated in a procedure, and that procedure was provided to the subcontractor as to how the screws and nuts should be installed.

Mr. FOSTER. Okay. So if you could get actually as a follow-up, the actual change control response, what the formalities of that actually were for this change that went in because I think a simple thing like having a nylon insert in the bolt would probably change the project history a little bit.

Now, into the big picture, the cost overrun, which in aggregate has been roughly tripling. I'm painfully familiar with a similar thing for the superconducting super collider in high-energy physics where the costs roughly doubled and eventually resulted in the cancelation. When you look in retrospect at the cost growth, it was almost entirely attributable to a decision that was made by the Department of Energy to task essentially a military contractor to reproduce a laboratory in a place—in a greenfield site with completely unrealistic cost estimates for that.

And so if you look at the cost growth, this was a project that was split between, you know, Goddard and Northrop Grumman and as well as I guess the launch facilities. Can you make generalities about where most of the cost growth occurred? Because there may be lessons learned about when you split projects, there may be better ways to do that split. Mr. Young, I guess. Well, it's a hot potato. Okay.

Mr. BRIDENSTINE. So the—I think originally the cost growth came from the idea that we changed requirements. We wanted to see further. We wanted to see further back in time, which required us to go with a larger mirror. And when that determination was made, the cost really went up very, very fast. And we made a decision—when I say we, it was NASA back in, you know, the mid-2000s—made a decision to go with the much bigger, more intricate kind of—

Mr. FOSTER. So that was a high-level decision——

Mr. BRIDENSTINE. It was.

Mr. FOSTER. —in terms of the execution of the project, independent of that. Are there any generalities that can be made about the circumstances under which—did most of the cost growth happen in one area or another, in the scientific instrument package versus the bus, and so on or just the schedule slippage?

Mr. BRIDENSTINE. I think the number-one thing was just excessive optimism from the beginning. We didn't know what we didn't know, and we believed that a lot of these, you know, very new technologies could be developed at a much lesser cost and a lot less time. And as we went through the process, we discovered that there's a lot to be developed that we didn't understand, and of course we have learned from that.

Mr. FOSTER. Yes. And, your report highlights these reporting gaps that happen very often between Goddard and Northrop Grumman. And I just wonder if there are lessons to be learned. Do future projects like WFIRST have that same sort of split responsibility between contractor and NASA——

Mr. BRIDENSTINE. So—

Mr. FOSTER. —as the lab?

Mr. BRIDENSTINE. —WFIRST is ultimately a mission that is far less complex than what we have with the James Webb Space Telescope, so—

Mr. FOSTER. Does it have the same split reporting problems that were highlighted——

Mr. LUCAS. The gentleman's time is expired but the witnesses may answer the question.

Mr. BRIDENSTINE. It—the organizational change that we made on James Webb Space Telescope ultimately will apply to WFIRST.

Mr. YOUNG. I think the other comment to make is I don't—the split's not unusual. In other words, it's common practice for NASA to have a prime contractor, so I think NASA has an overarching responsibility of—you know, for the total program, the prime contractor has a responsibility for executing their contract. And I don't think that's at all unusual, and I think it's—you know, it will be the way that many programs go forward in the future. And what it really says is that, you know, we do know how and we need to implement both on JWST and future missions a communications mechanism that is recognized, that that's the way we actually execute and implement projects.

Mr. FOSTER. Thank you, and I yield back.

Mr. LUCAS. The gentleman's time is expired.

The Chair now recognizes the gentleman from Alabama, Mr. Palmer, for five minutes.

Mr. PALMER. Thank you, Mr. Chairman.

You know, we've had a lot of talk about the prospects of a successful project and looking back and looking forward, and I want to do that right now on the project because I appreciate all the rah-rah that's gone on here. But in my opinion, the purpose of this hearing is to try to determine what happened and how we can prevent this from happening in the future.

So, Administrator Bridenstine, I'm going to ask you this, and, Mr. Young, you can jump in, but I don't want long answers because I've got a lot of questions, and if I have to, I'll stick around and do a second round. But who was responsible for the design on the front end? Was that NASA or Northrop?

Mr. BRIDENSTINE. NASA.

Mr. PALMER. Okay. Who was responsible for the estimating on the cost side?

Mr. BRIDENSTINE. We received proposals and then we make determinations based on those proposals.

Mr. PALMER. So you had a combination of NASA doing the design, Northrop Grumman evaluating the design and presenting a proposal that told you $500 million?

Mr. BRIDENSTINE. We ultimately—NASA is responsible for generating the requirements and the specifications.

Mr. PALMER. Did anyone take into account the feasibility of the project at the time to determine, first of all, was the project feasible and was the cost in line with the feasibility of the project?

Mr. BRIDENSTINE. Yes.

Mr. PALMER. And—but you still took—it's 2018, 22 years later. You still don't have it done, and it's 19 times the initial estimate. How is that possible?

Mr. BRIDENSTINE. Again, going back in time, the specifications changed. We determine—

Mr. PALMER. I understand that——

Mr. BRIDENSTINE. Sure.

Mr. PALMER. —that— I worked for two international engineering companies before I started a think tank, and we used to joke at one of them in particular that there's never a time to do it right, but there's always time to do it over. That's bad for everybody. And when you do a cost-plus contract and somebody else is paying the cost, the taxpayers, I just see it time and time again, whether it's military contracts, whether it's NASA, that there are a number of things that happen. They get concerned that they won't get the funding from Congress so they start a project before it's ripe, and then you have cost overruns. There's a NASA project right now I think that within six or eight months it was 50 percent cost overrun. And then you have things like this. The initial estimate was $500 million. With the launch cost, you're going to be at, what, $9.6 billion?

Mr. BRIDENSTINE. That's a lifecycle cost.

Mr. PALMER. Lifecycle cost. And I just have to wonder if we'd gone ahead and built the project to the initial specifications and launched it, how much would we have learned from that launch that could have been applied to a second generation, a third generation?

Mr. BRIDENSTINE. You're absolutely right. That's a wonderful point. I agree completely.

Mr. PALMER. Well, that's the kind of stuff that drives me crazy.

Mr. BRIDENSTINE. Yes.

Mr. PALMER. I mean, we're looking right now at a $21.5 trillion debt, and if we have another project that takes 20 years to complete, it won't get completed because we can't afford it. We'll be bankrupt. And we keep doing stuff like this, and we don't hold people accountable for doing it. The Committee doesn't exercise the proper oversight. I'm sitting here wondering after 22 years, Mr. Chairman, where's the oversight and where was the effort to hold anybody accountable for this? And this goes on and on and on.

I think what we're trying to accomplish here is breathtaking in its scope, but we can't continue to operate like this. I mean, somebody at some point should have had some oversight over this, and maybe we would have launched this ten years ago and we would have learned an enormous amount from it so that the money we're spending now really would've had a magnificent return. But we haven't gotten off the ground. So that's the kind of stuff that I think we've got to deal with.

For NASA to be able to achieve its mission, accomplish the objectives that NASA has set for itself, we have got to rethink how we do these contracts. I'm not a big proponent of cost-plus at all. I think if we did these things where we fund it up front at the design phase and then a certain percent at the next phase of construction, then you do the review, you correct the mistakes, and then you launch and you pay off after launch, I think we'd see things that cost a whole lot less and we'd see things get off the ground a whole lot quicker. So how do you want to respond to that as the new Administrator?

Mr. BRIDENSTINE. Well, I would say that the fundamental question is would we do it again? And I would say that not this way, we would not. The question is will it be worth it in the end? And

we don't have an answer for that right now, but I believe it will be.

Mr. PALMER. Well, I sat here and listened to you talk about your hopes, your visions for this project and NASA, and I heard one of our Democratic colleagues comment on you as the Administrator, and I just wonder why it took so long to confirm you. I appreciate what you're trying to do, and I want you to know that if there's any help that I can provide to you—I think I can speak for the Committee as well—that we can provide to you, particularly in avoiding other project mishaps like we've had for this, I think we would be more than happy to assist in any way we can.

With that, Mr. Chairman, I yield back.

Mr. LUCAS. The gentleman yields back, and before I turn to the gentleman from New York, I'd simply note to him I'm after you, so you're not last, sir.

Mr. TONKO. Okay.

Mr. LUCAS. The Chair recognizes the gentleman from New York, Mr. Tonko, for five minutes.

Mr. TONKO. Thank you. I thank the Chair and the Ranking Member for the opportunity.

Personally, I was inspired by the years leading up to the moon landing. I was in high school as we competed in the space race against the Soviet Union for spaceflight supremacy. We had a passionate resolve to use science and engineering to beat our rivals, and after years of investing and innovating, America led the world in this endeavor, and our Nation was the first to land on the moon. The memories from that day forever linger in my mind. It inspired me to believe that with the will and necessary resources America would lead the way in continued exploration, research, and development. It also inspired me to embrace an education in science and engineering.

So I am excited by the James Webb Space Telescope and even more so excited by the potential impact this work and related discoveries can have on engaging the public and inspiring our next generation of scientists and engineers. We should continue discussions on how to ensure mission success and how to do this the right way even if it takes longer than we would've liked.

On a different note, though, I would like to hear more on how NASA is utilizing Webb to engage the public and to build our next generation of scientists and engineers. I've told students in the capital region of New York that I represent that, through STEM, you can be the scientist who learns new secrets about our universe, you can be that astronaut who lands on Mars, or you can be that doctor or researcher who discovers the path to better ensure a healthy passage on long spaceflights, or you can be the engineer who designs or invents a new technology or the spaceship that will take us far past our own galaxy.

So, Administrator Bridenstine, what is NASA working on to engage the public on the inspirational undertaking?

Mr. BRIDENSTINE. That's a wonderful question, Congressman Tonko, and important because NASA is the one agency I believe in the U.S. Government more than any others that can inspire that next generation of—as you so correctly identified and to have an investment like this and not take advantage of it to accomplish

that I think would be a massive mistake. So what we do with James Webb is critically important for that.

One of the first things that we're going to do is—it's—the data and the information and the science that we receive from James Webb is going to be made available to the entire world, and it's going to be made available for free. We want people to know and understand what we're discovering and let them take the data and the information and make discoveries of their own, which we believe all around the world people will have the opportunity to do.

It's also true that we want to engage the public, as you've correctly identified, by having people come up with ideas on how to utilize the James Webb Space Telescope in ways that we're not even thinking about right now. What are the scientific inquiries that others all around the world have? And we're seeing right now an interest from nations all over the world with their universities and their scientists making recommendations to NASA. And of course we're compiling a lot of—there's more requests for utilization than there is ability to utilize, which is a good problem to have. And so it—I think it will provide a source of inspiration from around the world.

But more than any of that, just like we've seen with the Hubble, taking the new science that we learn and rewriting textbooks is game-changing. And so it will have—again, we're rewriting science textbooks. That's what NASA does, and that's what this will be, and that in itself is going to engage the public in ways that right now we don't even understand so——

Mr. TONKO. Are there—and I appreciate that, and I think that's a good outcome. Are there other specific things that NASA is doing to communicate and involve our students?

Mr. BRIDENSTINE. Certainly, NASA has a number of different programs that get universities involved and get children involved. And yes, so that—you know, we have an Office of Education, for example. We have an Office of Communications, and we're very active on social media. We have millions and millions of people that follow us. And every new discovery that we make, we're communicating it out to the public and trying to inspire that next—you know, the 7-year-old to become the next, you know, Neil Armstrong. We're doing that all the time.

Mr. TONKO. Well, I think the efforts here to engage the public and to pull the students into technical fields are so critically important to the future of this country, and to be able to do that through the auspices of NASA I think is an incredible thing. So I thank you for the leadership, and I wish us all well with the final outcomes here as we go forward and learn from our mistakes and build for a stronger future.

Mr. BRIDENSTINE. Thank you.

Mr. TONKO. With that, Mr. Chair, I yield back, and thanks for allowing me to be next-to-last.

Mr. LUCAS. Absolutely, my dear friend. Thank you for yielding back.

I recognize myself for five minutes to just simply offer an observation and a question. It's good, Administrator Bridenstine, my old fellow Oklahoma colleague, to have you here. You entered into your role in a challenging time. Perhaps not since Administrator Webb

have there been such opportunities and such challenges for the agency.

I'm about 18 months younger than NASA, so my entire life NASA has been the—as my mother used to say, a child of the 1930s—the Buck Rogers institution. It's been the whizbang of the federal government and the world. But as we enter into these ever-increasingly large and expensive science projects, the expectations and the anticipation of the constituents grow.

Your legacy, I suspect, will be determined by how well you, working with all of the wonderful people at NASA and other contractors, deliver on finishing James Webb.

Mr. BRIDENSTINE. That's right.

Mr. LUCAS. I have expectations that you can do that. My only question quite simply to you is, as we've discussed now at extent, not through this hearing but through hearings and hearings and hearings on James Webb, this has to be right. We can't go put a pair of glasses on it the way we did Hubble. We can't go make adjustments. It has to fly correctly. Your word is—and I'm asking—we won't fly until we're ready. We won't fly until we're perfect, and when we're perfect, we'll live up to the expectations that we've established in this Committee and in this country for this project, correct?

Mr. BRIDENSTINE. That's correct.

Mr. LUCAS. That's all I have to ask, and that's the reassurance I need.

With that, I thank the witnesses for their testimony and the members for their questions. The Committee stands in recess until tomorrow morning, at which time we'll reconvene for the continuation of this hearing.

[Whereupon, at 12:35 p.m., the Committee recessed, to reconvene at 9:30 a.m., Thursday, July 26, 2018.]

The Committee met, pursuant to call, at 9:39 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Lamar Smith [Chairman of the Committee] presiding.

Chairman SMITH. The Committee on Space, Science, and Technology will come to order. Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Good morning, and welcome to the second day of the hearing entitled "James Webb Space Telescope: Program Breach and its Implications." I'll recognize myself for five minutes for an opening statement.

Yesterday, the Committee heard discussions about the James Webb Space Telescope program breaches. NASA Administrator Jim Bridenstine and Independent Review Board Chairman Tom Young provided insights into the Northrop Grumman management problems. As a reminder of JWST's cost overruns and schedule delays, take a look at the chart on display, and this is the chart that I also showed yesterday.

[Slide.]

Chairman SMITH. The chart chronicles JWST's substantial cost growth and launch schedule delays starting in the lower-left corner with the 1996 initial projection of $500 million and a 2007 launch all the way to the—excuse me—upper-right corner with the IRB's 2018 projection of $9.6 billion and a 2021 launch. That is 19 times the original cost and a delay of 14 years. Who is going to be held accountable?

Beginning with TRW's 1990s developmental work on JWST through Northrop Grumman's acquisition of TRW and continuance of the project's development, it is clear that Northrop Grumman did not adhere to the best business practices. Digging into the details, the IRB report describes mistakes that have greatly impacted the JWST development schedule and its associated cost increases.

The IRB categorized those issues as follows: first-of-a-kind developments such as the complex sunshield for the telescope; avoidable human errors in the workplace, such as the use of a wrong solvent and applying excess voltage; lack of individual and organizational discipline in developing safety checks to catch human errors and minimize their impact; embedded problems with contractor quality control processes, such as not detecting technician and material errors until assembly and testing when those errors added to costs; lack of a contractor managed engineering audit process to catch embedded problems before those problems continued unchecked until testing and assembly.

The IRB's description of workplace errors and lack of good management has been found at other space missions associated with Northrop Grumman. The U.S. aerospace industry has the highest skilled workforce in the world. Their scientists, engineers, and technicians have built incredibly challenging and complex aerospace systems. So the workplace errors and lack of discipline, auditing, and quality control described by the IRB could lead us to believe that the real issue may be with Northrop Grumman.

Not that Northrop Grumman hasn't tried to convince the public that all is going well. As this hearing date approached, Northrop Grumman's JWST advertising campaign loudly proclaimed, quote "Making History Requires Mission Success" and "The Value of Per-

formance." But the full-page ad in The Washington Post, which may have cost as much as $200,000, didn't mention the lack of performance due to billions of dollars in cost overruns, years of launch delays, frustration of NASA managers, and avoidable workplace errors.

As I said yesterday, when government contractors make mistakes, typically no one is held accountable. The mistakes "just happened" or "were unavoidable" or "won't happen again." But in every case, the American people pick up the bill. We often forget there's no such thing as federal dollars. It is the American taxpayers' hard-earned money.

Going forward, Congress needs to have the necessary confidence in NASA's contractors to put us on the right path at a reasonable cost. Anything short of that will undermine Congressional confidence in contractors' ability to deliver on their promises.

Another adverse effect of cost overruns, of course, is that they can jeopardize other space programs. If space exploration is going to continue to earn the public's support, then contractors will have to deliver on time and on budget. If they cannot, they should be penalized.

[The prepared statement of Chairman Smith follows:]

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

For Immediate Release
July 26, 2018

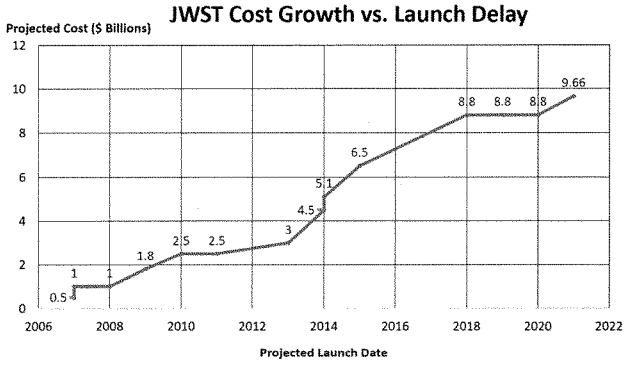
Media Contacts: Heather Vaughan, Bridget Dunn
(202) 225-6371

Statement by Chairman Smith (R-Texas)

James Webb Space Telescope: Program Breach and its Implications

Chairman Smith: Yesterday, the Committee heard discussions about the James Webb Space Telescope (JWST) program breaches. NASA Administrator Jim Bridenstine and Independent Review Board (IRB) Chairman Tom Young provided insights into the Northrop Grumman management problems.

As a reminder of JWST's cost overruns and schedule delays, take a look at the chart on display.



This chart chronicles JWST's substantial cost growth and launch schedule delays starting in the lower-left corner with the 1996 initial projection of 500 million dollars and a 2007 launch all the way to the upper-right corner with the IRB's 2018 projection of 9.66 billion dollars and a 2021 launch. That is nineteen times the original cost and a delay of fourteen years. Who is going to be held accountable?

Beginning with TRW's 1990's developmental work on JWST through Northrop Grumman's acquisition of TRW and continuance of the project's development, it is clear that Northrop Grumman did not adhere to good business practices.

Digging into the details, the IRB report describes mistakes that have greatly impacted the JWST development schedule and its associated cost increases. The IRB categorized those issues as follows:

- First of a kind developments such as the complex sunshield for the telescope.
- Avoidable human errors in the workplace, such as the use of a wrong solvent and applying excess voltage.
- Lack of individual and organizational discipline in developing safety checks to catch human errors and minimize their impact.
- Embedded problems with contractor quality control processes, such as not detecting technician and material errors until assembly and testing when those errors added to costs.
- Lack of a contractor managed engineering audit process to catch embedded problems before those problems continued unchecked until testing and assembly.

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Going forward, Congress needs to have the necessary confidence in NASA's contractors to put us on the right path at a reasonable cost. Anything short of that will undermine congressional confidence in contractors' ability to deliver on their promises. Another adverse effect of cost overruns is that they can jeopardize other space programs.

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

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Chairman SMITH. That concludes my opening statement, and the gentlewoman from Texas, the Ranking Member Ms. Johnson, is recognized for hers.

Ms. JOHNSON. Thank you very much, Mr. Chairman. Let me first apologize for being a little late. I had tox—was delayed from a previously scheduled meeting.

Good morning to everyone and welcome, Mr. Bush, and welcome back, Mr. Young.

The recently announced cost growth and schedule delay for the James Webb Space Telescope is not good news, and Northrop Grumman shares responsibility with NASA for the situation which we are facing. The human errors at Northrop Grumman that contributed to the cost and schedule growth on the project are indeed troubling.

But let me be clear. I am not here to berate Northrop Grumman and its associated subcontractors but rather to see what needs to be done to keep this from happening again. In addition, the Committee, in its oversight capacity, needs to take a hard look at whether appropriate mechanisms are in place to ensure accountability at both Northrop Grumman and NASA for the cost growth and delays to the James Webb Space Telescope project.

So I hope this morning's discussion will shed light on several issues, including the biggest risks to meeting the March 30, 2021, launch date and how much confidence Congress should have in Northrop Grumman's ability to meet that date. I also want to know what changes are being made to address the Independent Review Board's findings and recommendations on management communication on the James Webb Space Telescope project.

Before I close, Mr. Chairman, I want to thank the hundreds of employees at Northrop Grumman and NASA who are working tirelessly toward a successful completion and the commissioning of the James Webb Space Telescope. Many of them have worked long shifts, weekends, and have given up time with their families to meet the demands of this extraordinary project. We appreciate their important contribution. This project and the scientific discoveries it will enable would not be possible without them.

And before I yield back, I have a letter that I'd like to offer to the record, which is a support letter from Mr. Hoya and Anthony Brown.

Chairman SMITH. Okay. Without objection, the letter will be made a part of the record.

[The information follows:]

Congress of the United States
House of Representatives
Washington, DC 20515–2004

July 25, 2018

The Honorable Lamar Smith
Chairman
House Committee on Science, Space, and Technology
2321 Rayburn House Office Building
Washington, DC 20515

The Honorable Eddie Bernice Johnson
Ranking Member
House Committee on Science, Space, and Technology
394 Ford House Office Building
Washington, DC 20515

Dear Chairman Smith and Ranking Member Bernice Johnson:

We write in strong support of the James Webb Space Telescope (JWST) Program. When launched, JWST will be the largest, most powerful telescope ever built for space. This premier observatory will play an integral role for decades in the advancement of astronomy and astrophysics, and will preserve the United States' role as the global leader in science and space.

Managed by NASA's Goddard Space Flight Center (GSFC) in Prince George's County, Maryland, JWST is among the most complex scientific endeavors our nation has embarked on. This next generation observatory will allow us to see farther out into space and deeper into the past of the universe, answering many of mankind's biggest questions regarding the aftermath of the Big Bang. The telescope will use infrared detectors to look at the universe's first light; the origins of stars and planets, including ones that can potentially support life; the assembly of galaxies; and black holes. The scientists and engineers at GSFC are also responsible for providing components for the Integrated Science Instrument Module, which houses the telescopes' four main instruments: a near-infrared camera, a near-infrared spectrograph, a mid-infrared instrument, and a near infrared imager and spectrograph.

With any historic, complex, and cutting-edge undertaking such as JWST, there will be associated complications and risks. JWST has faced no shortage of challenges during its development and construction. After issuing its report, the Webb Independent Review Board (IRB) indicated its belief that the leadership at NASA and Northrop Grumman Aerospace Systems are committed to success. It is imperative that we move forward to address all remaining challenges and ensure that mission success is the highest priority. We are grateful that the IRB believes that JWST should continue and agree with this recommendation based on the "exceptional potential and science insight" JWST holds.

JWST represents a giant leap into the future for the United States and humankind, and we are confident it is worth the wait. The JWST team, including many of our constituents who work at GSFC, should be very proud. Thanks to their hard work, ingenuity, and creativeness, we now know that a telescope of JWST's complexity is possible.

We strongly support the JWST Program and its continuation. Thank you for your consideration and work on this crucial program, and we look forward to the successful completion of this important mission.

Sincerely,

Steny H. Hoyer
Member of Congress

Anthony G. Brown
Member of Congress

Ms. JOHNSON. Thank you, Mr. Chairman, and I yield back.
[The prepared statement of Ms. Johnson follows:]

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

House Committee on Science, Space, and Technology
"James Webb Space Telescope: Program Breach and its Implications"
July 26, 2018

Good morning. Welcome Mr. Bush and welcome back, Mr. Young.

The recently announced cost growth and schedule delay for James Webb Space Telescope is not good news, and Northrop Grumman shares responsibility with NASA for the situation we are facing. The human errors at Northrop Grumman that contributed to the cost and schedule growth on the project are indeed troubling.

But let me be clear. I am not here today to berate Northrop Grumman and its associated subcontractors, but rather to see what needs to be done to keep this from happening again. In addition, this Committee, in its oversight capacity, needs to take a hard look at whether appropriate mechanisms are in place to ensure accountability at both Northrop Grumman and NASA for the cost growth and delays to the James Webb Space Telescope project.

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Before I close, Mr. Chairman, I want to thank the hundreds of employees at Northrop Grumman and NASA who are working tirelessly toward a successful completion and commissioning of the James Webb Space Telescope.

Many of them have worked long-shifts, weekends, and have given up time with their families to meet the demands of this extraordinary project. We appreciate their important contribution. This project and the scientific discoveries it will enable would not be possible without them.

Thank you, and I yield back.

Chairman SMITH. Thank you, Ms. Johnson.

And let me ask unanimous consent that the opening statements of the Chairman of the Space Subcommittee, Mr. Babin, and the Ranking Member of the Space Subcommittee, Mr. Bera, be made a part of the record, too.

[The prepared statement of Mr. Babin follows:]

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

For Immediate Release
July 26, 2018

Media Contact: Heather Vaughan, Bridget Dunn
(202) 225-6371

Statement by Chairman Brian Babin (R-Texas)

James Webb Space Telescope: Program Breach and its Implications

Chairman Babin: Good morning. Welcome back to our 2nd hearing regarding the James Webb Space Telescope (JWST). As I stated yesterday, I strongly believe in the mission of NASA and commend the tremendous dedication of NASA and the industry team. But as the Chairman of the Space Subcommittee which oversees the agency, it is our responsibility to ensure they, as well as every other government agency, are managing their resources effectively.

However, as this Committee learned in yesterday's hearing, the program and resources relative to JWST have not been managed effectively with fault resting not only with the contractor, but also with NASA and Congress.

In his testimony, Tom Young, Chairman of the Independent Review Board (IRB), addressed many of the issues that led to the cost and schedule breaches with JWST. He also shared significant insight on contributing factors such as the contracting mechanisms used and the expertise of the program management and acquisition personnel.

Administrator Bridenstine provided testimony on NASA's response to the IRB and detailed actions being taken to avoid such development failures in the future. He further conveyed NASA's unwavering commitment to "get these problems solved on the ground"...before the system is launched.

For today's panel, the focus shifts to contractor performance and oversight. More specifically, I want to address implications and concerns over the US space industrial base.

The recent presidential space directives have emphasized the renewed importance of space operations to America's national security, scientific advancements, commercial innovation, and aerospace transportation infrastructure. Across all of these lines of effort, the robustness and resiliency of the space industrial base are critical.

Unfortunately, JWST development shortfalls and numerous other cost and schedule issues with multiple civil and national security space programs have given this Committee reason to be concerned with the health of the US space industrial base.

Since a high-visibility civil space mission like JWST is experiencing avoidable human errors in the workplace and embedded problems with engineering processes at a major aerospace firm, then it is important to ask if more widespread technical issues are occurring within national security space missions and other areas of the US space operations community.

The root causes of these issues need to be discussed today, especially if they are related to insufficient availability of highly-skilled employees and reduced STEM education enrollments affecting recruitment. Likewise, Mr. Young mentioned yesterday that the JWST trade space consists of acceptable risk versus available funding. Thus, we need to ask if the space industrial base is trading too much design resiliency to seek more cost efficiency.

Congress needs to understand the status of JWST today, as well as the plan going forward. Decisions made now can have long lasting implications on future missions. We need to know if the problems being experienced are systemic, based in our acquisition approach, or if they are fundamental management problems in how we plan and execute these larger, multi-year development strategic missions.

I gained significant insight from Administrator Bridenstine and Mr. Young's testimony yesterday. I look forward to Mr. Bush's testimony today, to better understand the perspectives from the JWST prime contractor. It is important to understand their view of the challenges, mistakes, current status, and corrective actions as we move forward. Thank you for your appearance today.

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[The prepared statement of Mr. Bera follows:]

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

House Committee on Science, Space, and Technology
"James Webb Space Telescope: Program Breach and its Implications"
July 26, 2018

Good morning. Mr. Bush, welcome to Day Two of the Committee's hearings on *"James Webb Space Telescope: Program Breach and its Implications"*. Welcome back Mr. Young. We appreciate your flexibility to appear both yesterday and today.

Mr. Chairman, as we will hear today, Northrop Grumman acknowledges that they have contributed to the telescope's delays. They also acknowledge that some of the challenges they have encountered have been the result of human error and procedures. Those errors were avoidable and we need to understand both why they occurred and what NASA and Northrop Grumman are going to do to prevent any more such errors.

As I indicated last month at the Space Subcommittee's hearing on NASA's Cost and Schedule Overruns, we, on this Committee, have the responsibility for making sure that agencies are being good stewards of taxpayer dollars. It is our job to ensure that we understand why programs run into difficulty, verify that necessary improvements are being put in place to put these programs back on the right course, and apply the lessons learned for future missions.

As we heard from Mr. Young yesterday, the JWST Independent Review Board (IRB) focused its energies on maximizing the probability of JWST mission success. It is worth highlighting that the IRB stated that it undertook *"a mission success review, not a failure review."* Another point worth noting is that the recognition of avoidable human errors that disrupted the integration and testing activities should not detract from the technological "miracles" that NASA and its industry partners had to bring about just to get us to this point. Indeed, while the human errors the IRB identified should not have happened, the American people should be given the context necessary to understand the technical complexity associated with building and testing JWST.

Thus, I hope that Mr. Bush can provide us with details on how Northrop Grumman will move forward and what they are doing to prioritize mission success such that a launch in March 2021 will lead to successful commissioning of this tremendous capability.

With that, I yield back.

Chairman SMITH. And also, at the outset, let me note—and for our witnesses to be aware of as well—that we expect votes in about 15 minutes at 10 o'clock. We will come back immediately after those votes. I think those votes will take around 20 minutes, and then when we come back, we should have close to an hour before the second series of votes, after which it will be impossible to get members to return. So I hope members will remember they were supposed to be here anyway and come back after that first set of votes.

Our first witness today is Mr. Wesley Bush, Chief Executive Officer of Northrop Grumman. Mr. Bush began his career with Northrop Grumman as President of the company's Space Technology Sector. Prior to Northrop Grumman, he served as President and CEO of TRW's United Kingdom-based Global Aeronautical Systems.

Mr. Bush earned both a bachelor's degree and a master's degree in electrical engineering from MIT. He also completed the University of California Los Angeles Executive Management Program.

And Mr. Tom Young is welcomed back. He testified yesterday. He is Chairman of the Independent Review Board. Mr. Young is the former Director of NASA's Goddard Space Flight Center, as well as the former President and Chief Operating Officer of Martin Marietta Corporation. He earned both a bachelor's degree in aeronautical engineering and a bachelor's degree in mechanical engineering from the University of Virginia and a master's in management degree from MIT.

Mr. Young testified yesterday, so he will not be making that statement a second time, but of course he will be available for questions.

So we'll begin and I look forward, Mr. Bush, to hearing from you.

TESTIMONY OF WESLEY BUSH,
CHIEF EXECUTIVE OFFICER,
NORTHROP GRUMMAN CORPORATION

Mr. BUSH. Thank you, Mr. Chairman. Well, Chairman Smith, Ranking Member Johnson, and Members of the Committee, thank you for the opportunity to appear before you today to discuss the status of NASA's James Webb Space Telescope. This telescope is the largest and most complex astronomical science telescope ever built. Like the iconic Hubble Telescope, Webb will reaffirm and solidify U.S. leadership in space, which is critically important as other nations are testing our will to lead in space. Webb also will inspire the next generation of scientists, engineers, astronomers, and innovators and transform our understanding of the physics of the universe. But Webb doesn't just stretch Hubble's limits, it is a true leap ahead in technology and capability.

From a technical standpoint, Webb is an incredible engineering feat with a 21-foot primary mirror and a sunshield roughly the size of a tennis court, we had to design and build Webb to fold up together to get it into the launch fairing.

After launch, Webb will slowly unpack itself in space as it progresses towards its operating location one million miles from Earth, where there will be a temperature swing of nearly 600 degrees between the optical mirror and the other side of the sunshield. Build-

ing a telescope that can operate in such a harsh environment beyond the reach of satellite servicing requires extensive testing on the ground to ensure that it will operate as planned in space.

All of Webb's major hardware components are now located at our Space Park facility in Redondo Beach, California, where they will undergo final integration and testing. If you could put the first slide up.

[Slide.]

Mr. BUSH. On the screen is a photo of the elements that make up Webb, altogether in the High Bay at Space Park, and it is absolutely a great site to see. And you can get a sense of the scale with the humans that are in the photo.

We're now assembling these major parts together and testing it to ensure mission success. The next picture if we could move to the next slide——

[Slide.]

Mr. BUSH. —shows the progress we have made in building up the major subsystems of the telescope and the remaining steps still before us.

The optical telescope element and the integrated science instrument module, which is called OTIS, is complete and fully tested. We are now focused on testing the spacecraft element, which includes the sunshield. Once we have successfully completed the spacecraft testing, both parts of the telescope will be put together, tested, and shipped for launch.

Northrop Grumman takes very seriously the trust placed in us to build this incredible telescope and our responsibility to ensure mission success. While we're proud of the technological accomplishments that we've achieved with our partners, we recognize that we have contributed to the telescope's delays. We worked closely with the Independent Review Board, and we appreciate the hard work by Tom Young and the IRB members in developing their recommendations, and we are currently implementing the IRB's recommendations and we fully support NASA's revised plans for the program. Mission success is our top priority.

My written testimony goes into much greater detail about the program and how we are implementing the IRB's recommendations, but let me focus on two key points that I want to make very clear. First, the complexity of this first-ever program inevitably creates opportunities for human error in design, manufacturing, integration, and testing. And we have experienced some errors, and unfortunately, several of them have occurred at a phase in the program where they result in significant schedule impacts. We've also learned that some things that we thought we could do more quickly are simply going to take more time to perform in a way that reduces the likelihood of other errors and gives us greater confidence that the system will operate as planned.

I know these delays create frustration and also impact funding available to other programs given the budget constraints, so I want to address your questions today as best I can to ensure that there is complete transparency on the facts.

Second, I want you to know that we are confident that Webb will work and will perform its mission in a way that will make all of us in this room proud that we were part of making it a reality. I'm

pleased to see that the IRB confirmed their confidence that we can be successful as well.

Mr. Chairman, Ranking Member Johnson, this Committee's decades-long bipartisan support has been essential to keeping Webb moving forward, and we are determined to make it a success. So thanks again for the opportunity to testify here today.

[The prepared statement of Mr. Bush follows:]

WRITTEN STATEMENT BY

WES BUSH
CHAIRMAN AND CHIEF EXECUTIVE OFFICER
NORTHROP GRUMMAN CORPORATION

NORTHROP GRUMMAN

BEFORE THE

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

HEARING ON

JAMES WEBB SPACE TELESCOPE

JULY 26, 2018

Statement by Wes Bush
Chairman and Chief Executive Officer
Northrop Grumman

Before the
Committee on Science, Space, and Technology
James Webb Space Telescope

Introduction

Chairman Smith, Ranking Member Johnson, and Members of the Committee, thank you for the opportunity to appear before you today on behalf of the women and men of Northrop Grumman supporting the National Aeronautics and Space Administration's (NASA) James Webb Space Telescope. My name is Wes Bush and I am the Chairman and Chief Executive Officer of Northrop Grumman Corporation.

Northrop Grumman is fully committed to Webb's success, including the completion of the remaining test and integration activities to enable launch within the revised budget and schedule. We worked closely with the Independent Review Board (IRB), and support NASA's revised plan based on the IRB's recommendations. As the IRB concluded, we have confidence that the telescope will meet its mission objectives. While we are proud of the technological accomplishments that we have achieved that will enable Webb to perform its important mission, we recognize that we have contributed to the telescope's delays. We are currently implementing the recommendations of the IRB report as well as continually applying lessons learned from Webb and other programs to reduce programmatic risk and cost while ensuring Webb is launched at the earliest possible date. Mission success is our top priority.

The Webb telescope is in its final phase of development – testing and integration. The mission has come a long way, but this didn't happen in isolation. We are honored to be part of the industry team developing this historic telescope.

Under NASA's leadership at Headquarters and the Goddard Space Flight Center, and with the significant contributions of NASA's Johnson Space Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory, as well as their international partners, our nationwide industry team has overcome immense engineering and technological challenges in our efforts to

develop the world's most powerful space telescope. The project also has benefited from the substantial contributions of the Space Telescope Science Institute (STScI), which serves as the Science and Operations Center for the mission and will ultimately manage Webb's data and operations. Ball Aerospace, Harris, the former Orbital ATK-- now Northrop Grumman Innovation Systems, Nexolve, and Raytheon have each made significant contributions to the Webb program.

We appreciate our close working relationship with Administrator Bridenstine and the NASA team. We also appreciate the diligent leadership of Mr. Tom Young on the IRB — his technical knowledge and program management experience will help ensure that we continue to take every step possible to appropriately reduce risk. The entire IRB is to be commended for their diligent and thorough review of the program.

Science

The IRB stated. "JWST is an observatory with significant complexity, risk and first time events necessary to accomplish established science requirements," and it was exactly right. NASA's James Webb Space Telescope is the largest and most complex astronomical science telescope ever built, and once launched, will be the world's premier infrared space instrument. Webb will build upon the legacy of NASA's Great Observatories, including the iconic Hubble Space Telescope.

Webb provides the essential next step in the search for life in space. NASA has built incredible survey telescopes like the Kepler Spacecraft and Transiting Exoplanet Survey Satellite (TESS) that see exoplanets, but in order to actually find signs of life, we must look even closer. That is exactly what Webb will do. Webb doesn't just stretch Hubble, it is a true leap ahead in technology and capability:

- Massive segmented mirrors and adaptable optics, that carefully unfold in space, provide a far more powerful eye than was previously possible to peer 13.5 billion years back to the creation of the first stars and galaxies;

- A deployable sunshield and sensitive instruments that operate at cryogenic temperatures to detect even the faintest light in the infrared, making it 100 times more powerful than Hubble; and
- An orbit 1 million miles from Earth that provides a cold and stable point to look across the universe.

Webb is a vital step forward as we seek to deepen our knowledge of the universe.

As the decadal survey stated, what we now call the James Webb Space Telescope is the top astrophysics priority. Webb will have four primary scientific missions: search for light from the first stars and galaxies that formed the universe; uncover the formation and evolution of galaxies; characterize the formation of stars and planetary systems; and study the origins of life. As a general-purpose observatory, one of the most exciting things about the James Webb Space Telescope is that it will help us answer questions we have not even thought to ask.

If Hubble's history is any indication, Webb's unique capabilities will change the way we view the universe. Like Hubble, Webb will reaffirm and solidify U.S. leadership in space, inspire the next generation of scientists and engineers, and transform our understanding of the origins of the universe. Webb's unique capabilities promise to be just as transformative for the next generation of astronomers and innovators.

Technology

From a technical standpoint, Webb is an incredible engineering feat that pushes the limits of existing technology and represents a significant step forward for the nation's space program. The team has constructed a telescope with a large 21-foot primary mirror and a sunshield roughly the size of a tennis court (40 feet by 70 feet). In the simplest terms, the larger the telescope, the more powerful it is. However, this telescope is so large that it cannot easily fit in a rocket. As a result, we had to design and build Webb like a piece of origami - with 18 hexagonal mirrors and a massive sunshield that can fold. After launch, Webb will slowly unpack itself in space as it progresses towards its operating location, 1 million miles from Earth, in an incredibly harsh environment. This is no easy task. The optical mirror, which faces away from the sun, will operate at a temperature of minus 388 degrees Fahrenheit while on the other side of the

sunshield it will be +185 degrees Fahrenheit – a temperature swing of nearly 600 degrees. Building a telescope that can operate in such a harsh environment beyond the reach of satellite servicing requires extensive testing to ensure that it will operate as planned. While NASA was able to repair and refurbish Hubble, which is in low Earth orbit about three hundred and fifty miles above the Earth's surface, Webb's operational location means this team only has one chance to get Webb right.

Webb is so complex and advanced that many thought it was an impossible task. In fact, at least ten innovative new technologies had to be invented to make this mission a reality. Some of these innovations have already spawned "spinoff" technologies that have proven useful in other fields such as medicine, science, aerospace, and commercial applications.

For example, to accurately measure the shape of Webb's mirrors during manufacturing, significant new improvements had to be made in the area of wave-front-sensing technology. The resulting measurement device is called a Scanning Shack-Hartmann Sensor. This Webb-inspired sensor improvement has enabled eye doctors to get much more detailed information about the shape of a patient's eye in seconds rather than hours. In fact, at least four different patents have been issued as a result of innovations driven by the Webb telescope program. According to Dr. Dan Neal of Abbott Medical Optics Inc., "The Webb telescope program has enabled a number of improvements in measurement technology for measurement of human eyes, diagnosis of ocular diseases and has potentially improved surgery."

Additionally, laser interferometers designed to precisely measure each of Webb's mirrors to ensure that they effectively act as one large optic has led to commercial applications. One of the toughest challenges for Webb engineers was to find a way to test mirrors and composite structures at the incredibly cold temperature that Webb will experience in space. With desired precisions of nanometers, vibration is a constant problem. To solve that problem, 4D Technology Corporation of Tucson, Arizona developed several new types of high-speed test devices that utilize pulsed lasers that essentially "freeze out" the effects of vibration. These have had a wide range of beneficial commercial applications in the astronomy, aerospace, semiconductor and medical industries.

Current Status

I am pleased to report that all of Webb's major hardware components are now located at Northrop Grumman's Space Park facility in Redondo Beach, California where they will undergo final integration and testing. I have included a photo of the elements that make up Webb, all together in the high bay at Space Park. It is a great sight to see – we have worked hard for so many years to reach this point where we are assembling these major parts together and testing it to ensure mission success. The second picture shows the success we have had in building up the major subsystems of the telescope, and the remaining steps still before us.

The optical telescope element and integrated science instrument module, what is called the OTIS, is complete and fully tested. We are now focused on testing the spacecraft element that includes the sunshield. Once we have successfully completed the spacecraft testing, both parts of the telescope will be put together, tested and shipped for launch. As an aside, I would like to invite the Committee to come out to visit so that you can see the hardware up close, meet the amazing engineers and technicians working on the program, and gain a deeper understanding of the program's complexity.

Following the 2011 Casani Report and replan, the Webb program has been on budget and on schedule until the program entered the current integration and test phase. Throughout this time several thousand parts and sub-assemblies were successfully built, tested, and delivered to the next level of assembly.

As I mentioned earlier, Northrop Grumman recognizes that we have contributed to some of the program's challenges. We have taken the appropriate corrective actions. Calculated risks were taken in the development plan for Webb and we are all disappointed that the plan did not go perfectly. As emphasized in the IRB report, we agree that mission success is the top priority and we want Webb to be launched at the lowest cost and earliest date possible. Unlike a few years ago when there were multiple simultaneous activities going on as we worked towards launch, there is only one path of integration and testing now. Consequently, as the IRB highlighted, even small problems at this stage have larger ripple effects throughout the program.

Although we have encountered some issues recently, which I will detail later, it is important to not lose sight of the fact that the purpose of testing is exactly that—to find problems with the program now versus finding them after launch. We need to ensure that we allow the necessary time through final integration and testing to get it absolutely right and ensure that Webb is able to fulfill its potential.

Independent Review Board (IRB) Report

Again, Northrop Grumman takes very seriously the trust placed in us to build this incredible telescope and our responsibility to ensure mission success. We fully support the revised program plan that NASA has put forward based on the IRB's findings. Let me take a moment to describe some of the technical and programmatic challenges referenced in the IRB report, as well as the steps taken by Northrop Grumman and NASA to ensure we adhere to the updated program budget and schedule. I think it is important to address several items in this statement:

Propulsion Execution Issues

The spacecraft bus – one of the four major elements of Webb – provides the necessary support functions for the operation of the observatory, and is home to six major subsystems, including the propulsion system. The propulsion system contains the fuel tanks and the rockets that, when directed by the Attitude Control System, are fired to maintain the orbit. Unfortunately, some of the challenges that we have encountered with the propulsion system have been the result of human error and procedures. In June 2016, an incorrect voltage was applied, damaging the pressure transducers that help monitor spacecraft fuel levels. Using a complicated welding process, we installed new pressure transducers on the spacecraft bus before testing and integration could continue. This repair process required many detailed operations to be safely performed, assuring it would not threaten the spacecraft's operations. It was important to take the time to get it right.

In May 2017, during testing of the spacecraft bus, we discovered that several valves in the propulsion system's thruster modules were leaking. After completing all testing it was

determined that 8 of the 16 valves did not meet spec and it was decided to remove all valves and refurbish them. We determined that the most likely cause of the leaks was an incorrect solvent used in cleaning procedures several years earlier. While we test, and test again, to identify and determine the root cause of these issues, which we did in this case, it nonetheless resulted in a several month delay to the schedule. In this instance, we simply did not have a clear enough cleaning process in place. As a result, we had to remove, refurbish and reattach the dual thruster modules. Additionally, in the course of our work on the propulsion system, a single thruster component was subjected to overvoltage, which required its replacement.

Although we may face challenges, one thing that I am immensely proud of is the Webb team's ingenuity and relentless pursuit of process improvement. A good example of this is when the Webb team deployed a new approach called induction brazing to reattach the thruster. The new approach was safer and faster than the previous method. In total, the unanticipated propulsion system issues added several months to the delivery and launch timeline. The good news is that the propulsion system is now checked out and ready for upcoming testing. All of these issues have been reviewed by our corrective action board and we have concurrence that everything is back on track.

Sunshield Complications

The detection of infrared light from very distant stars and planets requires the telescope to operate at extremely low temperatures. To shield the system's science instruments and mirrors from the sun's heat, Northrop Grumman developed a deployable sunshield. It is roughly the size of a tennis court (70 feet by 40 feet). The largest part of the entire observatory, it must fit within a rocket fairing 16 feet across. This is no small feat of engineering. This sunshield consists of five layers of aluminum and silicon-coated Kapton, which passively cools instruments to cryogenic temperatures. Each of the five layers are as thin as a human hair and must maintain precise separations upon deployment. In order to make certain the sunshield properly deploys in space, a gauntlet of strenuous tests must occur on the ground. Webb will orbit the sun at Lagrange Point 2, a location that is simply too far from Earth to be serviced, making it essential for us to test, re-test, and test again to ensure that we get it right. The largest driver to the recent schedule delays is that through rigorous testing, we have learned that it simply takes longer than

anyone had anticipated to safely fold, stow and deploy the massive and delicate sunshield. We then had to incorporate this additional time throughout each subsequent fold, stow and deployment phase.

The program team was thrilled to complete the first sunshield deployment in October 2017. However, during this process we realized that one of the six membrane tensioning systems experienced a snag. This was quickly mitigated but required a redesign to ensure it will not occur again while on orbit. Further complicating matters, during testing, we also uncovered small tears in several locations where the tension cables attach to the membrane. These were quickly treated with a localized solution but we also discovered a few small tears in the sunshield membrane layers. Due to the size of the sunshield, it had to be elevated off the ground to remediate the issues. Technicians had to slowly maneuver various lifts simultaneously to access the sunshield. The unanticipated challenges of testing the sunshield, as well as the risk reduction activities (inserting membrane retention devices) adopted to prevent additional tearing during space deployment increased the delivery and launch date timeline. The good news is that after multiple reviews by many parties, we have confidence that we have made all the necessary engineering changes to the unfolding mechanism to ensure that the sunshield will deploy without tearing the delicate membrane. Although disappointing, the sunshield obstacles were readily addressable and did not threaten the program's ultimate viability, but they did contribute to further schedule delays.

At the end of April 2018, following what appeared to be a successful acoustic testing of the spacecraft element, visual inspection revealed that a small fraction of the sunshield membrane fastening hardware that hold the retraction springs loosened during testing. During assembly that was performed several years back, engineering needed to deviate from the standard process because the original fasteners were sharp and tearing the covers. The redesigned fasteners did not threaten the membrane, but they were not as secure as the previous fasteners. When exposed to the spacecraft element acoustic testing, some became loose. A design modification is being incorporated to address this finding. This issue added significant time to the program's schedule because of the complexity of the sunshield. Nevertheless, by

identifying the issue and fixing it now, we are focused on ensuring the sunshield will work on orbit.

Optical Telescope Element and Integrated Science Instrument Module (OTIS)

OTIS is Webb's science payload. During the vibration testing of OTIS at NASA's Goddard Space Flight Center we concluded that more tests at slower speeds were necessary. Furthermore, although some previous tests had been planned in parallel, it would reduce risk to do them in sequential order instead. I mention these not to point out any mistakes, but rather to note that we need to allow a program of Webb's significance to the scientific community and importance to our nation the necessary time to test to ensure that we get it absolutely right.

Next Steps

As we move closer to the revised launch date, the next few months will be critical. Our immediate focus is the integration and testing of the spacecraft hardware (spacecraft bus and sunshield). The spacecraft elements then must successfully undergo acoustics, vibration, and thermal vacuum testing followed by post-environmental deployment and stow tests. Next we must integrate the completed OTIS and spacecraft elements before putting the full observatory through the final testing phase. After the electrical, acoustics, vibration and deployment tests are concluded, Webb will be prepared and shipped to the launch site in French Guiana, to complete its final site processing. Although important work remains, we are in a vastly different position than during the 2011 replan. All the hardware is complete. All the inventing is complete. The technical and engineering feats of creating the unique pieces of Webb are behind us. With all the hardware done, the once wide range of activities (and program variables) has now narrowed to a single path in integration and testing. However, every little deviation has larger impacts throughout the program as each piece is brought together for the first time. While risks remain, we believe we have an appropriately risk-managed program plan defined that is executable.

Corrective Actions

Building a one-of-a-kind scientific instrument is extremely challenging. Northrop Grumman is focused on mission success and supports the NASA defined plan based upon the IRB. We are implementing the recommendations.

The women and men of Northrop Grumman are doing Webb's final testing and integration, and we are proud of their commitment to Webb's mission. We recognize we have had some human errors, which for a one-of-a kind program of this complexity are to be expected. As the IRB identified, "Human errors must be minimized; however, they cannot be totally eliminated." In order to minimize the occurrence and impact of "human mistakes" as the IRB identified them, we are implementing these specific improvements:

Processes – assure they are well defined, current, accurate, implementable and not subject to interpretation.

Northrop Grumman stood down operations and performed an independent set of process reviews, which included feedback from those performing the processes. This resulted in rewrites of a number of procedures that were found to create the potential for errors. To further enhance robustness in I&T procedures, Northrop Grumman will be incorporating cross-program independent reviews of the table top and pre-task briefing processes.

Personnel certification – assure people capable of performing the task at hand.

In addition to formal training and certification for employees interfacing with the spacecraft hardware and the associated integration and test equipment, we are making certain that operations that are especially critical also require individual performers to have previously demonstrated expertise and prior successful execution of the specific type of critical process task. So, for example, a certified I&T mechanical technician would require an additional level of experience verification before working on the tasks associated with the sunshield membranes.

Discipline – assure individual accountability and follow the process, call a halt if the process appears questionable.

All employees supporting JWST are aware of their individual responsibilities to assure mission success through all of their actions, including thorough, careful and precise compliance with the defined processes. This is an ongoing part of the discussions with the teams. A core part of that responsibility is to speak up if the employee sees, or even suspects, that there may be something that is not correct, or that may lead to a problem. A process is in place to recognize

and reward performers who say 'Stop'. Additionally, we have brought in leadership from outside the program to meet with the various performing organizations (home-rooms of personnel assigned to work on JWST) to solicit feedback and to work with the program to incorporate that feedback into actions designed to enhance mission success.

Failure-proof "safety net" – testing, independent analysis, inspection.

We have taken steps to enhance the "safety net" around the program activities. Two organizations, in particular, have specific authorities and accountability for independent action. The Mission Assurance organization is independent of the program, and has full authority to stop any process it deems to be unacceptable. Members of the Mission Assurance team are assigned to be present with the technicians and engineers at all times when integration and test efforts are underway. The Engineering organization has the responsibility to conduct independent analyses to ensure that the right talent is reviewing critical decisions and that any concerns are immediately addressed. Just as we are focused on the training and capabilities of the team members assigned to the program, we also are assigning Mission Assurance and Engineering representatives in whom we have confidence in providing this "safety-net" process.

As the IRB recommended, NASA is undertaking a design audit aimed at identifying potential embedded risks, such as the fasteners previously mentioned. Northrop Grumman is supporting that audit. This activity will look at the pedigree of all the hardware and seek to identify other areas where lower level testing was deferred in order to identify possible additional challenges. We have also added more senior technical and management resources in engineering and leadership to ensure the Webb team can effectively meet the revised schedule demands. Many of the steps we are taking to integrate and test Webb hardware have simply never been done before. We are committed to providing the necessary training and resources to achieve mission success. We are undertaking additional reviews, strengthening communication across our team and ensuring that the people, process and tools are in place for Webb to fulfill its scientific promise.

There is frequent, in-depth dialogue between NASA's Science and Mission Directorate's front office and Northrop Grumman senior management. In addition, NASA has decided to

place additional Integration and Testing personnel and senior project management residents at Northrop Grumman, a crucial step. All of us at Northrop Grumman recognize our responsibility and the trust that you and the American people have placed in us to complete this important mission.

NASA's new launch schedule includes a 9-month schedule reserve. Given our current view of the remaining risks, we believe this provides adequate contingencies to achieve a successful launch in March 2021. Since the beginning of development, the Webb team has solved a wide array of difficult engineering and technical challenges. Most of the complex issues are now behind us: we have completed the construction of the spacecraft, the OTIS, and the sunshield. All those components are now ready for integration and final testing.

When I speak with the Webb team, everyone is laser focused on delivering a system that we are confident will perform its mission. The team also understands the importance of delivering the telescope to the launch site at the earliest date possible with the lowest cost, while not in any way jeopardizing mission success. We are all eager to see Webb's successful launch and activation and the amazing scientific discoveries it will yield for decades to come.

As of today, we are employing more than 400 engineers, technicians and support staff for integration and testing at our Space Park facility in Redondo Beach, California. To reach this point in the program, we have partnered with 511 suppliers across 39 states to complete the work to date. The reach of Webb is truly worldwide, harnessing the best technical expertise around the globe to fulfill this unprecedented engineering and science endeavor.

Conclusion

While we are incredibly proud of the technical achievements on the Webb program to date, we recognize that we have contributed to the schedule delays. At every level, from our technicians to our corporate leadership, Northrop Grumman is fully committed to mission success. I want to assure the Committee that we have worked with NASA to develop a high confidence plan for completion of the program. This revised plan has the benefit of additional testing, enhanced experiences and numerous internal NASA, Northrop Grumman and

independent reviews. We have learned from the recent challenges of the integration and test phase of the program. We have implemented the necessary corrective actions and put the people, processes and tools in place to better manage the remaining risks on the program.

Let me take a brief moment to specifically address the brilliant women and men across the James Webb Space Telescope program at NASA and in industry. Thank you for your hard work and dedication. Although we have had challenges, what you have already achieved on this program is absolutely incredible and deserves to be recognized. Your continued diligence, creativity and commitment to getting it right will ensure that Webb is a success.

This Committee's decades long, bipartisan support is essential to keeping the program on track. As difficult as this path has been, we should all take great pride in the incredible scientific contributions that Webb will deliver; the technological advances it will enable; and the millions of young girls and boys who will be inspired by its discoveries. Importantly, it will serve to advance our nation's leadership in physics. Again, we would be honored to have Members of the Committee visit the telescope's integration and test facility in Space Park before it is placed on a ship, travels through the Panama Canal, and is launched from French Guiana on its path to astounding scientific discoveries. We look forward to continuing to work closely with NASA, Congress, and our industry and international partners as we work towards making Webb the successful program that I have no doubt it will be.

WES BUSH

Chairman and Chief Executive Officer
Northrop Grumman Corporation

Wes Bush is chairman and chief executive officer of Northrop Grumman Corporation, a leader in global security.

He has served as chief executive officer since January 2010, and as chairman since July 2011.

Prior to 2010, Bush served as the president and chief operating officer of the company. Before that, he served as the corporate vice president and chief financial officer, and, earlier, as the president of the company's Space Technology sector. Prior to the acquisition of TRW by Northrop Grumman, he had served since 2001 as president and chief executive officer for TRW's UK-based global Aeronautical Systems. Bush joined TRW in 1987 as a systems engineer, and served in engineering, program management and business development roles in TRW's Space & Electronics business. Prior to joining TRW, he held engineering positions with both the Aerospace Corporation and Comsat Labs.

Bush earned a bachelor's degree and a master's degree in electrical engineering from the Massachusetts Institute of Technology. He also completed the University of California, Los Angeles' Executive Management Program. Bush serves on the board of directors of Norfolk Southern Corporation, as well as the boards of several nonprofit organizations, including the Aerospace Industries Association, the Business-Higher Education Forum, Conservation International, the U.S. Naval Academy Foundation, the Inova Health System and the USO Board of Governors.

Northrop Grumman is a leading global security company providing innovative systems, products and solutions in autonomous systems, cyber, C4ISR, space, strike, and logistics and modernization to customers worldwide. Please visit news.northropgrumman.com and follow us on Twitter, @NGCNews, for more information.

Chairman SMITH. Thank you, Mr. Bush. And I'll address my first questions to you.

Yesterday, Mr. Young suggested—no doubt you're aware—of the idea that all holding fees or all award fees be put in a holding account until the mission is a flight success. Would you agree to do that?

Mr. BUSH. So as a mechanism to ensure that we are all aligned on mission success, Northrop Grumman has actually discussed this with NASA, and we are willing to place all of the fee that we've already earned and the fee that we may earn in the future at risk based on successful activation and demonstration of the telescope on orbit. So we're very much aligned on that recommendation.

Chairman SMITH. I appreciate that positive response. I think you anticipated the question. Next question is this, this goes a step further. It seems to me that, given Mr. Young's description of JWST yesterday as a poorly managed program, that you ought to also put the $800 million and above cap expenses that were not anticipated and pay that yourself.

Mr. BUSH. Well, let me reaffirm that we are very committed to mission success, and as I said before, we are very proud of the progress that we've been making, but we do recognize that there has been cost growth. James Webb is structured as a cost-type contract, which is the typical contracting approach for such a large-scale development project that's never been done before. And a cost-type contract recognizes the inherent risk in the development and it provides the government the ability to direct our actions on an ongoing basis. So this type of contract gives the government the tools that it needs to ensure accountability through the direct control of our fee.

So to your question about the financial position on the program, to be clear, our financial position on this program has been degraded in a number of ways when we experienced cost growth and delays. First, our award fees have been very negatively impacted——

Chairman SMITH. Mr. Bush, let me interrupt you. My question was would you agree to pay the 800 above cap cost?

Mr. BUSH. Our view on that is that would create more of a fixed-price relationship on this program, which would significantly impede and impair the relationship between NASA and Northrop Grumman. And as we are focused on mission success, we think that would be the wrong approach.

Chairman SMITH. Okay. I think that that would be justified, given the poor record and given the poor management that Mr. Young referred to yesterday. And I only wish that Northrop Grumman was willing to take responsibility and show a little bit more good faith both for the taxpayer and for the cost overruns, but it sounds like you've made up your mind. I just happen to disagree with you.

Mr. Young, let me address my next question to you. Yesterday, you mentioned the cost-plus programs almost inevitably ended up being over cost, sometimes considerably over cost, and that was kind of baked into the system because when you're awarded a cost-plus contract, there's not much incentive to keep the costs down. I wondered if you had any ideas for how the bid criteria should be

changed so that in the future we can avoid the massive amounts of cost overrun that we've seen with JWST, as well as with other programs?

Mr. YOUNG. Yes, I think the point I was making yesterday was for cost-plus programs, competitive programs, contractors are encouraged to bid the lowest credible cost. And why do they do that? They do that because the sponsoring organization for the contract, basically that's what wins. And I think that's unfortunate, but it's a fact that exists. And my comment yesterday and my comment today really is that what's necessary is that being the lowest credible bidder should not be a criteria for winning the contract. And if I go a step further, I think it also should not be the input to NASA or the government or this Committee establishing what's the most probable cost for a program. And I think that should be done independent of the bid price.

So I fundamentally think that using JWST or programs like it in the future as an example, that NASA should develop a most probable cost for the program, not use a bid price from a cost-plus program, and that that should be the basis for budget into a program as being the most probable cost.

Chairman SMITH. And so it's not necessarily the low bid. It would be the——

Mr. YOUNG. In fact, I would say it certainly won't be the lowest bid.

Chairman SMITH. Okay.

Mr. YOUNG. Yes.

Chairman SMITH. Do you think that past performance should be taken into consideration?

Mr. YOUNG. I do. I think past performance—past performance is a strong motivator for corporations, and if I go back to my personal life, you know, at Martin Marietta, past performance was—that was a parameter that we treated as very, very important.

Chairman SMITH. Okay.

Mr. YOUNG. And even though we may be involved with a cost-plus contract, that did not negate the fact——

Chairman SMITH. Yes.

Mr. YOUNG. —that both——

Chairman SMITH. Yes.

Mr. YOUNG. —ourselves and our board——

Chairman SMITH. Yes.

Mr. YOUNG. —considered past performance to be part of it.

Chairman SMITH. Yes, I think past performance should be considered but I also—sometimes you get the feeling when you hear about, yes, something is complex, yes, it hasn't been done before, you almost get the feeling in regard to cost that the ends justifies the means. And I think that is a dangerous approach to take. I don't think the ends should always be used to justify the means, in this case the cost, but I think your suggestions will help us get to the goal, and I like the fact that you want us to consider past performance, so I appreciate——

Mr. YOUNG. If I could add just one item, and I know time is critical. If I could add just one item, I also think that for flagship missions that the kinds of things NASA does are not amenable to fixed price. In other words, you—I think that we collectively don't want

NASA pursuing the easy stuff, and we want NASA pursuing the challenging, the difficult stuff.

Chairman SMITH. I think there's some that would be fixed and some not depending on the nature——

Mr. YOUNG. I agree with that, but flagship missions by their nature probably would not be in the fixed category.

Chairman SMITH. Thank you, Mr. Young.

And the gentlewoman from Texas, Ms. Johnson, is recognized for her questions.

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

Mr. Young, due to time constraints on yesterday, there are a couple of questions I'd like to raise that I wanted to do yesterday. And you have, I think, partially addressed some of them this morning.

But the review board report found that the current NASA reporting structure for the project is complex, confusing, and ineffective. It seems to me that getting that structure right would be critical if the James Webb project is to succeed. So who should be accountable for the project specifically and who for the overall James Webb project—program?

And then secondly, there was some discussion yesterday about having the review board reconvene if NASA is following through to check to see whether they're following through with the recommendations. I'd like your opinion on whether or not you think this board is willing to reconvene.

Mr. YOUNG. Very good questions. On the first one, the management structure, it's our belief that a well-run program, clearly one of the characteristics is to have established accountability, responsibility, and authority individually for the key members of the organization and to fully use the resources. And you really describe what we found for JWST.

Our belief is that the accountability and responsibility and authority needs to be residing, one, at the Goddard Center Director level. The Goddard Center Director should be totally responsible for the program, not just providing resources to implement the program. And the full capability of the Center Director and his or her staff would be applied to the project, number one. Number two, that there be a project manager, which there is today, who's totally responsible for the program reporting to the Goddard Center Director. And three, that at the program level, which is a broader perspective of the project activity, that that be the responsibility totally of the Associate Administrator for Space Science and specifically that the Goddard Center Director would report to that individual for the execution of the program. That in our view is a crisp statement of individual accountability, responsibility, and most importantly, authority.

To your second item very quickly, it's NASA's decision obviously whether or not they want to have an examination of the implementation of our recommendations. Our belief is that it should be done. The IRB is willing to do that, and we personally think that it needs to be done early enough in the process that it's before—that it can have an impact and late enough where things have been done. So our recommendation would be like the latter part of September would be a terrific time to do that review if NASA believes it would be appropriate.

Ms. JOHNSON. Thank you very much.

Mr. Bush, what do you consider to be the most important corrective actions that you put in place to avoid some of the past shortcomings and if you're willing to work with the findings and recommendations of the review board?

Mr. BUSH. Thank you for that question. We do fully support the findings of the review board, and I, too, agree it would be a very good idea to have a follow-up in the process with the review board. I think the most important things that the review board pointed out in terms of ensuring that the steps that are being taken as we go forward are primarily focused on mission success are the areas where we are ensuring that when we align processes, when we align training, when we engage with our team on the floor who have their hands building this thing every day, that the discipline is there, that the understanding is they not only have the ability to put their hand up and say stop everything but they have the responsibility to do that if they even suspect something might be wrong.

We've also worked hard to enhance the safety net on the program, and let me explain that. And I think the IRB said it really well, that human errors are inevitable, but we have to do everything that we can to put a safety net behind them to make sure that we catch them as early as possible. So in our company, and I think in most in our industry, there are two organizations that work alongside the folks in the program who are, again, touching the program every day, the mission assurance organization, as well as the engineering organization. And we have given them the ability and the responsibility to be digging in deeply onto the program to go back, take a hard look at everything that we have done.

Mr. Young and his team used the term embedded errors. We want to make sure that we do not have those any place in the program. NASA is actually leading a process to go back and help do that scrub. Our team is highly engaged on that. So we've worked hard to enhance the safety net behind the team as well, so it is both reinforcing the team, giving them some extra tools, but also enhancing the safety net so that we can make sure that we're doing the right thing for mission success.

Ms. JOHNSON. Thank you very much.

Chairman SMITH. Thank you, Ms. Johnson.

After the gentleman from Oklahoma is recognized for his questions, we're going to recess until after these votes and then resume the hearing immediately after.

The gentleman from Oklahoma, Mr. Lucas.

Are you going to yield to the gentleman from Texas?

Okay. Thank you. The gentleman from Texas, Mr. Babin, the Chairman of the Space Subcommittee, is recognized.

Mr. BABIN. Thank you very much. I appreciate that, Mr. Chairman and Vice Chairman. The first question is for Mr. Young. Yesterday, Administrator Bridenstine called a schedule of testing for JWST "optimistic," and your report says the same thing. From your experience, what are your observations of overly optimistic expectations being an issue with other major NASA programs?

Mr. YOUNG. Well, I—there's probably a natural tendency for projects to be optimistic, so—and, fundamentally, people who as-

pire to be involved with projects are naturally I think optimistic. On the other hand, there really has to be a process that both encourages optimism and balances it with realism. And so I guess we would say that that process wasn't as strong as it should have been in this particular situation, and optimism in doing a lot of the INT planning dominated, which I think was a fundamental mistake. And that clearly is a Northrop Grumman responsibility, but NASA also plays a role in our view in being a damper, if I could say that way, on the optimism that is incorporated.

Mr. BABIN. All right. Thank you very much. Well, you don't want overly pessimistic people working on these programs——

Mr. YOUNG. You don't.

Mr. BABIN. —either——

Mr. YOUNG. That's right.

Mr. BABIN. —that's for sure.

And, Mr. Bush, the Trump Administration has emphasized space as part of the national security strategy. Do you think the JWST development issues signal an erosion in the quality of the American space industrial base to our near-peer adversaries, thus negatively affecting our national security strategy?

Mr. BUSH. I think what the Administration is doing with its emphasis on space is incredibly important for our country. As I said in my opening remarks, I am quite concerned that our will to lead is being tested every day, and because of that, I think it is especially important that we take on programs like Webb to demonstrate to the world that we can lead and that we can continue to set the pace on technology.

Your question related directly to concerns about the erosion in the industrial base, and I did have a number of concerns as we went through a very difficult period after the sequester where the industrial base, along with our customer communities, were very negatively impacted. But as I take a look and in particular at Webb, I do not see those particular issues evident. I think they are more along the lines of the issues identified by the Independent Review Board.

But as I look ahead and I think about our industry and I think about our capacity to really lead, there are concerns on the horizon that we need to be very focused on, concerns associated with workforce, STEM education, and our willingness to take on these very risky projects so that we can continue to lead.

Mr. BABIN. Okay. Thank you. Very well.

And, Mr. Young, during yesterday's testimony, you also mention that NASA and Northrop Grumman's plan for implementing the IRB's recommendations will be set in the next couple of months and that the implementation plan must be reviewed before it becomes set. Do you believe that an Independent Review Board should conduct this implementation plan review, and if not, should the SRB conduct this review?

Mr. YOUNG. I actually think it should be the IRB to do it. The review board was the one who obviously developed—established the recommendations. One of the things that's always difficult is putting on paper exactly what it is that, you know, review board thinks is necessary to be implemented, so we did the best job we thought we could in that regard, but there's also subject to inter-

pretation. So I think it's important to the people who sponsored the recommendations to be those who examined the implementation of the recommendations to assure that they're consistent with what was intended when they were developed.

Mr. BABIN. Yes, sir. And then one last question for Mr. Bush. Congress fully understands that JWST is a very complex mission both in terms of spacecraft design and its intended operating environment. Putting aside the sunshield situation, Mr. Bush, what other development areas have contributed to this schedule delay?

Mr. BUSH. So over the years there have been a variety of issues. They range back from the decisions early in the program to scale up the size of the optic and the approach to conducting the mission. I think those were very appropriate. It was a learning process in terms of what would really be needed to implement the physics objectives of the program. But as we have progressed through the program, we've had enormous success. There were basically 10 technological inventions that we had to get behind us to even enable us to get to the point that we are at today where we could be integrating and testing the full capability. We've had tremendous success in those technological developments.

But as we've gotten into the integration and test process, as the IRB I think very accurately pointed out, the issues have been finding the small things that aren't tested until later in the process, that when we find them, they have these big impacts that we have to go through to undo things, put it back together again, and then retest it because we're determined that we're going to test this thing comprehensively before we launch it.

Mr. BABIN. Yes, sir. Thank you very much. And I yield back, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Babin. And I understand the gentlewoman from Virginia, Mrs. Comstock, has a unanimous consent request? Okay.

Mrs. COMSTOCK. To submit a statement for the record.

Chairman SMITH. Okay. Without objection, the statement will be submitted for the record.

[The prepared statement of Mrs. Comstock follows:]

Rep. Barbara Comstock Opening Statement

Thursday, July 26, 2018

Mr. Chairman, thank you for holding today's important hearing to discuss NASA's James Webb Space Telescope.

The James Webb Space Telescope is the most complex telescope ever developed. Once launched, it will study the faintest light from the first stars and galaxies that formed the universe, uncover the formation and evolution of galaxies, characterize the formation of stars and planetary systems, and search for life. We truly cannot begin to understand the incredible discoveries that Webb will enable.

Like everyone in this room today, I am disappointed that Webb is taking longer than originally planned. However, I recognize that when building a first of a kind, incredibly complex systems, sometimes challenges arise. I believe that Webb is simply too important of a mission not to take the time and every possible step to ensure its success. I am pleased to see that Northrop Grumman and NASA have been working with the Independent Review Board (IRB) to improve management and efficiency.

Beyond its amazing science, the James Webb Space Telescope will inspire a new generation including young girls, to pursue STEM careers, an issue very important to me. In fact, just last summer, we showed a film about the making of the James Webb Space Telescope to my Young Women's Leadership Program. The girls were clearly excited about the scientific potential of Webb and inspired by its technical achievements. It will be impressive to see Webb's STEM inspirational abilities on a larger scale once it is launched and sending its images back to Earth.

I look forward to today's hearing, where we discuss this incredible project that is truly worthwhile. Thank you.

Chairman SMITH. We'll recess until after these votes and then resume immediately.

[Recess.]

Chairman SMITH. The Science, Space, and Technology Committee will resume our hearing, and the gentleman from California, Mr. Bera, the Ranking Member of the Space Subcommittee, is recognized for his questions.

Mr. BERA. Thank you, Mr. Chairman.

Thank you, Mr. Bush, for being here and, Mr. Young, for your patience and coming back for a second day. I talked about a little bit yesterday with projects of the size and scope and difficulty of James Webb, one of the challenges is appropriately budgeting, thinking about things, and figuring out the time to do something that you've never done before, understanding the science, et cetera, and there's a lot that we can learn from the contracting, the construction, and design and the overruns on James Webb.

I tend to be a simple person. As I talked about yesterday, putting it in simple terms, I think about it as the contract I made with our daughter when she decided she wanted to go to college. In this case, you know, a lot of us have done home remodels and you kind of lay out what you want to do and so forth and think about what—as you bid that out to various contractors and you make a decision. And most of us run into cost overruns when we do that.

Part of it is self-inflicted. As you're going to the project you realize, hey, you know what, we're doing this, let's remodel the kitchen as well. Those are conscious decisions to spend more money.

Again, as we look at the history of James Webb, as we started designing this, thinking about it. Science advanced. Consciously, we said, well, hey, if we're going to already send a telescope out there, science is advanced now; let's add some things on. Those are predictable cost overruns. And we should have conscious debate of whether that's what we should do, et cetera.

And my sense is we've done that multiple times over the length of the project. I'm not suggesting that we don't do that because if—it makes sense for us to add additional items and delay the project in order to advance science and get more information in a cost-effective way, that may make sense. But then there's also, I think, Mr. Young, you brought up some of the potentially avoidable cost overruns the human error component of this. And, you know, I know—I asked you, Mr. Young, some of the things that we've learned from this experience that we could— as we go forth and do additional sciences, Mr. Bush, from the contractors' side of things, I'd like to hear your side as you look to the IRB report what are the things in our oversight role as Members of Congress as we are going to have to make trade-offs and decisions from the contractors' side of things. What are things that Northrop Grumman has learned that could inform Congress?

Mr. BUSH. So I think a lot of this goes to this notion of how do you retire risk when you're managing complexity? And we all learn each time we take on something at the new level of complexity how you actually approach those types of steps in a process. So some of the risk retirement can occur actually before you start a program, and in fact there are some procurement approaches that a variety of places in NASA as well as DOD use where they attempt

to get as much technological—excuse me—risk retirement in place before you start the program. And if you're able to do that, then you are able to better define a path forward. The challenge with doing that is that sometimes actually takes a little bit longer at least at the beginning to do those risk retirements.

So on a program like Webb, as we have gotten into it, I think one of the big lessons learned was clearly that risk retirement was not only associated with the technologies themselves. I spoke earlier about this remarkable set of inventions that have already been successfully completed on Webb, which I think we should all be proud of. This—these in and of themselves, those inventions represent advancements not only for the space community but they have spinout effects as well. And NASA's been, I think, doing an incredible job of spinning things out.

But the issues were not only in the technology development for risk retirement. They were also in a lot of the processes, the actual processes for implementing the pieces as we went along. A good example, we've never done anything quite as complex in a deployment as folding up the sunshield, and what we've learned is it takes longer to fold it up and unfold it each time we go to test it than we had planned.

Mr. BERA. Since I'm going to run out of time, is there a way——

Mr. BUSH. Right.

Mr. BERA. We've talked a little bit about risk-sharing contracting as well. Certainly in health care we do some of that where if you're under budget, on time, or ahead of time, there's a benefit to the contractor. If you're over budget more delay, there's some risk that's borne. Is that a type of contract that actually could work in this particular space?

Mr. BUSH. Yes, those types of contracts need to be combined with a risk-management, risk-reduction process so that that—those risks can be understood. But yes, the answer is absolutely yes.

Mr. BERA. Great. And, Mr. Chairman, before I yield back, I'd ask unanimous consent. I've got a letter from Representative Ted Lieu, whose district represents where some of Webb is being constructed and put together in support of the James Webb——

Chairman SMITH. Okay. Without objection, the letter will be made a part of the record.

[The information follows:]

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33RD DISTRICT, CALIFORNIA

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Congress of the United States
House of Representatives
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July 26, 2018

The Honorable Lamar Smith
Chairman
House Committee on Science, Space and Technology
2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Smith,

I am writing in regards to today's hearing on NASA's James Webb Space Telescope.

NASA's Decadal Survey has identified the Webb Telescope as the top astrophysics priority. It will fundamentally alter our understanding of the universe. Webb will explore the first signs of light, the assembly of galaxies, the formation of stars and planetary systems, and even the origins of life. Academics and scientists around the world will utilize Webb's data to make previously unfathomable scientific discoveries. However, as important as Webb's science will be, potentially its biggest impact will be inspiring an entirely new generation to pursue science, technology, engineering and mathematics (STEM) careers.

I am proud that the final integration and testing for James Webb is taking place in California's 33rd Congressional District at Northrop Grumman's Space Park facility. I have seen Webb's hardware up close and it is technical marvel. From the tennis court-sized sunshield to the 21-foot, segmented adaptable optics, you can't help but be impressed by the telescope's size and complexity. I hope that all the Members of the House Science Committee will take the time to see the James Webb Space Telescope firsthand.

The Independent Review Board (IRB) established by NASA to assess progress on Webb cited employee morale as one of the risks to mission success. Although the program has had challenges, developing Webb required unprecedented technical achievements and numerous inventions. The Webb team, including many of my constituents, deserves our respect and gratitude. I share the broad disappointment that the James Webb Space Telescope's launch date has been delayed. But it is important for us to allow the time and dedicate the necessary resources to ensure mission success.

The James Webb Space Telescope is the most complex telescope ever developed. However, as the Independent Review Board (IRB) and NASA have both stated, the program is worth it—and I fully agree.

Thank you for your consideration and continued support of the James Webb Space Telescope.

Sincerely,

Ted W. Lieu

Ted Lieu
Member of Congress

Chairman SMITH. And the gentlewoman from Virginia, Mrs. Comstock, is recognized for her questions.

Mrs. COMSTOCK. Okay. Sorry. Thank you. Thanks. I appreciate the opportunity to talk with you today, and thank you. I think yesterday's testimony was very helpful hearing from Mr. Bridenstine and also hearing about how all of these evaluations and the critiques really have come together, and I certainly got that impression from him. I wasn't able to hear all of Mr. Young's testimony yesterday but certainly did get the understanding.

And I think, Mr. Young, you said this yesterday, "Space is a one-strike-and-you're-out business, and we can't have problems that are catastrophic." And I think from all the testimony we've had yesterday and today, that seems to be a very large part of the commitment that, given the Hubble Telescope is only 350 miles away, and it's been serviced five times, We were able to get there and do it, but when you're a million miles from Earth, that is not a potential solution so we have to work on all of the risks and changes here.

And with all this, I want to make sure that as we are doing all this evaluation, looking at taking the risk and everything, that people are going to feel comfortable coming forward. I want to make sure you—and it seemed like Mr. Bridenstine did feel comfortable with that yesterday—I want to make sure that all the teams that are working on this and the additional supervision now, that when there is a mistake, when there is a problem, even if that problem is going to lead to more costs, that we are going to catch that problem before. Do you think that the climate and the systems that are put in place now will still allow for that?

Mr. BUSH. Yes, let me let me remark on that if I might, Congresswoman Comstock. One of the most important things in our industry, particularly in the space industry, is the ability of employees to feel very, very comfortable to put their hand up when they—as I mentioned earlier, either when they know something's wrong or even if they suspect something might be wrong. So this goes to this culture of understanding what really mission success means on a day-to-day basis. So it's something that we work very, very hard on.

It gets reinforced constantly at all levels of engagement to the point that we take the extra step of rewarding and recognizing employees who put their hand up and say, wait a minute, let's stop, let's take a hard look even if it means an impact on schedule because much better to do it while we're building it, find it then, and be confident that it's going to work.

So I have a lot of confidence. I've seen our team do this now a number of times. These issues that we're talking about today are issues that our team found. And they did that. They put their hand up. And they are eager to go through this process that's underway now to see if there's anything else that we need to figure out, that we need to find. This is a team of people who are absolutely dedicated to mission success. They work on this thing all the time. And I've talked to many of them. They dream about it at night. They are inspirations in terms of how committed they are. And they are, I am confident, going to continue to put their hand up if they think something's wrong.

Mrs. COMSTOCK. And I'd like to thank both of you for your work on this front. I'd like to acknowledge—obviously, Northrop Grumman is in my district, and Mr. Bush, in all your work, I want to thank you. I really appreciate that your will to lead is being tested every day. Failure is not an option here. We need to have mission success. I appreciate all that you're doing in the STEM pipeline. I see you throughout my district all the time and all the work you're doing there, the importance of the workforce development that you had highlighted, and I know the first time we had met was when we were battling together—I was back in the state house—when Northrop Grumman was coming here and the Governor was working to get you here but also we were fighting the sequester together with Congressman Wolf, and I appreciate your work there and the importance of this.

And, Mr. Young, thank you also for your service on this front, and I think going forward it's important that we understand—that we all appreciate how challenging these missions are, and growing up we all saw all the movies and the challenges and the failures that have come with space, but also the great successes. We learn from the mistakes certainly as—the famous Thomas Edison quote, we want to make sure that any of the problems that we've had are all geared towards a successful mission, so thank you.

Chairman SMITH. Thank you, Mrs. Comstock.

And the gentlewoman from Oregon, Ms. Bonamici, is recognized.

Ms. BONAMICI. Thank you very much, Chairman Smith and Ranking Member Johnson. And to our witnesses, I regret that I was in another committee where I had a commitment yesterday and I missed Administrator Bridenstine's testimony, but in the event he's watching, I send greetings. He was on this Committee not that long ago, and I thank him for his work at NASA and for his service to the country.

You know, over the years, our country's investments in space exploration have led to so many exciting discoveries about our universe. I've been on this Committee my entire time in Congress, and we've often discussed planetary science and human space exploration. And an emerging theme is the role that NASA plays in sparking the imaginations of the next generation of students to pursue studies in science and astronomy. And certainly, members of this Committee understand the importance of making progress on restoring our sense of pride as a country and international leadership in space discovery. We also know that the James Webb Space Telescope is a high priority for NASA and that thinking big and taking risks is part of what space exploration is about.

I share the concerns, however, about the latest setbacks, and I applaud NASA for establishing the Independent Review Board. I hope this hearing, as well as the hearing yesterday, can help identify a path forward that minimizes risks and additional delays.

Mr. Bush, I want to follow up on Ranking Member Eddie Bernice Johnson's question. We understand the scope and complexity of the project, but some of this, as your testimony admits, was human error, so are you convinced that Northrop Grumman has put in place adequate practices to minimize the risk of additional errors? And, as you said in your testimony, most of the complex issues are

now behind us, so how can you be confident that from this point to launch you won't encounter additional complex issues?

Mr. BUSH. So to answers to your two questions there, first, with respect to our degree of confidence in finding the issues today, there was I think several important perspectives on that. One is—and Mr. Young and the IRB pointed this out. We're never going to be able to get human errors to zero. You know, the word human in that equation tells you that. So what we have to do is do our very best with the humans involved to make sure that they've got the right processes, that they're with discipline following those processes, and that they have the right qualifications to do the job. So that's a big part of it.

The second part of it, though, is the safety net and making sure that we have a robust approach to backing up the humans that are doing the job so that, if they do make an error, there is someone there or some other process involved that with high likelihood will identify before it propagates into the system.

Ms. BONAMICI. And are you convinced that you—that the company has done that——

Mr. BUSH. I feel very, very good about where we are in that regard, but we're going—we are continuing to self-test that.

So your second question I think related to what the Independent Review Board talked about as embedded problems, things that might still be there. So we are in process. NASA is leading this. We're going through all the records. We're going through taking a second pass to see if there is anything else that we can possibly find or conceive of that might be an issue that we need to get addressed quickly. I think we're going to be through this in just a number of weeks, and if it is the case that the Independent Review Board takes another look, I think that would be a great thing for them to look at as well.

Ms. BONAMICI. Thank you. And I'm going to ask Mr. Young a question, but I did notice that you said most of the complex issues are now behind us, not all.

Mr. BUSH. Well, we have to test the satellite, right? We test it for a reason.

Ms. BONAMICI. And, Mr. Young, thank you for your testimony. How can Congress—and following up on Mr. Bera's question—how can Congress assess NASA's progress in implementing the findings and the multiple recommendations from the Independent Review Board, and should the board be reconvened to determine if NASA is on track to meet those metrics, and if so, when?

Mr. YOUNG. My personal belief is the board should be reconvened and—because I think it's the group who's, you know, most formulated to assess the implementation, and it needs to be done after NASA and Northrop Grumman have had adequate time to understand and do—implement or begin the implementation of the recommendations.

Ms. BONAMICI. What do you think adequate time would be?

Mr. YOUNG. Well, I think it should be by probably this—sometime in September this year is when it should be done. And I think if this Committee is interested in the result of that, then I'm sure that, you know, that the—NASA and the review board would be delighted to report back to you what we find.

Ms. BONAMICI. Thank you. And I'm certainly not going to speak for the Chairman and the Ranking Member, but I'm pretty convinced that this Committee would be very interested. Thank you, Mr. Chairman. I yield back.

Chairman SMITH. Thank you, Ms. Bonamici.

And the gentlewoman from Arizona, Mrs. Lesko, is recognized for her questions.

Mrs. LESKO. Thank you, Mr. Chairman.

As I talked about yesterday, having a project 19 times over the original cost estimate is obviously very troubling, and I think it is a prime example of why taxpayers think that the Federal Government isn't spending taxpayer dollars wisely.

I used to be in the construction business years ago, and when we signed a contract for a certain amount, and when you had changes, there were change orders that set forth how much extra it would cost. So I'm trying to understand how something can be 19 times over the project. How often do you communicate with NASA? Is there a contract similar to what I described? Do you go back to them and communicate with them on a regular basis and say, you know what, we had human error and there was a problem and now it's going to cost $2 million more, or we're changing the project because technology is more advanced now and we want to do this and it's going to cost, you know, $1 billion more, or can you kind of explain the process? Because I need to understand how we got here.

Mr. BUSH. Yes, it's a very good question, and obviously for those who have not observed how something of this complexity gets created, a very, very spot-on question. It is the reason that this is a cost-type contract. We work side-by-side with NASA every single day. No significant decision is taken on the program unilaterally by us. So in terms of the degree of communication and coordination, it is exceptionally high. And NASA holds us to that transparency standard, that they do not want us unilaterally making decisions. And it is important that we be able to work hand-in-hand as we go through it simply due to the complexity.

NASA has extraordinary people who have great experience working on so many different things. Their experience applies to this program, just as the experience of our scientists and engineers apply to the program. We have to have both, and so we have to be able to make decisions on it together and it is a daily interaction. It's not just, you know, sending letters back and forth. It is daily communication, daily interaction so that the best decisions can get made together.

Mrs. LESKO. And so, Mr. Chair, either one of you can answer—so NASA gave you the okay at every step of the way for this extra cost, this extra time delay? Is that what you're saying?

Mr. BUSH. We would only take actions that NASA approves in that regard.

Mr. YOUNG. If I could add to your question, which also I think is very good, I think Wes' comments were right on. Space is not an awful lot different than what you described form your building experience. The most important thing I suspect in your business was to get the first bid correct, to get the price correct. I think if you look back through the history of this program and if you look at an earlier review group called the Casani team that reported out

in 2010 I think or '11, they highlighted that NASA had done an incredibly poor job of cost estimating on this program, and I think that's true. So if—again, in your business, if you don't start out with a good estimate, you're in trouble from day one.

The second thing is that your customers I'm sure, as was mentioned, decide they want to remodel the kitchen, it's very important when that's done that that be costed, priced, and be added to the budget so—and it should not be—which it's easy to do. We're just going to add this requirement and we won't worry about what it costs, and then it's obviously going to cause a problem down the stream.

The third thing is I suspect that you probably—I don't know the nature of the kind of stuff you were involved with, but you could envision that there was a very, very unusual staircase and that got underestimated as a cost to do it or the people who were doing it, it was stretching their ability to do it, so they ran into problems. So I think the analogy you're talking about—I'm really trying to just encourage you—is really quite good and it's not different than this. It's just that the multiplier is so much higher in doing this. And I'm not trying to excuse any of it, so don't read that into it. But the process is—just because it's a space activity, the process in my view is not a mystery. It's not significantly different than I'm sure your experience in the construction world.

Chairman SMITH. Okay. Does the gentlewoman yield back? Thank you, Mrs. Lesko.

The gentleman from Virginia, Mr. Beyer, is recognized.

Mr. BEYER. Thank you, Mr. Chairman.

Mr. Bush, thank you for coming to be with us today.

Mr. Young, thank you for bravely showing up the second day.

I want to take issue with the, I think, overstated allegations of poor management. I mean, it's always easy to be a Monday-morning quarterback. I've been managing businesses, organizations, even an embassy over 45 years, and I just—management is much like golf or baseball or bridge that it's not a game of perfect, that we make the best decisions we can on a minute-by-minute basis with the best advice we have, and sometimes, we're still going to get it wrong.

So let me—I think it's really important to put the total cost of James Webb in perspective. So first, Administrator Bridenstine yesterday said the lifecycle cost of James Webb is $9.66 billion, so I added up the NASA budgets from 1996, when this was first suggested, through 2020, which is a little before launch, and that's $396.357 billion. Quick math, 2.4 percent of the total NASA budget over the lifespan of JW is 2.4 percent, and that's an understatement because that assumes JW Webb falls out of the sky in 2020 and it will actually be up there for a long, long time. So we're talking maybe one percent of NASA's budget.

The second point, Mr. Bush, you were just a young systems engineer in 1996, but can you tell us how different the expectations of James Webb were in 1996 versus what NASA and the American public expects today before dark energy, before dark matter, before gravitational waves, before the state of science and cosmology is so very different? Is this even the same James Webb Telescope?

Mr. BUSH. Well, thank you, Congressman. It is a great question. When we originally conceived the telescope, we had no idea of all these discoveries that would occur in the time that has elapsed since then. And those discoveries themselves—and this is part of the great thing about space science—those discoveries set our ambitions a bit higher because we now know that there's a lot more we don't know and that we need to find out.

So as we went through that process really over the course of the last decade, the period from around 2002 through the Casani report that Mr. Young mentioned, the vision for the mission continued to expand appropriately because if we are going to make this magnitude of investment, we ought to be able to get the most return for our Nation that we can through this investment.

And while the original mission was very focused on sort of origins, you know, looking backwards in time, we did not know at that time about exoplanets, and now we've discovered thousands of these things. Your reference to dark matter and dark energy has really transformed the thinking around what the potential for scientific discovery might be with a system like Webb. And it is incredibly inspiring because if we can solve some of these tougher problems in physics, hopefully, we'll be able to translate that knowledge back into the engineering on Earth to make life a lot better for all of us humans. So this growth and the view of it is very, very important to understand because I think it goes to the real value of this program.

Mr. BEYER. Which tees up my next question to Mr. Bush is $9.6 billion, is there any way to measure the value to humanity of what we will learn compared to that $9 billion investment?

Mr. BUSH. I have no idea how to do that. I wish I could. But I can give you a couple of reflections in that regard. You know, the work that our Nation did to put us ahead decades ago in physics where we were able to gain a better understanding of things like quantum mechanics, if we had not done that work, had we not really understood how things operate at the quantum level, this silly little device we all carry around with ourselves and rely on constantly throughout the day to know what's going on in the world and communicate with each other, we wouldn't have been able to do that. And if you think about value in that regard, the multiple of return is extraordinary. Those are the types of discoveries in physics that we hope are still in front of us, and we believe they are based on the insights we've been able to gain from Hubble. And it's really just, I think, beginning to tickle the imagination what Webb is going to enable us to do. So it's a very exciting potential.

Mr. BEYER. I saved my hardest question for last. Both of you are MIT graduates I think, so do you guys believe in string theory?

Mr. BUSH. I'll let Mr. Young answer that.

Mr. YOUNG. I'll pass.

Mr. BEYER. Mr. Chairman, I yield back.

Chairman SMITH. Thank you, Mr. Beyer.

The gentleman from California, Mr. Knight, is recognized.

Mr. KNIGHT. Thank you, Mr. Chairman, and I thank the gentlemen for being here today.

I got to sit down with Scott Willoughby last week and ask him a lot of questions and kind of understand where Northrop is going and what his vision was. He was extremely excited. He was passionate about the future and passionate about when there are issues of how we get through these issues and how we move forward. And I think that's very important because what we're trying to do here is a mankind-changing event. I've said that a couple times, but I think that is exactly what we're trying to do.

As I tell my son, we will be smarter in 100 years than we are today, whether we have faster computers or we have just attained more knowledge or we are able to do more things by our engineering knowledge and our knowledge of just academics. And so some of the things that we try and do, we find problems.

Now, my question is how do you think that the IRB's report is? Do you agree with that, Mr. Bush? And I think I've heard all of the questions and all of the kind of what are we going to do, how do you do this, and all of that, I've heard all of that, but I want to hear if you agree with the IRB's report and if you think that that was a good, solid report on this issue.

Mr. BUSH. I absolutely believe that the IRB in many ways is a gift to this program. What the Independent Review Board did was, in addition to being very clear about specific matters and recommendations, which we fully agree with and which we are fully implemented in, what the IRB did I would say at a higher level was it was the big reminder that, as we make incremental decisions in this program, it all has to be about mission success.

We all feel the intensity of cost, we all feel the intensity of schedule. We've had teams working on this program seven days a week for a long period of time. And with their—this great reminder that everything is about mission success, it caused us to step back and ask were we doing everything the way we really needed to do in that regard? And we did make changes not just in terms of the specifics of the recommendations but with that broader perspective in mind.

So I think it was an outstanding thing that NASA did to commission the Independent Review Board. I'm grateful to the members who participated on it. And we are fully supportive of implementing all of their recommendations.

Mr. KNIGHT. And I think it's another part in what we're trying to achieve. If we only know what we know or if we only do what we know how to do, we never achieve. And that's what happens when we try and take leaps.

Administrator Bridenstine yesterday was trying to explain how the shield unfolds, how big it is, what it does, how it lowers the temperature so that it could get to the right temperature so that they could get the readings. And it went over my head. I'm sure it went over others or I would be ashamed that it only went over mine. But it really started you thinking how impressive this is and how important it is to get it right. Obviously, this is a fire and forget. This is a telescope that goes away and our—well, we don't have space shuttle anymore, but if we did, we can't go up and service it. We can't do those things.

We have another telescope through NASA called SOFIA. It's on the back of a 747. It comes down, lands after a 10-hour flight. They

do different things, they put things on it, and they do different experiments. James Webb is not that. James Webb is going to be a million miles away, and it's going to be looking at maybe the beginning of time, other galaxies, things that we have never even thought of.

So that is my kind of one minute on this of how we do have to get this right, and when there are problems, how quickly we can get to the solution. And that's everything. That's no matter if you're doing something that is game-changing or just a new product that we're trying to improve on, it's how quickly we fix the problems. It's not the problem, it's how fast do we get from A to B.

So thank you very much for being here today, and I look forward to the launch of the James Webb Space Telescope.

Mr. BUSH. Thank you.

Chairman SMITH. Thank you, Mr. Knight.

The gentleman from New York, Mr. Tonko, is recognized.

Mr. TONKO. Thank you, Mr. Chair, and welcome to our guests. Welcome, Mr. Bush, and welcome back, Mr. Young.

Yesterday, I shared how inspired I was by the years leading up to the moon landing, and I want to express the same sentiment to you, Mr. Bush. I was in high school as we competed in the space race against the Soviet Union for spaceflight supremacy. And we had a passionate resolve to use science and engineering to beat our rivals and, after years of investing and innovating, we won. America led the world in this endeavor, and our nation was the first to land on the moon.

The memories from that day will forever linger in my mind. It inspired me to believe that, with the will and necessary resources, America would lead the way in continued exploration, research, and development. It also inspired me to embrace an education in science and engineering. I'm excited by the James Webb Space Telescope and, even more so, I'm excited by the potential impact that this work and related discoveries can have on engaging the public and inspiring our next generation of scientists and engineers.

Yesterday, I was asking the Administrator how NASA is utilizing Webb to engage the public and to build our next generation of scientists and engineers. Mr. Bush, you put it well in your testimony when you referred to this project as an incredible engineering feat. I have told students in the capital region of New York that I represent that, through STEM, you can be the scientist who learns new secrets about our universe, you can be that astronaut who lands on Mars, you can be that doctor or researcher who discovers the path to better ensure healthy passage on long spaceflights, or you can be that engineer who designs or invents a new technology or the spaceship that will take us far past our own galaxy.

So, Mr. Bush, what is Northrop Grumman working on to engage the public at large on the inspirational undertakings?

Mr. BUSH. I really appreciate your perspective. You and I share a common motivation. The Apollo program is what inspired me to enter our industry and dedicate my career to this. And I know it has—it was the same way for so many others. And we want to continue to replicate that. We need that STEM talent. We need the innovators in our Nation to continue to focus on moving us ahead.

So we've done many things with the space telescope to help support that. We have a large model of the space telescope that we utilize to take to a variety of different organizations and gatherings to enable scientists to have something in front of them to talk about as they work to inspire youth.

We also sponsored the development of a film. It's called "Into the Unknown," and I would commend it to you if you have the opportunity and the interest in looking at it. We have played this film not only around the United States but around the world to let folks know what James Webb will be able to do, to expose them to some of the people who are working on it so they can see what real engineers and scientists do because oftentimes that's a challenge for those considering entering the STEM field. They don't actually know what engineers and scientists do. And when they're able to see it in the context of something that's so inspirational, our hope is that it will create more folks interested in pursuing these STEM careers as we go forward.

And I have to give NASA a lot of credit here. NASA has I think probably the very best approach to using what it's doing to inspire our youth. And James Webb needs to continue to be a part of that. I think they've done a fabulous job of communicating effectively. The website, if you want to learn about it, you can go on that website and learn about it.

I talk to a lot of the interns in our company, and part of the reason they're interested in coming to work with us and being a part of the things that we're doing is because they've heard about James Webb and they're inspired by it. So I think this is a fabulous opportunity for our Nation as we go forward to help us with much of the work that we need to do in motivating and leveraging STEM.

Mr. TONKO. Thank you very much. I appreciate that approach. Anything in general that you're doing in the youngest of the student population in those great schools to engage them early on?

Mr. BUSH. Yes, and we've all I think come to realize that we unfortunately lose too many folks who could otherwise be interested in STEM actually in middle school, so your point is right on. We have to hit them in grade school early on, and so we have a whole variety of grade school programs across our nation largely leveraging our employees. Our employees are very motivated to engage in the STEM efforts whether it's at science fairs or actually taking the movie that I talked about "Into the Unknown" or even—we have little paper models that we use where students can actually try and go through the paper model build-up of what James Webb will be. So there's a variety of activities. NASA as well, as I said. It's not just us. NASA has been very proactive in this.

Mr. TONKO. Thank you, gentlemen. And with that, Mr. Chair, I yield back.

Chairman SMITH. Thank you, Mr. Tonko.

And the gentleman from California, Mr. Rohrabacher, is recognized.

Mr. ROHRABACHER. Thank you very much, and I'm sorry that I cannot join you in this uplifting testimony that you've given today. Mr. Bush, I don't think that we should look to our young people and give them an example of being eight times over budget and

twice as long in cost overruns. That's not what you tell our young people and encourage them to get involved in your industry.

Let me just note—and again, this isn't your fault, okay? This is your—whoever was handling this in your company failed. They failed us and they failed the American people. And you can say "is the Jim Webb telescope going to be worth all that money?" That's not what the question is. The question is, "is it worth all those other projects that we have been unable to fund in this Committee because you have failed your job?" That's the question.

Yes, I have supported telescopes and astronomy, and I think that deep space astronomy is a good thing. You've done a disservice to achieving those goals by not being able to do your job. Now, let me ask you, did Northrop make a profit last year, Northrop Grumman Corporation?

Mr. BUSH. You can read our Securities and Exchange Commission filings and see exactly how we did. We're very transparent in that regard.

Mr. ROHRABACHER. I didn't hear. Did you make a profit last year?

Mr. BUSH. Yes, sir.

Mr. ROHRABACHER. Okay. How much was your profit last year?

Mr. BUSH. It's filed in our Securities and Exchange Commission filings. I don't remember the exact number off the top of my head.

Mr. ROHRABACHER. Is it hundreds of millions or billions? What is it in?

Mr. BUSH. It's a very large number.

Mr. ROHRABACHER. Okay. You had a profit last year, and you have spent money acquiring things like Orbital ATK?

Mr. BUSH. Yes, sir.

Mr. ROHRABACHER. Okay. So Northrop really hasn't suffered at all from the fact that we now have billions of dollars being spent that we were not told we were going to have to spend, and thus, those other science projects are now not even being considered here. But Northrop, by putting us in that spot, went ahead and made a profit.

Did they make any loss—obviously, your profit would have been higher had you been handling this project better—is there any loss at all that your company made by not being able to do this job as you contracted?

Mr. BUSH. So when we think about the economics of this project—and I've been clear about this before—this is not a particularly attractive economic proposition for our company, but that is not the objective for us at this point. We are focused on mission success. And clearly, you know, you can do the math a lot of different ways, but if you look at the resource we have invested in this program, both the capital resource and more importantly the human resource, our expectation is when we make that kind of investment on this magnitude of activity, that we would achieve a nice return. That will not be the case here.

Mr. ROHRABACHER. I understand you're not making a profit on this project now, and I think that is a factor that is going to try to influence people to try to make the right decisions and be tough on doing the right thing even though there's a lot of conflict going on over some decision among engineers or whatever. But the fact

is that Northrop hasn't had to suffer a penalty. The fact is that it's not just Northrop, Mr. Chairman, that's our system. And I'm not deriding Northrop because what Northrop is doing is exactly like the rest of the aerospace industry when we get involved in these projects. Hubble was that way, as we noted yesterday.

Mr. Young, is there something that we can do fundamentally to the process that's going to prevent that from happening? Is there some penalty that a company should have to pay if indeed they go way over budget and spend all this time? Otherwise, we're losing our ability to use that money on other projects, whether it's STEM projects or whatever projects they are. Mr. Young, what can we do?

Mr. YOUNG. Well, we talked about that a little bit. And I think that companies measure return on their programs in different ways. Financial is one. Reputation is an extraordinary motivator. And I think the people who are involved in these enterprises are clearly motivated by reputation, and that is the intent is to do a good job.

If I could span my comments—and I don't want to talk you out of your comments, and I know I wouldn't be able to anyway, but——

Mr. ROHRABACHER. You know me.

Mr. YOUNG. But I think it's—there's no question in my mind being appropriately critical of events that have happened is appropriate, so I don't think there's an issue. I do think that it's important for all of us to recognize that there's a lot of work in front of us on JWST, and there's an extraordinary opportunity for a success that is almost mind-boggling as to what it is that we can learn. So what I'm really trying to do is I'm really trying—I'm probably speaking to myself as well as to you, but I'm really saying that being appropriately critical, tough love is a very important part of this—let me just finish—a very important part of this. But equally important is a recognition that we've kind of all got to pull together and make this thing an enormous success because the worst thing that could happen on top of where we are now is not to have a success. So I'm an advocate for being self-critical, I'm an advocate for tough love, but I'm also an advocate for saying today's the first day of the rest of our lives——

Mr. ROHRABACHER. I agree with you.

Mr. YOUNG. —and let's make this a success.

Mr. ROHRABACHER. I agree with you on that, but we should be changing the policy so that this doesn't happen like this again. And perhaps a company that does not meet its goals or what it said it could do, perhaps we shouldn't be giving them the next contract that comes down the line, whatever their bid is. Anyway, that's just a thought. Thank you very much, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Rohrabacher.

The gentlewoman from Connecticut, Ms. Esty, is recognized for her questions.

Ms. ESTY. Thank you very much, both of you, for joining us here today and, Mr. Young, for your return visit.

And I have to say, with a son who pursued astrophysics as his major who was inspired—had rocketry models in his room from the time he was about three and use that Hubble space data to develop a program working with folks at Yale to allow high school students

to access the Hubble data to do exoplanet research, to make that data available for young people across the country, I can see just enormous opportunities with the James Webb Telescope.

And I think we cannot forget, as you have both mentioned, the value proposition. We've had a lot of discussion about cost, and the cost matters, but I will tell you, taxpayers and all of us are way more concerned about value than cost at the end of the day.

And I do think one of the big challenges we have is, given the rapid development and discoveries, as my colleague Mr. Beyer outlined from the first conception of the James Webb to where we are now, was unprecedented and not anticipated, those new avenues we would want to use this extraordinary device to research.

So I do think—and my dad was in construction, too. This is not like building a home. It's not like building a bridge. It's not like building a brand-new bridge either because every aspect of this is changing, and what we're looking for is changing, too. So I think some of what we have to think about is for the value proposition, we absolutely want to include those new elements. For the mission success, we want to do that, too, and we need to make sure we have safety.

So—but we do need to look at what we do to more appropriately cost because that is fair and proper, and that allows NASA and allows this Committee to do its work in terms of allocating, prioritizing other projects and that's what you hear concern about that.

Mr. Bush, yesterday, Mr. Young suggested that maybe it would be wise for the Committee to look to the—or for Congress to insist that all the remaining dollars are aggregated and are not paid until after we have, you know, a full and complete checklist through mission success, so that's one question I'd like to add—ask.

And another is, you know, how do we incentivize, identify, and correcting errors early? I mean, it's an ongoing problem in industry, but it's an issue in science, too. People don't like to come forward and say this isn't working. So we need to figure out ways to incentivize that.

And the last thing I'll put out there is I think it would make sense for us to work some with folks both in Silicon Valley, as well as in the business community to think about how to structure contracts in a way that would better perhaps share that risk of identifying problems early, correcting, minimizing, taking ownership of human error. So maybe there's cost-sharing when there's human error or overruns. There would be cost-sharing of those, not just cost-plus, but there would be cost-sharing to provide an incentive to more appropriately—and Mr. Young talked about how these contracts are bid and how they're incentivized. Everyone wants to get it on the cheap, but then we want it to be first-class when it's deployed. So we need to find a different way of, I think, structuring those contracts to enforce as much as possible honesty and anticipation and then tight controls and everyone taking ownership. So a few simple questions out there. Thank you.

Mr. BUSH. Well, thank you, Congresswoman. And let me just reiterate what I said in response to Chairman Smith's request along the same lines with respect to what Mr. Young mentioned yester-

day. And we do believe it is an appropriate mechanism to make sure that we are all aligned on mission success.

And we've been talking with NASA just recently about this, that we are willing to place all of the fee that is in front of us, as well as the fee we've already earned, into the mission success pool that will have that determination to make sure that it works. So we're all in on mission success and just want to confirm that again for you.

With respect to this question about catching errors early, it goes back to, in my mind, the approach that is taken on programs to actually mitigate risk. How do you identify and quantify and then mitigate risk? So some of this is in the design process, but also it is in the testing programs.

And I will just say broadly that in the rush oftentimes to go faster, there is an opportunity to make decisions to not test along the way, to wait until you have more things to together and test. And if you turn the clock back in the space industry, we didn't used to do that. We tended to test everything we possibly could at the lowest level of assembly. There was some criticism of that, particularly back in the 1990s, that that was somehow unnecessary, that it was wasteful, and that it attributed—or created more cost on programs than perhaps was necessary. But—and that may be the case for some more simple types of designs where we've done the same thing many times over and we're not exploring or discovering new things.

But a program of this complexity, I think if there are some important lessons learned on error discovery, it is reinforcing that more traditional approach of testing at the lowest level that you can and trying your best to break it at the lowest level that you possibly can so that the propagation of a later-discovered error is not as significant.

And back to the question about the independent review team and their work, that was a lot of their suggestion, to go back and look at what they were calling the embedded issues to make sure there wasn't something else that was skipped at a lower level that could come back and haunt the program later on. So we're well underway in that regard.

I see we're just about out of time, so I'll limit my comments to that.

Ms. ESTY. Thank you. And, Mr. Chairman, since I wasn't able to ask yesterday, if Mr. Young could——

Chairman SMITH. Okay.

Ms. ESTY. —ask that same—answer that same question, whether we should rethink that testing at a lower level because that would be a time frame and a cost issue.

Chairman SMITH. Without objection, Mr. Young is going to be recognized to answer that question, although this is the first time I've ever heard of a carryover from one day to the next.

Ms. ESTY. No, I was noting how far over my colleagues were going, 2.5, 1 and 2 and 3 minutes over yesterday, so I never—I missed my five minutes being able to say. Thank you. I appreciate your indulgence.

Chairman SMITH. Please, Mr. Young, feel free to answer the question.

Mr. YOUNG. The—one of the things that struck us in our review process is the small problems can have such big implications for a system as complex and challenging as James Webb. And what that really says—and I'm kind of following what Wes said—is that it's important to know the pedigree of the hardware all the way through the process. And what that really means is that when the piece of hardware is first built, from that point on, each step of the process there's an appropriate test to make sure that you know the pedigree of the hardware. And if you do that all the way through the final assembly of this observatory, then you can be pretty confident that you don't have embedded problem.

If I use the sunshield as an example, the sunshield was not tested as an individual item prior to being integrated with the spacecraft. Now, I don't know the full details of that, but I think that was a joint decision by NASA and Northrop Grumman, and I think it was derived primarily because there's only one sunshield, and that's the one that's going to fly, and so you don't want to wear it out so to speak. But had that test been done, my guess is that this fastener problem would have been found and the implication would have been much less.

So only as an example that that was an embedded problem that went forward so we kind of lost the pedigree of the hardware, and then it got to a higher level of integration when the problem was discovered, and therefore, the implication is much larger. So there really is a process of knowing this pedigree all the way through that results in when the final observatory is assembled and tested, you could have pretty good confidence that you don't have embedded problems. And that's a great question, by the way.

Chairman SMITH. Thank you, Ms. Esty.

Ms. ESTY. Thank you. I appreciate it.

Chairman SMITH. The gentleman from Texas, Mr. Cloud, is recognized for his questions.

Mr. CLOUD. Thanks for being here. First of all, it's certainly not lost on me or I think anybody here that you're literally dealing with rocket science, and that's way beyond my pay grade. Our job, though, is to manage the checkbook, and I'm curious about the process, because we all agree that mission success is critical, also the scientific, humanitarian, national security implications, but we're presented with thousands of good ideas every day, and we have to manage that on a budget.

So I'm curious about the bidding process, because it seems almost like it's a normal process in business that we bid a project, it gets approved, but we know that we'll actually be able to spend as much money as we want on it. You mentioned that everything went back to NASA and was approved, so does NASA think they have the right to spend more money on projects that Congress approves? It seems like that rebidding process or that extra work order, change order process that Mrs. Lesko talked about, should come back to Congress. Has that not happened?

And I understand it seems like part of the low-bid process is part of the problem in the sense that we put a low-bid project and then we take on these great, awesome projects and try to move them forward. Is there anything we can do in the bidding process to remedy that?

Mr. BUSH. So I think that is a really good question and Mr. Young talked about this a little bit earlier. I would simply reinforce what he said. We have found that the customer communities that implement an independent cost estimating process as a part of their source selection activities tend to end up with budgetary strategies and management strategies that are a bit more robust against the inevitable variability of some of these complex programs.

And we can turn the clock way back because we're talking about Webb. you know, where a contract decision was made I believe it was in 2002, but a lot has changed in acquisition strategies since then both at NASA, as well as some other customer communities. And the use of independent cost estimating, when done well, often results in contractors being selected who did not bid the lowest cost because the customer community then has the opportunity to evaluate bids against this broader analytic of what it should cost to do a job. And I think that's a healthy practice. I endorse its use.

And, Mr. Young, I would defer to you if you have some other things to add to it.

Mr. YOUNG. No, I don't. I mean, I think that's really what I would advocate. I don't mean this quite the way it sounds, but I would recommend that cost proposals or cost-plus contracts never be opened. I mean, I think they only, you know, confuse the situations. Independent cost estimating is really the quality of the process—

Mr. CLOUD. It seems to me, too, like putting together some sort of system where we could rate government contractors based on past performance of on-time delivery and on budget might be something to work into that project.

One other question, you testified that the sunshield was more difficult than was thought, and I can appreciate that. Maybe Mr. Young touched on this in the last question, but in the original bid, my understanding is that the sunshield was promoted as existing technology, yet we're finding out that a lot of the cost overruns had to do with them not being existing technology. Could you clarify?

Mr. BUSH. I can't speak to what may have been written some many years ago, but I would be very clear that the sunshield is a new invention and a new development, and as we've gone through it, it has been exciting to see how those developments have occurred. If you look at each of the levels of the sunshield, the membranes, they're about the thickness of a human hair, Kapton, silicon-coated. It is a phenomenal class of technology. It will have a lot of other applications over time, but this has clearly been a new development.

Mr. YOUNG. I think if I would add, you know—

Mr. CLOUD. Thank you, Mr. Chairman.

Chairman SMITH. Mr. Cloud, if you will, will you yield the balance——

Mr. CLOUD. Yes.

Chairman SMITH. —of your time to me?

Mr. CLOUD. Yes.

Chairman SMITH. Okay. Thank you. I've thought of another question, Mr. Bush, for you. In Mr. Young's report, there were several instances of preventable human error that were pinpointed that led

to millions of dollars of cost overruns. I'm just curious if those employees are still employed by Northrop Grumman.

Mr. BUSH. So we look very carefully each time we have an error to make sure we understand what the challenge is and what the issue is. And given the complexity—and yes, there have some—been some mistakes. But to answer your question very directly, with respect to the mistakes, we have not found instances of the type of behavior that were contributory to those mistakes that were deemed——

Chairman SMITH. I mean, you had a situation——

Mr. BUSH. —to be willful conduct.

Chairman SMITH. —where a solvent was used that was the wrong solvent that cost $100 million more of overruns. There had to be some actual human individual that applied that solvent. My question is are those types of individuals who committed the preventable human error still employed by Northrop Grumman?

Mr. BUSH. If we find issues with conduct that we think is willful misconduct, we act on it.

Chairman SMITH. Okay. But——

Mr. BUSH. In the cases where the individuals make honest errors——

Chairman SMITH. Right. So no one has lost——

Mr. BUSH. —then we want——

Chairman SMITH. No one has lost their——

Mr. BUSH. —we want them to learn.

Chairman SMITH. No one has lost their job because of any cost overrun to date?

Mr. BUSH. I would not say that.

Chairman SMITH. Okay.

Mr. BUSH. I'm talking about these individuals specifically——

Chairman SMITH. Okay. Well, how many people have lost their job?

Mr. BUSH. Are you talking specifically to this program?

Chairman SMITH. Yes, JWST.

Mr. BUSH. I don't have a number off the top of my head.

Chairman SMITH. It's more than zero?

Mr. BUSH. I can't confirm that for you here today. I'm simply telling you how we approach assessing what——

Chairman SMITH. No, no, I know. Of course, that wasn't responsive, but my question is—you do not know as CEO whether any employees lost their job because of the human errors?

Mr. BUSH. With respect to the mistakes that we're talking about here today, I do not recall any losing their jobs.

Chairman SMITH. Okay. And then going back to the question about profit, what was Northrop's profit last year in 2017, just to the nearest tenth of a billion?

Mr. BUSH. We can get you that for the record.

Chairman SMITH. I'm sorry?

Mr. BUSH. We can provide that to you for the record.

Chairman SMITH. Okay.

Mr. BUSH. I don't want to make a financial mistake——

Chairman SMITH. Isn't it——

Mr. BUSH. —by not recalling something exactly.

Chairman SMITH. Isn't it a matter of public record?

Mr. BUSH. Yes, sir. That's why we can easily get it to you for the record.

Chairman SMITH. Okay. But why won't you tell us today what it is?

Mr. BUSH. I don't have it in front of me.

Chairman SMITH. Well, do you not? How could a CEO not know what the profit of his company was last year?

Mr. BUSH. We will provide that to you for the record.

Chairman SMITH. And you say it's public information but you won't——

Mr. BUSH. Yes, sir.

Chairman SMITH. —tell us today? You just don't want to say what the figure is?

Mr. BUSH. No, I just want to make sure I get it right.

Chairman SMITH. Well, could it have been $6 billion in 2017?

Mr. BUSH. If that's what the filing says, then it will be exactly accurate.

Chairman SMITH. Okay. But why would you not tell us? I just don't understand. You've talked about transparency. You've talked about willingness to give us information. Why wouldn't you be willing to tell us what the profit is or what——

Mr. BUSH. I'm perfectly willing to tell you. I just want to make sure we get it exactly right.

Chairman SMITH. But you as CEO——

Mr. BUSH. I'm very careful about financial reporting——

Chairman SMITH. You—okay. How about this? You as CEO, what was the profit last year to the nearest billion? Do you know that, and are you willing to say it?

Mr. BUSH. Mr. Chairman, as I said, I would be happy to provide that to you with——

Chairman SMITH. Okay.

Mr. BUSH. —high precision.

Chairman SMITH. But you—okay. And you admitted it's public record, but you will not say the figure in front of us today, is that right, even to the nearest billion? And you're CEO?

Mr. BUSH. I'm happy to provide it and——

Chairman SMITH. Okay.

Mr. BUSH. —make it very, very public.

Chairman SMITH. All right. Thank you all for being here today, and we stand adjourned.

Mr. BUSH. Thank you.

[Whereupon, at 11:37 a.m., the Committee was adjourned.]

Appendix I

Additional Material for the Record

DOCUMENT SUBMITTED BY NASA

Material requested for the record by Representative Takano during the July 25, 2018 hearing at which Administrator Bridenstine testified.

Answer:

Northrop had submitted to NASA one overrun proposal since the 2011 replan. This proposal, which was received in July 2016, addressed Northrop overrun costs relative to Optical Telescope/ Integrated Science instrument (OTIS) Integration & Testing (I&T); vibration testing support; delays in the Particle Dampers; and risk reduction efforts to maintain project's critical path. The total negotiated value was $180M. Overrun proposals are not fee bearing.

On Friday, August 24, 2018, Northrop submitted a second overrun proposal for the slip to the new launch readiness date. This latest Northrop Grumman proposal is currently undergoing the customary assessment, evaluation, and contract modification process. NASA can make the final definitized amount available to the Committee when that amount has been negotiated. Again, overrun proposals are not fee bearing.

DOCUMENT SUBMITTED BY NORTHROP GRUMMAN

Additional Information Provided for the Record by Northrop Grumman:

During the hearing, Chairman Smith asked about Northrop Grumman's 2017 profits. That information is available on page 23 of Northrop Grumman's annual report, which can be found here: http://www.northropgrumman.com/AboutUs/AnnualReports/Documents/pdfs/2017_noc_ar.pdf