NASA EXPLORATION PLANS: WHERE WE’VE BEEN
AND WHERE WE’RE GOING

HEARING
BEFORE THE
SUBCOMMITTEE ON AVIATION AND SPACE
OF THE
COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE
ONE HUNDRED SIXTEENTH CONGRESS
FIRST SESSION

DATE JULY 9, 2019

Printed for the use of the Committee on Commerce, Science, and Transportation

Available online: http://www.govinfo.gov

U.S. GOVERNMENT PUBLISHING OFFICE
WASHINGTON : 2023
SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

ROGER WICKER, Mississippi, Chairman
JOHN THUNE, South Dakota
ROY BLUNT, Missouri
TED CRUZ, Texas
DEB FISCHER, Nebraska
JERRY MORAN, Kansas
DAN SULLIVAN, Alaska
CORY GARDNER, Colorado
MARSHA BLACKBURN, Tennessee
SHELLEY MOORE CAPITO, West Virginia
MIKE LEE, Utah
RON JOHNSON, Wisconsin
TODD YOUNG, Indiana
RICK SCOTT, Florida

MARIA CANTWELL, Washington, Ranking
AMY KLOBUCHAR, Minnesota
RICHARD BLUMENTHAL, Connecticut
BRIAN SCHATZ, Hawaii
EDWARD MARKEY, Massachusetts
TOM UDALL, New Mexico
GARY PETERS, Michigan
TAMMY BALDWIN, Wisconsin
TAMMY DUCKWORTH, Illinois
JON TESTER, Montana
KYRSTEN SINEMA, Arizona
JACKY ROSEN, Nevada

JOHN KEAST, Staff Director
CRYSTAL TULLY, Deputy Staff Director
STEVEN WALL, General Counsel
KIM LIPSKY, Democratic Staff Director
CHRIS DAY, Democratic Deputy Staff Director
RENAE BLACK, Senior Counsel

SUBCOMMITTEE ON AVIATION AND SPACE

TED CRUZ, Texas, Chairman
JOHN THUNE, South Dakota
ROY BLUNT, Missouri
JERRY MORAN, Kansas
CORY GARDNER, Colorado
MARSHA BLACKBURN, Tennessee
SHELLEY MOORE CAPITO, West Virginia
MIKE LEE, Utah

KYRSTEN SINEMA, Arizona, Ranking
BRIAN SCHATZ, Hawaii
TOM UDALL, New Mexico
GARY PETERS, Michigan
TAMMY DUCKWORTH, Illinois
JON TESTER, Montana
JACKY ROSEN, Nevada

(II)
CONTENTS

Hearing held on July 9, 2019 ................................................................................. 1
Statement of Senator Cruz ..................................................................................... 1
Statement of Senator Sinema ................................................................................. 3
Statement of Senator Capito .................................................................................. 4
Statement of Senator Gardner ............................................................................... 42

WITNESSES

Eugene F. Kranz, Former Apollo Flight Director, Speaker and Author .......... 6
  Prepared statement .......................................................................................... 8
Dr. Christine M. Darden, Retired, NASA Langley Research Center .......... 14
  Prepared statement .......................................................................................... 15
Dr. Mary Lynne Dittmar, President and Chief Executive Officer, Coalition
  for Deep Space Exploration ............................................................................. 16
  Prepared statement .......................................................................................... 18
Homer H. Hickam, Jr., Author, Rocket Boys ......................................................... 23
  Prepared statement .......................................................................................... 25
Eric Stallmer, President, Commercial Spaceflight Federation ......................... 27
  Prepared statement .......................................................................................... 29
OPENING STATEMENT OF HON. TED CRUZ,
U.S. SENATOR FROM TEXAS

Senator Cruz. This hearing is called to order. Welcome.

Fifty years ago, exactly one week from today, at approximately 9:30 a.m., three astronauts, sitting atop a rocket the size of a Navy destroyer packing seven and a half million pounds of thrust, took off from Kennedy Space Center in Florida. Roughly a million people had gathered on the ground to watch this historic event, including half of the U.S. Congress.

These three astronauts, as one of the newspapers put it at the time, carried with them the hopes of the world. The year was 1969, the year before I was born. The astronauts were Neil Armstrong, Buzz Aldrin, and Michael Collins, and the mission was Apollo 11.

Armstrong and Aldrin would go on to make history a little more than a hundred hours later when, with more than a third of the Earth watching or listening live, they became the first humans to ever set foot on the Moon.

The Apollo 11 mission would go on to make history again, a little less than 100 hours after that, as the first mission not only to put men on the Moon but to bring them home safely, as well.

Although President Kennedy hadn’t lived to see it, the bold goal that he had set 8 years earlier had been met. To steal a line from the flight director of that mission, “We had shown that what America will dare, America will do.”

Today, we rightfully celebrate the momentous occasion that is the upcoming 50th Anniversary of Apollo 11. As President Nixon said in a phone call to Neil Armstrong and Buzz Aldrin while they were still on the Moon, because of what they had done, “The heavens had become a part of man’s world.”

Indeed, not only did we succeed in putting men on the Moon and returning them safely to Earth, but we’ve gone on to put robotic
rovers on distant planets, celestial observatories in orbit that can literally peer into the beginnings of the universe, and we’ve established a presence in low-Earth orbit that is still there today.

However, while it’s tempting to focus only on the historic achievements that were Apollo 11, as some of our witnesses today will rightly highlight, the Moon landing and the entire Apollo Program, for that matter, didn’t happen in a vacuum.

It was the result of visionary leadership, national unity, and old-fashioned American tenacity. The success of Apollo 11 and our national space program was also due in large part to the tireless contribution of countless women who were working behind the scenes and whose stories have only recently become household names.

One of our witnesses today, Dr. Christine Darden, was one of the famed human computers at NASA. Without her work and the work of other computers, many of them African American women, we never could have sent astronauts into space, let alone brought them home safely.

Unfortunately, at the time Dr. Darden and the other human computers’ contributions were hidden and they remained hidden for far too long, relegated to the background.

After the movie *Hidden Figures* came out, a wonderful, wonderful movie that I recommend to everyone, I introduced legislation to rename the street in front of the NASA Headquarters as Hidden Figures Way.

The D.C. City Council in turn took up the idea. Just a few weeks ago, I was proud to join Dr. Darden and the family of those other legendary human computers at the dedication of the new street sign in front of the NASA Headquarters, so that a decade, or a generation, or a century from now, when a little girl or little boy goes to visit NASA, she or he will say who were they? Tell me their story.

As we look at the space landscape today, we see it’s far different from the landscape of 1969. America and the Soviet Union are no longer the only players in space. Government space programs are no longer the only game in town, and our technological capabilities, both in terms of our ability to plan mission and how long these missions are, have changed dramatically.

What will the next 50 years of space exploration look like, and what should we seek to accomplish? We need a bold vision, a vision that sees the commercial space industry thriving. I’ve long said that the first trillionaire, I believe, will be made in space.

In 50 years, we will have gone back to the Moon. Indeed, the United States will return to the Moon as part of the Artemis Program. Artemis is the twin sister of Apollo, and this time when we return to the Moon, NASA has committed that we will land the first woman on the Moon, an American astronaut, and on behalf of my two young daughters, let me say thank you and it’s about time.

From there, we’ll move toward having a more permanent and sustainable presence on the Moon and then ultimately to Mars. Just a couple of years ago, I was proud to author the bipartisan NASA Authorization Act signed into law in which every Member of Congress in the House and Senate and both parties united to say that the objective of space exploration for NASA is to go to the red
planet and land on Mars, and that the first boot to set foot on the surface of Mars will be that of an American astronaut.

The next 50 years have the potential to be even more consequential than the last. That’s why I’m glad to be engaged with Ranking Member Sinema, with Chairman Wicker, with Ranking Member Cantwell, on yet another NASA Authorization Act to help continue to lay out a bold visionary agenda for NASA and manned space exploration so that America continues to lead the world in exploring space and exploring the great frontiers above us.

With that, I recognize Senator Sinema.

STATEMENT OF HON. KYRSTEN SINEMA,
U.S. SENATOR FROM ARIZONA

Senator Sinema. Well, thank you, Chairman Cruz, for holding this hearing today.

As we approach the 50th Anniversary of Apollo 11, it is timely to look back at our country’s accomplishments in space. It’s also important for us to look ahead at new strategies and technologies that will maintain the United States’ leadership in space, grow our economy, and strengthen our country’s security.

Thank you, Dr. Dittmar, Mr. Hickam, Mr. Kranz, Mr. Stallmer, and Dr. Darden, for joining us today.

In 1961, when President Kennedy announced his ambitious goal for our country to send Americans to the Moon, we did not anticipate the lasting impacts that mission would have on our Nation. At the time, we didn’t have the capabilities or know what was needed for mission success.

Apollo 11 showed us what our country and NASA are capable of, demonstrated to the world that the United States is the leader in space, and chartered the space exploration path we continue on today.

The most impressive part is that we developed technologies and prepared for the mission on U.S. soil and my home state of Arizona played a critical role.

The data collected from the Lowell Observatory in Flagstaff, Arizona, was used to make maps of the Moon’s surface before the mission. The Apollo astronauts also spent time in Northern Arizona preparing for the mission. They hiked the Grand Canyon to learn about geology and visited Meteor Crater to get an up-close look at what they would encounter on the Moon.

During a test of the first generation space suits at Sunset Crater, also in Arizona, NASA learned that the suits were not thick enough to withstand damage from rocks, forcing a redesign.

The most significant training was done at Cinder Lake, just outside of Flagstaff. Scientists at the U.S. Geological Survey developed a 500-square-foot lunar environment, including 47 craters, to test wheeled rovers, hand tools, and scientific instruments.

These efforts show what we can do as a country when faced with a challenge and success achieving our goal brings.

National and political support, robust funding, and innovation made President Kennedy’s goal a reality on July 20, 1969.

As we enter the next phase of space exploration and return to the Moon, we need to continue to utilize American expertise and ingenuity and we need to work closely with our research univer-
sities, like the University of Arizona and Arizona State University, that provide leadership and do important work in these areas, and I'm looking forward to holding a hearing on university partnerships this year in this Subcommittee.

The United States has made significant technological advances since 1969 and we have a better idea of what is needed to explore space, but we still face many challenges.

Our workforce is aging and we have not sent humans to space on a NASA spacecraft in 8 years. We must evaluate the best use of taxpayer dollars to achieve our goals and maintain our leadership in space.

Thank you again to all of our witnesses, and I very much look forward to your testimony today.

Thank you, Mr. Chairman. I yield back.

Senator Cruz. Thank you.

I'd now like to introduce our distinguished panel of witnesses.

Our first witness is Mr. Gene Kranz, who is a retired NASA flight director and fighter pilot. In 1994, after 37 years of legendary Federal service, Mr. Kranz retired from NASA.

After college, Mr. Kranz worked as a flight test engineer for McDonnell Aircraft, developing the Quail Decoy Missile for B–52 and B–47 aircraft. In 1960, Kranz joined the NASA Space Task Group at Langley, Virginia, and was assigned the position of assistant flight director for Project Gemini. He assumed flight director duties for all Project Gemini missions and was branch chief for Flight Control Operations.

He was selected as division chief for Flight Control in 1968 and continued his duties as a flight director for the Apollo 11 Lunar Landing before taking over the leadership of the Apollo 13 Tiger Team.

He was discharged from the Air Force Reserves as a captain in 1972. Mr. Kranz has received many awards and honors, including the Presidential Medal of Freedom, which he received from President Nixon for the Apollo 13 mission, and his designation as a Distinguished Member of the Senior Executive Service by President Reagan.

Mr. Kranz received a Bachelor of Science degree in Aeronautical Engineering from Parks College of St. Louis University.

Our second witness is Dr. Christine Darden. It's good to see you again.

Dr. Darden spent an esteemed 40 years at NASA, becoming one of the world's experts on sonic boom predictions, sonic boom minimization, and super-sonic wing design.

During her career, she was appointed as the technical leader of NASA's Sonic Boom Group of the Vehicle Integration Branch of the High-Speed Research Program where she was responsible for developing the Sonic Boom Research Program internally at NASA.

In 1999, she was appointed as the Director in the Program Management Office of the Aerospace Performing Center where she was responsible for Langley Research in Air Traffic Management and Other Aeronautics Programs managed at other NASA centers.

Dr. Darden also served as a technical consultant on numerous government and private projects. She is the author of more than 50 publications in the field of high-lift wing design in super-sonic
flow, flap design, sonic boom prediction, and sonic boom minimization.

She earned a Bachelor of Science degree in Mathematics Education from Hampton Institute, a Master’s of Science degree in Applied Mathematics from Virginia State College, and a Ph.D. in Mechanical Engineering from George Washington University.

Our third witness is Dr. Mary Lynne Dittmar, who is the President and CEO of the Coalition for Deep Space Exploration.

A 25-year veteran of the space industry, Dr. Dittmar assumed leadership of the Coalition in 2015. Prior to joining the Coalition, from 2012 to 2014, she served as a member of the National Research Council Committee on Human Space Flight.

Prior to that, she acted as a special advisor to the NASA Astronaut Office before her appointment as Boeing Chief Scientist for Commercial Utilization of the ISS.

Dr. Dittmar also coordinated R&D and managed Flight Operations for the Boeing Company on the International Space Station Program.

Dr. Dittmar is a Fellow of the National Research Society and an Associate Fellow of the American Institute for Astronautics and Aeronautics.

Additionally, in June 2018, she was appointed to the Users Advisory Group of the National Space Council. In October of that year was appointed by the Secretary of the Department of Transportation to the Commercial Space Transportation Advisory Committee for the FAA.

Our fourth witness is Mr. Homer Hickam, who is best known for his memoir *Rocket Boys* about his West Virginia boyhood building model rockets. The book was subsequently made into the film *October Sky*.

Mr. Hickam is a Vietnam veteran of the 4th Infantry Division and a 30-year careerist with the Army Missile Command and NASA, where he trained astronauts on such missions as Space Lab and the Hubble Space Telescope Repair Mission.

He rounded out his career by negotiating with the Russians on how to train crews on the International Space Station. Besides his career as a writer, Mr. Hickam presently is the Chairman of the Board of the U.S. Space and Rocket Center in Huntsville, Alabama.

Mr. Hickam received a Bachelor of Science degree in Industrial Engineering from Virginia Tech.

And our final witness is Mr. Eric Stallmer, who is the President of the Commercial Spaceflight Federation, also known as CSF.

CSF is the largest trade organization dedicated to promoting the development of commercial spaceflight, pursuing ever-higher levels of safety and sharing best practices and expertise throughout the industry.

Before working at CSF, Mr. Stallmer served as Vice President of Government Relations at Analytical Graphics, Inc., AGI. Mr. Stallmer joined AGI in 2002. While there, he oversaw all Washington operations and represented AGI’s commercial off-the-shelf products and technology to defense, intelligence, Congress, and civil government sectors within the aerospace industry.

For more than two decades, Mr. Stallmer has also served as an officer in the United States Army and Army Reserves. He is cur-
Currently assigned to the Pentagon and the Office of the Deputy Chief of Staff Army for Logistics.

Mr. Stallmer earned a Master's of Arts degree in Public Administration from George Mason University and a Bachelor of Arts degree in Political Science and History from Mount St. Mary College.

Welcome to each of you and, Mr. Kranz, you may begin. Could you turn your mic on, please?

Mr. Kranz. I had a green button but now it's red.

Senator Cruz. And I do have——

Mr. Kranz. Green means go.

Senator Cruz. And I do have to say I never imagined I would be giving you technical advice.

[Laughter.]

Mr. Kranz. OK. I'll start over.

STATEMENT OF EUGENE F. KRANZ, FORMER APOLLO FLIGHT DIRECTOR, SPEAKER AND AUTHOR

Mr. Kranz. Chairman Cruz, Ranking Member Sinema, and Members of the Subcommittee, thank you for the opportunity to discuss NASA's early and future human spaceflight programs.

You know, this is an exciting time for me and for NASA and the space industry as we celebrate one of our Nation's greatest technological achievements, landing two American astronauts on the Moon and returning them safely to Earth on the Apollo 11 mission.

I was fortunate to be a part of that team for that endeavor. Growing up, I could have never imagined I would serve in such a role. As a young boy, all I wanted to do was fly. On the path to becoming an aviator, however, I learned of resilience.

I received an appointment to the U.S. Naval Academy, but unfortunately I failed the entrance physical and I believed my dream was gone.

I obtained a loan and attended Parks College of St. Louis University and earned a degree in aeronautical engineering, and I received an Air Force ROTC Commission.

After tours in Korea as a fighter pilot, I selected Reserve status and in 1958 was assigned as a civilian flight test engineer on the B-52 Program. At the completion of the Flight Test Program, I applied to NASA and was selected to join the Space Task Group at Langley in 1960.

Beginning with John Glenn’s Mercury Mission, I served under Christopher Kraft as the assistant flight director. Having never met him before, our initial introduction was short and to the point. He tapped me on the shoulder, said I'm Chris Kraft, you work for me. I want you to go down to the Cape, write some mission rules. When you're ready, give me a call and I'll come down and watch. That was Redstone 1 and I had been two weeks on the job.

As space missions became more challenging and the stakes became higher, we grew into a stronger, more unified and incredibly capable team.

During this period, we developed a set of values. We called them the “foundations,” which have guided our operations for the past 50 years and still apply to our work today.

For the past several weeks, I’ve done dozens of interviews for local, national, and global media, and many reporters have ques-
tioned whether we should go back to the Moon, should we go to Mars directly and skip the Moon, can we do it again, and why haven’t we done it already? All good questions. Should we go back to the Moon? The answer was simply yes, no questions.

There are tremendous opportunities that lunar missions would provide our space industry, including developing the new capabilities and technologies for space flight missions to the Moon and then beyond.

My answer, can we do it again and why haven’t we done it already, is much more complex. That’s really why I’m here today, to offer some perspective, based on my experience as a leader of one of the space flight teams which accomplished President Kennedy’s 1961 mandate to land an American on the Moon and return him safely to Earth.

The 1960s were not dissimilar to some extent where our Nation is today. President Kennedy faced a confident Soviet Union and a sleeping giant in the People’s Republic of China. We were at the beginning of the Vietnam War and the domestic turmoil over civil rights was building.

Getting to Kennedy’s goal was timely and masterful in utilizing the challenge of space exploration to unify our Nation and demonstrate the technical capabilities of the United States.

Today, we have many of the same issues. However, one critically important element is still missing. Kennedy’s mandate was the impetus but there was a national unity that assured our success.

I believe that today in our country, unity is necessary for great effort and it’s lacking within our country, our government, and within the space industry. We have an Administration that is strongly supportive of space, that is willing to provide the resources. We have an agency chartered to do the mission, top level leadership in place, and a very capable work force.

But each of the segments are philosophically divided on the goal. There’s infinitely more technological capability than in the early programs, but there is a lack of focus and prioritization.

I believe that the general support for space and a desire to see our Nation explore space will continue but without unity, the space exploration program will be grounded.

To answer the question, what made Apollo successful, it was leadership, unity, and the team. The Mercury and the Gemini Programs provided the knowledge, experience, and environment, and it developed the teams and the technologies and provided the training ground for time-critical, complex, high-risk leadership.

The three elements of the Space Task Group were literally incredible. They created a unique organizational energy of classical aeronautical engineers from the Langley Research Center. They had a team of flight test personnel from Avro, Canada, and we had knowledgeable and energetic young recruits from America’s colleges, resulting in a program-wide unity that was focused on a singular objective: space and the Moon.

As the programs evolved, we came face to face with various challenges and failures. We truly began to solidify our team’s values and our values were simple: discipline, competence, confidence, responsibility, and team work.
Toughness entered our vocabulary and it was learning the hard way after the Apollo 1 fire and the loss of the crew. Toughness meaning we are forever accountable for actions for what we do or in the case of Apollo 1 what we failed to do.

The leadership inherited from Langley and the Avro group developed organizations with leadership in all segments and every level. There were individuals capable of taking leader-like actions to make their piece work. Leaders with confidence in their ability to send word back up the line that designs, plans, and policies needed amendment or reversal.

Our mission, one team and one voice, was present in every aspect of our work, from the formation of the Space Task Group through subsequent programs.

The three primary elements, however, they contributed to success of the Apollo Program are well documented as NASA's Special Publication 287. They're spacecraft hardware that is the most reliable, flight mission is extremely well planned and executed, and flight crews superbly trained and skilled.

The key that I considered most pertinent, however, to system design is related to safety. NASA has six decades of experience in manned space flight and has written numerous papers related to design criteria, materials, fault tolerance, propellants testing, and many other space system designs.

From the start of Gemini and for subsequent programs, the NASA astronauts, safety engineers, design engineers, and my personnel were embedded in the space system design and change control process from the very beginning of program initiation.

This assured timely inputs to the system design, testing, development of the flight procedures and rules, the plans, and the correct configuration of the mission facilities and trailers.

It is essential in today's card programs that NASA has the insight necessary to ensure safe and successful design, test, and operations. With the emphasis on concurrent engineering and reinvesting NASA, we must assure that individual responsibility is not forever lost. For all of NASA's programs, we must have individuals accountable for design, development, and operations.

While the world has changed dramatically since Apollo and the Space Program since my retirement, the constant essentials for success are unchanged. Leadership, unity, and team work.

I thank you for the opportunity to testify and I look forward to answering your questions.

[The prepared statement of Mr. Kranz follows:]

PREPARED STATEMENT OF EUGENE F. KRANZ, FORMER APOLLO FLIGHT DIRECTOR, SPEAKER AND AUTHOR

Chairman Cruz, Ranking Member Sinema, and Members of the Subcommittees, thank you for the opportunity to appear before you today to discuss NASA's early and future human spaceflight programs.

This is an exciting time for NASA and the space industry as we celebrate one of our Nation's greatest technical achievements—landing two American astronauts on the Moon and returning them safely back to Earth on the Apollo XI mission.

I was tremendously fortunate to be a part of the team and that great endeavor. Growing up, I could have never imagined I would serve in such a role. As a young boy, all I wanted to do was fly airplanes—that was my dream. I grew up during the depression, my father was a World War I veteran and died when I was only seven. We lived near the American Legion and, to support her three children, my
mother opened a boarding house for military personnel. The influence of these military servicemen really sparked my drive to become a naval aviator.

On the path to becoming an aviator, I learned resilience, very early. I received an appointment to the U.S. Naval Academy but, unfortunately, failed the entrance physical and believed my dream was gone. Other than this appointment, there were no other scholarships pursued and we certainly didn’t have the financial means. But an angel in my life, Sister Mary Mark, one of the nuns at Central Catholic High School in Toledo, found an Elks scholarship for Parks College of Saint Louis University. I earned a degree in Aeronautical Engineering and an ROTC commission in 1954. I flew the first three mass produced jet fighters, the F–80, F–86, and the F–100. After a tour in Korea, I selected reserve status and in 1958 was assigned as a civilian Flight Test Engineer on the B–52 at Holloman AFB.

At the completion of the flight test program, I applied to NASA and was selected to join the Space Task Group at Langley in 1960, serving under Christopher Kraft, as the assistant flight director for John Glenn’s Mercury mission. Having never met him, our introduction was short and to the point—he tapped me on the shoulder and stated, “I’m Chris Kraft, you work for me, I want you to go down to the Cape and write a countdown and some mission rules. When you’re ready, give me a call, and we’ll come down and launch.” This was our first Redstone launch.

While the space missions became more challenging and the stakes higher, we grew into a stronger, more unified, and capable team. During this period, we developed a set of cultural values which guided our operations over 50 years ago and throughout the decades to come. These steadfast values still apply to our space programs, today.

For the past several weeks, I have done dozens of interviews for local, national, and global media. Besides the typical questions, “how do you feel about the 50th anniversary and what do you think about the Apollo Mission Control Center restoration?” Nearly all the reporters have followed with questions about our current space initiatives. Should the U.S. go back to the Moon? Should we go to Mars and skip the Moon? Can we do it again and why haven’t we already?

My answer to the question, “should we go back to the Moon” is simply—yes. There are tremendous opportunities lunar missions can provide our space industry from redeveloping the capability and honing the spaceflight experience for missions beyond the Moon, as well as commercial development and utilization of the resources. The benefits go well beyond the time available today and there are plenty of scientists and entrepreneurs who can expound on the economic benefits.

To answer the question, “Can we do it again and why haven’t we already,” is much more complex. But that’s why I am here today, to offer my perspectives based on my experience from having been one of many, key NASA leaders and part of the spaceflight team which accomplished President Kennedy’s,1961 mandate, “to land a man on the Moon and return him safely to Earth before the decade was out.”

The 1960s were not dissimilar to where our Nation is today relative to geopolitics, domestic turmoil, and patriotism. President Kennedy faced a confident Soviet Union and a sleeping giant in the Peoples Republic of China. We were at the beginning of the Vietnam War and domestic turmoil over civil rights was building. President Kennedy’s challenge was a timely, masterful distraction, it utilized the challenge of space exploration to unify our Nation and demonstrated the technical prowess of the United States.

Today, we have many of the same issues. However, unity, was essential to our success in the 60s—one goal, one team. However, I believe the most critical element we lack today is unity—across our country, our government, and within the space industry.

We have an Administration which is strongly supportive of space, clearly stated directives to align with the goals, and a willingness to provide the resources. We have a capable workforce and industrial base which are engaged in various aspects of the industry, they are anxious to explore, but philosophically divided in their business and technical paradigms. We have infinitely more technological capability than we had in the early programs, but there seems to be a lack of focus and prioritization of those what are explicitly needed to accomplish the mission. We have a Congress divided primarily down partisan lines on just about everything but, individually, have a passion for space and a desire to see our Nation continuing to explore.

It is my understanding that the objective of today’s hearing is to address those qualities that were contributors to the success of the Apollo Program. Many papers have been written on this topic so my comments should not be new.

What made Apollo a success? The Leadership. The Unity. The Team.

The Mercury and Gemini Programs provided the experience base for the Apollo, Shuttle, and subsequent programs.
The Mercury Program provided the initial understanding of the manned flight mission environment, the involved mission tasks, facility requirements and capabilities, training and the nature of the personnel most suited for the critical, high risk aspects of mission control.

The Gemini Program introduced the critical new space technologies; computers, fuel cells, maneuvering and attitude control systems, and the ability to accomplish rendezvous, docking, and support extravehicular operations. Computers, satellite communications, and improvements in display technology in Mission Control combined with effective simulation training established the relationship between the mission control team and crew needed for complex space operations. Possibly the most important was that it provided the training ground and mission experience required for making risk-based decisions during pre-mission and mission operations.

**Developing our Team and Our Values**

The Space Task Group was an enterprise, with three unique components. The foundation was provided by a small group of classical aeronautical engineers from the Langley Research Center. This group had the hands-on knowledge and experience from their work in the design and test of the breakthrough aircraft during and after World War II. The second group was composed of aeronautical engineers and flight test personnel from the Avro Arrow project from the Avro Arrow project in Canada. The cancellation of the AVRO Arrow project by the Canadian government made key engineers and flight test personnel available to the fledgling Space Task Group. The third component was comprised of a mixture of young engineers recruited from America’s colleges, former military personnel, and a small group experienced in early scientific satellite programs.

Each of these groups brought with them a unique organizational chemistry. The Langley group brought a classical aeronautical engineering skill to the Mercury Program. The Arrow group brought an incremental flight test approach. The third, younger group, brought a highly energetic and impatient, “let’s get going” approach. The interaction of these three groups created an organizational chemistry that was greater than the sum of its parts that I believe led to developing the incredible and gifted leadership that provided success during the early programs.

As the programs evolved and we came face-to-face with various challenges and failures, we truly began to solidify our team core values of discipline, competence, confidence, responsibility, and teamwork (ref. Foundations of Mission Control). Toughness, emerged as a core value, learned the hard way, after the Apollo 1 fire and the loss of the crew. Toughness, meaning, we are forever accountable for our actions, what we do, or, in the case of Apollo 1, what we failed to do (ref. Kranz Dictum).

The organizational structure for future space programs must consider the relationship between Headquarters personnel and those assigned to mission leadership. From Gemini through the early Shuttle Program a highly professional, personal, and friendly relationship existed to address issues on a variety of issues before they became problems.

**Leadership**

The leadership inherited from the Langley and Arrow groups recognized that for an organization to function, leadership must exist in all segments and at every level. There must be individuals capable of taking leader-like actions to make their piece work, leaders with confidence in their ability to send word back up the line that design, plans and policies needed amendment or reversal. There was a universal recognition that every member of the Space Task Group was responsible to develop the next generation of leaders. During the Shuttle Program, many organizational “fads” originated. Awards were given for “flattening organizations,” essentially eliminating mid-level supervisors. I believe this was detrimental, mid-level positions provide the primary training ground for higher level positions.

**Teamwork and Unity**

One mission, one team, one voice was present in every aspect of our work from the formation of the Space Task Group through all subsequent programs. There was so much to be learned, and work to be done that unification of both NASA and contractor organizations in every activity was universally recognized as essential to the program success. The unity I had seen through the early Shuttle Program began to shatter, reaching crescendo on the Space Station Program in the period after the Space Shuttle Challenger accident resulting in lost opportunities, schedule and cost impacts, and many good leaders deciding it was time to retire.
Policy

The three basic elements that contributed to the success of the Apollo Program are: spacecraft hardware that is the most reliable, flight missions that are extremely well planned and executed, and flight crews that are superbly trained and skilled. These policies have guided me and my teams in all programs. NASA document SP-287, What Made Apollo a Success, provides many of the specifics related to the Apollo Program. This report addresses spacecraft development, mission development, flexible yet disciplined mission planning and execution, flight crew training, and trajectory control techniques.

A key area I consider pertinent to system design is related to safety. NASA has six decades of experience in manned space flight, has written numerous papers related to design criteria, materials, fault tolerance, propellants, testing, and many other space systems design elements.

From the start of Gemini and for subsequent programs, the NASA astronauts, safety engineers, design engineers, and operational personal were embedded in the space systems design and change control process at program initiation. I had direct communications with the prime contractors’ design and test organizations. This assured timely operational inputs to the space system design, development of flight procedures and plans, and the configuration of mission facilities and trainers. My controllers were some of the best systems engineers in the world. Astronaut John Young assured the mission control cadre participated in every major accident review and contributed to the redesign when needed.

In today’s “Commercial Crew and Commercial Cargo,” NASA gets to see what is designed after the fact and often too late to make any critical changes.” I have asked NASA personnel on several occasions who is accountable for providing oversight to the commercial crew space systems design, test, and operations. The answers I received were not specific.

The day I retired, I left a memo for Dave Leestma, Chief of the Astronaut Office, containing testimony by Admiral Rickover on accountability. The Rickover memo described the lack of accountability for the 1963 submarine Thresher loss during a diving test with all crew aboard. This was the environment I experienced in the post-Challenger and early Space Station period.

“During the six years of the submarines design, the Portsmouth Naval shipyard had three shipyard commanders, three production officers and five planning officers. The Bureau of Ships during this period had two Chiefs of Bureau, five or six chiefs of the design division and three heads of the Submarine Type desk.”

I closed my memo to Leestma with these words, “With the emphasis on concurrent engineering and reinventing NASA, we must assure that individual responsibility is not forever lost. When the dust finally settles on the trials and tribulations of our programs, we must have individuals accountable for design, development, and operations.”

If a crew is lost on a commercial crew mission, who will be held accountable?

While the world has changed dramatically since Apollo, and in the Space Program since my retirement in 1994, the one constant essential to success, is unchanged, it is leadership.

John Gardner, in the preference to his excellent book “On Leadership” states, “In order for an organization to function, leadership must be dispersed throughout all segments, and at every level there must be individuals capable of taking leader like actions to make their piece work. Men and women who are not afraid to send word back up the line that newly announced plans and policies need amendment or reversal.”

Gardner then comments on the large numbers of people who are torn loose from values they may have held previously, what he calls the divergence of value systems. “Leaders are always seeking the common ground that will make concerted action possible. It is impossible to exercise leadership if shared values have disintegrated.”

In conclusion, I believe the book, “Apollo the Race to the Moon” by Charles Murray and Catherine Bly Cox, provides an in-depth perspective of the programmatic, engineering, and operational elements responsible for the success of the Apollo Program. I would recommend that this book is made “required reading” for those who would assume future leadership and programmatic functions.

Today, our National leadership and the NASA industry team are at a critical, “go, no-go” point. “Now is the time to take longer strides . . . time for this Nation to take a clearly leading role in space achievement which, in many ways, may hold the key to our future on Earth.” President John F. Kennedy.

Thank you for the opportunity to testify. I look forward to answering your questions.
Foundations of Mission Control

- To instill within ourselves these qualities essential to professional excellence:
  
  Discipline – Being able to follow as well as to lead, knowing that we must master ourselves before we can master our task.
  
  Competence – There being no substitute for total preparation and complete dedication, for space will not tolerate the careless or indifferent.
  
  Confidence – Believing in ourselves as well as others, knowing that we must master fear and hesitation before we can succeed.
  
  Responsibility – Realizing that it cannot be shifted to others, for it belongs to each of us; we must answer for what we do, or fail to do.
  
  Toughness – Taking a stand when we must; to try again, and again, even if it means following a more difficult path.
  
  Teamwork – Respecting and utilizing the abilities of others, realizing that we work toward a common goal, for success depends upon the efforts of all.
  
  Vigilance – Always attentive to the dangers of spacelift; Never accepting success as a substitute for rigor in everything we do.
  
- To always be aware that suddenly and unexpectedly we may find ourselves in a role where our performance has ultimate consequences.
  
- To recognize that the greatest error is not to have tried and failed, but that in the trying we do not give it our best effort.
The Kranz Dictum
(speech to the control team after the Apollo I fire)

Spaceflight will never tolerate carelessness, incapacity, and neglect. Somewhere, somehow, we screwed up. It could have been in design, build, or test. Whatever it was, we should have caught it. We were too gung-ho about the schedule and we locked out all of the problems we saw each day in our work. Every element of the program was in trouble and so were we. The simulators were not working. Mission Control was behind in virtually every area, and the flight and test procedures changed daily. Nothing we did had any shelf life. Not one of us stood up and said, ‘Dammit, stop!’ I don’t know what Thompson’s committee will find as the cause, but I know what I find. We are the cause! We were not ready! We did not do our job. We were rolling the dice, hoping that things would come together by launch day, when in our hearts we knew it would take a miracle. We were pushing the schedule and betting that the Cape would slip before we did.

From this day forward, Flight Control will be known by two words: ‘Tough’ and ‘Competent.’ Tough means we are forever accountable for what we do or what we fail to do. We will never again compromise our responsibilities. Every time we walk into Mission Control we will know what we stand for. Competent means we will never take anything for granted. We will never be found short in our knowledge and in our skills. Mission Control will be perfect. When you leave this meeting today you will go to your office and the first thing you will do there is to write ‘Tough and Competent’ on your blackboards. It will never be erased. Each day when you enter the room these words will remind you of the price paid by Grissom, White, and Chaffee. These words are the price of admission to the ranks of Mission Control.
Senator CRUZ. Thank you, Mr. Kranz.

Dr. Darden.

STATEMENT OF DR. CHRISTINE M. DARDEN, RETIRED, NASA LANGLEY RESEARCH CENTER

Dr. Darden. Mr. Chairman, Members of the Senate Commerce Committee, and Members of the Subcommittee on Aviation and Space, I am very honored to be present today to be participating in your committee hearings.

I am here as a child of the Space Race. On October 5, 1957, I vividly recall the headline about Sputnik as I took the newspaper into my high school library. I also vividly remember May 1961 when my dormitory halls were filled with screams about the challenge that President John Kennedy had just issued about landing a man on the Moon and safely bringing him back before the end of the decade.

Where have we been? It is the response to that challenge with Apollo that makes NASA and all of us so very proud. At that time, NASA Langley Research Center had existed as the National Advisory Committee for Aeronautics, NACA, Laboratory for 40 years and had spent countless hours thinking about how to leverage our aeronautics expertise to address the challenges of spaceflight.

NASA Langley had begun Project Mercury and trained its seven Mercury astronauts to fly in space. As preparation for Apollo, the Gemini Program focused on rendezvous, docking, and long-term space flight.

The Apollo Program captured the world’s attention and demonstrated the power of America’s vision and technology to inspire great achievements.

On July 16, 1969, though it was the NASA Space Centers that were visible to the public as the Saturn 5 set poised for liftoff, many workers from the Research Centers, like Langley, were several years removed from the simulators that they built for training the astronauts, from the wind tunnel tests that they did, which is where I worked. Those tests validated the spacecraft configuration and determined the re-entry safety.

But Apollo was in their hearts, and Apollo was supported by this country. After 11 and a half years, Apollo ended, having spent a record $23 and a half billion, having placed on the Moon and safely returned 12 men, and having inspired thousands of young engineers and space enthusiasts, like myself.

Sadly, after Apollo ended, there was a decline in the number of American students getting higher degrees in the STEM areas.

Where do we go from here? NASA is now poised to return American astronauts to the lunar surface by 2024 as part of our broader Moon-to-Mars Exploration. Artemis is the program to prove technologies, capabilities, and new business approaches for future missions to Mars. Through Artemis, NASA will establish a sustainable human presence on the Moon by 2028, inspiring the Artemis generation.

Certainly one of the necessary needs as we go forward is the development and preparation of a strong, energetic, and committed workforce as we had for Mercury, Gemini, and Apollo. A thriving, visible Artemis Program will do much to inspire the next genera-
tion and to pursue STEM careers, just as I was inspired as I saw the work being done at NASA result in Neil Armstrong walking on and safely returning from the Moon.

After Apollo, I spent 25 years working in supersonic aerodynamics and minimizing the sonic boom. When I retired from NASA, two young ladies came to my party and stated that it was because of my sharing my story of how I got to NASA and what I did at NASA that inspired them to become engineers at NASA.

I have over the past two years spoken to thousands of students about following their dream, about preparing themselves, and persevering, hoping that they, too, will be inspired to join the likes of an Apollo generation to push the boundaries of knowledge. They will pursue groundbreaking research to understand how to live and work on another planet.

Since retiring from NASA, I have remained an advocate for the agency and I will work in aeronautics and exploration.

I wish to thank the Committee members for your continued support of NASA and for the important work you are doing to pass NASA’s Authorization bill this Congress.

NASA really needs an authorization bill that supports our Nation’s plans for the Artemis Program and the overall approach for the Moon and Mars.

In summary, this lunar destination is promoting sustainability, a proving ground for Mars, a strategic presence for our nation, and a foundation for building international and commercial partnerships while also inspiring the next generation to be prepared for the excitement and groundbreaking new opportunities.

I thank you very much.

[The prepared statement of Dr. Darden follows:]

PREPARED STATEMENT OF DR. CHRISTINE M. DARDE, RETIRED, NASA LANGLEY RESEARCH CENTER

Mr. Chairman, Members of the Senate Commerce Committee, and Members of the Subcommittee on Aviation and Space, I am very honored to be present today to participate in your Committee Hearing. I am here as a child of the Space Race. I remember May 22, 1961, when President John Kennedy issued the challenge that we would put a man on the moon and safely bring him back before the end of the decade.

**Where We Have Been**

It is the response to that challenge with Apollo that makes NASA and all of us so very proud. At that time, NASA Langley Research Center had existed as the National Advisory Committee for Aeronautics (NACA) for 40 years, and had spent countless hours thinking about how to leverage our aeronautics expertise to address the challenges of spaceflight. NASA Langley had begun Project Mercury and trained its seven Mercury Astronauts to fly in space. The Gemini Program focused on rendezvous, docking and long-term space flight.

The Apollo Program captured the world’s attention and demonstrated the power of America’s vision and technology to inspire great achievements. On July 16, 1969, though it was the NASA Space Centers that were visible to the public as the Saturn V set poised for lift off, many workers from the Research Centers were now several years removed from the simulators they built for training the astronauts, the wind tunnel tests that validated the configuration and re-entry safety, and the discussions that led to decisions on how we would get to the moon. But Apollo was in their hearts and Apollo was supported by this Country. After 11.5 years Apollo ended, having spent a record $23.5B, having placed on the moon and safely returned 12 men, and having inspired thousands of young engineers and space enthusiasts.
Where We Go From Here!

NASA is now poised to return to the Moon in the next 5 years. This time the plan is to return to the moon as a pathway to further exploration but not alone, rather with government, industry and international partners in a global effort to build and test the systems needed.

Artemis is the program to prove technologies, capabilities and new business approaches for future missions to Mars. NASA has begun the next era of exploration and discovery! The plan is to return American astronauts to the lunar surface by 2024 as part of our broader Moon to Mars exploration approach. The first American woman and next American man will set foot on and explore the South Pole of the Moon, where no human has ever been before.

The first Artemis flight will be a test of the Space Launch System (SLS) rocket and Orion spacecraft as an integrated system. The second Artemis flight will ferry the crew to the Moon aboard SLS and Orion. The third Artemis flight will deliver the crew to the lunar surface. Through Artemis, NASA will establish a sustainable human presence on the Moon by 2028.

Inspiring The Artemis Generation!

A thriving, visible Artemis Program will do much to inspire the next generation to pursue STEM careers. This lunar effort will engage the entire nation and the world—uniting the brightest minds of academia, industry and communities of all sizes and types, from early career professionals to our international partners. Just think about it. The Artemis generation will push the boundaries of human knowledge. They will dream about and eventually pave the way for reaching new worlds and unlocking the mysteries of the universe. They will pursue groundbreaking research to understand how to live and work on another planet. This research will expand our knowledge of human anatomy, solar propulsion, biofuels, geology, astrophysics, and lunar and planetary science.

Since retiring from NASA, I have remained an advocate for the Agency and our work in aeronautics and exploration. I wish to thank the Committee Members for your continued support of NASA and for the important work you are doing to pass a NASA Authorization bill this Congress. NASA really needs an Authorization Bill that supports our Nation’s plans for the Artemis Program and the overall approach for Moon to Mars.

In summary, this lunar destination is promoting sustainability, a proving ground for Mars, a strategic presence for our nation, and a foundation for building international and commercial partnerships while also inspiring the next generation to be prepared for the excitement of new opportunities.

Thank you.

Senator CRUZ. Thank you, Dr. Darden.

Dr. Dittmar.

STATEMENT OF DR. MARY LYNNE DITTMAR, PRESIDENT AND CHIEF EXECUTIVE OFFICER, COALITION FOR DEEP SPACE EXPLORATION

Dr. DITTMAR. Chairman Cruz, Ranking Member Sinema, Members of the Subcommittee, thank you for the invitation to appear before you today with such an extraordinary and distinguished panel to discuss my thoughts on the topic of today’s hearing.

More than 50 years ago, the Apollo Program began, ultimately resulting in one of humankind’s most extraordinary achievements. Mission readiness was the driving force of the entire effort.

To achieve the mission, certain capabilities had to be developed. These included standing up a human space flight organization capable of developing and delivering a super-heavy lift vehicle, a crew capsule, ground systems, AVA suits, cruise systems, silence payloads, and related equipment. An entire operations concept and an organization called Mission Control had to be invented. I will defer here to Mr. Kranz.

The overarching goal, however, was the geopolitical one. The Apollo Program was the means to achieve it. Involving over
400,000 Americans and at the cost of 300 billion in adjusted dollars for the entire program, President Kennedy's challenge was fulfilled between July 16 and 24, 1969, with the lunar landing on July 20, 50 years ago.

With regard to today's goals, the primary objective of NASA's Human Space Flight Program viewed through a national lens remains a geopolitical one, although it is a different geopolitical objective. No longer in a race to the Moon with the Soviets, United States leadership in space depends upon creating a foundation that provides other nations and a nascent space-based economy with security and assurance regarding our national intentions and long-term commitment to aspire, inspire, and achieve, in short, to lead human space exploration and the development of space.

If we do not do this, rest assured that someone else will. Space remains the strategic competitive domain between nations.

Accordingly, the United States is developing core capabilities to enable our return to deep space. A super-heavy launch vehicle, a modern crew vehicle capable of long duration missions when paired with habitats and consumables, and ground-based infrastructure needed to support those missions.

Dubbed the Space Launch System, the Orion Crew Vehicle, and Exploration Ground Systems, respectively, these strategic assets are the foundation upon which national goals and human deep space exploration will rest for the foreseeable future.

Similar to the development of military capabilities, these are long lead time national assets, sustained as a guarantee against economic downturn, policy shifts, and as a message to the global community.

In addition, NASA's Artemis Program will engage industry and international partners. Sticking to aligned national objectives with those of commercial enterprises and global collaborators in the human exploration of deep space.

The momentum established by the current Administration with its focus on the Moon is a welcome one, but as report after report has shown, NASA is asked to do too much with too little and this is no exception.

Acceleration must be balanced with management of program risk, mission assurance, and safety. Forward momentum also must be matched by significant national investment above present levels.

The Administration has proposed $1.6 billion to begin the process of accelerating our Human Space Exploration Program. In addition, the NASA Administrator has estimated it will take between four to six billion per year over currently anticipated funding levels to meet more aggressive timelines.

While funding increases are always a political challenge, it is worth noting that the benefits of 10 times that amount in adjusted dollars invested in the Apollo Program are evident to all and form the foundation both for today's national effort and for the growing entrepreneurial sector.

A personal aside, I actually have been on crutches for the last two and a half years as a result of a connective tissue disorder, and during the launch and landing of Apollo 11, I was at home after having just gone through my fourth surgery. I now stand before you without crutches and due to two years of work in physical ther-
apy using technology that was developed in the Space Program. So for me, this is deeply personal. NASA plans to achieve architectural flexibility at the Moon by constructing a lunar orbital station, known as Gateway, in partnership with industry and international partners. Among other things, Gateway simplifies our ability to aggregate hardware in the vicinity of the Moon, including descent and ascent vehicles for transportation of humans back and forth to the lunar surface. Longer surface missions enabled by Gateway make it easier to conduct lunar operations over time. Entrepreneurial firms are teaming with investors and also established companies to develop technologies aimed at building up infrastructure on the Moon. With regard to science, the Moon has been called the Rosetta stone of the Solar System with evidence locked within it that has already taught us a great deal about the formation of the Earth-Moon system. We’ve explored only 5 percent of the surface. There’s a great deal more to learn. Finally, Gateway is the next logical step in developing a command and logistics capability that is extensible not just to the Moon but beyond the Moon toward Mars. The Gateway itself is a prototype, an evolution of lessons learned over the last 50 years and, in particular, from the International Space Station to create habitable space and systems to support human life and work in deep space. The Moon is an important stepping stone. What we learn there will not only create opportunities in lunar space but will open new discoveries and knowledge that would help us as we look toward Mars. But the Moon is not an end goal, it’s the beginning, a next step enabling the migration of technology, heavy industry, and humanity itself off the Earth and into the Solar System at a scale that is no longer constrained by a single planet, our original home. Thank you for your time and attention. I look forward to any questions you may have.

[The prepared statement of Dr. Dittmar follows:]

PREPARED STATEMENT OF DR. MARY LYNNE DITTMAR, PRESIDENT AND CHIEF EXECUTIVE OFFICER, COALITION FOR DEEP SPACE EXPLORATION

Chairman Cruz, Ranking Member Sinema, Members of the Subcommittee, thank you for the invitation to appear before you with such an extraordinary and distinguished panel to discuss my thoughts on the topic of today’s hearing: “NASA’s Exploration Plans—Where We’ve Been and Where We’re Going.”

Then: The Apollo Program and an Epochal Mission

More than 50 years ago, the Apollo program began, ultimately resulting in one of humankind’s most extraordinary achievements. Undertaken as part of the Kennedy administration response to the Soviet Union, and in the context of a perceived “missile gap” between U.S. and Soviet capabilities, the effort was virtually on a war footing and had a specific mission focus—“landing a man on the moon and returning him safely to the Earth” within a decade. This mission objective had a much broader and even more urgent underlying goal, however—to demonstrate the superiority of the technical, economic, and political system represented by American ideals of freedom and democracy versus that of a closed, communist state.

The mission outlined by Kennedy may not have survived had he not been assassinated—and if it had survived it may have evolved to a different mission, perhaps with a Russian partner. We will never know. In President Johnson’s hands, however, Kennedy’s space legacy—both the goal and the mission—became codified in a way that has never happened since in human space exploration.
Mission readiness was the driving force for the entire Apollo program. To achieve the mission certain capabilities had to be developed. These included standing up a human spaceflight organization capable of developing and delivering a super heavy lift vehicle, a crew capsule, ground systems, EVA suits, crew systems, and related equipment. An entire operations concept and organization called “Mission Control” had to be invented, in turn supporting and supported by development and execution of procedures, schedules, simulations, training, a logistics system (including communications and tracking both on the ground and from ground to space and back), medical support, and much more. Each capability was developed as part of a learning sequence with many moving parts, each building toward the successful landing and safe return of the crew of Apollo 11. The goal was a geopolitical one, the Apollo program was the means to achieve it, and the extraordinary work, time, and treasure it took to meet it—involving over 400,000 Americans and at the cost of $300B in adjusted dollars for the entire program1—was realized between July 16 and 24, 1969, with human beings setting foot on another celestial body 50 years ago on July 20.

Now: A Focus On Capability

With regard to today’s goals, it should be said from the beginning that the primary objective viewed with a national lens remains geopolitical, although it is a different geopolitical objective. No longer in a race to the Moon, United States leadership in space depends upon establishing a foundation that provides other nations and a nascent space-based economy with security and assurance regarding our national intentions and long-term commitment to aspire, inspire and achieve—in short, to lead. Space remains a strategic, competitive domain among nations. For example, China is pushing forward with technology, science, investment, a new space station in low Earth orbit, and lunar aspirations, and has announced development of a super heavy lift vehicle (SHLV) for human space exploration. Russia remains an active partner with us on the International Space Station but also has announced plans for an SHLV. For the U.S. to push forward and support our endeavors and those of our friends, we must be “out there”—physically present, with national assets at the ready, and we must be there sooner rather than later.

The success of the Apollo program—at great cost in treasure and in human lives—created a near-mythical template in the minds of both NASA and the public that has been at the heart of controversy about the role of the space program ever since, resulting in oft-repeated commentary as to whether NASA has a “mission”. The answer is emphatically “yes”, but not in the same way as Apollo. Instead, we are embarked upon a plan to create, manage, and execute deep space activities based on the development of national capability, defined here as the ability to achieve a variety of desired outcomes in a specific operating environment. Much like the development of military capability, a sustained national capability requires technical systems and equipment needed to perform the operations for which they are designed that also support a variety of missions that may not be known when the capability is being developed. These are typically long lead-time national assets that exist to perform certain functions necessary to meet operational requirements. As such they are sustained by national investment as a guarantee against economic downturns and policy shifts that may accompany short-term Administration and/or Congressional priorities.

Accordingly, the United States is developing core capabilities to enable our return to deep space: A super heavy launch vehicle (SHLV), a modern crew vehicle capable of long-duration missions when paired with habitats and consumables, and ground-based infrastructure needed to support those missions. Dubbed the Space Launch System (SLS), the Orion crew vehicle, and Exploration Ground Systems respectively, these strategic assets are the foundation upon which national goals in human deep space exploration will rest for the foreseeable future. In addition, the Artemis Program will engage industry and international partners, seeking to align national objectives with those of commercial enterprises and global collaboration in the exploration of deep space wherever practicable.2

The momentum established by the current administration with its focus on the Moon is a welcome one, but as report after report has shown NASA is asked to do too much with too little and this is no exception. Acceleration must be balanced with program risk and mission assurance, and forward momentum must be matched by significant national investment above present levels.

Happily, this increased investment will find a much broader portfolio in science, technology, and exploration than when the Apollo program began 60 years ago. A

---

revitalized space industry is building on previous government investments and experience gained during that extraordinary effort. New manufacturing methods, technologies, and advanced computing capabilities are reducing costs, encouraging new entrants, building new capacity, and attracting billions of dollars in new investment in the emerging space sector. Meanwhile, NASA has led the development of a global spaceflight community, collaborating with international partners while helping to open the door to human spaceflight and space science for over 100 countries via participation on the International Space Station.

Today’s need for operational readiness is every bit as great as during the Apollo program, but the overarching goal is less specific, more open-ended. While the recently-announced Artemis program, with its goal of returning Americans to the lunar surface by 2024 is a worthy effort, the “Artemis Lunar Landing-1” mission does not represent fulfillment of a policy objective in the same sense as did Apollo 11. Today, the policy objective is to establish a sustainable, strategic human presence beyond low Earth orbit, first at the Moon and then beyond, with an eye toward Mars. The key words here are “sustainable” and “strategic”. To succeed in this endeavor, however, several things must change.

Timely and Sufficient Funding

In the decades since the current, regular order for authorizing and appropriating tax dollars has been established (1974), Congress has managed to pass all of its required appropriations measures on time on less than half a dozen occasions. It is true that Congressional support for NASA and for human space exploration has been consistent. That said, for NASA programs, as for all long-lead time programs spanning years, last-minute political maneuvering, government shutdowns, delayed receipt of funds, and general instability and unpredictability of funding invariably creates inefficiency in program management and execution, forcing compromises in program planning that add cost, schedule and risk. In addition, report after report has found that NASA’s tasking and budget are mismatched. Alternate acquisition and procurement approaches when technologies are well understood is a useful means to reduce costs, but relying on industry to drive down costs while at the same time increasing speed of delivery, or seizing upon alternate means for acquisition without consideration of risk management implications, amounts to wishful thinking. Such approaches do nothing to change that fact that at no time since Apollo, with all of its extraordinary resources, has any human-rated system been deployed less than 4 years later than originally intended, no matter who is building it.

The Administration has proposed $1.6B to begin the process of accelerating our human space exploration program. In addition, the NASA Administrator has estimated it will take between $20 and $30B over currently anticipated funding levels to meet more aggressive timelines. While funding increases are always a political challenge, it is worth noting that the benefits of 10X that amount in adjusted dollars invested in the Apollo program are evident to all, and form the foundation both for today’s national effort and for the growing entrepreneurial sector.

It is absolutely true that inefficiencies in development and execution within government programs should be addressed. Congress can help by regularizing its own process. The hearing to which these remarks is addressed is a welcome aspect of that process.

Acquisition and Procurement Reform

As has been recognized by Congress over the past many years, the nature of the policy and regulatory framework guiding exploration and development of space is crucial, providing government, industry and the investment community alike with stable, predictable operating environments. The importance of stability also has been recognized across various Administrations and very recently has been reflected in the agreement upon 21 “Guidelines on the Long-Term Sustainability of Outer Space Activities” within the UN’s Committee on the Peaceful Uses of Outer Space (UN COPUOS).

Hand-in-hand with stability in “light touch” regulation however is the need for streamlined acquisition processes. As I testified before the National Space Council in February of 2018, the fiscal, programmatic, reporting and management burdens associated with government contracting and oversight cannot be overstated.

3 https://www.pewresearch.org/fact-tank/2018/01/16/congress-has-long-struggled-to-pass-spending-bills-on-time/  
4 https://www.hsdl.org/?view&did=794133  
5 See, for example: https://sites.nationalacademies.org/cs/groups/deposit/documents/webpage/dep0_080254.pdf  
slow nature of acquisition and the costs and schedule associated with program start-up also pose a threat to technology development and insertion into some of our most strategic programs, threatening U.S. leadership and security. This is not to say that traditional contracting should be abandoned. On the contrary, cost-plus contracts for managing large development programs with significant R&D components provide stability, reduce business risk and support the aerospace and defense industrial base that is so critical to U.S. security. That said, the ability to ramp up programs with much greater speed than typically seen together with renewed focus on accountability and constraints on cost and schedule growth are of primary interest in reform.7

The use of Other Transactional Authority (OTAs) and Public Private Partnerships (P3) may provide more flexibility than traditional contracting and, in some cases, offer economic incentives, but at the cost of reduced transparency. Each of these approaches may take many forms but their success depends upon informed allocation of risk on each side of the government-business relationship, a realistic business case in the case of P3 (an indispensable requirement) and the means to align business objectives with the public (national) interest. The rapidly-accelerating range of procurement activities in both the DoD and NASA requires the ability to evaluate acquisition models, understand their strengths and weaknesses for differing applications, situations and goals, assess business cases, grasp the complexities of risk allocation and management associated with different models, and understand the range of economic incentives and their likely downstream effects. Adopting an acquisition posture that balances risk, cost and schedule with the goal of rapid development and deployment of capabilities may require retraining the procurement workforce across the government.

Education and Diversity in the Workforce

Preparation and development of the A&D workforce is not limited to procurement professionals. It must begin much earlier and span a multitude of disciplines. The United States has remained in the upper third of countries for 4–12 grades students in math and science for the past 15 years though our test scores remain relatively flat.8 Of those students who eventually seek employment in the Aerospace and Defense (A&D) workforce, 71 percent of young A&D professionals report they first became interested in these careers during their grade school years. Continuing emphasis upon superior preparation and broad educational opportunities is critical to U.S. leadership across STEM disciplines, including in space.

In addition, and despite significant effort, the diversity of the A&D industry looks much the same as it did four decades ago. Greater diversity in a workforce has been demonstrated time and time again to result in higher rates of innovation, invention, and unique problem-solving and is key to both global competition and cooperation. At the same time, the shift in economic demographics nationwide since 2008 has resulted in a higher proportion of Americans remaining at work. This is also true of A&D: 29.8 percent of workers are 55 years of age or older.9 On the one hand, this benefits the industry since it requires legacy skills and experience in aerospace, electrical, mechanical and electrical engineers. On the other, the industry also requires skills in cognitive computing, artificial intelligence and materials. At present, terrestrial high technology careers in these fields are attracting the best and brightest young professionals. NASA and the Department of Defense must not only compete with them but with quicker-moving entrepreneurial firms.10

While job competition is good to spur interest in STEM careers and to drive up salaries, from the point of view of national interest, the stresses on the workforce (and the hundreds of small businesses that provide the A&D backbone in this country) are increasing, creating “talent gaps” in some critical fields ranging from IT to manufacturing talent—all of which are needed in space. Reorienting and revitalizing human capital processes, increasing investment in trade schools, and even embedding space into higher education curriculums in non-traditional fields are among the means to help address the growing workforce development issue.

The Near Future: Artemis and the Moon

Addressing funding, acquisition, and workforce development and diversity are fundamental to get to where we are going—which is to the Moon and then to Mars. As pointed out by the Committee on Human Space Exploration of the National

---

7 http://exploredeepspace.com/multimedia/coalition-statements/2018-02-22/
8 https://www.brookings.edu/blog/brown-center-chalkboard/2017/04/07/what-international-test-scores-reveal-about-american-education/
Academies, upon which I served, there are many roads the United States and its industry and international partners may take to create a sustainable presence beyond low Earth orbit. The “Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration” report (herein after referred to as “The Pathways Report”),11 published in 2014 after two years of study and debate, described several sequences and risk postures for NASA’s human exploration program but leaned heavily toward the Moon as an initial destination. The Pathways report also advised Congress and NASA to focus on “feed forward” development—that is, to maximize the potential for a sustainable approach by designing in readiness and flexibility. Among other means to achieve this design philosophy is to develop capabilities that can be deployed over decades.

Space Policy Directive-1, signed by President Trump in late 2017, is in alignment with the NASA Authorization Acts of 2008, 2010, and 2017 in its call for NASA to “lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities.”12 While the Administration’s target date of 2024 for the Artemis Lunar Landing-1 mission has injected some much-needed urgency into NASA’s planning and programs, one danger of shifting our focus from developing a longer-term capability to focus on a near term date is that we may inadvertently sacrifice flexibility and capability for the sake of meeting a short-term mission objective.

In military science, a major area of endeavor is to find methods to achieve missions that may not have been understood when systems were under development, using those capabilities that have since come on line both as intended and by exercising new concepts. With regard to deep space exploration, NASA plans to achieve flexibility at the moon by constructing a lunar orbiting station known as Gateway in partnership with industry and with international partners. Gateway is not, as some have stated, a waste of money or an unnecessary way station. Instead, Gateway is a component of a larger architecture that increases feed forward opportunities. The Gateway greatly simplifies our ability to aggregate hardware in the vicinity of the Moon—that is, to provide a central hub for docking, brief habitation, emplacement of consumables, descent and ascent vehicles for transportation to the lunar surface, transfer vehicles, etc. It is true that these can be aggregated in orbit without a Gateway; however, the transportation model becomes more complex and the timing less forgiving.

For example, without a Gateway, lunar sorties with humans are limited to four days due to the 21-day mission profile for the Orion crew vehicle. With the Gateway, crew are not solely dependent upon Orion’s systems but can rely on habitation and access to consumables that are present at the Gateway, enabling longer missions on the surface. In addition, over time the Gateway will enable in-space reusability by serving as a docking and refueling hub, greatly simplifying transportation requirements over time.

Longer surface missions in turn will enable a variety of activities to be undertaken by a variety of participants. Entrepreneurial firms are teaming with investors and also with established companies to develop technologies aimed at building up infrastructure on the Moon, making use of lunar regolith as raw material as one example. With regard to science, there is still a great deal to learn. The Moon has been called “The Rosetta Stone”13 of the solar system, with evidence locked within that has already taught us a great deal about the formation of the Earth-Moon system but also has implications for outer bodies. We have explored only 5 percent of the surface; there is a great deal more to learn.

Finally, Gateway is the next logical step in developing a command and logistics capability that is extensible not just to the Moon but beyond the Moon toward Mars. The Gateway itself is a prototype, and evolution of lessons learned over the past 50 years and in particular from the International Space Station to create habitable space and systems to support human life and work in deep space. As the Gateway evolves, it provides an opportunity for broader international and industry participation and utilization, providing options for continuing deep space development that do not necessarily depend upon descending to the surface.

---

11 https://www.nap.edu/catalog/18801/pathways-to-exploration-rationales-and-approaches-for-a-us-program
Our Horizon Goal: Mars (and Beyond?)

The Moon is an important stepping stone with geopolitical, scientific and the potential for commercial benefits. It is entirely possible that some of us will remain there for decades—for example, experimenting with in situ resource utilization (ISRU) technologies, conducting science, or seeking to extend our terrestrial economy to incorporate utilization and capitalization of resources found on or below the lunar surface. What we learn there will not only create opportunities in cislunar space but open new discoveries and knowledge that will help us as we look toward Mars. The Moon is not an end goal, but a beginning—a next step enabling the migration of technology, heavy industry, and humanity itself off the Earth and into the solar system at a scale that is no longer constrained by a single planet, our original home.

The Pathways report concluded that Mars is the “horizon goal” for the human exploration of space, the destination upon which the aspirations of all international space programs converge, and the farthest viable destination for human beings given foreseeable advances in technology. It is essential that this be an international effort, led by the United States in collaboration with others. The International Space Station has taught us that a multilateral enterprise such as Mars will bring forth intellectual capital, scientific abilities, research, engineering and interest in peaceful technology on the part of many nations. An international human Mars program, led by the United States, will build and expand on the foundation created by the ISS as well as lessons learned at the Moon.

At the same time, pushing further into deep space than humans have ever gone before offers the potential for technology breakthroughs—just as it did 50 years ago—unleashing American industry and investment in new and powerful ways. The fundamental barriers and challenges to planning and executing all large-scale enterprises—exploring space, mitigating climate change, controlling disease, or managing the rising global demand for clean water—are similar, whether on Earth or in space. Two of the most important needs in space—the availability and processing of water for life support and eventually propellant, and energy needs—obtaining, storing, managing, and transmitting energy or power—have direct relevance to many problems facing today’s world. With thought and proper planning, technology opportunities and challenges on the Moon and particularly at Mars with the constraints imposed by its vast distance from Earth can find natural alignment with many of humanity’s most pressing terrestrial problems.

In Closing . . .

Perhaps most importantly, our Nation needs the next generation of young scientists and engineers to advance our quality of life and remain globally competitive. The citizens of the United States also need a far better understanding of science and technology in order to exercise fully the rights and responsibilities of citizenship. The very future of our democracy depends on it. Nothing stimulates interest like truly great goals that require us to develop ourselves and advance the human condition as well as our technology in order to achieve them. Continuing the work begun with Apollo, returning to the Moon, and then reaching for the horizon of Mars, is just such a goal.

Senator Cruz. Thank you, Dr. Dittmar.
Mr. Hickam.

STATEMENT OF HOMER H. HICKAM, JR., AUTHOR, ROCKET BOYS

Mr. HICKAM. Good afternoon, Chairman Cruz, Ranking Member Sinema, and Members of the Subcommittee, with a special shout-out to Senator Capito from my home state of West Virginia, who’s probably thinking to herself, “Oh, my gosh, what’s Homer going to say now?” [Laughter.]

Mr. HICKAM. What Homer’s going to say now is that I believe most firmly that our destiny lies at the Moon. We need to go back to the Moon. We need to put an anchor there and from that anchor develop the Moon commercially and scientifically.
One of the stories left out of the movie *October Sky*, which was based on *Rocket Boys*, was the fact that I met Senator John F. Kennedy when he was running for President in the West Virginia primary that he had to win, and since I was a rocket boy headed toward the National Science Fair, he asked me what we should do in space, and I answered Senator Kennedy. I looked around at all the coal miners in the crowd and I said, “Well, I think we should go to the Moon and just mine the blame thing,” and all the coal miners, they just laughed and cheered, and he said, “Elect me President and maybe we will.”

Most recently, one of my books called *Back to the Moon*, Vice President Pence told me that that’s one of his favorite books and we talked at length and extensively about that. The next thing I knew, he was down in Huntsville, Alabama, at the Space and Rocket Center, at Space Camp, saying, “We’re going back to the Moon by 2024.”

So I’m kind of in the unique position of being able to take credit for both the Apollo——

[Laughter.]

Mr. HICKAM.—and the Artemis Space Program.

I do, I really do advocate going back to the Moon. There’s a lot of work to do there. There are decades of work yet to be done.

Where was I when Apollo 11 landed? I was in the hospital ward at Ft. Lewis, Washington, with some fellow veterans of the 4th Infantry Division, and we watched the Apollo land. At that point, even though my mind had been occupied a great deal by Vietnam and all of that struggle, I realized I really wanted to work for NASA. I was going to make that happen.

It took me a while. 1981, when the shuttle started to fly, I got to work for NASA and I loved it. I woke up every morning and said to myself, “Oh, my goodness, this is great, I get to go work for NASA today.” It’s a tremendous agency and I absolutely loved it.

Well, here we are and what are we going to do? Well, Mark Twain once said, “God looks after fools, drunks, and the United States of America,” and that comment was never more apt than the way our space program has evolved. Modern American industry is now moving forward in space in astonishing ways and just SpaceX and Blue Origin are just a couple of those bright new companies that are coming up. They’re able to come up with new designs and be more timely and create much less expensive ways to get in space. They’re even beating out the heavily-subsidized space programs around the world, like China’s. So we have every right to be proud of that.

Why are they able to do that? Because of a number of parallel forces. They include modern computer systems, the rise of the internet, new manufacturing techniques, and along other parallel lines, we see a demand for clean and abundant energy and awareness that Earth is in danger of being permanently polluted, and the gradual development of a new philosophy that seeks to put mankind in context with the universe.

As all engineers know, parallel lines never intersect until they do. These parallel lines of force I just mentioned intersect primarily at one place; our Moon, Luna, the small planet that circles us, our 8th continent, torn from the Earth a millennial ago, and so it is
at this moment given to us by the benevolent hand of Creation that all of the elements needed to go back to the Moon and set up shop have come to us so as to utilize its mineral wealth and discover all that is there. And this includes, by the way, the possibility of evidence of life.

We've never looked at a single water molecule from space. We're going to find a lot of water ice on the Moon and in there might be evidence of life because the Earth and Luna have been sharing DNA for millions of years because of meteors and asteroids, sort of God's little space program. It didn't work out for the dinosaurs but it may work out for us.

In summary, I applaud the essentials of the Artemis Program to take us to the Moon, but I do say so with this proviso, that what we do on Luna must make sense to the American people both economically and philosophically, and should be designed in such a way that it may cost the people's money to place an anchor there but not so forever in order to sustain our presence.

The riches on the Moon, rare earth medals, thorium, titanium, helium3, and other minerals, should be gathered to boost our economy and thus put money in the pockets of all Americans. Our citizens should be assured that a base on the Moon will make this country stronger and safer, and I have to say I don't really much care who the next professional astronaut on the Moon is. What I care about who the next American plumber, electrician, construction worker, and blue collar worker on the Moon because when that happens, we know that we are finally a space-bearing nation.

Thank you.

[The prepared statement of Mr. Hickam follows:]

PREPARED STATEMENT OF HOMER H. HICKAM, JR., AUTHOR, ROCKET BOYS

Good afternoon, Chairman Cruz, Ranking Member Sinema, and members of the Subcommittee: It is a privilege to come before you today to speak on this vital topic during an exciting and dynamic new era of space flight that I hope will result in a permanent American anchor on the moon.

You may know me as the fellow who wrote the #1 New York Times best-seller Rocket Boys: A Memoir which told the story of some boys in the West Virginia coalfields of the 1950s who were inspired by Sputnik to build rockets. As you may also know, they made a movie titled October Sky based on that memoir which is still shown everywhere, especially in classrooms. That book and film has inspired many tens of thousands of young people to become engineers and/or work in the space business. For a West Virginia boy, son and grandson of coal miners, this is the most pleasing result possible for my work.

It should be noted that I have long been an advocate for a permanent American presence on the moon. This goes back to 1960 when I encountered then-Senator John F. Kennedy in McDowell County, West Virginia. At the time, I was 17 years old and heading for the National Science Fair with my rocket designs. He was running in the West Virginia primary for the Democratic nomination for President, a primary he had to win. After one of his speeches, he asked for questions and I asked him what he thought we should do in space. This was not a question I believe he expected in the coalfields and so he asked me what I thought we should do and I said we should go to the moon. Then, looking around at the coal miners in the crowd, I said we should just go up there and mine the blame thing. The miners cheered at this and Kennedy joined in, saying, "Well, elect me president and maybe we will!" He won the primary. It is why—very wryly to be sure—I sometimes take credit for the entire Apollo program although I know he was much more influenced by others such as Wernher von Braun.

It was my boyhood dream to get into the space business. However, this dream took awhile to happen. There are moments in our lives that beg the question: "Where were you when?" Such moments include the landing on the moon of Apollo 11. For me, I was in a hospital ward at Fort Lewis, Washington to watch the land-
all the elements needed to go to the moon and set up shop have come to us so as might sustain that life for centuries to come. Our friend in the sky without which life would not have evolved on Earth and now small planet that circles us, our eighth continent torn from the Earth millennia ago, lines of force I just mentioned intersect primarily at one place, our moon—Luna, the universe. A new philosophy that seeks to put humankind in context within the universe, awareness that Earth is in danger of being permanently polluted, and the gradual development of a new philosophy that seeks to put humankind in context within the universe.

A number of parallel forces that include modern computer systems, the rise of the Internet, new manufacturing techniques and materials, and the imaginations stirred by popular science fiction films and books. Along other parallel lines, we see a demand for clean and abundant energy, an awareness that Earth is in danger of being permanently polluted, and the gradual development of a new philosophy that seeks to put humankind in context within the universe.

As all engineers know, parallel lines never intersect—until they do. Those parallel lines of force I just mentioned intersect primarily at one place, our moon—Luna, the small planet that circles us, our eighth continent torn from the Earth millennia ago, our friend in the sky without which life would not have evolved on Earth and now might sustain that life for centuries to come. And so it is at this moment given to us by the benevolent hand of Creation that all the elements needed to go to the moon and set up shop have come to us so as
to utilize its mineral wealth, and discover all that is there. This includes the possibility of the evidence of life in the water ice that we now know is so abundant there; for it is well known that the Earth and Luna have been sharing their DNA for billions of years through meteor and asteroid strikes which might be called God's space program. Our rendezvous with destiny on the moon is at hand.

Let me briefly speak of Mars. It is my belief that Mars, which is often mentioned by NASA officials and others as the ultimate destination for its astronauts and the moon only a stop on the way, should stay in the future for now. The truth is the technology to go there doesn’t yet exist and for the blood and treasure it would take to put humans there, we could place thousands of robots on its surface and eventually artificial intelligence. Mars is interesting scientifically but it’s the moon that should be our focus for the next several decades because, not only is there yet some great science to be done there, Luna has the potential of creating an economic powerhouse for our country and the world.

In that regard, I have to say I have little interest on who the next professional astronaut on the moon might be. My interest is who will be the first plumber, electrician, miner, or construction worker because when our blue collar workers arrive on the moon, we will truly and finally be a spacefaring nation and see all of our citizenry fully engaged in this magnificent adventure.

In summary, I applaud the essentials of the Artemis program to take us to the moon but I do so with this proviso, that what we do on Luna must make sense to the American people both economically and philosophically and should be designed in such a way that it may cost the people’s money to place an anchor there but not to forever sustain our presence. The riches on the moon—rare earth metals, Thorium, Titanium, Helium-3, and other minerals—should be gathered to boost our economy and thus put money in the pockets of all Americans. Our citizens should also be assured that a base on the moon will make this country stronger and safer while also gathering knowledge for all the world so that humanity might rise above the immaturity evidenced by our endless conflicts, and become, as intended by our Creator, the responsible, mature adults of the Universe we were sent forth to be.

Thank you very much for your time. I look forward to your questions.

Senator Cruz. Thank you, Mr. Hickam, and when you invoked the Twain quote about fools and drunks, I assume most people at home just assumed you were talking about the U.S. Congress.

[Laughter.]

Mr. Hickam. No, sir.

Senator Cruz. Mr. Stallmer.

STATEMENT OF ERIC STALLMER, PRESIDENT, COMMERCIAL SPACEFLIGHT FEDERATION

Mr. Stallmer. I have a tough act to follow. Homer was there to inspire the Apollo Program. I wasn’t even born for Apollo 11. So you raised the bar quite a bit.

Chairman Cruz, Ranking Member Sinema, and Distinguished Members of this Committee, thank you for inviting the Commercial Spaceflight Federation today to discuss how rapid advances by U.S. commercial space industry can help NASA truly honor the Apollo legacy by leading humanity into the Solar System further and faster.

In the past two years, NASA has crystallized an ambitious agenda to commercialize low-Earth orbit, establish a long-term presence on the surface of the Moon, and send humans to Mars. These goals are all linked together and collectively they will enable an expansion of our civilization in the Solar System.

It is the breadth of this vision of space as a frontier for all that makes the recent emergence of the strong U.S. commercial spaceflight industry so uniquely valuable. It didn’t just happen overnight.
For two decades, NASA has fostered the development and increasing success of this industry, sharing technologies and expertise, co-investing in private innovation and using its purchasing power to serve as an initial customer.

Those steps have enabled private companies to develop, own, and operate their own human spaceflight hardware to serve the public needs as well as the private sector markets.

These efforts were established in NASA’s mandate to seek and encourage, to the maximum extent possible, the fullest commercial use of space, as well as the bipartisan legislation and administrative policies under both Democratic and Republican presidents.

Over just the past two years, Space Policy Directives 1, 2, and 3 have strengthened this partnership between government and industry and helped remove barriers to industry growth, and under your leadership, this Committee has worked to facilitate industry’s development via the Space Frontier Act. We thank you.

At the start of the Space Age, the United States established its leadership in space with government-funded and led exploration projects. When President Kennedy proposed sending an American to the Moon, there were no alternatives to the all-government strategy.

But today, five decades after Apollo, the United States is enjoying a renaissance in space with commercial space enterprises playing a leading role. The details are in my written testimony but in summary, the U.S. has leapt forward in 2018 in every commercial space sector with more launches, more spacecraft pursuing both old and new space applications benefiting more and more stakeholders here on Earth.

So today, as we seek to further develop low-Earth orbit, place an enduring American presence on the Moon and sending not just two but many brave pioneers to Mars, policymakers like yourself have newer, more affordable, and sustainable options than just repeating Apollo.

The ingredients of a successful strategy have proven themselves over and over in recent years. Future LEO infrastructure, every operational element of returning to the Moon, and most of any affordable Mars architecture should be purchased commercially or developed via COTS-like partnership.

For example, allowing the private sector to develop its own solution for the Lunar Gateway Power Propulsion Element, NASA was able to generate a fixed price bid that was more than $200 million less than the closest competitor.

While science is appropriately a government-led activity, the basic engineering and infrastructure that supports it can be provided commercially with only the leading edge tools and instruments required by government stewardship.

NASA should specify clear high-level outcome-based requirements and allow entrepreneurs to innovate and create affordable and basic capabilities to meet essentially all the operational needs, and NASA must pay for results, not effort, on all developmental programs but the most esoteric technical challenges.

Whenever possible, NASA should award multiple competitively chosen funded Space Act agreements to commercial partners willing to put up private capital at their own risk. That leverage, plus
ongoing competition, will replace any need for the costly micro-
management and bureaucracy of typical FAR-based contracts.

Competition also allows for greater diversity in technical ap-
proaches and much lower strategic program risk. None of this will
be easy. Commercializing low-Earth orbit will be hard. Human
travel to the Moon is hard and staying there will be even harder.
Mars will be harder still but with even greater rewards as we ex-
plore a different planet and its moons.

But American industry is ready to help NASA chart an afford-
able and sustainable path into this challenging future.

This month, it’s natural to venerate the past, but we should also
be proud of the great new things we are achieving today and what
we can do together tomorrow if we build a true partnership be-
tween government, including Congress, and the American people
on their enterprise.

Chairman Cruz, Ranking Member Sinema, thank you for your in-
vitation and attention. I look forward to your questions.

[The prepared statement of Mr. Stallmer follows:]

PREPARED STATEMENT OF ERIC STALLMER, PRESIDENT,
COMMERCIAL SPACEFLIGHT FEDERATION

Chairman Cruz, Ranking Member Sinema, and distinguished members of the
Committee—thank you for inviting the Commercial Spaceflight Federation (CSF) to
discuss our members’ views on the state of the U.S. commercial space industry. We
also appreciate the opportunity to honor the 50th anniversary of Apollo 11 by look-
ing at NASA’s exploration plans and examining how our past experiences and les-
sions learned can guide space exploration efforts going forward. In addition to
NASA’s world-leading space exploration capabilities, the United States now has a
vibrant, highly capable commercial space sector that can accelerate and complement
NASA’s internal development efforts. As we look to the future, true public-private
partnerships between this domestic industry and the Government represent the
most effective path to rapidly, safely, and cost-effectively return to the Moon and
venture on to Mars.

CSF is the leading national trade association for the commercial space industry,
with more than 85 member companies and organizations across the United States.
Founded in 2006, CSF is focused on laying the foundation for a sustainable space
economy and democratizing access to space for scientists, students, civilians, and
businesses. CSF members are responsible for the creation of thousands of high-tech
U.S. jobs driven by billions of dollars in investment. Through the promotion of tech-


mmercial space industry development, most recently with its efforts on the Space Frontier Act.

Today, I will outline CSF’s perspectives as to how we all can collectively advance our Nation’s space goals through innovative, strategic partnerships with American industry.

I. America’s Vibrant, Highly Capable Commercial Space Sector

The United States established its leadership and dominance in space with government-funded and government-controlled space exploration.1 When President Eisenhower founded NASA and President Kennedy outlined a goal to send Americans to the Moon, there was no other choice; NASA literally had to invent whole new fields of technology, not just new hardware. The agency’s accomplishments are a marvel for the ages, progressing from sending an American into space for the first time in 1961 to landing a crew on the Moon just eight years later.

Thanks in large part to NASA’s leadership, pathfinding, and partnerships with the private sector in the decades since, a broad and dynamic space industry has emerged. Since 2000, investors have supported 375 private space companies with nearly $19 billion of private capital.2 As NASA continues to drive the frontier outward with groundbreaking research in space, the commercial sector is making space affordable and accessible to everyone.

Today, the United States is enjoying a renaissance in space, with commercial space enterprises playing a leading role. To update the Committee on the commercial space industry’s recent major milestones:

• Last year, U.S. commercial space companies achieved an unprecedented 32 licensed orbital and suborbital launches as well as 14 licensed reentries. SpaceX conducted the majority of those licensed activities, with 21 launches and 12 first stage landings. American commercial providers of medium-to-heavy lift launch services now represent a supermajority of global commercial launches each year.

• Over the past several years, there has been a surge of progress from dedicated small orbital class launch vehicles. In 2018, Rocket Lab conducted the first successful launch of its Electron rocket. Rocket Lab has already launched three more times in 2019, orbiting 35 satellites—including two for U.S. Special Operations Command. Relativity Space is building an autonomous rocket 3D printing factory in Mississippi, expanding capabilities at NASA’s Stennis Space Center. Vector Launch and Vox Space (a Virgin Orbit subsidiary) have been selected to compete for DARPA’s Launch Challenge. And, Virgin Orbit has completed several captive carry tests of its LauncherOne vehicle attached to a 747 aircraft in preparation of flights to space in the near future.

• A growing number of companies are restoring and expanding America’s human spaceflight capabilities. This year SpaceX—in close partnership with NASA—will launch American astronauts to space in an all-American system, ending the country’s drought on orbital human spaceflight capability left by the retirement of the Space Shuttle in 2011. Already, SpaceX and NASA conducted a successful flight qualification mission of the Crew Dragon spacecraft in March. Virgin Galactic successfully launched three spaceflight participants on its spacecraft—SpaceShipTwo —into space for the first time, reaching an apogee of 51.4 miles. Blue Origin has conducted a series of uncrewed suborbital test flights on its New Shepard vehicle and plans to conduct a test flight with crew soon. Both companies plan to fly spaceflight participants to space for revenue by the end of the year.

• American companies continue to make significant progress commercializing the International Space Station (ISS) and LEO.

○ Sierra Nevada Corporation’s (SNC) Dream Chaser spacecraft—in an uncrewed cargo configuration—passed a key milestone in its development to be the third commercial cargo vehicle for the International Space Station.

○ Nanoracks has supported more than 750 payloads at the ISS to-date and has deployed 243 satellites through a commercial dispenser, in partnership with NASA. The company is also building the first-ever commercial airlock, designed to be integrated with the ISS in the coming years.

---


2 Proprietary Data, Space Angels, September 30, 2018.
The ISS National Lab has facilitated more than $150 million in external, non-NASA funding to support the full ISS National Lab portfolio—a 50 percent increase in FY18.

Axiom and Bigelow are developing commercial space habitats, and each has made major technical progress over the past year.

Made In Space, TechShot, and Space Tango continued to demonstrate additive manufacturing and other interesting commercial applications in microgravity.

- Planet, Blacksky, and Maxar Technologies deployed dozens of new commercial remote sensing satellites to orbit.
- Southwest Research Institute (SwRI), University of Colorado, Boulder, and Maxar Technologies were selected by NASA to build three new lunar science and technology payloads to fly on future flights through NASA’s Commercial Lunar Payload Services (CLPS) project. NASA selected three commercial Moon landing service providers that will deliver science and technology payloads via the CLPS as part of the Artemis program.
- The first licensed flights to space of two American suborbital reusable launch vehicles: Blue Origin’s New Shepard and Virgin Galactic’s SpaceShipTwo. I emphasize the word licensed, because a license allows the company to earn revenue from the flight, unlike an experimental permit.
- World View performed its longest flight to date of its stratospheric balloon, demonstrating its ability to carry out missions traditionally reserved for satellites.
- And, in May, NASA has entered into partnerships with 11 companies—including CSF members Blue Origin, SpaceX, Sierra Nevada, and SSL (a subsidiary of Maxar Technologies)—to conduct advance development on human lunar lander concepts.

These recent achievements are just a few of many by the commercial industry, and they set the stage for even greater accomplishments the rest of this year and beyond for a broad set of stakeholders.

II. Apollo 50th: Partnerships with Commercial Industry are Fundamental to Achieve a Sustainable Return to the Moon

50 years after Americans first stepped on the surface of the Moon, President Trump, NASA and Congress have established a national commitment to return Americans to the Moon—not just to plant footprints and flags, but to establish long-term habitation and sustainable activity on the lunar surface. This will provide the spaceflight community a valuable proving ground for NASA’s goal of sending astronauts to Mars.

This ambitious objective should be applauded and, if executed appropriately, will serve to reinforce American leadership in space as international competitors like China, Russia, and India focus their own exploration efforts on the Moon. In January 2019, China achieved a major milestone in its lunar space exploration program, landing the Chinese space agency’s Chang’e-4 spacecraft on the far side of the Moon for the first time in history.3 This achievement builds on the China’s 2013 success of landing its first rover on the Moon, joining the United States and the Soviet Union as the only nations to have carried out a soft landing on the Moon. In September this year, India hopes to become the fourth country to soft land on the Moon.4 The United States should ensure it remains the leader in space exploration—and private industry is here to help.

Long-term, sustainable exploration on the lunar surface, and ultimately Mars, requires an integrated effort that includes the development of capable landers, the operation of robust deep space habitats, and routine transportation of astronauts and large cargo. Public-private partnerships with commercial companies are fundamental to developing these capabilities. NASA’s Fiscal Year 2020 budget request and budget amendment prudently highlight partnerships with commercial providers as a key tenet of this strategy.

Undeniably, the systems that brought Americans to the Moon during the Apollo program were and remain a marvel. But, as we consider our options for the future, we should look not only to technologies of the past, but to the new advancements of today. CSF companies are proud to be playing a role in this new era.

III. Flexible COTS-like Development Agreements and Firm, Fixed-priced Services Contracts

These capabilities are already helping to support NASA’s exploration goals, and they will continue to support NASA as it works to return to the Moon. As this Committee begins to help ensure the country’s ongoing leadership in space, it must carefully review development and acquisition efforts to ensure responsible use of finite taxpayer dollars and to encourage, rather than hamper, rapid innovation.

True commercial partnerships for development and operation of some elements of the exploration architecture represent the most rapid and cost-effective path to return to the Moon. By even the most conservative independent evaluation, the COTS Commercial Cargo public-private partnership saved the agency hundreds of millions of dollars and allowed NASA to redirect those savings towards funding its other priorities, including earth observation and deep space exploration.

A 2014 NASA report further praised the program’s use of innovative, flexible Space Act Agreement (SAA) development arrangements: “Because these were partnerships, not traditional contracts, NASA leveraged its $800M COTS program budget [for both providers combined] with partner funds. This resulted in two new U.S. medium-class launch vehicles and two automated cargo spacecraft and demonstrated the efficiency of such partnerships.”6 A 2017 NASA Cost Analysis review was more direct: “the COTS development and later the operational Commercial Resupply Services (CRS) are significant advances in affordability by any measure.”6 Simply put, this approach works.

As NASA looks to define a development and acquisition approach for its lunar lander and habitat systems, it should adopt a COTS-like structure that would:

• Leverage the commercial industry’s ability to innovate quickly, improving safety and reliability. The sector’s high cadence of development and test-like-you-fly approach provides for far greater system maturity than relying purely on simulations and ground tests. This approach was what NASA followed during the Apollo era, and it should return to its roots.

• Establish clear, high-level, milestone-based requirements that enable creative, innovative, and cost-effective solutions and avoid overly-specified and ever-changing Government requirements. This structure forces the Government customer to get the requirements right and clearly communicate priorities at program start.

• Use firm, fixed-priced, pay-for-performance, milestone-based agreements that drive toward a successful conclusion and focus on an outcome-oriented commercial service. This commercial structure incentivizes companies to provide the deliverable at the time, place, and price negotiated with the Government, and discourages continuous Government requirement changes that add costs and delay schedules.

• Maximize competition throughout the entirety of the program. Competition is critical to accelerating progress, driving value and performance, and improving the quality of service to the customer. Price competition obviates the need to

---

levy expensive, anti-competitive, non-value added requirements for certified cost or pricing data.

• Require a significant private capital contribution to the overall program. Commercial partners should share costs and provide a significant percentage of the overall investment, resulting in lower costs to the Government and enabling it to stretch its budget further.

• Tolerate programmatic risk and allow easy termination for failure to meet early requirements. The Government needs the flexibility to terminate contracts and cut bad actors when programs go far over budget and behind schedule.

• Encourage new, non-traditional companies to work with NASA. Traditional FAR-based contract requirements are complex and costly, which often detours small, less-experienced companies from working with the Government. As a result, the Government is often not at the cutting edge of new commercial technology offerings. The use of COTS-like contracts can help enable such companies to do business with the Government.

• Facilitate the development of new markets and leverage market-driven pricing to support Government requirements and missions.

Not only must NASA plan prudently to save money, it likely must also anticipate and plan for funding levels below its requests to Congress, due to budget issues entirely unrelated to the agency. Indeed, NASA is already anticipating and planning for such a scenario.

When faced with budget shortfalls, NASA often attempts to make up for the shortfalls by: 1) drawing funding one part of the agency to pay for another part of the agency; and 2) deferring, de-scoping, or discontinuing lower priority programs and activities within the agency. Both options are demonstrably bad choices and lead to even worse results for the agency—undermining support for the Moon initiative, destabilizing other programs and missions, and leading to increased costs and schedule delays across the agency. Instead, the Committee should encourage NASA to follow a third way that avoids these pitfalls: public-private partnerships.

True commercial partnerships for development and operation of some elements of the exploration architecture represent the most rapid and cost-effective path to return to the Moon. Pay-for-performance creates the proper incentives on both sides of the Government/company relationship. Here, the GAO has reported: “[f]irm-fixed-price contracts place the onus on the contractor to provide the deliverable at the time, place, and price negotiated by the contractor and the government. In addition, firm-fixed-price contracts place the maximum risk on the contractor as well as full responsibility for all costs and any resulting profit or loss.”

To succeed, NASA must employ fast, flexible, lean contracting agreements like SAAs to incentivize rapid and affordable development of U.S. transportation and habitat systems to safely land humans on the Moon by 2024.

IV. Lessons from Apollo: Constant Innovation and an Eagerness to Test New Concepts

By any accounting, the Apollo program represents humankind’s greatest and most inspirational technological achievement. It was an enormous undertaking, costing about $177 billion in 2019 dollars. Only the building of the Panama Canal rivaled the Apollo program’s size as the largest non-military technological endeavor ever undertaken by the United States and only the Manhattan Project to build the atomic bomb in World War II being comparable in a wartime setting. As we honor the 50th anniversary of Apollo 11, CSF commends the Committee for examining how our experiences and lessons learned can guide space exploration efforts going forward.

Several important lessons from Apollo need to be remembered and should guide space exploration efforts going forward. Iterative, evolutionary, and risk-tolerant development was the cornerstone of NASA’s Apollo-era progress:

• From 1958 to 1963, the Mercury program conducted twenty uncrewed development test flights, and six successful flights with astronauts. Mercury’s early uncrewed test flights helped NASA find and fix problems. For example, of the

---


9 https://history.nasa.gov/Apollo/11/Apollo.html
twenty uncrewed test flights, half of the flights resulted in failure or partial success. But, the agency learned how to put astronauts in orbit around Earth. It learned how people could live and work in space, and it learned how to operate a spacecraft in orbit.

- Following Mercury, during a 20-month span of the Gemini program from March 1965 to November 1966, NASA flew ten Gemini crews to Earth orbit, each testing new capabilities in preparation for the landing on the Moon.
- And, of course, Apollo followed these programs. From 1961 to 1966, NASA launched increasingly capable iterations of the Saturn rocket 14 times to learn valuable insights into the complexities of building and launching a large cryogenic system so that, before the decade was out, they had the capability to land people on the Moon.

The Apollo-era attitude that enabled NASA to land on the Moon 50 years ago was based on constant innovation and an eagerness to test new concepts. These are the same principles that underpin the success of the commercial spaceflight industry today. For example:

- Small-, Cube-, and Nano-Satellites are increasingly effective and efficient platforms for remote sensing and communication applications, and commercial providers developing and operating these systems are revolutionizing the satellite industry.
  - From 2013 to 2018, Planet, an Earth imaging company, launched nearly 300 satellites into orbit, 150 which remain active. Combined, they constitute the largest constellation ever put into orbit.
  - Planet is not alone, companies like Advanced Space, Amazon, Arianespace, BlackSky, Maxar Technologies, and SpaceX are each developing their own systems, with SpaceX launching the first 60 satellites of its Starlink broadband constellation this past May.
  - Thanks to the advances by the commercial space industry, NASA is now utilizing these platforms to augment and support the scientific investigations carried out by the agency’s larger flagship missions.
- Suborbital reusable launch vehicles are providing low-cost and frequent access to suborbital space for humans and research payloads that are contributing to NASA’s science, exploration, and technology development missions. During a six-month span from December 2018 to May 2019, Blue Origin and Virgin Galactic flew to space and back four times, carrying 54 research and technology payloads, 24 of which were NASA-sponsored payloads testing new capabilities for the agency.
- The commercial industry has established and self-funded the world’s first marketplace of diverse reusable rockets, both suborbital and orbital, which successfully launched for commercial and government customers.
- Commercial landers: successfully hotfired large lander engines, which have been under development for several years, and exclusively developed with private capital;
- Commercial heavy lift: successfully launching the world’s most powerful operational rocket by a factor of two, exclusively developed with private capital; and successful test-firings of large methane rocket engines and development of heavy lift launch vehicles;

The need for flexibility serves as another important lesson for Apollo. For example, NASA was the was the first Federal agency to be granted Other Transaction Authority (OTA) in the 1958 Space Act, in order to provide NASA with the full flexibility to beat the Soviets in the space race to the Moon.10 Now, as then, NASA must adapt when new technologies and architectural approaches are introduced.

V. Conclusion

With the technological advancements and increased knowledge achieved through decades of work by NASA in deep space, including Mars, the United States is now

---

10“This was 1958 and NASA was a big deal,” said Ralph Nash, a government procurement law expert and founder of the Government Contracts Program at George Washington University’s National Law Center, where he is a former dean of graduate studies and professor emeritus. “We were in a space race with the Russians and President [John] Kennedy said we would get to the moon in this decade,” he explained. “This was there to give them full flexibility.” See here: https://www.nextgov.com/it-modernization/2018/03/otas-scary-new-contracting-model-isnt-scary-or-new/146964/
well-positioned to build upon and surpass our past achievements in space. With NASA resources and expertise, coupled with American ingenuity, the principles of free enterprise, and the benefits of competition, the United States can do more in space than has ever been accomplished previously. We just need to appropriately recognize and leverage our advantages.

As the Nation commits to returning to the Moon by 2024, it is buoyed by a vibrant commercial space industry powered by agile and innovative development processes, flexibility and some level of risk tolerance, private capital co-investment, and more intensive innovation. In its return to the Moon, NASA does not need to go it alone, nor should it. The most efficient and realistic way of returning to the Moon is a hybrid approach between Government and commercial partners.

Going to the Moon is hard. Staying there is harder, and moving beyond to Mars is harder still. But American industry stands ready. The Commercial Spaceflight Federation supports NASA’s Fiscal Year 2020 budget request and budget amendment to more fully utilize public-private partnership programs and commercial service buys to accelerate cost-effective deep space exploration objectives, including sending landers and astronauts to the lunar surface by 2024.

It is now time for the United States to build on Apollo’s important legacy. To do so, CSF recommends the following:

1. Use flexible development agreements like SAAs for development activities and firm, fixed-price contracts for services;
2. Focus procurement approaches and requirements on an outcome-oriented integrated commercial service rather than a government owned or operated systems;
3. Competitively awarded, firm, fixed-price contract with payment for meaningful deliverables and milestones, not just for effort;
4. Maintain competition throughout—two or more companies should proceed through the flight demonstration phase for each program element and into follow-on service phase;
5. Eliminate Cost Accounting Standards (CAS) when there is competition and fixed price contracting—CAS degrades speed and adds costs without improving contract performance. Fixed-price milestone contracts place risk on the contractor for costs and schedule, obviating the need for cost reporting elements. Cost Accounting Standards also serves as a barrier to entry for non-traditional firms, artificially limiting the competitive pool; and
6. Mirror commercial terms and conditions to the maximum extent. Eliminate all other FAR-derived provisions that are not essential to incentivizing the core outcome.

These are exciting times in spaceflight. We should all be proud of what the American space enterprise—both the Government and the private sector—is achieving. The challenges we face to achieve our goals today are not small, but we have the ability and opportunity to address them in a thoughtful and impactful manner given Congress’ and the Administration’s support.

Indeed, NASA’s budget amendment states that to “achieve our goals, we will not go forward alone,” and “strong commercial partnerships will accelerate our human exploration plans.” We are ready to take that step with NASA, and we look forward to continuing to work with this Committee to the Nation sustainably returns to the Moon and ventures to Mars. Chairman Cruz, Ranking Member Sinema, I appreciate your invitation to testify before the Committee today. Thank you for your attention, and I look forward to your questions.

Senator Cruz. Thank you, Mr. Stallmer. Thank you to each of the witnesses for your testimony today.

As we sit here today reflecting back on the last 50 years and the journey that America has traveled and that space exploration has traveled since that giant leap for mankind, I think it is also appropriate for us not just to look backward but to look forwards and to ask what do the next 50 years hold?

In the year 2069, perhaps our kids or grandkids will be participating in another hearing marking the 100-year anniversary of man landing on the Moon, and so my first question I want to ask the panel is in the next 50 years, what should we hope to accom-
plish in space? What should our objectives be? What should we be looking forward to?

Mr. STALLMER. I think what is paramount is that over the last 50 years, we could have and should have done a lot more. As young people that looked at the Apollo era 50 years ago and said, gosh, we landed a man on the Moon, in 1985, what are we going to do, and 20 years later what could we be doing, and what have we done? We haven't really returned back to the Moon as humans.

I think we really need to accelerate and not think as much the next 50 years but maybe the next 20 years what we can do and I think we have all the ingredients to do it properly.

I think this reinvigorated look to the Moon, to the exploration, to setting up a base on the Moon, what Gateway will provide, and the outlook and future vision for what we can do on Mars. I don't think we should focus so far in 50 years, but I think in the next 25 years, when a lot of these young people in this room behind me are coming of age and these engineers that they will have that opportunity to live and work in space and develop the new businesses that are going to help promote—I mean, the global space market right now is a $360 billion industry.

I agree with you that it's going to be a trillion dollar industry, probably within a decade, and we have to look at what are those commercial opportunities that are going to be available in space and that's what excites me.

Mr. KRANZ. I think from my standpoint, we had an excellent plan that was written by Tom Paine. It was probably the most widely distributed plan with participation from industry, commerce, academia, right on down the line. It was called Pioneering the Space Frontier.

I think the key thing that we have to do is establish a plan and stick with it. Since then, there have been at least three other plans. It was interesting in that Pioneering the Space Frontier, Gateway was discussed but never showed up in any of the subsequent plans.

So the question is, is that there's good work out there. What we have to do, I think really this Administration should do to fit into the Artemis plans here, is truly take a look at those plans that have been written and see what parts still are viable, what parts fit together, because you're talking about a direction well beyond the Moon. You're talking about a direction for the future and this plan was really—the Pioneering the Space Frontier was a 50-year plan, I believe. I think it's worthwhile to address.

Senator CRUZ. Mr. Kranz, in your testimony, you stated that you don't see the same national unity that we saw in the 1960s that led to the successful Apollo Program.

Mr. KRANZ. Yes.

Senator CRUZ. Can you elaborate on that——

Mr. KRANZ. Well, this——

Senator CRUZ. —and what we need to do to achieve that unity once again?

Mr. Kranz. I could talk for hours on this. I've finished writing a book. I don't know if it'll get published because I've addressed my perspective of the agency and our work in space since the time I joined back in 1963 through actually the first four decades. It was very influential from my standpoint.
I was trying to figure out why—I was director of Mission Operations for a while and why we got such confusing change of plans, directions, right on down the line. Aaron Cohen in the oral history described the period after Challenger as the time worse than chaos. He was one of the center directors. He’d been up at headquarters. That was his part of his oral history.

Dick Truly did the same thing. He talked about rough seas, steadying the course. So it’s really a question that I go back into the leadership focus that we need within the agency but it starts at the very top and says this is what we’re going to do.

What I want you to do is give me a set of plans to accomplish that objective. I’ll work with you to pick the people but we need to find leadership. We ought to go to the—you know, when I was growing up in space, we had very competitive industries. We had incredible aircraft and aerospace industry in there. We were able to get people from McDonnell Aircraft, John Yardley to come down and show us how to start a program and get it started. He was teaching us the business of program management.

Dale Myers came in, the same thing. I hated the Falcon telcons, but they were places where we learned the business from the professionals of the business. So I think the key thing is the future is there. A lot of the plans are there. We have to establish which plan we’re going to subscribe to and get on with it and then find the leaders to implement it.

Senator Cruz. So final question. In your judgment, what are the benefits to Americans of returning to the Moon and establishing a sustainable habitat on the Moon? Mr. Hickam, you addressed this already.

Mr. Hickam. Yes, you know, I was raised in a little town of Coalwood, West Virginia, and in places like Coalwood, bituminous coal was brought up in the early 20th Century that basically fueled the American economy and really the civilization of this country.

So what would I like to see in 50 years? I’d like to see Coalwood on the Moon. I’d like to see families raised on the Moon. I’d like to see blue collar workers, miners, getting money in their pockets and essentially creating a space-based economy because I agree with you; the first trillionaire is going to be from space. The place to go to make that happen is the Moon, and how can we make that happen?

When Mr. Carter who built Coalwood first went in there, he went on the back of a mule but that mule went—first, he got off the railroad, took the mule and him on the railroad to a certain station, then got off of that on a road that was built that took him into Coalwood and there he sunk the shaft and brought up about a million tons of coal.

Then it’s the government’s responsibility, in my opinion, to do very much the same on the Moon. We need to put an anchor on the Moon, a place where people can go, companies can go, countries can go, and from there they can branch out and develop Coalwoods on the Moon and basically cause a real space economy to develop.

Senator Cruz. Well, and I’m looking forward to seeing the space suit that we can fit a mule into.

[Laughter.]

Mr. Hickam. Me, too.
Senator CRUZ. Senator Sinema.

Senator SINEMA. Thank you, Mr. Chairman. Thank you again for your testimony.

My first question is for Dr. Darden and Mr. Kranz. Both of you worked at NASA leading up to and during the Apollo missions and can offer a unique perspective on how NASA achieved its ambitious goal in the 1960s.

What lessons do you believe NASA’s current leadership and workforce can learn from your experiences at NASA during the Apollo missions as we prepare to return to the Moon?

Dr. DARDEN. Well, when I went to NASA, they were two years away from walking on the Moon, I went in 1967, but I think his comments about the leadership, the commitment, and the background that they had in working with the other programs, Project Mercury and Gemini, I think all of those were factors of how these persons pulled together and were committed to making that a successful program, successful project.

Mr. Kranz. From my point, I think that there was the mutual sharing of knowledge. When I first got to NASA, I told you I didn’t know anything about rocket spacecraft, Mercury spacecraft, but I could walk around Hangar S where the spacecraft. I could go down to the Block House, talk to the booster people. I could go over to the Marine Safety people.

So it was a question. There was so much to do and so much to learn that literally everybody spent the entire day telling everybody what they learned and vice versa.

So I think we have to re-establish this passion, the energy, the imagination in our organizations, and I think this starts right at the top in the leadership. I think somewhere along the line our leadership values have sort of been subtly changed. It might be generational to a great extent, but I think the generation I came from, I call it the Apollo generation, the sons and daughters of the Greatest Generation, I think they had a, what I’d say, growing up, born in the Depression.

I think we have to sort of like—we constitute what our Nation is and what it stands for and what we expect from our people. What are the expectations we have for all employees at NASA, Federal Government, right on down the line?

And Mission Control, right after the Apollo 1 fire, which was disastrous, many of us lived through that 18 seconds, but we sat down after we finished and wrote up the searing impressions we had in such a fashion that we would never go through this again and we call it The Foundations. In fact, it’s on the Internet and I get requests for this every day but I’m surprised going to Fortune 500 companies and see it on the wall.

I see the Kranz Dictum where I was angry, passionate, accept responsibility for the Apollo 1 fire. The crew could have called it off. I could have called it off. The touch conductors could have called it, but nobody said stop, it’s not right.

So it’s a question we have to redefine expectations that we have for ourselves, our organizations, our people, and our leadership, and I think it’s there. What we’ve got to do is put it in words. We need to establish some shared values that we’re all working to.
Senator Sinema. Thank you. GAO’s 2018 Assessment of Major Projects at NASA pointed out that more than half of NASA’s workforce is over the age of 50 and 21 percent of NASA’s workforce is already eligible for retirement.

Workforce challenges exist beyond NASA. Since the Shuttle Program ended in 2011, many of the commercial manufacturers and suppliers who had for decades supported NASA missions were left to close up shop and many of the skilled employees who worked to support NASA programs went and found work elsewhere.

So my next question is for Dr. Dittmar and Mr. Stallmer. As the United States prepares again to send Americans into space and return to the Moon, do you believe the current workforce at NASA and its commercial partners is sufficient to support a long-term series of American space leadership?

Dr. Dittmar. So in my written testimony, I did address this to some extent, but let me just sort of recap briefly.

There have been several studies recently that have looked at when people first become interested in going into aerospace and about 71 percent of them become interested while they’re in grade school.

The pressure that you’re describing with regard to people continuing to work, stay in the workforce longer does make it difficult for younger people to enter. At the same time, however, there are terrestrially based activities, IT, computing, advanced artificial intelligence, a number of those, and those high-tech firms, they actually have been attracting for some time some of the best and brightest in the country.

So the situation that we’re facing is we have an aging workforce. We do have positions opening up but a lot of those positions are being competed for by other industries that are very attractive and so as a country, I think it’s very important that we focus on making sure that we continue to provide educational opportunities, that that education is top-notch.

The United States remains in the third, the upper third by almost every measure I’ve seen in the last 10 years, we haven’t moved very much, the upper third of other nations with regard to STEM education. Upper third is OK. It’s better than the lower third, but it’s not where we should be.

So I think a national focus on making sure that our folks are actually prepared to go into this work, continuing development of jobs, both through national programs and through commercial development, I think is very important, so we open up opportunities for people to be able to come into that.

The same is true for science. We underfund science in this country to an extraordinary extent. That’s been noted for the last 20 years, since the Augustine Rising Above the Gathering Storm. Actually it’s a little bit older than that now. I’m getting older than that. And so I think for quite some time, we’ve had a lot of indications that we really need to remain focused on this.

I do think aerospace and defense continue to inspire and I think the sooner we get back to the Moon and start doing some great things on the Moon, the more we’ll be pulling people into these industries, but we need to make sure that they have the basis to come and work.
Diversity also, forgot to mention that, also that's another problem, is that in the last 20–30 years, the face of the workforce really hasn't changed very much and people have worked on it very hard in aerospace and defense and yet it's about the same as it was 40 years ago, yet we know that a more diverse workforce is actually a more competitive workforce. So this is another issue that it's a tough-to-crack but it's one that we need to keep on working on.

Mr. STALLMER. Yes, I think it's a great question and I see it a little differently.

I see NASA as really one of the marquee government agencies. I just traveled to Europe and everywhere you go, people are wearing NASA logo tee-shirts. NASA is a brand. It is an inspirational brand, and I understand the aging workforce issues.

Why I say I see it a little differently, from the commercial companies that I represent, companies like SpaceX and Blue Origin and Virgin Galactic, they can't hire enough people and there's a line out the door for people that want to work for these type of companies, these innovative, cutting-edge companies that are really pushing the envelope in a fantastic way that's really moving the needle for our industries.

We also represent universities. There are two universities in Arizona that we represent, Arizona State University, where we'll be having our next board meeting, and U of A out there, and the programs that they're having, the innovative programs and studies, the space studies programs that they have are fantastic and they're really preparing these students well to go into the workforce.

I caution myself to tread lightly on this next issue, but there is an immigration problem that we have or maybe a visa problem. We're the most generous country in the world. We educate people from all over the world and we give them one of the finest educations, some of the advanced educations, doctorates in aerospace engineers, and we're so generous that we give them a diploma and we also give them a ticket home.

Those are the people that we want to keep, some of the best and the brightest, instead of sending them back to China and India and elsewhere. Let's keep those people. They can help the workforce. As Mary Lynne said, the diversity of the workforce, I think we're making efforts. I'm not going to turn around and look, but I know that this week, there's a program called the Brooke Owens Fellowship Program that gets 36 young women from across the country.

Is there anyone from the Brooke Owens Fellowship Program behind us or alumni? I think there are some here.

But they're all coming into town. There are internships all across the country and I think we're doing a better job of inspiring young women to go into the fields of math and science. We're not there yet, but I think the effort is being made and I see a lot of the companies that I work with trying to advance that, as well.

Senator SINEMA. Thank you all so much. Thank you, Mr. Chairman.

Senator CRUZ. Thank you.

Mr. HICKAM. Can I just add? Just as the Chairman of the Board of the Space and Rocket Center, that includes Space Camp and Space Academy. So I would like to add that we have kind of a shadow space workforce program down there. We've trained hun-
dreds of thousands of young people, including 11 astronauts, all women, by the way, so far. So that program down there completely self-funded is doing a remarkable job of getting young men and women interested in STEM.

Senator Sinema. Thank you. Thank you, Mr. Chairman.
Senator Cruz. Thank you.
Senator Capito.

STATEMENT OF HON. SHELLEY MOORE CAPITO,
U.S. SENATOR FROM WEST VIRGINIA

Senator Capito. Thank you, Mr. Chairman. Thank you to Ranking Member Sinema. It’s great to be here to listen and to see my good friend, Mr. Hickam, here, Homer.

You’d be surprised that West Virginia has a great history of space. We started—we didn’t start but we do have Chuck Yeager, who was quite a wild one and he’s still around. We also had John McBride, who was a commander on the shuttle, and then our mathematician, Katherine Johnson, and then Homer, as well.

I just had the honor of dedicating, renaming the NASA IV&V Center in Fairmont, West Virginia, in honor of Katherine Johnson, and I’ve heard some very much concern today about the next generation, but I’m going to tell you we had about 250 to 300 people there and by far the greatest majority of them were younger people that were so excited to see and, of course, it’s a cross-section of sort of the media and the book but to recognize her and her great accomplishments at NASA over her lifetime.

Roy Lee Cooke was there because we weren’t able to get you to come and Roy was waiting for you but, anyway, he’s doing well. He’s doing well, I report. He was another rocket boy.

The other thing we learned on the Artemis, there was quite a lot of discussion about the Artemis Project because the Administrator was there and did a great job to sort of inform everybody, people don’t know about this. This is a problem, I think. Maybe we’re not tuned into it, but we’re not—I had never heard of Artemis until I walked into that dedication later in the day and it talked about the sustainability of the mission and how we’re going to have a long-term presence in and around the Moon.

I said of course we are because it’s going to be the first one where a woman is going to go to the Moon and we will sustain it for you guys. So don’t worry about that.

Also, Yvonne Cagle was there, who’s an astronaut, and she was expressing her desire to go to Mars, which to me sounds just so are you kidding me, go to Mars? You know, I’m having trouble going back and forth from West Virginia to Washington and I said why do you want to go to Mars? Why do you really want to go to Mars? She goes I really want to see what effect it has on my body. She’s a physician. So she’s very curious about the science of what it would have on her own body and is willing to do this for her but also for the country and for the advancement of science.

In the back of the room, there were robotics teams. There were about 15 of them from high school and middle school and It was interesting because in the robotics teams, they all had mentors who was either a parent or somebody who did something else and did this in their free time once a week, twice a week, and during the
competitive times more than that, and I think, you know, about you, Homer, and I think about your book and how the emphasis you had on your teachers in Coalwood and everything, and I thought why aren't we incorporating more of this into the regular curriculum of our schools so that the teachers are there.

Mentors are great, but they're volunteers, and it's tough for them. They have another job. They have other family responsibilities. So I would just like to ask you, Homer, if you could talk about the influence of your teacher and your mentors on you and your investment in science and how you see that now in the context of what we want to do in the future.

Mr. HICKAM. Thank you, Senator Capito, for the question.

Of course, one of the major elements that I wrote about in Rocket Boys was our teachers, especially one teacher, our Ms. Riley, who was our science teacher at Big Creek High School, who so influenced us, who brought us a book that was called Principles of Guided Missile Design when we were trying to figure out how to build rockets.

I later saw that book in a Ph.D. program for rocket science. It required a working knowledge of calculus and differential equations and I personally was having trouble with algebra at the time. But Ms. Riley said all I've done is give you a book. You've got to have the courage to learn what's inside of it.

So she and other inspiring teachers right there in little McDowell County, West Virginia, were pretty amazing and they raised a generation of coal miners' kids who went out and did some pretty great things, I'd have to say, not me especially, but we have captains of industry that came out of that era before, of course, the coal industry ran into problems.

Now the way I look at it now is and try to support that again is that Space and Rocket Center, Space Camp, and Space Academy, Honeywell, Grumman, and other aerospace companies send and pay for teachers to come to Space Camp and I make a special room on my calendar to go out and talk to those teachers when they come in and, my goodness, they are so enthusiastic about the space program. And the neat thing about a teacher, you know, we can teach a young person at Space Camp and Space Academy and they will have all this knowledge, but if you teach a teacher, my goodness, you think of the hundreds and thousands of students that they then are able to pass this knowledge along and the enthusiasm for the space program.

So we must never forget our teachers. God bless them all.

Senator CAPITO. Thanks. Thank you.

Senator CRUZ. Thank you.

Senator Gardner.

**STATEMENT OF HON. CORY GARDNER,**
**U.S. SENATOR FROM COLORADO**

Senator GARDNER. Thank you, Mr. Chairman, and thank you for hosting this hearing today.

This is a pretty incredible panel for a kid who grew up on the Eastern Plains of Colorado and wanted to be an astronaut. I failed miserably at that, but I'll never forget the letters that I wrote to NASA and the pictures I got back from NASA.
Mr. Kranz, Dr. Darden, Mr. Hickam, there’s a reason people wrote books about you and made movies about you, that you’re featured in our culture and our ideas and our society. It’s because of the impact you’ve had on kids like me.

Turn around and look at the young people in this room. Please turn around. Look at them all. Raise your hand if you’ve been inspired by the work that any one of these have done on the panel. Please raise your hand right now if you want to lead better lives because of the people on this panel.

[Majority of the room raising their hands.]

Senator Gardner. This is what it’s about. You didn’t just change the 1960s. You’ve changed the world with an impact that will last forever.

I mean, Mr. Hickam, all I’ve done is given you a book. You have to have the courage to find out what’s inside it. That comment that your teacher made is so powerful. Thank you for being here. Thank you for the work you’ve done, and I hope that as we look at things like the *Rising Above the Gathering Storm* and the America COMPETES Bill and the American Innovation and Competitiveness Act, the work that we will continue to do to rise above the storm that often is Washington, we’ll make every single one of the people that raised their hands in this auditorium, this committee room proud of the policies this Congress pursues and this country pursues because the day that somebody else lands on Mars and not the United States, the day that somebody else invents the next better light bulb, the day that somebody else has created the next better internet, the next better algorithm, is the day that those jobs, those ideas, those teachers, those people go somewhere else, and the power of that innovation, the power of that idea, that thought is no longer here.

We have to maintain that incredible power that is the United States and not the military prowess but the power of the people sitting before this committee, what’s in your head, the knowledge that you have that you’ve given to this country.

Thank you for the work that you continue to do to inspire, to dream, to hope, to aspire, to create, because you’ve made this country a great place.

Thanks. That’s all I have.

Senator Cruz. Thank you, Senator Gardner, and thank you for in particular pointing out all the young people here and all of us who are inspired.

Dr. Darden, I wanted to ask a follow-up question. As I mentioned in my opening, you and I visited a couple of weeks ago at the dedication of the new street sign in front of the NASA Headquarters, Hidden Figures Way, and so now NASA Headquarters is on a street named after you and named after your colleagues and fellow pioneers and as you and I discussed then, I’m particularly inspired because like you, my mom was a mathematician who became a computer programmer in the 1950s and 1960s, and indeed at the Smithsonian helped work on computing the orbit of Sputnik and when I went to see the movie *Hidden Figures*, I took my mom and my wife and both my daughters, and afterwards, I was talking with my girls and telling them that Meme, their grandmother, had been doing much the same as you were doing and your colleagues.
I was commenting—I asked my mother at the time. I said, “All right, how accurate was the movie in terms of what it was like to be a woman and a mathematician in the 1960s?”—or in her case starting in the 1950s. And her reaction was she thought it was quite accurate, and I said one of the odder things to me listening to it was seeing people called computers.

You know, we think of a computer as a hunk of metal on a desk, not a human being who’s computing, and my mother began laughing and she said when she came out of Rice in 1956 and went to work at Shell, her first job title was computer and so I would just ask you, Dr. Darden, if you could tell this Committee what it was like to be a human computer, to be helping drive the incredible success of NASA all these years?

Dr. DARDEN. Well, I think we worked with great people. I would say to you, and it’s a confession, I did not like being called a computer.

[Laughter.]

Dr. DARDEN. But the support work that we did—I could program when I went there. So the support work that we did with engineers and everything was very great. I think that what really inspired me is to know what the work that I was doing, the equations I worked with, what they were doing to the real world,—

Senator CRUZ. Right.

Dr. DARDEN.—how they were evaluating the wind tunnels there, such that when we used that data to go fly, everything was correct, and so that really inspired me, but I worked with wonderful people and so that’s when I—and I went there as a data analyst, but soon after, about the time that the Apollo Program ended, I began asking to be switched to an engineer and I switched to the engineer at about a year after super-sonic flight across the Continental United States had been banned by law and the SST Program had been canceled, and so that became my life after that and, I mean, I kind of dreamed that and lived with it for 25 years and still hoping that the airplane that Lockheed-Martin builds will be able to have us get rid of that law. We can have supersonic flight in this country.

So it was great. Certainly when Apollo was going up and everything, it was just fantastic to see these things happening in our lives and my vision for the space in a few years, I guess, is that we can actually start operating in space like we operate the airplanes on Earth. So I actually dream of that kind of mobility within space.

Senator CRUZ. I look forward to that.

Mr. Stallmer, in your testimony, you mentioned that “since 2000, investors have supported 375 private space companies with nearly $19 billion in private capital.”

Like you, I think that is a wonderful development. I think that is key to expanding into space at the level we need to.

My question for you, and Dr. Dittmar, feel free to chime in here, as well, if you have thoughts, what should we be doing turn that $19 billion to increase it tenfold and then a hundredfold to get the resources invested that will be needed to go to the Moon and build a habitat and go to Mars and go to Europa and explore space?
Mr. STALLMER. I think it's critical for investors to see that the government is a partner, not an adversary, and I wouldn't say that any such agency, you know, is deliberately trying to impede what we are doing, but when you have that partnership, that stability of working with these various government agencies, it provides a sense of assurance, I think, for other investors.

There are a lot of investors out there, not just in the U.S. but around the world, and of that $19 billion, over $4.3 billion of that came from last year alone. So 71 unique investors, you know, that have invested in space companies in the last two years alone. So there's money out there. They want to see the stability of the government.

I think that what the Senate has done with your committee, the bipartisanship of your committee working together has been a real beacon for many to see. I think the President's enthusiasm on the space program with the creation of the National Space Council, the UAG, which Homer and Mary Lynne and I all serve on, and the passion, the reinvigorated passion, I should say, for the Space Program, I think that's sending a great message to investors and the regulatory environment, and I think this was highlighted in the Space Frontier Act.

Now how do we streamline this regulatory environment to make it more accessible and streamlined, you know, to access space? A lot of the rules and regulations that we're under under the current regime go back to the 1980s when there wasn't a commercial space industry at all. It was all government space. So how do we adapt to that, and I think your Committee has done a fantastic job on trying to address these issues, and I thank you both for that.

Senator CRUZ. Thank you.

Dr. Dittmar, did you have——

Dr. DITTMAR. Yes, no. I'll just agree with everything that Eric has said.

I think in my testimony I made some references to essentially how we go forward with government. Government acquisition processes make a lot of sense when you have very long lead time. Programs take a long time. They have a heavy R&D component using traditional acquisition processes under those circumstances make sense, although accountability is also very important and should not be lost.

But I think also the Nation needs to have a conversation with itself about what are the goals with regard to developing an off-Earth economy, however it is you want to talk about it.

Right now, that's sort of been left with NASA, right, because, I mean, it's the space agency, but I think there are reasonable questions to be asked. We need to talk about economic development of low-Earth orbit, for example. NASA is not an economic development agency. It's a space agency.

So it recently rolled out—because Eric's going to talk about this a little bit tomorrow, but NASA recently rolled out some commercial development ideas on July 7th. Does all that belong in NASA's hands? Should we be talking to the Department of Commerce? Does it make sense to sort of get some other—including NGOs, I mean, to sort of look at this?
This is really significant. We’re talking about doing economic development off the Earth. I mean, let that sink in for a minute. We’re not so hot at it down here. It could take 20 years, it could take 20–30 years, and we don’t have the sort of barriers that we have once we’re trying to launch.

So I think there needs to be a serious conversation probably in the halls of government, perhaps in Congress and other places, about how do we really go about doing that and how much investment do we want to make in that and what kind of investment? Do we want to start talking about government-backed loans? I mean, there are lots of means to talk about economic development. How do we go about doing it?

Senator CRUZ. Well, thank you very much, and let me thank each of the witnesses for, I think, very helpful and productive testimony. Thank you for being here. Thank you for your careers and lifetime that has inspired so many young girls and young boys and augers well for the future.

The hearing record will remain open for two weeks, closing on July 23. During that time, Senators are asked to submit any questions for the record and upon receipt, the witnesses are requested to submit their written answers to the Committee as soon as possible.

And with that, the hearing is adjourned.
[Whereupon, at 4:29 p.m., the hearing was adjourned.]