FUNDING OUR FUTURE
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I was in high school during the Apollo moon landing program and I recall the technological optimism that it fostered and the amazing achievements it spawned. It helped me – and many others in my generation – to see science and engineering as exciting professions where you could accomplish great things and so, after graduation, I pursued an engineering degree when I enrolled at West Point. I am certain that if you had asked me back then, I would have told you that by 2017, we would certainly have landed humans on Mars, that human spaceflight would be frequent and routine and that we would be regularly flying supersonically through the skies.

In the intervening years, NASA has done great things – our robotic spacecraft have visited every planet in the solar system, we have discovered that nearly every star in the sky has its own planetary system and we have begun to understand our planet as a complex system. We also have developed a reusable spaceship – the now retired Space Shuttle – that allowed us to build the football field-sized International Space Station which has had crews living onboard for sixteen years. And today’s civil aircraft are quieter, more cost effective and safer than ever.

These are amazing accomplishments, but we should acknowledge that we have fallen short of our potential as a nation. Why?

AIA believes that our nation is underfunding NASA and shortchanging our future. While we’re not advocating for a return to 1960s-era funding levels of four percent of the Federal budget, we believe our investment should be substantially more than today’s 0.4%. But if you did want to spend more on NASA, where should it be spent and how could you be certain that would be the best use of those funds?

In my career as an Army officer, I was often grateful that the Congress allowed the military service chiefs to annually present their unfunded priorities – the needs of the service that failed to receive funding in the President’s budget – to congressional appropriators. It often really made a difference in meeting the requirements for the Army and other services. Unfortunately, unlike the Pentagon, NASA is not given an opportunity to share its unfunded priorities, so it is difficult to objectively argue for more NASA funding beyond the President’s Budget Request.

Fortunately, industry is not so constrained and we are free to seek additional resources for NASA to do great things. And thanks to the decadal plans developed by the National Academies of Science, the National Research Council and other expert organizations, we have some good objective ideas for how best to spend additional NASA dollars.

It is our firm conviction that strong funding for these NASA priorities would greatly strengthen our nation’s leadership in aeronautics, science, solar system exploration and development of new space technologies. It is AIA’s hope that this report, based on these expert analyses of aerospace and scientific priorities, will help convince Congress and the new Administration to provide more funding for NASA in a balanced and predictable way that will benefit our nation, inspire the next generation of students and help NASA and the nation to achieve its true potential.
This report describes the potential for NASA's bright future through a collection of readily implemented horizon missions and projects. The missions described herein represent a preview of what can be accomplished with only a modest increase to NASA's recent levels of funding. This guide is intended for Congressional members and staff, members of the new President's team, aerospace advocates, and those interested in national science and technology policy and budgets. We seek to articulate the critical role NASA plays vis-à-vis other national priorities and demonstrate some of what NASA can achieve when we truly harness the power of our national space program.

The potential new missions described here would continue NASA’s strong tradition of scientific discovery. Scientific endeavors funded by NASA have proven foundational to our space program’s success in revolutionizing our understanding of our world and the universe while conferring prestige and goodwill around the globe. Scientific decadal surveys have outlined future programs that would send us throughout our solar system like never before. These missions would investigate grand questions as only NASA is capable: from searching for evidence of life’s origins beyond Earth to explaining the fundamental events leading to the origins of our universe and solar system. NASA-led scientific discovery would also deliver practical benefits by guarding against potentially harmful impacts of space weather, improving air transportation and better understanding of the increasing frequency of natural disasters.

Scientific discovery is only the start. NASA is now preparing to send humans deeper into the solar system than ever before. To develop the technology and understanding to reach Mars in this generation, we will first explore the proving ground surrounding Earth. These missions will reinforce recognition of American commitment to leadership in space. Closer to home, an improved aeronautics program will enable environmentally friendly supersonic flight to become widespread, while continuing development of the next generation air traffic control system will make air travel safer and more efficient. Finally, the potential that is described in the following pages will serve to feed our basic curiosities and inspire STEM education in our youth – ensuring the United States remains a global leader in space for generations to come.

We are a spacefaring nation. This idea is central to our identity, but has been taken for granted for a quarter of a century. Despite recent increases, NASA remains hamstrung by reduced resources and is no longer able to realize its mandated potential. However, there is room for optimism. We largely have the peer-validated plans for an expanded NASA already in place. With a few simple steps, and a modest fiscal rededication to our future, NASA can again prove testament to the power and ability of our great nation.
A Call to Action

When President Kennedy called on our nation to land a man on the Moon and return him safely to the Earth, it was NASA that enabled this dream to be realized. Following that historic moon landing, NASA’s triumphs in air and space have come to demonstrate to the world that, as Americans, technological achievement and scientific discovery are hallmarks of our national identity. Today NASA seeks to continue this legacy, yet recent successes take far longer than they did at the dawn of the space program. For instance, the International Space Station program took 27 years from congressional approval to achieve full functionality. How is it that a nation that so famously executed Apollo “before this decade [was] out” now drags out its space ambitions over decades? A common answer resonates across the space community: NASA is being called upon to deliver critical missions with too little in resources.

The tremendous successes of Apollo era NASA demonstrate that when national investment and resources combine with a worthwhile objective, we can accomplish remarkable feats. But for too long, NASA’s performance has been suboptimal compared to its potential. In the last two decades, NASA’s real budget has undergone a quiet but troubling decline. After peaking in 1991, NASA’s budget has declined by 22 percent in inflation adjusted dollars. Exacerbating the problem, the index of aerospace inflationary costs over the same time period has steadily increased. For Congress and successive Administrations, a flat budget in nominal dollars seemed harmless. Some even proffered that “flat [was] the new up.” In reality, however, the cumulative effects of sub-inflationary budgets – despite otherwise low inflation – has significantly reduced NASA’s ability to execute programs in a timely manner, delayed the agency’s progress with crewed deep space missions and neutered its ability to fund transformative research.

Despite its waning purchasing power, NASA continues to deliver impressive successes. In 2012, NASA captured the world’s imagination as the two-ton, nuclear-powered, Curiosity rover descended to the surface of Mars. Worldwide coverage of the rover’s many images and discoveries continues to this day. In December 2014, NASA’s Orion Crew Capsule was launched and successfully recovered – a terrific demonstration of the first spacecraft since Apollo capable of carrying humans beyond low-Earth orbit. In July 2015, gorgeous photos of an icy Pluto taken by the New Horizons spacecraft changed the public’s perception of our solar system. For the first time, Pluto’s blurry gray circles from 20th Century textbooks became beautiful and data rich high definition images of mountain ranges covered with methane snow. The summer of 2016 saw the Juno spacecraft arrive at Jupiter and begin to peel back the gas giant’s inner secrets. Beyond its technical accomplishments, NASA has also innovated with its adoption of new commercial procurement practices for resupplying the International Space Station with cargo, and soon with crew.

However, this string of recent accomplishments masks the agency’s current budget trajectory. Funding for missions typically begins five to ten years prior to launch, so NASA’s recent accomplishments reflect investments of the past. Without greater funding, NASA’s mission tempo will slow and the grand vision of our space aspirations will dim.

Paradoxically, efforts to cut cost – either by arbitrarily limiting top line budgets or maintaining flat funding under continuing resolutions – actually increase overall program costs by stretching out the engineering development cycle. For programs as technically complex and demanding as NASA’s missions, each stage – conceptual definition, research and development, design, testing and production – must be tightly scheduled. When funding fails to meet initial projections, NASA is forced to retain contractors and facilities beyond expectations, driving up overall costs. The impact of these short-term budget constraints adds unnecessary levels of complexity.

Accounting only for the agency’s loss of purchasing power since 1991, NASA now has $4.3 billion less to spend in the FY2016 budget. If we restored the amount of lost purchasing power from just one year of NASA’s budget, we could fund the average yearly cost of every science mission mentioned in this report, restore the space technology and aeronautics budgets by close to 15 percent, and add nearly a half-billion additional dollars per year toward human missions to deep space. Those lost billions nearly would be sufficient to fund the development of three additional commercial spaceflight programs. Budgetary losses on this scale are not trivial. The current NASA budget is preventing us from advancing our aeronautical and space capabilities, resulting in recent decisions to cancel programs and allowing other nation’s space programs to close the gap with the United States.

To address these trends, this report provides an accessible tool for professional space advocates and grassroots enthusiasts who wish to clearly articulate a vision for the future of NASA. We seek to show what NASA could do with a revitalized budget and explain why this is worthy of focused attention. We issue a clarion call for renewed vitality in U.S. space science, human exploration and aeronautics research and offer a tantalizing preview of achievable accomplishments if America chooses to adequately invest in NASA’s future.

“The most challenging aspect of management and successful execution of these programs is the impact of constrained budgets and unplanned changes to operating budgets, whether real or contrived. The technical challenges are fun in comparison and engineers can solve them.”

– Doug Cooke, congressional testimony, 2015
AIA recommends a modest but sustained increase in NASA’s budget of at least three percent above inflation. This increase will restore NASA’s budget and purchasing power and better align NASA investments with a growing GDP and discretionary spending. A renewed NASA budget will enable the pursuit of a broader range of space science, space technology and aeronautics investments; promote timely and cost effective project completion; and shore up international competitiveness. With this budget expansion, NASA’s work will continue to drive the technological and economic leadership of our nation.

An annual NASA budget increase of three percent above inflation would:

- Provide program stability. Increased funding would provide NASA needed stability in programs, allowing us to pursue ambitious and consistent mission goals that both deliver compelling achievements and discoveries and maintain our advanced aerospace workforce.

- Enable greater efficiency. Increased funding would allow NASA to optimize program planning, allowing for more efficient design and mission options, leading to more expeditious program completion, and avoiding the cost of maintaining development infrastructure for longer than necessary.

- Facilitate more public-private partnerships that will allow NASA to utilize its budget to the maximum extent. The United States is a leader in commercial space and future commercial partnerships will allow NASA to continue to research and explore the unknown in inventive and resourceful ways.

- Bolster the economy. Increased funding would assure continued U.S. civil aviation progress, creating and sustaining jobs that contribute to local communities and fueling the development of technologies that save lives, ensure national security and expand our export economy.

- Position our nation to lead in space through the 21st century. Increased funding would enable NASA to develop an executable plan to send humans beyond low-Earth orbit. It would also encourage international partners to join the United States in its quest to explore the solar system with confidence that NASA would meet its schedule commitments.
In just 50 years, the National Aeronautics and Space Administration has revolutionized our understanding of humanity's place in the universe. For less than half of one percent of each tax dollar spent, NASA has visited every class of object in the solar system, along the way revealing new wonders and creating new opportunities for exploration and economic activity. Through the human exploration program, NASA has sent hundreds of Americans into space, put twelve astronauts on the moon, spurred economic growth and inspired people across the globe. In this report, we outline a series of professionally vetted missions and projects that could define the coming decades at NASA if adequate budgets are enacted. Our intent is not to advocate for any specific program, but to illustrate, through example, the breadth of NASA's potential with just a modest budget increase and the promise of a commitment to our nation's future journeys into space.

Decadal surveys, division roadmaps, and supporting documents were used to identify a series of unfunded projects for this report. For the sake of brevity and clarity, this report limits its scope to large missions, projects and programs that tend to define topline budget issues. As the voice of the American aerospace and defense industry, AIA is uniquely positioned to bring attention to a broad collection of sought-after missions and articulate a robust and exciting vision for a well-funded future at NASA. The following examples provide a glimpse into what a restored NASA budget could accomplish for our nation and for the world.
Today the pace of scientific exploration at NASA is bounded not by imagination or ingenuity, but by the budgetary restrictions imposed on the agency. While numerous important science mission concepts are suggested by scientists and engineers across the country each year, many worthwhile missions ultimately go unfunded as a result of budget limitations. Providing enough funding to cover even a few additional missions per decade would give us greater insight into our universe and would add fuel for the technological advances necessary for the growth of the American economy. A budget increase of just three percent above inflation during the next decade would result in a cumulative net gain of nearly $12 billion for NASA’s Science Mission Directorate. A review of the decadal science recommendations produced for NASA’s science divisions reveals how this reasonable increase in funding could unlock enormous potential benefits.

**Prominent Science Missions**

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Photo courtesy of NASA
From frozen ice giants near the edge of the solar system to the blistering surface of Venus, our planetary neighbors are exotic targets for exploration. NASA's planetary science efforts reach out into the trove of worlds in this cosmic backyard. The Mariner and Pioneer programs gave us our first glimpses of Venus, Jupiter, Saturn and beyond. The Viking landers provided an unprecedented look at the Martian surface and spurred the search for life on other worlds. More recently, the Cassini spacecraft unveiled the beauty and complexity of the Saturn system, while New Horizons gave us our first detailed look at Pluto and its moons. The Jet Propulsion Laboratory (JPL) has delivered four rovers to the Martian surface culminating in the dramatic landing of the Curiosity rover in 2012. On July 4, 2016, the Juno spacecraft arrived at Jupiter and began to peer deep into the planet, providing insight into the history of the entire solar system. Through planetary exploration, we widen our understanding of solar system, we seek life beyond Earth and we inspire future generations to explore.

Expanded funding at three percent above inflation would provide the Planetary Science division with an additional $3.04 billion over the next decade.

Missions:

**Uranus Orbiter and Probe**
A mission to Uranus would investigate the internal structure of this ice giant, observe its moons and rings, and deliver a probe on a fiery descent into the planet’s atmosphere. The study of Uranus may also reveal clues to the nature of the many ice-giant planets recently found around other stars.

**Enceladus Orbiter**
With a global ocean, geologic activity and organic compounds, Enceladus possesses many of the elements thought to be important to nurturing life. A mission to Enceladus would first enter into orbit around the small moon, and then provide direct sample collection of the liquid water geysers that are active from the moon’s southern pole.
The astrophysics division seeks to understand the fundamental building blocks of our universe by exploring the content and behavior of all matter and energy in the universe. Scientific investigation into the nature of galaxies, nebulae, black holes, supernovae and large-scale theories like dark matter and relativity lie in the realm of the astrophysics division. Images from missions like the Hubble Space Telescope have revealed distant galaxies and have characterized previously unseen stellar events for the first time. These discoveries transcend their importance to scientific advancement by stirring a lasting curiosity from the general public. On top of cultural and scientific contributions, our investment in astrophysical instruments also drive cutting edge developments in optics, electronics and spacecraft technology. These developments fuel the U.S. economy and preserve national security. Unfortunately, recent funding limits have forced NASA to back out of several international collaborations in astrophysics. As a result, potentially ground-breaking projects seeking to observe gravitational waves and utilize revolutionary X-ray technologies to observe the stars have been abandoned.

Expanded funding at three percent above inflation would provide the Astrophysics division with an additional $1.53 billion over the next decade.

**Missions:**

**Explorer Program Expansion**
Small to medium missions that provide scientific responsiveness, diversity and flexibility are key to the Astrophysics Division. Like their peer missions in other science divisions, these missions are led by teams of scientists and are often designed to address focused scientific questions using a much lower budget than traditional flagship missions. Missions such as an evolved Laser Interferometer Space Antenna would deliver critical information about gravitational waves and restore U.S. international leadership. Small missions lead to a faster cadence of launches and better serve the changing interests and concerns of the scientific community.

**CMBPS – Cosmic Microwave Background Polarization Surveyor**
The violent and compressed early universe left unique, but limited, clues about the nature of universes, the inflation of our universe, and the slight density variations that led to the formation of today’s galaxies. The CMBPS is designed to extract comprehensive information from temperature fluctuations and microwave polarization imprinted during the high-energy birth of our universe.
Thou should be 93 million miles from the Earth, the Sun's emissions are energetic enough to burn our skin via ultraviolet rays. Large pulses of radiation from the Sun are capable of damaging critical satellites like those used for GPS. On the Earth's surface we are shielded from much of the Sun's raw power; however, exceptional bursts of energy can even destroy ground-based power and communications networks. A warning system capable of predicting solar weather in much the same way we predict thunderstorms would help safeguard our critical orbital and ground-based infrastructure. Presently a combination of sparse observation platforms and the extended length of the solar cycle have limited our ability to accurately predict space weather. This leaves the Earth vulnerable – along with U.S. military, navigational, communications and power grid assets. NASA's heliophysics division seeks a deeper understanding of solar physics and attempts to tame the perilous outbursts of our local star.

Current heliophysics missions include the Solar Dynamics Observatory (SDO), Magnetospheric Multiscale (MMS), and Solar Probe Plus. SDO is the flagship solar observer for the United States, imaging the Sun over multiple wavelengths and delivering images and videos back to Earth for monitoring by scientists and space weather experts. MMS is the Heliophysics Division's newest mission. By employing four small spacecraft flying in formation, MMS innovatively investigates the magnetic connections between the Sun and the Earth. The explosive process of magnetic fields connecting and disconnecting helps determine how radiation travels through the solar system during solar storms. A better understanding of this structured energy transfer will enhance our fundamental understanding of magnetism, while also helping us predict and prepare for potentially devastating solar events. Set to launch in 2018, Solar Probe Plus is billed as a mission to "touch the sun." This mission will provide unprecedented insight into the workings of the Sun as it spirals toward the surface. During its mission, the probe will become the fastest object ever launched from the Earth.

Expanded funding at three percent above inflation would provide the Heliophysics division with an additional $1.34 billion over the next decade.

Missions:

**IMAP – Interstellar Mapping and Acceleration Program**
Using data from the final years of the Voyager probes, coupled with research from a newly launched spacecraft, IMAP would image the boundary between our solar system and interstellar space. This mission would allow a better understanding of our sun's interface with the interstellar medium and squeeze one last burst of innovation from the distant Voyager spacecraft now in interstellar space.

**GDC – Geospace Dynamics Constellation**
Understanding the mechanism by which the solar wind interacts with and propagates downward through geospace toward earth will be critical to managing its impact. The GDC consists of a constellation of six satellites that would monitor the impact of the solar wind on the Earth. An improved understanding of this periodic energy transfer from the Sun will aid our predictions for the timing and severity of future solar storms.
As the global population continues to grow, threats such as more fragile food production, faster spreading diseases, water scarcity and more intense severe weather challenge our nation and our allies. Population growth also makes coastal communities – including major cities around the globe – more vulnerable. Astronauts often remark that they only fully appreciate their home planet after viewing it from the vantage of space. This global perspective reminds them of Earth’s role in nurturing humanity and of our own responsibility to safeguard a hospitable world for future generations. NASA Earth Science embraces this responsibility through its suite of Earth observing missions. Earth observation delivers numerous practical benefits, including weather forecasts, natural disaster warnings and global monitoring of changing sea levels. Furthermore, study of our own planet is the best analog for understanding basic surface and atmospheric science on Earth-like planets around other stars. As the only world we know to have produced life, the study of our home planet will provide critical information as we seek to understand life’s universal principles.

AIA published its first Earth Observation Report in 2016, emphasizing the integration of many economic, national security, and disaster response benefits from space-based Earth system science missions. These observatories are helping to save lives, enable commerce and improve our understanding. The next Earth Science Decadal Survey – an independent review with recommendations – will be completed in 2017, guiding the next ten years of NASA Earth Science missions. Funding this study, along with continuing and new measurements, will enhance our prosperity and security into the future.

The crown jewel of the Earth Science division – and key to much of our weather and surface process awareness – is the “A-train” fleet of Earth observing satellites. The A-train ("A" for afternoon) streaks across the North American sky at midday, when bright sunlight is best available for observations. Processing in single file, the A-train is comprised of six satellites with unique missions to monitor water dynamics, atmospheric chemistry, climate change, cloud effects and more. These satellites are crucial to our evolving understanding of Earth’s complexity and pave the way for technology that can later be deployed around other planets.

More so than other mission directorates, NASA Earth Science has faltered under decreased funding in recent years. Expanded funding at three percent above inflation would provide the Earth Science division with an important $3.75 billion over the next decade. This funding would allow the agency to push ahead with delayed missions that have received high ratings from the scientific community.

**Missions:**

**ACE – Aerosol-Cloud-Ecosystem**
In order to understand the impact of a changing climate and help policy makers decide how to respond, we need better Earth Science. The ACE mission would serve as the nation’s premier climate monitoring and prediction effort. ACE science would aid the development of more accurate climate models through observation of carbon dioxide absorption by the Earth’s oceans.

**HyspIRI – Hyperspectral Infrared Imager**
Whether from wildfire, drought or volcano, natural disasters strike with increasing frequency and destruction. The HyspIRI mission would seek to provide a benchmark to understand the changing behavior of a range of natural disasters. Using multispectral bands and an imaging spectrometer this single satellite mission will take a holistic picture of the state of a number of the Earth’s ecosystems.
It was the work of NASA and its industry partners that put John Glenn into orbit, launched John Young and Bob Crippen on the first space shuttle, and landed Neil Armstrong on the Moon. This same team has also made a home for humans on the International Space Station (ISS) for more than sixteen years.

We are poised to send humans farther into the cosmos than ever before, with ambitious goals that include visits to asteroids, the moon and ultimately Mars. Unfortunately, these dreams are not supported by the resources required to make them a reality. Filling the funding gap are commercial partnerships that serve as stepping stones to deep space exploration. NASA’s Commercial Crew Program is working with the aerospace industry to achieve safe, reliable and cost-effective access to and from the ISS and low-Earth orbit. By encouraging industry to provide routine transportation services, NASA can expand its focus on building spacecraft and rockets for deep space missions.

To take the next giant leaps in space, technological development and engineering capabilities must be advanced by next-generation systems. Discoveries from robotic missions – such as the Space Launch System (SLS) – lay the groundwork for future exploration and scientific discovery, and are foundational to future missions whether human or robotic.

With a potential to lift more than 130 metric tons to low-Earth orbit, the SLS would empower scientists to plan missions that otherwise would not be technically possible or economically infeasible. While Congress has supported SLS, funding is also needed to develop the full suite of technologies for future long duration exploration-class missions. These deep space missions will require development of better radiation protection, new guidance and navigation systems, improved proximity and docking operations, and in-space power and propulsion systems. These technologies can bring NASA closer to the long-term goal of becoming Earth independent.

These and other deep-space missions depend on reliable supporting technologies with a proven track record. We shouldn’t wait for final Mars mission architecture to develop the requisite technologies to get us there. In fact, the development of technologies that precede final mission plans could enable initially unforeseen mission goals. For example, the F-1 engines used in Saturn V rockets to power the Apollo missions were initially developed as part of an unrelated U.S. Army rocket program begun 15 years earlier. Funding of this program accelerated the development of a reliable engine, without which NASA might have missed Kennedy’s goal of landing a man on the moon “before the decade [was] out.” Similarly, early SLS flights will incorporate updated, flight-tested and reliable shuttle engines and external tanks.

American human space exploration would strongly benefit from the extra funding proposed in this report. At three percent above inflation, the $19.0 billion in additional resources over the coming decade would enable the development of a suite of exploration-class technologies to power future missions. This funding would also reinforce cost-efficiency, stimulate the rapid completion of deep space technology projects and finalize mission roadmaps, architectures and projected launch dates for a new era of space exploration.

A reaffirmed national commitment to grow NASA’s resources for exploration over time may lead international partners to make similar commitments, synergistically growing human exploration capabilities.

**Missions:**

**Lunar outpost at Shackleton crater**

Located nearly coincident with the Moon’s south pole, Shackleton crater is positioned to be partially sunlit and partially in shadow at all times. Its location also makes the crater a prime candidate for a lunar outpost due to the potential for natural resources such as ice and sequestered volatiles. A lunar mission would serve as a good analog in planning operations for a future mission to the Martian surface, as it raises similar concerns with regards to hardware and human physiology.

**Habitat Earth-Moon L2 Lagrange point**

A mission to the Earth-Moon L2 would serve as a proving ground for deep space operation. Designed to last at least six months, this mission would establish the necessary technology improvements for deep space life support. Deep proximity operations and docking procedures could be practiced and refined.
A potential human journey to Mars ignites the hopes and dreams of Americans and citizens around the globe. In October 2015, NASA released its plans for the Journey to Mars, outlining current technologies in development and necessary steps that will require further funding. Despite a stated goal to land humans on Mars by the 2030s, the latest study of the human spaceflight program undertaken by the National Academies’ Space Studies Board concluded that under current funding trends, which adhere only to inflation, we are unlikely to arrive before 2050. This board analyzed an approach that echoes NASA’s Journey to Mars architecture, but did not include program estimates with a below-inflation “flat budget” – as this scenario was not believed to permit deep space human activities. If we are to realize near future human exploration employing the architecture outlined by NASA’s approach, an increase in funding is needed today.

Though NASA advocates for its stated plan, alternative approaches to the red planet have also been considered, both from within and outside of NASA. These approaches seek to capitalize on unique advantages. “The Humans to Mars” minimal architecture from NASA’s Jet Propulsion Laboratory offers one such approach. By focusing on existing technologies, rather than spending on new launch systems, Humans to Mars attempts to balance the budgetary and technology challenges explored in the “Pathways to Exploration” report. Notably, the Humans to Mars plan employs conventional rocket engines to minimize the technology development required to get to Mars. The architecture first calls for a mission to the moons of Mars using the Orion capsule, a deep space habitat, propulsion stages needed to stop at Mars and return to Earth, and a Phobos exploration base. Later missions would reuse most of these components, adding elements to allow humans to reach and return from the surface of Mars by the late 2030’s.

Multiple approaches to get to Mars do not need to be mutually exclusive. Technologies developed for one approach may benefit others. For instance, funding the requisite technologies necessary for the Pathways Approach in an incremental manner could allow a hybrid plan to develop. By funding and ensuring the reliability of key pieces of technology today, leaders of the future could choose which mission best suits their current needs and resources. Having multiple options further assures that NASA’s goal of landing on Mars will be achieved. But in order for any of these plans to move forward, greater funding is needed today.

“As long as flat NASA human spaceflight budgets are continued, NASA will be unable to conduct any human space exploration programs beyond cislunar space. The only pathways that successfully land humans on the surface of Mars require spending to rise above inflation for an extended period.” – Pathways to Exploration
For more than fifty years, NASA has achieved things previously thought to be impossible through advances in space technology. These investments in space technology both power our efforts to travel beyond Earth and generate spin-off technologies that benefit all of humanity. Working with industry, government and academia, the Space Technologies Mission Directorate (STMD) focuses on high-payoff technologies that anticipate future needs. Across fourteen interconnected technology areas, STMD researches the knowledge and capabilities necessary for space travel. Projects in one area may further NASA leadership in aerospace technology while also enhancing our capacity in seemingly unrelated areas such as medicine and transportation safety. In fact, active pixel sensor imager technology, developed by NASA’s Jet Propulsion Laboratory, later became the technology used in cell phone cameras and other electronic imaging devices.18

Unfortunately, funding for NASA’s space technology division is far below initial requests. A budget increase of three percent above inflation would help meet the agency’s needs by providing an extra $1.26 billion beyond inflationary increases during the coming decade. Technology roadmaps produced every five years update and refine priorities as new objectives arise. In the most recent roadmap released in 2015, several projects were found to be among the most urgent.19

Projects:

Radiation Mitigation for Human Spaceflight
Monitoring radiation, shielding against it, refining medical risk models and developing countermeasures will be vital to successful space exploration beyond low-Earth orbit. In addition, the ability to predict space radiation events will ensure added safety for astronauts as well as those of us on Earth.

Autonomous Systems and Artificial Intelligence
The further from Earth a mission seeks to travel, the more independent it must be. NASA missions must be able to autonomously detect and correct their orientation in space. Improved autonomy raises agility and reliability, lowers operating costs and paves the way for more capable space systems and spacecraft constellations.

In-situ Resource Utilization
The ultimate goal of becoming Earth-independent will rely on the ability to locate, control and put to use local materials and other resources. The ability to harness local materials such as water and ice, derive energy that is encountered along the way and manage Earth-originating waste will ensure our long-term survival while driving down costs in the near term.
In October of 1947 Chuck Yeager strapped into his Bell X-1 and achieved an historic first for humanity, breaking the sound barrier. Nearly 70 years after his flight, commercial supersonic transport still remains out of reach in our daily lives. Now NASA Aeronautics, along with industry partners, is taking steps that – with the right investment – will soon lead to major advances in aviation. They are focusing on high efficiency, high mobility and low emissions technologies. Improvements in noise reduction and low carbon propulsion will modernize our understanding of aeronautics. The developing Next Generation Air Transportation System will allow these new technologies to integrate seamlessly with our existing systems. But without funding for flight demonstration, industry cannot take the risk of commercial development of these promising technologies.

Since the early days of aviation, new technologies have spurred economic development and contributed trillions of dollars to the U.S. economy. Investments in aerospace fostered an internationally competitive industry that today returns a positive trade balance back to U.S. shores. However, development and growth around the globe now threaten U.S. preeminence in aeronautics. In early 2016, NASA detailed plans for major new programs in aeronautics, including a return to flying “X-Plane” technology demonstration test aircraft. These investments will ensure the United States remains competitive and continues its tradition of cutting edge aeronautics innovation. The Advanced Air Vehicles Program (AAVP) will help translate major developments in aeronautics research into real world test hardware. The aviation directorate’s New Aviation Horizons program seeks to cultivate transformative changes to commercial air travel through advances in fuel efficiency, emissions and noise reduction.

Over the previous decade, NASA Aeronautics experienced a traumatic reduction in budget, resulting in an FY2015 level that was about half of the budget allocations from the early 1990s. A new commitment to aeronautics was outlined in early 2016, the first step in restoring and recommitting to aeronautics. Unfortunately, some of this new funding is tied to other legislation that could jeopardize this new commitment. In addition to the recent corrective actions, the budget increase recommended here would provide NASA Aeronautics with $1.34 billion dollars above inflationary increases over the next decade.

Projects:

Low Boom Flight Demonstrator (LBFD)
Demonstrator aircraft are particularly important for alternative vehicle technologies needed to meet long-term goals. The first new generation X-plane project will provide ground testing and flight demonstration necessary to spur development of commercial supersonic flight technologies.

Ultra efficient subsonic transport
With a renewed high efficiency subsonic test vehicle program, NASA research will help enable the rapid development and evolution of promising technologies. These investments will lead to transformational improvements in efficiency, emissions and low carbon technologies.
Research and technology innovation in aerospace has driven our economy for the past fifty years. But today as NASA tries to fulfill its vital mission, important programs are on unstable footing and new potentially transformative programs are unable to secure support at all. With funding tight and aspirations high, the agency is being asked to do too much with too little. Immediate action is needed to reverse the nearly 11 percent loss in purchasing power that occurred over the past 20 years.

If the United States is to recapture its leadership in aerospace, we must begin by restoring reasonable levels of investment in NASA. By presenting this roadmap for a bright future, with specific areas for recommended investment, the Aerospace Industries Association intends to make our nation’s decision makers aware of this affordable opportunity to realize the potential of our great nation. Growing NASA’s budget by three percent above inflation for the foreseeable future will strengthen our economy, empower our innovators and further America’s legacy of exploration.

Investments in aviation will spur the development of the next generation of air transport, making air travel safer and more efficient. Developing new Earth observation and science missions will save lives, preserve property and deepen our understanding of the requirements of space travel. And expanding NASA’s exploration program would enable human development of cis-lunar space and beyond and achieve the goal of landing on Mars.

For more than half a century, the United States has led the world in spaceflight in the face of challenging economic conditions, wars, threats to our nation’s security and tumultuous political realities. NASA’s amazing success has yielded economic returns, new discoveries and devices, a robust industrial capability and inspiration for billions of people. In crafting legislation to support NASA’s fullest ambitions, we deliver on the promise of a bold American future and prove that while our struggles may be numerous, we are a mighty people when we choose to do mighty things.

“All that we have already accomplished, and all in the future that we shall achieve, is the outgrowth not of a soulless, barren technology...rather, it is the product of unrestrained human talent and energy restlessly probing for the betterment of humanity.”

- Dwight D. Eisenhower

Photo Credit: (NASA/Joel Kowsky)
REFERENCES
14. Ibid.
15. Ibid.
16. Ibid.