

Why Mars?

**A SERIES OF ARTICLES AND REASONS
WHY HUMANITY SHOULD EXPLORE MARS**



AN EXPLORE MARS PUBLICATION

VOLUME I

There are many compelling reasons why we should send humans to Mars. In this first Why Mars publication, Explore Mars, Inc. has assembled a series of opinion pieces, published in 2016 and 2017, that answer the question, “Why Mars?” This compilation also provides information about messaging as well as data that will assist the space community in communicating to policy makers and the general public the vital importance of sending humans to Mars.

Explore Mars will continue to work with our partners, public relations experts, and others to advance the Why Mars messaging. Indeed, as humanity moves forward with plans to send humans to Mars – and as we gain more knowledge of the Red Planet – the reasons why we should explore Mars will probably expand and even transform over time. Although many of the reasons stated below might also apply to other space exploration goals, working to achieve the goal of sending humans to Mars is the one that clearly has the greatest potential not only to inspire but also to improve life on Earth.

Core Reasons: Human exploration on the surface of Mars will:

- be a catalyst for American innovation and discovery and inspire students to study science, mathematics, engineering, and technology (STEM fields),
- advance American leadership in space, and
- help us understand who we are, where we came from, and where we can go.

Expanded reasons why we must explore Mars:

1. **Discovery and Scientific Knowledge:** Mars is the most scientifically interesting location in our solar system that humans can reach in the foreseeable future. Most experts agree that it will probably take human explorers to determine whether there ever was or even still is life on Mars and to conduct many other scientific investigations that are not possible with robots alone. This endeavor will dramatically expand human knowledge and stimulate education.
2. **Inspiration and Innovation:** Space exploration – particularly Mars exploration is widely recognized to be one of the most effective ways to inspire students to become interested in STEM education, and it is also a well-known driver of technology and innovation. Mars-focused STEM programs and simulations around the country have informed and inspired millions of students.
3. **Prosperity and National Morale:** Apart from national prestige, morale is essential for a nation’s growth and prosperity. It also elevates the human spirit and strengthens the economy. Mars provides this, and more. As a result, Mars holds a special place in the public consciousness: As seen in recent public opinion polls and in popular culture, Mars excites the public, particularly young people. Mars will be their legacy.
4. **Security and Diplomacy:** While Mars missions will not be run by the military, many of the capabilities required to achieve these missions have potential security applications. In addition, an ambitious and strong space program can be one of our most effective diplomatic tools, as people around the world look at our space program with awe and appreciation.
5. **Advancement and Expansion of Humanity:** The human exploration of Mars is the most significant and achievable goal in space within the next several decades. Can humans establish a permanent presence on another planet? Mars offers a potential for self-sufficiency that simply does not exist elsewhere in our solar system.
6. **To Understand Earth:** Mars is the planet in our solar system that is most similar to Earth. Mars used to be a warm and wet planet like Earth, when Mars had a much thicker atmosphere than it does today. What happened to Mars, and could the same thing happen on Earth? Our analysis of what could happen to the Earth cannot be based on just one data point – that of the Earth. We must study Mars to learn about our home planet.



The Time for Mars is Now

The technology and systems needed for humans to travel to Mars are being developed and built across our nation. Contrary to myth, the cost of sending humans to Mars is not outside of our means, but rather is achievable within current budget levels. The general public and American industry, as well as the legislative and the executive branches of government, all support the goal of sending humans to Mars, and our nation must continue our momentum towards achieving that goal.

Why Mars? An Introduction To A 10-Part Series On Sending Humans To Mars

Chris Carberry, Contributor CEO, Explore Mars

Originally published - October 10, 2016

Momentum is steadily and inexorably building toward sending human missions to Mars beginning in the 2030s. While this goal has been an integral part of United States space policy over the past fifty years, the reality of achieving that goal has always seemed so very far in the future. Recently, however, a critical mass of support, technical progress, and scientific momentum has coalesced that may very well finally propel humanity to the Red Planet.

Mars has been the subject of a great deal of media coverage in recent years, with frequent images and scientific updates coming from various United States and international Mars robotic missions. Hollywood has also been drumming the Mars beat, with movies such as *The Martian*, as well as the upcoming six part National Geographic series, *Mars*, and the feature film *The Space Between Us* (with more to come).

As for policy, Congress has included Mars in multiple authorization bills — and the Senate is currently moving forward with a Transition Authorization bill that contains the most comprehensive language in support of Mars exploration ever to appear in a major bill.

NASA has also embraced this goal, with its Journey to Mars program, and last October it also held its first workshop to investigate potential landing sites for the first human explorers. Industry has also jumped on the bandwagon, with companies such as Boeing, Lockheed Martin, and Aerojet Rocketdyne having released their own proposals as to how to send humans to Mars — and in late September SpaceX joined the chorus when it announced its own ambitious plans.

Recent polls have also shown overwhelming public support for this goal. Yet, some people still ask Why? Why should we take the time and spend taxpayer dollars? Some even ask why should we take the risks inherent in any space mission — let alone missions to a planet millions of miles away?

Unfortunately, much misinformation has been disseminated



History teaches us that ambitious exploration and innovation projects of this kind have always tended to benefit humanity.

claiming that such missions would cost upwards of \$1 trillion. In reality, none of the current credible plans would require anywhere close to that amount, and in fact they would require far less. (To put this in perspective, all NASA budgets combined since 1958 don't come close to totaling \$1 trillion — even with adjusted dollars).

Others ask why we should send humans to Mars when there are problems here on Earth that need to be addressed; but history teaches us that ambitious exploration and innovation projects of this kind have always tended to benefit humanity. Our home world will undoubtedly end up far worse off if we don't engage in such ambitious missions that will improve life on Earth.

To better answer the question why (and how) we should send humans to Mars,

Explore Mars launched a series of opeds that appeared in The Huffington Post from prominent individuals from a variety of disciplines to answer the question "Why Mars?." These opinion pieces came from individuals from the following backgrounds:

- 1) Scientist
- 2) Astronaut
- 3) Policy Expert
- 4) Student
- 5) International Representative
- 6) Mission Architect
- 7) STEM professional
- 8) Entertainment industry

The United States — including government, industry, academia, and the general public — and our international partners are on the verge of moving forward with one of the most significant and awe-inspiring endeavors in human history. There are many compelling reasons why we should undertake this great journey. Over the next several weeks, you will read perspectives from prominent people in the United States and in Europe, each explaining their own visions of why we should explore Mars.

We Should Explore Mars So That Our Students Will Keep Dreaming Big

Janet Ivey, Contributor CEO, Janet's Planet

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Why send humans to Mars? Because as Gene Roddenberry said, "We are on a journey to keep an appointment with whatever we are." As a space science educator, a lover of Star Trek, and someone who played "astronaut" on the playground, sending humans to Mars is more than just a good sci-fi fantasy, it is an imperative for humanity. Mars is the first outpost in the colonization of other worlds. And thanks to countless orbiters, landers, and rovers... the more we learn about it, the more Mars beckons.

For the past 16 years, I have endeavored to find ways to connect students' natural curiosity with the wonders of our solar system and the universe, and always with an eye looking back at Earth. As a STEM/STEAM educator, I believe that we must teach science as the greatest adventure story of all time; and allow and inspire students to dream beyond their house, their town, and their own Earth-bound experience.

Listen to any scientist, engineer or entrepreneurial visionary who is passionate and committed about going to Mars and you will see that the parallels between a human endeavor to Mars and an education

that elevates STEM/STEAM skills are remarkably similar. Getting to Mars and creating a skilled labor force for our nation is all about building with the same

organic material. And I am not talking about aluminum, steel or titanium. I am talking about the robust material of minds... young, brilliant, future scientific and engineering minds. Howard Bloom, founder, and chair of the Space Development Steering Committee says it this way: "Rockets roar into space using two forms of fuel. One is the liquid in the rocket's tanks. The other is the fuel in the human heart. Yes, big dreams are fueled by the raw stuff of the human spirit: excitement, awe, and desire. Those emotions power us to do the impossible. So when you're looking for a goal, find the one that excites you and your fellow humans the most."

And what is more exciting than the possibility of donning your spacesuit and hopping in a rocket headed roughly 140 million miles away from Earth to solve mysteries awaiting and to make discoveries on the Red Planet that are yearning to be known?

All you have to do is introduce students to Mars and the possibility of going there, have them imagine walking on its surface, invite them to think about how to make the planet habitable, and you'll have students leaning forward, asking questions, and getting curious. Ask, did life arise independently on Mars and then fall into total extinction or does some tiny remnant remain in the water ice of a deep martian crater? Conversations, hypotheses, and scientific investigation will then commence. Let students know that the best explorers aren't rovers but humans, and how what takes a rover weeks to analyze could be done by human hands and minds in mere hours. As they ruminate on the fact that the finest computer ever built sits atop their shoulders, show them Ray Bradbury's, *The Martian Chronicles*, and amazing space illustrations by Chesley Bonestell, Fred Freeman, and Rolf Klep. Watch as they become enthralled with Mars. It is an inspiration by visual stimuli. Then ask the students to write, draw, graph, or calculate their version of what a 21st-century manned mission to Mars would be like,

and there will be a virtual martian dust storm of ideas.

A brilliant girl named Resaiah heard me say in a presentation that twelve men had walked on the Moon, but no women. The next day she handed me a story she had written called "Astronaut World." In it, she wrote about a future mission when the people of Earth landed on Mars and a woman named Resaiah took her first bold steps on the martian surface. This young student had a moment of engagement and an experience of wonder, and she used creativity to envision herself in the future. As Socrates once said, "Wonder is the beginning of wisdom."

In May, at the Humans to Mars Summit in Washington, D.C., scouts from the area were invited to attend a workshop to imagine and create their version of a settlement on Mars. Later that evening, three scouts (average age 11) came on stage and in great detail shared everything from how they were going to melt the polar ice caps, to where they would store the water, to how they would use greenhouses to grow food, to the underground tunnels they would build to traverse between habitats to avoid the harsh effects of radiation, to where they would park their

rovers: creative enough to imagine to be the ones who will first step foot on Martian soil.

Many challenge the expense of a human Mars mission when Earth already has so many problems.

But where would we be without the knowledge developed by America's space program in the past 50 years? GPS, better robotics for human prostheses, nanotechnology, smartphones and the list goes on. Kaci Heins, Education Supervisor for Space Center Houston, says, "We must go to learn the story of Mars and to push the next level of science, technology, engineering, and math. It is problem-solving some of the toughest challenges humans can face in a relentlessly harsh environment." When we address the challenges related to human space missions, we expand technology, create new industries, and help to foster collaborations beyond our borders. Furthermore, the knowledge and innovations created for human survival on Mars will present solutions to solve problems and challenges we humans face here on Earth such as food insecurity, water shortages, alternative energy/fuel sources, among much else.

And that's what makes Mars such an effective STEM/STEAM tool. Communicating the thrill of exploration is as good as it gets when educating students about what a future on Mars might entail. Curiosity is in our DNA. We humans have always been driven to explore the unknown, discover new worlds, push the boundaries of our scientific and technological limits, and then push further. There is an insatiable thirst of the soul to challenge the confines of what we know and the only way for human exploration on Mars to be a reality is if we inspire the students of today to be the scientists, technologists, engineers, artists, mathematicians, programmers and astronauts of tomorrow. We must set our course for Mars, and we must do it now.

Ask the man for whom Pluto was his goal for 25 years, "Why Mars?" and Alan Stern, Chief Principal Investigator of the New Horizons Mission, will tell you, "Because the world needs new frontiers, because humans are explorers, and because kids of every generation need role models and inspiration. Why Mars? Because it will bring out the best in our species."



We must teach science as the greatest adventure story of all time; and allow and inspire students to dream beyond their house, their town, and their own Earth-bound experience.

Why Study Mars? To Better Understand The Earth

Philip Christensen, Contributor Professor of Planetary Geoscience, Arizona State University

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"Why should we study Mars, when there is still so much to learn here on Earth?" ask those who are skeptical about the benefits of space exploration. The answer, of course, lies in the fact that the two planets are remarkably similar, yet distinctly different in important ways. Quite simply, studying Mars can teach us much about the Earth.

Mars, like Earth, has an atmosphere, winds, clouds, weather, and dust storms. It also has massive volcanoes, great rift valleys, dry river channels, and huge sand seas. Mars has polar ice caps, snow banks, and glaciers that have striking similarities to those here on Earth. And, most importantly, Mars has evidence for liquid water and habitable environments, both in its past and today. This breadth of landforms, processes, and environments, by themselves, make Mars

a fascinating place to explore. But the most compelling reason to study Mars is not necessarily in the similarities, but rather in the differences with Earth that will help us to better understand our own planet's history and evolution. Why is the current climate of Mars, which is very cold and dry, so different from the Earth's? Why have the climates of the two planets diverged over time? What processes have led to those differences? And what can we learn about possible future changes in our own climate from studying Mars?

Perhaps the most fundamental insight that will come from comparing Mars to Earth is in the understanding that we will gain in how life emerged on Earth and what conditions were essential to its origin and persistence. Water is one of the key necessities for life, and evidence for water early in Mars's history, at the same time when life was gaining a foothold on Earth, has been discovered numerous times over the past fifteen years, with each of these discoveries providing unique new insights. We have found mineral evidence for ancient hot springs on Mars similar to those found today in Yellowstone National Park: massive salt deposits that formed when lakes of salty water evaporated, sediments deposited in fresh water streams and deltas, minerals that formed from highly acidic underground water, and pure snow and ice. Each of these ancient, water-rich environments would have provided life with a different habitat in which to originate and survive. Such a rich diversity of ancient environments on Mars provides us with the opportunity to determine which of these early environments may have been the most conducive to life's origin.

As we advance our exploration of the solar system, we are discovering that many of the moons around the outer planets are remarkable, ice-covered, ocean worlds that may provide their own opportunities for finding life beyond the Earth. With the existence of these other exciting possibilities, why does cold, dry Mars remain such an important place to study life's origins? Because Mars provides two crucial ingredients that the icy moons do not: its early history is very well preserved in its geologic rock record, and this rock record is relatively easy for human explorers to access. Life began on Earth over 3.5 billion years ago, but the record of that early time has been

almost completely destroyed by erosion and geologic activity. As a result, we have very little knowledge of what Earth's environment at that time was like, and very few clues as to what key conditions made life possible. But we can look to Mars for these clues, where conditions on Mars at the time when life was beginning on Earth may have been similar. At that time Mars had a warm, thick, carbon dioxide atmosphere, liquid water, energy from the Sun and volcanic heat, and the key elements that life would need. If we find that life did begin on Mars as it did on Earth, then this discovery would suggest that life could start on any planet with

similar conditions, which would provide strong evidence that life is ubiquitous throughout the universe.

But what if life never did begin on Mars? If not, then why not? What



was missing on Mars?

What were the key factors that allowed life to begin on Earth but not on our very similar neighbor? The answers to such questions may provide as much insight into how life began as would finding life elsewhere. And this is where Mars becomes important, because we can look for the answers in the martian rocks. Scientists studying life's origin believe that environmental conditions, such as water temperature and chemistry, the physical environment, and the available minerals and chemical compounds, all played crucial roles in allowing the early precursors to life to form and develop. A rock record preserves the evidence for these conditions, and while very little of this record is left on Earth, the martian rocks, formed at the same time and under similar conditions to those on Earth, are beautifully preserved in ancient sediments that are sitting at the surface and are patiently awaiting more detailed examination by humanity.

Beyond the question of life, the study of Mars continues to expand our understanding of the planet on which we live. For example, we have learned that the magnetic field of Mars, generated by motions in the planet's core, protected its early atmosphere from being stripped away by high-energy particles from the Sun, allowing Mars to have an early warmer, wetter climate. But Mars's small size caused it to lose its internal heat rapidly, and as a result its core froze, and the protective magnetic field disappeared. Much of the atmosphere was then lost, the climate cooled, and Mars began down the path to its current cold, frozen state. In contrast, the Earth's magnetic field continues to shield our atmosphere and sustains our warm climate and life as we know it.

Over time we have come to realize that anticipating the Earth's future will require a deep understanding of the complex interplay between the surface, interior, atmosphere, hydrosphere, and biosphere. Comparing and contrasting these systems with those on other planets will lead to a better understanding of how they work and how their different components interact. The closer the similarity the more useful the comparison and the deeper the insight. Mars, with its remarkable similarity to Earth, provides us with a unique opportunity to learn.

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Why Mars? An Astronaut's Perspective

John M. Grunsfeld, Contributor Astronaut, Scientist, Explorer

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I have dedicated my life to answering the great scientific questions of our time, and to the incredible adventure of space exploration.

As a young boy growing up on the South Side of Chicago, I was inspired by the nascent space age. At the age of six I declared that I wanted to be an astronaut. My mother thought that was just fine, as it would encourage me to learn science, and besides, there really was no chance I would ever actually become an astronaut. While I watched the Apollo astronauts walking on the Moon, I imagined that I might some day travel to Mars, to do science, of course. Indeed, I felt compelled to study nature, science, and engineering, eventually earning a PhD in physics. As a scientist, I sent experiments to near-space on high altitude balloons as well as into space aboard the Space Shuttle. But the explorer in me still wanted to go to space in person. To the amazement of my mother, in 1992 I was selected to become a NASA astronaut. I had the privilege to fly five missions on the Space Shuttle, including three missions to the Hubble Space Telescope. I have dedicated my life to answering the great scientific questions of our time, and to the incredible adventure of space exploration.

Of all the planets in our diverse solar system, Mars is unique in that it is the only planet where we can some day live in a somewhat similar fashion to the way we live on Earth. It is large enough to have a suitable surface gravity, and has an atmosphere and resources we can use to live off the land. Scientists using the intrepid Curiosity Rover have shown us that billions of years ago Mars was very much like Earth, with fresh water lakes, rivers, and warm salty seas. At about the same time that Mars was very much a habitable planet, life started on Earth. Did life also emerge on Mars? The question of whether we are alone in the universe is for the first time a discrete scientific question we can answer. We are exploring Mars for signs of past or extant life. We are also preparing to explore Jupiter's icy moon Europa, which might harbor a habitable ocean, and with future large telescopes we will look for signs of life on planets orbiting nearby stars. But Mars beckons us like no other world, and we will exponentially increase the pace of discovery when we have women and men explorers — planetary scientists and astrobiologists — on the surface of the Red Planet performing scientific research. These intrepid explorers will also be opening up a new frontier.

NASA has always been at the forefront of opening the frontier of space, whether with astronauts or robotic scientific explorers. Our national investment in NASA, pushing the boundaries of science and technology, has a tremendously positive impact on our economy, is critical to our national defense, and has provided inspiration to generations of young explorers. In the 1945 report *Science, The Endless Frontier*, which was presented to the President of the United States and which discussed the role of research by the government, Vannevar Bush wrote, "It has been basic United States policy that Government should foster the opening of new frontiers,... [that this] American tradition ...has made the United States great... [and] that new frontiers [should].. be made accessible for development by all American citizens." This is the grand purpose of NASA, and as suggested by Star Trek, "to boldly go where no one has gone before" -

to open a frontier that is so vast that it defies comprehension, challenges our imagination and forces us to be our very best!

Building on developments from nearly 60 years of space exploration, the dream of sending humans to Mars has never been closer to becoming a reality. Today there is a convergence of technical readiness, public engagement, and political will that might make a human expedition to Mars possible in the near future. However, achieving this challenging goal will require leadership, teamwork and focus beyond that seen in the last few decades. But these traits are exactly what NASA and our nation learned from Project Apollo, the Space Shuttle, and the International Space Station. The high performance challenge of landing people on Mars and returning them safely will require closer ties between scientists and the engineers developing human systems, closer ties between the U.S. and our international partners, and closer ties between traditional government contractors and emerging entrepreneurial space industries.



When we decide to send women and men to Mars it may well be the highest risk endeavor ever attempted by human explorers. But there is no doubt in my mind that it will be worth the risk.

The essential elements of what we need to go to Mars are at hand. On orbit now is the amazing International Space Station (ISS). This orbiting laboratory is the ideal proving ground for learning what it takes to get to Mars. Astronauts (and cosmonauts) launch from Earth to a habitat in space. Their six-month expedition mirrors the time in weightlessness that astronauts will experience on the cruise to Mars. After their ISS mission, the explorers descend to a planetary surface. It happens to be Earth, but it offers the perfect chance to learn and practice what future Martian explorers will do once they land on the Red Planet. NASA and its partners must substantially increase the utilization of the ISS, a precious resource, for the purpose of learning how to go to Mars. Other than radiation, it offers the ideal testbed for technologies and research into

human physiology and human factors for the long cruise to Mars.

Sending humans (and all that they will need to accompany them) to Mars will require substantial launch capabilities. This need for heavy launch capabilities goes back more than half a century, thus confirming concepts by Werner von Braun and others for Mars exploration. NASA is investing in the Space Launch System (SLS) to launch its large payloads for its expeditions to Mars. But there is more than one way to launch such heavy masses into space — and go to Mars. Indeed, SpaceX and Blue Origin are both investing in their own heavy lift rockets — and SpaceX plans to start sending its own missions to Mars starting in 2018. One way or another, we're going to Mars.

On the robotic exploration front, NASA is building the Mars2020 rover that will continue the exploration of Mars seeking signs of past life in the geologic record and will drill a couple of dozen small core samples for future return to Earth for detailed analysis. The Mars2020 rover also has an experiment to produce oxygen from the Martian atmosphere — the first time that resources will have been extracted from another celestial body that are needed to support human exploration.

NASA is also in the planning stages for a high-power solar electric robotic mission to an asteroid. While I am in favor of learning more about asteroids (as will be done with the recently launched asteroid sample return mission OSIRIS-Rex), the

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The Mars Generation: Why We Must Go To Mars

Abigail Harrison, Contributor Aspiring NASA astronaut & Board Chair at the Mars generation

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"Are we human because we gaze at the stars, or do we gaze at the stars because we are human?"

– Neil Gaiman, Stardust

This is a quote from my favorite movie, Stardust. This quote has defined my life and, I believe, defines humanity as well. I, like every other person on this planet, was born curious. As a kid I marveled at many things on Earth (and off!): the way that the leaves of trees would change color with the seasons, the way that ants moved in cohesion, the way that my fingernails would grow or a glass would shatter when it fell off a table. The world around me was exciting and full of new things.

I, like all children, was born a scientist: curious. But something happens to many children as they grow up, something along the way subdues this natural inclination for discovery that keeps humans alive, that inspires new technology to advance our abilities and that creates new ways to do things. Keeping children curious and engaged in the quest for knowledge through their teen years and into adulthood is essential to the future of humanity. So the question is, how can we stop kids from losing the drive to discover new things and keep them engaged and excited about the world around them? I believe that we already have an answer: human space exploration.

Human space exploration has an incredible capacity to excite and inspire even the most curmudgeonly person. What will we find out there? How will life be different for us in 50 years? These are the same questions that humans have asked themselves every time they have ventured afar whether it be traveling to new continents, exploring the depths of our oceans, or exploring outer space. Humans have a drive to explore, to push further than they have gone before, to test our limits and challenge the impossible. It is the human drive to explore that kindles and nurtures the fire of curiosity in young people, and continues the will to produce future generations ready to do



For the sake of the future of humanity here on Earth, we must put humanity elsewhere. We must send humans to Mars.

great things, just as those before them have done.

But space exploration isn't enough. And even human space exploration isn't enough. In order to inspire the next generation to stay curious and motivated to do great things, we must do great things now. We must push forward in human space exploration and challenge the impossible. We must set our minds to tasks that we have never before done. It is not enough to orbit the Earth, or send probes to other planets. For the sake of the future of humanity here on Earth, we must put humanity elsewhere. We must send humans to Mars.

So why Mars? What is it about Mars that will inspire and excite young people to stay interested in STEM? Mars is far away. It's hostile, without a breathable atmosphere, protection from radiation, or usable water. But it's exactly these hellish conditions that make Mars a desirable destination for our next giant steps as humankind. Mars is a challenging journey, which will push our understanding of our solar system, our knowledge of what we are capable of accomplishing, and our scientific and technological abilities. Mars is just difficult enough to provide us with the

challenge humans need to keep pushing ourselves to innovate and advance our own abilities on earth. While Mars provides a challenge beyond anything humans have ever taken on before, it is a challenge that we are capable of taking on and being successful.

Mars is the logical next step in human space exploration. Just as the Moon was a giant step for humankind in the 1960s and provided generations with inspiration to dream big and do great things, human Mars exploration will do that during my lifetime. We have the capability to send humans to Mars, and even more importantly, we have the obligation to do so. It is our duty to take on this challenge whole-heartedly, to inspire a new generation of kids to stay curious, and in doing so, to create a better future. We are the Mars generation, and this is our future.

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stated driver for the asteroid redirect mission is technology development for Mars exploration. Redirecting this mission to Mars would allow for significantly more Mars-relevant technology development. It would make possible a first ever round trip between Earth and Mars. Combined with a landed robotic mission in the mid-2020s, this mission would also return the first samples from the surface of Mars. The high power solar arrays that power the Xenon ion engines can also power a radar which could provide a global map of the subsurface ice on Mars. This map is required for future human explorers so they can use the ice for water to drink, to produce oxygen to breathe, and for rocket fuel for the return home. The mission can also provide high resolution imaging and communications — critical elements for all Mars exploration, human and robotic. A common saying

within the military is "amateurs talk strategy, professionals talk logistics." Overhead imaging, maps, resource reconnaissance and communications are the logistics we need for Mars exploration. This round trip mission should be regarded as a prerequisite to sending the first human explorers to Mars.

All space exploration is risky. As an astronaut I had to decide each and every time I went to space whether or not to risk my life for the mission. When we decide to send women and men to Mars it may well be the highest risk endeavor ever attempted by human explorers. But there is no doubt in my mind that it will be worth the risk, not only for our own nation but for the rest of humanity as well. The broad international clarion call to explore the Red Planet is a strong sign that we are ready to try, and the time is now.

John Grunsfeld is former Associate Administrator of the NASA Science Mission Directorate and served as an astronaut on five Space Shuttle flights.

Why Mars Can Be Affordable And Achievable

Joe Cassidy, Contributor Executive Director for Space Programs, Washington Operations, Aerojet Rocketdyne

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Why should humans venture to Mars? In some sense, it is to fulfill a longing in our collective psyche. Humanity has dreamed of walking on Mars since travel above the Earth's surface became feasible... Those dreams seemed to be on the verge of being realized with the dawn of the Space

Age in the mid-20th Century, but for decades Mars remained out of reach to human explorers on site. That frustrating situation has resulted in what many have come to see as Mars being perpetually "20 years away." In the terminology used for space launches, we have been in a "hold" for the past 30 years. Today, however, we can finally say that the countdown clock is running. We are going to Mars, twenty years and counting! If we stay the course, the first humans will set foot on the Red Planet by the year 2033.

New technologies have become available that have allowed us to take a fresh look at how to approach human Mars missions and, as a result, to tackle the hardest technical problems that had previously led to a hold in the countdown. And these approaches have given us the ability to design an architecture that can be brought on line incrementally, which keeps the annual expenditures within a reasonable projected NASA human spaceflight budget.

The key to this architecture is to separate much of the supplies and equipment and send them in advance of the crew. By prepositioning equipment, supplies, and even return rocket stages (more than 80 percent of the total mass), using propulsion systems such as solar electric propulsion (SEP) that are extremely energy efficient for long-haul cargo missions, we can save more than half the costs versus transporting everything using chemical propulsion systems that are needed to reach orbit.

On the other hand, the Space Launch System (SLS) is the key to placing large blocks of payload into Earth orbit. An analogy here on Earth would be how intermodal shipping of supplies and manufactured goods is accomplished. Short haul is accomplished by trucks or rail, while long haul is accomplished by massive ships. In this same way, SLS accomplishes the short haul mission to orbit, whereas the cargo is transported over the much larger distance to Mars by solar electric transport ships. The two different propulsion systems, each of which is appropriate for its particular type of mission, are complementary. And to transport the astronauts, we add in a third element: the Orion multi-

purpose crew vehicle as well as a deep-space habitat module, which together provide living space and life support systems.

Once all the elements arrive in Mars orbit, the final two pieces of the mission come into play. Improved entry, descent, and landing (EDL) approaches will safely and precisely land larger payloads on the surface. The largest payload elements, such as the surface habitat and the ascent vehicle to return the crew to Mars orbit, weigh 30 to 40 metric tons. Today we know how to land only one metric ton on Mars, so this is one of the challenges that still need to be overcome. However, NASA is already working on improved decelerators and other techniques such as supersonic retro propulsion. Such technologies need to be perfected within the next ten years, because the most massive payload elements will need about four years to be prepositioned. Once all of these are safely in Mars orbit, the crew can launch for the roughly seven-month transfer to Mars using cryogenic chemical propulsion stages to propel Orion and the deep space transit habitat.

The power of this approach is that we can use in-space technologies that we already know work well and scale them up to accomplish the first Mars missions. Other technologies, such as on-orbit refueling or nuclear thermal propulsion, can be proven and incorporated later as they are matured. The ultimate goal of manufacturing propellant from space resources, however, requires several steps before we can utilize such methods. First, we must locate the resources and determine their abundance. Next, methods of extracting and processing the material must be developed. Then the process of manufacturing the desired propellant, such as oxygen and methane, in the quantities required must be proven in either deep space or on the planetary surface. Therefore, while in-situ propellant production is a very attractive ultimate goal, it does not make sense to place in the critical path for the first missions.

Mars is within our grasp. With a sustained program of risk reduction activities over the next 10 to 15 years, we will eliminate the knowledge gaps that still remain and we will build up an infrastructure that is capable of sustaining human missions of ever-increasing capability. As we mature approaches that improve upon this architecture, we will incorporate them into the overall structure. We need to take the first step that proves the possibility. Mars beckons us and we may be living now at the perfect time – a combination of technology readiness, public interest, and political will – to answer that call.

Joe Cassidy is Executive Director, Space, Aerojet Rocketdyne

My Personal Mission To (And For) Mars

Clementine Poidatz, Contributor Actress

Originally published - November 15, 2016

Frankly, I was ignorant. I freely admit that. Before I joined the cast of the National Geographic series, Mars, I didn't know very much about Mars — and to be honest I didn't really care. Like many people, I didn't see how it related to me and why we should spend the money to go to Mars when there are so many problems in the world today that I deemed more important.

But as I prepared for my theatrical role as a crew member of the first mission to Mars, something wonderful happened. As I studied for my part by watching videos, reading articles, and finding out as much as I could about how and why we plan to send humans to Mars, to my great surprise I found my perspective changing. Later, when I was on the set, I found an infectious passion among the crew and cast. I wasn't the only one who was

future. Sending humans to Mars, however, is my generation's opportunity for a positive future, and we should embrace it.

I also believe, as Elon Musk has stated, that humanity needs a backup plan, so to speak. I'm not someone who believes that Armageddon is around the corner, but I do think that Mars gives us the chance to assure the future of humanity if something terrible were to happen on Earth. I'm reminded of a cartoon that depicted a dinosaur looking up at the heavens seeing a huge asteroid about to hit, and stating, "Maybe we should have started a space program..."

I now want to go to Mars, and not just in a movie but for real. I'd even go one way — and I sincerely mean that. And I'm not someone who is dissatisfied with my life here on Earth. I'm



I now want to go to Mars, and not just in a movie but for real.

transformed by our participation in Mars. Many of my fellow cast members also discovered themselves as being passionate advocates for making humanity a multi-planet species. We all realized that this was not like an ordinary film project. Instead, we were part of something that was bigger and of more lasting importance. We had the potential to inspire students and show the world that sending human to Mars will be one of the most important and historic events in human history.

We need big dreams. Children in France (where I'm from) don't seem to have big dreams these days. In fact, I'm not sure that they are even aware that sending humans to Mars is no longer science fiction but is now within our reach. I was born in 1981, and many people in my generation simply don't believe that we as a species are capable anymore of doing great things. And I find that sad and even a little scary. This wasn't the case when my parents were growing up. The world was far from perfect, but they had big dreams. My parents told me that the most amazing thing that they remember — the event that inspired them and made them hopeful for the future — was when the Apollo 11 astronauts first stepped foot on the surface of the Moon. They made small steps on the Moon, but it was a giant leap forward for humanity, and they came in peace for all humanity. Unfortunately, the most transforming memory I have (and I'm sure it's true of my generation as a whole) is the September 11th attacks — clearly a very significant event, but not the type of event that makes anyone hopeful for the

a happy person and I love life on Earth, but I long to explore. I want to feel the Martian soil in my hands and hike through the canyons, gullies and craters of Mars. I want to learn to live off the land and discover whether life ever existed on Mars. And even if it didn't, I will know that it does now!

When humanity is living and working on Mars, it will change everything, and I am convinced that it will also transform Earth for the better. I know that some people claim that we shouldn't go to Mars because there are many problems to solve and that there is much suffering here — and I was one of those people — but I now get it. I truly believe that exploring Mars will inspire the world, lead to new and important perspectives as well as result in new and innovative ways of doing things. Thus, life on Earth will noticeably improve if we send humans to Mars and otherwise explore beyond the confines of our home planet.

I hope that this series — Mars — will help inspire people and that they will view its storyline as being both realistic and important, because it is truly both of those things. It's about brave and inspiring people who could be flying real missions to Mars in the near future. Indeed, the people who will first walk on Mars are alive today.

I can't think of anything more fulfilling and personally rewarding than if, on the first actual human mission to Mars, the astronauts look back and say that the National Geographic series Mars inspired them to become astronauts and go to Mars.

Clementine Poidatz plays the role of Dr. Amelie Durant in the National Geographic series Mars.

Why Mars? – A Perspective From The United Arab Emirates

Talal M. Al Kaissi, Contributor Director of U.S.–U.A.E. Space Affairs, Embassy of the United Arab Emirates

Originally published - November 29, 2016

Multiple nations now have Mars in their sights as one of the most challenging goals humans can imagine. Here, Talal M. Al Kaissi of the United Arab Emirates explains why his country is one of the most recent to join the effort to explore Mars.

When His Highness Shiekh Mohamed Bin Rashed Al Maktoum, the UAE's Vice President, Prime Minister, and Ruler of Dubai made that proclamation, it was July of 2014, and the UAE was 43 years old. The comment was made shortly after the establishment of the UAE Space Agency. At that point, the UAE's investments in the "space" sector had already exceeded \$5 billion, including Al Yah Satellite Communications Company (YAHSAT) and Thuraya, which specialize in satellite telecommunication. Another UAE entity (EIAST) had even built and launched two earth observations satellites. The UAE was far along on its path to diversify its economy away from hydrocarbons, with approximately 70 percent of the country's GDP represented by non-oil based activities. With the global financial crisis finally beginning to recede, the country decided to aim even higher. In that spirit, 2021 was set as the target year to have the spacecraft achieve Martian orbit, to coincide with the country's 50th year anniversary. And as though six and a half years was not ambitious enough, roughly a year will need to be shaved off to complete preparations by the launch window in 2020.

So "Why Mars?" Those who recall U.S. President John F. Kennedy's speech in 1962, later dubbed "the Kennedy Moonshot," understand how inspirational a simple message can be: "Not because it is easy, but because it is hard." The U.S. was 186 years old at the time. Of course, Sputnik and the Cold War may have contributed to the drive behind that goal. The UAE's objective, while similar in its attempt to galvanize inspiration, rests on a different motivation.

Anyone who has followed the UAE over the last two decades understands that while it is a small nation in a geographic region that is more notable for unfortunate geopolitical issues, the country stands out for a number of reasons: Its visionary leadership and good governance, its advanced first class infrastructure and position as an important logistical hub, and perhaps most importantly, a solid commitment by the government to providing education for every citizen.

The result is evident in the 200 nationalities that coexist in a country the size of the state of Maine, whose population is just under 10 million people (with roughly 10 percent UAE nationals) and where most Fortune 100 multinational companies have a regional headquarters. With recently inaugurated federal Ministries of Tolerance, Happiness, and Youth, the UAE is a pioneer regionally as well as globally in effective government and business promotion. Many sectors, including tourism, logistics, aviation, heavy industry and technology have been part of the economic diversification process, utilizing the comparative and competitive advantage the UAE holds. In that regard, the UAE's entrance into the space sector was an inevitable eventuality and has garnered a lot of attention in the past two years.

The Emirates Mars Mission, called "Hope", has a few main high-level objectives.



The Emirates Mars Mission is one way the UAE can contribute to the knowledge that will prove critical for human missions to Mars in our lifetime.

Building human capital and capabilities

At the Mohamed Bin Rashed Space Center (MBRSC), which is leading the Mars Mission under the supervision of the UAE Space Agency, the average age of the 100 percent Emirati project management and engineering team is 27 years old. Over 40 percent of these engineers are women. In partnership with international organizations and academic institutions, the UAE is working on applying lessons and experiences accumulated in previous endeavors with home-grown satellite manufacturing. They are laying the groundwork for an increasingly knowledge-based economy that will train the UAE's engineers and scientists of the future.

Youth Inspiration and Education

Around a third of the world's population live in predominantly Arab countries within the Middle East and North Africa and around 50 percent are under the age of 25. Unemployment rates are staggering, usually in the double digits, and economic opportunities for youth are increasingly rare and sometimes non-existent. With a growing number of disenfranchised youth, oftentimes educated, but affected by political instability, the UAE leadership hopes that an initiative like "Hope" helps inspire youth, encourages STEM education in the Arab world, and attracts talent to participate in the country's drive toward a sustainable commercial space sector.

The Mission and Science Objectives

The Hope Probe aims to provide a true holistic picture of the Martian atmosphere for the first time in the history of Mars exploration, answering questions previously unanswered by other missions, to complement what humanity already knows about the Red Planet. By studying the atmospheric layers of Mars in detail, the mission will allow us to study the reasons for the drastic climatic change in the Martian atmosphere from the time it could sustain liquid water to today. In order to understand how and why Mars is losing its hydrogen and oxygen into space, it is crucial to understand the connection between the upper and lower levels of the Martian atmosphere. Data from the Hope Probe will also help model the Earth's atmosphere and study its evolution over millions of years. All data gained from the mission will be made freely available to 200 universities and research institutions across the globe for the purpose of knowledge sharing.

The probe will be equipped with three scientific instruments:

Emirates eXploration imager (EXI): Measures properties of water, ice, dust, aerosols and abundance of ozone in Mars' atmosphere.

Emirates Mars Ultraviolet Spectrometer (EMUS): Measures global characteristics & variability of the thermosphere, and hydrogen & oxygen coronae.

Emirates Mars Infrared Spectrometer (EMIRS): Examines temperature patterns, ice, water vapor and dust in the atmosphere.

There are many reasons Mars is a planet that has continued to fascinate generations of scientists, enthusiasts, and individuals of various ages and backgrounds. It more than likely is due to the curiosity we naturally possess as human beings.

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Why Mars? For Today's Students, Exploring Mars Represents So Much More Than The Red Planet Itself

Lance Bush, President and CEO, Challenger Center

Originally published - March 8, 2017

For as long as we can remember, the space industry has created moments that have inspired, and often defined, a generation: The first human-piloted space flight, the Moon landing, the Apollo 13 crisis, the Space Station, the beginning and end of the Shuttle era, the Apollo, Challenger and Columbia tragedies, the Hubble Space Telescope, Mars Science Laboratory Curiosity rover, New Horizons, the introduction and continued growth of commercial space companies, and so much more. In addition to providing those moments, I believe the community also represents the perseverance of the human spirit. Even after the worst of times, like the loss of the Challenger crew, it came back with stronger, more innovative plans.

Now the next generation is looking for that inspiration, dreaming about how they will change the world and what they will do to benefit mankind. For today's students, that motivation and inspiration is Mars. These students know they are the ones who will step foot on the Red Planet. They will also be the ones who find cures for previously untreatable diseases, identify new energy sources, design new aircraft, improve our ability to care and feed for a growing population, just for starters. They are the future of our industries, our economy, our planet and beyond. These students are the Martians of Tomorrow. This is why Mars is so important. It's more than the Red Planet itself. It represents a potential-defining moment for a new generation. This is what today's students are working toward – to be the leaders, innovators and explorers that will strengthen our country and our world.

In order to reach these goals, the Martians of Tomorrow will need to be the most technologically advanced, innovative generation we have ever known. But there are reasons for

concern. A report of international math and science assessments indicates that U.S. students continue to rank behind many other advanced industrial nations. Research shows that as a student advances into middle school, opinions on science change drastically. One-third of students lose interest in STEM subjects in fourth grade and by eighth grade that number jumps to half. This means the STEM pipeline is narrowed by 50 percent by the time students enter 9th grade. As the STEM pipeline is shrinking, STEM occupations are projected to grow significantly compared to non-STEM occupations, and employers will struggle to find truly qualified candidates. In addition, there is increasing concern that students lack the basic STEM knowledge required in even non-STEM industries.

All of these factors have a negative impact on students' ability to succeed in our competitive workforce. Not only is a strong STEM foundation critical to the future success of today's students, but it is also imperative for the continued growth of our industries and economy.

But we can all help. We can all play a part. It will take a global commitment from parents, teachers, community members, education leaders, STEM and non-STEM professionals and organizations to address these issues and provide inspiration and encouragement for today's students on their journey to becoming tomorrow's STEM leaders.

These students need our support so that they can exceed these expectations and create their own defining moment. This is why Mars represents so much more than the Red Planet itself. It can define a new generation. Join the #MartiansOfTomorrow movement here.



Now the next generation is looking for that inspiration, dreaming about how they will change the world and what they will do to benefit mankind.

Lance Bush is President and CEO of Challenger Center, a leading STEM education organization that inspires, engages, and prepares today's students for the future through innovative science, technology, engineering and math (STEM) education programs.

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We know it's in our solar system's "habitable zone" with water in the form of ice on the polar caps. We know that liquid water has flowed before — and still occasionally flows in small quantities — and the atmosphere historically was thicker. But something happened. And we want to know what and why. More importantly, what we learn may explain something about our own planet that we otherwise would not have discovered. We studied so much through the various missions whether orbiters or landers. And NASA, along with many other countries, as well as private industry, have the objective of manned missions to Mars or to establish a self-sufficient colony. The Moon and the International Space Station in Low Earth Orbit have been the focus of our attention since the '60s. Mars is the next destination.

It has been two years since the announcement and incredible progress has been made. The project team at MBRSC is ahead of schedule and the UAE Space Agency has also made some

great strides in the overall space sector. A National Space Policy is nearing completion. MOUs with several other space agencies and countries have been executed. On the U.S. side where I support Space Affairs under our Commercial Attache at the UAE Embassy in Washington DC, we have helped the UAE Space Agency conclude a Framework Agreement with NASA and signed a Space Situational Awareness Agreement with STRATCOM, as well as hosted the NASA Administrator in the UAE. We have also interacted and visited with various "New Space" companies across the U.S., hoping to identify synergies and collaborate on other very exciting opportunities before and after the Mars Mission. The Emirates Mars Mission is one way the UAE can contribute to the knowledge that will prove critical for human missions to Mars in our lifetime. This is only the beginning of what the UAE hopes to achieve in space and to contribute to the broader scientific community.

Why Mars? Because It Will Change Our World For The Better

Mary Lynne Dittmar, Contributor Executive Director, Coalition for Deep Space Exploration

Originally published - January 24, 2017

Imagine, if you will, a multinational crew busily preparing for launch on the first human mission to Mars. As the days tick by, round-the-clock coverage streams across cable networks, computer screens and millions of cell phones. By the time liftoff is at hand, a million and a half people have jammed the Florida coast, creating gridlock for miles and breaking the internet.

As the countdown nears zero, billions across the globe hold their collective breath. A sudden flash, a plume of smoke and then a searing light completely envelops the launch pad. All is eerily silent for a few seconds as the shock wave rolls across the water. Then a low rumbling begins, followed by the reaction of onlookers as a wall of sound hits them squarely in the chest before building to a deafening roar. Slowly, America's super-heavy rocket emerges from fire and smoke to clear the tower, shaking the Atlantic shoreline with power the world has not known since Apollo.

As days blend into weeks the crew goes about their routine, relaying back their lives over a 6-month journey through deep space. Finally, after a nerve-wracking but successful landing the hatch opens and the first human beings to set foot on another planet begin to walk on Mars. From millions of miles away, we watch as they work together to construct living quarters. A few days later they climb into a land vehicle and set off across the Martian landscape. Locating an ancient riverbed they steer into it, following as it opens into a valley where they disembark. Gloved hands feel along the eroded cliff walls as their eyes search for stratification. Chattering back and forth on helmet mics they huddle together, staring up at an outcropping of rock, trying to understand what it tells them about the planet's history.

In a tough and hostile environment like Mars, survival comes first. Our crewmembers are careful, methodical, following their training and procedures. But burning hot on the heels of survival is their desire — their need — to see what lies over the next hill. And so, after chipping out a few samples of rock for later analysis, they eagerly press on.

Back on Earth, we share that need. Their hunger to learn is our hunger too. As our lifestyles grow more sedentary it is easy to forget that we are a species of wanderers. Every great civilization arising on our planet has sent out explorers and benefited in return. Many of these explorations were expensive, took decades and came at great risk with loss of life. Human arrival and survival upon Mars will be no different. But the journey also will generate global interest and open the door to scientific discoveries we can barely imagine — including, possibly, resolving questions like "Are we alone?" and "Is there life on other worlds?" Among the planets of the inner solar system, Mars is most likely to hold the answers.

Lest all this sound like science fiction, be assured that it is not. NASA and other space agencies are working toward that future right now. All this may seem unreal, but that's because we cannot reach Mars today. It's difficult for us to think of what may happen across the decades that lie ahead. At the same time it would be foolish to dismiss such things because they are in the future. All great inventions, technologies and historic developments among nations were in the future at one time or another. Reaching Mars and laying the groundwork for permanent human life on



In a very real sense Mars is at the far end of the infrastructure we are preparing to revitalize in this country.

its surface is a long-term yet achievable goal that fosters forward-looking policies, plans and perspectives. Such things are important for any society.

A major study conducted by the National Academies of Science, Engineering and Medicine 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. It is essential that this be an international effort, led by the United States in collaboration with others, beginning but not ending with our existing partners in the International Space Station Program. The ISS has taught us that a multilateral enterprise such as Mars will bring to the table 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 and achievable within a decade with sufficient resources, would build and expand on the foundation created by the ISS with benefits to the entire world.

Why Mars? Why not the Moon? Simply put, Mars is the best place to develop a "local" infrastructure enabling us to live on another planet, albeit one millions of miles away. In a very real sense Mars is at the far end of the infrastructure we are preparing to revitalize in this country. NASA's approach to Mars initially moves human beings out into the region of space between the Earth and Moon, establishing the first deep space living quarters there. Nations or companies wishing to visit the lunar surface may do so supported by the infrastructure NASA is building now.

The Moon may turn out to be an important stepping stone with geopolitical, scientific and commercial benefits, but it is not the end goal. In addition to the fact that it is more accessible to human life than the Moon, Mars is much more interesting in both scientific terms and in public engagement. It is a dynamic planet, with seasonally changing icecaps, the possibility of past or present life, and signs of past climate change that we should understand. Mars once had running water, broad lakes and warmer temperatures but is now locked in an eternal deep freeze. What might this teach us about the changing face of our own planet? If we don't go, we won't find out. We must not hesitate to act boldly in our own interest and in the interest of our species.

Perhaps most importantly, our nation needs the next generation of eager, bright young scientists and engineers to advance our quality of life and remain globally competitive. In this rapidly changing world 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. Mars is such a goal.

In a world too often fraught with tensions and violence, the arrival of human beings and the eventual development of human communities on Mars will be an important and powerful symbol of what we can achieve together. When nations cooperate peacefully toward a common goal, when

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Why Mars? To Discover How Life Originates

Ramses Ramirez, Contributor Planetary scientist and astrobiologist, Carl Sagan Institute at Cornell University

Originally published - December 14, 2016



In 1964, Mariner 4 became the first spacecraft to successfully arrive at Mars. While some scientists of the time were expecting a world much like our own, one filled with rivers, oceans, and maybe even life, Mariner's images instead unveiled a heavily-cratered surface, not unlike the Moon's. That's why it was such a surprise when later NASA missions, such as Viking, benefiting from improved technology, revealed a martian landscape more like our Earth's. These newer images showed large fluvial features in ancient terrains, including the ancient river valley networks, inferred to have formed nearly 4 billion years ago. Therefore, many have argued that Mars may have once possessed a warmer climate, perhaps with a thicker atmosphere that could have supported potentially habitable conditions. Such a warmer early Mars may have been more "Earth-like" in many ways. So, it may be natural to wonder: How Earth-like does a planet need to be to host life? Did Mars ever have life? Does Mars have life now? Scientists operating on Mars could address these and similar questions that ultimately stem from one overriding question: Are we alone in the universe?

The size and scope of the ancient martian valley networks are impressive. Often hundreds of meters deep, and extending for hundreds of kilometers, these immense fluvial features likely required a climate that was warm enough, at least transiently, to have produced enough rain (or snow) to carve them. These valleys would have been difficult to form in a cold climate because much of the water would have been present as ice instead. To be fair, salty water — known as brines — perhaps flowing from underground sources, could remain in liquid form at below freezing temperatures. However, it is difficult to envision how a sufficient volume of briny flows to form these massive features could be produced in a cold climate with little precipitation. If the atmosphere was also significantly thinner than the Earth's, even if surface life had arisen in such a cold climate, that life would have had to contend with less protection from harmful radiation.

Likewise, life has yet to be found on today's martian surface. The average surface temperatures are well below the freezing point of water. Furthermore, the combination of a tenuous atmosphere and lack of a magnetic field allow harmful solar and cosmic rays to pass through and impact the surface. Nevertheless, it is conceivable that microbial life may currently be living in the planet's subsurface, shielded from the worst of

the radiation. And even if no life exists today, extinct organisms from earlier times may be preserved underground as fossils, waiting to be unearthed by explorers from Earth.

Moreover, Mars lends itself better to manned scientific exploration than does our other neighbors. For example, modern spacecraft cannot withstand the crushing atmospheric pressures and infernal surface temperatures of Venus. The surface of Venus also appears to have undergone periodic gigantic volcanic eruptions that have engulfed the entire planet in lava numerous times, destroying any potential evidence of fluvial features from an earlier period. Mercury is too hot and close to the Sun. The atmospheres of both the Moon and Mercury are

too thin to have ever sustained substantial amounts of liquid water on their surfaces for a significant amount of time, even if both worlds may have some water ice residing in permanently shadowed regions. Thus, Mars presents a unique opportunity as the only neighboring world that exhibits clear observational evidence of a climate that was once warm and wet enough to

create extensive fluvial features across its surface, often similar to ones seen on our Earth.

If we imagine that explorers from Earth find fossils proving that life had existed on Mars during this hypothetical early warm period (assuming that scientists rule out possible microbial contamination from the Earth), it may suggest that life has a high probability of emerging under atmospheric conditions not unlike those on our planet. However, even on Earth, we know that certain organisms thrive in extreme conditions very unlike those you or I experience daily on the surface. These extremophiles can withstand extreme heat, cold, acidity, pressures, and even salt content, all at levels that would be deadly to most other Earth life. What if similar hardy micro-organisms are thriving today on Mars' cold, dry, and irradiated surface? We can only definitively answer such questions by sending scientists to Mars who are dedicated to finding evidence of past or present life. The results of such an endeavor would clarify our perspective as to what is possible even as we speculate about life on the more distant targets of Europa, Enceladus, Titan, and (ultimately) exoplanets.

Humans on Mars is not a capricious whim, but rather is an imperative to scientific progress. Orbiters, rovers, and landers have all made great strides in increasing our understanding of the Red Planet but they cannot replace the judgment, ability to respond to unexpected situations, and sheer ingenuity of human scientists. As much as we have learned about Mars from afar, we would learn so much more by sending people there.

Humans on Mars is not a capricious whim, but rather is an imperative to scientific progress.

Ramses Ramirez is a planetary scientist and astrobiologist from the Carl Sagan Institute at Cornell University.

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entrepreneurs and citizen scientists and great institutions come together to address tough problems, it sends a powerful message to those who would seek to undermine free and open societies and return us to the dark ages. That said, human footsteps on Mars are not a panacea. They will not cure the world of its ills nor address the deficit of spirit that leads to madness in some of its more unfortunate denizens. And it will be a challenge to

maintain long-term political interest in and commitment to this long journey.

But our nation has done such a thing many times before. The vision of humans on Mars, imagined for centuries, is now within our grasp. We owe it to ourselves, our country and our posterity to press forward toward this great vision of an optimistic future for humankind — one that, once realized, will forever change our world for the better.



Public Support for Mars Exploration is Strong and Consistent

Findings of the 2013 & 2016 National Public Opinion Polls on Mars Exploration

<https://www.exploremars.org/national-opinion-polls-on-mars-exploration>

2016 Mars, Robotics and Exploration Poll:

This national public opinion poll on attitudes and support for the United States space program and deep space exploration was conducted by Phillips & Company, an independent consulting firm, and the results were released in May 2016.

This scientific survey was designed to elicit at least 1,067 responses to ensure a representative sampling of the U.S. population that is statistically accurate results at a 95% confidence level and an error rate of $\pm 3\%$.

Highlights include:

- 84% of Americans agree or strongly agree that America leads the world in space exploration (regardless of education level)
- 64% of Americans agree that the U.S. should send humans to Mars
- Regardless of demographics, all groups overwhelming support the statement that "Exploration is critical to prosperity and progress."
- 62% of those surveyed believe humans are necessary for space exploration (as opposed to robots)

2013 The "Mars Generation" National Opinion Poll:

The "Mars Generation" survey was conducted by the independent market research team of Phillips & Company (www.phillipscompany.com) and sponsored by Explore Mars, Inc. (www.exploremars.org), a non-profit 501(c)(3) organization, and The Boeing Corporation. This survey was conducted between February 4, 2013, and February 6, 2013, targeting a stratified random sample of 1,101 respondents representing a 95% confidence level and margin of error of $\pm 3\%$.

Highlights include:

- NASA's budget in FY2011 was \$18.4 billion representing 0.5% of the federal budget. On average, Americans believe that NASA spending represents 2.43% of the federal budget with a standard deviation of 1.68%.
- 75% of Americans strongly agree or agree that it is worthwhile to increase NASA's percentage of the federal budget to 1 percent to fund a mission to Mars.
- 67% of Americans agree the U.S. should send both humans and robots to Mars, and 84% of Americans support sending humans to Mars if Curiosity finds signs of past or present life.
- Americans rank sending humans to Mars as the most important mission to our country.
- When asked to rank potential barriers to Mars exploration, 73% of Americans believe that the greatest barrier is affordability and 67% believe politics to be a limiting barrier. Technology and motivation are not seen as significant barriers by most Americans.
- 71% of Americans are confident that humans will go to Mars by 2033; and both men and women agree with no distinguishable difference.
- Americans from all diverse racial groups support Mars exploration. 71% of both white and black Americans, and 79% of Asian Americans and 80% of Native Americans, are confident that humans will go to Mars by 2033.

Additional Interesting Statistics:

Jobs:

Space exploration generates thousands of jobs around the country, not only in government but also in small and large businesses as well as in academia, and those jobs are located in every state and in virtually every congressional district.

See NASA's annual procurement data at - <http://www.lpi.usra.edu/exploration/multimedia/NASABudgetHistory.pdf>.

As we plan to send humans to Mars, the number and quality of jobs around the United States will increase.

Small Business:

Over 800 small businesses located across 47 states have contributed to the Orion program.

Over 800 small businesses located across 43 states have contributed to the Space Launch System Program.

Small businesses received approximately \$5 billion in contracts during Fiscal Year 2015 including approximately \$2.5 billion awarded directly to small businesses in prime contracts

Budget:

NASA's budget is less than 1/2 of 1% (that is, 0.5%) of the overall federal budget. In comparison, the military budget is greater than 16%, and entitlements represent greater than 60%, of the overall federal budget.

Learn more:

Pathways to Exploration: Rationales and Approaches for a U.S. Program of Space Exploration. National Academies Press, 2014.
Journey to Mars, NASA, 2014.

