The New Space Race

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Once in a great while something happens that is so significant we realize that our world has been changed forever. As we look back, we have separate memories of what life was like before the event, and how our life was different from that point forward.

Yesterday was the 60th anniversary of one such event. Back in 1957, life was much simpler than it is today. Eisenhower was president, "Leave It to Beaver" was premiering on black and white television, and people were following the World Series between the New York Yankees and the Milwaukee Braves. On October 4th, 1957, Americans woke to newspaper headlines that the Soviet Union had launched the first manmade object into space. They named it Sputnik.

This was not a propaganda stunt drummed up by the Soviet Union. Americans could see Sputnik for themselves as it moved across the nighttime sky, reflecting sunlight from its highly polished outer shell. Anyone with a shortwave radio could tune to 20 MHz and hear the pulsating 'beep, beep, beep' sound of the satellite each time it rounded the earth. The Soviets were very deliberate in making sure that everyone knew Sputnik was real.

Not only had the Russians beat us to space, they also proved they had the technology to launch nuclear missiles at the United States, which had a serious geopolitical impact on the United States. How could this happen? How could a group of backwards Russian peasants, who could barely even build a working refrigerator, beat us to space? The space race between the United States and the Soviet Union had begun.

The Soviet Union surprised the world again by launching Yuri Gagarin, the first man into space, on the capsule Vostok 1 on April 12, 1961. By this time, there was intense political pressure on American politicians to address the Soviet lead in space. President Kennedy, in his famous "We choose to go to the moon" speech in 1962 at Rice University, outlined the vision of sending a man to the moon and returning him safely to the earth by the end of the decade. NASA launched Project Gemini, followed by project Mercury, and finally the Apollo lunar missions, successfully landing man on the Moon on July 16, 1969. Many people in this room remember the excitement of the Apollo lunar missions. I remember watching Neil Armstrong step on the moon on a black and white television when I was 8 years old.

This was a period of amazing American advancement in space that could not be matched by the Soviet Union, which eventually cancelled their lunar landing program in 1973. The United States won the space race. America conducted seven more missions to the moon, eventually cancelling the remaining missions and ending the lunar program in December 1972 due to budget cuts and public indifference to the space program.

In stark contrast to President Kennedy's clear vision of sending a man to the Moon by the end of the decade, subsequent administrations followed with series of vague, unfunded plans, without a deadline, that eventually stalled. In 1989, President George H.W. Bush called for construction of a new space station and a 10-year plan for a mission to Mars. President Bill Clinton committed to finishing the International Space Station, but quietly shelved the plans for the Mars mission. In 2004 President George

W. Bush proposed the Constellation program, which called for Americans to return to the moon by 2020 and eventually reach Mars. President Barak Obama cancelled the Constellation program in favor of a mission to an asteroid as a stepping stone to a "Journey to Mars" without any firm plan or timeline.

After decades of shifting priorities and lack of funding, it should be no surprise that American's human spaceflight capabilities have declined. Since the retirement of the Space Shuttle fleet in 2011, the United States has not had the capability to launch an American astronaut into space from American soil. The United States must rely on Russia to launch its crews to the International Space Station aboard the Russian Soyuz spacecraft. Most people, including myself, have lost interest in routine space travel. Today, anyone with enough money can buy a trip aboard a Soyuz spacecraft as a space tourist. It seems like nothing remarkable in space travel has happened in many years.

Today, however, a new dynamic in space exploration is evolving, sparking a renewed interest in space travel. Last week, at the 2017 International Astronautical Congress in Australia, two organizations, Lockheed Martin and SpaceX, laid out some exciting plans for travelling to Mars. Lockheed Martin and NASA have teamed up and aim to reach Mars by 2030. SpaceX plans to travel to Mars by 2022. These two groups, one, an established aerospace contractor and government agency, and the other, a young ambitious, energetic company, are taking two completely different approaches to landing a human on the Red Planet. The new Space Race is on, and it's

going to be a very exciting ride to Mars. This paper will describe NASA's and SpaceX's plans to travel to Mars, as well as discuss one of the biggest risks in travelling to deep space.

NASA/Lockheed Martin

[Human Exploration Slide]

The NASA/Lockheed Martin plan for travelling to Mars consists of three stages, each with increasing challenges as humans move farther from Earth. Within each stage, the exploration objectives are grouped into three categories: transportation, working in space, and staying healthy.

Earth Reliant Exploration

In the Earth Reliant stage, the current stage, NASA is researching and testing technologies on the International Space Station. NASA is sending supplies (and soon crew) to the station from American soil via commercial spacecraft, including the SpaceX Falcon 9 rocket and dragon capsule. On the space station, the orbiting microgravity laboratory serves as a test bed for the technologies and communications systems needed for human missions to deep space. Astronauts are learning about what it takes to live and work in space for long periods of time, increasing our understanding of how the body changes in space and how to protect astronaut health. Astronauts aboard the International Space Station have conducted many long duration space flights to study how microgravity affects the human body. Research has shown that astronauts

experience bone density loss during prolonged weightlessness, regardless of the amount of exercise they get. Impacts of prolonged space travel on the immune system and cardiovascular system have been thoroughly studied as well.

Proving Ground

Proving ground missions will build on the accomplishments made in the earth reliant stage. The first objective will be to demonstrate the safe operation of the Space Launch System (SLS) rocket and the Orion spacecraft.

[SLS Slide]

The SLS is the next generation of heavy lift rockets developed by NASA with the capability to take us to the Moon and beyond. The SLS looks like a combination of the old Saturn V rocket and the space shuttle. It has the same familiar solid rocket boosters used on the space shuttle, but instead of the space shuttle orbiter and its orange external fuel tank, the SLS has the central Core Stage. The rocket is powered with 4 of the space shuttle's RS-25 Liquid Oxygen engines.

[Orion Slide]

Riding on top of the SLS will be the Orion Multi-Purpose Crew Vehicle, America's next manned spacecraft. The capsule has been in development since 2005.

[Orion Slide 2]

The Orion spacecraft has three main components. The Launch Abort System positioned on a tower atop the crew module, can activate within milliseconds to propel the vehicle to safety and position the crew module for a safe landing. Orion's Crew Module houses four astronauts for deep-space missions lasting up to three weeks. The shape looks very familiar to the crew modules of the Apollo missions. Inside the module are advances in life support, avionics, power systems and advanced manufacturing techniques. Finally, the service module provides propulsion, power, thermal control, altitude control, and water and air support to the crew.

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NASA plans two missions to verify the operation of the SLS and the Orion space capsule. The first flight, designated Exploration Mission 1 or EM-1, will take place sometime in 2018 and will be a 25-day unmanned mission. EM-1 is like the 1968 Apollo 8 mission to the moon designed to test the Apollo Command and Service Modules

Following EM-1, NASA plans to launch Exploration Mission 2, EM-2, the first crewed mission of NASA's Orion on the Space Launch System. During this mission, NASA plans to deliver the first components of a Deep Space Gateway in Lunar Orbit.

[The Deep Space Gateway slide]

The Deep Space Gateway, also part of the Proving Ground stage, will be a crewed spaceport in lunar orbit used for scientific research and as a staging area for resources and crew bound for Mars. It will have several solar power arrays, a small

crew habitat, docking capability, an airlock, and have attached logistics and research modules. Building the deep space gateway will allow engineers to develop new skills and test new technologies that have evolved since the assembly of the International Space Station.

[Asteroid Redirect Mission]

The Proving Ground stage also includes an Asteroid Redirect Mission. An unmanned spacecraft will retrieve an asteroid boulder and put it in an orbit near the moon. An Orion crew will visit the boulder and collect samples in the mid-2020s.

The Proving Ground stage will culminate at the end of the 2020s with a one-year mission in lunar space before venturing on crewed missions beyond the Earth-Moon system to validate its exploration and extended deep space travel capabilities.

Journey to Mars

What NASA learns in the proving ground will pave the way for Earth independent missions to Mars. To travel to Mars, we must break the reliance on frequent resupply missions and dependence on ground control. This stage enables scientists to identify and pioneer innovative solutions to technical and human challenges that could only have been discovered in deep space. The capabilities needed for operations in the Earth Independent period will depend on knowledge and experience that is expected to be gained in the previous two periods.

The concept for this mission is named Mars Base Camp. It's an orbiting platform with four main sections and redundant systems. It is comprised of four large solar powered arrays to generate electricity and power the station. For populism it has two cryo-genic stations with pods to store the fuel, liquid oxygen and liquid hydrogen. Mars Base Camp has two crew habitats. Two Orion spaceships will provide a command platform comprised of the avionics and navigation systems.

SpaceX

[SpaceX Slide]

SpaceX, led by Elan Musk, a hyper-achieving, risk-taking billionaire, just last week unveiled ambitious plans for deep space travel to Mars. Elon Musk's Mars ambitions are driven by both adventure and a feeling of self-preservation of the human species, believing an interplanetary species has the best chance of survival.

Musk says that SpaceX's goal is to land at least two cargo missions on Mars by 2022.

[BFR Rocket Slide1]

To get there, the company will start building a huge new rocket the next 6 to 9 months they call the "BFR". The B stands for big, the R stands for rocket.

The new BFR is 106 meters tall with a 9-meter diameter. The booster rocket uses 31 Raptor engines and there are six Raptor engines on the second stage spacecraft. The BFR will have space for 150 tons of cargo. The payload section can also be configured to hold 40 cabins, with 3 people in each cabin.

[BFR slide 2]

The BFR will be the largest rocket ever built. Here's a slide showing the relative size of the BFR compared to other rockets.

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Financing these plans is a major factor in SpaceX's success. Musk plans to replace all current SpaceX launch vehicles and spacecraft, including the Falcon 9 and the Dragon capsule, with the BFR. This will allow all SpaceX financial resources to be redirected to the BFR. Reusability is also a major factor in saving money. All of SpaceX's rockets are reusable. You may have seen video last year of the SpaceX Falcon 9 landing upright on an ocean barge. If you haven't, you need to see it. It is truly amazing. Musk says that the precision of the rocket landing is now so precise that they will be able to land the BFR back on its launchpad.

[Orbit Slide]

After the two cargo missions in 2022, further missions will follow in 2024 consisting of four ships, including two cargo vessels and two crewed ships.

[BFR Slide 2]

During this stage, the goal will be to build a propellant plant as well as take the first people to mars, and to build up a base in preparation for an expanded surface presence. And then to build that into a city, blossoming across the red dirt of Mars. Musk foresees this Mars city growing, and over time "making it really a nice place to be."

[BFR Slide 3]

At the conference last Friday, Musk said if you build a ship capable of going to the moon and Mars, why not use it for high-speed transport here at home. He proposes using his still-in-the-design-phase rocket for whisking passengers from New York to Shanghai in 39 minutes flat. Los Angeles to New York, or Los Angeles to Honolulu in 25 minutes. London to Dubai in 29 minutes.

"Most of what people consider to be long-distance trips would be completed in less than half an hour," Musk said. A seat should cost about the same as a full-fare economy plane ticket, he noted.

Compared to youthful energy of SpaceX, NASA looks like an old bureaucratic, slow moving dinosaur. The millennials who work for SpaceX pride themselves in working faster than the government. It's interesting to note that the average age of NASA engineers at the time of Apollo 11 was 28. Nowadays it's 47.

Time will tell if Musk's ambitious plans will succeed. Considering that from going from Sputnik to landing man on the moon took only 12 years, his timeline may be possible.

Space Radiation

With all this talk about going to Mars, there is one fact that is remarkable to me.

[Deep space vs Low Earth Orbit Slide]

Since the beginning of human spaceflight, 560 humans have spent a total of 139 man-years (50,000 days) in space. Despite all this time in space, it surprised me to realize that only the 12 Apollo astronauts on lunar missions have ever travelled beyond low earth orbit into deep space. Man has only spent 82 days in deep space, which is less than 2 tenths of one percent of our total time in space. To date, we have almost no experience with actual deep space travel.

There is a significant difference between travelling in deep space compared to travelling in low earth orbit.

[Magnetic field slide]

In low earth orbit, the Earth's magnetic field serves to protect us from the harmful effects of high-energy radiation found in deep space. By deflecting the particles around our planet, we are not exposed to the harmful effects of this radiation. Life on earth would be impossible without this protection. This radiation protection extends out to

1200 miles in space, within the area of all low earth orbit space travel, including the International Space Station.

The types of radiation we experience on Earth and in low earth orbit is different than in deep space. On earth we are exposed primarily to x-rays and gamma rays. In deep space, the radiation risk is much more intense. During interplanetary travel, Astronauts are exposed to multiple forms of radiation, primarily galactic cosmic radiation, solar particle events, and trapped radiation in the Van Allen belts. Galactic cosmic radiation consists of high-energy protons and atomic nuclei, originating outside the Solar System and even from distant galaxies, travelling nearly the speed of light. A solar particle event (, or "proton storm", occurs when particles (mostly protons) are emitted by a solar flare. The Van Allen radiation belt is a zone of energetic charged particles, most of which originates from the solar wind, that is held around our planet by that Earth's magnetic field.

Scientists first became aware of deep space radiation when the Apollo astronauts reported seeing spontaneous light flashes on moon missions, especially when the cabin was dark, although some astronauts said they saw the lights flashes even in bright light. The frequency of the flashes varied but typically they occurred about every two minutes. Researchers concluded that the flashes were caused by galactic cosmic radiation particles interacting with the retina.

Galactic cosmic radiation particles, because of their high atomic number and high energy, cause much more biological damage than other forms of radiation. Despite

being an area of great concern to scientists, surprisingly there have been very few studies on the long-term adverse effects of exposure to galactic cosmic radiation. One recent study in 2016 on the mortality rates of the Apollo astronauts suggest that the damage caused by deep space can be severe.

[Study Slide]

The study compares the proportional mortality rates due to cardiovascular disease of four groups: the general US population and astronauts. The astronaut group was further divided into non-flight astronauts, astronauts that only travelled in low earth orbit, and the Apollo Lunar astronauts.

The study shows that the Apollo lunar astronauts who travelled into deep space have a significantly higher mortality rate from Cardiovascular disease than either astronauts that never flew in space or astronauts that only flew in low earth orbit. Moreover, the lunar astronaut mortality rate was significantly higher than the age-matched general US Population, even though the Apollo astronauts are an elite, highly educated, physically fit group. Considering that the lunar missions only lasted between 8 and 12 days in deep space, the study suggests that even short durations of exposure to deep space radiation can have significant detrimental long-term health effects.

Developing shielding to protect our astronauts from deep space radiation during long Mars missions is a top priority for NASA. One strategy is to use shields consisting of hydrogen rich plastics or water. Another option being investigated is to use a

magnetic field to deflect radiation around the spacecraft. None of these strategies currently provide a method of protection that would be known to be sufficient for extended space travel. In my opinion, protecting our astronauts from deep space radiation is the biggest technical challenge we face travelling to mars.

Conclusion

Sixty years ago, the fear generated when the Russians launched Sputnik into orbit overshadowed the thought that this day would bring about the start of the Space Age. The technical challenges involved in launching Sputnik were immense given the technology of the time. Its development timeline was also incredibly compressed.

Likewise, NASA and SpaceX are also facing huge technical challenges and compact timelines in their effort to travel to and colonize Mars. NASA's and SpaceX's plan for Mars includes numerous firsts – the creation of permanent, inhabited structures on the surface of another world, using the resources present on Mars, and a requirement that hundreds of people willingly uproot their lives from one planet to live on another.

While the challenges will be difficult and numerous, they are – importantly – not insurmountable. As it did 60 years ago, it comes down to ambition and a desire to look at into the future and ask the question "Why can't we to do this?"