DARE MIGHTY THINGS

Athenaeum Society

I was born in 1980. Demonstrating my boldness, and my lack of wisdom and judgment, I'm opening this paper with a reminder of just how youthful and vigorous I am, and how, well, youthful and vigorous some of you aren't. During my formative years I was inspired to take an interest in various subjects because of the advancements, and setbacks, of a field of study that has just recently, and rightly, been pushed back to the front burners of our collective attention: Space Exploration.

Many of you well remember the fist celestial satellite, Sputnik [**PHOTO**], launched in October 1957, weighing just under 200 lbs and making its first orbit of the Earth in 98 minutes. Along with its launch came the decades-long space race. The United States's first orbital success, Explorer 1 [**PHOTO**], came 3.5 months later in late January 1958. NASA itself wasn't created until that October. I don't remember space exploration as a race against Russia, or anyone else. I remember being inspired by the discovery of what's up there and out there. I remember shuttle launches. I remember the Challenger [**PHOTO**] explosion in 1986, though of course I couldn't fully appreciate its costs. I was, and continue to be, excited about the promise of the Hubble [**PHOTO**] space telescope — first proposed in 1946 and launched 31 years ago next month[1] aboard Discovery[2]— and the Kepler "K2" Mission [**PHOTO**] — another space based telescope launched in March 2009, repurposed even after a mechanical failure for ongoing surveys of space. The images and discoveries of those two incredibly

[1] https://www.nasa.gov/content/goddard/hubble-history-timeline

[2] STS-31, Space Transportation System, https://science.ksc.nasa.gov/shuttle/missions/sts-31/

advanced scientific instruments are stunning and ongoing. Over the last decade or so we have seen the discoveries of the Curiosity Rover on Mars, first launched in November 2011, landing in Gale Crater (about the size of Connecticut and Rhode Island combined) in August 2012, and which to date has spent over 3000 Sols (Martian days) roaming the surface, and snapping 768,000 photos along the way. The InSight lander arrived on Mars in 2018 and is a stationary device for deep-surface observation and experimentation. We could spend days discussing and learning about the exciting Artemis Mission that I'm thrilled to see NASA advance, putting the first woman and the next man back on the surface of the Moon hopefully by 2024. But tonight I'd like to discuss the most recent newsworthy space venture, and a new source of inspiration for people, young and old, the Mars Perseverance Rover.

Earth's first trip to Mars was back in 1975 with the launches of the [**PHOTO**] Viking 1 and Viking 2 orbiter/lander pairs. The Viking landers had, by today's standards, very rudimentary camera equipment on board. Their mission was supposed to last 90 days, but Viking 1 served for nearly six years and Viking 2 for nearly four before they made their last transmissions back to Earth.

The twin rovers Spirit and Opportunity [**PHOTO**] landed in January 2004, each with 90-day missions that lasted years. Spirit operated for more than six years, traveling 4.8 miles, and Opportunity continued in service more than 14 years, shooting 214,000 images, and traveling 28 miles across the Martian surface.

The Mars Curiosity Rover continued the mission of searching for past signs of life, being sent to answer the question, "Did Mars ever have the right environmental conditions to support small life forms called microbes?"[3] Curiosity samples rocks and soil, and particularly looking for signs of interactions with water.[4] Curiosity has been steadily moving since it made it arrived, and between its landing in 2012 through November of 2020, has traveled about 15 total miles.[5] [**PHOTO**]

The newest inhabitant of Mars, Perseverance, has a similar mission, to "seek signs of ancient life and collect samples of...broken rock and soil for possible return to Earth."[6] Perseverance, named by contest winner and Virginia seventh-grader, Alexander Mather, is designed roughly the same as the Curiosity Rover, using many of the same components. The external dimensions of both rovers are identical, coming in at 9.5' wide, 8.8' long, and a surprising 7.2' tall (the mast), though Perseverance checks in at just under 2300 lbs compared to Curiosity's 1982 lbs.

Perseverance, like Curiosity and two dozen other spacecraft launched over the last half century before, is powered by a radioisotope thermoelectric battery, converting the heat generated by the natural decay of radioisotopes into energy, a process known as the

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[3] https://mars.nasa.gov/msl/mission/overview/

[4] https://mars.nasa.gov/msl/mission/overview/

[5] https://mars.nasa.gov/msl/multimedia/map-archive/?page=0&per_page=25&order=sol+desc&search=&category=176%3A295&url_suffix=%3Fsite%3Dmsl

[6] https://mars.nasa.gov/mars2020/

Seebeck Effect.[7] NASA requires the radioisotope to "(1) exist in an insoluble form and/or otherwise not be readily absorbed into the body in the unlikely event of a launch accident, (2) exist in a form such that it presents no or minimal chemical toxicity when taken into the body, (3) have relatively low neutron, beta and gamma radiation emissions, so as to not adversely affect spacecraft instruments or require excessively massive shielding, (4) be stable at high temperatures, so its characteristics remain essentially unchanged over many years, (5) have a long enough half-life (at least 15 to 100 years), so that it can generate for many years sufficient heat for transformation into electricity, (6) have a high power density, so a small amount of it can generate a substantial amount of heat."[8] The only radioisotope that meets that wishlist is Plutonium Dioxide[9] which loses half of its energy every 87.9 years.[10] Perseverance has 4.8 kg of it on board.

Perseverance is specifically designed to study and identify, if it can, signs of life on Mars: Astrobiology. Depending on our orbital paths, mars is between 60 Million and 250 million miles, but our spacecraft don't make a bee-line to Mars. The orbital path took Perseverance for a 300 Million mile trip to the Red Planet. [**VIDEO**] Eighty seconds into entry of the atmosphere the heat shield hits its hottest point at approximately 2100º C. The aircraft entered the Martian atmosphere at a blistering 13,000mph and at 90

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[7] https://www.britannica.com/science/Seebeck-effect

[8] https://rps.nasa.gov/about-rps/about-plutonium-238/

[9] https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/plutonium.html

[10] https://rps.nasa.gov/about-rps/about-plutonium-238/

seconds into its entry procedure experiences the greatest amount of deceleration. At four minutes in, the parachute deploys. Curiosity's parachute was triggered by an algorithm that detected when the target speed of 900 mph was reached. But for Perseverance, the parachute opened only after the computer on board detected the right combination of speed and trajectory. Once the aircraft jettisoned its heat shield and slowed sufficiently, the rocket powered sky crane engaged to lower Perseverance the remaining distance to the ground, about 68 feet. The sky crane remains in the air to avoid damaging the landing site or the rover itself. The lines are cut once the rover makes landfall and the sky crane blasts off a safe distance away to crash land on the surface. After these complicated landing maneuvers, Perseverance landed in Jezero Crater, near a structure that seems to the plain eye like a delta that may have once held water, pouring into or out of a lake like structure roughly the side of Lake Tahoe. Jezero Crater is about 2300 miles away from Curiosity's home in Gale Crater.

While there many structural similarities to Curiosity, Perseverance, nicknamed "Percy," has a number of new designs and accoutrements. Unlike the Curiosity Rover, [**VIDEO**] Percy is equipped with a drilling apparatus that captures samples of rock or soil about the size of a piece of chalk, measures the volume of each sample, and stores the sample in a sealed tube for future retrieval from a subsequent Mars mission machine, and takes images using one of its 23 on-board cameras at every step of the process.[11]

[11] Animation: https://mars.nasa.gov/multimedia/videos/?v=423

[12] This new drill is accompanied by both a gas chromatograph and mass spectrometer, which are machines that have been in use in forensic chemistry for decades.

Perseverance is also equipped with an X-Ray imager used to determine whether microbes have been on the surface of the planet, and to detect the presence (or absence) of various elements in the soil. Perseverance has a ground penetrating radio imager known as RIMFAX to detect subsurface features, and perhaps even the presence of water. For the first time, we now also have a microphone on board. If you haven't already, I encourage you to google the sound tonight when you get home. As dull and empty as it is, it's exciting to bear first witness to the sounds from another planet!

Perseverance has on board the Mars Environmental Dynamics Analyzer (MEDA), verbose description for "a weather station to measure atmospheric pressure, temperature, humidity and winds."[13]

Another new feature that serves no scientific purpose, but adds to the inspiration and aspirational impact of the Mars missions, three silicon chips [**PHOTO**] have saved on them the names of nearly 11 Million human beings that wanted to get as close as possible to visiting the Red Planet. Those names are also accompanied by 155

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[12] https://mars.nasa.gov/multimedia/videos/?v=423

[13] https://mars.nasa.gov/mars2020/spacecraft/rover/

finalist's essays, chosen from 28,000 submissions, to name Perseverance. All of those have been permanently stenciled onto the fingernail-sized chips by an electron beam.[14]

The very capable brains of Perseverance is still operating on the same PowerPC 750 [**PHOTO**] chipset that was used in the 1998 G3 iMac.[15] I don't have specs on how much more capable it is in terms of processing power, but the chip does have significant improvements to live on Mars. "BAE Systems manufactures the radiation-hardened version of the PowerPC 750, dubbed RAD750, which can withstand 200,000 to 1,000,000 Rads and temperatures between –55 and 125 degrees Celsius (-67 and 257 degrees Fahrenheit)."[16] The chip also costs a bit more than the off-the-shelf variety inside a 23-year-old desktop iMac, coming in at a whopping $200,000.

The first Martian photo was taken by one of the Viking landers, and was transmitted back to Earth very slowly. Today, we are able to view, though not in real time, high resolution panoramic photos stitched together, and high definition video of the landing itself. I assumed communication with Perseverance, and Curiosity for that matter, was relatively constant. It is not. Since 1963, NASA has operated the DSN, or the Deep Space Network, to keep tabs on nearly every object we've set loose in the Solar System. The DSN consists of three enormous antennas located 120º apart, one in the Mojave Desert, one in Madrid, Spain, and one in Canberra, Australia. Each site has

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[14] https://mars.nasa.gov/news/8634/109-million-names-now-aboard-nasas-perseverance-mars-rover/

[15] https://www.macrumors.com/2021/03/02/nasa-mars-perseverance-rover-imac-powerpc/

[16] https://gizmodo.com/a-1990s-imac-processor-powers-nasa-s-perseverance-rover-1846380844

multiple antennas, but the biggest as about 230' in diameter. [**VIDEO**] Together, the Network array is able to maintain a constant ear for the signals from our space craft. For those curious, Perseverance, on its own, has service that makes AT&T's service in North Christian County seem speedy. According to NASA, "the data rate direct-to-Earth varies from about 500 bits per second to 32,000 bits per second (roughly half as fast as a standard home modem). The data rate to the Mars Reconnaissance Orbiter is selected automatically and continuously during communications and can be as high as 2 million bits per second. The data rate to the Odyssey orbiter is a selectable 128,000 or 256,000 bits per second (4-8 times faster than a home modem)."[17] Because the Network has to listen for traffic from everything, the dish time for Perseverance is shared with everything else. "The rover's downlink sessions...are generally roughly 15 minutes each, with usually two downlink sessions per relay orbiter (ODY, MRO) per martian day (sol), with two sessions overnight and two sessions in the late martian afternoon."[18] Curiosity gets only about 30 minutes each day on the Network.

Another one of the new features of Percy is a personal favorite of mine. He comes complete with his own detachable drone! The Ingenuity Mars Helicopter, [**VIDEO**] a 4-lb rotorcraft equipped with six lithium-ion batteries will remain attached to Percy for 30-60 days while the batteries go through a series of charging cycles. Once it is deployed and departs from Percy, Ingenuity will be subsequently recharged via its own on-board solar panels. The test-flight period is 30 Martian days (approximately 31 Earth days). Much

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[17] https://mars.nasa.gov/msl/mission/communications/#data

[18] https://mars.nasa.gov/msl/mission/communications/#data

of the effort behind Ingenuity is just to see whether or not it can even be done at all. According to NASA, "If Ingenuity succeeds in taking off and hovering during its first flight, over 90% of the project's goals will have been achieved. If the rotorcraft lands successfully and remains operable, up to four more flights could be attempted, each one building on the success of the last."[19] The engineering feats of the entire Mars exploration enterprise are each incredible. The same lithium-ion battery technology that powers the phones in your pockets has to survive day-time Martian temperatures around -81ºF and brisk nights that fall to -130ºF, and still manage to fly the autonomous drone up to five times, and all that after it travelled for months through outer space. The aircraft also has to be powerful enough to lift the 4-lb package into the air with an atmosphere less than 1% the density of our own, with rotor speeds around 2400 RPM.[20] Ingenuity can fly for up to 90 seconds, each time about 10-15 feet off the surface over a distance of about 980 feet.

Spring is approaching and 'tis the season for Easter Eggs. Just like Steven Spielberg or any number of Disney movies, NASA is fond of hiding Easter Eggs in and on its spacecraft. One of my favorites from Curiosity were its tires. Seemingly random holes were made into the tread pattern, but the holes actually represented in Morse Code the letters "JPL" (Jet Propulsion Laboratory), which were imprinted in the Martian soil as the rover traveled. NASA delivered a big one for the world to see during the landing of Perseverance. When the now widely circulated video footage [**VIDEO**] was released

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[19] https://www.nasa.gov/feature/jpl/nasa-s-mars-helicopter-reports-in

[20] https://mars.nasa.gov/technology/helicopter/#Five-Things

one of the cameras was aimed upward toward the 72' supersonic parachute designed to dramatically slow the descent of Perseverance until the sky crane could make the final drop off. The experts at JPL aimed to build a parachute that could inflate "in a Mach 2 wind in about half a second."[21] To test under conditions as close to the comparibly scant Martian atmosphere, JPL tested the parachute at the upper limits of our own atmosphere at Mach 2 speeds. Needless to say, their research paid off. But my favorite part has to be what the hid in the parachute. The red and white patterns in the different concentric rings was a message written in binary code. The inner three rings, when translated, spelled "Dare Mighty Things," a reference to JPL's motto, pulled from a speech given by Teddy Roosevelt, known as the "Strenuous Life" speech. "Far better is it to **dare mighty things**, to win glorious triumphs, even though checkered by failure ... than to rank with those poor spirits who neither enjoy nor suffer much, because they live in a gray twilight that knows not victory nor defeat." The outermost ring includes longitude and latitude for JPL headquarters itself.

Perseverance [**PHOTO**] also had an obligatory rear window sticker set on board, showing the whole Martian rover family.

I would be remiss if I didn't make an effort, in the spirit of our distinguished fellow member, Mr. William Turner, to make a Kentucky connection to this presentation. Kentucky, certainly famous for basketball, bourbon and fried chicken, can brag that its

[21] https://www.jpl.nasa.gov/news/testing-proves-its-worth-with-successful-mars-parachute-deployment

biggest export industry is actually none of those, but rather the aerospace industry. Kentucky also enjoys a strong research relationship with America's space program.

Specifically, Kentucky has several partnerships and research projects in collaboration with NASA through something called the NASA EPSCoR program. The University of Kentucky Engineering program has a Space Grant from NASA Glenn on electric aircraft systems, and both Murray State and UK are involved with a grant from JPL related to satellite data. Professor Alexandre Martin at UK is operating NASA-funded research on heat shields for hypersonic atmospheric entry, the very kind of circumstances experienced by the Perseverance heat shield. According to UK, its the only university with this capability, and the research has been an integral "part of the design and post-flight analysis of the Orion vehicle (Artemis missions), Mars Science Lab, and Mars2020 - the Perseverance mission. In April, UK's NASA-funded research team will deliver three UK-designed space capsules that re-enter from the International Space Station, testing the first 3D printed NASA heat shield.

I feel I have failed by not finding a Hopkinsville connection to Mars, or even NASA, though I'm confident some of you may be able to enlighten me during the comments. The closest I've been able to get is the service of Colonel Terry Wilcutt of Russellville, a US Marine, TOPGUN graduate, and on multiple occasions served as space shuttle pilot for both *Atlantis* and *Endeavor*.

Whether extra-terrestrial or Earthbound, may we all dare to do mighty things.