AEROSPACE

AMERICA

Homo sapiens astronauta

Should we modify our bodies for deep space travel? Here's how it might be done.

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SHAPING THE FUTURE OF AEROSPACE

WOMEN REFLECT ON APOLLO

There was only one woman in Mission Control when Apollo 11's lunar module landed on the moon; today women make up 34% of NASA's workforce. Debra Werner talked to one of the pioneers.

BY DEBRA WERNER | werner.debra@gmail.com

JoAnn Morgan was the only woman engineer among scores of men listening to Vice President Spiro Agnew congratulate the members of NASA's Apollo 11 launch team in the Firing Room at the Kennedy Space Center on July 16, 1969, after the spacecraft launched. NASA

When Neil Armstrong first stepped onto the moon, Frances "Poppy" Northcutt wasn't at her desk at NASA's Manned Spaceflight Center, now Johnson Space Center. She was resting up for her job the next day: helping guide the astronauts home.

As the only woman on the Mission Control technical staff to that date, Northcutt was highly visible not simply for her blonde hair and fashionable miniskirts. Most of the women working for NASA or its contractors during the Apollo 11 mission typed letters, sewed spacesuits or assisted the overwhelmingly male engineering staff with calculations and reports.

"There were some extraordinary women who stood out," says William Barry, NASA chief historian. "But for the most part the roles women played at NASA and in many government agencies at the time were secretarial and those sorts of jobs."

Fifty years later, NASA is poised to begin sending astronauts to the International Space Station in commercial crew taxis. This time female engineers, while still in the minority, will share far more of the credit.

At Boeing's Space and Launch Division, chief engineer Michelle Parker oversees the engineering team building CST-100 Starliner, the crew capsule scheduled for an October flight debut. Aerospace engineer Melanie Weber leads Starliner's launch-pad team, and Starliner's crew and cargo accommodations subsystem. Weber appreciates the mix of men and women working on Starliner after college courses in which she was sometimes the only woman in a class of 200. "Being female and Hispanic isolated me even more," she says.

▲ **NASA biomedical** engineer Judy Sullivan was one of the people who kept track of astronauts' respiration, body temperature and heartbeat through small sensors attached to their bodies, including the Apollo 11 crew.
NASA

▲ **Frances "Poppy" Northcutt**, left in her early NASA days. Right, she talks about her role at the agency during a panel discussion of the PBS documentary "Chasing the Moon," which premieres July 8-10.
LBJ Library/Jay Godwin

SpaceX, NASA's other Commercial Crew contractor, did not make anyone available for interviews, but Gwynne Shotwell, the company's president and chief operating officer and a mechanical engineer by training was recognized by Women in Aerospace with its outstanding achievement award in 2012 for her "extraordinary technical and business sense with a charisma and passion for space, education and advancement of sciences."

Jessica Jensen directs mission management for the Dragon vehicles, including the cargo and crew versions. Crew Dragon could fly for the first time with crew by the end of this year.

Women still make up only 34% of NASA's 17,373-person civil servant workforce and 28.4 percent of space agency employees are not white, according to NASA's Workforce Strategy Division and Office of Diversity and Equal Opportunity. But that's a dramatic change from the late 1960s, when women comprised about 17% of a staff of 218,000, Barry said. NASA began tracking minority employment in 1970 when 4.7% of civil servants were not white.

As the only woman in Mission Control, Northcutt attracted the attention of fellow engineers and media coverage. She was featured in Life magazine and Paris Match, the French weekly magazine. "I always felt that as a woman, I needed to prove myself more because people were watching," she says. "I also felt the media coverage was an opportunity to get a message out to other women and to girls that women could do these jobs."

A graduate of the University of Texas with a bachelor's degree in mathematics, Northcutt took a job with NASA contractor TRW Systems Group

▲ **Katherine Johnson, shown in 1968,** has become world renowned as one of the black women whose work was at the heart of many NASA achievements. She has a doctoral degree in mathematics, and her calculations helped synch Apollo's lunar lander with the command module. Her professional life was a focus of the book and movie "Hidden Figures." President Barack Obama awarded her the Presidential Medal of Freedom in 2015.
NASA

in 1965 as a computress, a title like "computer" given to women who performed complex calculations. By the time Armstrong, Buzz Aldrin and Michael Collins traveled to the moon in July 1969, TRW had promoted Northcutt to an engineering role. Beginning with Apollo 8, she led a trans-Earth injection team, plotting the command module's optimal trajectory on its return trip, tracking its progress in flight and revising the engine firing schedule if necessary to ensure the spacecraft would enter Earth orbit at the proper angle to splash down within range of U.S. Navy recovery ships.

Northcutt was still working for TRW in the early 1970s as she became increasingly involved in the women's rights movement, inspired primarily by demands for equal pay, and in 1978 when she attended night school at the University of Houston Law Center. After graduating in 1981, Northcutt worked in the district attorney's office prosecuting domestic violence before becoming a criminal defense attorney. "I'm semiretired at this point," Northcutt says, "but I still do a lot of work for women's rights. My experience in the space program illuminated that for me."

IN THEIR WORDS

Elaine Denniston

Keypunch operator for Apollo Guidance System Data at the MIT Instrumentation Lab (now Draper Laboratory)

I punched the cards that eventually were turned into the program for the guidance system for the Apollo project. Punching cards is punching cards whether you're in an insurance company or working on the Apollo project. The programmers would give me 11-inch by 17-inch sheets of paper. They would write the program in blocks. My job was to keypunch it onto the cards. Remember, direct access to computers didn't happen back then. After I'd been doing it for a while, I could spot a missing symbol and say, "Should you have that?" They would say, "Yeah. Thanks." I was known for that and for telling them to get their programs in on time.

Denniston became a lawyer following her role punching computer cards during Apollo.
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Mary Gene Dick

Secretary to the deputy director Mississippi Test Operation now Stennis Space Center)

I did whatever needed to be done: type something up, run a letter, make travel arrangements, take somebody to the airport. We were on a mission to do the biggest exploration mankind had ever done, and it was thrilling. My husband and I were invited to the launch at Cape Canaveral. When we saw it was a good launch, I cried, I sang. I wanted to wave my American flag and sing "God Bless America." We were on our way to the moon.

Mary Gene Dick meets astronaut Fred Haise, who flew on Apollo 13.

NASA

"My husband and I were invited to the launch at Cape Canaveral. When we saw it was a good launch, I cried, I sang. I wanted to wave my American flag and sing 'God Bless America.' We were on our way to the moon."

Mary Gene Dick, a secretary at the Mississippi Test Operation, now NASA Stennis.

Frances "Poppy" Northcutt

Apollo 11 engineer

You can't communicate directly with the spacecraft when they are doing their maneuver, and you don't have any tracking because it's on the backside of the moon. You don't know whether the maneuver went well or didn't go well. You lose signal for about 30 minutes. Bad things can happen if they overburn or underburn or the burn doesn't start on time. When they come around, it takes a few minutes for folks to tell you where the spacecraft is. Is it where it's supposed to be? If it's not, you might have to act quickly to get the information up there to correct their trajectory. Their onboard computer didn't have nearly enough capacity to compute trajectories.

Saydean Zeldin

Apollo software engineer, MIT Instrumentation Lab (now Draper Laboratory)

I started as an engineer working on Apollo guidance. The astronauts knew it as P40 [software] because that's what they would key in when they wanted to burn an engine. I had to figure out the change in trajectory, when to burn an engine and how long it should burn. I did the programming for the Apollo computer and for the simulator, which used a very sophisticated compiler that could use matrix and vector equations. Every time you would key in a matrix times a vector, you had to use three punch cards: one for the exponent, one for the mainline and one for the postscript. I had three daughters. I would work all day, come home late in the afternoon, let the babysitter go, have dinner and go back to the lab.

Zeldin circa 1969

DRAPER

TAKING INSPIRATION FROM APOLLO

The art of the impossible

Generation Z has some big science and technology goals in mind, from stopping climate change to going to Mars. Much of this zest can be traced to the Apollo 11 landing. Morgan Kopecky, a 2019 high school graduate and aspiring engineer, explains.

BY MORGAN KOPECKY

MORGAN KOPECKY
graduated in June from Woodbridge High School in Irvine, California. She will be a freshman at the University of California, Los Angeles, where she will study engineering.

With the benefit of hindsight, I now know that the moon landing on July 20, 1969, made it possible for me, a 17-year-old California girl, to discover her passion for space. I didn't always know that I was interested in space or even STEM. I knew of the moon landing from history class, but I was not an Apollo wonk. In fact, I never felt a true connection to space until my freshman year in high school.

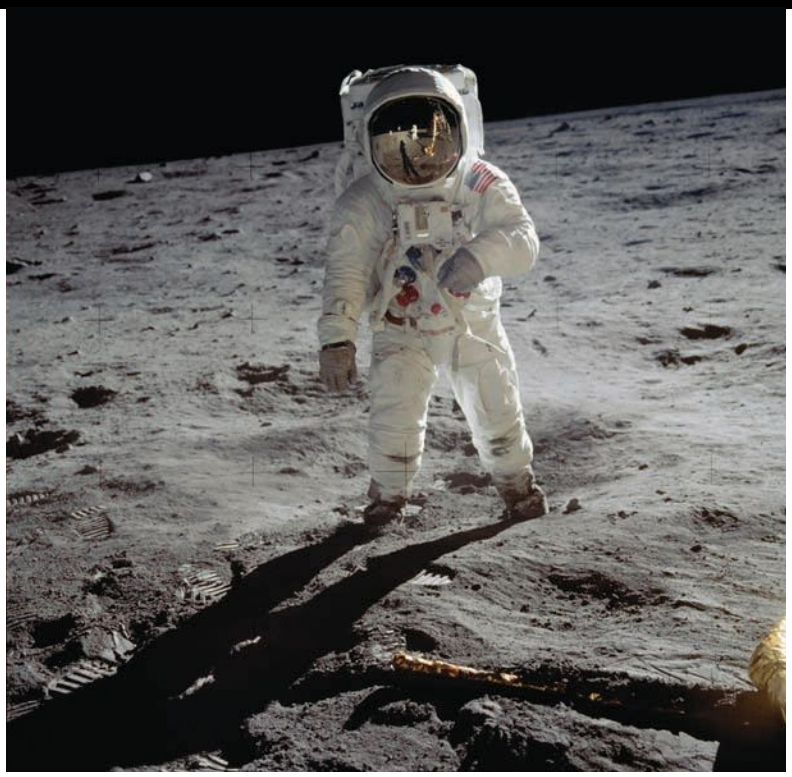
I was sitting in my biology class when a teacher walked into the classroom to pitch a new program that our school was going to participate in called Irvine CubeSat. The six high schools in my school district would work together to build and launch nanosatellites called cubesats. This teacher spoke about how we would have the opportunity to work with professional scientists and engineers from around the world and how we would be launching our satellites into space. I was 14 years old at the time and had next to zero experience in science, but I decided to try out for our school's team anyway. When I opened my acceptance email a few weeks after applying, I was excited. Looking back four years later, I could not have comprehended the ways that this opportunity would change my life.

I did not realize it at the time, but without the moon landing and work of thousands of brilliant scientists before my generation, the opportunity to build cubesats would not have come about, especially for high school students. Through this program, I have assembled satellites, spoken to NASA scientists and tracked cubesats in space. I built relationships with my team, our mentors and experts in industry. But the moon landing means so much more to me than the actual opportunities that it has provided for my classmates and my generation.

When I spoke at the 2019 Goddard Memorial Dinner, I stated, "Space is not generational," meaning our triumphs belong to no single generation. Space unites the generations. The greatest generation watched the moon landing, baby boomers remember where they were when the space shuttle Challenger was lost, and my generation, Generation Z, watched online as Falcon 9 stages flew back from space. When Generation Z thinks about space, we are excited about going to Mars. We cannot wait to watch rocket launches, and we understand the importance of using satellites to monitor climate change. These are things that everyone can be excited about regardless of their scientific background. The moon landing has made all this possible, even though not everyone lives and breathes the details of the historic mission.

For this essay, I spoke to my high school classmates who possess a large range of interests. Whether my classmates aspire to be engineers or are non-STEM majors, everyone said they found meaning in those grainy black and white images from 50 years ago. We realize that when President John F. Kennedy promised to put a man on the moon in 10 years, he did not know how we would get there. We did it anyway. No two of my classmates are the same, but one thing that unites us is that we each have a professional passion. Many of us are interested in technology, and we want to change the world. Our can-do attitudes, undying need to explore and desire to do the seemingly impossible were born on July 20, 1969.

When I asked my high school friend Rohan Go-



▲ **Buzz Aldrin** walks on the moon in this photograph taken by Neil Armstrong.

NASA

rajia what the moon landing meant to him, he said, "I was not alive for it, but it helped show me that the technology at your disposal is not what is holding you back. It is the will to work hard for what you are trying to achieve." When I asked my Russian friend Vasily Tremsin, he told me, "It serves as a guide for my own life, and drives me to do the next big thing that may seem undoable or impossible." And when I asked my art-oriented 13-year-old sister, Ava, she said, "It inspires me to achieve my own dreams."

Apollo 11 affects our cubesat team too. We have a running joke that goes: "If we can put a man on the moon, we can arrive to our meetings on time … get our cubesat's communication radio system to work … figure out how to code" and so on. We laugh at these jokes, but we also find motivation in them. Putting a man on the moon was the greatest generation's "impossible." Our team's "impossibles" are balancing our homework so we can get to meetings on time, solving issues with our radio even when we can't find a solution in the manual and learning new programming languages. If our past generations can achieve their impossibles, we can certainly achieve ours.

The events of the first moon landing may live half a century in the past, but its influence will undoubtedly carry us into the future. My generation has our fair share of challenges ahead of us. Our impossibles are climate change, bacteria resistance, science education and technology addiction, among other issues. We need our can-do attitudes now more than ever. When I look at the people around me, I see that the moon-landing mentality lives in all of us. My generation is ready to tackle our impossibles, and we have Neil and Buzz to thank for that.

Curb your disillusionment

Today's space program is not the space program of the 1960s. True, but the changes are not all bad, says Samantha Walters, a 2015 graduate of the University of Maryland.

BY SAMANTHA WALTERS

SAMANTHA WALTERS is a space mission planner at the Johns Hopkins University Applied Physics Lab. She graduated from the University of Maryland in 2015 and was an Alexander R. Norris intern at AIAA.

When I was born in 1993, the space shuttle program had been around for 12 years, and launches were almost routine. The push for Mars exploration was still in its early days, and the Curiosity Rover wouldn't launch for almost two decades. As a kid growing up in Woodbury Heights, New Jersey, where there was no real connection to the space industry, from my perspective, there wasn't much happening.

For most of my childhood, I didn't think much about space exploration. Then, as a middle schooler, I saw the movie "Apollo 13" for the first time. That movie, and specifically the scene where NASA engineers dump boxes of random junk onto a table and work together to create a CO2 filter to keep the astronauts alive, showed me exactly what I wanted to be. There was something about the fearless risk-taking, the almost-impossible goals and, of course,

▲ **Deke Slayton,** center, director of flight crew operations, explains to NASA officials how a lithium hydroxide canister aboard the command module could be adapted to remove excess carbon dioxide from the Apollo 13 lunar module cabin. The emergency was depicted in the movie "Apollo 13."
NASA

those stylish short-sleeved white button-downs that completely captivated me. Now, 14 years and a whole lot of studying later, I'm a real-life, grown-up aerospace engineer, working at the Johns Hopkins Applied Physics Laboratory in Maryland on NASA missions to explore our solar system.

In going from a space program superfan to a full-time employee, I have realized that the Apollo-era NASA that I dreamed about is not the same agency that exists today. Rapid technology development has been slowed by shrinking budgets and increased risk aversion. Without leaders like John F. Kennedy to rally support for human spaceflight, opportunities to work on such missions have decreased. Plus, I've never once been offered a cigar in a control room.

I love my work, but I spend most days behind a desk, writing computer code and responding to emails; a stark contrast to the slide-rule-carrying, astronaut-saving engineers I saw in "Apollo 13." I find myself feeling somewhat disillusioned, but I'm not the kind to accept disillusionment.

To better understand this feeling and see if my millennial peers had a similar perspective, I called a friend who helps to develop future human missions to Mars. He has greater natural optimism than I do and generally disagreed with the idea that today's space industry is less exciting than that of the 1960s. He pointed out that the Apollo missions were extremely risky — maybe too risky by today's standards — and that increased cautiousness means more safety for future astronauts. He asserted that engineers who work with missions to the International Space Station probably feel similar excitement and intensity to the Apollo engineers we look up to. I'm not sure if I agree with him, but neither of us knows anyone working on current human missions to ask. If there are any ISS engineers reading this, I'd love to know what you think!

Our talk got me thinking about the many reasons that I am lucky to be a part of today's space industry, not the least of which is that, because I am a woman, I probably would not have been an Apollo engineer. My options would have been, in a best-case scenario, to work as a human computer or a secretary. But most likely I could have been a housewife to a NASA engineer. Since joining the workforce in 2015 initially at NASA, I have had more bosses who were women than men. I have had the privilege of working with people of different races, sexual orientations, ages and nationalities who have each brought their unique perspectives to the industry. This is a welcome change from the wall of white, cisgender, middle-aged men who can be seen in most photos from the Apollo era.

Diversity has also increased with the advent of international and private-industry collaborations. Some large missions involve dozens of collaborators, including universities, international space agencies, private companies and research centers like APL, where I work. Payloads are launched on Russian rockets, or more recently by SpaceX. While reliance on foreign and private entities is sometimes seen as a negative, I am excited to be working in a time when space exploration is encouraging international cooperation instead of Cold War-era competition. In the 1960s, the fear of falling behind drove our innovation in human spaceflight. Today, human missions to places like Mars will be made possible by global collaboration and will be celebrated as human achievements, not just American ones.

With the lowered focus on crewed missions beyond low Earth orbit to explore our universe, NASA has focused its efforts on robotic exploration. While landers and orbiters don't often inspire the public to crowd around their TVs the same way the Apollo landing did, spacecraft are going farther for less money and without risking human lives. Advances in space robotics have allowed us to discover water on Mars, dive through the rings of Saturn and fly past Pluto on interstellar trajectories. While putting footprints on Mars is still further off than we might like, I'd argue that rover tracks are a pretty good start.

For better or worse, the space program of today looks a lot different than it did in 1969. Sometimes, while sitting behind my computer on my fourth conference call of the day or reading through what seems like thousands of mission requirements, I wish NASA could be like it was then. I wish things moved a little faster, or that we had a little more funding, or that I could sit around a table and try to "put a square peg in a round hole" and save some astronauts like the engineers in "Apollo 13." My peers and I may never get to experience the magic of the Apollo era, but we're creating our own, through innovative technologies and international collaboration, in workplaces that are more diverse than ever before. I'm confident that before I retire, I'll get to witness, and even be a part of, a few more giant steps in the exploration of our universe. Maybe I'll even get my first celebratory cigar (in a designated outdoor smoking area, of course). ★