Exploring Space, Exploring the Earth: The Apollo Program's Terrestrial Legacy

When the first human set foot on the moon in July 1969, it ushered in a new age of space exploration and technological innovation, and marked humanity's first steps into a new frontier. The moon landing was made possible by huge strides in technology brought about by the combined efforts of the United States government and researchers from all walks of life. The innovations created for Apollo were later used to generate new technologies in a wide variety of different fields. This essay will show that the space program—itself designed to take humanity to a new frontier—opened up new frontiers back on Earth in the realms of technology, materials science, ideology, and international cooperation.

The word "frontier" often evokes images of a place that sits beyond a boundary dividing two areas, one familiar, one unfamiliar. Frontiers appear in many forms, tangible and intangible; they can be places, ideas, or events. As places, they may be remote or previously unknown areas that people have yet to reach. Going a bit farther, mental frontiers reflect consideration or creation of new concepts to help their creators better understand themselves or the world around them.

When Neil Armstrong set foot on the moon, he famously stated that it was "one small step for man, one giant leap for mankind." It was indeed, for the Apollo Program gave birth to a wide variety of new technologies. Among other things, it facilitated the creation of advanced computing, miniaturized technology, and Durette flame resistant fabric. The space program also advanced the cause of women's rights and spawned a new area for international cooperation.

Technology and Materials Science

The Apollo Program was pivotal for the development and innovation of computer technology and enhanced the speed of computing while dramatically reducing the size of computers, enabling mankind to progress toward a world of digital technology. The Apollo missions would have been impossible without computers. Flying to and landing on the moon required many precise calculations that no individual person (or even a team of people) could possibly do. The solution was the creation of a new type of computer.

The centerpiece of the Apollo Program was the Saturn V, a massive 3,000-ton rocket powered by five engines that generated 3.4 million kilograms of thrust.[1] Most of the space on the rocket was devoted to fuel, so the room left for astronauts and their equipment was limited. In the early 1960s, computers were massive and sometimes occupied the space of an entire room.

NASA contracted with the Massachusetts Institute of Technology to produce the computer, which became known as the Apollo Guidance Computer (AGC). The completed computer weighed 70 pounds, which was "miniaturized from the size of seven side-by-side refrigerators to a one-foot cube."[2] The AGC reduced the space occupied by a computer by shrinking the components and performing calculations using integrated circuits rather than vacuum tubes, which would have required a great deal of space and required extensive and tedious preparation. Robert Noyce, the co-founder of Fairchild Semiconductor, developed the idea of putting the integrated circuits onto silicon boards, which led to the creation of the first microchip and, by extension, a more efficient, powerful, and effective calculation system.[3]

[1] Bongat and Walker, "NASA - Saturn V."
[2] Potter, "Exploring the Moon Promises Innovation and Benefit at Home."
[3] Hack the Moon, "How Integrated Circuits Saved the Moon Landing."

Integrated circuits were the predecessors of the microchip; almost all electronic devices today make use of such technology. In order to manufacture enough integrated circuits for the Apollo Program, NASA partnered with private sector businesses (including defense contractors), such as Fairchild. The massive demand for integrated circuits generated by NASA created economies of scale and helped to reduce the per unit cost of integrated circuits, a precondition to the use of the technology in government, business, and—later—consumer electronics.[4] The first digital computer, ENIAC, was completed in 1946 for $500,000 dollars (over $8 million dollars today). By reducing the per-unit cost of integrated circuits and other components, the cost of finished products such as computers began to drop; by the 1980s and 1990s the cost had come down so much that many people had computers in their homes. Today, such circuits power now-ubiquitous cell phones, laptops, and other portable electronic devices.[5]

In 1967, three Apollo astronauts died in a fire during a launch rehearsal test because of an excess of pure oxygen, a highly flammable gas that was required for the operation of the Apollo rocket.[6] In order to avoid another such tragedy, NASA decided to increase its attention to fire prevention,[7] specifically the development of fire-resistant materials for space suits.

NASA approached several major U.S. companies and asked whether they could develop a flame-resistant fabric for use in the space program. After negotiations with several different entities, NASA chose to partner with the Monsanto Company and worked with it to invent the flame-resistant fabric known as Durette. Durette was resistant to burning or producing noxious fumes in an environment that contained high concentrations of oxygen. It passed flammability tests and fit the safety rubric developed by NASA. The invention of Durette not only supported

[4] AnySilicon, "The History of the Integrated Circuit."
[5] Gaudin, "NASA's Apollo technology has changed history."
[6] Harbaugh, "Liquid Oxygen – Rocketology."
[7] Mars, "55 Years Ago."

the moon exploration program, but it became absolutely crucial for firefighters all over the world and significantly reduced deaths and injuries among them.[8]

Another role for Durette that was almost certainly not imagined by its creators was the use of the material in auto racing. Durette was adopted by both race car drivers (who are at risk of fire if their car crashes), as well as support teams who help with repair and refueling.[9] Durette is also used to make furniture, clothing, and interior walls in U.S. Navy drying chambers.[10] Durette was also applied in the manufacture of Durette bags, which are used for filtering gases from boilers, as well as in other systems operating in high temperature environments.[11]

Ideology and International Cooperation

The Apollo Program not only broke through the technological boundaries of the immediate post-World War II period; it also pushed the limits of gender norms by enabling women to make full use of their scientific and technological knowledge. NASA provided women with opportunities to fill a wide variety of roles in the space program, which focused public attention on the positive things women could accomplish in traditionally male fields. Apollo provided an opportunity for female scientists and engineers to contribute to a great scientific endeavor and their efforts made the moon landing possible. For instance, Margaret Hamilton and her team developed an important software system for Apollo 11 which became standard for all subsequent Apollo Missions, and she was awarded the Presidential Medal of Freedom for her work in 2016.[12]

[8] Spinoff, "Fire Resistant Materials." 1-2
[9] Spinoff. 2-3
[10] Spinoff.
[11] Spinoff.
[12] Nelson, "Ladies who Launch."

Another prominent woman involved in the Apollo Program was Frances "Poppy" Northcutt, the first female to work in the Mission Control Center and the person who was responsible for planning the return-to-Earth trajectory for Apollo missions.[13] Northcutt rose to prominence as a result of being filmed at NASA during the launch of Apollo 11 while working on technical aspects of the Program. The fact that a woman was working in such an environment demonstrated to the public that women could also work on the space mission in non-clerical roles. Given that so many people watched news coverage of Apollo, Northcutt's role would have been visible to tens of millions—even hundreds of millions—of people. In the 1960s, the public conceptualization of Mission Control and the STEM field in general featured only men; her appearance on the news was a sensation that resulted in many follow-up news reports.[14] Having females so visibly involved in a national scientific endeavor helped changed the public's view of which types of people could take part in the space program, particularly inspiring more women to participate in the study of space. Northcutt became a role model for girls and young women who aspired to careers in engineering and science. She received the 20022 Pioneer in Tech Award for her outstanding contributions to women's rights.[15]

In addition to her highly visible role on television, Northcutt's substantive contributions to the Apollo Program were equally significant. One of her major achievements at NASA was assisting with the calculations that helped bring the Apollo 13 crew back safely after the service module on their rocket exploded. She was among the members of the Apollo 13 Mission Operations Team that received the Presidential Medal of Freedom in 1970.[16]

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[13] Nelson.
[14] Crewdson, "Women's Advocate Now Fights Houston Council to Keep Her Job."
[15] NCWIT, "2022 Pioneer In Tech Award Winner."
[16] The American Presidency Project, "Remarks on Presenting the Presidential Medal of Freedom to Apollo 13 Mission Operations Team in Houston. | The American Presidency Project."

During the Apollo Program, Northcutt was inspired to become an activist in part because of the vast pay gap between male and female employees of NASA.[17] In the 1970s she worked with a small group of women at NASA to shrink the pay gap between the sexes. After Apollo ended, she became a women's advocate in Houston, Texas and worked in the mayor's office to promote gender equality, later becoming president of the Texas chapter of the National Organization for Women.[18] Reflecting on her role as an inspiration for women and girls during the 1960s and 1970s in a 2019 PBS documentary, *Chasing the Moon*, she stated "I thought it was important that people understand that women can do these jobs—going into science, going into technology, doing something that's not stereotypical."[19]

According to 2020 data compiled by NASA's Workforce Strategy Division and Office of Diversity and Equal Opportunity, of a total workforce of 17,761, 35.6% of NASA employees are female and well-represented in scientific and engineering roles.[20] While men still outnumber women, female representation is far better than it was in the 1960s, when only about 17% of the workforce was female and concentrated in clerical roles rather than scientific or engineering ones.[21] Apollo clearly laid the foundation for women to take on technical, engineering and scientific roles at NASA.

The Apollo Program not only established the foundation for expanded female roles in scientific fields; it also ushered in a new era of international cooperation among space-traveling countries. Compared with other human endeavors, space travel is extremely expensive and dangerous. Broad cooperation—particularly international cooperation—can help reduce the costs

[17] Guest Blogger for Women Around the World, "A Woman on the Moon and Equality on Earth."
[18] Waxman, "Meet Poppy Northcutt, the Woman Who Helped Bring the Apollo 11 Astronauts Home Safely."
[19] Smithsonian, "Women of Apollo."
[20] The National Aeronautics and Space Administration, "WICN."
[21] Lineberry, "NASA - Women in Aerospace."

and risks of space travel and the Apollo Program laid the foundation for such collaboration among countries involved in space exploration. Behind the tensions of the Cold War, the U.S. and the Soviet Union established scientific partnerships around the exploration of space for what both sides called the "benefit of mankind."[22] The partnership between the two started with the exchange of information, data, and operations fundamentals related to weather satellite systems. In 1962, U.S. President John Kennedy and Soviet leader Nikita Khrushchev acknowledged that international cooperation could be beneficial. Kennedy wrote to the Soviet leader, "Perhaps we could render no greater service to mankind through our space programs than by the joint establishment of an early operational weather satellite system."[23] Cooperation between the two superpowers was not perfect, however, and American scientists were initially quite disappointed in the quality and quantity of Soviet participation. However, the two sides overcame those challenges and in 1968, the World Weather Watch system became functional and provided data to both researchers and weather forecasters.[24] Though one small step in international cooperation, this was nevertheless a significant one for two countries that a few years earlier (during the Cuban Missile Crisis of 1962) had been at risk of going to nuclear war.

Throughout the 1960s, cooperation between the U.S. and the Soviet Union was limited to the exchange of information and data. In the 1970s, both the U.S. and the Soviet Union sought to involve more countries in space exploration, as the staggering cost and complexity of space research became increasingly clear. As a result, both countries shared lunar samples and other data with scientists from other countries. In addition, on July 17, 1975, the U.S. launched its last Apollo space capsule and docked it with a Soviet Soyuz spacecraft. This rendezvous in space,

[22] Callahan, "Sustaining Soviet-American Collaboration, 1957-1989," 128.
[23] Callahan, 128.
[24] Callahan, 132.

known as the Apollo-Soyuz Test Project, featured five astronauts and two spacecraft from the two major powers of the Cold War. The astronauts exchanged souvenirs, national flags, and certifications that represented the success of the mission. This endeavor, though small, was an important step in deepening international cooperation and reducing tension between the scientific establishments of the U.S. and the Soviet Union.

Before the two craft docked, astronauts from both countries had to learn about the culture of their counterparts and eliminate the prejudices they may have held against the other side. Recalling the mission 25 years later, crew member Vance Brand said,

> we thought [the Soviets] were pretty aggressive people and…they probably thought we were monsters. So we very quickly broke through that, because when you deal with people that are in the same line of work as you are, and you're around them for a short time, why, you discover that, well, they're human beings.[25]

The development of a docking mechanism to connect the Apollo and Soyuz modules created the possibility of international space rescue, which theretofore had been impossible. While tensions between the U.S. and the Soviet Union persisted to the end of the Cold War, the Apollo-Soyuz Test Project opened up dialogue between scientific and space exploration agencies working for both superpowers. The two countries engaged in discussions throughout the 1980s and after the end of the Cold War, American astronauts visited the Russian space station *Mir* in what became known as the "Shuttle-Mir Program."[26] Later, the two were at the forefront of the creation of the International Space Station (ISS). Today, the ISS includes five space agencies representing Canada, Europe, Japan, Russia, and the U.S.[27]

[25] Wilson, "Apollo-Soyuz."
[26] The National Aeronautics and Space Administration, "NASA - Shuttle-Mir."
[27] Drake, "International Space Station, Facts and Photos."

International cooperation in space exploration continues to this day. For instance, it is an important element in China's lunar and deep space exploration, and China's recent Chang'e missions (which are designed to further explore the moon) carried experiments from Germany, Sweden and the Netherlands.[28]

Conclusion

The Apollo Program started a new era of space exploration. In the historical memory of the U.S.—and very likely the rest of the world—the Earth tended to be "left behind"; after all, the purpose of journeying to the moon was to enable humanity to reach a new planet. The moon landing did not only reveal a new frontier in space to mankind, but it also opened up new frontiers on Earth. Despite centuries of attempts to settle and conquer new frontiers, many of these efforts never realized their objectives. Though people first set foot on the moon in 1969, we remain very far from establishing a durable presence there. On Earth, humanity continues to explore new technological and ideological frontiers; there is no end in sight to the creation of new technologies, and the quest for prized things like women's rights and equality continues to this day. In the realm of international cooperation, much work remains to be done in establishing cooperative relationships among countries. Some frontiers eventually cease to be frontiers. However, humanity's quest in space and on Earth will almost certainly continue well into the future.

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[28] Tillman, "We're Still Learning from the Apollo Moon Landings, But What If We Went Back?"

Appendix A

U.S. President John F. Kennedy delivering a speech at Rice University in 1962, declaring America's intention to land a person on the moon "before the decade is out."[29]

[29] Jones, "How Space Exploration Has Changed, 60 Years Since JFK's 'We Choose the Moon' Speech."

Appendix B

Durette fabric provided fireproofing in Neil Armstrong's spacesuit (pictured above)[30]

[30] National Air and Space Museum, "Pressure Suit, A7-L, Armstrong, Apollo 11, Flown."

Appendix C

Materials developed for the space program contributed to the development of fire-resistant fabrics for firefighters.[31]

[31] York, "Fighting Fire."

Appendix D

A Formula 1 pit crew's protective uniforms are made with Durette flame-resistant fabric.[32]

[32] Ramnath, "The Pit Stop In F1."

Appendix E

Frances "Poppy" Northcutt sitting next to a model of the Apollo 14 Lunar Module, 1971.[33]

[33] Showell et al., "Frances 'Poppy' Northcutt, an Engineer at NASA's Mission Control."

Appendix F

Margaret Hamilton poses with the Apollo Guidance Software she and her team developed at MIT.[34]

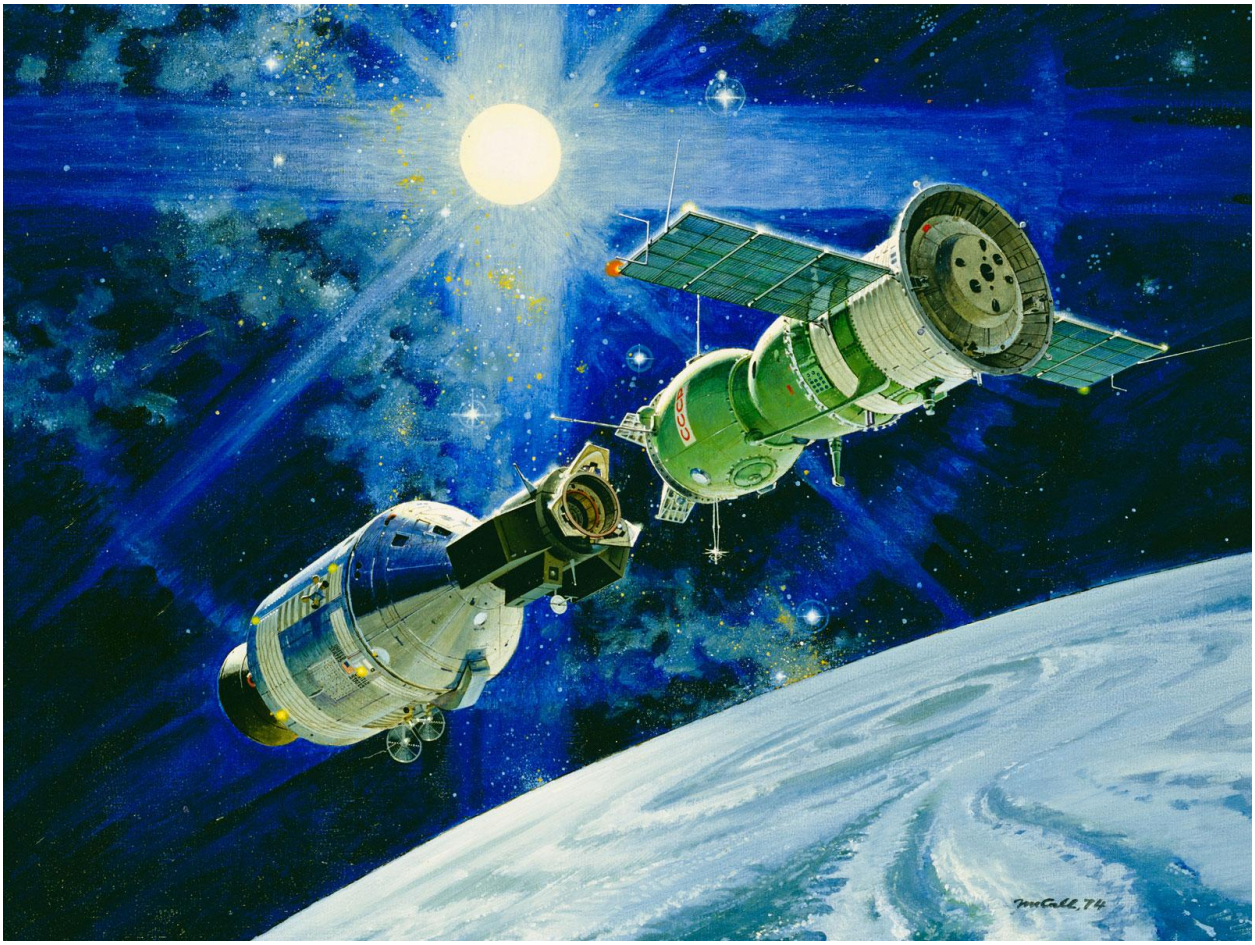
[34] "Margaret Hamilton | Computer Scientist."

Appendix G

Harry Wexler (USA) and Victor Bugaev (USSR), founders of the World Weather Watch, pictured on the cover of the *World Meteorological Organization Bulletin* (April 1962).[35]

[35] World Meteological Organization, "Cover."

Appendix H



Artist's rendering of the docking of the U.S. Apollo capsule and a Soviet Soyuz capsule[36]

[36] Wilson, "Apollo-Soyuz."

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