ARE WE ALONE IN THE COSMOS?

COULD WE ONE DAY LIVE ON A DIFFERENT PLANET?

HOW DID LIFE FIRST FORM?

WHAT SECRETS DOES OUR UNIVERSE STILL HOLD?

Travel deep into space through the eyes of seven remarkable women who are seeking to answer some of the biggest scientific questions we can possibly ask.

NICOLE MORTILLARO is an author, a science reporter with CBC News, editor of *The Journal of the Royal Astronomical Society of Canada*, and an amateur astronomer. She lives in Toronto, Ontario.

AMANDA KEY is an illustrator and graphic designer from Vancouver Island.

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MORTILLARO • KEY

SEARCHING BEYOND THE STARS

SEVEN WOMEN IN SCIENCE TAKE ON SPACE'S BIGGEST QUESTIONS

annick press

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SEVEN **WOMEN** IN SCIENCE TAKE ON SPACE'S **BIGGEST** QUESTIONS

WRITTEN BY
NICOLE MORTILLARO

ILLUSTRATED BY
AMANDA KEY

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toronto • berkeley

For all the women who have been told they couldn't or shouldn't,
and for my daughter Sara: "Never cruel or cowardly.
Never give up, never give in."
—N.M.

For my family.
—A.K.

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OPENING UP THE UNIVERSE

When you think of a scientist, what image comes to mind? If you're like a lot of people, you might see a man in a lab coat or a man peering through a telescope. I know that was the case for me when I was growing up as I dreamed of heading to the stars. That's because, for the most part, that's all I saw: on TV, in the movies, and in the news.

As I got older, I realized that there are *so many* women who have contributed to what I love most: space and space exploration. But their stories were left untold as they stood in the shadows of men who were doing the same things they were.

Today, we are starting to recognize many more women for their remarkable contributions and achievements—women who are discovering new worlds, searching for alien signals, and unlocking the mysteries of the universe. So I wanted to highlight some of them in this book. Some did their research in the recent past, paving the way for others to continue breaking barriers and exploring exciting new frontiers of space research.

For this book, I was able to speak with Jill Tarter, who was at the forefront of the search for the first extraterrestrial intelligence; Sara Seager, who is searching for potentially habitable planets; and Ashley Walker, who is one of the first Black women in the field of astrochemistry and is looking at what chemical combinations might give rise to life. Emily Lakdawalla shared with me her passion for communicating the wonders of space to the public, Tanya Harrison bubbled with excitement about all the wonders on Mars, and Renée Hložek pondered about our universe's beginnings . . . and how it may end. I truly consider it an honor to have been able to speak to some of the women I had read about and learned so much from, especially as a science communicator. Their enthusiasm is infectious. We all share an intense curiosity and a common passion: the love of the universe in which we live.

These incredible women are opening the entire universe up to us. They are looking back in time to the Big Bang, when everything we know and see came into existence; they are looking for planets that may harbor life or that may be good places to at least *start searching* for signs of life; and they are looking back at Mars to a time when it may have once had an ocean. Most of all, they are trying to learn what all of this means for humans.

I want anyone who reads this book to know that nothing can stop you from pursuing your dream, despite the challenges that you may need to overcome. Anyone who has a curious mind, who seeks answers to the tough, nagging questions—Where do we come from? How did life arise on Earth? What happened to the water on Mars? How will the universe end?—can try to get the answers.

So dip in and meet these women. See how they're all searching beyond the stars every day and how you might one day, too.

NAVIGATING THIS BOOK

Want to learn more about the science and the history behind these scientists' awesome achievements? Or maybe you'd like to read some of the strangest space facts out there? Look for these sidebars throughout the book:

A LITTLE BIT OF HISTORY
The sidebars with this icon give context for each scientist's work and life—whether that's talking about the findings that paved the way for their own discoveries or the social realities that impacted the way their careers took shape.

BEHIND THE SCIENCE
From physics to chemistry to geology and beyond, these sidebars give insight into the factors that influenced the scientists' methods and approaches.

SPACE ODDITY
Space science is full of out-there attempts and unusual phenomena—just look to these sidebars for proof!

DEFINITION

Words in **bold** are further defined in the glossary at the back of the book.

LEADING THE RACE

KATHERINE JOHNSON TAKES US INTO ORBIT

AN EYE FROM ABOVE

It's October 4, 1957.

Across the world, people crane their heads upward, searching for a faint light crossing the sky among the stars. It's not a comet or an asteroid—it's Sputnik, the first artificial satellite to be launched into space. Many people look on in fear as the beachball-sized satellite—built by the Union of Soviet Socialist Republics (U.S.S.R.), also known as the Soviet Union—looks down on them.

The U.S.S.R. is considered a powerful enemy to the United States, and Americans fear that this launch could usher in a new type of warfare. Were the Soviets using Sputnik to monitor their every move?

Katherine Goble is one of the people silently tracking the steadily moving dot across the night sky. But Katherine doesn't feel afraid. For her, it is the dawn of a new age—the Space Age.

KATHERINE'S TIMELINE

1939

Becomes one of the first African American students to enroll at West Virginia State

1918

Born Katherine Coleman in White Sulphur Springs, West Virginia, USA

1960

Coauthors paper on calculations for getting a spacecraft into orbit

1961

Calculates suborbital path for Alan Shepard, the first American astronaut in space

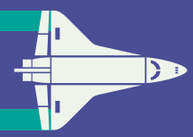
1962

Helps confirm calculations for the spaceflight for John Glenn, the first American to orbit Earth

2015

Awarded the U.S. Presidential Medal of Freedom

YOU NEED TO KNOW



ARTIFICIAL SATELLITE

A human-made object that orbits Earth

PROJECT MERCURY

The first U.S. human space program, created on October 7, 1958, and made up of seven astronauts

APOLLO PROGRAM

The U.S. program, which ran from 1961 to 1975, that sent humans to the moon

THE FIGHT FOR FLIGHT

When World War II ended in 1945, a new conflict began between the United States and the **U.S.S.R.**, two superpower countries that had both fought against Germany. The U.S.S.R. was afraid that Germany would be able to regain power. To prevent this from happening, they installed Communist governments like their own across Eastern Europe. As the United States watched this unfold, they began to worry about just how much control the U.S.S.R. was starting to hold.

This was the start of the Cold War—a race for superiority and dominance. Instead of fighting on battlefields, both countries began to stockpile weapons, build stronger armies, and work on advanced technologies.

THE U.S.S.R.

Known today as Russia, the Union of Soviet Socialist Republics was a former federal socialist state in northern Eurasia that existed from 1922 to 1991.

It was clear that the U.S. National Advisory Committee for Aeronautics (NACA) had to expand their focus to study the potential of spaceflight. The U.S.S.R. had already set their sights on getting to space, and this only ramped up the fear in the Western world. If the Soviets took hold of space, would they be able to rain bombs down on other countries?

The United States began by working on supersonic flight—planes that could go faster than the **speed of sound**. And they beat the U.S.S.R.: on October 14, 1947, U.S. army captain Chuck Yeager broke the speed of sound, also called the sound barrier, in the Bell X-1. America was ahead—at least until the launch of Sputnik.

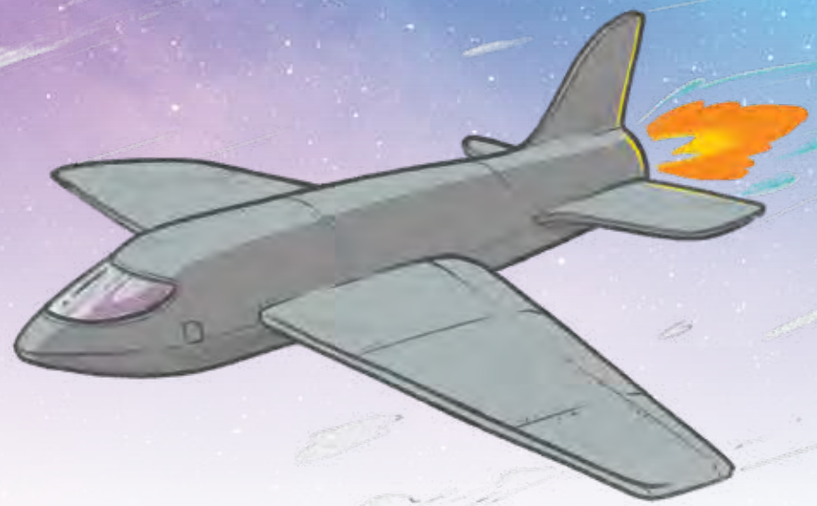
SPEED OF SOUND

The distance that a sound wave travels per unit of time. This differs depending on the material that the sound travels through—when traveling through air at 20°C (68°F), its speed is around 343 meters per second or 1,125 feet per second (1,235 kilometers per hour or 767 miles per hour).

As this new technological warfare was being developed, Katherine was working as a schoolteacher. She had always been fascinated with numbers. As a child, she would count anything she could, from forks and knives while doing dishes to the steps it would take her to walk to church. But at the time, being of African American descent meant that she wouldn't get the type of quality education white students would.

But her father recognized how bright she was, and he sent her to the best schools available to Black students. She skipped a couple of grades and eventually enrolled in a high school that was on the West Virginia State University campus, becoming one of just three Black students. She breezed through that, too, graduating when she was just 14. At 18, she started attending the university and eventually got a job teaching math.

"THE WHOLE IDEA OF GOING INTO SPACE WAS NEW AND DARING. THERE WERE NO TEXTBOOKS, SO WE HAD TO WRITE THEM."



NASA/NACA

The National Advisory Committee for Aeronautics (NACA) was formed by the United States in 1915 to study flight. It was renamed the National Aeronautics and Space Administration (NASA) in 1958 when their research focus expanded to include satellite and spaceflight programs.

That all changed in 1952, when she was alerted to a job at **NACA** at the Langley Research Center in Hampton, West Virginia. The committee was looking for "computers"—people, mostly women, who would conduct complex mathematical calculations for flight.

The idea of being a mathematician—and one who was serving her country in one of the most ambitious programs around—appealed to her greatly. And Katherine got the job.

Though she was well qualified, Katherine was still working in a highly segregated time when there was a definite division between Black people and white people across all areas of society. At NACA, the West Area Computers were made up of Black women, and the East Area Computers were made up of white women. Even bathrooms were divided by race.

No matter how smart Katherine proved herself to be, most white people—including some of her colleagues—viewed her as inferior simply because of her race. But Katherine didn't let it get to her. She simply concentrated on her work, and that work meant breaking new scientific barriers.

HARVARD'S COMPUTERS

In 1881, the director of the Harvard Observatory, Edward Charles Pickering, faced a problem: he was collecting more data than his staff could go through. He decided to hire women, who were cheap labor, to pore over the data. Many of the "Harvard computers" went on to produce significant findings—despite receiving little recognition for their efforts at the time.

THE HUMAN SPACE RACE

On January 31, 1958—four months after Sputnik was launched—the Americans had their own satellite, Explorer 1, in orbit around Earth.

What next? The Americans wanted to beat the Soviets at achieving human spaceflight. Flying a plane was one thing. So was sending an object into orbit around Earth. But sending a human being? There was far more at stake, and Katherine wanted to help.

Though the division between the East and West Computing facilities was finally dissolved in 1958, Katherine was still a woman, and a Black woman at that—and women weren't allowed to attend official meetings. When she asked why she couldn't attend, her supervisors didn't have a real explanation—they just said it wasn't something that was done. Rather than giving up, Katherine remained persistent, and later that year, she became the first woman to attend scientific briefings that discussed research findings. Instead of having to chase down information, she now had access to all the knowledge her male coworkers had. Shortly afterward, she also became the first woman in the division to author a report. For her, this fight wasn't about being Black or a woman. It was about having the access she needed to do her job right.

RACISM IN AMERICA

After World War II, there was a push for equality for Black people, who had long been persecuted and discriminated against due to the violent legacy of slavery in America. In some parts of the country, Black people were forbidden from eating at restaurants or using the same water fountains as white people, and they were forced to ride at the back of buses. These rules have changed, but the fight for equality continues to this day.

As NASA worked hard to get the first man into space—under the mounting tension of the Cold War—Katherine pored over complicated calculations. She checked and rechecked her math. The first American trip into space would be **suborbital**, meaning the spacecraft would not complete an entire orbit around Earth. An **orbital flight** would be even more complicated, and it was NASA's eventual goal to get there.

It was planned for the spacecraft to splash down into the ocean. That meant additional rocket fuel wouldn't be needed to slow it down and the water would provide a natural cushion for the **astronaut** after his parachute deployed. Katherine was under enormous pressure to calculate the **trajectory** for the spacecraft—where it would go and where it would land.

There was so much riding on this flight. Calculations that were off even by a little bit could lead to tragedy: the rocket could come crashing down to Earth or drift off into space. Either way, the astronaut wouldn't survive. Though the stakes were incredibly high, NASA had faith in their "computers."

COSMONAUT VS. ASTRONAUT

Cosmonauts are trained and certified by the Russian Space Agency to work in space, while astronauts are trained and certified by NASA or by the European Space Agency (ESA), the Canadian Space Agency (CSA), or the Japanese Aerospace Exploration Agency (JAXA).

But even Katherine's most brilliant work couldn't save NASA and the United States from yet another devastating defeat in the space race. On April 12, 1961, the world once again looked up in awe as Soviet **cosmonaut** Yuri Gagarin became the first human in space. The American spirit was crushed, and the nation's fear and doubt in the midst of the Cold War took an even deeper hold. Everyone at Langley took it hard, but while Katherine was disappointed, she knew that America wasn't actually that far behind. They may have not been the first, but they would find a way to make their mark in the space race—she would make sure of it.

CALCULATED SUCCESS

The engineers and scientists at NASA doubled their efforts. In their rush to try to get into space, they tested rockets that exploded, didn't launch, or suffered other catastrophic malfunctions. All the while, Katherine's head was deep into calculations.

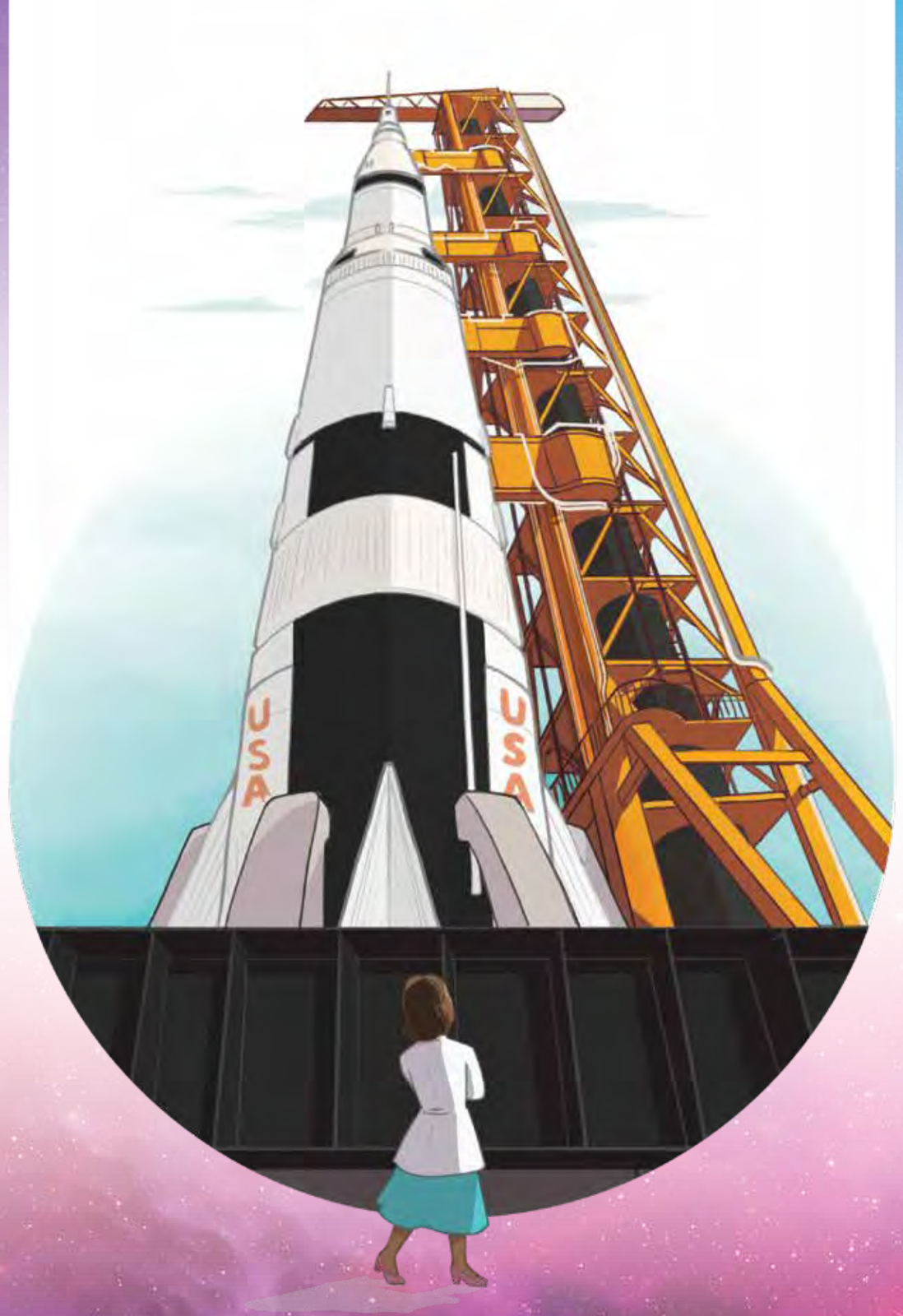
To her, getting a human into space was simple geometry. It was sort of like throwing a ball: it moves in an arc, or a parabola. Katherine was purported to say: "You tell me when you want it and where you want it to land, and I'll do it backwards and tell you when to take off." Finally, after weeks of intense effort, Katherine's work paid off. On May 5, 1961, the first U.S. astronaut, Alan Shepard, was ready to take flight on board a Mercury-Redstone rocket. But even as everyone at NASA prepared for launch, there were still lingering doubts. So many other rockets before this one had exploded. Were they rushing this launch just to try to catch up to the Soviets? Was it worth it with a life hanging in the balance?

THE FORCES BEHIND FLIGHT

The science of flight is called aerodynamics. There are four forces of flight: lift, weight, thrust, and drag. A plane's wings provide lift to hold it in the air, but its weight pushes it down toward Earth. As the plane flies, drag from the air slows it down, which it overcomes with thrust, or forward movement, by using its engines. If any of these forces are disrupted, the plane can crash, which is why planes are fitted with ultrasensitive instruments.

While we take human spaceflight for granted today, with hundreds of people having successfully made the perilous voyage, Shepard would be only the second person to strap himself into a rocket, with a controlled explosion hurtling him off toward the stars. Millions of Americans—and millions more across the world—sat around their television sets, holding their collective breath.

The rocket blasted to life, the thunderous noise echoing across the Florida landscape. All eyes turned skyward as the black-and-white missile lifted into the blue sky and eventually disappeared out of sight. For more than 15 minutes, everyone watching at home and at Langley waited in suspense. Now that the United States had sent a human into space, the question remained: Would he survive, or had they just witnessed a man rocketing to his death?



Finally, word arrived: Shepard had splashed down safely in the Atlantic Ocean. He had reached a breakneck speed of 8,336 kilometers per hour (5,180 miles per hour) and a height of 187 kilometers (116 miles) in his short trip. America had finally gotten to space. Now that they'd done it once, they had renewed confidence that they could continue to do it. Katherine's work had barely started.

NASA's next goal was orbital spaceflight. The launch was scheduled for February 20, 1962, with the intention of having astronaut John Glenn complete seven full orbits. This was a whole new type of launch—including a new Atlas rocket—and landing, and Katherine knew it.

Glenn had faith in NASA—you'd have to in order to agree to sit atop a 260,000-pound (130-ton) rocket full of fuel that could explode at any time—but as with any good pilot, he wanted to review the numbers ahead of his launch. They had been generated by an IBM computer, relatively new to the organization, but he wanted to be sure the calculations were correct.

"Get the girl to check the numbers," he said. He meant Katherine.

Katherine worked diligently for almost two days to ensure the numbers were correct. She went over different scenarios, accounting for any kind of situation. In the end, the numbers matched. Though Glenn had to cut short his planned seven orbits due to a problem with the capsule, he landed just 64 kilometers (40 miles) off-course after 4 hours and 56 minutes in orbit around Earth. The difference in landing location wasn't a result of any miscalculation; it was because of the unexpected weight of more fuel on board.

The mission was deemed a success. It was clear that Katherine was just as precise and reliable as the IBM computer, and her work gave Glenn the assurance needed to make this remarkable spaceflight possible.

TO THE MOON

More missions followed Glenn's, all of them successful. Meanwhile, the Soviets also continued to launch more of their cosmonauts. Now, the United States decided to go one giant leap further: to the moon. If they could pull this off, they would prove their technical might to the Soviet Union on the world stage—once and for all. On September 12, 1962, President John F. Kennedy issued a bold statement: Americans would land on the moon before the end of the decade.

NASA had a daring task ahead of them. For one, they would need a rocket far bigger than any they had. And landing a rocket on the moon while the moon also moved through space would require extensive and extremely precise calculations. The margin for error would be even smaller than with Glenn's orbital flight. Tens of thousands of people worked on the program—engineers, scientists, computers, and technicians. By this time, Katherine had joined NASA's Space Mechanics Division and computed backup navigational charts for the missions in case the electronics failed.

Eventually, the scientists and engineers devised a spacecraft that would be like no other: it would consist of two separate parts—the command module and the lunar lander—that would be joined together for the trip to the moon. Then, once at their destination, the two parts would separate, with the lander heading to the moon with two of the astronauts on board. One astronaut would stay in the command module, which would remain in orbit. There was one essential question left to answer: How would NASA get those two astronauts to rendezvous with the orbiter?

It required complex geometry and calculating the speed and movement of both the lander and the moon itself—and Katherine worked with the team to get those answers. It was in part due to her incredible skill as a mathematician that the men of Apollo 11 made history as the first humans to walk on another world: our moon.

THE MOON

How did the moon come to be? Astronomers still don't know for certain, but the most popular theory is that at some point in our solar system's formation, a giant body—perhaps the size of Mars—smashed into our newly forming planet. The debris left over from the impact circled our planet and finally came together, forming our planet's closest companion.

. . . AND BEYOND

Katherine retired from NASA in 1986. During her time at the organization, she had broken through incredible barriers, both as a Black woman and as a scientist. But her lifelong contributions remained unknown to many until 2015, when Katherine was given the Presidential Medal of Freedom by President Barack Obama.

In 2016, Margot Lee Shetterly wrote a book, *Hidden Figures*, on the contributions of the Black women mathematicians at NASA. It was made into a movie of the same name, which gained critical praise for finally bringing the Black women of NASA out of the shadows. After the success of the movie, 98-year-old Katherine was finally rocketed to well-deserved recognition. She was honored by NASA and remained in the spotlight for months.

Katherine died on February 24, 2020, but her work continues to help pave the way for further moon missions. NASA has a bold plan to return to the moon with its Artemis mission, which will see the first woman land on our dusty, rocky neighbor. Her historical arrival on the lunar surface will be thanks, in part, to Katherine—the woman who first got us to the moon.