CHAPTER TWENTY-ONE

Out of the Past, the Future

Sending a man into space was a damn tall order, but it was the part about returning him safely to Earth that kept Katherine Johnson and the rest of the space pilgrims awake at night. Each mission presented myriad pathways to disaster, starting with the notoriously temperamental Atlas rocket, a ninety-five-foot-high, 3.5-million-horsepower intercontinental ballistic missile that had been modified to propel the Mercury capsule into orbit. Two of the Atlas's last five sallies had ended in failure. One of them had surged into the sky before erupting into spectacular fireballs with the capsule still attached. That wasn't exactly a confidence builder for the man preparing to ride it into orbit, but it was the more powerful Atlas that would be required to accelerate the Mercury capsule to orbital velocity. The capsule itself was the most sophisticated tin can on the planet. The vehicle's oxygen and pressurization systems stood between the astronaut and the life-crushing vacuum of space. Those functions and more—every switch, every indicator, every gauge—had to be tested and retested for any whiff of possible failure. As the rocket blasted from the launchpad and accelerated into the sky toward maximum velocity, the aerodynamic pressure on the capsule also increased to a point known as "max Q." If the capsule wasn't strong enough to withstand the forces acting on it at max Q, it could simply explode. A Republican senator from Pennsylvania called the Mercury capsule-Atlas rocket pairing "a Rube Goldberg device on top of a plumber's nightmare."

Everything rested upon the brain busters' mastery of the laws of physics and mathematics. The mission was colossal in its scope, but it required both extreme precision and the utmost accuracy. A number transposed in calculating the launch azimuth, a significant digit too few in measuring the fully loaded weight of the capsule, a mistake in accounting for the rocket's speed and acceleration or the rotation of the Earth could cascade through the chain of dependencies, causing serious, perhaps catastrophic, consequences. So many ways to screw the pooch, and just one staggeringly complex, scrupulously modeled, endlessly rehearsed, indefatigably tested way to succeed.

Nobody, of course, understood this better than astronaut John Glenn. In 1957, the former Marine test pilot had campaigned fiercely—and unsuccessfully—to be the first of the Mercury Seven to navigate to the heavens. Now, NASA had picked Glenn for MA-6, the orbital flight that would cast the die on the space agency's future, and he was leaving nothing to chance. He pushed himself to his physical limit, running miles each day to stay fit, tag-teaming with fellow astronaut Scott Carpenter to practice water egress from the capsule in the Back River on Langley's East Side. With the experience of Alan Shepard and Gus Grissom as a guide, NASA physicians worried a little less about the health hazards Glenn might face while on board, since in the capsule he would be hooked up to wires like a lab rat, his every vital sign transmitted to and monitored by the doctors on the ground. The specter of human error was ever-present, of course, so Glenn worked the simulators and procedures trainers obsessively, putting himself through hundreds of simulated missions, honing his responses to every failure scenario the engineers could imagine.

As a seasoned test pilot, Glenn knew that the only way to remove all danger from the mission was to never leave Earth. The former Marine was the first pilot to average supersonic speeds in a transcontinental flight. From Project Mercury's outset, the NASA engineers had the delicate task of balancing the drive to get into space as quickly as possible

with the risk they felt they could reasonably ask their human cargo to accept. Experience and analysis informed them that somewhere along this venturesome path they were certain to encounter unforeseen problems or run smack into the simple bad luck of statistics, that one time in a thousand when the worst-case scenario played out. What was within their control, however, they took pains to bulletproof, even if it meant stretching—then breaking—their timeline. Project Mercury's first orbital flight was originally slated to take place at the end of 1960, on President Eisenhower's watch. Additional testing and fine-tuning—a cooling system bug here, an oxygen delivery glitch there, the need to implement improvements based on previous unmanned and suborbital flights—conspired to push the date into the administration of incoming President Kennedy. NASA set July 1961 as the new date for the orbital flight, then rescheduled it for October, then to December. Finally the mission slipped into 1962.

While NASA appeared to be dithering on the ground, Russian cosmonaut Gherman Titov followed Yuri Gagarin's April 1961 triumph with a successful seventeen-orbit flight, nearly a *full day* in space, on October 6, 1961. American government officials, the press, and the public expressed their disappointment with the delays, many impugning the agency's judgment and competence. Even when the technical issues were in hand, the launch team had to contend with the weather. A long stretch of low, overcast skies at Cape Canaveral put the kibosh on two more scheduled launches, on January 20 and February 12, 1962. Finally, the Space Task Group affixed February 20, 1962, as John Glenn's debut.

The incessant delays and high stakes would have caused most individuals to lose their focus, but John Glenn gave even-tempered, optimistic interviews to the impatient press and busied himself by keeping his mind and body in peak condition. Three days prior to the most significant date of his life, Glenn went through a final simulation, carrying out a full checkout of his flight plan. Before commending himself to his destiny, however, the astronaut implored the engineers to execute one more check: a review of the orbital trajectory that had been generated by the IBM 7090 computer.

Many of the operational aspects of John Glenn's upcoming flight had been refined by testing during the years following Sputnik, and the knowledge and experience gleaned during the early days were consolidated during the execution of the suborbital flights. The recovery team confidently manned their stations around the globe, ready to haul the astronaut and his capsule out of the water. NASA put considerable effort into building redundancies and fail-safes into the network of IBM computers and the eighteen-station Mercury tracking network.

The astronauts, by background and by nature, resisted the computers and their ghostly intellects. In a test flight, a pilot staked his reputation and his life on his ability to exercise total, direct, and constant control over the plane. A tiny error in judgment or a speck of delay in deciding on a course of action might mean the difference between safety and calamity. In a plane, at least, it was the pilot's call; the "fly-by-wire" setup of the Mercury missions, where the craft and its controls were tethered via radio communication to the whirring electronic computers on the ground, pushed the hands-on astronauts out of their comfort zone. Every engineer and mathematician had a story of double-checking the machines' data only to find errors. What if the computer lost power or seized up and stopped working during the flight? That too was something that happened often enough to give the entire team pause.

The human computers crunching all of those numbers—now *that* the astronauts understood. The women mathematicians dominated their mechanical calculators the same way the test pilots dominated their mechanical planes. The numbers went into the machines one at a time, came out one at a time, and were stored on a piece of paper for anyone to see. Most importantly, the figures flowed in and out of the mind of a real person, someone who could be reasoned with, questioned, challenged, looked in the eye if necessary. The process of arriving at a final result was tried and true, and completely transparent.

Spaceship-flying computers might be the future, but it didn't mean John Glenn had to trust them. He did, however, trust the brainy fellas who controlled the computers. And the brainy fellas who controlled the computers trusted *their* computer, Katherine Johnson. It was as simple as eighth-grade math: by the transitive property of equality, therefore,

John Glenn trusted Katherine Johnson. The message got through to John Mayer or Ted Skopinski, who relayed it to Al Hamer or Alton Mayo, who delivered it to the person it was intended for.

"Get the girl to check the numbers," said the astronaut. If she says the numbers are good, he told them, I'm ready to go.

The space age and television were coming into their own at the same time. NASA was acutely aware that the task before them wasn't only about making history but also about making a myth, adding a gripping new chapter to the American narrative that worshipped hard work, ingenuity, and the triumph of democracy. At the Cape, a behind-the-scenes camera captured extensive footage of the astronaut as he walked through each station of the trip he had already taken hundreds of times in NASA simulators, fodder for a documentary to be released later in the year. The agency sent a film crew to each of the remote tracking stations, recording the communications teams as they completed their preflight checkouts. And the footage that showed the second-by-second drama in Mission Control—white guys in white shirts and skinny black ties wearing headphones, facing forward at long desks outfitted with communications consoles, mesmerized by the enormous electronic map of the world on the wall in front of them—created the enduring image of the engineer at work.

Meanwhile, away from the front lines, out of sight of the cameras, the black employees, whose numbers had been growing at Langley and all the NASA centers since the end of World War II, busily calculated numbers, ran simulations, wrote reports, and dreamed of space travel alongside their white counterparts, as curious as any other brain buster about what humanity might find once it had ventured far from its spherical island, and just as doggedly pushing for answers to their inquiries. At the Lewis Research Center in Ohio, a black scientist named Dudley McConnell was among the researchers working on aerodynamic heating, one of the most serious challenges facing the astronauts as they reentered Earth's atmosphere and plummeted toward the ocean. Annie Easley, who had joined the Lewis Laboratory in 1955, was staffed on Project Centaur, developing a rocket stage that was ultimately used in the Atlas. At the Goddard Space Flight Center in Maryland, which was charged with the operation of the two IBM 7090s that would track the spaceship and relay information to Mission Control, a Howard University graduate named Melba Roy oversaw a section of programmers working on trajectories.

Also at Goddard was Dorothy Hoover, embarking on the third (or fourth, or maybe fifth) act of her career. Following her graduate work at the University of Michigan, Hoover had worked at the Weather Bureau for three years. Perhaps nostalgic for the agency that had boosted her mathematical career, she transferred to Goddard in 1959, the only one of the centers that had been created organically out of NASA. Her career advance had continued; she now held a senior ranking of GS-13. While her colleagues at Langley put their minds to work on the engineering project of the century, Dorothy Hoover folded herself back into the theoretical work she loved, continuing her publication record with a coauthored book on computational physics.

It was at Langley where the progress of the last two decades was most evident. At the Transonic Dynamics Tunnel, Thomas Byrdsong got a head start on the long road to the Moon by testing a model of the Saturn rocket, a launch vehicle the size of a redwood tree. Engineer Jim Williams, still on the team with John D. "Jaybird" Bird, was already helping to work toward President Kennedy's pledge of a Moon landing. The division would be associated with lunar orbit rendezvous, one of the most ingenious and elegant solutions to the challenge of propelling extraordinarily heavy objects on the several-hundred-thousand-mile journey to the Moon and back.

West Computing no longer existed as a physical space, but its alumni pushed their minds and hands in the service of the space program—though in Dorothy Vaughan's case, it was an indirect effort. The computer minders of the two IBM 7090s being used to track the flight were ensconced at Goddard, and much of the analysis was being done in the Space Task Group's Mission Planning Analysis Division. The women and men in ACD were as busy as ever, however. Dorothy's hunch that those who knew how to program the devices wouldn't want for work

was a correct one. Though she wasn't on the front lines of the programming that was being done for Project Mercury, she did have a hand in the calculations that were used in Project Scout, a solid-fuel rocket that Langley tested at the Wallops Island facility. She had even been making trips up to the test range for work. The Scout rocket had been an important part of laying the groundwork for the manned spaceflight efforts. Engineers used it to take a "dummy" astronaut, weighing as much as a real astronaut, for a four-orbit flight in November 1961.

Other West Computers had a closer view. Miriam Mann worked for Jim Williams, running the numbers for the "rendezvous" research that would allow two vehicles to dock while in space. At the Four-foot SPT, Mary Jackson conducted tests of the Apollo capsule and other components, honing their fitness for the portion of the journey that would take place in the supersonic speed regime. That work would earn her an Apollo Team Achievement Award. Sue Wilder was rolling up her sleeves among the "mad scientists" of Langley's Magnetoplasmadynamics (MPD) Branch, her work also concerned with the physics of a vehicle reentering the atmosphere.

But because of her close working relationship with the pioneers of the Space Task Group, it was Katherine Johnson who found herself in a position to make the most immediate contribution to the pageant that was about to begin in Florida. The broader implication of her role as a black woman in a still-segregated country, helping to light the fuse that would propel that country to achieve one of its greatest ambitions, was a topic that would occupy her mind for the rest of her life. But with the final countdown in sight, that was a matter for the future. Right now, she was a mathematician, an American citizen whose greatest talents had been recognized, and who was about to offer those talents in the service of her country. Katherine Johnson had always been a great believer in progress, and in February 1962, once again, she became its symbol.

When the phone call came in, forty-three-year-old Katherine was at her desk in Building 1244. She overheard the call with the engineer who picked it up, just as she had overhead the conversation between Dorothy Vaughan and the engineer in 1953, the request that sent her to the Flight Research Division two weeks after she arrived at Langley. She knew she was the "girl" being discussed in the phone conversation. She had seen the astronauts around the building, of course; they had spent many hours in the hangar downstairs, preparing for their missions on a simulation machine called the Procedures Trainer. Some of their briefings with the brainy fellas had happened upstairs, though she was not invited to attend those meetings. That John Glenn didn't know, or didn't remember, her name didn't matter; what did matter, as far as he was concerned—as far as *she* was concerned—was that she was the right person for the job.

Many years later, Katherine Johnson would say it was just luck that of all the computers being sent to engineering groups, she was the one sent to the Flight Research Division to work with the core of the team staffed on an adventure that hadn't yet been conceived. But simple luck is the random birthright of the hapless. When seasoned by the subtleties of accident, harmony, favor, wisdom, and inevitability, luck takes on the cast of serendipity. Serendipity happens when a well-trained mind looking for one thing encounters something else: the unexpected. It comes from being in a position to seize opportunity from the happy marriage of time, place, and chance. It was serendipity that called her in the countdown to John Glenn's flight.

In the final section of the Azimuth Angle research report she completed in 1959, Katherine had marched through the calculations for two different sample orbits, one following an eastward launch and the other a westward, as Glenn was scheduled to fly. Once she had worked out the math for the test scenarios on her calculating machine, substituting the hypothetical numbers for variables in the system of equations, the Mission Planning and Analysis Division within the Space Task Group took her math and programmed it into their IBM 704. Using the same hypothetical numbers, they ran the program on the electronic computer, to the pleasing end that there was "very good agreement" between the IBM's output and Katherine's calculations. The work she had done in 1959, double-checking the IBM's numbers, was a dress rehearsal—a simulation, like the ones John Glenn had been carrying out—for the task that would be laid on her desk on the defining day of her career.

When the Space Task Group upgraded their IBM 704 to the more powerful IBM 7090s, the trajectory equations were programmed into those machines, along with all the other programs required to guide and control the rocket and capsule and compare the vital signs of the flight at every moment to the flight plan programmed into the computer. During the launch phase of the mission, a computer in the Atlas rocket, programmed with the launch coordinates, communicated with Mission Control. If the rocket misfired and was on track to inject the capsule into an incorrect orbit, the flight controllers could decide to abort the mission—a go–no go moment—automatically detaching the capsule from its rocket amd sending it off into the sea in a mangled suborbital trajectory.

Once the capsule climbed through the launch window, separated from the Atlas, and settled into a successful orbit, it established communication links with the ground stations. As the craft flew overhead, it telemetered a torrent of data to the closest tracking station, everything from its speed and altitude to its fuel level and the astronaut's heart rate. The tracking stations captured the signals with their sixty-four-foot receiving dishes, then relayed this data plus voice communications through a jumble of submarine cables, landlines, and radio waves to the computer center at Goddard. The IBM machines used the inputs they received to make calculations based on the orbit determination programs. Via high-speed data lines—a blazing 1 kilobyte per second—Goddard sent Mission Control real-time information on the spaceship's current position. There, on the front wall of the room that served as NASA's nerve center, was a huge lighted map of the world. On the map were inscribed sine wave–shaped tracks, one for each orbit. Hovering over the map was a little cutout of a Mercury capsule, suspended on a wire. As tracking data from the spaceship filtered into Mission Control, the toy capsule moved along the orbit grooves on the map too, a puppet controlled by its master in the sky. The capsule's signal bounced from one tracking station to the next as the orbit proceeded, like a very fast and expensive game of telephone, constantly communicating its position and status. *He's passing over Nigeria! He's just about to reach Australia!* The crude setup seemed like a miracle:

looking at the puppet ship, they could actually "see" the spaceship as it made its rounds.

The Goddard computers also sent the flight controllers their projection of the remainder of the voyage. Where was the capsule compared to where they had calculated it to be at the given time? Was it too high, too low, too fast, too slow? The output included a constantly updated time for retrofire, the moment when the capsule's rockets had to be fired in order to initiate its descent back to Earth. Retrofiring too soon or too late would bring the unlucky astronaut back down far afield of his navy rescuers.

The engineers had actually taken the IBM 7090 and the orbital equations for a test drive on two prior occasions: once for Mercury-Atlas 4, an orbital flight using a mechanized astronaut "dummy" as a passenger, and then with the trained chimpanzee Enos at the controls of MA-5. Enos' flight was ultimately successful, but it faced computer glitches and communications dropouts (in addition to more serious problems with the capsule's cooling system and a faulty electrical wire). To mention that the stakes increased dramatically with a person on board was an understatement (if disaster did befall John Glenn, one secret military document proposed blaming it on the Cubans, using it as an excuse to overthrow Fidel Castro). Katherine Johnson, suffice it to say, was very nervous about the momentous task she had been handed.

For the entire project to succeed, each individual part of the mission—the hardware, the software, and the human—had to function according to plan. A breakdown would be immediate and potentially tragic, and broadcast live on television. But Katherine Johnson, like John Glenn, was not prone to panic. Like him, she had already gone through a simulation of the job in front of her. The moment that had arrived, despite the time pressure and the frenzy of activity surrounding her, felt somehow inevitable. Katherine Johnson's life had always seemed to be guided by a kind of providence, one that was unseen by others and not fully understood by her, perhaps, but obeyed by all who knew her, the way one obeys the laws of physics.

• • •

Katherine organized herself immediately at her desk, growing phone-book-thick stacks of data sheets a number at a time, blocking out everything except the labyrinth of trajectory equations. Instead of sending her numbers to be checked by the computer, Katherine now worked in reverse, running the same simulation inputs that the computer received through her calculator, hoping that there would be "very good agreement" between her answers and the 7090s', just as had been the case when she originally ran the numbers for the Azimuth Angle report. She worked through every minute of what was programmed to be a three-orbit mission, coming up with numbers for eleven different output variables, each computed to eight significant digits. It took a day and a half of watching the tiny digits pile up: eye-numbing, disorienting work. At the end of the task, every number in the stack of papers she produced matched the computer's output; the computer's wit matched hers. The pressure might have buckled a lesser individual, but no one was more up to the task than Katherine Johnson.

February 20 dawned with clearing skies. No one who witnessed the events of the day would ever forget them. One hundred thirty-five million people, an audience of unprecedented size, tuned in to watch the spectacle as it unfolded on live television. Many Langley folks joined the Space Task Group down at Cape Canaveral to see the flight in person. Katherine sat tight in the office, watching the transmission on television.

At 9:47 a.m. EST, the Atlas rocket boosted Friendship 7 into orbit like a champion archer hitting a bull's-eye. The insertion was so good that the ground controllers cleared Glenn for seven orbits. But then, during the first orbit, the capsule's automatic control system began to act up, causing the capsule to pull back and forth like a badly aligned car. The problem was relatively minor; Glenn smoothed it out by switching the system to manual, keeping the capsule in its correct position the same way he would have flown a plane. At the end of the second orbit, an indicator in the capsule suggested that the all-important heat shield was loose. Without that firewall, there was nothing standing between the astronaut and the 3,000-degree Fahrenheit temperatures—almost as hot as the surface of the Sun—that would build up around the capsule as it passed back through the atmosphere. From Mission Control came an executive decision: at the end of the third orbit, after the retrorockets were to be fired, Glenn was to keep the rocket pack attached to the craft rather than jettisoning it as was standard procedure. The retropack, it was hoped, would keep the potentially loose heat shield in place.

At four hours and thirty-three minutes into the flight, the retrorockets fired. John Glenn adjusted the capsule to the correct reentry position and prepared himself for the worst. As the spaceship decelerated and pulled out of its orbit, heading down, down, down, it passed through several minutes of communications blackout. There was nothing the Mission Control engineers could do, other than offer silent prayers, until the capsule came back into contact. Fourteen minutes after retrofire, Glenn's voice suddenly reappeared, sounding shockingly calm for a man who just minutes before was preparing himself to die in a flying funeral pyre. Victory was nearly in hand! He continued his descent, with the computer predicting a perfect landing. When he finally splashed down, he was off by forty miles, only because of an incorrect estimate in the capsule's reentry weight. Otherwise, both computers, electronic and human, had performed like a dream. Twenty-one minutes after landing, the USS *Noa* scooped the astronaut out of the water.

John Glenn had saved America's pride! That he'd had to stare death in the face to do so only increased the power of the myth that was created that day. An audience with the president, a ticker-tape parade in New York, seventy-two-point newspaper headlines from Maine to Moscow. America couldn't get enough of its latest hero. Even the Negro press cheered Glenn's accomplishment. "All of us are happy to call him our Ace of Space," wrote a columnist in the *Pittsburgh Courier*.

Nowhere, perhaps, was the hero's welcome as warm as in Hampton Roads. Thirty thousand local residents turned out on a blustery day in mid-March to fete the men they had adopted as hometown heroes. Not since the end of the last war had Hampton seen such an exuberant celebration. Glenn rode in the lead vehicle of the fifty-car parade carrying the Mercury astronauts and their families and the top leadership of NASA. The motorcade departed from Langley Air Force Base and traced a twenty-two-mile route through Hampton and Newport News: along the shipyard, over the Twenty-Fifth Street Bridge, down Military Highway, with throngs standing on the sides of every thoroughfare. The procession passed by Hampton Institute, cheered on by Katherine Johnson's daughter Joylette and Dorothy Vaughan's son, Kenneth. Tiny Christine Darden stood on tiptoe to see over the exuberant crowds.

The parade ended at Darling Stadium, the namesake of the oyster magnate whose creative entrepreneurship had brokered the land deal with the federal government for the Langley laboratory a half century before. Glenn ascended to the podium, grinning broadly as he stood behind a sign reading SPACETOWN, USA. The people of Hampton and Newport News beamed with pride. With the heart of the space program shipping out for Houston, the celebration was tinged with melancholy, but the cities of the Virginia Peninsula were determined to commemorate their legacy as the birthplace of the future. The city of Hampton changed its official seal to depict a crab holding a Mercury capsule in its claw, adopting the motto *E Praeteritis Futura*: Out of the past, the future. Military Highway, the town's main drag since Hampton's days as a war boomtown, got a new name: Mercury Boulevard.

John Glenn was a bona fide hero, but he wasn't the only one being cheered. Word of Katherine Johnson's role in Glenn's successful mission began making the rounds in the black community, first locally, then farther afield. On March 10, 1962, a glamorous Katherine Johnson, bedecked in pearls and an elegant suit that would have made Jackie Kennedy proud, smiled from the front page of the *Pittsburgh Courier*. "Her name . . . in case you haven't already guessed it . . . is Katherine Johnson: mother, wife, career woman"! (Below the feature on Katherine Johnson, another headline inquired: "Why No Negro Astronauts?") The newspaper recounted the lady mathematician's background and accomplishments with pride, detailing the report that sent Glenn's rocket cone whizzing through the sky. Katherine accepted the recognition graciously: all in a day's work.

She and some of the engineers turned out for the parade, enjoying the celebration, allowing themselves, perhaps, just a sliver of pride in having been a part of such an achievement. They watched for a while but didn't tarry long. It was fine to celebrate past accomplishments, but there was nothing more exhilarating than getting back to work on the next thing.

CHAPTER TWENTY-TWO

America Is for Everybody

"America Is for Everybody," proclaimed the US Department of Labor brochure that landed on Katherine Johnson's desk in May 1963. On the cover, a black boy of eight or nine, barefoot and dressed in a striped short-sleeved shirt and worn dungarees, sat on the ties of a dusty railroad track, his apparent circumstances and open-faced glower a rebuke to the promise of the title. Inside, President Kennedy and Vice President Johnson waxed poetic in statements about the Negro's epic hundred-year journey up from slavery. Photos of black employees who "occupied positions of responsibility" at NASA, all of them involved with the space program, accompanied the text. At NASA's High-Speed Flight Research Center on Edwards Air Force Base—the place where pilot Chuck Yeager first cracked through the sound barrier in 1947—engineer John Perry manned an X-15 simulator. Mathematicians Ernie Hairston and Paul Williams conferred on "orbital elements, capsule position, and impact points" at Goddard. One picture showed Katherine Johnson sitting at her desk at 1244, pencil in hand, "analyzing lunar trajectories and computing trip time to the Moon and return to Earth by a space vehicle." The document, created by the Labor Department to commemorate the centennial of the Emancipation Proclamation, certainly also served as another propaganda tool for the US government to