NEW YORK TIMES BESTSELLER

THE BOOK THAT INSPIRED THE FILM

THE AMERICAN DREAM
AND THE UNTOLD STORY OF
THE BLACK WOMEN MATHEMATICIANS
WHO HELPED WIN THE SPACE RACE

HIDDEN FIGURES

MARGOT LEE SHETTERLY

HIDDEN FIGURES

The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race

MARGOT LEE SHETTERLY

WILLIAM MORROW
An Imprint of HarperCollins *Publishers*

DEDICATION

To my parents, Margaret G. Lee and Robert B. Lee III, and to all of the women at the NACA and NASA who offered their shoulders to stand on

CONTENTS

AUTHOR'S NOTE

"Negro." "Colored." "Indian." "Girls." Though some readers might find the language of *Hidden Figures* discordant to their modern ears, I've made every attempt to remain true to the time period, and to the voices of the individuals represented in this story.

PROLOGUE

Mrs. Land worked as a computer out at Langley," my father said, taking a right turn out of the parking lot of First Baptist Church in Hampton, Virginia.

My husband and I visited my parents just after Christmas in 2010, enjoying a few days away from our full-time life and work in Mexico. They squired us around town in their twenty-year-old green minivan, my father driving, my mother in the front passenger seat, Aran and I buckled in behind like siblings. My father, gregarious as always, offered a stream of commentary that shifted fluidly from updates on the friends and neighbors we'd bumped into around town to the weather forecast to elaborate discourses on the physics underlying his latest research as a sixty-six-year-old doctoral student at Hampton University. He enjoyed touring my Maine-born-and-raised husband through our neck of the woods and refreshing my connection with local life and history in the process.

During our time home, I spent afternoons with my mother catching matinees at the local cinema, while Aran tagged along with my father and his friends to Norfolk State University football games. We gorged on fried-fish sandwiches at hole-in-the-wall joints near Buckroe Beach, visited the Hampton University Museum's Native American art collection, and haunted local antiques shops.

As a callow eighteen-year-old leaving for college, I'd seen my hometown as a mere launching pad for a life in worldlier locales, a place to be from rather than a place to be. But years and miles away from home could never attenuate the city's hold on my identity, and the more I explored places and people far from Hampton, the more my status as one of its daughters came to

mean to me.

That day after church, we spent a long while catching up with the formidable Mrs. Land, who had been one of my favorite Sunday school teachers. Kathaleen Land, a retired NASA mathematician, still lived on her own well into her nineties and never missed a Sunday at church. We said our good-byes to her and clambered into the minivan, off to a family brunch. “A lot of the women around here, black and white, worked as computers,” my father said, glancing at Aran in the rearview mirror but addressing us both. “Kathryn Peddrew, Ophelia Taylor, Sue Wilder,” he said, ticking off a few more names. “And Katherine Johnson, who calculated the launch windows for the first astronauts.”

The narrative triggered memories decades old, of spending a much-treasured day off from school at my father’s office at the National Aeronautics and Space Administration’s Langley Research Center. I rode shotgun in our 1970s Pontiac, my brother, Ben, and sister Lauren in the back as our father drove the twenty minutes from our house, straight over the Virgil I. Grissom Bridge, down Mercury Boulevard, to the road that led to the NASA gate. Daddy flashed his badge, and we sailed through to a campus of perfectly straight parallel streets lined from one end to the other by unremarkable two-story redbrick buildings. Only the giant hypersonic wind tunnel complex—a one-hundred-foot ridged silver sphere presiding over four sixty-foot smooth silver globes—offered visual evidence of the remarkable work occurring on an otherwise ordinary-looking campus.

Building 1236, my father’s daily destination, contained a byzantine complex of government-gray cubicles, perfumed with the grown-up smells of coffee and stale cigarette smoke. His engineering colleagues with their rumpled style and distracted manner seemed like exotic birds in a sanctuary. They gave us kids stacks of discarded 11×14 continuous-form computer paper, printed on one side with cryptic arrays of numbers, the blank side a canvas for crayon masterpieces. Women occupied many of the cubicles; they answered phones and sat in front of typewriters, but they also made hieroglyphic marks on transparent slides and conferred with my father and other men in the office on the stacks of documents that littered their desks.

That so many of them were African American, many of them my grandmother's age, struck me as simply a part of the natural order of things: growing up in Hampton, the face of science was brown like mine.

My dad joined Langley in 1964 as a coop student and retired in 2004 an internationally respected climate scientist. Five of my father's seven siblings made their bones as engineers or technologists, and some of his best buddies —David Woods, Elijah Kent, Weldon Staton—carved out successful engineering careers at Langley. Our next-door neighbor taught physics at Hampton University. Our church abounded with mathematicians. Supersonics experts held leadership positions in my mother's sorority, and electrical engineers sat on the board of my parents' college alumni associations. My aunt Julia's husband, Charles Foxx, was the son of Ruth Bates Harris, a career civil servant and fierce advocate for the advancement of women and minorities; in 1974, NASA appointed her deputy assistant administrator, the highest-ranking woman at the agency. The community certainly included black English professors, like my mother, as well as black doctors and dentists, black mechanics, janitors, and contractors, black cobblers, wedding planners, real estate agents, and undertakers, several black lawyers, and a handful of black Mary Kay salespeople. As a child, however, I knew so many African Americans working in science, math, and engineering that I thought that's just what black folks did.

My father, growing up during segregation, experienced a different reality. "Become a physical education teacher," my grandfather said in 1962 to his eighteen-year-old son, who was hell-bent on studying electrical engineering at historically black Norfolk State College.

In those days, college-educated African Americans with book smarts and common sense put their chips on teaching jobs or sought work at the post office. But my father, who built his first rocket in junior high metal shop class following the Sputnik launch in 1957, defied my grandfather and plunged full steam ahead into engineering. Of course, my grandfather's fears that it would be difficult for a black man to break into engineering weren't

unfounded. As late as 1970, just 1 percent of all American engineers were black—a number that doubled to a whopping 2 percent by 1984. Still, the federal government was the most reliable employer of African Americans in the sciences and technology: in 1984, 8.4 percent of NASA's engineers were black.

NASA's African American employees learned to navigate their way through the space agency's engineering culture, and their successes in turn afforded their children previously unimaginable access to American society. Growing up with white friends and attending integrated schools, I took much of the groundwork they'd laid for granted.

Every day I watched my father put on a suit and back out of the driveway to make the twenty-minute drive to Building 1236, demanding the best from himself in order to give his best to the space program and to his family. Working at Langley, my father secured my family's place in the comfortable middle class, and Langley became one of the anchors of our social life. Every summer, my siblings and I saved our allowances to buy tickets to ride ponies at the annual NASA carnival. Year after year, I confided my Christmas wish list to the NASA Santa at the Langley children's Christmas party. For years, Ben, Lauren, and my youngest sister, Jocelyn, still a toddler, sat in the bleachers of the Langley Activities Building on Thursday nights, rooting for my dad and his "NBA" (NASA Basketball Association) team, the Stars. I was as much a product of NASA as the Moon landing.

The spark of curiosity soon became an all-consuming fire. I peppered my father with questions about his early days at Langley during the mid-1960s, questions I'd never asked before. The following Sunday I interviewed Mrs. Land about the early days of Langley's computing pool, when part of her job responsibility was knowing which bathroom was marked for "colored" employees. And less than a week later I was sitting on the couch in Katherine Johnson's living room, under a framed American flag that had been to the Moon, listening to a ninety-three-year-old with a memory sharper than mine recall segregated buses, years of teaching and raising a family, and working

out the trajectory for John Glenn's spaceflight. I listened to Christine Darden's stories of long years spent as a data analyst, waiting for the chance to prove herself as an engineer.

Even as a professional in an integrated world, I had been the only black woman in enough drawing rooms and boardrooms to have an inkling of the chutzpah it took for an African American woman in a segregated southern workplace to tell her bosses she was sure her calculations would put a man on the Moon. These women's paths set the stage for mine; immersing myself in their stories helped me understand my own.

Even if the tale had begun and ended with the first five black women who went to work at Langley's segregated west side in May 1943—the women later known as the "West Computers"—I still would have committed myself to recording the facts and circumstances of their lives. Just as islands—isolated places with unique, rich biodiversity—have relevance for the ecosystems everywhere, so does studying seemingly isolated or overlooked people and events from the past turn up unexpected connections and insights to modern life. The idea that black women had been recruited to work as mathematicians at the NASA installation in the South during the days of segregation defies our expectations and challenges much of what we think we know about American history. It's a great story, and that alone makes it worth telling.

In the early stages of researching this book, I shared details of what I had found with experts on the history of the space agency. To a person they encouraged what they viewed as a valuable addition to the body of knowledge, though some questioned the magnitude of the story.

"How many women are we talking about? Five or six?"

I had known more than that number just growing up in Hampton, but even I was surprised at how the numbers kept adding up. These women showed up in photos and phone books, in sources both expected and unusual. A mention of a Langley job in an engagement announcement in the *Norfolk Journal and Guide*. A handful of names from the daughter of one of the first West

Computers. A 1951 memo from the Langley personnel officer reporting on the numbers and status of its black employees, which unexpectedly made reference to one black woman who was a "GS-9 Research Scientist." I discovered one 1945 personnel document describing a beehive of mathematical activity in an office in a new building on Langley's west side, staffed by twenty-five black women coaxing numbers out of calculators on a twenty-four-hour schedule, overseen by three black shift supervisors who reported to two white head computers. Even as I write the final words of this book, I'm still doing the numbers. I can put names to almost fifty black women who worked as computers, mathematicians, engineers, or scientists at the Langley Memorial Aeronautical Laboratory from 1943 through 1980, and my intuition is that twenty more names can be shaken loose from the archives with more research.

And while the black women are the most hidden of the mathematicians who worked at the NACA, the National Advisory Committee for Aeronautics, and later at NASA, they were not sitting alone in the shadows: the white women who made up the majority of Langley's computing workforce over the years have hardly been recognized for their contributions to the agency's long-term success. Virginia Biggins worked the Langley beat for the *Daily Press* newspaper, covering the space program starting in 1958. "Everyone said, 'This is a scientist, this is an engineer,' and it was always a man," she said in a 1990 panel on Langley's human computers. She never got to meet any of the women. "I just assumed they were all secretaries," she said. Five white women joined Langley's first computing pool in 1935, and by 1946, four hundred "girls" had already been trained as aeronautical foot soldiers. Historian Beverly Golemba, in a 1994 study, estimated that Langley had employed "several hundred" women as human computers. On the tail end of the research for *Hidden Figures*, I can now see how that number might top one thousand.

To a first-time author with no background as a historian, the stakes involved in writing about a topic that was virtually absent from the history books felt high. I'm sensitive to the cognitive dissonance conjured by the phrase "black female mathematicians at NASA." From the beginning, I knew

that I would have to apply the same kind of analytical reasoning to my research that these women applied to theirs. Because as exciting as it was to discover name after name, finding out who they were was just the first step. The real challenge was to document their work. Even more than the surprisingly large numbers of black and white women who had been hiding in a profession seen as universally white and male, the body of work they left behind was a revelation.

There was Dorothy Hoover, working for Robert T. Jones in 1946 and publishing theoretical research on his famed triangle-shaped delta wings in 1951. There was Dorothy Vaughan, working with the white "East Computers" to write a textbook on algebraic methods for the mechanical calculating machines that were their constant companions. There was Mary Jackson, defending her analysis against John Becker, one of the world's top aerodynamicists. There was Katherine Coleman Goble Johnson, describing the orbital trajectory of John Glenn's flight, the math in her trailblazing 1959 report as elegant and precise and grand as a symphony. There was Marge Hannah, the white computer who served as the black women's first boss, coauthoring a report with Sam Katzoff, who became the laboratory's chief scientist. There was Doris Cohen, setting the bar for them all with her first research report—the NACA's first female author—back in 1941.

My investigation became more like an obsession; I would walk any trail if it meant finding a trace of one of the computers at its end. I was determined to prove their existence and their talent in a way that meant they would never again be lost to history. As the photos and memos and equations and family stories became real people, as the women became my companions and returned to youth or returned to life, I started to want something more for them than just putting them on the record. What I wanted was for them to have the grand, sweeping narrative that they deserved, the kind of American history that belongs to the Wright Brothers and the astronauts, to Alexander Hamilton and Martin Luther King Jr. Not told as a separate history, but as a part of the story we all know. Not at the margins, but at the very center, the protagonists of the drama. And not just because they are black, or because they are women, but because they are part of the American epic.

Today, my hometown—the hamlet that in 1962 dubbed itself "Spacetown USA"—looks like any suburban city in a modern and hyperconnected America. People of all races and nationalities mingle on Hampton's beaches and in its bus stations, the WHITES ONLY signs of the past now relegated to the local history museum and the memories of survivors of the civil rights revolution. Mercury Boulevard no longer conjures images of the eponymous mission that shot the first Americans beyond the atmosphere, and each day the memory of Virgil Grissom fades away from the bridge that bears his name. A downsized space program and decades of government cutbacks have hit the region hard; today, an ambitious college grad with a knack for numbers might set her sights on a gig at a Silicon Valley startup or make for one of the many technology firms that are conquering the NASDAQ from the Virginia suburbs outside of Washington, DC.

But before a computer became an inanimate object, and before Mission Control landed in Houston; before Sputnik changed the course of history, and before the NACA became NASA; before the Supreme Court case *Brown v. Board of Education of Topeka* established that separate was in fact not equal, and before the poetry of Martin Luther King Jr.'s "I Have a Dream" speech rang out over the steps of the Lincoln Memorial, Langley's West Computers were helping America dominate aeronautics, space research, and computer technology, carving out a place for themselves as female mathematicians who were also black, black mathematicians who were also female. For a group of bright and ambitious African American women, diligently prepared for a mathematical career and eager for a crack at the big leagues, Hampton, Virginia, must have felt like the center of the universe.

CHAPTER ONE

A Door Opens

Melvin Butler, the personnel officer at the Langley Memorial Aeronautical Laboratory, had a problem, the scope and nature of which was made plain in a May 1943 telegram to the civil service's chief of field operations. "This establishment has urgent need for approximately 100 Junior Physicists and Mathematicians, 100 Assistant Computers, 75 Minor Laboratory Apprentices, 125 Helper Trainees, 50 Stenographers and Typists," exclaimed the missive. Every morning at 7:00 a.m., the bow-tied Butler and his staff sprang to life, dispatching the lab's station wagon to the local rail depot, the bus station, and the ferry terminal to collect the men and women—so many women now, each day more women—who had made their way to the lonely finger of land on the Virginia coast. The shuttle conveyed the recruits to the door of the laboratory's service building on the campus of Langley Field. Upstairs, Butler's staff whisked them through the first-day stations: forms, photos, and the oath of office: *I will support and defend the Constitution of the United States against all enemies, foreign and domestic . . . so help me God*.

Thus installed, the newly minted civil servants fanned out to take their places in one of the research facility's expanding inventory of buildings, each already as full as a pod ripe with peas. No sooner had Sherwood Butler, the laboratory's head of procurement, set the final brick on a new building than his brother, Melvin, set about filling it with new employees. Closets and hallways, stockrooms and workshops stood in as makeshift offices. Someone came up with the bright idea of putting two desks head to head and jury-

rigged the new piece of furniture with a jump seat in order to squeeze three workers into space designed for two. In the four years since Hitler's troops overran Poland—since American interests and the European war converged in an all-consuming conflict—the laboratory's complement of 500-odd employees at the close of the decade was on its way to 1,500. Yet the great groaning war machine swallowed them whole and remained hungry for more.

The offices of the Administration Building looked out upon the crescent-shaped airfield. Only the flow of civilian-clothed people heading to the laboratory, the oldest outpost of the National Advisory Committee for Aeronautics (NACA), distinguished the low brick buildings belonging to that agency from identical ones used by the US Army Air Corps. The two installations had grown up together, the air base devoted to the development of America's military airpower capability, the laboratory a civilian agency charged with advancing the scientific understanding of aeronautics and disseminating its findings to the military and private industry. Since the beginning, the army had allowed the laboratory to operate on the campus of the airfield. The close relationship with the army flyers served as a constant reminder to the engineers that every experiment they conducted had real-world implications.

The double hangar—two 110-foot-long buildings standing side by side—had been covered in camouflage paint in 1942 to deceive enemy eyes in search of targets, its shady and cavernous interior sheltering the machines and their minders from the elements. Men in canvas jumpsuits, often in groups, moved in trucks and jeeps from plane to plane, stopping to hover at this one or that like pollinating insects, checking them, filling them with gas, replacing parts, examining them, becoming one with them and taking off for the heavens. The music of airplane engines and propellers cycling through the various movements of takeoff, flight, and landing played from before sunrise until dusk, each machine's sounds as unique to its minders as a baby's cry to its mother. Beneath the tenor notes of the engines played the bass roar of the laboratory's wind tunnels, turning their on-demand

hurricanes onto the planes—plane parts, model planes, full-sized planes.

Just two years prior, with the storm clouds gathering, President Roosevelt challenged the nation to ramp up its production of airplanes to fifty thousand per year. It seemed an impossible task for an industry that as recently as 1938 had only provided the Army Air Corps with ninety planes a month. Now, America's aircraft industry was a production miracle, easily surpassing Roosevelt's mark by more than half. It had become the largest industry in the world, the most productive, the most sophisticated, outproducing the Germans by more than three times and the Japanese by nearly five. The facts were clear to all belligerents: the final conquest would come from the sky.

For the flyboys of the air corps, airplanes were mechanisms for transporting troops and supplies to combat zones, armed wings for pursuing enemies, sky-high launching pads for ship-sinking bombs. They reviewed their vehicles in an exhaustive preflight checkout before climbing into the sky. Mechanics rolled up their sleeves and sharpened their eyes; a broken piston, an improperly locked shoulder harness, a faulty fuel tank light, any one of these could cost lives. But even before the plane responded to its pilot's knowing caress, its nature, its very DNA—from the shape of its wings to the cowling of its engine—had been manipulated, refined, massaged, deconstructed, and recombined by the engineers next door.

Long before America's aircraft manufacturers placed one of their newly conceived flying machines into production, they sent a working prototype to the Langley laboratory so that the design could be tested and improved. Nearly every high-performance aircraft model the United States produced made its way to the lab for drag cleanup: the engineers parked the planes in the wind tunnels, making note of air-disturbing surfaces, bloated fuselages, uneven wing geometries. As prudent and thorough as old family doctors, they examined every aspect of the air flowing over the plane, making careful note of the vital signs. NACA test pilots, sometimes with an engineer riding shotgun, took the plane for a flight. Did it roll unexpectedly? Did it stall? Was it hard to maneuver, resisting the pilot like a shopping cart with a bad

wheel? The engineers subjected the airplanes to tests, capturing and analyzing the numbers, recommending improvements, some slight, others significant. Even small improvements in speed and efficiency multiplied over millions of pilot miles added up to a difference that could tip the long-term balance of the war in the Allies' favor.

"Victory through airpower!" Henry Reid, engineer-in-charge of the Langley laboratory, crooned to his employees, the shibboleth a reminder of the importance of the airplane to the war's outcome. "Victory through airpower!" the NACA-ites repeated to each other, minding each decimal point, poring over differential equations and pressure distribution charts until their eyes tired. In the battle of research, victory would be theirs.

Unless, of course, Melvin Butler failed to feed the three-shift-a-day, six-day-a-week operation with fresh minds. The engineers were one thing, but each engineer required the support of a number of others: craftsmen to build the airplane models tested in the tunnels, mechanics to maintain the tunnels, and nimble number crunchers to process the numerical deluge that issued from the research. Lift and drag, friction and flow. What was a plane but a bundle of physics? Physics, of course, meant math, and math meant mathematicians. And since the middle of the last decade, mathematicians had meant women. Langley's first female computing pool, started in 1935, had caused an uproar among the men of the laboratory. How could a female mind process something so rigorous and precise as math? The very idea, investing $500 on a calculating machine so it could be used by a girl! But the "girls" had been good, very good—better at computing, in fact, than many of the engineers, the men themselves grudgingly admitted. With only a handful of girls winning the title "mathematician"—a professional designation that put them on equal footing with entry-level male employees—the fact that most computers were designated as lower-paid "subprofessionals" provided a boost to the laboratory's bottom line.

But in 1943, the girls were harder to come by. Virginia Tucker, Langley's

head computer, ran laps up and down the East Coast searching for coeds with even a modicum of analytical or mechanical skill, hoping for matriculating college students to fill the hundreds of open positions for computers, scientific aides, model makers, laboratory assistants, and yes, even mathematicians. She conscripted what seemed like entire classes of math graduates from her North Carolina alma mater, the Greensboro College for Women, and hunted at Virginia schools like Sweetbriar in Lynchburg and the State Teachers College in Farmville.

Melvin Butler leaned on the US Civil Service Commission and the War Manpower Commission as hard as he could so that the laboratory might get top priority on the limited pool of qualified applicants. He penned ads for the local newspaper, the *Daily Press*: "Reduce your household duties! Women who are not afraid to roll up their sleeves and do jobs previously filled by men should call the Langley Memorial Aeronautical Laboratory," read one notice. Fervent pleas from the personnel department were published in the employee newsletter *Air Scoop*: "Are there members of your family or others you know who would like to play a part in gaining supremacy of the air? Have you friends of either sex who would like to do important work toward winning and shortening the war?" With men being absorbed into the military services, with women already in demand by eager employers, the labor market was as exhausted as the war workers themselves.

A bright spot presented itself in the form of another man's problem. A. Philip Randolph, the head of the largest black labor union in the country, demanded that Roosevelt open lucrative war jobs to Negro applicants, threatening in the summer of 1941 to bring one hundred thousand Negroes to the nation's capital in protest if the president rebuffed his demand. "Who the hell is this guy Randolph?" fumed Joseph Rauh, the president's aide. Roosevelt blinked.

A "tall courtly black man with Shakespearean diction and the stare of an eagle," Asa Philip Randolph, close friend of Eleanor Roosevelt, headed the 35,000-strong Brotherhood of Sleeping Car Porters. The porters waited on passengers in the nation's segregated trains, daily enduring prejudice and humiliation from whites. Nevertheless, these jobs were coveted in the black

community because they provided a measure of economic stability and social standing. Believing that civil rights were inextricably linked to economic rights, Randolph fought tirelessly for the right of Negro Americans to participate fairly in the wealth of the country they had helped build. Twenty years in the future, Randolph would address the multitudes at another March on Washington, then concede the stage to a young, charismatic minister from Atlanta named Martin Luther King Jr.

Later generations would associate the black freedom movement with King's name, but in 1941, as the United States oriented every aspect of its society toward war for the second time in less than thirty years, it was Randolph's long-term vision and the specter of a march that never happened that pried open the door that had been closed like a bank vault since the end of Reconstruction. With two strokes of a pen—Executive Order 8802, ordering the desegregation of the defense industry, and Executive Order 9346, creating the Fair Employment Practices Committee to monitor the national project of economic inclusion—Roosevelt primed the pump for a new source of labor to come into the tight production process.

Nearly two years after Randolph's 1941 showdown, as the laboratory's personnel requests reached the civil service, applications of qualified Negro female candidates began filtering in to the Langley Service Building, presenting themselves for consideration by the laboratory's personnel staff. No photo advised as to the applicant's color—that requirement, instituted under the administration of Woodrow Wilson, was struck down as the Roosevelt administration tried to dismantle discrimination in hiring practices. But the applicants' alma maters tipped their hand: West Virginia State University, Howard, Arkansas Agricultural, Mechanical & Normal, Hampton Institute just across town—all Negro schools. Nothing in the applications indicated anything less than fitness for the job. If anything, they came with more experience than the white women applicants, with many years of teaching experience on top of math or science degrees.

They would need a separate space, Melvin Butler knew. Then they would