BOLD THEY RISE

The Space Shuttle Early Years, 1972–1986

David Hitt and Heather R. Smith

FOREWORD BY BOB CRIPPEN

"Read this book to experience the Space Shuttle as it matured. Smith and Hitt tap sources that made this aerospace wonder's early history. You'll feel the needs and wants of those involved; the joys and sadness that came with conceiving, building, and flying this vehicle. It's a trip—I know."

—CHARLES D. WALKER, engineer, corporate executive, first commercial industry astronaut, STS-41D, STS-51D, STS-61B

"Essential reading."

—Emily Carney, americaspace.com

"A rich, engaging account of the first years of the Space Shuttle era, *Bold They Rise* recounts the development and pioneering missions of a truly magnificent flying machine that helped open the door to space for scientists such as myself."

—DONALD A. THOMAS, NASA astronaut, STS-65, STS-70, STS-83, and STS-94

"Space enthusiasts will enjoy this work."

—*Choice*

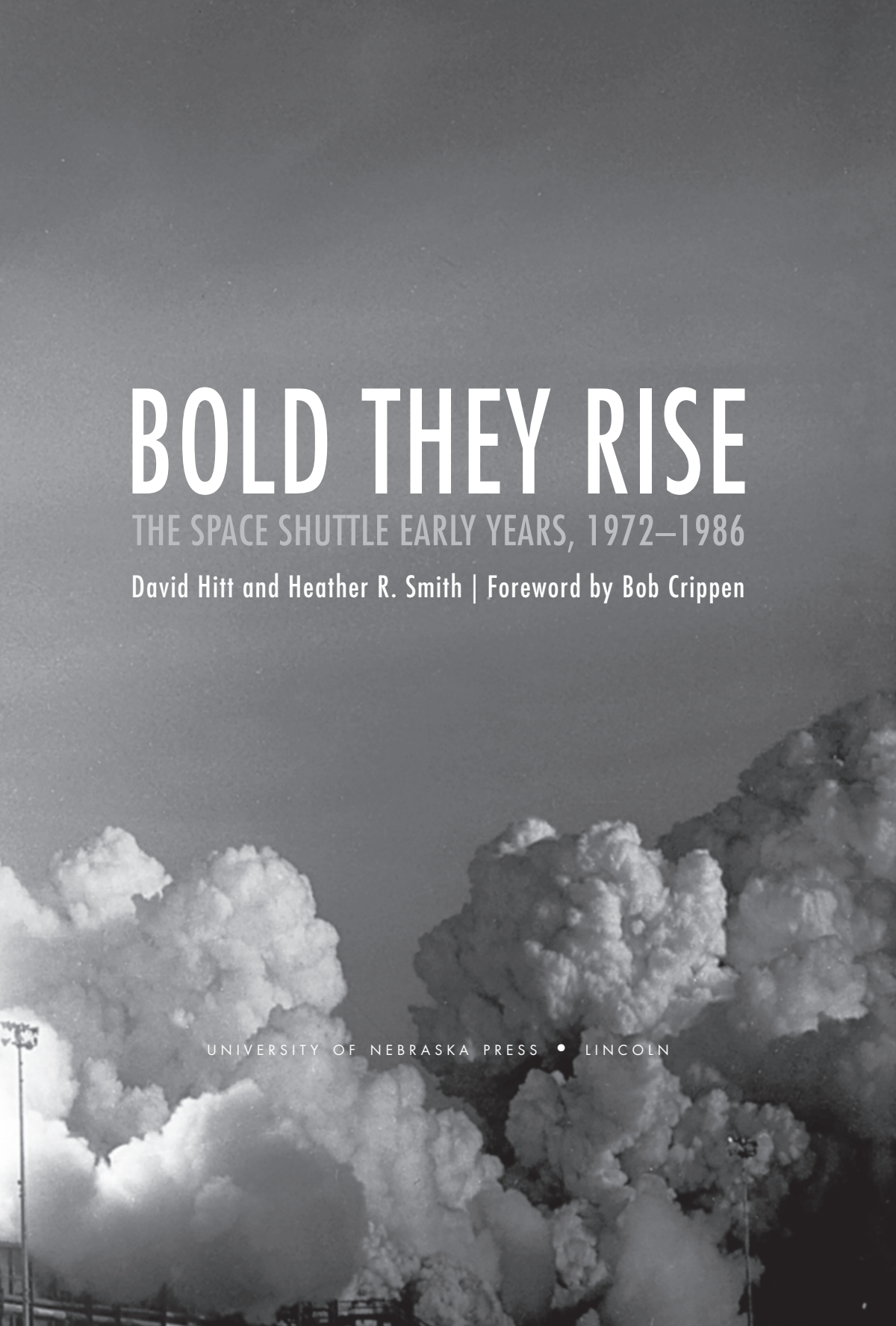
"This book is a welcome addition to the spectacular Outward Odyssey series, and any space enthusiast's collection that does not carry it is missing something vital. . . . [*Bold They Rise*] is at times gripping with the thrill found only in the 'firsts' involved with anything to do with space exploration. . . . [This is] a solid read which provides important information regarding NASA's program of record for more than thirty years."

—JASON RHIAN, spaceflightinsider.com

Bold They Rise

Outward Odyssey
A People's History
of Spaceflight

Series editor
Colin Burgess



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David Hitt and Heather R. Smith | Foreword by Bob Crippen

UNIVERSITY OF NEBRASKA PRESS • LINCOLN

Library of Congress Cataloging-in-Publication Data
Hitt, David.
Bold they rise: the space shuttle early years, 1972–1986 / David Hitt and Heather R. Smith; foreword by Bob Crippen.
pages cm.
—(Outward odyssey. A people's history of spaceflight)
Includes bibliographical references and index.
ISBN 978-0-8032-2648-7 (hardcover: alk. paper)—
ISBN 978-1-4962-2940-3 (paperback)—
ISBN 978-0-8032-5548-7 (pdf (web))—
ISBN 978-0-8032-5549-4 (epub)—
ISBN 978-0-8032-5556-2 (mobi) 1. Space Shuttle Program (U.S.) 2. Space shuttles—United States—History. 3. Manned space flight—History. I. Smith, Heather R. II. Title. III. Title: Space shuttle early years, 1972–1986.
TL795.5.H58 2014
629.44'1097309048—dc23
2013047054

Designed and set in Garamond Pro
by L. Auten.

To Finn, Caden, Owen, Bethany, Nathan, Lillian, Lila Grace, Will, Baxter, Amelia, Andrew, Peyton, Sabrina, Kean, Elliott, Rhys, Daniel, Lainey, and millions of other children who will be the ones to carry on the exploration of tomorrow.

They venture forth, into the spangled night
Lured inexorably by dreams;
With vision
And resolve
To go beyond the quest of yesterday

Bold they rise, these winged emissaries
To wonders transcendent;
With audacity
And faith
In the divine promise of tomorrow.

Colin Burgess, "Bold They Rise"

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Foreword

After John Young and I made the first flight of the Space Shuttle aboard *Columbia* all those years ago, people would sometimes ask me what the best part of the flight was. I would always use John's classic answer: "The part between takeoff and landing."

Now that it's all said and done, I think that describes what the best part of the Space Shuttle program was: the part between our first launch in April 1981 and the last landing in July 2011.

There were some low points in between, particularly the loss of both of the orbiters I had the privilege to fly and their crews, but as a whole I think the shuttle has been one of the most marvelous vehicles that has ever gone into space—a fantastic vehicle unlike anything that's ever been built.

The Space Shuttle has carried hundreds of people into space and delivered hundreds of tons of payloads into space. The shuttle gave us the *Galileo* and *Magellan* probes, which opened our eyes to new worlds, and it let us not only launch the Hubble Space Telescope but also repair and upgrade it time and time again, and Hubble has revolutionized our understanding of not only our solar system but the entire universe. The shuttle carried a lot of classified military payloads early on that probably helped the United States win the Cold War.

The Space Shuttle let us build the International Space Station. The Space Station is an incredible accomplishment, a marvelous complex, but it was the Space Shuttle that taught us that we could build a complicated space vehicle and make it work very well. The Space Station would not have been possible without the Space Shuttle.

But in those early days, I think the shuttle did something else, a little less concrete but just as important. The late '70s and early '80s weren't really a great time for the United States. We'd basically lost the Vietnam War. We'd been through economic hard times, through the hostage crisis in Iran.

President Reagan was shot just before our flight on STS-1. And morale for a lot of people in the country was really low. People were feeling like things just weren't going right for us.

And that first flight, it was obvious that it was a big deal. It was a big thing for NASA, but it was a big thing for the country. It wasn't just our accomplishment at NASA; it was an American accomplishment. It was a morale booster for the United States. It was a rallying point for the American people. And the awareness may not be as high now as it was then, but I think that's still true today. I think you saw that when the shuttle made its last flight; the pride people had in what it had accomplished and the fact that a million people watched it. When I talk to people, they think space exploration is something we need to be doing, for the future of the United States and humankind.

The retirement of the shuttle was kind of bittersweet for me. I'm proud of all it's accomplished, and I'm sorry to see it end. But I believe in moving on. I'd like to see us get out of Earth orbit and go back to the moon, and to other destinations, and eventually to Mars.

John and I got to see a lot of the development of the Space Shuttle firsthand. As astronauts, we were involved from an operations standpoint, and as the first crew, John and I visited the sites where they were working on the shuttle, getting it ready to fly. We had an outstanding, dedicated team, people who really believed they were doing something important for the nation. When we finally got into the shuttle for that first flight, meeting those thousands of people gave me a lot of confidence that we had a good vehicle to fly on.

I never expected to be selected for that first flight. I thought they would pick someone more experienced to fly with John. I was excited that they picked me, and I was honored to be a part of that flight. All told, that flight was the beginning of something truly amazing, and I'm honored to be one of the thousands of people who made it happen.

Bob Crippen

Preface

When I (David) first became involved in the Outward Odyssey series, working on the Skylab volume, my coauthors and I were shown a list of proposed titles for the first eight books in the series. As authors working on our first book, coming up with a title seemed like one of the more exciting parts of the job. We were thus somewhat pleased to be disappointed with the working title the publisher had provided: "Exemplary Outpost." It was an accurate title, but it lacked the poetry of the other titles on the list—titles like *Into That Silent Sea* and *In the Shadow of the Moon*. I'm not sure that we quite lived up to that standard with *Homesteading Space*, but we made our best effort.

Even though it meant giving up the privilege of titling this volume, Heather and I were quite happy to go along with the name the publisher had suggested for this book: *Bold They Rise*. It was, quite literally, poetic, taken from the poem by series editor Colin Burgess that appears as the epigraph.

When we first read the poem, very early on in the process of writing this volume, we pictured the title as being about the Space Shuttles themselves, reflecting the poem's reference to "winged emissaries." As the book took shape, however, we realized that was no longer true; the title had taken on a new meaning for us. Rather than being about the hardware, it was about the men and women who risked their lives to expand humankind's frontiers.

And in that vein, this book owes an incredible debt of gratitude to the NASA Johnson Space Center (JSC) Oral History Project, without which it quite literally would not exist.

With *Homesteading Space*, it was relatively easy to create a book that filled a unique niche—with a few notable exceptions, such as a handful of official NASA publications and David Shayler's *Skylab*, very little had been written about America's first space station. Breaking new ground was not a particular challenge.

With this book, the challenge was a little greater. There are more books about the Space Shuttle program, so it was somewhat harder to create something unique. Most of the previous works, however, fall into one of three categories—technical volumes, which span the entire program but include none of the human experience; astronaut memoirs, which relate the human experience, but only from one person's perspective; or specific histories, which are more exhaustive but focus on only a limited slice of the program.

Based on the overall goal of the Outward Odyssey series, a new niche we could address became clear—a book relating the human experience of the Space Shuttle program, not limited to one person's story but including a variety of viewpoints and spanning the early years of the program. Originally the goal was to create a "*Homesteading Space* of the shuttle program," but it quickly became apparent that was a misdirected goal. *Homesteading* had only three manned missions to cover, and thus we could delve much deeper and more broadly in covering them. To attempt to write about the subject of this book in that manner would be to do either the subject or the reader a grave disservice; we needed to narrow our approach to create something that was both relevant and readable.

When we began reading from the JSC oral history interviews early in our research, the ideal approach for the book became apparent. Here was a wealth of first-person experience, describing in detail what it was like to be there—what it was like to involved in the design of a new spacecraft, what it was like to risk one's life testing that vehicle, what it was like to do things that no one had done before in space, what it was like to float freely in the vacuum of space as a one-man satellite, what it was like to hold thousands of pounds of hardware in one's hands, what it was like to watch friends die.

This book almost exclusively offers the astronauts' perspective on the early years of the Space Shuttle program, and, while research for the volume drew on several resources, the extensive quoted material draws heavily from the JSC Oral History Project. It's the astronauts' story, told in their own words, about their own experiences.

Bold They Rise is not a technical volume. We would love for this volume to inspire you seek out another book that delves more deeply into the technical aspects of the shuttle. There are parts of the story that we had to deal with in what seemed like a relatively superficial manner; even dedicating an entire chapter to the *Challenger* accident and the effects it had seems woeful-

ly insufficient. Entire books could, and have, been written about the *Challenger* accident. If this book leaves you wanting to know more about that incident or other aspects of the shuttle's history, we encourage you to seek out those volumes. And of course, individual astronauts have told their stories in memoirs with more personality than we were able to capture here. The subject of this book is such that it can't be covered by any one volume exhaustively, but hopefully we have provided a unique, informative, and engaging overview here.

The chronological scope of the book was also set by the publisher to fit within the Outward Odyssey series. (Another volume, written by Rick Houston, picks up the Space Shuttle story where this one leaves off.) Initially, the ending point of the book was a bit discomfiting; the *Challenger* accident seemed a rather low note on which to end a book. There were any number of successes both before and after *Challenger*. Why would one pick the lowest point of the early years as a place to end the story? But, in a very real way, it was the best possible way to turn this history into a story arc.

As astronaut Mike Mullane wrote in his memoir *Riding Rockets*,

The NASA team responsible for the design of the Space Shuttle was the same team that had put twelve Americans on the Moon and returned them safely to Earth across a quarter million miles of space. The Apollo program represented the greatest engineering achievement in the history of humanity. Nothing else, from the Pyramids to the Manhattan Project, comes remotely close. The men and women who were responsible for the glory of Apollo had to have been affected by their success. While no member of the Shuttle design team would have ever made the blasphemous claim, "We're gods. We can do anything," the reality was this: The Space Shuttle itself was such a statement. Mere mortals might not be able to design and safely operate a reusable spacecraft boosted by the world's largest, segmented, uncontrollable solid-fueled rockets, but gods certainly could.

That, then, is the story of this book—a Greek tragedy about hubris and its price. It's a story of the confidence that bred some of the most amazing achievements in human history but also led to overconfidence.

But make no mistake, this book is also a love letter. Both authors of this volume were born after the end of the last Saturn-Apollo flight; the Space Shuttle is "our" spacecraft. The *Challenger* accident occurred when we were still children; it was our "where were you" equivalent of the Kennedy assas-

sination. In our "day jobs" as NASA education writers, we wrote extensively about the shuttle, its crews, its missions, its accomplishment and ultimately its retirement. We write this with a fondness for the shuttle, even when that means telling the story with warts-and-all honesty.

It's been an honor and a pleasure to tell this story. We hope you enjoy reading it.

David Hitt
Heather R. Smith

Acknowledgments

As mentioned in the preface but bears repeating, this volume owes a great deal of gratitude to the Johnson Space Center Oral History Project, without which it would not exist.

In addition, we are grateful to the University of Nebraska Press, and in particular to senior editor Rob Taylor, for their dedication to chronicling the history of space exploration through their publication of the Outward Odyssey series and specifically through their help and support with this volume. In addition, the authors wish to express their substantial thanks to Outward Odyssey series editor Colin Burgess, who has been a loyal shepherd, a wise counsel, and a good friend during the process.

It was an incredible honor to have astronaut Bob Crippen agree to write the foreword for this volume. For David, the journey to writing this book begins in a very real way in front of a television set in 1981 watching Bob Crippen and John Young make history, and to conclude that journey with Crippen being a part of this project is a surreal bookend to the experience.

Astronaut (and *Homesteading Space* coauthor) Owen Garriott provided much assistance early in the project, making contacts and helping to get things moving, and that assistance is much appreciated. In addition, astronaut Bo Bobko was also involved in the early stages of the book and provided insight into its direction and helped open some doors. Astronauts Hank Hartsfield and Joe Kerwin and NASA legends Chris Kraft and George Mueller also provided us with material for the book.

Phillip Fox, Jon Meek, Jordan Walker, Rebecca Hitt, Lauren McPherson, and Suzanne Haggerty read early portions of this book in progress and provided feedback.

On a personal note, the authors wish to acknowledge Finn and Caden Smith, ages seven and five at the time the original manuscript was finished, for their sacrifices during deadline work on this book.

In addition, David would like to thank the following:

Heather, who for years has made my writing better and without whom I could not have written this book.

As per last time, my father, Bill Hitt, for engendering my interest in spaceflight that set me on the path to, among other things, writing this book. Jim Abbott, for giving me my first break and being a brilliant editor and a wonderful mentor and for shaping the man I am today. Holly Snow, for opening the door for my new involvement with NASA.

Owen Garriott and Joe Kerwin, for sponsoring me through Olympus and for sharing their stories, their insight, their knowledge, their expertise, and their friendship.

All of those who traveled with me on multiple road trips to Kennedy Space Center, which occasionally involved successfully watching shuttle launches.

Heather would like also to thank the following:

David, for offering me the opportunity to coauthor a book and for shepherding me through the process.

Mrs. Hughes, for seeing potential in the writing skills of a young, tenth-grade Heather and inviting her to write for the school yearbook staff, sparking an interest in writing and communication that led me down this career path. Mr. Sandy Barnard, for believing that I could write and write well whatever I put my pen to.

The *Times-Mail* in Lawrence County, Indiana, the proud home to three astronauts, including Charlie Walker, who is quoted extensively in this book, for giving me my first professional writing job and an occasional space-related assignment that made a big difference in me ending up writing at NASA and thus ending up writing this book. I was blessed to work in a community that adores its hometown astronauts and that still gets excited about spaceflight.

Starbucks locations in Huntsville, Alabama, and Nashville, Tennessee, and the Flint River Coffee Company in Huntsville, Alabama, for hospitality and tasty coffee. Portions of this book were written and edited there.

And most important, God my Father. Any writing talent that I possess is a gift from You, and You have shepherded my life and career. May You get any and all glory for this volume.

Bold They Rise

1. The Feeling of Flying

On the one hand is the idea. On the other, the reality.

Sometimes the latter fails to live up to the former. The reality of experience doesn't always measure up to the way we picture it. So often in the case of space exploration, however, it is the idea that utterly fails to do justice to the reality.

For example, countless descriptions of the Space Shuttle document its specifications to the smallest of details. But knowing that the vehicle stands 184 feet tall and weighs 4.5 million pounds fueled for launch doesn't begin to capture the experience of standing at the base of the vehicle as it towers on the launchpad.

"I wasn't intimidated by it," recalled astronaut Mike Lounge of the first time he saw the fully stacked vehicle. "Well, that's not exactly true. The first time we went down to the Cape on our class tour, my reaction when seeing the pad, at seeing the orbiter and all that, is, 'My God, this stuff's too big. It can't possibly fly.' I think that's a common reaction. I knew how big it was, but it's different when you actually see it and you're walking underneath the orbiter and all this stuff. But having gotten over that, it was kind of fun to be there with the hardware. Everyone enjoys hardware over simulations and paper."

If the vehicle itself transcends expectations, NASA's astronauts found that so, too, did the experience of actually flying aboard the Space Shuttle. Those expectations would have gradually mounted during months of mission preparation and training, but the experience would truly begin in earnest when the highly anticipated launch day arrived.

For an astronaut, that first launch day comes only after years with NASA. Since 1978 astronauts have first been selected as "candidates" and must complete an initial orientation period, replete with training in almost every aspect of the agency's work, before becoming official members of the corps.

Then there are ground assignments supporting the program in ways that have nothing to do with getting ready for a mission.

And then, finally, years after selection, there's the crew assignment. Followed by more training and preparation. There's practice on the general things that will occur during the mission, like launch and landing, to make sure everyone is ready. There's practice for all the things that theoretically could occur during the mission but shouldn't, the potential anomalies and malfunctions the astronauts have to be ready for. There's training on mission-specific tasks, the unique things each astronaut will have to do on this particular flight. There's preparation, working with the scientists or engineers or companies or countries responsible for the mission payloads to make sure that those, too, are ready to go. So when launch day finally arrives, it's a long-awaited culmination of a great deal of time and effort.

Astronaut Terry Hart recalled his launch day at NASA's Kennedy Space Center (KSC) in Florida, home of the Space Shuttle's launch complexes: "It was a clear, cool morning there and we went through the whole morning, going through the traditions of having breakfast together, and there was always a cake there for the crew before they go out. And then going into the van and realizing that all the Mercury guys went on that van, it was really a very heady experience."

For three-time shuttle veteran David Leestma, that experience of waving to people while walking out to the Astrovan, suited up and ready for launch, was a memorable moment. "We always called that the last walk on Earth," Leestma said. "There's always crowds of people there to see you in case you never come back or something. It was one of those little bits of kind of gruesome humor. And then you go out to the launchpad, and you've been through this. You've been there many times before, because you train in the orbiter a few times and you have countdown demonstration tests and things. And this time you get to the pad and there's nobody there. You go, 'Ooh.' And the vehicle is steaming and creaking and groaning and you go, 'This is for real.'"

On the launchpad, the Space Shuttle is positioned vertically, its three major components having been stacked together in the enormous Vehicle Assembly Building at Kennedy Space Center before having been rolled out—slowly—to the launchpad atop a huge crawler. Standing tallest is the orange-brown external tank. The external tank has no engines of its own

but carries the liquid fuel for the launch in two separate tanks, one containing liquid oxygen and the other holding liquid hydrogen. The tanks are supercooled to maintain the fuels at the cryogenic temperatures needed to keep them in liquid state—below minus four hundred degrees Fahrenheit in the case of the hydrogen. Fully fueled, the external tank weighs about 1.7 million pounds.

On either side of the external tank is a slender, white solid rocket booster (SRB), the two of which together provide the bulk of the power for the first two minutes of the launch. Once ignited, they together provide 6.2 million pounds of thrust. Their name comes from the fact that they carry their propellant—consisting largely of aluminum mixed with an oxidizer to cause it to burn—in a solid, rubbery form.

And then there's the orbital spacecraft itself, the winged, white-and-black orbiter. Near the nose of the orbiter is the crew cabin, where the astronauts fly the vehicle and live during their mission. Farther aft is the payload bay, with its two large doors. And in the rear are the three Space Shuttle main engines, fueled by the external tank, each capable of generating a thrust of almost half a million pounds.

By launch day, the launch complex's servicing structure has been rotated back, revealing the orbiter. The shuttle is ready for its crew. The entrance to the orbiter is through a hatch in the side of the crew cabin, near the top of the vertically stacked vehicle, almost 150 feet above the launchpad.

Leestma recalled the process of boarding the vehicle via an elevator in the launch tower and a gantry arm near the top of the structure:

As usual, people don't say much in elevators. It's true whether you're in a hotel or on the launchpad. You kind of watch the numbers tick by, and instead of floors, they do everything in feet in the elevators, so you're so many feet above sea level. And then across the gantry, and when you walk across the gantry you're looking down into the flame trench. And you've been there before, but the obvious thing that's striking you is that this is for real, we're going to go. At least you hope we're going to go today. . . . You get up to the White Room, the access arm, and there's only two, maybe three people there and that's it. There's nobody else on the pad and everybody's blocked off for four or five miles away. This is for real. And it's groaning and moaning and you know that it's going to launch, and it's fueled and ready to go. It's a big bomb there, sitting on the pad. And you hope that all

the fire goes down and you go up, and let's go, let's get on it with it. It's great. . . . We got strapped in, and again, the guys strapping us in were a lot of the same guys that strapped in Al Shepard on his flight [to become the first American in space during Project Mercury]. So it was a very heady time. . . . You get in and you just can't wait for it to happen.

Astronaut Jerry Ross, who was the first to launch into space seven times, said journeying out to the launchpad when the vehicle is fully fueled and ready to go is quite different than going out there any other time, not only because of the reality of the situation, but because the shuttle itself is different.

The vehicle really does give you this sense that it's an animal that's awake and just ready to go do something. When you go out there and the vehicle's not fueled, it's not hissing, it's not boiling off vapors, it's not making noises that you don't hear, that you do hear when it's fueled. And there's the tremendous amount of anticipation. My first flight was the twenty-third flight of the shuttle, and I had listened to every crew come back, and I took very detailed notes of their debriefings, which were quite exhaustive early on. I listened to everything they said, and they would give us a very detailed description of what it was like, what the sensations were of launch. I put that into my databank, and I would daydream about that when I'd go running or work out at the gym or something like that. I knew it was going to be a pretty exciting ride.

The crew cabin of the shuttle has two levels. The "upper" deck is the flight deck, where the commander and pilot sit at the vehicle's controls, with a bank of large windows in front of them. The flight deck has room for up to two more astronauts to sit during launch, and behind them are windows looking into the payload bay and the controls for the orbiter's robotic arm.

Below the flight deck is the mid-deck, where the rest of the crew sits during launch. Once in orbit, the mid-deck serves as the primary living area for the crew, with storage lockers and the orbiter's kitchen and bathroom and main sleeping area. The mid-deck also provides access to the vehicle's payload bay. During launch, the mid-deck has very limited visibility, and the astronauts sitting there depend largely on word from the flight deck and the very obvious physical sensations of launch to know what's going on during ascent.

Prior to launch, once the crew members have boarded the orbiter and been strapped into their seats, the waiting begins. Traditionally, the astro-

1. STS-1 crew members Commander John Young (*left*) and Pilot Bob Crippen inside Space Shuttle *Columbia* in the Orbiter Processing Facility at the Kennedy Space Center. Courtesy NASA.

nauts board about three hours before the scheduled launch time, lying on their backs in their chairs until launch.

Very often, this is as far as things get. Any number of issues, from unacceptable weather conditions to a technical glitch with the vehicle and more, can result in the launch being scrubbed and pushed back. In those cases, the astronauts are helped out of the vehicle, and work begins to prepare for the next launch attempt. "Probably one of the most frustrating things is when you get near your takeoff time, your launch time, and then you know there's a problem, and you go, 'Please solve it. We don't want to wait here. Get us off the pad,'" noted Leestma. "The last people you want to have to make the real technical decision whether you go or not is the crew, because they're always, 'Go.' 'Yeah, we'll be fine. Let's go.' That's why you've got a whole team of folks in the launch control room doing that."

But on other occasions, the weather does what it's supposed to, the vehicle is operating properly, any number of other factors come together as they should, and launch preparations continue to proceed. Finally, as launch nears, the Space Shuttle main engines "gimbal," or tilt, to test that they will move properly, and at five seconds before launch they are ignited to make sure all three engines are functioning properly. The vehicle continues to sit on the pad, but the firing of the engines causes it to pitch slightly. It then rocks slightly back, a process called the "twang," and when the stack is vertical again, at T minus zero, a spark at the top of the fuel casing of the solid rocket boosters ignites the propellant. With more than seven and a half million pounds of thrust pushing the Space Shuttle upward, it begins to move.

Shuttle pilot and commander Fred Gregory recalled the feeling of the main engines first firing, describing it as almost a nonevent. "You could hear it; you were aware of it. It sounded like some kind of an electric motor at some distance, but you looked out the window and you saw the launch tower there and the launch tower moved back. At least that's what you thought, but then you realized the orbiter was moving forward and then back, and when it came back to vertical, that's when those solids ignited and there was no doubt about it. You were going to go someplace really fast, and you just watched the tower kind of drop down below you."

At the very beginning of the ascent, there's the brilliant light of the engines, which no photograph or video can truly capture: a brightness that

seems to puncture the sky. The brilliance of the flames from the engine is dramatic during the day, and far more so when they light up the sky at night. Payload specialist astronaut Charlie Walker recalled the experience of launching on the Space Shuttle in the dark:

At night, you look outside, and this launchpad is a blue gray from the xenon light reflections bouncing off of it, with a completely black background behind it. All of a sudden the launchpad brightens up with the solid rockets igniting. The launchpad brightens up to a yellow gray, but then the whole background, suddenly there's like a sunrise that's happened over Florida. You can see the Florida landscape for miles back that way. Sure, the sky is still black, but suddenly Florida has been illuminated by a new sunrise. I can see the Florida countryside, and it's a yellow, white-yellow-orange color, the coloration of the brilliant, hot flame from the solid rocket boosters.

Like Gregory, Jerry Ross recalled that, while he was aware when the main engines first ignited, things didn't really get exciting until the solid rocket boosters fired.

As the shuttle's main engines came up, you could really feel the vibrations starting in the orbiter, but when the solid rocket motors hit, when they ignite, it's somebody taking a baseball bat and swinging it pretty smartly and hitting the back of your seat, because it's a real "bam!" And the vibration and noise is pretty impressive. The acceleration level is not that high at that point, but there is that tremendous jolt as the solid rocket motors ignite, and you're off. I'll never forget the vibrations of the solid rocket motors. As we accelerated in the first thirty seconds or so, the wind noise on the outside of the vehicle just became really intense, like it was just screaming. It was screeching on the outside. I was already thinking about "what am I doing here" before then, but [it was] just a sheer, incredible experience of the energy.

In many ways the flight deck, with its large windows, is the superior seating for experiencing the launch. In one way, however, the mid-deck has the advantage. Since the pilot and commander are busy with the tasks of making sure the vehicle is operating properly during ascent, they don't have the luxury of stopping to really take in the experience of the launch. While the astronauts on the mid-deck don't have the same view as those on the flight deck, they have the freedom to focus more on the sensations. Hart, for example, recalled being able, as a mission specialist, to really enjoy the experience.

You talk a lot [to other astronauts about what launch is like], obviously, and you see a lot of pictures, and you think about it a lot, so you think you're pretty well prepared and you probably won't have too many surprises, but I had a couple of surprises. The shake, rattle, and roll for the first two minutes, that was about what I thought, maybe even a little bit less than what I thought it would be, because the solid rockets kind of have a "whoof-whoof" [rumble]. You don't really hear it; you more feel it. It's like a very low-frequency rumble, and just a tremendous sense of power as you lift off and all.

Another part of the experience that simply cannot be replicated on the ground is the pressure of the g-forces during ascent, according to STS-6 commander P. J. Weitz: "The value of our simulators ends when those engines light and you lift off. They try to fake you out a little bit by tipping the Shuttle Orbiter Simulator and that, but it doesn't compare with three shuttle main engines and two solids going. As I tell people, I said, 'You know you're on your way and you're going somewhere and you hope they keep pointed in the right direction, because it's an awesome feeling.'"

Weitz compared the launch of the Space Shuttle to the launch of a Saturn IB, which he took into space on the first Skylab mission. The Saturn, he said, produced about half again as much acceleration force as the shuttle's three gs, and the force was felt in somewhat different ways on the two vehicles. In the Saturn, the thrust was "actual," or directly in line with the vehicle, so the crew was pressed directly back into the couches. With the shuttle, on the other hand, because of the way the orbiter is stacked on the external tank, the thrust from the main engines is offset from the vehicle's center of gravity, meaning that the crew members aboard felt the pressure pushing them not only into the back but also into the bottom of their seats.

After clearing the launchpad, the shuttle begins to roll so that the orbiter is below the external tank, to better allow its engines to offset the tank's weight. Around one minute into flight, the shuttle encounters "Max Q," the period in which the increasing velocity of the vehicle produces the maximum amount of pressure on the shuttle before the decreasing resistance of the atmosphere reduces that pressure. To reduce the strains of the pressure of Max Q, the vehicle throttles down its engines and then, seconds later, past the point of maximum pressure, throttles back up.

Just over two minutes into the launch, the solid rocket boosters separate from the vehicle, and the orbiter and external tank continue toward orbit. The solids deploy parachutes and land in the ocean, where recovery ships locate them and bring them back for refurbishment and reuse.

"At the solid rocket motor separation . . . there was this brilliant orange flash, orangeish-yellow flash across the windscreen, and then the solid rocket motors are gone," Ross recalled. "As the solid rocket motors tailed off, like at a minute forty-five or so, it almost felt like you had stopped accelerating, almost like you'd stopped going up. At that point we were already Mach 3-plus and well above most of the sensible atmosphere at that point, some twenty miles high or so. And at solid rocket motor jettison, then you're at four times the speed of sound and twenty, twenty-five miles high."

Hart also recalled the separation of the solid rockets as a memorable experience. For the first two minutes of ascent, the g-forces that the crew experiences have been building up, and then, at SRB separation, they drop off dramatically.

Very quickly, then, the solid rockets taper off and separate, and that was the first surprise I had. . . . The sensation that you have at that point I wasn't quite prepared for, because you go from two and a half gs back to about one and a half. Well, when you get used to two and a half, and it feels pretty good. You're going somewhere, you know. When you go back to one and a half, [it] feels like about a half. So you don't think like you're accelerating as much as you should be to get going. And, of course, I had worked the main engine program anyway, so I was very familiar with what the engines could do or not do. And I think in the next minute, every five seconds I checked the main engines to make sure they were running, because I swear we only had two working, because it just didn't feel like we had enough thrust to make it to orbit. But then gradually the external tank gets lighter, and as it does, of course, then, with the same thrust on engines, you begin to accelerate faster and faster. So after a couple of minutes I felt like, yes, I guess they're all working.

Ross also had the experience of worrying that all main engines were not working when they actually were.

I literally had to look to see that the three main engines were still working, because it became so smooth, and it almost felt like you weren't going anywhere;