Space Shuttle Columbia

Her Missions and Crews

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To Michelle – for always being there

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Preface

On 1 February 2003, high above Texas, the unthinkable happened. With horrifying suddenness, Space Shuttle Columbia disintegrated during her descent from a highly-productive 16-day science mission. Her entire crew of seven, including Israel's first astronaut, perished in the disaster. On that terrible Saturday, a spectre that had haunted NASA for 17 years, since the 1986 loss of Challenger, returned with a vengeance. I was only nine years old when Challenger exploded and remember little of what happened; the destruction of Columbia, by stark contrast, seemed far closer and more personal.

Almost two years earlier, in the spring of 2001, I was fortunate to speak to Rick Husband, who was in command of Columbia on her final mission. I found him to be courteous and warm, with an enthusiasm and openness so typical of many spacefarers. An avid collector of astronaut autographs, I have personalised signed portraits of five of the ill-fated STS-107 crew – Husband, Willie McCool, Dave Brown, Kalpana Chawla and Mike Anderson – and countless others of Columbia veterans. I treasure them all, but those of the STS-107 fliers I now prize particularly highly.

This book is not meant as a study of what happened to Columbia on her last flight, but rather as a celebration of her entire incredible career. Over the past two years, I have spoken to many people who, upon hearing the name of America's first Space Shuttle, have remembered her only as "the one that broke up during re-entry". I feel that this is, to say the very least, an unfair epitaph. Columbia has a long and chequered history and in her 28 missions since April 1981 has scored some remarkable triumphs.

She was the first 'used' manned spacecraft to be blasted into orbit more than once. She supported the debut of the European-built Spacelab research facility and Canada's Remote Manipulator System (RMS), the latter of which is routinely used today to build the International Space Station. She was first to prove the Shuttle's worth as a mini-space station in its own right and as an Earth-circling launch pad from which to boost satellites into geosynchronous and higher orbits to provide communications and reconnaissance, support research in geodetics and electro-dynamics, process semiconductors and peer into the Universe with state-of-the-art X-ray and ultraviolet eyes.

Columbia has also plucked spacecraft *from* orbit in delicate, 28,000 km/h orbital ballets, staged ambitious spacewalks to upgrade the Hubble Space Telescope and holds the current record for having flown the longest Shuttle mission, at almost 18 days. Yet this is scarcely half of her story. Her history is far more than 'just' 28 standalone mission reports: she has countless other tales from the 126 men and women, representing eight different nations, who have spent more than 300 days gazing Earthwards or outwards into the Universe through her windows.

My goal in writing this book was to gather technical esoterica about Columbia and attempt to balance it with 'human' stories from the remarkable pilots, physicists, engineers, doctors and professors who flew on her. I have attempted to weave 'mundane' technical facts, payload details and processing issues with stories of "incredible" rides into orbit, "oh, wow" glimpses of the grandeur of Earth, the unique and highly coveted ability to pull one's trousers onto both legs at the *same time* and a congressman's light-hearted disappointment at being greeted with Californian, rather than Floridian, oranges and grapefruits upon landing at Edwards Air Force Base.

At the time of writing, Space Shuttle Discovery is only weeks away from undertaking the crucial Return To Flight mission and NASA's three surviving orbiters will have their work cut out over the next five years if they are to complete the International Space Station before being retired in 2010. It is with intense sadness, as astronaut Jay Buckey once said, that Columbia will never take pride of place in the Smithsonian; but her mission and legacy are far from over. In fact, her shattered remains are now used by engineers and materials scientists to help to design future hypersonic vehicles.

A fitting tribute, if ever one were needed, for a quite remarkable spacecraft.

Acknowledgements

This book would not have been possible without the assistance of a number of individuals far more knowledgeable than I on the intricacies of the Solid Rocket Boosters, Shuttle main engines, External Tank fuelling procedures, crew training activities and, of course, the operation of the orbiter's multi-million-dollar toilet. I must thank the ever-patient Clive Horwood of Praxis for his support and advice, David Harland for reviewing each chapter, pointing out my mistakes and sharpening up the text, and to the project's copy editor, Alex Whyte.

I owe an immense debt of gratitude to Ed Hengeveld for 'saving my bacon' by kindly giving up his time to supply high-quality illustrations for this book from his own extensive collection. Had it not been for his efforts, and David Harland's tireless work to prepare illustrations for final production, this project would not have reached fruition.

Several astronauts who have flown Columbia have provided fascinating insights into what they all agree was an incredible machine and without doubt the flagship of the Shuttle fleet. Thanks go to Gordon Fullerton and Vance Brand and the late Rick Husband for taking the time to speak with me over the telephone, and to Kacy Carraway, Roberta Ross and Beth Hagenauer of NASA for arranging the interviews.

My interest in space has spanned two decades and might not have lasted so long if not for a remarkable group of friends at the Midlands Spaceflight Society. Andy Salmon has proved to be a goldmine of space information, with the infectious enthusiasm of a true expert in his field, while Rob and Jill Wood have shared more facts about astronauts and cosmonauts with me over the years than I suspect even the astronauts and cosmonauts *themselves* know! None of my work would have seen the light of day were it not for Mike Bryce, editor of the society's newsletter, *Capcom*.

To each of them, I extend my thanks. My family have constantly supported my interest and I must thank my fiancée, Michelle Chawner, for her endless love and enthusiasm; it is to her, for making all this possible, that I would like to dedicate this book. Additional love and thanks go to my parents, Marilyn and Tim Evans, to Sandie Dearn and Ken Jackson, to Malcolm Chawner and Helen Bradford and, of course, to our golden retriever, Rosie.

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“It will take a hundred flights . . .”

THE ASTRONAUTS’ ASTRONAUT

John Young was out of this world when he learned that NASA’s plans for a reusable manned spacecraft called the Shuttle had finally won Congressional approval.

It was Sunday 23 April 1972 and the 41-year-old Young stood in the sun-drenched desolation of the Cayley plains, participating in the penultimate Apollo lunar-landing mission. A short, dark-haired man with a quiet, country-boy drawl, he had been an astronaut for 10 years and even now, on his fourth spaceflight, showed little desire to do anything else. In fact, when he first set foot on the Moon two days earlier – becoming only the ninth person to do so – his words included the enigmatic phrase, “I’m glad they got ol’ Brer Rabbit, here, back in the briar patch where he belongs.”

Some Apollo historians have explained the quote by identifying Young himself with Brer Rabbit and the briar patch with his love of space exploration. If this was the case, it could hardly have been more fitting, for until 2002 Young held the record for having been launched into space more times than any other human being, with an impressive six missions under his belt. Even the respected Shuttle astronaut Jerry Ross, who finally broke the record, has pointed to Young as his personal hero. Truly, John Young has become ‘The Astronauts’ Astronaut’.

He came to NASA in 1962, a little over a year after President John F. Kennedy had promised to land a man on the Moon before the end of the decade. Even at the age of just 32, Young’s credentials as a test pilot were already impressive: earlier that same year, he had set world time-to-climb records in the F-4 Phantom fighter. His first four spaceflights were devoted to accomplishing, step-by-step, the complex chain of objectives – engineering tests, rendezvous and docking exercises and risky spacewalks – needed to achieve Kennedy’s goal.

His first flight, in March 1965, was a short, five-hour ‘hop’ on board the first two-man Gemini spacecraft, which did little more than whet his appetite. During the mission, he and Commander Gus Grissom had the task of showing that the Gemini, which would be used to rehearse procedures needed for lunar missions in the relative safety of Earth orbit, was spaceworthy. The flight succeeded and Young returned with a reputation as something of a practical joker, having craftily smuggled a corned beef sandwich – Grissom’s favourite fare – on board the Gemini before launch and offered it to his partner while in orbit.

A year later, he was back in space on board another Gemini; this time as Commander, teamed with rookie Mike Collins. Their three-day mission featured rendezvous with two unmanned Agena target rockets, one of which boosted them into a higher orbit, en route to the other. Collins also made a spacewalk to recover micrometeoroid material affixed to one of the Agenas. On Young's third mission, Apollo 10 in May 1969, he and his crewmates conducted a rehearsal of the first lunar landing in orbit around the Moon. This set the stage for Armstrong and Aldrin's "one small step" two months later.

Three years after his return from Apollo 10, and as one of NASA's senior astronauts, Young finally stood in the unrelenting glare of the lunar Sun, in a place where the temperature difference between daytime and nighttime could top 400 Celsius, and joined an elite club of moonwalkers that even today numbers no more than a dozen. In the wake of such a stupendous achievement, one could be forgiven for expecting Young's astronaut career to end after his return to Earth. Surely he could do few other things in his professional life to match or possibly upstage a Moon landing?

Young could not have felt more differently and unlike so many of his fellow astronauts, who left NASA for pastures new, he was eager to tackle America's next challenge in space. His devotion was perfectly epitomised that Sunday in April 1972 when, as he stood amidst the grandeur of the ancient lunar mountains, his breathing harsh and laboured after a long day's work in a bulky spacesuit, he received a call from Mission Control. It was from a rookie astronaut named Tony England, who was acting as the control centre's liaison (nicknamed the 'Capcom') with the men on the Moon.

"This looks like a good time for some good news," England began. "The House passed the space budget yesterday, 277 to 60, which includes the vote for the Shuttle."

Immediately, and in unison, Young and fellow moonwalker Charlie Duke exulted, "Beautiful! Wonderful! Beautiful!" Then Young quietly added, "The country needs that Shuttle mighty bad. You'll see."

Four days later, Young, Duke and the third member of their crew, Ken Mattingly, splashed down in the Pacific Ocean, their 11-day mission over. For Duke, it would be the end of his astronaut career; following a foray into the world of business, he became a born-again Christian and later described his experiences as being so much more fulfilling that walking on the Moon was "the dust of my life" in comparison. Both Young and Mattingly, on the other hand, remained with NASA and each would command two Shuttle missions during the course of the 1980s.

By the mid-1970s, Young had retired from the US Navy with the rank of Captain and was able to concentrate fully on his new duties as chief of NASA's Astronaut Office and immerse himself in the development of the Shuttle. It seemed inevitable, with his breadth of expertise, that he would be a leading contender to command its maiden flight into orbit; by the middle of 1978 it was official and he began training with rookie astronaut Bob Crippen for what would be his fifth mission overall and, in many ways, the most challenging of his entire career.

BIRTH PAINS

With less than eight weeks to go before her first orbital flight, Space Shuttle Columbia finally got the chance to flex her muscles on 20 February 1981. By now, the Shuttle was running three years behind its advertised schedule; its first launch was originally targeted for 1978 and its highest-profile mission – a delicate orbital ballet to reboost America's Skylab space station and prepare it for reoccupation – had been missed. Unexpectedly fierce solar activity in the closing months of the decade caused Earth's atmosphere to inflate, increasing air drag at orbital altitude and Skylab burned up during re-entry in July 1979.

Billions of dollars had been invested in the Shuttle, which was to be the most advanced spacecraft yet to depart Earth. The achievement had not, however, come without problems. Since the original contracts to build the Shuttle had been signed almost a decade earlier, its designers had faced setback after setback: frustrating problems with the development of a patchwork of heat-resistant tiles to shield it during its searing, high-speed re-entry and maddening failures of its throttleable, liquid-fuelled main engines. There was political fallout, too, with the Shuttle's powerful Congressional opponents questioning the need for a multi-billion-dollar reusable manned spaceplane.

For this was another of its advertised qualities: the Shuttle, said NASA, would be the world's first reusable manned spacecraft, capable of flying once every fortnight and carrying commercial satellites, scientific laboratories, space probes, astronomical instruments and – for the first time – *ordinary civilians* into orbit. Plans were already afoot to send teachers, journalists and foreign nationals into space, with up to seven seats available on each flight. The Shuttle, it seemed, was aptly named: it would whisk people into orbit frequently, reliably, relatively cheaply and in conditions a world away from the cramped, one-use-only capsules of the 1960s.

Before such an advanced machine could be declared 'operational', it had to be exhaustively tested. Many of these tests had taken place during and after its construction and a series of high-altitude approach and landing runs were conducted in mid-1977 using a dummy vehicle called Enterprise, taken aloft by an adapted 747 airliner. Fred Haise, one of her pilots, later called it "a magic carpet ride". Although she was never actually capable of flying into space and now sits gathering dust in the Smithsonian, Enterprise demonstrated the Shuttle's aerodynamic performance and ability to make precision landings on predetermined runways.

Ground tests, however, were no substitute for actually flying it in space. Original plans called for six Orbital Flight Tests (OFTs), each carrying two astronauts – a Commander and Pilot – to demonstrate the Shuttle's capabilities, test its manoeuvrability and evaluate its Canadian-built robot arm with different-sized payloads. The number of OFTs was later reduced to four, all of which would be flown by Columbia, the first space-rated Shuttle. Assuming that all four went to plan, the system would be declared 'operational' and become eligible to fly commercial missions on its fifth flight.

Columbia was physically identical to Enterprise, at least at first glance. Both vehicles were not dissimilar in shape and dimensions to the DC-9 airliner, roughly 36 m long with wings spanning 24 m from tip-to-tip, and comprising a two-tier cockpit, cavernous, 18-m-long payload bay with clamshell doors and an aft compartment to house a cluster of three main engines, bulbous Orbital Manoeuvring System (OMS) pods and vertical stabiliser fin.

Unlike Enterprise, however, Columbia would fly further than just the last few minutes from the low atmosphere to the runway. She would, for the first time, undertake the violent climb into space under the combined thrust of her main engines and two behemoth Solid Rocket Boosters (SRBs), withstand the swinging extremes of heat and cold in Earth orbit and bear the full brunt of a fiery descent back through the atmosphere. Moreover, in spite of carrying thousands of items whose failure could doom the Shuttle and kill the crew, Columbia's audacious first launch would be done *with astronauts on board!*

A CALCULATED RISK?

Never in the history of the American space programme had a crew been on board for the first launch of a new spacecraft. The Mercury capsules, which carried Al Shepard and John Glenn on their historic ventures into space, had been extensively tested unmanned, as had Gemini and Apollo. The Soviets, too, had never flown a crew without first testing their spacecraft in an unmanned capacity. The risks were just too high. There can be little doubt, therefore, of the heroism and bravery of the first Shuttle crew: Commander John Young and Pilot Bob Crippen.

One astronaut closely involved in the Shuttle's development was Fred Haise, a veteran of the ill-fated Apollo 13 mission. He had been instrumental not only in its aerodynamic testing in the low atmosphere, but also would probably have commanded one of its early missions had he not resigned from NASA in 1979. He saw an unmanned first flight as potentially much trickier than a manned one. "It would have been very difficult to have devised a scheme, in my view, to have flown [the Shuttle] unmanned," Haise recalled in a 1999 interview.

"I guess you could've used a [communications] link and really had a pilot on a stick on the ground like they have flown some other programmes. But to totally mechanically programme it to do that, and inherent within the vehicle, would have been very difficult. There *was* initially a planned unmanned flight, [but] it was of great complexity and handling the myriad of potential systems problems [made it hard to automate]. With a crew on board [to] be able to handle the multitude of things that you could work around, inherently made the success potential of a flight a lot greater."

Others, including NASA's former director of engineering and development, Henry Pohl, were more sceptical about sending the first Shuttle aloft with a crew on board. "I didn't see any need in risking humans and I didn't think humans would be as proficient as automated equipment," he said. "By that time [the late 1970s], we had the know-how and we could build robots or the automated equipment that can detect things long before a human can detect it, and I thought the vehicle was going to be so difficult to land that we really ought to land it with automated equipment."

THE BUTTERFLY AND THE BULLET

Paradoxically, compared to flights that would follow, the first mission of the Space Transportation System – dubbed 'STS-1' – was relatively straightforward. Its objective was to fly Columbia into space, test her systems and bring her home two days later to a desert landing in California. Yet with so many unknowns and a history of technical problems, it was also the most complicated mission ever attempted. Not only would Columbia herself be tested, but so would the untried boosters and the giant External Tank (ET) that would feed the Shuttle's engines with over 1.9 million litres of liquid propellants.

"Like bolting a butterfly onto a bullet" was how veteran astronaut Story Musgrave, who flew Columbia in late 1996, described the unusual appearance of the combined Shuttle, tank and boosters. It is an appropriate description. The 46.6-m-long ET, reminiscent of an enormous aluminium zeppelin standing on end, is indeed bullet-like, but is actually far more than 'just' a container. Its upper quarter houses liquid oxygen and its lower three-quarters carry liquid hydrogen.

Separating the two sections of the ET is an unpressurised 'intertank', which contains instrumentation and umbilical interfaces to the launch pad's purging and hazardous-gas-detection systems. Above the intertank, the liquid oxygen tank holds up to 542,640 litres of oxidiser and, beneath it, the liquid hydrogen tank holds around 1.4 million litres of fuel. Both are then fed through two 43-cm-wide fuel lines into disconnect valves in the Shuttle's aft compartment, and from thence into the main engines' combustion chambers.

"[The main engine is] very high-performance," said Henry Pohl, "[with a] very high chamber pressure for that day and time [and] very lightweight for the thrust that they were producing. I would say that we came out with that program in the only time in [US history] when it would have been successful. If we had waited another two years before starting development on [the] Shuttle, we probably would not have been able to do it, [because] the people that designed the main engine were the same that designed [previous rocket] engines. That group of people had designed and built seven different engines before they started the Shuttle development. A lot of [them] retired [and so] if we'd waited another two or three years, those people would all been gone and we would have had to learn all over again on the engine development."

Built by Rocketdyne – formerly part of the Shuttle's prime contractor, Rockwell International, but now owned by Boeing – the engines burn for about eight minutes of ascent and are shut down a few seconds before the ET is jettisoned, right on the edge of space. Each engine measures 4.2 m long, weighs 3,400 kg and is 'throttleable' at 1% incremental steps from 65% to 104% rated thrust. This ability, which is controlled by the Shuttle's onboard General Purpose Computers (GPCs), helps to reduce stresses on the vehicle during periods of maximum aerodynamic turbulence.

Despite the immense thrust generated by each engine and the colossal amount of propellant needed to run them for such a short length of time, they in fact provide only 20% of the power needed to get the Shuttle into space. The remainder comes from the two 45.4-m-long SRBs, which are the only solid-fuelled rockets ever used in conjunction with a manned spacecraft. Loaded with a powdery aluminium fuel and an oxidiser of ammonium perchlorate, the boosters, built by Morton-Thiokol in Utah, are mounted like a pair of Roman candles on either side of the ET.

This unusual combination, referred to as 'the stack', is not, in fact, totally reusable and came about following a series of financial and technical compromises dating to the early 1970s. The Shuttle in its present form is designed to fly a hundred times before major modifications become necessary and the SRBs about a quarter of that figure. The ET, on the other hand, is discarded about eight-and-a-half minutes after launch to burn up in the atmosphere over the Indian Ocean. It was considered more costly to modify the tank for reusability than to simply build a new one for each mission.

"The Shuttle is an asymmetric vehicle," said former NASA flight director Neil Hutchinson. "It doesn't look like it ought to launch right, because it's not a pencil! Some of us, in the early days, wondered how that was going to work. In fact, it's [still] a very tricky vehicle to launch. It has to be pointed carefully in the right direction at certain times or you'll tear the wings off or tear it off the External [Tank]. It's *not* a casual launch process."

THE ROCKY ROAD TO STS-1

Preparing for each Shuttle flight takes several years, but the actual bringing together of the components begins with setting up the boosters on a Mobile Launch Platform (MLP) in the gigantic Vehicle Assembly Building (VAB). This 160-m-tall structure – the world's largest scientific building, so vast that *clouds* once formed in its upper reaches before an air-conditioning system was fitted – has dominated the swampy landscape of the Kennedy Space Center (KSC) on Merritt Island in Florida for the best part of four decades. It was used to assemble the massive Saturn V Moon rockets and, since 1980, the Shuttle.

Each SRB comprises six blocks, called 'segments', each of which is hauled with pinpoint precision into place, one on top of the other. To prevent a leakage of searing gases during ascent, a series of rubbery O-rings seal the joints between the segments. After propelling the Shuttle and ET to an altitude of about 45.7 km, explosive rockets at the nose and tail of each booster push them away and parachutes lower them to a gentle splashdown just off Cape Canaveral in the Atlantic Ocean. They are then recovered, refurbished and reused.

When the assembly of the SRBs is complete, the ET is moved into position between them and connected by a series of spindly attachment struts. Following checks of their mechanical and electrical compatibility, the Shuttle itself is moved from the nearby Orbiter Processing Facility (OPF), tilted on its tail and mated to the ET. In the early days of the programme, the Commander and Pilot of the mission boarded the vehicle while it was in a vertical position inside the VAB to rehearse pre-launch procedures. Nowadays, this is done by the entire crew after the Shuttle has been rolled to the pad.

The transfer of the 1.8-million-kg Shuttle stack from the VAB to one of two pads

Attached to her External Tank and Solid Rocket Boosters, and mounted on top of the crawler, Columbia is readied for her first launch.

of Launch Complex 39 – a distance of 5.6 km – takes six hours, with the aptly named 'crawler' inching the MLP and its precious, $2-billion national asset along a track made of specially imported Mississippi river gravels. Once the stack is 'hard-down' on the pad surface, further checks are conducted, payloads installed and the crew participates in a Terminal Countdown Demonstration Test (TCDT), essentially a full dress-rehearsal of the last part of the countdown, followed by a simulated main engine failure and emergency escape procedures.

By 20 February 1981, these preparations in readiness for STS-1 had long been completed; in fact, attached to her tank and boosters, Columbia had sat majestically on Pad 39A since 29 December the previous year. She had been at KSC for even longer. Her construction took almost five years from the start of work to build her cockpit in June 1974 to rollout of the finished article in March 1979. A week later, to the amazement of motorists in the sweltering California heat, Columbia was towed overland from prime contractor Rockwell International's Palmdale plant to Edwards Air Force Base.

By late March, she had been flown 'piggyback' on top of the modified 747 aircraft to KSC and ensconced in one of two bays in the OPF. The latter is positively dwarfed by the immense VAB and is still used to prepare the Shuttle fleet for their missions, to repair and refurbish them and to install and remove their payloads. It is, however, far more than just a spacecraft hangar; due to the extreme volatility of the propellants carried on board the Shuttle, the OPF is fitted with detectors that are so sensitive to explosions that visitors are forbidden from using camera flashes when taking photographs.

After her arrival at KSC, Columbia underwent a protracted period of pre-launch preparations that lasted almost two years. Although she was structurally 'complete', she was far from ready to fly. She had no main engines, her thermal protection system needed attention and her ET and SRB segments were not destined to arrive until the summer of 1979. By the end of the following year, however, significant progress had been made and in November Columbia rolled into the VAB for stacking. Following checks, she moved to the launch pad a few days after Christmas in readiness for launch the following spring.

The thermal protection system – particularly its thousands of tiles, each of which was *individually designed* and not interchangeable – had been the biggest headache during this time because of the sheer novelty of its design. "When it took off on the back of the 747 from Palmdale, a whole bunch of the tiles came off as they went down the runway," former Shuttle manager Arnie Aldrich wryly recalled. "That led to the requirement to have a better understanding of how the tiles were attached and how to know they were well attached and that problem took two years to solve."

Much work still had to be done before Young and Crippen could even board the orbiter, however. One of the most critical exercises was a Wet Countdown Demonstration Test (WCDT), which lasted six days and culminated on 20 February 1981 in a 20-second firing of Columbia's engines. This Flight Readiness Firing (FRF) was necessary to demonstrate their ability to throttle between 94 and 100% thrust, and gimbal just as they would be expected to do in flight. Similar 'wet' – or fully fuelled – tests had been performed before the Saturn V launches, although on those occasions the engines had not been test-fired.

Preparations for the FRF proceeded in a manner not dissimilar to a real countdown: launch controllers started the clock at T – 53 hours when they powered-up the SRBs, ground-support equipment and Columbia herself. Four seconds before the simulated 'liftoff', the Shuttle's engines roared to life at 120-millisecond intervals, reaching 90% rated thrust within three seconds and hitting the 100% mark precisely at T – zero. Three seconds later, engineers simulated retracting the ET umbilical and the SRBs' hold-down posts; a further 15 seconds elapsed before shutdown commands were issued to all three engines. The test was a success and a significant milestone had been cleared.

According to the STS-1 press kit, released around this time, the launch was provisionally booked for "no earlier than" 17 March, but a number of technical issues and a human tragedy conspired to delay Columbia's first flight by several weeks. Following the FRF, engineers had to repair a section of super-light ablator insulation, which had become debonded from the ET during a test of its cryogenic propellants back in January. This pushed the target date for launch back to 5 April, followed by another delay until the 10th, caused by a strike against Boeing by machinists and aerospace workers.

Throughout March, the attention of the world's media focused on Young and Crippen as they maintained their proficiency training, participating in a TCDT and practising how to escape from Columbia in the event of a main engine failure seconds before launch. The biggest fear in such a scenario was the presence of invisible hydrogen flames, through which the pressure-suited astronauts would have to run to reach a slidewire escape basket that would whisk them from the 58-m level of the launch pad down to the ground and a waiting M-113 armoured personnel carrier.

Although Young and Crippen had not been directly involved in the Enterprise approach and landing runs – which had been conducted by two other teams of astronauts, Joe Engle and Dick Truly and Fred Haise and Gordon Fullerton – they nevertheless achieved proficiency in flying the Shuttle Training Aircraft (STA). This Grumman Gulfstream had been modified to fly almost exactly like the Shuttle, approaching the runway at several times the angle of a commercial aircraft and nearly twice the speed. The men also honed their skills in flight software laboratories, visual motion simulators, full-scale Shuttle mockups and on board Columbia herself.

It was just a few days after Young and Crippen had returned to Houston, following their TCDT, when the Shuttle claimed its first two lives. Several technicians working inside Columbia's aft compartment were rendered unconscious by a dangerous build-up of nitrogen gas; and although they were pulled out, one died that same day and another two weeks later. The cause was traced to a breakdown of communications: a warning sign had been mistakenly removed and a supervisor called away. Crippen would later pay a personal tribute to the two dead men, John Bjomstad and Forrest Cole, while in space.

SOFTWARE: THE BIGGEST STUMBLING BLOCK

Meanwhile, despite the setbacks, Columbia was now firmly on schedule to lift off on 10 April 1981, which, as it happened, was two days shy of the 20th anniversary of Yuri Gagarin's pioneering spaceflight. The six-and-a-half-hour launch 'window' – necessitated by a need to have adequate lighting conditions to satisfactorily photograph Columbia's ascent for engineering analysis – opened that day at 11:50 am GMT.* The window also provided for daylight landing opportunities at White Sands Missile Range in New Mexico, should a launch abort require Young and Crippen to perform an emergency return to Earth after one orbit.

Shortly before 9:00 that morning, after a traditional astronauts' breakfast of steak and eggs in the crew quarters, Young and Crippen boarded Columbia for what turned out to be an uneventful countdown – at least, that is, until its final stages. Then, with just nine minutes to go, during a pre-planned hold, a problem cropped up in one of Columbia's five GPCs. It was described as a 'timing skew'; in effect, the backup flight software was unable to synchronise with the primary set.

Unlike previous manned spacecraft, the Shuttle is totally dependent upon its computers to run the main engines, move the elevons, control its heading and operate the thrusters, to name just a few of many thousand different functions. These units are so critical that five GPCs are carried: four primaries, which run the same software and 'vote' before issuing commands, and a backup. If one of the primaries disagrees with the others, it is 'outvoted' and considered faulty. The backup contains its own, different set of flight software, so that if *all four* primaries became corrupted, it can take over control.

The problem that Columbia experienced on 10 April was essentially that the four primary GPCs were not communicating with each other correctly. Taking advantage of the lengthy launch window, the liftoff was rescheduled for 3:20 pm as computer engineers wrestled with the software, but when a solution could not be found it was decided to stand down until 12 April. A disappointed Young and Crippen clambered out of Columbia and would spend the next couple of days maintaining their proficiency flying the STA.

Meanwhile, the GPC problem was isolated late on the 10th and the countdown resumed next day. "The software", remembered Gordon Fullerton, who flew Columbia in March 1982, "became the biggest stumbling block. The software in these computers not only control where you fly and the flight path, but almost *every other* subsystem! Getting the software wrung out and simulators writing the checklists . . . we didn't really have it nailed down by STS-1. There were a lot of

* All times throughout this book are given as Greenwich Mean Time (GMT). This has been done to avoid possible confusion, as different time zones apply in Florida, California, New Mexico and other locations mentioned in these pages. As a general rule of thumb, Florida is approximately five hours 'behind', New Mexico some seven hours 'behind' and California around eight hours 'behind' GMT.

unknowns [but] you just finally have to set a launch date and say 'We're going to go'. You cannot be 100% sure of everything."

Young and Crippen again departed the crew quarters in the early hours of 12 April and took their seats on Columbia's flight deck. Both were clad in bulky US Air Force high-altitude pressure suits, which afforded them full-body protection and were destined to be worn by the first four OFT Shuttle crews. Since these were considered 'test flights' and were also equipped with ejection seats, the full-pressure garments were mandatory; on later operational missions, when restrictions were relaxed somewhat, it was intended for astronauts to fly in lighter overall-type flight suits and helmets.

If an emergency had necessitated their use, the rocket-propelled ejection seats would have fired Young and Crippen through two overhead hatches, but they could only be used to an altitude of 30.5 km, meaning they would not realistically work during the ascent phase and only at selected intervals during re-entry. Astronaut Jack Lousma, who commanded Columbia's third test flight in March 1982, would later remark that his Shuttle launch was far riskier than his Apollo ascent a decade earlier and his opportunities to escape in the event of an emergency were much reduced.

Whereas most previous manned spacecraft had taken the form of ballistic capsules attached to the top of expendable boosters – so that, in the event of problems, an escape rocket could lift them several thousand metres into the air and parachute them a couple of kilometres out to sea – the Shuttle did not offer that option. An on-the-pad emergency would have precluded the use of the ejection seats, because the astronauts would have hit the ground before their parachutes had opened; also, ejections during the first couple of minutes of ascent would have sent them straight into the SRBs' roiling exhaust plumes.

Consequently, the seats could only realistically have been used at selected points of re-entry, after the period of maximum atmospheric heating, and even then the astronauts' chances of survival were slim.

Young and Crippen again boarded Columbia on 12 April, lowered their visors and encountered their first problem: neither man could breathe properly. It turned out that a quick-disconnect fitting for the oxygen system, situated beneath the control panel, had been mispositioned. After this was resolved, the countdown proceeded smoothly.

RIDE OF A LIFETIME

The history of jokes and pranks between astronauts and the ground crews responsible for strapping them into the spacecraft before launch has become the stuff of legend, since the days of pioneering Mercury missions in the early 1960s. "John Young made a big deal about the size of the American flag on his suit," said KSC spacesuit technician Jean Alexander. "It came in with kind of a small version and they got several sizes before he was satisfied and it was kind of a joke. So on launch morning, there was a motel that we stayed at Cocoa Beach and they had this

STS-1 liftoff.

huge flag on a pole [outside] a real-estate office next door. One of the suit tech[nician]s that was down there for launch talked the real-estate people into letting him take that flag down and he took it to the suit room for suit-up morning and had it actually cover[ing] one whole wall! When John walked in, he said 'John, is *that* big enough?'." The mood was sufficiently lightened for what was to follow.

After almost four years training together for the most complex engineering and test flying challenge of their careers, the smoothness of the countdown on only their second attempt surprised both Crippen and his veteran colleague. As the clock ticked inside the final minute, their excitement began to build: despite Young's vast experience and four previous missions to his credit, both men were rookies as far as flying the Shuttle was concerned. Neither man fully knew what to expect.

Six seconds before midday, with a low-pitched rumble that soon turned into a thundering crescendo, Columbia's three main engines ignited. Young and Crippen would later recall that the Shuttle rocked perceptibly backwards and forwards, accompanied by a sharp noise increase in the cabin. Then, precisely on the hour, in front of an estimated three-and-a-half thousand media spectators at KSC, and doubtless hundreds of thousands more glued to television sets around the world, came the ear-splitting crackle of the two SRBs.

"We have liftoff of America's first Space Shuttle, and the Shuttle has cleared the tower," exulted the launch commentator over the public-address system as Columbia broke the shackles of Earth and lumbered off the pad. Crippen would later comment that, although the low-pitched roar of the main engines certainly grabbed their attention, it was the punch-in-the-back ignition of the SRBs that convinced them that they were really heading somewhere.

For the first few seconds, as the Shuttle cleared the tower and roared into the clear Florida sky on top of the two dazzling orange columns of flame from its boosters, the cockpit instruments were blurred by the vibrations, but according to the crew were still just about readable. By the time Columbia rolled onto her back under GPC control about 10 seconds after liftoff, setting herself on the correct heading for a 40.3-degree-inclination orbit, the two men reported that the vibrations had lessened to a point that allowed them to read their instruments without problems for the remainder of the ascent.

"When you get the vehicle going uphill and you're still in the 'sensible' atmosphere," said Neil Hutchinson, "there are tremendous aerodynamic pressures on it and you have to get the angle at which it is going through the airstream exactly correct. [The vehicle] has a *very* narrow performance corridor. In order to get the proper inclination, when the Shuttle takes off, it 'rolls'. What it's doing is getting itself oriented so [it] goes into orbit on its back. It goes upside down, with the crew *upside down*. You've got to get that roll out of the way and get that whole thing set up long before you get the max[imum] dynamic pressure, [which is] when the amount of atmosphere combined with the direction the vehicle's going and the velocity is the worst."

"As the Shuttle's main engines come up, you really feel the vibrations starting in the orbiter," said Jerry Ross, who has flown the reusable spacecraft a record-tying seven times since 1985, including one mission on board Columbia, "but when the

[SRBs] ignite, I describe it as somebody taking a baseball bat and swinging it pretty smartly and hitting the back of your seat, because it's a real 'bam'. The vibration and noise is pretty impressive! The acceleration level is not that high at that point, but there is that tremendous jolt and you're off!"

At the post-flight briefings, Young would tell engineers that Columbia's ascent was considerably more rapid that he had experienced during his two Saturn V launches to the Moon. Analysis also later showed that STS-1 had caused significant damage to Pad 39A which could have been catastrophic: the shockwaves produced by the Shuttle's engines and the SRBs had buckled a strut linking Columbia to the ET's liquid oxygen tank. Had the strut failed, it was determined, the result could have been the loss of the vehicle and crew and steps were taken to strengthen the struts in readiness for later missions.

"As [it accelerated] in the first 30 seconds or so, the wind noise on the outside of the vehicle became very intense," recalled Ross, "like it was *screaming*! It was *screeching* on the outside!"

A minute into the flight, as Columbia approached an altitude of 15 km, she passed through a period of maximum aerodynamic turbulence which required the GPCs to throttle the main engines back to just under two-thirds of their rated thrust. The passage through this period was described by the astronauts as marked by an increase in the noise and vibration of the engines, although their performance was within expectations. The sound from the SRBs remained sporadic and decreased to virtually nothing as the time approached, 2 minutes and 12 seconds into the flight, for their separation.

Shortly before the boosters burned out, the Capcom, rookie astronaut Dan Brandenstein, told the crew they were now "negative seats", meaning that Columbia was too high to use the ejection seats; questionable though their usefulness would have been. Fortunately, the vehicle was performing admirably. The SRBs actually turned out to generate more 'lift' than predicted and they separated at an altitude 2.9 km higher than anticipated. When the separation rockets fired and the SRBs fell away, Young and Crippen reported a bright, orange-yellow 'flash' which appeared to stream up in front of the Shuttle's nose and back above the front windows.

"As the [SRBs] tail off, like at 1 minute-45 or so [after launch]," said Ross, "it almost felt like you had *stopped accelerating*, like you'd stopped going up. At that point, [you are] already Mach 3-plus and well above most of the 'sensible' atmosphere, some 20 miles high or so. And at [SRB] jettison, then you're at four times the speed of sound and 25 miles high!"

The SRB separation was also accompanied by a harsh grating sound which Young likened to the noise made by the Saturn V's final stage. Both SRBs parachuted into the Atlantic Ocean, splashing down five minutes later about 250 km downrange of KSC. With the cumbersome boosters gone, the crew found it much easier to flip switches in the cockpit. At this stage, the so-called 'T-fail-pitchover' manoeuvre was executed, placing the horizon in their view for the first time, and the two men spotted penny- to fist-sized white particles flooding past the windows.

"What a view! What a view!" radioed a jubilant Crippen four-and-a-half minutes into the ascent.