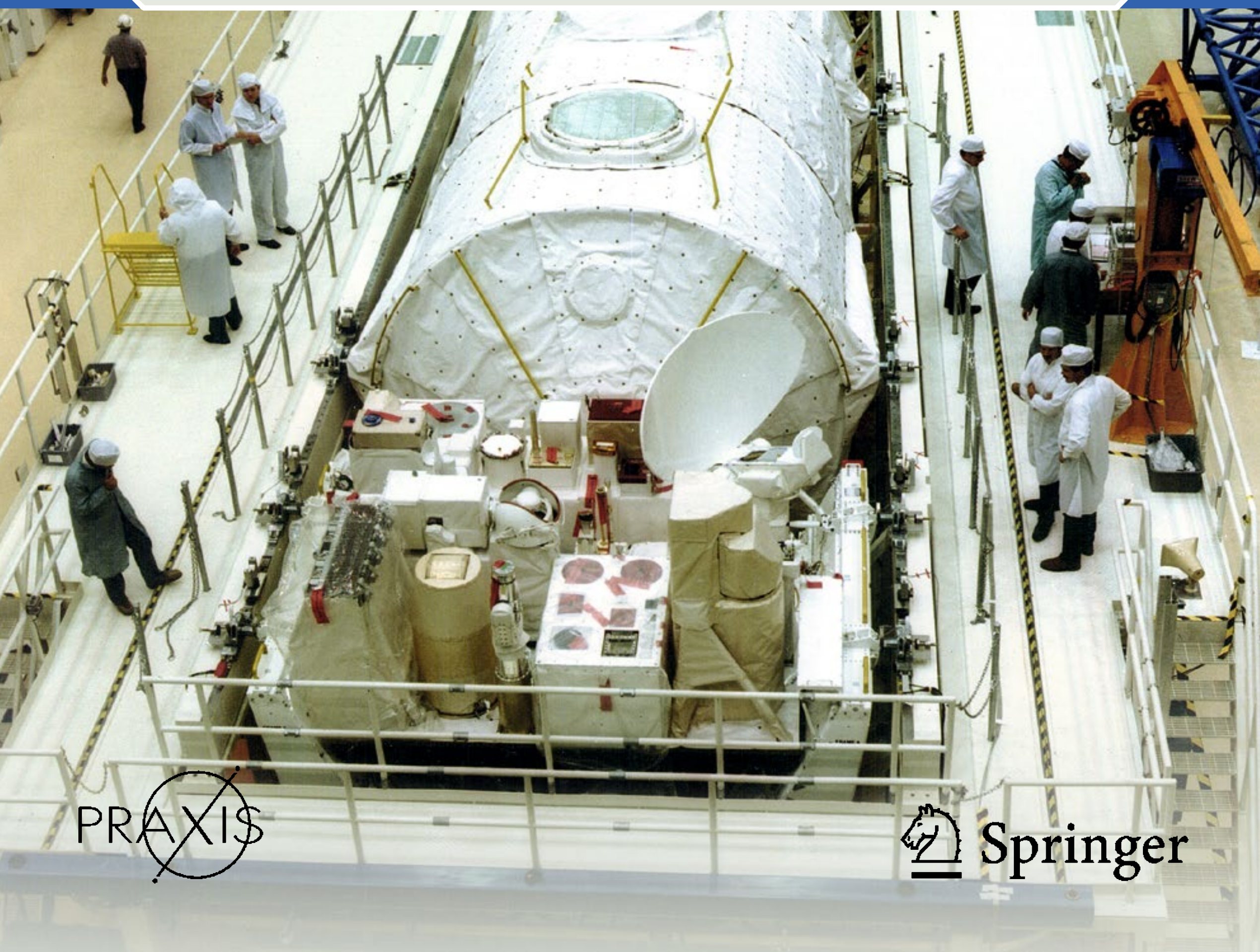
SPACELAB PAYLOADS

Prepping Experiments and Hardware for Flight

Michael E. Haddad and David J. Shayler



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Michael E. Haddad
NASA Systems Engineer, Retired
Cocoa Beach, FL, USA

David J. Shayler
Astronautical Historian
Astro Info Service Ltd
Halesowen, UK

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Front cover (top): Neurolab Rack Train, in the Operations and Checkout Building, Kennedy Space Center, being moved from Level-IV area to Level-III/II area, c. November 1997.

Front cover (bottom): Spacelab-1 in Cargo Integration Test Equipment (CITE) stand, Operations and Checkout Building , Kennedy Space Center, c August 1983. Being prepared to transfer to Orbiter Processing Facility for installation into the Space Shuttle *Columbia*. Spacelab Pallet with experiments in foreground (red “Remove Before Flight” tags), Spacelab Module, gold handrails in the middle.

Back Cover: The Neurolab payload for STS-90 undergoing further processing in the O&C Building at KSC, c. December 1997. Neurolab was designed to study the effects of microgravity on the nervous system. The crew, of Commander Richard Searfoss, Pilot Scott Altman, Mission Specialists Richard Linnehan, Dafydd (Dave) Williams, M.D. (Canadian Space Agency) and Katherine (Kay) Hire, and Payload Specialists Jay Buckey, M.D., and James Pawelczyk, Ph.D., flew STS-90 and Neurolab between April 17 and May 3, 1998, on Space Shuttle *Columbia*. Photo: NASA/KSC

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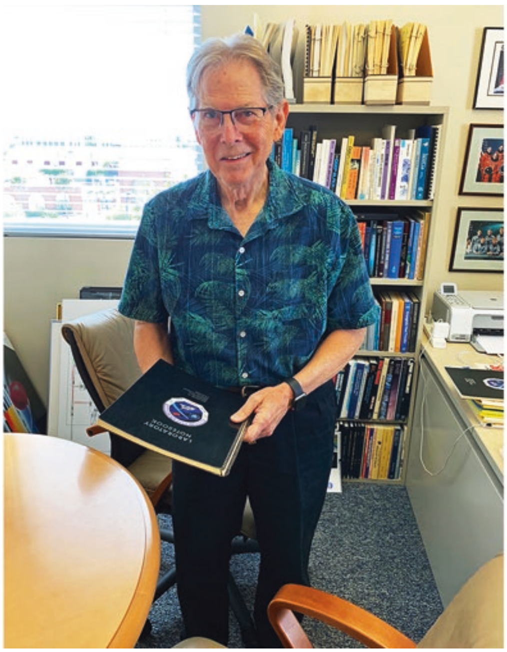
Foreword



Sam Durrance, May 16, 2019, with the Astro Log Book he used during the 1980s.

This book describes what "Level-IV" was; its purpose, and the people that did their job to make my mission, as well as all the other Spacelab missions, a success.

Mike Haddad was working the Level-IV mechanical engineering aspects of the Astro payload when I met him though his good friend Scott Vangen. Scott was a Level-IV Electrical Engineer who was responsible for preparing the flight hardware, as well as myself, for the Astro-1 mission. During that time, we developed a good working and personal relationship.

Riding a rocket into space, the exhilaration of zero-g, the satisfaction of operating the Astro Observatory, or the emotional impact of seeing Earth from orbit – how can I possibly describe space flight?

So many talented people had worked so hard for so long to make this moment possible. I felt extremely proud to be part of it. I was well prepared for all the technical aspects of our mission. But nothing could have prepared me for the sight below.

It was broad daylight somewhere over the Atlantic Ocean far below. The Cape Verde islands were speeding lazily by. An intricate pattern of brilliant white clouds laced the deep rich blue of the Ocean. The African continent was rapidly approaching from the horizon. The thin-blue line that defines the extent of the atmosphere was visible just over the bright limb of the Earth. We were a lone, magnificent, flying-machine, careening through the black void of space at five miles per second; and yet, somehow, at the same time, floating effortlessly above the Earth.

Soon our orbit carried us past the terminator. The setting Sun created a brilliant light show unmatched by anything I have seen. The full Moon cast a beautiful, serene glow over the Earth below. The airglow layer, out on the horizon, above the limb, seemed to blanket and protect the cities below, whose lights drifted silently past. It was time to go back to work; we came to observe the stars, but I couldn't keep my eyes off the Earth.

The amazing light show of sunrise or sunset flashed by every 45 minutes. I saw continents and oceans scroll by at a startlingly fast pace. I could see the imprint of geology on a global scale that seemed to make it come to life. And I saw the *impact of humanity* on this delicate, isolated, island of life, set in a black-black void of endless space. I was left with a sense of the beauty and fragility of planet Earth, and a feeling that it is imperative to protect and preserve it.

I left Earth with great anticipation, great excitement, and a little apprehension. I returned with a new feeling of wonder, a new perspective – a space traveler's perspective. It is something I will always have.

Also, to this day, Mike, Scott, and a number of Level-IV people have remained very good friends of mine.

Thank you Level-IV.

Samuel T. Durrance
Space Shuttle Payload Specialist
STS-35 (Astro-1) and STS-67 (Astro-2)

To all those men and women who worked so hard and sacrificed so much to make the Spacelab Program a success.

"Every time I saw a Spacelab mission lift off, I got a very special feeling inside that lasted about two weeks. The performance of the experiments and the Spacelab was an unqualified success on every mission, and it would be hard to be more proud of the work we did. The fact that we got to work with a bunch of great people from KSC, other NASA centers, and from around the world, as well as working on a new complement of experiments every few months, made it a fun, exciting, and interesting job that could easily be called a passion rather than work."

Tracy Gill, Level-IV Electrical Engineer

Authors' Preface

It is widely said that each of us has the potential to write a book. That may be true, but although the prospect of such an idea may indeed be within us, getting that idea or desire down, traditionally on paper or more recently on a computer file, is another matter.

The gestation from idea to book is a long and involved one, with many hurdles, pitfalls, delays and disappointments before a final product is found on a shelf or available as a commercial download. To cooperate on a book project adds to the logistics and molding of the story into a final product with which to approach a publisher. The next challenge, to get a publisher to support the book's production, brings a new dimension to the conversion of a good idea into a physical book. Above all, each title is an incredibly personal journey from idea to shelf, one that takes a significant amount of time to be completed successfully, as recounted by the authors below.

Michael E. Haddad

There have been many books, journals, articles, papers, documentaries and films about the Space Shuttle Program. And why not? It was an amazing engineering achievement, as shown in the 1981 film "*Space Shuttle: A Remarkable Flying Machine*". The "payloads", which used to be called "cargo" before someone pointed out that the name did not quite suit the function since cargo is what is transported in the bowels of a ship, have also been documented a great deal. This covered not only what the payload was but also what they accomplished during each Space Shuttle mission.

The missing piece – and the reason why I, Michael E. Haddad, wanted to write this book – is because very little has been documented about *how* those elements, primarily focusing here on the Spacelab-related payloads, were prepared at Kennedy Space Center (KSC) for their mission. The timeframe is from the mid-1970s through to the early 2000s. The assembly, integration, testing, servicing and final closeouts – essentially making sure the payloads were 100 percent operational before launch – was called the "Level-IV" function at KSC. I know, because

I was hired into Level-IV as a Mechanical Engineer in 1982, near the beginning of the Spacelab program, and worked there for seven years. Level-IV referred to the starting point of the physical work begun at KSC, but our job was not just focused at that single location, or just at KSC in general. We would go to the design centers before the hardware and software arrived at KSC, support the mission at whatever control center was in charge of the on-orbit experiment, and then perform post-flight operations at landing locations. Because our responsibility included all these other locations and functions, the term was changed from "Level-IV" to "Experiment Integration".

The idea for this book began back in 2000 following the STS-99 Shuttle Radar Topography Mission (SRTM), the last Spacelab-related mission. I have written many professional papers and performed hundreds of presentations, but had no clue about how to write a book. So, I began to reach out to those who had such experience to see if they would take on the task of writing it, with my help to provide the information to be included. Most of the people I contacted liked the idea and provided me with information regarding their contributions and work performed during Level-IV, but were too busy with other commitments to take on the task.

Over the course of the next 17 years, a number of events took place where discussions of the book came up.

In October 2002, a group of NASA and contractor employees attended a Level-IV Reunion. In October 2010, Dean Hunter, my Lead Engineer during Level-IV, a super engineer and great friend, sadly passed away. Dean was the best mentor I had. I learned so much from him that I was able to use to carry me through the rest of my career.

Six months later, in May of 2011, we had a Level-IV Party at *Fish Lips* restaurant in Port Canaveral, Florida. With the end of the Shuttle program approaching, we wanted to get together for one last time before many of us either retired or moved on to other projects.

When Janice Voss, a very good friend and astronaut who flew five times on the Shuttle, also passed away, a Celebration of Life occurred at Johnson Space Center (JSC) in March 2012 which included a Tree Planting Ceremony in her name. In attendance were a number of us from Level-IV and many of her fellow astronauts. To honor her and the work she did, the book once again was talked about and a decision made to try other paths to get the project moving again.

Over the next two years, I reached out to a number of persons I thought could help get the ball rolling. I contacted Kenneth Lipartito, co-author for the book "*A History of Kennedy Space Center*", who had interviewed me for the part of his book that dealt with payload integration, including the Level-IV tasks. "I thought the sections of the book that dealt with payload integration on the Orbiter were among the most original and interesting," he told me. But like many times before, everyone thought it was a good topic but could not help.

Jay Barbree, a seasoned NBC reporter who covered the space program for decades, stayed in a home in Cocoa Beach when covering KSC activities. This was right next door to what would become known as the "Payload Beach House", not to be confused with the "Astronaut Beach House" located on-site at KSC. Located directly on the Atlantic Ocean in south Cocoa Beach, The Payload Beach House (its name was shorted to just the Beach House) was occupied at first by three Level-IV Engineers, Scott Vangen, Craig Jacobson and Jim Dumoulin. Eventually, 12 different people called it home, including myself, and it became the focal point for many social activities related to the Level-IV work and personnel. The most famous was as the location for the annual Payload Halloween Party, a tradition which began in 1986. This will be described later in the book. Talking the idea of the book with Jay, he stated "Mike, you will never get rich writing it, but it is a good story to tell." I was very sad to hear the news of Jay's passing on May 14, 2021.

I had just finished reading Mike Mullane's book, "*Riding Rockets*" and thought maybe he could help us. Mike was very cordial and responded: "Mike, I doubt that Simon & Schuster [his *Riding Rockets* publisher] would have an interest in this type of 'niche' book… in this case, one that's aimed at us space geeks." He suggested a few contacts and wished us "Good luck!" Very good feedback and helpful, but still no promising leads.

To celebrate the 30th Anniversary of Spacelab-1, we threw a huge celebration at the Kennedy Athletic, Recreational and Social I (KARS-I) park in November 2013. It was attended by more than a hundred people from all aspects of the Spacelab Program, not just Level-IV. Invitations even went out to the crew members from STS-9, many of whom responded but unfortunately could not attend.

For the next number of years, many events took place that would always bring up a discussion about our work in Level-IV, but finally in July of 2017, Mike Lienbach, a good colleague of mine, had written the book "*Bringing Columbia Home*" and so I contacted him and his co-author Johnathan H. Ward about the possibility of Johnathan writing this book. As with many others, Johnathan really liked the idea but could not take on the task. But he suggested I contact David J. Shayler, an accomplished author in the space field who has written many books about the American and Russian space programs and someone who was really interested in the Spacelab Program. First contact with David was in July 2017. He was very enthusiastic about the idea and as we talked it became apparent that he was in 100 percent but really wanted me to co-write it as well. Actually, instead of him taking the lead and me helping out, he stated that I needed to lead the effort. The idea was that his extensive background in writing space-related books and my background on really living Level-IV would make the perfect team to accomplish the task the correct way and help sell the idea to a publisher. More dialogue occurred and finally he convinced me to do this. Lots of discussions and formal processes needed to take place over the next few months, but by May 2018 we had a contract with Springer publishing. David and I were finally going to be writing this book.

David J. Shayler

A flight into space comprises many elements, the foremost being the mission itself from launch through – for a crewed mission – to the recovery. There is so much more to each mission that is often overlooked or simply not reported outside of the program itself. This includes: the preparation for the mission, in terms of developing the mission itself, preparing the hardware, creating the experiments and formulating crew training; the support during the flight, by teams on the ground in Mission Control, at communications centers and in various support rooms, and also during recovery with the vast network of search and rescue teams; and of course, postflight in ensuring the crew readjusts to life back on Earth, the results from the experiments are analyzed and the physical hardware is examined to understand how it stood up to the rigors of spaceflight. All of these elements then go into creating a better understanding of the mission flown against what was planned, and how these results can help improve subsequent missions and future investigations, or improve new hardware and refine procedures to obtain even greater return from the huge investments in spaceflight, both human and robotic.

As a long-term enthusiast of human space exploration, over the years I have become more interested in these ancillary aspects of each mission, which expand the understanding of what the flight itself is trying to achieve and what is involved not only in creating the mission, but also in supporting it and safely recovering the crew and vehicle at its conclusion. It is one thing to have an interest in such things but quite another to obtain the information and, more importantly, to understand it. To ensure accurate and in-depth material is at hand to create the core of what becomes a book, a significant network of contacts and sources is essential. In addition to the referenced material, first-hand contact with those who were "up close and personal" with a mission or program is just as important. Access not only to the flight crew but also the flight controllers, the launch and recovery teams, and the experiments all adds little pieces of information to fill in the gaps in the wealth of written data, and provides a priceless insight into how all this worked (or in some cases did not work) on the real mission. As a writer, I have also benefited from access to some wonderful archives, resources, contacts and personalities which have added special insights into the topic being written about.

As a youngster growing up with Apollo and its follow-on Skylab, I was disappointed when those programs ended but fascinated by the concept of the Space Shuttle and the anticipation of what it had to offer. Even though the reality of the program fell far short of what the original estimates were projected to be, following each Shuttle mission as they unfolded offered an intriguing insight into as near to routine space operations as the Shuttle program could offer. As the Space Shuttle Program developed, so did my writing career, and the opportunities to record aspects of the program beyond that of just logging each mission and those who flew them. I became fascinated with what happened to the Shuttle Orbiters on the ground in between the missions and in trying to track the process of placing payloads on the mission and assembling the hardware to fly it.

This type of research was useful when I was asked by fellow author Harry Siepmann to write what turned out to be my first book on the Space Shuttle,[1] having already authored articles, delivered presentations and compiled and published a monthly magazine called *Orbiter* through my company Astro Info Service. That book was followed the same year by a large coffee-table book on the Space Shuttle *Challenger*.[2] Both of these titles included detail of hardware and payloads, some of which in the second title was specially sourced from the contractors for the hardware elements. This type of detail and research helped compile the monthly *Orbiter* magazines published between 1984 and 1991.

Since those early days in my writing career in the 1980s, I have continued to collect and record data on the Space Shuttle ground operations, its missions, hardware, experiments and payloads, and of course the crews. This has created an archive and resource which has continued to be of assistance in compiling more recent titles I have produced, detailing aspects of the Shuttle Hubble Servicing Missions and the development of the Shuttle/Space Station docking and assembly missions. There are plans to continue this work in future titles and in publications by Astro Info Service, and so when I was approached by Michael Haddad with the view to cooperating on a book on Shuttle payload processing, I jumped at the chance.

Living in the UK made regular access to the Shuttle Launch Facility (SLF) and archives at KSC in Florida difficult, so having my co-author Michael write his story of being involved in the day-to-day activities down at the Cape seemed logical. When he explained that the account focused upon the Spacelab missions I was even more pleased, being both a Brit and a European. Spacelab was part of Europe's contribution to the Shuttle program and the Pallets were fabricated right here in the UK. I have often felt that Spacelab has been unjustly overlooked in the accounts of the payload system within the Shuttle program. Here was a change to redress that omission.

This is not a "users guide" to Shuttle payload processing, but a layperson's insight into how that processing came about and was operated, by those who were involved in making it happen. Without this team, the Shuttle Spacelab payload could not and would not have flown, and being mostly "under the radar", it is clear

[1] *From the Flight Deck 2: NASA Space Shuttle,* published in 1987 by Ian Allen.

[2] *Challenger, Aviation Fact File*, Salamander Books, 1987.

that the work they did was both effective and done well to achieve the results it did with so few failures in the whole system.

The Space Shuttle has had many critics, which is fine, but it also has many things to be proud of, and the Level-IV team at the Cape who processed the majority of the science payloads, up to the early 2000s, can justly be proud of what they accomplished. It is their personal involvement, dedication and sacrifice which helped make flying the Spacelab hardware look so easy, whereas in fact the truth was far from that impression.

This, then, is the story of Level-IV at NASA KSC, Florida, through the eyes and experiences of those who were directly involved, as told to Mike Haddad and molded by both of us into the account you read here. This is where you can learn just how challenging and involved getting an experiment or items of hardware off the ground and into space actually was. We hope you enjoy the journey.

Acknowledgements

As with any book project of this nature, there are a far greater number of people who are involved than those names who appear on the front cover and who are credited with the account herein. Each author therefore offers his thanks to those who made this book possible, and whose names number far too many to be listed.

Michael Haddad

This book is not an official NASA-endorsed account but a private recollection and explanation. Some of the information stated within the many interviews may differ from what people may have heard or opinions written in other documentation, but we have done our best to ensure all the data is correct and reflects the memories of the people who lived it.

The majority of the images used in this book originate from NASA, various military service organizations, this author's own collection and those of other personnel – those credited in the individual captions – unless specifically stated. However, despite extensive searches, we have been unable to determine the exact origin of some of the images and would therefore welcome any input to enable us to credit the appropriate source. We can provide copies of photos upon request.

Throughout this process, there have been a few people always willing to help, with Maynette Smith, a Level-IV engineer, being the main support. She had maintained the email distribution list we had created to stay in contact with as many ex-Level-IV personnel as possible. She also created a Facebook site to try and document our work and reach out to as many people as possible that worked Level-IV, to get correspondence started that would help populate a possible book with facts from those who lived it.

Dean Hunter, a super engineer, one of the best bosses I ever had and a good friend, taught me so much that is documented in this book. He was also greatly admired by others around him. Dean expected excellence and at times seemed to get really mad with me but, as stated to me by one of my co-workers, you always knew when Dean was really mad at you, something I'll get into in more detail in the Spacelab-1 section of this book. Dean passed away unexpectedly on October

8, 2010. The inscription on the most cherished of all his awards, the Spacelab panel with parts from many missions mounted upon it that was presented to him by the technicians and engineers that worked with him, as mentioned in the Preface, read: "Presented this day, March 23, 1995, to Dean Hunter. Inspired by your innovative leadership, technicians and engineers have continually pushed the edge of the envelope, repeatedly finding elegant solutions to seemingly insurmountable technical challenges. Represented here are the fruits of but a few of these unheralded innovations. Undoubtedly, these are among our best efforts during our finest hours."

Dean Hunter, pointing out details of the Spacelab to a co-worker. [NASA/KSC.]

Janice E. Voss (b. 1956), known to her friends as "JV", passed away on February 6, 2012, aged only 55. As an astronaut, she flew five times on the Shuttle. I met JV through some friends at KSC who worked with her on a number of missions. She was a very kind person, a very smart person and a wonderful friend who would have made a huge contribution to this book. She loved her chocolate and she became very good friends with my cousin, Lisa Thomas, sharing lots of chocolate samples that JV acquired over the years through her travels around the globe. But one of my most vivid memories of JV was the day I received my Silver Snoopy

Award, October 22, 2001. The Silver Snoopy is an award for outstanding performance, contributing to flight safety and mission success. An astronaut always presents the Silver Snoopy because it is the astronauts' own award and less than one percent of the aerospace program workforce receive it annually, making it a special honor to receive this award. Mine was from the crew expressing their appreciation for the outstanding support that I had given to the Space Shuttle Program as a Flight Crew Extra-Vehicular Activity (EVA) and Intra-Vehicular Activity (IVA) Interface.

Janice Voss ("JV") at the CITE stand in the Operations and Checkout (O&C) Building, participating in testing for the STS-99 Shuttle Radar Topography Mission (SRTM) payload. Insert: Silver Snoopy award (l to r): Mike Haddad, Janice Voss, Sam Haddad. [NASA/KSC.]

The way this worked was that your family was informed about the award but you were not. At the time, they would have you attend what appeared to be a normal meeting with all your co-workers, but really it was a gathering for presenting the award, and your family was positioned outside the meeting room. When the astronaut arrived, they and your family would enter the room for the surprise and presentation of the award. My brother, Samuel Haddad, also worked at KSC and he was part of my family that entered the room with JV, and right away it hit me

that I was going to receive a Silver Snoopy. What my brother didn't know was that he was also going to receive a Silver Snoopy. Normally, one crew member would present one award to one employee, but JV found out we both were going to receive the awards so she set it up to present the awards to both of us at the same time. She started by asking me to come up to read the reason for the award, which for my brother seemed weird. Why would Mike read for his own award? But as I started reading, it was details of why my brother was receiving the award, not me. So "Surprise," Sammy, you're receiving a Silver Snoopy. After the presentation to him, he was asked to stay at the front of the room and then read the reason for my Silver Snoopy. This was the first and only time in the history of NASA that two brothers received Silver Snoopy awards at the same time**.** All thanks to JV, a super person who is truly missed.

To all of you who contributed information to me to write this book, especially those that I interviewed, you provided incredible stories of how each of you performed your job and the innovative solutions to many problems encountered. A number of them made me laugh so hard my stomach hurt, but there were also the touching moments and heartaches that each of you endured during some very sad days at NASA. Thank you all.

I also appreciate Astro-1 and -2 Payload Specialist Sam Durrance for his excellent Foreword and Riley Duren for his Afterword.

Thanks also to my co-Author David J. Shayler, who has helped me so much on this journey of writing a book. His experience with the many books he has written and awesome suggestions for this process were huge in helping me to streamline tasks when I was heading in the wrong direction. A master of words, which I am NOT, our Project Editor Michael D. Shayler, Dave's brother, added so much of the personality to this effort, something I could have never done by myself.

Finally and especially, thanks to my wife Kathy, my soul mate, the love of my life, who put up with all my craziness during the writing and production of this book. I bounced so much off her during this multi-year process and she stuck it out the whole time, giving me great feedback and inspiration to keep going many times when I wanted to say the hell with it and walk away.

David Shayler

The majority of the content in this book was supplied by my co-author Mike Haddad and his colleagues who worked in the KSC Level-IV team and associated facilities. I also would like to thank them for their patience and assistance in detailing their part in the story.

For my own research and participation, I thank those at the KSC PAO (Public Affairs Office) who have assisted me over many years in detailing operations at the Cape. These include Kay Grinter, Margaret Persinger, Ken Nail and Elaine Liston. I also take this opportunity to thank PAO Specialist Manny Virata for his personal guidance around the facilities at KSC during a memorable first visit to the facility in November 1990 for the launch of STS-38, and a second in November 1993. Those tours brought the information I had gathered over the preceding two decades to life. The cooperation with my co-author in this current project has offered an even greater understanding of everything that I had read and later saw in person. In addition, my contacts at the NASA History and PAO departments at JSC have provided additional information on Shuttle operations over a period of four decades.

In detailing the various Spacelab missions for this and other projects, I am indebted to astronauts Vance Brand (Astro-1), Michael Foale (ATLAS-1 and -2), Robert Gibson (Spacelab-J), Tony England (Spacelab-2), the late Karl Heinz (Spacelab-2), Jeff Hoffman (Astro-1), Don Lind (Spacelab-3), Story Musgrave (Spacelab-2), Rhea Seddon (Spacelab Life Sciences-1 and -2), and the late Bill Thornton (Spacelab-3).

Thanks as always goes to my brother Mike Shayler, our Project Editor, for his skills and talent in turning our original draft into the polished, finished format you read here. Thanks also to Jim Wilkie for interpreting our cover design into the finished cover.

Thanks go to Hannah Kaufman from Springer for guidance through the publication process, and her predecessor Maury Solomon who initially saw potential for the project through the Springer portfolio and suggested the authors get together for a joint partnership. Thanks also to Clive Horwood of Praxis books for mentoring the project and to the referees who supported the early proposal.

Thanks to all those who worked at KSC over the years in preparing not only the Spacelab-related hardware in Level-IV but also in processing all the payloads and hardware at the Cape to enable each Shuttle to fly. This is a story focused on the Level-IV Spacelab processing, but it is also part of the history of operations at the Cape and the lives of those who worked there, and to their families who understood their dedication to their work to make each element as safe and as reliable as they possibly could. This is their story too.

Finally, thanks to my mother Jean, who for once was spared reading the proofs of one of my books because she was reading those from a different project, and to my wife Bel, who once again saw me embark on yet another book project, albeit less writing and more proof-reading and pre-editing this time, while at the same time working on other titles, taking on a new editorial role, and still having time to work in our kitchen and enjoy time with our beloved white German Shepherd Shado. Thank you once again to all for your support of my passion for recording the developing story of human spaceflight.

List of Abbreviations and Acronyms

Glossary

Airlock
An intermediate location to permit passage between two dissimilar environments.

Flight Hardware
Hardware that is qualified to fly in space.

Long Module
Two short, pressurized Spacelab Modules, comprising the Core and Experiment segments, attached together as one.

Mission Peculiar Experiment Support Structure
A structure that spanned the Orbiter Payload Bay and could carry smaller payloads not needing the larger Spacelab Pallets.

Orbiter
The crewed element of the Space Transportation System commonly referred to as the Space Shuttle. This winged vehicle provided accommodation for the crew during their mission in Earth orbit, facilities to support scientific experiments, and capabilities to handle large payloads.

Pallets
'U'-shaped structures that carried unpressurized payloads and were launched in the Payload Bay of the Orbiter.

Payloads
Scientific experiments, satellites, planetary spacecraft, and large sections of the International Space Station. Hardware that would be launched in the crew compartment and/or Payload Bay of the Orbiter.

Payload Bay
A 60-foot (18-m) long by 15-foot (4.6-m) diameter location for carrying cargo and payloads, such as Spacelab Modules and Pallets, in the Space Shuttle Orbiter.

Payload Specialist
A flight crew member who was not a professional career astronaut but a specialist to operate scientific equipment in orbit, usually for a single mission. Nominated by members of the Principal Investigators of the given mission.

"Ship-and-Shoot", or "Ship-n-Shoot"
A payload arriving at KSC that is launched with little or no pre-launch testing.

Short Module
A single Spacelab pressurized Module, namely the Core segment. This configuration was never flown.

Spacelab
European-designed and built pressurized Module and unpressurized Pallet system for conducting extensive scientific research for up to 18 days in Earth orbit from the Payload Bay of a Space Shuttle Orbiter.

Test Stands
Physical structure locations where payload assembly, integration and testing occurs.

Turnaround
Time between missions

User Rooms
Rooms assigned to payload customers and used as a control room for their payload.

AFD	Aft Flight Deck
AFRC	[Neil A.] Armstrong Flight Research Center (formerly DFRC)
ARC	[Joseph Sweetman] Ames Research Center, California
Astro	abbreviation for "Astronomy"
ATE	Automated Test Equipment (Level-III/II)
ATLAS	Atmospheric Laboratory for Applications and Science (STS-45, 56 and 63)
ATM	Apollo Telescope Mount (Skylab)
C/D	Design and development phases

CCAFS	Cape Canaveral Air Force Station, Florida
CCTV	Closed Circuit Television
CDMS	Command and Data Management System
CDR	Critical Design Review
CFES	Continuous Flow Electrophoresis System
CHROMEX	Chromosome and Plant Cell Division in Space
CITE	Cargo Integration Test Equipment
CSA	Canadian Space Agency
CRF	Canister Rotation Facility
CWA	Clean Work Area
DEVs	Deviations
DFRC	[Hugh L.] Dryden Flight Research Center, California
DOD	Department Of Defense
DR-xxx	Double Rack
Exxx or EM	Engineering Model
EAFB	[Glen] Edwards Air Force Base, California
EBA	European Bridge Assembly
ECLSS	Environmental Control and Life Support System
ED	Experiment Developer
EDO	Extended Duration Orbiter
EDL	Engineering Development Lab
EGSE	Experiment Ground System Equipment
EI	Experiment Integration
ESA	European Space Agency/Engineering Support Area
ESPS	Experiment Segment and Pallet Simulator
ELDO	European Launcher Development Organization
EMP	Enhanced Multiplexer/demultiplexer
EOM	Earth Observation Mission (became ATLAS)/End of Mission
ESR	Engineering Support Room
ESRO	European Space Research Organization
ESTEC	European Research and Technology Center
ET	External Tank (Space Shuttle)
EVA	Extra-Vehicular Activity (spacewalk)
Fxxx	Flight (serial number)
FMPT	First Materials Processing Test (Spacelab-J)
FOP	Follow On Production
FOST	Flight Operations Support Team
FU	Flight Unit
GAS	Get Away Special (experiment)
GIRD	Ground Integration Requirements Document
GIRL	German Infrared Radiation Laboratory (Spacelab D-4 unflown)

GRC	[John H.] Glenn Research Center, Cleveland, Ohio
GSE	Ground Support Equipment/Government Supplied Equipment
GSFC	[Robert H.] Goddard Space Flight Center, Greenbelt, Maryland
GSOC	German Space Operations Center, Oberpfaffenhofen, Germany
GOWG	Ground Operations Working Group
HMF	Hypergolic Maintenance Facility
HOSC	Huntsville Operation Support Center
HST SM	Hubble Space Telescope Servicing Mission (STS-61, 82, 103, 109 and 125)
IML	International Microgravity Laboratory (STS-42 and 65)
IPS	Instrument Pointing System
ISS	International Space Station
IVA	Intra-Vehicular Activity
JAXA	Japanese Aerospace Exploration Agency
JEM	Japanese Experiment Module
JSC	[Lyndon B.] Johnson Space Center, Houston, Texas
KARS	Kennedy Athletic, Recreation and Social
KSC	[John F.] Kennedy Space Center, Florida
LC	Launch Complex
LCC	Launch Control Center
LM	Long Module (Spacelab)
LMS	Life and Microgravity Spacelab (STS-78)
LPS	Launch Processing System
LSSF	Life Sciences Support Facility
MBB	Messerschmitt-Bölkow-Blohm, Germany
MCC	Mission Control Center, JSC, Houston
MDAC	McDonnell Douglas Aircraft Corporation
MDE	Mission Dependent Equipment
MDM	Multiplexer/demultiplexer
MFD	Manipulator Flight Demonstration
MHI	Mitsubishi Heavy Industries
MPE	Mission Peculiar Equipment
MPESS	Mission Peculiar Equipment Support Structure
MPLM	Multipurpose Logistics Modules
MPS	Main Propulsion System (Space Shuttle)
MSFC	[George C.] Marshall Space Flight Center, Huntsville, Alabama
MSL	Material Science Laboratory (became USML)/Material Science Laboratory (STS-83 and 94)
MMSE	Multi-Mission Support Equipment
MOU	Memorandum of Understanding
MVAK	Module Vertical Access Kit

NASA	National Aeronautics and Space Administration
NASM	National Air and Space Museum, Washington, D.C.
O&C	Operations and Checkout
OFT	Orbital Flight Test
OMI	Operation and Maintenance Instructions
OMRF	Orbiter Maintenance & Refurbishment Facility (OPF-3)
OMRSD	Operations and Maintenance Requirements Specifications Document
OPF	Orbiter Processing Facility, KSC
OSF	Office of Space Flight
OSS	Office of Space Science
OSTA	Office of Space and Terrestrial Applications
OV	Orbital Vehicle (Space Shuttle)
PCR	Payload Changeout Room
PCTC	Payload Crew Training Complex
PCU	Payload Checkout Unit
PD	Payload Developer
PDR	Preliminary Design Review
PETS	Payload Environmental Transportation System
PGHM	Payload Ground Handling Mechanism
PHSF	Payload Hazardous Servicing Facility
PI	Principal Investigator
PMA	Pressurized Mating Adapter
POCC	Payload Operations Control Center
PON	Payload Operations Network
PPCU	Partial Payload Checkout Unit
PPLF	Partial Payload Lifting Fixture
PR	Problem Report
PRCU	Payload Rack Checkout Unit
PSR	Payload Support Room
PSSIT	Pallet Segment Support Integration Trolley
PTE	Payload Test Engineer
R/R&D	Research/Research and Development
RAHF	Research Animal Holding Facility
RAM	Research and Applications Module
RFP	Request for Proposal
RMS	Remote Manipulator System (Canadarm)
RSS	Rotating Servicing Structure
SAEF	Spacecraft Assembly & Encapsulation Facility
SBIR	Small Business Innovation Research
SEB	Source Evaluation Board

SED	Spacelab Experiments Division, KSC
SEIS	Spacelab Experiment Integration Support
SLDPF	Spacelab Data Processing Facility, GSFC
SLF	Shuttle Landing Facility, KSC
SL-M	Spacelab-Mir (STS-71)
SLS	Spacelab Life Sciences (STS-40 and 58)/Spacelab Simulator
SM	Single Module (Spacehab)/Short Module (Spacelab) – not flown
SOM	Spacelab Operational Mission
SPCDS	Spacelab Payload Command and Data System
SR-xxx	Single Rack
SRB	Solid Rocket Booster
SRL	Space Radar Laboratory, (STS-59 and 68)
SRM	Satellite Retrieval Mission (STS-51A)
SRR	Systems Requirement Review
SRTM	Shuttle Radar Topography Mission (STS-99)
SSHIO	Space Station Hardware Integration Office
SSME	Space Shuttle Main Engine
SSPF	Space Station Processing Facility
STA	Structural Test Article (STA-099)
STS	Space Transportation System
TAP	Test & Assembly Procedures
TDRSS	Tracking and Data Relay Satellite (System)
TIM	Technical Interchange Meeting
TPS	Test Preparation Sheets
TSS	Tethered Satellite System (STS-46 and 75)
UA	Unexplained Anomalies
USA	United Space Alliance
USML	US Microgravity Laboratory (STS-50 and 73)
USMP	US Microgravity Payload (STS-52, 62, 75 and 87)
VAB	Vehicle Assembly Building, KSC
VAFB	Vandenberg Air Force Base, California
VFT	Verification Flight Test (Spacelab-1, Spacelab-2)
VPF	Vertical Processing Facility
WAD	Work Authorization Documents

Prologue
A new generation of 'Rocket Scientists'

In the early 1980s, NASA was preparing to launch the first Space Shuttle to begin a new era of human spaceflight by the United States, "after Apollo". The Space Shuttle was a combination of several elements: two reusable Solid Rocket Boosters (SRB) and three overhaulable Main Engines fueled from a single-use huge External Tank (ET), which combined was called the Main Propulsion System (MPS). This unique combination would launch a multi-flight Orbital Vehicle, one of a fleet of five, containing a human crew and its manifested cargo into low Earth orbit. From here, missions lasting from a few days up to nearly three weeks would be conducted before the vehicle was returned to Earth, landing on a runway for processing and repeating the operations, with a different payload, time and time again. The whole combination of Orbiter, SRBs, and ET was known as "The Stack".

This "manifested cargo" carried on the Orbiter consisted of new hardware being developed at the same time as the Shuttle which carried it. Called "payloads", these would be taken into low Earth orbit either in the Orbiter's large Payload Bay or on the pressurized "middeck" area. These payloads contained a multitude of science experiments from all over the world, a significant amount of which would be contained in a pressurized laboratory or on unpressurised Pallets under a program called "Spacelab", which was being developed by NASA in cooperation with the European Space Agency (ESA).

The question was "How would these payloads be prepared for launch?" The answer was to reintroduce the concept of allowing NASA personnel to perform the job that a contractor would normally perform. Instead of overseeing a contractor, NASA personnel would instead perform the engineering function themselves and get their own hands dirty. Thus was created the "Level-IV – Experiment Integration" organization at Kennedy Space Center (KSC). Many young NASA personnel, most of them right out of college, would be responsible for preparing domestic and foreign multi-million-dollar experiments for spaceflight. This book tells the story, from the engineers' point of view, of how that unique group accomplished this task, details the technical decisions made that contributed to the success of the Spacelab and science programs, describes where the experience gained was distributed throughout other areas of the space program, and reveals how knowledge of that work is being used for current and future spaceflight activities. This, therefore, is the inside story of how major scientific payloads were prepared and flown successfully and safely many times by the Space Shuttle system, creating a useful prelude for the successful development and operation of much more complex and long-term science programs on the International Space Station (ISS).