

# Countdown to a Moon Launch

Preparing Apollo  
for Its Historic  
Journey



Jonathan H. Ward

# Countdown to a Moon Launch

Preparing Apollo for Its Historic Journey

---

**Also by Jonathan H. Ward  
for Springer-Praxis**

*Rocket Ranch: The Nuts and Bolts of the Apollo Moon Program at Kennedy Space Center*  
2015  
ISBN 978-3-319-17788-5

Jonathan H. Ward

---

# Countdown to a Moon Launch

Preparing Apollo for Its Historic Journey



Published in association with  
**Praxis Publishing**  
Chichester, UK



Jonathan H. Ward  
Greensboro, NC, USA

---

SPRINGER-PRAXIS BOOKS IN SPACE EXPLORATION

---

Springer Praxis Books

ISBN 978-3-319-17791-5

ISBN 978-3-319-17792-2 (eBook)

DOI 10.1007/978-3-319-17792-2

Library of Congress Control Number: 2015938576

Springer Cham Heidelberg New York Dordrecht London

© Springer International Publishing Switzerland 2015

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Cover illustration: Cover images courtesy of NASA

Cover design: Jim Wilkie

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media ([www.springer.com](http://www.springer.com))

# Contents

<b>Acknowledgments</b> .....	xi
<b>Dedication</b> .....	xv
<b>About the Author</b> .....	xvii
<b>Foreword</b> .....	xix
<b>Preface</b> .....	xxiii
<b>1 Introduction</b> .....	1
How Was That Even Remotely Possible?.....	1
Why a Book About Kennedy Space Center? .....	2
How This Book is Organized.....	3
24,000 Perspectives.....	4
<b>2 Controlling Complexity</b> .....	7
The Unrelenting Pace.....	7
1965.....	8
1966.....	8
1967.....	8
1968.....	8
1969.....	8
KSC and the Flight Hardware.....	9
Managing the Program.....	9
Managing the Work.....	12
Managing Operations for Multiple Missions.....	12
Firing Room 4.....	13
Rocco Petrone’s Daily Staff Meeting.....	16
DLO Schedule.....	17
The 72-Hour/11-Day Schedules and Snoopy.....	18
Managing the Contractors.....	24

Padding, Sandbagging, and Umbrellas .....	25
Contractor Scheduling and Reporting.....	26
Communication Was Key .....	27
<b>3 Requirements, Tests, and Computerization.....</b>	<b>29</b>
Controlling the Configuration.....	29
It All Started with Requirements.....	29
Configuration Inspection Log and Engineering Orders .....	31
Testing to the Requirements.....	32
Test and Checkout Procedure (TCP).....	32
Test Preparation Sheet (TPS).....	32
Integrated Test Procedure (ITP).....	32
Pre-test Briefings.....	33
Test and Inspection Record (TAIR) .....	35
Test Problem Report (TPR) .....	36
Discrepancy Record (DR) and Material Review (MR) .....	37
Roles in Test and Checkout.....	38
Quality Control Inspection.....	39
Developing Tests and Procedures .....	41
Working with the Process .....	43
Logbooks.....	44
Certifications.....	46
Computerization.....	46
Saturn Launch Computer Complex .....	48
Programming the 110A.....	50
Launch Vehicle Test System Operation .....	51
Other Launch Vehicle Computer Systems .....	52
Digital Data Acquisition System.....	52
Digital Events Evaluator (DEE).....	52
Post-test Analysis.....	53
The Marshall Breadboard .....	53
The ACE-S/C System .....	54
Spacecraft Testing with ACE.....	56
The Quick-Look Data Station.....	57
Central Instrumentation Facility (CIF) .....	59
Timing and Countdown System.....	61
Propellant Tanking Computer System .....	61
Computers Were Vital to Success .....	63
Was the Paperwork Worth It? .....	64
<b>4 The MSOB and the CSM Processing Flow.....</b>	<b>67</b>
Why Assemble and Test at Kennedy Space Center?.....	67
The Apollo Spacecraft.....	68
The Command/Service Module (CSM).....	69
The Command Module .....	69
The Service Module.....	71
Block I and Block II CSMs.....	72

The Lunar Module (LM).....	72
The Launch Escape System (LES) .....	74
Spacecraft/Lunar Module Adapter (SLA).....	76
The Hectic World of Spacecraft Operations .....	77
Roles and Responsibilities .....	80
Senior Leadership .....	80
The Test Teams .....	80
Work on the Assembly and Checkout Floor .....	86
Other Roles .....	89
Resident Apollo Spacecraft Program Office (RASPO) .....	90
Remote Support .....	90
Working with the Astronauts.....	91
Spacecraft Testing with ACE .....	92
The Spacecraft Flow in the MSOB .....	92
The CSM Processing Flow .....	94
Week of January 20, 1969: L Minus 177 Days.....	94
Week of January 27: L Minus 170 Days.....	95
Week of February 3: L Minus 163 Days.....	100
Week of February 10: L Minus 156 Days.....	100
Weeks of February 17 and 24: L Minus 149 Days.....	102
Week of March 3: L Minus 135 Days.....	104
Week of March 10: L Minus 128 Days.....	105
Week of March 17: L Minus 121 Days.....	108
Week of March 24: L Minus 114 Days.....	110
Week of March 31: L Minus 107 Days.....	113
Week of April 7: L Minus 100 Days.....	113
SIM Bay Experiments.....	114
Skylab Orbital Workshop Modules and <i>ASTP</i> Docking Module.....	119
<b>5 The LM Processing Flow .....</b>	<b>125</b>
Initial Inspections.....	125
Weeks of January 6 to January 20: L Minus 191 Days.....	125
Problem LMs .....	126
LM-1 .....	127
LM-3 .....	129
LM-8 .....	130
Buildup and Testing .....	132
Week of January 27: L Minus 170 Days.....	132
Week of February 3: L Minus 163 Days.....	132
Week of February 10: L Minus 156 Days.....	133
Week of February 17: L Minus 149 Days.....	136
Week of February 24: L Minus 146 Days.....	139
Week of March 3: L Minus 135 Days.....	141
Week of March 10: L Minus 128 Days.....	141
Week of March 17: L Minus 121 Days.....	143
Week of March 24: L Minus 114 Days.....	145



Week of March 31: L Minus 107 Days .....	146
EASEP and ALSEP Processing.....	153
Lunar Rover Processing on <i>Apollo 15</i> Through <i>17</i> .....	155
Final Spacecraft Assembly.....	159
Processing the SLA.....	159
Mating the Lunar Module to the SLA.....	161
Mating the Command/Service Module to the SLA.....	164
Transferring to the VAB.....	165
<b>6 The Launch Vehicle Processing Flow in the VAB .....</b>	<b>173</b>
The World of Launch Vehicle Operations.....	173
Launch Complex 39.....	174
The Saturn Launch Vehicles .....	176
The S-IC.....	179
The S-II.....	179
The S-IVB.....	179
Instrument Unit .....	180
The S-IB.....	180
The Launch Vehicle Processing Flow.....	180
Stage Checkout Prior to Delivery to KSC .....	181
Transport to KSC .....	182
Weeks of January 20 to February 3: L Minus 177 Days.....	182
Sabotage on Apollo 11's S-IVB in the VAB? .....	183
The S-II Arrives: February 6, 1969.....	186
Week of February 17: L Minus 149 Days.....	189
Erecting the S-IC.....	190
Week of February 24: L Minus 146 Days.....	196
Week of March 3: L Minus 135 Days.....	198
The S-II Spacer "Spool": AS-501/AS-502 .....	201
The AS-500F Twang Test.....	209
Week of March 10: L Minus 128 Days .....	210
Testing Protocol in Launch Vehicle Operations.....	210
Week of March 17: L Minus 121 Days .....	212
Week of March 24: L Minus 114 Days .....	213
Week of March 31: L Minus 107 Days.....	214
Week of April 7: L Minus 100 Days .....	217
Stacking the Spacecraft: April 14, 1969 .....	217
Week of May 5: L Minus 72 Days.....	219
Week of May 12: L Minus 65 Days.....	221
Week of May 19: L Minus 58 Days.....	225
<b>7 The Processing Flow at the Launch Pad.....</b>	<b>227</b>
The Processing Flow at the Launch Pad.....	227
Week of May 19: L Minus 58 Days.....	227
Rollout: Tuesday, May 20, 1969.....	228
Mating the LUT to the Pad .....	233
Positioning the MSS to Work on the Spacecraft.....	234

Week of May 26: L Minus 51 Days .....	238
The Apollo 16 Bladder Incident.....	239
Week of June 2: L Minus 44 Days .....	242
Flight Readiness Test (FRT) .....	243
Post-FRT work .....	244
Last-Minute Problems and Changes to LM-5.....	246
Week of June 9: L Minus 37 Days .....	252
Launch Readiness Review .....	252
Week of June 16: L Minus 30 Days .....	256
Week of June 23: L Minus 23 Days .....	261
<b>8 Countdown Demonstration Test .....</b>	<b>265</b>
The Dress Rehearsal .....	265
Wet Test and Dry Test .....	266
Launch Blocks .....	267
The <i>Apollo 4</i> CDDT: “The Test from Hell” .....	268
The <i>Apollo 10</i> Fuel Tank Collapse.....	273
The <i>Apollo 13</i> Oxygen Cloud and Vehicles to Burn.....	275
Week of June 30: L Minus 16 Days .....	277
Three Strikes Against <i>Apollo 13</i> During CDDT .....	278
Week of July 7, 1969: L Minus 9 Days.....	285
Is That a Cold Solder Joint?.....	286
<b>9 Launch Countdown .....</b>	<b>289</b>
Introduction to Launch Countdown .....	289
Launch Windows for <i>Apollo 11</i> .....	289
Monthly Launch Window .....	290
Daily Launch Window .....	290
Countdown Procedures .....	291
Sub-tasks .....	294
Launch Mission Rules Document .....	295
Interrupting the Countdown.....	296
Procedure Change Requests.....	299
Staffing During Countdown.....	299
ACE Rooms .....	300
Launch Pad.....	301
Other Support Operations .....	302
Preparations Start: T Minus 130 Hours.....	303
Pre-count: T Minus 93 Hours.....	305
Countdown Start: T Minus 28 Hours .....	308
Power Transfer Test .....	310
Range Safety Tests .....	312
LM Closeout .....	313
MSS Rollback .....	317
Sidebar: The S-II Sensor Short .....	318
Propellant Loading: T Minus 9 Hours .....	321
Going on Station in the Final Hours .....	323

x **Contents**

The Countdown Resumes .....	324
LH <sub>2</sub> Leak! T Minus 3 Hours 38 Minutes .....	329
Astronauts on Board: T Minus 2 Hours 40 Minutes .....	330
Recycle Point: T Minus 22 Minutes .....	336
Terminal Count: T Minus 3 Minutes 10 Seconds .....	337
Terminal Countdown Sequencer (TCS).....	337
Interlocks.....	337
Terminal Count to Liftoff.....	338
<b>10 Plus Time and Near Misses .....</b>	<b>345</b>
The Saturn V Takes Flight: T Zero .....	345
Forward Observers.....	351
Safing the Pad .....	352
Turnaround After Scrub .....	354
24-Hour Turnaround .....	356
3-Day Turnaround.....	356
Other Scrub Options .....	356
Lessons Learned From Countdown And Launch.....	356
AS-502 ( <i>Apollo 6</i> ): The Successful Failure.....	357
The Apollo 12 Lightning Strike.....	359
Apollo 17: Cutoff at T minus 30 Seconds.....	362
Battle Damage in the Skylab Orbital Workshop Launch .....	365
Skylab 2: Milliseconds from Disaster.....	367
<b>11 Epilogue .....</b>	<b>369</b>
Would It Actually Work? .....	369
<b>Appendix A Acronyms and Abbreviations.....</b>	<b>375</b>
<b>Appendix B Missions with Apollo and Saturn Hardware .....</b>	<b>381</b>
<b>Appendix C S-II Stage Checkout Tests .....</b>	<b>391</b>
<b>Appendix D Apollo 11 OIS Call Signs .....</b>	<b>401</b>
<b>Appendix E Firing Room Staffing During Apollo 11 and 14 Countdowns.....</b>	<b>409</b>
<b>Appendix F Recommended Reading and References .....</b>	<b>417</b>
<b>Appendix G Interviewees .....</b>	<b>423</b>
<b>Index.....</b>	<b>427</b>

## Acknowledgments

This book was a collaborative effort of many, many people. All who I interviewed gave their time generously. A few others went above and beyond the call to help the project succeed, because they felt it was important to their legacies and the KSC story.

Frank Bryan (NASA) is at the top of my list, both because he was the first KSC Apollo/Saturn worker I met and because he has been a consistent source of information and encouragement during the research and writing process. Frank appears frequently throughout this book, for good reason. As one of the go-to troubleshooters for the launch vehicle operations directorate throughout the Saturn era, Frank found himself in the middle of more interesting situations than you can possibly imagine. Frank spent many hours going over my draft chapters on launch vehicle processing to ensure that I correctly represented the technology and the workflow. Frank is conducting his own research and gathering the names of the people seen in photos from the era. I encourage you to visit the NASA Alumni League-Florida Chapter's webpage if you, a friend, or a family member worked on the space program at KSC. See [http://nalfl.com/?page\\_id=2441](http://nalfl.com/?page_id=2441) for more information.

Fred Cordia, one of Rockwell's senior managers on the S-II stage, likewise spent many hours immersing me in the life of a launch vehicle stage contractor. Fred pulled out his notes from his Saturn days and prepared the test procedure flow charts you will see in Appendix C. One of the serendipitous joys of writing this book was putting Frank and Fred back in touch with each other for the first time in many years.

NASA launch vehicle test conductor Norm Carlson quickly became a dear friend. He made many phone calls and opened many doors on my behalf, for which I am very thankful. He made his home my home for my many weeks of research in the Space Coast. I regret not having finished this book in time for him to see it before he passed away in March 2015. He touched many lives, and he will always have a special place in my heart.

Ernie Reyes (NASA) and John Tribe (Rockwell) are the spacecraft folks who merit my special thanks for their outstanding contributions, support, and friendship. John took me to places at Kennedy Space Center that I never dreamed I would see firsthand. Ernie can always be counted on for no-holds-barred and entertaining accounts of personalities and

## xii Acknowledgments

work practices. Both John and Ernie fact-checked my chapters on spacecraft operations to ensure that I accurately represented the work on the CSM.

Bob Sieck (NASA) encouraged me from the outset of this project. He introduced me to many of his colleagues from the spacecraft organization. He worked closely with me on the account of the events leading to the *Apollo 13* accident that you will read in the countdown demonstration test chapter in this book.

What can I say about Ike Rigell, chief engineer and deputy director of launch vehicle operations? I hope that someone (maybe me, if I'm lucky) writes a book about this amazing man someday. Ike was with the Marines on Midway and Iwo Jima, played minor league baseball, worked in Wernher von Braun's Missile Firing Lab, was instrumental in the launches of Explorer 1 and Alan Shepard...the list goes on and on. Ike sat at the start of the first row in the firing room and had his own call sign on the intercom system! And yet, he is one of the most gentle and humble souls you will ever meet, and he is universally respected in the NASA community. I was honored to spend several days with him and thrilled that he agreed to write the foreword for my other book.

Frank Penovich (NASA) kindly allowed me to use his detailed notes and photographs of early launch vehicle test computers, and he fact-checked my sections on computerization. Ed Fannin (NASA) provided many fascinating accounts of the Saturn's mechanical and propulsion systems, and he reviewed the sections on launch vehicle operations. Steve Coester (Boeing) graciously permitted me the opportunity to incorporate a story from his web site into the chapter on launch countdown. Bill Heink (Boeing) provided detailed accounts of the dangers of working with liquid oxygen, and he also reviewed portions of the book for technical accuracy.

Alan Contessa (Grumman) shared some of his personal photos from his work on *Apollo 11's* lunar module. Marcus Goodkind, Grumman's test manager for *Apollo 11's Eagle*, shared fascinating insights and photos.

Jerry Bostick and Glynn Lunney of Houston's Mission Control Center provided the initial idea that sparked this book. Jerry has been a good friend and advisor throughout the writing process.

Charlie Mars, Karan Conklin, and Lee Starrick at the Space Walk of Fame Museum deserve a big "thank you" for their assistance and access to their files. Special thanks also go to Carol Nelson at the Cradle of Aviation Museum in Garden City, New York, for inviting me to be a special guest at the Grumman *Apollo 11* 45th anniversary reunion. Be sure to visit those museums if your travels ever take you nearby. If you have not been to either museum, you owe it to yourself to make a special trip. They are both amazing facilities run by people who have a personal connection to the space program.

Dave Mohr is a treasure trove of knowledge, and he provided fascinating insights into technology on the Saturn V and the launch systems at Kennedy Space Center. Tim Burk provided me with some of the first documents I had seen on the electrical support equipment at KSC and stimulated my interest in learning more about launch processing operations. Bill Sawchuck has been a longtime friend and resource on badges and people at the Cape. Ivan Blejec shared his advice and many source documents with me as well.

Thank you to Jerome Bascom-Pipp and J. L. Pickering for making so many NASA images available to me. You saved me countless hours of trolling the Internet for the "perfect" picture. Thanks also to the good folks who scan the NASA images for the online Apollo Image Gallery and *Apollo Lunar Surface Journal*.

On April 22, 2013, my good friend the Rev. Meghan Froehlich said to me, “You need to write a book.” Her suggestion took me aback, as I couldn’t imagine what I would possibly want to write a book about. I’m happy she planted that bug in my brain. Special thanks to Holly Williams for coaching me through the book writing process and keeping me from feeling overwhelmed. Without her, I might still be trying to get started. Thanks also to authors Martin Impey, Rick Swegan, W. David Woods, Francis French, Colin Burgess, and Susan Roy for their encouragement and sage advice during the writing and editing process. Their books have places of honor on my shelves. I appreciate the support provided by Emily Carney, Rebecca McWhirter, and other members of the Facebook “Space Hipsters” group. Thanks also to Maury Solomon and Nora Rawn at Springer for their excellent advice and patience with a new writer navigating the publication process for the first time.

And of course, I am grateful to my wife, Jane Gwyn Ward, for letting me cover every flat surface in the house inches deep in technical manuals, flow charts, and photos. She never doubted that I needed to write this book. She gave me complete freedom to pursue it, without question or complaint, even agreeing that I put aside any income-producing work for a year while I researched and wrote. She took many trips to the Space Coast in Florida when she could have asked to go some place more fun. After listening to so many stories about 1960s technology, she suggested that this book be subtitled, “How Cavemen Went to the Moon.”

Many thanks to you, dear reader, for your curiosity about Kennedy Space Center during the glory years of Apollo and Saturn. Everyone I interviewed was deeply grateful that there are still people who are interested in the Apollo era and what went on behind the scenes at KSC. You honor them and their legacy when you read this book. I hope that my writing conveys some of the thrill I experienced in hearing their stories, and in reliving the excitement of the inexorable progression of a countdown to the launch of a mighty Saturn V.



*This book is dedicated to Norm Carlson (1934–2015), NASA Launch Vehicle Test Conductor for Apollo 11, and to the nearly 24,000 men and women of Kennedy Space Center who assembled, tested, and launched America's Apollo missions.*





## About the Author

American author Jonathan Ward spent several years of his childhood in Japan, but he considers the Virginia suburbs of Washington, D. C., to be his hometown. Although he has a wide variety of interests and has worked in many fields, space exploration is his lifelong passion. His joy of bringing the space program to life for the general public began in high school, when he served as a volunteer tour guide at the National Air and Space Museum during the Apollo 15 and 16 missions. He continues his public outreach today, as a Solar System Ambassador for the Jet Propulsion Laboratory, as a frequent speaker on space exploration topics to interest groups and at regional conferences, and as an author for Springer-Praxis. Jonathan is also a frequent contributor to online space exploration forums.

Jonathan brings a unique perspective to his writing that marries a systems view of the topic, fascination with the technology, passion for space exploration, and deep respect for the people who make it all happen. He holds an MS in Systems Management from the University of Denver and a BS in Psychology from Virginia Commonwealth University. He is professionally certified as an executive coach by the International Coach Federation and serves on the adjunct faculty at the Center for Creative Leadership. His professional experience includes extensive work with leadership teams and several years with Boeing on the Space Station Freedom program.

Jonathan and his wife Jane now reside in Greensboro, North Carolina. He is fiercely proud of his two grown children and their families, and he wishes they lived closer to him. He maintains a web site at [www.apollo-saturn.com](http://www.apollo-saturn.com) to document his research on the Apollo era at Kennedy Space Center. He collects and restores artifacts from the Apollo era, including several control panels from the Firing Rooms. Jonathan also notes that he might possibly be the only current space author who has appeared on two GRAMMY-winning albums, which were recorded during his years as a Bass II section leader, soloist, and eventually president of The Washington Chorus.



## Foreword

Jonathan Ward approached me in the summer of 2013 with the idea of telling the story of early human spaceflight from the point of view of the launch processing team at the Kennedy Space Center. No one had ever put together a detailed description of what it actually took to get the Apollo spacecraft, along with its rockets and facilities, ready for launch, so I immediately encouraged him. There are many books written by astronauts, members of the flight team in Houston, and others that characterize the adventures and challenges experienced by those involved in the missions. But the stories of those who made these missions possible by preparing for launch are equally interesting. What Jonathan proposed, and has accomplished, is different than the other early human spaceflight era books. With this book, the Kennedy Space Center is getting its “day in the sun.”

During Apollo, KSC resembled a city with scores of factory buildings. More than 20,000 workers were busy around the clock. There was activity 7 days a week and heavy rush hour traffic. It was called KSC, the Rocket Ranch, Moonport, or just the Cape. For the workforce, long days and nights were the norm. We ate in cafeterias, snack bars, from vending machines, or at mobile canteens we referred to as “the roach coach.” We didn’t have the attitude that our work was just a job. We knew what we did was important. We were on a mission to get our astronauts into space and back home safely. High quality was essential, and discipline was required.

I remember the first time I entered the blockhouse at pad 19 on the Cape for a Gemini test. I stood speechless taking in the scene: Dozens of people sat at cramped consoles that featured meters, red, green, and yellow lights, ink pen recorders, and tape decks. The test conductor gruffly told me to sit down and put my headset on. I quickly learned that these guys (we were all guys then—only a few women were in test operations) ruled the blockhouse and control room operations. They demanded discipline, as did their bosses. Discipline was not much of an issue, as most of the guys had served time in the military, and we knew what discipline was.

For those of us in spacecraft operations during early Gemini, our administrative home was hangar S, on Cape Canaveral Air Force Station. The Mission Control Center was also on the Cape. Organizationally, we were part of the Manned Spacecraft Center, in Houston,

Texas. After the Manned Spacecraft Operations Building, now called the Neil Armstrong Operations and Checkout (O&C) Building, was completed on Merritt Island, we moved there and became employees of KSC's spacecraft operations directorate.

My first assignment as a journeyman NASA systems engineer was to oversee the astronauts' biomedical instrumentation on the first manned Gemini mission. I was a member of a team that included the astronauts, spacesuit and medical equipment engineers, technicians, and flight surgeons. It was great way to start my career. It reinforced what management told newcomers: "Your work is all about the crew and their mission." I still remember the emotions of my first manned launch as a member of the team. I was outside in the fallback area with the launch scrub recovery team personnel, and I had a great view of the Gemini 3 launch. I didn't know then that I would be a member of the launch team for approximately 100 more human missions. But I seldom got such a good view of a human launch event again until after I retired and became a spectator.

For Apollo, the O&C Building was the administrative home for NASA spacecraft personnel and our contractors—Grumman for the lunar module, and North American Rockwell for the command and service modules. It was also the factory for final assembly and checkout of the spacecraft. Similarly, the Vehicle Assembly Building and Launch Control Center area provided the administrative home and factory for NASA and contractor launch vehicle operations teams.

In the O&C, our offices were bullpens, with dozens of people in the same room. Four desks were pushed together so we could share just two phones. The bosses had partitions. The O&C high bay always had at least one mission's spacecraft in process, sometimes two. Each mission required two spacecraft with two major elements each. The lunar module's ascent and descent stages for the lunar landing were paired with a command module and service module for the trip to lunar orbit and return.

Our test control rooms were on the third floor of the O&C, a few steps from the astronaut quarters. This is where all the KSC spacecraft test operations were managed. With the spacecraft team concentrated in one building, we benefited from closeness. Communication was good, and management presence was continuous.

The downside was we saw little of our launch vehicle operations teammates. Their activity was mostly in the Launch Control Center, in the area where the Vehicle Assembly Building and launch pads 39A and B were. Their challenge was probably even greater than ours. They had the world's largest three-stage rocket to assemble and test. Each stage had different contractors and multiple interfaces with the launch accessories. A lot of them considered our spacecraft as their nose cone.

Our presence there was minimal until the spacecraft was mated to the Saturn V. Then, we could have a small number of attendees for the lengthy integrated scheduling meetings and test briefings. There was no doubt as to who was in charge of this activity. It was Rocco Petrone, launch operations director. His leadership and management style is legendary. He was very visible, involved, and demanding. Although Petrone's office was in the O&C, he spent most of his time attending to the integrated activity in the LCC area. We spacecraft folks were thankful for that.

We did see a lot of the astronauts during our work. Each mission had a prime and backup crew that often participated in our spacecraft test briefings, and who visited the workers in the control rooms and the other worksites. We enjoyed social events with them

also, notably softball games in the evenings. They had simulators for the lunar module, command and service module, and lunar rover here that were connected to Mission Control in Houston. They spent a lot of time training here, and all of us, both NASA and contractors, felt we knew them.

Accordingly, we all were very concerned when the *Apollo 13* event occurred. During the *Apollo 13* drama I believed, along with many others on the team, that since the crew had survived the explosion they would return okay. Thanks to the heroics of the flight team and the crew, it turned out that way. I personally learned some lessons from my involvement in that activity which were helpful when I was Shuttle launch director.

Jonathan did extensive interviews and information collection in writing this book. It is an accurate description of what the KSC NASA/contractor team did during the Apollo era. Yet, it is difficult to capture in words how the KSC team members personally dealt with maintaining a balance between their personal and family lives, and the almost 7 year marathon of work during the Apollo era. I believe that the team members had a passion for their work because they knew what they did was important to the country, and that made the successes we all enjoyed possible.

Alan Shepard, after receiving accolades for his space flight accomplishments, commented, “We need to remember the people who made it possible, because so little is said about them.” This book tells what we did. Shepard would have liked that.

February 2015

Bob Sieck  
Gemini Spacecraft Systems Engineer  
Apollo Spacecraft Project Engineer  
Shuttle Launch Director  
Kennedy Space Center



## Preface

I knew that this was a book that needed to be written and a story that deserved to be told. I'm not so vain as to claim that it needed to be written specifically by *me*, but here I am nonetheless.

I like to say that the idea for this book came as a flash of inspiration. In a very real sense, that is true—I had one of those “wake up with an epiphany” experiences that everyone hopes for at least once in their lifetimes. The muse not only sang in my ear; a full chorus and orchestra backed her up. Her song to me would have been useless, however, without my accumulated years of half-formed ideas, good intentions, and enough knowledge to be a little dangerous. Permit me to tell you a little about my background.

I was lucky enough to be born at a time that allowed me to watch America's manned space program from the outset. Two of my earliest memories are of watching Alan Shepard's Mercury/Redstone flight in May 1961 and being taken outside one night to see the Echo I satellite float silently overhead among the stars. I grew up devouring the *Life* magazine accounts of every Gemini and Apollo mission. I made spaceship cockpits out of cardboard boxes. My best friend and I turned the top panel of a washing machine into a starship control console and view screen. I spent many nights outdoors with my telescope.

In the summer of 1971, when I was 14, I finagled a position as a volunteer summer tour guide at the Smithsonian's National Air and Space Museum in Washington, DC. The *Apollo 15* mission flew in late July and early August. For a few days beginning on August 2, while the mission was underway, NASA briefly loaned the museum a full-size working model of the lunar rover. A few of us lucky teenagers drove the rover out of the museum and onto the Mall to demonstrate it for tourists. How many people can claim that they drove a lunar rover before they had even driven a car?

On Thursday, August 5, astronaut Al Worden performed the first deep space EVA as *Apollo 15* was on its way back from the Moon. I went upstairs after lunch to the museum's library, where I knew I could watch the spacewalk on a small portable black and white TV. As I watched alone in the back of the library, the museum's director, *Apollo 11* astronaut Michael Collins, quietly came in and sat down next to me at the table. I was too much



in awe to ask him any questions or even to say anything to him, which was probably just fine with him! The two of us stared at the TV in silence. It was a profoundly moving experience to watch Worden walking in space while I was in the presence of a man who had been to the Moon only 2 years earlier, and who had performed America's third space walk just 3 years before that.

I did not pursue engineering or astronautics as a career, but I never lost my enthusiasm for spaceflight. My first job out of college was two blocks from NASA headquarters. Back in the days when security was lax, I was able to get into the auditorium at NASA HQ to watch the reentry and landing of *Columbia* on the first Space Shuttle mission. Six years later, I worked for Boeing on the Space Station Freedom program. After I left Boeing, I watched the Space Shuttle program with interest as a spectator, grateful that NASA's web sites shared photos that never made it into the popular press.

I became aware of eBay and some of the auction houses in the mid-2000s, and I was surprised to find that there was an active trade in Apollo-era artifacts. I developed a particular interest in Apollo-era access badges and items associated with the Launch Control Center at Kennedy Space Center (KSC). In my eyes, every piece told a story about someone with an interesting role during Apollo. Many of the items came from people selling off a deceased relative's estate. I frequently heard stories such as, "My uncle worked for NASA, but I have no idea what he did, and he didn't leave a diary or memoirs." I mourned the history that was lost with the passing of every space worker.

After I put up a web site highlighting some of my research about the Launch Control Center of the Apollo era, former NASA engineer Frank Bryan began corresponding with me in late 2011 after Frank saw the web site. Frank let me pick his brain about obscure aspects of KSC hardware from the 1960s. Fortunately for me, Frank's memory was amazing. His recollections provided intriguing behind-the-scenes insights into what really went on at KSC during Apollo. The more I learned, the more I wanted to know.

About a year later, I met NASA flight director Glynn Lunney and flight controller Jerry Bostick, both of whom were in the thick of the action in Houston's Mission Control Center. Glynn inspired and pushed his Apollo-era flight controller colleagues to tell their personal stories in the excellent collection, "From The Trench of Mission Control to the Craters of The Moon: Stories from the Men of Mission Control's Flight Dynamics Group: 'The Trench'." I told Glynn and Jerry that I was interested in trying to kick-start a similar process for people who worked at Kennedy Space Center. Their sage advice was that, while it was a great idea, it would be difficult for an outsider to run the process. It would have to be facilitated from someone inside the group.

Frank concurred with their assessment, as did Bob Sieck, an Apollo project engineer who went on to become the longest-running Space Shuttle launch director. They said that the old hands from KSC are much more comfortable swapping stories with each other at their monthly breakfasts or lunches than they are talking to people from outside the program. Most of the men are distrustful of people who introduce themselves as being interested in space history, but then subsequently turn the conversation toward offers to buy memorabilia. The fastest way to get the door slammed in your face by many Apollo/Saturn workers is to ask them if they want to sell their priceless mementos.

The people of the Apollo era at KSC have long felt forgotten by the public. Although they would not use these words, they seem somewhat envious and frustrated that Houston

and the astronauts stood in the spotlight during the Apollo era. They wish their own accomplishments had received more public recognition. At the same time, they are reluctant either to brag about themselves to an outsider or to spend the time writing down their recollections. Without being willing to crow a little about one's own achievements, the lack of recognition becomes a self-fulfilling prophecy. You are upset that no one tells your story, yet you will not tell it yourself or trust someone else to do it for you.

I could not give up. I was sure that the story of the Apollo/Saturn era at Kennedy Space Center needed to be told in some way. The 1970s classic "Moonport" was a wealth of information about building the facilities at Launch Complex 39, but it seemed to be lacking something. I just couldn't put my finger on it.

So, back to the muse that sang into my ear: I was on vacation at the beach. My light summer reading included David Woods' excellent book, "How Apollo Flew to the Moon," and my dog-eared copy of "Moonport." On the morning of July 30, 2013, I awoke with a start. I had a crystal-clear vision for what was missing from the KSC story and how to structure a book of my own. The answer was a combination of a systems view of the work—how all the pieces and processes fit together—combined with a more intimate view of what it was actually like to work on the Apollo spacecraft and the Saturn V launch vehicle every day. I would follow the workflow for a mission from the time the stages of the rocket and spacecraft arrived on the dock at KSC, through the assembly and test process, rollout to the pad, and finally countdown and launch.

Armed with this idea, I asked Bob and Frank for their opinions. They both thought it was an interesting and workable approach. Then I asked if they would be willing to introduce me to some of their colleagues so I could start filling in the blanks. The snowball began rolling. Every interview ended with the person saying, "Let me put you in touch with..." Before long, I could barely keep up with all the accumulated information and the interview schedule.

As people thought about potential interviewees for the project, it seemed that far too often they realized, "Oh, he's got Alzheimer's now," or "He passed away last year." Most of the people I interviewed were in their late 70s or early 80s, some as old as 94. Time is not anyone's friend at this age.

If time was my worst enemy, it was also a great motivator. The men and women who worked on Apollo lived under the constant pressure of a deadline to meet a bold vision. I also felt an overpowering need to move ahead at full speed on this project. The richness of the experience of these people is forever lost as they slip away. I moved quickly on this project, not just because I wanted to capture what information I could from these remarkable men and women. As I got to know these folks better, it became blindingly obvious that they and their achievements at Kennedy Space Center deserved to be remembered, shared, and celebrated much more widely. I want the people of Apollo and Saturn at KSC to see this book come to fruition, to let them know that their story is finally being told to a broader audience.

My objectives were to put as much information into the book as possible, while keeping the detail at a manageable level, so that it all fit it all into one book. They turned out to be mutually exclusive goals.

After reading my first manuscript, my wise editor at Springer advised me that a book over 700 pages long would prove too daunting for most people. She suggested that there

were actually two books trying to emerge from this material. I resisted that notion at first, but she was correct.

This book and its companion (“Rocket Ranch: The Nuts and Bolts of the Apollo Moon Program at Kennedy Space Center”) have distinct and complementary topic areas and viewpoints. Each can be read on its own, but my hope is that you will find that both of them together tell a compelling story. Read this book to learn how the workers at KSC prepared the Apollo missions, from loading dock to launch. “Rocket Ranch” will give you more depth on the amazing facilities and technology at KSC and what it was like to work in such extraordinary circumstances in the 1960s.

I read more than 1,200 source documents and conducted over 300 hours of interviews with more than 70 people to prepare for writing this book. I know that I have only scratched the surface. I’m very happy with the results, and I hope you will be, too. It was the most fun I’ve had in a long, long time. I can also truthfully say that I feel this work is the culmination of my lifelong passion.

While there are nearly 300 photos and diagrams in this book, I left many out because their details would be lost by shrinking them down to book size. My web site ([www.apollo-saturn.com](http://www.apollo-saturn.com)) contains supplementary information to accompany this book, and it will be kept up to date. There will also be a place to post errata and corrections for this book. Please visit the site and check back often!

So, that’s the story of how this book came to be. I hope you will enjoy reading it, and that you will celebrate the incredible people who gave their all to send men to the Moon.

Greensboro, NC

Jonathan H. Ward

# 1

## Introduction

We live at a time when people appear to be less conscious of manned spaceflight than any period in the past 50 years. Humans have maintained a continuous presence onboard the International Space Station since November 2, 2000, and yet few people are even aware that there *is* an International Space Station. In the minds of the youngest generations, spaceflight is more likely to be the realm of science fiction or distant history. The Apollo era seems an impossibly long time ago to many people. Indeed, nearly two-thirds of the current population was born in the years after men last walked on the Moon. Is it any wonder that many people dismiss the possibility that we could have even gone to the Moon?

And yet, America *did* send 24 astronauts to the Moon on 9 missions in the late 1960s and early 1970s. We did it when computers were the size of rooms, when there were few communications satellites, there was no Internet, and there were still plenty of people alive who were around when the *airplane* was invented. A mere 34 years after Charles Lindbergh made the first solo transatlantic airplane flight, President Kennedy issued the May 25, 1961 challenge to land a man on the Moon and return him safely to the Earth. The Apollo program was conceived, the facilities were designed and built, three generations of spacecraft were tested in flight, and men landed on the Moon, all within the space of less than a decade.

### HOW WAS THAT EVEN REMOTELY POSSIBLE?

The Moon landing program was a massive effort to prove the superiority of the American way of life over that of the Soviet Union. The US needed to show the world that it could mobilize its best minds and its best workers to achieve a very difficult but peaceful objective. One consequence of that campaign was that the US government and NASA made sure that every aspect of the Apollo program was conducted openly and thoroughly documented for the whole world to see. Many dedicated individuals have been working over the past two decades to scan, preserve, and make publicly available the priceless records from the Apollo program.

Skeptics doubt it could possibly have happened, but the documentation clearly shows that landing on the Moon was achievable with 1960s technology, because it was a scientific and engineering challenge that could be broken into manageable pieces.

## 2 Introduction

Apollo technology was the culmination of the 60 previous years of development, the age when we conquered the skies. We learned how to propel airplanes through the air and how to shoot rockets into place in the first six decades of the twentieth century. Apollo was the capstone of the work in which scientists and engineers had already been engaged for many years. With lots of money available and disciplined, tenacious chipping away at the obstacles, there was no magic involved, no need for special effects.

The program achieved its political goal of demonstrating what a free society is capable of doing if it sets a lofty vision, commits to and funds a long-term plan, and then lets the experts work the challenges without political interference. Shared purpose, adequate funding, disciplined management of the program, dedication of workers at every level, brainpower, willingness to take risks, communication, and hard work—those were the factors that made the Moon landing possible.

### WHY A BOOK ABOUT KENNEDY SPACE CENTER?

Those of us who were fortunate enough to be alive in the 1960s watched Apollo on our new television sets. We read about the program every day in newspapers, and we looked forward to the latest copy of *Life* magazine and its glossy photos of the latest space mission.

Nearly 50 years later, what do most of us remember about the Apollo program? First and foremost in the memories of the public at large and space historians in general are the astronauts and what they did on their missions. I would speculate that *Apollo 11* is remembered for being the first landing, and *Apollo 13*, “Houston, we’ve had a problem.” The general public is much less clear about what went on in the other missions.

Because of the movie *Apollo 13*, Mission Control in Houston is probably the next best remembered part of the Apollo program. Mission Control rightly shared the spotlight with the astronauts during the performance of missions, as they kept the spacecraft and astronauts safe and successfully solved a myriad of problems as they cropped up.

Kennedy Space Center was the place where the rockets were launched. However, I am surprised at the number of people I meet who believe that Mission Control and Kennedy Space Center were the same thing. What went on at Kennedy Space Center before the launch of the mighty Saturn V rocket is beyond most people’s recollection. They may have seen photos of the rocket being assembled inside the Vehicle Assembly Building or being wheeled out to the launch pad, but how or why or when any of this happened is unclear.

What actually *did* go on at Kennedy Space Center? What was the day-to-day workflow? How did technicians and engineers assemble and test the spacecraft? Who did what? Why did it take so long? Why so many tests? What was it like to work at the launch pad on a Saturn V? What went on in the launch control center during a countdown?

More than 400,000 people across the United States worked on the Apollo program. The Apollo spacecraft and the Saturn rockets took shape from thousands of parts in plants in Louisiana, California, Alabama, and New York. Six months before the scheduled launch date, all the stages, modules, equipment, spacesuits, rock boxes, experiments, and everything else that was going into space, began to arrive at Kennedy Space Center. KSC was where it all came together—where 24,000 men and women assembled, tested, and

launched the most sophisticated manmade object of its time, and its brave crew of three astronauts, on a journey to the Moon. During the hectic years of 1968 and 1969, all of this activity was going on for three missions at a time.

This book tells the story of the hive of activity at Kennedy Space Center in those final 6 months of a Saturn rocket and Apollo spacecraft's life on Earth—how workers performed the final assembly and test on the vehicles for Apollo/Saturn, stacked them into a rocket, ran through all the tests on the launch pad, and then blasted the Saturn V on its way to the Moon.

## HOW THIS BOOK IS ORGANIZED

This book's scope is the operations at Kennedy Space Center that prepared *Apollo 11* for launch. The organizing principle is the processing flow of the hardware through KSC, from when the stages and modules first showed up at the loading dock, through assembly and test, and culminating in launch. The KSC processing flow was essentially the same for all Apollo lunar missions. At appropriate times in the description of the *Apollo 11* flow, we will bring in discussions of interesting—and often frightening—mishaps that occurred during the workflow on other missions.

Rather than trying to re-tell what has been better told elsewhere, we will concentrate on the story that has not been told as often—the behind-the-scenes processing flow at KSC. Throughout this book, you will find first-hand accounts of the challenges and dilemmas faced by KSC workers preparing the Apollo missions. Was one of *Apollo 11*'s Saturn V stages sabotaged? How could last-minute changes to *Eagle*'s landing gear be made and tested while it was at the launch pad? What caused security cars to explode near the launch pad on *Apollo 13*? How did the launch of *Skylab 2* almost end in disaster, without anyone even knowing that it was in danger?

The book has four primary sections:

In Chaps. 2 and 3, we will describe the processes for controlling the work. These are the management practices that made order out of chaos and assured that the Apollo/Saturn hardware was as reliable as possible. We will examine the challenges of managing and coordinating 24,000 people working on three simultaneous missions, and the processes for controlling the configuration and changes to the flight hardware. We will also look at one of the most important innovations in the Apollo/Saturn era—computerization in the test and checkout process.

Chapters 4 through 6 tell the story of the first 4 months of *Apollo 11*'s life at KSC. We will follow the assembly and testing of the spacecraft and the Saturn V, with photos of every aspect of the process and first-hand accounts from the people who made it happen. First, we look at the processing flows for the command/service module and the lunar module in the altitude chambers of the Manned Spacecraft Operations Building. We will then follow the stacking and testing of the Saturn V in the Vehicle Assembly Building. After the spacecraft and the Saturn V come together to form the *space vehicle*, we will witness the final tests in the VAB and prepare for rollout.