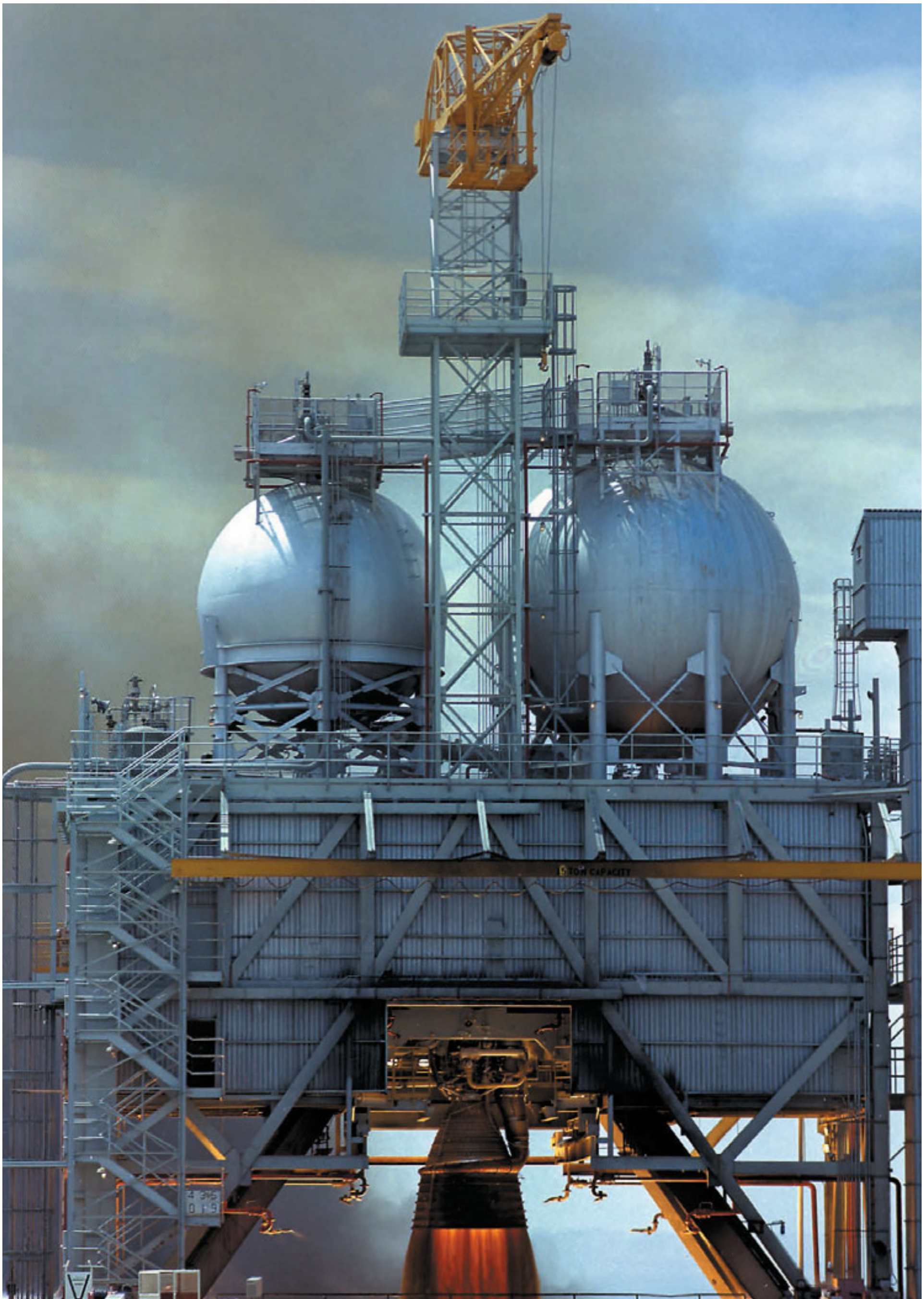
The Saturn V F-1 Engine

Powering Apollo into History


TON CAPACITY

Anthony Young

The Saturn V F-1 Engine

Powering Apollo into History

Springer

Published in association with
Praxis Publishing
Chichester, UK

PRAXIS

Anthony Young
Space Historian
Miami
Florida
USA

SPRINGER–PRAXIS BOOKS IN SPACE EXPLORATION
SUBJECT *ADVISORY EDITOR*: John Mason B.Sc., M.Sc., Ph.D.

ISBN 978-0-387-09629-2 Springer Berlin Heidelberg New York

Springer is part of Springer-Science + Business Media (springer.com)

Library of Congress Control Number: 2008930113

Printed in Germany

Cover design: Jim Wilkie
Editor: David M. Harland
Typesetting: Originator Publishing Services, Gt Yarmouth, Norfolk, UK

Printed on acid-free paper

Contents

Illustrations

Color section

Foreword

Power to boost the mighty Apollo and Skylab Saturn V launch vehicles required designing and developing a liquid propellant rocket engine with nearly four times the thrust of any rocket engine then in service in the free world. This new high thrust engine, designated the F-1, began design in 1958 and subsequently boosted 13 Saturn V launch vehicles with 100 percent reliability through 1973.

Anthony Young has captured the story of the F-1 engine design and development, through extensive documentation research and interviews with people still available, to provide the history of the F-1. Anthony not only presents the story of the F-1, but also much insight into early NASA and contractors' moon-landing launch vehicle trade studies. His story also includes a description of the role of NASA F-1 Project Management, Boeing S-IC stage development, and Saturn V launch vehicle stacking and processing. Of course, no F-1 story would be complete without coverage of the next generation F-1, the F-1A, which was in test with its 1.8 million lbs of sea level thrust before the Saturn V program was cancelled.

The F-1 story had its roots in the 1940's and 1950's as America developed missile and space launch vehicle systems. Power increased as well until the Rocketdyne E-1 engine system reached 400,000 lbs of sea level thrust. In the late 1950's, before NASA was formed, the Air Force and Rocketdyne engaged in studies to answer the question "What would be the maximum thrust of a rocket engine that would ever be required?" The study answer identified a thrust level of 1,000,000 lbs of sea level thrust. With this target thrust level, the Air Force gave Rocketdyne the go ahead and provided modest funding for design, production and testing of a 1,000,000 lb thrust solid wall thrust chamber. In keeping with the alphanumeric designation system it had established, Rocketdyne identified the 1,000,000 lb thrust engine as the F-1.

Concurrent with the time of the Air Force contract, the U.S. Congress established a civilian space agency and, on October 1, 1958, NASA came into being. Almost immediately the F-1 rocket engine tasks were transferred from the Air Force to NASA in keeping with the agency's charter. The target thrust had increased to 1.5 million lbs along the way. Development continued on the solid wall chamber, and, as the thrust chamber testing began, high noise levels rumbled across the mountains at the Santa Susana Field Laboratory such that the name 'King Kong' was used to describe the system.

During design and development of the F-1, the many challenges were met by a very determined and skilled workforce. Combustion instability, turbopump LOX pump failures, and minor problems like small cracks, erosion and leaks, had to be overcome. Just the very size of the F-1 engine required a lot of technical skills and equipment to handle, transport, and protect it during production, test and launch. The furnace brazing of the thrust chamber coolant tubes, nozzle extension (skirt) design, handling, and installation, and the thermal insulation system to protect the engine during launch and flight, all required many engineering innovations.

F-1 production was at Rocketdyne's Canoga Park facility, and engine level testing was primarily conducted at the Edwards Field Laboratory. Initially, three test stands were constructed there, but as testing increased three more stands were announced by NASA in 1962.

Rocketdyne assigned and relocated me with my family to MSFC as a participant in the early F-1 engine integration into the S-IC stage and its subsequent testing. Many exciting achievements were accomplished there over the next three years by the NASA, Boeing and Rocketdyne team. There were a lot of modification upgrades (approximately fifty) that had been identified during development at Rocketdyne. These could not be installed during the production process before engine delivery, and had to be installed in the initial test and flight engines after delivery to MSFC. Modifications such as welding studs onto the thrust chambers for attachment of the thermal insulation, and welding gussets on the thrust chamber for strengthening the support of the 'thrust-OK' pressure switches, were required. These were installed by Rocketdyne Traveling Production Teams. Other modifications like transducer and harness changes were accomplished by NASA technicians with Rocketdyne Field Engineering technical support, or by the single Rocketdyne technician assigned to MSFC. Rocktedyne also operated a large modification kit and support hardware warehouse at MSFC for NASA that we were all proud of, and that contributed to the processing success of the F-1 engines at MSFC.

On the S-IC-T test vehicle, the F-1 engines were installed vertically into the stage with the stage installed in the test stand. The first three tests of the S-IC-T were of the center engine only. The first two tests were premature cutoffs, with the first inadvertently cutoff by an observer and the second due to a broken wire in a safety circuit. The third test successful ran for approximately the programmed 15 seconds. The next test, conducted on April 16, 1965, was with all five engines running for the programmed duration of approximately seven seconds. The five F-1 engine cluster with a thrust of over 7.5 million lbs shook all of north Alabama when fired. What a thrill to watch and feel. I don't recall the actual distance, but the control center at MSFC in the Test Division seemed quite close to the test stand, and one got a good feel for the power during an F-1 engine cluster test. Communications then were not as electronically networked as they are today, and I had the thrill of relaying by telephone the countdown and the initial test firings from the control center to a room full of F-1 executives and engineers at Rocketdyne, Canoga Park.

The overall success of the F-1 program resulted from a strong team effort by NASA and Rocketdyne Program/Project Management, Engineering, Quality, Procurement, Production, Test and Launch Personnel. The F-1 engines remaining after completion of the Apollo and Skylab programs can be found today mounted on S-ICs at the U.S. Space & Rocket Center, Alabama, the Kennedy Space Center, Florida, and the Michoud Assembly Facility, Louisiana, and as standalone displays in several museums throughout the U.S. and some foreign countries. An F-1 engine stands proudly in front of the Rocketdyne (now Pratt & Whitney Rocketdyne) plant in Canoga Park, California. The engine was placed there on the tenth anniversary of the Apollo 11 lunar landing as a tribute to the men and women who designed and developed it.

Vincent J. Wheelock
Rocketdyne Director (retired)
Field Engineering & Logistics

Author's preface

One of the most powerful machines ever conceived and built was Rocketdyne's F-1 engine. It had a dubious start—proposed for a rocket that did not exist, for a mission that was not defined. Nevertheless, the company began studies on a 1 million pound thrust rocket engine for the Air Force in the 1950s. When it took over the contract, NASA increased the thrust requirement to 1.5 million pounds. This was fortuitous, as it was instrumental in enabling America to achieve President Kennedy's challenge of landing astronauts on the Moon and returning them safely to Earth within the decade of the 1960s.

After completing *Lunar and Planetary Rovers: The Wheels of Apollo and the Quest for Mars* for Springer–Praxis, I pondered which subject relating to the Apollo program I could write about next. No book had been written on the Rocketdyne F-1 engine that powered the first stage of the Saturn V launch vehicle. I knew the story of this engine's development would involve human interest as well as engineering. I was mystified as to why no one had yet written a history of this superb engine with a 100 percent success record in flight. I decided to take up this challenge. Sadly, the passage of decades since the end of the F-1 engine program has taken its toll on the roster of men who worked on it at Rocketdyne and the Marshall Space Flight Center. Two key individuals whom I would have particularly liked to interview were David Aldrich, Rocketdyne F-1 Engine Program Manager, and his deputy, Dominic Sanchini, but both had passed away some years ago. I had hoped to interview Leland Belew, who managed the engine programs at MSFC, but owing to his age he was unavailable. There were others, both at Rocketdyne and NASA, whom I could not interview. As a result, this book is an imperfect history of the F-1 engine. However, there were sufficient engineers and managers both at Rocketdyne and NASA able to speak, and they provided information and materials that helped to fill the gaps.

While establishing the content for this book, I realized that the F-1 engine and the S-IC stage it powered were an integral system. I therefore chose to include chapters about the S-IC and to discuss the overall Apollo program management.

This actually helped to properly round out the F-1 engine program. If I had not done so, I am sure that I would have received queries from readers asking why I had not covered these subjects.

With the advent of solid rocket motor technology for the Titan rocket and Space Shuttle, and their forthcoming use by the Ares launch vehicles of the Constellation program, it is unlikely that a liquid propellant rocket engine of the size and power of the Rocketdyne F-1 will again see service—it will remain one of the greatest engineering achievements of the 20th century.

Anthony Young
May 2008

Acknowledgements

Early in this project, I was fortunate to get the generous help of Rocketdyne veteran Vince Wheelock. He offered suggestions on chapter structure, volunteered to ferret out information from Rocketdyne's archives, gave me priceless documentation on the F-1 engine program (including rare articles, brochures, press releases and other information) and, above all, many of the photographs included in this book. His wife Gail assisted him in scanning the photos and putting them on CD for me to use. Mr. Wheelock also reviewed the chapters specific to the F-1 engine. He put me in touch with Rocketdyne engineers, some retired and others still active, most notably Ted Benham and Bob Biggs, as well as those with whom he worked while at the Marshall Space Flight Center. I am indebted to Mr. Wheelock for his tireless help in recording the history of the F-1 engine.

I found other Rocketdyne engineers by following threads on the internet. One of those was Dan Brevik, who shared with me at length some of the inner workings at Rocketdyne during the F-1 program. Another was Ernie Barrett, who worked to set up the test stands at the Propulsion Field Laboratory, later called the Santa Susana Field Laboratory.

My visit to Huntsville, Alabama in April 2007 was very fruitful. Archivist Anne Coleman at the M. Louis Salmon Library of the University of Alabama in Huntsville helped immensely by directing me to MSFC documentation on the F-1 program and Boeing S-IC stage. Mike Wright at the MSFC History Office helped me to retrieve some very rare F-1 engine documentation and photographs that I could find nowhere else. My interviews in Huntsville were also very productive. In particular Saverio "Sonny" Morea, F-1 Engine Project Manager at MSFC; his deputy, Frank Stewart; and Richard Brown and Ron Bledsoe, who worked in the Engine Program Office; Konrad Dannenberg of the Technical Liaison Office; and Bill Sneed, who worked in the Saturn V Program Office.

Heinz-Hermann Koelle was an instrumental member of Dr. Wernher von Braun's team in Huntsville from the late 1950s until 1965 as Chief of Preliminary

Design for the Army Ballistic Missile Agency, and subsequently Director of the Future Projects Office at MSFC reporting directly to Dr. von Braun. Prof. Koelle reviewed the first two chapters of this book, and his comments were most helpful.

I had the very good fortune to learn about Harold C. Hall, who worked in the Engine Program Office during the 1960s, during which time he compiled binders of photographs and photo descriptions routinely sent to the F-1 Engine Program Office at MSFC to record progress with the engine's development. Hall had organized this material by year for the entire life of the program at MSFC. These binders had been in storage for 40 years until I visited Mr. Hall in Huntsville. He generously loaned them to me in order that I could scan some of the photos for this book.

Shelly Kelly, the University Archivist at the Neumann Library of the University of Houston at Clear Lake in Houston, Texas, was of immense help. Ms. Kelly pulled all the relevant taped interview transcripts conducted by Roger Bilstein for his book, *Stages to Saturn*. Bilstein rarely used quoted passages from these interviews. I found a wealth of information in the transcripts relating to the F-1 engine and S-IC stage, and have made use of it with appropriate annotation.

Fellow author Dr. David M. Harland edited the manuscript for Praxis, for which I am most grateful.

Introduction

As the train made its way southwest across Texas, Dr. Wernher von Braun occasionally looked out the window in curiosity. The flatlands were totally unlike the landscape of Germany and Bavaria that he had left behind some months earlier. The saga of how he led many of the engineers, technicians and scientists of his team from Peenemünde to surrender to the U.S. Army's 44th Division in the final days of the war in Europe as part of Operation Overcast would be recalled in future books and articles. For now, however, he and the others were part of a top secret program, now codenamed Operation Paperclip, to tap their collective technical genius and apply it to American rocketry.

With von Braun was Maj. James P. Hamill of the Office Chief of Ordnance, Sub-Office, Rocket, and Capt. William E. Winterstein, Commanding Officer of the 9330 Ordnance Technical Service Unit, Sub-Office, Rocket. Hamill had been charged by Col. Holger Toftoy, Chief of Army Ordnance Technical Intelligence, to transfer the first wave of these Germans safely from Europe to Ft. Bliss, Texas, along with V-2 components, machine tools, instruments and documentation. Von Braun's team were a scientific and engineering treasure trove, and Toftoy wished to ensure their identity, the work they had performed on Germany's rocket programs, and their new duties in the U.S., remained absolutely secret. It was Hamill's job to prevent information 'leaks' and to make sure that none of the Germans went missing in transit. Because anti-German sentiment in America was understandably high as a result of the war, von Braun passed himself off as being Swiss, and his colleagues took on a variety of nationalities and occupational aliases. Their families had been temporarily housed in Landshut, Germany, and if all went well they would be shipped over toward the end of 1946. At Ft. Bliss the underutilized William Beaumont Army Hospital Annex was to be converted into living quarters for the families. In fact, the Operation Paperclip Germans were under contract to the U.S. Government for a period of six months. If after this time a contract was not extended, the man would be returned to Germany. Von Braun doubted that he would be sent back to Germany, however.

At the close of World War II, Operation Paperclip secretly brought many Germans who had worked on the V-2 to America to work on American missile and rocket development, and eventually the Saturn V. Front row, fourth from the left is Dr. Arthur Rudolph. Front row, seventh from the right is Dr. Wernher von Braun. (White Sands Missile Range)

His country had been ravaged by war, many of its cities were in ruins, and its infrastructure was decimated; to rebuild it would take years, with all the shortages that this would entail. He felt his prospects were better in America, and he looked forward to having his sweetheart Maria von Quistorp join him in order that they could be married.

Von Braun was a rocket engineer first and foremost. At Peenemünde on the north coast of Germany his team had worked to design, test and build the A-4/V-2 rocket. Although it was made clear that his task now was to advance American missiles, he explained to anyone who would listen that it would be possible to use rockets to explore 'outer space'. When the train halted in El Paso that October day in 1945, he disembarked and stood with Maj. Hamill, and the others congregated to await their transport to Ft. Bliss. In order not to draw undue attention, the team of 120 men was traveling in small groups, and this was the first. It included Dr. Walter Dornberger, Dr. Kurt Debus and Dr. Eberhard Rees, who would all go on to profoundly influence America's future in space exploration. An American concern was that an even larger number of Germans, including specialists in jet propulsion and nuclear physics, had ended up in Russia. This divided German brains' trust would provide the impetus for the United States and the Soviet Union to compete in both the build up of missiles and the exploration of space.

The 9330 Ordnance Technical Unit was responsible for the security, housing and general welfare of the Germans at Ft. Bliss. The initial accommodations were rather spartan, but starting in the fall of 1945 the Germans began taking up residence in the remodeled Beaumont Hospital Annex buildings. The Army Ordnance Department had hired General Electric, aided by the Germans, to assemble, checkout and launch V-2s at the White Sands Proving Grounds in New Mexico, which had been activated on July 13, 1945. It is not true that completed V-2s were shipped from Germany. At the time of the capture of the production facilities at Peenemünde and Nordhausen, many rockets were in various states of assembly. At White Sands, therefore, many crucial components were either in short supply or were completely unavailable. For example, each rocket's guidance system needed two gyroscopes, but only fifty were brought to America. General Electric had no option but to reverse-engineer many of the components, including gyros, servo motors, electrical distribution panels, wiring, propellant piping etc. Every V-2 component from Germany had to be inspected, and either refurbished or replaced. In addition to working with the Americans to prepare and launch V-2s, von Braun began a research and development program to improve the performance of the rocket.

In fact, the U.S. had begun to fund the development of rockets in the mid-1930s, and had progressed far beyond the pioneering experiments of Robert H. Goddard. In 1936 Dr. Theodore von Karman at the California Institute of Technology (CalTech) started work at the Guggenheim Aeronautical Laboratory of the California Institute of Technology (GALCIT) to develop a rocket to 'sound' the upper atmosphere. In July 1939, he formally initiated the Rocket Research Project; the nation's first center devoted to propulsion systems. Their first project was to develop Jet-Assisted Take-Off (JATO) solid rocket motors for aircraft. The first demonstration was performed in July 1941. Liquid propellant JATO rocket motors followed. Von Karman's team

The WAC Corporal was America's first high-altitude 'sounding' rocket. It had a short duration solid propellant booster (visible on the left) and liquid propellant main stage. It was first launched at the White Sands Proving Grounds in New Mexico in 1945. (White Sands Missile Range)

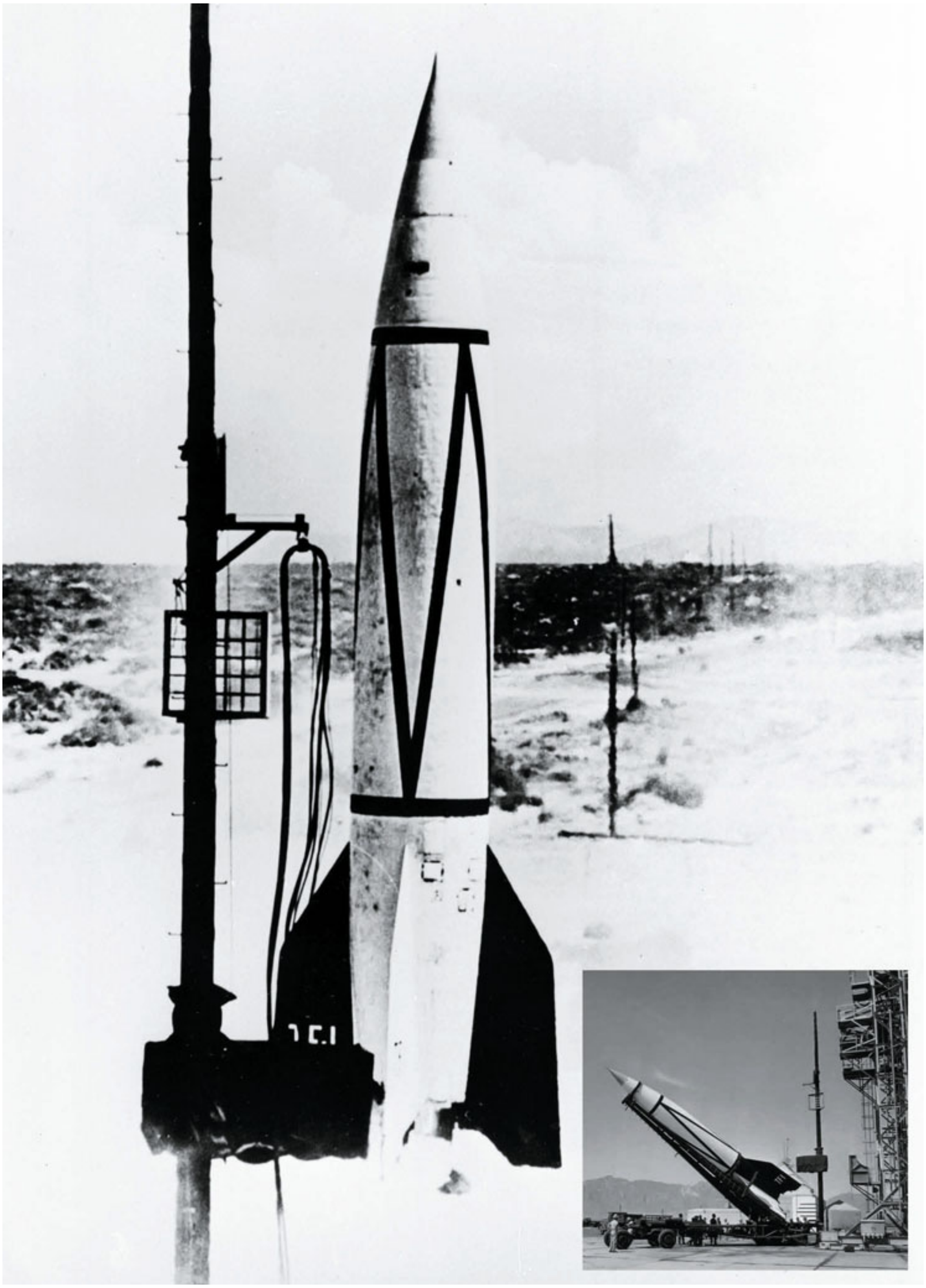
created the Aerojet Engineering Corporation in 1942 to manufacture JATO for the Army. In 1943, the Army Ordnance Department urged CalTech to expand its work in rocket propulsion, and in 1944 Project ORDCIT (Project Ordnance—California Institute of Technology) was begun. In November 1944 the Rocket Research Project was reorganized and renamed the Jet Propulsion Laboratory (JPL). The first rocket

JPL developed was the Private. It was followed by the Corporal, which employed an Aerojet engine that burned a hypergolic mix of alcohol as fuel and fuming nitric acid with aniline as the oxidizer. Development then began on the smaller WAC Corporal. The fact that it was assisted at liftoff by a cluster of small solid rocket motors made it the first two-stage rocket made in the United States. It was to conduct atmospheric research. It had no attitude control system, but used fins for stability. The first fully operational WAC Corporal launch was at White Sands on October 11, 1945, and the rocket achieved an altitude of 70 kilometers.

An interesting development in the fall of 1945 was the assistance and support of the U.S. Navy Bureau of Ordnance at White Sands. The Naval Ordnance Missile Test Center was established there in 1946. The synergy of the two branches of the military with CalTech and von Braun's team accelerated the development of rockets in America. Space is defined as starting at 80 kilometers, and on March 22, 1946 a WAC Corporal attained that altitude. This accomplishment was made against a backdrop of research into high energy rocket fuels, both by JPL and others. In 1945, the Navy's Bureau of Aeronautics had set up the Committee for Evaluating the Feasibility of Space Rocketry. It focused on single-stage-to-orbit research, with hydrogen and oxygen being viewed as the most likely combination of propellants. In their report entitled *Investigation on the Possibility of Establishing a Space Ship in Orbit Above the Earth's Surface* in November 1945, Lt. Cmdr. Otis E. Lancaster and J.R. Moore concluded that although single-stage-to-orbit was impracticable, a multi-stage rocket powered by hydrogen and oxygen could put a satellite into orbit. (History would prove the validity of multi-staging.) JPL evaluated this report, and in July 1946 recommended that Aerojet conduct research and development of such an engine. These pioneering investigations would ultimately lead to the development of the upper stages of the Saturn V.

The U.S. Army Air Force was also interested in exploring rocket research. Donald Douglas, President of the Douglas Aircraft Company, proposed that the Air Force establish a research and development organization for advanced propulsion in aircraft and rockets. The result was the Project RAND brains' trust, created in 1946. On the basis of the largest rocket so far developed, the V-2, it assessed the potential for a variety of propellants and studied the possibility of a satellite. Its report entitled *Preliminary Design of an Experimental World-Circling Space Ship* concluded that a multi-stage rocket powered by liquid oxygen with either hydrogen or alcohol could orbit a payload.

Both the Navy and the Army Air Force (the Air Force would separate from the Army in 1947) were motivated to pursue the rocket research recommended by these reports, but in the immediate post-war environment Congress was unwilling to make available the large amount of money that would be required. Instead, more modest programs involving less exotic propellants would be the order of the day for several years to come. Central to these development missiles and upper atmospheric studies were the Private A, Private F, Corporal, WAC Corporal and the V-2s modified at White Sands—as well as the first two-stage liquid propellant rocket in which a WAC was mounted on top of a V-2 in a configuration known as Bumper WAC. The first V-2 firing at White Sands was a captive, 57-second live-fire test on March 15, 1946.



The V-2 rockets launched from the White Sands Proving Grounds in the late 1940s and early 1950s were built from refurbished and American-made components. (White Sands Missile Range)

Gen. John B. Medaris was the first Commanding General of the U.S. Army Ballistic Missile Agency at the Redstone Arsenal, Alabama. (Redstone Arsenal Historical Information)

Four weeks later, the first V-2 flight abruptly ended after climbing to an altitude of only 5.5 kilometers. However, on May 10 the third rocket achieved an altitude of more than 112 kilometers, with instruments from the Applied Physics Laboratory of Johns Hopkins University to measure cosmic radiation. Thereafter, launches were made two to three times per month. By December 1946, the 17th V-2 reached an altitude of over 186 kilometers.

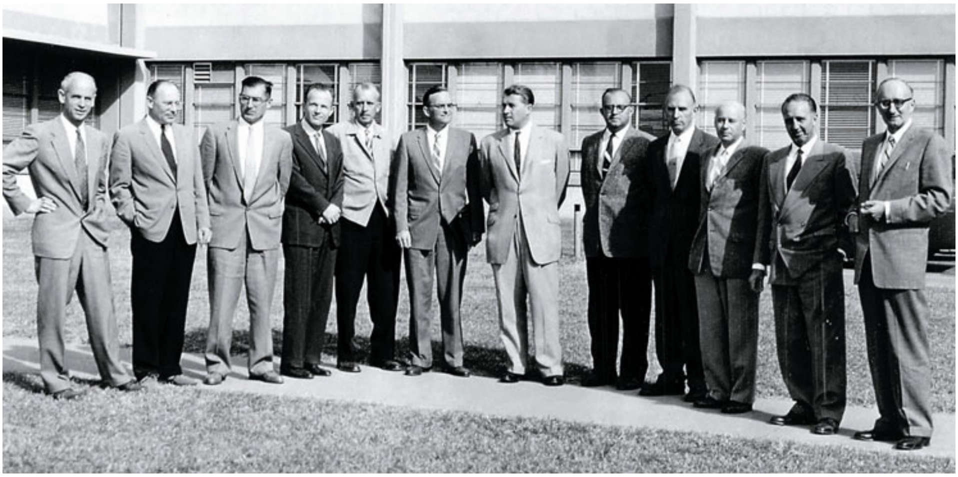
Another pivotal event took place in 1946. Capt. Winterstein had been in contact with von Braun, and many of his team, almost on a daily basis that year. He would occasionally invite von Braun and several members of the team to his home, and his wife would serve a home-cooked meal that was much appreciated. The conversation often centered on space travel, and the possibility of flying to the Moon. During one of these dinners, Winterstein asked von Braun how much money and time would be involved in a program to put a man on the Moon and return him to Earth. Von Braun said that he would make some calculations. A few weeks later, he told Winterstein it would cost $3 billion and take a decade. This timetable would prove prophetically accurate, although the cost was rather optimistic. By this point, Winterstein knew von Braun well, and was aware that the brilliant Germans could serve America well. In particular, he felt that their contributions to America's fledgling rocket program would be vital to national security and technical progress. As Winterstein told this author in 2006:

> I was struck by von Braun's dynamic leadership—the way he talked and acted. He had the charisma of a true leader. I was soon convinced he was something that

> was good for America then, and good for America later. Here was this German rocket team still technically enemy aliens. They fully knew we were going to have problems with Russia, because they knew of the turn over of the V-2 factory [at Nordhausen] to the Russians from the Potsdam Agreement. They were very anxious to get started on missiles for defense, but the Congress said 'No.'
>
> I remember a conversation I had with von Braun one evening in 1946 at the La Hacienda Restaurant south of Las Cruces, New Mexico. He was going to get married in the spring, and he was looking for financial security. He asked me what the outlook was at Ft. Bliss for rocket research, and I told him it was bad news; which was the truth, I didn't lie to him. He said, 'Well, after we get out from under this Army surveillance I am thinking of going to private industry.' I had to agree he could make a lot more money that way, but I said, 'Wernher, if you go to private industry you can kiss your trip to the Moon goodbye. Things will probably turn better later on. If it ever comes around to the point where man goes into space, the Army will be the best place to be. You'll probably be known as the top rocket scientist in America and possibly the world. How about sticking with the Army?'
>
> The way I saw it, the rocket team had to stay together as a team. He listened to me and decided to keep the team together, even though every member of the team that stayed with the Army sacrificed a small fortune, knowing they could have made a lot more money going to private industry.

In 1947, with the combined efforts of Douglas Aircraft, JPL, General Electric and von Braun's team at Ft. Bliss and White Sands, research and development began on the Bumper WAC. In May 1948, Bumper No. 1 was successfully launched, with the dummy second stage achieving separation from its booster. On February 24, 1949 Bumper WAC No. 5 reached the impressive height of 393 kilometers and the WAC attained a maximum speed of 8,867 kilometers per hour.

The German rocket team had spent nearly four years in the New Mexico desert. It had become a metaphor for their technical skills and engineering creativity. But this was about to change. In 1948, the Army's Chief of Ordnance had designated the Redstone Arsenal in Huntsville, Alabama as a center for rocket and missile research and development. Construction was to start in the near future on research and testing facilities and housing. That same year, a public statement by Col. Toftoy had greatly encouraged von Braun. It reminded him of the prophetic advice by Capt. Winterstein two years before. ''It is possible,'' Col. Toftoy stated, ''this generation will see huge rocket ships carrying passengers, that can circle the Moon and return to Earth safely. If work could begin on such a project immediately, and enough money to finance it in the interests of pure science, it could be done and witnessed by persons who are alive today.'' On October 28, 1949, the Secretary of the Army approved the transfer of the Ordnance Research and Development Division, Sub-Office, Rocket, from Ft. Bliss to the Redstone Arsenal, with a change in the name to the Ordnance Guided Missile Center. The transfer would start in April the following year. White Sands Proving Grounds would remain just that, but the majority of the Army's rocket and missile research and development would now take place in Huntsville.



Dr. Wernher von Braun (center) in Huntsville with the directors of the newly formed laboratories at the Marshall Space Flight Center in 1960. From left, Dr. Ernst Stuhlinger, Dr. Helmut Hoelzer, Karl Heimburg, Dr. Ernst Geissler, Erich Neubert, Von Braun, William Mrazek, Hans Hueter, Eberhard Rees, Dr. Kurt Debus, and Hans Maus. (NASA/MSFC)

After the Soviet Union detonated its first atomic bomb in August 1949 and the war in Korea broke out in 1950, the pace of America's development of rockets and missiles accelerated. Although some members of von Braun's team did opt to take professions in private industry, the majority remained and their patience proved out. The early 1950s were marked by the development of new rockets and missiles for the Army that included the Redstone and Jupiter, and by the deployment of the Nike surface to air missile. Meanwhile, the Navy developed its Viking rocket and in 1951 the Air Force began Project MX-1593, which led to the Atlas intercontinental-range ballistic missile.

But the exploration of space was never far from von Braun's mind, and he seized every opportunity to promote its possibilities. In the 1940s and 1950s, the acclaimed space illustrator Chesley Bonestell inspired a generation with the stark beauty of the Moon, the planets and the prospect of space travel. In 1949 Bonestell and engineer-turned-writer Willy Ley collaborated on the book *The Conquest of Space*. It became a bestseller and, by inspiring thousands of young men and women to pursue careers in aerospace, had a major impact on America's future in space. Bonestell's paintings of orbiting space stations, traveling to the Moon and the surfaces of the planets were rendered in such exquisite detail, and the text, which was backed up by hard science that reflected emerging technology, was so believable, that the book instilled a sense of wonder and belief that the exploration of space would indeed be possible within the lifetime of its readers. At the invitation of Cornelius Ryan, editor of the popular *Collier's* magazine, in 1951 Bonestell attended a symposium in San Antonio, Texas on the topic of space flight. There, he met von Braun and other rocket scientists. The March 22, 1952 issue of *Collier's* included an article in which artwork by Bonestell illustrated exposition by von Braun. It was the first of a series. The October 18, 1952 issue featured the cover story *Man on the Moon: Scientists Tell How We Can Land There in Our Lifetime*. To follow up this collaboration, the book *Conquest of the Moon* was published in 1953. It described how bases would be established, and how explorers would travel about on the Moon's surface.

By 1953, von Braun had become Chief, Guided Missile Development Division, Ordnance Missile Laboratory at the Redstone Arsenal. In September 1954 he wrote a proposal called *A Minimum Satellite Vehicle Based Upon Components Available from Missile Development of the Army Ordnance Corps*. No nation on Earth had yet placed a satellite into Earth orbit, but von Braun knew that America could do so, and he recognized the significance of America being the first to achieve this task. In the proposal, he wrote:

> The establishment of a man-made satellite, no matter how humble, e.g. five pounds, would be a scientific achievement of tremendous impact. Since it is a project that could be realized within a few years with rocket and guided missile experience available *now*, it is only logical to assume that other countries could do the same. *It would be a blow to U.S. prestige if we did not do it first*.

His warning was prophetic. America's satellite program came under the auspices of the International Geophysical Year project of the National Academy of Sciences. In the mid-1950s, there was no sense of urgency in the U.S. to launch a satellite by using whichever rocket might be capable of achieving the task, and, as events would prove, this apathy would later cost the nation dearly.

Von Braun eagerly pursued other ways of getting his message across. One outlet was Walt Disney, who made a series of TV shows devoted to space exploration. The first, *Man In Space*, was broadcast on March 9, 1955. *Man and the Moon* aired later in the year. The final of these three memorable programs, *Mars and Beyond*, was in 1957. The estimated audience of about 40 million viewers made von Braun a household name in the U.S.

On February 1, 1956 the Army Ballistic Missile Agency was established at the Redstone Arsenal, with Gen. John B. Medaris in command. The Army Rocket and Guided Missile Center was established at the same time to handle other research and development programs at the Arsenal, with Gen. Toftoy in command. Intelligence was available that the Soviet Union was preparing to launch a satellite. This prospect had always concerned von Braun. He continued to lobby for permission to prepare a satellite, but the fledgling ABMA was rebuffed by Washington. The official U.S. effort to launch a satellite to mark the International Geophysical Year was being run by the Navy, using a multi-stage rocket named Vanguard. Unfortunately, this rocket was complex and its development was behind schedule. In January 1957 the Army's Chief of Research and Development, Lt. Gen. James M. Gavin, sought information from ABMA on the possibility of using the Jupiter-C missile as a satellite launch vehicle. In April ABMA advised Lt. Gen. Gavin that as a backup to the troubled Vanguard program a Jupiter-C could launch a satellite as soon as September 1957. The first launch of a Jupiter-C had been on September 20, 1956 and it had

Dr. von Braun photographed with (from left) Maj. Gen. Holger Toftoy, Dr. Ernst Stuhlinger, Hermann Oberth and Dr. Robert Lusser. (U.S. Army)

boosted a 14 kg payload representing a dummy satellite to a height of 1,100 kilometers while traveling in an arc some 5,300 kilometers across the Atlantic from Cape Canaveral in Florida. However, the Pentagon did not want ABMA in the satellite launching business, and Gen. A.P. O'Meara went to Huntsville to make it absolutely clear that a Jupiter-C was not to 'accidentally' place anything into orbit!