The Saturn-Apollo Launches: The Man Who Built Stage Zero and Lit the Fuse for Stage One

By Dr. Edgar J. Manton

Introduction

In July 2019, there will be a national celebration to recognize one of the most significant technological achievements by mankind, the *Apollo 11* lunar landing, which took place on 20 July 1969. This was the fulfillment of the goal set by President John F. Kennedy on 21 May 1961, to send a man to the Moon and return him safely by the end of the decade. Almost fifty years have passed since the occurrence of this proud national event. Between 1968 and 1972 twenty-four Americans traveled to the Moon, including three who flew twice, with twelve of them walking on its surface. All were brought back safely to earth.

This celebration will appropriately focus on the astronauts, Houston Mission Control, and the American success in the space race between the U.S. and the Soviet Union. But another contribution to the effort to reach the Moon must not be minimized or forgotten. This is the fascinating story of the work performed at the John F. Kennedy Space Center (KSC) concerning:

- The tremendous technological achievement in building the unique and massive launch facilities needed to stack, integrate, and checkout the gigantic Saturn V rocket and the Apollo spacecraft (Building Stage Zero).

- The development of the intricate, precise, and dangerous process to checkout, countdown, and launch the assembled Saturn V rocket (Lighting the Fuse for Stage One).[1]

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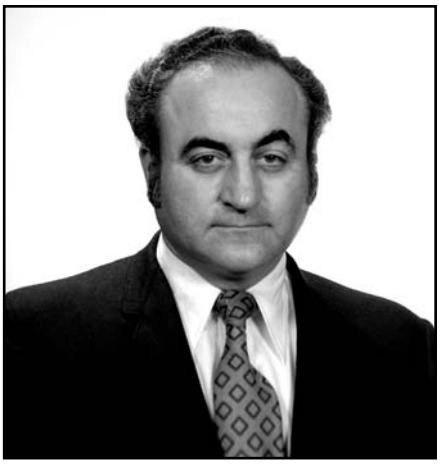
The dedication and superb efforts of the men and women involved in launching the Saturn V rocket from KSC must be recognized. For it was at KSC where all elements of the Apollo Program came together for the launch – the ground support facilities and equipment, the rocket stages, and the spacecraft. The KSC engineers and technicians had to bring these elements together and assure that every component and system functioned properly. Without the dedication, planning, and engineering expertise of the KSC rocket launch team, the Apollo Moon missions would not have been possible. The NASA and contractor personnel at KSC provided the technical skills and the engineering environment that made things work.[2]

There have been many books and TV documentaries produced by and about the astronauts, the Houston flight controllers, newscasters, and others that focus directly on the activities involved with achieving the mission, but little is available describing what occurred at KSC in preparation for a launch. As Gordon Harris, a KSC publicist back then noted, "During manned space missions the press was led to believe that NASA began and ended in a Texas control center. Little recognition came to the thousands who built the rockets and spacecraft, who launched them, and those who manned a world-wide network of communication stations."[3]



Rocco Petrone. Credit: NASA

There was not much excitement generated by the launch process until rocket ignition, which was shown to the public in real time and on television newscasts. Then shortly after liftoff, the mission responsibility was shifted from KSC to the Manned Spacecraft Center (MSC) in Houston, which after Apollo ended was renamed the Lyndon B. Johnson Space Center (JSC). Interest in the Apollo spacecraft flight progress and the safe return of the astronauts understandably became much higher and was accompanied by greater TV and news coverage as the flights progressed. But it was at KSC where the unique and gigantic facilities and ground support equipment (GSE) for the Moonport had to be constructed and where new and innovative launch concepts and procedures required to check out and launch the mighty Saturn I, Saturn IB, and Saturn V rockets had to be developed.

The public was generally unaware of the five-month marathons required to prepare a Saturn V to launch an Apollo spacecraft. Before a launch took place, all the stages and spacecraft of the revolutionary rocket had to be individually checked out and then erected, mated together, checked out as a unit in a huge assembly building, and then be transported in an upright position to the launch site. Rarely witnessed by the TV viewing audience was the awesome sight of moving the massive 36-story Saturn V rocket in a vertical position from its checkout facility to its launch site. The author worked at the Kennedy Space Center from 1963 until 1972 and can personally attest to the magnificent sight of a Saturn V, the size of a Navy destroyer, being slowly transported in an upright position three and a half miles to its launch site.

Complicating matters for KSC were the accelerated launch schedules, which called for two or three launch vehicles to be processed simultaneously. Modifications and changes were continuously being made by the rocket and spacecraft designers, which necessitated that corresponding changes to facilities, support equipment, and launch procedures be made at KSC.

Then there was very significant danger involved in launching the Saturn rockets, especially the Saturn V. A fully fueled Saturn V held six million pounds of propellants and, along with the presence of high-pressure gases, an extremely hazardous situation was created. An explosion on the launch pad would have incurred the damage of a medium sized nuclear bomb. When asked what the most dangerous phase of the mission was, Astronaut Buzz Aldrin answered, "The launch."[4]

The Saturn V on the Crawler Way. Credit: NASA

Unsung Apollo Heroes

There were several Apollo Program leaders whose contributions were essential for the Moon landing to have been achieved in 1969. Among these were: John Houbolt—who was critical to making the lunar orbit rendezvous decision, which allowed the use of the Saturn V rocket for the Moon mission, rather than waiting for a more powerful rocket required by other methods; Dr. George Mueller—who pushed for the "all up" testing of the Saturn V stages and the Apollo spacecraft simultaneously, rather than sequentially, saving valuable time, rockets, and funding; and George Low—who recommended switching the *Apollo 8* and *9* missions, which allowed *Apollo 8* to orbit the Moon, before the delayed lunar landing vehicle was ready for flight, a major decision in achieving Kennedy's deadline. What these men recommended involved considerable risk, but the 1969 lunar landing would not have happened without their bold proposals.[5]

There were others whose contributions to the success of the program were also crucial. At KSC there were Dr. Kurt Debus, the center director, and Rocco Petrone, the director of Launch Operations. These men were well known and respected within NASA, but they have not received the public recognition that they deserved for their efforts.[6]

Unquestionably the key person for the Apollo Program at KSC was Rocco Petrone. Debus provided the overall management of KSC and the vision for the launch process, but Petrone was the person who implemented and assured the successful launch process for the Saturn V. He was responsible for overseeing and coordinating the construction of the Saturn I and IB rocket Launch Complexes 34 (LC-34) and 37 (LC-37) and for building the massive Launch Complex 39 (LC-39), from where the Saturn V would be launched.

After completion of the construction of LC-39, Petrone was named Director of Launch

Operations, and he directed all Saturn-Apollo launches through *Apollo 11*. All were highly successful, except for *Apollo 6*, which experienced engine failures in the second and third stages, but still reached orbit.[7]

The overall success of these launches was a remarkable achievement by KSC personnel. It was an unheard record in rocketry at that time, as evidenced by the many failures of the Thor, Atlas, and Titan missiles launched from the Cape during the late 1950s and early 1960s.[8]

It is a commonly held belief among retired workers at the Kennedy Space Center that President Kennedy's goal would not have been achieved without Petrone's dedicated leadership. KSC retiree Ed Fannin, the chief of KSC's Mechanical, and Propulsion Division, explained: "Petrone was the person who kept everyone's eyes on the ball and was totally committed to the program. He was unquestionably the right man for the job. Without his effort the Moon landing would not have happened in 1969."[9] Another NASA retiree, Graydon Corn, stated: "I served at NASA, KSC, as an engineer. My duties allowed me to observe Rocco in nearly every facet of his varied positions. He was a 100 per cent, no-nonsense, manager, and set an example to all who worked for him. Without Rocco's leadership, it is doubtful that the space program would have survived."[10]

In another tribute, John Tribe, North American Rockwell Corp. engineer said: "I had the privilege of working with Dr. Petrone throughout the Apollo program at KSC and again when he headed up Rockwell Space Division. To my mind, he was a giant among men, a true leader and a dedicated American whose unheralded contribution to the space program has never been recognized. Without him, I doubt that the lunar landing would have occurred within Kennedy's timeline."[11]

Isom A. "Ike" Rigell, Deputy Director of KSC Launch Vehicle Operations, stated:

> And I can't say enough about Rocco Petrone, the Director of Launch Operations for Dr. Debus. I am not sure that many people know or appreciate what Rocco meant to the success of the Apollo Program, but we never would have gotten to the Moon on time, or maybe never got there at all, without Rocco. I attended Rocco's staff meeting every morning and I observed what he did to shape up not only KSC but also Houston and Huntsville.[12]

This article will discuss what was achieved at KSC to support the Saturn rocket launches and the tremendous accomplishments of the personnel at KSC under the project management skills of Rocco Petrone. The primary focus will be on the efforts to build the launch complex facilities and to develop the countdown procedures required to launch the Saturn V rocket.

How to Fly to the Moon, Which Rocket, and From Where?

Several major questions needed to be answered before construction of the Moonport could begin. Which rocket would be used? From where would it be launched? How would the rocket be assembled, checked out, and launched? And, how was this all to be done within nine years?

There were three methods under consideration for traveling to the Moon. The direct method involved flying the spacecraft directly to the Moon and returning to Earth. This approach would require the powerful Nova rocket, which was in very early conceptual stages. The Earth orbit rendezvous method would require sending multiple rockets into Earth orbit to deliver stages, spacecraft, and provisions to assemble a vehicle to travel to the Moon.[13]

The lunar orbit rendezvous approach would employ a rocket having multiple stages with the Apollo spacecraft linked to the lunar landing vehicle, which would contain a descent stage and an ascent stage. Together the spacecraft and the lunar landing vehicle would travel to the Moon. After entering lunar orbit, the lunar landing vehicle would descend from the Apollo spacecraft to the Moon's surface for lunar exploration, while the spacecraft remained in orbit. The ascent stage of the lunar landing vehicle would lift off from the Moon's surface and rendezvous with the orbiting spacecraft, which would bring the astronauts back to Earth.[14] After much debate, the lunar orbit rendezvous approach was selected in June of 1962. With this approach, the Saturn V rocket, which was already in development, could be used for the Moon mission, crucially saving time and money.[15]

The next question was, from where should the Saturn V be launched? After a lengthy study of eight possible locations, Debus and Petrone recommended that Merritt Island be the launch site. It had available land, a small population, the advantage of the Earth's rotation, established tracking stations of the U.S. Air Force, and was adja-

cent to LC- 34 and LC- 37 at the Cape, where the Saturn I and IB rockets would be used to test the Saturn V's third stage, the S-IVB, and the Apollo spacecraft.[16]

Major Factors Affecting the Kennedy Space Center

Immediately after President Kennedy's announcement for the Moon Mission, Debus, who was then the director of the Launch Operations Directorate (LOD) at the Marshall Space Flight Center (MSFC) in Huntsville, Alabama, which was responsible for launch operations at Cape Canaveral, made a crucial decision. He placed U.S. Army Major Rocco Petrone in charge of all planning and operations for the Saturn/Apollo launch effort for the LOD. As the new director of the Heavy Space Vehicle Systems Office, Petrone had responsibility for all Saturn Program resources and quality control efforts related to launching the Saturn rockets. This position gave him extraordinary powers over all NASA Saturn rocket launch preparation efforts at Cape Canaveral. He was responsible for the planning and activation of all launch facilities at the Cape and on Merritt Island, including LC- 34 and LC-37 for the Saturn I and IB rockets and for LC-39 on Merritt Island, from where the Saturn V rocket would be launched.[17]

Major Petrone had previously been assigned to the Army Redstone Arsenal in Huntsville Alabama in 1953 and had been involved in the development and launches of the Army's Redstone, Jupiter, and Juno missiles. He graduated from West Point in 1946, where he had been a tackle on the Army national championship football teams of 1945 and 1946. These teams featured Doc Blanchard and Glen Davis, who respectively won the Heisman Trophies in 1945 and 1946. In 1951 he received a master's degree in mechanical engineering from the Massachusetts Institute of Technology.[18]

Debus considered Petrone to be a dynamic, forceful, and tough no-nonsense leader who could get the launch site and rocket checkout and launch procedures ready to meet President Kennedy's goal of a Moon landing by 1969. He had shown himself to be a dedicated, take-charge, and detail-oriented manager who would obsessively focus on the launch preparation task. Debus realized the attention to detail that would be required to land a man on the Moon by the end of the decade, and he knew that Petrone was the man for the job.[19]

When he accepted this position, Petrone turned down an important career progression assignment to the Army's Command and General Staff School. This decision somewhat limited his advancement in the Army. He retired from the Army in 1966 as a Lt. Colonel, a relatively modest retirement rank for a West Point graduate.[20]

To assure the success of the Apollo Program, NASA required a strong presence at the launch site. The launch organization needed to be at the center level to permit its personnel to effectively interact and communicate with the other NASA centers and with the launch vehicle stage and spacecraft contractors. This center would also have to contract directly for its launch support and base support contractors and would have to work directly with the U.S. Army Corps of Engineers and the U.S. Air Force operations at the Cape.[21]

Dr. Wernher von Braun (Marshall Space Flight Center Director 1960-1970) and Dr. Rocco Petrone (Marshall Center Director 1973-1974) talk during a lull in the preparations of a Saturn 1 vehicle launch at Cape Kennedy's Launch complex 37 Control Center. 25 May 1965. Credit: NASA

In March 1962, the Launch Operations Directorate was separated from MSFC and was reconstituted as the Launch Operations Center (LOC), which reported directly to NASA's Washington Headquarters.[22] Debus became the LOC's director and the recently promoted Lt. Colonel Rocco Petrone was appointed to be the director of the Apollo Plans, Programs and Resources Office. This position gave him virtual control over all Apollo Program activities at LOC.[23] After the death of President Kennedy in November 1963, the LOC was renamed the John F. Kennedy Space Center.[24]

The Mobile Concept

The gigantic Saturn V at LC-39 required the development of radically new checkout and launch procedures. The enormous size of the rocket, the power it generated, the need for the highest level of reliability, and the need to support varying launch rates had to be addressed.[25]

It was determined that it would be impractical to erect the large rocket stages and the spacecraft at the launch site as had been

done with earlier rockets. This method would expose the launch vehicle to storms, heavy winds, lightning, and corrosion. Due to the stresses on the missile frame and its systems, assembling and checking out the large launch vehicle in a horizontal position in a hangar and then transporting it to and erecting it on the launch pad would not be feasible.[26]

Petrone and Debus focused on the "mobile concept," where the Saturn V stages and the Apollo spacecraft would be stacked, integrated, and checked out in a huge enclosed building and then be transported to the launch pad in a vertical position. The size of the Saturn V necessitated the construction of a gigantic assembly building. To launch the number of rockets needed to meet the mission schedule, the building would have to be large enough to process four Saturn rockets simultaneously. Thus, Petrone recommended that NASA construct the largest enclosed building in the world at that time. It was originally known as the Vertical Assembly Building (VAB), and later called the Vehicle Assembly Building.[27]

The mobile concept required developing a revolutionary mode of transport to bring the giant Saturn V from the VAB to the launch site. A barge system using a canal and another employing a rail system were initially considered, but these methods posed significant problems. A chance encounter with an employee of the Bucyrus-Erie Manufacturing Company and a subsequent visit by MSFC and KSC officials to the Peabody Coal Company in Paradise, Kentucky, led to another possibility. They observed the operation of a large crawler coal shovel, which led to the consideration of a large tank-like vehicle being used to carry the Saturn V from the VAB to the launch pad. At a conference held between 12-13 June 1962, at KSC, attended by NASA Headquarters, MSFC, KSC, and private industry representatives, the three methods of transport were discussed and compared. The barge and rail systems were considered to be problematic and too expensive. The presenter, Donald Buchanan, recommended using the crawler-transporter method and it was decided that the large tank-like vehicle, the crawler-transporter, would be developed to perform the task of delivering the mammoth Saturn V to the launch pad on a specially developed roadway.[28]

The mobile concept was viewed skeptically by NASA Headquarters, but Petrone presented a strong case for it by citing lower costs, less staffing, greater reliability, and more flexibility in launch rates that would be provided by this method. Through his zeal, logic, and persuasive powers, Petrone was able to overcome the objections of the NASA Office of Manned Space Flight in Washington D.C., and Congress, and authorization to proceed with the mobile launch procedure for LC-39 was approved.[29]

The rocket and spacecraft design engineers at MSFC and JSC assumed that they completely understood how their systems would perform when launched. KSC merely had to assemble and checkout the rocket stages in the VAB, transfer the vehicle to the launch pad, and launch it—referred to as "ship and shoot." But the KSC experts' experience during facility construction and the previous rocket checkout and launch operations caused them to differ vastly from that notion. They were required to make many modifications and changes to facilities and ground support equipment (GSE) while they were being constructed, and make modifications to launch vehicles during preparations for launch. And after each launch was completed, there would be modifications and changes dictated by issues and problems arising from the flights which would have to be performed by KSC.[30]

Apollo Program Tasks for the Kennedy Space Center

MSFC had already been authorized in 1960 to construct Launch Complexes 34 and 37 at Cape Canaveral to launch the Saturn I and IB rockets, which would perform initial tests and launches of the Apollo spacecraft and the third stage of the Saturn V, the S-IVB, in Earth orbit. These tests and launches were necessary for the Apollo spacecraft and the third stage to be ready when the first and second stages of the Saturn V became operational.[31]

The effort to design and build LC-39 for the countdown and launch of the Saturn V would proceed simultaneously with the launch activities occurring at LC-34 and LC-37. To launch the Saturn V, Petrone would have to develop and implement the critical and complex procedures to receive, stack, integrate, checkout, and launch it. To do these tasks, he drew extensively upon his experience, dating back to his service with Wernher von Braun and his U.S. Army team during the development of the Redstone rocket in the early 1950s.[32]

Petrone's Vision and Operational Guidelines

Petrone was determined to meet President Kennedy's national goal to land a man on the Moon by the end of the 1960s. His efforts at KSC were guided by an often-stated vision statement and two operational guidelines that permeated his actions and decisions throughout the Apollo Program. As headlined in several of his early professional presentations, his vision boldly predicted that "One day within this decade an American will land on the Moon."[33] This statement described his complete dedication to achieving Apollo's goal and his view of man's place in space exploration.

An important guideline for his decisions was that "the flight vehicle has got to dominate." This meant that the design of the specialized launch facilities and the complex and detailed launch countdown procedures required for the Saturn V would be dictated by the vast size of and the massive power generated by this rocket.[34]

The second guiding principle was "concurrency," which Petrone felt was the real challenge of the program. This meant that everything had to come together at the same time and function properly at KSC. The rocket stages, spacecraft, ground support equipment (GSE), and their components came from all over the country, and they were not tested together before arriving at KSC. The rocket stages and their equipment had to fit together and interact with the KSC facilities and GSE.[35]

Concurrency also meant that to meet launch schedules, two or three Saturn V's would be processed simultaneously while in the VAB or on the launch pads. And while all this was taking place on LC-39, checkout and launches of the Saturn I and IB rockets would be occurring simultaneously at Launch Complexes 34 and 37. Petrone had the tremendous responsibility for coordinating and integrating all of these activities.[36]

Petrone's Management Style

Though he occupied various positions at KSC during the Apollo Program, Petrone determined his responsibilities to be whatever needed to be done to accomplish the task. A title or an organization chart did not constrain his decisions relating to the program. He had a "take charge" personality, and he ruled everything at KSC with an iron hand.[37] According to Ike Rigell, Ray Clark, director of Technical Support Operations Directorate, lamented that "Rocco would be running the Saturn Program if he was in charge of the Motor Pool."[38]

Early in the program, contractor and NASA personnel who attended meetings to brief Petrone were high-level executives, overall program managers, financial managers, or contractor management personnel. These executives were typically not familiar with the status of their systems to the level he demanded. They were prepared to discuss the overall condition of their systems related to budget and contracts. Petrone demanded more—much more. He sought in-depth insights into a system or component and identification of any impact upon an upcoming test or launch. He insisted that NASA and contractor management officials provide personnel who were intimately knowledgeable with the systems and components under their responsibility and who could give current and accurate status reports.

Petrone was an excellent judge of character, and he could find capable individuals whom he could trust. He relied more on his personal experience with individuals than on an organization structure. He assembled a strong team that provided him confidence in status reports and would deal directly with a government or contractor engineer, whoever knew specifically what was happening and could provide accurate information.

Petrone worked through the line organizations directly contacting and working with people in the organization who could get the job done. He did not want people who did not keep up with daily operations and tests attending meetings to provide status. He would routinely call NASA officials and contractor management to replace people who were not up to date on their activities. There was no doubt who was in charge of this activity. It was Rocco Petrone. His leadership and management style was legendary. He was very visible, involved and demanding.[39]

Petrone was very knowledgeable about the Saturn launch vehicle systems and the associated GSE. He delved very deeply into the rocket launch systems and components to assure safety, reliability, and launch readiness. His strong and focused questioning on the details of system readiness reflected this. He could be intimidating and his probing could be severe. He had no problem challenging personnel, even his superiors.[40]

Al Koller, engineer retiree from the Launch Vehicle Operations Directorate, commented on Petrone's focus on details. He speculated that "…had Petrone still been in charge at KSC, the

Challenger disaster would not have happened." He added "Petrone was too thorough to have missed the booster problems, and he kept things headed in the right direction while he was at KSC."[41] (In fact Petrone, who had become the president of Rockwell Corp. Shuttle Operations after leaving NASA, had been at KSC for the launch of the *Challenger*, but had returned to California when the launch was delayed. Prior to the re-scheduled launch on 26 January 1986, he held a top-level telephone conference call with Rockwell program managers at the Cape. Following the discussion, he instructed his representatives at KSC to inform NASA that Rockwell recommended delaying the launch because they had not previously launched in such low temperatures and that falling ice might damage the orbiter.).

In preparing for a launch or a test, Petrone had early morning meetings with the Chief Test Supervisor to learn what had happened during the night shifts. Then he would meet with representatives of the Spacecraft Operations (SCO) and Launch Vehicle Operations (LVO) Directorates and their shift test conductors. In these meetings, Petrone would seek to learn in detail exactly what had taken place at the VAB and the launch pad the night before and how the launch might be impacted. Ike Rigell noted that "The meetings were 'no-nonsense.' The whole staff meeting was generally Rocco trying to understand what problem they had the night before and why they didn't have it cleared up."[42]

In the meetings and reviews conducted by Petrone, problems and issues were reviewed broadly at the stage or spacecraft level or in precise detail to the system or component level. Perhaps it could be a major issue dealing with the S-II stage, the latest report on the Lunar Module (LM), or down to a component level dealing with a solenoid valve, a faulty instrument, a propellants leak, or a defective switch. He knew the launch vehicle systems and GSE intimately, and his questions were laser focused. Through these meetings, he would be well informed about system status and test results. He had very high expectations of professionalism from the members of the launch team and would not tolerate any system briefer who was unprepared.[43]

If a briefer tried to deflect Petrone's attention from an issue, Petrone would tell him to "Stop bugling," an Army term he used when a presenter wandered off subject.

Petrone had a phenomenal memory. On many occasions, he would catch contradictions in reports many months apart. He was so good at cross-examination that it was suggested he missed his calling as a district attorney. One NASA manager observed:

> Rocco was the only senior manager I worked with who truly had a photographic memory. If you gave him a ''fact'' related to your program during a briefing, woe unto you if you changed anything a week, month, or year later. Rocco would catch or challenge you, and he was almost always right. Rocco's meetings were lively, especially if there were discussions of delays or unexpected changes. He was never shy about showing his displeasure, and it was reinforced by his imposing frame.[44]

For all tests, Petrone required a pretest briefing. System engineers had to be well prepared and have a complete report. The thoroughness of these reviews enabled Petrone to exert his complete will and control over the launch preparation process. Every procedure had to be certified as current and all operators had to have the final printed copies in their possession. Open items from previous tests were included. No write-in "markups" were allowed. John Talone, of the KSC Test Conductor Office, indicated that a typical report would include the task to be accomplished, the procedure involved, the personnel assigned, their certification on the system, and the schedule for completion. Problems were to be identified with any constraints they presented and if they would affect the test. If so, how far could the test proceed before having to stop the procedure? Following the briefings, changes could be made through Launch Vehicle Operations (LVO) or Spacecraft Operations (SCO) management with formal distribution and tracking and then a review by Petrone. It was a grueling but effective and disciplined system, which focused upon the status of critical items. It had effective checks and balances and did not depend on an extensive documentation system.[45]

Debus held weekly staff meetings with his directorate chiefs, and Petrone would invariably take the lead in these discussions, demonstrating more knowledge than the line organization functional directors. He was not beloved by several of these men. But it did not matter. His primary focus was upon the mission and whatever it took to achieve it.[46] As a high-ranking staff member noted: "In all the

meetings I attended with line directors there was NEVER any question about Rocco's ABILITY, AUTHORITY or REASON to not FOLLOW him!! He knew what he was talking about, and experience taught all of us that it was wise to follow his directions. The launch record speaks for itself."[47]

Petrone was equally effective at working with JSC and MSFC and their contractors. He was a natural program manager who handled KSC's external relations with the other centers and with the stage and spacecraft designers very effectively. He kept up with the activities and schedules of the MSFC, JSC and the stage and spacecraft design and manufacturing contractors.

There were scheduling issues with the other centers and their contractors. On occasion, JSC and MSFC were desperate to meet a schedule deadline, and they would ship open work to be completed by KSC at the launch site so it would appear that KSC was delaying the schedule. Petrone clearly demonstrated to NASA Headquarters where the problems were actually located and had pressure applied on JSC and MSFC to reduce the amount of incomplete work sent to KSC.

Petrone's knowledge of the overall program and status was phenomenal, and he was quickly able to assess any delay's impact upon KSC, JSC, or MSFC operations and take necessary action to minimize any effect on KSC.[48] He was able to get answers or reports accurately and effectively from these Centers on what affected KSC. Ike Rigell recalled that "in dealing with the other NASA Centers or the vehicle and spacecraft contractors, KSC personnel who worked for Petrone were able to get answers or responses due to Petrone's reputation. No one wanted to be called by Rocco."[49]

Petrone's Confrontations

On occasion, when a systems engineer gave incorrect or outdated information or tried to bluff him, Petrone could be intimidating. NASA and contractor engineers reporting system status had to be prepared. Many times he knew more about the situation than the briefers. He would accept an engineer not being current on an issue dealing with his system, but the engineer needed to admit it. At the next meeting, Petrone would expect an answer showing either progress or the solution to the problem. As noted by Ike Rigell, "If you were straight up with him that you didn't have all the answers, that's okay – just go get them. But you should never try to fool him. Chances were that he already knew more about a situation than you did."[50]

Here are several examples of Petrone's in-depth knowledge of systems and his strong reactions to inadequate reports or poor tests results.

Humboldt C. Mandell Jr., a retired manager of JSC, recalled what occurred to one unprepared systems engineer:

> Rocco was grilling the contractor people on some program delays. Rocco, who was never content with an answer, kept probing this one young contractor engineer, who quickly reached the limit of his knowledge. Instead of admitting it, he tried to bluff. Rocco took him physically off the podium. He told the boss that the young man was to be removed from the program. Brutal? Maybe, but it made us all know our subjects thoroughly from then on.[51]

In another example, Noel Hinners, a former NASA executive and a one-time director of the Smithsonian Air and Space Museum, related that "Rocco could be a tyrant in the formal meetings. On one occasion he demanded I tell him if it was a Phillips-head or a straight-head screw in a box under discussion. I annoyingly responded, 'How the hell would I know?' Years later I deduced that this was Rocco's technique for getting you to the point where you'd best say, 'I don't know,' rather than try to fake it and was part his 'pay attention to detail' mentality."[52]

When the Lunar Module (LM) was first delivered to KSC, it experienced significant problems. During a post-test briefing, Petrone was relentless in his criticism of Grumman in front of the entire briefing audience. Tom Kelly, Grumman LM chief engineer, recalls that George Skurla, LM Project Manager, was berated by Petrone because of the LM's unsatisfactory performance. "George, what kind of two-bit garage are you running up in Bethpage? That LM you sent us yesterday is supposed to fly in space, but I wouldn't even allow it on the launch pad. Its propulsion tanks and plumbing leaked like a sieve. It's a piece of junk, garbage! You should be ashamed. And four months late besides."[53]

Petrone went on "What kind of so-called tests did they do in New York before sending this wreck to us? You guys were supposed to be a cut above North American, but now it seems you're even worse. NASA won't stand for this. They had better get it fixed.

Your name is mud around here until you get it fixed."[54]

On another occasion, a glass blast proof plate was installed over a TV monitor which viewed engine seals for gaseous oxygen leaks in the Saturn V's first stage's engines. It was continuously cracking due to heat buildup from lamps used to light the area. John Talone, the engineer in charge, thought the situation had been fixed. Two hours before a test he had the lights turned on and personally moved into an uncomfortable position to reach into the TV cavity to check the glass. It had not cracked. Later during the propellant preloading briefing, he gave a status report of his system providing all of the information that Petrone demanded. He felt that his report was going well, but during the entire presentation Petrone had stared intensely at him.

At the end of the presentation, Petrone asked about the glass over the TV in the engine trench. Talone indicated that he had personally checked on it and it was OK. Then Petrone held up his finger with a Band-Aid on it and asked: "Then how come I cut myself when I was out there an hour ago?" From there Rocco went off. "You guys don't take this seriously! I can't trust you for anything!" He continued on a rant for 10 minutes and then turned to the director of Launch Vehicle Operations and said "I don't understand why you can't get this fixed right!" and stormed out of the meeting.[55]

Petrone could be volatile and explode when frustrated and dissatisfied with a status briefing. But his relentless focus upon safety and reliability was all for the good of the Program.

Building Stage Zero (1963-1966)

As Chief of KSC's Apollo Plans, Program and Resources Office, Petrone directed and oversaw the planning and construction of the facilities and equipment that was required to launch the powerful Saturn rockets at LC-34, LC-37 and LC-39.[56] He was also responsible for the Apollo Program schedule and for assuring that required support was provided for the Saturn I, IB, and V launches. To carry out these responsibilities Petrone had three project offices reporting to him. One office dealt with both Saturn I and IB launch vehicles and Launch Complexes 34 and 37. A second project office dealt with the Saturn V and Launch Complex 39. These two offices planned and evaluated facilities and GSE development and launch operations for their respective rockets.[57]

The third, but critically important office was responsible for the program resources management, a reliability program, and scheduling of U.S. Air Force range support. Through this office, and the control of resources, Petrone wielded extraordinary power over the construction of the launch facilities 34 and 37, and oversight of the early Saturn I and IB rocket launches. In directing the construction of the LC-39 facilities and launch preparations for the Saturn V, Petrone had a completely free hand.[58]

Managing the construction of the LC-39 facilities would be a much more difficult task than Launch Complexes 34 and 37 had been. For LC-39, Petrone was responsible for the planning and implementing the "mobile concept" which required:

- Constructing the Vehicle Assembly Building, where the massive Saturn V would be stacked and integrated with its mobile launcher.

- Designing and building the crawler-transporter that would transport the rocket to the launch pad.

- Constructing the launch control center from where the Saturn V would be checked out, both while in the VAB and on the launch pad.

- Building the launch pads, where the vehicles would be checked out, fueled, and launched.[59]

To perform the planning and coordination of the facilities to implement the "mobile concept," the Launch Complex 39 Site Activation Board was established with Petrone as Chairman. Its charter stated that "…. the Board was responsible for ensuring that all facilities and support equipment comprising the Apollo-Saturn V operational launch base were constructed, outfitted, installed, interconnected, and tested in preparation for subsequent operations."[60]

KSC was a functional line organization, and the KSC Directorate chiefs expressed concerns about the broad powers of the Site Activation Board. Several of the KSC Directorate chiefs feared that Petrone would interfere with their operations and authority, and voiced strong objections to the role of the Site Activation Board.[61]

Despite these objections, Debus made it clear that Petrone was the project manager in charge of KSC Apollo/Saturn operations, and in carrying out his responsibility he could cut across organizations

to find the people, whether contractor or NASA, who had the knowledge to address a problem directly. Thus it was clear that Petrone had complete responsibility for coordinating all the work necessary to prepare the LC-39 facilities and GSE.[62]

Consider the awesome responsibility this posed for first a Major, and then Lieutenant Colonel, in the U.S. Army. To manage the construction of LC-39, Petrone would have to deal with the U.S. Army Corps of Engineers, the other NASA Centers, construction contractors, stage, spacecraft, and KSC base and launch support contractors. In 1964 there were 7,000 construction workers building the LC-39 facilities, and there were frequent jurisdictional disputes at KSC between the construction workers, the various Saturn rocket contractors, and NASA.[63] While attending to these matters at LC-39, he would also be responsible for overseeing the Saturn I and IB launches from LC-34 and LC-37, and have to deal with the U.S. Air Force and its support contractor, Pan American. But Petrone was up to the task, and he was accorded tremendous respect from the KSC launch team.[64] He was a tireless hands-on manager who routinely worked weekends and late into the night when other managers had gone home.[65]

There were thousands of components and pieces of equipment that were needed to prepare LC-39 for the countdown and launch of a Saturn V. The GSE included some 40,000 parts, which arrived at KSC from all over the country, and they had to fit and function together properly. A valve fabricated in California had to fit pipes delivered from Louisiana. Switches manufactured in Massachusetts had to operate dials from Wisconsin. Electrical components from different companies needed to have the same voltage and current ranges to operate together correctly. Some parts required high levels of cleanliness, special packaging, and temperature controls. Every part had to be checked individually or verified within their systems to be operational at KSC.[66]

Facility and GSE verification had to be performed simultaneously with the ongoing design and development of the rocket's stages and spacecraft. Any design changes to the spacecraft or the rocket stages would have to be accommodated in the KSC facilities and GSE. And conversely, it was crucial for KSC to identify needed changes discovered during checkout and launch of the rockets to the rocket designers and manufacturers for incorporation into the follow-on GSE and vehicle designs.[67] Petrone completely understood this situation.

We often look at the launch site and those things on the ground that don't fly as "Stage Zero". Rocco Petrone said, "You had to have all of the intricacies of a stage, things like swing arms, hold down arms, feeding the gases in, all the propellants. When you've released your Stage One is flying, but if you haven't done all of these things on Stage Zero, Stage One would never get a chance to fly." The Cape's task was to design and build all the ground support equipment and facilities even as the Apollo/Saturn stack itself was being designed. "That was a hell of a challenge" Petrone continued, "and I think, a challenge not very well understood. Here you have the launch vehicle stages going down the road with the spacecraft and they develop more juice, need more wire, and require more propellants. You've got to be in the right rhythm because when they come together you must all be in the crossroads at the same time.[68]

The Saturn V outside the Vehicle Assembly Building. Credit: NASA

Saturn-Apollo Checkout and Launch Facilities

The Operations and Checkout (O&C) Building, also known as the Manned Spacecraft Operations Building (MSOB), was located about five miles south of LC-39 (Since 2014, it has been known as the Neil Armstrong Operations and Checkout Building). Here the spacecraft would be received, assembled, and checked out prior to being moved to the VAB to be lifted to the top of and integrated with the Saturn V. The MSOB is a 5-story building containing offices, laboratories, the astronaut quarters, two high altitude chambers, and the spacecraft processing and checkout areas. It has a large conference room which could accommodate the numbers of NASA and contractor managers, engineers, and technicians attending the reviews for launch and flight preparation.

Everything about Launch Complex 39 was on a large scale. To process the 363-foot Saturn V

The Crawler-Transporter for the Saturn V. Credit: NASA

and to hoist and connect the stages, the VAB was 525 feet tall, occupied 8 acres and contained four high bays to allow for processing 4 Saturn V's simultaneously. Each bay had a cascading roll-up door that was 456 feet high. Accompanying the rocket in the VAB was its attendant mobile launcher (ML), which consisted of a 25-foot-tall launch platform with the 4 hold-down arms and a 380-foot umbilical tower, containing 2 elevators, and 18 platform levels. The tower had 9 swing arms for access to the vehicle, to load propellants, and to provide power and high-pressure gases to the rocket stages, and it had a 25-ton hammerhead crane at its top. The launch platform had six 22-foot posts, or mount mechanisms, which allowed the crawler-transporter access to lift and lower the ML and Saturn V into position. The ML was used to check out the launch vehicle both while in the VAB and on the launch pad.[69]

The crawler-transporter was a triumph of engineering. It weighed 3,000 tons, had an adjustable height from 20 to 26 feet, and lifted the 363-foot-tall Saturn V and its ML, and carried them to the launch pads. It was powered by four double-tracked crawlers at each corner and had two control cabs on either end so it could move forward or backward and did not have to turn around. Its top speed was two miles per hour without a load, but when carrying a Saturn V with its ML, it moved at one mile per hour. It had a level sensing system that kept the Saturn in a nearly perfect vertical position, even while travelling up the incline of the elevated 42-foot high launch pad.

After the launch vehicle was in place on the launch pad, the 402-foot-high mobile service structure (MSS) was moved to the launch site by the crawler-transporter. It weighed 12 million pounds and had an elevator and eight adjustable platform levels, providing 360-degree access to the launch vehicle while it was on the launch pad. Before the launch, the MSS was returned to its standby position by the crawler-transporter.[70]

A 48-foot tall steel triangle shaped flame deflector was required to deflect the tremendous flames generated by the S-IC stage engines away from the vehicle and ML during ignition and liftoff. It weighed 317 tons and was positioned under the ML by a rail system.[71]

The Launch Control Center (LCC) was the nerve center for the Saturn V launches. The launch vehicle stacking and checkout functions performed in the VAB and the Saturn V checkout and launch countdown on the launch pad were controlled from the LCC. The building had four firing rooms. Ultimately, only three firing rooms were activated for Saturn V processing. Firing Room #4 became the flow processing center to track launch preparations, and it included a large floor to ceiling "waterfall" flowchart system which depicted significant events to track vehicle system status.[72]

Launch Complex 39 pad A was 3.5 miles from the VAB, and LC-39 pad B was 4.2 miles away. These were massively large complexes, much larger than their predecessors, LC-34 and LC-37. Both were elevated 42 feet from the crawler roadway and were encircled by propellant and high-pressure gas supply tanks and piping. Located around each pad were a liquid oxygen tank, a liquid hydrogen tank, and an RP-1 tank. Nitrogen and helium gases, provided to both launch pads from a centrally located converter-compression station, were stored in a high-pressure gas storage facility under

each launch pad.[73]

What was achieved between 1963 and 1966 at KSC in completing the activation of the Launch Complex 39 facilities that would be required to carry out the mobile concept was amazing. Under the management of Petrone, KSC had completed the design and construction of the VAB, two crawler-transporters, three mobile launchers, the mobile service structure, launch pads A and B, and the Launch Control Center. And this was done while the various Saturn V stages and the Apollo spacecraft were being designed, built, and checked out at distant locations, and while launches of the Saturn I and IB rockets were occurring at Launch Complexes 34 and 37.

The successful rollout of the Saturn 500F test vehicle from the VAB to launch pad A took place on 25 May 1966. It was exactly five years to the day from President Kennedy's announcement of the goal to send a man to the Moon. The Saturn 500F was the facilities integration vehicle used to test the vehicle stacking and checkout in the VAB and to transport it to the launch pad to assure that everything fit.[74] The 36-story Saturn V, with its mobile launcher's swing arms and hold-down arms connected to the vehicle, was transported to Launch Pad 39A by the crawler-transporter demonstrating that the Launch Complex 39 facilities and GSE were operational and ready to support a Saturn V launch.[75] While briefing visiting dignitaries who were observing the spectacular sight of the SA-500F emerging from the VAB, Petrone stated "I guess that's a sight that speaks for itself. I'll give no commentary on that."[76]

Lighting the Fuse for Stage One (1966—1969)

After completing construction of the Launch Complex 39 facilities and the successful rollout of SA 500F, Debus had to make a difficult personal decision. Until then he had held two positions—Center Director and Director of Launch Operations. Due to his increased responsibilities at KSC, the Saturn V workload, and the fact that Rocco Petrone was participating directly in the launch director function for the Saturn I and IB rockets, he realized that he should relinquish his day-to-day launch operations responsibilities.[77]

He assigned Rocco Petrone to replace him as Director of Launch Operations. Petrone had sat beside him in the Launch Complexes 34 and 37 blockhouses during launches of the Saturn I and IB rockets. Over time they had evolved into effectively being co-launch directors, but Petrone had become more active in the role due to his in-depth system knowledge and his familiarity with the launch crews. Coincidentally, Petrone had retired from the Army in 1966. In his new position, the Center's main operational divisions, Launch Vehicle Operations and Spacecraft Operations, reported directly to him, and he was completely responsible for directing the testing, checkout, and launch of all Saturn-Apollo launch vehicles.[78]

Launch control center at Kennedy Space Center.
Credit: NASA

Launch Pad 39A, Kennedy Space Center.
Credit: NASA

The Director of Launch Operations at KSC has never received the media or national attention of a Spacecraft Flight Controller at JSC in Houston. The Director's responsibilities were over when, upon launch, the Saturn V cleared the launch tower, about 12 seconds after the engines ignited. But what was involved in the four or five months of preparation for the launch was formidable, and what was monitored and controlled during a launch countdown was daunting. Putting three men on a fully fueled Saturn V and launching them toward orbit was a pressure-packed situation.

The launch of a Saturn V was much more complicated than any previous rocket launch conducted at KSC. It involved the efforts of many more organizations and personnel than earlier Saturn I and IB launches. The launches from LC-34 and LC-37 had included the NASA KSC personnel, two stage contractors, the Instrumentation Unit (IU) contractor, the spacecraft contractor, the U.S. Air Force Cape support contractor, Pan American, and the Air Force's Eastern Test Range Office.

To perform the checkout and launch efforts for the Saturn V, Petrone would have to coordinate and supervise the tasks of the KSC civil service engineers, three stage contractors, the IU contractor, two spacecraft contractors, along with the efforts of five major support contractors, and the U.S. Air Force. There were 26,500 workers at KSC in 1968. Bringing all these entities and personnel together would be a challenging task for one man.[79]

To comprehend the complexity of the systems and components monitored by KSC personnel during a countdown for launch, the number of manned console positions might be considered. During the *Apollo 11* launch, Firing Room #1 of the Launch Control Center at KSC had 463 engineers monitoring 150 console positions for the launch. They were augmented by 50 spacecraft personnel in the MSOB, and consultant system engineers from MSFC in a separate room in the LCC. Additionally, there were some 5,000 backup personnel available on standby throughout the country.[80]

The launch team consisted of about 80 percent contractors and 20 percent NASA civil service personnel.[81] Both had their functional line organizations, and Petrone had to deal with the conflicting managerial chains of command when interacting with them. Petrone also had to contend with two vastly different cultures in dealing with NASA and contractor engineers. The spacecrafts were the responsibility of JSC and its contractors, North American and Grumman, while the rocket stages and engines were the responsibility of MSFC and its contractors Boeing, North American, Douglas, and the rocket stages' engine provider, Rocketdyne. The spacecraft contractors were steeped in the U.S. Air Force contracting approach, where the government management penetration was not deep, and much of the work was left to the contractor with less oversight until the product was completed and checked for compliance with design specifications. They worked more of a team approach dealing with each system in a broad sense. Quality assurance was a separate function from the design and operational organizations.

On the other hand, the stage contractors were managed by MSFC and KSC engineers who were strongly influenced by MSFC's German scientists, who exercised substantial control over their specialized tasks. The German managers emphasized personal responsibility and worked from a discipline orientation. They and their civil servant and contractor engineers were deeply involved in the functional operations of the specific components within each system and, thereby, responsible for their own quality assurance. Complicating matters further, the spacecraft contractor worked a three-shift schedule while the vehicle stage contractors worked a two-shift schedule.[82]

This difference in work cultures required that Petrone deal with NASA personnel and contractor personnel depending upon who knew the system in the detail that he wanted. For his launch team, he looked for the engineer who could get the job done. Organization charts did not matter. He wanted direct access to the individuals who knew the systems intimately.[83]

Assembling the stages and the spacecraft, checking out the overall Saturn V, delivering the vehicle to the launch site, and successfully launching the Saturn V working with these widely different organizational cultures presented many difficulties. That Petrone was able to integrate and manage the diverse NASA and contractor organizations and meet the aggressive Apollo launch schedule was a triumph in the application of project management techniques to a challenging and complicated task of national importance.[84]

The Director of Launch Operations had the ultimate responsibility of deciding to launch, but if during the countdown any systems engineer observed a problem he could call a hold or stop the launch. When major a problem occurred causing a hold or a launch postponement concerned engineers could convene in the launch vehicle documentation room, also referred to as the "woodshed." This room was adjacent to each of the four firing rooms in the Launch Control Center. It contained engineering system blueprints, manuals, and configuration control documentation, which were used for troubleshooting problems. It was a place where engineering experts could study a problem as a team. During some tests when a serious problem arose, Petrone would call

for meetings in the woodshed. Sometimes these meetings were heated and intense, and some lasted all night. No doubt these occasions resulted in the room being referred to as the "woodshed" and the expression that "no one wants to be taken to the wood shed by Rocco." When needed, Petrone was relentless in solving the problem at hand no matter what and how long it took.[85]

Petrone was in complete charge of the firing room during tests and launch countdowns. He maintained rigorous control of the primary launch control communications system. Depending on their function some launch team members could speak over the network while others were limited to listening. Petrone demanded that everyone stay on the main communications loop. He wanted to be aware of everything said about a problem.[86] If someone even stood up to take a stretch, he would tell them to sit down. He demanded a disciplined firing room.[87]

There was tremendous pressure on the launch team members worked the consoles during their 12- and 13-hour shifts in preparation for launch. Petrone would be constantly vigilant for team member fatigue. He would walk through the Firing Room 45 minutes prior to launch to check on the alertness of the engineers.[88]

After analyzing any problem, the Launch Director would decide whether to continue with the countdown and whether or not to launch. Launching with an unresolved problem presented a difficult situation, but with the expertise of the KSC personnel advising him and his deep system knowledge, Petrone made such decisions with a high probability of success. And the successful launches of all Saturn rockets stand as a testament to his decision making.

The Saturn V Stages and the Apollo Spacecraft

The three stages of the Saturn V and the Apollo spacecraft involved some 5.6 million components and parts and 1.5 million systems and sub-systems. All of these components and parts had to be checked out individually or within their assembled systems at KSC.[89] When assembled, the rocket stages and spacecraft had to fit together and function correctly with the launch facilities and GSE. Between stages, every wire, plug, switch, connector, and pipe had to join precisely with its counterpart. The instrumentation unit at the top of the third stage had to send thousands of signals through sensors and micro switches throughout the rocket stages without electrical interference or change of signal strength.

The three stages of the Saturn V were built by different companies under contract with MSFC.

The first stage, the S-IC, was developed by Boeing and was produced in a plant at Michoud, Louisiana, near New Orleans. It used RP-1 (kerosene) and liquid oxygen for its propellants. It had five Rocketdyne F-1 clustered engines which combined developed 7,800,000 lbs. of thrust at liftoff.[90]

The second stage, the S-II, was built by North American Rockwell Corporation in Seal Beach, California. It used liquid oxygen and liquid hydrogen as its propellants. It had five Rocketdyne J-2 engines which developed 1,100,000 lbs. of thrust upon separation from the first stage. It would operate in near vacuum conditions and separate the S-II stage from the S-IC, the first stage.[91]

The third stage, the S-IVB, was the built by Douglas Aircraft and used liquid oxygen and liquid hydrogen for its propellants. It was built in Huntington Beach, California and had a single J-2 engine that developed 200,000 lbs. of thrust and had to ignite twice in space. It was first fired to separate itself from the S-II stage and achieve Earth orbit, and later it was restarted to place the spacecraft into trans-lunar injection.[92]

IBM built the Instrumentation Unit in Huntsville, Alabama. This was the brain for the Saturn V rocket, which provided flight guidance, controlled the stage engines for flight control, and performed the stage separations.[93]

For the Apollo spacecraft, North American in Downey, California, provided the CSM, which was a sophisticated spacecraft consisting of two modules. The Command Module (CM) provided the work and living area for the astronauts and would carry them back to earth. It had Rocketdyne thruster engines for maneuvering and earth re-entry. The Service Module (SM) provided propulsion, electric power, and storage of consumables for the flight. It had a large engine, supplied by Aerojet General Corporation for mid-course corrections and lunar orbit entry and exit. It also had thruster engines built by Marquardt Corp. The propellants for the engine and thrusters were hypergolic. These were used for self-ignition of the engines to assure reliability for making mid-course corrections and for firing when entering and leaving lunar orbit.[94]

Grumman was responsible for the Lunar Module, which was built

in Bethpage, New York and it consisted of a descent stage and an ascent stage. The LM's stages' thruster engines were provided by Marquardt. The descent stage engine was provided by Space Technology Laboratory, and the ascent stage engine was supplied by Bell Aerospace Corp. These engines used hypergolic fuels for reliable operation for landing on and leaving the Moon.[95]

When assembled, the Saturn V rocket stood 363 feet tall – about 36 stories. When fully fueled it weighed 6,500,000 pounds and generated 7,800,000 pounds of thrust at liftoff.[96]

The Saturn V Launches

There were a total of thirteen Saturn V vehicles launched during the Apollo Program. Rocco Petrone was in charge of the first six of these, culminating with *Apollo 11*. The process for launching the Saturn V was considered to be a "marathon," starting with an extensive three or four-month checkout in the VAB, followed by a one-month preparation period on the launch pad.

Each rocket stage was individually inspected, stacked, and mated to the other stages in the VAB, and an end to end electrical verification was performed and controlled from the Launch Control Center (LCC). Then the malfunction overall test recovery and "safing" tests were conducted using plausible malfunctions. Following these tests, a plugs-out-test was performed, which checked the power for the launch sequence.

After the plugs-out-test, the spacecraft, which had been checked out in the Manned Spacecraft Operations Building (MSOB), was installed onto the Saturn rocket and an interface check was performed. The fully assembled Saturn V was then transported to the launch pad where, after an overall vehicle end to end test, the Flight Readiness Test (FRT) was conducted. The FRT would simulate the entire launch and flight of the vehicle and spacecraft, operating valves and electrical switches, but propellants were not loaded. The launch sequence for the FRT was controlled from the LCC, while the spacecraft was controlled from the MSOB.

Following the FRT, hypergolic fuels were loaded onto the CSM and the LM. This was followed by the Countdown Demonstration Test (CDDT), where RP-1 and liquid oxygen were loaded onto the S-IC stage and both liquid oxygen and liquid hydrogen were loaded onto the S-II and the S-IVB stages. The countdown test would be taken to 14 seconds before ignition, where the count would be terminated. After the CDDT, the liquid oxygen and liquid hydrogen would be off-loaded from the stages, while the RP-1 and hypergolic fuels would remain onboard for the launch.[97]

There were two reviews performed prior to launch, the Launch Readiness Review (LRR) and the Flight Readiness Review (FRR). These reviews were held in the MSOB's briefing room. The LRR was a review of KSC's readiness for launch. This was overseen by Rocco Petrone. The FRR was an overall mission review involving KSC, MSFC, JSC, Goddard Tracking, and the Navy recovery forces to indicate readiness for launch. Every aspect of the mission from pre-launch preparation to splashdown and recovery was reviewed in detail. Action items or deficiencies recorded during earlier mission reviews were carefully analyzed to be sure they had been properly addressed.

After declaring the vehicle launch ready, the launch count was started as scheduled and propellant loading began. Liquid oxygen and liquid hydrogen were loaded onto the rocket and spacecraft, along with the helium and nitrogen gases used for pressurization. This was a very hazardous time for launch pad workers. Ultra cooled liquid fuels and high-pressure gases were flowing requiring monitoring pressures, opening and closing of valves, watching for leaks, and testing tanks for temperature and pressure problems.[98]

While preparing to launch the Saturn V, launches of the Saturn I and IB were occurring on launch complexes 34 and 37. It was on 27 January 1967, during a spacecraft test at LC-34 where the tragic accident of *AS 204* / *Apollo 1* occurred, and Astronauts Gus Grissom, Ed White, and Roger Chaffee lost their

Assembled Saturn V on the launch pad. Credit: NASA

lives. The causes of the accident were determined to be a spark igniting material which became combustible in the 100 percent oxygen environment in the spacecraft cabin, and the inward opening entry hatch that was difficult to open from inside the spacecraft. The accident delayed the program for about nine months while an investigation was conducted. The program underwent heavy scrutiny, and the 1969 Moon landing goal seemed very doubtful.[99]

However, on 9 November 1967, eight months after the *Apollo 1* accident, *Apollo 4*, with an improved Block I spacecraft was launched on the first Saturn V. This was a prototype of the Apollo spacecraft used to test the flight systems in Earth orbit and the effectiveness of the heat shield in flight and reentry. During checkout of the vehicle in the VAB, and on the launch pad, numerous problems arose and the CDDT took 23 days to complete. But this lengthy test proved to be invaluable in molding the launch personnel into an effective team and providing valuable information for conducting future launch countdowns. The *Apollo 4* flight itself was highly successful and it verified the effectiveness of Apollo's propulsion system and the heat shield. The flight was also successful in testing the spacecraft and all three stages together, including the S-IVB engine restart in space, which was crucial for lunar flight. This flight validated Dr. George Mueller's push for "all up testing," which tested all Saturn V stages and the spacecraft simultaneously during a launch rather than conducting sequential tests. This was a major factor in achieving the goal of landing a man on the Moon by 1969.[100] Petrone now felt confident that Kennedy's goal would be met.[101]

A Saturn IB rocket successfully launched *Apollo 5,* from Launch Complex 37 on 22 January 1968. This flight carried the LM into Earth orbit and verified the operation of the ascent and decent stage engines and propellant systems.[102]

On 4 April 1968, *Apollo 6* was launched on the second Saturn V and it experienced serious problems. Early in the flight "pogo" oscillations occurred in the first stage's F-1 engines, resulting in violent vibrations which would have caused extreme discomfort and disorientation for the astronauts. Subsequent analysis found the cause to be incorrect tuning of the frequencies among the five first stage F-1 engines. This would be easily corrected in future flights.

Shortly into the S-II stage's burn, engine #2, a J-2 engine, shut down, followed immediately by engine #3 also shutting down. It was later found that engine #2 shut down due to in line vibrations rupturing the flexible bellows in the fuel line which fed liquid hydrogen to the engine's spark igniter. The flow of propellants was stopped to engine #2, but the liquid oxygen pre-valves of engines #2 and #3 had been accidently cross-wired, so the liquid oxygen flow to engine #3 was also cut off, resulting in its shutdown. However, the S-II's three remaining J-2 engines were able to compensate for the power loss and subsequently, with the S-IVB engine burning longer, the spacecraft achieved orbit. During the flight a similar fuel line bellows rupture had occurred in the S-IVB stage's single J-2 engine, so later, when an attempt was made to restart the engine to test for translunar injection, it failed. The problem was solved in future flights by eliminating the bellows and redesigning and hard lining the fuel lines.

Another issue occurred during the flight. The spacecraft lunar module adapter (SLA) panels, which were designed to protect the LM, broke free while flying through the atmosphere, due to trapped air and water buildup in the panels' aluminum honey comb structure. After the flight, the S-IC's pogo issues and the fuel line problems in the S-II and the S-IVB stages were quickly found and corrected. And an easy fix was made for the SLA by to drilling small holes into the panels to allow for expansion of the honeycombs. Because of these problems, *Apollo 6*'s mission goals were modified somewhat to emulate the *Apollo 4* goals and these were successfully achieved. So by understanding the first and second stage engine issues and the SLA problem experienced in the flight, and finding relatively easy solutions to them, the flight of *Apollo 6* provided NASA with enough confidence to use the Saturn V for manned launches.[103]

Apollo 7, the first manned flight for the reworked Block II Command Module, was successfully launched on 11 October 1968, from LC-34 using the Saturn IB rocket. The CSM flew for 11 days and completed 163 earth orbits, proving it could sustain a flight to the Moon. Thus, the Saturn V rocket and the Apollo spacecraft were now operational and ready to be combined for manned lunar flights. *Apollo 8* was scheduled to be launched into Earth orbit to test the LM in manned flight and rendezvous techniques with the CSM.

However, the LM was months behind schedule. George Low, at that time Manager of the MSC

Apollo Spacecraft Program Office, made the bold recommendation to switch the *Apollo 8* and *9* missions. This change in schedule would send *Apollo 8* and three astronauts to the Moon and into lunar orbit prior to returning to earth. And *Apollo 9* would be manned and used to test the LM in flight and rendezvous techniques while in earth orbit.[104]

NASA management received this proposal with much skepticism because the third Saturn V would be used for the *Apollo 8* mission to fly to the Moon, and the previous Saturn V launch of *Apollo 6*, had experienced significant problems. But since these problems were completely understood and reliable fixes had been made, it was decided that the flight would be an acceptable risk. And by orbiting the Moon, valuable lunar flight information on communications and navigation in space could be obtained and photographs could be taken which would provide information on sites for future lunar landings. It was recognized that this flight would dramatically increase the risk for *Apollo 8*, but that it would reduce risks for follow-on flights to the Moon.[105]

All NASA Centers had to quickly assess their capabilities and determine what would be required to launch *Apollo 8* in December of 1968, which had been a tumultuous and challenging year for the nation. The Vietnam War was raging; President Johnson had announced that he would not seek reelection; Martin Luther King had been assassinated, causing race riots; and Senator Robert Kennedy had been shot and killed during his presidential campaign. Adding pressure to the decision was speculation that the Soviet Union was planning a manned launch to orbit the Moon, which would significantly diminish the importance of a U.S. lunar landing.[106]

The decision to send *Apollo 8* to the Moon had to be made quickly to meet the proposed December launch date. Petrone called in his key personnel to discuss the situation. Ike Rigell, Deputy Director of LVO, recalled that "to a man, they knew what he wanted to do and they immediately committed to the project."[107]

Apollo 8 was launched on 21 December 1968, and orbited the Moon 10 times. It was a tremendous success and restored Congress's and the countries' faith in NASA after the tragic accident of *Apollo 1*. Reversing the *Apollo 8* and *9* missions was another crucial decision which contributed to the achievement of President Kennedy's goal of landing a man on the Moon before the end of the decade.[108]

Apollo 9 conducted the first manned flight of the LM. It was launched on the 3 March 1969, and, during nine days of Earth orbit, it successfully tested the LM's ascent and decent engines and rendezvous techniques with the CSM. *Apollo 10* was successfully sent to the Moon on 18 May 1969, to test the LM in rendezvous operations with the CSM while in lunar orbit. It was a full dress rehearsal for *Apollo 11*. The LM descended to about 8 miles above the Moon's surface. All was now ready for the *Apollo 11* lunar landing.[109]

Petrone noted:

> At last everything was coming together—all those elements that had been committed piecemeal—the command module on *Apollo 7*, the first manned flight away from the bounds of Earth in *Apollo 8*, the flying of the lunar module with men on board in *Apollo 9*, and then *Apollo 10* which went to the Moon and did everything short of landing. It all led up to that hot July morning in 1969, when Apollo's moment of truth was irreversibly upon us.[110]

As Director of Launch Operations, Rocco Petrone was in charge of the *Apollo 11* countdown and launch on 16 July 1969. In Firing Room #1 seated next to him were Kurt Debus, KSC director, and Wernher von Braun, director of MSFC and the designer of the Saturn V rocket. The countdown and launch went flawlessly.

Four days later, on 20 July, astronauts Neil Armstrong and Buzz Aldrin landed safely on the Moon and gathered lunar rock samples. They returned to earth safely on 34 July. The success of *Apollo 11* was the magnificent result of the dedicated efforts of thousands of individuals in government and industry. Undeniably the personnel at KSC under the stellar leadership of Rocco Petrone played a huge role in achieving Kennedy's goal.

One month after *Apollo 11*, Petrone was promoted to be NASA's Apollo Program Director. He was now in charge of the entire Apollo Program. Debus hailed Petrone's appointment by noting that "Petrone played a vital role in the design, construction and outfitting of the LC-39 launch facilities that successfully launched our astronauts to a landing on the Moon. His service to the program as Launch Director has been so superb that he was the logical candidate to take over the management of Apollo for the continuing lunar exploration missions."[111]

Conclusion

Rocco Petrone was unquestionably one of the most important contributors to the success of the Apollo Program. He was the key person at KSC for the Apollo Program until *Apollo 11*.

Without Petrone's project management skills and obsessive commitment to the program, it is doubtful that the Moon landing would have taken place by President Kennedy's deadline.[112]

The Apollo Program was a major national endeavor. It required the efforts of a vast number of NASA and industry engineers and technicians at KSC to successfully launch the gigantic Saturn V and send the Apollo spacecraft on the lunar mission. Petrone's ability to create an effective launch team, which constructed the facilities and developed the complex procedures to safely and reliably launch the Saturn V, demonstrated extraordinary project management skills. He established an effective process on how to effectively and efficiently plan and manage large and complex technical projects under extreme time limitations.[113]

Petrone did not give many interviews, did not write a book, does not appear in many historical films or documentaries related to Apollo, and he is not well known to the general public. But he is highly regarded within NASA and the aerospace industry. His toughness and intimate knowledge of the Saturn-Apollo systems gained him great respect and admiration from the KSC launch team. During tests and launch countdowns, his questioning was keenly focused on safety and reliability issues. He had a remarkable ability to ask the right questions at the right time to evaluate the readiness of a system for launch. He also dared to make difficult and risky decisions, even when under great stress. His methods were demanding and sometimes harsh, but they achieved the desired results. The highly successful launch records of the Saturn I, IB, and V rockets attest to the work performed by the NASA and contractor engineers at KSC under his leadership.

Roger Launius, a former NASA Chief Historian, aptly summarized the work done at KSC by stating that "The value of the work that Mr. Petrone and other engineers and designers contributed to the success of Apollo cannot be overstated...he was one of a band of brothers captured by the dream of spaceflight. While they didn't get to go themselves, they are the ones who made it real."[114]

In 1973, Petrone became the Director of MSFC, overseeing that Center's work for Skylab, and the following year he was appointed to be the Associate Administrator of NASA. He retired from NASA in 1975, and in that year he was elected to the National Academy of Engineering, which cited him "For pioneering accomplishments in the design, development and implementation of space launching capacities for the Apollo Program."[115]

He recognized that Apollo was the beginning of the exploration of space and the universe. In his retirement speech he emphasized the role of space research in the discovery of new knowledge and the need for man to be involved in space exploration:

> I see man in the program as the essential element of adventure and discovery that we need. You start talking about adventure and discovery and anyone who tells you what's going to come out of it has got to be a fool to try, because out of discovery man has moved from the caves to where he is today, and we ain't finished moving. I look upon all those things out there (in space) as challenges, put there by someone for us to try to understand, and in trying to understand, we're going to be better.[116]

Apollo 11 liftoff. Credit: NASA

After leaving NASA, Petrone spent most of the 1980s working in the Space Shuttle Program as a manager at Rockwell International before retiring in 1989. Rocco Petrone died in Palos Verdes, California on 24 August 2006. He was 80 years old.

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Professor of the Texas A&M University System. He received his bachelor's degree in general engineering from the U. S. Naval Academy and the masters and doctorate degrees in management from Florida State University. Upon graduation from the Naval Academy, he entered the United States Air Force as a missile control officer for the Atlas intercontinental ballistic missile. After leaving the service, he was employed by NASA at the Kennedy Space Center from 1963 until 1972, during the Apollo Program. His first position was Chief of the Planning and Technical Support Office of the Launch Support Operations Division, where he was involved in planning, budgeting, contract management, and technical support. Later he served as Assistant to the Director of Support Operations, and he participated in the overall management of the directorate which was responsible for the operation and maintenance of the LC 39 facilities, including the VAB facilities equipment, the launch pads, and the crawler-transporter.

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