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Chapter 2

Engineering the Saturn V: Personal Recollections of the Development and Testing of the Rocket That Transported Man to the Moon*

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Abstract

The Saturn V rocket enabled the greatest spacefaring achievement of the 20th century; the landing of human beings on the moon. From the initial 1961 proclamation of US President John F. Kennedy that the United States would be "landing a man on the moon and returning him safely to Earth," to the lunar touchdown of the "Eagle" on July 20, 1969, a singular goal was focused upon by thousands of engineers. One of those individuals was an enthusiastic young engineer—named Aloysius (Al) Ignatius Reisz Jr.—who worked on the Saturn V program during the critical development and testing years. Mr. Reisz worked as a propulsion engineer at Boeing supporting the National Aeronautics and Space

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Administration (NASA) efforts at Marshall Space Flight Center (MSFC) in Huntsville, Alabama. Boeing was the key NASA Saturn V contractor beginning in 1964. Mr. Reisz was involved with the development and testing of the Saturn V's F-1 and J-2 engines. He initially supported the development of the first stage (S-IC) F-1 engine's propellant management system, and subsequently moved to support development of the second stage (S-II) J-2 engine's propellant management system. Mr. Reisz's knowledge and recollections of events, such as the bold first launch of the Saturn V on November 9, 1967, provide a firsthand account of spaceflight history. Mr. Reisz was witness to this daring, and successful, "all-up" launch that was deemed critical in order to meet President Kennedy's goals and timeline. On that suspense-filled day in 1967, Mr. Reisz was involved with the complex data recording and analysis of the F-1 engines. On the next unmanned launch of the Saturn V in 1968, Mr. Reisz surreptitiously played an interesting role in US spaceflight history. The present chapter will highlight Mr. Reisz's experiences during the development of the Saturn V, as well as additional interesting facts. During the Apollo era, Mr. Reisz, and other US engineers and scientists, represented the epitome of what could be accomplished with a single-minded goal, and the determination to achieve excellence and transform society.

I. Introduction

The "Greatest Generation" is a term that typically refers to individuals raised during the US Great Depression and bravely fought during World War II (WWII) [1]. Many would argue that, with respect to spacefaring endeavors, the greatest generation were the men and women who enabled mankind to step foot on the moon. While most of the stalwarts of this tremendous achievement are no longer present to share overlooked personal details and stories, there still exists individuals who were young professionals during that era and are eager to share their story. Al Reisz is one of those individuals—a mechanical engineer who witnessed the greatest spacefaring achievement of the 20th century, and played a critical role in the development and testing of the Saturn V engines.

Al Reisz, as well as thousands of other individuals, were inspired by the 1961 edict of President Kennedy to safely land a man on the moon before the end of the decade. The "space race" between the Soviet Union and the United States had already begun due the success of the Soviet Union's spacefaring efforts and the desire of the United States to gain space superiority. The US space workforce was determined to succeed, and it was supported by a nation determined to fulfil President Kennedy's goals.

The most critical factor to landing a man on the moon was developing the propulsive means to reach it. After WWII, Wernher von Braun's rocket team arrived in the United States from Germany; these engineers had a wealth of rocketry experience due to their work on the German V-2 military rocket. Von Braun and his team of engineers received US Department of Defense (DoD) funding to develop the Saturn rocket while working at the US Army Ballistic Missile Agency (ABMA) in Huntsville, Alabama [2]. The Saturn rocket was originally intended to launch US DoD payloads. However, when the von Braun team began working at NASA's MSFC, upon its creation in 1960, the Saturn vehicle program became the foundation of the heavy lift technology needed for the Apollo program—the NASA program created to land astronauts on the moon and return them safely to Earth.

The present chapter will focus upon historical facts regarding the Saturn V launch vehicle development and testing, along with Al Reisz's personal experiences as a young engineer working on various Saturn engine programs. Additionally, Mr. Reisz's post-Apollo era engineering achievements will be highlighted.

II. Background

Developing a Heavy Lift Launch Vehicle

During the last days of US President Dwight D. Eisenhower's administration, Keith Glennan, the first administrator of NASA—which formed in October 1958—authorized two engine development programs, the F-1 and the J-2, which became critical to the Saturn V propulsion system [3]. These engine programs, and the successful Mercury missions, laid the technical groundwork that made the Saturn V vehicle possible. However, the aggressive timeline laid out by President John F. Kennedy in May of 1961 would continue to be a challenge for the Saturn program. As a result, NASA immediately began extensive program planning and feasibility studies [3].

One early NASA concept for a manned lunar mission launch vehicle was the "Nova." The Nova vehicle was designed for a direct ascent approach to the surface of the moon, carrying enough fuel for a return flight to Earth [4]. This approach would have required a massive heavy lift launch vehicle. The first stage of Nova would have required eight F-1 engines delivering 12 million pounds of thrust. Earth orbit rendezvous, whereby two smaller launch vehicles would deliver payloads to be combined in Earth orbit before traveling to the moon, was also considered. Finally, NASA selected the Lunar Orbit Rendezvous (LOR) approach. LOR required a single launch vehicle to deliver the payload to lunar orbit, where the spacecraft would separate, one part descending to the Moon and then rejoining the orbiting portion before returning to Earth [4]. For this, a Nova vehicle would not be needed; NASA would select a Saturn V configuration.

Although the Saturn program began at the ABMA shortly after the Soviet Union's launch of Sputnik on October 4, 1957, with the intent to use existing tooling from the Redstone and Jupiter rocket programs, the program was transferred to the newly formed NASA. NASA continued its studies on engine configuration for the first stage. A four-engine booster was considered, but mass and performance uncertainties led to the more conservative selection of the five-engine booster, Saturn V [4].

The development of the Saturn V launch vehicle was centered at MSFC where von Braun was the Director from 1960–1970. The Saturn V project was different than any previously managed by MSFC, and required a major reorganization of the center. Rather than contractors simply providing support personnel or manufacturing products developed by NASA, the Saturn V contractors would now be responsible for designing, building, and testing sub-systems of the vehicle. Al Reisz's employer, Boeing, won the contract for the Saturn V first stage. The second and third stages went to North American Aviation and Douglas Aircraft, respectively [4].

The F-1 engines on the first stage used the common kerosene-liquid oxygen propellant. This propellant had been used in existing engines, so the design challenge in applying this concept to the Saturn V was in the scaling needed to achieve the desired thrust. Building larger engines than ever before, and grouping those engines together in clusters drove new developments in propellant management systems [5]. For the second and third stages, NASA decided early on that new, more powerful liquid hydrogen (LH2)/liquid oxygen (LO2) engine technology would be used. Although NASA had inherited an early LH2/LO2 engine program from the US Air Force, by 1960 the much higher performing J-2 engine was under development [5].

Due to the visibility of the Apollo program and the schedule pressure from the US government, along with the importance of astronaut safety, the development of a reliable launch vehicle was critical. In the end, Saturn successfully launched 32 consecutive times, with nine missions reaching the Moon [5].

The Saturn Rockets

While different versions of the Saturn rocket were developed, the Saturn V was the launch vehicle that ultimately propelled US astronauts to the moon. The Saturn V also launched Skylab—the first US space station—into orbit. Two smaller versions of the Saturn rocket were the Saturn I, first launched on October 27, 1961, and Saturn IB, which were used to launch US astronauts into Earth orbit, as well as conduct unmanned test flights of the Apollo spacecraft lunar module. Even though the Saturn rocket program was initiated at the ABMA, the Saturn I was the first rocket developed primarily for the peaceful exploration of space; previously, NASA used military rockets to launch scientific payloads and men into space [6]. Differences in the engines, stages, and size—among the three boosters—are shown in Figure 2–1.

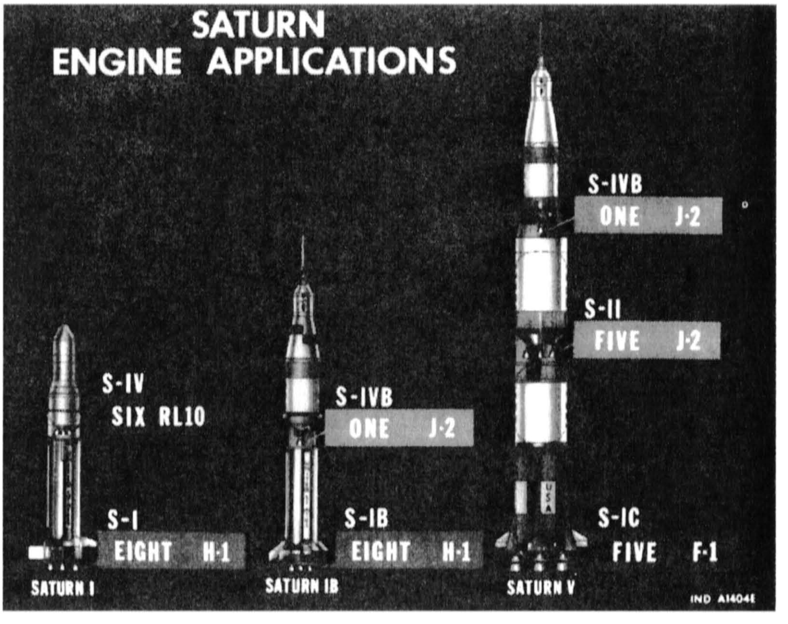

Figure 2–1: The Saturn rockets. [7]

The Saturn V was a three-stage rocket designed under the technical direction of von Braun's team at MSFC and is shown in Figure 2–2. The first stage was built by Boeing at NASA's Michoud Assembly Facility in New Orleans, Louisiana, the second stage by North American Aviation in California, and the third stage by Douglas Aircraft, also in California. The rocket provided over 8,850,000 pounds (lb), or 39,367 kilonewtons (kN), of thrust. The overall height of the rocket was 363 feet (ft), or 111 meters (m), and weighed more than 6 million lb, or 2.72 million kilograms (kg). The first launch occurred on November 9, 1967 and was unmanned.

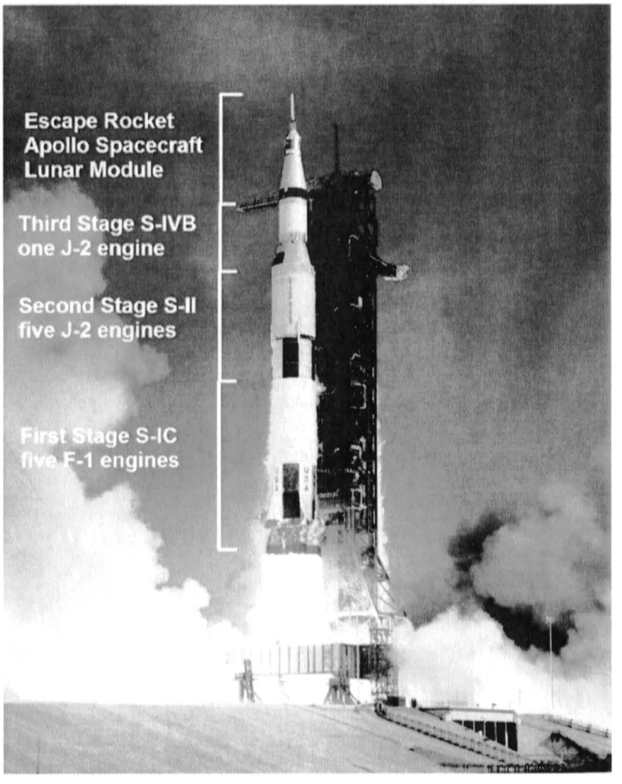

Figure 2–2: The Saturn V AS-506 upon lift-off on launch pad 39-A on July 16, 1969. [8]

A Future Engineer

Al Reisz was born toward the end of the US Great Depression (1929–1939) on September 28, 1937, in Henderson, Kentucky. He was born to Aloysius Ignatius Reisz and Susan Elizabeth Ward Reisz; he was the oldest of 11 children. His ancestors emigrated from Germany and proved to be innovative and creative individuals. In fact, Al's paternal grandfather, James Daniel Reisz, held a US patent for a tractor plow attachment that allowed previously inaccessible corners of fields to be fully accessed and cultivated; an image of the patent is shown in Figure 2–3.

Al was raised on his family's Henderson farm, along the Ohio River. As shown in Figures 2–4 and 2–5, his childhood was immersed in farming culture and life, but he had far-reaching aspirations. Al's father wanted him to also become a farmer; however, Al had different ambitions, and they had to do with space. His nature was explorative and he wanted to help mankind discover the unknown territory of outer-space. As Al himself stated [9]:

"Somehow I've had the intellect that we need to explore space. Humans will learn more from exploring space, than on Earth doing research and development. It is out there, and we will learn from it. There is far more out there than we know."

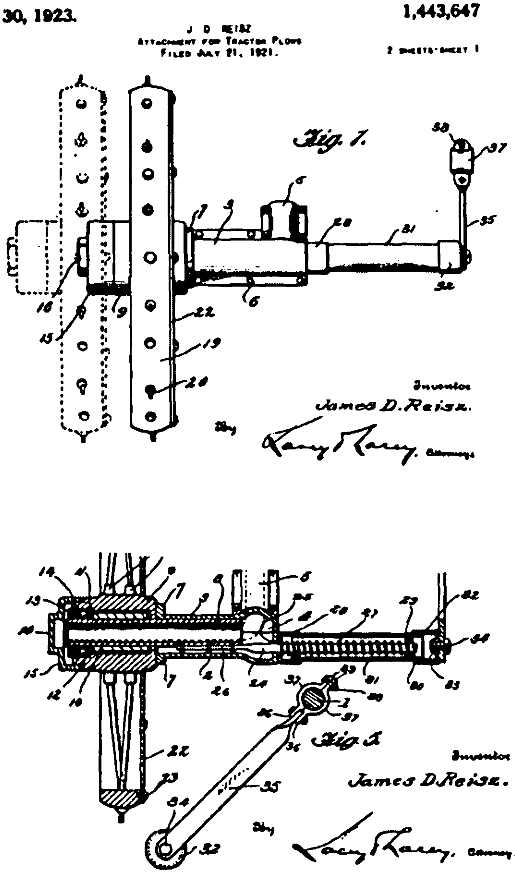

Figure 2–3: US patent 1,443,647 awarded to James D. Reisz in 1923. Courtesy J. M. Reisz.

After graduating from high school in 1955 from Holy Name Catholic School (established in 1872), Al decided to make his dream of working in the space program a reality. He attended the University of Kentucky, earning a Bachelor's degree in Mechanical Engineering in 1961. After college, Al was commissioned as a Lieutenant—specifically an artillery officer—in the US Army. Al, shown in Figure 2–6, served for two years on active duty and continued serving in the Army National Guard for another 18 years prior to retiring as a Lieutenant Colonel. At one point, during his active duty service, he worked on the Redstone Rocket program in Huntsville, Alabama. According to Al, this particular work experience is likely what helped him secure a job as an engineer with Boeing in 1964.

Figure 2–4: Al Reisz (far right) shown with his father and four siblings on the family farm in 1944; note the brick factory, on the left, behind the farm. Courtesy Al Reisz.

Figure 2–5: Al Reisz, shown at nine years old, riding the family tractor. Courtesy Al Reisz.

Figure 2–6: US Army Lieutenant Al Reisz in 1961. Courtesy J. M. Reisz.

III. The Saturn V Engines

The heart of the Saturn V rocket was its engines. Five first stage F-1 engines ignited on the launch pad and propelled the vehicle to an altitude of 38 miles, or 61.16 kilometers (km), before first stage separation. Subsequently, five J-2 engines ignited on the second stage and enabled the vehicle to reach an altitude of 118 miles (189.9 km). Finally, upon separation of the second stage, the third stage single J-2 engine ignited to place the vehicle into Earth orbit. The same J-2 engine ignited a second time to achieve a trajectory to the moon. Highlights of the Saturn V technical specifications are provided in Table 2–1.

Al Reisz garnered an intimate knowledge of the Saturn V engines during his career at Boeing. He had a unique perspective as a witness to the history-making unmanned and manned Saturn launches. His analysis of the Saturn V engines proved critical to ensuring a multiple engine failure scenario would not result in the catastrophic failure of a mission.

The F-1 Engine

The F-1 engine was a bipropellant liquid rocket system developed by Rocketdyne under the technical direction of MSFC. The rocket engine utilized Liquid Oxygen (LO2) as the oxidizer and Rocket Propellant (RP)-1 (kerosene) as fuel. The initial version of the engine had a fixed thrust of 1.5 million lb (6,672 kN). Later versions, first used on mission Apollo-Saturn (AS) 504—also known as Apollo 9—that launched on March 3, 1969, had an uprated thrust to 1.522 million lb (6,770 kN) [11].

	First Stage S-IC	Second Stage S-II	Third Stage S-IVB
Engine	F-1	J-2	J-2
# of Engines	5	5	1
Thrust	7,500,000 lb* (33,362 kN)	1,125,000 lb (5004 kN)	230,000 lb (1023 kN)
Propellants	RP-1 and LO2	LH2 and LO2	LH2 and LO2
Burn Time	150 seconds (sec)	359 sec	480 sec (total time for 2 burns) 1st burn: to Earth orbit, 2nd burn: trajectory to moon
Height	138 ft (42 m)	81.5 ft (24.84 m)	58.5 ft (17.83 m)
Diameter	33 ft (10.06 m)	33 ft (10.06 m)	21.7 ft (6.61 m)
Weight-Loaded	5,017,000 lb (2,275,673 kg)	1,101,000 lb (499,405 kg)	263,800 lb (119,658 kg)
Weight-Dry	289,900 lb (131,496 kg)	78,050 lb (35,403 kg)	78,050 lb (35,403 kg)
Speed	6,000 mph 9,656 kilometers per hour (kph)	14,000 mph (22,531 kph)	25,000 mph (1st burn) (40,233 kph)
Altitude at Burnout	38 miles (61.16 km)	118 miles (189.9 km)	Trajectory to moon after 2nd burnout
***Saturn V mission AS-504 and subsequent missions utilized uprated F-1 engines with a thrust of 1,522,000 lb Rocket Propellant-1 (RP-1) Liquid Oxygen (LO2) Liquid Hydrogen (LH2)**			

Table 2–1: Saturn V stage and engine specifications [10].

A schematic of the F-1 engine, with sub-systems labeled, is shown in Figure 2–7. The basic components of the F-1 include a tubular wall thrust chamber, direct drive turbo-pump, a gas generator, and various controls. The gimbal at the top of the F-1 engine allows for thrust vector control. The engine was designed such that all components were mounted on either the thrust chamber, the turbo-pump, or the plumbing system between the two; this eliminated the need for flexible high-pressure ducting during gimbal movement of the engines [12]. Five F-1 engines were attached to the Saturn V first stage in an arrangement shown in

Figure 2–8. All five engines were identical except that the center engine was statically mounted.

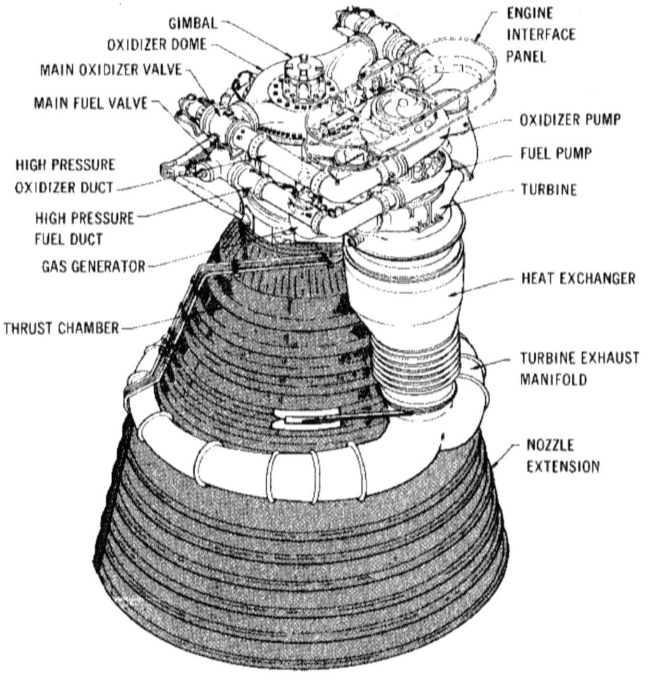

Figure 2–7: Saturn V S-IC F-1 engine. [11]

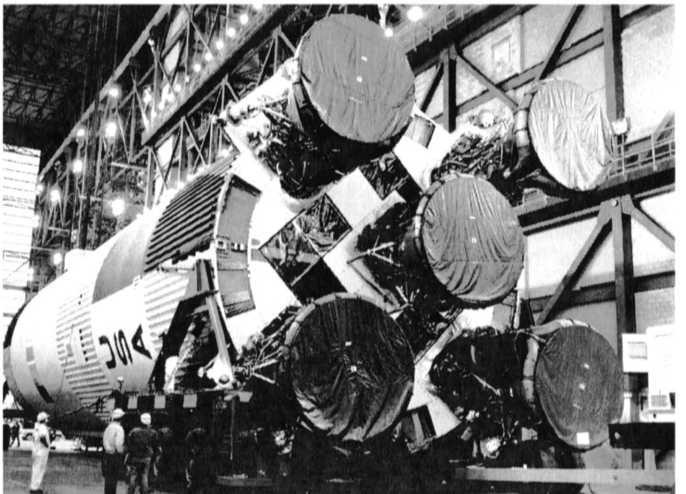

Figure 2–8: The Saturn V S-IC in the vehicle assembly building at Kennedy Space Center with five F-1 engines attached to S-IC. [13]

Rocketdyne delivered the first F-1 production engine to MSFC on October 30, 1963. Numerous other F-1 engines were delivered to MSFC for testing, as shown in Figure 2–9. Subsequently, the engines were delivered to the Michoud Assembly Facility in LA for S-IC integration.

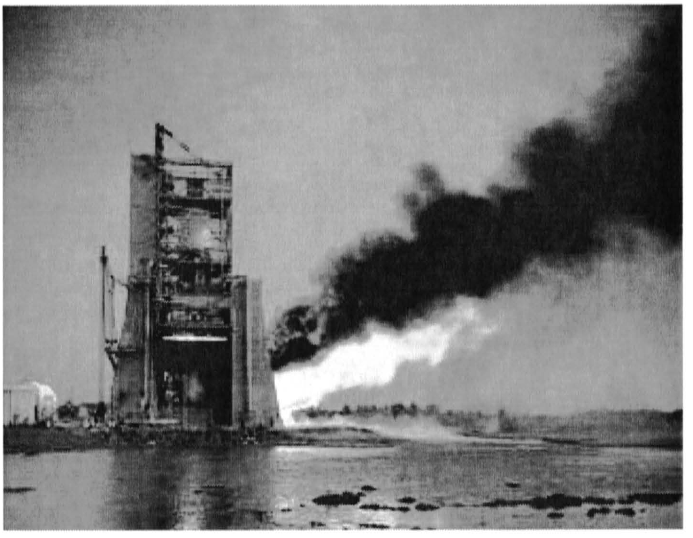

Figure 2–9: MSFC test firing of all five F-1 engines for the Saturn V S-IC test stage. [14]

The J-2 Engine

The J-2 engine was also developed by Rocketdyne; five J-2 engines propelled the Saturn V S-II stage and one propelled the S-IVB stage. The engines' propellants were LH2 and LO2 and each engine provided 230,000 lb (1,023 kN) of thrust. On the S-IVB stage, the J-2 engine was equipped to be restarted; the first burn took the vehicle to Earth orbit and the second burn on a trajectory to the moon. All J-2 engines were gimbal mounted except for the center engine on the second stage—just as the F-1 engine configuration on S-IB. All components of the J-2 were mounted on the thrust chamber [15].

The length of the J-2 was 11 ft, 1 inch (3.3782 m)—compared to 19 ft (5.7912 m) for the F-1 engine. A component labeled schematic of the J-2 is shown in Figure 2–10, and a cutaway image of the S-II, showing the J-2 engines, is provided in Figure 2–11.

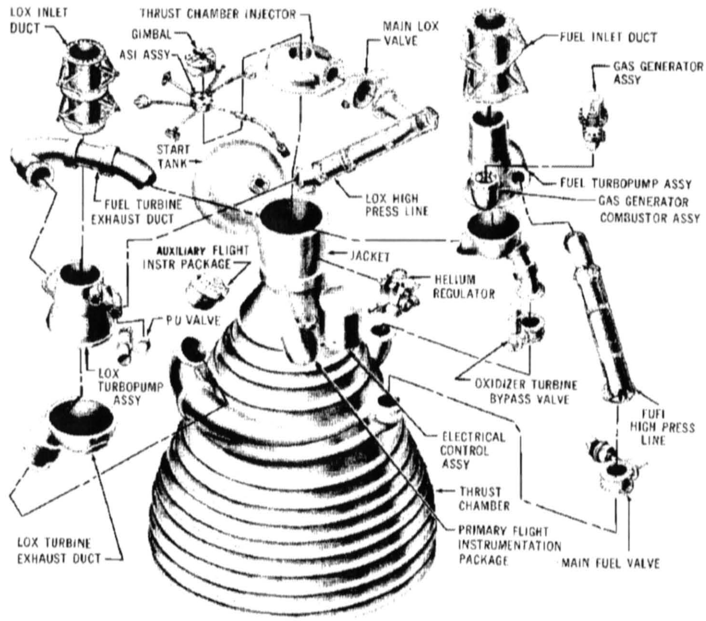

Figure 2–10: The Saturn V S-II and S-IVB J-2 engine. [15]

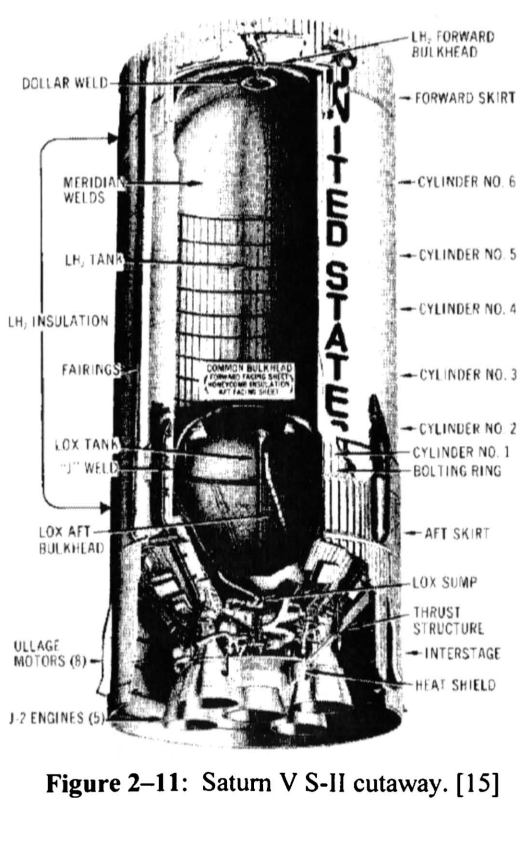

Figure 2–11: Saturn V S-II cutaway. [15]

A Young Apollo Engineer

Having graduated from the University of Kentucky with a mechanical engineering degree, as well as having served active duty in the US Army for two years, Al Reisz was anxious to work on the Apollo space program. Al was fortunate enough to have been hired by Boeing as a Propellant Management Engineer in Huntsville, Alabama. Boeing designed, fabricated, and assembled the S-IC at the Michoud facility in Louisiana, as well as tested the first stage at the Mississippi Test Facility (now known as NASA's Stennis Space Center) [16]. Boeing continued to support the Apollo program via systems engineering, vehicle integration, and mission support for the entire Saturn V vehicle at MSFC. Boeing also supported spacecraft assessment and engineering at KSC in Florida, and technical staff support for the Apollo program at NASA Headquarters in Washington, DC [16].

Al Reisz's Apollo and Skylab program engineering efforts occurred at MSFC (building 4610) and were focused on the Saturn I and IB rockets, as well as the Saturn V. The Saturn IB booster was used for Earth orbit flights, while the Saturn V enabled lunar missions. While working on the Saturn V, Al initially worked with the first stage engines specifically, F-1 engine propellant analysis-and later moved to analysis of the J-2 engine on S-II and S-IVB. His Saturn efforts focused upon propellant management systems development, flight predictions, and flight reconstructions. He was also involved with static testing of the first stage at MSFC.

IV. Saturn V Testing

Stage and Engine Testing

Verification of the Saturn V launch vehicle involved extensive component and material testing. All materials underwent a battery of tests to include tensile/compressive strength and fracture toughness. Individual components were then subject to functionality testing to verify that they met the design criteria. However, the most important tests that occurred during the Apollo program were those of the stages that comprised the Saturn V launch vehicle. Over a period of several years, during the early-to-mid 1960s, a total of 45 flight-rated stages were built, as well as many other stages that were constructed solely for a variety of unique tests that would prove the worthiness of the design.

Although testing of the engines for the Saturn V stages took place in both Santa Susana and Sacramento, California, as well as at the former Mississippi Test Facility, the testing of the Saturn V stages occurred mainly at MSFC. In order to accommodate the manufacturing and testing of the Saturn V so that the goal of landing a man on the moon prior to the end of the decade could be realized, new test stands were designed and built that would allow for testing under a wider variety of conditions. The tests were required to ensure that the Saturn V could withstand the operational and environmental conditions the spacecraft would encounter during the launch and trans-lunar injection phases of the flight. The main types of stage testing that occurred at MSFC were static testing and dynamic testing.

Saturn V Static Testing

Static testing at MSFC involved the test stage being held in place in order to conduct a series of hot fire tests that were designed to analyze the operation of the Rocketdyne built engines, as well as the firing equipment and other systems related to the operation of the engines. The static test facility was called the S-IC Stage Static Facility, as the stages being tested were all Saturn V first stages (S-IC) or S-IC-T for test-only stages [17]. The first S-IC-T stage was lifted into the static test stand on March 1965, and was tested throughout the month. The first ground test firings of this stage occurred in April 1965, with a successful single-engine test firing which lasted less than 17 seconds (sec). By mid-April, MSFC had tested each of the five engines on the initial S-IC-T stage, as well as successfully conducted a hot fire test involving all five of the engines for more than 6 sec. This final test firing produced more thrust (7.5 million lb or 33,361 kN) than had ever been produced in any previous hot fire static test. During this firing, more than 500 data points detailing the S-IC-T stage's performance were collected. In August 1965, the S-IC-T stage was successfully tested for the first full-duration (150 sec) hot firing of a test stage, and by mid-December fifteen additional firings had been conducted; three of those tests being full-duration hot fires, which lasted a total of 450 sec. By early 1966, tests were being conducted on the S-IC stage that had been designed to fly in space. In February of that year, three individual static hot test firings were performed on the S-IC stage, for 120 sec total burn time. During these static tests of the flight stage, 7.5 million lb of thrust was produced, as all five of the F-1 engines burned simultaneously. In order to produce the 1.5 million lb of thrust required of each engine, fifteen tons of both kerosene and oxygen were needed to combust for each second of the 40 sec hot fire test [17].

Saturn V Dynamic Testing

Dynamic testing of the Saturn V launch vehicle was required in order to determine how shaking and oscillations encountered during launch would affect the operation of the vehicle during flight. Using data obtained under dynamic testing conditions, engineers would be able to accurately design control systems needed for the vehicle's structural, guidance, and flight requirements. Dynamic testing was needed for three different simulated flight scenarios, which included: (1) a test of the entire stack of stages (including the service and command modules) as if the entire vehicle had just launched, (2) a test simulating separation of the first stage and the second stage firing, and (3) a test simulating separation of the second stage and the third stage firing [18].

The three simulation scenarios were known as Configurations I, II, and III. Configuration III testing occurred first, in late 1965, as the third stage and boilerplate Apollo command and service modules were ready for dynamic testing using the S-IB Dynamic Test Facility. Configuration I testing, which required the entire vehicle, and was conducted using the Saturn V Dynamic Test Stand, occurred from January to March 1966. Configuration II testing, in which the first stage was removed from the stack, was conducted later in 1966 using the same test stand [18]. The dynamic testing of the different launch and flight configurations resulted in various engineering changes to alleviate vibrations and oscillations that would be encountered during flight. To conduct these dynamic tests, the vehicle was mounted on four hydraulic/pneumatic actuators, which were designed to shake or vibrate the vehicle, simulating expected operational conditions. By adjusting the simulated amount of fuel during the test, it was possible to determine how the vehicle would behave at critical points during flight. Dynamic testing of the three individual flight configurations lasted 450 hours [19]. By August 1967, all static and dynamic testing was successfully completed, and the Saturn V launch vehicle was certified for flight.

Saturn V "All Up" Tests

One of the critical decisions that was made during the testing phase of the Saturn V launch vehicles was to test the vehicles using an "all up" approach, meaning that the entire vehicle was tested all at once, instead of sub-systems being test-launched separately [20]. George Mueller, then the Director of NASA's Office of Manned Space Flight, quickly concluded that NASA would not achieve the nation's space mission if a different approach to testing the vehicle was not implemented. Although Wernher von Braun was strongly against this approach, George Mueller persisted, and the first launch of the Saturn V in November 1967, which was an unmanned flight designated as Apollo 4 (AS-501), was completely successful in all phases of the flight. The second test launch in April 1968, of the unmanned Saturn V rocket, was labeled Apollo 6 (AS-502). The third flight of the Saturn V launch vehicle, in December 1968, was designated

Apollo 8 (AS-503), and it carried the first manned crew on a cislunar trajectory around the far side of the moon and back to Earth [21]. The three aforementioned launches of the Saturn V will be described via the personal experiences of a young Apollo engineer.

AS-501: Personal Recollections

During the significant, unmanned, AS-501 (Apollo 4) all-up launch of the Saturn V on November 9, 1967, Al Reisz was in Huntsville positioned in front of monitors watching a live video feed as he and his colleagues anxiously assessed the propellant performance of the engines. There were live communications from Cape Canaveral, Florida, and Houston, Texas. According to Al [22]: "the mood among the engineers was anticipatory as we knew history was being made; space history was being made. So we were all kind of anxious and anticipating what was happening." As a Propellant Management Engineer, Al was responsible for assessing the engine performance. While there were hundreds of engineers evaluating every aspect of the vehicle, Al worked closely with one colleague, Ken Roberts, in preparation for AS-501. According to Al,

> "To get 40 miles up you need more power and that's kerosene (F-1 engines); the first stage has got kerosene as power. At 40 miles up, the second stage has already ignited and you've got liquid oxygen that goes with your liquid hydrogen. The second stage has got liquid hydrogen, and that's speed; that's what you want. When you get 40 miles up you want speed. The launch of the Apollo Saturn 501 was perfect. And I knew that night that we were going to put American astronauts on the moon."

Another interesting story personally conveyed by Al regarded analysis he conducted that would determine the engine power required to reach Earth orbit. During this time, Al and his team were still using slide rules to complete calculations. According to Al:

> "To get to the moon, that's the 3rd stage. You get into orbit and you can then break into the lunar path. And you've got to hit within 100 miles. We were simulating that one time. We were trying to hit within 100 miles and couldn't quite get it there. So there was this guy that came up. He looked at what we were doing, this older gentleman, and he said 'add another digit to pi.' We listened and it worked!"

Al's team had some very intelligent engineers who completed their analysis without computers—a testament to their dedication and determination.

AS-502: Personal Recollections

The next unmanned Saturn V launch was AS-502 (Apollo 6), which occurred on April 4, 1968—winter solstice. According to Al,

> "The 502 was different. It started having instability in the first stage. I was working second stage by then. When the vehicle was more than 40 miles up, I was anxiously waiting to see if the first stage instability was going to affect the second stage engines, and it did. We had two engine-outs. So what we did, of course, was extend burn time on the other three J-2 engines. We had a fuel manifold, so you had the same amount of fuel. You got out to where you intended, but it took a little longer to get there. It took a little longer, but other than that, it didn't compromise the mission."

Al discussed the cause of the second stage engine outs as follows:

> "Basically it was vibrations in first stage engines. The F-1 engines were originally developed by von Braun; they were his development. He had developed them for the Redstone Rocket. They had been developed for an intercontinental, inter-range ballistic missile—and they worked for that purpose. But basically, that's what we had to work with to go to the moon."

Interestingly, the two engine-out occurrence during AS-502 did not cause Al to be gravely concerned that the mission would end in failure; this is due to a noteworthy fact regarding prior analysis he had conducted [23]. While working on second stage burn analysis, one of Al's tasks was to create a timeline chart to track the burn times for the five S-II J2 engines. He was also tasked with creating a second timeline in case one of the five J2 engines failed during the burn or had to be shut down. He would mark the time in seconds when an engine would shut down and that would inform him as to how much longer to burn the other four engines in order to empty the tank. Al conveyed to his manager that he had finished the timeline chart and was going to create a third timeline burn chart in case two S-II engines failed. His manager told him "not to waste time on that," and that "there is no way we will ever lose two J2 engines." Eventually, however, the engineers were required to analyze multiple engine outs and Al's team continued the extra effort, completing the much more difficult multiple engine out scenario chart. The day came to launch the Saturn V 502 and the first stage burn experienced severe vibrations. In fact, the violent shaking, referred to as the "pogo" effect, caused there to be modulations as high as +/– 0.6 g—as recorded in the command module; this exceeded the design criteria as well as the 0.25 g upper limit for the manned Gemini missions [24]. Although the S-IB vibrations were troubling, the first stage did reach its altitude. However, upon firing of the second stage engines, two engines quickly went out, leaving only three functioning J-2 engines. Because of the analysis performed by Al and his team, the engineers knew the remaining J-2 engines would need to burn longer. However, the remaining three J-2 engines did not allow the second stage to achieve the required altitude of 118 miles (189.9 km) and, as result, the S-IVB single J-2 engine had to burn longer, as well. Compounding the situation, the third stage J-2 engine would not restart for the second burn, so the command and service modules were separated from the third stage [24]. Even though NASA announced that Apollo 6 had done its job well, George Mueller (NASA Associate Administrator of the Office of Manned Space Flight) and Lt. General Samuel Phillips (Apollo Program Director) did not declare the mission a success. As a result, the Huntsville team had a great deal of work to do to resolve the AS-502 problems and understand why the J-2 engines failed, before a manned launch could occur.

AS-503: Personal Recollections

On December 21, 1968, AS-503 (Apollo 8) launched a manned mission beyond Earth's orbit for the first time. The mission entailed circling the moon 10 times, as well as taking numerous, awe-inspiring, pictures. The holidays of 1968 proved to be personally transforming and inspiring to Al for many reasons. Among many others, Al provided the following observations of the effect Apollo 8 had upon his views and motivation to continue to promote the US space program [25]:

- Forever changed his perception of the fragile planet we inhabit
- New sense of awareness of Earth and its uniqueness in the solar system
- The mission proved that mankind is not bound to Earth
- Provided a new sense of confidence in human intelligence.

In addition to the aforementioned statements, Al stressed that "above all, the view of the graceful Earth from the moon inspired us to engineer better systems for our home planet."

V. July 21, 1969 and Beyond

Man Lands on the Moon

On July 16, 1969, the Saturn V AS-506 (Apollo 11) launched three US astronauts into space on a mission to the moon. Apollo 11 was the fifth manned Saturn V launch. Astronauts Buzz Aldrin, Neil Armstrong, and Michael Collins navigated the eight-day mission to a successful and history-making conclusion. Five days into the mission, on July 21 at 02:56:15 Greenwich Mean Time (GMT), Commander Neil Armstrong took the first step on the lunar surface. Al Reisz and his colleagues were ecstatic at the success of the mission, and Al simply described Apollo 11 as follows: "it was perfect." There was great jubilation among the Huntsville team and celebrations followed, as shown in Figure 2–12.

Figure 2–12: Wernher von Braun celebrating with the community in Huntsville, Alabama, after the successful Apollo 11 mission. [26]

US Commitment to a Lunar Landing

An interesting assessment was made by Al regarding the US commitment to landing a man on the moon. In the early 1960s, the United States announced the lunar mission plans as a result of the space race and to ensure superiority in space; many regarded it as a matter of national security. As Al stated [22]:

> "President Kennedy had asked von Braun what the US could do 'to beat the Russians—to get ahead of the Russians in space?' And von Braun told him that it was that we could beat the Russians to the moon. He told John Kennedy, 'We will beat the Russians to the moon, and we will do it in this decade.'"

However, as conveyed by Al, in the last half of the 1960s, the race really wasn't against the Soviet Union any longer; it was with the US Congress, to ensure they would continue to support NASA's efforts. Al stated that by the mid to late 1960s the space race changed due to the Soviet Union losing their own version of Wernher von Braun—a man named Sergei Korolev. Korolev died in January 1966. Al stated that

> "when he died, they (the Soviet Union) were out of it. The US public didn't know it. But when he died, Russia was out. Korolev is the man that launched the first satellite and the first humans into space—both male and

female. He launched women into space. He launched the first space ships. And he made a lot of space discoveries. He was quite a man."

Al had a great deal of respect for individuals that sought to explore outer space. In fact, over 43 years after Korolev's death, Al had a meeting with his daughter and discussed her father's contributions to spaceflight history, as shown in Figure 2–13.

Figure 2–13: Al Reisz meeting with Sergei Korolev's daughter in 2009. Courtesy Al Reisz.

Al stated that "when Korolev died we knew we weren't racing the Russians any longer, we were racing the US Congress. And it depended on the political-social situation. It was the American public we needed." The late 1960s saw a great deal of turmoil in the United States, but Americans were still driven to honor the commitment made by President Kennedy. The Apollo program provided the US population a great source of national pride. Al Reisz understood that.

VI. Post Apollo

After the Apollo and Skylab programs ended, there was a shortage of work for space professionals in Huntsville. Al, undeterred, started his own business in 1974, Reisz Engineers. Throughout his career, Al maintained an active Professional Engineering license in the states of Alabama and Kentucky. Reisz Engineers employed many individuals from the Apollo program. As stated on the Resiz Engineers website [27]:

> "Apollo program engineers had learned that visionary endeavours can be achieved with the intelligent application of scientific knowledge and with an unselfish dedication to achieve objectives in timely manner. Ordained with this awareness, Reisz Engineers is dedicated to providing quality engineering services to develop better engineered systems for life on Earth and to explore space."

Because of the lack of space industry work, Reisz Engineers branched out and accepted industrial engineering projects for several years. Reisz Engineers clients included Daimler Chrysler, Mercedes Benz U.S., Teledyne Brown Engineering, PPG Aircraft Products, Goldkist, Inc., the Tennessee Valley Authority, the US Army Missile Command, the US Army Corps of Engineers, and NASA, to name a few.

While Al worked on other projects, he always stayed involved with the space program. As Al once stated: "I'm always interested in space exploration. I'm more interested in space exploration than anything. I always intended to explore what is beyond. That's what I like. And I still like it."

Al always admired Wernher von Braun. As an Apollo program engineer, Al met von Braun several times. In fact, he once got into an argument with a retired Apollo astronaut regarding von Braun. As Al stated:

> "you know I got into a fight with him (former Apollo astronaut) up in Washington. He never liked von Braun. We were at a formal dinner (in a large hall) and guests started talking about how we were going to go to Mars. But then, for some reason, the ex-astronaut stated that he didn't like von Braun. Of course, I always defended von Braun. Now those Apollo astronauts were never much taller than me—I am 5 ft, 8 in—if that. Now the ex-astronaut was heavier by then, as he lifted weights and worked out. After he made derogatory comments about von Braun, I told him 'well, he made you famous. He put you on the moon. You would be a nobody today if you hadn't been on that moon. And it was von Braun that put you on there.' We had a verbal argument. But he was kind of muscular. And people told me after that encounter that I was lucky he had his girlfriend with him or else he would have punched me out in no time. So I almost got into a physical fight with an Apollo astronaut over Wernher von Braun."

Solar Powered Soy Bean Plant

Having grown up on a farm, and having just left the Apollo program, Al and his employees at Reisz Engineers become involved with an engineering design opportunity at a soybean processing plant in Decatur, Alabama. According to Al:

> "I worked for my father, farming our land for many years. My father was a farmer, but he was also the manager of a soybean processing plant, which was new at that time. He had brought in a new process to his plant called a

solvent extraction process. That plant became famous, as did my father. Years later, when I started my own business, I saw they were going to build a soybean processing plant in Decatur. I went over there and the plant manager, Travis Mitchell, knew my name—due to my father—and gave me some of my first work as a former Apollo engineer."

The Decatur, Alabama, Gold Kist soybean plant design project involved energy conservation via the use of solar panels. With the advent of the US energy crisis of the mid-1970s, Reisz Engineers specialized in designing and developing energy efficient systems. In 1976, when fuel oil supplies needed for plant operation of the new soy processing plant in Decatur were curtailed, the company designed and developed a large-scale solar energy system. The soybean facility processed soybeans into high protein foodstuffs and vegetable oil. Reisz Engineers designed a solar panel system to power the facility. This was one of the earliest large-scale solar energy systems used in industrial processing, and served as a model for subsequent industrial solar energy systems.

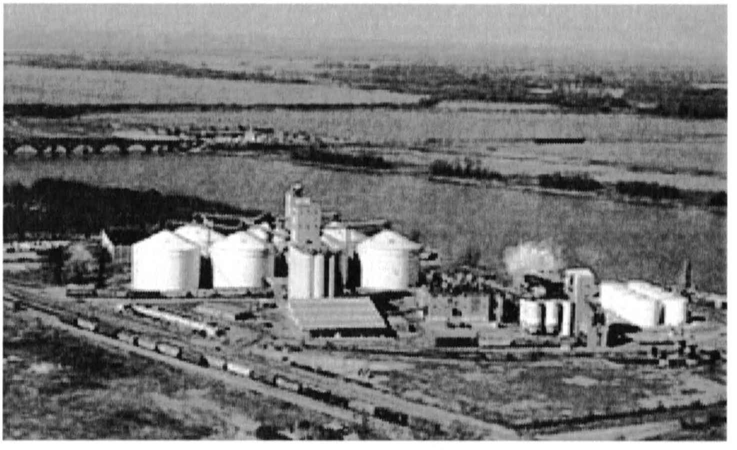

Figure 2–14: The soybean plant in Alabama—note the rectangular shaped solar panel system in the forefront. [27]

Additional Projects

Reisz Engineers industrial clients were in the manufacturing, grain and food processing, automotive, and aerospace fields. In 1978, Reisz Engineers designed and developed a system for the Tennessee Valley Authority that utilized a power plant's waste warm water to provide the facility with both winter heating and summer cooling. The project received national recognition and was selected as a ten most outstanding engineering projects in the United States in 1978 by the National Society of Professional Engineers [27].

The company also worked with the Chrysler Corporation in developing Chrysler's T-Van electric vehicles and in developing an improved four-cylinder ignition system. They also developed a large test chamber at Redstone Arsenal whose interior can be programmed to simulate Earth's atmosphere environment at any global location. With the rising concerns of environmental pollution and passage of environmental regulations in the 1970s, the company developed environmental services to complement the firm's engineering services. Reisz Engineers has worked with industrial, government and academic organizations in developing new industrial fuels, improved manufacturing processes and more efficient energy systems [27].

Of course, Al continuously maintained an active presence in the space industry—on both a professional and a voluntary basis. He was an active member and volunteer in many organizations including, but not limited to, the American Society of Mechanical Engineers (ASME), the American Institute of Aeronautics and Astronautics (AIAA), and the National Space Society, among many others. Al frequently volunteered at NASA events such as the Human Rover Exploration Challenge (formerly the Great Moonbuggy Competition) held at the US Space and Rocket Center (USSRC) in Huntsville, Alabama. He enjoyed providing tours for individuals at the USSRC, as he knew the details of the Apollo era displays and could convey stories about von Braun and his fellow rocket team members, see Figures 2–15 and 2–16.

Figure 2–15: Al Reisz discusses the von Braun display at the USSRC. Courtesy Al Reisz.

Figure 2–16: Al Reisz provides a tour of the Saturn V rocket at the USSRC. Courtesy Al Reisz.

Al was friends with many engineers on the von Braun team including Guenther Haukohl, Ernst Stuhlinger, Fritz Muller, Karl Heimberg, Walter Haeussermann, Konrad Dannenberg, Willibald Prasthofer, and many others. At one time, Mr. Prasthofer even worked with Reisz Engineers. Due to Al's German heritage, he shared a common heritage with the von Braun rocket team's homeland. Von Braun's mentor in Germany, the person who taught him about rocketry and whose book von Braun read as a teenager was Dr. Hermann Oberth. Dr. Oberth wrote the first book on rocketry and space travel that was not science fiction, in 1923, *Die Rakete zu den Planetenräumen* (*The Rocket into Interplanetary Space*). Al met Dr. Oberth at his 90th birthday party in Huntsville. It was fitting that in 2011, Al received the AIAA Hermann Oberth award for his work on the Apollo program. Al admired all of the aforementioned individuals, and once stated the following: "I learned from these men. They performed such incredible feats in rocketry and space, and had such incredible stories."

Recent Propulsion Research Efforts

In the last 10–15 years, Reisz Engineers has been actively developing advanced space propulsion systems. An electron cyclotron propulsion system effort was conducted with the University of Michigan beginning in 2004. Working at the propulsion research labs at MSFC, research and development of an advanced propulsion system resulted in an Electron Cyclotron Resonance (ECR) in-space propulsion system developed through phase 1 and phase 2 NASA contracts. Further research and development promises ideal in-space propulsion for missions to the planets and asteroids. These efforts are shown in Figures 2–17, 2–18, and 2–19. Al Reisz has also been involved with developing the J-2X engine at MSFC.

Figure 2–17: Al Reisz (left) and Dr. Jerry Brainerd inspect a small in-space thruster attached to a vacuum chamber. [27]

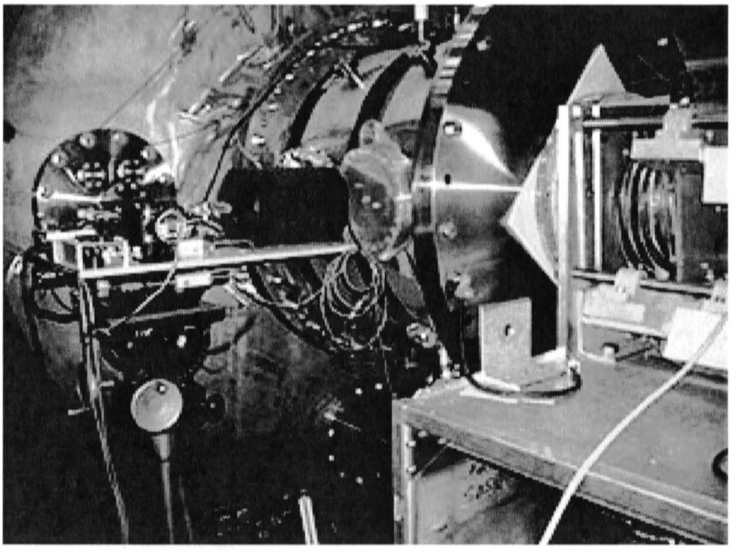

Figure 2–18: Reisz Engineers Laser Induced Fluorescence plasma particle measuring instrumentation [27]

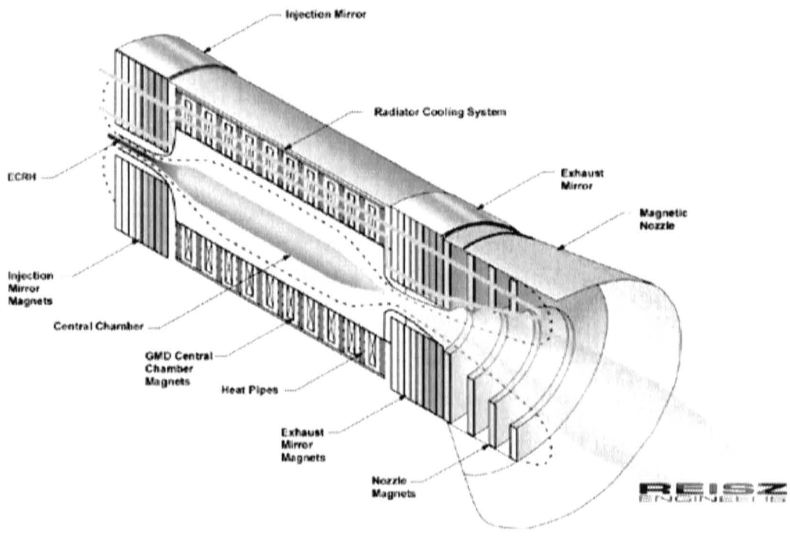

Figure 2–19: Reisz Engineers Resonance Electron-Cyclotron Throttleable Rocket. [27]

In 2014, Boeing once again signed a NASA contract as the primary developer for a heavy lift launch vehicle—the Space Launch System (SLS). The SLS will be the largest and most powerful rocket ever built. In 2014, Boeing called upon Al to present to the SLS development team and discuss the Saturn V development process, choices, methods, and other pertinent information that could be garnered. As always, Al was enthusiastic about supporting a major space flight program. The Boeing engineers were honored to learn from the experiences of a seasoned Apollo engineer.

Within the last few years, Al has been frequently asked to discuss his career on the Apollo program, and has gladly obliged. Hundreds, if not thousands, of individuals have been honored to hear his presentation, titled "Engineering the Saturn V" [28, 29]. One topic that is a great passion for Al is to convey to all generations the importance of the space program and why the United States should continue to fund NASA. Al created a timeline to show the explosion in innovations, products, and technologies that were derived from the space program, as shown in Figure 2–20. The young engineer who worked on the Saturn V engines (Figure 2–21) made a substantial impact during his lifetime, and continued to educate younger generations regarding the importance of space and exploration.

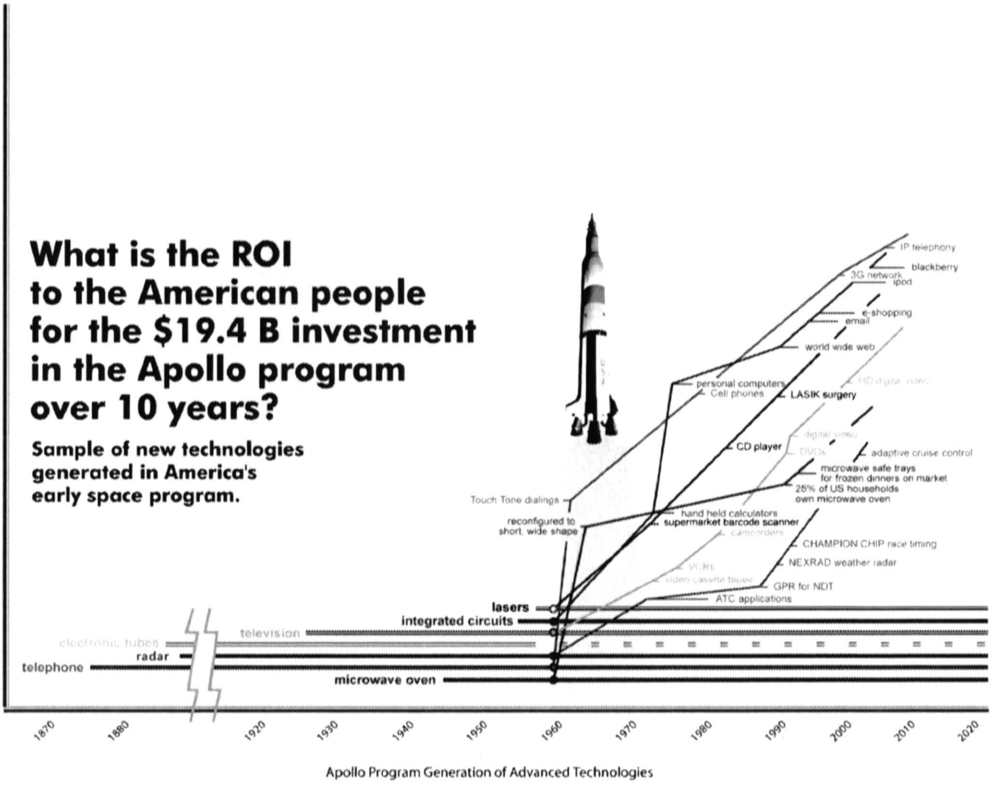

Figure 2–20: Timeline of technologies resulting from the space program. [28]

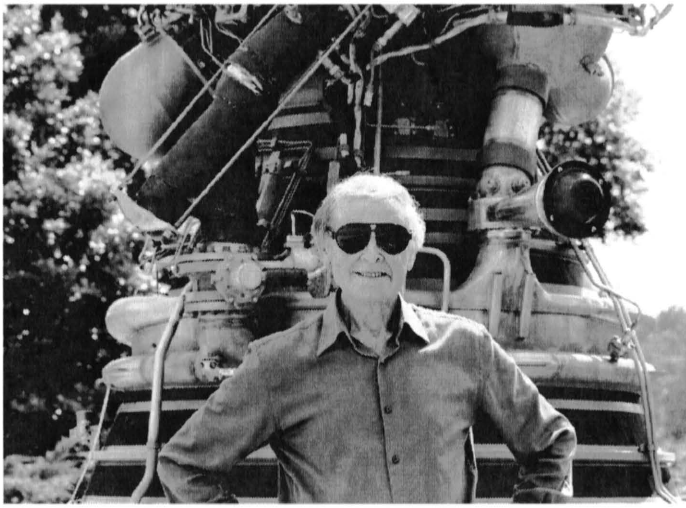

Figure 2–21: Al Reisz standing in front of a Saturn V engine. Courtesy Al Reisz.

VII. Conclusions

The Saturn V had 13 missions—all for the Apollo program except for the last, which launched Skylab into orbit. At the center of the most exciting time in US space flight history was a young engineer named Al Reisz. Al was an integral part of the team that enabled the successful landing of man on the moon. His work on the Saturn rockets and the Saturn V missions, where he assessed and analyzed the performance of the F-1 and J-2 engines, has been honored by numerous organizations over his lifetime—from NASA and Boeing, to professional and student organizations. When Al was recently asked what the most memorable moment of his career had been, his answer was definitive:

> "That's easy. It was November 9, 1967—the launch of the 501 Saturn V. It was a complete success. It was unbelievable. The fact that it was a success on the first try—it was just hard to believe. Now the second flight, the 502, had problems. But we fixed it."

Al was part of space flight history. Great things were achieved that inspired a nation and generated great national pride, even in the midst of great social adversity and upheaval in the United States. On the day of the SA-502 launch on April 4, 1968, Martin Luther King Jr. was assassinated and US President Johnson announced he would not seek re-election. Additionally, the United States was in midst of a war in Vietnam. The efforts of engineers such as Al reminded the United States, as well as the world, that while strife and turmoil may exist on Earth, the efforts of those dedicated to a glorious and ambitious mission can elevate society for generations to come.

Sadly, Aloysius Ignatius Reisz passed away on July 21, 2016—exactly 47 years, to the day, that Neil Armstrong first stepped foot on the moon. There is a certain, nearly poetic, comfort in this fact. Al previously stated: "humanity has got to advance. If we don't advance, humanity on Earth will die out." As long as the space program exists, there is hope for finding solutions to the problems on Earth. For as Al once said after the AS-502 problems: "we fixed it." We did indeed, fix it.

Acknowledgments

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Al's work on the Saturn V. Finally, much gratitude is extended to Herb Guendel and Dr. Jim Parsons for reviewing the chapter.

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