



# America's Greatest Projects - Apollo Project - Part 2

An Online Continuing Education Course for Engineers

**Course Number: M-4049**

**Credit: 4 Hours / 4 PDH / 4 CPD**

# America's Greatest Projects - Apollo Project - Part 2

Dominic Perrotta, P.E.

## Table of Contents

I. Plans to Land on the Moon Are Committed .....	2
II. NASA's Plans and Objectives .....	11
III. Lunar Landing Mission .....	18
IV. Apollo 13 – Miraculous Recovery .....	35
V. Final Apollo Lunar Landing Missions .....	40
VI. Summary .....	60

## I. Plans to Land on the Moon Are Committed

### A. Process Decisions Are Reconciled

Following President John F. Kennedy's challenge to a joint session of Congress on 25 May 1961 to land an American on the Moon and return him safely to Earth by the end of the decade, several critical decisions had to be made by NASA (National Aeronautics and Space Administration). Key among these was to develop and ensure that the actual procedure for doing this would be both successful and less expensive to the American taxpayers. As was noted in Part 1 of the Apollo Project, these were the options that confronted NASA:

#### Options and Evaluations

- a. Direct flight from the Earth to the Moon
  - b. Earth Orbit Rendezvous (EOR)
  - c. Lunar Orbit Rendezvous (LOR)
- 
- a. The Space Task Group, which was responsible for Project Mercury and the Headquarters Office of Launch Vehicle Programs, favored using the huge Nova rocket for a direct flight from Earth to the Moon. Landing the entire spacecraft on the lunar surface, as would be necessary with a direct flight approach, would have required an increase in rocket thrust because of the much more massive load of fuel tanks and fuel.
  - b. Marshall Space Flight Center (MSFC) in Huntsville, Alabama advocated an Earth Orbit Rendezvous. This method would require the use of several smaller Saturn launch vehicles to rendezvous in a Low Earth Orbit (LEO). One of the vehicles would then be refueled in orbit for the long flight to the Moon.
  - c. Key members of the Langley Research Center advocated the LOR. Its premise was to have one spacecraft launched from Earth, travel and orbit the Moon's surface, and detach a separate spacecraft, known as a LEM (Lunar Excursion

Module), down to the Moon's surface. The LEM would then rendezvous and re-attach to the Moon-orbiting spacecraft.

To compound the old dilemma with the project, some in NASA did not think that the mission was possible, and many more had severe doubts the project would accomplish its goal by the end of the '60s. We do know that NASA authorized several important studies for a direct landing method for the Apollo program, but dropped the ideas because they would require too big a rocket.

## **Decisions Made**

After much review by NASA administrators and engineers, the LOR method was selected. The payload for the LOR was estimated to be just slightly over 45 tons, as opposed to more than 100 tons for a direct flight. Also, the LOR method would require only one large booster instead of the two required for either of the other two options. At the time the decision to not need so big a rocket was very logical; the Atlas rocket for the Mercury Project was still in development, which had necessitated that the smaller Redstone rocket is used to launch the first American astronaut (Alan Shepard) into space for a suborbital flight in April 1961. Furthermore, the Titan I and Titan II rockets, which would eventually be used for the crewed spaceflights of Project Gemini, were still on the drawing board at Aerojet General since the "bridge project" between Mercury (Gemini) and Apollo had yet to be announced. Even though this decision was not reached until July of 1962, this did allow NASA to proceed full speed ahead for a potential lunar landing.

## **B. Design Considerations and Equipment Are Established**

### **1. Rockets – Launch Vehicles**

The U.S. Army Ordnance Missile Command (AOMC), was established at Redstone Arsenal in Huntsville, Alabama in the early 1950s, and they were permitted by the ABMA (U. S. Army Ballistic Missile Agency) to develop a large space booster of approximately 1.5 million-pounds thrust using a cluster of available rocket engines.

However, this booster was a Department of Defense (DOD) missile and was not to be used in the U. S. Space Program. In early 1959, this vehicle was first designated as Saturn. However, the U.S. staffed satellite space program was struggling and had to use the Redstone rocket to launch the first American satellites as well as the first two suborbital flights of Project Mercury. There followed a typical political squabble over the next eighteen months when the Air Force proposed a Super Nova rocket that would be better and cheaper than the Saturn. However, its development was barely in the design stage, whereas the Saturn had construction drawings and parts on the ground. NASA solved the infighting by absorbing the ABMA.

The ABMA, under the direction of Dr. Wernher von Braun, had begun to develop the Saturn I Rocket in 1957. The unique first stage was composed of a cluster of eight Redstone booster rockets around a Jupiter tank. This clustering of smaller boosters, rather than manufacturing larger rockets, allowed the use of tooling from the Redstone and Jupiter missile programs. The first Saturn rocket to fly was the **Saturn I**, which had a thrust capacity of about 200,000 lbf, and was the first launch vehicle that can carry more than 20,000 pounds into outer space and propelling the load into a Low Earth Orbit (LEO). Explicitly designed to launch larger payloads, most of the rocket's power came from a clustered lower stage consisting of boosters taken from older rocket designs strapped together to make a single large supporter. Its design proved sound and very flexible. Although it served only for a brief period for NASA, ten Saturn I rockets were flown before it was replaced by the Saturn 1B, its successor, which featured a more powerful upper stage and improved instrumentation.

Chrysler Corporation had opened a Huntsville operation in the 1950s, which was designated as their Space Division. It became Marshall Space Flight Center's prime contractor for the first stage of both the Saturn 1 and Saturn 1B rocket versions. The design, based on this cluster of boosters from the Redstone as well as the Jupiter missiles, was the first nuclear-tipped, medium-range ballistic missile (MRBM). Chrysler built them for the early Apollo program at their huge Michoud Assembly Plant, one of the largest manufacturing plants in the world, in East New Orleans. Between October

1961 and July 1965, all of Chrysler's missiles and boosters were successful and NASA never suffered a launch failure.

## **Saturn V Chosen**

On 10 January 1962 NASA announced plans to build the **C-5**, a three-stage rocket consisting of the S-IC first stage, the S-II second stage, and the S-IVB third stage. The C-5 would be designed for a 90,000-pound (45 ton) payload capacity, capable of carrying American astronauts to the Moon. This was to be the largest production model of the Saturn family of rockets and was already in the process of being designed at the Marshall Space Flight Center in Huntsville under the direction of Dr. von Braun. He and his team had been working on significantly improving rocket thrust in Huntsville since the early 1950s and had created a less complex operating system, designing better mechanical systems. During these revisions, the decision to reject the single engine of the V-2's design had come about, and the team moved to a multiple-engine design. **Arthur Rudolph**, an integral part of the V-2 rocket team coordinated by von Braun, was the assistant director under von Braun at the Marshall Space Flight Center.

## **Saturn V Design**

The Saturn V's size and payload capacity dwarfed all other previous rockets which had successfully flown at that time. With the Apollo spacecraft on top, Saturn V had an overall height of 363 feet and was slightly more than 33 feet in diameter, including guidance fins. Fully fueled, the Saturn V weighed nearly 6.5 million pounds and had a thrust capability of 7.5 million lbf. Its Low Earth Orbit capacity was initially estimated at 261,000 pounds, and it was designed to send at least 90,000 pounds to the Moon, including the third stage (S-IVB), necessary fuel, the Command Service Module (CSM) and the Lunar Excursion Module (LEM). The phases were designed by the Marshall Space Flight Center (MSFC) in Huntsville, and numerous outside contractors were chosen for the construction. By late 1962, NASA had finalized its plans to proceed with von Braun's Saturn designs, and the Apollo space program gained speed. The C-5 was confirmed as NASA's choice for the Apollo Program in early 1963 and was renamed the

**Saturn V** and used by NASA between 1967 and 1973. It would be a three-stage, heavy-lift launch vehicle, human-rated and liquid-fueled but expendable. The Saturn V was designed and manufactured to be a vehicle capable of launching a crewed spacecraft on a trajectory to the Moon. In addition to Saturn V being used for human exploration of the Moon, it was later used to launch Skylab, the first American space station.

A total of fifteen flight-capable Saturn V vehicles were built, and it was the launch vehicle from the Kennedy Space Center in Florida for thirteen missions, never losing a crew or a payload. As of this day, the Saturn V remains the tallest, most massive, and most powerful rocket ever brought to operational status, and holds records for the most massive payload launched and largest payload capacity ever placed into Low Earth Orbit (LEO). The weight of the lunar expedition system, which included the third stage and propellant necessary for translunar navigation as well as the Command Service Module and the Lunar Module, exceeded 160,000 tons. With the configuration of Saturn V finalized, NASA turned its attention to procedural missions for the translunar flights. Despite much controversy, the lunar orbit was chosen with a lunar module had been chosen. Issues such as the type of fuel injection, the length of such a trip, and rocket manufacturing procedures for the Saturn V were accelerated.

## 2. Spacecraft

Once the decision was made that two astronauts would remain on the lunar module (LM) with the other astronaut, many other aspects of the mission were significant. Realizing that space rendezvous would be necessary, NASA inaugurated Project Gemini, a bridge between the Mercury and Apollo programs, which would focus on spacecraft rendezvous and docking techniques. They also chose the

*To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.*

*Close this window and click "Add to cart" on the product page.*