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Chapter 24

Gemini: Paving the Way for Apollo*

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Abstract

In the era of routine flights to the International Space Station it can be difficult to remember the days of the beginning of the Space Age. The Cold War was raging, and the threat of nuclear destruction was very real. The struggle between the United States and the Soviet Union was carried out in significant measure in the space race. The United States entered the space race behind the Soviet Union, but when the lunar challenge was laid down by President Kennedy, the effort of both sides went into high gear. The Apollo Program was tasked with the ultimate landing on the Moon, but little was known about human or spacecraft capabilities in space and no one knew how to rendezvous and dock two space craft. It was placed on Project Gemini's to-do list to accomplish these objectives which it did in fine form.

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I. Nothing in Apollo Makes Sense Except in Light of Gemini

I.1. Introduction and the Mercury Project

It can be said of the fall of 1957, "It was the best of times, it was the worst of times." For twelve years following the close of World War II, the United States was the only real economic, scientific, or military power. While the United States emerged from the conflict stronger and with its homeland unscathed, the rest of the world, in particular the Soviet Union, was devastated physically and economically. The American people and the nation as a whole carried a feeling of deserved superiority. They gave thanks for their blessings, of course (whereas less than 40 percent of Americans attend religious services today, over 90 percent did so in 1945), but they had a sense that they had rightfully risen to the top through their own efforts. Those feelings came crashing down on October 4, 1957, with the launch of Sputnik by the Soviet Union. They were further crushed by the launch of the 1,120-pound Sputnik 2 one month later. That the satellite carried with it a dog only added insult to injury. All feelings of superiority were buried on December 6, 1957, with the televised failure of the Vanguard launcher.

The result of the Fall of Failure was a call for STEM classes before there was STEM, the institution of very early morning television programs such as Continental Classroom, the development of National Defense Education Act (NDEA) fellowships for study in the sciences, and the founding of NASA less than one year after the Sputnik shock.

NASA quickly ramped up and developed a two-program agenda for human spaceflight. The initial program was named Mercury, after the Greek and Roman god of speed and travelers. Mercury was developed to get a man into space at the earliest moment possible. The second program was Apollo, named for the Roman and Greek god of light and knowledge. Apollo was developed to do . . . something. What that something was, was unclear at the outset but became quite clear when President Kennedy made his "We choose to go to the Moon" announcement.

The objectives of the Mercury Project were specific:

- To orbit a manned spacecraft around Earth.
- To investigate man's ability to function in space.
- To recover safely both man and spacecraft.

After the broad objectives were established for Project Mercury, a number of guidelines were developed to ensure that the project would accomplish its goals in an expeditious and efficient manner.

The key guidelines were:

- To use existing technology and off-the-shelf equipment wherever practical [1].
- To follow the simplest and most reliable approach to system design.
- To use an existing launch vehicle to place the spacecraft into orbit.
- To follow a logical and progressive and logical test and implementation program.

In addition, specific requirements for the Mercury spacecraft were established:

- The spacecraft was to be fitted with a reliable launch-escape system to separate the spacecraft and its crew from the launch vehicle in emergency situations.
- The spacecraft was to provide the pilot with the ability to manually control the spacecraft’s attitude.
- The spacecraft was to be equipped with a retrorocket system capable to reliably and on command bring the spacecraft out of orbit.
- The spacecraft was to be a zero-lift body utilizing drag braking for reentry.
- The spacecraft was to be capable of a water landing.

Project Mercury consisted of six manned flights from 1961 to 1963, two suborbital flights by Alan Shepard and Gus Grissom and four orbital flights by John Glenn, Scott Carpenter, Wally Schirra, and “Gordo” Cooper. Cooper’s program-concluding flight was a 34-hour, 22-orbit flight in May 1963.

At the same time that Project Mercury was underway, planning and development began for the Apollo Project. Many options for a mission profile were presented, but when President Kennedy publicly committed in May 1961 the United States to a successful manned lunar mission before the end of 1969, the Apollo Project had its *raison d'être*. There were two significant problems with the plan for Apollo. First, we didn’t know how to accomplish a number of tasks that the Apollo would be called on to perform and Mercury was not capable of providing those answers. Second, there would be a significant time gap between the conclusion of the Mercury program and the first flight of the Apollo Program, a period during which Soviet space accomplishments would go unanswered. So, there was a challenge to get to the Moon in seven years ahead of the Soviet Union, and the Soviet Union was leading in the space race, but we had no idea of how to accomplish our objective, therefore Project Gemini was developed. The Gemini Project would be the bridge between what the Mercury Project would teach and what the Apollo astronauts and ground personnel had to know in order to land a man on the Moon before 1970.

I.2. Project Gemini Goals

The follow-on to the Mercury program was originally named Mercury Mark II. When it became obvious that the spacecraft and launcher would be completely new to NASA, the program was renamed Gemini. Gemini was the second manned program for NASA. It would carry a crew of two astronauts. It would be put in orbit by the Titan II, two-stage launcher. Because of all the above, it was renamed Gemini, Latin for twins and the name of the third constellation of the Zodiac with the twin stars Castor and Pollux.

The broad goals of Project Gemini were twofold. The first goal was to fill the gap that would exist between Projects Mercury and Apollo, years in which any Soviet accomplishments in space would have gone unchallenged. Project Mercury was scheduled to end in early 1963 and the first uncrewed Project Apollo flight was optimistically scheduled to be launched in 1967, leaving a major gap. As it ultimately turned out, the Soviet space program had its own difficulties and launched no cosmonauts during the entire Gemini manned flight program, nonetheless the concern, based on earlier Soviet successes, was very real.

The second broad goal for Project Gemini was the result of the lunar landing decision that NASA ultimately made. The options available to Apollo were direct ascent, Earth orbit rendezvous, and lunar orbit rendezvous. Direct ascent, much like the science fiction movies of the time, would have required a launcher significantly more massive and powerful than the Saturn V that was ultimately used for Apollo. A rocket would be launched from Florida and fly directly to the Moon, shedding stages as it went. The rocket would land on the Moon, the astronauts would do their work, and then some portion of what landed would take off and fly back to the Earth [2]. This approach sounds simple, but you have to take all of the fuel required for the return voyage down the gravity well of the Moon and back out again. It was estimated that the booster would need 12,000,000 pounds of thrust to launch the rocket. The Atlas that launched the Mercury orbital flights had only 350,000 pounds of thrust.

The second possible mission profile was Earth-orbit rendezvous—the International Space Station approach. This would have required the launching of multiple smaller rockets in quick succession followed by the assembly of the lunar vehicle while in Earth orbit via extravehicular activity. This lunar ship would then follow the direct ascent approach to the Moon and back meaning that the gravity well issue would occur here, too.

The third approach was lunar orbit rendezvous, mission profile that frightened almost everyone. This required a launcher that continuously shed stages from the initial take-off from Earth to the return flight from the Moon. Only a small lander/return-to-orbit craft would descend to the lunar surface meaning that significantly less fuel would have to be taken to the surface of the Moon. The problem that frightened many was that rendezvous and docking would have to occur in the vicinity of the Moon.

When direct ascent and Earth orbit rendezvous were eliminated and lunar orbit rendezvous was selected, NASA had its mission profile along with a list of things that would have to be accomplished before the Apollo mission could take place. The solution was Project Gemini.

I.3. Overview of Goals

The goals of the Gemini program were:

1. To subject two men and their supporting equipment to long duration flights of up to two weeks in space.
2. To achieve rendezvous and docking with another orbiting target vehicle and to develop efficient and reliable rendezvous techniques. The ability to dock on the first revolution was highly desired.
3. To maneuver the spacecraft in space after docking, using the target vehicle propulsion system.
4. To perform extravehicular activities requiring one of the flight crew to exit the spacecraft while in orbit and to develop the capability and techniques for extravehicular operations in space.
5. To provide a controlled reentry whereby the spacecraft was brought to a specific landing site. The initial goal was a land landing using a paraglider, or “Rogallo wing.” This portion of the goal was cancelled in 1964 and the landings all took place at sea [3]. The goal of a targeted landing, however, remained.
6. To provide training for the flight crew members, both astronauts and ground crew, who will operate in the Apollo Program.
7. To perform appropriate engineering and scientific experiments in support of the national space program.

In addition to the official goals of the project, there was one goal that was implicit in all the planning and operations of the program. The major unofficial but clearly understood goal was to overtake and surpass the Soviet Union in space accomplishments.

II. Assessment of the Gemini Goals

II.1. Goal 1—Long-duration Flights

The trip from Earth to the Moon would require four days of travel in each direction, outbound and return. Add to this time on the lunar surface for experimentation and travel, and a mission length of at least ten days would be required. The longest flight in the Mercury Program was thirty-four hours. Mercury was a good beginning, but much remained to be learned before a lunar landing could occur—or before the United States could overtake the Soviet Union in space.

Among the issues that had to be addressed were:

- Food—both quantity, quality (taste), and safety. As an example of the complexity of the issues that had to be addressed in a single area, the following are some of the questions had to be resolved:
  a. Can food be preserved so it will be safe unrefrigerated for fourteen days?
  b. Can bacteria be kept from growing in the food supply?
  c. Can food be made that will reduce the biological waste of the astronauts?
  d. Can food be made palatable enough that astronauts would enjoy eating it? It is one thing to eat bad-tasting food for one day as they did on the Mercury flights, but on a fourteen-day flight it would be totally unacceptable.
  e. Can leftover food and packaging be managed in a way that keeps the leftovers from rotting for two weeks?
  f. Can sufficient water be carried for two men on Gemini and three men on Apollo to drink, prepare food, and clean-up with for fourteen days?

The remaining items on the list, as shown below, were equally as complex as those for this one area.

- Sanitation—management and disposal.
- Water—sufficient quality and quantity—a number of Mercury astronauts had ended their flights dehydrated.
- Comfort—something that is tolerable for an hour or a day can be debilitating after a ten-day flight.
- Psychological/mental health issues—both interpersonal relationships in confined quarters and the feeling of isolation in space were concerns that had to be examined.
- The examination of the physical health of astronauts after extended periods of weightlessness was a concern.

- The generation of sufficient electric power for the duration of the flight. Batteries would last only four days, so an alternative power source was required.
- The development of a rocket motor that would be restartable after an extended period of nonuse in the cold of space.
- The development of an environmental control that would sufficiently manage temperature, humidity, as well as the provision of oxygen and carbon dioxide removal.

II.2. Goal 2—Rendezvous and Docking

As previously discussed, to mission planners, there were three ways to get to the Moon: Direct Ascent, Earth-orbit Rendezvous (EOR), and Lunar-orbit Rendezvous (LOR). Direct Ascent is just what it sounds like—a single, massive launcher travels from the Earth to the Moon, shedding stages as it goes. The remaining stages land on the lunar surface, the astronauts complete their experiments, and at least some portion of the lander leaves the Moon and Returns to the Earth. This means, of course, that the lunar lander has to carry fuel to brake itself and the return craft when it reaches the Moon, lift off the surface of the Moon (which, even though Lunar gravity is one-sixth of that of Earth, requires significant energy), and power the ship that returns to the Earth. The fuel requirement for this is high, also requiring heavier spacecraft which in turn requires more fuel… The booster for this approach (called Nova) was thought to require 12,000,000 pounds of thrust at lift-off from the Earth. Developing the Nova launcher would have been a major undertaking. The first stage of the Nova would have been 50 feet in diameter. The weight at lift-off for the Nova would have been 10 million pounds. All of this was to be developed at a time when the Titan I, with a thrust of 430,000 pounds and a liftoff weight of 230,000 pounds, was our most powerful launcher [4]. Direct ascent was a no-go.

Earth-orbit rendezvous was the second possibility for a lunar mission profile. For EOR, a smaller launcher is required, but multiple launchers would have to be used to place on orbit the components to be assembled for a lunar flight. While this eliminated the need for a super launcher such as Nova or Saturn, EOR carried with it the disadvantages of having to land on and lift-off from the Moon heavier craft carrying their own fuel combined with multiple launches from Earth. EOR was ultimately rejected in favor of Lunar-orbit Rendezvous, but EOR is one of the tasks that the Gemini Program perfected as a secondary effort. Of course, the techniques used for EOR were translatable to any type of rendezvous and particularly to the LOR used in the Apollo Program.

Lunar-orbit Rendezvous was championed by John Houbolt, a research engineer who had to fight to even get an audience for the proposed method. With LOR, only those materials and fuel required for the next phase of a mission need be carried. Thus, the fuel required for a spacecraft to return from the Moon does not have to be carried to the lunar surface and then lifted off the surface for the return flight. The concern in selecting LOR was two-fold: first, rendezvous of any kind had never been accomplished, and second, the rendezvous and docking of LOR would take place in the vicinity of the Moon itself with no possibility of rescue should something go wrong. Thus, rendezvous and docking techniques would have to be perfected on the Gemini flights.

In addition to the general issues with rendezvous itself, there were two complicating factors, both around the issue of rescue. In one instance, an emergency onboard a lunar lander could arise whereby an immediate rendezvous would be required. For this, Gemini would have to perfect rendezvous on the first orbit. The second instance is one in which a lunar lander became unable to power itself to a rendezvous with a mothership, and the mothership had to affect a rescue. For this Gemini needed to practice multiple types of rendezvous such that any possible scenario could be addressed.

II.3. Goal 3—On-orbit Maneuver

Once the mode of the lunar mission was determined (LOR), it became understood that three separate spacecraft would be required in the vicinity of the Moon. The Lunar Module would consist of two stages, a descent stage, and an ascent stage. The descent stage would take the astronauts along with the ascent stage to the surface while the ascent stage would serve as a habitat on the lunar surface and launch the astronauts back into lunar orbit. Waiting in lunar orbit would be the combined command and service module spacecraft. Should a problem occur with the ascent stage, the command/service module would have to leave its parking orbit and rescue the astronauts. Should there be a problem with the command/service module, as was the case on Apollo 13, the ascent stage would have to power the craft back to Earth. The maneuver of two joined spacecraft, therefore, was a planned-for contingency, and Gemini had to develop the techniques that would be required to accomplish this.

II.4. Goal 4—Extra-vehicular Activity

When the Gemini Program was planned, the space program was in its absolute infancy. Much had to be learned about what astronauts would and could do during a space mission. Certainly, astronauts would walk on the lunar surface. They might also be called on to inspect a suspicious satellite or to travel between two American spacecraft. For all of this, the ability for an astronaut to function in the vacuum and under the conditions found in space (including weightlessness which proved to be much more difficult than anticipated) would be necessary. Protective clothing—a space suit—would be required. Methods for personal movement would have to be developed. Techniques for the various possible work activities would have to be identified. Given that no one had ever done it before, much had to be learned during the Gemini Program.

II.5. Goal 5—Precision Landing

The risks involved in a rocket launch are easy to understand. For Gemini, two men sat on top of 250,000 pounds of fuel and oxidizer which was ignited in hopefully a controlled way. Then, a stable launch path had to be followed. The stages had to separate and fire as designed, and a precise orbit had to be followed. Perhaps not as obvious are the difficulties involved with landing. Retrofire of the right strength and for the correct duration had to take place at precisely the right time to permit the spacecraft to make a precision landing. The returning spacecraft would reenter the atmosphere at 18,000 miles per hour, generating friction with the atmosphere that resulted in 2,000 degrees temperatures. A parachute system would have to function gently, so as not to injure the astronauts, yet firmly, to bring the spacecraft to a soft landing in the ocean—which presents its own problems. When Project Mercury began, at great cost twenty-eight US Navy ships were pre-positioned as a rescue and recovery fleet and even then, NASA almost lost one astronaut to drowning. Because of this, NASA wanted to be able to return the spacecraft to a soft landing on dry ground. If this could be achieved, it was believed that astronaut safety would be immeasurable improved and program costs would be dramatically decreased.

II.6. Goal 6—Provide Training for Future Apollo Astronauts and Ground Crew

The Apollo Program was well underway when Gemini began. While little was known about the surface of the Moon as a landing site (that would have to wait until the missions of Luna 9 and later Soviet spacecraft and Surveyor 1 and later US lunar landers, both beginning in 1966), the nature of the Apollo missions was clear, and the demands on the astronauts were known. If the United States was to be able to land a man on the Moon by 1969, astronauts would have to be prepared for spaceflight in mission profiles that provided learning opportunities. The Apollo missions would include rendezvous and docking, extra-vehicular activities (at least on the surface of the Moon), and long duration flights for which on-the-job training during the missions would not be acceptable.

II.7. Goal 7—Perform Engineering and Scientific Experiments [5]

There was much to be learned about space and spaceflight, and Project Mercury barely scratched the surface. Mercury astronauts logged a total of less than fifty-four hours in space and were more at the mercy of the capsule than they were in command of it. Each astronaut was a highly experienced fighter pilot with many hours of experience in experimental aircraft. Yet in Project Mercury, they had little to do except go along for the ride and complete some simple experiments. It was up to Gemini to assess the true capabilities of astronauts in extended missions and to bring an early understanding of the ionosphere and the nature of the Earth itself. Each Gemini mission was to be given more and more, increasingly difficult experiments to conduct that were to yield basic data for scientists, engineers, and mission planners to analyze and use.

NASA did not have the answers to the questions that were raised by the Gemini goals, and it was left to the Gemini project to determine the answers. When the Gemini project concluded, all of the official and unofficial goals had been met.

III. Gemini Project Schedule

The Project Gemini ran from December 7, 1961, to February 2, 1967. There certainly were a number of key dates, but in addition to the flights themselves, only a few will be identified here:

- Project start date as Mercury Mark II—December 7, 1961
- Named Project Gemini—January 3, 1962
- All major Gemini systems were under contract—March 1962
- James Chamberlin replaced as Project Manager by Charles Matthews—March 19, 1963
- First uncrewed flight—April 8, 1964
- First manned flight—March 23, 1965 [6]
- Mid-program conference—February 23–24, 1966
- Last manned flight—November 11–15, 1966
- Concluding conference and closing of the Gemini Project Office—February 1–2, 1967

In today’s world of lengthy program delays, it is worthy to note that all major Gemini systems were under contract within four months of program start, ten crewed flights took place in less than twenty months, and complete program length was less than five years.

IV. Gemini Flights

Project Gemini had twelve successful flights, ten of which were crewed. With the exception of the first all-up systems test flight, eleven flights were successfully completed in less than a two-year period. The launcher chosen for the effort was the US Air Force Titan II, a craft that used storable hypergolic propellants. The launcher was to rendezvous with an Atlas Agena target vehicle, and despite delays in the development of this vehicle, four successful dockings were achieved. A quick summary of the flights, the crew members' names, the flight length, the key accomplishments, and the closeness of the landing to the target point are shown below.

Flight	**Date(s)**	**Crew**	**Major Goals**	**Duration**	**Landing Success**
Gemini 1	4/8/64	Uncrewed	Systems tests	3 orbits	
Gemini 2	1/19/65	Uncrewed	Reentry systems tests	Suborbital	Landing—14-mile miss
Gemini 3	3/23/65	Grissom, Young	First crewed flight Conduct orbital maneuvers	3 orbits	Landing—60-mile miss
Gemini 4	6/3–7/65	McDivitt, White	First EVA	4 days	Landing—44-mile miss
Gemini 5	8/21–28/65	Conrad, Cooper	First use of fuel cell for power	8 days	Landing—91-mile miss
Gemini 6A	12/15–16/65	Schirra, Stafford	First rendezvous with another spacecraft	2 days	Landing—11-mile miss
Gemini 7	12/4–18/65	Borman, Lovell	Long duration mission	14 days	Landing—6.4-mile miss
Gemini 8	3/16/66	Armstrong, Scott	Rendezvous, docking, emergency reentry	1 day	Landing—1.1-mile miss [7]
Gemini 9	6/3–6/66	Stafford, Cernan	Rendezvous, EVA	4 days	Landing—0.38-mile miss
Gemini 10	7/18–21/66	Young, Collins	Rendezvous, docking, EVA	3 days	Landing—3.0-mile miss
Gemini 11	9/12–15/66	Conrad, Gordon	Rendezvous on 1st orbit, docking, EVA	3 days	Landing—2.65-mile miss
Gemini 12	11/11–15/66	Lovell, Aldrin	Rendezvous, docking, EVA with work completed	4 days	Landing—2.6-mile miss

V. Shakedown Flights—Gemini 1 and 2

The Gemini flights began with two uncrewed missions. The Titan II launcher needed significant modifications to allow it to serve for manned missions, and the first two flights of Gemini were the final tests of systems readiness. Gemini 1 and Gemini 2 were the flights that gave the designers the confidence they required and the ground crews the experience they would need to launch two men into orbit and to surpass the Soviet Union in the space race.

V.1. Gemini 1

Primary Objectives

Demonstrate Gemini launch vehicle (GLV) performance.
Flight qualify subsystems.
Determine exit heating of GLV and spacecraft.
Demonstrate structural integrity of GLV and spacecraft.
Demonstrate GLV and ground guidance systems performance in achieving proper orbital insertion.
Monitor and evaluate GLV switchover circuits.

Secondary Objectives

Evaluate operational procedures for GLV trajectory and cutoff conditions.
Verify orbital insertion by tracking C-band transponder in spacecraft.
Demonstrate performance of launch and tracking networks.
Provide training for flight controllers and prelaunch and launch crews and facilities.

The purpose of the mission was to subject both space and ground systems to a full-scale test to ensure not only human survivability but also operational capability of all facets. The launch was near-nominal, and the spacecraft was monitored for the planned mission length of three orbits and was then allowed to de-orbit naturally with a splashdown in the South Atlantic four days later. The Gemini program was now ready for its final unmanned launch. It would have to wait nine months for that to happen.

V.2. Gemini 2

Primary Objectives

Demonstrate reentry heat protection during maximum heating reentry.
Demonstrate structural integrity of spacecraft.
Demonstrate satisfactory performance of major subsystems.

Demonstrate checkout and launch procedures.

Evaluate backup guidance steering signals through launch.

Secondary Objectives

Obtain test results on fuel cell and reactant supply, cryogenics, and communications systems.

Demonstrate and further flight-qualify GLV and spacecraft from countdown thru insertion.

Train flight controllers and qualify ground communications tracking system.

The flight of Gemini 2 was scheduled for November 1964, but multiple tropical storms delayed the launch until January 1965. The main purpose of the flight was to test the newly developed heat shield that would have to protect the returning spacecraft during its descent through the atmosphere. The flight went as planned, and Gemini 2 reached an apogee of 106 miles. Re-entry was at a sharp angle in order to subject the heat shield to a rapid temperature increase. With the exception of a newly designed fuel cell, which was deactivated prior to launch, all systems checked out, and the Gemini spacecraft was ready for the first manned flight.

V.3. Gemini 3

Primary Objectives

Demonstrate manned orbital flight in the new spacecraft.

Evaluate the two-man design.

Demonstrate and evaluate the almost world-wide tracking network.

Demonstrate capability in orbital maneuvers and retrofire backup.

Demonstrate controlled reentry and landing.

Evaluate major spacecraft subsystems.

Demonstrate systems checkout as well as prelaunch and launch procedures.

Demonstrate and evaluate recovery procedures and systems.

Secondary Objectives

Evaluate flight crew equipment, biomedical instrumentation, and the personal hygiene system.

Perform three experiments.

Evaluate low-level longitudinal oscillations (Pogo) of the GLV.

General photographic coverage in orbit.

The Gemini 3 spacecraft was named by Commander Gus Grissom the "Molly Brown" after the Broadway show, *The Unsinkable Molly Brown.* When

Grissom landed in the Atlantic Ocean in the Liberty Bell 7 at the end of the second Project Mercury manned mission, the hatch release mechanism malfunctioned and the hatch blew open before the recovery team was fully in place. The spacecraft filled with water, and Grissom barely managed to escape with his life. Grissom chose "Molly Brown" for Gemini 3 because of the unsinkable connection [8].

The first major goal for Gemini 3 was to perform the first orbital change maneuvers by any spacecraft. This it did once on each of the three orbits, altering the shape of the orbit twice and changing the plane of the orbit once. This may not sound like much in today's space world, but it was the first time that orbital changes had ever been made. A second goal was to make a controlled landing. This objective was only partially met. The Gemini spacecraft had been designed with the center of gravity offset enough to provide lift and to make the capsule maneuverable by the astronaut. It was discovered that the actual lift generated was quite a bit less than wind tunnel tests had predicted, and the spacecraft landed well short of the intended target. The landing, however, provided the Gemini team with the data they needed for the ensuing flights.

V.4. Gemini 4

Primary Objectives

Evaluate the effects of prolonged spaceflight on systems and people.
Demonstrate and evaluate the performance of the spacecraft and systems in a four-day flight.
Evaluate the procedures for crew rest, work cycles, eating schedules, and to perform real-time flight planning.

Secondary Objectives

Demonstrate and evaluate extravehicular activity (EVA) and control by use of a hand-held maneuvering unit (HHMU) and tether.
To rendezvous and station-keep with the second stage of the GLV.
Evaluate spacecraft systems.
Complete in-and-out-of-plane maneuvers.
Further test retro systems backup capability.
Perform eleven experiments.

The first of the major tasks was to perform station-keeping with the second stage of the launcher. The booster was located in space and the spacecraft was accelerated to catch up with it. To the crew's surprise, the booster appeared to move away. The spacecraft was realigned and again accelerated toward the booster. Once more, the distance between the two spacecrafts increased. As is now understood, until you are immediately adjacent to an object, motion in space is quite different from motion on the Earth. Unfortunately, having used too much fuel in the two failed attempts, the rendezvous effort was abandoned, but much was learned from the experience.

The second major task was the first spacewalk by a US astronaut. The EVA was scheduled for the second orbit, but the level of effort required to prepare for the EVA in the confines of the small spacecraft caused Ed White to overheat [9]. The spacewalk was delayed until the third orbit. Astronaut Ed White floated out and began what he said was the greatest experience of his life. White used the HHMU to move about and had no difficulty controlling his motions. He practiced movements in space and took photographs of the Earth beneath (beneath?) him. When mission control directed White to return to the ship, he commented that "It's the saddest moment of my life."

V.5. Gemini 5

Primary Objectives

Evaluate rendezvous guidance and navigation system with Rendezvous Evaluation Pod.
Demonstrate eight-day capability of spacecraft and crew.
Evaluate the effects of weightlessness on astronauts for an eight-day flight.

Secondary Objectives

Demonstrate controlled reentry guidance.
Evaluate fuel cell performance.
Demonstrate all phases of guidance and control system operation needed for rendezvous.
Evaluate capability of both crewmen to maneuver spacecraft to rendezvous.
Checkout rendezvous radar.
Perform seventeen experiments.

Rendezvous and docking were prime objectives for the entire Gemini program, and the Gemini 5 spacecraft was to rendezvous and dock with the Agena second stage of the Atlas Agena target vehicle. Production of the Agena was delayed, so no rendezvous target was ready for Gemini 5. Therefore, to practice rendezvous, a Rendezvous Evaluation Pod (REP) consisting of an Agena radar transponder, location lights, batteries, and an antenna was developed and carried aloft in the aft section of the Gemini spacecraft. Perhaps surprisingly today, Gemini 5 was the first spacecraft with a radar unit installed on the factory floor. The REP was ejected during the second orbit, and Cooper and Conrad were ready to begin testing. Unfortunately, problems with the new fuel cell reduced the available power and this presented the possibility of an early return to Earth. When power was sufficiently restored, it was impossible to rendezvous with the REP and NASA called on Buzz Aldrin, who was known as “Dr. Rendezvous” for his doctorate in orbital mechanics at the Massachusetts Institute of Technology. Aldrin calculated a new mission profile that would allow the Gemini 5 astronauts to go through all of the orbital maneuvers required to allow them to rendezvous with a phantom Agena. A spot in space was identified, and Cooper and Conrad maneuvered their way toward it. In fact, these maneuvers were more difficult for Cooper and Conrad to perform than if the Agena had been real. The “point” in space that was their target was not only invisible to them but was, as will be realized, moving in an orbit as they were—a *different* orbit, of course. Cooper hit all four maneuvers precisely, and Gemini 5 came to rest at precisely at the rendezvous point designated. Rendezvous would no longer be a cause for concern for Gemini or the Apollo Program to follow. Lunar Orbit Rendezvous definitely would be possible for the Apollo Moon lander.

The landing of Gemini 5 revealed another key factor in the success of the Gemini, and ultimately Apollo, especially Apollo 13 Program: it wasn’t only astronauts that needed preparation and training for spaceflight, ground crews did as well. After eight days of flight, Gemini 5 was directed to land one orbit early due to a moving storm system in the Atlantic Ocean. Cooper moved through the deorbit sequence perfectly—and discovered that the spacecraft would overshoot the landing zone. He induced additional drag to shorten the landing and gently hit the water some 90 miles short—but closer than would have been the case without his corrective action. Subsequent investigation showed that the astronauts had performed well and that the computer had done the correct calculations, but a programmer had informed the computer that Earth rotated 360 degrees per day. It does not. Earth actually rotates 360.98 degrees per day. A seemingly small error such as this would have doomed the Apollo 13 astronauts on the return trip of their crippled spacecraft.

The mission of Gemini 5, despite its difficulties, was deemed to be a success. All of the scheduled experiments with the exception of one involving the REP were completed successfully, rendezvous was shown to be possible, and man successfully completed a mission of a duration equivalent to the United States flying to the Moon and back.

V.6. Gemini 7

Primary Objective

Conduct a fourteen-day mission and evaluate the effects on the crew.

Secondary Objectives

Conduct twenty experiments.
Evaluate a lightweight pressure suit.
Evaluate spacecraft reentry capability.
Conduct systems tests.
Serve as a target for Gemini 6A.
Station-keep with Gemini 6A and with the second stage of GLV.

Gemini 7 before Gemini 6? Yes, and this is a story in and of itself. While the mission of Gemini 6 is discussed in detail in the next section, what needs to be known here is that Gemini 6 was designed to be the first rendezvous and docking mission with an Atlas-Agena target vehicle. The Gemini 7 mission was to be a long-duration flight some two months later. The launch of the Atlas-Agena target vehicle which was to precede the Gemini Titan II by 100 minutes was not successful. After a period of careful calculation, NASA decided to postpone the Gemini 6 mission until Gemini 7 had been launched and then rendezvous with it. While no docking would be possible, to bring two manned spacecraft together had never been attempted much less accomplished, and this is what moved the Gemini 7 mission ahead of the mission of Gemini 6.

The launch and early portion of the mission went smoothly. It was on the ninth day that Gemini 6 was to be launched for rendezvous Gemini 7. A malfunction on the ground postponed the launch, and it wasn't until three days later that the renamed Gemini 6A was launched. The two spacecrafts rendezvoused, and all four crew members practiced a number of different rendezvous techniques. Mission accomplished, Gemini 6 returned to Earth and Gemini 7 remained on orbit for the full fourteen-day mission. When astronauts Jim Lovell and Frank Borman landed and were welcomed aboard the USS Wasp on recovery. Jim Lovell said, "Frank and I would like to announce our engagement."

With the conclusion of Gemini 7, NASA had proven in a one-year period that man could function well in space and that a trip to the Moon by Apollo was within the reach of the United States. Rendezvous was now a staple of American spaceflight, and long-term spaceflight was easily manageable. Remaining to be accomplished were docking and an easily managed EVA by an astronaut for the Gemini program to be a complete success.

V.7. Gemini 6 and 6A

Primary Objective

Rendezvous with Gemini 7.

Secondary Objectives

Perform closed-loop rendezvous in the fourth orbit.

Station-keep with Gemini 7.

Evaluate reentry guidance capability.

Conduct visibility tests for rendezvous, using Gemini 7 as a target.

Perform three experiments.

Gemini 6 was scheduled to fly in late October and was to be a rendezvous and docking mission with the Gemini spacecraft chasing and rendezvousing with the Agena spacecraft followed by the first ever docking. Unfortunately, the Atlas-Agena target vehicle launch was a failure, so Gemini 6 was cancelled. With this, Gemini 6 had lost its target. Because Gemini 7 was designated as a long-duration but non-rendezvous mission, there was thought of switching the Gemini 7 spacecraft with Gemini 6, but because the Gemini 7 was a fourteen-day mission, the spacecraft, loaded with extra supplies weighed 257 pounds more than the Gemini 6 capsule and was too heavy for the GTV-6 launcher to handle. A repeat of the rendezvous with a phantom Agena as was done on Gemini 5 would prove nothing. As a result, a new mission plan was developed. Gemini 7 and a now renamed Gemini 6A would be launched in rapid succession for rendezvous. It took three days to develop a mission plan and convince NASA officials all the way up to President Johnson to approve it, but by October 28 a completely different mission had been developed and approved, demonstrating the level of technical and managerial competence that the Gemini project had developed in NASA personnel in the space of one year, competence that would be called upon during the Apollo 13 emergency.

With the new mission profile, Gemini 7 would be launched first with Gemini 6A to follow a few days later. The problem this raised was the fact that there was only one launch pad that was constructed to service the Gemini Titan II launcher. The launch pad would have to be refurbished after the launch of Gemini 7 in six days rather than the usual six weeks that were required. Gemini 6 would then be erected on the launch pad and prepped for its mission. The time between the launches of the two spacecraft could only be eight to ten days, and nothing like this had ever been done before.

Gemini 7 launched as scheduled on December 4. The launch complex and Gemini 6A were miraculously ready for liftoff on December 12. The Titan II fired exactly on time—and then immediately shut down. Protocol dictated that the astronauts were to eject in such an instance, but because they could sense that the launcher had not risen, they chose not to eject. Had they ejected, the mission would have been scrubbed. The fault was identified and corrected, and the launcher and complex were readied for another attempt three days later. Fortunately, this launch of Gemini 6A was a success. By the fourth orbit, Gemini 6A had been guided to a point 40 meters from Gemini 7 and a true rendezvous had been achieved.

The Gemini 6A mission was a real coming-of-age event for NASA. The entire team had faced two major emergencies and had overcome both so well that the United States totally eclipsed the Soviet Union in space. Within a one-year period, six spacecraft, five of them crewed, had been successfully launched. When Gemini 7 landed safely two days later, the year came to a fitting close.

V.8. Gemini 8

Primary Objectives

Rendezvous and dock with the Gemini Agena target vehicle.
Conduct EVA operations.

Secondary Objectives

Rendezvous and dock in the fourth revolution.
Perform docked-vehicle maneuvers.
Evaluate systems.
Conduct ten experiments.

The mission of Gemini 8 was to perform the first docking of two vehicles in space. The mission began smoothly, and docking was accomplished on the fourth orbit. Not long after this, the mated spacecraft and Agena target vehicle began to slowly roll. The roll was corrected but then it returned at an even faster rate. Thinking that the problem was with the Agena, the two spacecraft were separated—but the tumbling increased to one revolution per second. Recognizing he source of the emergency, the commander, Neil Armstrong, deactivated the orbital maneuvering system and fired the reentry control system, bringing the spacecraft under control. The emergency over, Gemini 8 returned to the Earth, the major objective was accomplished, but effective EVA was put off for a later mission.

V.9. Gemini 9

Primary Objectives

Perform rendezvous and docking.
Conduct EVA.

Secondary Objectives

Rendezvous with ATDA (launched June 1, 1966, from Complex 14) in third revolution.

Conduct systems evaluations.

Execute seven experiments.

Practice docking, rendezvous from above and demonstrate controlled reentry.

The basic mission plan for Gemini 9 was similar to the previous two missions. The Atlas-Agena target vehicle was to launch first and the Gemini-Titan II would follow 100 minutes later, rendezvous, and dock. Once again, the Atlas-Agena failed to achieve orbit, but this time a second Atlas launcher with separate docking device, the Augmented Target Docking Adaptor (ATDA), was available to provide something with which to dock. On the second attempt, both the Gemini Titan II and the target vehicle launched successfully. The Gemini spacecraft maneuvered to be in position to dock with the ATDA, but when it arrived it was discovered that the protective shroud covering the docking apparatus had not completely separated from the ATDA but remained in place, its two panels separated at a 30-degree angle. A retaining strap at its base had prevented the shroud from separating, and the astronauts were faced with what they said looked like an "angry alligator." No docking would take place on this mission. Remaining to be accomplished was the EVA in which real work was to be performed. Very early in the EVA it was discovered that everything took much more energy than had been anticipated. During the work attempt, the astronaut's heart rate hit 155 beats per minute, then 180. The exertion generated heat that his suit was unable to control, and his faceplate fogged over to the point that he couldn't see. The EVA was called off. It became obvious that more handholds and more training were needed before EVA would be a success.

V.10. Gemini 10

Primary Objective

Rendezvous and dock with an Atlas-Agena target vehicle.

Secondary Objectives

Rendezvous and dock in fourth revolution.

Use the target vehicle as a propulsion system.

Conduct EVA.

Practice docking.

Perform fourteen experiments.

Perform system evaluation on bending-mode tests.

Perfect reentry guidance.

Park the Atlas-Agena target vehicle in a 352-km orbit for use by later missions.

While the Gemini program continued to accomplish its assigned missions, NASA was learning that operating in space is more difficult than imagined. The mission of Gemini 10 therefore was to provide a learning and practice ground for NASA and the astronauts.

Both the Atlas-Agena target vehicle and the Gemini Titan II launcher and spacecraft left the launch pad on time and entered their planned orbits. The mission plan was to rendezvous with the Agena which they did on the fourth revolution, but the activity contained both bad and good elements. The bad news was that Young had slightly misaligned the spacecraft had been slightly misaligned during an orbital maneuver and the intercept trajectory was off. The good news was that the error was recognized and was corrected by using only two mid-course corrections. Thus, at only the cost of extra fuel, NASA learned how to address and solve a problem in real-time.

Gemini 10 completed its multiple rendezvous successfully but found the EVAs devilishly difficult to complete. When the EVAs and other mission objectives were completed, the spacecraft deorbited and landed just three miles from the recovery ship. The mission showed, however, that additional work had to be done to perfect EVA techniques. Gemini 9 had amply shown this, but unfortunately there was not sufficient time between the flights of Gemini 9 and Gemini 10 to address the issue. It remained something that would have to be addressed in the last two missions if the coming Apollo Program was to be a success.

V.11. Gemini 11

Primary Objective

Rendezvous and dock with Gemini Agena target vehicle which had been parked in space.

Secondary Objectives

Practice docking.
Perform successful EVA activities.
Conduct eleven experiments.
Maneuver while docked (a high apogee excursion).
Conduct tethered vehicle test.
Demonstrate automatic reentry.

If Gemini 11 accomplished one specific thing, its mission would be considered a success: it was to rendezvous and dock with an orbiting Agena on the first revolution, something that had never been done before. If it could be accomplished, NASA and Gemini would have come a very long way in a very short time. To take away the suspense, they did it. A look at rendezvous history shows just how rapid this progress was.

Date	Flight	Accomplishment
8/19/1965 and earlier	—	No rendezvous had been accomplished by anyone.
8/20/1965	Gemini 5	The first effective rendezvous but with a phantom spacecraft.
12/15/1965	Gemini 6	The first actual rendezvous with an actual spacecraft.
3/16/1966	Gemini 8	The first rendezvous and docking.
9/12/1965	Gemini 11	The first rendezvous and docking on the first revolution.

The planned spacewalks again proved difficult to master, but the crew was able to use the Agena target vehicle's rocket engine as a booster and soar to a new altitude record, 850 miles, a record that lasted until the flight of Apollo 8. Finally, the landing, performed by the computer, proved to be successful, adding assurance that NASA could return a spacecraft to Earth unaided by an astronaut.

V.11. Gemini 12

Primary Objectives

Rendezvous and docking.
Perform successfully and evaluate EVA techniques.

Secondary Objectives

Tethered vehicle operation.
Perform fourteen experiments.
Demonstrate automatic reentry.
Perform docked maneuvers.
Practice docking.
Conduct system tests.
Park the Gemini Agena target vehicle in a 555.6-km (300nm) orbit.

"Roger" was all that was said when Jim Lovell signaled to the ground team that Gemini 12 was docked with the Agena target vehicle. There was no celebration: the fourth docking exercise of the Gemini Program was just a routine maneuver for NASA and the astronauts. Jim Lovell and Buzz Aldrin were Commander and Pilot respectively of the capstone Gemini mission. Both would go on to even greater fame in the Apollo Program where Lovell was Commander of the ill-fated Apollo 13 mission and Aldrin made the first landing on the Moon. They were well chosen for this mission—and for those.

Three EVAs were scheduled, and all three were successful. The second EVA lasted over two hours and consisted of a number of tasks that had frustrated previous astronauts. Aldrin's preparation in a neutral buoyancy tank in a high school swimming pool in Maryland along with the handholds and footholds developed as a result paid great dividends.

The return to Earth was managed by computer and was nominal. With the splashdown, the active part of the Gemini Program came to an end. All that was left was the Gemini Summary Conference that was held on February 1–2, 1967. Gemini met all of its program goals. NASA was now ready to turn its full attention to the Apollo Program and the challenge of making a lunar landing in less than three years.

VI. Gemini Technical and Managerial Contributions

Both by design and by good fortune, many lessons that would prove to be highly valuable for the Apollo Program were learned. Among them were:

- Systems were designed to be independent units so operational defects could be quickly traced to the source. This was a plus for testing, check-out, and replacement.
- As opposed to the Mercury Project, key systems were located outside the pressure vessel rather than inside. Systems were accessible through external panels. This allowed multiple systems to be accessed at the same time and work to be done in parallel as opposed to Mercury where systems were placed inside the capsule and could be reached only one at a time. Connectors were located at the equipment so wiring bundles could be left untouched during system check-out and replacement. Independent systems testing was possible, and last-minute changes could be made without significantly impacting the schedule.
- There was an intentional focus on future program requirements, both future Gemini flights and in particular, those of Project Apollo.
- All-up testing, which became known in the Apollo Program actually began in Project Gemini.
- Computers produced massive amounts of data that had to be analyzed in a very short amount of time in order to be of use for the next Gemini flight. NASA implemented what has become known as the "dashboard" approach for data processing and analysis: (1) Select a limited number of important data elements and key time periods in the mission. (2) Do discrepancy

analysis—look for anomalous data that fall outside pre-established limits. (3) Have data analysis completed by the personnel responsible and therefore knowledgeable about the design and operation of the systems.

- There was a strong emphasis on the motivation of both NASA personnel and contractors. Some of the tools used were the outcomes assessment, accountability, astronaut involvement, incentive contracts, and recognition and awards. Astronauts frequently visited both NASA offices and contractors to both encourage and thank the people who would make their flights possible.
- The program director was able to contact any staff member or contractor involved on the project to manage the many engineering changes that came about on a daily basis.
- An atmosphere of trust and cooperation was established between NASA and contractors. Systems changes were often completed before contract changes were made.
- There was a focus on outputs, not on process, and personnel had a high degree of personal responsibility. The attitude of staff members was “this won’t fail because of me.”
- There was a high emphasis on academics in astronaut training. Where the Soviet program had a major emphasis on physical training, Gemini had 568 hours (fourteen weeks) dedicated to academic subjects with only one hour per day for physical exercise. The Russian program had a major emphasis on physical training.
- Failures and mistakes were accepted as a part of the learning process and not punished along the way. Failures were not accepted in the final product.
- The program had specific goals, tight deadlines, and almost enough money to do the job.

VII. Project Gemini Learnings

What was learned from the engineering and managerial features that proved relevant to current and future space missions?

- Common sense was the rule.
- Cooperation at all levels and between organizations was expected and occurred.
- There was a common, clearly stated, publicly known purpose.
- There was a specific and inflexible schedule and goal.

- There was almost enough money available to do the job. Running lean helps.
- The program used “stretch goals.”

VIII. Gemini Accomplishments

1. Two-man flight—ten successful flights accomplished.
2. Precision reentry and landing—to within 0.38 miles of target.
3. Long duration flight—a fourteen-day mission—by astronauts including eating, sleeping, waste disposal, and productive work.
4. Extra-vehicular activity—activities on five flights with one major success.
5. The first astronaut-controlled orbital changes using the Orbit Attitude and Maneuvering System (OAMS).
6. The first use of an onboard digital computer for guidance and control operations.
7. Rendezvous (ten rendezvous using seven different modes) and docking (nine operations) including docking on first revolution as would be required for the Lunar Orbit Rendezvous planned for Apollo.
8. Perform docked-vehicle maneuvers which raised the spacecraft to a 1,370-km apogee.
9. The integration of fuel cells as the power source which produced water as a byproduct were developed for the Apollo Program.
10. A project management board that was the model for the Apollo Project was developed and implemented.

IX. Conclusion

As was said at the beginning:

Nothing in Apollo makes sense except in light of Gemini.

Without the Gemini Program, Apollo would not have been able to land a man on the Moon within the timeframe established by President Kennedy. When the lunar challenge was laid down, the United States has just fifteen minutes of manned spaceflight, and that was suborbital. Gemini identified and mastered all of the significant technical and managerial issues that Apollo would face and paved the way for a splendid success.

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Endnotes

[1] Note that this was not a COTS-type program because there were essentially no “C,” Commercial, products available at that point in time.

[2] For an early discussion of this mission profile, see the 1865 novel *From the Earth to the Moon* by Jules Verne.

[3] The initial goal was for Gemini to land on hard ground rather than water for both safety reasons (the memory of Mercury Redstone IV’s loss was still fresh) and for cost reasons. For *Gemini 4,* for example, 10,384 personnel, 134 aircraft, and twenty-six ships were a part of the recovery team. See Gemini Summary Conference, p. 193.

[4] The Saturn V that was ultimately used was the most powerful launcher ever built before or since. It was “only” 33 feet in diameter and weighed just 6.5 million pounds at launch. Could von Braun and his team have developed the Nova launcher? Most likely, yes, but the time required would have meant that there would have been no Moon landing in the 1960s. The Space Launch System, scheduled for a first launch in 2020 (after promised launches in 2017, 2018, and 2019), will have a lift-off thrust of 8.9 million pounds.

[5] For a complete list of experiments, see Gemini Summary Conference, pp. 225–226 and 291–317.

[6] It is worth noting that the lengthy gap between the first uncrewed flight and the first manned flight was due primarily to weather conditions at the launch site in Florida not because of technical or managerial issues.

[7] The emergency landing took place in the Pacific Ocean rather than in the Atlantic Ocean. The distance from the target in the Pacific Ocean was 1.1 miles. The distance from the original landing target in the Atlantic Ocean was 8,622 miles.

[8] As a footnote, the choice of “Molly Brown” was not popular with NASA officials and they asked Grissom to choose a different name. When Grissom suggested “Titanic,” NASA opted to go with Grissom’s first choice. To protect themselves in the future, *Gemini 3* was the last mission to have a named spacecraft until Apollo 9 in March 1969 when multiple spacecraft flew on the same mission for the first time.

[9] The same overheating problem for astronauts would occur during the spacewalks themselves. This problem wouldn’t be satisfactorily solved until Buzz Aldrin’s spacewalks in *Gemini 12*. It was through practice in a neutral buoyancy tank that EVA was mastered.