Apollo Program Essay, Research Paper

IINTRODUCTION Apollo Program, American manned lunar-space program designed to land an astronaut on the moon and return him safely to earth, as well as to overtake the former Soviet Union in the race to dominate space exploration. Conducted between May 1961 and December 1972 by the National Aeronautics and Space Administration (NASA), the program successfully landed Neil Armstrong-the first person to walk on the moon-and 11 other astronauts on the moon. The program included 12 manned missions: 2 into earth orbit (Apollo 7 and 9); 2 into lunar orbit (Apollo 8 and 10); 3 lunar landing missions (Apollo 11, 12, and 14); and 3 lunar exploration missions (Apollo 15, 16, and 17), which involved extended stays on the moon’s surface and more in depth scientific exploration. One mission was lost during a test on the launch pad (Apollo 1), and one mission returned to the earth before making a scheduled lunar landing (Apollo 13). Following the Apollo program, Apollo spacecraft were used to shuttle astronauts to and from the Skylab space station, and an Apollo spacecraft docked with the orbiting Soviet spacecraft Soyuz 19 in the Apollo-Soyuz Test Project.

The Apollo program was initiated by United States President John F. Kennedy on May 25, 1961. It was preceded by the manned Gemini program, which engineers used to develop the techniques that would be needed for the ambitious trip to the moon, and the unmanned Surveyor Program, which scientists used to probe the lunar surface. At the peak of Apollo preparations in 1965, NASA employed 36,000 civil servants, 376,700 contractor employees, and a yearly operating budget of $5.2 billion. Between 1961 and 1973, NASA spent approximately $25.4 billion on the Apollo missions.

During the same time period, the Soviet Union scheduled a manned mission to circle the moon (Zond 7)-just three weeks before Apollo 8. This mission was postponed and the spacecraft was later launched unmanned. The Soviets continued to develop and test their one-man Lunar Lander spacecraft in the earth’s orbit through August 1971, but a Soviet cosmonaut never reached the moon.

IISPACECRAFT AND SUPPORTING SYSTEMS Each manned Apollo mission consisted of two spacecraft: the Command and Service Module (CSM) designed for orbital and reentry operations; and the Lunar Module (LM) designed for lunar landing, surface operations, ascent from the moon, and rendezvous with the CSM. The exceptions were Apollo 7 and 8, which flew the CSM only. The CSM comprised the command module, with the crew compartment and the reentry heat shield, and the service module, with the major support systems and consumables (such as propulsion systems, electrical power, food, and water). The LM comprised the descent stage, for landing and delivery of the lunar-surface equipment, and the ascent stage, with the crew compartment and independent systems for ascent from the moon’s surface and rendezvous with the CSM.

Apollo missions used a crew of three astronauts. During launch, all three astronauts were in the CSM. After leaving the earth’s orbit, the crew separated the CSM from the LM and the part of the launch vehicle surrounding the LM, then maneuvered the CSM to dock with the LM to extract the LM from the launch vehicle so that the crew could transfer between the two craft. After three days transit time to the moon, the CSM and LM entered into lunar orbit. Two astronauts then transferred to the LM, separated from the CSM, and descended to the lunar surface. The third astronaut continued to operate the CSM in lunar orbit.

ALaunch System The launch vehicle used for lunar missions was the Saturn V rocket designed specifically for Apollo craft. The Saturn launch vehicle family and the design of its support facilities were derived from technology developed by rocket engineer Wernher von Braun and his team at Peenem nde, Germany, during World War II. Von Braun brought his work and his team to the United States in 1945.

The Saturn V consisted of three stages used in sequence to boost spacecraft into the earth’s orbit and on toward the moon. The CSM and LM were mounted separately, in tandem, on top of the Saturn rocket system. At liftoff, the entire launch vehicle (including spacecraft) was 109 m (363 ft) high; it weighed 2.8 million kg (6.3 million lb); and the five Saturn first stage engines generated 3.5 million kg (7.7 million lb) of thrust. During the Apollo program, 12 Saturn V rockets were launched from the Kennedy Space Center at Cape Canaveral, Florida, and all were successful.

BLunar Surface Systems After landing, the LM became a habitable lunar base serving as living quarters, communications center, storage facility, equipment carrier, and supply center for food and water. The cylindrical LM crew compartment was less than 2.4 m (8 ft) in diameter and only 1 m (1.5 ft) deep. The lifetime and capacity of this lunar base was increased from less than two days for the first three lunar landing missions to over three days for the final three lunar exploration missions.

The performance of the astronaut Extravehicular Mobility Unit (EMU) was a key element in the success of Apollo. The EMU consisted of the astronaut space suit and the Portable Life Support System (PLSS). The EMU provided oxygen and pressure to sustain life in the vacuum of space; it protected the astronaut from thermal, radiation, and optical effects as well as meteorite impact; and it provided sufficient mobility and dexterity to enable the astronaut to perform useful work on the lunar surface. The PLSS was recharged with oxygen and cooling water from LM supplies after each outside excursion, known as an Extra Vehicular Activity (EVA). On the final three lunar exploration missions, the PLSS life-support capability for a single excursion was more than doubled to over seven hours.

Lunar surface equipment included a variety of cameras, geology tools, rock and soil sample containers, several individual science experiments, and the multidiscipline Apollo Lunar Surface Experiments Package (ALSEP). ALSEPs measured topological and geophysical characteristics of the moon and were set into place and left behind by the astronauts. They were nuclear powered and designed to operate for at least five years-several lasted much longer. The final three missions (Apollo 15-17) also carried the two-man Lunar Roving Vehicle (LRV) with additional geology tools, experiments, and sample containers. The LRV vastly increased the range and capability of lunar surface exploration.

CSupport Facilities The success of Apollo also was dependent on a number of facilities on the earth. Foremost among these were the test and qualification facilities for spacecraft, launch vehicles, and the EMU; simulators and trainers to prepare the astronauts for the mission; the launch complex at Cape Canaveral; the worldwide tracking and communications network; and the Mission Control Center in Houston.

IIIAPOLLO MISSIONS The Lunar Orbit Rendezvous (LOR) technique used for the Apollo missions consisted of launching the spacecraft into a stable orbit around the earth; setting a path toward the moon; moving the spacecraft into orbit around the moon; landing the LM on the lunar surface; taking off in the LM from the lunar surface and returning to the moon’s orbit; rendezvousing and docking with the CSM; and finally, setting a course home to the earth. On return to the earth, the spacecraft was slowed by drag from the earth’s atmosphere and by parachutes (just before splashdown), before landing in the ocean. The transit time to and from the moon was approximately three days each way. Depending on the specific mission, the time in lunar orbit ranged from less than one day for Apollo 8 to over six days for the final three missions, and the time on the lunar surface ranged from less than one day for Apollo 11 to over three days for Apollo 15, 16, and 17.

AApollo Test Missions A total of 16 unmanned Apollo missions were flown between October 1960 and April 1968. The objectives of these missions were to test the Saturn rocket launch system and certain systems of the CSM and the LM. The launch vehicle systems and the CSM abort system were tested in ten missions. Launch vehicle/spacecraft compatibility and the CSM heat shield were tested in four missions. The Saturn launch vehicle for the complete lunar landing configuration was tested by launching CSM and LM test vehicles into very high earth orbit paths.

BApollo 1 On January 27, 1967, the launch crew and flight crew of the first manned Apollo mission were conducting a simulated countdown to test the operations and compatibility of the CSM and the launch vehicle prior to their scheduled launch the following month. The spacecraft was ready for a simulated launch, with hatch locked, power on, and an internal atmosphere of pure oxygen. The crew of Virgil I. Grissom, Edward H. White, II, and Roger B. Chaffee were in their space suits and performing the normal sequence of prelaunch activities.

At about 6:30 PM, after over five hours of delays and problems, a spark inside the spacecraft ignited flammable material and instantly engulfed the closed compartment in flames. By the time the hatch was pried away more than five minutes later, the crew had died from asphyxiation.

The precise source of the spark and fire was never determined; neither were any individuals or specific organizations implicated in the fire. Upon retrospect, the actual cause was due to the combination of several conditions: an oxygen-rich atmosphere; flammable interior materials such as paper, the space suits, velcro, and other flight equipment; a vast array of exposed internal wiring, which presented many potential sources of electrical sparks; and the design and manufacture of the spacecraft.

As a result of the fire, many changes were made to the design, manufacturing, test, and checkout procedures of the vehicles and the management of the entire Apollo program. Many of these changes were tested in the unpiloted Apollo missions 4, 5, and 6. The vast improvements to the CSM, in particular, and the process by which it was prepared for flight, proved highly successful. The CSM performed almost flawlessly during the remainder of the Apollo program (with the exception of Apollo 13).

CApollo 7 Apollo 7 was the first manned earth orbit flight test of the CSM. This ten-day mission was launched on October 11, 1968. On board were Walter M. Schirra, Donn F. Eisle, and R. Walter Cunningham. While orbiting the earth, the crew practiced maneuvers that would be used in a lunar mission. After exiting orbit and reentering the atmosphere, the capsule and crew were safely recovered in the Atlantic Ocean.

DApollo 8 Apollo 8 was launched on December 21, 1968, and was the first manned mission to achieve lunar orbit. The crew of this six-day mission, Frank Borman, James A. Lovell, Jr., and William A. Anders, conducted a complete test of the CSM flight profile for lunar missions. The CSM entered lunar orbit on December 24, 1968, and orbited the moon for ten revolutions (20 hours 7 minutes) before returning to the earth and a controlled reentry into the Pacific Ocean.

EApollo 9 Apollo 9 was the first flight test of the complete lunar landing mission including the CSM, the LM, and the EMU. The crew consisted of James A. McDivitt, David Randolph Scott, and Russell L. Schweickart. The first Apollo spacecraft to be named, Gumdrop (CSM) and Spider (LM) were launched into the earth’s orbit on March 3, 1969. During ten days of operations, the crew demonstrated all Apollo mission maneuvers. Remaining in the earth’s orbit, the crew simulated a lunar landing with the LM and conducted the first actual LM rendezvous with the CSM. The astronauts conducted a 56-minute EVA to demonstrate EVA crew transfer from the LM to the CSM. The crew also practiced backup safety maneuvers, including a procedure in which astronauts used the LM as a lifeboat in case the command module was rendered inoperable or uninhabitable. This procedure was subsequently used to recover Apollo 13.

FApollo 10 Apollo 10 was a dress rehearsal for a lunar landing mission and was conducted in lunar orbit, but it excluded the actual landing. Launched on May 18, 1969, the spacecraft Charlie Brown (CSM) and Snoopy (LM) spent over two days and 31 revolutions in lunar orbit. The crew of Thomas P. Stafford, John W. Young, and Eugene Andrew Cernan conducted all propulsive maneuvers required for a lunar landing mission. During lunar orbit, Stafford and Cernan descended in the LM to within 14.5 km (9 mi) of the lunar surface before completing the first lunar orbit rendezvous with the CSM. This eight-day mission was recovered in the Pacific Ocean and was completed less than two months prior to the planned launch of the first lunar landing mission.

GApollo 11 Apollo 11 was the first lunar-landing mission. Launched on July 16, 1969, the crew of Neil A. Armstrong, Edwin E. Aldrin, Jr., and Michael Collins flew the spacecraft Columbia (CSM) and Eagle (LM). On July 20, 1969, Armstrong and Aldrin landed the Eagle at the relatively flat and unobstructed Tranquillity site on the moon, while Collins remained in the CSM. The LM spent 21 hours 36 minutes on the lunar surface, and the crew spent 2 hours 31 minutes outside the LM in a local area excursion on foot to a distance of approximately 50 m (160 ft) from Tranquillity Base. Armstrong and Aldrin evaluated the capability of working on the lunar surface, established a small scientific station, and collected 22 kg (49 lb) of lunar rocks and soil. Using the descent stage of the LM as a launching platform, the ascent stage of the LM took off from the moon’s surface to rendezvous and dock with the CSM. The spacecraft departed lunar orbit over two days after arrival. This eight-day mission landed and was recovered safely in the Pacific Ocean. As a precautionary measure, the astronauts were quarantined for 14 days.

HApollo 12 Apollo 12 was the second lunar landing mission and the first mission to make a pinpoint landing on the moon. Launched on November 14, 1969, the crew of Pete Conrad, Richard Francis Gordon, Jr., and Alan LaVern Bean flew the spacecraft Yankee Clipper (CSM) and Intrepid (LM). Conrad and Bean landed the LM on the southeastern Oceanus Procellarum region of the moon within 200 m (660 ft) of their target. The crew spent 31 hours 31 minutes on the lunar surface conducting two excursions for a total of 7 hours 45 minutes. They traversed 2.0 km (1.2 mi) on foot and ranged up to 470 m (1500 ft) from their base, the Intrepid craft. The first excursion included an inspection of the Surveyor 3 lunar probe, which had landed on the lunar surface years earlier. Several components were extracted from the probe for engineering analysis. During their stay, Conrad and Bean set into place an ALSEP scientific station, conducted geological observations, and collected 34 kg (75 lb) of lunar rocks and soil. After LM ascent, rendezvous, and docking with the CSM, the CSM departed lunar orbit just under four days after arrival. This ten-day mission landed without incident in the Pacific Ocean.

IApollo 13 Apollo 13 was launched on April 11, 1970, as the third planned lunar landing mission. The crew of James A. Lovell, Jr., John L. Swigert, Jr., and Fred Wallace Haise, Jr., flew the spacecraft Odyssey (CSM) and Aquarius (LM). Two days after launch, as Apollo 13 approached the moon to begin lunar operations, an explosion occurred that caused the service module of the CSM to lose its oxygen, electrical power, and other systems, including its capability to perform an abort maneuver for a direct return to the earth. The crew quickly moved to the LM which became their lifeboat in space. All of the systems in the command module of the CSM, which remained functional, were deactivated to preserve its capability to reenter the atmosphere upon return to the earth. The LM had no heatshield and therefore could not be used for earth reentry.

At the time of the explosion, the return time to the earth was over four days. Because the LM did not have enough oxygen or water for this length of time, it became necessary to use the LM lunar landing engine for a major propulsive maneuver in space to change the spacecraft’s path and speed its return to the earth. Overcoming numerous life-threatening problems, including near freezing temperatures and excess carbon dioxide in the LM, Apollo 13 successfully reentered the earth’s atmosphere for a landing in the Pacific Ocean on April 17, 1970, over five days after launch.

The cause of the explosion was traced to a chain of events resulting in the ignition of the insulation covering a wire inside one of the three liquid oxygen tanks in the CSM. It occurred when a fan (to which the wire was connected) was turned on to stir the liquid oxygen inside the tank.

JApollo 14 Apollo 14, the third mission to land on the moon, was launched on January 31, 1971. The crew of Alan B. Shepard, Jr., Stuart A. Roosa, and Edgar D. Mitchell piloted the spacecraft Kitty Hawk (CSM) and the Antares (LM) to a landing in a hilly region just north of the Fra Mauro Center. Using the Mobile Equipment Transporter, a two-wheeled cart, Shepard and Mitchell traversed 3.3 km (2.1 mi) on foot and reached a distance of approximately 1400 m (4600 ft) from the LM. During two surface excursions, they set into place an ALSEP scientific station, conducted geological observations, and collected 43 kg (95 lb) of lunar rocks and soil. After LM ascent, rendezvous, and docking, the CSM departed lunar orbit nearly 3 days after arrival. This nine-day mission landed safely in the Pacific Ocean. After this mission, scientists at NASA decided that a full quarantine of returning astronauts was no longer necessary.

KApollo 15, 16, and 17 Apollo 15 was the first of three extended scientific explorations of the moon using the LRV, the extended-duration PLSS, more mobile space suits, and more highly trained crews. These last three missions established the first lunar bases on the moon. Launched on July 26, 1971, the crew of David Randolph Scott, Alfred M. Worden, and James A. Irwin flew the spacecraft Endeavour (CSM) and Falcon (LM). On July 30, 1971 Scott and Irwin landed the LM on the western edge of the Apennine mountains, and, during the nearly three days they spent on the moon, the crew conducted four explorations outside their home base, called Hadley Base. They traveled a total distance of 27.9 km (17.3 mi) on the LRV, ranging up to 4.9 km (3.0 mi) from the LM, and moving over the horizon and out of view of their home base for the first time. They set into place an ALSEP scientific station, made extensive geological observations and interpretations, and collected a total of 77 kg (170 lb) of lunar rocks and soil. This 12-day mission landed safely in the Pacific Ocean.

Apollo 16 was launched on April 16, 1972. The crew of John W. Young, T. Kenneth Mattingly, and Charles Moss Duke, Jr., flew the spacecraft Casper (CSM) and Orion (LM). On April 20, 1972, Young and Duke landed the LM near Descartes Crater and during the nearly three days they spent on the moon, the crew collected a total of 94 kg (207 lb) of lunar rocks and soil. They traveled a total distance of 27 km (17 mi) on the LRV, ranging up to 4.5 km (2.8 mi) from Descartes Base. This 11-day mission landed and was recovered in the Pacific Ocean on April 27, 1972.

Apollo 17 was the third extended scientific exploration of the moon and the final mission of the formal Apollo program. Launched on December 7, 1972, the crew of Eugene Andrew Cernan, Ronald Elwin Evans, and Harrison Hagan Schmitt flew the spacecraft America (CSM) and Challenger (LM). On December 11, 1972, Cernan and Schmitt landed the LM in the Taurus Littrow Valley region of the moon. During the more than three days they spent on the moon, the crew traveled a total distance of 35.0 km (22 mi) on the LRV, ranging up to 7.8 km (4.8 mi) from Taurus Base. They collected a total of 110 kg (240 lb) of lunar rocks and soil. This 12-day mission landed in the Pacific Ocean.

IVMISSIONS TO SKYLAB The Skylab space station project originated in the 1960s to demonstrate that humans could live and work in space for extended periods and to expand the knowledge of solar astronomy. The Skylab station was launched unmanned on May 14, 1973. It was placed into a near-circular earth orbit at an altitude of 430 km (270 mi). However, it was damaged during launch when one of two solar panel wings was ripped off.

On May 25, 1973, the first three-man crew to occupy Skylab was launched aboard an Apollo CSM. The crew of Pete Conrad, Paul Weitz, and Joseph Kerwin conducted an extensive EVA to repair the damaged Skylab station and carried out experiments in orbit for 28 days, after which they reentered the atmosphere in the command module.

A second mission to Skylab, with a crew of Alan LaVern Bean, Owen Garriott, and Jack Robert Lousma, was launched on July 28, 1973. They occupied the station for 59 days. The final mission to Skylab, with Gerald Carr, Edward Gibson, and William Pogue, was launched on November 16, 1973. These astronauts occupied the station for a record 84 days. Each Skylab crew set a manned spaceflight endurance record, and all of the objectives of the Skylab program were accomplished. The Skylab station decayed in orbit and reentered the atmosphere over the Indian Ocean on July 11, 1979.

VAPOLLO-SOYUZ TEST PROJECT The primary objective of the Apollo-Soyuz Test Project (ASTP) in the mid-1970s was to conduct a joint diplomatic mission with the Soviet Union. ASTP was designed to test the compatibility of U.S. and Soviet spacecraft and rendezvous and docking systems as a prelude to international space rescue, as well as future international space missions.

The ASTP mission was planned and conducted using existing Apollo and Soviet Soyuz spacecraft as well as launch vehicles and operational techniques. The only new technologies used were a universal docking system and docking module designed and constructed by NASA to serve as the connection and airlock transfer tunnel between the two spacecraft.

On July 15, 1975, the Soyuz 19 spacecraft and its crew of Alexei Leonov and Valerei Kubasov were launched from the Baikonur Cosmodrome in Kazakhstan. Precisely 7 hours and 30 minutes later, the final Apollo CSM, with its crew of Thomas P. Stafford, Deke Slayton, and Vance DeVoe Brand, was launched from Cape Canaveral.

After a flawless rendezvous, the Apollo spacecraft and Soyuz 19 docked-45 hours and 22 minutes after Apollo liftoff. After stabilizing the systems of the spacecraft and the docking module, the first international handshake in space occurred when Tom Stafford and Alexei Leonov met at the edge of the open docking tunnel.

The two spacecraft remained together for over 47 hours, during which a brief separation and redocking were conducted to further demonstrate the operations and compatibility of the docking system. Approximately 43 hours after final separation, Soyuz 19 completed its mission and reentered to a precision landing in central Russia on July 21, 1975.

The Apollo spacecraft remained in space for an additional six days to conduct experiments. The craft reentered the earth’s atmosphere for a landing in the Pacific Ocean on July 24, 1975.

VIAPOLLO ACHIEVEMENTS The Apollo program demonstrated effective human geological exploration in the hostile environment of another planet. During the initial Apollo 11 lunar landing mission, the crew remained on the moon for less than one day and conducted a single excursion of less than three hours, during which they ventured only 50 m (160 ft) from the LM. By the sixth and final lunar exploration mission, the distance traveled on the lunar surface had greatly increased. By the last mission to the moon, Apollo crews had traversed a total distance of more than 97 km (60 mi) on the lunar surface and spent over 160 man-hours outside the LM.

A broad range of over 60 scientific experiments were performed on the lunar surface, and 30 experiments were conducted from lunar orbit. Six long-term scientific stations were manually placed and activated on the moon by the astronauts. The last four operating stations (set up by Apollos 12 and 15 through 17) were finally turned off by NASA in 1977.

The experiments carried out on the Apollo missions provided important information about the moon as well as the solar system. A total of 381.7 kg (841 lb) of lunar material was returned from six unique and scientifically significant lunar locations. Additionally, almost 30,000 high-resolution photographs were taken on the surface and from orbit during Apollo missions, recording the characteristics and features of the moon in great detail.