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Project Number: JMW AEGS - 46

A Chinese Critique of the Apollo Program

An Interactive Qualifying Project Report

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

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Date: March 1999

Approved:

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Introduction:

The Chinese are presently at a technological level comparable to the United States in the early 1960's with regards to manned space flight. In the next twenty years China will also have the capability to accomplish lunar travel. This creates an interesting moment in U.S.-China relations since the U.S. dismantled its space systems capable of reaching the Moon. Certainly any nation considering a lunar exploratory mission would carefully study the U.S. Apollo program, critique it and then construct a superior program by avoiding Apollo's faults. The U.S. visited the Moon but did not stay, so it is clear how one would surpass their achievement. Hence, I have given myself the task of predicting future Chinese actions in space by planning a lunar mission from their perspective.

China wants to be viewed as it was 500 years ago, a superior technological power in the world. The Chinese take pride in their ancient moral and philosophical traditions. China feels deeply humiliated by centuries of imposed foreign political, military, and economic control that showed little respect for Chinese culture. China's sense of honor and pride is important.[1] Great national prestige and world acknowledgement as a technologically advanced nation will be given through manned space flight and a presence on the moon.

In critiquing the United States' Apollo Program from the vantage point of a team charged with creating a Chinese plan of going to the moon (with the intention of establishing a permanent presence there) my interactive study achieves WPI's goal for the IQP by enabling me to explore how society shapes technology. By analyzing the faults of the Apollo program China can construct and implement a program superior to the Apollo mission in terms of both efficiency and Chinese values. Hence, I will also be addressing WPI's emphasis on globalization and cross culture perspective in undertaking this study. To prepare a lunar mission plan for China the following three questions were addressed:

1. **Does the Chinese space program have the ability to attempt such an undertaking at the present time? If not, how long will it take for them to achieve this capability?**

China has some of the world's largest rockets and a strong space program that dates back to its first domestic launch in 1970. Since then China has launched more than forty telecommunications and remote sensing satellites for itself and commercial clients.[2] Highly publicized launch failures early in this decade have given the Chinese space program an undeserved reputation of inferiority and low reliability. The United States had more failures at a similar level of development. By having successful consecutive launches since late 1996, the Chinese have proven themselves again.

The Chinese succeeded in recovering their first Fanhui Shi Weixing (FSW) satellite from orbit in 1975. It was their first satellite recovery attempt. This equaled the Soviet Union's success on their first satellite recovery attempt. The U.S. did not succeed in recovering a satellite from orbit until Discoverer 13. China has launched and recovered nine FSW-0 satellites, four of five FSW-1s and three FSW-2 satellites. The Chinese have therefore succeeded at one important area of manned flight.[3]

China is aiming for a possible manned launch before 2000 even though almost all major aspects of China's manned space program began within the last five years. One of the strongest motivations for the program is political prestige. The Chinese tentatively planned a manned flight for October 1, 1999 to commemorate the 50th anniversary of the People's Republic of China. This may be delayed until 2000 due to setbacks. Testing of the launch vehicle, a Long March 2-EA, was planned for late 1998 but never occurred. The Chinese rocket can put about 9 metric tons into low Earth orbit. China's manned spacecraft supposedly weighs about 8.4 metric tons. The limit of the new Long March has been speculated to be 12 tons. They have a 90% chance of success, the same as other world space powers.[4] They have or will shortly have the capability for manned space flight. The next logical question therefore is what they intend to do with this capability.

2. Does China have a desire to pursue manned space flight and travel to the Moon?

The number one priority of the Chinese government is internal stability, which occurs through economic development and prosperity.[5] The Communist Party views stability as a way to avoid any form of upheaval or dissent in a population of 1.2 billion people. Stability is maintained by providing returns that contribute to economic development for the people. Beijing wants to link China's wealthy urban and poor rural areas, knowing that political discontent has come from rural areas in the past.[6] The average Chinese, aware of the political problems of the last century, is more interested in peace than democracy and freedom. The Chinese population will support Communism if only for the stability it seeks. Chinese know that continued economic advances will lead to political changes and are waiting patiently.[7]

Space is very important to China. China's leaders realize that along with economic returns from commercial launches many areas critical to continued economic growth and stability are provided by the space program. These include satellites, a crucial necessity as more Chinese gain television, phone and computer services.

Satellites are also extremely important for military and meteorological needs. World prestige given through technology is another area well recognized and understood by China's leaders. China wants to pursue manned space flight in the future but is more concerned with stability at the present time. So, there is no firm time table as there was for Apollo but the future intention is clear.

3. How would China view the Apollo Program based on their ideals and what parts of the plan would they incorporate and which would they change?

Forming critiques based on the Chinese psyche was difficult. Material specifically examining the Chinese cultural point of view is difficult to locate. The process often entails piecing together information from various sources to form a policy stance and worldview into a viewpoint that you believe is correct. After creating views or ideals, a comparison of American and Chinese societies was undertaken. This was accomplished by using two societal types defined by Robin Williams, author of "American Society". Examining core-value system differences is a step toward understanding how China, based on one type of society tends to differ in both thought and action from the United States, which is based on an opposite societal form.

There are two types of societies: community and association. Gemeinschaft and Gesellschaft describe a communal society and an association society respectively. Communal societies are usually based on small internally homogeneous units and have stable systems. Association societies are rapidly changing, specialized and segmented. These polar extreme alternatives are called "Ideal Types" in sociology and do not describe any real society perfectly. Two areas used to compare cultures and give greater credibility to my ideas on the contrasting mindset of the space program covered in this project were:

A. The communal society is slow to embrace social change, and the integration of sub-units is evident. There are many universally accepted values, goals, and conduct. The association society lacks universally accepted goals and behavioral codes; importance is given to law and administrative controls. Integration is based on interdependence of units that are part of an elaborate division of labor.

B. One of the central characteristics of associational relations is the furthering of one's own interests. Relationships are instruments to achieve a personal goal. Communal relationships are valued for their own sake and stress attitudes such as respect, affection and loyalty. In association relations, emphasis tends to center on performance; in communal relations questions of meaning, intent, motive and feeling are emphasized.

Robin Williams states that "Many other societies have maintained the unity and the rigidity or stability of the folk society to a high degree but have developed a fairly elaborate division of labor, complex social stratification and political systems, and differentiated and highly organized religious groupings".[8] This seems to be true for China, making their system and mentality much more difficult to categorize. It is not absolutely communal but relative to an extremely associational American society China can be considered communal.

The following report is written from the point of view of the Space Leading Group (SLA) of China's State Council. SLA is the top group responsible for policy making and mission coordination. Members include the Prime Minister of the State Council, the Chairman of The Commission of Science, Technology and Industry for National Defense (COSTIND), the Vice-Chairman of the State Committee of Science and Technology, the Minister of Aerospace Industry, the Vice-Minister at the Ministry of Foreign Affairs, and the Vice-Chairman of the State Committee of Central Planning.[9]

The document is classified as top secret and is only available to this government agency at present. No agencies or individuals under SLA are to have knowledge of this report until it is deemed necessary. Included in this report is an overview of the American Apollo Program. A precise examination of the technology of Apollo has not been documented. Although additional information regarding design, manufacturing, testing and test results would be an important and useful source for China, it is beyond the scope of this report. The assumption can be made that if this program is approved China can study the wealth of published technological data made available by the U.S.. The Chinese are very good at adapting and cross-utilizing space technology. An example of this is the location of the Xichang launch site. It is located at latitude coordinates similar to Kennedy Space Center. This enables the Chinese to compare results with published U.S. rocket launch reports on proper rocket attitude and altitude.[10]

Because this report is written from a Chinese mindset, reasoning behind SLA decision making may not always be obvious to the reader. Decisions were formed from the examination of Chinese mindset and psyche. Ideals and values were stated outright whenever possible but some situations did not allow a discussion of specific reasoning to be given. Therefore, the following is a list of Chinese points of view that may help the reader better understand decision making throughout this report:

1. Age is greatly respected in China.
2. China is a collective culture. Chinese are hesitant to take credit for an individual achievement. China is a society that focuses on and rewards group efforts rather

than individual ones. Business and political decisions are made from consensus and represent group interests.

3. Preserving one's reputation and contributing to the reputation and prestige of others is an important moral responsibility.

4. Chinese feel they must fulfill responsibilities to their family, community, work group, society and country.

5. Americans are seen as having material wealth and technology but lack morals and have little culture. The Chinese feel that Westerners lack the knowledge that comes from hardship, are straightforward, candid and seldom subtle. They are creative but often self-centered and don't recognize the importance of teamwork. They are passionate but impatient when dealing with personal achievement.[11]

6. Family is very important in China. A Chinese who cannot be identified by family and danwei (work unit) has no identity and therefore no strength or protection.

7. Education is highly respected in China.[12]

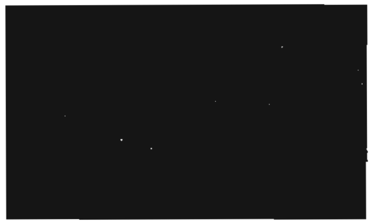
8. The Chinese dislike casual or informal relationships. Social standing is very important in China.

9. The only point Communist Party factions agree on is maintenance of Party power and suppression of dissent. Political upheaval may arise from the extreme difference in wealth between rural and urban areas, suppression of dissent by the government, mass consumerism and growth in Western cultural values and greed and Party corruption.

10. Chinese culture teaches that one should be suspicious of haste and should proceed cautiously. Time is fluid, rather than something that is best compartmentalized.[13]

11. China believes that as an emerging world power it is entitled to up-to–date military forces.[14]

Overview and Critique of the U. S. Apollo Program



Most political decisions made by the United States are an effort to deal with unsatisfactory situations. Project Apollo was not an exception. It was undertaken to address the world perception of Communism's superiority over Democracy in leadership and technology. President John F. Kennedy wanted Apollo to show that the U.S. remained the world leader in technology. He also hoped Apollo would restore American pride and self-confidence damaged by Soviet space achievements. Project Apollo, if evaluated by these goals, accomplished the objectives for which it was created.[15]

Although Project Apollo was an important early step in space exploration, it was not flawless or, more precisely, truly successful. A successful Apollo program would have ensured thirty years of continued space achievements for the United States. Between 1950 and 1970 NASA believed lunar bases and manned trips to Mars were attainable well before the end of the century, but very little, if any progress has been made in these areas. The lack of U.S. space spectaculars for twenty five years initiates the question, "How could an organization such as NASA, after the "success" of Apollo not continue its space achievements?"

The answer to this question is that due to budgetary extravagance, the U.S. obsession with being the first, biggest and best destroyed the future of America's space program. An opportunity arises, therefore, with our present technological space ability (that of the U.S. in the 1960's) to reach a point unattained by the United States or the rest of the world. This is the ability to go to the moon and stay there. By just landing a man on the moon we will achieve a feat accomplished by only the United States, since all Russian lunar missions were unmanned. If we avoid the mistakes made by the United States we can create a valuable space program for the future. An examination of Apollo must be undertaken to make our effort better both in terms of efficiency and Chinese values. To do this a neutral abbreviated view of the technology of the Apollo program will be given, followed by a critique of Apollo problems we feel can be changed or improved. An outline detailing our proposed plans for getting to the moon and staying there will conclude this report.

Project Mercury:

The first goal of NASA was to successfully launch a manned satellite. This was named Project Mercury. Project Mercury began in 1958 and was completed in 1963. It was the United States' first manned program and placed the U.S. in a "catch-up" mode with the Soviet Union, which had already successfully orbited a cosmonaut. Mercury's objectives were to orbit a manned spacecraft around Earth, to study man's ability to function in space, and to safely recover man and spacecraft.[16]

The Mercury spacecraft was developed to protect a human from the temperature extremes, vacuum and radiation of space and the high-speed reentry through Earth's atmosphere. It was a wingless capsule designed for a ballistic reentry, with an ablative heat shield that burned off as it returned to Earth.[17]

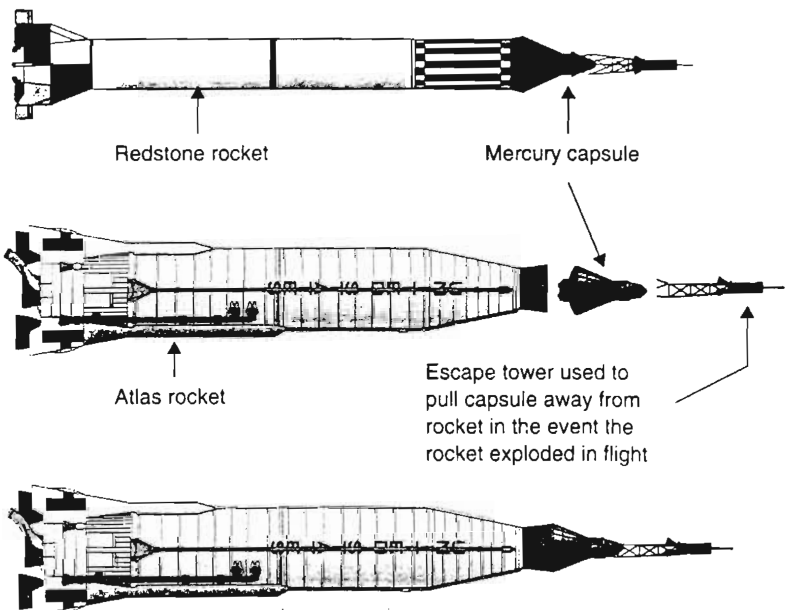
The Mercury spacecraft was a one man cone-shaped capsule with a cylinder mounted on top. It was 9.5 ft in length and 6.2 ft in diameter. A 19 ft escape tower was attached to the capsule's cylinder. The Mercury capsule weighed 3000 lbs and had only 39.8 cubic feet of volume. A heat shield covered the blunt end of the spacecraft for protection against the 3000 °F reentry heat.[18] There were 120 controls, 55 electrical switches, 30 fuses and 35 mechanical levers inside the spacecraft.

The Mercury program used a Redstone launch vehicle for suborbital flights and an Atlas launch vehicle for orbital flights. Unmanned tests of the booster and the capsule were made to test the safety of the spacecraft. These flights carried two rhesus monkeys, a chimpanzee, and an electronic crewman simulator mannequin.

Six Mercury flights between 1961 and 1963 put two men in suborbit and four into Earth orbit. Life support and reentry technology was devised along with the development of tracking, communications and recovery operations. Ground engineers discovered the difficulty of launch preparations and that a worldwide communications network was necessary for manned space flight.[19]

Figure 32: *First Steps into Space* ◀

Dimensions of Mercury:	2.90 meters (9.51 feet) long 1.89 meters (6.20 feet) diameter	Dimensions of Atlas:	29.0 meters (95.1 feet) high 3.05 meters (10.0 feet) diameter
Weight of Mercury:	1,355 kilograms (2,987 lbs) in orbit on the *Friendship 7* mission.	Weight of Atlas:	117,915 kilograms (259,958 lbs) on average.
Crew:	One astronaut for up to one day.	Redstone:	Used for Mercury sub-orbital flights.



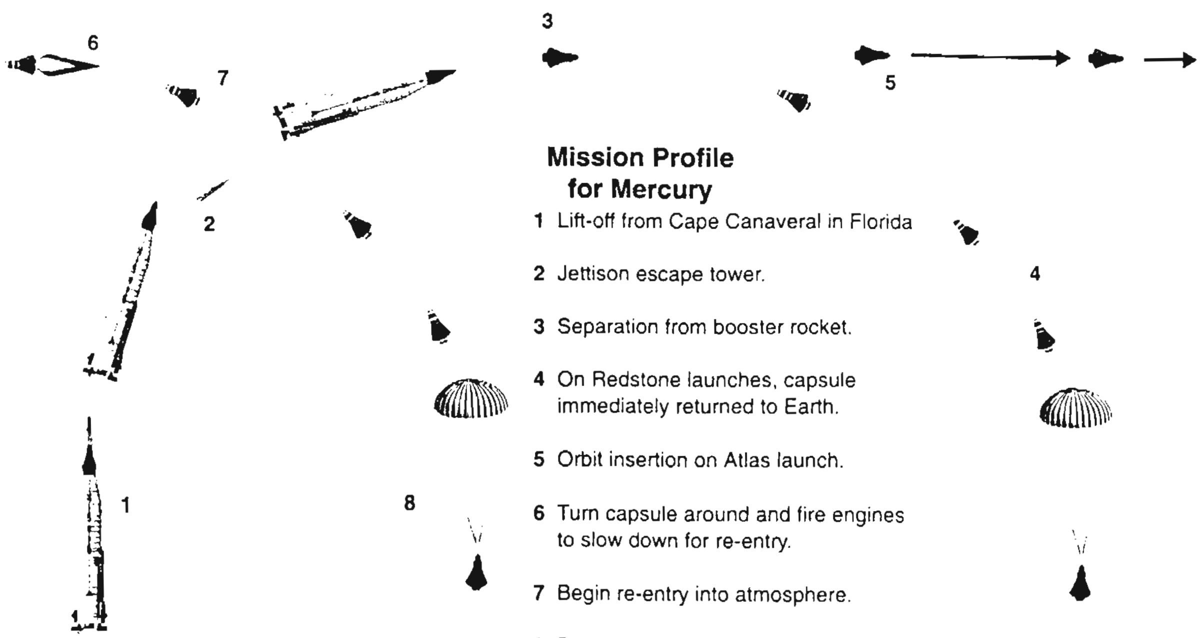
Fully Assembled View of Atlas

Redstone Launcher

This rocket was less powerful than the Atlas, and could only put the Mercury on a sub-orbital trajectory. It was used on the first two Mercury missions.

Atlas Launcher

NASA used the Atlas for the last four of the six Mercury missions. All of these four missions reached orbit. Atlas was a modified ICBM originally designed by the Air Force to drop nuclear weapons on the Soviet Union in the event of war. It was modified for astronaut use by NASA. Unfortunately, Atlas had a notorious reputation for exploding in flight.



Mission Profile for Mercury

1 Lift-off from Cape Canaveral in Florida

2 Jettison escape tower.

3 Separation from booster rocket.

4 On Redstone launches, capsule immediately returned to Earth.

5 Orbit insertion on Atlas launch.

6 Turn capsule around and fire engines to slow down for re-entry.

7 Begin re-entry into atmosphere.

8 Deploy parachute for splash-down.

Project Gemini:

NASA created Project Gemini to gain experience in three major areas that could not be studied in Project Mercury. Gemini involved 12 flights, including two unmanned test flights. Gemini's objectives were to study the effects of space flight on man and equipment; to gain experience in space rendezvous and docking-techniques; and to perfect methods of entering the atmosphere and landing at a preselected point.[20]

The Gemini spacecraft improved on both Mercury's size and capability. It had a length of 19 ft, a 10 ft diameter, and weighed 8400 lbs. The spacecraft was designed to endure the temperature and vacuum of orbital flight, the heat of reentry, and the impact of a water landing. Two astronauts could attempt flights of more than two weeks.[21]

A reentry module and an adapter module form the Gemini spacecraft. The reentry module is designed to withstand the heat of reentry. It is protected by heat resistant shingles and an ablative heat shield. The heat shield is a dish-shaped structure that forms the large end of the reentry module. The surface of the reentry module is covered with overlapping shingles which provide heat protection and hold pads of insulation in place. The shingles are identical to those used on Mercury.

The biggest difference between the Gemini and Mercury spacecraft is the adapter module. The adapter module is 7.5 ft in length and 10 ft in diameter at its widest point. It provides space for systems and equipment necessary for the completion of mission objectives. It also contains the mating structure between the reentry module and the launch vehicle. The adapter is joined to the reentry module by three titanium tension straps located on the outside of both the reentry and adapter modules.[22]

Gemini was launched by an Air Force Titan II launch vehicle. The rendezvous target was an unmanned Agena upper stage, which was launched ahead of the Gemini. After meeting in orbit, the nose of the Gemini capsule would fit into a docking collar on the Agena. Unlike Mercury, which could only change its orientation in space, Gemini needed to rendezvous with another spacecraft. Gemini had to move forward, backward and sideways in its orbit. It also had to change orbits. The complexity of rendezvous required two astronauts on the Gemini spacecraft and more piloting than had been possible with Mercury. It also required the first onboard computers to calculate rendezvous maneuvers.[23]

Gemini enabled U.S. astronauts to gain experience with living and working in space. It was the first ship to use fuel cells instead of batteries as a source of power and included many modifications to Mercury's hardware.[24] Although Gemini spacecraft were made more serviceable with subsystems that could be removed and replaced easily, problems occurring throughout the Gemini program increased the cost of an estimated $350 million program to over $1 billion.[25]

Gemini gained the necessary orbital rendezvous and docking techniques necessary for Apollo and proved that humans could live and work in space. Gemini also completed many onboard science experiments, including space environment studies and Earth photography. The program added 1,000 hours of space-flight experience between the Mercury and Apollo projects.[26]

The Apollo program could not have occurred without detailed information about the Moon. This included radiation and magnetic fields between the Earth and the Moon, possible landing sights on the Moon, surface conditions, soil properties and solar radiation. The first attempt at this was the Pioneer Program. The first three Pioneer missions ended in failure. The fourth was successful and flew within 37,000 miles of the moon collecting data on radiation. Following this was the lunar program Ranger. The goal of Ranger was to return television pictures of the lunar surface as it crashed into the Moon's surface. Rangers one through five were failures. Ranger 6 reached the Moon but its television cameras were dead. Ranger 7 was a success and returned 4,316 pictures before it crashed into the surface. Following Ranger missions were used to view potential landing sites.[27] For a manned landing to take place photographs had to be taken and surface conditions had to be checked for possible landing sites. This was to be done by the Surveyor and Lunar Orbiter programs.

The Surveyor program would soft land vehicles on the Moon and the Lunar Orbiter program would map the Moon's surface. By 1966 five Surveyors had landed on the Moon and returned 76,589 pictures and information on the lunar surface.[28] A small craft with tripod landing legs, it could take post-landing photographs and perform measurements of the composition and strength of the lunar crust, and readings on the thermal and radar reflectivity of the soil. The Lunar Orbiter program began in August 1966 and photographed 99.5% of the Moon. In addition to a powerful camera that could send photographs to Earth tracking stations, it carried scientific experiments, meteoroid detection, and radiation measurement. The information obtained from these programs enabled NASA planners to create a plan for the Apollo missions.[29]

▶ Figure 33: *On the Shoulders of Titans*

Dimensions of Gemini: 5.61 meters (18.4 feet) long; 3.05 meters (10.0 feet) diameter

Weight of Gemini: 3,760 kilograms (8,289 lbs) on the *Gemini 12* mission.

Crew: Two astronauts for up to 14 days.

Dimensions of Titan 2: 33.2 meters (109.0 feet) high; 3.05 meters (10.0 feet) diameter

Weight of Titan 2: 185,000 kilograms (407,855 lbs) on average.

Stages: Titan 2 was a two-stage rocket.

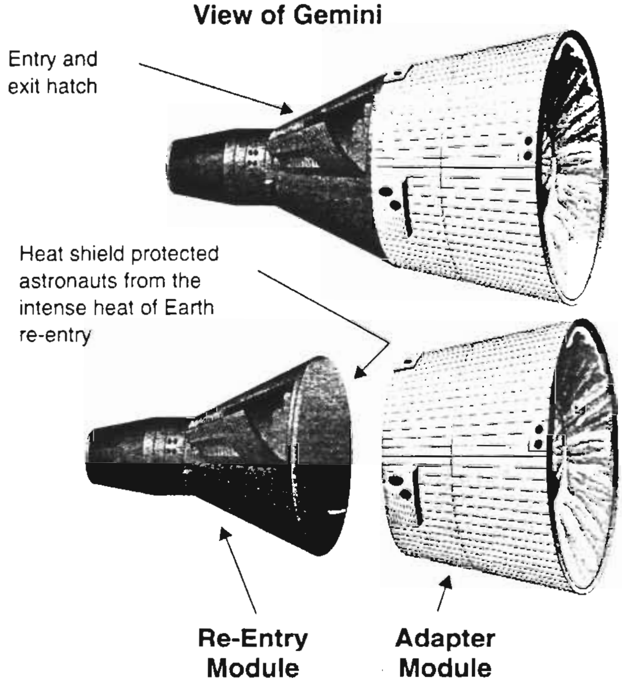
Titan 2 Launcher

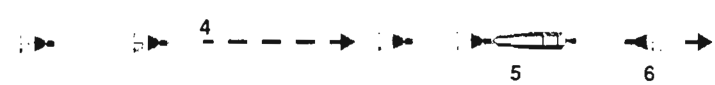
The Titan 2 was designed as an ICBM capable of dropping nine-megaton hydrogen bombs on the Soviet Union in the event of nuclear war. NASA modified it for use in launching Gemini astronauts.

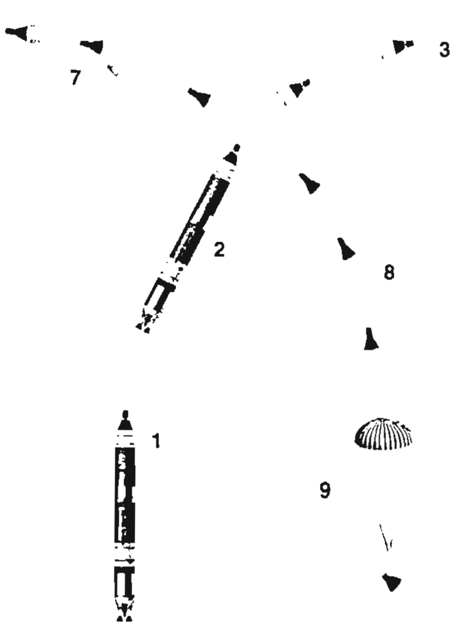
Gemini Spacecraft

Gemini was a two-section spacecraft. The astronauts sat in the front module, called the re-entry module. This section was the only part of the Gemini that returned to Earth. The rear section, named the adapter module, contained the propellant, water, oxygen tanks for the astronauts, and other supplies. It was jettisoned shortly before re-entry.

Fully Assembled View of Gemini







Typical Gemini Mission Profile

1 Lift off from Cape Canaveral in Florida.

2 Ascend to orbit on Titan 2 rocket.

3 Separate from Titan 2 and insertion into orbit

4 Rendezvous with Agena target vehicle.

5 Dock with Agena and practice spacewalks.

6 Turn vehicle blunt end first in preparation for re-entry

7 Jettison adapter module.

8 Re-enter through atmosphere.

9 Deploy parachute for safe splash-down in ocean.

The Apollo Program:

There were four goals of the Apollo program. They were: to establish the technology to meet national interests in space; to achieve preeminence in space for the U.S.; to carry out scientific exploration of the Moon; and to develop man's capability to work in the lunar environment.[30] The decision to begin Apollo was made with two program objectives. The first was to show the world the ability of the U. S. and its people. The second was to develop scientific, military, commercial and prestige related activities in space. The Moon landing was chosen because it was the only project far enough beyond Soviet capabilities that the U.S. could achieve a space first. At the time Kennedy announced the program the U.S. had only carried out one manned space flight. The approval of the program began Saturn rocket development.[31]

The Saturn rocket's evolution began with the Redstone which was a descendant of the German V-2. The Redstone was 70 ft in length and 5.8 ft in diameter. The first generation Saturn launch vehicle was a combination of eight Redstone boosters around a Jupiter fuel tank. Saturn I could generate a thrust of 205,000 lbs with a fuel combination of liquid oxygen (LOX) and RP-1 (refined kerosene). The second stage of the Saturn I, known as the Centaur, was developed with difficulty because the LOX and liquid hydrogen fuel mixture was extremely explosive. Although it was dangerous, the stage could produce an additional thrust of 90,000 lbs. In 1964 Saturn I was launched with the ability to orbit a cargo of 26,000 lbs. The next step in Saturn development was the Saturn IB. The first stage engines generated a thrust of 1.6 million lbs. The two-stage combination Saturn IB could place 62,000 lb payloads into Earth orbit.

The main problem with Saturn V development was the German and American scientists' and engineers' different philosophies toward development and testing. Werner Von Braun tested each component of each system individually. Each stage would then be launched separately before assembling the whole system for flight tests. This practice was thorough but was costly and time-consuming.[32]

The Saturn V including the Apollo spacecraft is 363 ft in length. It weighs 6.1 million lbs fully loaded. The vehicle has three stages: the S-IC, SII, and S-IVB. The first stage is 138 ft in length, 33 ft in diameter and weighs 300,000 lbs empty. Fully loaded it weighs 4,792,000 lbs. The first stage's five F-1 engines generate 7.5 million lbs of thrust and burn 203,00 gallons of RP-1 and 331,000 gallons of LOX in 2.5 minutes.

The second stage of the Saturn V is 81.5 ft in length, 33 ft in diameter and weighs 95,000 lbs empty. It weighs 1,037,000 lbs loaded. The second stage's five J-2 engines generate a total thrust of 1 million lbs and burn 262,000 gallons of liquid hydrogen and 83,000 gallons of LOX during a 6 minute flight.

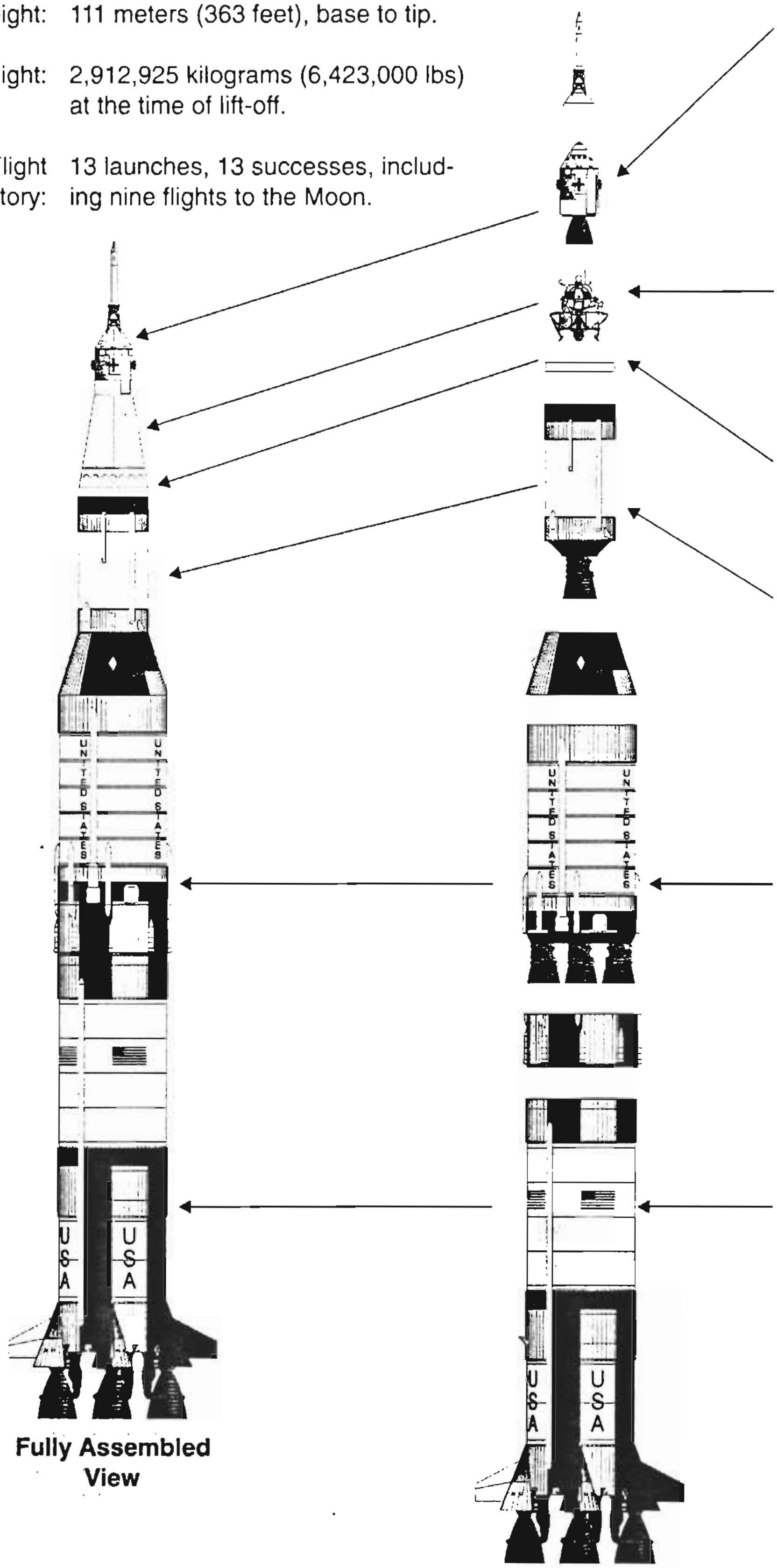
The third stage is 58.5 ft in length, 21.7 ft in diameter and weighs 34,000 lbs empty. It weighs 262,000 lbs loaded. The third stage's single J-2 engine generates 225,000 lbs of thrust and burns 63,000 gallons of liquid hydrogen and 20,000 gallons of LOX. The vehicle instrument unit is on top of the third stage. It is 3 ft in length, 21.7 ft in diameter and weighs 4,500 lbs. It contains the electronic gear that controls all Saturn V functions including engine ignition and cutoff and steering.[33]

▶ Figure 35: *Parts of the Saturn 5 Moon Rocket*

Height: 111 meters (363 feet), base to tip.

Weight: 2,912,925 kilograms (6,423,000 lbs) at the time of lift-off.

Flight History: 13 launches, 13 successes, including nine flights to the Moon.



Apollo Spacecraft

All three astronauts sat here for the trip to the Moon and back. The Apollo spacecraft stayed in lunar orbit while the lunar module landed.

Lunar Module

Two of the three astronauts used this spacecraft to go from lunar orbit to the surface of the Moon.

Instrument Unit

Contained electronics to guide the Saturn 5.

Third Stage

Stage three employed a single J-2 engine. It fired briefly after stage two jettison to place the rocket into low Earth orbit. Later, it fired again to propel the Apollo to the Moon.

Second Stage

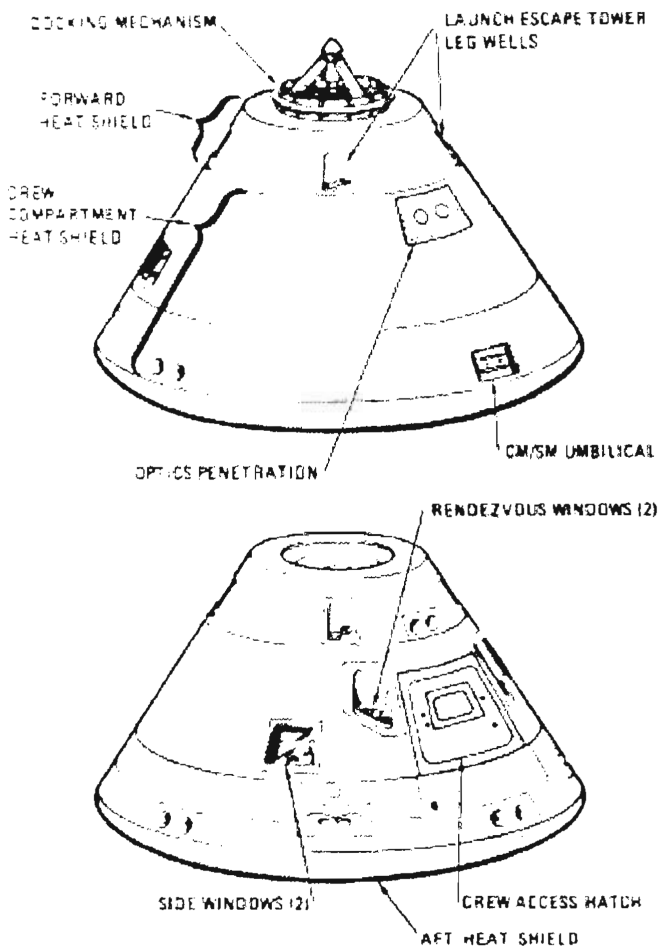
This stage used five J-2 engines and burned for about six minutes after the first stage was jettisoned. The job of stage two was to propel the rocket to an altitude of roughly 174 kilometers (108 miles), just short of low Earth orbit.

First Stage

Largest and most powerful stage on the Saturn 5 used five F-1 engines. It burned for about 2.5 minutes after lift-off and its propellant made up over half of the Saturn 5's lift-off weight. Stage one was dropped off at an altitude of roughly 61 kilometers (38 miles).

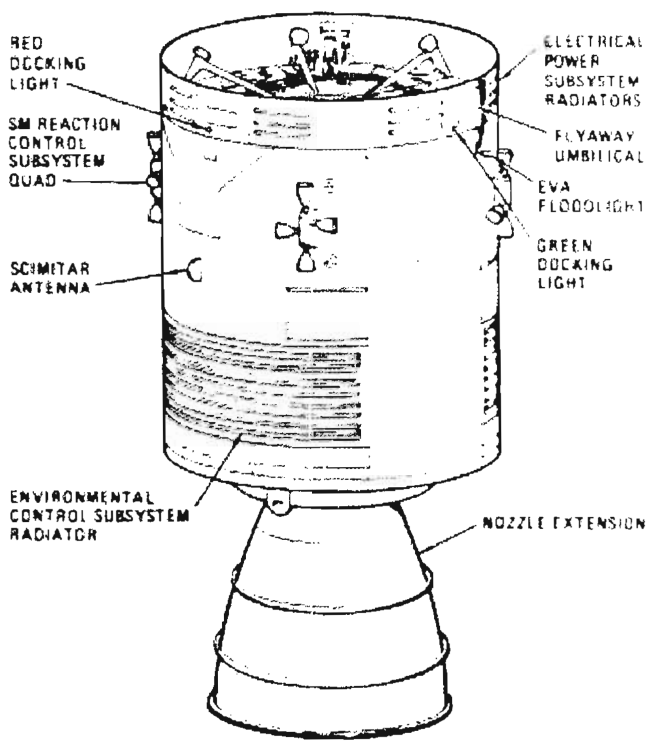
The Apollo spacecraft is the structure on the top of the Saturn V. It has a length of 82 ft, a weight of 109,608 lbs and has three parts, the command module, the service module, and the lunar module. The Apollo Command Service Module was developed for Earth and lunar orbit missions.[34] The spacecraft's control center is the command module. The teardrop-shaped CM has a different shape than the conical-nosed Gemini and Mercury. It provides living and working areas for the three-man crew. It is the only part of the spacecraft that returns to Earth from space. The CM is made up of two shells: an inner crew compartment and an outer heat shield. The inner shell consists of aluminum honeycomb between aluminum alloy sheets. A layer of insulation separates the two shells. The outer shell is made of stainless steel honeycomb between stainless steel sheets, and is covered with heat-dissipating material. This material chars and falls away during reentry. The CM is constructed to make it light but strong enough to withstand the acceleration of launch, the heat of reentry into Earth's atmosphere, the force of landing, and the impact of meteorites.

While in space, the CM's atmosphere is 100% oxygen, and the pressure is 5 psi. The cabin is air conditioned between 70-75 °F. The CM's controls enable the crew to direct it during flight. Television, telemetry and tracking equipment, and two-way radio provide communication with Earth and among the astronauts during Moon exploration and the Moon orbit rendezvous. Subsystems including reaction control, guidance and navigation, earth landing, environmental control and electrical power are located in the CM. Although crewmen can move from one station to another, much of their time is spent on their couches. The couches can be adjusted so the crew can stand or move around. Space by the center couch allows two men to stand at one time. The couches are made of steel framing and tubing and covered with fireproof fiberglass cloth. They rest on eight shock struts which absorb the impact of landing. Control devices are attached to the armrests.



Command module

The service module's function is to support the command module and its crew. The electrical power subsystem, reaction control engines, part of the environmental control subsystem, and the service propulsion subsystem are located in the SM. The service propulsion subsystem includes the main propulsion engine for insertion into orbit around the Moon, for return from the Moon, and for course corrections. The SM is constructed of aluminum alloy. Its outer skin is aluminum honeycomb between aluminum sheets. Propellants and various subsystems are located in six segments surrounding the main engine. The SM is attached to the CM until just before Earth entry.



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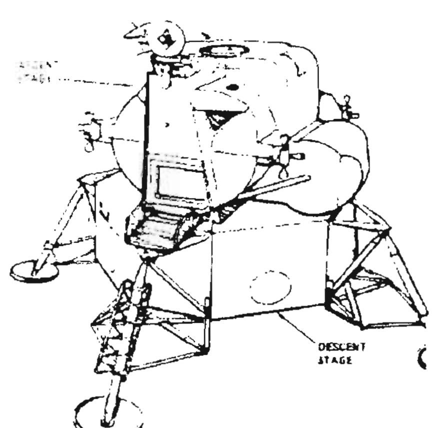
Service module

The Lunar Module carries two men from the CSM to the surface of the Moon, provides a base of operations on the Moon, and returns the astronauts to the orbiting CSM. It was the first spacecraft designed to fly only in a vacuum and has no aerodynamic qualities. The LM is divided into two components: the ascent stage and the descent stage. The ascent stage contains the crew compartment, the ascent engine and its propellant tanks, and all LM controls. The descent stage has a descent engine and propellant tanks, landing gear assembly, a section that contains scientific equipment, and extra oxygen, water, and helium tanks. It has the same kind of subsystems as the CM and SM, including propulsion, environmental control, communications, and guidance and control. Portable scientific equipment carried in the LM included an atmosphere analyzer, instruments to measure the moon's gravity, magnetic field and radiation, rock and soil analysis equipment, a seismograph, a soil temperature sensor, and cameras.[35]

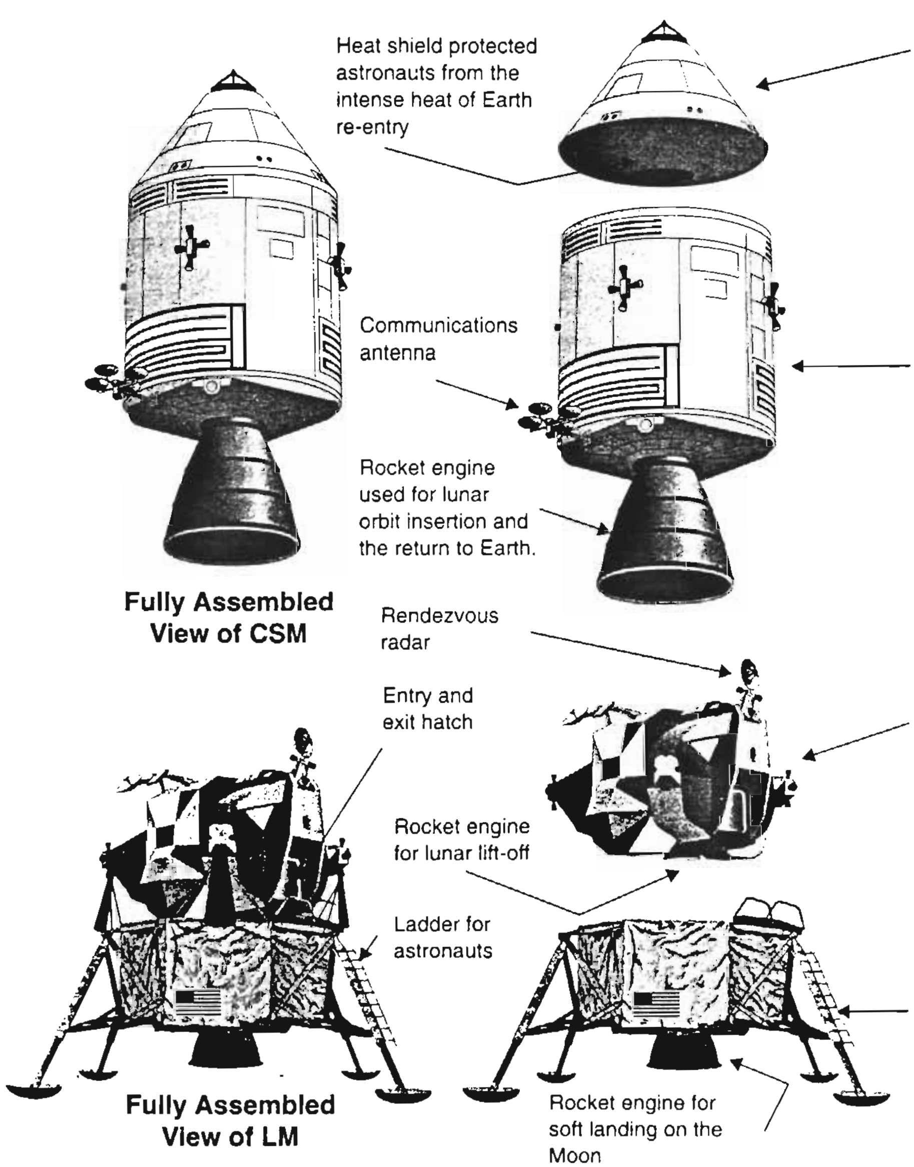


Lunar module

Figure 34: *Tools for Apollo*

Apollo Parts:	Command module (CM) and service module (SM), combined pair was called the CSM.
Dimensions of the CM:	3.23 meters (10.6 feet) high 3.90 meters (12.8 feet) width at base
Weight of the CM:	5,900 kilograms (13,007 lbs) fully loaded with propellant and crew.
Dimensions of the SM:	7.41 meters (24.3 feet) high 3.90 meters (12.8 feet) diameter
Weight of the SM:	24,500 kilograms (54,013 lbs) fully loaded with propellant and supplies.

Lunar Module Parts:	Ascent stage and descent stage, combined pair was called lunar module (LM).
Dimensions LM Overall:	6.98 meters (22.9 feet) high 9.45 meters (31.0 feet) width when measured diagonally
Weight of the LM:	16,440 kilograms (36,244 lbs) fully loaded for the *Apollo 17* mission. Mass varied with each mission depending on amount of supplies.
Who Made Them?	CSM - Rockwell International LM - Grumman



Command Module

All three Apollo astronauts sat in here for the ride from the Earth to the Moon and back. One of the three remained in the CM with the Apollo in lunar orbit while the other two explored the Moon. This module was the only part that returned to Earth.

Service Module

This module stored the propellant for the Apollo's rocket engine (SPS), housed oxygen tanks for the astronauts in the CM, and provided electricity to run the electronics and computers in the CM. The SM was jettisoned just hours before returning to Earth.

Ascent Stage

Two of the three Apollo astronauts sat in here during the descent from lunar orbit to the surface. It was also used to blast off from the Moon to rendezvous with the Apollo for the trip home.

Descent Stage

This stage contained the rocket engine that provided for a soft landing on the Moon, and served as the launch pad for the ascent stage for lunar lift-off.

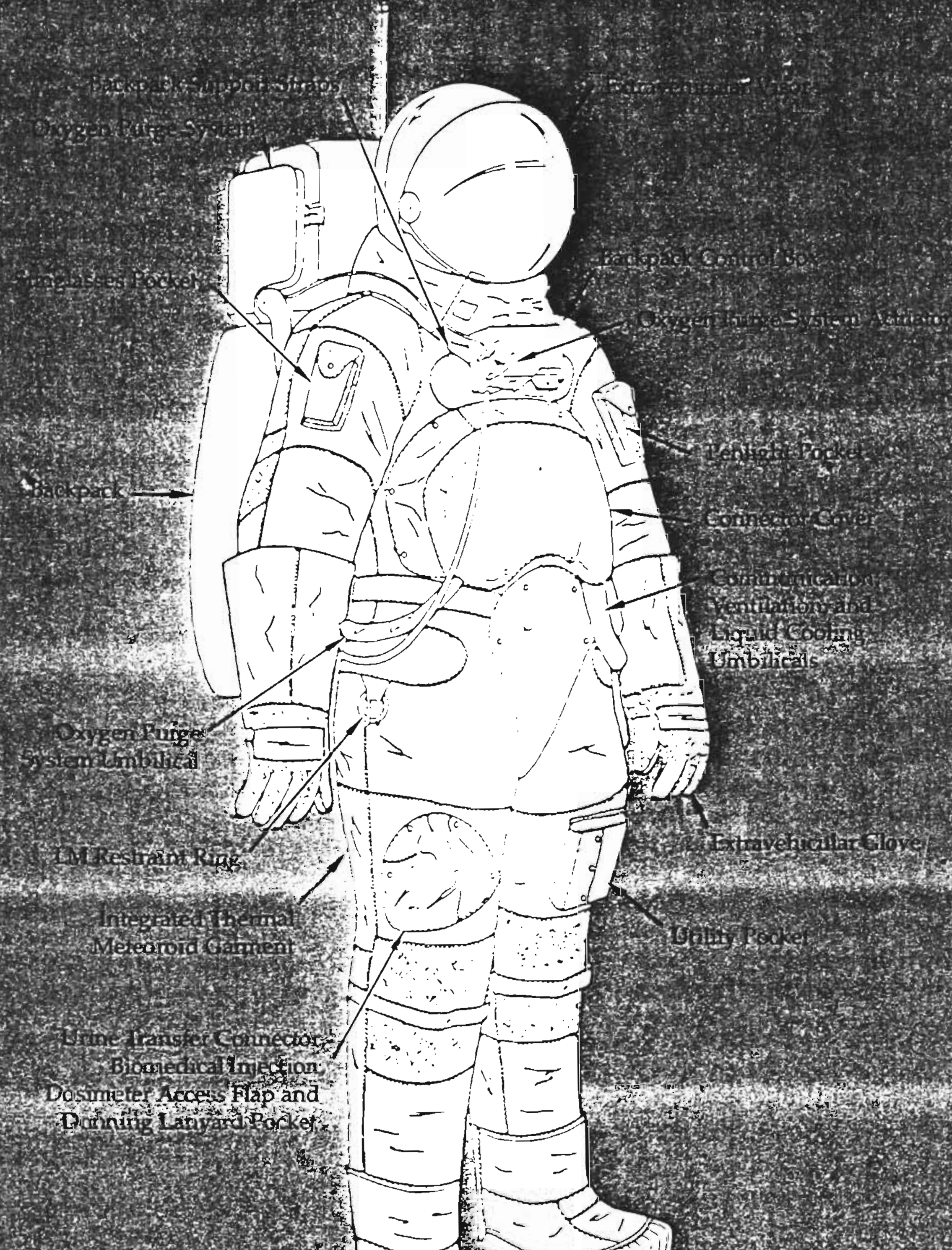
One of the most important aspects of astronaut safety is the equipment worn outside the spacecraft. Inside the spacecraft the atmosphere is controlled and special clothing is not needed. Above 63,000 ft, humans must wear spacesuits that supply oxygen for breathing and that maintain a pressure around the body to keep body fluids from boiling. The spacesuit provides protection from micrometeoroids and insulation from extreme temperatures. The side of the suit facing the Sun may reach 250 °F while the side exposed to darkness may get as cold as –250 °F.

The Mercury spacesuit consisted of an inner layer of Neoprene-coated nylon fabric and an outer layer of aluminized nylon. The suit was worn unpressurized and was used only as a backup for possible spacecraft cabin pressure loss. The Gemini spacesuit had a combination of a pressure bladder and a link-net restraint layer that made the whole suit flexible when pressurized. The gas-tight pressure bladder was made of Neoprene-coated nylon and covered by link-net of Dacron and Teflon cords. The net layer, which was smaller than the pressure bladder, reduced the stiffness of the suit when pressurized and served as a structural shell.

Apollo spacesuits had to protect against sharp rocks and extreme heat. The suits had to be flexible enough to allow astronauts to perform mission objectives. An outer protective layer on the Apollo spacesuit was used for protection against micrometeoroids that constantly hit the lunar surface. A portable backpack life support system provided oxygen for breathing, suit pressurization, and ventilation for moonwalks up to seven hours. Apollo spacesuit mobility was improved over earlier suits by molded rubber joints at the shoulders, elbows, hips and knees.

The first layer of the Apollo spacesuit was a liquid-cooling garment that contained a network of tubing sewn onto the fabric. Cool water, circulating through the tubing, transferred heat from the astronaut's body to the backpack to space. Worn over this was a layer of lightweight nylon, followed by a gas-tight pressure bladder of Neoprene-coated nylon, a nylon restraint layer to prevent the bladder from expanding, a lightweight thermal superinsulation of layers of Kapton and glass-fiber cloth, several layers of Mylar and spacer material, and protective outer layers of Teflon coated glass-fiber Beta cloth.

Apollo space helmets were made of high strength polycarbonate and were attached to the spacesuit by a pressure-sealing neckring. While on the Moon Apollo astronauts wore an outer visor over the helmet to protect against ultraviolet radiation. Lunar surface gloves were designed for adjusting sensitive instruments and consisted of structural restraint and pressure bladders molded from casts of the astronauts' hands. The gloves were covered with superinsulation for thermal and abrasion protection. Thumb and fingertips were molded of silicone rubber. Pressure-sealing disconnects, similar to the helmet-to-suit connection, attached the gloves to the spacesuit arms. The lunar boot, designed for exploring, was an overshoe that the astronaut put on over the integral pressure boot of the spacesuit. The outer layer of the lunar boot was made from metal-woven fabric, the sole was made of silicone rubber and the tongue was made from Teflon-coated glass-fiber cloth. The boot inner layers were made from Teflon-coated glass-fiber cloth covered with 25 layers of Kapton film and glass-fiber cloth.[36]


Backpack Support Straps
Extravehicular Visor
Sunglasses Pocket
Backpack Control Box
Oxygen Purge System Actuator
Penlight Pocket
Backpack
Connector Cover
Communication, Ventilation, and Liquid Cooling Umbilicals
Oxygen Purge System Umbilical
LM Restraint Ring
Extravehicular Glove
Integrated Thermal Meteoroid Garment
Utility Pocket
Urine Transfer Connector, Biomedical Injection, Dosimeter Access Flap and Donning Lanyard Pocket
Lunar Overshoe

Due to the program's deadline, personnel had to be increased to accomplish Apollo. From 1960 to 1966 NASA's employees increased from 10,000 to 36,000. NASA also realized that outside researchers and technicians were needed to complete Apollo. This was the only way to use the talent and institutional resources in existence. The increase in contractor employees working on Apollo grew tenfold from 36,500 in 1960 to 376,700 in 1965. Most personnel were from private industry, research institutions and universities. Between 80 and 90 percent of NASA's overall budget went for contracts to purchase goods and services from others. NASA also realized its physical capacity had to be increased to accomplish Apollo. The cost of this expansion was more than $2.2 billion.[37]

Numerous buildings needed to accomplish Apollo were constructed at Kennedy Space Center. The facility created to combine the Saturn V, the Instrument Unit, and the Apollo CSM and LM was the Vehicle Assembly Building(VAB). The VAB was 526 ft high and had four bays. As the three sections were put together they were placed on mobile launchers or Launch Umbilical Towers (LUT). The towers were 445 ft high and weighed 12 million lbs. To move the LUT a crawler-tractor was constructed. The crawler-tractor, weighing 6 million lbs, carried the LUV and the vehicle 3.5 miles to the launch pad at a maximum rate of 1 mph.[38] The crawler-tractor uses six diesel engines to turn generators that power 16 electric motors. These motors create the 6,000 hp needed to move the crawler. It's engines burn 150 gallons of fuel per hour. 825 to 1000 gallons of fuel are needed for the 3.5 mile trip from the VAB to the launchpad. It needs 500 gallons of water in its six radiators and on its largest radiator, a 75 hp motor is used to pump water through the cooling systems. It has six mufflers, the largest weighing 3,000 lbs and extending 9 ft in length. The total weight of the LUV, vehicle, and crawler-tractor was over 18 million lbs. The crawler-tractor's path was topped with 8 inches of river rock to relieve stresses caused by the crawler-tractor as it moved toward the launch pad. After the LUV and vehicle were placed on the pad, the crawler-tractor would bring a 402 ft high Mobile Service Structure weighing 11.6 million lbs to the launch pad for access around the launch vehicle.[39]

A few days before the launch, hundreds of thousands of liters of kerosene, liquid oxygen, and liquid hydrogen were pumped into the three stages of the Saturn. Apollo greatly increased the complexity of ground operations, both before launch and during the missions, when ground controllers had to track two spacecraft at the same time. Support forces after the launch totaled about 7,000. Included were aircraft for tracking, video, and voice relay, ships and aircraft in case of an aborted mission, a large number of medical support units, and recovery forces.[40]

When launch approaches, the astronauts enter the spacecraft and check their equipment. While the astronauts are in the command module, the launch control center crew directs launch operations. The last two minutes of the countdown are automatic. As the countdown ends, the first stages' five F-1 engines ignite and produce a thrust of 7.5 million lbs. The holddown arms release the vehicle while turbopumps force 15 tons of fuel per second into the engines. As the rocket's speed increases, 4.5 times the force of gravity is generated. The first stage burns 4,492,000 lbs of propellants in 2.5 minutes and is discarded at an altitude of 38 miles. The second stage's five J-2 engines then ignite. Velocity is now 5,330 mph and the escape tower is discarded. The five J-2 engines burn for 6 minutes, lifting the Apollo spacecraft to a 115 mile altitude and a 15,300 mph velocity. After burnout the second stage is cast off. The third stage's J-2 engine ignites and burns for 2.75 minutes. The spacecraft accelerates to an orbital velocity of 17,500 mph. Twelve minutes after liftoff the spacecraft enters a parking orbit around the Earth. The third stage engine is now shut down. As the spacecraft circles the earth, a complete check of the third stage and the spacecraft is made by the astronauts.

After the spacecraft has been examined in Earth orbit, the third stage J-2 is reignited. It burns for about five minutes until the spacecraft reaches an escape velocity of 25,000 mph. The command and service modules now separate from the third stage. The nose of the command service module docks with the lunar module and the rocket's third stage is jettisoned. After one day, Earth's gravity slows the spacecraft's speed to 6,500 mph and to 1,500 mph after two days. As the spacecraft approaches the Moon, the SM's engine ignites to place the spacecraft in an elliptical orbit around the Moon. A slow-down burn then places the spacecraft in a circular orbit about 60 miles above the Moon's surface. Two astronauts transfer to the LM from the CSM through the nose of the command module. The LM undocks and separates from the CSM. Its engine is ignited and the LM goes into a low trajectory to inspect the landing site. The CSM remains in orbit around the moon.

A large glass area in the LM allows the astronauts to view the landing site. The LM descends to within 100 ft of the lunar surface as its retrorocket fires and its legs extend. The LM can hover for almost a minute or move sideways for about 1,000 ft to choose the best landing site. After landing, the LM is examined. If no problems are found the astronauts begin exploration.

After surface exploration is completed the two astronauts ignite the LM's ascent stage, using the burned out descent stage as a launch pad. The descent stage remains on the Moon. The orbiting CM containing the third astronaut will be above the Moon's horizon when the LM's ascent stage is launched. Radar and visual contact are maintained between the two vehicles, and docking is made by manual crew control.

After docking, the two astronauts transfer back to the CM. The LM is jettisoned. After inspection of the spacecraft, the main engine of the CSM is ignited to perform a trans-earth trajectory. After the spacecraft attains the necessary velocity and performs a mid-course correction, the SM is jettisoned. The CM is turned around for reentry. It must return to Earth at an exact trajectory because the reentry corridor is only 40 miles in depth. If the approach is too shallow the Earth is missed completely and if the approach is to steep the spacecraft will burn up as it passes through the atmosphere.

The module enters the atmosphere at an angle traveling 25,000 mph. The heat encountered by the spacecraft is ten times higher than project Mercury re-entries. Atmospheric pressure and friction followed by a drag chute slow the module, and at 10,000 ft the main parachutes open. Radar and optical instruments track its descent, and recovery teams retrieve the three astronauts.[41]

Figure 36: *Apollo Mission Schematic Diagram (Leaving Earth)*

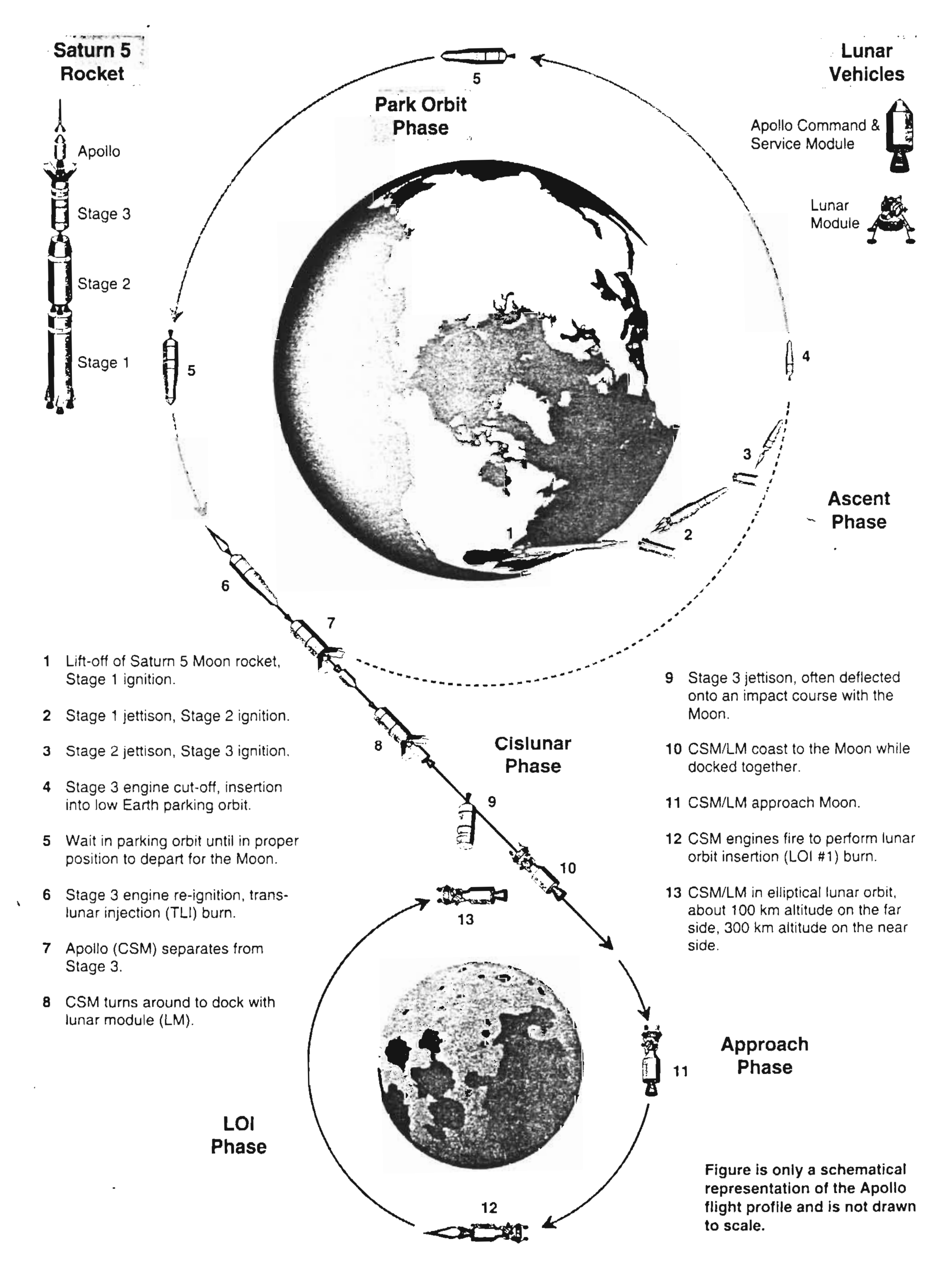
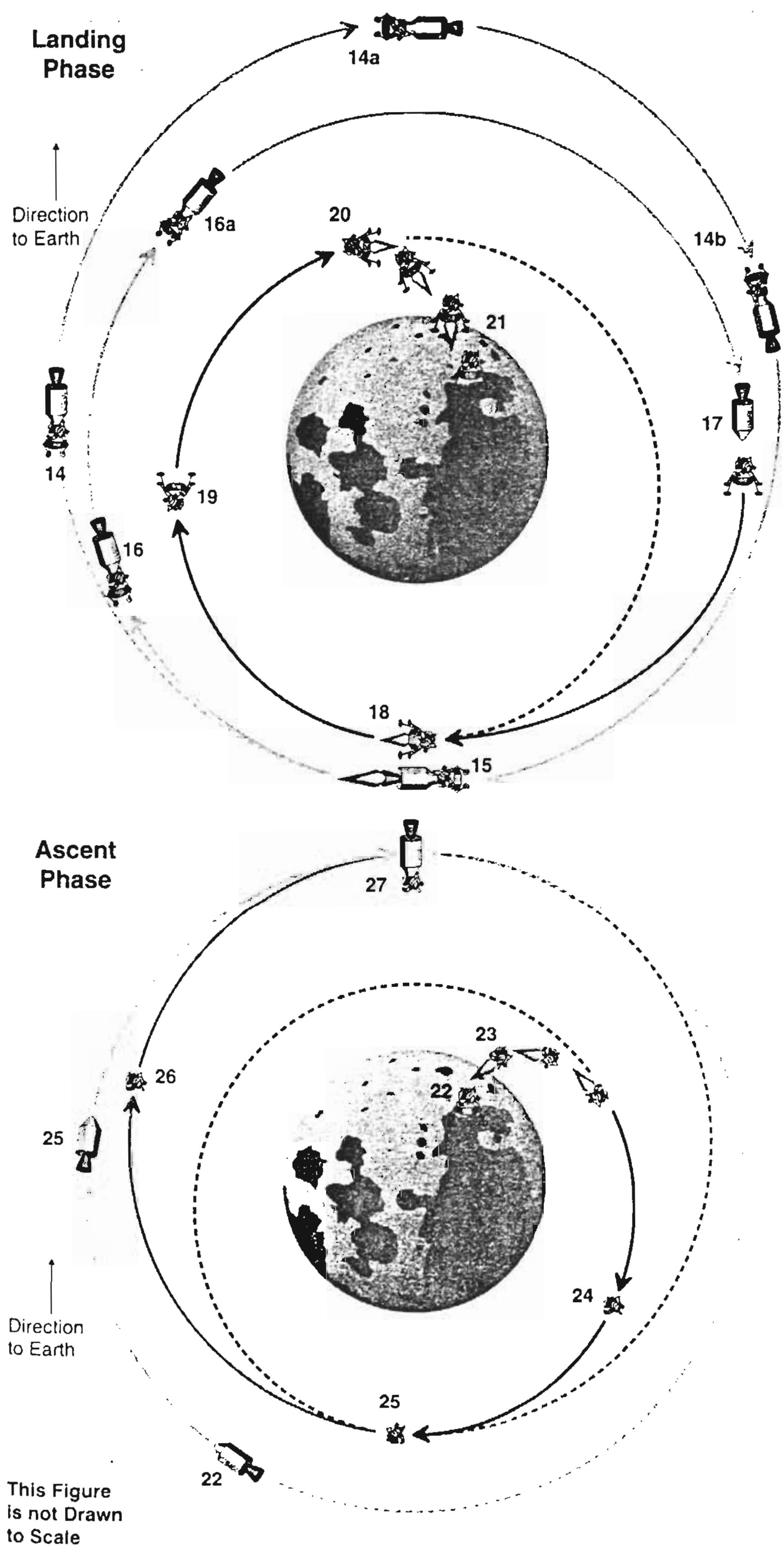


Figure 37: *Apollo Mission Schematic Diagram (Landing on the Moon)* ◀



14 Apollo (CSM) and Lunar Module (LM) orbit the Moon 100 km over the far side, 300 km over the near side after Lunar Orbit Insertion burn (LOI #1).

15 Slow-down burn (LOI #2) puts CSM/LM into a circular orbit at about 100 km in altitude.

16 Astronauts wait in 100-km orbit and prepare for landing. Two of them transfer to the LM from the CSM.

17 LM undocks and separates from the CSM.

18 Descent orbit insertion burn (DOI) slows LM down and puts in an elliptical orbit with a low point of about 14 km.

19 LM plunges toward the lunar surface on the DOI orbit.

20 Powered Descent Insertion (PDI) burn eliminates LM's forward velocity and takes it out of the DOI orbit.

21 LM uses its rocket to slow to a gentle landing.

22 One astronaut remains with the CSM in a 100 km-altitude orbit around the Moon while the other two explore on the surface.

23 After surface exploration is complete, the two astronauts on the Moon blast off in the ascent stage of the LM, using the descent stage as a launch pad.

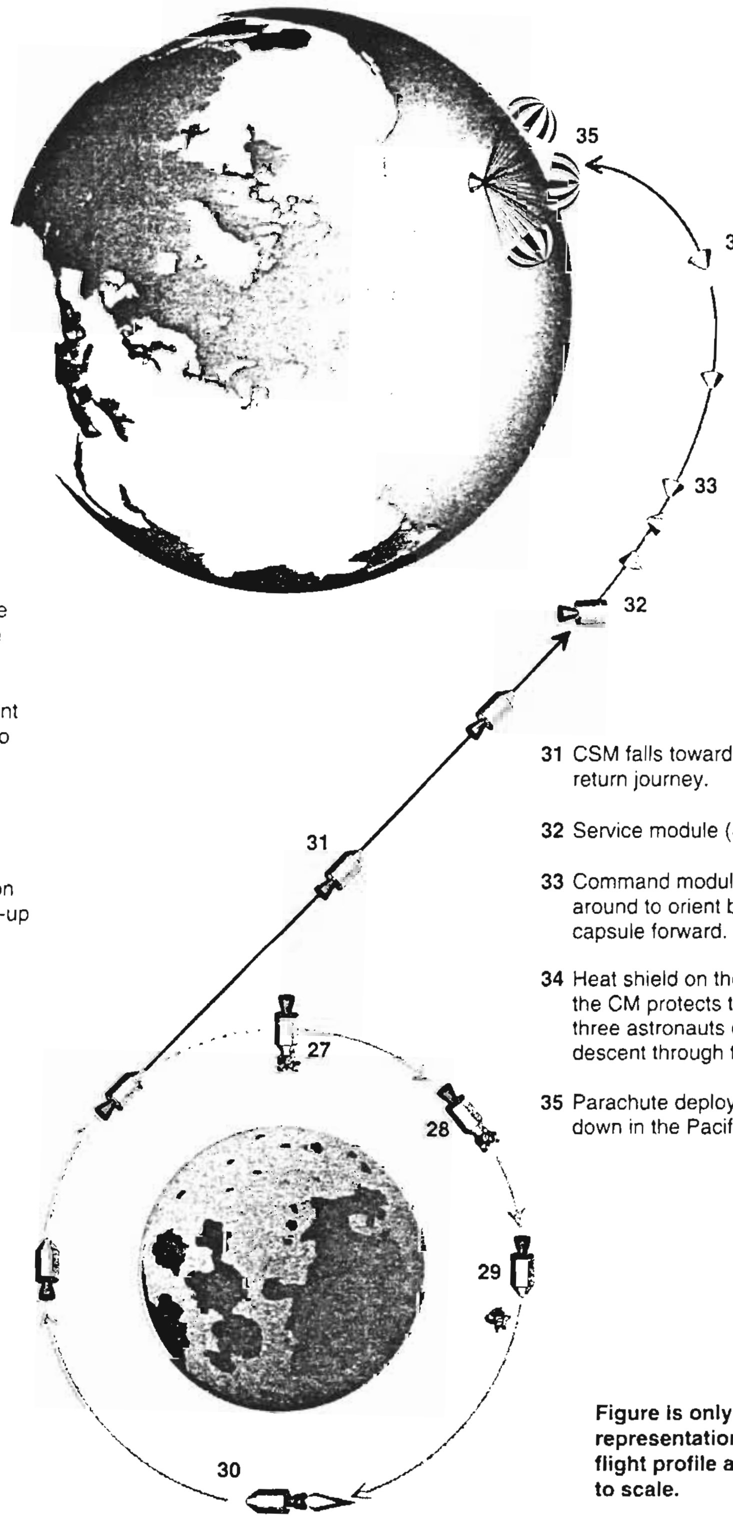
24 LM enters a low elliptical orbit with a 16-km low point on the near side, and 70-km high point on the far side. Since the LM is in a lower orbit than the CSM, it moves faster and begins to catch up.

25 At the right time, the LM uses tiny rockets to climb up to the CSM's altitude at 100 km.

26 LM approaches the CSM and performs final corrections to their rendezvous trajectory.

27 LM catches and docks with the CSM. The two astronauts in the LM transfer back to the CSM.

▶ Figure 38: *Apollo Mission Schematic Diagram (Returning Home)*



27 After lift-off from the Moon's surface, the ascent stage of the LM catches and docks with the Apollo spacecraft (CSM).

28 The two astronauts in the ascent stage of the LM transfer back to the CSM.

29 LM jettison

30 Main engine on CSM fires to perform the trans-Earth injection burn (TEI). This velocity speed-up allows the CSM to escape the Moon's gravity.

31 CSM falls toward the Earth on the return journey.

32 Service module (SM) jettison.

33 Command module (CM) turns around to orient blunt end of the capsule forward.

34 Heat shield on the blunt end of the CM protects the capsule and three astronauts during the descent through the atmosphere.

35 Parachute deploys for splash-down in the Pacific Ocean.

Figure is only a schematical representation of the Apollo flight profile and is not drawn to scale.

Unmanned missions included AS-201 through AS-204 which tested system operation, Control Module reentry, launch system and orbit operation, and Saturn booster capabilities with different payloads. Apollo 4 was the first launch of a Saturn V vehicle. Apollo 5 tested lunar module systems. Apollo 6 was the final unmanned test flight and verified the design and operation of the launch vehicle. The following is a list of the Apollo manned missions and their accomplishments:

Apollo 7: Saturn IB Oct. 11-12 1968
1st manned operation in lunar landing program. 1st live T.V. from manned spacecraft.

Apollo 8: Saturn V Dec. 21-27 1968
1st manned lunar orbital mission. Support facilities tested. Photos taken of Earth and the Moon.

Apollo 9: Saturn V Mar. 3-13 1969
1st manned flight of all lunar hardware in Earth orbit. Testing of human reactions to space and weightlessness. 1st manned flight of lunar module.

Apollo 10: Saturn V May 18-26 1969
Rehearsal for the moon landing. Simulation of 1st lunar landing module. 1st live color T.V. from space. Lunar module ascent stage jettisoned in orbit.

Apollo 11: Saturn V July 16-24 1969
1st manned lunar landing. The landing site was the Sea of Tranquillity. The American flag and a plaque was placed on the surface. 20 kg of material were gathered and returned to the earth.

Apollo 12: Saturn V Nov.14-24 1969
Retrieved parts of unmanned Surveyor 3. Gathered 34 kg of material. Deployed Apollo Lunar Surface Experiments Package (ALSEP)

Apollo 13: Saturn V April 11-17 1970
Aborted due to a rupture of the service module Oxygen tank.

Apollo 14: Saturn V Jan. 31 - Feb. 9 1971
ALSEP and other instruments deployed. 1st use of hand cart to gather material. 42 kg of material were collected.

Apollo 15: Saturn V Jul. 26 - Aug. 7 1971
ALSEP. 1st to use the Lunar Roving Vehicle (LRV). 169 lbs of material gathered.

Apollo 16: Saturn V Apr. 16-27 1972
Use of LRV. Ultraviolet camera and spectrograph are placed on the Moon. 95.8 kg of material are collected.

Apollo 17: Saturn V Dec.7-19 1972
1st scientist-astronaut to walk on the Moon. Longest Apollo mission. 110.4 kg of material collected. [42]

Critiques of the Apollo Program:

1. Cost

NASA initially estimated Project Apollo would cost \$20 billion, a figure equaling \$150 billion in 1992 dollars. In actuality Apollo cost \$25.4 billion. NASA funding represented 5.3% of the federal budget in 1965. In 1992, 5.3 % of the \$1.23 trillion federal budget would equal \$65 billion. NASA's actual budget was \$15 billion. Each year 50% of NASA's funds went directly for human space flight, and the majority of that went directly toward Apollo. Between 1959 and 1973 NASA spent \$23.6 billion on human space flight, excluding infrastructure and support, which cost \$20 billion. Due to Project Apollo's definition beyond landing humans on the Moon, projects such as the Ranger, Lunar Orbiter, and Surveyor probes were not funded under Apollo but were used to support the mission.

Reliability was emphasized heavily in the Apollo program. Apollo used redundant systems so that failures would be predictable and minor. This forced cost to increase much higher than if a more leisurely lunar program was followed.[43]

By no means can we afford costs similar to Apollo and therefore have no desire to run a similar "crash" program without regard to cost. Our budget will simply not allow senseless spending. We feel that a carefully planned future program will allow us to compensate for the present lack of available funds. Currently the annual budget for civil space activities including research and development, launch vehicle and satellite production, and launch site tests, is 1.45 billion Yuan (\$175 million U.S.) Actual launch and satellite control operations are financed separately.[44] As our economy increases in the future we will have the ability to increase the space budget.

It is very important therefore to keep plans beyond manned space flight confidential. Members of the U.S. Congress would not be startled if the European Space Agency or Japan announced lunar exploration plans because they are U.S. allies. Any evidence of our plans will certainly be met with American disapproval and a possible new space race. At present, Mars and the International Space Station hold the U.S.'s interests. The moon is being ignored, which is to our advantage. But if they sense a possible threat, no matter how small, they will react. The Japanese are also a concern. The PRC's first domestic space launch took place two months after Japan's first launch in 1970, and since then our paths have been similar. Like Japan, we average only a few missions a year and are capable of reaching both LEO and GEO. Although China has launched relatively few scientific satellites, we have extensive experience with recoverable spacecraft.

2. Safety

The U.S. government will not accept unnecessary casualties willingly. It fears the reaction of an American population intolerant of unnecessary risk. NASA can not afford the bad publicity and public anger of an avoidable event responsible for an astronaut's death. The 1967 Apollo 204 test flight accident exemplifies this. Three astronauts died in a fire during a ground test and it set the American program back almost two years, even though the exact cause of the accident was never found and blame was never assigned to its correct owners, NASA's high management. What factual results can be expected when NASA investigated itself? NASA was taking risks with a spacecraft atmosphere of 100% oxygen. With that atmosphere and the given pressure, the spacecraft was considered an oxygen bomb by most chemists. NASA also neglected the fact that on the ground, unlike in space, human strength from the inside of the spacecraft was not great enough to open the hatch in case of an emergency. Although loss of life is tolerable, to equal American accomplishments of zero astronaut casualties in space, safety must be taken under consideration.

As our space program becomes more visible to outsiders, mistakes will be increasingly difficult to cover-up. Events such as astronaut or civilian deaths can not always be kept secret, unlike in the Soviet Union program of the 1960's. Foreign satellite technology will not allow it. Beyond the amount of time that will be lost correcting our mistakes, worldwide perception of our space program and our technological ability will diminish. An example of this has already occurred to our commercial launch services. A small number of failed launches took both contracts and confidence away from our program. The U.S will criticize what it sees as an unsafe program and view our program as inferior even though Apollo was not as safe as their public relation agencies boasted. This form of hypocrisy is expected and further shows that the U.S. acts in accordance only with its own self-interest. We therefore can not fall into the same complacency and cockiness as the U.S. did if our program is to be viewed as superior to Apollo. It must be pointed out, if only to counter possible U.S. charges, that:

A. The Gemini program's success led to overconfidence and complacency which caused the Apollo 204 fire and two year delay of the space program.[45] NASA was very complacent about pure oxygen environments. Several fires had occurred in pure oxygen tests previously run by NASA and yet they chose to ignore them. The Russians decided early in their space program that pure oxygen environments were hazardous and were dissuaded by one electrical fire.[46] The U.S. Defense Department felt the same way about their manned space projects. The fires showed the inefficiency of the whole NASA organization which continually violated spacecraft safety recommendations.

B. Mission success and crew safety were treated as two separate problems. The rockets were designed first and men were forced to fit in them.[47] Numerous warnings were ignored by NASA management because greater concern was given to hardware than to basic principles of safe design.[48]

C. NASA repeatedly turned failures into successes in order to beat a challenging politically motivated ten year schedule as illustrated by the Apollo 6 test flight, in which NASA defined the Saturn V's performance as "unrated". In actuality it was an absolute failure. The Saturn V rocket had never been man rated before its initial use for the Apollo 8 flight.[49]

D. Poor workmanship and faulty inspection were common in the space program. It had occurred in Mercury and Gemini and carried over into Apollo. During the Mercury program loose wires, washers, wire cuttings, bolts, alligator clips, dust and other debris were left in Mercury spacecraft by workmen. Even the oxygen and water supplies were contaminated in one Mercury spacecraft.[50]

3. The effect on NASA from Administration politics and the adoption of dead-end goals.

NASA's budget for the last thirty years shows that not all Presidential administrations feel space is a worthwhile objective. Depending on the political motives of the current administration or the public's changing attitudes, NASA's budget continually lacks stability.[51] The U.S. political system can not institute long term plans because an administration is in power for a maximum of eight years. After this, a new administration, possibly with opposite goals or fiscal and defense philosophies can gain power. Government organizations are therefore unable to rely on continued support from a new administration. Americans' lack of a stable political culture is probably due to the short history of their nation which has existed only 214 years. Hence, it is unlikely that the U.S. is capable of matching us in a carefully planned long term space program with sustained effort over a century. In the fifty years since our revolution a steady stress on rocket capability has been maintained. In the fifty years since the U.S. gained access to German missile technology they have continually neglected it. The U.S. fell behind the Soviets, caught up, neglected missile technology again and then shifted to a space missile defense system and a space station. They constantly failed to refocus their efforts on a sustained program.

NASA's post Apollo manned space program was full of uncertainty. It was the perfect time to build on the achievements of Apollo. The booster capability and hardware already developed could be utilized, but manned exploration of the planets was so expensive at the time of Apollo that even the U.S. Congress found it difficult to fund. NASA was a bureaucratic giant created by Congress and industry and had nowhere to go. A proper foundation had not been constructed and NASA did not have a clear direction or goal.[52] While one faction wanted to continue to travel to the moon, another wanted to go on to Mars. However, conventional wisdom at the time was that without a space station, sustained access to the Moon was not feasible. Hence the shift to the space shuttle, which was designed to build a space station and possibly service it.

However, this was a seriously underfunded effort with little new research and development involved.

The Apollo decision was an exception in the national decision-making process. Apollo had not been conducted under normal political circumstances and the circumstances surrounding Apollo would never be repeated.[53]

4. Strict Deadlines and Schedules

The U.S. laid down a timetable demanding that all the pieces of the space program fall into place by a specific time.[54] Compressed time schedules prevented the orderly development of technology. This was shown in a speech made by George Lowe, NASA's director of Spacecraft and Flight Missions, in February 1963. He stated "A number of specific problems have arisen which we would welcome solutions ... However, many of the existing solutions may have to suffice. Our time scales may just be too short...to permit major design changes in Apollo."[55] Working around problems was a major change from the Gemini philosophy that a malfunction represented a problem which would probably recur at the worst possible time.[56] Facilities made for the Apollo program have little use now. Post Apollo missions were mainly done to use up excess hardware. Because the main goal was to beat the Soviets in a space race over a decade, a long range plan of NASA's goals concerning the moon after the surface landings was never made.[57]

We do not understand the American preoccupation with time and deadlines. Their obsession with deadlines almost destroyed the entire U.S. space program.[58] Their obsession with time created a space program that wandered aimlessly for thirty years.

Because we believe that time is fluid, schedules can be very loose. This allows us to put more emphasis on planning than is possible in a market economy such as the U.S.[59] We believe over the long term this course of action will put the U.S., with its use and discard mentality, to shame. The extremely long Chinese history gives us perspective. We realize we can outwait other systems and prevail, just as Chinese culture changed the Mongol invasion of our land into a brief period of occupation, since over a few generations the invaders ceased to be Mongol.[60]

5. Management of an extremely large project

Project Apollo had to meet difficult systems of engineering, technological, and organizational integration requirements because of short term goals. NASA's belief that its management system and technology would eliminate human error and undue hazard was a major problem.[61]

NASA had to acquire and organize an extremely high amount of resources to accomplish Apollo. NASA employed a program that centralized authority and emphasized systems engineering.[62] A program office with centralized authority over design, engineering, procurement, testing, construction, manufacturing, spare parts, logistics, training, and operations was created.

NASA had to combine different cultures and approaches into an organization moving along the same path. Each NASA installation, university, contractor, and research facility had different ideas on how to accomplish Apollo. Differences between the scientific and engineering communities within NASA were great. Representatives from industry, universities, and research facilities, who only wanted to further their own scientific and technical areas was also a major problem.

China is a society that rewards group efforts, rather than individual ones. Chinese consider boasting or self-promotion to be poor form and usually minimize their own accomplishments.[63] Self-recognition is purely narcissistic and common to NASA and the U.S.. Their cockiness is evident by their audacity to name the program Apollo - "he who was born ahead of his time, ancient god of light, prophecy and truth, protector of explorers and colonizers."[64]

Because of the magnitude of Apollo, and its time schedule, another important issue was that most work had to be done outside NASA. NASA scientists and engineers generally did not build much flight hardware or operate missions. They planned the program, prepared guidelines, took care of contracts, and oversaw work done elsewhere. If scientists or engineers did not have the same competence as the individuals doing the work, how could they oversee contractors actually creating the hardware and performing experiments necessary for the mission?[65] Various parties concerned never got together and discussed development issues. Each responsible person in NASA thought that someone else was handling the job.[66]

We acknowledge that the Chinese space organization is over-bureaucratized, but this is only for security purposes.[67] Our system is complex because of historical and cultural factors and is deliberately elaborated in its complexity to frustrate outsiders.[68] Still, offices and agencies are continually being combined for better efficiency.

6. Economic rewards from Apollo were small. U.S. scientific and research projects suffered due to Apollo.

Apollo could not be justified on its direct economic benefits. A 1968 National Academy of Sciences reported that "the NASA budget directly aimed at developing practical applications of space technology is now about $100 million per year or 2% of the total NASA budget." NASA had to perform manned space spectacles to justify Apollo and thought manned spectaculars were necessary to maintain support for any space program at all.[69] Further, President John F. Kennedy viewed Apollo as an alternative to a conflict with the Soviets over client states such as Cuba, Korea and Vietnam and related insurgencies in Africa and Latin America. Kennedy liked the idea that Apollo was difficult, big, dangerous and expensive. Apollo was a contest between two political and economic systems and Kennedy's response to the embarrassment of the Bay of Pigs fiasco and the Cuban missile crisis.

We will not perform a program for the sole purpose of creating a spectacle but the idea of space as a peaceful way to demonstrate technical prowess in areas that have military implications has considerable merit. Compared to war, losses in space are quite acceptably modest and are all volunteers. China has developed its space program to meet strategic, commercial and domestic goals. Commercial goals have priority now, in order to meet the domestic goal of stability.[70] However, it is time to consider the strategic questions raised by the Moon quest.

Apollo provided jobs for 300,000 people at the time but the technology did not enter the mainstream economy despite NASA claims to the U.S. Congress about valuable technology transfers of everything from paint to computers. Most of the money spent in the U.S. Apollo program was directed toward life support and boosters that have little relationship to marketplace needs.[71] NASA's managers were aware that the strains created by Apollo on the nation were becoming apparent in the 1960's. Many feared that NASA's rapid expansion was draining the nation's science and engineering talent, creating a technological imbalance in favor of aerospace rather than commercial trade goods. Every month the program became more of a government-sponsored industry and less of a scientific program. Apollo's scientific results were of interest to only a small fraction of the scientific community and did not completely answer the questions scientists had hoped the program would.[72] NASA also received the majority of America's research dollars for project Apollo. Apollo accounted for three-fifths of NASA's budget and NASA claimed about one third of the entire national research budget in 1963.[73]

U.S. Congress and administrative spending for science and technology has always been all or nothing. Either an expensive, extravagant program such as Apollo is approved and funded or funding is nonexistent. Concern for priorities and a sensible progression in research and development is rare in government-financed projects.[74] Technology is critical to our future development. We want to be seen as a technological leader. We often compromise ourselves to gain international assistance, signing treaties for this purpose alone. We do not mind receiving help from other nations, especially if it is free.[75] Because our space program links the technology base for both military and commercial applications our ability to contribute to many areas of the economy by investing in space is greater than that of the U.S.. Huge profits could be earned from offering launch services to wealthy, technologically challenged, Middle East nations.

This will enable us to improve our own satellite services, and with the income created, build our manned space program on a pay as you go basis to the point of having a permanent base on the Moon. There are some ways to get that to pay for itself too, but we should not be afraid to invest in the defense of the nation by symbolic and economic means. We must invest as the U.S. did to make a point, but we must do so in a steady way with a greater yield. At that point we can then examine how to make the space infrastructure self supporting.

Current and Future Goals of the Chinese Space Program

The past fifty years of our nation's history have been marked with political instability. Throughout this time though, government approval of the space program has remained constant. Our leaders may differ on other things, but all have realized that the space program earns both internal political support and world recognition. Continued approval of the space program shows the superiority of China's technological leadership. Our leaders recognize that supporting a space program will strengthen the nation, even if they personally do not recognize the benefits of space exploration. The space program advances both military and economic objectives and technological capabilities.

Our space program is currently favoring short term goals until funding is available for projects that do not support economic advancement. The funding for a manned space program must therefore come from commercial launches. Manned space flight will not be cancelled, only developed at a slower pace. We do not view this as a disadvantage, rather it is a means of consistently increasing efficiency and technological ability while keeping cost to a minimum.

Because cost is a major concern at the present time, a means of augmenting our technological ability is to increase involvement in international cooperation. This will allow us to gain a great deal of free technology. Our ability to offer technology in return is limited but we have something that capitalists find extremely attractive, an emerging market with one billion consumers. The prospect of entering our market is a useful tool in gaining a favorable advantage in technology exchange. If this is unsuccessful, U.S. political party donations have worked to get licenses for selected technology purchases in the past. At present, cooperation with the U.S. involves only small space science projects. U.S. concern over the transfer of technology has hindered our efforts to increase exchange and purchase programs with American companies. Aside from the U.S., considerable advancement has been made leading to cooperation with other space-faring nations. In 1997 an agreement with France was signed on space research and satellite construction. Also in 1997 an agreement was reached with the Ukraine on space cooperation, so we now have access to the Soviet creations of the 1960's and 1970's. We are also currently developing a remote sensing satellite with Brazil, which has convenient access to European and U.S. technical components that we do not.[76]

Russian technology is the most convenient method of quick modernization. An agreement on space cooperation was signed with Russia in April 1996 which we feel is extremely advantageous.[77] Our students have studied at the Moscow Aviation Institute for years. Our top astronaut candidates, military pilots Wu Tse and Li Tsinlung, trained at Russia's Yuri Gagarin Cosmonaut Training Center throughout 1996 and 1997.[78] They were accompanied by fifteen other Chinese Space Scientists who observed training and had access to training techniques. A better understanding of training techniques will increase our ability to train future astronauts.[79]

This is an ideal time to deal with Russia due to their economic problems. Russia will currently sell almost any technological system to generate currency. As our economy continues to grow we will be in a position to purchase a wide range of valuable information from Russia. The amount of help received is therefore directly proportional to what is financially possible for China. Current purchases from Russia include components of the Soyuz, which was used to travel back and forth to Mir, a navigation/docking system, a Soyuz life support system, and a Soyuz Pressure Suit. We do not need to copy the technology we acquire. We learn from it and then apply that knowledge to our program.[80] However, some systems are cheaper to buy than to develop. As a backup system, this is a proven, though crude, way to service a space station if we never gain access to the International Space Station.

The Russians may also assist us in launching a 20 ton spacecraft into orbit. The exact details of this are now being discussed. China may need to use Russia's tracking network for manned flight if the necessary communications are not in place by then. Russia also agreed to sell us an RD-120 rocket engine for a larger rocket that we plan. The new rocket would be able to put a 50 ton space vehicle into low earth orbit. However, this rocket is at least a decade away from launch.[81]

In addition to international cooperation, acquisition of present-day technology can be purchased through foreign companies. The U.S. is satisfied as long as they feel technology acquired by China is not used in any way detrimental to national security or U.S. interests. Luckily, certain tracking, communication and computing components that we are in search of are often found in non-military items. These components can later be used for military applications. The U.S. is also an easy target so long as monetary donations to political party fund-raising efforts from companies that sell technology are condoned. The parties are then unlikely to resist their supporters' opportunities to make money through overseas trade opportunities. Unfortunately, President Clinton's lack of moral aptitude has engulfed him in controversy and he has become more cautious. The media and Congress have are now exploring other potential misdoings, including our supposed dealings with U.S. companies. This does not present a problem. The American public has a very short memory and the President has a wonderful ability of getting into scandals and then successfully diverting attention away from them. We can only hope for a Presidential successor half as adept and equally amoral. Companies who had previously dealt with China will probably be allowed to operate with us again in the near future.

Before discussing possible methods of lunar landing we will describe our current manned program and give a brief overview of organizations that will be responsible for implementing manned flight and future plans of lunar colonization. Launch vehicles and satellite recovery are the two most important aspects of manned launch. The Long March launch vehicles have been developed in China since the mid-1960's. Many launch vehicles, each with different capabilities have been developed. This allows China to compete in domestic and international markets for missions using different orbits.[82] Top organizations responsible for launch services are China Great Wall Industry Corporation(CGWIC), China Academy of Launch Vehicle Technology(CALT), and China Satellite Launch and TT&C General.

CGWIC is a foreign trade company responsible for launch service marketing, commercial negotiation, contract execution and performance and legal administration. China Satellite Launch and TT&C (tracking, telemetry, and control) General is responsible for satellite launches and TT&C Services. CLTC runs three satellite launch centers, two research institutes, one satellite control center and a global TT&C network. CLTC organizes and executes satellite launch operations, TT&C and post-launch services. CALT is responsible for the development, production and testing of launch vehicles. The Long March launch vehicles are its major products. CALT has 13 research institutes and six factories. It can develop, design and test launch systems. It can undertake the complete production process from parts manufacturing to integrated assembly. CALT is primarily responsible for the launch vehicle technical issues, but it also is involved in contract negotiation and execution.[83]

There are three launch centers in China, each with a different purpose. Jiuquan Space Launch Center is the largest launch center in China and is used to launch medium and low orbit inclinations. Taiyuan Space Launch Center is used for polar orbits. Xichang Space Lunch Center launches geostationary spacecraft, including all satellites. A new launch complex capable of launching larger vehicles than those currently used has been built at Jiuquan. The new launchpad will be used for medium-heavy lift launch vehicles that will be using LOX/kerosene in their lower stages rather than N2O4/UDMH as well as the existing CZ-2E vehicle.[84]

Ballistic re-entry vehicle techniques were perfected with FSW satellites. The FSW satellites are domestic recoverable satellites that use the LM-2C and LM-2D as launch vehicles. China has successfully launched and recovered 14 satellites since 1975. The FSW satellites provide ideal test platforms for flight orbit altitude, flight duration, high vacuum, microgravity environment and reliability.[85] The FSW has a mass comparable to a small manned capsule, but the re-entry vehicle is too small to hold a human.[86] The latest model weighs three tons and can stay in orbit for 15 days. It has a life span similar to the Vostok and Mercury capsules. Dogs and mice have been successfully launched on suborbital flights in the 1960's. In 1990 a biosat carrying 60 plants and animals including rats and guinea pigs was launched and returned safely to Earth.[87] Top organizations responsible for satellites include Chinese Academy of Space Technology(CAST), Shanghai Bureau of Astronautics (SHBOA), and China Satellite Launch and Tracking Control General.

CAST develops scientific research satellites and application satellites. It has advanced technology for satellite recovery, multi-satellite launching with one launch vehicle and positioning of geosynchronous communications satellites. CAST's research institutes and factories can develop, design and produce application satellites, sounding rockets and related technical engineering projects. They can also supply technology and equipment to users in the fields of vacuum, low temperature, automatic control, remote sensing, radio and precision machinery. Test equipment and technical services are also offered for simulation tests. SHBOA is a research and production base. It supervises 10 research institutes and 12 factories. SHBOA develops and produces the first, second, and third stage structures of the LM-3 launch vehicle, and the inertia components and instruments for the guidance and stabilization system. SHBOA also developed the LM-4.[88] China Satellite Launch and Tracking Control General operates three launch sites and the control and tracking network. It provides commercial launch and tracking, telemetry, and control services and manages the TT &C network. This includes the command and control center, fixed and mobile stations, instrumentation ships, and reentry instrumentation airplanes.

After a year and a half, Yuanwang, China's space tracking ship fleet, completed its modernization. With more advanced equipment on board, the upgraded ships are now capable of global tracking and control. Its data transfer rate increased by 400 times. The fleet will be put into service this year for several satellite launches and the Project 921 spacecraft test launch. Three Yuanwang tracking ships will be deployed in the Pacific Ocean, the Indian Ocean and the Atlantic Ocean during the spacecraft's test launch.

Project 921:

China now has the technological ability to launch a man into space. Successful manned flight will bestow upon our nation international prestige and respect. China will join the U. S. and Russia as the only nations to have a successful manned launch.[89] World recognition as a technological power will further show China's strength and ability to advance after our past centuries of difficulty. China's technological history has had periods of advancement often followed by destruction.[90] As discussed previously, technology, our economy, and therefore our nation can only advance if stability exists.

Although prestige from manned spaceflight is competing with the more practical needs of communications and remote sensing, the government has long been interested in a manned program.[91] Our manned program, named Project 921, has been under development since 1992 and has been kept top secret. A manned flight with two astronauts was tentatively planned for 1999 to celebrate the 50th anniversary of the Chinese Communist State. Delays due to launch vehicle design and production problems have pushed back the manned flight schedule. We are optimistic that an unmanned test flight will occur late this year or early next year. This will allow for a manned flight by late 2000 or early 2001. We have purposely remained vague on manned flight testing and execution. Releasing a definite launch date will only tarnish our reputation if launch failure or postponement occurs.

The Project 921 launcher will be a LM-2EA, an improved version of the LM-2E and will be ready for launch in 2000. The LM-2EA has eight strap-on boosters compared to the LM-2E, which has only four. It will be capable of launching 16 tons to LEO compared with the CZ-2E's 9 tons. The launch will take place from Jiuquan and will be the first flight of a type CZ-2E from this site.

A spacecraft similar to the Russian Soyuz will be used. The spacecraft, named Red Mao(name assigned by me), will be a wingless ballistic reentry vehicle. It will weigh 8.4 tons and although modeled after the Soyuz, it will have many differences. Red Mao will have two pairs of solar panels for onboard power generation. Four people could fly inside, although initially we will begin with only two. Red Mao will be equipped with an androgynous docking system and an internal transfer tunnel. Two Red Maos can therefore be docked nose to nose and the crews can move between spacecraft. The Russian Soyuz had no transfer tunnel. Spacewalks were performed to transfer between spacecraft. Two docked Red Maos could form a small orbital laboratory for a short duration of time and be an initial step toward the establishment of our own space station, possibly by 2020.[92] We were in discussion with Russia on possibly funding the continued use of the Mir Space Station, but Chinese investors have backed out.

A shuttle is being planned, but it is not a reusable vehicle. It will be modeled after the Russian Salyut, and will leave part of the payload in orbit while the astronauts return to Earth in a capsule. Each flight that follows attaches other payloads. We can therefore claim a working space station. Plans for a station larger than Mir are not being developed. A large station is not necessary for future planet exploration if lunar bases are constructed. We feel that a small station will help us scientifically, to get experience in space as did the Russians; and prestige-wise it can't hurt. The U.S. never succeeded in orbiting a space station during the timeframe of Apollo. Plans for our own space station may be altered or discarded if we are allowed to join the International Space Station within the next ten years. The prospect of our own station may allow us to gain admittance in the International Space Station due to the perceived possible threat of our advancement in space. Cooperation on the ISS will allow us to attain the technology developed by others involved while designing the lunar habitats. At present, chance of acceptance of China in the ISS is not very good. The United States has consistently voiced disapproval of our inclusion. If it becomes necessary we will and can act independently from the rest of the world, although at a slower pace. Unlike the Europeans who need the help of Russia or the U.S. to put people into orbit, China can do everything itself.[93] Mir-sized space stations or smaller will be launched by the LM-3BA which will be available in 2002.[94] The LM-3BA with liquid strap on boosters could place about 25,000 pounds into low Earth orbit.[95] The LM-3BA will be launched from Jiuquan because the launchpad at Xichang is not able to handle such a large rocket.[96]

During construction of the space station, unmanned exploration of the Moon will begin by 2015. Lunar probes similar in purpose to 1960's Russian and American vehicles will be sent to conduct scientific studies and map possible landing sites for initial manned landings and future habitats. Unmanned exploration will also give us valuable experience in performing landings at preselected sites, both soft-landing vehicles and hard-landing vehicles.

Lunar Landing Method Comparisons:

During the history of our program we have never attempted a project whose only purpose was to create a spectacle. Programs have included remote sensing, photo reconnaissance, meteorology, communications and military operations as priorities.[97] As explained in the Apollo critique section of this report, it is obvious why the U.S. space program chose to proceed directly to the most difficult goal in the shortest amount of time possible. Apollo was viewed as the climax of the space program, not as the development of a long-term space capability.[98]

The Lunar Orbital Rendezvous Mode was selected by NASA in 1962 as the most achievable and least expensive method of reaching the moon before 1970. Lunar-orbit rendezvous cost $1.5 billion less than earth-orbit rendezvous and direct flight and would allow lunar landings six to eight months sooner. NASA studies of these methods showed that any possible technical problems could be overcome given time and money. Lunar Orbit Rendezvous, using a Saturn V booster, was found to be the most advantageous because it allowed for a separate craft to be designed for lunar landing. Earth-rendezvous had the lowest possibility of mission success and the greatest development complexity. Direct flight allowed greater mission capability but demanded development of launch vehicles larger than the Saturn V.[99] The choice of Lunar-orbit rendezvous as the mission mode, made mainly because of strict deadlines and schedules, produced two spacecraft perfectly adapted to their function but without the ability to evolve. The launch vehicles that carried men to the moon were too expensive for other missions.[100]

A decision on mode of flight must be made before spacecraft design begins. The mode will affect the spacecraft developed. It must incorporate the presupposed evolution of our technology. Methods that have been studied include:

1. Direct Flight:

Direct Flight is the simplest way to travel to the moon and return. Two different techniques are available. The spacecraft can first orbit the moon and then land or it can land directly in either in an upright position on deployable legs or horizontally using skids.[101] An extremely large booster would be used to launch the spacecraft, send it on a course directly to the Moon, land a large vehicle, and send part of it back to Earth. This makes it easier than any type of rendezvous, which requires finding and docking with a vehicle in space. The biggest problem of Direct Flight is the use of a large rocket which would be costly and difficult to develop. A launch vehicle comparable to NASA's 1960's proposed Nova booster would be needed. It could generate a thrust of 40 million lbs.[102] The direct ascent approach is technologically unfeasible for the near future. The huge cost and technological sophistication of the booster rule out this option.

2. Earth-Orbit Rendezvous:

Earth-Orbit Rendezvous is accomplished by launching various modules required for a moon trip into an orbit above the Earth. The modules would then rendezvous, be assembled into a single system, refueled, and sent to the Moon. This could be accomplished using a booster comparable to the Saturn V. An important aspect of this approach is the establishment of a space station in Earth orbit to serve as the rendezvous, assembly, and refueling point. A space station will therefore be crucial for long-term planning. It will serve as starting point for space exploration.

Positive aspects of this method include the use of smaller vehicles. It also supports the construction of a space station. Problems include launching up to 15 boosters right after each other to be able to rendezvous and dock in orbit.[103] Difficulties also include finding methods of maneuvering and rendezvousing in space, assembling components in a weightless environment, and safely refueling spacecraft.

3. Lunar-Orbit Rendezvous:

Lunar-Orbit Rendezvous launches the entire lunar spacecraft on one booster. The spacecraft would travel to the Moon, enter into orbit, and send a small lander to the surface.[104] When surface activities were concluded, the lander would ascend from the lunar surface and rendezvous with the command module, which remains in orbit about the moon. The lunar crew would then transfer to the command module for the return flight to the Earth.

Positive aspects include that reduces the total weight of the spacecraft and therefore eliminates the need for gigantic boosters.[105] It is the simplest method in terms of development and operational costs, but it is risky. Rendezvous will take place in lunar orbit instead of Earth orbit and there will be little room for error or the crew will not get home. Some of the hardest course corrections and maneuvers are done after the spacecraft has been committed to a circumlunar flight. Earth-orbit rendezvous keeps all the options for the mission open longer than the lunar-orbit rendezvous.[106] The critique of Apollo has shown this to be an option we do not favor.

4. Lunar-Surface-Rendezvous:

Lunar-Surface-Rendezvous is a link-up of vehicles on the moon. The Americans are now considering a similar plan for their mission to MARS, called Mars Direct. A number of unmanned payloads, including a vehicle designed to return to Earth and one or more tankers, would land on the lunar surface at a preselected site. Using automatic devices, the return vehicle could then be checked out by ground control before the crew left the earth. After the manned spacecraft arrives on the moon, the crew transfers to the fully fueled return vehicle for return flight.

A booster comparable to the Saturn II would be adequate, unmanned spacecraft could develop the techniques of vertical descent and soft landings, the launches could be spaced months or years apart, and a manned capsule will not have to be fully designed until very late in the program. Small payload capability of our boosters would restrict early missions to one-man flights but it is easy to extend the technique for larger missions, as larger rockets become available.

5. Rendezvous and Refueling in Space:

Positives include that rendezvous and refueling while traveling to the moon could improve the mission capability of fixed-size earth launch systems. Negatives include rendezvous on the way to the moon would save very little weight and fuel than earth-orbit rendezvous and would be far less reliable and far more hazardous.

6. One Way Flight:

This method would send a spacecraft on a one-way trip to the moon. The astronaut would be deliberately stranded on the lunar surface and resupplied by unmanned payloads until the space agency developed the capability to bring him back.

While the astronaut waited for a return trip to be developed, he could perform scientific work. Although this method would be the quickest method of attaining a manned lunar mission, it would most likely be viewed by other space powers as "desperate" and "inferior". The ridicule that would result would not serve our political purposes. There must be no further grounds for calling our technology second-rate.[107]

The final mode decision was narrowed down through careful analysis of two methods, Lunar- Orbit Rendezvous and Earth-Orbit Rendezvous, that we know would work, against the leading concept, as yet untried. After taking into effect all that has been previously discussed in this report, we conclude that Lunar-Surface Rendezvous, though untried, is superior, and will successfully accomplish all of our goals. Most importantly it is a method that will enable China to surpass the exaggerated technological wonder that was Apollo. Earth-orbit rendezvous, where construction of a space station is critical, has been judged less efficient than Lunar-Surface Rendezvous. due to our long term goals. One really does not need a space station as an assembly area if one has a base on the Moon. The Americans seem to have erred in having reached the Moon and then setting it aside to build a space station. We do not feel a large space station is necessary for lunar or future planet exploration. The ability to launch 15 boosters in rapid succession is also not attainable at present. Although Direct Flight is not possible at the moment, with our continued advance in launch vehicles, we will in the future have the engine thrust required to lift such a heavy payload. We have no doubt that in 60-100 years we will develop that capability and therefore must plan accordingly. Direct Flight may be available at the same time that medium-size lunar base construction is beginning. Designs can be incorporated to include runways or landing platforms that will be used for Direct Flight as it becomes available.

Lunar-Surface Rendezvous should begin by 2020-2030. Boosters will initially send unmanned payloads of a refueled return vehicle and a small temporary living station to the lunar surface. Previously executed unmanned exploration of the moon will allow China to gain experience in landing vehicles at pre-selected locations. As more crews travel to the lunar surface additional small habitats can be connected. The habitats will have wheels attached to them and will be able to be moved short distances. Lunar vehicles more durable than the American "rovers" will also be necessary at this point. Initial manned landings will be attempted for "scientific" reasons. During these programs studies will be conducted to locate the most favorable sites for construction of medium-sized lunar bases that will follow initial small habitats.

Moon colonization will begin in the most inconspicuous manner possible, and an announcement will only be made after initial construction has begun. Under existing U.N. guidelines military use of the Moon is forbidden. This is a topic that must be discussed in the future after manned exploration has been accomplished. Under the U.N. treaty our stations would have to be open to any nation, without exception. All that is required is an advanced notice of a visiting nation's arrival. We feel this is an invasion of our privacy and may reveal information that is crucial to national security. The decision to remain in the United Nations and therefore compliance to previously signed treaties will be based on world structure at that time. A notice one year in advance is required to withdraw from the U.N. However, we could set up a "visitor" and "stranded astronaut" habitat structure with basic lab equipment for visiting scientists who are not from allied nations to use. If that satisfies the U.N. we can remain a member in good standing at an acceptable cost.

Any program not completely devoted to scientific research will be criticized by other world powers. Our program has been viewed by the world as having military undertones throughout its history so this will be nothing new. If we are met with extreme criticism and possible sanctions it will be an acceptable cost. Decisions based on our economic and military power at that time will dictate our level of response. The U.S. will be especially harsh, although they have no right to criticize us. NASA will undoubtedly be trying to whip up hysteria to receive funding to match our effort. If so, providing access for a reasonable "rental" on facilities we build for their use might be worth doing, so as to reduce their independent presence and capability. They went to the Moon to visit and could undoubtedly do so again, so we don't want to provoke them, even though we have no intention of giving up the fruits of our labor to intruders.

NASA's farce as a civilian space agency has continued since its inception. Many chose to ignore the military undertones of the space program during Apollo since it was a "civilian" space agency. Well, the astronauts were not civilian for a long period of time. The defense strategy of stockpiling military ballistic missiles, both of which the United States and Soviet Union depend on, is the critical part of each nation's space program. A ballistic missile would send a payload five to eight hundred miles into space. The warhead would then face the same conditions of re-entry as the Mercury, Gemini, and Apollo flights. There is no question that ICBM designers used the data NASA gathered to good effect. Most peaceful launches serve various military roles. It has been the Department of Defense, and not NASA, that has long called the shots in

America's space program. Not only is NASA's open program defense oriented but there has always been, concealed from the public view, a Defense Department space program called SpaceCom that does surveillance tracking and "Star Wars" interception research. They can eliminate satellites at will and we must be able to do the same.[108] The Air Force helped fund the U.S. Space Shuttle and specified its dimensions. It suggested a considerably larger shuttle than NASA's original concepts. The current administrator Dan Goldin can not even publicly state his qualifications because of the work he has done for the military.

The International Space Station and Mars manned flights will not occur on the timeline dictated by NASA. The current world economy is in such a horrible state that a major acceleration in ISS construction is not possible. Russia recently announced that it may not even be able to finish and launch the next component (the life support module) because of budget difficulties. Current economic conditions in the United States will not last. The U.S. economy is booming and their space program is still not receiving budget increases but rather budget cuts. As their economy weakens in the next five to ten years, budgets will be cut and the space program will again be put behind schedule. Mars exploration or lunar colonization by the U.S. will only occur in a shortened time frame if the U.S. feels it is forced into another space race. NASA will try to create that impression. No other country is capable of competing with the U.S. other than ourselves or Japan. At present a threat comparable to the Soviet Union in the 1960's does not exist. There is no threat to democracy and therefore capitalism, as occurred during the space race. Indeed the opposite is true, democracy is spreading throughout the world. The only powerful Communist nation in existence is China, and we have no intention of openly forcing the U.S. into another space race. We want them to focus on a visit to Mars. We can not compete in a full scale race and therefore must keep any motives regarding the moon other than unmanned and scientific hidden until we can accomplish them. Hence a space station that looks crude and obsolete, to get space experience should be orbited as a decoy, a place to explain our early manned flights. It should be designed for long term use as a "life boat" facility, but not compete in any way with the ISS. The U.S. population would not support a crash program similar to Apollo if a threat is not perceived. The Americans will therefore stay on a path from the space station to Mars. We will seem to be lagging behind at a safe twenty year deficit in capability.

Our plan although unfathomable to a culture such as the U.S. would be implemented over a period of between fifty and one hundred years. This is a period that is half of the time the U.S. has actually been in existence and well beyond their planning horizon for institutional reasons. A constant effort on our part will enable us to pass the U.S. over time and will allow us to regain our rightful place as the Middle Kingdom. This century will become the 'Chinese Century', when our nation becomes the richest, most populous, and most powerful on Earth. With lunar colonization we will be effectively doubling our populated land area over the next millenium without recourse to war, but with the goal of greatly expanding our access to resources and our strategic position.

Conclusion:

Three questions relating to China's Space Program were posed in the introduction. Answering these questions were the first step in deciding if China's goal of manned lunar landing and colonization could possibly be undertaken in the near future. This was critical. Without addressing these questions this report would not adequately represent China's current space capabilities, the reasoning behind decisions relating to the space program and possible future space program goals. The questions were based on present-day technological abilities and cultural characteristics. A very brief overview of the answers to these questions are as follows:

1. **Does the Chinese space program have the ability to attempt such an undertaking at the present time?**

   The Chinese do not have the ability to attempt a moon landing at this time. Manned orbital flights are a distinct possibility in the near future.

2. **Does China have a desire to pursue manned space flight and travel to the Moon?**

   The Chinese have a great desire for manned flight for both technological and political reasons. At present more practical economic needs are the priority, but their eyes are probably on the Moon.

3. **How would China view the Apollo Program based on their ideals and how would they incorporate changes?**

   The critiques based on Chinese mindset have shown that many aspects of the Apollo program would be done completely different by China, due mainly to cultural and social structural differences. A superior lunar program to that of the U.S. could easily result.

Once these questions were answered the process of creating a possible plan for a Chinese lunar landing began. The validity of future directions chosen for China in this report is based on three areas and in a sense obstacles, that had to be studied in great detail. These three obstacles were the form China would assume as it evolves economically over the next half century, information on the Chinese space program and information on the Chinese space mindset and cultural world view which would shape the political point of view. Although the Chinese mindset was examined in the introduction and was the basis for Apollo critiques, it is of primary importance in creating a future plan that might closely resemble Chinese actions. A good understanding of these areas of political economy and culture are needed to accurately predict the general form that Chinese lunar plans would take.

1. China's Possible Future Form:

China's growing economy will force an evolution of the political system. Within the next fifty years, China is expected to have the largest economy in the world. With the largest economy, China's consumerism will naturally proliferate. Once Chinese acquire Western products and begin to adapt aspects of Western culture, as they are already doing, they will not want to regress politically as the Russians have in ending their Socialist system too abruptly. To write this report in a manner that will consider the political decisions of the future, the question "What political form will China assume as China's population becomes wealthier?" must be asked. I took as a model for this project a China that is based on medium growth. This situation represents an economy not in total economic collapse and an economy not booming out of control.

The ideal representation is a China that has steady continual growth. Political change will be a progression towards democracy in the context of strong nationalism. Democracy will not occur during the thirty to fifty year period of proposed space plans outlined in this report. It will most likely be a market-driven form of socialism for the near future, throwing off the command economy structure only when other banking and corporate structures have emerged to take over the strategic planning role in a more competitive economic system. For now, competition will be for world rather than domestic markets.

China's population, vastness and social diversity make it increasingly difficult to rule from Beijing. Central leaders must gain approval for new policies from party members, local and regional leaders, influential non-party members and the general population. Because there is no orderly process for the selection of new leaders in the Communist system, political selection takes place through party maneuvering. Key leaders try to place their own loyal allies in power positions while countering the maneuvers of rival leaders.[109] China is therefore a country where deals are made by Guan Xi. These invisible social networks are crucial if one is to avoid being tied up in the complicated bureaucratic structure. One must realize that level of position is not completely indicative of power in China. One has to go to the person who has the right relationships.[110] Government officials want to show their support for economic development. Economic gains through commercial space launches will allow technology to advance for the Chinese people in terms of tangible services such as phones and television. For government officials to maintain power they need to satisfy consumer demands and encourage foreign investment.[111] The space program is a means to do both while fostering traditional concerns with defense, trade and public image. These are things the Chinese population is willing to make sacrifices for given the social cost of having fallen behind the world militarily in the 19^{th} century and being preyed upon by colonial powers and their traders.

2. Chinese Space Program Information:

Most material regarding China's space program is considered to be related to national security and is kept top secret. Information that is released may or may not be the truth. China purposely uses misinformation as a tool to confuse outsiders as to their real intentions, but over time these have been convincing statements by highly placed people indicating an interest in manned space flight and the Moon as a goal.

The Chinese have never officially announced plans for moon colonization. In fact, anything beyond developing a manned flight capability is not officially discussed. Small pieces of information leak out on occasion, and one must filter through this information to deduce the validity of possible projects. I feel the information relating to the Project 921 spacecraft, launch vehicle, and schedule is accurate and choose to read the shape of the technology as much as the public statements. Technology is an aspect of culture created by a social organization. From what people do one can examine the artifacts and estimate the nature of the organization behind it. Archaeologists do this all the time when trying to reconstruct ancient civilization. Purchases made from Russia are also based on published material from both China and Russia. Speculation on my part regarding program direction begins after Project 921 and successful manned flight. Post manned flight plans are based on my research on the current manned program and the mindset of the Chinese government and space program. The critiques of Apollo through the Chinese mindset were the basis for projected lunar exploration and colonization.

I feel that the mode chosen for manned flight in this report is a mode the Chinese would consider. Based on the Chinese decision making process and psyche I feel confident of the mode decision as fitting in with the other aspects of this report. Information regarding actual construction of a Chinese space station and spacecraft to reach it are less clear and are to a great extent dependent on future space program proceedings. The inclusion of the Chinese in the International Space Station would have a great effect on Chinese decisions, although at present evidence suggests ISS inclusion will not occur. Spare docking ports could provide attachment points for Chinese modules. However, the likelihood the Chinese being involved in ISS is small because of China's current space capability and the complicated political relationship between U.S. and China. Hence, Chinese planners will not be counting on access to this facility and will have a "go it alone" backup plan.

3. Chinese Point of View:

The accuracy of this report is most influenced by my interpretation of the Chinese mindset. If I was correct on this part of the mindset then the critique of the Apollo program and a future plan based on what Chinese view as important have some merit, though they are speculative. The Chinese cultural mentality and space mindset were the most difficult and yet necessary part of this study and hence the resulting report. Material on Chinese space mindset is scarce. Through books and interviews the

Chinese culture and worldview were examined as it effects technology and the political economy and culture was formed. Once I thought I had the general outlook correct I took the next step of applying it to the space program's driving mindset. A prior WPI student, Neil Scannell, did some of the groundwork on this subject on the degree to which the mindset of NASA and the MOA were comparable. His paper really did not get past policy pronouncement and organizational structure and into culture, but he did feel there was an interest in a long-term Chinese program with regards to the Moon. On that foundation I have built a speculative edifice. To the best of my knowledge and that of Neil's, these are grounded speculations that may prove to be predictive of the future course of the Chinese space program. I have formed a possible outcome. The Chinese could do this. Whether they will continue on this course as the need to prove themselves as a world power diminishes remains to be seen. I think they will announce their arrival as a world power dramatically but peacefully, demonstrating technological prowess in strategic areas through space spectaculars. Further, I expect them to take the longer, slower course necessary to stay on the Moon once they arrive. A permanent colony will be established by a sustained step by step effort.

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