APOLLO PROJECT STATUS

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ABSTRACT

Apollo is the project of the U. S. manned space flight effort whose objective is to land men on the moon and return them safely to Earth. It differs from Project Mercury in sophistication of maneuver and spacecraft design, since Apollo is composed of several modules and will have the capability of landing on the lunar surface. The spacecraft is the responsibility of the NASA Manned Spacecraft Center in Houston; the launch vehicle, of Marshall Space Flight Center; and ground operational support, of several Centers and other agencies. The spacecraft proper consists of a command module, service module, launch escape system, adapter (all being developed under contract by North American Aviation), and a landing stage, which will be either a lunar excursion module or a staged landing system for the command module. The command module houses the astronauts and all controls and instrumentation. The service module provides propulsion and secondary power support for midcourse, retro, and return maneuvers and for daily operations.

Almost all major modules are under contract. Those that still need to be started are not the pacing items.

INTRODUCTION

The Apollo program has as its objective the landing of the United States astronauts on the lunar surface at the earliest possible time, limited exploration in the landing area, and return of the crew with scientific data to the Earth.

It should be noted here that Apollo is only one of the space systems involved in the U. S. national space effort which will

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lead to further manned explorations of our universe. Mercury was the first in this program. It is interesting to compare the capabilities of Mercury and Apollo, as shown in Table 1. Of particular interest is the degree of sophistication in maneuvering and in spacecraft environment. The Apollo system will be capable of the large midcourse corrections required for cislunar portions of the trajectories. In the vicinity of the moon, the Apollo system is also capable of placing an astronaut on a landing site on the moon.

The present discussion is concerned with only one portion of the Apollo system. Table 2 shows the major elements of the Apollo system, the management of which is directed by D. Brainerd Holmes through the Office of Manned Space Flight. The Apollo system has three major elements: the spacecraft, the launch vehicle, and the ground operational support system. The Office of Manned Space Flight has delegated responsibility for the spacecraft to the Manned Spacecraft Center, Houston, Texas. Responsibility for the C-5 launch vehicle has been delegated to the Marshall Space Flight Center at Huntsville, Ala.; the responsibility for the ground operational support system is distributed among the Launch Operations Center at Cape Canaveral, Fla.; the Goddard Space Flight Center, Greenbelt, Md.; the Jet Propulsion Laboratory, Pasadena, Calif.; and the Manned Spacecraft Center at Houston. An important portion of the ground operational support system is supplied by the Department of Defense, particularly recovery support.

DISCUSSION

This paper covers only one element of the system: the spacecraft, which is shown in the launch configuration in Fig. 1. The portion of the total spacecraft which includes the launch escape system, the command module, the service module, and the adapter has been contracted to the North American Aviation Inc., Downey, Calif. A contract for the landing stage has not yet been issued; and, in fact, at this point, a decision has not yet been reached as to whether descent to the lunar surface will be accomplished by braking from lunar orbit and providing a soft touchdown for the entire spacecraft or whether descent to the surface of the moon will be made through the use of a lunar excursion module which will permit the astronauts to leave the command and service module in lunar orbit. Figs. 1 and 2 show a comparison of the two spacecraft required for descending to the surface of the moon by either method.

SPACECRAFT ELEMENTS DESCRIPTION

At this point the hardware now currently under development by North American Aviation Inc. will be discussed. Fig. 3 shows that portion of the spacecraft for which NASA has contracted with North American. The launch escape systems provide a means for lifting the command module away from the booster in the event of a booster failure, either on the pad or during the boost phase (through separation of the S-1 stage). The command module is the primary command stage for the astronauts and provides all the controls, instrumentation, and navigation equipment. The service module includes the energy source and rocket motor for making midcourse corrections, retromaneuver into lunar orbit, and for acceleration back into the return or trans-Earth trajectory. The service module also contains the fuel cell power source as well as the hydrogen/oxygen storage for this power source.

Fig. 4 shows a schematic of the command module which gives the crew stations during the flight to the moon and return. There is a couch position for flight control in which the astronaut has before him displays which indicate his position in space. Another couch position for sleeping is achieved by moving the center of the three couches to an extended position. The command module is also fitted with an extended air lock which permits egress of the crew without depressurizing the cabin.

Fig. 5 shows a more detailed view of the command module, particularly the structure which is double walled, the outside of which is fitted with ablation material to provide a heat shield for re-entry. During the terminal phases of the return flight from the moon, the service module is jettisoned, and only the command module returns to the surface of the Earth. The command module is so designed that the center of gravity is offset from the axis of symmetry so that the spacecraft is balanced in a condition in which there is a lateral force vector. This force vector can be used for lifting re-entry or for controlling the lateral dispersion during the re-entry by operating the reaction control system to rotate the command module so that this force vector lies in the required direction. Ballistic re-entries can be made by spinning the command module which then enters along a helical path.

Navigation of the spacecraft is done through optical fixes obtained through instruments as shown in Fig. 6. The spacecraft contains both a sextant and a scanning telescope. The information obtained by these optical devices flows into a computer which makes a comparison of the true position in space with that which the spacecraft should have to be on a correct trajectory. If the trajectory is shown to be in error, the spacecraft is positioned to make a velocity correction with the service module propulsion system. It is necessary, if such a correction is required, to orient the spacecraft appropriately. The orientation is read from the computer, and corrections in orientation are made with the reaction control system on the service module. This control system uses an Earth-storable hypergolic fuel and is actuated by a logic sequence which is a part of the stabilization and control system. The service module engine which makes the midcourse corrections is shown schematically in Fig. 7. This engine also uses Earth-storable hypergolic fuels and utilizes a single, gimballed, ablative nozzle.

The major piece of hardware yet to be contracted for will either be the lunar excursion module, shown as an artist's conception in Fig. 8, or the lunar braking module shown in Fig. 9. In the former case, that of lunar orbit rendezvous, a direct descent is made with a single C-5, and injection into the translunar flight is made with the S-IVB stage. With the spacecraft as shown in Fig. 9, the spacecraft and injection station are assembled in Earth orbit by rendezvousing two C-5 payloads. A detailed study of these two methods is currently underway under the direction of the Office of Manned Space Flight. Work is being pursued both at the Marshall Space Flight Center and at the Manned Spacecraft Center. Recommendations and results of analyses have been submitted relative to these two modes.

PARTICIPATING ORGANIZATIONS

One final point of interest concerns the distribution of the prime effort centers for the Apollo Spacecraft Project as currently contracted. The principal contractor for the Apollo Spacecraft is North American Aviation Inc., Downey, Calif., at which site there is a Resident Apollo Spacecraft Project Office. A suborbital booster is under development by General Dynamics/Convair, San Diego, Calif., for the qualification test program. These tests will be performed at White Sands Missile Range, N. Mex., where there is a Resident Apollo Spacecraft Project Office. The focal point of spacecraft direction is at the Apollo Spacecraft Project Office at the Manned Spacecraft Center, Houston, Texas. There is, of course, a strong interface with the booster which is carried on at the Marshall Space Flight Center. The Project Office also works very closely with the Launch Operations Center at the Atlantic Missile Range, Cape Canaveral, Fla., as well as with the Preflight Operations Division, Manned Spacecraft Center, at the Atlantic Missile Range. There is a Resident Apollo Spacecraft Project Office representing the Apollo Manager at the Launch Operations Center and Preflight Operations Division. The navigation and guidance system is under technical development by the Instrumentation Laboratory of Massachusetts Institute of Technology, Cambridge, Mass., and is supported by three major contractors: Standard Killsman for the optics, Raytheon for the computers, and A. C. Spark Plug for the measurement unit, assembly, and test. Another major contractor is expected for the lunar excursion module or the lunar braking stage in the not too distant future. In addition to these prime effort centers, there is a great deal of effort going on throughout the country through subcontractors to North American Aviation Inc., who also supply critical subsystems to be assembled by North American at the Downey facility.

Table 1 Capabilities of Mercury and Apollo

Capability	Mercury	Apollo
Crew	Single	Multi-man
Mission duration	4-1/2 hr	2 wk
Re-entry velocity, ft/sec	26,000	36,000
Maneuvers	Attitude only	Attitude Midcourse Lunar
Landing	Earth only	Earth & moon
Spacecraft environment	Pressure suit	Shirtsleeve

Table 2 Major Program Elements

Spacecraft	
	Launch Escape System
	Command Module
	Service Module
	Lunar Landing Module
C-5 Launch Vehicle	
	S-IB
	S-II
	S-IVB
Ground Operation Support System	
	Launch Control Center
	Mission Control Center
	Tracking Network
	Recovery Support

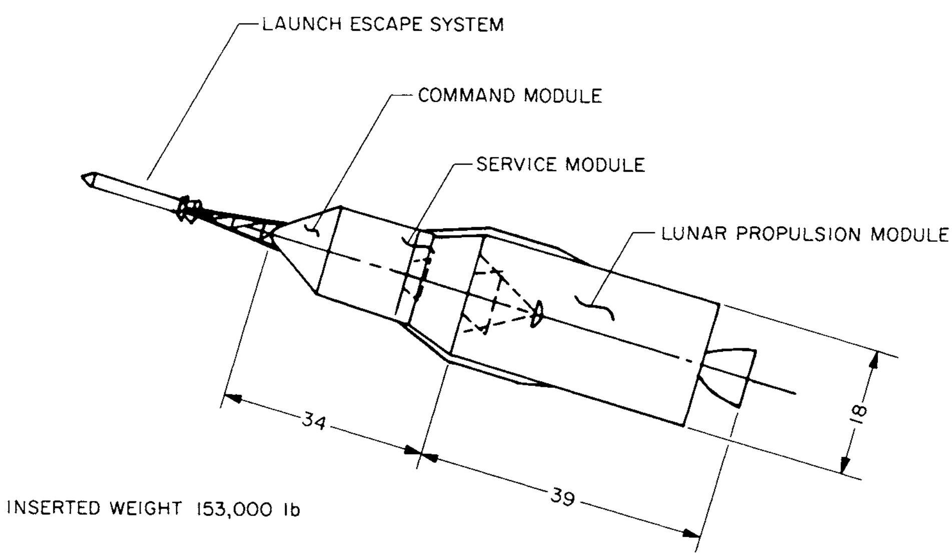


Fig. 1 Apollo spacecraft configuration

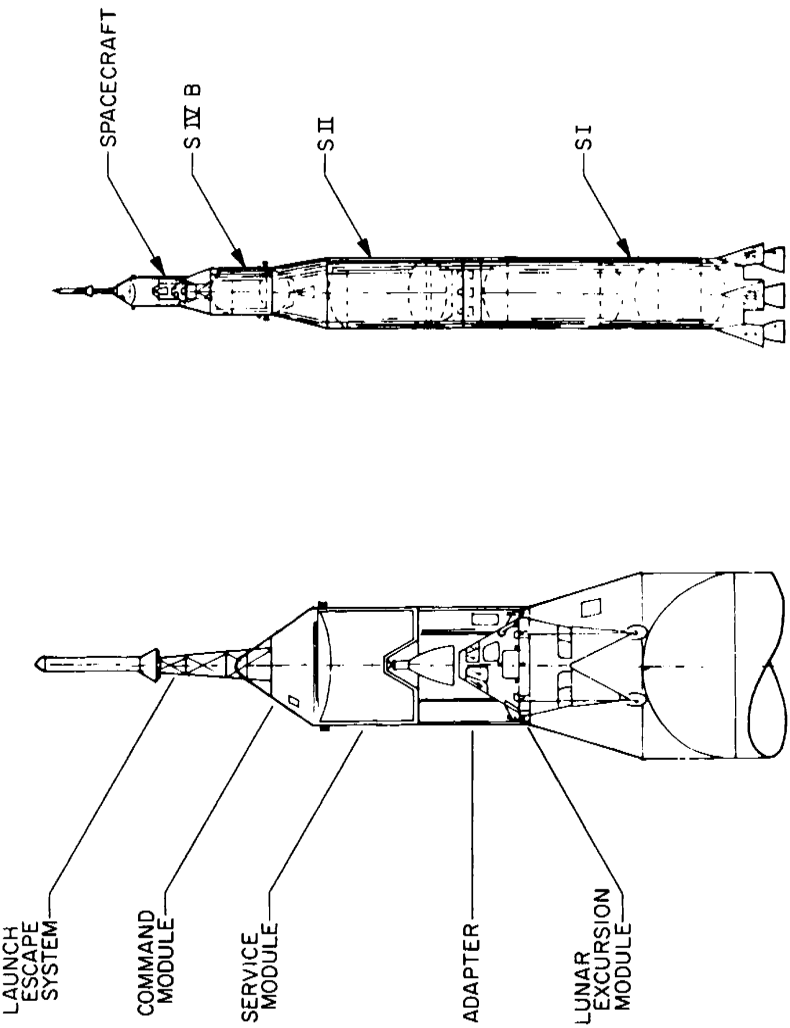


Fig. 2 Apollo spacecraft and launch vehicle

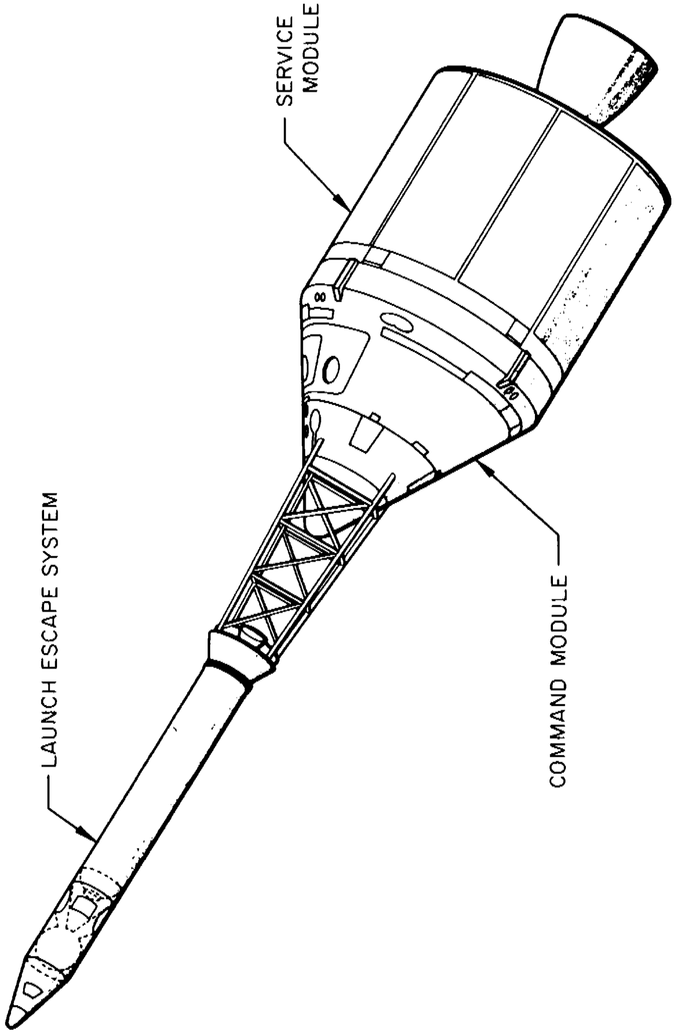


Fig. 3 Apollo spacecraft at separation

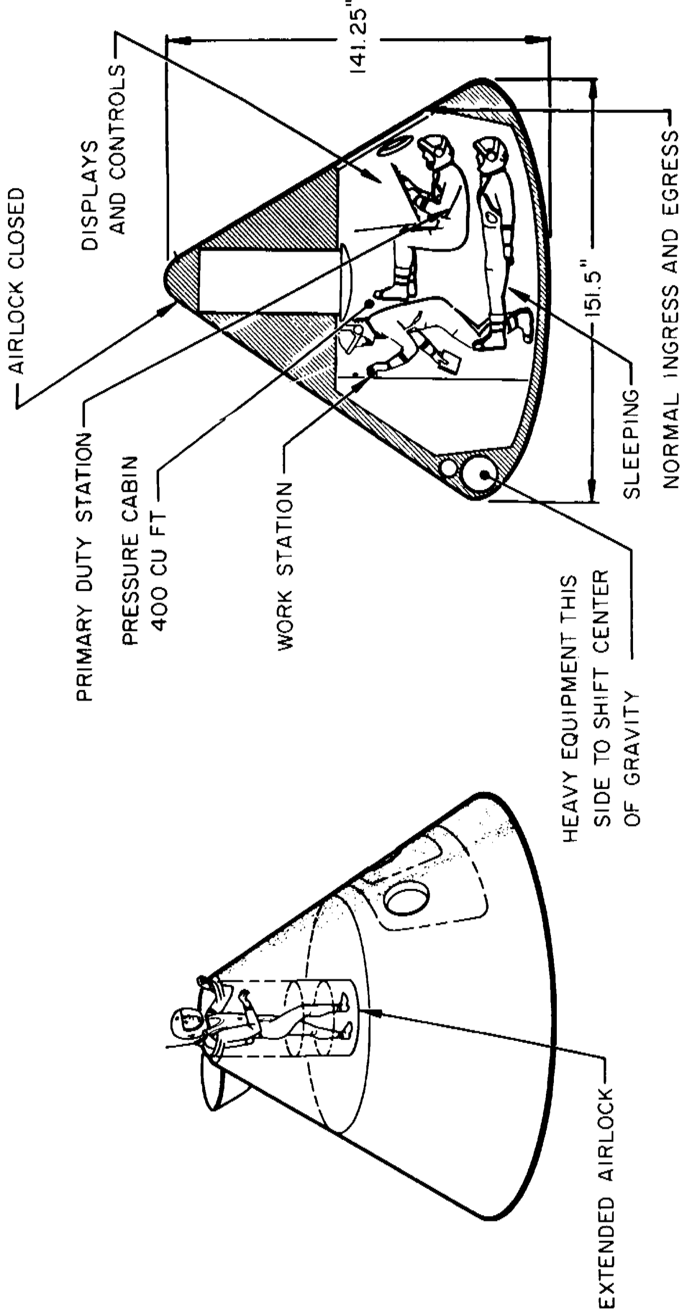
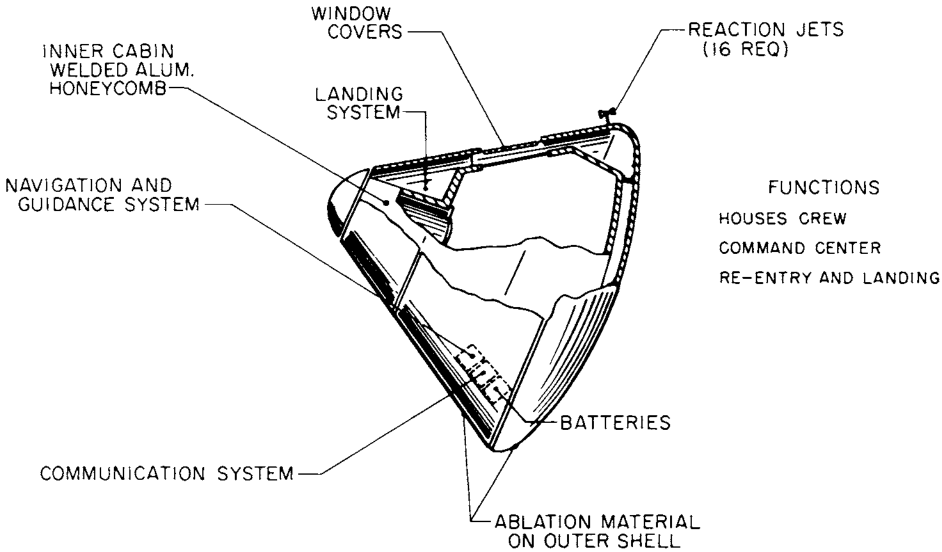


Fig. 4 Command module



SYSTEMS	CHARACTERISTICS
LANDING	PARACHUTES
ENVIRONMENTAL CONTROL	SHIRTSLEEVE
RE-ENTRY POWER	SILVER ZINC BATTERIES
HEAT PROTECTION	ABLATIVE
STABILIZATION AND CONTROL	REACTION
NAVIGATION AND GUIDANCE	STELLAR INERTIAL
STRUCTURAL	HONEYCOMB
COMMUNICATION	TELEMETRY, VOICE, TV

Fig. 5 Command module elements

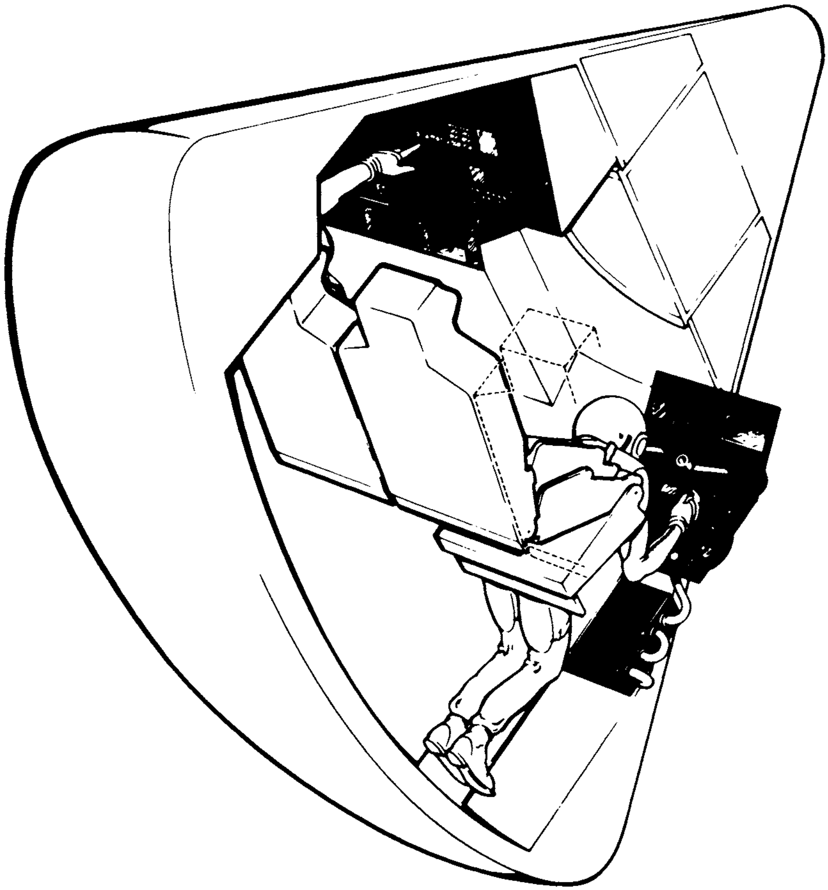


Fig. 6 Spacecraft navigation operations

DUTIES

- EARTH-ORBIT RETROGRADE
- MIDCOURSE VELOCITY CHANGES
- EXTRA ATMOSPHERE ABORT
- LUNAR ORBIT (PHASE B)
- LUNAR LAUNCH

SYSTEM DESCRIPTION

- EARTH STORABLE, HYPERGOLIC
- SINGLE, GIMBALED ENGINE
- ABLATION COOLED
- PRESSURE FED
- CONTRACTOR, AEROJET

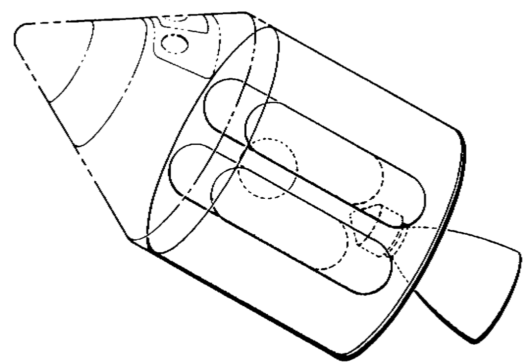


Fig. 7 Service propulsion system

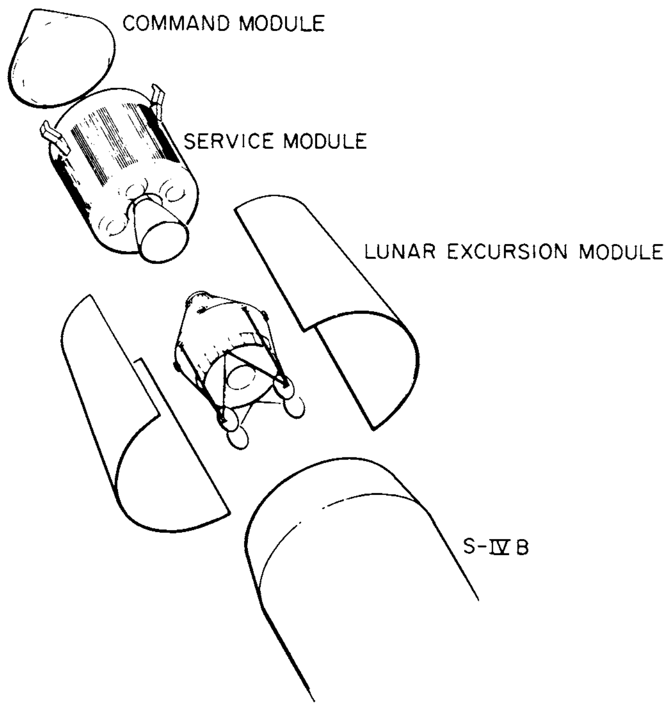


Fig. 8 Component separation - Apollo lunar orbit rendezvous

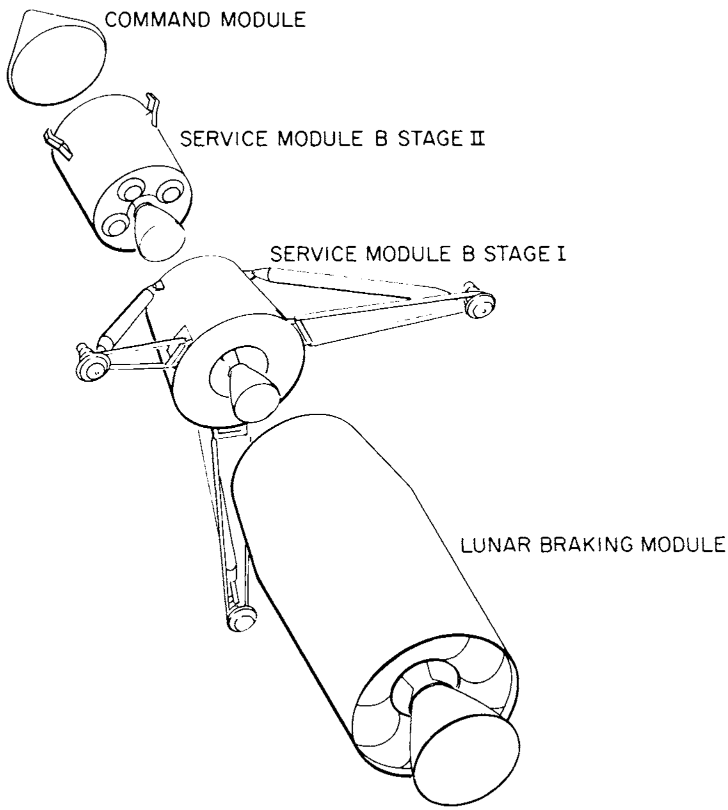


Fig. 9 Component separation - Apollo direct landing