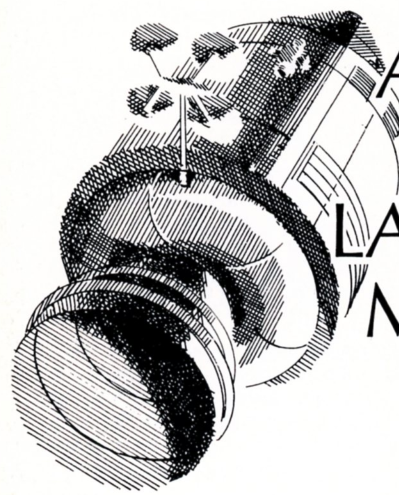
APOLLO

Stabilization and Control

BY HONEYWELL



APOLLO LUNAR LANDING MISSION

Program Objective

The "journey of a thousand miles" that the United States began with a single step in the early days of President John F. Kennedy's administration culminates with the flight of Apollo 11 and the realization of man's timeless dream to set foot on the Moon.

The successful completion of the Apollo 11 mission will be achieved with the safe return of the first men to have trod the Moon. It is both the End and the Beginning.

It is the end of a long and demanding struggle by government and industry that has seen insurmountable barriers surmounted and impossible tasks performed; and the beginning of an age that beckons man into a realm of limitless possibility and endless challenge.

Honeywell Program Role – Stabilization and Control

Everything is critical in space. Man is an explorer in an environment that is inhospitable at best and hostile in most respects. There is no air to breathe, the temperature is either unbearably hot or cold, the distances are vast and the imponderables are manifest.

Nothing is more critical under these conditions than is control of the spacecraft through the incredible range of distances and velocities encountered by the men and the vehicle.

Honeywell has performed an essential role in achieving this control capability and has been a significant contributor to the success of the Apollo team, as a major subcontractor to North American Rockwell Corp. and the Grumman Aircraft Engineering Co., since the inception of the program.

The stabilization and control subsystem (SCS) that performs vital functions throughout an Apollo flight is manufactured by Honeywell, as is equipment aboard the lunar module that provides essential control for key maneuvers in the descent, ascent and re-docking phases of the mission.

This subsystem enables the Apollo crew to maneuver the spacecraft, either manually or automatically, during the various stages of the flight.

The SCS function includes rotational control (angular thrusting control) about each of the spacecraft's three axes — pitch (up or down motion of the nose), yaw (side-to-side motion of the nose), and roll (the sidewise rolling movement of the spacecraft around its longitudinal axis).

The subsystem also provides translation control (line of flight thrusting control) of the spacecraft — movement straight forward or backward, straight up or down, or straight out to either side. As with the rotational controls, commands may be transmitted for translation maneuvers either manually or automatically.

The SCS is in operation throughout an Apollo flight from launch to touchdown. The display, or attitude reference, system is functioning before the spacecraft leaves the pad. At that stage, the system is providing fuel pressure data from the gimbal position/fuel pressure indicator. The flight director attitude indicators also are operative on the pad, and they give readings of spacecraft attitude during all mission phases.

Some of the key junctures of an Apollo mission at which the Honeywell SCS and lunar module equipment are utilized are in link up with the lunar module (after the S-IVB has inserted the command service module into a trans-lunar trajectory), during any subsequent mid-course corrections enroute to the Moon, for lunar orbit insertion, during the descent of the lunar module and in ascent and re-docking with the command module, for trans-earth injection, to execute any mid-course corrections required during the return flight, and for orientation of the command module for re-entry into the Earth's atmosphere after it has separated from the service module.

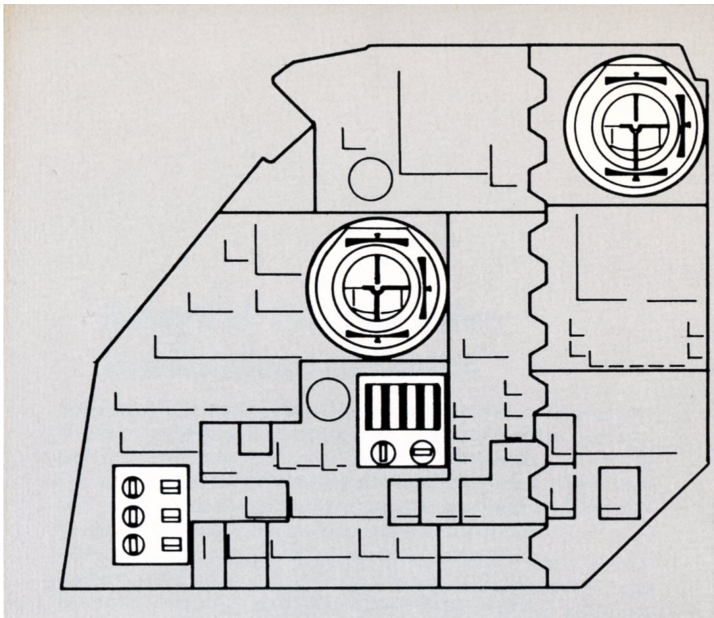
To effect control of the combined command/service modules, the stabilization and control subsystem directs the firing of reaction jet thrusters installed in four clusters or quads at equidistant points around the perimeter of the service module, or positions the service propulsion engine properly (by swiveling or gimballing it to the correct angle) before it is fired. The SCS also directs the firing of jet thrusters installed in the command module to achieve proper attitude orientation for re-entry into the Earth's atmosphere at the conclusion of the mission.

Another part of the subsystem displays attitude information to the astronaut crewmen on instruments called flight director attitude indicators mounted in the command module cockpit panel.

In addition to these functions, the 14-component stabilization and control subsystem serves as a backup for the guidance and navigation subsystem (manufactured by AC Electronics Division of General Motors, another Apollo subcontractor). This backup capability may be utilized in the event of guidance and navigation system failure, or when the system is shut down to conserve power.

Apollo systems are highly integrated. The stabilization and control subsystem is an integral part of the overall spacecraft system. As such, it functions co-operatively with the guidance and navigation subsystem, or uses components of other subsystems, to achieve its control mission.

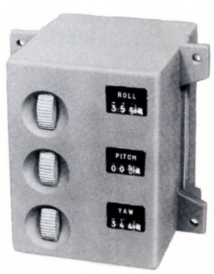
The basic functions performed by the stabilization and control subsystem cover control of the service command module reaction jets, thrust vector control of the service propulsion system engine, and the display of vital attitude information.



Components of the subsystem are:

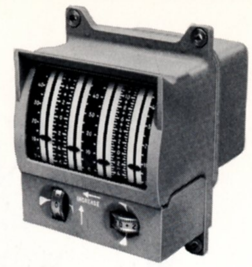
Flight Director/Attitude Indicator

These two indicators are mounted in the command module cockpit panel. They display pitch, yaw, and roll attitude, plus attitude error and angular rates, to give astronauts a visual reference of the actual spacecraft attitude.



Attitude Set Control Panel

This unit, mounted in the lower left hand corner of the main panel, displays roll, pitch, and yaw in degrees. Three thumbwheels provide the means for manually setting desired spacecraft attitude.



Gimbal Position/ Fuel Pressure Indicator

This display contains redundant indicators for both the pitch and yaw channels. During the boost phase of the launch it displays second-stage fuel pressure on the pitch indicators and third stage fuel pressure on the yaw indicators. For SCS-controlled velocity change maneuvers, thumbwheels enable crewmen to manually set the service propulsion engine angles (Gimbal Position).

Thrust Vector Control Amplifier

The most important single element of the 14 components that comprise the stabilization and control subsystem is the thrust vector control amplifier. It is the "star" of the SCS cast. The unit is used to position the gimbaled service propulsion engine for all major thrust sequences (those involving a service propulsion system engine burn).

Gyro Display Coupler

Provides signals to either of the attitude indicators for display of the spacecraft's total attitude and attitude errors.

Electronic Control Assembly

Contains the electronics for attitude control and thrust direction control. It also serves as backup to the SCS, providing for manual control in all axes.

Reaction Jet/Engine On-Off Control

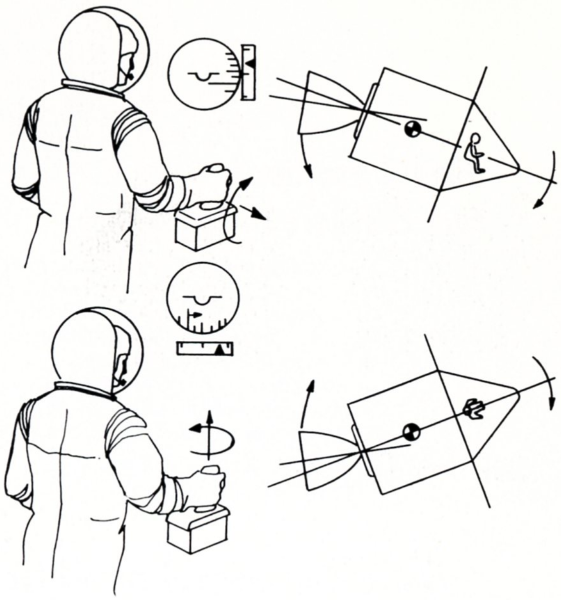
Contains the automatic reaction control subsystem logic and drivers that provide commands to the reaction control engines.

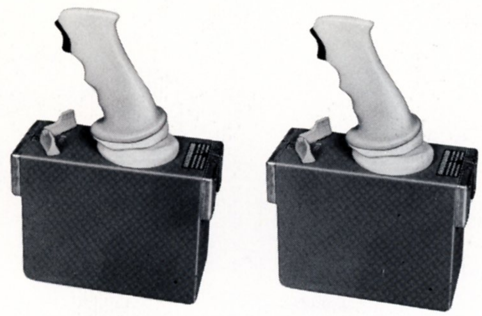
Electronic Display Assembly

Contains the electronics and logic used to condition the various signals that are displayed on the flight director attitude indicator and gimbal position fuel pressure indicator.

Gyro Assemblies

Two units each contain three attitude gyros, mounted along the spacecraft's axes to sense pitch, yaw and roll angular motion.



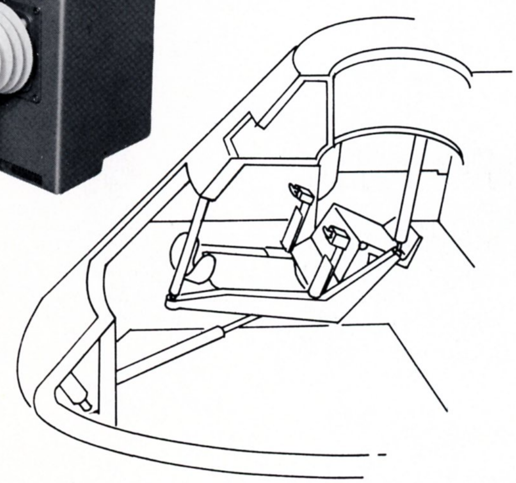


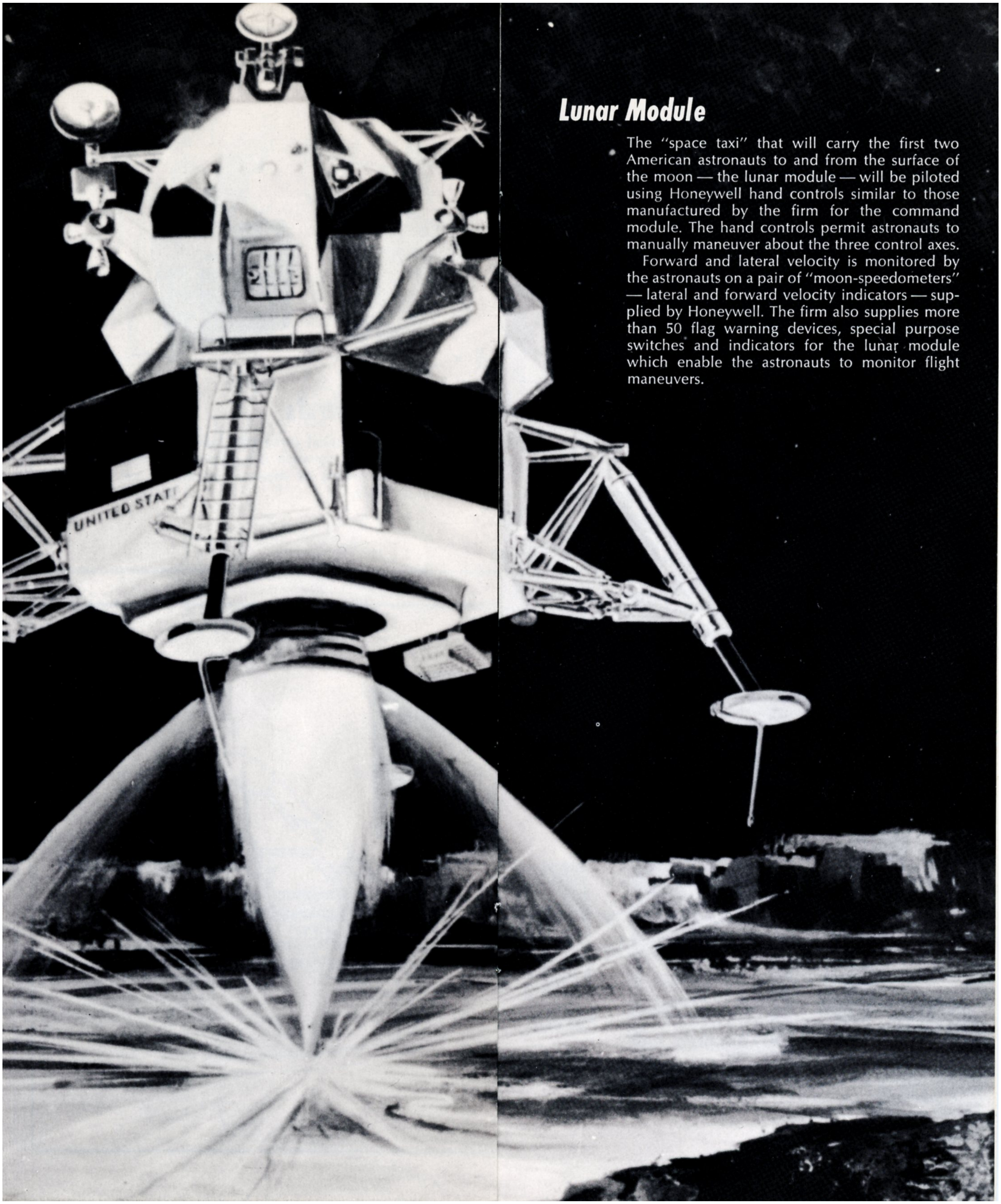
Rotation Controls

Two identical three-axis rotation control sticks mounted between the astronauts' couches provide means of manual control of roll, pitch, or yaw.

Translation Control

T-stick handle control provides a means of manually moving the spacecraft up, down, right, left, forward or back. This capability is essential in docking and rendezvous maneuvers. This control is also used to initiate a manual abort during the launch phase.

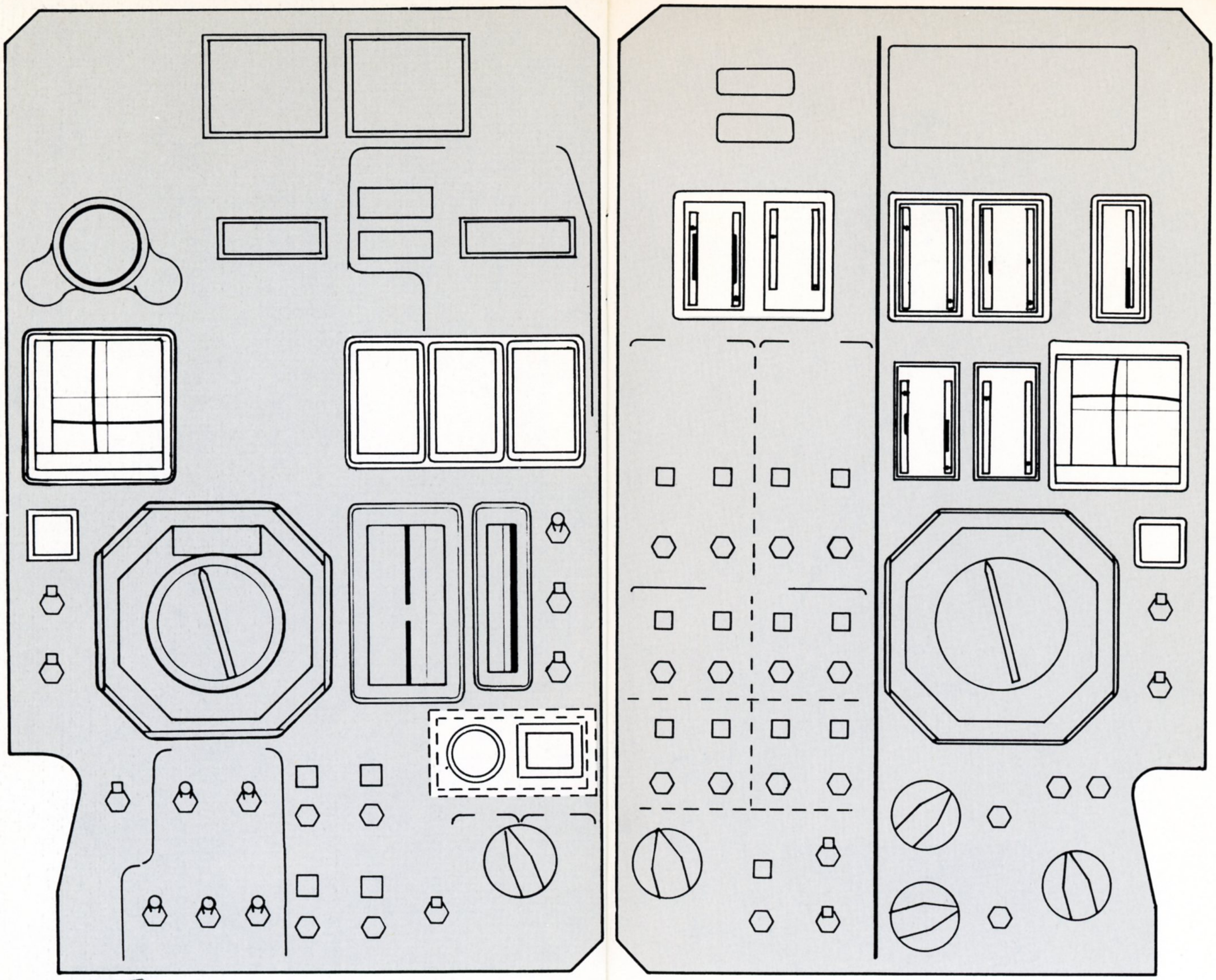




Lunar Module

The "space taxi" that will carry the first two American astronauts to and from the surface of the moon — the lunar module — will be piloted using Honeywell hand controls similar to those manufactured by the firm for the command module. The hand controls permit astronauts to manually maneuver about the three control axes.

Forward and lateral velocity is monitored by the astronauts on a pair of "moon-speedometers" — lateral and forward velocity indicators — supplied by Honeywell. The firm also supplies more than 50 flag warning devices, special purpose switches and indicators for the lunar module which enable the astronauts to monitor flight maneuvers.



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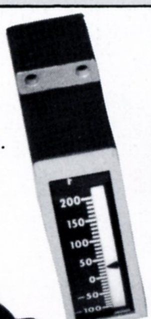

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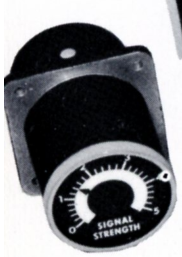
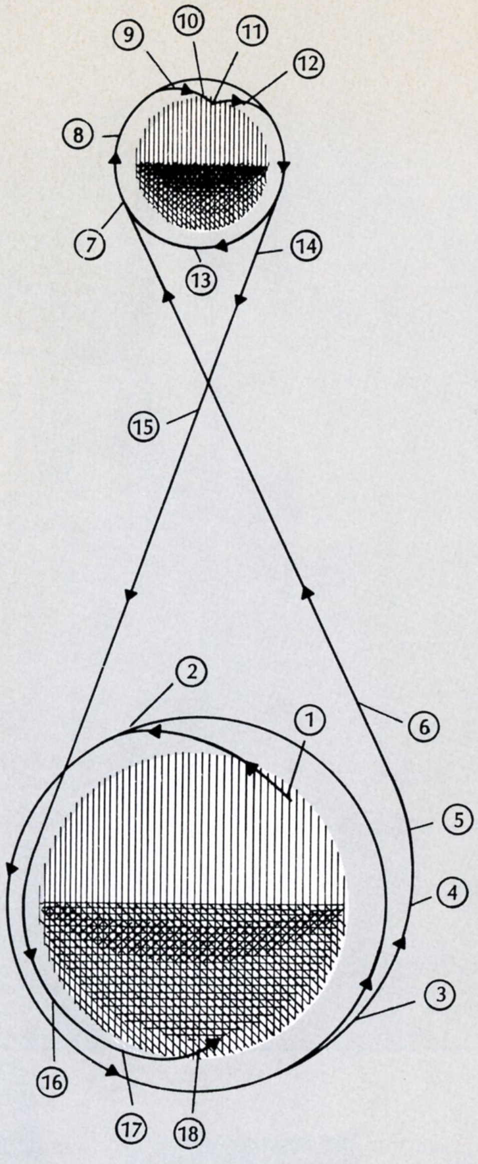


1.

Lunar Module Main Control Panel Elements

1. *Radar Signal Strength Indicator*
2. *Velocity, Elevation and Azimuth Indicator*
3. *Suit/Cabin Pressure Indicator*
4. *Main Engine Thrust Indicator*

These elements are typical of more than 50 displays, switches and flag warning devices provided by Honeywell for the Lunar Module.



Apollo Mission Profile

1. Liftoff
2. Staging
3. Translunar Injection
4. Transposition and Docking
5. Jettison S-IVB
6. Midcourse Corrections
7. Lunar Orbit Insertion (two burns)
8. LM-CSM Separation
9. Powered Descent
10. Hover to Touchdown
11. Lunar Exploration
12. Powered Ascent
13. Rendezvous and Docking
14. Jettison LM and Begin Transearth Injection
15. Midcourse Corrections
16. Jettison SM
17. Enter Earth's Atmosphere
18. Landing and Recovery

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