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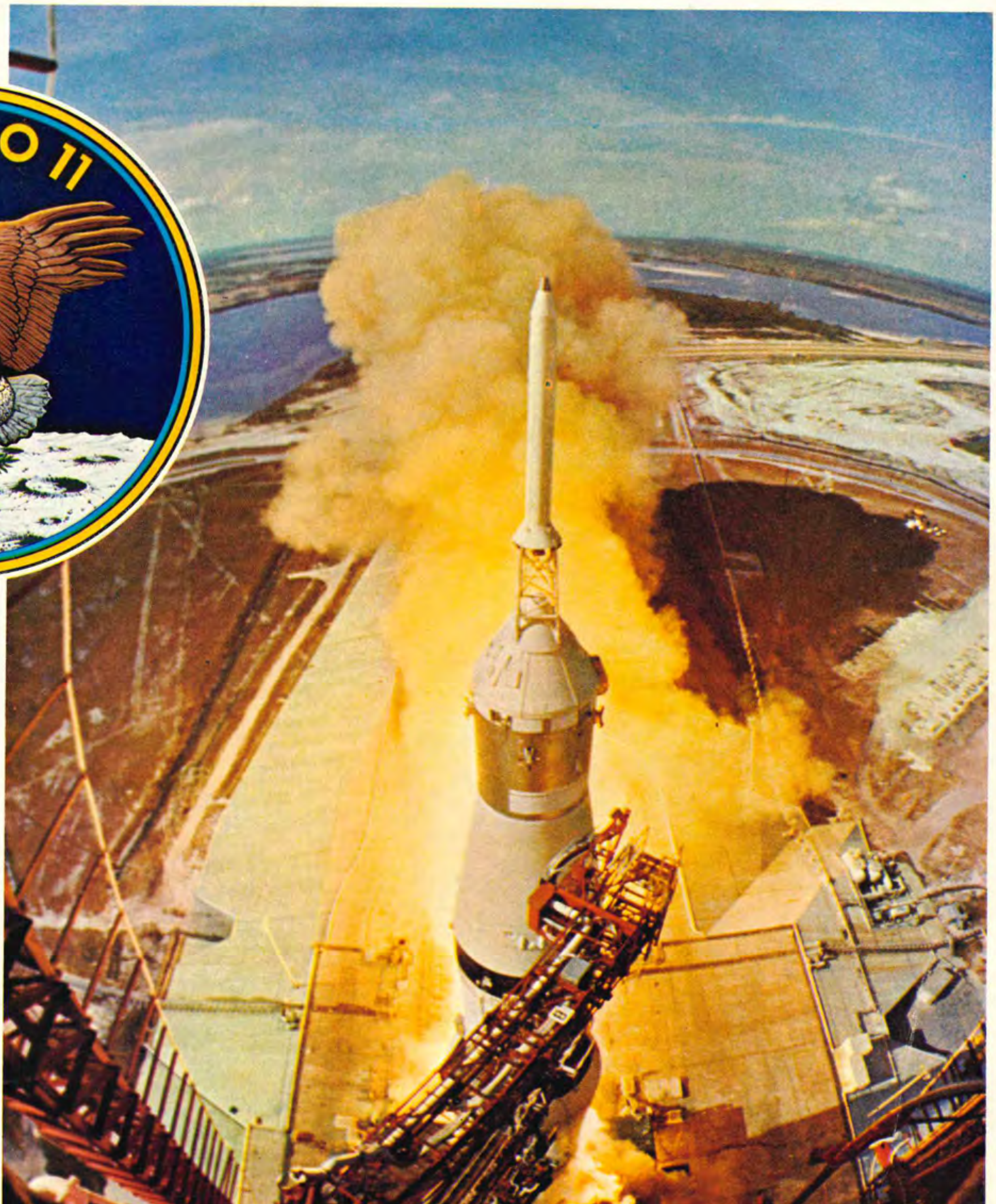

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VOLUME XXIV

Apollo 11 Mission Report

Tri-jet Evaluations by TWA and Air Canada

The Concorde in Flight Testing

No. 9/1969

The Apollo 11 Moon Landing

by Werner Büdeler

On July 20, 1969, one of the earliest dreams of civilised man—that of landing on the moon—was realised by the crew of *Apollo 11*. The first mention of this dream in the literature of the world occurred some 1,800 years ago, in the works of the Greek satirist Lucian of Samosate. But its final realisation, in the twentieth century, was achieved only after eight years of concentrated development work involving the efforts of 350,000 men and women from some 20,000 industrial firms, from the various branches of America's National Aeronautics and Space Administration and from other technical and scientific institutes, and at a total cost around 24,000 million dollars.

To-day we may sit back and ask, what is the tangible outcome of this huge expenditure of effort and dollars. And we will find the answer lies not merely in the achievement of Armstrong, Aldrin and Collins but, equally, in the development of numerous new manufacturing and management techniques, in the production of new materials which can withstand extreme conditions, and in the realisation of a new potential amongst scientific and technical workers, who have learned to tackle phenomenal tasks on a scale hitherto unknown. All these are by-products of the *Apollo* programme. Other tangible results are the hardware resulting from the programme—the boosters, payload components, space suits and so on—all contributing to a solid basis for the future exploration of space.

Origins and conception of the Apollo programme

First formulated by US President John F. Kennedy in the course of an address on May 25, 1961, the objective of carrying men to the moon, and safely back, before the end of the decade was successfully achieved on the fifth manned flight in the *Apollo* programme. The flight was, in fact, the fourth launch of a manned mission by a *Saturn* booster out of a total of six flights. In the original plans, the Moon landing had not been anticipated before the 18th or 20th flight by a booster of this type, so the much earlier success must be taken as a brilliant justification of the correctness of the *Saturn* concept and design. At the same time, numerous modifications to the concept were made, especially in the early stages of the programme.

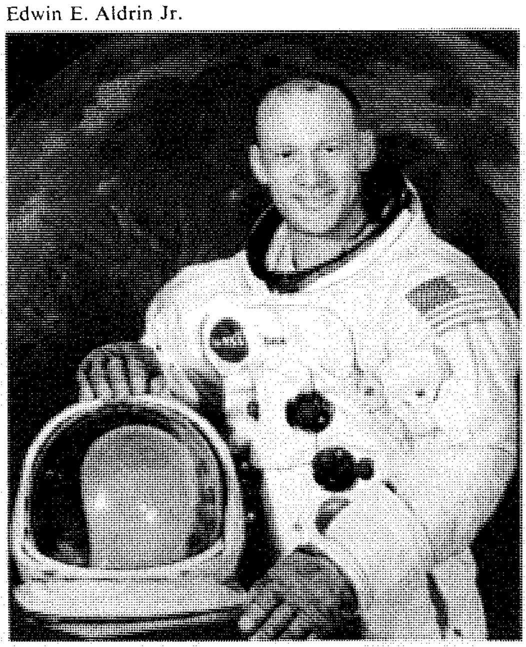
In 1959 a Manned Space Flight Research guidance committee was formed, under the chairmanship of Professor Harry C. Goett. This committee,—which came to be known generally as the Goett Committee, took the view that the next major space programme after *Mercury* must have as its objective a manned flight to the Moon, though at that time no practical experience of manned space missions existed. In 1960, on the basis of the Goett Committee recommendations, the initial guidelines of the programme were laid down by the Space Task Group, who were then responsible for the *Mercury* project. The Group proposed that booster rockets should first be developed only for manned lunar *orbital* missions, and could not therefore be used for a moon *landing*, and that the space vehicles developed in this context should also be usable for alternative Earth-orbital missions.

After President Kennedy's announcement, specifications which had already been issued to industrial contractors for the design of a Command Module (CM) and an associated Service Module (SM), were modified to accommodate requirements for a lunar landing. The primary concept of the mission envisaged a very powerful booster (not yet in existence at that time) which would inject the Command and Service Modules together with a third stage into a trans-lunar trajectory, and that this three-section vehicle would, by firing the retro-rockets in the third section, then make a direct landing on the lunar surface. The specifications for the booster required for this direct lunar landing concept were, however, never clearly defined, but it would obviously have been very large, similar to the *Nova* rockets then being studied.

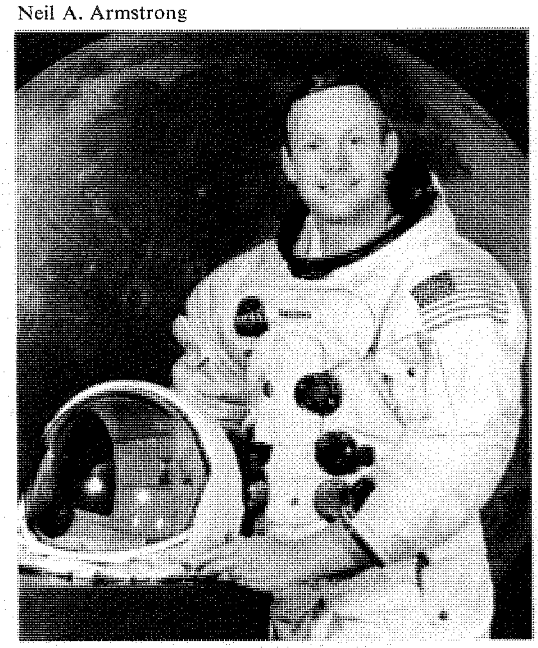
By the autumn of 1961 studies carried out at NASA's George C. Marshall Space Center and other establishments to define the choice of booster, then designated *Saturn C-5,* showed quite clearly that the concept of a direct flight and landing was not feasible. There remained two alternatives: utilisation of two vehicles which would rendezvous and dock in Earth orbit and then fly to the moon; or direct injection of these two vehicles on a course to the moon, followed by a rendezvous and docking manoeuvre in lunar orbit.

The first of these alternatives envisaged use of two *Saturn C-5* rockets, each of which would put a vehicle independently into earth orbit. One vehicle would be an *Apollo* spacecraft, the other a fully-fuelled rocket stage. For the trans-lunar flight the two vehicles would rendezvous and dock in Earth orbit, then would fly to the moon, land and return to Earth without the

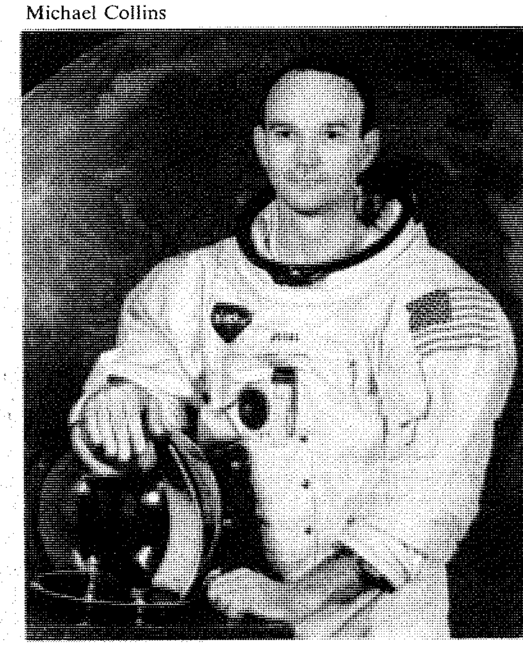
Edwin E. Aldrin Jr.



Neil A. Armstrong



Michael Collins



need for any further docking or fuelling manoeuvres.

The second alternative, however, envisaged injection of the combined 3-section *Apollo* spacecraft into a trans-lunar trajectory by a single *Saturn C-5*, but the third section of the spacecraft, which was originally conceived only as a landing and take-off motor for the lunar surface excursion, was now converted to a manned vehicle. In lunar orbit it would detach from the CM and SM (CSM) assembly, and whilst these latter remained in lunar orbit, would descend to the surface of the moon. After completing its tasks, this vehicle would return to orbit and would dock with the Command and Service Modules, which would then carry the lunar landing vehicle and crew back to Earth.

In November 1961 the original Space Task Group had moved from Langley to Houston into NASA's Manned Spacecraft Center, and by early Spring 1962, the Group had decided in favour of the second alternative. Specifications for the Lunar Excursion Module (LEM, later abbreviated to Lunar Module, LM), were then worked out and towards the end of 1962 major contractors were selected to develop this vehicle and also the Command and Service Modules. Design studies for the whole *Apollo* system had, in fact, been proceeding at the Massachusetts Institute of Technology (MIT) since 1960, and, in collaboration with industrial firms, this Institute had also been developing the necessary navigation and guidance systems. But with the allocation of contracts (see table 3) the programme definitely entered the construction stage.

Under the direction of Dr. Robert R. Gilruth, NASA's Manned Spacecraft Center was made responsible for developing the payload components, the spacesuits and similar accessories and assemblies. The Center also assumed responsibility for astronaut training. NASA's Marshall Space Flight Center at Huntsville, Alabama, under the direction of Dr. Wernher von Braun, assumed responsibility for development of the booster rocket, in which industrial firms were also consulted.

The technical equipment

To begin with, three types of *Saturn* launch vehicle were developed. These are now known as the *Saturn 1, Saturn 1B* and *Saturn 5. Saturn 1,* ten of which were launched, was purely a technical test vehicle and was never intended for use in manned flight. It was a two-stage vehicle, the first S-1 stage having a launch thrust of 1.5 million lb. All proving flights with this rocket were successful.

The *Saturn 1B,* which superseded *Saturn 1,* featured a first stage *(S-1B)* with an increased launch thrust of 1.6 million lb, light construction and a new, more powerful second stage. In both types the first stage motors were powered by kerosene and liquid oxygen, the second stages by liquid hydrogen and liquid oxygen. The second stage of the *Saturn 1,* known as the S-4, was powered by six RL-10 engines, each of 15,000 lb vacuum thrust, giving an overall total thrust of 90,000 lb. In the *Saturn 1B,* this arrangement was replaced by a J2 engine with 206,000 lb vacuum thrust and the stage was designated the S-4B. To date, the *Saturn 1B* has made five flights, one of these—the *Apollo 7* mission—being a manned flight. It will also play a part in future American space operations, in connection with the Orbital Workshop programme—the first manned space station project.

The *Saturn 5* rocket is a three-stage booster with a height of 363 ft over payload. Its first stage (S-1C) is propelled by five F-1 engines, each of 1.5 million lb thrust, giving a total power of 7.5 million lbt (from *Apollo 11* onwards its total thrust will be 7.7 million lb). Fuel used is kerosene, with liquid oxygen as oxidizer. The second and third stages are powered by motors using liquid hydrogen and liquid oxygen. The *Saturn 5* second stage, designated S-2, develops just over 1,000,000 lb vacuum thrust from its four J-2 engines. The S-4B third stage is identical with the second stage of the *Saturn 1B*.

The payload capacity of the *Saturn 5* rocket enables it to put 125 tons into a circular Earth orbit at a height of 115 miles, or 45 tons into a lunar trajectory. At lift-off, the *Apollo* payload weighs over 45 tons, made up as follows:

Command Module (CM)	13,000 lb	
including fuel weight		270 lb
Service Module (SM)	55,000 lb	
including fuel weight		41,900 lb
Lunar Module (LM)	32,400 lb	
including fuel weight		23,400 lb
Escape system	8,000 lb	
including fuel weight		5,500 lb
total:	108,400 lb	71,070 lb

The *Apollo* Command Module is the manned space capsule, and it is in this vehicle that the 3 men travel to the moon and return from it. To achieve the moon landing, two of the crew transfer to the Lunar Module, leaving the remaining man in moon orbit. Access from command to Lunar Module is by way of a tunnel, which is closed by a hatch at either end. The coupling of the two vehicles throughout the journey is achieved by a complex system of twelve latch-type locking lugs.

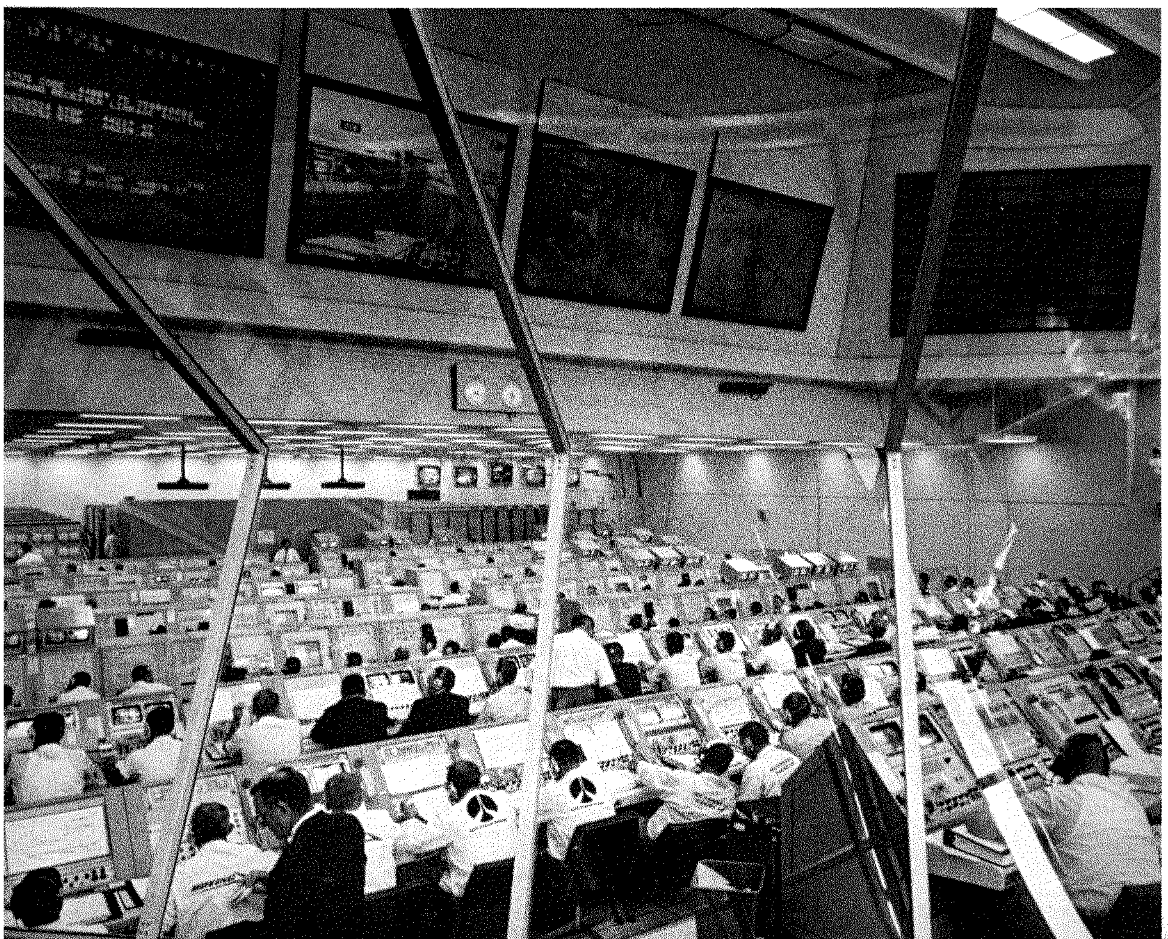
The Command Module, with a cabin space of about 212 cu. ft. is the only part of the 3-part *Apollo* assembly which will make a controlled return to Earth. The Lunar Module will be left in permanent moon orbit after the Command Module has been separated for return to Earth. The Service Module is dumped prior to the re-entry phase of the mission. Only the Command Module has a heat shield of phenol synthetic resin which will stand up to the high temperatures encountered in passing through the lower levels of the Earth's atmosphere. After separation of the Command Module from the service module, the CM relies on two duplicated sets of six attitude nozzles to give positional control in the last phase of the operation. These nozzles are powered by hydrazine fuel, with nitrogen tetroxide as oxidator. Each nozzle can develop a thrust of 93 lb.

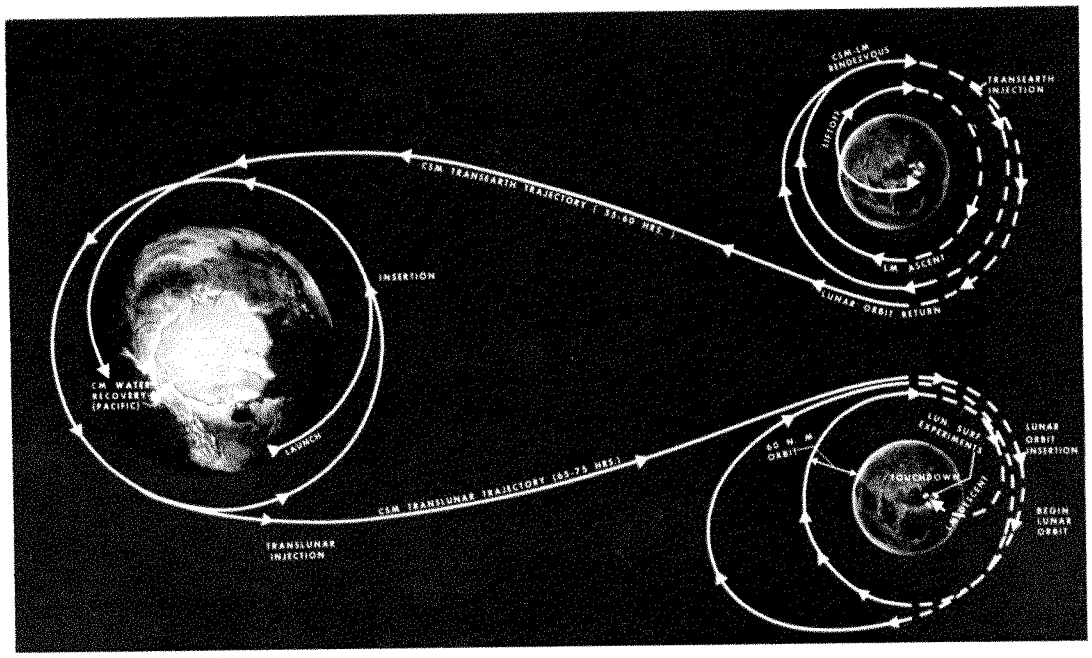
The structure of the Command Module is in two main parts—an inner, pressurised cabin and the outer heat shield. To ensure thermal insulation, the space between the two is partly filled with glass fibre material. The Environmental Control System (ECS) inside the CM provides a continuous supply of oxygen at a maximum rate of 1.3 lb (600 gram) per hour. It also absorbs the carbon dioxide expelled in the astronauts' breath, controls temperature and humidity and provides hot and cold water for crew usage.

In shape, the Command Module resembles a cone, with a convex bottom (the re-entry shield) and flat, truncated top. It is 12 ft high and at its widest point has a diameter of 12.8 ft. All the equipment needed for the re-entry and splashdown manoeuvres—i. e. parachutes, inflatable air bags etc., are stored in the upper, tapering portion of the capsule. The complex probe docking mechanism is located at the top of the cone shape, which also forms the entry to the astronauts access tunnel when LM and CM are linked together.

The *Apollo* Service Module (SM), which is connected to the Command Module throughout the mission, until shortly before the latter re-enters the Earth's atmosphere, provides propulsion for the spacecraft assembly after it has been injected into a flight path to the moon. It also supplies the astronauts in the Command Module with oxygen, water and electric current. An unmanned, cylindrical section, the Service Module stands 24.2 ft (7.37 m) high and has a 12.8 ft (3.91 m) diameter. The outside shell, which embraces six segments divided by radial struts, consists of a core of aluminium sandwich construction, enclosed on both the inside and outside by aluminium plating. In the various segments are the fuel tanks, tanks for pressure supply of the fuel, oxygen tanks, fuel elements and part of the communications equipment. The Service Pro-

View of Room 1 at Cape Kennedy Launch Control Center. This picture was taken during the *Apollo 11* launch count-down. On the screens at the rear, are being projected television pictures showing parts of the *Saturn 5*. The room contains no fewer than 450 control consoles.





Apollo 11 mission profile.

pulsion System (SPS)—the main motor of the *Apollo* assembly—occupies 75 per cent of the volume and 75 per cent of the gross weight of the Service Module. The motor supplies the thrust for all major manoeuvres during the flight, after separation from the third stage of the Saturn booster. Tasks of the SPS are, therefore, an injection into a flight path to the moon (achieved by negative acceleration) injection into the return flight path from moon to Earth, from lunar orbit (achieved by positive acceleration) and all major changes of course and altitude during the trans-lunar and trans-earth trajectories. The gimbal-mounted engine develops a thrust of 205,000 lb (9,300 kp). The fuels used are Aerozine 50 (a mixture of 50 per cent hydrazine and 50 per cent asymmetric di-methylhydrazine) and nitrogen tetroxide: this gives a hypergolic combination. Operation of the engine is, therefore, automatic, but the Apollo pilot can switch this to "manual", if he wishes.

The Service Module contains besides these main engines, four independently operating reaction control engine clusters. Each of these consists of four small engines set at 90 degrees to one another. These engines, each with a thrust of 100 lb, can operate up to 10,000 times for periods of between 12 millseconds and 500 seconds, the total burn time being 1000 seconds. The same fuel is used in the reaction control engines as in the main engines.

The Lunar Module (LM) is a two stage vehicle consisting of descent/ascent stages. With landing gear extended, the LM has a height of 25.5 ft and a base diameter of 31 ft. The swivable descent engine, which is situated underneath the octagonal descent stage, gives a thrust variable between 1,050 and 9,870 lb, and besides this it can be re-ignited twenty times. The total burn time is 910 seconds during which 17,500 lb of fuel is consumed. The fuel employed is Aerozine 50 (50/50 blend of hydrazine and unsymmetrical dimethyl hydrazine) and nitrogen tetroxide. As well as this engine, the descent stage contains tanks for fuel, oxidizer, and pressurised helium, and also some batteries and antennas, a scientific equipment bay, egress platform and a ladder as well as the telescopic landing gear struts.

The ascent stage consists of the hermetically sealed two-man crew compartment, ingress/egress hatch, overhead hatch and transfer tunnel, four reaction control assemblies each containing four engines for attitude control, stabilization and orbital correction, control and display equipment, antennas, and fuel tanks. The crew compartment has a diameter of 7.5 ft. The vehicle skin is of welded aluminium alloy surrounded by a 2 in thick layer of insulating material and an outer cladding of aluminium. The crew compartment has three windows, two of which are used during descent to the moon, whilst the third is for vision in rendezvous and docking manoeuvres with the CSM. The ascent engine gives a constant thrust of 3,500 lb in a fixed direction.

The LM is carried above the third stage of the launch vehicle. A conical cover 28 ft long, 21.6 ft and 12.8 ft diameter at its lower and upper ends respectively, is fitted to protect it during launch and ascent and at the same time give it the necessary stability.

Apollo Preparatory Missions

After several unmanned test flights of individual components and complete systems, the first manned flight of an *Apollo* spacecraft took place when *Apollo 7* was launched into Earth orbit between October 11th and 22nd, 1968 (see table 1). The launch vehicle employed was a *Saturn 1B* and the payload consisted only of the two part combination of Command and Service Modules, a full-size dummy been carried in place of the Lunar Module. This flight served for manned technical evaluation of the CM and SM.

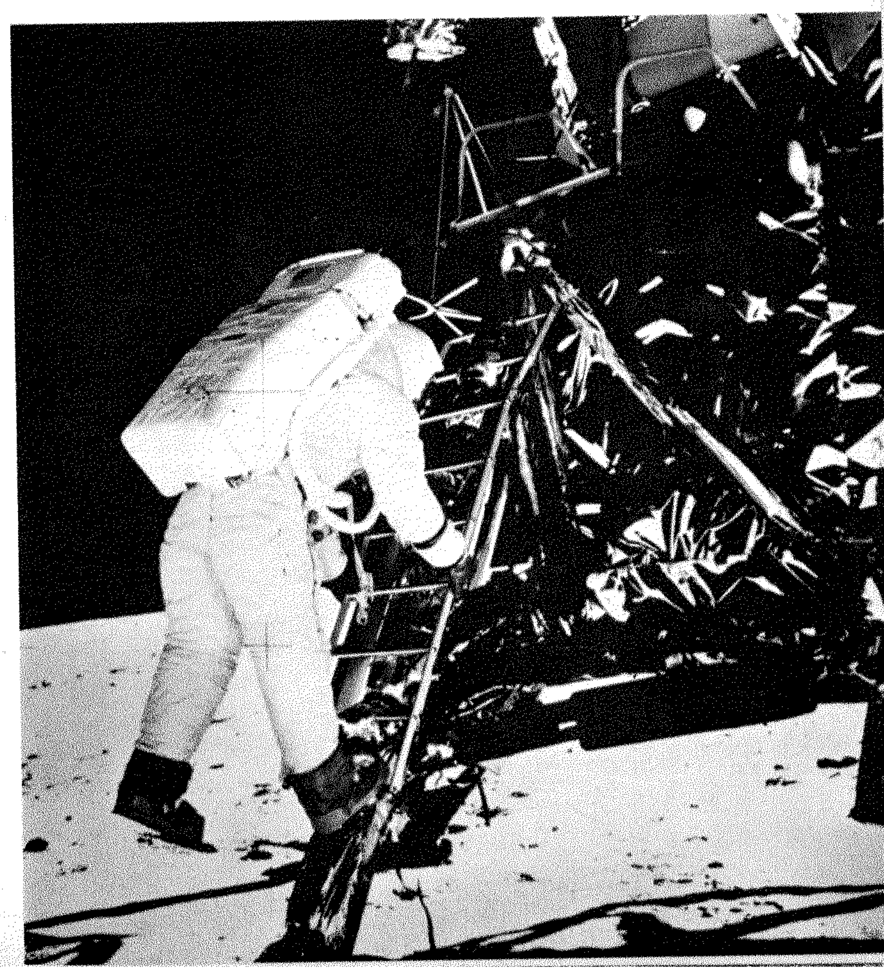
Apollo 8, the second manned flight in the Apollo programme and the first manned flight in which a *Saturn 5* launch vehicle was used, circumnavigated the moon in the period December 21st to 27th, 1968. The astronauts manoeuvred firstly into an elliptical and then a circular orbit around the moon at a distance of 70 miles from the lunar surface. This mission, which also took place without the LM, established the requirements for the actual lunar landing.

The first manned test of the LM was carried out with the *Apollo 9* mission during flight in earth orbit between March 3rd and 13th, 1969. In this orbit, separation, rendezvous and docking manoeuvres between the CM and the LM were tried out for the first time.

Apollo 10, from May 18th to 26th, 1969, undertook the second lunar orbital flight. The astronauts tested the LM in lunar orbit and descended to within 4.5 miles of the lunar surface, this distance being later confirmed by data analysis. Their flight had the objective of testing all the systems once more before the lunar landing mission and also to obtain orbital data and position coordinates in and around the potential landing areas on the moon.

The Apollo 11 mission

Apollo 11, the actual lunar landing mission, commenced with the punctual lift-off of Saturn rocket No. 506 on July 16, 1969 at 09.32 American EDST (13.32 GMT) from Pad A of Launch Complex 39 at the John F. Kennedy Space Center in Florida. The spacecraft commander was the 38 years old astronaut Neil A. Armstrong, Command Module pilot was Michael Collins, aged 38, and the Lunar Module pilot was Edwin E. Aldrin, 39 years old. The CM and SM were S. No. 107, and the LM was S. No. 5.



Edwin E. Aldrin Jr. descends the steps of the Lunar Module ladder as he prepares to step on to the surface of the moon. His pack-shaped Portable Life Support System is clearly recognisable. The picture was taken by Neil A. Armstrong with a 70 mm Hasselblad lunar surface camera.

Aldrin standing by the aluminium sheet, deployed to catch solar wind particles. This is an experiment from the Mineralogical Institute of Berne University and the Swiss Federal Technical College, Zurich. The principal investigator is Dr. Johannes Giess from Berne.

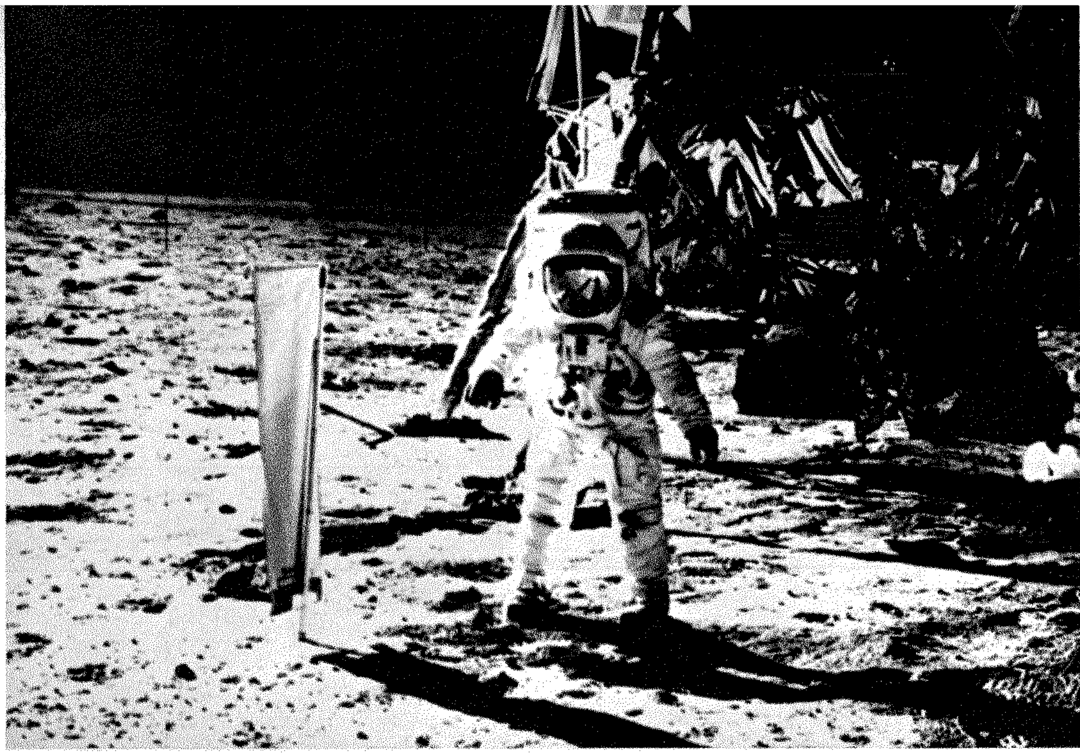


Table 2 lists the most important events during the mission and also compares planned and actual times. It can be seen from this that the flight and landing was carried out substantially on schedule and that there were no major hold-ups. The launch countdown ran according to programme, and was, particularly in the final stages, running half an hour ahead of the nominal planned times. Only in the final phase when a leak occurred in the valve of a liquid hydrogen pipe some 2 h 50 min before launching did a fault occur. The technicians were, however, able to bypass this fault without interrupting the countdown. At 11.25 GMT, the hatch was closed behind the three astronauts who had entered the spacecraft between 10.54 and 11.03. *Apollo 11* lifted off on schedule at 13.32. A few seconds later control was passed from Cape Kennedy launch control to the Mission Control Center in Houston, Texas. During the ascent into earth orbit, all stage engines operated perfectly, no unusual vibrations or similar instabilities being observed. Stage separation, jettisoning of launch escape tower and connecting rings etc took place according to schedule. Minor errors in the spacecraft navigation system during the launch phase were corrected and did not present any problems for Trans-Lunar Injection (TLI). Trouble occured during an unscheduled television transmission from Earth orbit (nearly circular orbit of 114 by 118 miles altitude) via the Goldstone, California ground station, but the cause was apparently due to faults in the ground installations and not in the spacecraft.

TLI took place at the scheduled time. The separation of the C/SM from the launch vehicle in preparation for the transposition manoeuvre was three minutes later than programmed. Command Module pilot Collins thrust the C/SM out to a distance of about 100 ft from the LM and launch vehicle third stage—some 40 ft further than planned. Fuel consumption during these separation, transposition and docking manoeuvres was somewhat higher than expected, but did not however give any cause for alarm. A momentary fault in a valve which controlled fuel flow to one of the SM's four assembly blocks fitted with four reaction control motors was quickly eliminated. An anomaly occurred during the S-4B slingshot manoeuvre, in which residual launch vehicle liquid propellants were dumped through the J-2 engine bell, in that the pilot could not see the rocket stage through the spacecraft's window.

The trajectory resulting from the TLI manoeuvre was so accurate, that only the second of the four planned midcourse corrections needed to be carried out. The first Lunar Orbit Insertion burn (LOI) took place after a flight time from earth to moon of nearly 76 hours. As usual this manoeuvre, which placed the spacecraft into an elliptical 196 by 70 mile lunar orbit, was carried out behind the moon. Only after *Apollo 11* had flown around the moon to reappear on the side facing Earth was it possible to know on Earth if the manoeuvre had been successful. A second LOI burn placed *Apollo 11* into a near circular orbit. In both the *Apollo 8* and *Apollo 10* missions, perturbations of the lunar gravitational potential caused orbital changes. For this reason the orbit selected for *Apollo 11* was slightly excentric with a perigee of 62 miles and an apogee of 75 miles. It was expected that the orbital disturbance would cause the orbit to become circular at the time of rendezvous with the LM. This effect did not, however, occur with *Apollo 11,* but it did not cause any difficulties in rendezvous and docking manoeuvres.

Preparations for separating the LM from the CM in lunar orbit commenced early. Aldrin and Armstrong had already during translunar coast on the evening of July 18th undertaken a rehearsal which involved opening the transfer tunnel and entering the LM. At the same time they checked all systems in the LM and also made a television transmission to Earth. In the final preparation for the separation manoeuvre, Aldrin transferred from CM to LM at about mid-day on July 20, 1969 about half-an-hour earlier than planned. From then on Houston *Apollo 11* mission control centre no longer spoke to the complete spacecraft, but differentiated between the C/SM and the LM by using the callsigns *Columbia* for Collins in the Command Module and *Eagle* for the other two astronauts in the Lunar Module.

The separation of C/SM and LM took place during the 12th lunar orbit whilst on the far side. First ignition of the LM descent engine occured some 2 minutes earlier than scheduled, and the burn time of 29.8 seconds was 1.4 seconds longer than expected. The elliptical descent orbit had a pericynthion of 48,000 ft (planned altitude 50,000 ft). As the LM reached this point at 20.05.05 GMT on July 20th, the engine was reignited to initiate the powered descent and landing manoeuvre. During the final descent phase the on-board computer gave several alarm signals, possibly because the data requirements were so high that the computer

Table 1: Apollo Programme Flights

Flight	Date of Launch	Crew		Launch vehicle	Mission	Duration	Result
Apollo 7	11 October 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	CM CMP LMP	Saturn 1B	Earth orbit 163 orbits	260 h 09 min	First manned Apollo flight
Apollo 8	21 December 1968	Frank Borman James A. Lovell, Jr. William A. Anders	CM CMP LMP	Saturn 5	Lunar flight 10 lunar orbits	147 h	First manned flight around the moon Approach to 70 miles
Apollo 9	3 March 1969	James A. McDivitt David R. Scott Russell L. Schweickart	CM CMP LMP	Saturn 5	Earth orbit 151 orbits	241 h 01 min	First manned test of Lunar Module Rendezvous and docking manoeuvre in Earth orbit
Apollo 10	18 May 1969	Thomas R. Stafford John W. Young Eugene A. Cernan	CM CMP LMP	Saturn 5	Moon flight 31 lunar orbits	192 h 03 min	First test of Lunar Module in lunar orbit Approach to within 23,000 ft of lunar surface
Apollo 11	16 July 1969	Neil A. Armstrong Michael Collins Edwin E. Aldrin, Jr.	CM CMP LMP	Saturn 5	Moon landing with Lunar Module Lunar orbit for C/SM with Collins 31 lunar orbits	195 h 18 min	First landing on the moon by Armstrong and Aldrin; duration of stay on the moon 21 h 38 min; EVA 2 h 31 min 24 sec (hatch opening to hatch closing)

CM = Commander; CMP = Command Module Pilot; LMP = Lunar Module Pilot was overloading. Mission Control Centre in Houston intervened, however, to assure the two astronauts that all LM systems were in order for the landing. After a 757 second burn (planned time 718 seconds) the LM settled on the lunar surface. The reduction in speed achieved during braking amounted to 6775 feet per second. The burn time was 39 seconds longer than planned because in the final phase of descent, the astronauts switched programmes from automatic to semi-manual in order to avoid a 260 ft diameter crater that was filled with boulders. They had already descended to within 40 ft of the lunar surface, and then with a horizontal velocity of nearly 4 mph flew past the crater, finally landing on the Sea of Tranquillity at 20.17.39 GMT. Some 65 seconds before touch-down, a warning lamp indicated that in the fuel tank, there was only sufficient fuel remaining to allow 114 seconds burn at 25 per cent thrust. On touch-down, the fuel reserve amounted to 49 seconds burn time. The exact landing position could only be determined several days later, its selenographic coordinates being longitude 23°30′11″ east, latitude +0°38′50″. It lies in the south western part of the planned landing ellipse, whose semi-major axis measured 2.5 miles and semi-minor axis 1.5 miles.

The stay on the moon

Immediately after landing, the astronauts made an extensive check-out of LM systems and also preparations for contingency ascent staging. Several time blocks, designated T-1, T-2 etc, had been defined based on the rendezvous possibilities with the CSM, so that after each of the time blocks a start was possible from the moon, always supposing that the situation necessitated a premature departure. According to technical conditions existing then, it was up to Houston to decide whether or not the LM should lift-off or if the next time block could be released for remaining on the moon. The first possible departure time, T-1, occurred five minutes after landing, the second after one orbit of the C/SM (two hours) and the third after a longer planned stay on the lunar surface. All three time slots were passed by.

For physiological reasons, the mission plan originally included a four hour rest period for Armstrong and Aldrin after landing, before they set foot on the lunar surface. However, both of them had had adequate time for sleeping during the three day journey to the moon, so that they were rested sufficiently enough to bring the EVA (Extra Vehicular Activity) manoeuvre forward by this four hours. Moreover, even if they had not already had sufficient rest for an immediate EVA, it would have been psychologically impossible for them to sleep for four hours. In fact, a delay did occur in preparing for egress with the result that the LM hatch was opened not four hours, but 1 hour 25 minutes earlier than the scheduled time. On July 21, 1969 at 02.56.20 GMT, Neil Armstrong became the first man to set foot on the moon. Pictures of this historic moment were transmitted to earth, and it has been estimated that some 528 million people in the entire world followed the event on television.

The first step made by Armstrong from one of the landing pads on to the actual surface was made with caution. "That is a small step for a man, one giant leap for mankind". These were the first words that Neil Armstrong spoke

Table 2: Apollo 11: Timetable of Events

Event	Date	Planned Time GMT	Planned Time GET	Actual Time GMT	Actual Time GET
1. First motion	16 July 1969	13 : 32 : 00	00 : 00 : 00	13 : 32 : 00	00 : 00 : 00.6
2. S-1C, Centre engine cut-off		13 : 34 : 15	00 : 02 : 15	13 : 34 : 15	00 : 02 : 15.2
3. S-1C, Outboard engines cut-off		13 : 34 : 41	00 : 02 : 40.8	13 : 34 : 41	00 : 02 : 41.7
4. S-1C/S-2 separation		13 : 34 : 41	00 : 02 : 41	13 : 34 : 42	00 : 02 : 42.3
5. S-2 ignited (command)		13 : 34 : 43	00 : 02 : 43.2	13 : 34 : 43	00 : 02 : 43.0
6. Aft interstage jettisoned		13 : 35 : 12	00 : 03 : 11.5	13 : 35 : 12	00 : 03 : 12.3
7. Launch Escape Tower jettisoned		13 : 35 : 17	00 : 03 : 17.2	13 : 35 : 17	00 : 03 : 17.9
8. S-2 engines cut-off		13 : 41 : 11	00 : 09 : 11.4	13 : 41 : 08	00 : 09 : 08.3
9. S-4B ignited (command)		13 : 41 : 15	00 : 09 : 15.4	13 : 41 : 12	00 : 09 : 12.2
10. S-4B first cut-off		13 : 43 : 40	00 : 11 : 40.1	13 : 43 : 39	00 : 11 : 39.3
11. Earth orbit insertion (space referenced velocity 25,567 fps orbit 115 × 118 miles)		13 : 43 : 43	00 : 11 : 53	13 : 43 : 49	00 : 11 : 49.3
12. Translunar injection (S-4B engine ignition). Burn 347 sec, velocity increase 12,874 fps		16 : 16 : 15	02 : 44 : 14.8	16 : 16 : 16	02 : 44 : 16.2
13. Translunar coast		16 : 16 : 26	02 : 44 : 26	16 : 22 : 13	02 : 50 : 13.0
14. Separation S-4B/CSM		16 : 46 : 46	03 : 14 : 46	16 : 49 : 04	03 : 17 : 04.6
15. First docking manoeuvre		16 : 57 : 00	03 : 25 : 00	16 : 57 : 00	03 : 25 : 00
16. Separation of spacecraft from S-4B		17 : 41 : 45	04 : 09 : 45	17 : 49 : 14	04 : 17 : 14
17. Spacecraft evasive manoeuvre SPS burn 3 sec, velocity increase 19.7 fps		18 : 11 : 45	04 : 39 : 45	18 : 12 : 01	04 : 40 : 01.8
18. First mid-course correction carried out (MCC 2), Burn 3 sec, velocity increase 20.9 fps	17 July 1969	16 : 22	26 : 50 : 26	16 : 16 : 58	26 : 44 : 58.8
19. Lunar Orbit Insertion (LOI 1) into elliptical lunar orbit. SPS burn 357.5 sec, velocity retrograded by 2,927 fps	19 July 1969	17 : 26	75 : 54 : 28	17 : 21 : 50	75 : 49 : 50.5
20. Orbit adjusted from elliptical to circular (LOI 2). Burn 17.0 sec, velocity retrograded by 157.6 fps		21 : 42	80 : 09 : 30	21 : 43 : 37	80 : 11 : 37
21. Undocking C/SM and LM	20 July 1969	17 : 47	100 : 15 : 00	17 : 45 : 38	100 : 13 : 38
22. Separation manoeuvre RCS burn 8.2 sec, change in velocity 2.6 fps		18 : 12	100 : 39 : 50	18 : 11 : 51	100 : 39 : 51
23. LM elliptical Descent Orbit Insertion (DOI). Descent engine burn 29.8 sec, change in velocity 76.4 fps (nominal 69 fps)		19 : 11	101 : 38 : 48	19 : 08 : 15	101 : 36 : 15
24. Powered Descent Initiation (PDI) manoeuvre. Descent engine burn 757 sec (nominal 718 sec), velocity retrograded by 6,775 fps		20 : 07	102 : 35 : 11	20 : 05 : 05	102 : 33 : 05
25. LM touchdown on lunar surface		20 : 19	102 : 47 : 03	20 : 17 : 39	102 : 45 : 39.9
26. Extra-Vehicular Activity commenced (hatch opened)	21 July 1969	4 : 05	110 : 33 : 00	2 : 39 : 36	109 : 07 : 36
27. Extra-Vehicular Activity ended (hatch closed)		8 : 42	115 : 10 : 00	5 : 11 : 00	111 : 39 : 00
28. LM ascent. Ascent engine burn 439.9 sec. Velocity attained 5,060 fps		17 : 55	124 : 23 : 21	17 : 54 : 00	124 : 22 : 00
29. Lunar orbit insertion		18 : 03	124 : 30 : 44	18 : 01 : 21	124 : 29 : 21
30. Coelliptical orbit insertion (CSI). Burn 47 sec, change in velocity 51.5 fps		18 : 53	125 : 21 : 19	18 : 51 : 36	125 : 19 : 36
31. Constant Delta Height (CDH) manoeuvres. Burn 18.1 sec, change in velocity 19.7 fps		19 : 52	126 : 19 : 37	19 : 49 : 47	126 : 17 : 47
32. Terminal phase initiated. Burn 22.8 sec, change in velocity 25.3 fps		20 : 30	126 : 58 : 08	20 : 35 : 32	127 : 03 : 32
32A. Terminal phase final manoeuvre, LM RCS burn 28.4 sec, change in velocity 21.4 fps				21 : 15 : 08	127 : 43 : 08
33. Second docking manoeuvre		21 : 32	128 : 00 : 00	21 : 35 : 00	128 : 03 : 00
34. LM jettisoned	22 July 1969	1 : 25	131 : 53 : 05	23 : 41 : 00	130 : 09 : 00
35. Separation manoeuvre. Burn 71 sec. Change in velocity 3.2 fps				0 : 02 : 01	130 : 30 : 01
36. Trans-Earth Injection (TEI) SM SPS burn 151.4 sec, velocity increased by 3,279 fps		4 : 57	135 : 24 : 34	4 : 55 : 42	135 : 23 : 42.6
37. Second actual mid-course correction (MCC 5). Burn 10.8 sec, change in velocity 4.69 fps		19 : 59	150 : 27 : 00	20 : 01 : 56	150 : 29 : 56
38. Entry interface (400,000 ft altitude)	24 July 1969	16 : 35	195 : 03 : 27	16 : 35 : 07	195 : 03 : 07
39. Communications blackout commenced		16 : 36	195 : 03 : 45	16 : 35 : 24	195 : 03 : 24
40. Communications re-established		16 : 39	195 : 06 : 51	16 : 38 : 59	195 : 06 : 59
41. Stabilizing parachute deployed		16 : 44	195 : 11 : 39	16 : 44 : 09	195 : 12 : 09
42. Main parachute deployed		16 : 45	195 : 12 : 27	16 : 44 : 57	195 : 12 : 57
43. Splashdown		16 : 51	195 : 19 : 06	16 : 50 : 35	195 : 18 : 35

on the moon. Then he moved slowly step by step away from the Lunar Module, but remained initially in the spacecraft's shadow.

Moving under the unusual gravity, only a sixth of that on Earth, proved to be relatively easy. Already on his first steps, Armstrong discovered that he was sinking very little into the powdery surface of the moon. Even the LM landing pads pressed in only one to two inches deep. The cohesive strength of the lunar material was nevertheless so high that the footprints made by the astronauts remained clearly visible and will probably do so for tens or even hundreds of years. The adhesive power of the lunar material was nearly as strong as its cohesive force but it did form a light layer on the astronauts boots. By means of a lanyard, Aldrin lowered a camera to Armstrong before himself climbing down on to the moon's surface. Oxygen for breathing and for suit pressurization was supplied to the astronauts from the Portable Lift Support System (PLSS) packs carried on their backs. The PLSS also supplied cooling water to a liquid cooling garment. The water circulated in a closed loop via a heat exchanger. Return oxygen was cleansed of solid and gas contaminants by a lithium hydroxide canister contained in the PLSS, which also controlled the relative humidity in the suit.

The working programme on the moon for both astronauts included collection of lunar samples and setting up several instruments. The first sample of surface material was collected by Armstrong shortly after setting foot on the moon. This was a contingency sample collected not by careful selection, but simply as quickly as possible, so that if an emergency return was necessary, then at least some lunar material would have been obtained.

After Aldrin had left the LM, he examined the surface area underneath the descent engine and discovered like Armstrong that there were scarcely any traces of the landing. The engine had not produced a crater, only a few rays could be seen which had clearly been caused by the engine. Whilst Aldrin was inspecting the surface, Armstrong took photographs and set up the television camera so that it would transmit panoramic views of the lunar landscape. He then uncovered the plaque which was fixed to one of the LM landing gear legs as a record of man's first landing on the moon. It is inscribed "Here men from the planet Earth first set foot upen the moon, July 1969, AD. We came in peace for all mankind".

The first experiment was then set up by Aldrin. It consisted of a mast, which the astronauts pushed into the surface, and a sheet of aluminium foil hanging from it. Before leaving the moon, the foil was rolled up and sealed in an air tight sample container. Particles of the solar wind should have been caught by the

Table 3: Contractors in the Apollo Programme

System or Component	Subject of Contract	Company
Launch Escape Tower	System	North American Rockwell Corp. Space Division Downey, Calif.
Command / Service Modules and Lunar Adapter	System	North American Rockwell Corp. Space Division Downey, Calif.
	Service Propulsion Engine (SPE)	Aerojet-General Corp. Space Division Sacramento, Calif.
	Ablative heat shield	Avco Corp. Space Systems Division Lowell, Mass.
	Environmental Control System (ECS)	Garrett Corp. AiResearch Mfg. Division Los Angeles, Calif.
	Guidance computer system	General Motors Corp. AC Electronics Division Milwaukee, Wisc.
	Stabilisation and control subsystem	Honeywell Inc. Minneapolis, Minn.
	Space suits	ILC Industries Dover, Del.
	Reaction Control Engines for Service Module (RCE)	Marquardt Corp. Van Nuys, Calif.
	Guidance and navigation system (research and development)	Mass. Institute of Technology Cambridge, Mass.
	Structure	North American Rockwell Los Angeles Division Los Angeles, Calif.
	Reaction Control System for Command Module (RCS)	North American Rockwell Corp. Rocketdyne Division Canoga Park, Calif.
	Adapter structure (LM)	North American Rockwell Corp. Tulsa Division Tulsa, Okla.
	Earth landing subsystem and accessories	Northrop Corp. Ventura Division Newbury Park, Calif.
	Television cameras (Block 1)	Radio Corporation of America Astro Electronics Division Princeton, N. J.
	Main communications antenna systems	Textron, Inc. Dalmo Victor, Inc. Belmont, Calif.
	Portable Life Support System (PLSS)	United Aircraft Corp. Hamilton Standard Division Windsor Locks, Conn.
	Fuel cell powerplants	United Aircraft Corp. Pratt & Whitney Aircraft Division Hartford, Conn.
	Television camera (Block 2)	Westinghouse Electric Corp. Baltimore, Md.
Lunar Module	System	Grumman Aircraft Engineering Corp. Bethpage, New York
	Apollo Lunar Surface Experiments Package (ALSEP) integration	Bendix Corp. Detroit, Mich.
	Primary guidance and navigation system	General Motors Corp. AC Electronics Division Milwaukee, Wisc.
	Reaction control subsystem engine	The Marquardt Corp. Rocket Systems Division Van Nuys, Calif.
	Ascent engine	North American Rockwell Corp. Rocketdyne Division Canoga Park, Calif.
	Communication subsystem	Radio Corp. of America Communications Division Camden, N. J.
	Descent engine Abort guidance system	TRW, Inc. TRW Systems Group Redondo Beach, Calif.
	Lunar television camera	Westinghouse Electric Corp. Pittsburgh, Pa.
Instrument Unit	System	IBM (International Business Machines Corp.) Federal Systems Division Gaithersburg, Md.
Saturn S-4B (third stage)	System	McDonnell Douglas Corp. Astronautics Division Huntington Beach, Calif.
	Attitude control rocket engines	TRW, Inc. Cleveland, Ohio
	Retrorocket motor	Thiokol Chemical Corp. Elkton Division Elkton, Md.
J-2 Engines (third and second stages)	System	North American Rockwell Corp. Rocketdyne Division Canoga Park, Calif.
Saturn S-2 (second stage)	System	North American Rockwell Corp. Space Division Downey, Calif.
	Ullage rocket motors	North American Rockwell Corp. Rocketdyne Division McGregor, Texas
Saturn S-1C (first stage)	System	The Boeing Company Seattle, Wash.
	Retrorockets	Thiokol Chemical Corp. Elkton Division Elkton, Md.
F-1 Engine (first stage)	System	North American Rockwell Corp. Rocketdyne Division Canoga Park, Calif.
Launch Support	NASA launch complex (installation and maintenance)	Bechtel Corp. San Francisco, Calif.
	Launch support services	Bendix Corp. Cocoa Beach, Fla.
	Launch support S-1C stage	Boeing Co. Seattle, Wash.
	Propellant storage facilities	Chicago Bridge & Iron Co. Chicago, Ill.
	Design of launch pad A	Griffels and Rossette Detroit, Mich.
	Launch support service Lunar Module	Grumman Aircraft Engrg. Corp. Bethpage, N. Y.
	Crawler transporter	Marion Power Shovel Co. Marion, Ohio
	Launch support S-4B stage	McDonnell Douglas Corp. Santa Monica, Calif.
	Launch support S-2 stage	North American Rockwell Corp. Downey, Calif.
	1101 Computer for Saturn checkout	Radio Corp. of America Van Nuys, Calif.
Mission Control and Evaluation	Early Apollo Scientific Experiments Package (EASEP)	Bendix Corp. Aerospace Systems Division Ann Arbor, Mich.
	Lunar Receiving Laboratory (LRL)	Brown & Root/Northrop Houston, Texas
	Mobile Quarantine Facility (MQF)	Melpar, Inc. Falls Church, Va.
	Mission Control Center, Houston (Development, installation and engineering support)	Philco-Ford Corp. Western Development Lab. Division Palo Alto, Calif.
Communications and Data Acquisition	Communication circuits for NASA communications network	American Telephone & Telegraph Co. Washington, D.C.
	Re-entry ships	Ling-Temco-Vought, Inc. Dallas, Texas
Systems integration and Analysis	Systems analysis and technical support for manned space flight programmes	Bellcomm, Inc. Washington, D.C.
	Apollo/Saturn 5 technical integration and evaluation	Boeing Co. Space Division Seattle, Wash.
	Apollo checkout equipment, data processing, quality control and technical support	General Electric Co. Command Systems Divisions Daytona Beach, Fla.

foil and analysis on earth should enable the rare gas content of the solar plasma current to be measured and also the tritium (heavy hydrogen) produced by influence of cosmic rays. This experiment represents an international contribution to the *Apollo* programme since the apparatus was developed in Switzerland.

After the solar wind composition experiment had been set up, both astronauts planted the American flag on the moon. Then they made experimental movements, during which they described how it felt to move about on the lunar surface. The overall impression obtained is that moving about on the moon does not present any difficulties and that it can be fully mastered after very little practice.

A telephone conversation between President Richard Nixon and the two astronauts was inserted into the programme. The conversation could be followed by television on Earth. The United States President congratulated both astronauts on their success and remarked that this was, without doubt, the most important telephone conversation ever made.

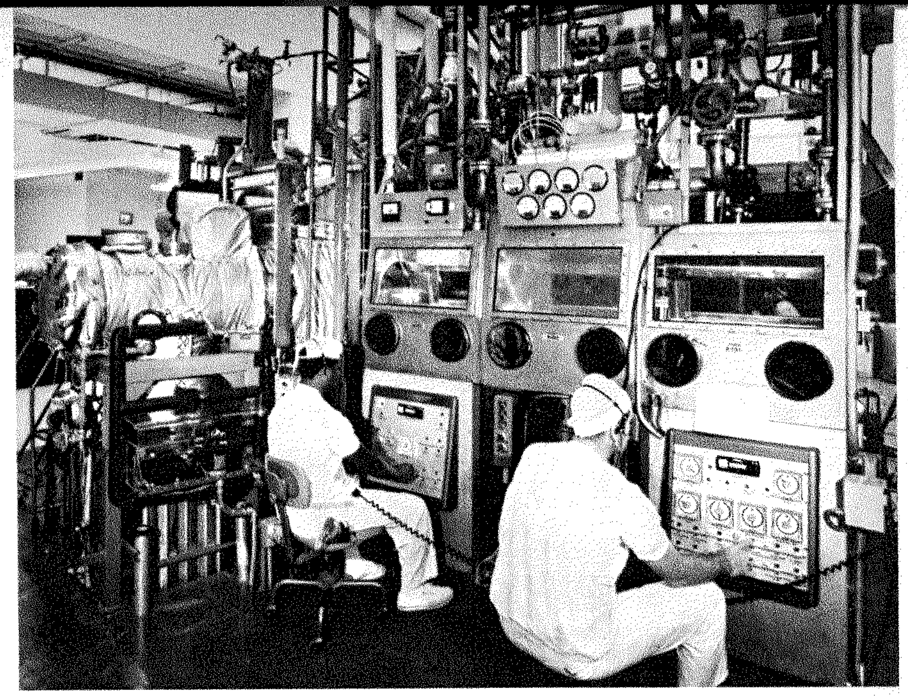
Whilst in continuing their EVA, Aldrin took photographs of the LM from many different angles, Armstrong collected further surface samples. Then the astronauts took two instruments, a seismometer and a laser reflector, from a compartment in the LM descent stage. Aldrin set up these instruments, which were to be left on the moon, some 70 ft and 80 ft respectively away from the LM. The passive seismometer began transmitting data to earth already during the astronauts stay on the moon. The seismometer data should provide a measure of lunar tremors. Over the next few months it promises to provide interesting information on the interior activity of the Earth's satellite.

The laser reflector was not exactly located from earth by the Lick Observatory until August 1st, some two weeks after the astronauts returned. It will be used for measuring the distance from the Earth to the moon, and should provide the celestial mechanics foundation for a more exact determination of the moon's orbit. The instrument is expected to have a lifetime of ten years.

Among Aldrin's other tasks was that of obtaining material samples from a greater depth. For this purpose he had two special tools which he drove in to the lunar surface. At about 11 in depth, however, he met with resistance and could therefore only obtain samples from this depth and not from the tool's maximum depth of 1 ft.

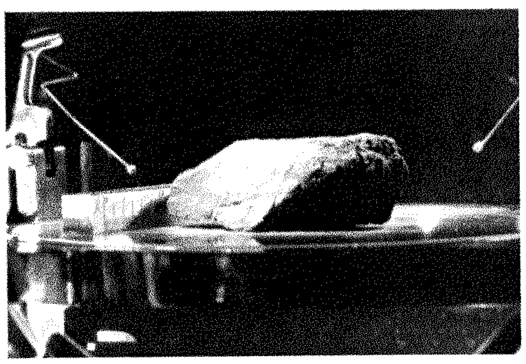
Aldrin, who egressed the LM as second astronaut, ingressed before Armstrong and hauled up from him by means of a lanyard cameras, sample containers and other equipment. At 111 h 37 min 32 s GET (05.09.32 GMT on July 21st, 1969) Armstrong also left the lunar surface. As the first man from Earth to set foot on another celestial body, he had spent 2 h 13 min 12 s outside the LM and on the surface of the moon.

After closing the hatch and repressurizing the cabin, the astronauts removed their boots and other equipment. Then with their spacesuits connected to the LM life support system, they depressurized the cabin, reopened the hatch and jettisonned all unnecessary equipment. This included the two PLSS, the LM armrests, which had been needed on the landing, a lithium hydroxide container, the boots and a camera. The seismometer duly registered the impact of this equipment on the surface. The jettisonning could be seen on television, since the transmission from the moon was still not finished. After this operation was completed, Armstrong and



After their return Armstrong, Aldrin and Collins were placed in quarantine at the Manned Spacecraft Center Lunar Receiving Laboratory. The lunar samples also underwent a preliminary investigation there, before being distributed. The picture shows an installation with sterile airlock, ultraviolet light radiation equipment, acid bath and a cabinet where the boxes are dried with hot sterile nitrogen, all to ensure that they are germ free before being opened.

Lunar Sample No. 10003, the first to be photographed in the Lunar Receiving Laboratory. It is fine grained and appears similar to several igneous rock types found on earth. ▼



Aldrin closed the hatch for the last time and repressurized the cabin. They had already eaten whilst preparing for jettisonning, and now after carrying out a few technical checks and answering some questions, they went to sleep.

Armstrong and Aldrin's state of health whilst on the moon had not given any reason for alarm. Biomedical telemetry signals were continually monitored by doctors on Earth. Dr. Charles Berry in Houston stated that the heart beat of both astronauts during the EVA period reached a minimum value of 90. For Aldrin a maximum value of 125 was recorded twice, and for Armstrong a maximum of 160 was recorded three times.

After the July 21, 1969 rest period of 15 h 10 m—the period was used to restore the programme to schedule—the two astronauts began preparations for the return flight.

The return flight

Because the exact position of the LM on the lunar surface was not known, two additions were made to the flight plan. The first concerned Michael Collins in the Command Module. It required him on the afternoon of July 21st, to measure his position with reference to a known landmark on the moon. From this the inclination of the CSM's orbit with respect to the lunar equator could be calculated, this value being required for the rendezvous manoeuvre.

The second task concerned the astronauts in the LM. They had, with the aid of their radar, to determine the position of the CSM in relation to time whilst it was on their horizon. From these two sets of data, the position of the LM on the moon was determined and it was thus possible to calculate the trajectory corrections necessary during the LM ascent into lunar orbit in order to successfully carry out the planned rendezvous and docking manoeuvres.

Lift-off and ascent of the LM into an elliptical lunar orbit ran practically—with regard to time, power and fuel factors—according to plan (see also table 2). The LM ascent engine burn time was about 1 second longer than scheduled. An additional orbital correction was deemed to be unnecessary.

Rendezvous and docking manoeuvres between the LM and the CSM involved only a few small technical problems, but generally they were carried out fully as planned. Occasional disturbances in communications with Earth were no more than usual. During LM ascent, the LM landing radar was switched off, because it was suspected that the on-board computer alarm during landing was caused by too great a flow of radar data. Up to the present, this theory has not definitely been proven to be correct, but nevertheless during the ascent phase, no computer alarms occured.

Although the transfer of LM crew to the CM was carried out quicker than expected, it was nevertheless without detriment to the time consuming quarantine measures, which had already to be taken into account. The separation of CSM and LM could therefore be made earlier than scheduled in the flight plan.

Trans-Earth insertion and trans-Earth coast ran according to programme and without any technical incidents. The actual coast course was practically identical to the theoretical trajectory and it was therefore possible to limit mid-course corrections, just as on the outward journey, to a single braking manœuvre. Because of bad weather conditions in the planned splash-down area, the landing point was moved some 250 miles to longitude 169°09′ west, latitude 13°19′ north. Using the left capability of the *Apollo* spacecraft, this area was easily reached. The recovery and transport of the astronauts to the Lunar Receiving Laboratory in Houston passed off without trouble.

Immediately after Armstrong, Aldrin and Collins returned, it was already manifestly clear that the *Apollo 11* mission was a total success. The detailed technical evaluation of the mission has confirmed this. With *Apollo 11* the task that President J. F. Kennedy had made America's national goal in 1961 was completed. But with this flight a profusion of scientific and technical knowledge has also been obtained, that will first be evident when the analysis of the lunar samples brought back by Armstrong and Aldrin is completed, when the wealth of data has been evaluated and when it has been thoroughly discussed in scientific circles. ++

NASA's Manned Spacecraft Center

Many thousands of people in all parts of the United States, as well as several other countries, were involved in the successful fulfillment of the late President J. F. Kennedy's objective of landing men on the moon, and bringing them back safely, before 1970. About 13,000 of those engaged were directly involved in the historic *Apollo 11* mission. They were employed at NASA's Manned Spacecraft Center Houston, Texas, an establishment which can justifiably be described as the nerve centre of the operation (though this description by no means detracts from the services rendered by those at Cape Kennedy, on the recovery ships, and in the tracking stations).

The Manned Spacecraft Center is one of the largest, and most modern research and development facilities of the United States National Aeronautics and Space Administration. The Center is situated some 25 miles from Houston and is basically responsible for the following tasks:

- drawing up technical specifications to enable manned spacecraft to be developed both for current and for future programmes;
- project control of companies involved in design, development, and manufacture of spacecraft for the current programme;
- selection and training of astronauts for NASA manned spacecraft flights;
- control of manned spacecraft flights from launch to landing;
- management of medical, scientific and technical experiments, which are carried out during manned spacecraft flights.

In all these tasks the Manned Spacecraft Center is supported by the other NASA facilities, as well as by many other government departments – including the Department of Defense – industry, and many universities and institutions in other Western countries.

The Manned Spacecraft Center and its predecessor, the Space Task Group, were responsible for the *Mercury* and *Gemini* programmes, with which the Americans obtained their first knowledge of man's capabilities during spaceflight. These two programmes, which enabled many new methods of operation to be developed, played a major part in the success of the *Apollo* programme.

During the *Mercury* programme, two ballistic trajectory missions and four single Earth orbit missions were undertaken with the one-man capsules. This programme was completed on May 16, 1963 with splashdown of the *Faith 7* capsule. This was followed by the *Gemini* programme using two-man spacecraft, the last mission, *Gemini 12,* ending November 15, 1966. This second NASA programme provided the opportunity to discover more about the effects of long-term weightlessness on human beings. During the programme, tasks were carried out outside the spacecraft, rendezvous and docking manoeuvres were practised and many scientific and technical experiments were undertaken. All the experience gained with the *Mercury* and *Gemini* programmes has been utilized and extended still further in the course of the current *Apollo* programme. The recent landing on the moon was of course the highest achievement to date, but with this the programme was by no means completed and the work in Houston is being continued in preparation for the next *Apollo* mission.

The Director in charge of all activities at the NASA Manned Spacecraft Center is Dr. Robert R. Gilruth. Six functional Directors (Engineering and Flight Development, Flight Crew Operations, Medical Research and Operations, Science and Applications, Flight Operations, Administration) and two Programme Directors are responsible to him. These latter are concerned with the *Apollo* programme and the AAP (Apollo Applications Program), and their responsibilities also include supervisory mission control of all flights with manned spacecraft. For this purpose the Manned Spacecraft Center is equipped with a Mission Control Center, which contains a wide range of electronic equipment for communication and data transmission, data presentation, simulation and training, as well as for computation. This installation serves two mission control rooms, which can simultaneously support both a real and a simulated mission and constitute the real nerve centre of the *Apollo* moon landing mission. It was on information fed into this Center, that the decisions were based on whether or not the mission should proceed.

Of course, this is only one aspect of the activities of the Manned Spacecraft Center. Over the last few weeks, the Lunar Receiving Laboratory has been much in the news. It was here that the three astronauts and the lunar material samples were housed after their return and the preliminary examination of the returned samples was undertaken before their distribution to 110 scientists in various countries. The laboratory served as a quarantine station for both the astronauts and also people who came into contact with them. NASA designed and constructed the Lunar Receiving Laboratory at a cost of $ 15 million, in accordance with a recommendation of the National Academy of Sciences.

Another important installation on the 2.5 square mile area of the Manned Spacecraft Center is the Laboratory for Simulation of Space Environment, which is used for testing complete spacecraft. There are two space simulation chambers in this laboratory, Chamber A being 120 ft high with a diameter of 64.9 ft, Chamber B 42 ft high and 35 ft in diameter. In these chambers, temperatures varying between plus 127 and minus 173 degrees Centigrade can be produced, as well as very low pressures.

The Manned Spacecraft Center also possesses a remarkable acceleration installation. This consists of a centrifuge, the 12 ft diameter gondola of which weighs 8,000 lb including three occupants and instruments, and this load, at the end of a 50 ft long arm, can be subjected to a continuous acceleration of 29 g, and of 30 g for short periods. Finally, the anechoic chamber in which trials and tests of spacecraft telecommunications equipment are carried out should also be mentioned in this brief survey.

As already stated, one of the chief tasks of the Manned Spacecraft Center is the selection and training of spacecraft crews. This activity commenced as long ago as 1959 and the number of astronauts and scientist/astronauts in training has increased over the years to cater for the increased demand. Now that the United States Air Force has abandoned its Manned Orbital Laboratory (MOL) programme and transferred some of its astronauts to NASA there are now more than fifty in training. All receive a broad training in many fields, as well as a thorough grounding to meet their particular assignments. They are also kept up-to-date with the latest developments in equipment and methods, receiving not only theoretical instruction but also participating in practical exercises, for example, in survival after an unplanned landing in jungle, desert or in the arctic. They practise spacecraft exit manoeuvres and working under conditions of zero gravity. In addition, an attempt is made to simulate the lunar environment as closely as possible, which based on experience gained with the *Apollo 11* mission, should now be more realistic than before. As soon as a crew is selected for a definite mission, they undergo special training which includes hundreds of hours in flight simulators.

After the main target of the *Apollo* programme, a landing on the moon and a safe return to Earth, had been achieved, the activities of the Manned Spacecraft Center shifted in emphasis to the AAP. The important tasks here are planning of the missions, preparation of the crews, and operational control. It is here that, to the greatest possible extent, use is made of experience gained in earlier missions.

The Science and Applications Division's main activity is maintaining contact between all the scientists interested in manned space missions. Essentially, the Division is concerned with scientific exploration of the moon, detection and investigation of mineral sources on Earth, and meteorological investigation. It is also involved with the provision of data to aid in constructing and improving spacecraft, mission planning from the point of view of physical investigations, the design, development and integration of instruments and equipment for scientific and applications purposes, and with the obtaining of data and real time information on radiation, micrometeorites and conditions on the lunar surface.

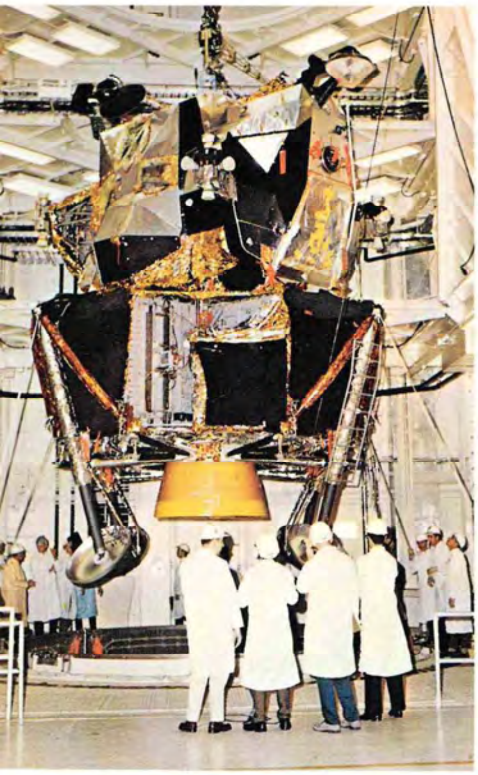
The Manned Spacecraft Center will evaluate a number of operational systems and data acquisition methods which may be of value in the detection and investigation of mineral sources on the Earth, studies of air and water pollution, oceanographic investigations, and geological and geographical surveying. It will also attempt to determine the potential value of spacecraft crews in the task of assessing the world's water resources and cultivation potential more accurately than is possible at present. The majority of this work will not be undertaken by the Manned Spacecraft Center alone, but in close conjunction with other NASA centers or government departments. ++

The Moon

Diameter	2,160 miles (about ¼ that of Earth)
Circumference	6,790 miles (about ¼ that of Earth)
Mass	16.2×10^{22} lb (1/81 that of Earth)
Volume	77.68×10^{16} (1/50 that of Earth)
Mean distance from Earth	238,857 miles
Surface temperature	+121°C (sun at zenith) –173°C (night)
Mean velocity in orbit	2,287 miles per hour
Surface gravity	5.58 ft/s² (about 1/6 that of Earth
Escape velocity	1.48 miles per second

The Apollo programme in pictures

2



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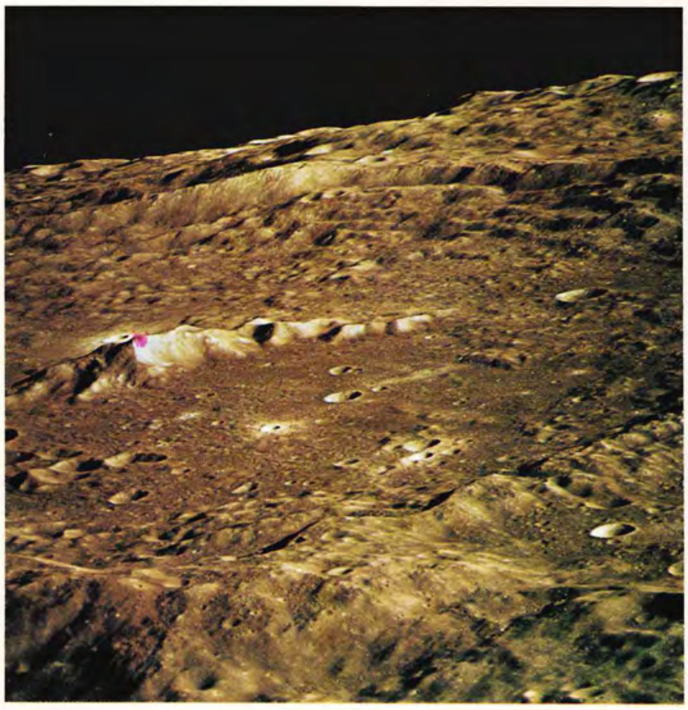

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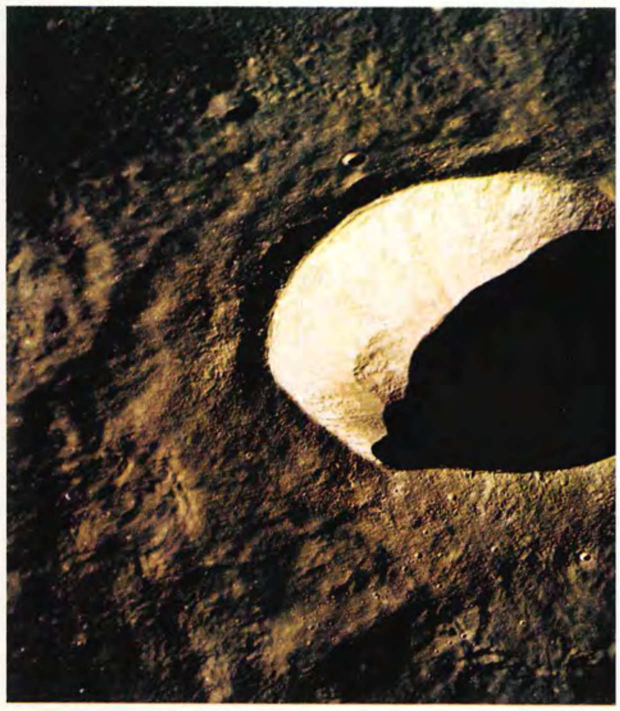


1
The Apollo lunar module LM4, during assembly at Cape Kennedy. The LM consists of two main parts, the ascent stage and descent stage.

2
This unusual picture of the two Apollo modules linked in earth orbit was taken by Russell L. Schweickart during the Apollo 9 mission of 3–13 March this year. At the time he made the exposure, the astronaut was standing on the "porch" of Spider (the name given to the LM during this mission). David R. Scott, pilot of the command module (known as Gumdrop) can be seen in the open hatch of the vehicle. James A. McDivitt, the third crew member, was inside the lunar module at the time the picture was taken, but he also was temporarily in a space environment.

3
The view seen from the lunar module by the two astronauts McDivitt and Schweickart on the fifth day of the Apollo 9 mission. The docking mechanism can be seen in the nose of the command module, whilst the object projecting from the aft bulkhead of the service module is the S-band antenna.

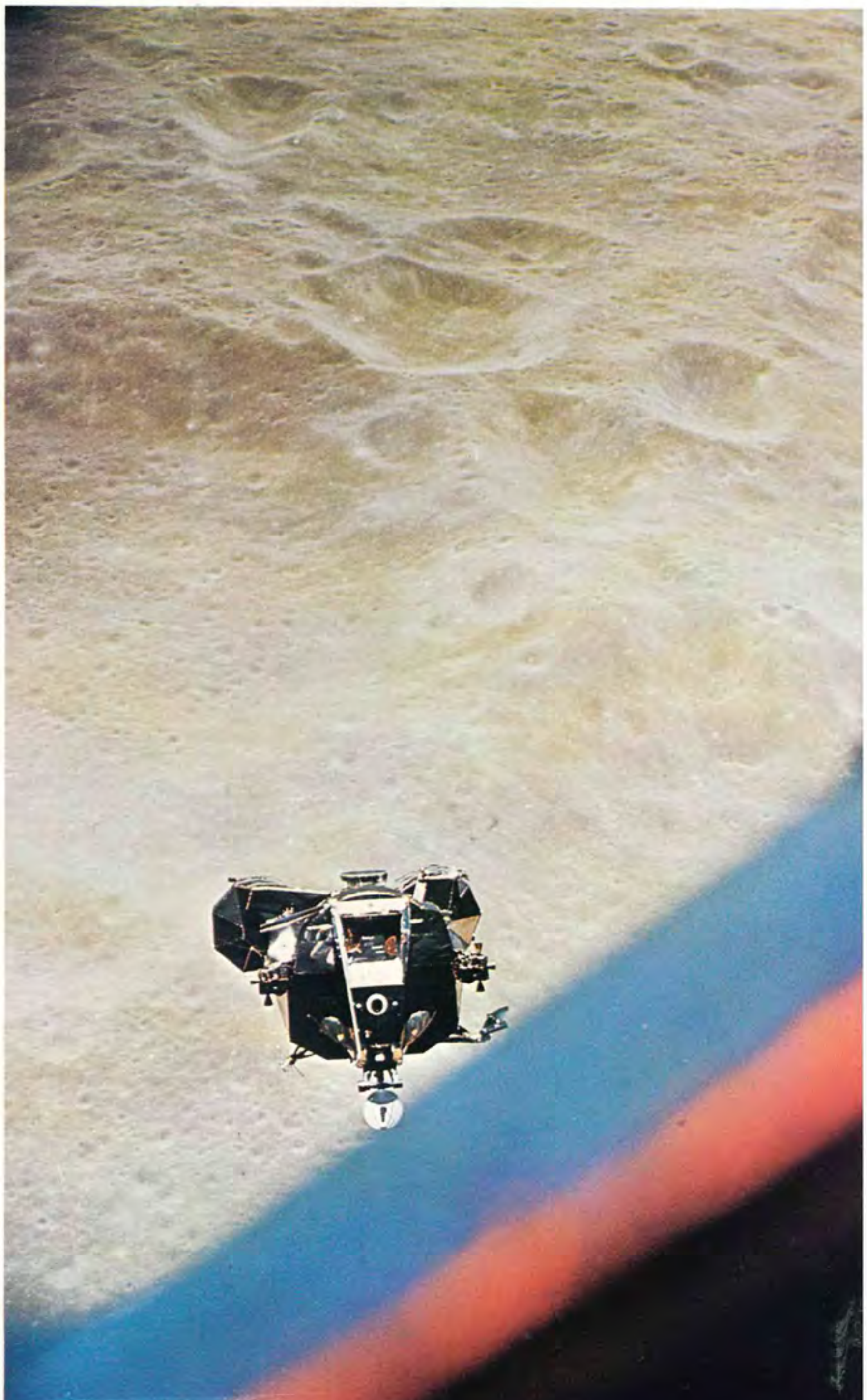
4
Another picture taken by the Apollo 9 astronauts shows the southern end of the Bahama island Andros, the Great Bahama Bank and the area known as the Tongue of the Ocean.

5
A photo taken by the Apollo 10 astronauts from a height of some 60 n. miles above the hidden side of the moon. It shows crater No. 302 in the International Astronomical Union catalogue. The crater exhibits terrassing and central peaks.

6
This photo of the Schmidt crater was also taken by the Apollo 10 crew. Schmidt lies just south of the crater Ritter and immediately west of the crater Sabine: it is some 7 miles in diameter.

7
The ascent stage of Snoopy, the lunar module on the Apollo 10 mission, with astronauts Tom Stafford and Eugene A. Cernan on board, returning to the command/service module (designated Charlie Brown) after descending to within 9.4 miles of the lunar surface. Astronaut John Young remained in the command module in lunar orbit.

7



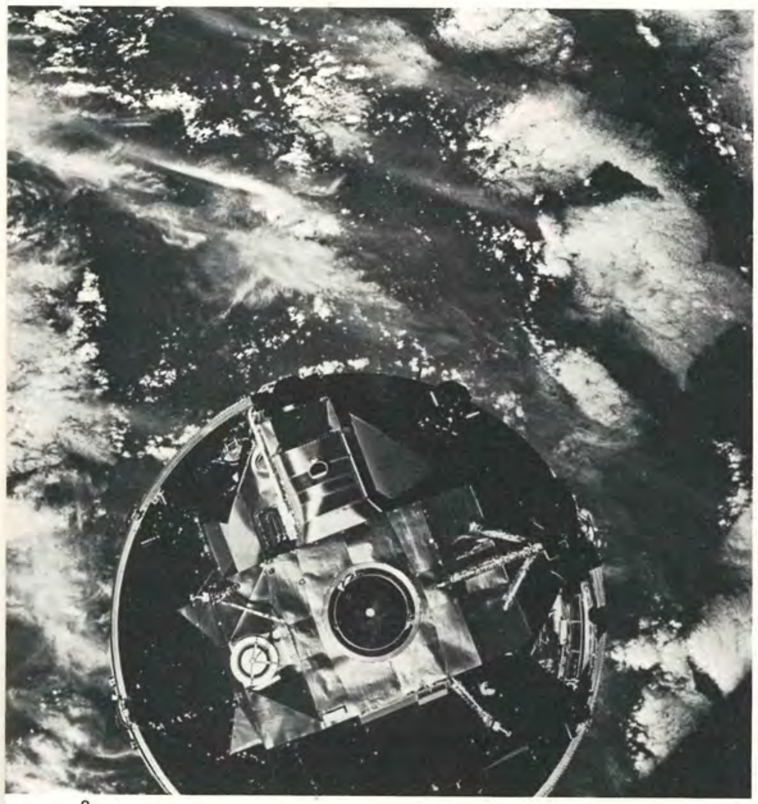
8
A view from the window of the command module during the first day of the earth-orbit Apollo 9 mission. The CM is approaching lunar module LM3, which is still held by the S-4B third stage of the Saturn 5 launch rocket. The adapter panels have already been jettisoned from the latter, and after completion of docking between the LM3 and the command module, the remainder of the third stage was also separated and abandoned.

9
During their 124th earth orbit, the astronauts in the Apollo 9 command module took this picture of a very pronounced low pressure system over the Pacific, about 1200 miles north of Hawaii. On March 11, 1969, the same system was shown equally clearly on a picture taken by the ESSA-7 weather satellite.

10
Technicians making final preparations for the Apollo 10 mission of 18–26 May this year are dwarfed by the 363 foot high Saturn 5/Apollo assembly. The entire rocket/spacecraft combination is 60 feet higher than the statue of Liberty and its base, and is thirteen times the weight of the statue. The Saturn 5 fuel/payload ratio is 50:1 (by weight). The 39B launch complex, shown in this picture, was used for the first time for the Apollo 10 launching.

11
A picture of the Triesnecker crater and the complex of linear features to the right, known as the Triesnecker rills, taken by the Apollo 10 crew from a distance of about 85 miles. This 17-mile diameter crater is situated in the north-east of the Central Bay area. Beyond the highlands at the top of the picture, the smooth surface of the Sea of Vapours stretches to the 375-mile distant horizon.

12
Astronauts Gene Cernan and John Young inspecting the Apollo 10 command module on the recovery vessel Princeton, after their successful return from lunar orbit. Apollo 10 was the second manned vehicle to orbit the moon and, like its predecessor, served as a rehearsal for the historic landing of Apollo 11 crewmen Neil A. Armstrong and Edwin E. Aldrin in the Sea of Tranquility on July 20.



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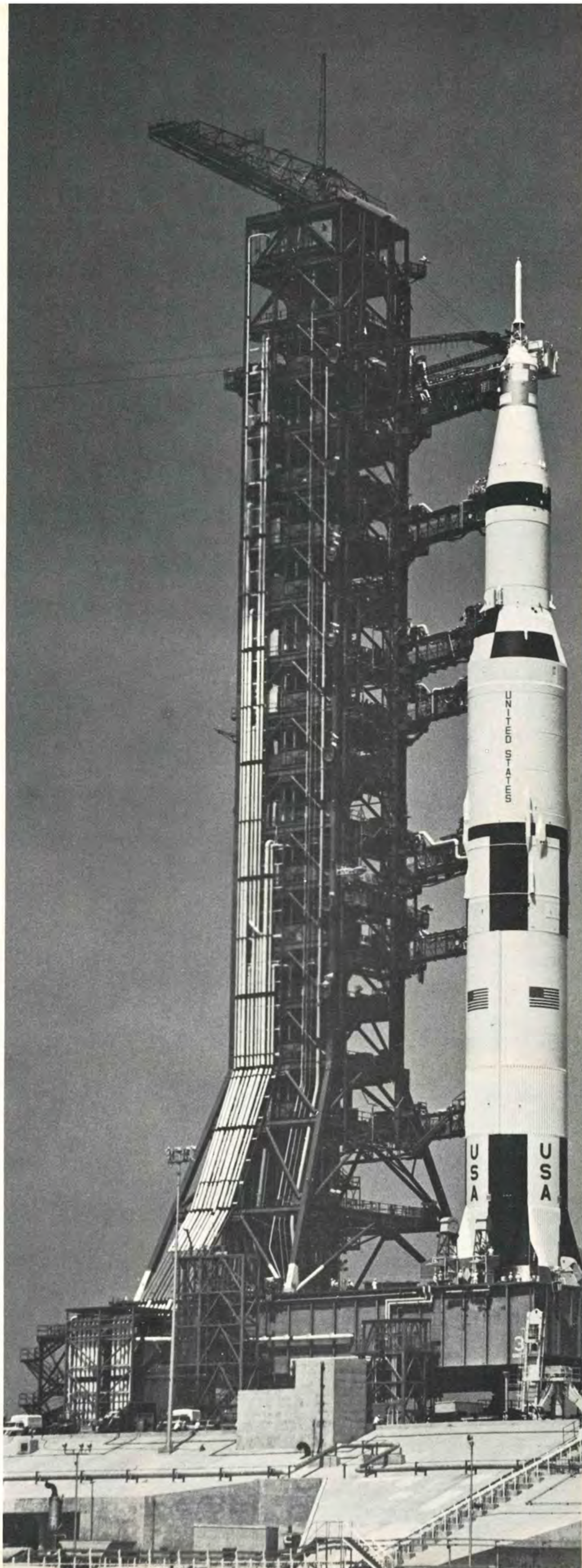

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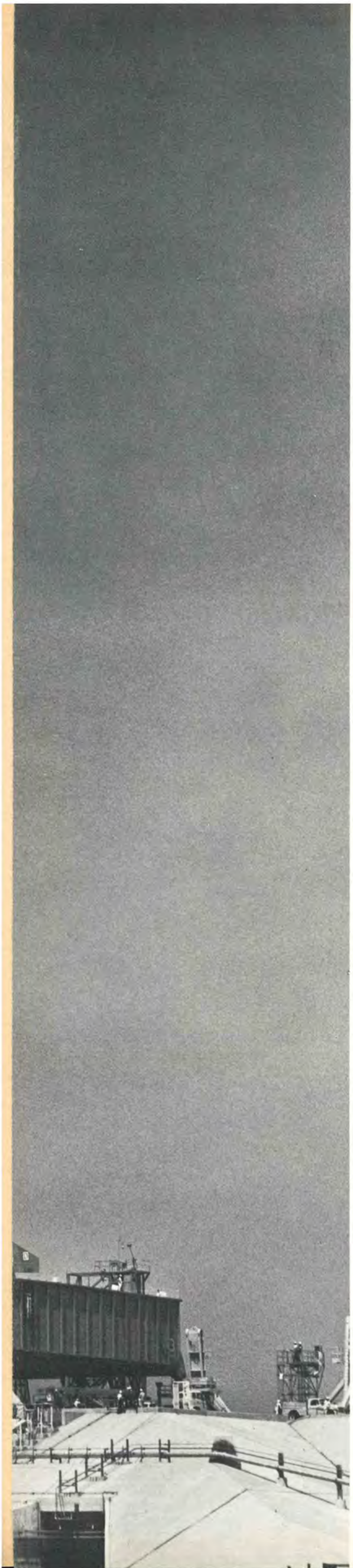

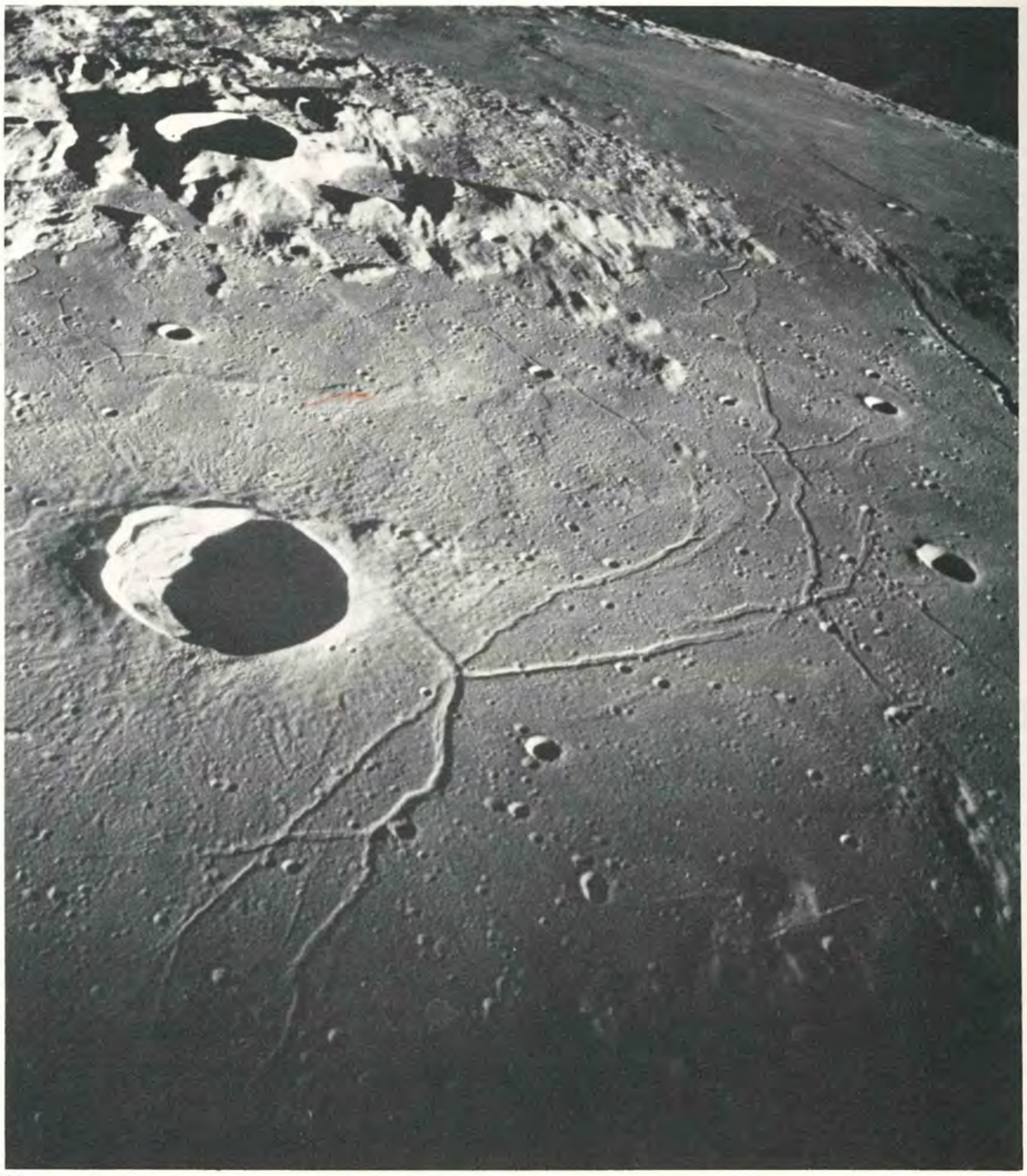

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The Apollo astronauts' space suits

Technical and scientific progress is continually bringing man face-to-face with new and hostile environments. In many cases these simply present the human being with an exaggeration of normal terrestrial conditions — but space exploration has presented him with his toughest environmental challenge so far. It faces the explorer with surroundings and an atmosphere so hostile, so completely different from anything experienced on earth, that an entirely new form of protective clothing must be devised if he is to carry out his exploratory tasks with success. As far as the *Apollo* mission was concerned, NASA entrusted ILC Industries Inc, of Dover, Delaware, with the responsability for producing clothing suitable for the lunar walk.

The successful conclusion of *Apollo 11* marked the end of the most technically demanding enterprise undertaken by mankind to date. In a sense, the moment astronauts Armstrong and Aldrin set foot on the moon the aim of the long NASA programme had been achieved. But Armstrong's first " small step " was no simple routine move. Every action which, on earth, is the outcome of normal reflex or automatic behaviour—breathing, walking, descending the steps of a ladder—is, on the moon, only possible as the result of carefully developed techniques and mechanisms. As man could not exist for more than a few seconds in the airless environment of the moon, he must carry his own earth atmosphere with him. And if he is not merely to survive in this environment, but also to move about in it and carry out various research tasks, he needs with him a complete life support system, light in weight, easily donned and removed, easily stowed and, above all, 100 per cent dependable. In effect, it must be a small walking space ship.

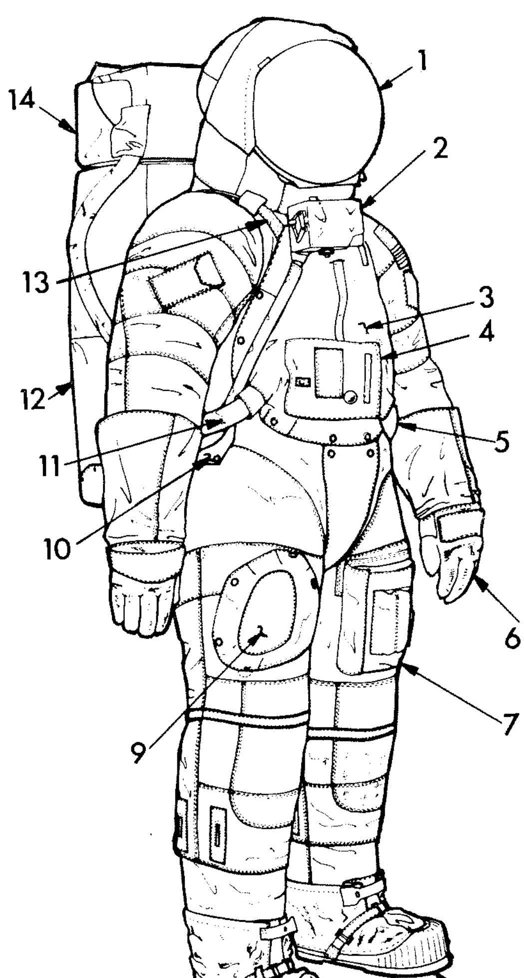
All this was achieved for the astronauts by the combination of their lunar space suits and their PLSS (Portable Life Support System) back packs. During their walk on the moon, this combination provided the men with the artificial atmosphere to enable them to breathe, and with communications and protection. It shielded them from the effects of the pressureless luna environment, exposure to which would rapidly cause the body fluids to " boil " and insulated them against the extreme moon temperatures, which can vary between —120° and +160° C. The suit was also designed to protect the lunarnauts against high speed micro-meteorites and had been made flexible enough to enable them to set up the lunar experiments without difficulty.

Another task which the suit had to be ready to fulfil, was to support the astronauts if any malfunction occured in the lunar module/command module docking system, so that they had to transfer back to the command module through space. The suit also had to be one which they could put on fairly quickly, before the cabin pressure fell too low to support life, if any fault accurred in the pressurisation system. Thanks to this facility, the astronauts were able to take off their space suits for the major part of the voyage, knowing they could be quickly donned in an emergency.

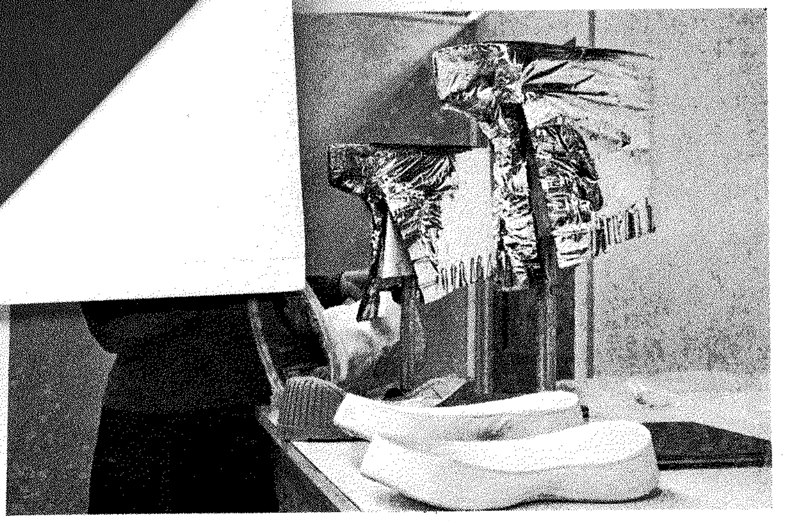
As individual members of the *Apollo* crew were to carry out different tasks, two versions of the space suit were produced. There was one version of the two astronauts who were to leave the lunar module and walk on the moon, and another for the crew member left in the command module in lunar orbit. Over his basic garments, the latter wore a special fire protection suit known as the Intra-Vehicular Cover Layer (IVCL). Instead of this, the two moon walkers carried an outer protection assembly, designated the Integrated Thermal Micrometeoroid Garment (ITMG). This performed the dual function of protection against meteorites and insulation from lunar temperature variations. When the moon walkers connected their suits with their PLSS back-packs they were then provided with oxygen for breathing, pressurisation and ventilation and with telecommunications equipment, to enable them to be completely independent of the spacecraft.

The gas for each astronauts' personal pressure and ventilation system circulates in his suit, helmet and pressure gloves, enclosing him in a habitable atmosphere. The gas enters through either of two inlet connectors and flows to helmet and torso via a system of ducts. It exits via either of two exhaust outlets and is conveyed through hoses either to the environmental control system (when the astronauts are in the spacecraft) or to the PLSS back-pack. The two sets of connectors are provided, to enable the astronaut to check the functioning of his back pack, whilst he is still connected to the oxygen system in the lunar module. The gas flows into the helmet and over its inner surface to prevent fogging of the visor and is then directed to the face area, to facilitate breathing and removal of exhaled air. The flow then passes through the neck connector and is distributed over the body area, contributing to the removal of body heat and moisture. The normal inlet temperature of the oxygen is about 5° centigrade, at a pressure of 3.75 psi (.25 kg/cm^2).

Whilst they are in the space vehicle, the astronauts wear a cotton constant wear garment next to their skin : for their walk on the moon, however, the two men replaced this with a liquid cooling garment. In both cases, the pressure and ventilation suit is worn over this first layer of clothing. The liquid cooling garment



The most important features of the *Apollo* extra-vehicular (EV) space suit. *Key :* 1 – EV helmet and gold-coated visor; 2 – Portable Life Support System (PLSS) control box; 3 – flap covering PLSS connectors; 4 – purge valve access flap; 5 – communications, ventilation and liquid cooling umbilical tubes; 6 – EV gloves; 7 – utility pocket containing lanyards; 8 – lunar overshoes; 9 – urine transfer connector, bio-medical injection and dosimeter access flap; 10 – access to lunar module tether attachment; 11 – umbilical tube for oxygen purge; 12 – PLSS back pack; 13 – PLSS support straps; 14 – oxygen purge system.



Manufacture of the A-7L *Apollo* space suit at the International Latex Corporation (ILC). This picture shows a stage in the production of the lunar overshoes, worn by Armstrong and Aldrin during their moon walk. The suits currently used by the astronauts for use both inside and outside their space vehicles are more comfortable, more flexible and more fire-resistant than earlier models. They have been designed in accordance with recommendations made by the committee set up to investigate the *Apollo* disaster of January 1967.

consists of an outer layer of *Lycra* elastomer fibre, supporting a network of tubes next to the skin, through which cool water is passed, to keep the astronaut's body at a comfortable temperature.

The cooling system used in the command module relies upon circulating oxygen for temperature reduction, this being adequate to deal with the limited movements of the astronauts in this environment. On the moon, however, the astronauts' work-load is much heavier. Without an efficient cooling system to conduct away body heat the men would suffer the results of dehydration, sweat in their eyes and so on. At the same time, however, they still need the ventilation system to replenish oxygen, remove carbon dioxide and control overall pressure.

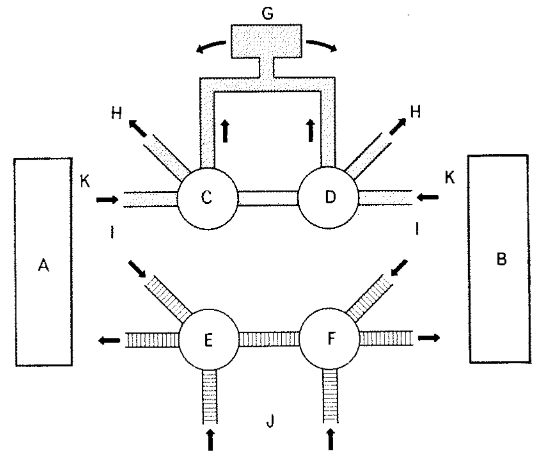
The next layer worn by the astronauts is known as the torso limb suit. This consists of an inner comfort liner of *Nomex* high temperature nylon, a *Neoprene-coated* nylon bladder and an external nylon overall layer. Specially designed joints at the shoulders, elbows, wrists, thighs, knees and ankles provide the flexibility to accomodate body movements. Unlike those in the earlier *Mercury* and *Gemini* suits, the joints in the *Apollo* garment are based on a convoluted bellows design which makes a lower demand on the wearer's muscular effort. The design was developed and patented by ILC Industries.

On top of the torso limb suit goes the astronauts' final, outer garment. As stated earlier, this exists in two versions—the IVCL or Intra-Vehicular Cover Layer for the man remaining in the command module and the ITMG or Integrated Thermal Micrometeoroid Garment for the moon walkers. The IVCL, which is, in fact, worn by all the astronauts at critical moments in the space vehicule, is specially designed for fire protection and consists of three layers of fabric. The inner layer is of *Nomex* fibre and on top of this are two layers of *Beta* glass cloth, woven from yarn coated with *Teflon* fluorocarbon.

The ITMG was designed to protect the moon walkers from micro-meteorites and to insulate them from the extremes of heat and cold on the lunar surface—thereby also reducing the work-load imposed on the PLSS back pack. The garment works on the same principle as an ordinary vacuum flask. It consists of an inner layer of *Neoprene*-coated nylon, alternate layers of perforated aluminised film separated by a low heat conducting spacer fabric and an outer layer of fire-resistant cloth. Specially designed gloves and boots protect the extremities of the space suit against damage due to extreme temperature conditions.

The astronauts' final precaution before leaving the lunar module was to place over their helmet a special gold-coated extra-vehicular visor assembly. The purpose of this was to reduce the intensity of heat and light radiations from the sun and reflections from the lunar surface and to protect the astronauts' eyes from dangerous ultra-violet radiation. The helmet, made from high impact resistant polycarbonate, permits the astronaut free head movement and a wide field of vision. This latter facility was of great importance to the moon walkers, who needed to see their own feet, to enable them to select their steps carefully on the uneven lunar surface.

Diagrammatic illustration of the space suit pressurisation and ventilation system. *Key:* A – Portable Life Support System; B – command module or lunar module life support system; C – left gas inlet connector; D – right gas inlet connector; E – left gas exhaust connector; F – right gas exhaust connector; G – helmet area; H – gas ducts to upper torso; I – gas ducts from upper extremities; J – gas ducts from lower extremities; K – oxygen. The shaded area *(above)* shows gas entry into suit, the lined area *(below)* show gas exit from suit. ►



Another stage in the production of the A-7L Apollo suit: this worker is making ear cups for communications receivers/headsets.

Materials used in the production of the Apollo space suit (Working from the outside to the inside of the suit)

Material	Function	Material	Function
1. **Extra-vehicular suit**		2. **Liquid Cooled Garment**	
Fabric made of fluorocarbon yarn	Scuff and abrasion protection.	*Lycra* elastomer fabric	Retains tubing close to skin
Beta glass fibre fabric coated with *Teflon* fluorocarbon	Fire protection (completely non-flammable in an oxygen atmosphere).	Vinyl tubing	Distributes water to reduce body temperature
Aluminised *Kapton* polyimide film/*Beta* marquisette (for superinsulation)	*Kapton* gives reflective insulation. *Beta* glass fibre acts as spacer to separate reflective surfaces.	Porous lightweight nylon	Comfort layer
		3. **Intra-Vehicular suit**	
Aluminised *Mylar* polyester film	Reflective insulation	*Beta* glass fibre fabric coated with *Teflon* fluorocarbon	Fire protection (completely non-flammable in oxygen atmosphere)
Non-woven *Dacron* polyester fibre	Spacer material	*Nomex* high temperature resistant nylon	Snag and fire protection
Neoprene-coated nylon	Inter-liner	Nylon fabric	Restraint layer for inner fabric
Nylon fabric	Restraint layer for inner fabric	*Neoprene*-coated nylon	Impermeable layer containing suit pressurisation oxygen
Neoorene-coated nylon	Serves as an impermeable layer containing the suit pressurisation oxygen	Lightweight *Nomex* fabric	Comfort liner
Lightweight *Nomex* high temperature resistant nylon	Comfort liner	4. **Constant Wear Garment**	
		Cotton	Comfort layer

Teflon, Nomex, Lycra, Kapton, Mylar and *Neoprene* are all products of the Du Pont Company.

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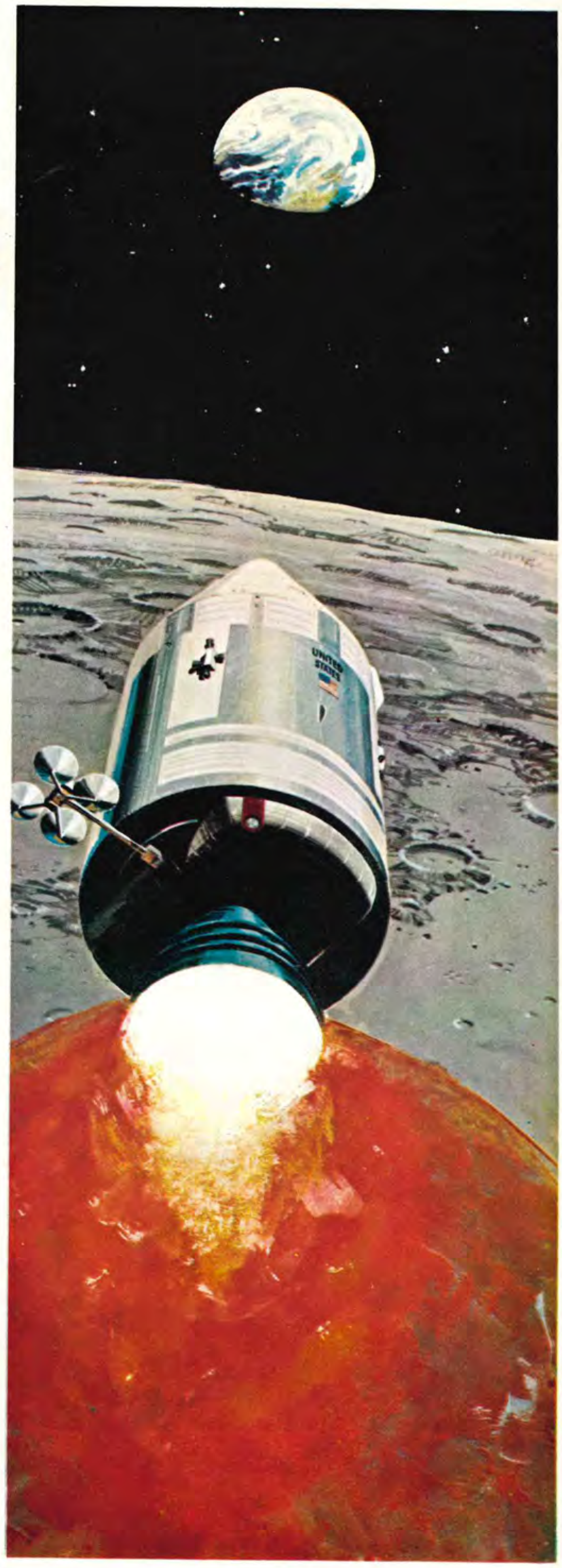

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Space Probes investigate Mars, the Moon and the Sun

America's two Martian probes, *Mariner 6* and *Mariner 7* (see also brief report in *Interavia* 8/1969, page 1038) flew by Mars on July 31 and August 5 respectively, at distances of approximately 2,125 and 1,990 miles. *Mariner 6*, launched from Cape Kennedy on February 24, had been programmed to pass over and photograph the Martian equatorial region, whilst *Mariner 7*, launched on March 27, was to investigate the South Pole and Southern hemisphere. The first pictures from *Mariner 6* were received on July 28 and somewhat disappointed technicians by their poor quality. It must be remembered, however, that these were taken from a distance of some 771,500 miles. But the second series of pictures from the probe more than made up for the disapointment, showing craters and mountain features whose presence had hitherto been unsuspected. These photographs were taken at 42.5 second intervals over a period of 17 minutes.

Mariner 7's behaviour gave NASA scientists some anxious moments when radio communication was lost only a few hours before the fly-by. The interruption lasted some hours, and 78 of the probe's 93 available telecommunications channels were out of action. Jet Propulsion Laboratory technicians, however, were able to overcome the difficulty and *Mariner 7* sent back its first pictures on August 2, when the probe was still at a distance of about 1.1 million miles from the planet. A second series of pictures, taken from much closer, was noticeably better, particularly in contrast, than those from *Mariner 6*. One of these showed a long dark feature, measuring some 75 miles wide by 1,000 miles long, stretching about halfway between the Martian equator and the South Pole. It is believed that this is a feature known as the Agathadaemon "canal", which has already been photographed from earth through astronomical telescopes. On the same picture could be seen a dark area, the Solis Lacus, also known as "the eye of Mars." *Mariner 7* took and transmitted almost 100 pictures of the Martian surface, about 30 of these being close-ups of the South polar region.

Both spacecraft also carried instruments to make various measurements while in the Martian vicinity. Early evaluation of the data transmitted suggests that the planet's atmosphere is totally lacking in nitrogen, but does contain hydrogen, oxygen and traces of carbon monoxide and carbon dioxide. On the basis of present evidence, however, there appears to be little likelihood of finding traces of life of any kind similar to that on earth.

Mariner 6 also registered Martian surface temperatures varying from 24°C by day to —237°C by night. Ice formation was detected in low-lying areas and radar measurements indicated that north of the Martian equator there are surface height variations of as much as 8 miles.

A decisive role in tracking the two American probes was played by the Australian tracking stations of Island Lagoon and Tidbinbilla. Pictures received by the Goldstone, California tracking station were relayed by the Australian telecommunications centre at Deakin, Canberra, working for the Australian Ministry of Supply on behalf of NASA. Island Lagoon was used, at fixed time slots, to transmit steering commands to the space probes. When *Mariner 6* reached the vicinity of Mars, Tidbinbilla took over the job of tracking *Mariner 7*.

At a Washington Press Conference early in August, NASA Director Dr. Thomas Paine commented on the future Mars research programme for the 1980s, the most important of these being a projected manned mission. It is assumed that the space vehicles taking part would consist of a number of large components which would be assembled in earth orbit. Propulsion of the actual Mars research craft would be by a cluster of nuclear engines, each of the component assemblies having its own engine. The launch vehicle would have three stages, two of which would be intended for recovery and re-use. Each spacecraft would be built to carry six astronauts and the whole mission would be carried out as a multiple operation, with a second vehicle accompanying the first and ready to act as a rescue ship in case of emergency. Once the two vehicles had been inserted into a Mars orbit, a Mars landing module, with a crew of three, would be detached and would land on the Martian surface. The astronauts would spend about a month on the planet. The entire mission, including the Martian landing and the return to Earth, would take about two years.

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On August 8, the Soviet Union launched *Zond 7*, an unmanned spacecraft which travelled to the Moon, orbited it and returned to earth. The probe was recovered on August 14 after a soft landing in the scheduled area of Kazakhstan, Central Aia. According to Tass, recovery was made by the "double immersion" technique, previously successfully used for the recovery of *Zond 6*. This involves selecting a return trajectory which causes the spacecraft to encouter the earth's atmosphere at an angle, resulting in a "bounce-off" which has an aerodynamic braking effect. The recovery parachute was deployed at about 30,000 ft.

Among the more important tasks carried out by *Zond 7* was an investigation of solar radiation conditions between the Earth and the Moon, especially with respect to any radiation connected with solar chromospheric eruptions. This was similar to investigations carried out by the *Zond 5* and *6* spacecraft. Another similarity to the two previous *Zond* probes was the photo-emulsion package carried by the spacecraft. This had, as its purpose, an investigation of the multiple charged components of high energy primary cosmic rays.

Zond 7 was also equipped to measure intensity of micrometeorites and to photograph the Lunar surface. In certain respects, therefore, the probe's mission appeared to be a repetition of that of its two predecessors, *Zond 5* and *6*, which were launched in September and November 1968, respectively.

The Leningrad astronomer, Nikolai Kosirev advocated even closer research into the nature of the Moon. Well-known for his research into lunar volcanic phenomena, Kosirev is an advocate of the theory that the moon is still active. He believes that further investigation should certainly reveal whether there are any molecules of organic matter or if there is water in a frozen state, in the interior of the moon. In Kosirev's opinion colonies of scientists should be set up on the moon, with laboratories established either in natural lunar caves or below the surface, as a protection against radiation and meteorites.

★

During the night of August 8/9, satellite OSO-6 (Orbiting Solar Observatory) was launched by a two-stage *Delta* rocket from Cape Kennedy and placed into earth orbit. This solar probe is now circling the earth on a 308 × 347 mile orbit, which differs slightly from the planned 350 mile circular orbit, but is close enough for the purposes of the experiment. The main aim of the 640 lb satellite is to observe solar eruptions and gather information on their effects on radio communications and on the overall weather situation.

It should be remembered that the coming year is expected to be one of peak solar activity and OSO-6 is carrying a total of seven sets of scientific equipment for observation and recording of phenomena. One apparatus from the Department of Physics Mullard Space Science Laboratory, University College, London, designed to measure the intensity of ultra-violet radiation, includes an ultra-violet spectrometer with a range of 170 to 1,216 Angström and an 0.4 A degree of resolution. Earlier satellites in the OSO series, i.e. OSO-3, which was placed in orbit on May 8, 1967 and OSO-4, launched on October 18 of the same year, are still active and continue to transmit a stream of scientific data.

● **Satellite ATS-5,** fifth in the U.S. Applications Technology Satellites series, was launched from Cape Kennedy on August 12 this year. Intended for communications and meteorological research, the satellite began to tumble shortly after separation from the last stage of the launch vehicle and subsequent stabilisation caused such a drain on fuel that NASA decided to place the vehicle in its parking orbit some eleven hours earlier that intended. It was then considered it would take some twenty days to bring ATS-5 into its planned geo-stationary orbit over South America. The satellite weighed about 1,985 lb at launch and will weigh some 660 lb in orbit. ATS-5 is gravity-stabilised and carries thirteen experiments. One of its tasks will be to conduct firings of an on-board ion engine to test its suitability for making orbital corrections.

● **The launch of the second Intelsat 3 satellite,** on Saturday July 26, 1969 did not go according to schedule. It went into an orbit, 173 × 2,963 miles, that was too low and highly elliptical to enable it to be used as a communications satellite. It was however possible to reactivate the first *Intelsat-3*, which launched on May 21 this year, had ceased to function on June 29. This satellite is now in its originally planned position, so that its transmitting antenna is directed towards the earth.

● **Further firings in the Soviet Cosmos series** have been as follows:

Cosmos 291, launched on August 6, 1969.

Cosmos 292, launched on August 14 into an orbit with perigee of 464 miles, apogee of 488 miles, orbital period 99.9 min, and inclination of 74°.

Cosmos 293, launched on August 16 into a 130 × 160 mile orbit, with inclination of 51.8° and period of 89.1 min.

● **Satellite Pegasus 3** burned up over the Indian Ocean on August 4, 1969. Launched on July 30, 1965, this was one of the largest and heaviest American satellites ever orbited, its purpose being to investigate the frequency of micro-meteorites in space. The two previous satellites in this series, *Pegasus 1* and *2* are still orbiting the earth. These two probes were launched on February 16, 1965 and May 25, 1965, respectively.

● **The CNES (Centre Nationale d'Etudes Spatiales)** original request for a budget of 850 million francs for the year 1970 may be cut back to 500 millions by the new French Government—according to reports in the French Press. The amount had already been cut back to 650 million francs by the Finance Minister of the previous Government. This latest reduction, if carried out, will particularly affect French participation in the *Europa* booster rocket and *Symphonie* communications satellite programmes.

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