SPACEFLIGHT

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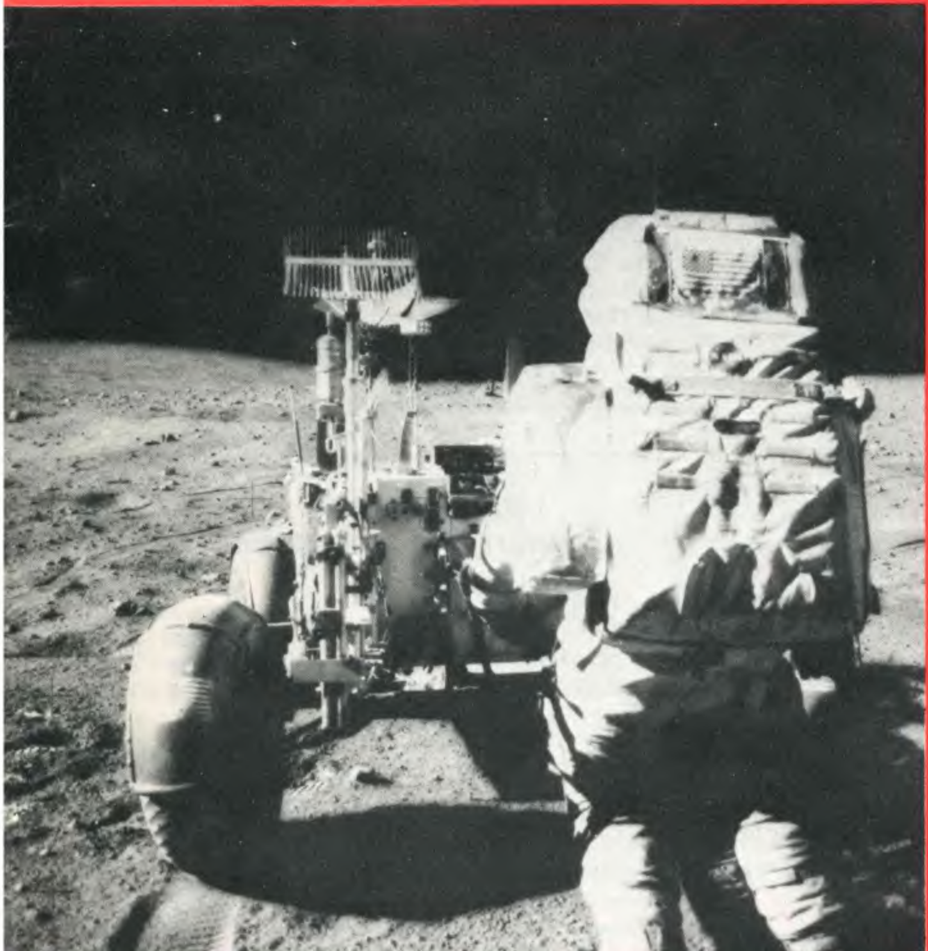

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SPACEFLIGHT

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COVER

MEN OF THE LUNAR HIGHLANDS. Despite a number of technical problems which afflicted both the parent craft Casper and the lunar module Orion, the Apollo 16 mission to the Descartes highlands was immensely successful. Another group of B.I.S. members witnessed the launching at Cape Kennedy on 16 April and visits were also made to Mission Control in Houston and Patrick Air Force Base, Florida. The party returned home in time to follow the landing and the 3 EVA's on TV. *Top left,* commander John Young works at the rear of the lunar rover. *Right,* Charles Duke collects rock samples with the aid of rake and tongs. *Below,* beyond the foreground shadow cast by Orion, the lunar rover is seen on the crest of the landing area. The astronauts travelled a total distance of some 16.7 miles (27 km) in the battery-powered vehicle.

United States Information Service

MILESTONES

Mar

29 United States, Soviet Union and United Kingdom in Washington sign convention on international liability for damage caused by space objects. (These three nations were depository States for the treaty, to which many other nations have since applied signatures). The convention complements two earlier treaties governing Man's space activities: the Outer Space Treaty of 1967 and the Astronaut Rescue Agreement of 1968.

31 Soviets launch second Venera probe of current launch window from Baikonur into parking orbit. Injection rocket fails to impart sufficient velocity and probe (which separates) is stranded in Earth orbit of 210 x 9,813 km inclined at about 52° to equator. Soviet designation is Cosmos 482.

Apl

4 Soviets launch 15 kg SRET (Satellite for Environmental and Technical Research) as double payload with Molniya 1 communications satellite. Orbits range from 480 - 39,260 km (apogee in Northern Hemisphere) inclined at 65.6° to equator. SRET studying effect of radiation and temperature on solar cells by constant passage through radiation belts and Earth's shadow.

7 Soviets launch Intercosmos 6 to investigate high-energy cosmic ray particles' interaction with nuclear photo-emulsions, and to examine physical and chemical properties of dust particles in terrestrial space. Initial orbit is 203 x 248 km inclined at 51.78° to equator; period 88.94 min.

11 Capsule from Intercosmos 6 recovered in Soviet Union.

14 Soviets launch 845 kg solar research satellite 'Prognoz' (Forecast) to record solar radio, gamma, X-ray and plasma emissions and study interaction with Earth's magnetosphere. Orbit ranges between 950 and 200,000 km inclined at 65° to equator; period about 97 hr.

14 ELDO Council announces decision to begin development work on £190 million Europa III launch vehicle programme on 1 October 1972, assuming approval by European Space Conference in July.

16 Apollo 16 with astronauts John W. Young, Charles M. Duke, Jr., and Thomas K. Mattingly II launched from Kennedy Space Center at 1754 GMT.

19 Apollo 16 achieves lunar orbit at 2023 GMT with 6 min. 15 sec. retro-burn (initial orbit 107 x 315 km, modified 4 hr. later to 19 x 107 km).

20 Guidance system fault in main propulsion system of Apollo 16 service module at 1930 GMT delays orbit-raising burn after LM separation.

21 Apollo 16 LM 'Orion' with John Young and Charles Duke begin powered descent 0211 GMT nearly 6 hours later than scheduled; lands in Descartes region at 0224 GMT. One orbit later CSM 'Casper' is repositioned into 80 x 93 km orbit.

24 Apollo 16 LM ascent stage lifts off from Moon at 0126 GMT and docks with CSM.

MISSION TO DESCARTES – 1

By David Baker

Introduction

The story of Apollo 16 really began 4 years ago when interested scientists pressed NASA for a chance to visit, just once, a region of the Moon where formations lie virgin upon the changing scenario of basaltic flow and fresh remodelling. In short, they requested a flight to the lunar highlands, a place apart from the finite moulding of enormous lava lakes that provided footholds for the first lunar landings.

When cutbacks in the NASA budget decreed that Apollo 20's launch vehicle should be re-assigned to Skylab and Apollos 18 and 19 were cancelled, this guaranteed that NASA could make just one attempt in the programme to reach a high lunar plateau.

Men of Apollo 16

Interest in the Descartes site goes back some four flights, to Apollo 12 in November 1969; but not until Apollo 14 had returned with 70-mm handheld views of the area could the green light be given for an actual landing attempt. Since 3 March 1971 John Young, Thomas Mattingly and Charles Duke had been familiarising themselves with the Apollo 16 spacecraft and generally remaining close to decision making procedures. Who were these men?

At 41 years of age Young was a space veteran in every sense of the word. He waited only 30 months after selection as a member of the second group of astronauts to fly with the late Virgil Grisson aboard Gemini 3 which completed 3 Earth orbits, thereby introducing for NASA the era of the multi-man spacecraft.

Thus, Young played an historic role in being aboard the first vehicle designed to prepare men for a lunar landing.

More than a year later his space wings were to carry him toward another epic first. As Command Pilot to Michael Collins aboard Gemini 10 he docked with an Agena target vehicle and used its propulsion system to ascend to a record 475 miles above the Indian Ocean. Subsequently, he took Gemini 10 in pursuit of the Agena used for the first space docking (Gemini 8), using optical systems only and a station-keeping exercise, which allowed Collins to retrieve experiment packages sent aloft 4 months earlier.

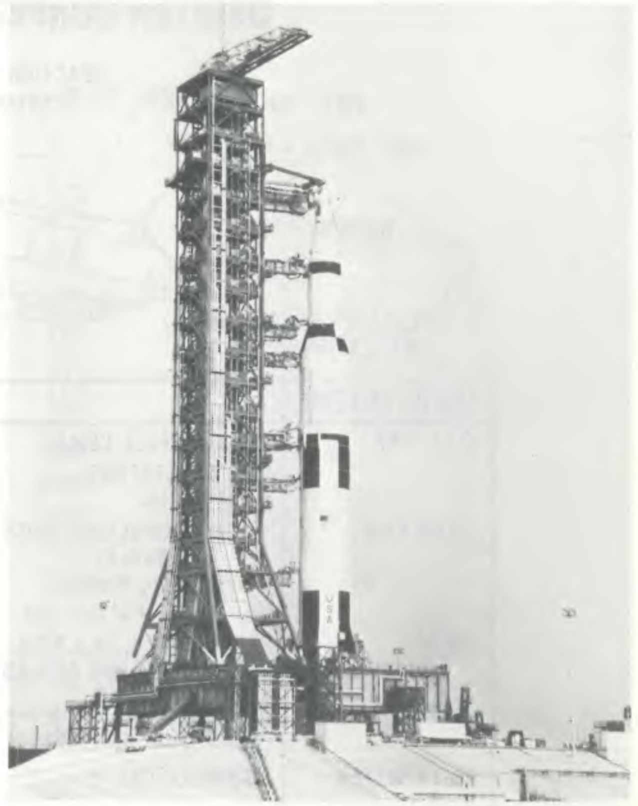
Young's third space flight came in May 1969 when he flew a lone Command Module in lunar orbit while fellow astronauts Tom Stafford and Eugene Cernan put a Lunar Module through its paces and descended to the point of powered descent initiation on a simulated landing mission.

With back-up assignments to Gemini 6, Apollo 7, and Apollo 13 this fifth landing gave Young his seventh nomination to crew status and his fourth operational flight.

Thomas K. Mattingly was selected as a member of the astronaut corps in 1966 and waited only 3 years before assignment to Apollo 13. Three days from lift-off, in April 1970, he was forced to stand down because of exposure to German measles, his place being taken by Jack Swigert.

Selected with Mattingly, Charles M. Duke held the position of back-up to Fred Haise on Apollo 13 and from there went to nomination for Apollo 16.

But what of the vehicles? From the basic capability of Apollo 11 to the evolving maturity of Apollo 12 and 14 we reach, with Apollos 15 and 16, the development plateau for spacecraft of this type. Basically identical to Apollo 15, the CSM and LM of this flight differed only in the scientific equipment they carried.



Members of the British Interplanetary Society toured the John F. Kennedy Space Center on 13 April just 3 days before Apollo 16 blasted off for the Moon.

All pictures National Aeronautics and Space Administration

Only minor changes were made to the launch vehicle (SA-511). One of note was the reinstatement of the full complement of 8 retrorockets located around the base of the first stage. On Apollo 15 four had been removed as a weight-saving measure but insufficient clearance between stages was observed at separation.

The entire Apollo 16 space vehicle was heavier by far than any before, weighing in at over 6,525,000 lb. The total first stage thrust output was slightly reduced from SA-510 (Apollo 15) and this noticeably reduced the acceleration during the first few seconds of flight. Slight variations in the trajectory were optimised around this additional weight.

The Geologic Record

It would be far too presumptuous to assert that we are in a position to relate confidently the history of lunar surface morphology. Indeed, the enigmas that remain after 3 years of manned lunar exploration throw up more problems than have been solved.

All 4 previous lunar landings investigated a different Mare-type surface. Apollo 11 visited the very old *Serenitatis* basin, subsequently filled with basaltic lava flows. Apollo 12 went to the younger and more ambiguous *Oceanus Procellarum.*Apollo 14 settled onto the pre-Imbrian ejecta blanket, and 15 expanded its investigations to encompass pre-Imbrian massifs and Imbrian lava flows. All these areas were a product of the mountain building extrusions from major impact basins or the younger melts that flowed within their interiors.

Nowhere had a landing been effected on the rolling undulations of solidified lava beds laid down by internal convulsions. It was largely a matter of operational confidence that now allowed exploration to emerge from the flat plains of the mare regions to these difficult but more rewarding areas. With only 2 flights remaining,a site 60 km north of *Descartes* was selected in June 1971 for the first true exploration of the lunar highlands, a site as high in elevation as the Hadley Mountains explored by Apollo 15.

To recap events associated with the various lunar periods, the pre-Imbrian record forms the earliest visible remains of deposits predating the excavation of the major basins and includes those features cut by the multi-ring structures of the Imbrian period. This latter is responsible for the major feature-modelling upheavals on the Moon and extends from the deposition of circum-Imbrian materials and structures, through features moulded upon these deposits (post-basin craters), to the filling of these enormous basins with dark mare flow material. The *Eratosthenian* period encompasses those deposits from ejected fields now almost obliterated, substantially defaced by subsequent impact, or craters whose rays are eroded by this same deposition of later material. The *Copernican* period provides the young, fresh, rayed craters whose ejecta patterns overly the earlier formations.

In summary, the first of the 3 geologic eras (pre-Imbrian) laid down the giant multi-ring basins, the second (Imbrian-early *Eratosthenian*) was dominated by volcanic extrusions and massive lava flows, and the third (Eratosthenian-Copernican) decelerated the geologic activity and established a comparatively quiescent Moon. It is the second era that produced the volcanic flows thought to have originated in the early *Imbrian* period and anticipated at the Apollo 16 site.

The precise landing area lies south-west of *Mare Tranquilitatis,* slightly north-east of the crater *Albufelda* and is contained within the *Theophillus* quadrangle. The site straddles the juxta-position of *Descartes* and Cayley plains formations, each encompassing massive areas of the surrounding highlands. Together with the Kant plateau directly east of the site and extending as far north as the lunar equatorial plane and as far south as the latitude of *Albulfelda,* lava flows of varying viscosity have moulded plains, undulations, ridges and hills from the elevated mountain plateau that form the highlands.

Beneath the dominating Cayley formation, a volcanic flow unit of low viscosity, it is presumed that material of the Fra Mauro formation (Imbrian basin ejecta) lies on top of fragmental debris covering deposits from the *Nectaris* basin. Beneath this, pre-Nectaris materials would represent the early pre-Imbrian moulding of the original crust.

The Cayley plains area selected as the landing site is flanked to the north, east and south by Descartes material, a more highly viscous material forming ridge lines, undulations and steep hillocks which have flowed from beneath the Cayley formation and deposited a thick blanket. Sixty kilometres due east of the site lies the Kant plateau, a material mid-way in viscosity between the Cayley and Descartes formations and presenting a topography of broadly rolling surfaces similar in many respects to the Cayley formation but present also in a moderately congealed form on slopes rather than responding to inclinations like the mare fill of the great basins.

Fifty kilometres west of the site a presence of scarps amid numerous fault lines, grabens and fissures provide evidence of a crater wall that probably pre-dates the major basins and lies deep beneath the overlying ash deposits. This giant crater some 150 km across has its eastern rim covered by Kant material and the landing site and total area of geological traversing lies close to its centre. The crater Dolland B straddles the western rim and itself is of pre-Imbrian origin.

The local area of the Apollo 16 landing site centres on a

A group of 48 members and friends flew to Houston, Texas, on 14 April to visit NASA's Manned Spacecraft Center. They toured the Mission Control Center (above), the Lunar Receiving Laboratory and inspected astronaut training facilities for Apollo and Skylab.

At the Kennedy Space Center Apollo 16 mission commander John W. Young looks back at crewmen Thomas K. Mattingly II, left, and Charles M. Duke, Jr., prior to entering the command module mission simulator 4 days before the actual blast-off. The day's practice ranged from simulated lift-off to translunar injection.

3 by 4 mile embayment of Cayley material, with the Descartes formation rising to the north and south as Smoky and Stone Mountains respectively.

Two very conspicuous, rayed craters both of the late Copernican period, appear to the north and south of the landing site. North Ray, is situated high above the Cayley Plains and may well have excavated Descartes in addition to exposing the lower strata of the plains material. Visible layering detectable in the north wall would confirm this. The younger South Ray lies 10 km SSW of North Ray, its rays overlapping those from the earlier impact. All craters in the areas are of impact origin. Less than 3 km north-east of South Ray a very young bright crater, Baby Ray, has punctured the ejecta from its larger neighbour and straddles a rimless depression. Directly north-east of the landing site, situated some 1½ km away are the companion craters Palmetto and Gator, larger in diameter than either North or South Ray. Of *Eratosthenian* age they appear very subdued and present a well eroded profile. Younger than Palmetto and Gator but older than North Ray are the smaller craters Flag and Spook located due west of the landing site.

All of these craters are far too small to have punctured the Cayley formation down to the Imbrian basin deposits or indeed to have excavated much of the Cayley material itself. However, they do reveal various stratified layers of highly fluidic magma flow and can adequately expand upon the relationship of the Descartes Mountains to both the Cayley Plains and the Kant Plateau.

The Mission

The original schedule for Apollo 16 specified lift-off on Friday 17 March 1972 but subsequent events were to bring about a postponement of one month.

The Saturn V SA-511 supporting CSM-113 and LM-11 was originally taken out to Launch Complex 39A on 13 December 1971, to be returned to the Vehicle Assembly Building on 17 January in order to change RCS propellent tanks in the service module.

By early January, Charles Duke had contracted pneumonia and was admitted to Patrick Air Force Base hospital late in the afternoon of the 4th. Within 3 days potential trouble areas had re-cycled the launch date to 16 April. During tests associated with the docking ring jettison procedure on a Skylab mission a failure was recorded that indicated the presence of small empty cavities in the potting compound used to retain the explosive charge. This was the same hardware as installed on Command Module 113 and necessitated a complete re-potting.

Also, during capacitance tests on the Lunar Module descent batteries a flunctuation was noted that required a major design change. The batteries themselves were replaced but a large amount of time was required to compile adequate test data.

Finally, modifications were needed to the swage fitting of a pressure suit restraint cable, additional tape was required on the boots, and it was necessary to make further tests to validate the modifications. The enforced one month postponement allowed sufficient time for the Lunar Module Pilot to recover from his illness.

On 9 February back went the huge assembly to LC-39A. A Flight Readiness Test was held on 1 March and a 'go' from the launch director to proceed with the loading of hypergolic fuels was given on 10 March. The corrosive effect of these chemicals restricts the vehicle to a 3-month capability beyond which removal of the fuels and flushing of the tanks adds to the required time to achieve a launch readiness. The countdown demonstration test was held on 19-30 March, with the crew present on the latter date.

As launch day approached preparations assumed a more comforting tranquility and the terminal countdown began without trauma. Within hours of the projected launch time of 17:54 G.M.T. problems were overcome with a fluctuating gyro in the Instrument Unit of Saturn V used for back-up trajectory control. A reported leak in a pressurisation tank of the launch vehicle was ultimately to prove no threat.

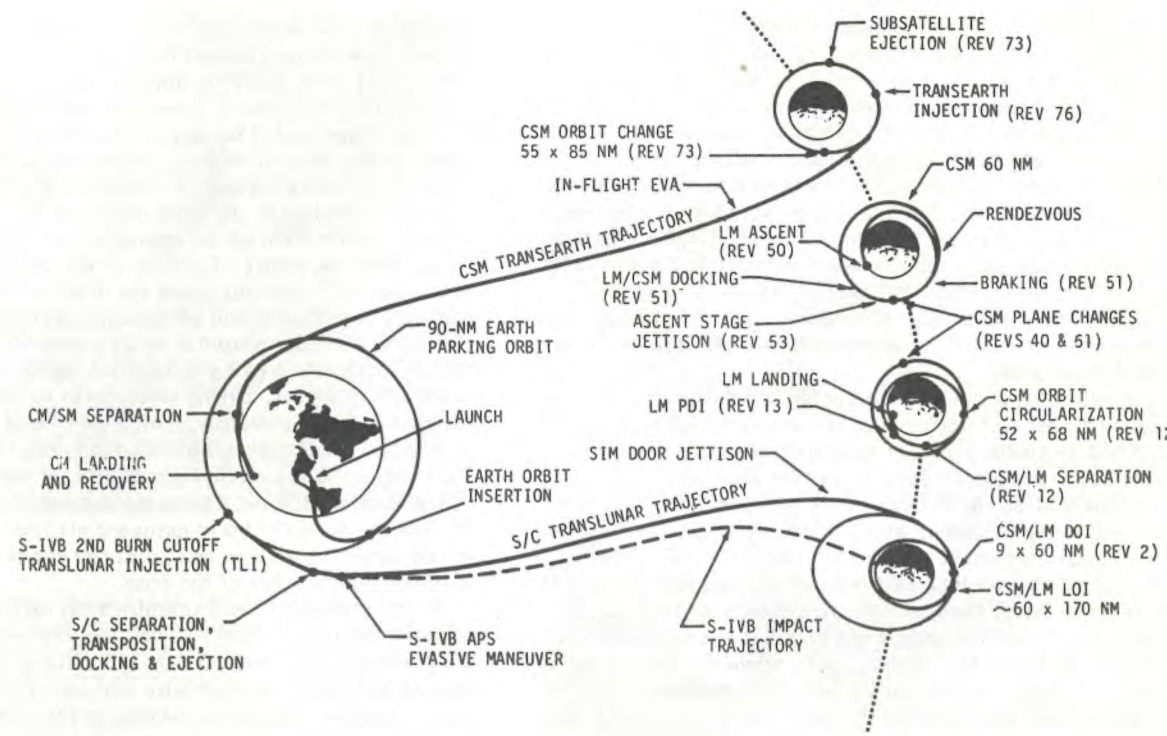
Lift-off came on time and all the way into orbit the events associated with staging and vehicle thrusting occurred with clockwork precision. A minor problem with the guidance platform aboard the CSM was quickly rectified and trans-lunar injection came less than 2½ hours after achieving orbit, with the now familiar ARIA aircraft tracking the S-IVB burn over the Pacific Ocean.

For the next 3 days the spacecraft coasted toward its lunar encounter due late in the evening of 19 April.

On-board Experiments

One of the in-flight experiments carried by Apollo 16 was called Biostack. Consisting of several layers of bio-

This was the original Apollo 16 flight plan. Owing to a technical problem with the propulsion system of the service module in lunar orbit, the Moon-landing was delayed 6 hr. and 3 lunar revolutions. Despite this a full exploration programme was performed though the mission returned to Earth one day early.



logical materials interspersed with radiation track detectors, its object was to provide additional information on the effect which cosmic rays have on biological structures. This was done by measuring the energy of high-energy heavy ions and noting their influence on the materials contained within a 3½ x 5 in. cylinder housed at the base of the docking tunnel opposite the radiation monitor which is fitted to all command modules.

One of the most evasive NASA acronyms was given to the device carried by the crew to obtain a physical record of the passage of high-energy particles through the structure of the spacecraft and themselves. Called ALFMED, for Apollo Light Flash Moving Emulsion Detector, the device resembled 2 flat boards joined at the front and attached to the astronaut's head in the manner of a medieval visor. Two emulsified plates are mechanically moved in parallel and wearing the device the crewmember keeps a verbal record of light flashes registered by his brain. Later, this can be correlated with cosmic ray tracks actually left in the boards and aligned to determine the direction of travel and hence the trajectory of the particle. In this way additional information is available to analyse the nature of the flashes and to help to confirm whether they are due to Cerenkov radiation from high-energy particles entering the eyeball, atomic particles ionising upon collision with the retina or cerebal cortex, or simply visual phosphenes induced by the penetration.

Originally carried by Apollo 14, the electrophoretic separation demonstration was improved on Apollo 16 more clearly to effect particle separation when energised. The successful completion of this experiment has direct relevance to the preparation of hybrid chemicals on permanently manned space stations. Tests similar in nature but more advanced in concept are planned for Skylab flights next year.

Operation of all these experimental tasks required the attention of the crew during the translunar coast period, but one designed to study by photography the streams of particles moving along with the spacecraft got an unexpected dowsing. Paint particles were observed by a TV camera to be flaking off the upper part of the lunar module from an area surrounding the docking drogue.

In-flight Problems

Approaching the Moon, minor crises were to raise doubts on the continuation of the mission and none more so than the 'lock-up' in the guidance platform caused by an indication to the computer that a gyro had been gimballed to its tolerance. A manual reset followed star alignment checks by Mattingly.

The only mid-course correction manoeuvre required was a 2 second burn of the big service propulsion system and, with the door of the Scientific Instrument Module bay jettisoned, the docked vehicles swept around the western limb of the Moon to enter orbit little more than 74½ hr. into the flight. Troubles, however, prevented the inert S-IVB from impacting its planned area west of the Apollo 12 site; a faulty pressure valve moved the point farther north and nearly 200 miles to the east.

Once again a slight procedural change had reduced the time spent in lunar orbit prior to landing by one revolution. The timeline was preserved intact up to the point of separation. Hitherto the CSM circularised its orbit from the elliptical 57 x 12 nm imparted on the second revolution, to a constant 57 x 54 nm at the end of rev. 12. This is usually followed on the 13th rev. by landmark tracking to define fully the orbital path following the final manoeuvre: the separation of the 2 craft. Landing has always been effected on the 14th revolution.

Due to the increased stay time attempted with Apollo 16, the improved topographic model for this site, and the confidence of 4 flights over approximately the same area, the Lunar Module was scheduled to attempt a landing directly after circularisation of the CSM on rev. 13.

From orbital insertion the events were cycled off with the precision now familiar from the spacecraft and Houston Mission Control. The descent orbit insertion was satisfactorily accomplished on rev. 2 and, as expected, there was no need for a trim manoeuvre as carried out by the CSM of Apollo 15. The giant basin-seated mascons of *Imbrium* and *Serenitatis* lay directly below the flight path of Apollo 15 and over several orbits the altitude was reduced considerably causing David Scott to perform a slight trim that effectively raised the altitude again.

Apollo 16 did not have this problem as its path was aligned across vast expanses of pulverised highland deposits that hid no visible traps for trajectory planners. No trim manoeuvre was planned and none was necessary.

Shortly after 18:00 GMT on 20 April, a little over 96 hr. into the mission, Casper let loose 'Orion' to prepare for its circularisation burn at the end of revolution 12. 'Orion', nursing a defective high-gain S-band antenna that refused to steer on to Earth alignment, drifted slowly away from its parent craft. Around they went together over the western limb of the Moon and 46 min. later, when the time came and went for Casper's appearance, the communications officer told the flight director that the burn had not occurred and the vehicle was still locked in low orbit.

Acquisition of signal confirmed this. It was a serious problem. In contrast to the epic abort of Apollo 13, when realisation of disaster crept up slowly over 2 or 3 hours, the Mission Operations Control Room at Houston had the full impact of a heart stopping implication from Tom Mattingly that his life and those of 2 men, by now a mile away, were seriously imperiled. The thrust vector control system, when slaved to the manual back-up mode, would not hold the engine bell steady if fired in that configuration.

With a constantly changing mass it is necessary to have an off-centre alignment of the engine so that the thrust vector, in line with the centre of gravity of the entire vehicle, can boresight the burn right down the desired flight path. In the primary, or guidance and navigation control system mode the command module computer sends pulses through 2 potentiometers located in a yaw gimbal drive motor and a pitch gimbal drive motor, driving screw jacks to physically 'turn' the entire engine assembly. Roll control is effected by rolling the entire spacecraft with the small 100 lb. thrust RCS engines mounted in 4 quads of 4 on the outer surface of the Service Module. The computerised control compares the alignment of the body-mounted attitude gyros (BMAG's) to the desired deviation and holds the engine at this offset level for the duration of the burn.

In the manual mode 2 thumbwheels on the main display console, the pitch wheel vertical, the yaw wheel horizontal, are overriden by a vertical strip indicator doubling as a second and third stage pressure indicator (redundant when these stages are separated). Slaved to the translation hand controller the crewmember can control the gimbal angles with his left hand and hold roll attitude with his right.

Always, when setting up the computer and the displays

APOLLO 17
TAURUS-
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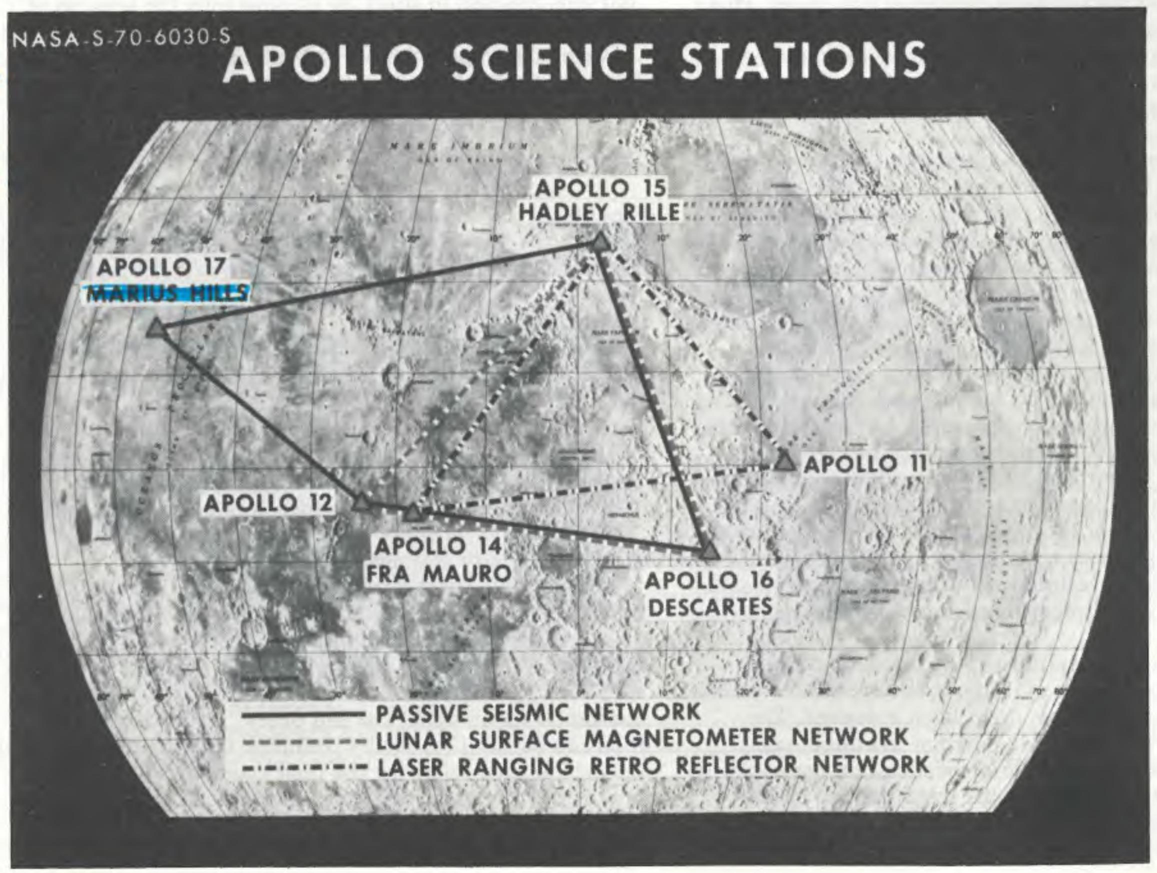


After the final Apollo mission next December there will be a network of 5 ALSEP stations on the Moon. The laser ranging retro reflector network is already complete at the landing sites of Apollo 11, Apollo 14 and Apollo 15.

Two of the 3 Apollo 16 prime and backup crewmen compare notes during spacecraft mission simulator practice sessions at the Kennedy Space Center. From left are Charles M. Duke, Jr., prime lunar module pilot; Edgar D. Mitchell, backup lunar module pilot; Fred W. Haise, Jr., backup commander; John W. Young, prime commander. *Right*, John Young and Charles Duke during an EVA exercise in preparation for their lunar landing.
National Aeronautics and Space Administration

the manual, or stabilisation and control system, is tested so that it too is in standby and known to be operational prior to punching the proceed button on the computer keyboard for automatic SPS iginition and control. It was during this test of the SCS that Mattingly noticed a wide divergence in the gimbal angle, with the engine bell thrashing uncontrollably in yaw ±1° from the desired setting. In every firing to date on all lunar flights the gimbal trim angles have never been required to move more than ¾° from the fixed axis of the spacecraft. Yet if the manual mode were used a 2° travel out of alignment would occur, playing havoc with the resulting trajectory.

Immediately the problem was understood it remained to be confirmed that oscillations would not also occur in the primary, computer controlled mode. If this was confirmed the safety of the return flight would depend upon the descent engine in the LM.

The landing attempt was called off for revolution 13 and Young and Duke ordered to close once again with Casper, there to station keep and await further results from tests already being run in simulators at California and the Manned Spacecraft Center in an attempt to resolve the problem. If no solution was found the LM could not land as it would rob the crew of a back-up engine to return home. Just 5 revolutions remained before the orbital ground track would migrate too far west and south of the landing site for the LM guidance to steer back to the Cayley Plains.

As the spacecraft went around the western limb of the Moon on revolution 14 a decision was awaited on the fate of the mission. Top NASA management convened to discuss the situation, review the problems, evaluate the consequences and announce the course of action. For the first time the Flight Director stood down and waited word from a higher level. It was James B. Fletcher the NASA Administrator himself, who gave the 'go' for a landing attempt on revolution 16.

With the Service Module propulsion system problem resolved Thomas Mattingly, alone in the Command Module, fired up the SPS on a computer-controlled burn to circularise the orbit at the end of the 15th revolution, reporting the success on acquisition of signal.

New updates were fed to the Lunar Module computer for the descent and ignition came on time for a perfect descent to the lunar surface, only seconds beyond the nominal 12 min. 2 sec. duration in the flight plan. Touching down within several hundred yards of the designated spot. Young and Duke became the 9th and 10th men to land on the Moon. From a mission that only hours before had bordered on failure the confidence and expertise built up through years of hard-won experience had paid off handsomely. The most successful lunar expedition in terms of scientific return was about to begin.

[To be continued.

NEXT MONTH

Next month's issue will include a further illustrated report on Apollo 16 and the first detailed account of a highly successful British experiment with an Earth Resources Skylark. There will also be the first of two articles, 'Missions to Jupiter', and a personal profile of Rocket Engineer Charles E. Tharratt.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

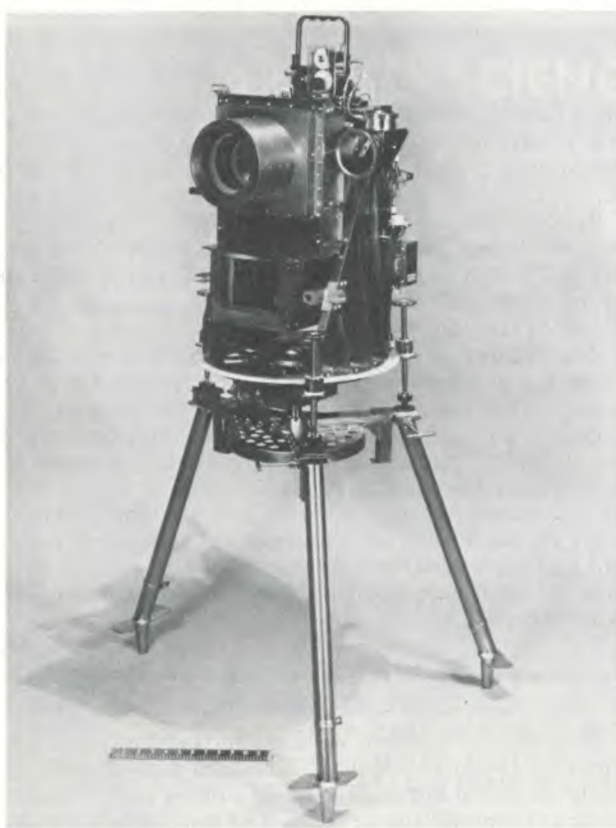
ASTRONOMY ON THE MOON

Astronauts John Young and Charles Duke opened a new age of astronomy in April by operating a combination camera and spectrograph on the Moon, writes David Dooling, Jr., Designed and built by the U.S. Naval Research Laboratory, the experiment was intended to obtain far ultra-violet images of the Earth's geocorona and its interaction with the solar wind, the solar wind itself and its interaction with interstellar gases, and extragalactic sources. Scheduled objects for study included the Andromeda Galaxy, the Magellanic Clouds and the Coma clusters of galaxies.

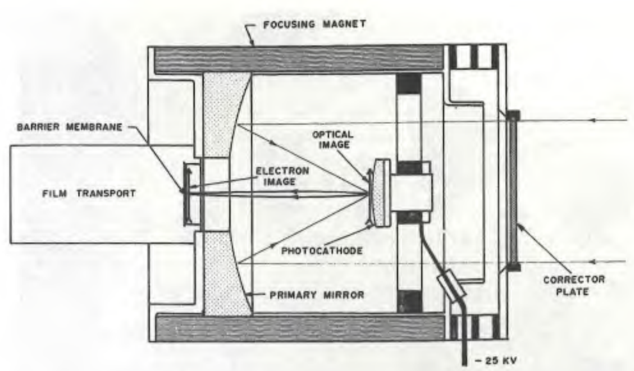
The Naval Research Laboratory had previously carried out many scientific and sounding rocket experiments aimed at the ultra-violet output of the Sun and will be responsible for one of the Apollo Telescope Mount experiments on Skylab.

Observing the Universe in the ultraviolet spectrum is restricted on Earth because the atmosphere absorbs and scatters ultra-violet light many miles above our heads. Sounding rockets and satellites can do much to alleviate this problem, but in turn find their targets partially veiled by the geocorona (gases and particles that form the tenuous upper atmosphere or are trapped in the Earth's magnetosphere). Observing the geocorona itself from within is also difficult – the only satisfactory way is to observe it from without.

Instead of directly photographing its targets with UV light, a process that yields one to three blackened film grains per



The NRL Far UV Camera/Spectrograph.



Simplified cross-section of the electronographic Schmidt camera.

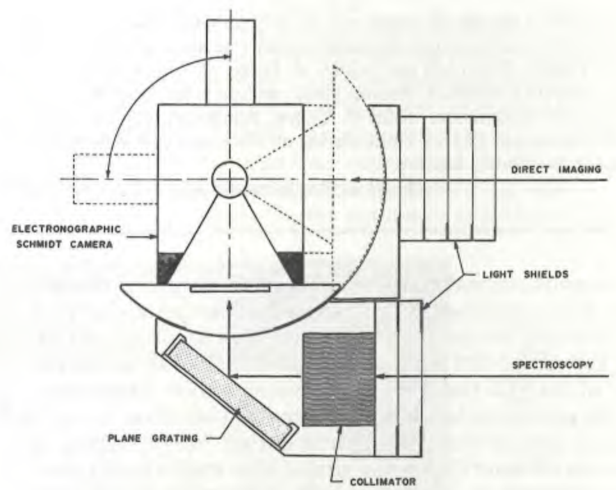


Diagram of the two-mode operation of the Lunar Surface UV Camera/Spectrograph.

100 UV photons, experiment S201 used electronographic imaging, a technique that yields 50 or more high energy electrons per 100 UV photons (in turn yielding about one blackened film grain per electron).

The first part of the instrument is a 3 in. aperture, f/1.0 Schmidt camera. Incoming light passes through a corrector plate, strikes the spherical primary mirror, and is focused on a potassium bromide photocathode with an electric potential of -25,000 volts. This high potential level acts as a filter for visible and near UV light – only photons with wave-lengths shorter than 1600 Å will cause photons to be emitted and pass on to the film magazine and grounded primary mirror (a cylindrical magnet focuses the electrons). An aluminized plastic membrane, held against the film with a pressure membrane, prevents stray light from over-exposing the film. Only the discharged electrons can penetrate the plastic.

Two different corrector plates, one of lithium fluoride that transmits to a limit of 1050 Å (including the Lyman

α line), and one of calcium fluoride that transmits to 1230 Å (excluding Lyman α), were used to obtain differing images. The Lithium fluoride plate permits imaging of hydrogen gas emissions, calcium fluoride filter imaging of atomic oxygen, molecular nitrogen, and red-shifted Lyman α light (from receding extragalactic objects with speeds of 3700 km/sec or more).

For spectrographic operations, the electrongraphic Schmidt camera is rotated from facing forward to down. Incoming light must now pass through a collimator and be reflected upward by an objective grating. In this mode the camera uses either the lithium fluoride filter or no filter at all (which gives a wave-length limit of 500 Å as determined by the grating and mirror coatings).

The 50 lb. instrument was stored in the forward right hand quadrant of the LM. After landing, it was set up in the shadow of the LM with the battery pack some distance away in sunlight. Although the instrument must be protected from direct sunlight, it is gold plated to absorb reflected infrared light and keep it from freezing; the battery must be kept warm for operation. After levelling, the shadow of the LM was used to determine the zero azimuth setting. Since it was the only target visible, the Earth was used as the reference point for all other images (this was expected to be accurate to 2 degrees).

Operations were semi-automatic, with the astronaut aiming the experiment and triggering an automatic sequencer. This made 3 exposures each in direct imaging, with both filters, and spectrographic imaging, with the lithium fluoride filter and with no filter. The sequence then repeated. Exposure times could be varied. There was no clock drive to keep the instrument pointed at its target.

REFERENCES

1. Carruthers, George R., and Thornton Page. A Lunar Surface Ultra-Violet Camera/Spectrograph.
2. NRL Camera/Spectrograph to Fly on Apollo 16, Naval Research Laboratory Press Release 55-71-10.

EUROPE'S OBSERVATORY SATELLITE

The European Space Research Organisation reports that the Thor-Delta 1A astronomical observatory satellite is operating as planned. Launched by a NASA Delta rocket at 8:55 p.m. EST on 11 March from the Western Test Range, Lompoc, California, the 472-kg satellite is in a near polar orbit of 538 by 532 km, close to the one planned. Inclination to the equator is 97.5° and the orbital period 95 min.

Thor-Delta 1A is the largest and most complex satellite ever built in Western Europe. Its mission is to study energy coming from stars and galaxies over a period of at least 6 months.

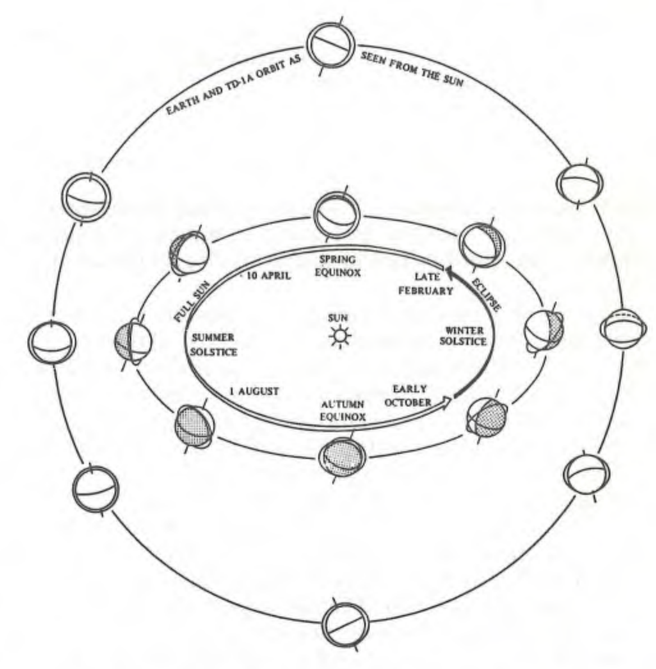
The satellite was developed by MESH, a European consortium of which Hawker Siddeley Dynamics has provided the power supplies and ground support equipment. The same firm was prime contractor for the British contribution to the experiment.

The experiment was originally proposed by Dr. H.E. Butler of the Royal Observatory Edinburgh. A joint UK/Belgium ultra-violet telescope, designated S2/68 was funded by the Science Research Council and represents a significant collaboration between stations of the Council and Industry.

The satellite system enables the telescope to scan a great circle of the sky during one orbit the plane of which is maintained orthogonal to the Earth-Sun line. As the Earth moves in its orbit, the great circle rotates until complete sky coverage is obtained in 6 months. It is estimated that about 40,000 early type (hot) stars will be detected by the system and these measurements will lead to a greater understanding of the atmosphere of these objects. These observations will also enable the ultra-violet extinction effects of the inter-stellar dust grains to be determined throughout the Milky Way and lead to a better understanding of the nature of these particles which play a role in star formation.

The fact that stars are observed more than once – over a hundred times for objects near the ecliptic poles – means that studies can also be made of stellar variability. The complete coverage of the sky ensures the sampling of all detectable objects within and without the Milky Way and a full coverage of our galactic companion – the Magellanic Clouds. It is expected that some galactic and extragalactic nebulae will also be within the range of the telescope.

British participation in the project has been under the direction of Dr. Robert Wilson, Head of the Council's Astrophysics Research Unit at the Culham Laboratory. Project and scientific management have been carried out from the Rutherford Laboratory by Messrs Peter Barker and Harold Wroe respectively and calibration measurements undertaken at the Royal Observatory Edinburgh by a group headed by Dr. C.M. Humphries. The enormous quantity of



Orbital configuration of the 472 kg TD-1A astronomical observatory launched from the Western Test Range, California, on 11 Mar. 1972. Outer circle shows the orbit as it would appear from the Sun.

European Space Research Organisation