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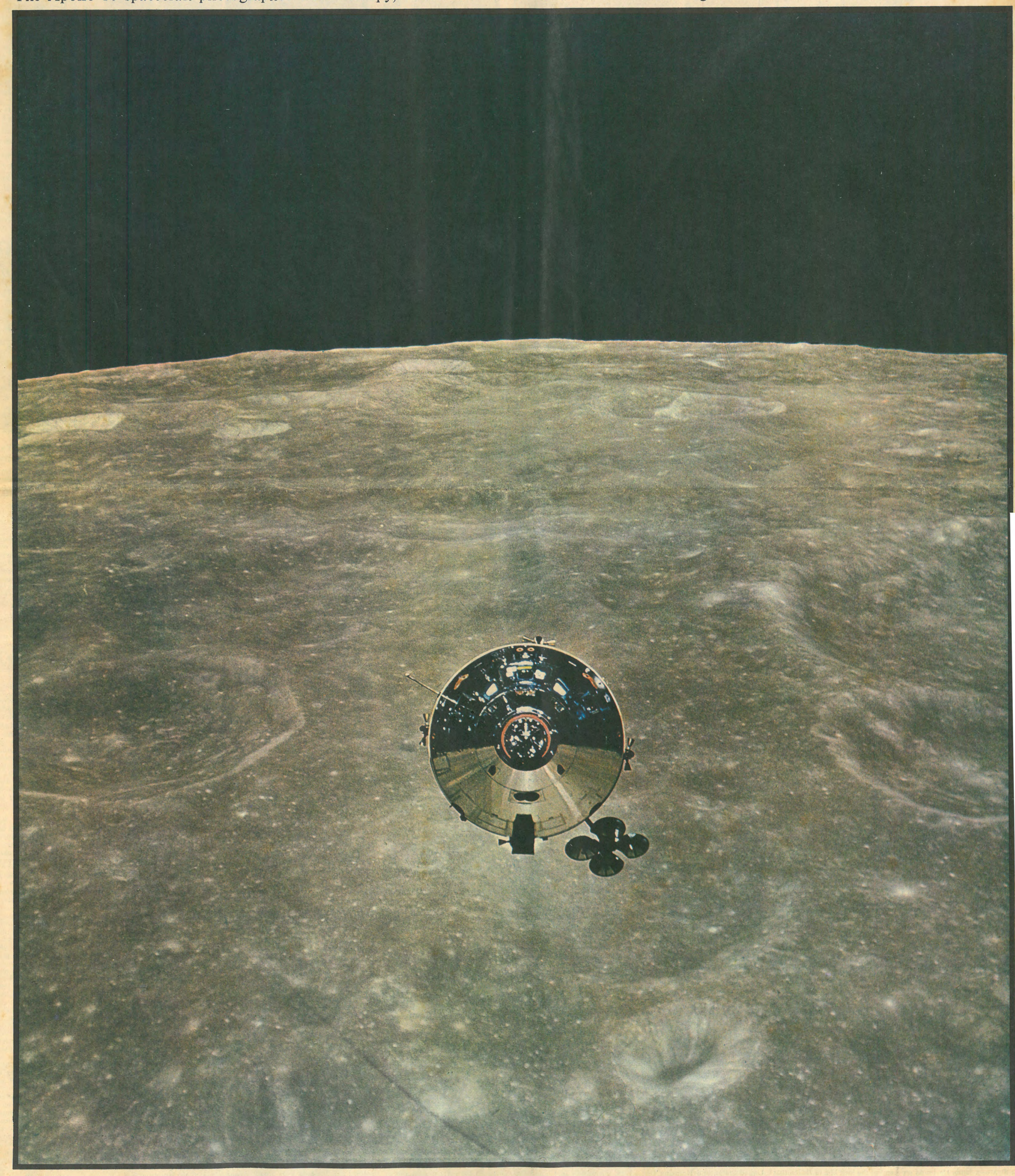
FOUR PAGE RECORD
OF MAN'S PURSUIT OF
THE MOON

On the edge of the moon

The Apollo 10 spacecraft photographed from Snoopy, the module which carried man to within eight miles of the moon's surface



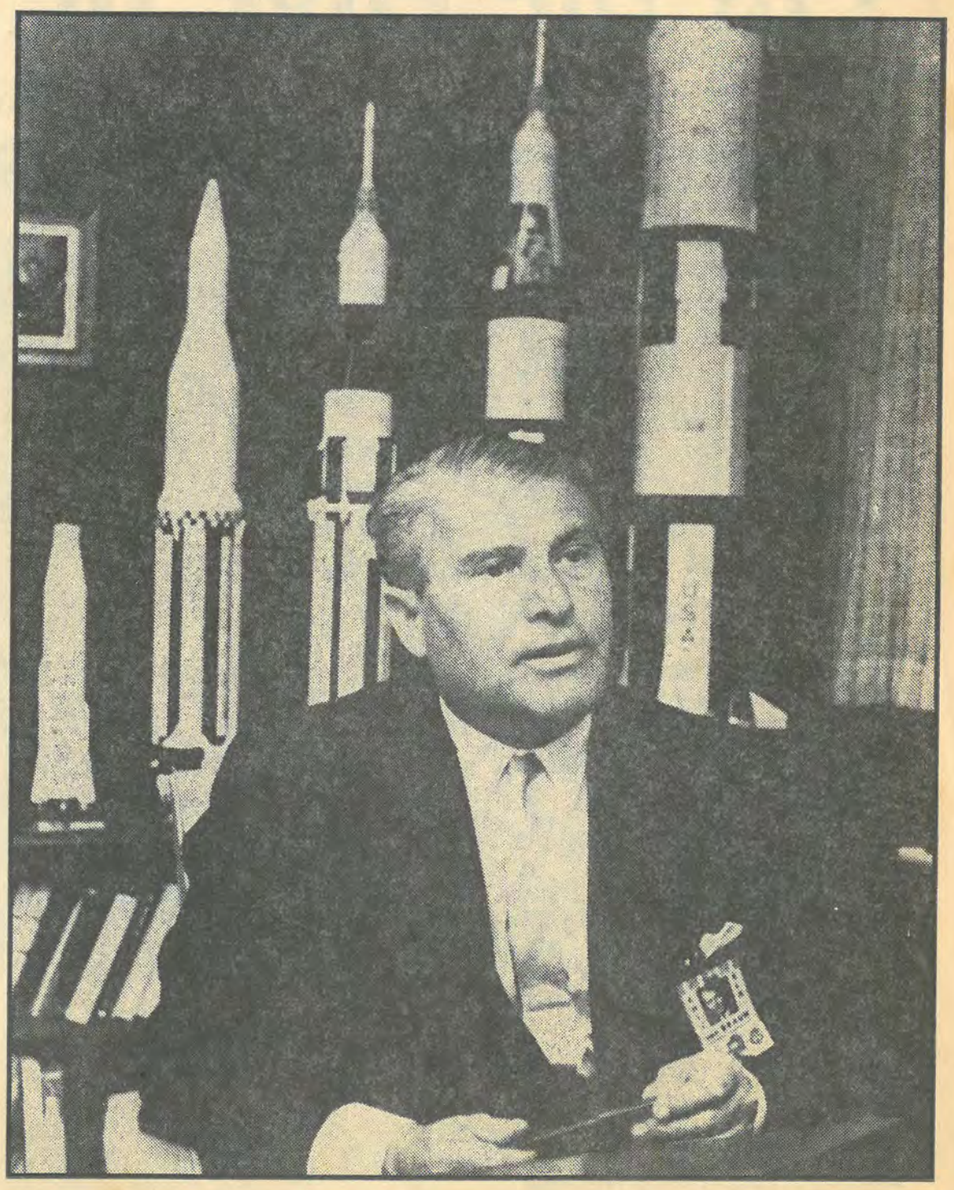
One hundred years ago three astronauts took off from a hill in Florida, near what is now Cape Kennedy, and flew round the moon in a space capsule. They 'splashed down' in the Pacific and were picked up by an American ship. Their stories included vivid descriptions of weightlessness and acceleration 'black-out'. They were the heroes of two of Jules Verne's great science fiction books. The impact such science fiction has had on history cannot be measured, but it undoubtedly inspired many boys to become great scientists, and some great scientists to study the feasibility of space travel. The three men most often described as the fathers of space flight, Konstantin Tsiolkovsky in Russia, Robert H. Goddard in America and Hermann Oberth in Germany, all traced their early interest in space travel to Verne's two books. Now reality has overtaken fantasy.

Three hundred years before the Apollo programme, Cyrano de Bergerac imagined himself propelled majestically into the air by rockets.

Robert Goddard launched the world's first liquid-propellant rocket on March 16, 1926, from a snow-covered field at Auburn, Massachusetts.

Konstantin Tsiolkovsky

Hermann Oberth: pioneered theory of modern astronautics.



The "dean of American rocketry", Wernher von Braun leads the team that launched the first American satellite and put together the world's most powerful rocket to send three men to the moon.

1,800 years of space travel: from dream to reality

Man has been travelling to the moon for centuries: to dig the gold, eat the cheeses, explore the forests or wrestle with Dan Dare's Mekon. His transport has been romantic, ingenious, foolish and brilliant: chariots of swans, giant guns, artificial clouds and enormous metal springs; even rockets.

These journeys, dreams that ranged between ludicrous fantasy and prophetic imagination, are not recorded much before the second century A.D. But later, as writers discovered science fiction and the appetite men had for it, the stories proliferated.

At times, either by luck, reasoning, knowledge of science, or uncanny inspiration, they foresaw details of voyages like Apollo 10's and that planned for next month.

In 1646 Cyrano de Bergerac, accomplished wit, swordsman and satirist, imagined himself lifted towards the moon in a flying machine propelled by rockets. But tales of space travel can be traced back at least as far as 160 A.D., when the Greek satirist, Lucian of Samasota, wrote *Vera Historia* (True History), which had all the basic ingredients of space travel fiction: the outward journey, the moon landing, a description of the moon, and the journey home. It set the pattern for many that followed.

Lucian's hero found himself on the moon by accident. His sailing ship was caught in a violent whirlwind that snatched it from the sea and carried it through space. On the moon the traveller found lunar inhabitants called Hippogypi, who rode on three-headed vultures with wings that were "bigger than the mast of a ship".

Until the end of the middle ages apparently little was written of man's dream. Then in the sixteenth and seventeenth centuries works by Kepler, Copernicus and Galileo started what has been described as a "veritable astronomical revolution". Johannes Kepler's work, *Somnium* (The Dream), a space fantasy, spoke of transportation by demons who abhorred the sunlight and could travel only by night. Travellers were given an anaesthetic potion as protection against the ill effects of rarefied air.

Another weird fantasy was that of Francis Godwin, a seventeenth-century bishop of Hereford. His *Man in the Moone* travelled by a chair-like device drawn by 25 geese. Like modern man, he used an animal for the test flights—a lamb. He found on the moon a "huge and mighty sea", "herbes, bestes and birds", but none was like anything he had seen on Earth.

Cyrano de Bergerac in one of his schemes "planted my selfe in the middle of a great many glasses full of dew, tied fast about me; upon which the Sun so violently darted his rays that the heat, which attracted them, as it does the thickest clouds, carried me up so high that at length I found my selfe about the middle region of the air". The voyage was a failure—Cyrano landed not on the moon but in Canada.

His next attempt, by a rocket-powered "machine", was also a failure. Firecrackers were tied to a large wooden box, the fuses were lit and Cyrano jumped on board. He swept through the clouds to a great height but the fireworks went out and he plunged back to Earth.

David Russen in *Iter Lunare* (Voyage to the Moon), writing at a time when space travel was becoming increasingly popular, imagined a giant launching spring constructed on the top of a mountain. Other writers bizarrely devised great ladders.

Capsule shot from a gun

However, ideas for leaving the Earth were changing. Readers were becoming more aware of science, and writers were becoming more sophisticated as they struggled to make their fiction more realistic. Some machines were fitted with "anti-gravity" devices; space travellers even tried balloons.

Jules Verne in *De la terre à la Lune* was as scientifically accurate as knowledge at the time permitted. His scheme to shoot a capsule at the moon from an enormous gun was not feasible because its occupants would have been crushed by the acceleration. However the story was good enough to excite his readers into wondering whether it was a possibility.

Columbiad, the name Verne gave his spaceship, was fired from a place called Stone Hill, Florida, little more than 100 miles from what is now Cape Kennedy. It was 9ft. wide and 15ft. high. Made of aluminium, it was luxuriously furnished and had gas to provide light and heat. There was an ingenious system for smoothing the impact of take-off, and a chemical plant to produce oxygen.

H. G. Wells's great science fiction works—including *War of the Worlds*, published first as a magazine serial in 1897—came at the end of the long line of fiction that had searched for a method of leaving the Earth. Towards the end of the nineteenth century fantasy was increasingly overtaken by reality—the rocket engine was the solution. Although the dreams of space travel did not falter, science began to dictate terms to the writers.

The exact date of the rocket's invention is lost in history. Stories and legends suggest it was in use before the thirteenth century, but these are hard to confirm. Most authorities point to 1232 when the Chinese were besieged in the town of Kai-Feng by Mongols. They tied rockets, apparently used by them for signalling, to flaming arrows.

Certainly in 1258 a war rocket was used at Cologne, Germany. The Paduans apparently employed them to attack the town of Mestre, near Venice, in 1379. Two years later Bologne, which was under siege, was destroyed by a "fearful device".

In following centuries rockets were continually used as battle weapons. Spewing fire in all directions, they at least caused severe psychological damage. But they were inaccurate. Unless the gas flow from a rocket's tail were directed straight backward, it would curve in flight wide of the target. Guns were much more effective, and impatient military inventors tended to concentrate on these.

The potential of the rocket first began to fascinate European military strategists in the late eighteenth century, mainly because it was being used effectively by their oriental enemies to resist the encroachment of imperialism.

Troops of the Indian state of Mysore had used rockets on British colonial troops in the battles of Seringapatan, in 1792 and 1799. Weighing between 6lb. and 12lb., their casing was made from iron piping and they had a large stick attached for stability. They had a reported range of up to a mile.

Accounts of these battles differ, but one young officer named Bayly wrote: "So pestered were we with the rocket boys that there was no moving without danger from the destructive missiles." He added: ". . . every illumination of blue lights was accompanied by a shower of rockets some of which entered the head of the column passing through to the rear, causing death, wounds, or dreadful lacerations from the long bamboos of 20 or 30 feet which are invariably attached to them."

Passed over by the military, the reaction rocket gradually took shape in the minds of scientists around the turn of this century. Its potential for space travel was realized independently by three men: Konstantin Eduardovitch Tsiolkovsky, of Russia, Robert Hutchings Goddard, of the United States, and Hermann Oberth, of Germany.

Tsiolkovsky, born in 1857, was of humble origin. He showed an early talent for mathematics and physics, and had an inventive mind. The germ of the idea of interplanetary travel occured to him while he was still in his teens. Most of what he learnt in the early days was self taught. In 1878 he became a "people's school teacher" and moved to Borovsk. In a home laboratory he started experimenting. On the basis of papers he later produced he was elected to the Society of Physics and Chemistry in St. Petersburg.

In 1903 Tsiolkovsky published in the journal *Naootchnoye Obozreniye* (Scientific Review) an article entitled "The probing of space by means of jet devices". The first to understand and develop the use of rockets in space travel, he created the mathematically precise theory of rocket propulsion.

The spaceship that Tsiolkovsky planned was to be powered by heated gases produced by mixing liquid oxygen and liquid hydrogen—the basic chemical formula that powered the upper stages of the Saturn 5 rocket and enabled it to send nearly 50 tons to the moon.

Tsiolkovsky's theories on escaping from the Earth's atmosphere and gravitational field place him, in the view of many historians, at the head of all rocket scientists. But he confined himself mainly to the conception and development of theories.

Robert H. Goddard devoted most of his work to the practical application of rocket propulsion. Born 25 years after the Russian, his interests in rocketry also started in his youth. From the age of 16 Goddard started keeping notes of his ideas. Though his work almost certainly had enormous influence on rocket research, he did not receive the recognition due him until after his death in 1945.

'It might cost a million dollars'

Until 1920 most of his research was devoted to powder and solid propellents. His most famous work, published in 1919, was "A method of reaching extreme altitudes". In it Goddard speculated that it would be possible to send a rocket to the moon with enough magnesium powder for the impact to be visible from the Earth through telescopes.

After a great deal of calculation and initial experimenting, Goddard launched on March 16, 1926, the world's first liquid fuel rocket. It rose 41ft. from the ground at a maximum speed of 60 m.p.h. and was in the air for about 2½ minutes.

Three years later he told Charles Lindbergh, the aviation pioneer, that it was possible to send a multi-stage rocket to the moon. "But he smiled a little bit and said it might cost a million dollars—and of course that was out", Lindbergh recalls. The 1969 budget for the Apollo programme will be [illegible] times Goddard's estimate.

During the Second World War Goddard worked under contract with the U.S. Navy Bureau of Aeronautics and the Army Air Corps. The principles he developed were applied to missiles used by the Navy.

After his death Goddard received a number of honours and awards. In 1960 the United States Government paid the Guggenheim Foundation and Mrs. Goddard $1m. in settlement for government use of more than 200 of the pioneer's patents.

Hermann Oberth's interests in space travel started at the age of 11 when his mother gave him Jules Verne's famous books. It set him on a series of experiments into weightlessness and propulsion. In one he even went to the extent of taking drugs, to deaden his nerves, and immersing himself in water. The feeling of weightlessness, he concluded, would at first be very frightening.

His interest in combat rockets drove him to propose to the German war department, in 1917, the development of a liquid-propelled, long-range bombardment missile.

Oberth's first book, *Die Rakete zu den Planetenraumen* (The Rocket into Planetry Space) was published in Munich in 1923. It became a classic. He discussed thoroughly almost every aspect of rocket travel, including the effects of pressure and weightlessness on the human body. The book, only 92 pages of text, was packed with reasoned thought: how a rocket could operate in a void, that it could move faster than the velocity of its own gases, and that it could launch a pay-load into orbit.

Six years later Oberth published a 423-page expansion of The Rocket into Planetary Space. Retitled The Road to Space Travel, it earned for Oberth what is believed to be the first international astronautics prize, instituted by Robert Esnault-Pelterie and Andre Hirsch.

During the Second World War Oberth worked on rocket developments including the V-1 and V-2 at Peenemünde and Reinsdorf. After the war, before retiring, he worked for a few years in the United States with Wernher von Braun, his erstwhile pupil and the man who completed the bridge between the early rockets and today's giants like Saturn 5.

Tsiolkovsky, Goddard and Oberth did much more than is recorded, however. Their work inspired many to follow, and the impetus provided by their publications attracted numerous scientists and engineers to rocket and space travel research.

Space travel, like rockets and rocketry, owes much to fear and war. Had there been no Second World War, no east-west arms race and no nuclear weapons, it is doubtful that man would have achieved so much so soon.

If there is one other man whose name is likely to loom as large in space history as those of Oberth, Goddard and Tsiolkovsky, it is Dr. Wernher von Braun. Now 57, he lives and works in America, where he is Director of the Marshall Space Flight Centre. It was he who turned Hermann Oberth's idea of long range bombardment missiles into reality. Luckily for Britain and the rest of Europe his V-2 was not ready until the end of the war. In spite of successes at Peenemünde, Hitler could not be persuaded of the value of von Braun's weapon.

Nevertheless, southern England and the Continent were to experience the horrors of rocket warfare in 1944 and 1945. Some 4,000 V-2s, each carrying a one-ton warhead, were fired during those two years. Travelling at speeds faster than sound, they gave little or no warning of their approach.

Both Russia and the United States were quick to realize the value of the V-2. As they invaded Germany at the end of the war they competed in capturing rockets, plans and the men who designed them.

Von Braun went to the Americans.

Though it was probably the Americans who won this scramble for German minds and machinery, it was Russia that was first off the mark in the space race.

Sputnik 1 went into orbit on October 4, 1957. It caused bitter disappointment in America, and recriminations in Washington. The U.S. Army had planned to put a satellite into orbit in September but apparently red tape had prevented it. The world marvelled at Russian technology.

A month after Sputnik 1, the Russians launched the dog Laika in Sputnik 2 and demonstrated that life in a spaceship was possible.

America launched Explorer 1 three months later but by this time Russia's success had made a jarring impact on the West. Americans and Europeans were thinking of space an an advantage in the battle for nuclear superiority . . . and Russia seemed to have that advantage. It seemed that the man with superiority in space had superiority in missile power. Many people envisaged the Russians planting the hammer and sickle on the moon and declaring it their own. The Russians would dominate the world. They would be able to aim a rocket at the earth and they would be invincible.

We now know that in a nuclear war the time it takes a missile to reach its target is critical. A missile launched from the moon would probably arrive when the war was over.

Somewhere in the race that followed Sputnik 1, the Russians adjusted their sights. Whether they raised them from the moon to the planets or kept them on the moon but fell behind in shooting capacity we may know only when the Russians land elsewhere in the solar system.

First glimpse of the dark side

If, as now seems certain, the Americans are the first to step on to the moon's barren surface, it will not mean that the moon is American. Thanks to an agreement signed by some 60 nations in 1967, the moon is international territory.

In 1961 President Kennedy set the target for a moon landing "within the decade", but it was not until the mid-60s that the Americans seemed to be catching up.

On September 13, 1959, Russia's Lunar 2 crashed into the moon's surface. A month later Lunar 3 provided the first glimpse of the moon's dark side. On April 12, 1961, they put Yuri Gagarin into orbit. One month later the Americans put Alan Shepard into space, but it was a short, 15-minute, sub-orbital flight. The Russians sent back the first television pictures in August, 1962. In 1963 they acheived a flight of over 100 hours, in 1964 they put three cosmonauts up together, and in 1965 they made the first space walk.

But by 1965 the Americans were only a few months behind, and midway through their Gemini programme they started to take the lead. They managed a successful docking—the linking of two space vehicles—essential for reaching the moon by the American method of separate "excursion module".

By 1967 the space commentators were saying that America was ahead. The two-man Gemini flights had been such a success that there was even an air of over-confidence. It may well have contributed to the disastrous fire of January, 1967.

Three astronauts, Edward White, the first American to walk in space, Virgil Grissom, who had made two flights, and Roger Chaffee were doing a simulated countdown for the first manned Apollo flight. At this time the Americans were using pure oxygen for the atmosphere of their space craft.

A small spark from the electrical system is thought to have started the fire: the men were sealed in the capsule and had no chance of escape. They died within seconds.

Apollo underwent sweeping design changes. The atmosphere was changed and new, quick-opening hatches were fitted. The added weight ran into hundreds of pounds and the work on reducing this put the programme back.

Apollo 7, the first Apollo flight, flew in October, 1968. It stayed up for more than 260 hours, making 163 Earth orbits. Two months later Frank Borman, James Lovell and William Anders piloted Apollo 8 on two Earth orbits and 10 moon orbits. They came within 70 miles of the moon's surface and travelled farther from Earth and faster than any man before.

They demonstrated that man could travel through space, and that the dreams of Lucian of Samasota, Kepler and Verne—of going to the moon and of looking back at the Earth—were not to remain dreams for ever.

Man had been to the moon, the next problem was to land on it.

For this task, the Americans developed the lunar module, a spidery-looking vehicle which, like a flying bedstead, cannot glide. When tested in the Earth's gravitational pull, six times stronger than the moon's, it proved to be one of the biggest stumbling blocks in the whole Apollo project.

The Russians had decided on a jumping-off platform in Earth orbit. The Americans, after years of debate, had chosen to have their platform circling the moon. Thousands of millions of dollars made the decision irreversible. No wonder those who were sniffing the first hints of victory were shocked when the lunar module, crashed repeatedly during Earth tests and seemed uncontrollable. But its designers stood by it and were vindicated by the in-flight trials of the Apollo 9 and 10 missions.

Man is expected to stand on the moon's surface in little more than a month. He will owe much of his achievement to the science fiction writers and the rocket men. But it will not be the end of the dream. Fiction tells too of journeys to Mars, Venus and to other solar systems. The men who devoted themselves to the science of space travel looked on the moon only as a first step.

How two men will walk on the Sea of Tranquillity

The perilous journey to the moon of Apollo 11's marvellous ironmongery began, at a grinding speed of less than half-a-mile-an hour, while Apollo 10 was blazing a triumphant trail in space.

Since superlatives are inseparable from space pioneering, it was the world's largest tracked vehicle, "the crawler", that carried the 3,000 tons of Saturn 5 rocketry from its lofty assembly building to launchpad 39A. It took some six laborious hours, the most laggard progress it is likely to make.

Apollo 11 makes its thunderous, fiery exit from Earth at teatime on July 16 with its three-man crew: Mr. Neil Armstrong, a civilian who is destined to be first on the moon, Lieutenant-Colonel Edwin Aldrin, who will walk the surface with him, and Lieutenant-Colonel Michael Collins, who will stay in the orbiting command module.

Following the flight of Apollo 10, the lunar voyagers will orbit the earth one-and-a-half times before firing their third stage Saturn 4B rocket that shoots them on to their moon course.

Ninety-eight hours into the flight the 16-ton lunar module will extend four spidery legs, and part from its mother craft to begin its descent to the moon. Its two-man crew, held only by a safety harness, will stand at the controls, peering through canted triangular windows.

For a quarter of an orbit Apollo 11 and its offspring will fly cautiously in formation a few hundred feet apart, in case a quick rescue is necessary. The two moon-walkers will be in the lunar module's upper, or ascent stage. The lower, descent stage will become a launching pad from which they will take off after their 22-hour stay.

The module will take an hour to drop to 50,000ft. (eight nautical miles). Its descent engine will be fired and in eight minutes it should land on a chosen site in the Sea of Tranquillity.

To the men on the previous mission, the spot, from a distance less than twice the height of Everest, looked firm enough. According to Colonel Tom Stafford, the Apollo 10 commander: "There's plenty of holes there. The surface is actually very smooth like a very wet clay . . . with the exception of the bigger craters."

Automatic radar will continuously measure the angle, speed, altitude and range as the lunar module approaches. The pilot takes over, manually, only in the final seconds. He can hover, if he wishes, and take it up again without landing, if necessary. Pads on the module's legs take the touchdown impact.

The module must land cleanly and evenly if it is not to jeopardize its take-off later. As soon as they are down, Mr. Armstrong and Colonel Aldrin will spend two hours checking the module's systems. Then they will stop for a meal, and a four-hour rest. They will eat a second meal before they depressurize their craft and open its hatch for the first time. In fact they will have been on the moon for 10 hours before Mr. Armstrong ventures outside, and into the world's history books.

Wearing a bulky space suit and a special thermal garment over it to protect him from radiation, temperature extremes and particles of meteoroids, and carrying a life support system on his back. Mr. Armstrong will climb down the ladder attached to one of the module's legs.

Colonel Aldrin will televise and photograph the moment from the module before following Mr. Armstrong down the ladder 31 minutes later. Because of the moon's curvature, the astronauts standing on the surface will be able to see only two miles, rather than the 20 they could see on Earth. Under a cloudless black sky the landscape will glare whitely.

They will set up a television camera to send pictures of the module back to Earth. Then the astronauts will rig a solar wind collector—which they are to take back with them—and seismic equipment and a laser reflector which will be left behind.

The wind collector, developed and paid for by the Swiss Government, is a thin sheet of aluminium on a frame like a window screen. It will trap rare gases like argon, helium and xenon from the sun's rays.

The 100lb. seismic station will collect power from the sun which it will use to radio volcanic movement or lunar activity below the surface back to Earth for perhaps a year.

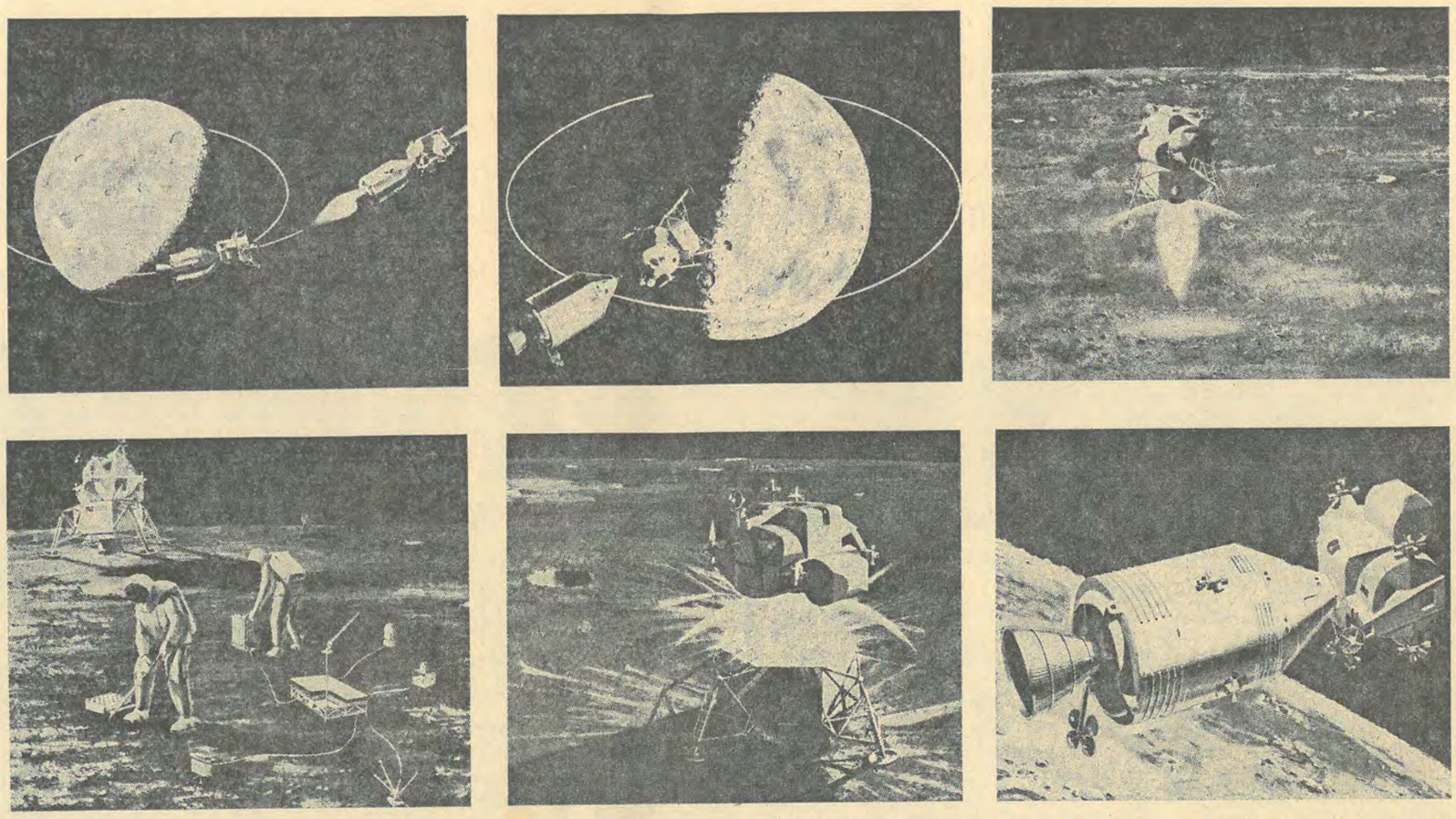
The reflector, which weighs 70lb., will reflect laser beams directed from Earth. These will enable the distance between the Earth and the moon to be measured with great accuracy and any variations to be recorded. Measurements will be repeated several times a day for a year or more. This should enable scientists to refine their knowledge about the shape and size of the moon.

Perhaps the greatest prize awaited from the journey is the 50lb. of lunar rock and soil the astronauts are expected to gather for international distribution to scientists.

When Mr. Armstrong first descends the ladder it will be to familiarize himself with the surface and its stability. He will climb back then for a contingency sample bag into which a handful of rock or soil can be thrust quickly in case they need to leave in an emergency.

The astronauts' life support systems allows them four hours air. They will work for three, with an hour in hand as a precaution. Though the moon's gravity is one-sixth of the earth's, movement in their enveloping suits and equipment will be slow and awkward.

Simulation tests have improved ways in which they can go about it. One astronaut, for instance, will carry both experimental packages because his balance is improved, in the same way as when a suitcase is carried in either hand. The packages have to be moved about 70ft. from the lunar module and on the Earth weigh a total of some 160 lb. Special design has made them relatively simple to set up. Lanyards are pulled, releasing springs holding the instruments together as a parcel.



When the spacecraft enters the gravitational field of the moon (top left) it will manoeuvre into orbit and the lunar module will separate from the command module (top centre) before dropping to the surface (top right). Ten hours after landing, the astronauts emerge and set up instruments (bottom left). They leave the surface 12 hours later (bottom centre) abandoning the descent stage. The ascent stage briefly rejoins the command module (bottom right), while astronauts transfer, before being jettisoned.

Adjustments are then made to solar panels capturing the sun's rays to provide electrical power for both pieces of experimental equipment. Radio aerials connected to the units will be adjusted so that they send a continuous stream of information back to earth. The equipment starts to operate as soon as the panels are unfurled.

The astronauts will have three prospecting tools for collecting samples. One is a scoop to gather loose soil, another is a pair of tongs for picking up rocks, and the third is a boring instrument. This is hammered into the ground to take a 12 inch core sample, which it automatically ejects into a container. It will give scientists material uncontaminated by man or rocket exhaust. While they are on the surface the astronauts will stay within 300ft. of their craft.

At 7.32 a.m. on July 21 Colonel Aldrin and Mr. Armstrong will climb back into the lunar module. They will eat two more meals, with a rest of nearly five hours between before blasting off from the moon at 5 p.m. The lower half of their craft, which now becomes a launching pad, remains on the moon. It may be useful to subsequent visitors for fuel or spare parts.

The ascent stage, just 12ft. high, weighs under a ton on the moon. The astronauts must fire themselves into an elliptical orbit between 15 and 36 miles high and them make this circular with another burn. The lunar module will be travelling in a lower, and therefore faster, orbit than the command module. They will narrow the gap for two hours before they dock.

The two spacecraft must equalize pressure before the hatches are opened for the two moon-walkers to return to the command ship. The lunar module will then be jettisoned.

The mothership will circle the twice while preparations are made for the return. To leave lunar gravity its speed must rise from 3,600 m.p.h. to about 5,400 m.p.h. to begin the long journey home and the dangerous reentry procedure.

Apollo 11 is due to splash down at 5.52 on July 24, eight epoch-making days after they set out. But their personal welcome by an incredulous world will be delayed. They will go into isolation for 21 days from the time they left the moon to be minutely examined by scientists.

Before they leave their spacecraft they will even vacuum clean the inside to prevent possible contamination of the earth by particles from the moon, which may be dangerous. As soon as the astronauts emerge from the spacecraft they will don isolation garments and be sponged off with organic iodine.

Neil Armstrong, *aged 38, the only civilian in Apollo 11, will set man's first foot on the moon. Like his two companions he is a skilled fighter pilot. His selection for a first place in history is felt to be a token to science at large as well as a means of avoiding American inter-Service squabbling. Married, with two sons, Mr. Armstrong flew 78 combat missions for the United States Navy in the Korean war. He became a Nasa research pilot in 1955 and flight-tested the X-15 rocket plane which was launched from a bomber's wing. This took him to a height of 40 miles and a speed of 4,000 m.p.h. His space-flying hours, however, are limited to one 10-hour mission. He commanded Gemini 8, which performed the first space-docking with a target rocket.*

Edwin Aldrin, *aged 39, the lunar module pilot who will walk with Mr. Armstrong on the moon, is an Air Force colonel as well as a scientist. He is the world's most experienced space walker. He spent a total of five-and-a-half hours outside Gemini 12, during which he walked round the world three times. Colonel Aldrin has a wife, two sons and a daughter. He received a doctorate from Massachusetts Institute of Technology for a thesis on rendezvous techniques in orbit. During the Korean war he flew 66 combat missions and shot down two MiG-15 aircraft. His riskiest, but more peaceful, task in Apollo 11 will be to fly the ungainly lunar module on to the moon and take it up again to rejoin the mothership orbiting the moon.*

Michael Collins, *aged 38, command pilot, will stay in the mothership orbiting the moon while his fellow astronauts drop to the surface. An Air Force Lieutenant-Colonel, he has taken part in one previous space mission, in Gemini 10, during which he walked twice outside the craft. A former jet fighter test pilot, he is married with two daughters and a son. If anything goes wrong after the lunar module leaves the mothership, Colonel Collins will have to do his best to go to its aid. But once the module lands, he can do little to help if it gets into difficulties. Colonel Collins had to miss the Apollo 8 mission because of a spinal operation.*

What the scientists are hoping to learn from the moon

By Nature-Times News Service

If the engineering of the Apollo project passes its final test with the flight of Apollo 11 in July, the National Aeronautics and Space Administration planners will have the moon in their grasp. In deciding what to do with it, their first goal will be to explore the lunar terrain. The results of this may be crucial to the longer term schemes envisaged by enthusiasts for man's role in space, such as manned lunar bases, the construction of telescopes and the use of the moon as a launching pad for flights to the planets.

The geology of the moon is not only of great interest in its own right but will also help in reconstructing the early history and structure of the Earth. This is not just because two planetary bodies will be easier to understand than one. Whatever the origin of the moon, its crust may still retain the fossil evidence, long since vanished from Earth, of events that occurred at the dawn of the solar system. The geological forces that continually remould the face of the Earth have destroyed all but the vestiges of its primordial crust and left a gap in the record from the time of the Earth's formation, some 4,900 million years ago, until the appearance of the first sedimentary rocks nearly 2,000 million years later.

The scale of geological activity on the moon has been much smaller, and the moon's surface, perhaps not greatly altered since the time of its formation, may help to make good the pages missing from the early history of the Earth. Nonetheless, the occasional eruptions seen in lunar craters and the volcanoes spotted by the Apollo 10 astronauts suggest that the moon may not be the fossil planet it is sometimes supposed.

The astronauts of Apollo 11 will spend 2½ hours outside their landing module, long enough to set out a package of instruments and scoop up some samples of lunar soil. Ten more flights are planned with existing Apollo equipment or slight adaptations of it, the pattern of which will be to allow progressively more time on the lunar surface.

Apollo 12 will allow two excursions of 2½ hours each, and the astronauts of Apollo 13 will have up to three days on the moon. But short excursions, even at different landing sites, will bring back diminishing returns. In further flights the lunar module will be equipped with extra oxygen tanks so as to prolong the stay to a week, together with some kind of transport which will give the astronauts a range of five to 10 miles from the module.

One proposal, still very much in the air, is to combine the payloads of two Apollo flights. The lunar module of the first would be replaced by an unmanned capsule capable of landing some 7,000lb. of logistic support for the astronauts who would arrive on the second flight. The extra equipment would probably include shelter and life systems for a fortnight's stay, and a roving vehicle to explore the surface.

The flights after Apollo 11 will probably be interspersed with unmanned flights designed to reconnoitre the best spots for manned landings. The first landings are planned for sites along the moon's equator. These are easier to attain than polar landings and the orbit of the spacecraft is least at risk there from disturbances by the curious gravity anomalies of the moon. But unmanned spacecraft suggest that the lunar poles may promise more surprises for the explorer.

Just how interesting the moon turns out to be will determine the rate at which it is explored and exploited after the first Apollo landings. If President Kennedy had not made the landing of men on the moon before 1970 a national goal it is unlikely that the scientific aspects of the mission alone would have commanded the necessary funds—the return tickets for the two Apollo 11 astronauts will have cost some $10,000m. each.

After Apollo, space flight will have to be justified by scientific rather than political considerations, and in present circumstances scientists will choose to devote a large slice of what funds may be available to making unmanned flights to the planets. But priorities could change overnight if the moon were to yield any big surprises, such as if, for example, an astronaut were to pick up a fossil skull from the lunar soil.

Apart from exploration, the other possible uses of the moon will depend on the tempo of space activity, and particularly on the demand for manned flights around the solar system. It requires very much less energy to launch a planetary probe from the moon than from Earth, and the economics of doing so might become attractive if rocket propellants such as hydrogen and oxygen could be extracted from the moon. This is why advocates of manned space flight, and science fiction writers before them, have pointed out the advantages of maintaining a manned lunar base which, it is hoped, would be largely self-supporting and need only a minimum of supplies to be ferried from Earth.

Nobody envisages that a manned base would be set up on the moon before the 1980s, but even this date may be too optimistic if the Apollo landings fail to find water, which is the key to any large-scale exploitation of the moon. Water can be separated by electrolysis into oxygen and hydrogen and these three substances between them would provide the bulk of the material needs of a lunar colony. But does water exist on the moon? One possibility is that there is a layer of frozen water, like the permafrost of Siberia, a few feet below the lunar surface. Another is that water molecules may have been trapped in the permanently shaded craters at the poles of the moon and over million of years have grown into glaciers perhaps 100ft. deep.

Even if both these suggestions are proved false, and there is no positive evidence to support them, it may conceivably be economic to extract oxygen from the lunar rocks for the benefit of a lunar colony.

A lunar base, which would be an economic alternative to more than a certain number of individual return trips, would be manned by some 20 to 60 people living in prefabricated aluminium chambers. A small nuclear power station, machinery for exploiting lunar water, and a hydroponic farm would be the essential supports of the colony's existence. Geological exploration would be a major part of the colony's role, but there might also be opportunities to construct an observatory, for which the moon offers several unique advantages. The moon has no ionosphere and its far side is the only place in the solar system that is permanently shielded from man-made electromagnetic disturbances by 2,000 miles of solid rock, which makes it an ideal site to pitch a radio telescope.

X-ray observations, which at present can be made only from balloons and rockets launched to the top of the Earth's atmosphere, could be carried out on a more permanent basis from the surface of the moon. Optical astronomy would also benefit. Without the interference of an atmosphere telescopes could be designed and operated to the theoretical limit of their resolution. Their structure would be far less massive than on Earth because of the smaller pull of the moon's gravity. The 200-inch reflector on Mount Palomar weighs 500 tons whereas a 200-inch telescope constructed on the moon's surface would probably weigh only 10 tons.

An observatory on the moon would be able to reach farther out into space than Earth-based telescopes, with incalculable advantages for astronomy. The counting of various types of very distant stars might help to resolve the debate about the origin and structure of the universe. The precision of astronomical measurements would be extended so as to put the determination of stellar distances on a much firmer basis. A lunar telescope might also be able to detect the planets of the nearer stars. Nevertheless the benefits to astronomy would afford only a marginal justification for a lunar base because many of the advantages offered by lunar sites can be gained far more cheaply by telescopes put in orbit round the Earth.

The costs of running a lunar base have been estimated at around $1,000 million a year for a 20-man base. Labour costs on the moon are expected to work out at nearly $100,000 an hour, and the price of transporting supplies from Earth to moon would be of the order of $10,000 per kilogram. If these estimates are even approximately correct, it is clear that a manned lunar base will be justified only as part of a space programme much larger than what is envisaged for the immediate future, and too large, perhaps, for the resources of any one nation.

But this has not stopped Mr. Barron Hilton, for example, from putting forward his ideas for a three-floor hotel beneath the lunar surface, or Mr. Arthur Clarke, who predicted communications satellites some 20 years before the event, from giving a warning that in two centuries conservationists will be trying to save what little is left of the lunar wilderness.

Lowdown on Snoopy

The lunar module, nicknamed Snoopy by the Apollo 10 crew, was the fragile moon ferry that took Colonel Thomas Stafford and Colonel Eugene Cernan to within 50,000ft. of the lunar surface. It was made of two halves which together stood 22ft. 11in. high; its width, measured across the landing gear, was 31ft. Its total weight at launch was 30,849 pounds.

The ascent stage housed the two crew members throughout the journey from the command and service module to the surface. It was 12ft. 4in. high by 14ft. 1in. across. It consisted of three sections; the crew compartment, midsection, and aft equipment bay. Only the first two sections were pressurized; all the rest of the lunar module was unpressurized. The habitable volume was 160 cu. ft.

The crew compartment was equipped with two triangular windows and an inward-opening hatch. A thermal and micrometeoroid shield of multiple layers of mylar and a single thickness of aluminium skin encased the entire ascent stage structure.

The descent stage—10ft. 7in. high by 14ft. 1in. across—housed the descent engine and descent propellant tanks. Its landing gear struts were retracted until the crew were on board the lunar module. These ended in pads 37in. in diameter.

Engines: The Reaction Control System comprised four clusters of four 100lb. thrust engines. The clusters were mounted on outriggers 90° apart on the ascent stage.

The Descent Propulsion System: The maximum rated thrust of the descent engine was 9,870 lb., and could be throttled between 1,050lb. and 6,300lb. The engine could be turned through 6° in any direction for offset centre of gravity trimming.

The Ascent Propulsion System: The 3,500 lb. engine performed at full thrust. It remained dormant until after the ascent stage separated from the descent stage.

All three systems were propelled by nitrogen tetroxide (the oxidizer) and Aerozine 50—an equal blend of hydrazine and unsymmetrical dimethyl hydrazine.

Prime contractors for the lunar module were the Grumman Aircraft Engineering Corporation in Bethpage, Long Island, New York. Both halves of the module were jettisoned as planned.

Green, brown or grey?

What colour is the moon? "Grey and white, like pumice stone", according to Colonel Frank Borman, the Apollo 8 mission commander. But their photographs showed it a muddy green.

It was "brownish-grey" according to the Apollo 10 crew. But their first colour television pictures from space showed it as a sandy brown.

On the back of the moon the colours seemed different again, lighter than on the side nearer earth. "It is shades of black and white and browns in there, and as near as I can tell there is some brown in that thing", Commander John Young said.

Actually, the moon is monochromatic, according to the scientists. Centuries of exposure to sunlight have probably bleached the colour contrast out of the moon's landscape.

The different colours that emerge in photographs are probably the effect of a change in the colour response of the film, the National Aeronautics and Space Administration say.

Report by the News Team, Pearce Wright and Ian McDonald

Just how good was the lunar module?

In the early hours of the morning of Friday, May 23, a touch on a button at headquarters in Houston fired the ascent stage engine of the lunar module, Snoopy, and sent it swinging into an eternal orbit around the sun. An hour earlier Snoopy's two passengers—Colonel Thomas Stafford and Commander Eugene Cernan—had rejoined Commander John Young aboard the command and service module, the celebrated Charlie Brown.

As the engine fired—it was programmed to keep firing until the fuel was exhausted—and Snoopy, now filled with rubbish, vanished towards the sun, Commander Cernan observed: "I feel sort of bad about that, because he's a pretty nice guy. He treated us pretty good today."

In the coming days it will be the chief task of an anonymous legion of scientists and engineers at Houston to evaluate just how "nice a guy" Snoopy was, and just how well he did treat the astronauts.

The testing of the lunar module was the most important job that Apollo 10 had to do. The two-stage module—the disposable landing ferry that takes the astronauts from their circling spacecraft to the lunar surface—is at the heart of the American plans to land two men on the moon this summer.

The lunar module had been tested in earth orbit, on Apollo 9, but never before in lunar orbit. Its total success is imperative, because if anything goes wrong and the crew find themselves unable to rejoin their command ship, they would have no chance of survival. The Apollo 10 mission uncovered a number of teething troubles in the intricate Snoopy.

The most dramatic moment of the flight came as Colonel Stafford and Commander Cernan, standing side by side in an elaborate harness, prepared to ditch the descent stage of the module and return to Charlie Brown. They fired the ascent stage engine. At first nothing happened. Then Commander Cernan muttered: "Son-of-a-bitch", as Snoopy span in a "wild gyration". "Something went wild on that staging", he reported. He seemed to sense catastrophe, and his heartbeat leapt from its usual 60 a minute to 129.

In Houston it was at first thought that the fault was in the design or an inaccurate check list but later it appeared that human error was to blame. Commander Cernan had failed to move a switch from one position to another. As a result, a stabilizing device that would have locked the ascent stage into position for its next manoeuvre did not come into operation, and a computerized stabilizer began to act on information that was no longer valid. The lunar module began to spin as it tried to lock automatically on to irrelevant reference points.

Houston was quick to claim that the situation would have been put right automatically, even if Colonel Stafford had not reacted quickly and overridden the control. There was no danger of a crash-landing on the moon.

What is exercising the technicians at Houston far more is the poor quality of the communications between the spacecraft and ground control, especially when Snoopy was close to the moon's surface. There is no question of an attempted landing until it can be guaranteed, as far as is humanly possible, that good communications can be maintained with the astronauts at all times.

The experts believe they know what caused the loss of communication, but they will have to wait a few more days before detailed analysis is completed. They were most worried about the loss of "high bit rate data"—the stream of coded information broadcast directly from the spacecraft's transmitters into computers at Houston. Without this information, it would be extremely difficult to analyse the cause of any mishap that might occur in flight.

One possible explanation is that the radio tracking stations scattered across the world locked on to a "side lobe", one of the least powerful sections of the beam of radio signals being sent back to Earth.

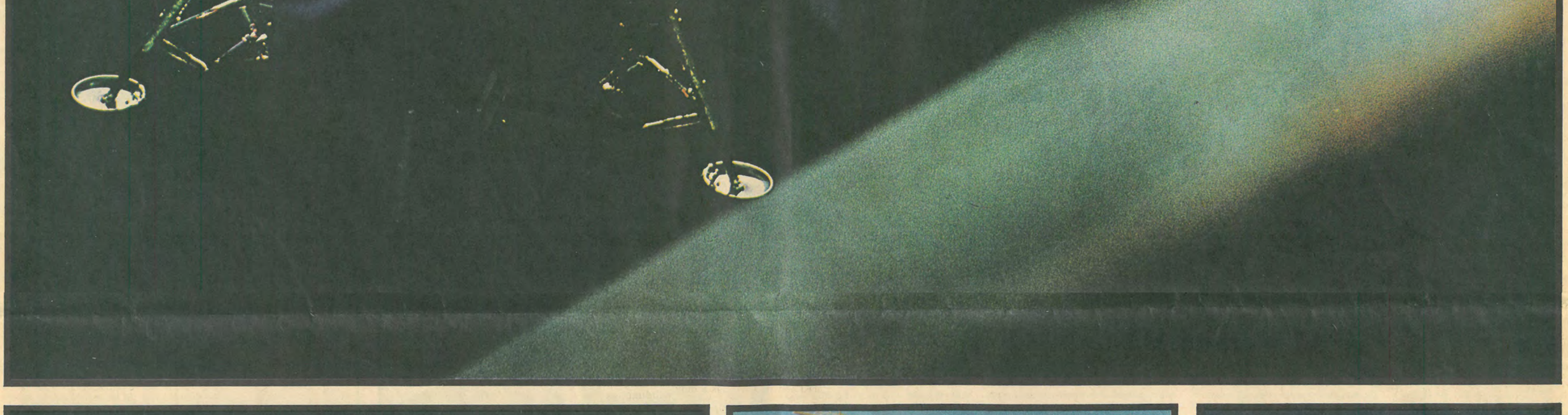
Colonel Stafford and Commander Cernan were not able to adjust their antenna to improve the link because at the time they were too busy taking observations and trying to photograph the terrain at site 2, where the July landing has been tentatively scheduled.

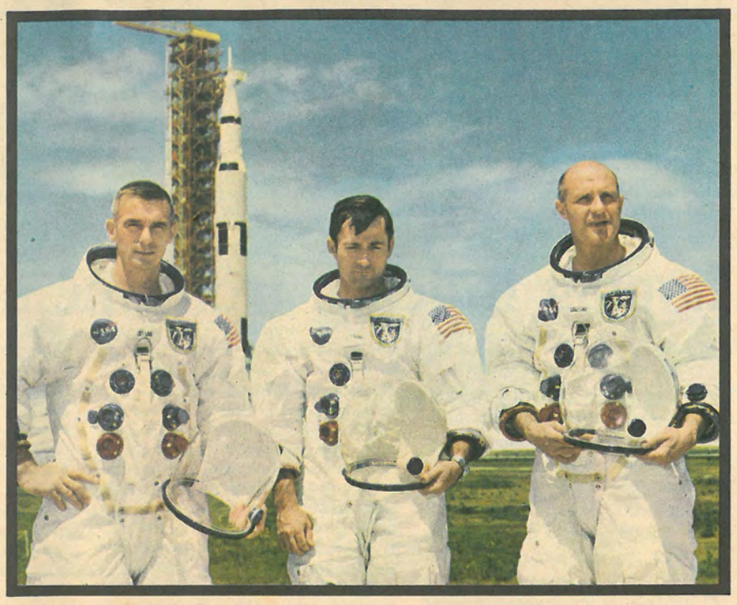
Less serious, but still a cause of considerable annoyance, was the failure of the cameras which were to photograph the landing site; the film jammed. Failure to get pictures of the site will not, however, necessarily jeopardize the timing of Apollo 11. The crew are able to describe the site, which they have seen twice from 50,000ft. and several times from 60 miles up in space, and that should be enough.

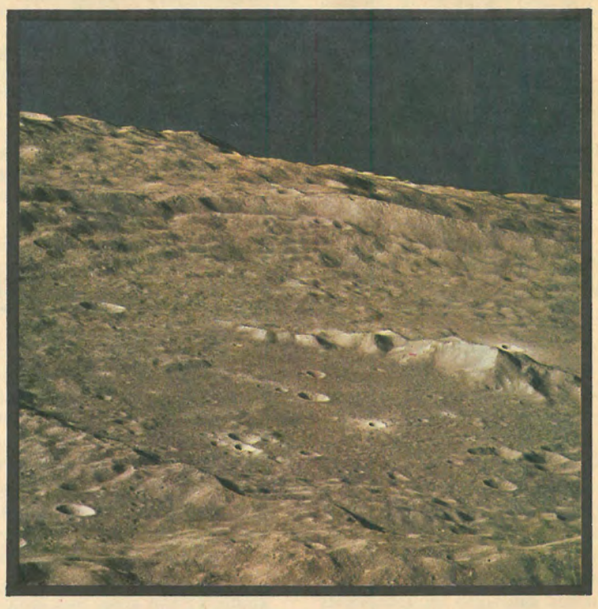
The last hitch came as Snoopy headed back to the rendezvous with Charlie Brown. The astronauts complained of noise and vibration.

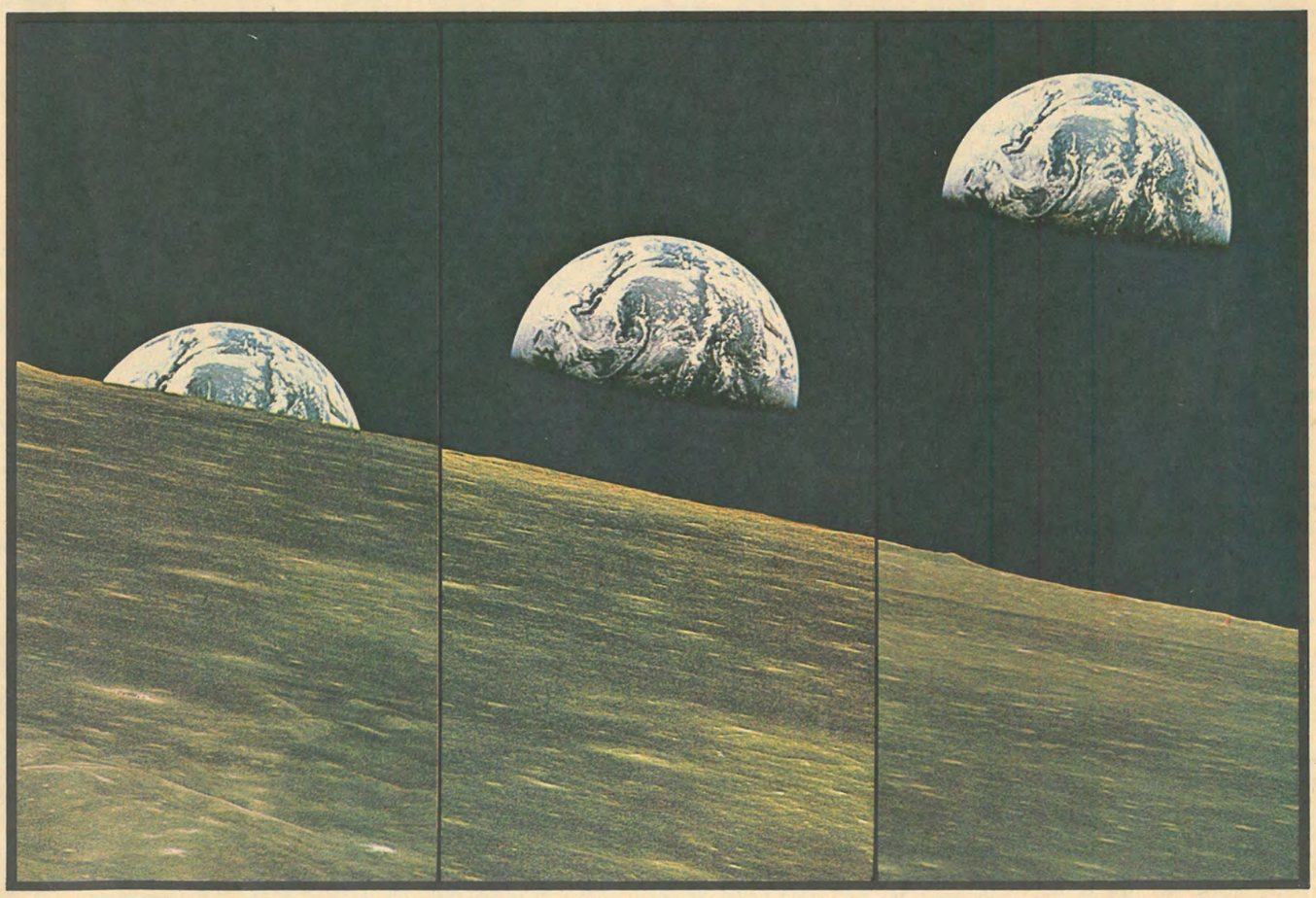
With the possible exception of the communications problem, all these snags should be ironed out fairly easily. These apart, the $100m. Snoopy did all it was asked.

Below: Snoopy, the fragile lunar ferry, its legs catching the sunlight, manoeuvres near the mothercraft during its historic swoop down towards the surface. Lower centre: The Apollo 10 crew before take-off: left to right, Commander Eugene Cernan, Commander John Young and Colonel Thomas Stafford. Behind them waits the mighty Saturn 5 rocket, man's most powerful space launcher, which blasted them off on their 600,000 mile journey. Lower right: A mountainous area of the moon's surface showing the type of terrain which awaits the first man to make a landing. Bottom right: The earth slowly rises above the moon's horizon as seen from Charlie Brown. A similar view brought excited gasps of "It's magnificent" from Colonel Stafford and Commander Cernan as they swept along at more than 3,000 m.p.h. during Snoopy's low orbits. Bottom left: Where man will first set foot on the moon: at the lower left corner of the large Sea of Tranquillity in the centre of the picture.









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