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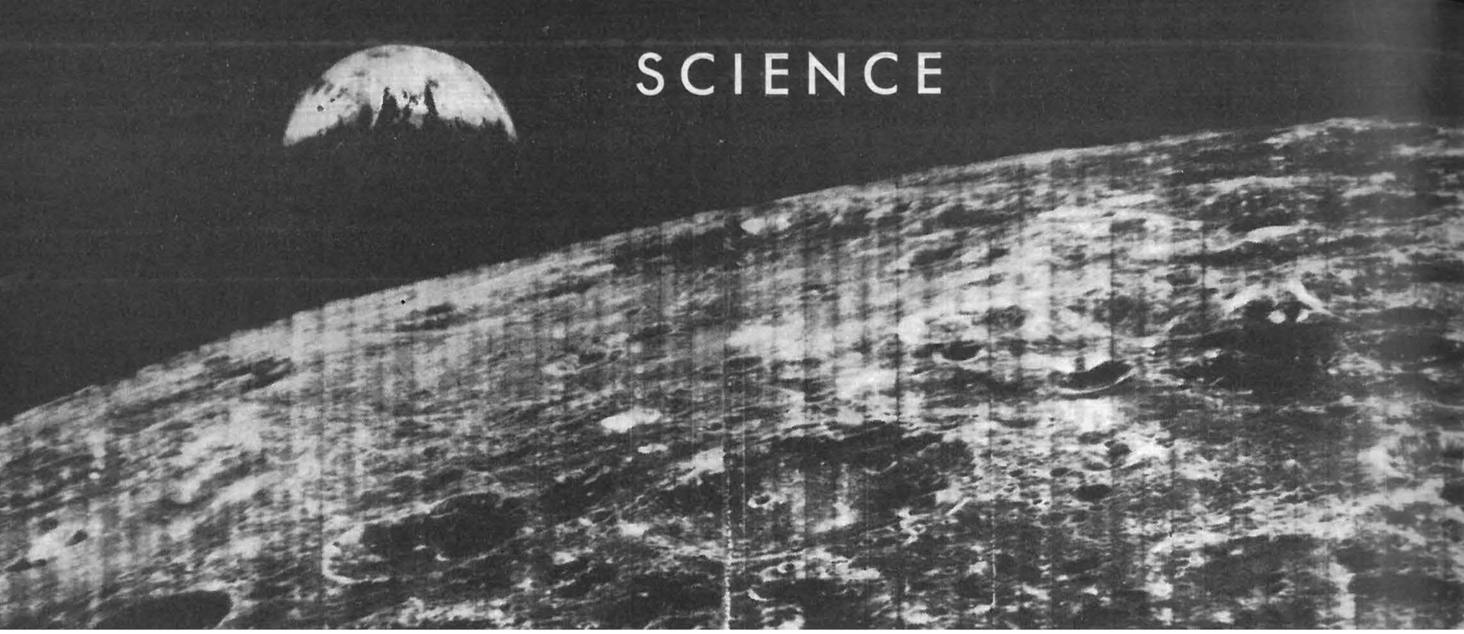


THE EARTH AS SEEN FROM THE MOON BY LUNAR ORBITER I

NASA

COVER STORY

Poised for the Leap

FROM the moment when living organisms appeared in the seas billions of years ago, they seemed driven by an instinctive urge to move beyond their own environment. Out of the dark waters they groped across aeons, toward the light and land and air. Like those remote ancestors, man, too, has striven continually to seek what he has never known before. He has ranged restlessly across the surface of his world; he has traveled back into the primordial oceans; he has learned to fly through his now familiar skies. For the past seven years, he has probed the vacuum of space, soaring as high as 853 miles above the earth. Now, after billions of years of evolution—and, incredibly, within the present blink of history—he is ready to make the great escape from his own planet.

This month, fulfilling the yearnings and predictions of untold generations, man will attempt to propel himself across 230,000 miles of emptiness in a bold voyage toward a shining and beckoning target: the moon. Before December ends, if all goes well, he will circle the moon and look down from his spaceship at lunar craters and "seas" as little as 70 miles below. Staring up, he will see the dominant feature of the black lunar sky—the blue-green, partly illuminated globe that is his home: the earth.

The sheer drama of man's first flight to the moon—the spectacle, the perils and the uncertainty—has been heightened by the prospects of a close race between the U.S. and Russia. The U.S. has announced that on Dec. 21 it hopes to launch three astronauts aboard Apollo 8. According to the projected schedule, they will circle the moon ten times, starting on Christmas Eve, then return to the earth, where they will land 2½ days later. Russian plans, as usual, are cloaked in secrecy. But many Western experts who have pieced together clues from Moscow rumors, recent Soviet space shots and past Soviet behavior are convinced that at least one, and perhaps as many as three cosmonauts will attempt to loop around the moon and return early in December. Although such a shot would be far less sophisticated than the Apollo 8 mission, it would be an undeniable victory for the Soviets.

If the Russians do indeed plan to steal the limelight from Apollo 8, their best opportunity for launching a manned circumlunar shot will occur during a brief period beginning around the first week in December. At that time, a spacecraft could be launched in daylight, streak around the moon, and return for a landing in Russia or the Indian Ocean during daylight hours, when it is easier to locate and reach the downed craft. The mission almost certainly will follow closely the trail of Zond-5 and Zond-6, the first craft to circle the moon and return safely to earth.

Stranded in Orbit

Tass, the Russian news agency, has confirmed that both Zonds were preparatory shots for a manned flight and carried living creatures to test radiation effects near the moon. U.S. scientists suspect that Cosmonaut Georgy Beregovoy successfully tested life-support systems for a manned lunar mission during the earth-orbit flight of Soyuz-3. If so, a Soviet lunar spacecraft may finally be manrated—ready to carry passengers to the moon in December.

No matter what the Russians do, the U.S. astronauts should be on their way moonward on or soon after Dec. 21. Colonel Frank Borman and Major William Anders, both Air Force officers, and Navy Captain James Lovell are already at Cape Kennedy, spending 16 hours a day in preparing for every detail of a complex mission that has been planned and plotted to the last second. They spend 20 hours a week in simulators, training their minds and hands to react almost automatically to every conceivable contingency.

Again and again, at endless conferences, the three men review their flight plan, talk through the sequence of actions that they must take to carry out normal maneuvers, the emergency measures that they must follow to correct equipment failures. For at critical points during their trip, a balky rocket could leave them stranded in orbit around the moon or drive them into collision with the lunar surface. By the time they are fired from Cape Kennedy's launch pad 39A by the world's most powerful rocket, Saturn 5, Borman, Lovell and Anders will be the most thoroughly prepared adventurers ever to have dared the unknown.

Generating 7,500,000 lbs. of thrust, Saturn will thunder to an altitude of 38 miles and a speed of 6,000 m.p.h. in only 2½ minutes. Then, having carried out the herculean task of lifting a 3,100-ton, 363-ft.-long vehicle through the thickest layers of the atmosphere, the giant booster rocket will drop away, and the S-2 second stage will take over. With its five engines producing 1,125,000 lbs. of thrust, the S-2 will accelerate the shortened vehicle to a speed of 14,000 m.p.h. and hurtle it to an altitude of 119 miles. After the S-2 is jettisoned in turn, the third-stage S-4B will ignite, using its 225,000-lb.-thrust engine to increase the spaceship's speed to 17,400 m.p.h. and insert it into a "parking" orbit around the earth.

Once the ship is in orbit, the astronauts and ground controllers will check out all the systems on board, making certain that they are operating properly and that the duplicate and backup systems are in working order. On their second revolution around the earth, if no problems have arisen, the Apollo crew will reignite the S-4B rocket engine over the Pacific near Hawaii. In a 5-min. 11-sec. burning period, the S-4B will accelerate to an "escape" velocity of 24,200 m.p.h., pushing Apollo out of earth orbit and off toward the moon.

As the earth recedes behind them, the astronauts will separate their spacecraft from the S-4B, move about 50 ft. ahead of it, and then turn to face it. During this maneuver, protective panels will be jettisoned from the S-4B, exposing the dummy lunar module (LM) carried in its nose. The astronauts will then simulate docking with the LM—an operation that will be particularly important on the lunar-landing mission next year, when an Apollo spacecraft will dock nose-to-nose with a real LM before taking it into orbit around the moon. Finally, after the astronauts have jockeyed their craft some 8,000 ft. away, the S-4B will dump its remaining fuel into space. That action will generate just enough thrust to shove the S-4B out of the way and into orbit around the sun. Alone in space, the Apollo craft will continue coasting in powerless flight through the final leg of the moon trip, its velocity gradually decreasing as the earth's gravity attempts to pull it back.

TV Spectaculars

Some 30,000 miles from the lunar surface, Apollo will have slowed to a space-age snail's pace—2,170 m.p.h. At this point, lunar gravity will overcome the earth's diminishing pull, and the spacecraft will begin accelerating once more. Ahead, the moon will loom ever larger in the spacecraft windows. By the time Apollo curves around the western edge of the moon, its speed will have risen to 5,720 m.p.h.

Without any additional thrust, Apollo's own momentum and the weak lunar gravity would combine to carry it around the moon and fling it back toward earth in a spatial version of crack-the-whip. Indeed, if a recheck of systems and equipment convinces ground controllers and the astronauts that serious problems have developed, the crew will merely continue in this new course and travel back to earth. But if everything seems all right, Apollo's powerful SPS (service propulsion system) engine will be fired for 246 sec. to slow the spacecraft and allow it to be pulled by the moon into a 70- by 196-mile elliptical lunar orbit. Two revolutions later, a brief 10-sec. burn will change the path to a 70-mi.-high circular orbit. Traveling at 3,640 m.p.h., Apollo will circle the moon once every two hours. For 45 nerve-racking minutes during every revolution—when it is behind the moon and blocked from radio communication with the earth—it will be out of touch with ground controllers.

During their lunar orbiting, the astronauts will take turns shooting still, motion and stereo pictures in color and black-and-white. They will study craters and ridges to see how easily they can be recognized as landmarks. They will plot their position for navigational fixes that will be useful for lunar-landing

The Crew of Apollo 8

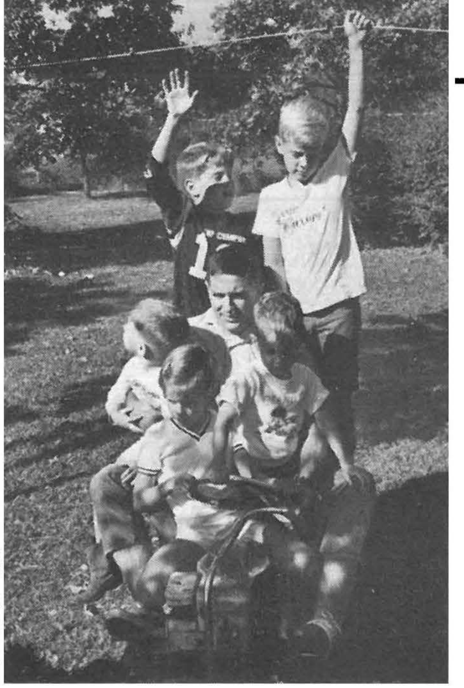
ON its mission to the moon, Apollo 8 will carry a three-man crew that is unusually well qualified, both by experience and temperament, for the pioneering flight: they are Veterans Frank Borman and James Lovell, both 40, and Rookie William Anders, 35.

In December 1965, Borman and Lovell were pilots of Gemini 7 on man's longest space flight—a 330½-hours' orbital mission that included the history-making rendezvous with Gemini 6. Both took their long confinement in the cramped spacecraft with equanimity and quiet humor, and displayed competence and stability that helped win them their Apollo 8 assignments. Eleven months later, Lovell and Edwin Aldrin were the crew on the 94½-hour flight of Gemini 12, the last U.S. manned flight before Apollo 7. Between them, Lovell and Borman have a total of 755½ hours in space, about 125 man-hours more than all the Russian cosmonauts combined have compiled during their ten manned space flights.

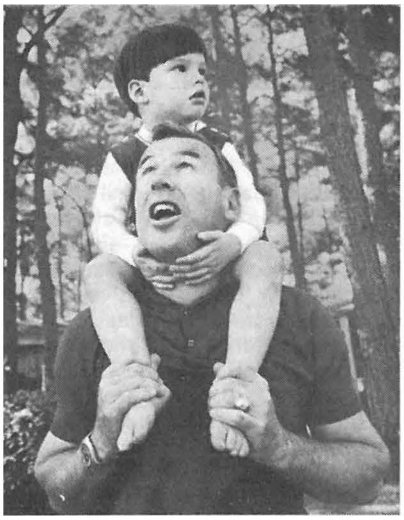
Borman has been air-oriented from youth, when he built model airplanes and sold newspapers to pay for flying lessons. A West Pointer who opted for the Air Force, he earned a master's degree in aeronautical engineering from Caltech, broke an eardrum during a practice dive-bombing run and for a while was certain that he could never again take to the air—let alone fly to the moon. But when his eardrum healed completely, he resumed flying, and now has a total of more than 5,400 hours of flying time. Between training sessions he is a lay reader in an Episcopal church.

Lovell also has looked to the skies for a long time. At 16, he designed and built a rocket that rose 80 ft. on a fuel mixture of gunpowder and airplane glue. And in a term paper at Annapolis, he predicted that rockets would really have their day after man finally penetrated the vacuum of space. Early in his astronaut training, Lovell bubbled over with so much nervous energy that fellow astronauts called him "Shaky"—although he has since proved that he is nerveless in space.

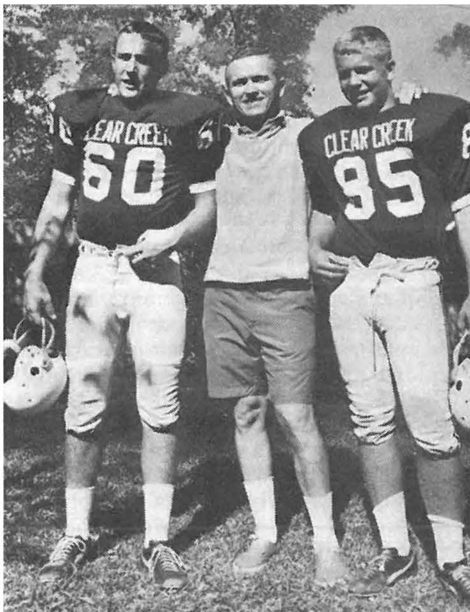
Anders is a service brat who was born in Hong Kong, while his father was there as a Navy commander. After graduating from Annapolis, he switched to the Air Force, won his master's degree in nuclear engineering and became a flying instructor. Until he was forced to abandon it because of his time-consuming space training, Anders owned a Cessna 172 and flew it every time he got a chance. Unusually conscientious, he once won a good-driver's award after an Albuquerque policeman saw him stop his car, remove a cinder block from a crowded highway and drive off.


RALPH MORSE—LIFE

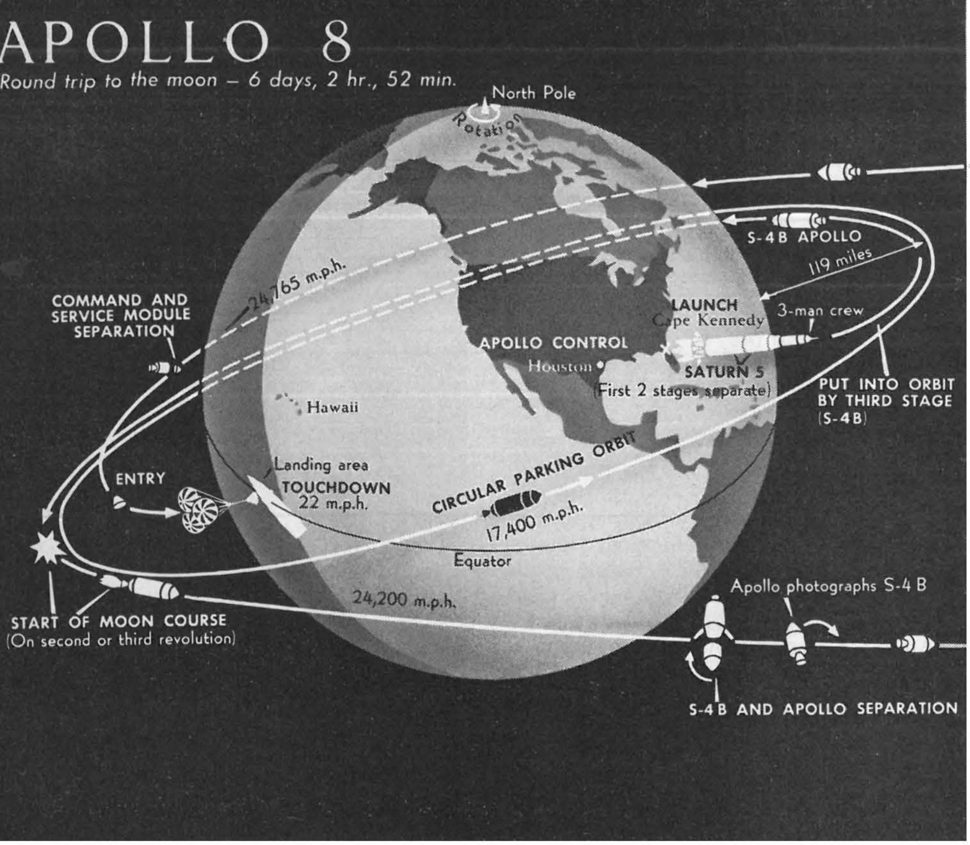
ANDERS & CHILDREN



LOVELL & YOUNGER SON



BORMAN & HIS BOYS



crews on later missions. On the seventh revolution, they will be able to survey a prime LM landing site at a time when illumination is ideal for observation: the sun will be 6.6° above the horizon, casting the long shadows that best bring out distinctive surface features. During lunar orbit, and on both the outgoing and return legs of the mission, the astronauts will shoot television pictures of the moon and the earth and transmit them back to ground stations as Christmastime TV spectaculars.

Chilling Perils

At the end of the tenth lunar revolution, the Apollo crew will fire the SPS engine again—this time for 206 sec. —boosting their speed to 6,060 m.p.h., more than enough to break the moon's gravitational hold and start the spacecraft back toward the earth. About 57 hours later, accelerating under the pull of terrestrial gravity, the astronauts will position their craft properly and then jettison the service module. Streaking into the earth's atmosphere at an angle of 6.5° and a velocity of 24,765 m.p.h., the 11,700-lb. command module—all that will remain of the 3,100-ton vehicle that left Cape Kennedy—will glide downward along a curving 1,300-mile path, deploy its main parachutes at 10,000 ft., and drop gently into the Pacific. Elapsed time for the great lunar adventure: six days, 2 hr. and 52 min.

Acting NASA Administrator Thomas Paine believes that risks to Apollo 8's astronauts "will be within the normal hazards of test pilots flying experimental craft." The careful design, redesign and check-out of rockets and spacecraft, the policy of including duplicate systems wherever possible, and the logical, step-by-step progression of unmanned and manned Saturn and Apollo space shots, he says, "give us a great deal of assurance" about the moon flight.

No matter how carefully it is planned and executed, however, the December flight of Apollo 8 will involve some chilling perils. Besides anticipating the kinds of problems that could occur in a simple near-earth orbital flight, lunar-mission planners must plan realistically for troubles that would be magnified by sheer distance from earth. Should life-support or power systems begin to fail on earth-orbital flights, astronauts are usually within half an hour to three hours of recovery on land or water; a relatively small thrust from a retrorocket can lower their orbit into the atmosphere, where friction provides the additional braking necessary to return them to earth. In the vicinity of the moon, the astronauts might be as long as a three-day journey from home. They could fall victim to minor malfunctions —like a deteriorating oxygen supply— that would not necessarily be fatal in an earth-orbital flight.

There are other moon flight worries, most of them centered around the functioning of the Apollo command module's SPS engine. Should the SPS fail to ignite, or should it burn for less than 80 sec. during the attempt to place Apollo in lunar orbit, there would be little difficulty; the spacecraft would simply continue around the moon and be whipped back toward the earth and safety. But if the SPS should fail between the 80- and 110-sec. marks of its scheduled 246-sec. burn, Apollo would enter what NASA euphemistically describes as an "unstable orbit." After rounding the moon, it would begin heading back toward earth, but not fast enough to escape the moon's gravitational pull. Depending on the length of the abortive burn, Apollo would sooner or later fall back and crash into the lunar surface.

Another tragedy could occur during what Apollo 8 Flight Director Clifford Charlesworth calls the mission's "longest hour." If, after completion of Apollo's tenth lunar revolution, the SPS engine fails to ignite or burns for too short a time, the astronauts would be stranded in orbit without any chance of rescue; they could live only until their oxygen supply was gone. To minimize the possibility of SPS failure, NASA has made nearly all of the engine's components redundant. If one part were to fail, a duplicate would be on hand to take over. But SPS has only one combustion chamber, one propellant injector and one nozzle. All these must operate reliably to avoid disaster.

Skipping Stone

There is one final, crucial phase of Apollo 8's mission: re-entry. As it plunges back to earth, traveling some 7,000 m.p.h. faster than a returning earth-orbit mission, Apollo will have to reenter the atmosphere at an angle no greater than 7.4° nor less than 5.4°. Reentry at too steep an angle would cause too sudden a deceleration. The force on Apollo and its occupants could then exceed 20 g's, and friction with the atmosphere would heat the spacecraft far above its design limits. Says Lieut. General Samuel Phillips, Apollo program director: "There would be a structural breakup and loss of the spacecraft and the crew."

An equally dreadful fate would befall Apollo if it hit the atmosphere at too shallow an angle. Like a flat stone skipping on water, it would bounce off the atmosphere and sail into a large elliptical orbit around the earth. Having shed Apollo's service module before reentry, the astronauts would have insufficient oxygen and electrical power to survive the several hours it might take to return to the atmosphere and land. In Phillips' laconic words, "It's a crew-loss kind of situation."

Other, less perilous problems could turn Apollo 8 from a space spectacular into a humdrum engineering flight. Allowing for such contingencies as the failure of a backup system, an inadvertent early cutoff of the S-4B rocket while it is blasting Apollo toward the moon or unusually intense radiation from the sun, NASA has devised a number of alternative flight plans. Thus, Apollo 8 might merely remain in earth orbit, duplicating Apollo 7's eleven-day flight. It could also loop out as far as 25,000 miles from the earth and then descend into a low earth orbit for several days— or it could re-enter the atmosphere after traveling as far as 69,000 miles into space. Or, just as the Russians will probably do, the spacecraft could simply make a circumlunar flight, loop around behind the moon, and return directly to earth.

Although they freely acknowledge the numerous possibilities of failure, NASA officials nonetheless exude confidence in Apollo 8 and its crew. They expect the mission to go all the way. In the thorough investigation that preceded the decision to send the spacecraft into lunar orbit, says Manned Space Flight Director George Mueller, "we found no incipient problems. The odds for complete success of Apollo 8 are as good as they were for Apollo 7."

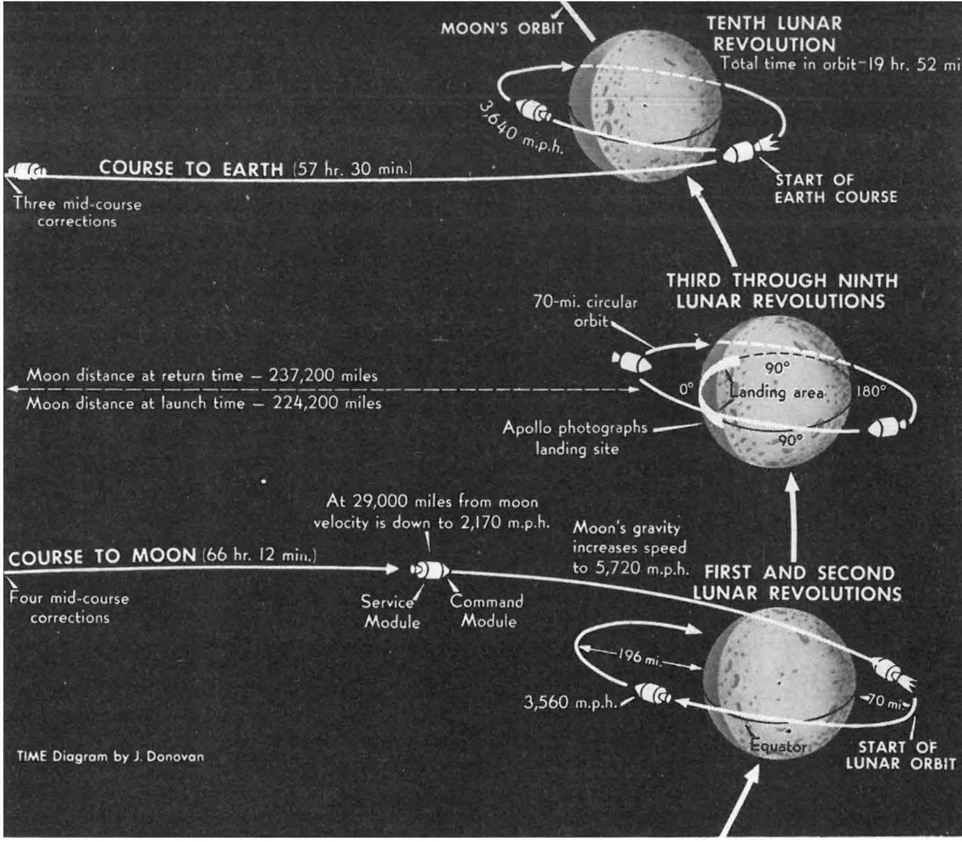
Man in the Moon

In their most inspired moments, visionary authors of the past never imagined a mission so complex. Still, they dreamed endlessly of Apollo-like moon flights. Then, as now, some men yearned for a military base from which terrible new weapons could dominate earth. Some speculated on vast new reserves of mineral wealth. Others yearned for no more than the challenge of the trip. For whatever reason, the moon, as it still does, beckoned to all. Its lure seems irresistible.

In his *True History,* written in the 2nd century A.D., a Syrian named Lucian told how a ship and its crew were caught in a whirlwind while sailing beyond the Pillars of Hercules and were lofted all the way to the moon. There the sailors witnessed a war between moonmen and invaders from the sun. It was all so alluring that, in a second book, another Lucian character went there on purpose: he simply donned wings and flew.

Galileo's 17th century use of the telescope to study the heavens spawned a host of moon stories. *The Man in the Moone,* written by Francis Godwin, Bishop of Llandoff, and published in 1638, offered a hero who was carried to his destination on a frail raft pulled by swans. Unaware of the vacuum in space, the traveler had no difficulty breathing on the trip, but he did find that his weight lessened as he left the earth. That remarkable scientific insight by Godwin preceded Newton's discovery of the laws of gravity by many years.

Cyrano de Bergerac's *Voyage to the Moon,* 1656, was the first novel to suggest the use of rockets for moon flight.



But it was not in the same scientific league with *Somnium,* a piece of science fiction by Johann Kepler, the famed 17th century astronomer and mathematician who explained the laws of planetary motion. Describing space flight, Kepler called the "initial movement," or launch, "most uncomfortable and dangerous, for the traveler is torn aloft as if blown up by gunpowder." He explained the bitter cold and airlessness of space, discussed weightlessness, and even suggested the equivalent of reverse thrust to land gently on the moon.

Nursery rhymes, too, began to reflect man's growing lunar interest. One, printed in 1805, even closely anticipated Apollo 8's timetable:

"What is the news, good neighbor, I pray?"
"They say a balloon has gone up to the moon
And won't be back till a week from today."

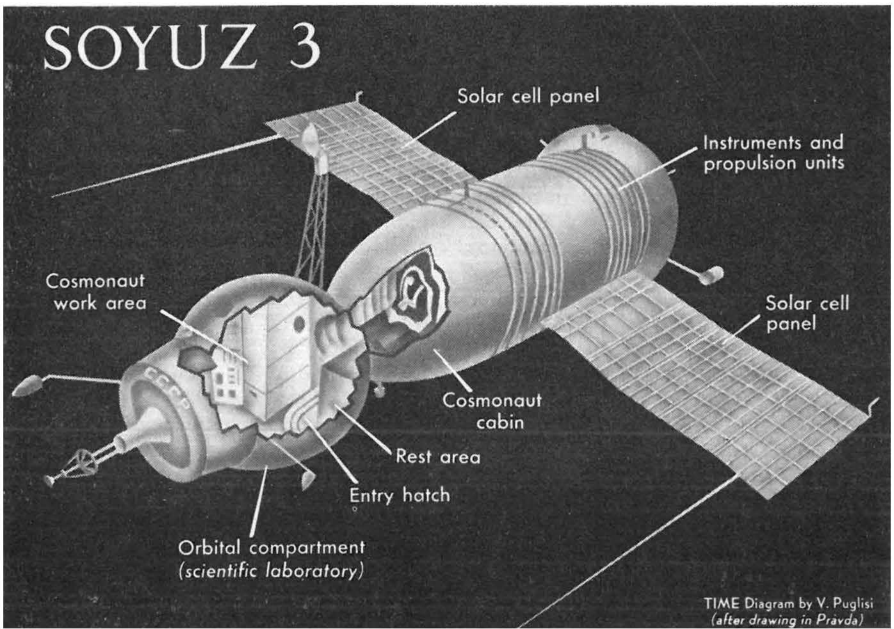
In his classic science-fiction novel, *From the Earth to the Moon,* published in 1865, Jules Verne moved even closer to an accurate description of 20th century space flight. His man-carrying space projectile was shot from a giant cannon in Florida, reached an escape velocity of almost 25,000 m.p.h., became almost red-hot as it passed through the atmosphere, was steered by rockets, and circumnavigated the moon.

Flash Powder

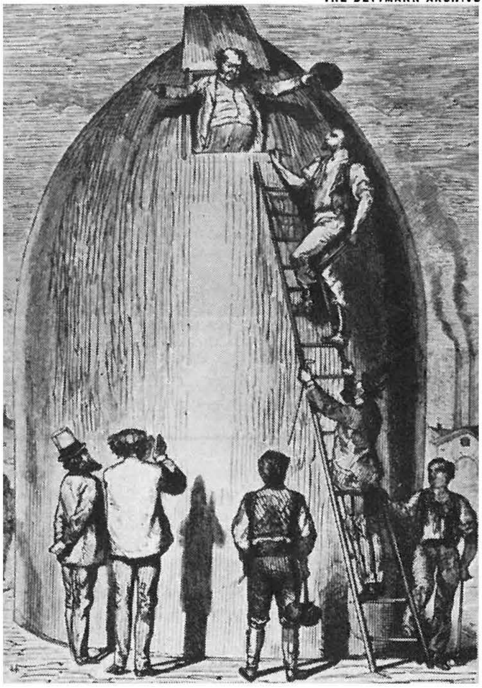
Not until close to the turn of the century was man ready to turn his attention from fanciful to actual space flights. By 1898, a deaf Russian schoolteacher named Konstantin Tsiolkovsky had calculated the mathematical laws of rocket motion and begun to publish scores of articles about space travel. His descriptions of earth satellites, liquid-fuel rockets, space suits, solar energy and the eventual colonization of the solar system, stimulated Russia's insatiable appetite for space travel.

By World War I, a New England physics professor, Robert Goddard, had become interested in the use of rockets for studying meteorology. In 1919, he published a mathematical analysis of a meteorological rocket and pointed out that the same principle could be used to carry a charge of flash powder to the moon, where its ignition would be visible from earth. In 1926, he launched the world's first successful liquid-fuel rocket. It rose all of 184 ft.

Soon, European amateurs and scientists alike were also experimenting with rockets, most of them inspired by *The Rocket into Interplanetary Space,* a booklet published in 1923 by Ru-



THE BETTMANN ARCHIVE



RETURN OF VERNE'S MOON VOYAGER
By whirlwind, swan and cannon.

manian Professor Hermann Oberth. German rocketeers eventually constructed a liquid-fuel rocket strikingly similar to Goddard's. By 1942, under the direction of Walter Dornberger and Wernher Von Braun, it had evolved into the dread V-2, the first space-age rocket. After the successful test-firing of the V-2, Dornberger turned to Von Braun and shouted exultantly: "Do you realize what we accomplished today? Today the spaceship was born."

The V-2 rocket and its designers eventually helped launch both the U.S. and the Russian missile programs, as well as the moon race that was to follow. Even today's liquid-fuel rockets are simply highly evolved descendants of that original V-2.

Although Russia and the U.S. recognized the role that rockets could eventually play in space exploration, both nations were more immediately concerned about arming themselves with the most devastating military weapon: the nuclear-tipped ballistic missile. Because U.S. scientists had already begun to master the art of packing enormous power into small nuclear warheads, the Redstone, Jupiter and Atlas missiles designed to carry them were only of modest size. The Russians, who were behind in nuclear technology, had only more primitive and massive warheads to use; they were forced to build enormous rockets to loft them. But the Soviet's military liability eventually became a prime scientific asset. By 1961, when President Kennedy proclaimed a national goal of landing men on the moon before the end of the decade, the Soviets had already used huge rockets to blast far ahead of the U.S. In September 1959, only two years after they successfully orbited Sputnik 1, the Soviets hit the moon with Luna 2. That was 2½ years before the U.S. matched the feat with Ranger 4. One month after Luna 2's flight, Luna 3 passed around the moon to shoot the first pictures of the hidden lunar backside. Not until more than six years later did Lunar Orbiter 1 televise similar shots to the U.S.

The Soviets took an equally big lead in manned flights. Yuri Gagarin orbited in Vostok 1 more than a month before Kennedy's 1961 speech, and ten months before the U.S. could place John Glenn in orbit in Mercury 6. Russian cosmonauts also compiled an enviable list of other space records: first woman in orbit, first two-man crew, first three-man crew and first space walk.

In the middle '60s, however, a vitalized U.S. space program all but wiped out the Soviet lead in the moon race. U.S. Gemini astronauts broke orbital endurance records and completed the first rendezvous and docking in space. Unmanned Rangers, Lunar Orbiters and Surveyors returned tens of thousands of lunar photographs, and Surveyors made the first soft landings on the moon. They sent back closeup pictures of the moon's surface, and they clawed up and analyzed actual moon soil.

Manned Landing

In 1967, by successfully flying the mammoth Saturn 5 rocket, about 2½ times as powerful as the Proton, Russia's largest booster, the U.S. may well have ensured that it would be first to place men on the lunar surface. Next February, Saturn is scheduled to launch Apollo 9, a mission that will include the first manned test of the module designed to land on the moon. Two months later, the giant rocket is scheduled to boost Apollo 10 into a lunar orbit from which a manned module will descend to within 50,000 ft. of the moon's surface—and may even try for a landing. If the attempt is not made, the manned landing might well occur on the Apollo 11 mission, scheduled for June.

With only Proton to fly its cosmonauts to the moon, the Soviets will find it difficult to beat the U.S. schedule. U.S. officials estimate that it would take as many as eight Proton launches to orbit parts and assemble a spacecraft powerful enough to fly directly to the lunar surface and take off again. The Russians have yet to dock a manned craft in earth orbit, and they will need considerably more practice before they can assemble a number of craft in space. Past performance suggests that they will conduct a number of these operations with unmanned automatic craft to make certain that cosmonauts can fly them safely. And although Russian scientists are rumored to be building a rocket with between 10 million and 14 million lbs. of thrust—enough to launch a spacecraft that can fly directly to the moon, land, and then blast off for earth—they have yet to test it, let alone use it for manned flights.

THE BETTMANN ARCHIVE

EARLY VERSION OF LUNAR LANDING
On rafts, ships and balloons.

Despite the obvious commitment to manned moon programs by both Russia and the U.S. some scientists have continued to argue against sending men to do what they say machines can accomplish as well or better. A month before the Apollo 8 blast-off, British Astronomer Sir Bernard Lovell lashed out against the mission. "On a scientific basis," he complained, "this project is wasteful and silly. We've reached the stage with automatic landings when it's not necessary to risk human life to get information about the moon."

Speaking for NASA at a press conference at Cape Kennedy, Astronaut Anders talked back to the famed astronomer. Although Apollo 8 is not primarily a scientific flight, he said, it would give science its first chance to have in the vicinity of the moon "an eyeball connected to a brain connected to an arm that can write or a tongue that can speak. We think that by having a man in space, you can do a job that you can't do with unmanned vehicles."

The Russians obviously agree. Says Mstislav Keldysh, head of the Soviet Academy of Sciences: "Man will always strive to take a direct part in scientific space research. Automatic devices can never fully replace man." Russia and the U.S. are both realistically aware that manned flight to the moon, more than any other feat, will capture the imagination of the world and produce great political and psychological benefits to the nation that accomplishes it first. And both may well be driven toward the moon more by the age-old instincts of their species than by the most compelling of practical reasons.

It all comes down to this: man long ago picked the moon as a goal, and there is no turning back.