Collier's

March 22, 1952 • Fifteen Cents

Man Will Conquer Space Soon

TOP SCIENTISTS TELL HOW IN 15 STARTLING PAGES

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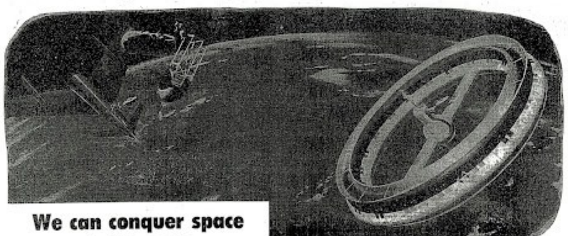

Collier's

EDWARD ANTHONY, *Publisher*
LOUIS RUPPEL, *Editor*

March 22, 1952

ARTICLES

FICTION

The characters in all stories and serials in this magazine are purely imaginary. No reference or allusion to any living person is intended.

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MAN WILL CONQUER SPACE SOON

Some of the scientists and illustrators who took part in Collier's symposium (left to right): Rolf Klep, Willy Ley, Dr. Heinz Haber, Dr. Wernher von Braun, Dr. Fred L. Whipple, and Chesley Bonestell

What Are We Waiting For?

ON THE following pages Collier's presents what may be one of the most important scientific symposiums ever published by a national magazine. It is the story of the inevitability of man's conquest of space.

What you will read here is not science fiction. It is serious fact. Moreover, it is an urgent warning that the U.S. must immediately embark on a long-range development program to secure for the West "space superiority." If we do not, somebody else will. That somebody else very probably would be the Soviet Union.

The scientists of the Soviet Union, like those of the U.S., have reached the conclusion that it is now possible to establish an artificial satellite or "space station" in which man can live and work far beyond the earth's atmosphere. In the past it has been correctly said that the first nation to do this will control the earth. And it is too much to assume that Moscow's military planners have overlooked the military potentialities of such an instrument.

A ruthless foe established on a space station could actually subjugate the peoples of the world. Sweeping around the earth in a fixed orbit, like a second moon, this man-made island in the heavens could be used as a platform from which to launch guided missiles. Armed with atomic war heads, radar-controlled projectiles could be aimed at any target on the earth's surface with devastating accuracy.

Furthermore, because of their enormous speeds and relatively small size, it would be almost impossible to intercept them. In other words: whoever is the first to build a station in space can prevent any other nation from doing likewise.

We know that the Soviet Union, like the U.S., has an extensive guided missile and rocket program under way. Recently, however, the Soviets intimated that they were investigating the development of huge rockets capable of leaving the earth's atmosphere. One of their top scientists, Dr. M. K. Tikhonravov, a member of the Red Army's Military Academy of Artillery, let it be known that on the basis of Soviet scientific development such rocket ships could be built and, also, that the creation of a space station was not only feasible but definitely probable. Soviet engineers could even now, he declared, calculate precisely the characteristics of such space vehicles; and he added that Soviet developments in this field equaled, if not exceeded, those of the Western World.

We have already learned, to our sorrow, that Soviet scientists and engineers should never be underestimated. They produced the atomic bomb years earlier than was anticipated. Our air superiority over the Korean battlefields is being challenged by their excellent MIG-15 jet fighters which, at certain altitudes, have proved much faster than ours. And while it is not believed that the Soviet Union has actually begun work on a major project to capture space superiority, U.S. scientists point out that the basic knowledge for such a program has been available for the last 20 years.

What is the U.S. doing, if anything, in this field?

In December, 1948, the late James Forrestal, then Secretary of Defense, spoke of the existence of an "earth satellite vehicle program." But in the opinion of competent military observers this was little more than a preliminary study. And so far as is known today, little further progress has been made. Collier's feels justified in asking: What are we waiting for?

We have the scientists and the engineers. We enjoy industrial superiority. We have the inventive genius. Why, therefore, have we not embarked on a major space program equivalent to that which was undertaken in developing the atomic bomb? The issue is virtually the same.

The atomic bomb has enabled the U.S. to buy time since the end of World War II. Speaking in Boston in 1949, Winston Churchill put it this way: "Europe would have been communized and London under bombardment some time ago but for the deterrent of the atomic bomb in the hands of the United States." The same could be said for a space station. In the hands of the West a space station, permanently established beyond the atmosphere, would be the greatest hope for peace the world has ever known. No nation could undertake preparations for war without the certain knowledge that it was being observed by the ever-watching eyes aboard the "sentinel in space." It would be the end of Iron Curtains wherever they might be.

Furthermore, the establishment of a space station would mean the dawning of a new era for mankind. For the first time, full exploration of the heavens would be possible, and the great secrets of the universe would be revealed.

When the atomic bomb program—the Manhattan Project—was initiated, nobody really knew whether such a weapon could actually be made. The famous Smyth Report on atomic energy tells us that among the scientists there were many who had grave and fundamental doubts of the success of the undertaking. It was a two-billion-dollar technical gamble.

Such would not be the case with a space program. The claim that huge rocket ships can be built and a space station created still stands unchallenged by any serious scientist. Our engineers can spell out right now (as you will see) the technical specifications for the rocket ship and space station in cut-and-dried figures. And they can detail the design features. All they need is time (about 10 years), money and authority.

Even the cost has been estimated: $4,000,000,000. And when one considers that we have spent nearly $54,000,000,000 on rearmament since the Korean war began, the expenditure of $4,000,000,000 to produce an instrument which would guarantee the peace of the world seems negligible.

Collier's became interested in this whole program last October when members of our editorial staff attended the First Annual Symposium on Space Travel, held at New York's Hayden Planetarium. On the basis of their findings, Collier's invited the top scientists in the field of space research to New York for a series of discussions. The magazine symposium on these pages was born of these round-table sessions.

The scientists who have worked with us over the last five months on this project and whose views are presented on the succeeding pages are:

- **Dr. Wernher von Braun,** Technical Director of the Army Ordnance Guided Missiles Development Group. At forty, he is considered the foremost rocket engineer in the world today. He was brought to this country from Germany by the U.S. government in 1945.
- **Dr. Fred L. Whipple,** Chairman, Department of Astronomy, Harvard University. One of the nation's outstanding astronomers, he has spent most of his forty-five years studying the behavior of meteorites.
- **Dr. Joseph Kaplan,** Professor of Physics at UCLA. One of the nation's top physicists and a world-renowned authority on the upper atmosphere, the forty-nine-year-old scientist was decorated in 1947 for work in connection with B-29 bomber operations.
- **Dr. Heinz Haber,** of the U.S. Air Force's Department of Space Medicine. Author of more than 25 scientific papers since our government brought him to this country from Germany in 1947, Dr. Haber, thirty-eight, is one of a small group of scientists working on the medical aspects of man in space.
- **Willy Ley,** who acted as adviser to Collier's in the preparation of this project. Mr. Ley, forty-six, is perhaps the best-known magazine science writer in the U.S. today. Originally a paleontologist, he was one of the founders of the German Rocket Society in 1927 and was Dr. Wernher von Braun's first tutor in rocket research.

Others who made outstanding contributions to this issue include:

- **Oscar Schachter,** Deputy Director of the UN Legal Department. A recognized authority on international law, this thirty-six-year-old lawyer has frequently given legal advice on matters pertaining to international scientific questions, which lately have included the problems of space travel.
- **Chesley Bonestell,** whose art has appeared in the pages of Collier's many times before. Famous for his astronomical paintings, Mr. Bonestell began his career as an architect, but has spent most of his life painting for magazines and lately for Hollywood.
- Artists **Fred Freeman** and **Rolf Klep.** Both spent many months working in conjunction with the scientists.

For Collier's, associate editor Cornelius Ryan supervised assembly of the material for the symposium. The views expressed by the contributors are necessarily their own and in no way reflect those of the organizations to which they are attached.

Collier's believes that the time has come for Washington to give priority of attention to the matter of space superiority. The rearmament gap between the East and West has been steadily closing. And nothing, in our opinion, should be left undone that might guarantee the peace of the world. It's as simple as that.

THE EDITORS


Dr. Joseph Kaplan


Oscar Schachter


Fred Freeman


Cornelius Ryan

DRAWINGS BY ROLF KLEP

rolf klep

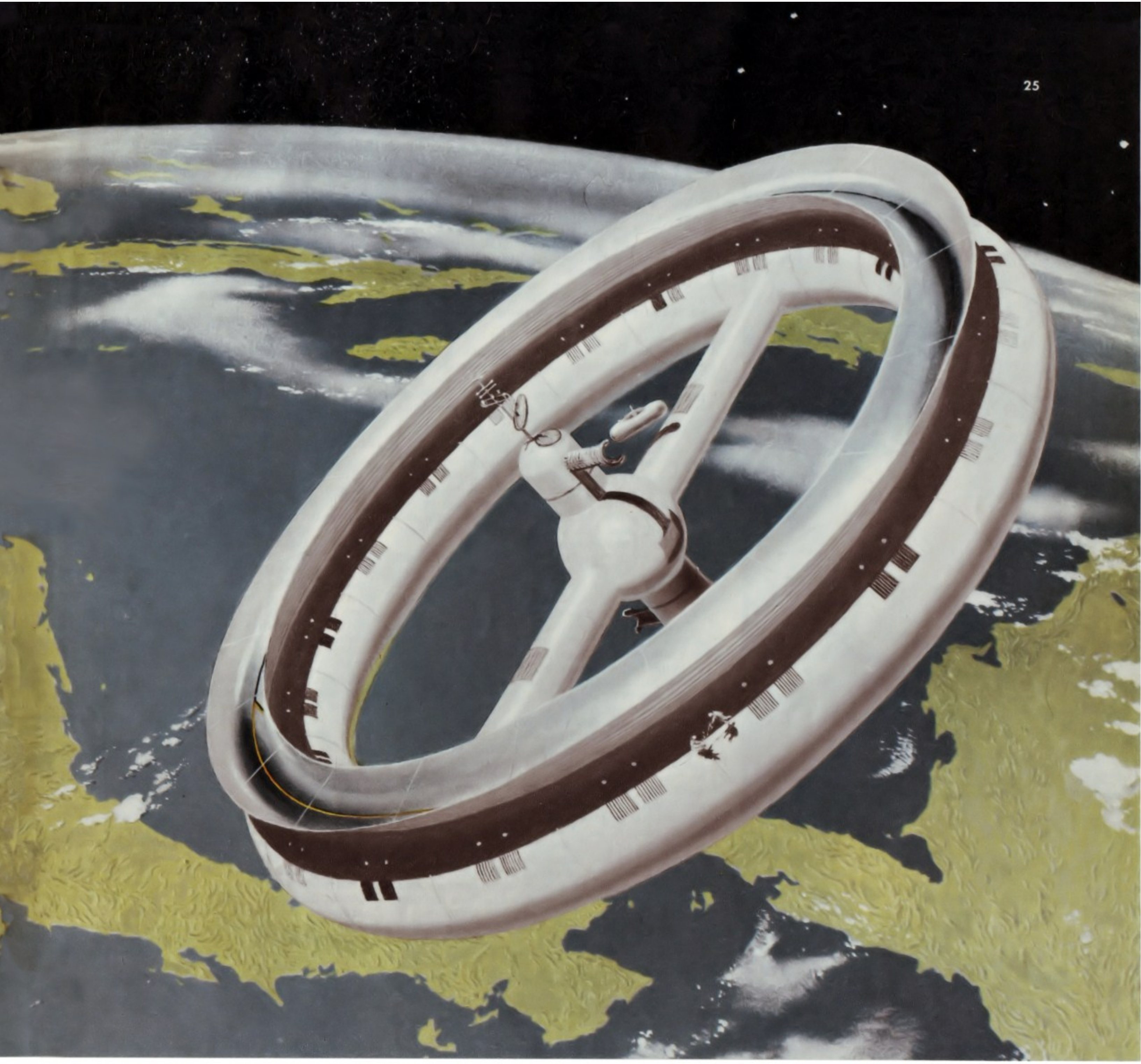
Men and materials arrive in the winged rocket and take "space taxis" to wheel-shaped space station at right. Men wear pressurized suits

CROSSING THE LAST FRONTIER

By DR. WERNHER von BRAUN

Technical Director, Army Ordnance Guided Missiles Development Group, Huntsville, Alabama

Scientists and engineers now know how to build a station in space that would circle the earth 1,075 miles up. The job would take 10 years, and cost twice as much as the atom bomb. If we do it, we can not only preserve the peace but we can take a long step toward uniting mankind



Three "space taxis" can be seen—one leaving rocket, another reaching satellite, a third near the already-built astronomical observatory

WITHIN the next 10 or 15 years, the earth will have a new companion in the skies, a man-made satellite that could be either the greatest force for peace ever devised, or one of the most terrible weapons of war—depending on who makes and controls it. Inhabited by humans, and visible from the ground as a fast-moving star, it will sweep around the earth at an incredible rate of speed in that dark void beyond the atmosphere which is known as "space."

In the opinion of many top experts, this artificial moon—which will be carried into space, piece by piece, by rocket ships—will travel along a celestial route 1,075 miles above the earth, completing a trip around the globe every two hours. Nature will provide the motive power; a neat balance between its speed and the earth's gravitational pull will keep it on course (just as the moon is fixed in its orbit by the same two factors). The speed at which the 250-foot-wide, "wheel"-shaped satellite will move will be an almost unbelievable 4.4 miles per second, or 15,840 miles per hour—20 times the speed of sound. However, this terrific velocity will not be apparent to its occupants. To them, the space station will appear to be a perfectly steady platform.

From this platform, a trip to the moon itself will be just a step, as scientists reckon distance in space.

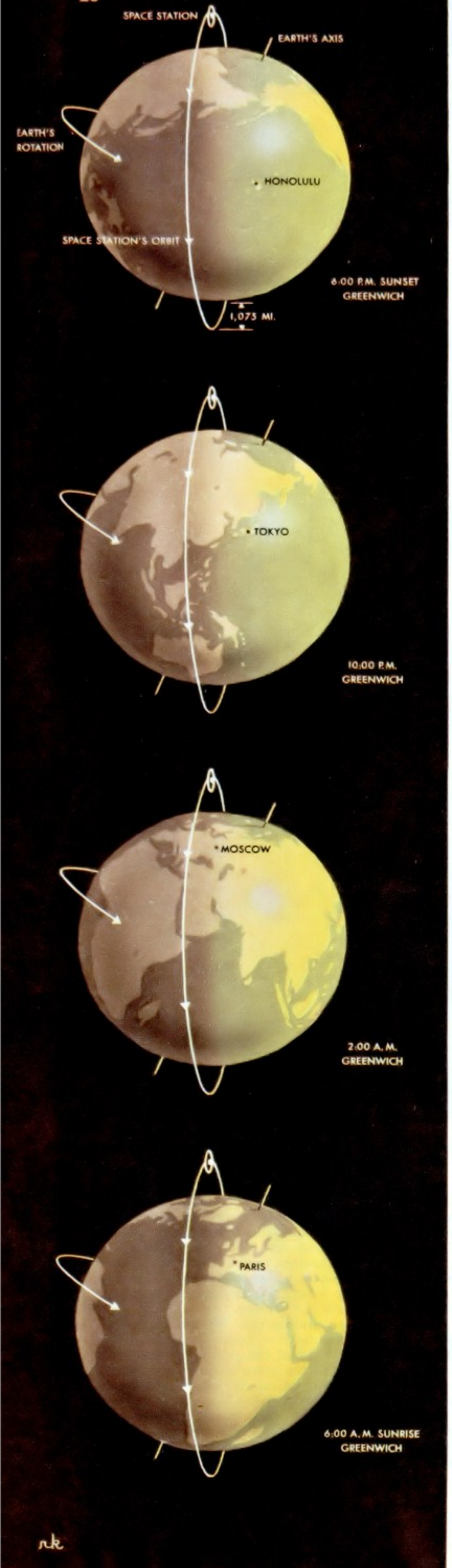
The choice of the so-called "two-hour" orbit—in preference to a faster one, closer to the earth, or a slower one like the 29-day orbit of the moon—has one major advantage: although far enough up to avoid the hazards of the earth's atmosphere, it is close enough to afford a superb observation post.

Technicians in this space station—using specially designed, powerful telescopes attached to large optical screens, radarscopes and cameras—will keep under constant inspection every ocean, continent, country and city. Even small towns will be clearly visible through optical instruments that will give the watchers in space the same vantage point enjoyed by a man in an observation plane only 5,000 feet off the ground.

Nothing will go unobserved. Within each two-hour period, as the earth revolves inside the satellite's orbit, one twelfth of the globe's territory will pass into the view of the space station's occupants; within each 24-hour period, the entire surface of the earth will have been visible.

Over North America, for example, the space station might pass over the East Coast at, say 10:00 A.M., and, after having completed a full revolution around the earth, would—because the

PAINTING BY CHESLEY BONESTELL



earth itself has turned meanwhile—pass over the West Coast two hours later. In the course of that one revolution it would have been north as far as Nome, Alaska, and south almost to Little America on the Antarctic Continent. At 10:00 A.M. the next day, it would appear once again over the East Coast.

Despite the vast territory thus covered, selected spots on the earth could receive pinpoint examination. For example, troop maneuvers, planes being readied on the flight deck of an aircraft carrier, or bombers forming into groups over an airfield will be clearly discernible. Because of the telescopic eyes and cameras of the space station, it will be almost impossible for any nation to hide warlike preparations for any length of time.

* * *

These things we know from high-altitude photographs and astronomical studies: to the naked eye, the earth, more than 1,000 miles below, will appear as a gigantic, glowing globe. It will be an awe-inspiring sight. On the earth's "day" side, the space station's crew will see glaring white patches of overcast reflecting the light of the sun. The continents will stand out in shades of gray and brown bordering the brilliant blue of the seas. North America will look like a great patchwork of brown, gray and green reaching all the way to the snow-covered Rockies. And one polar cap—whichever happens to be enjoying summer at the time—will show as a blinding white, too brilliant to look at with the naked eye.

On the earth's "night" side, the world's cities will be clearly visible as twinkling points of light. Surrounded by the hazy aura of its atmosphere—that great ocean of air in which we live—the earth will be framed by the absolute black of space.

Development of the space station is as inevitable as the rising of the sun; man has already poked his nose into space and he is not likely to pull it back.

On the 14th of September, 1944, a German V-2 rocket, launched from a small island in the Baltic, soared to a peak altitude of 109 miles. Two years later, on December 17, 1946, another V-2, fired at the Army Ordnance's White Sands Proving Ground, New Mexico, reached a height of 114 miles—more than five times the highest altitude ever attained by a meteorological sounding balloon. And on the 24th of February, 1949, a "two-stage rocket" (a small rocket named the "WAC Corporal," fired from the nose of a V-2 acting as carrier or "first stage") soared up to a height of 250 miles—roughly the distance between New York and Washington, but straight up!

These projectiles utilize the same principle of propulsion as the jet airplane. It is based on Isaac Newton's third law of motion, which can be stated this way: for every action there must be a reaction of equal force, but in the opposite direction. A good example is the firing of a bullet from a rifle. When you pull the trigger and the bullet speeds out of the barrel, there is a recoil which slams the rifle butt back against your shoulder. If the rifle were lighter and the explosion of the cartridge more powerful, the gun might go flying over your shoulder for a considerable distance.

This is the way a rocket works. The body of the rocket is like the rifle barrel; the gases ejected from its tail are like the bullet. And the power of a rocket is measured not in horsepower, but in pounds or tons of recoil—called "thrust." Because it depends on the recoil principle, this method of propulsion does not require air.

There is nothing mysterious about making use of this principle as the first step toward making our space station a reality. On the basis of present engineering knowledge, only a determined effort and the money to back it up are required. And if we don't do it, another nation—possibly less peace-minded—will. If we were to begin it immediately, and could keep going at top speed, the whole program would take about 10 years. The estimated cost would be $4,000,000,000—about twice the cost of developing the atomic bomb, but less than one quarter the price of military materials ordered by the Defense Department during the last half of 1951.

Our first need would be a huge rocket capable of carrying a crew and some 30 or 40 tons of cargo into the "two-hour" orbit. This can be built. To understand how, we again use the modern gun as an example.

A shell swiftly attains a certain speed within the gun barrel, then merely coasts through a curved path toward its target. A long-range rocket also requires its initial speed during a comparatively short time, then is carried by momentum.

For example, the V-2 rocket in a 200-mile flight is under power for only 65 seconds, during which it travels 20 miles. At the end of this 65-second period of propulsion it reaches a cut-off speed of 3,600 miles per hour; it coasts the remaining 180 miles. Logically, therefore, if we want to step up the range of a rocket, we must increase its speed during the period of powered flight. If we could step up its cut-off speed to 8,280 miles per hour, it would travel 1,000 miles.

To make a shell hit its target, the gun barrel has to be elevated and pointed in the proper direction. If the barrel were pointed straight up into the sky, the shell would climb to a certain altitude and then simply fall back, landing quite close to the gun. Exactly the same thing happens when a rocket is fired vertically. But to make the rocket reach a distant target after its vertical take-off, it must be tilted after it reaches a certain height above the ground. In rockets capable of carrying a crew and cargo, the tilting would be done by swivel-mounted rocket motors, which, by blasting sideways, would cause the rocket to veer.

* * *

Employing this method, at a cut-off speed of 17,460 miles per hour, a rocket would coast halfway around the globe before striking ground. And by boosting to just a little higher cut-off speed—4.86 miles per second or 17,500 miles per hour—its coasting path, after the power had been cut off, would match the curvature of the earth. The rocket would actually be "falling around the earth," because its speed and the earth's gravitational pull would balance exactly.

It would never fall back to the ground, for it would now be an artificial satellite, circling according to the same laws that govern the moon's path about the earth.

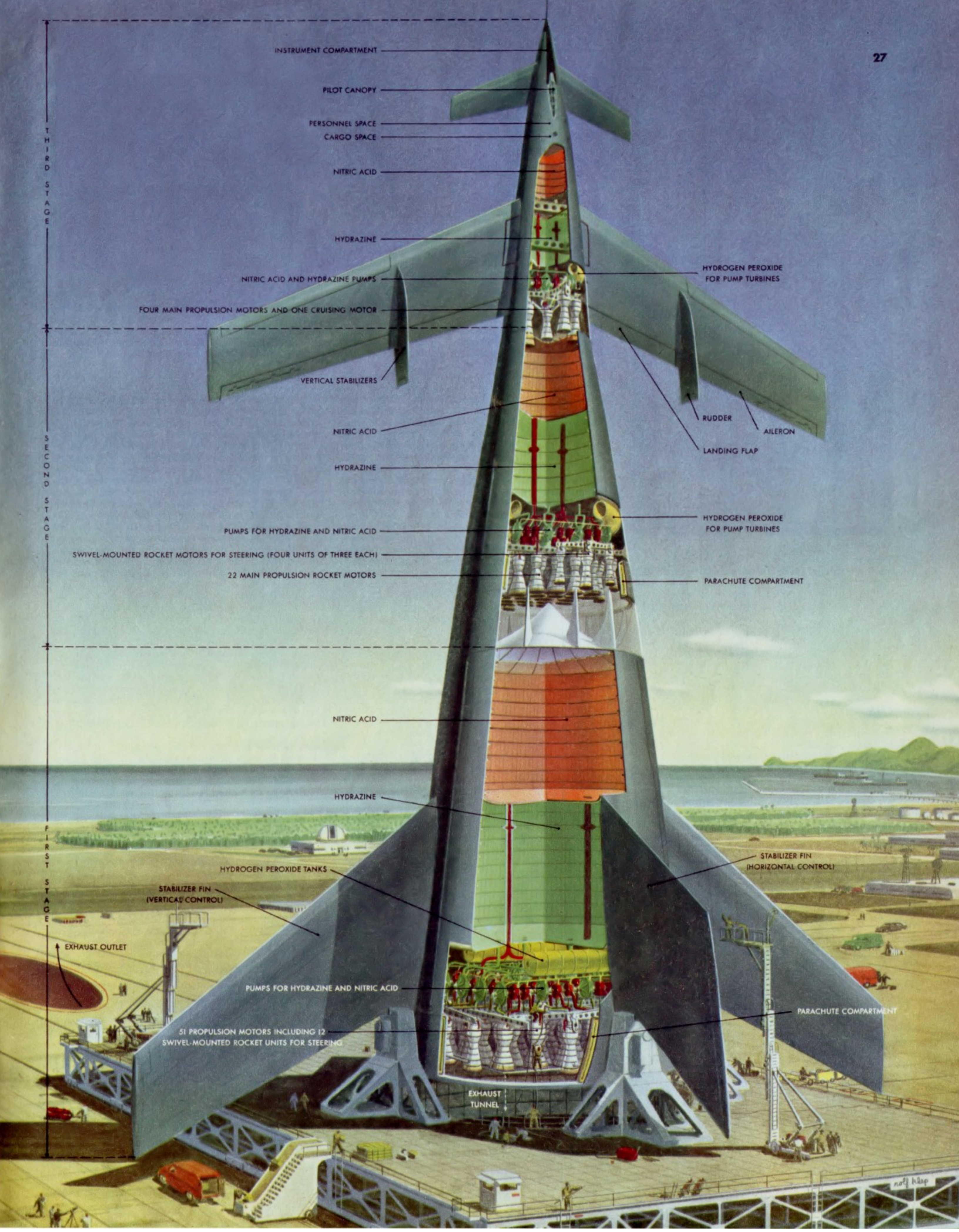
Making it do this would require delicate timing—but when you think of the split-second predictions of the eclipses, you will grant that there can hardly be any branch of natural science more accurate than the one dealing with the motion of heavenly bodies.

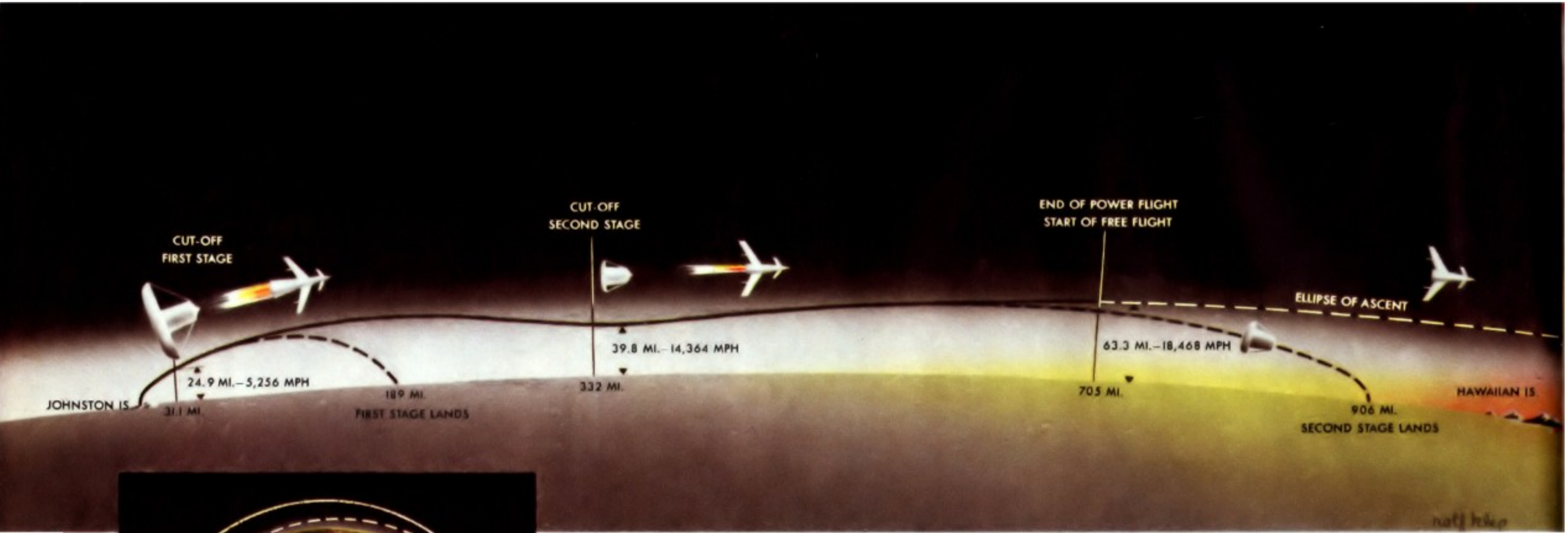
Will it be possible to attain this fantastic speed of 17,500 miles per hour necessary to reach our chosen two-hour orbit? This is almost five times as fast as the V-2. Of course, we can replace the V-2's alcohol and liquid oxygen by more powerful propellants, and even, by improving the design, reduce the rocket's dead weight and thereby boost the speed by some 40 or 50 per cent; but we would still have a long way to go.

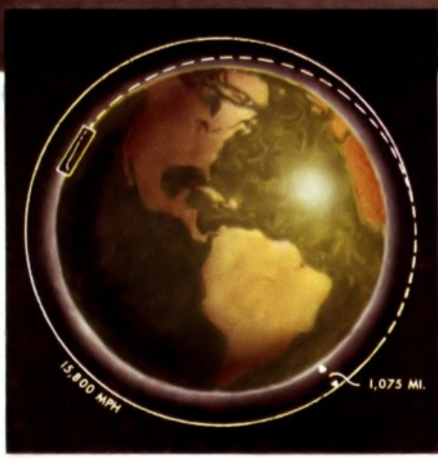
The WAC Corporal, starting from the nose of a V-2 and climbing to 250 miles, has shown us what we must do if we want to step up drastically the speed of a rocket. The WAC started its own rocket motor the moment the V-2 carrying it had reached its maximum speed. It thereby added its own speed to that already achieved by the first stage. As mentioned earlier, such a piggyback arrangement is called a "two-stage rocket"; and by putting a two-stage rocket on

Scale drawings at left show how the space station, depicted by the tiny ring at top of each sketch, will circle the earth. Actually, the man-made satellite, in the 1,075-mile orbit selected as the most desirable, will go around the world every two hours. The four drawings indicate, from top to bottom, time intervals of four hours; during each, the satellite will have made two revolutions. Thus, as the globe turns beneath them, occupants of the station will view every spot on the earth during a 24-hour span. At right is Von Braun's rocket ship design. Tall as a 24-story building, it will weigh 7,000 tons and have a 65-foot base

DRAWINGS BY ROLF KLEP


THIRD STAGE
SECOND STAGE
FIRST STAGE
INSTRUMENT COMPARTMENT
PILOT CANOPY
PERSONNEL SPACE
CARGO SPACE
NITRIC ACID
HYDRAZINE
NITRIC ACID AND HYDRAZINE PUMPS
HYDROGEN PEROXIDE FOR PUMP TURBINES
FOUR MAIN PROPULSION MOTORS AND ONE CRUISING MOTOR
VERTICAL STABILIZERS
RUDDER
AILERON
LANDING FLAP
NITRIC ACID
HYDRAZINE
HYDROGEN PEROXIDE FOR PUMP TURBINES
PUMPS FOR HYDRAZINE AND NITRIC ACID
SWIVEL-MOUNTED ROCKET MOTORS FOR STEERING (FOUR UNITS OF THREE EACH)
22 MAIN PROPULSION ROCKET MOTORS
PARACHUTE COMPARTMENT
NITRIC ACID
HYDRAZINE
STABILIZER FIN (HORIZONTAL CONTROL)
HYDROGEN PEROXIDE TANKS
STABILIZER FIN (VERTICAL CONTROL)
EXHAUST OUTLET
PUMPS FOR HYDRAZINE AND NITRIC ACID
PARACHUTE COMPARTMENT
51 PROPULSION MOTORS INCLUDING 12 SWIVEL-MOUNTED ROCKET UNITS FOR STEERING
EXHAUST TUNNEL





ROLF KLEP

Contrary to widespread notion, rocket ship does not travel straight up all the way. After covering first eight miles vertically, rocket proceeds at angle. Inset art shows complete flight path into two-hour orbit; section in rectangle marks flight segment detailed above

another, still larger, booster, we get a three-stage rocket. A three-stage rocket, then, could treble the speed attainable by one rocket stage alone (which would give it enough speed to become a satellite).

In fact, it could do even better. The three-stage rocket may be considered as a rocket with three sets of motors; after the first set has given its utmost, and has expired, it is jettisoned—and so is the second set, in its turn. The third stage, or nose, of the rocket continues on its way, relieved of all that excess weight.

* * *

Besides the loss of the first two stages, other factors make the rocket's journey easier the higher it goes. First, the atmosphere is dense, and tends to hinder the passage of the rocket; once past it, the going is faster. Second, the rocket motors operate more efficiently in the rarefied upper layers of the atmosphere. Third, after passing through the densest portion of the atmosphere, the rocket no longer need climb vertically.

Imagine the size of this huge three-stage rocket ship: it stands 265 feet tall, approximately the height of a 24-story office building. Its base measures 65 feet in diameter. And the over-all weight of this monster rocket ship is 14,000,000 pounds, or 7,000 tons—about the same weight as a light destroyer.

Its three huge power plants are driven by a combination of nitric acid and hydrazine, the latter being a liquid compound of nitrogen and hydrogen, somewhat resembling its better-known cousin, ammonia. These propellants are fed into the rocket motors by means of turbopumps.

Fifty-one rocket motors, pushing with a combined thrust of 14,000 tons, power the first stage (tail section). These motors consume a total of 5,250 tons of propellants in the incredibly short time of 84 seconds. Thus, in less than a minute and a half, the rocket loses 75 per cent of its total original weight!

The second stage (middle section), mounted on top of the first, has 34 rocket motors with a total thrust of 1,750 tons, and burns 770 tons of propellants. It operates for only 124 seconds.

The third and final stage (nose section)—carrying the crew, equipment and pay load—has five rocket motors with a combined thrust of 220 tons. This "body" or cabin stage of the rocket ship carries 90 tons of propellants, including ample reserves for the return trip to earth. In addition, it is capable of carrying a cargo or pay load of about 36 tons into our two-hour orbit 1,075 miles above sea level. (Also, in expectation of the return trip, the nose section will have wings something like an airplane's. They will be used only during the descent, after re-entering the earth's atmosphere.)

Years before the actual take-off, smaller rocket ships, called instrument carriers, will have been sent up to the two-hour orbit. They will circle there, sending back information by the same electronic method already in use with current rockets. Based on the data thus obtained, scientists, astronomers, and engineers, along with experts from the armed forces, will plan the complete development of the huge cargo-carrying rocket ship.

The choice of the take-off site poses another problem. Because of the vast amount of auxiliary equipment—such as fuel storage tanks and machine shops, and other items like radio, radar, astronomical and meteorological stations—an extensive area is required. Furthermore, it is essential, for reasons which will be explained later, that the rocket ship fly over the ocean during the early part of the flight. The tiny U.S. possession known as Johnston Island, in the Pacific, or the Air Force Proving Ground at Cocoa, Florida, are presently considered by the experts to be suitable sites.

At the launching area, the heavy rocket ship is assembled on a great platform. Then the platform is wheeled into place over a tunnel-like "jet deflector" which drains off the fiery gases of the first stage's rocket motors. Finally, with a mighty roar which is heard many miles away, the rocket ship slowly takes off—so slowly, in fact, that in the first second it travels less than 15 feet. Gradually, however, it begins to pick up speed, and 20 seconds later it has disappeared into the clouds.

Because of the terrific acceleration which will be experienced one minute later, the crew—located, of course, in the nose—will be lying flat in "contour" chairs at take-off, facing up. Throughout the whole of its flight to the two-hour orbit, the rocket is under the control of an automatic gyropilot. The timing of its flight and the various maneuvers which take place have to be so precise that only a machine can be trusted to do the job.

After a short interval, the automatic pilot tilts the rocket into a shallow path. By 84 seconds after take-off, when the fuels of the first stage (tail section) are nearly exhausted, the rocket ship is climbing at a gentle angle of 20.5 degrees.

When it reaches an altitude of 24.9 miles it will have a speed of 1.46 miles per second, or 5,256 miles per hour. To enable the upper stages to break away from the tail or first stage, the tail's power has to be throttled down to almost zero. The motors of the second stage now begin to operate, and the connection between the now-useless first stage and the rest of the rocket ship is severed. The tail section drops behind, while the two upper stages of the rocket ship forge ahead.

After the separation, a ring-shaped ribbon parachute, made of fine steel wire mesh, is automatically released by the first stage. This chute has a diameter of 217 feet and gradually it slows down the tail section. But under its own momentum, this empty hull continues to climb, reaching a height of 40 miles before slowly descending. It is because the tail section could be irreparably damaged if it struck solid ground (and might be dangerous, besides) that the initial part of the trip must be over the sea. After the first stage lands in the water, it is collected and brought back to the launching site.

The same procedure is repeated 124 seconds later. The second stage (middle section) is dropped into the ocean. The rocket ship by this time has attained an altitude of 40 miles and is 332 miles from the take-off site. It also has reached a tremendous speed—14,364 miles per hour.

Now the third and last stage—the nose section or cabin-equipped space ship proper—proceeds under the power of its own rocket motors. Just 84 seconds after the dropping of the second stage, the rocket ship, now moving at 18,468 miles per hour, reaches a height of 63.3 miles above the earth.

At this point we must recall the comparison between the rocket and the coasting rifle shell to understand what occurs. The moment the rocket reaches a speed of 18,468 miles per hour, at an altitude of 63.3 miles, the motors are cut off, even though the fuel supply is by no means exhausted. The rocket ship continues on an unpowered trajectory until it reaches 1,075 miles above the earth. This is the high point, or "apogee"; in this case it is exactly halfway around the globe from the cut-off place. The rocket ship is now in the two-hour orbit where we intend to build the space station.

* * *

Just one more maneuver has to be performed, however. In coasting up from 63.3 miles to 1,075 miles, the rocket ship has been slowed by the earth's gravitational pull to 14,770 miles per hour. This is not sufficient to keep the ship in our chosen orbit. If we do not increase the speed, the craft will swing back halfway around the earth to the 63.3-mile altitude. Then it would continue on past the earth until, as it curves around to the other side of the globe, it would be back at the same apogee, at the 1,075-mile altitude.

The rocket ship would already be a satellite and behave like a second moon in the heavens, swinging on its elliptical path over and over for a long time. One might well ask: Why not be satisfied with this? The reason is that part of this particular orbit is in the atmosphere at only 63.3 miles. And while the air resistance there is very low, in time it would cause the rocket ship to fall back to earth.

Our chosen two-hour orbit is one which, at *all* points, is exactly 1,075 miles above the earth. The last maneuver, which stabilizes the rocket ship in this orbit, is accomplished by turning on the rocket motors for about 15 seconds. The velocity is thus increased by 1,030 miles per hour, bringing the total speed to 15,800 miles per hour. This is the speed necessary for remaining in the orbit permanently. We have reached our goal.

An extraordinary fact about the flight from the earth is this: it has taken only 56 minutes, during which the rocket ship was powered for only five minutes.

From our vantage point, 1,075 miles up, the earth, to the rocket ship's crew, appears to be rotating once every two hours. This apparent fast spin of the globe is the only indication of the tremendous speed at which the rocket ship is moving. The earth, of course, still requires a full 24 hours to complete one revolution on its axis, but the rocket ship is making 12 revolutions around the earth during the time the earth makes one.

We now begin to unload the 36 tons of cargo which we have carried up with us. But how and where shall we unload the material? There is nothing but the blackness of empty space all around us.

We simply dump it out of the ship. For the cargo, too, has become a satellite! So have the crew members. Wearing grotesque-looking pressurized suits and carrying oxygen for breathing, they can now leave the rocket ship and float about unsupported.

Just as a man on the ground is not conscious of the fact that he is moving with the earth around the sun at the rate of 66,600 miles per hour, so the men in the space ship are not aware of the fantastic speed with which they are going around the earth. Unlike men on the ground, however, the men in space do not experience any gravitational pull. If one of them, while working, should drift off into space, it will be far less serious than slipping off a scaffold. Drifting off merely means that the man has acquired a very slight speed in an unforeseen direction.

He can stop himself in the same manner in which any speed is increased or stopped in space—by reaction. He might do this, theoretically, by firing a revolver in the direction of his inadvertent movement. But in actual practice the suit will be equipped with a small rocket motor. He could also propel himself by squirting some compressed oxygen from a tank on his back. It is highly probable, however, that each crew member will have a safety line securing him to the rocket as he works. The tools he uses will also be secured to him by lines; otherwise they might float away into space.

* * *

The spacemen—for that is what the crew members now are—will begin sorting the equipment brought up. Floating in strange positions among structural units and machinery, their work will proceed in absolute silence, for there is no air to carry sound. Only when two people are working on the same piece of material, both actually touching it, will one be able to hear the noises made by another, because sound is conducted by most materials. They will, however, be able to converse with built-in "walkie-talkie" radio equipment. The cargo moves easily; there is no weight, and no friction. To push it, our crew member need only turn on his rocket motor (if he shoved a heavy piece of equipment without rocket power, he might fly backward!).

Obviously the pay load of our rocket ship—though equivalent to that of two huge Super Constellations—will not be sufficient to begin construction of the huge, three-decked, 250-foot-wide space station. Many more loads will be required. Other rocket ships, all timed to arrive at the same point in a continuous procession as the work progresses, will carry up the remainder of the prefabricated satellite. This will be an expensive proposition. Each rocket trip will cost more than half a million dollars *for propellants alone.* Thus, weight and shipping space limitations will greatly affect the specifications of a space station.

In at least one design, the station consists of 20 sections made of flexible nylon-and-plastic fabric. Each of these sections is an independent unit which later, after assembly into a closed ring, will provide compartmentation similar to that found in submarines. To save shipping space, these sections will be carried to the orbit in a collapsed condition. After the "wheel" has been put together and sealed, it will then be inflated like an automobile tire to slightly less than normal atmospheric pressure. This pressure will not only provide a breathable atmosphere within the ring but will give the whole structure its necessary rigidity. The atmosphere will, of course, have to be renewed as the men inside exhaust it.

On solid earth, most of our daily activities are conditioned by gravity. We put something on a table and it stays there, because the earth attracts it, pulling it against the table. When we pour a glass of milk, gravity draws it out of the bottle and we catch the falling liquid in a glass. In space, however, everything is weightless. And this includes man.

This odd condition in no way spells danger, at least for a limited period of time. We experience weightlessness for short periods when we jump from a diving board into a pool. To be sure, there are some medical men who are concerned at the prospect of permanent weightlessness—not because of any known danger, but because of the unknown possibilities. Most experts discount these nameless fears.

However, there can be no doubt that permanent weightlessness might often prove inconvenient. What we require, therefore, is a "synthetic" gravity within the space station. And we can produce centrifugal force—which acts as a substitute for gravity—by making the "wheel" slowly spin about its hub (a part of which can be made stationary).

To the space station proper, we attach a tiny rocket motor which can produce enough power to rotate the satellite. Since *(Continued on page 72)*

PAINTING BY CHESLEY BONESTELL

Skin of rocket ship's third stage (shown over Cape Town, South Africa) glows red hot on return trip. Phenomenon does not occur during ascent

Crossing the Last Frontier

CONTINUED FROM PAGE 29

there is no resistance which would slow the "wheel" down, the rocket motor does not have to function continuously. It will operate only long enough to give the desired rotation. Then it is shut off.

Now, how fast would we like our station to spin? That depends on how much "synthetic gravity" we want. If our 250-foot ring performed one full revolution every 12.3 seconds, we would get a synthetic gravity equal to that which we normally experience on the ground. This is known as "one gravity" or, abbreviated, "1 g." For a number of reasons, it may be advantageous not to produce one full "g." Consequently, the ring can spin more slowly; for example, it might make one full revolution every 22 seconds, which would result in a "synthetic gravity" of about one third of normal surface gravity.

The centrifugal force created by the slow spin of the space station forces everything out from the hub. No matter where the crew members sit, stand or walk inside, their heads will always point toward the hub. In other words, the inside wall of the "wheel's" outer rim serves as the floor.

* * *

How about the temperature within the space station? Maybe you, too, have heard the old fairy tale that outer space is extremely cold—absolute zero. It's cold, all right, but not that cold—and not in the satellite. The ironical fact is that the engineering problem in this respect will be to keep the space station comfortably cool, rather than to heat it up. In outer space, the temperature of any structure depends entirely on its absorption and dissipation of the sun's rays. The space station happens to be in the unfortunate position of receiving not only direct heat from the sun but also reflected heat from the earth.

If we paint the space station white, it will then absorb a minimum of solar heat. Being surrounded by a perfect vacuum, it will be, except for its shape, a sort of thermos bottle, which keeps hot what is hot, and cold what is cold.

In addition, we can scatter over the surface of the space station a number of black patches which, in turn, can be covered by shutters closely resembling white Venetian blinds. When these blinds are open on the sunny side, the black patches will absorb more heat and warm up the station. When the blinds are open on the shaded side, the black patches will radiate more heat into space, thereby cooling the station. Operate all these blinds with little electric motors, hook them to a thermostat, and tie the whole system in with the station's air-conditioning plant—and there's your temperature control system.

Inflating the space station with air will, as we have indicated, provide a breathable atmosphere for a limited time only. The crew will consume oxygen at a rate of approximately three pounds per man per day. At intervals, therefore, this life-giving oxygen will have to be replenished by supply ships from earth. At the same time, carbon dioxide and toxic or odorous products must be constantly removed from the air-circulation system. The air must also be dehumidified, inasmuch as through breathing and perspiration each crew member will lose more than three pounds of water per day to the air system (just as men do on earth).

This water can be collected in a dehumidifier, from which it can economically be salvaged, purified and reused.

Both the air-conditioning and water-recovery units need power. So do the radar systems, radio transmitters, astronomical equipment, electronic cookers and other machinery. As a source for this power we have the sun. On the earth, solar power is reliable in only a few places where clouds rarely obscure the sky, but in space there are no clouds, and the sun is the simplest answer to the station's power needs.

Our power plant will consist of a condensing mirror and a boiler. The condensing mirror will be a highly polished sheet metal trough running around the "wheel." The position of the space station can be arranged so that the side to which the mirror is attached will always point toward the sun. The mirror then focuses the sun's rays on a steel pipe which runs the length of the mirrored trough. Liquid mercury is fed under pressure into one end of this pipe and hot mercury vapor is taken out at the other end. This vapor drives a turbogenerator which produces about 500 kilowatts of electricity.

Of course, the mercury vapor has to be used over and over again, so after it has done its work in the turbine it is returned to the "boiler" pipe in the mirror. Before this can be done, the vapor has to be condensed back into liquid mercury by cooling. This is achieved by passing the vapor through pipes located behind the mirror in the shade. These pipes dissipate the heat of the vapor into space.

Thus we have within the space station a complete, synthetic environment capable of sustaining man in space. Of course, man will face hazards—some of them, like cosmic radiation and possible collision with meteorites, potentially severe. These problems are being studied, however, and they are considered far from insurmountable.

Our "wheel" will not be alone in the two-hour orbit. There will nearly always be one or two rocket ships unloading supplies. They will be parked some distance away, to avoid the possibility of damaging the space station by collision or by the blast from the vehicle's rocket motors. To ferry men and materials from rocket ship to space station, small rocket-powered metal craft of limited range, shaped very much like overgrown watermelons, will be used. These "space taxis" will be pressurized and, after boarding them, passengers can remove their space suits.

On approaching the space station, the tiny shuttle-craft will drive directly into an air lock at the top or bottom of the stationary hub. The space taxi will be built to fit exactly into the air lock, sealing the opening like a plug. The occupants can then enter the space station proper without having been exposed to the airlessness of space at any time since leaving the air lock of the rocket ship.

* * *

There will also be a space observatory, a small structure some distance away from the main satellite, housing telescopic cameras for taking long-exposure photographs. (The space station itself will carry extremely powerful cameras, but its spin, though slow, will permit only short exposures.) The space observatory will not be manned, for if it were, the movements of an operator would disturb the alignment. Floating outside the structure in space suits, technicians will load a camera with special plates or film, and then withdraw. The camera will be aimed and the shutter snapped by remote radio control from the space station.

Most of the pictures taken of the earth, however, will be by the space station's cameras. The observatory will be used mainly to record the outer reaches of the universe, from the neighboring planets to the distant galaxies of stars. This mapping of the heavens will produce results which no observatory on earth could possibly duplicate. And, while the scientists are probing the secrets of the universe with their cameras, they will also be planning another trip through space—this time to examine the moon.

Suppose we take the power plant out of our rocket ship's last stage and attach it to a lightweight skeleton frame of aluminum girders. Then we suspend some large collapsible fuel containers in this structure and fill them with propellants. Finally, we connect some plumbing and wiring and top the whole structure with a cabin for the crew, completely equipped with air and water regeneration systems, and navigation and guidance equipment.

The result will be an oddly shaped ve-

COLLIER'S "Herb beat up a guy to defend my honor, then I had to beat up Herb to defend it myself" KATE OSANN hicle, not much larger than the rocket ship's third stage, but capable of carrying a crew of several people to a point beyond the rear side of the moon, then back to the space station. This vehicle will bear little resemblance to the moon rockets depicted in science fiction. There is a very simple reason: conventional streamlining is not necessary in space.

The space station, as mentioned previously, has a speed of 15,840 miles per hour. Our round-the-moon ship, to leave the two-hour orbit, has to have a speed of 22,100 miles per hour, to cover the 238,000-mile distance to the moon. This additional speed is acquired by means of a short rocket blast, lasting barely two minutes. This throws the round-the-moon ship into a long arc or ellipse, with its remotest point beyond the moon. The space ship will then coast out this distance, unpowered, like a thrown stone. It will lose speed all along the way, due to the steady action of the earth's gravitational pull—which, though weakening with distance, extends far out into space.

Roughly five days after departure, the space ship will come almost to a standstill. And if we have timed our departure correctly, the moon will now pass some 200 miles below us, with the earth on its far side. On this one trip we can photograph most of the unknown half of the moon, the half which has never been seen from the earth. Furthermore, we now have an excellent opportunity to view the earth from the farthest point yet; at this distance, it appears not unlike a miniature reproduction of itself (from the vicinity of the moon, the earth will look about four times as large as the full moon does to earth-bound man).

It is not necessary to turn on the space ship's motors for the return trip. The moon's gravity is too slight to affect us substantially; like the shell which was fired vertically, we simply "fall back" to the space station's orbit. The long five-day "fall" causes the space ship to regain its initial speed of 22,100 miles per hour. This is 6,340 miles per hour faster than the speed of the space station, but, as we have fallen back tail first, we simply turn on the motors for just two minutes, which reduces our speed to the correct rate which permits us to re-enter the two-hour orbit.

* * *

Besides its use as a springboard for the exploration of the solar system, and as a watchdog of the peace, the space station will have many other functions. Meteorologists, by observing cloud patterns over large areas of the earth, will be able to predict the resultant weather more easily, more accurately and further into the future. Navigators on the seas and in the air will utilize the space station as a "fix," for it will always be recognizable.

But there will also be another possible use for the space station—and a most terrifying one. It can be converted into a terribly effective atomic bomb carrier.

Small winged rocket missiles with atomic war heads could be launched from the station in such a manner that they would strike their targets at supersonic speeds. By simultaneous radar tracking of both missile and target, these atomic-headed rockets could be accurately guided to any spot on the earth.

In view of the station's ability to pass over all inhabited regions on earth, such atom-bombing techniques would offer the satellite's builders the most important tactical and strategic advance in military history. Furthermore, its observers probably could spot, in plenty of time, any attempt by an enemy to launch a rocket aimed at colliding with the giant "wheel" and intercept it.

We have discussed how to get from the ground to the two-hour orbit, how to build the space station and how to get a look at the unknown half of the moon by way of a round trip from our station in space. But how do we return to earth?

Unlike the ascent to the orbit, which was controlled by an automatic pilot, the descent is in the hands of an experienced "space pilot."

To leave the two-hour orbit in the third stage, or nose section, of the rocket ship, the pilot slows down the vehicle in the same manner in which the returning round-the-moon ship slowed down. He reduces the speed by 1,070 miles per hour. Unpowered, the rocket ship then swings back toward the earth. After 51 minutes, during which we half circumnavigate the globe, the rocket ship enters the upper layers of the atmosphere. Again, it has fallen tail first; now the pilot turns it so that it enters the atmosphere nose first.

* * *

About 50 miles above the earth, due to our downward, gravity-powered swing from the space station's orbit, our speed has increased to 18,500 miles per hour. At this altitude there is already considerable air resistance.

With its wings and control surfaces, the rocket closely resembles an airplane. At first, however, the wings do not have to carry the rocket ship. On the contrary, they must prevent it from soaring out of the atmosphere and back into the space station's orbit again.

His eyes glued to the altimeter, the pilot will push his control stick forward and force the ship to stay at an altitude of exactly 50 miles. At this height, the air resistance gradually slows the rocket ship down. Only then can the descent into the denser atmosphere begin; from there on, the wings bear more and more of the ship's weight. After covering a distance of about 10,000 miles in the atmosphere, the rocket's speed will still be as high as 13,300 miles per hour. After another 3,000 miles, the speed will be down to 5,760 miles per hour. The rocket ship will by now have descended to a height of 29 miles.

The progress of the ship through the upper atmosphere has been so fast that air friction has heated the outer metal skin of body and wings to a temperature of about 1,300 degrees Fahrenheit. The rocket ship has actually turned color, from steel blue to cherry red! This should not cause undue concern, however, inasmuch as we have heat-resistant steels which can easily endure such temperatures. The canopy and windows will be built of double-paned glass with a liquid coolant flowing between the panes. And the crew and cargo spaces will be properly heat-insulated and cooled by means of a refrigerator-type air-conditioning system. Similar problems have already been solved, on a somewhat smaller scale, in present-day supersonic airplanes.

At a point 15 miles above the earth, the rocket ship finally slows down to the speed of sound—roughly 750 miles per hour. From here on, it spirals down to the ground like a normal airplane. It can land on conventional landing gear, on a runway adjacent to the launching site. The touch-down speed will be approximately 65 miles per hour, which is less than that of today's air liners. And if the pilot should miss the runway, a small rocket motor will enable him to circle once more and make a second approach.

After a thorough checkup, the third stage will be ready for another ascent into the orbit. The first and second stages (or tail and middle sections), which were parachuted down to the ocean, have been collected in specially made seagoing dry docks. They were calculated to fall at 189 miles and 906 miles respectively from the launching site. They will be found relatively undamaged, because at a point 150 feet above the water their parachute fall was broken by a set of cordite rockets which were automatically set off by a proximity fuse.

They, too, undergo a thorough inspection with some replacement of parts damaged by the ditching. Then all three stages are put together again in a towerlike hangar, right on the launching platform, and, after refueling and a final check, platform and ship are wheeled out to the launching site—ready for another journey into man's oldest and last frontier: the heavens themselves. THE END

A self-contained community, this outpost in the sky will provide all of man's needs, from air conditioning to artificial gravity

When man first takes up residence in space, it will be within the spinning hull of a wheel-shaped structure, rotating around the earth much as the moon does. Life will be cramped and complicated for space dwellers; they will exist under conditions comparable to those on a modern submarine. This painting, which is scientifically accurate, shows how the spacemen will live and work inside their whirling station.

The wheel's movement around its hub will provide centrifugal force as a substitute for gravity in weightless space; however, this "synthetic gravity" will not be equal in all parts of the station, since the amount of spin will decrease toward the center. Thus, the topmost of the three decks (the one on the inside of the wheel) will have the least gravity, and the hub itself will have virtually none.

At the extreme left of the painting (below), on the top deck, is the communications center, which maintains radio contact with the earth, with rocket ships in space, and with the space taxis that carry men from rocket ship to space station. Below the communications room, meteorologists chart the weather for the entire earth; on the lowest deck at extreme left is a bunk room.

Next door to the communications and weather sections is the earth observation center, occupying two decks. On the top deck is a large movable map on which "ground zero," the territory the station is passing over at the moment, is spotted. Immediately below the map is a telescopic enlargement of ground zero. Under this, on the center deck, are additional telescopic screens showing other territory (figures over each screen refer to the amount of territory covered by the picture, not to the apparent distance away from the scene).

The electronic computer on the top deck, between the earth observation and celestial observation centers, solves complicated mathematical problems. The large screen in the celestial observation room enables astronomers to study enlarged photographs taken from the satellite's tiny sister station, the observatory. The bottom deck contains a photographic darkroom and part of the system which recovers and purifies waste water.

The next section over is devoted to the handling of cargo. Material arrives from the hub by elevator, and is distributed from the loading room in accordance with decisions made by the weight control center, which is charged with preserving the station's balance. Fuel storage and air-conditioning return ducts are located under this area.

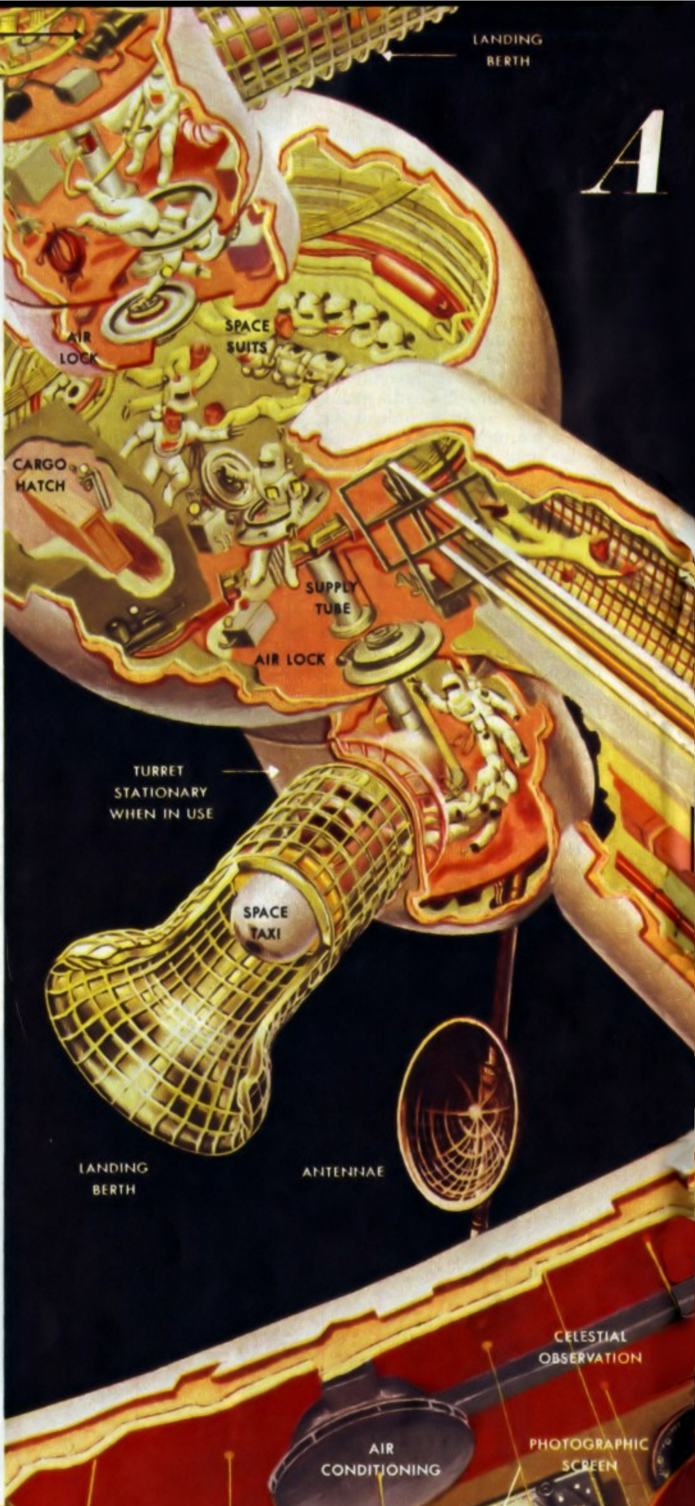
The layers of skin enclosing the space station are shown covering part of the loading area. The outer skin, or meteor bumper, is attached to the inner skin by studs. The view ports are of plastic, tinted to guard against radiation; protective lids are lowered when the windows are not in use. The two black squares, which absorb the sun's heat and warm the satellite, have shutters to control heat absorption. On the meteor bumper wall are hook-on rings, to which spacemen tie lines while outside, to keep from floating away into space.

The sections beyond the pump room (top deck) form the heart of the system which keeps the space station supplied with air. The air control room regulates air pressures in the satellite. The components of the air mixture are determined by chemists in the air testing laboratory. In the room housing the air-conditioning machinery, the interior wall of the space station's inner rim is cut away to show secondary cables and ducts, which furnish power, air and the like, when the main system (right, overhead) fails.

The trough and pipe in the extreme upper-right corner of the picture are a part of the satellite's power plant. The trough is polished to catch the rays of the sun; the heat thus obtained is picked up by mercury in the tube. The mercury, emerging as hot vapor in the room below, drives a turbo-generator.

Inside the shaft which leads to the satellite's hub is a landing net to assist men in moving into and out of the gravity-free area. Since the hub is the center of all entrances, departures and loadings, it is kept fairly clear, except for the space station's supply of pressurized suits. At the top and bottom of the rotating hub are turrets which can be turned so space taxis can land in the bell-shaped landing berths. The taxi's body seals the turret shut, and the men move to the space station proper through air locks.

This drawing, of course, shows only a part of the space station. Its many other sections also contain equipment, supplies and living quarters. Balance must be carefully maintained, with each section painstakingly adjusted to the same weight as the section diametrically opposite it on the wheel. If this were not done, the revolving station might wobble, making the synthetic gravity uneven, disturbing the delicate measurements of the scientists within—and weakening the entire structure dangerously.



Station in Space

By WILLY LEY
Noted Rocket Scientist and Author

PAINTING BY FRED FREEMAN

The Heavens Open

By Dr. FRED L. WHIPPLE

Chairman, Department of Astronomy, Harvard University

Once above the atmosphere which blindfolds our scientists now, a revolution will take place in astronomy. Man will, for the first time, get a good, clear look at the universe

IN MANY respects, today's astronomers might as well be blindfolded in a deep, dark coal mine. The earth's atmosphere, even on a perfectly clear day or night, blankets out many of the secrets of the universe. Details of the surface of the moon, planets and star groups disappear in a dancing blur because the atmosphere is never really quiet. The extremely significant far ultraviolet light, the X rays and gamma rays of space are indiscernible because the atmosphere permits free passage only to the visible light rays.

The establishment of a telescope and observatory in space will end this era of blindness. It will be as revolutionary to science as the invention of the telescope itself.

The sun, for example, photographed from the space station by X rays, will be an amazing sight. Astronomers have deduced that it very probably will look like a mottled, irregular sunflower. And what we now see as the sun's disk will, in all likelihood, prove to be only the central core of a large fuzzy-looking ball. It will be covered with bright specks and pulsing streaks, while the usually invisible corona will show up as the main source of light.

Similarly, familiar star constellations may look very strange when photographed from the space station or space observatory with plates sensitive to all the wave lengths of ultraviolet light.

Stars send ultraviolet as well as visible light. Some, however, radiate mostly ultraviolet. These appear weak to the eye, but will be exceedingly bright to the special camera. Those which send out very little ultraviolet light will hardly show on the special photographic plates. The Milky Way itself might be markedly changed—I wish I knew just how.

What is even more fascinating to the astronomer than acquiring "full vision" is the fact that space travel will permit him to change position in space. For instance, there is our moon, relatively near and under observation since the first telescope was built. But the moon always turns the same side toward the earth, and almost one half of its total surface has never been seen by man.

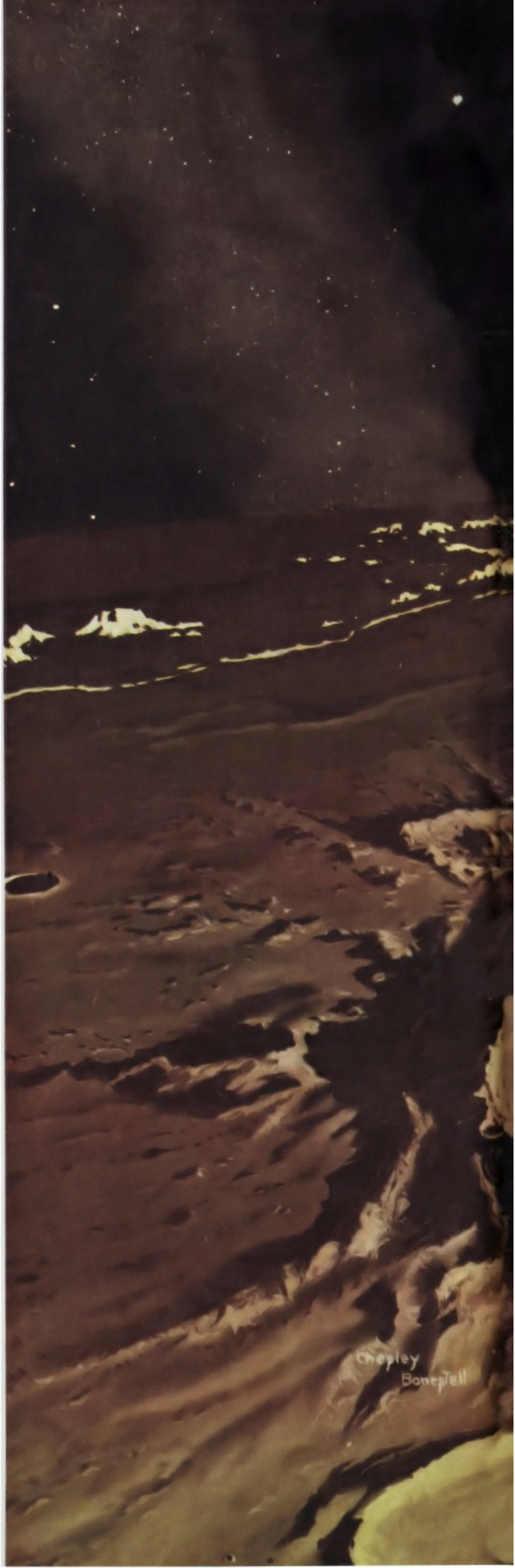
What are the first astronomers who make a round-the-moon journey going to see on that completely unknown portion? Will they find mountains, plains and craters like those we see on the side visible to us now? Or will they find a plain, serrated with jagged canyons—or a landscape unmarked by anything? And were the moon's gigantic craters formed by some type of volcanic action or are they a result of collision with flying mountains from space? Is there really a thick layer of dust covering the moon's surface? Observation from a space ship will give us conclusive answers to all these questions.

The astronomers in the space station will also have a very practical job awaiting them. When the sun becomes temperamental, as it frequently does, it develops gigantic storms on its surface, emitting excessive amounts of ultraviolet light and X rays, and even ejecting high-speed atoms. Although they cannot be observed directly, these emanations knock out our long-range radio communications, cause transcontinental teletypes to go berserk and sometimes even burn out long-range telephone and power cables.

There is little doubt that our space station astronomers, maintaining a 24-hour surveillance of the sun and all its radiations, not only will find the explanation for these solar storms but will learn to predict them in advance. Preparations could then be made to protect our electronic equipment.

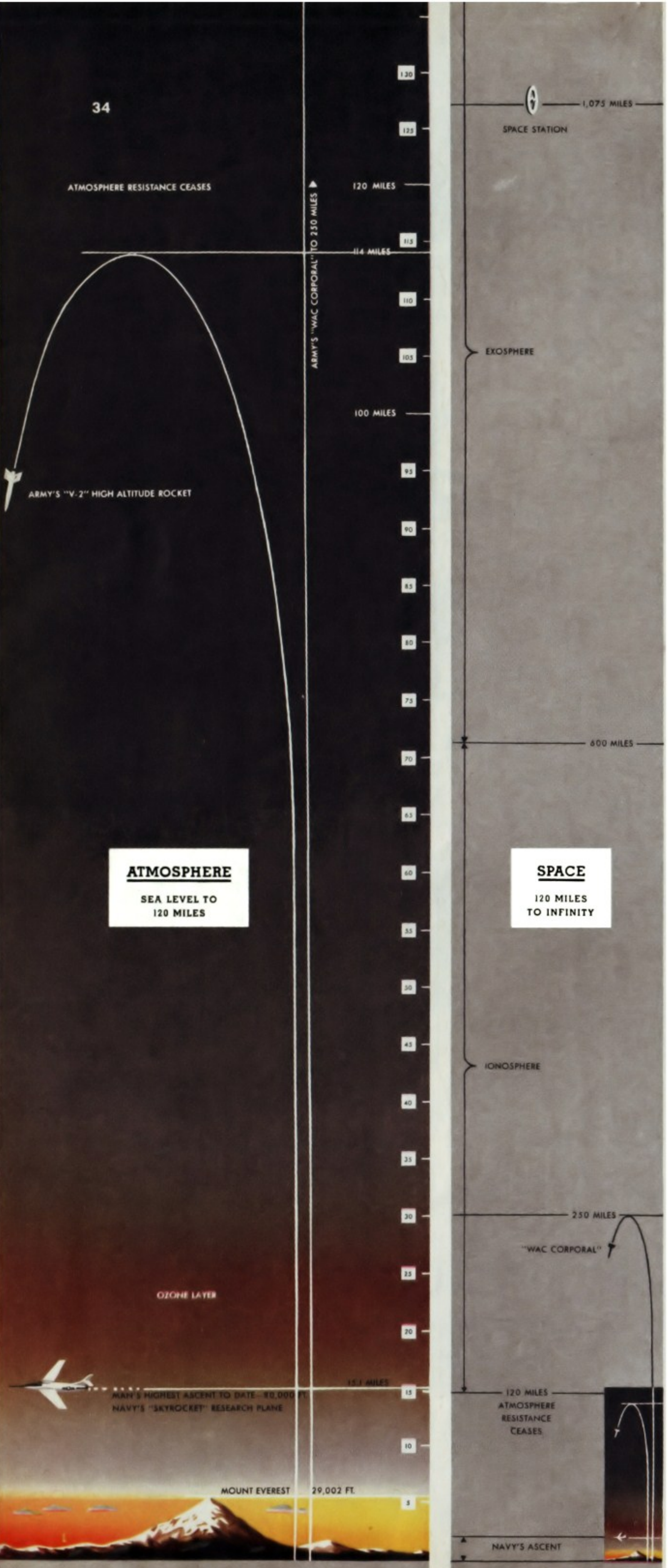
I can mention only a few more projects which will fascinate the astronomers of space. Among them: (1) the mysteries of the superhot and exploding stars; (2) the composition of the atmospheres of other planets, such as Mars; (3) details of the surfaces of other planets (which may offer evidence concerning possible life there); (4) analysis of the great dust and gas clouds of the Milky Way, where stars are born; (5) mapping of similar regions in other great galaxies comprising billions of stars. They should discover important clues regarding the expansion of the universe, its dimensions and its nature.

The astronomer will no longer be limited to seeing as "through a glass, darkly." The universe will spread out clearly before him. ▲▲▲



Specially designed round-the-moon ship hovers 200 miles above lunar surface as space scientists take close-up photographs. One-way journey from station in space will take five days to cover 239,000 miles. Never-seen face of the moon is to right. Trip will have to be timed so that sun lights hidden side

PAINTING BY CHESLEY BONESTELL



This Side of Infinity

By Dr. JOSEPH KAPLAN

Professor of Physics, Institute of Geophysics, University of California

WE ARE living at the bottom of a great envelope of air which provides us with life-giving oxygen and water, protects us from the harmful effects of the sun's ultraviolet rays, and shields us from the high-speed projectiles called meteorites. Without this envelope, all life, as we know it, would cease.

This protective covering around the earth is the atmosphere, a mixture of about 20 per cent oxygen, almost 80 per cent nitrogen, and minute quantities of other gases. The mixture is thickest at sea level; with increasing altitude, it becomes thinner and thinner until eventually, for all practical purposes, we may say that it disappears. At 10,000 feet, the air is so thin that man usually has difficulty breathing. Over 20,000 feet, death awaits anyone not carrying oxygen. Over the years, scientists have found it convenient to divide the atmosphere into levels, as shown in the accompanying charts. These layers have distinctive properties which make them of special interest to particular branches of science. The first layer, from sea level to an altitude of eight miles, is of primary scientific importance to meteorologists, for it is here that all weather occurs. In 1898, the French meteorologist, Léon P. Teisserenc de Bort, named it the troposphere.

Until recent times, aeronautical engineers also devoted their main attention to the troposphere. Then, with the development of airplanes that could climb to an altitude of 60,000 feet, they began to show interest in the next level, the stratosphere (also named by De Bort), which extends from eight to 60 miles up. Extremely powerful winds have been found in this layer of the atmosphere, moving at the entirely unexpected rate of 200 miles per hour.

Here, too, was found a section 10 miles thick which attracted the special attention of physicists. For this layer contains an unusually high percentage of ozone (another form of oxygen) produced by the interaction of the sun's ultraviolet rays and oxygen. It is this ozone layer, which they themselves create, that prevents the ultraviolet rays from striking earth and killing all life.

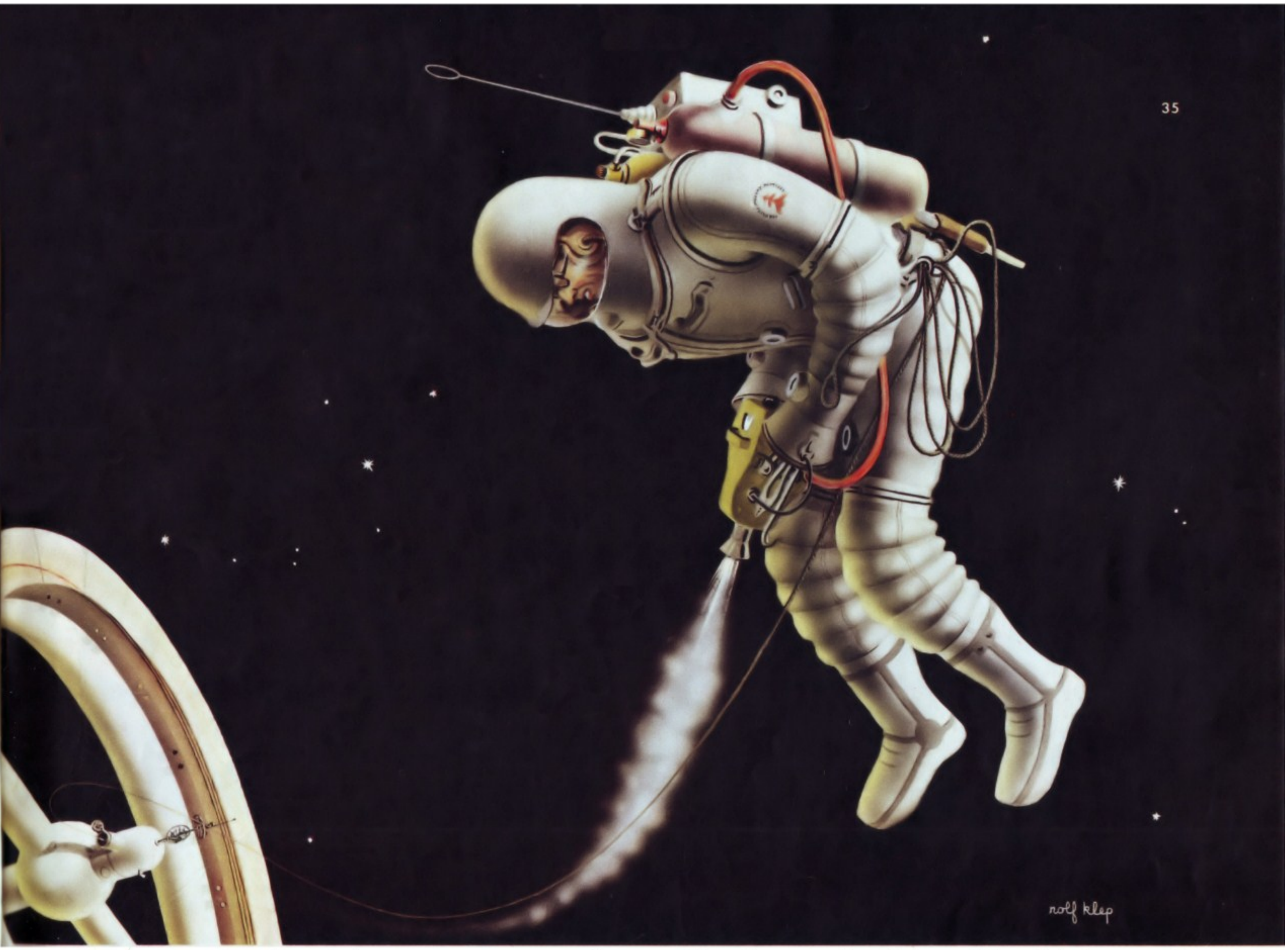
The thermometer, which shows widely varying temperatures on earth, suddenly stabilizes at the lower edge of the stratosphere, reading a constant 67 degrees below zero. Not long ago, it was believed the whole stratosphere remained at this temperature. Recently, however, a warm belt was discovered at 32 miles; the temperature here is a steady 170 degrees *above* zero. Higher up, it sharply decreases again.

The layer from 60 miles to 120 miles is called the ionosphere, of great importance to radio engineers because what little air exists there is electrically charged. This region is subdivided into several strata, each reflecting certain high-frequency radio waves back to earth. It is this charged air which makes it possible to send short-wave radio communications over long distances. The only radio waves which can penetrate this layer without being reflected back to earth are the ultra-short waves used for radar. Their ability to get through was proved conclusively in 1946, when the U.S. Army Signal Corps successfully made radar contact with the moon.

Also in the ionosphere we find the strange, pulsating glows of the aurora borealis and the aurora australis (these phenomena probably would be invisible to anyone passing through them on a flight to space). Because the auroras have traditionally been considered in the domain of the astronomers, members of this branch of science are, like radio experts, interested in the ionosphere.

Above the ionosphere, the air becomes so thin that it no longer serves any function. Scattered single particles of air (molecules and atoms) have been found here, and scientists have noted this fact by giving the area above the ionosphere a name of its own, the exosphere. But the particles are so rare that it is impossible to establish the limits of this layer. There are so few of them that at the 250-mile record altitude reached by the Army's "WAC Corporal" rocket, there is less air than in the best vacuum tube obtainable on earth. (See drawings. Reduced figure, right, shows "WAC Corporal's" course.)

It is at the boundary between the ionosphere and the exosphere that the upper limit of the atmosphere—and the lower limit of space—has been arbitrarily established by the two groups of scientists most interested: the astronomers and the rocket engineers. Their decision was based on the fact that both are concerned with the friction produced by air—the rocketmen because it creates a difficult barrier for rocket ships to cross; the astronomers because meteorites, which are in their scientific province, ignite upon striking fairly dense air. At 120 miles, air friction becomes, for the purposes of both groups, negligible. There space begins.



Tied to space station so he won't float away, spaceman wears radio and oxygen supply on back of pressurized suit, gets propulsion from portable rocket motor. Actual helmet will have dark glass to ward off dangerous ultraviolet rays; artist made it light to show face

CAN WE SURVIVE IN SPACE?

By DR. HEINZ HABER

Department of Space Medicine, United States Air Force School of Aviation Medicine, Randolph Field, Texas

A multitude of problems will beset us, says this authority, but nothing we can't lick

ALL day long, the frail little man attending the forum had listened to the engineers and scientists discuss the conquest of the heavens with huge rocket ships and space stations. Now he had a question.

"Mr. Chairman," he said, "you fellows seem to have worked out all the details. You know how your rocket ships should be designed, you even have plans on paper for machines to reach the moon and other planets. But as an ordinary layman who knows little about these matters, I would like to ask this one question:

"Who is going to design the crew?"

The questioner had put his finger on the greatest difficulty facing the engineers, scientists and doctors in reaching space—man himself.

If the jet plane, guided missile or rocket ship is not perfect, the engineer can redesign the machine over and over until all the kinks have been ironed out. He has a great variety of materials and devices at his disposal. He may eventually succeed in developing a flawless machine. The same cannot be said for man. He is the most important link, and yet the weakest one, in any attempt to conquer space. And he cannot be redesigned.

True, man can adapt himself to extraordinary conditions—he manages to survive anywhere on the face of this globe. But what will happen to him if he ventures into the alien environment known as space—the void beyond the atmosphere?

There is no oxygen for breathing.

The lack of atmospheric pressure can cause his blood to boil.

Dangerous radiation (ultraviolet rays) from the sun hits him with full force and can broil him within minutes.

Atomic bullets, called cosmic rays, plow through his body.

He will be weightless, floating helplessly about, with no up or down.

In short, man was not made to survive in the "hostile territory of space." It becomes the problem of the engineers, therefore, to create a highly mobile, self-contained, "packaged" environment for space-faring man. In other words, he needs an airtight shell to produce and preserve earthly conditions as nearly as possible.

Man is extremely hard to please in his demands, but the engineer can lick the problem and supply the crew of a rocket ship or space station with all the necessities for survival. Neither rocket ship nor space station will have the snug comfort of Mother Earth, and flying through space will be a rough job that will call for healthy, tough and physically well-trained individuals. But it can be done.

Some pessimists maintain *(Continued on page 65)*

DRAWINGS BY ROLF KLEP

Can We Survive in Space?

CONTINUED FROM PAGE 35

that the crew members of a rocket ship wouldn't live to experience space, because they wouldn't even survive the tremendous stresses placed upon them during the ascent. The thrust of the operating rocket motors exerts strong forces upon the ship and its passengers. A motorist gets an inkling of one of these forces: if he steps on the accelerator, he is gently pressed against the back of the automobile seat. But this soft pressure in a car becomes a crushing force in a fast-rising rocket ship. As the space vehicle is whipped forward by the fiery jet of its escaping gases, the force increases in a slowly rising, irresistible surge. To the passenger, it will appear as though several men his own weight are standing on his chest. He will find it difficult to breathe. The fantastic acceleration will distend his features into a grotesque mask.

* * *

For short periods of time, similar stresses occur in present-day fighter aircraft when the pilot pulls out of a steep dive. For this reason, detailed studies have been made on the tolerance of humans under these conditions. In some experiments, men have been strapped into cockpitlike chairs which were then whirled around like a bucket on the end of a string. With such machines, the stresses encountered in modern aviation are being studied and measured. The results indicate that sturdy and healthy individuals will be able to withstand the rigors which the engineer deems inevitable for breaking free from the earth in a rocket ship. Probably the same medical requirements now applicable to Air Force or commercial pilots will be the yardstick used.

The stress of acceleration is not, of course, the only hazard man will encounter as he leaves the friendly atmosphere of the earth. A continuously flowing supply of breathing air is a necessity in the emptiness of space. Man can live without food or water for a considerable length of time. But without oxygen he can live only a few minutes. The crew of the space station must not be allowed to run low on oxygen at any time. Rocket ships will replenish the oxygen containers of the satellites at regular intervals.

Another problem, also tied up with the elementary fact that man cannot live without oxygen, is created by the existence of meteorites. They are the most important single danger to all space-travel projects.

Unfortunately, "empty" space beyond the atmosphere is by no means completely empty. In fact, you may call it a "no man's land" in which ultra-high-speed cosmic "bullets" fly about at random. Hundreds of millions of these "bullets" of various sizes enter the earth's atmosphere every day and often can be seen as meteors or shooting stars. When a cosmic pebble the size of a pea strikes the upper atmosphere, the air resistance heats it until it burns away. This can be seen hundreds of miles distant as a bright streak or flare. Such a meteor hurtling through space at 25 miles a second would puncture more than an inch of armor plate. Very small meteors, the size of large grains of sand, could riddle the thin walls of the space station, permitting the air to escape into space.

The reason for their penetrating powers is the extremely high speed with which these tiny objects move. At an altitude of 1,000 miles, the gravity of the earth pulls them in with a minimum speed of about six miles per second—21,600 miles per hour. Most meteors, however, would strike the earth (if they didn't almost invariably burn away first) much faster than this, even if the earth had no gravity at all. The earth moves around the sun at a rate of 18½ miles per second, or 66,600 miles per hour, while many of the meteors are moving in the opposite direction, and more rapidly. Head-on collisions between the earth and a meteorite raise the observed maximum speed, as calculated from photographs, to about 45 miles per second, or 162,000 miles per hour.

* * *

A radar warning system, unfortunately, would be useless in protecting the space station from meteors. If a meteor were large enough to be detected by the most sensitive radar, it would be large enough to destroy a complete compartment of the space station. And it probably wouldn't be seen until a split second before the collision; in that short interval, we could do nothing to prevent the collision, even if the space station were as mobile as a rocket ship.

That the chance of collision is great enough to cause alarm has been asserted repeatedly by Dr. Fred L. Whipple, of Harvard University's Department of Astronomy.

Dr. Whipple has made a careful study of that question and for the last 15 years has been photographing meteors and measuring the way in which they burn away by friction in the upper atmosphere. He has calculated that an artificial satellite or space station, such as is suggested on these pages, would be punctured by a meteorite about twice a month on the average.

This hazard is far too serious to be ignored in our engineering design. It is probable that the holes made by most meteors will be small enough so that the air would take some time to escape from a single section of the station, but these minutes of grace offer no real security. Even though bells and flashing lights might warn the occupants in time for them to put on oxygen masks before the air pressure became dangerously low, only the most steel-nerved space traveler could sleep calmly, knowing that at any moment the air might suddenly disappear from his quarters.

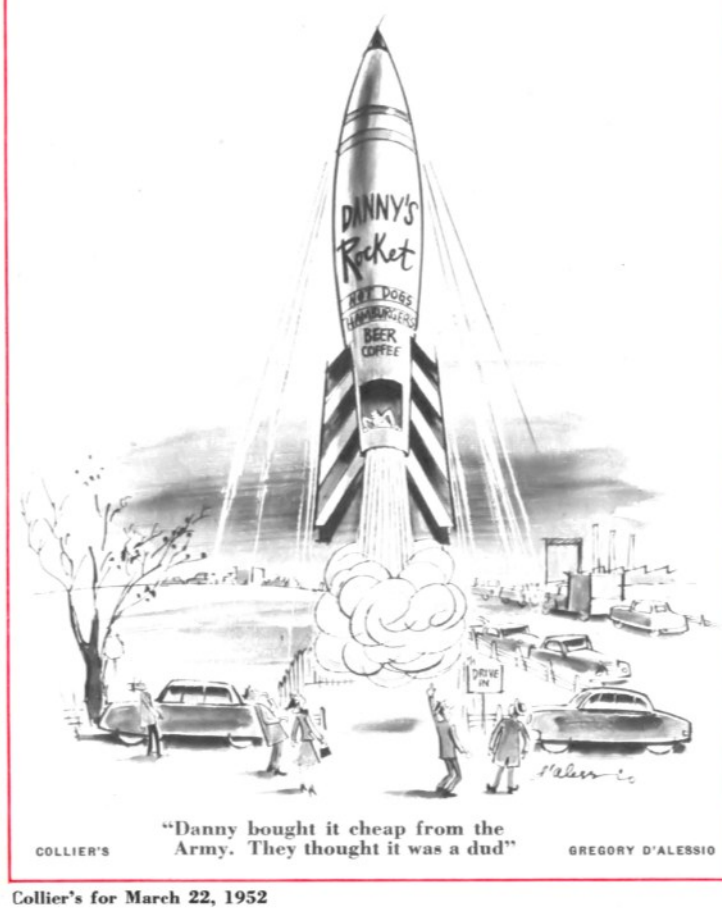
However, engineering can do something even about the meteoric menace. One device, suggested by Dr. Whipple, is called a "meteor bumper" and consists of a thin secondary wall placed an inch or so outside the main wall of the space station or rocket ship. Incoming meteors would shatter on the outer wall, leaving the inner wall intact. If properly constructed of heavy enough materials, the meteor bumper could reduce the hazard very considerably, stopping 99 out of 100 meteors.

Added protection could be gained by having automatic plugging devices, similar in principle to the Air Force's self-sealing fuel tanks, between the two walls.

* * *

For the space station, Dr. Wernher von Braun, Technical Director of the Army Ordnance Guided Missiles Development Group at Huntsville, Alabama, suggests another method. Each compartment would have a small pressure gauge which would automatically close the doors in the section the moment the pressure dropped as a result of a meteor hit. At the same time, it would automatically start an emergency air blower which would build up the air pressure in the damaged section. Dr. von Braun believes that sufficient time might be bought in this way for the occupants to climb into their space suits. To find the small hole, he also suggests that a harmless colored gas be pumped into the section. This gas would immediately drift toward the opening, which could then be plugged.

But even with these safety measures, there remains a probability that once every few years a relatively large meteor will



COLLIER'S "Danny bought it cheap from the Army. They thought it was a dud" GREGORY D'ALESSIO

"Sorry, but our regulations don't permit us to sell an A-bomb kit *and* a globe to the same little boy . . ."

COLLIER'S GARDNER REA

smash through both walls of the space station. What would happen to the crew in that compartment?

The air would whistle out, and there would be a rapid drop in pressure. As a result, the crew would be "explosively decompressed." Even the lungful of air the men had inhaled with their last breath would be torn from their chests. They would have exactly 15 seconds left to restore their oxygen supply, before losing consciousness; without the oxygen they would die in a few minutes.

These prospects sound grim, but things are no different today in our modern rocket-driven airplanes. Last fall, the Navy's Douglas Skyrocket—actually a man-carrying rocket craft—rose to an altitude where the air was so thin that breathing became impossible. In this respect the pilot of the Skyrocket was actually in space. He wore a pressurized space suit even though he sat in a pressurized cockpit, for he couldn't risk one of his canopy panels being torn out. If he had lost his cabin air, he would still have had enough oxygen in his airtight suit to have escaped space death.

In the early days of space exploration, it may be found safest to wear a pressure suit even in the pressurized cabin of the rocket ship. But because of the protective devices inside the space station, pressure suits might be worn there only in times of emergency. A slow leak would not be considered serious, for the crew would have plenty of time to retreat into an adjacent compartment and seal off the damaged section until repaired.

* * *

Pressure suits for use by the crew outside the space station can be made of several layers of rubberized nylon topped by a sturdy metal helmet. The helmet's window would have to be made with a darkened piece of transparent material to ward off the sun's excessive ultraviolet rays. Of course, the crew members will carry their own oxygen, and the suits will be equipped with a small air-conditioning unit for removing the exhaled stale gases.

Humidity control will also be very important. The humidity in the suit might be compared to that endured in a three-hour stay in a telephone booth on a summer day, with a temperature of 90 degrees Fahrenheit and a relative humidity of 95 per cent.

For a brief stay in space, the removal of carbon dioxide and water vapor and the replenishing of oxygen will be sufficient. But the space station must be fully air-conditioned, because a proper atmosphere must be permanently maintained.

The skin of the space station, the paint, the cargo, the complex machinery which is in constant operation and even the bodies of the crew all give off fumes. On the ground we hardly notice the smell in a machine shop, for example, because it is dissipated by air currents. However, in the space station such vapors might in time poison the occupants, if they were allowed to accumulate. Even smoking will probably be strictly rationed, partly to save oxygen and partly to avoid overloading the capacity of the air-conditioning unit.

In venturing into space, man abandons the powerful shield or filter of the atmosphere which protects him on earth from the hazards of the little-known effects of cosmic rays. These atomic bullets—which, like the meteors, crisscross space at enormous speeds—are one of the great mysteries of the region beyond our atmosphere. Scientists know they exist and believe they may be dangerous, but little other information on them has come to light.

Cosmic rays are potentially dangerous because they are related to some of the types of rays produced in atomic explosions and in the manufacture of the A-bomb. Civil defense has made the public conscious of the term "radiation sickness." Will exposure in space cause radiation sickness?

We have no clear-cut answer to this question. Cosmic rays are so powerful that they cannot be reproduced artificially in the laboratory. But, although we do not know where they come from, we do know that they are extremely rare. We can conclude, therefore, that short trips through the thin rain of cosmic rays will almost certainly be harmless affairs. A round-the-moon trip can be made without getting radiation sickness. At this time practically no information is available as to the possible ill effects of extended cosmic-ray exposure. But if it should be found that man can absorb only so much cosmic radiation with safety, frequent rotation of the space station personnel will be the answer.

Of course, long before man ventures into space, animals will be sent up in small rocket ships for the study of radiation effects over extended periods of time. A sheep, a rooster and a duck were the first living beings to take to the air in a balloon, more than 150 years ago. And it seems that more such honors are in store for the animal kingdom. Unfortunately, however, these dumb animals will be unable to communicate their experiences. So, in the final analysis, the exploration of space must await the arrival of man.

* * *

It will be, needless to say, a strange experience. And one of its strangest aspects will be the absence of gravity (except within the space station, which will provide its own "synthetic gravity" by spinning slowly to produce centrifugal force). The result of the lack of gravitational pull will be weightlessness—and there can be no doubt that weightlessness will be the most unearthly and unforgettable experience shared by those who venture beyond the earth's atmosphere. Space and weightlessness will become synonymous, like desert and thirst, or arctic and cold.

The consequences of weightlessness are being discussed in many circles of medical science, and the opinions expressed cover a wide range of possibilities. Some believe that weightlessness will be entirely harmless; others have gone so far as to predict that man can survive only a few minutes without gravity. This latter point of view, in the opinion of top experts, is almost certainly wrong.

In the first place, blood circulation will be affected only slightly. The heart pumps the blood through the body whether it has weight or not. Secondly, eating does not require the help of gravity. We can even eat "upward," while hanging head downward from a bar. Neither will the digestion be influenced.

* * *

While the machinery of the body will go on operating in an orderly fashion even if it is weightless, man will possibly encounter trouble when he attempts to go about his daily routine. Weightless man may well find himself in this position:

Imagine a muscular weight lifter taking a good grip on what he thinks is a solid 300-pound weight, but is actually a much lighter contraption made of wood. His anticipation is utterly deceived, and the ill-adjusted strength he applies, to his great surprise, throws the fake weight violently upward.

Space-faring man will consistently experience much the same thing: he will find that his co-ordination, based on a lifelong experience with gravity, suddenly fails him in this new environment. A simple movement on earth, such as rising from his chair, will, in space, jerk him across the cabin toward the opposite wall. The co-ordination of the body, which is so automatic here on earth that we take it for granted, will have to be acquired all over again.

Since the customary effects of gravity are absent, there is no "up" or "down"—a factor certain to prove confusing. Normally, we rely to a great extent on gravity for orientation. But in a rocket ship, all orientation will depend on the eyes. It probably can be acquired, but until it has been learned, there exists the possibility of "space sickness," which will reduce efficiency even if it does not completely incapacitate the crew.

Not only the men will float around aimlessly in the weightlessness of a coasting rocket ship—objects will do the same, and this will cause trouble if careful thought is not given to the design beforehand.

In space, we must use other forces to substitute for gravity. Every metal object must be made of steel, or at least have a steel strip inlaid somewhere on it. Such tools can be kept in place with magnets, along the lines of the magnetic knife board in use in many of today's kitchens. Where magnetism cannot do the job, as with papers, friction will have to substitute for gravity—the clip-board is an everyday example of such a device.

As for eating utensils, the function of the knife and fork will remain the same. The knife still cuts and the fork utilizes friction to hold food after it has been speared. The spoon, however, is useless aboard a rocket ship (and so is the fork when used like a spoon), so the well-planned table in space will include some offspring of the sugar tongs, something which will hold food by friction.

Liquids will be especially annoying; any liquid from milk to Burgundy is likely to imitate what any bottled heavy sauce does on the ground. If you tilt a bottle in space nothing will come out, for, since the liquid does not weigh anything, there is no reason for it to pour. But when you shake the bottle, all the contents will come out in one splash. The solution to that particular problem is a very old invention: the drinking straw, which does not rely on gravity but on air pressure. Another method: plastic bottles, which, when squeezed, eject liquid.

Cooking aboard the space station will not be too difficult, because the satellite enjoys synthetic gravity. However, in rocket ships it will be quite different from the same process on the ground. Open pots or pans are useless, for boiling water will simply erupt from an open pot because of the steam bubbles which form at the bottom. Likewise, the first explosive sizzle of a steak's fat will send the meat floating across the cabin. Only closed cooking pots can be used and the ideal broiler is the so-called electronic range which cooks by short wave. (Naturally, if the crew members of the rocket ship are wearing pressure suits, they will have to open the visors of their helmets to eat.)

In long rocket-ship trips from the space station to other planets, seasoned space travelers may enjoy sleeping literally on an air cushion, just floating in air, possibly with a string tied to their wrists or ankles so that the reaction of their breathing will not "float" them away.

* * *

So far, we don't know whether the familiar pressure of a bed against the body is necessary for falling asleep. If it is, it can be "faked" during the weightless state by having a set of rubber straps force the body against a board or other flat surface. Beginners, however, will have to sleep in special bunks. These will look like six-foot lengths of pipe, upholstered inside and equipped with wire mesh covers at both ends. These wire mesh covers—the "wire" would probably be nylon string and the mesh widely spaced—would keep the sleeper inside his "bed." Without them, he might push himself out of it by unconscious movements or even be sucked over to the outlet end of the air-conditioning system.

For most of us, weightlessness will hardly be an agreeable and welcome feeling, and learning to live with it may prove a painful lesson. However, man has an astonishing ability to adjust himself to extreme conditions. A few individuals may even get to enjoy weightlessness, after a fashion. The crew members will probably be able to master its intricacies and go about their daily chores with ease.

We can be reasonably certain that man will be able to survive in space because we have sufficient knowledge of what will happen to the rocket ship or space station and to man himself. We can plan intelligently for his survival. Unlike the earth's early explorers, the pioneers of space know pretty well what they are headed for, and they know that they will be equipped adequately.

The conquest of space hinges on man's survival in space. And the crews of rocket ships and space stations, while they can never be completely protected against hazards such as meteors, will probably be safer than pedestrians crossing a busy street at a rush hour. THE END

"It must be wonderful going with a man who can write books. I always get the kind that can tear them in half"

COLLIER'S FRANKLIN FOLGER

Mars, at its closest 35,000,000 miles from the earth, as seen from its outer moon Deimos, where man could land before going on to the planet

Who Owns the Universe?

By OSCAR SCHACHTER

Deputy Director, Legal Department, United Nations

The approaching age of space travel poses legal problems that lawyers already are grappling with. The freedom-of-the-seas principle may solve some of them

WE HAVE all heard about attempts to sell real estate on the moon and have laughed at the poor suckers who bit. Indeed, to say that someone wants the moon means simply that he wants the impossible. But now that scientists have shown that man can conquer space and that new worlds lie within his reach, the question of "owning" the moon and the planets no longer seems to be so much of a joke. Today, the question is not at all farfetched and, in fact, it may well have important consequences for all of us.

Of course, the real issue is not whether private individuals may sell real estate on the moon or go into business outside of the earth. The serious question, like so many others today, concerns national governments and their respective rights and powers. Will these governments claim "ownership" (or, more correctly, sovereignty) of the moon and other celestial bodies, just as today claims are being made to the barren wastes of the antarctic? Will there be national rivalry to plant the Stars and Stripes, the Union Jack and the Hammer and Sickle far off in space, so that the governments can then assert exclusive control and keep others away?

And what of rocket ships and space stations? What rules will govern them and, most important, will they be free to move about high above peaceful nations, laden with weapons of mass destruction? In this time of international tension, it may not be too soon to think about these questions.

Where can one find principles and precedents to answer these problems? Interestingly enough, we have to go back four centuries, to the great age of exploration and conquests, when Columbus, Magellan, Vasco da Gama and the Cabots found and claimed new worlds for their royal sovereigns. It was these colorful adventurers, hunting for treasure and glory, who set the scene for the development of new legal principles— indeed, of the whole new system of international law that was to govern the relations between independent nations for centuries thereafter. The reason for this was that the discovery of these new territories immediately presented political and legal issues.

The great maritime powers of that day, Spain and Portugal, had to find a method of settling their claims to avoid war. With the advent of British sea power, further adjustments had to be made. There was the obvious problem of deciding who was to exercise sovereignty over the new areas. (The lawyers referred to these regions as *"terra nullius,"* that is, land which belonged to no one.) Was it enough that the navigators made the initial discovery and then sailed away after planting the royal emblem? Or was it necessary that there be an occupation, at least a small settlement, in order to acquire dominion over the newly found region? And, finally, could the seas themselves be claimed as national territory?

At first, it was thought that these questions could be settled through the authority of the Pope. Almost immediately after Columbus' discovery, the famous Papal Bull of 1493 was issued, dividing the world between Spain and Portugal by a meridian line running a hundred leagues west of the Azores, through both poles. What *(Continued on page 70)*

PAINTING BY CHESLEY BONESTELL

Who Owns the Universe?

CONTINUED FROM PAGE 36

is probably most significant about this papal bull (and others like it) was that it introduced the notion of law to the problem of new territories. It was based on the assumption that sovereignty was not just a matter of naked power or, as it has been called, of the "divine right of grab"; at least there had to be a legal basis.

However, the papal bull did not settle the actual problem. England for one, as a Protestant country, did not accept it; moreover, English freebooters like Sir Francis Drake and Sir John Hawkins soon made a mockery of Spanish claims to dominion over the seas. With the victory over the Armada, all claims to exclusive ownership of the high seas by Spain were effectively ended. The significant result was the development of the principle of freedom of the seas, a fundamental feature of international law, and one which has contributed greatly to the peace and economic development of the world.

In regard to the land, as in the case of the sea, the decree of the Pope was not a final settlement, but only the beginning of the development of rules of law. Both Spain and Portugal were soon obliged to justify their claims by legal principles. It was then that new rules emerged which were to decide what countries were to govern the new territories.

What were these rules? Perhaps the most important was that the mere discovery of new territory was not considered sufficient to confer sovereignty. Even extended exploration was not enough; nor did the giving of names to portions of the lands or waterways make any difference. It was, however, agreed that if a country effectively occupied new territory, through settlement it acquired sovereignty. Thus Columbus felt obliged to leave some of his crew on the island of Hispaniola (Haiti) to justify legally the Spanish claims.

* * *

But it is important to note that settlement was not always essential. In many cases, claims rested merely on certain symbolic acts of possession. The French and Portuguese would erect crosses or monuments bearing the royal arms. The Spanish and English used more elaborate ceremonials, usually a whole ritual, to denote the formal taking of possession. For example, the English sometimes used a "turf and twig" ceremony, taking from the land a clod of earth and a twig as tokens of acquiring ownership. The Russians also employed symbolic acts, such as burying copper plates bearing their coat of arms in the Aleutian Islands and the Alaskan coast. These various rituals were generally considered effective, though it is by no means certain that they would be accepted today.

In recent years there has been further development. The emphasis has shifted from the taking of physical possession and settlement to displaying the authority of government in a practical way. The whole problem is presented sharply today in connection with claims to the antarctic region. This great area has been claimed by a number of nations on the basis of exploration and display of governmental authority. But so far none of these claims has been accepted and the controversy remains unresolved.

The dispute over the antarctic shows how the principles of law developed in the period of the discovery and exploration of America have their effects today. Moreover, the controversy foreshadows the conflict that may arise when the first rocket ships reach the moon and other celestial bodies.

Governments will, of course, tend to think and act in terms of their own particular interest; they will normally use past practice to further their special claims. If this pattern is followed, we may expect to see that the first landings on the moon will involve all sorts of acts intended to support claims of sovereignty. Obviously, the flag will be planted and, very likely, names will be given to places on the moon (though astronomers have already named the larger lunar features). We might then be reading of lunar "Washingtons" and "New Yorks," perhaps of King George mountains and Stalin craters.

In place of the old ceremonials with crosses and coats of arms, scientific instruments might be left behind, and these might be regarded as having symbolic as well as practical value. Finally, there might be attempts by governments to exercise control, perhaps even to issue licenses, and to claim the right to exclude those who are not licensed. All of this would be the old story of territorial rivalry—but this time extended into the heavens themselves.

We may well ask whether this is the only way governments can deal with the problem. Would it not be possible to by-pass the whole problem of national sovereignty in outer space?

The answer to this might be found in the analogy with the system governing the high seas. We have already seen that at one time governments maintained that the open seas as well as the land belonged to them. These were not just theoretical claims; they were enforced by men-of-war. Passage was often prohibited and tolls were levied. It was not until the time of Queen Elizabeth I that this system was challenged.

When the Spanish ambassador lodged a protest against Francis Drake's voyage to the Pacific in 1577, Elizabeth rejected the protest, declaring that the sea, like the air, was common to all mankind and that no nation could have title to it. The Dutch (like the English, a rising maritime and commercial power) also flouted Spanish and Portuguese claims. Their jurists, including Grotius, the father of international law, argued that the sea was common property and that all peoples were to use it. Gradually this idea prevailed.

Why not extend the same principle, now applicable to the open seas, to outer space and the celestial bodies? These areas would then be considered as belonging to all mankind, and no nation would have the right to acquire any part of them, any more than a nation now has the right to acquire parts of the open sea. The whole idea of national sovereignty outside of the earth would thus be eliminated.

But it might be asked whether this would not result in a state of anarchy, with no rules or restraints whatsoever. The simple answer to this might again be drawn from the analogy with the high seas. Obviously, the open sea is not in a condition of lawlessness; it is, in fact, subject to law, although not to the authority of any single nation.

Similarly, laws would have to be developed to apply to outer space. Certainly a principal object of such laws would be to encourage scientific research and investigation. Thus, there would be the idea of free and equal use rather than exclusive use. Space travel, like navigation on the seas, would be permitted to everyone, no matter what country he came from or under what flag he traveled. In general, interference with such travel would be prohibited and governments would not have the right to appropriate portions of space.

* * *

There might have to be exceptions to the general principle that outer space is completely free and cannot be appropriated. Perhaps governments might be given the right to own and maintain scientific installations, just as today countries are permitted to have lightships and weather stations permanently installed on the open seas. Suppose also that valuable mineral deposits are found on the moon or a planet—would there not have to be a rule permitting countries to exploit these resources when they have discovered and developed them? True, this would be a departure from the idea of free and equal use, but on the other hand it would be quixotic to declare that valuable minerals found and developed by one country should be available to anyone and everyone.

A more immediate problem is presented by the rocket ship itself. When we consider the possible uses of such ships, all sorts of questions arise. Will they be permitted to move about, free from the authority of any particular country and free of any other restraints? One might, for instance, envisage a space station high above the earth equipped to send radio or television signals to the earth. Would that satellite, therefore, be free of all the regulations, both international and national, which safeguard the public interest in this field? And if control is to be exercised, how should it be made compatible with the principle of freedom of outer space which we have urged?

The best way to meet this problem, it

COLLIER'S "We in Outer Space yet?" PERRY BARLOW seems to me, is to begin with the idea that each space craft must bear the flag of a particular country; that is, it must have a nationality (perhaps, as an exception, there might be some space craft which could belong to an international organization). If a ship tried to evade this rule, it would be in the same position as a pirate of old and it would be subject to seizure by any government able to lay hands on it.

By requiring that each space craft have a nationality and a flag, it becomes possible to supervise them and control them. They then become subject to the discipline and the laws of the flag-state. If they failed to comply with those rules, they would become subject to penalties. At the same time, the government whose flag they fly would have to guarantee the proper use of the craft. The flag would also protect them against any abuses from other governments.

Since the craft would be mainly subject to national rules, it would be desirable that these have common features. By way of illustration, there would have to be agreement regarding signals for radio communications and similar matters. For the most part, however, the regulation would be left to the government whose flag the craft bears. That government would, in the first place, decide whether the craft was entitled to bear its flag. It would also determine the authority which the captain would exercise; it would provide for the safety of the personnel aboard and it would define and punish criminal acts. To a large extent these rules would be similar to those applicable on the high seas and many questions could be decided simply by referring to the law governing vessels at sea.

Let us return to the example of the space station engaged in broadcasting radio or television programs. In the first instance, the regulation of that station would be carried out by the country to which it belongs. Thus, an American television station operating in outer space presumably would be subject to the authority of the Federal Communications Commission. Perhaps new regulations would have to be devised to meet engineering problems which might arise; but, in any case, it would be clear that a station would not be free to evade control by its own government.

* * *

A much more difficult problem would be presented by a rocket ship or space station devoted to military purposes. In this case, the analogy with the high seas may be questionable. The high seas, as we well know, may become a theater of war and, generally speaking, there is no prohibition against belligerent vessels utilizing the open seas for warfare. However, when one conceives of a rocket ship or space station operating far above the earth with bombs of mass destruction, there can be little doubt that the potential danger to mankind would far exceed that which could be caused by a ship of war on the high seas.

This factor may lead to a demand that the use of outer space for military purposes be outlawed. But whether space craft as implements of warfare should be considered separate from other questions of security and disarmament might well be a controversial question in this period of international tension.

Although we have been talking about outer space, we have said nothing about where outer space begins; or to put it in another way, how far up does the territory of a country extend?

Now, this is not a brand-new question. In ancient Roman law, the landowner was considered to own the space above the land upward "to the heavens." But the idea of a private landowner owning all the space above his land has long been abandoned. Today, a man no more owns the air above his land than a man with a house on the seashore owns all the sea in front of his house. However, in contrast, it is well established that a nation does own the space above its territory. This principle obviously has considerable importance in regard to aviation. Thus, when governments entered into treaties relating to aviation they declared that "every power has complete and exclusive sovereignty over the airspace above its territory." This is accepted in international law.

Now, what does the term "airspace" mean in this sense? Does the term "air" extend only to the upper atmospheric regions? Should it be defined in terms of the composition of the gases or their density? So far there has been no authoritative answer to this question. The reasonable answer, it would seem, is to consider that the term is used in aviation treaties and therefore it is presumably intended to refer to the part of the atmosphere which contains enough air to allow aircraft (including balloons) to fly. Up to now balloons have gone as high as 21 miles, but it is estimated that air sufficient for flight extends about 60 miles above the earth. Beyond that there is no airspace so far as aircraft are concerned.

Whatever may be the precise boundary of the airspace, it is clear that when we go beyond it we are legally in a no man's world. The whole idea of national territory above the "airspace" would be based on a theoretical and fanciful notion, without any practical application.

* * *

It has been proposed that the upper territory be limited in terms of a country's power to exercise effective control. Presumably, this means that if a state can "control" (*i.e.*, stop) the flight of another nation's rocket at a certain distance, then territorial sovereignty should be limited to that distance. This position has been put forward by a distinguished authority, Mr. John C. Cooper, the director of the Institute of International Air Law. He has proposed "that at any particular time, the territory of each state extends upward into space as far as the then scientific progress of any state in the international community permits such state to control space above it."

It is interesting to note the resemblance between this approach and the old three-mile rule which has fixed the area of a country out into the ocean. This three-mile rule was also based on the idea of effective control—in particular, on the range of shore artillery batteries. At the end of the eighteenth century, these batteries had a range of about three miles, and therefore it was considered that that portion of the sea was within the control of the state.

Although the principle of effective control has been important in international law, one wonders whether it should be applied to this new problem of space travel. It would seem to mean that whenever a country could prevent or interfere with the movement of a rocket ship or space station it would have the legal right to do so. Would this not, in effect, simply be a rule that "might makes right"? And would it not place rocket ships and space stations at the mercy of those national states which would be able to interfere with their free passage?

There certainly does not appear to be any compelling reason in law or principle to carry national sovereignty this far. Indeed, any attempt to extend national territory higher than the airspace is bound to involve difficulties. Why not, then, fix the limit at the upper boundary of the airspace and no higher?

Beyond the airspace, as already noted, we would apply a system similar to that followed on the high seas; outer space and the celestial bodies would be the common property of all mankind, and no nation would be permitted to exercise domination over any part of it. A legal order would be developed on the principle of free and equal use, with the object of furthering scientific research and investigation. It seems to me that a development of this kind would dramatically emphasize the common heritage of humanity and that it might serve, perhaps significantly, to strengthen the sense of international community which is so vital to the development of a peaceful and secure world order. THE END

...SPACE QUIZ

The fascinating aspects of man's study of space are—like space itself—infinite. Naturally, not every one of them could be incorporated in this symposium. However, some of the most intriguing questions which arose during the preparation of this issue, and the answers provided by the scientists who participated in it, are listed below

Q. ***Is interplanetary travel possible?***

VON BRAUN: Certainly, once we have a station in space that would enable us to take off refueled and unimpeded by the earth's atmosphere. Although Venus is the closest planet (26,000,000 miles when it swings toward the earth), the easiest interplanetary trip would probably be to Mars (35,000,000 miles), since either of its two moons is close enough to serve as a space station for the return voyage. To land on Venus, we would have to establish a temporary space station around it. Traveling at the most economical speed, a rocket could make the one-way trip to Mars in 258 days, or to Venus in 146 days.

Q. ***Have any living creatures already been rocketed into space?***

LEY: Yes. It has been announced that certain plant seeds and specimens of the fruit fly (the species *Drosophila melanogaster,* widely used in experiments in genetics) were sent up in V-2 rockets a few years ago. They made the trip unharmed. It seems reasonable to assume that larger creatures have been rocketed past the atmosphere since then.

Q. ***How large can we expect the meteorites to be which will endanger space travel?***

WHIPPLE: They will vary in size from pellets much smaller than a grain of sand (the tiniest of these are called cosmic dust) to monstrous—and, fortunately, rare—affairs that might be termed "flying mountains." The largest meteorite on exhibit anywhere in the world is the Ahnighito, found in Greenland, which is on display at New York's Hayden Planetarium and weighs at least 35 tons. But there is one embedded in the ground at a place called Hoba West, near Grootfontein, South-West Africa, estimated by some to weigh as much as 60 tons. Cosmic dust will not pose a real threat in space, but it will be a nuisance. For although it will not be able to puncture the walls of a space station or rocket ship, it will slowly sandblast all windows continuously exposed, making them more and more difficult to see through. The solution might be transparent plastic window coverings, which could be discarded when rendered useless by the tiny meteorites.

Q. ***What are some of the unsolved hazards that man will encounter in space?***

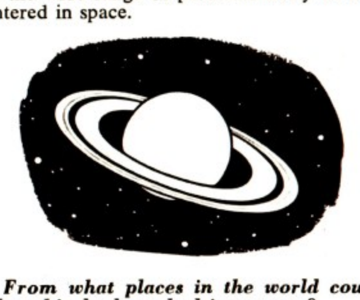
HABER: Granting that scientists have found a workable solution for the menace of meteorites, the greatest remaining hazard is that of the mysterious cosmic rays—nuclear bullets like those released by the atomic bomb, which streak unpredictably through space. To bar them entirely from space craft would require an extremely thick wall of lead or an armor of nickel-steel at least two inches thick. Either of these would be prohibitively heavy. Fortunately, although no one knows how dangerous cosmic rays are, many experts are quite optimistic. Another unsolved hazard is a psychological one: men cooped up in small rocket ships, on long trips through space during which there is little to keep them occupied, will suffer from such severe boredom that it may become a very important factor in space travel. There are lesser problems, too, of course, but in all probability most of the hazards of space will be solved by the time construction of the first space station is completed.

Q. ***Since some of the planets have no atmosphere, is it possible that someday we may lose ours?***

KAPLAN: Not unless two very unlikely events occur: (a) if the earth inexplicably loses much of its weight (and, therefore, much of its gravity); or (b) if we move closer to the sun. The more heat the sun pours into the molecules of air that comprise the atmosphere, the faster the molecules move; the faster they move, the more they tend to break away from the gravitational pull that keeps them close to the earth. Those heavenly bodies which lack atmosphere—like the planet Mercury, and all the moons of all the planets, except for Titan, the largest moon of the planet Saturn—lack it because their gravitational pull is too weak.

Q. ***What special training, if any, will space travelers require?***

HABER: They will have to be both physically sound and well informed on pertinent subjects. Besides a complete physical checkup, they probably will have to undergo tests to determine their reaction to acceleration and to weightlessness. One important requirement will be familiarity with the theory of space travel; another will be a reasonably good education in astronomy. As knowledge of space travel progresses, special tests for space aptitude doubtless will evolve; meanwhile, most of the early spacemen are likely to be pilots who have flown in jet or rocket airplanes, who are in good health, who have the necessary theoretical knowledge—and who are sufficiently versatile to deal with the wide range of problems likely to be encountered in space.



Q. ***From what places in the world could a rocket ship be launched into space?***

VON BRAUN: There are a number of places which might prove practical. The requirements are simple: any seacoast with 1,000 miles of water in an easterly direction—so that the rocket, which must be launched into space toward the east, could drop its two booster stages over water—would be satisfactory. That description applies to countless islands in various oceans; to the whole east coast of both North and South America; much of the east coast of East Asia; the east coast of the Japanese Islands; the east coast of Madagascar and Africa; and the east coast of both islands of New Zealand, plus part of the east coast of Australia (only part, because in some places either New Zealand or the Great Barrier Reef might interfere). However, it would be desirable to have islands a few hundred miles east of the launching site, from which the vessels could operate which retrieve the two booster stages. That would further restrict our choices.

Q. ***How about rocket travel on earth?***

LEY: Plans for long-range rockets which could travel between two distant points on earth have been developed by various scientists. The latest proposal, for a trip between Los Angeles and New York, is that of Dr. Hsue-shen Tsien of the California Institute of Technology. His winged rocket would rise to a top altitude of more than 300 miles, being powered for only the first third of the climb. Then it would swoop down until it reached an altitude of 27 miles, some 1,200 miles east of its take-off point; the remainder of the trip would be a supersonic glide at that height. Here are some of Dr. Tsien's figures: take-off weight, 50 tons; duration of powered flight, 150 seconds; duration of entire flight, one hour; landing speed, 150 miles per hour. Although such a rocket could be developed now, it is doubtful that a coast-to-coast rocket line would be commercially feasible at present.

Q. ***What is the temperature in space?***

KAPLAN: There isn't any. It may be hard to imagine, but since space is a vacuum it lacks temperature entirely (a vacuum is "nothing," and "nothing" cannot have a temperature). A rocket ship near the orbit of the earth would, however, have an internal temperature determined by the amount of heat it absorbed from the sun (93,000,000 miles away) on one side, and the amount of this heat it lost on its shaded side. This can be controlled to a certain degree. If the ship were of a dark (heat-absorbent) color, it would assume a temperature of about 60 degrees Fahrenheit. If its color were lighter, the temperature would be lower. And if the ship were nearer the earth, it would be somewhat warmer—because it would catch additional sunlight reflected from the earth.

Q. ***Will atomic energy be used to power a rocket ship?***

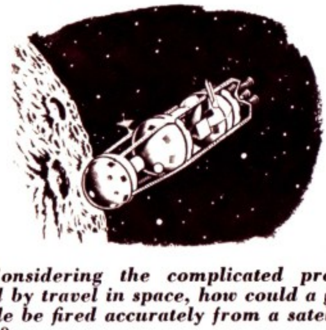
VON BRAUN: Not for some time to come. Atomic power is being developed for submarines and is

Around the Editor's Desk

planned for airplanes, but in both these cases an atomic "pile" will merely substitute for part of the conventional engine; actual propulsion will still be the work of a propeller. In a rocket ship, the rocket does its propelling by ejecting powerful gases behind it. Even if a new method of space propulsion is found, permitting the use of atomic power, an additional problem will be the heavy wall of steel or lead required to protect the crew from radiation. Furthermore, an atomic rocket motor will never be practical for launching rocket ships from the earth, because of its radioactive exhaust. In any event, we need not wait for atomic-powered rockets; known chemical fuels will do the job.

Q. ***Would the artificial air pumped into a space station or the cabin of a rocket ship have the same composition as the air that men breathe on the earth?***

LEY: As part of the necessary protection against meteorites, helium may prove a desirable substitute for the 80 per cent of nitrogen present in the air we normally breathe (the other 20 per cent could continue to be oxygen, as it is on the earth). If a meteorite punctured the skin of a space station or rocket ship, the resultant drop in air pressure would be hazardous even if the loss of oxygen could be countered by wearing masks. Like deep-sea divers brought to the surface too fast, the spacemen might suffer an attack of "the bends"—an often fatal affliction caused by the fact that some of the nitrogen we breathe forms painful and dangerous bubbles in the blood when the pressure drops suddenly outside the body. Helium does not dissolve easily in the blood stream. The Navy has tested a helium-oxygen mixture in deep-sea diving with good results.



Q. ***Considering the complicated problems posed by travel in space, how could a guided missile be fired accurately from a satellite to earth?***

VON BRAUN: The principle would be much the same as that used to fly a rocket ship from space to earth. As our space station circled the globe, the missile would be launched *in the opposite direction*. The reason is this: if the missile were simply detached from the space station, it would continue circling the earth, just like another satellite in the same orbit; if it were fired in the same direction as that in which the station was moving, it would fly off farther into space. Only if fired "backward" would it lose sufficient speed, in relation to the earth, to descend from the orbit. It would leave the station at a speed of 1,048 miles per hour; at the time it was fired, the target at which it was aimed probably would be invisible, located on the back side of the spinning earth below. The weapon would enter the atmosphere on a course roughly paralleling the surface of the earth; its position and relationship to the target (when it finally came into view of the satellite) would then be determined by radar. Remote radio control would guide the missile to its destination. Naturally, the guided projectile would not be slowed down further for its "landing," in the way that a rocket ship would be as it came close to the earth. Instead, the weapon would approach the target moving faster than the speed of sound. No place on earth, from pole to pole, would be safe from such a weapon fired from a satellite in space.

Q. ***To what tribunal would questions of space law be referred?***

SCHACHTER: A dispute in space that involved two or more governments could be submitted to the International Court of Justice at the Hague, just as international disputes are today. Naturally, precedents in such a case would be difficult to determine; but the court could apply rules expressly agreed to by the contesting governments. If no such agreement could be reached, international custom or the general principles of law might provide a guide. Alternatively, the governments might submit the case to a special court set up just to decide that one dispute. In a dispute between individuals, rather than governments, jurisdiction might lie with a local court in the place where the individuals normally lived, or perhaps with a court where the space station or rocket ship involved was registered.

Q. ***What, specifically, would be bought by the $4,000,000,000 estimated as the cost of establishing a station in space?***

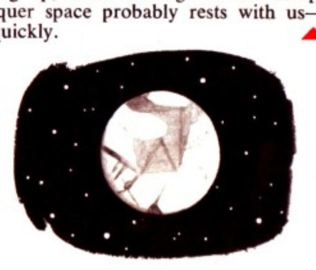
VON BRAUN: The great bulk of the money would be spent for experimentation, testing, construction of a fuel-producing plant, and other preliminaries to a permanent space program. Once the initial phases of the program had been paid for, costs would drop abruptly. For example, it would be necessary to make special high-altitude test shots with unmanned rockets before actually proceeding with the establishment of a space station. This might involve constructing and firing into space a small version of the three-stage rocket that promises to be the main space vehicle of the immediate future. This small model would be sent into the "two-hour" orbit later to be occupied by the artificial satellite; instruments inside the rocket, employing methods already in use, would transmit vital information back to earth. The fuel to be used in our projected space travels would consist of nitric acid and hydrazine; the first of these ingredients is being mass-produced for commercial use, but special factories would have to be built to manufacture the hydrazine, which has little commercial application at present. In short, the $4,000,000,000 would buy everything from the paper on which the experts did their initial calculations to the circling space station itself. Perhaps a dozen cargo-carrying rocket ships would be needed to carry the components of the station to its orbit around the earth; thereafter, presumably, production of rocket ships would continue. As an indication of how expenses would drop once the project was under way, the ultimate cost of these rocket-powered vehicles probably would be less than $1,000,000 each—no more than the current purchase price of a large air liner.

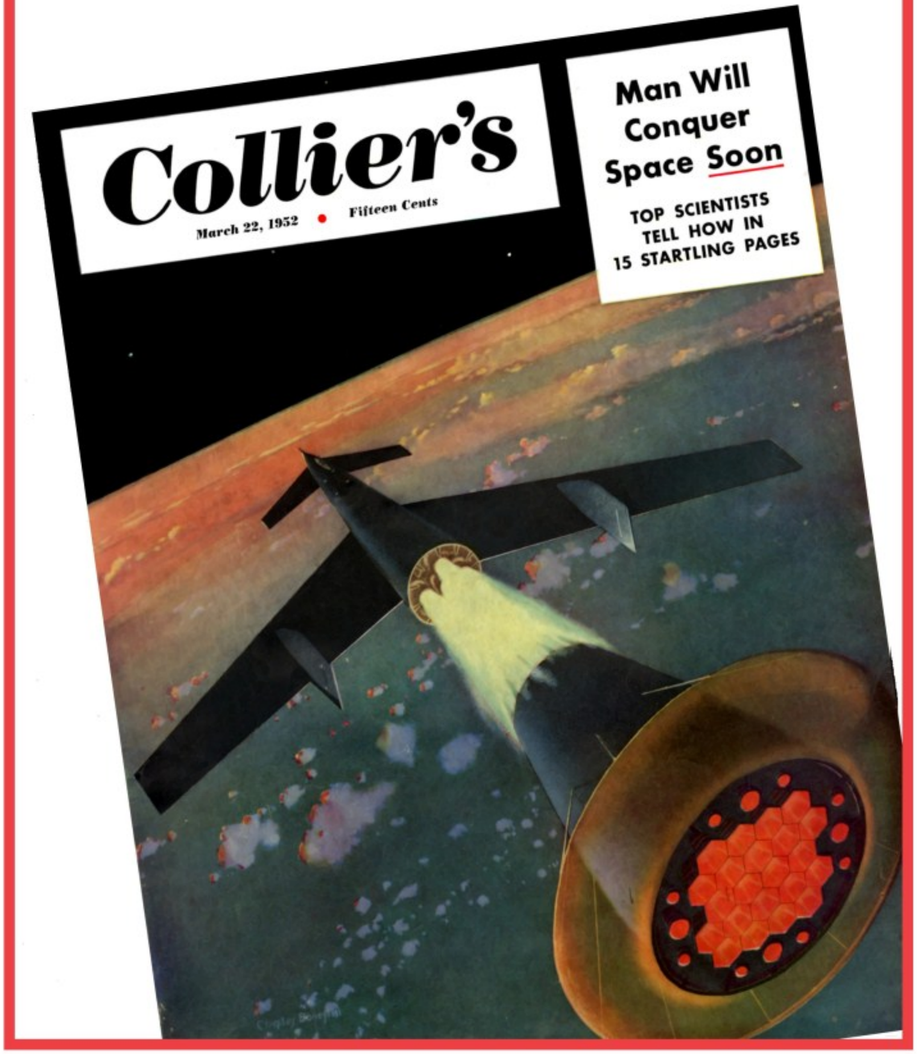
Q. ***Is there life on other planets?***

LEY: Most astronomers agree that there is primitive plant life, like lichens and algae, on Mars. The presence of this potential food supply has led a number of biologists (although not all of them) to conclude that there may be some form of animal life there, too. It is very doubtful that life of any kind exists on the other planets, however. The five which are farthest from the essential warmth of the sun—Jupiter, Saturn, Uranus, Neptune and Pluto—are much too cold to support life as we know it. Venus, which is closer to the sun than we are, is considered too hot. Peculiarly, Mercury, which is closest of all to the sun, offers the only other possibility of life. That's because Mercury keeps one face turned constantly toward the sun, just as our moon shows only one side to the earth. The "daylight" side of Mercury is extremely hot—hot enough to melt lead. Its "night" side is correspondingly cold. However, these two extremes are separated by a so-called "twilight belt," where temperatures approach those of the earth and Mars. It is just conceivable that life may have taken hold in that dim, narrow strip between the unbearable heat of Mercury's daylight and the terrible cold of its night.

Q. ***Would Soviet Russia enjoy any advantages in a race for space superiority?***

VON BRAUN: Just one advantage of any importance, so far as is known. Because the country is huge, and barricaded behind the Iron Curtain, the initial phases of a space program could be kept secret much more easily in the Soviet Union than in the Western World. One other advantage *may* exist: the Soviets claim a head start. There is no way of telling whether that is true. Obviously, there are several conditions which must be met before any nation could establish a satellite in space, and thus assume space superiority. First, of course, that country would need trained rocket researchers. Whether the U.S.S.R. has such scientists in any number (and of sufficient caliber) is uncertain. Of the experts who gave Germany its enormous lead in rocketry during World War II, only one, Helmuth Groettrup, is working for the Soviet Union; several are employed by the United States. Another major requirement is a highly diversified industrial economy; in this respect, the United States is certainly far advanced over Soviet Russia. Finally, in the matter of the necessary natural resources, it is doubtful that either side has an advantage. The raw materials needed for a space program are fairly common and probably are as easily available in the U.S.S.R. as in the West. Summing up, the advantage in the competition to conquer space probably rests with us—if we move quickly. ▲▲▲





Next Comes the Moon

THE ILLUSTRATION for this week's editorial will be familiar to most Collier's readers, for it was the cover of our issue of March 22, 1952, which contained a number of articles under the collective title Man Will Conquer Space Soon. Since that issue appeared, some things have occurred which we believe lend strength to our slogan, Collier's Makes Things Happen.

For one thing, an expanded version of those March 22d articles appeared last week as a book called Across the Space Frontier (Viking Press), and already its sales are right up there in the hot-cake category. For another, the Third International Congress on Astronautics met in Stuttgart, Germany, a few weeks before to discuss the conquest of space.

Now, we don't say that Collier's made this Stuttgart conference happen. But our March 22d issue did anticipate and deal with the very same subjects that the 200 scientists from 13 countries discussed in Stuttgart, from the cost, design and time factors involved in constructing a space rocket, to the technical problems of building an artificial satellite in outer space and the legal problems regarding possession and "ownership" of that space. And while Dr. Wernher von Braun, who wrote our leading article on space travel, was not able to appear in person at the astronautical congress, his paper on Space Travel: A Common International Task, which was read before the conference, was one of the key documents of the discussion.

The very fact that the word astronautical exists in our language seems proof enough to us that space travel has passed from the realm of conjecture to the field of rather imminent reality. There are many difficulties to overcome. But the technical details have been worked out beyond the point of doubt or failure. And in working them out the astronauts have succeeded in making science fact vastly stranger and more intriguing than science fiction. The fanciful activities of the space travelers met in comic books, television and movies can't compare with what actual men will accomplish within the lifetime of many of us.

For man *will* conquer space. There is no longer any real question about it. It is the last great frontier that challenges human intelligence, ingenuity and courage. And, as the title of Dr. von Braun's paper states, the meeting of that challenge is a common international task. It is also a disturbing international problem.

The development of rockets, upon which space travel depends, was born of the desire for destruction and conquest in World War II. It might now—and in a happier period of world history it surely would—become an instrument for opening vast new horizons to the traditionally nonpolitical, non-nationalistic, peaceable brotherhood of world scientists. But, in the Soviet Union, political theory has long since taken over science and warped and perverted it to political uses. Thus true international co-operation in the conquest of space is impossible.

Whether the free world's scientists will pool their wisdom, or whether the United States will have to go it alone in the conquest of space, remains to be seen. But Collier's believes that it behooves this country to start some real activity. For the first power that builds and occupies a space satellite will hold the ultimate military power over all the earth. This the Soviet government knows, too, and it is not idle.

In the hands of a peaceful country like ours, a space satellite would be the first step in a series of infinite and perhaps unimagined possibilities. For it must be remembered that an artificial satellite, though a staggering accomplishment, would be only a beginning. Beyond this threshold of outer space lies the moon, and beyond the moon the nearer planets.

Collier's told you the details of the first step last March, but we haven't neglected outer space in the meantime. In next week's issue and the issue following we shall bring you the story of Man on the Moon, by the same scientists who conducted our first symposium. It's a feasible, technically accurate story and a highly important one, too, because it is someday going to come true.

A Really Fine Restraint

SINCE WE ADMIT to a few tender and old-fashioned sensibilities, we cannot but admire the restraint with which certain newspapers handled a certain news story which broke not long ago. The story had to do with a newly developed chemical compound called diacetylhydroxyphenylisatin, which, we gathered, is derived from prunes. Or maybe it just resembles prunes, or certain properties thereof. We were always pretty shaky in high-school chemistry.

Anyway, you know about prunes. Or do you? Well, if you don't, you wouldn't have been much enlightened by the newspaper stories we read.

One of them said that Grandma had been dead right about prunes all along. Another stated that diacetylhydroxyphenylisatin was an essence of the best, the very best, that the prune had to offer to the human system. Still another brought the soothing announcement that the new compound is not harsh, and that it can be taken with absolutely no harmful side effects. But nothing more specific than that.

Maybe that isn't full and accurate reporting. But somehow we find it refreshing in this day of the four-letter-word novel, in this day when such terms as vice lord and call girl have become household words via press and radio, to discover that the school of Nice Nelly journalism still exists. Even Queen Victoria could not have been shocked to read these veiled, discreet hints that—dare we say it?—a new laxative has been developed.

Collier's

OCTOBER 18, 1952 • FIFTEEN CENTS

MAN ON THE MOON

Scientists Tell How We Can Land There In Our Lifetime

MAN on the MOON

Scientists have dreamed for centuries of a lunar voyage. Now we know it can be done within the next 25 years—if we get started right away. In this symposium, a distinguished panel tells how

WE WILL go to the moon in the next 25 years. We have the knowledge and the tools to do it now, but years of preparation and detailed planning are needed first. What we *can* do now is get the project started.

The first step has been taken: our scientists have developed rockets which have shot through the earth's atmosphere into airless space beyond. All we need now are better rockets—and we know how to build them.

Our trip to the moon will not be a simple nonstop flight from the earth. We'd need too large and expensive a rocket ship for that. Instead, we'll make a stopover in space. We'll change vehicles, shifting from one especially designed to break away from the earth's atmosphere into one specifically designed for a moon voyage. There will be other advantages to a two-step trip, too, among them a 15,840-mile-an-hour running start on the second leg of the journey. Here's how it's done:

Within the next 10 or 15 years, we can expect to see a permanent station erected in space, 1,075 miles high, in an orbit which will carry it around the earth once every two hours. The details of this project were given in Collier's issue of March 22, 1952.

The station will be built of materials carried to the two-hour orbit by great rocket ships—called three-stage rockets because they will have three separate batteries of motors to be used one at a time, then dropped off. At a speed of 15,840 miles an hour, 1,075 miles up, these rockets become satellites of the earth, unaffected by gravity. Without power, they will cruise around the globe as long as we let them. Their cargo will do the same, since it travels at the same speed. So we merely unload our building supplies in space and let them drift there until needed.

From these prefabricated parts, we'll build a wheel-shaped structure 250 feet in diameter, with pressurized compartments and a crew of 80. The space station's ability to scan all parts of the earth will make it one of the most powerful forces for peace ever developed—or, in the wrong hands, a terrible weapon of war. Collier's still believes that the station must be built by free men; that means the United States, the only nation which can afford the satellite's $4,000,000,000 cost. In 1948, the late Secretary of Defense James V. Forrestal indicated that work on an earth satellite program had already begun. It should not be allowed to lag.

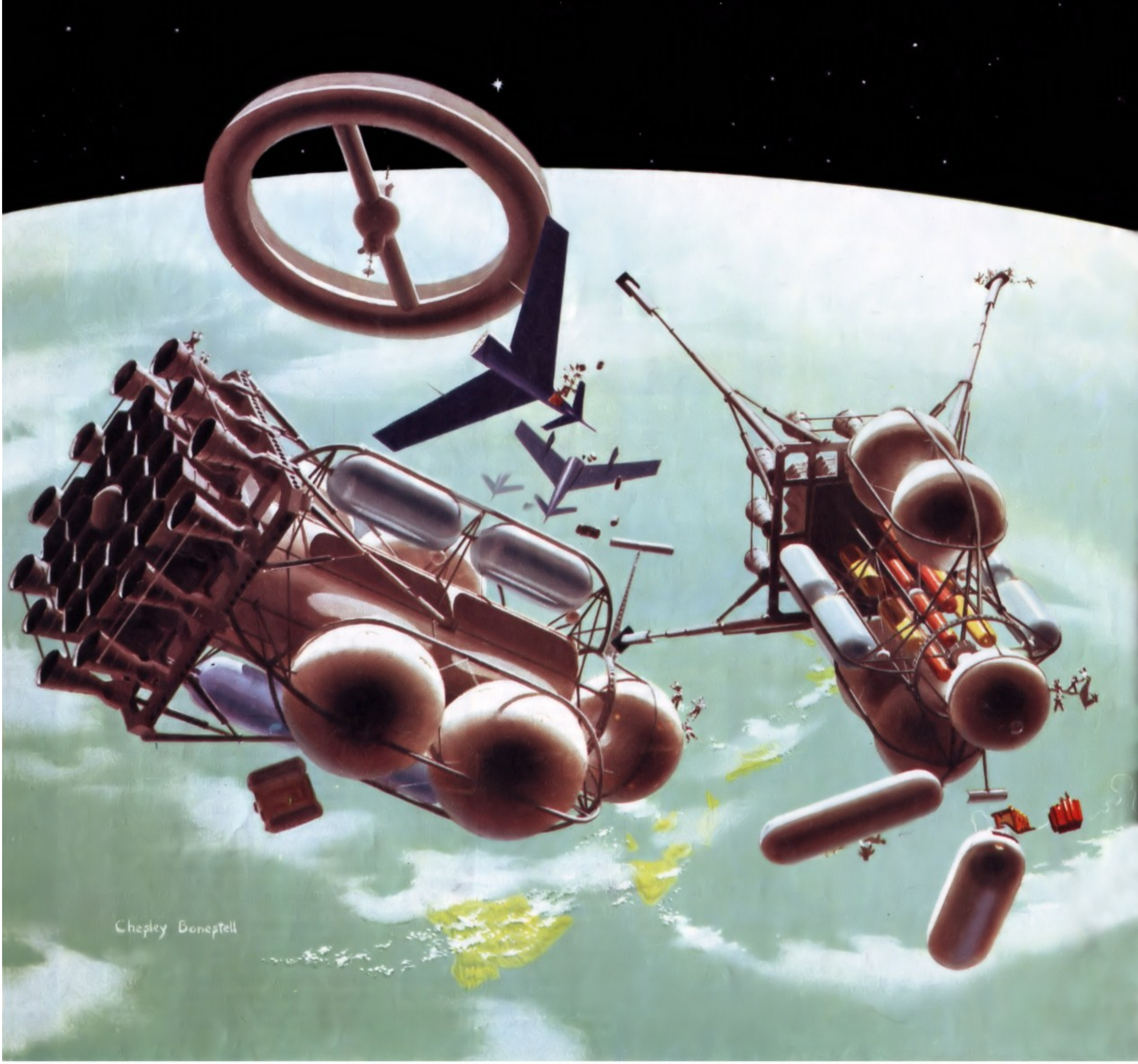
For, besides serving as a roving, ever-watchful guardian of the peace, the station in space will provide the springboard for one of the greatest scientific advances in history: the lunar journey men have dreamed of for centuries. The space station should be a reality by 1967. By the time it's completed, many of the preliminary plans will be ready for the next long step into space.

By 1977, the first scientists may set foot on the ancient dust of the moon.

HANS KNOPF

Contributors to symposium: Willy Ley, left, writer on scientific subjects; Dr. Fred L. Whipple, chairman of Harvard University astronomy department; Dr. Wernher von Braun, world's top rocket expert; artists Chesley Bonestell, Rolf Klep, Fred Freeman; associate editor Cornelius Ryan, who assembled material

MOON PHOTO COURTESY LICK OBSERVATORY



Weightless in orbit 1,075 miles above earth, workers in space suits assemble three moon ships. Hawaiian Islands lie below. Winged transports unload

Man on the Moon

THE JOURNEY

By DR. WERNHER von BRAUN

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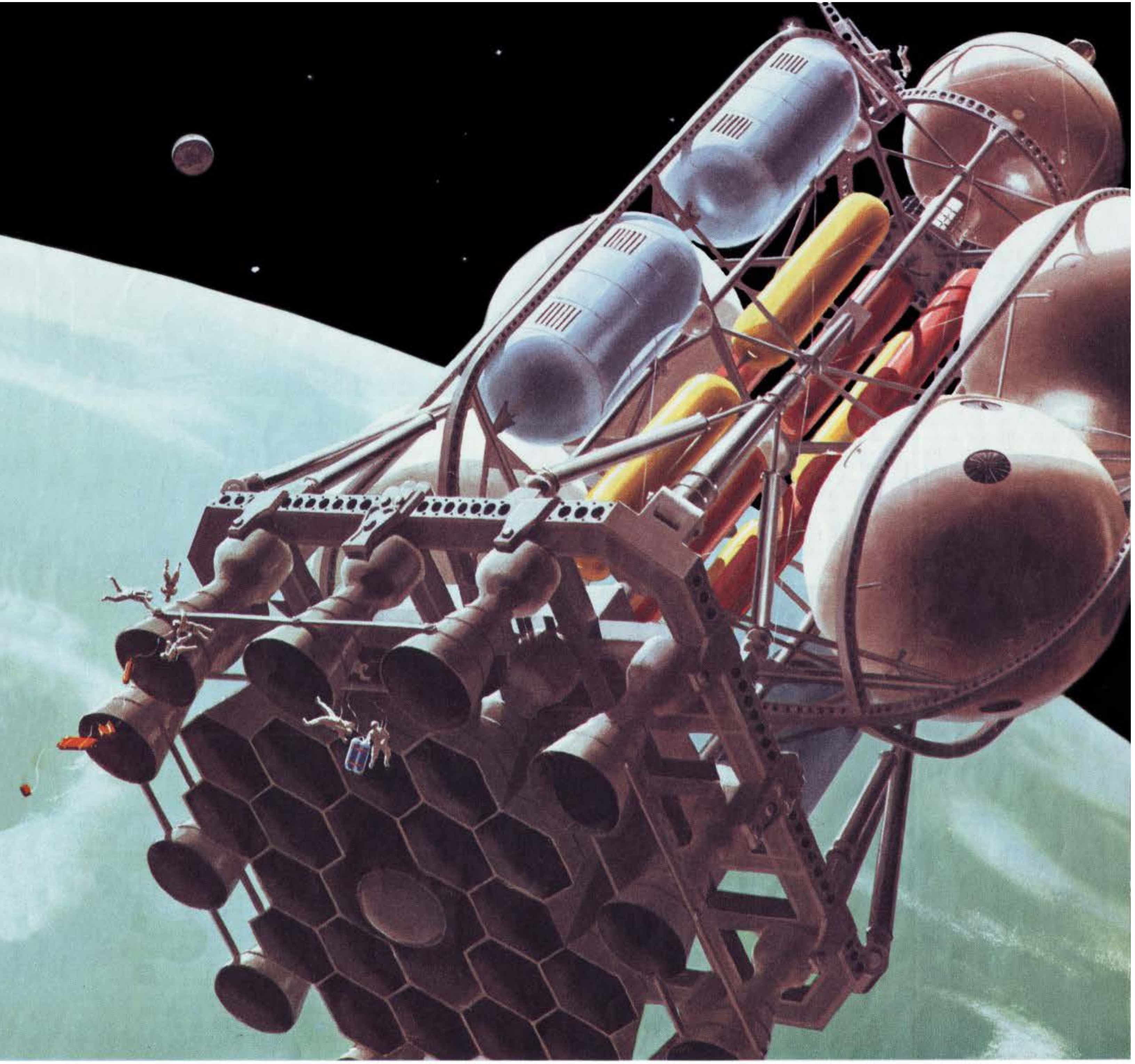
For five days, the expedition speeds through space on its historic voyage —50 men on three ungainly craft, bound for the great unknown

HERE is how we shall go to the moon. The pioneer expedition, 50 scientists and technicians, will take off from the space station's orbit in three clumsy-looking but highly efficient rocket ships. They won't be streamlined: all travel will be in space, where there is no air to impede motion. Two will be loaded with propellant for the five-day, 239,000-mile trip and the return journey. The third, which will not return, will carry only enough propellant for a one-way trip; the extra room will be filled with supplies and equipment for the scientists' six-week stay.

On the outward voyage, the rocket ships will hit a top speed of 19,500 miles per hour about 33 minutes after departure. Then the motors will be stopped, and the ships will fall the rest of the way to the moon.



supplies near wheel-shaped space station top left. Engineers and equipment cluster around cargo ship lower left, passenger ships center and right

Such a trip takes a great deal of planning. For a beginning, we must decide what flight path to follow, how to construct the ships and where to land. But the project could be completed within the next 25 years. There are no problems involved to which we don't have the answers—or the ability to find them—right now.

First, where shall we land? We may have a wide choice, once we have had a close look at the moon. We'll get that look on a preliminary survey flight. A small rocket ship taking off from the space station will take us to within 50 miles of the moon to get pictures of its meteor-pitted surface—including the "back" part, never visible from the earth.

We'll study the photographs for a suitable site. Several considerations limit our selection. Because the moon's surface has 14,600,000 square miles—about one thirteenth that of the earth—we won't be able to explore more than a small area in detail, perhaps part of a section 500 miles in diameter. Our scientists want to see as many kinds of lunar features as possible, so we'll pick a spot of particular interest to them. We want radio contact with the earth, too; that means we'll have to stick to the moon's "face," for radio waves won't reach across space to any point the eye won't reach.

We can't land at the moon's equator because its noonday temperatures reach an unbearable 220-degrees Fahrenheit, more than hot enough to boil water. We can't land where the surface is too rugged, because we need a flat place to set down. Yet the site can't be too flat, either—grain-sized meteors constantly bombard the moon at speeds of several miles a second; we'll have to set up camp in a crevice where we have protection from these bullets.

There's one section of the moon that meets all our requirements, and unless something better turns up on closer inspection, that's where we'll land. It's an area called *Sinus Roris*, or Dewy Bay, on the northern branch of a plain known as *Oceanus Procellarum*, or Stormy Ocean (so called by early astronomers who thought the moon's plains were great seas). Dr. Fred L. Whipple, chairman of Harvard University astronomy department, says *Sinus Roris* is ideal for our purpose —about 650 miles from the lunar north pole, where the daytime temperature averages a reasonably pleasant 40 degrees and the terrain is flat enough to land on, yet irregular enough to hide

PAINTING BY CHESLEY BONESTELL

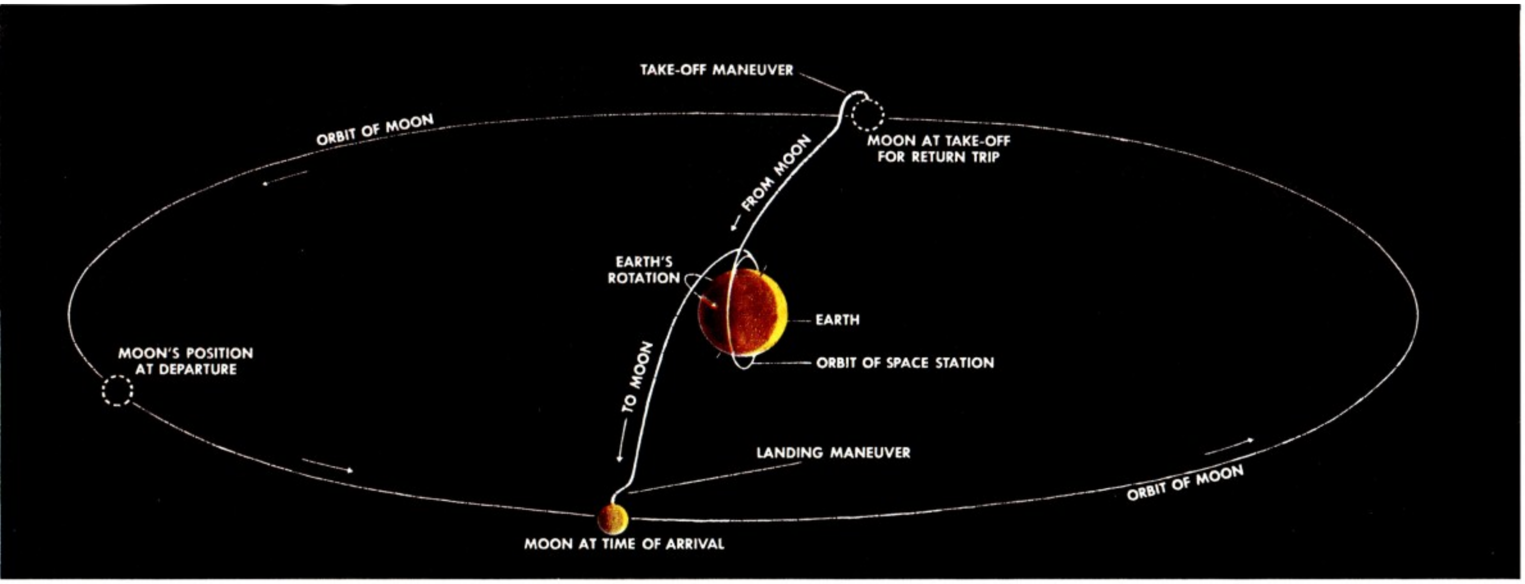
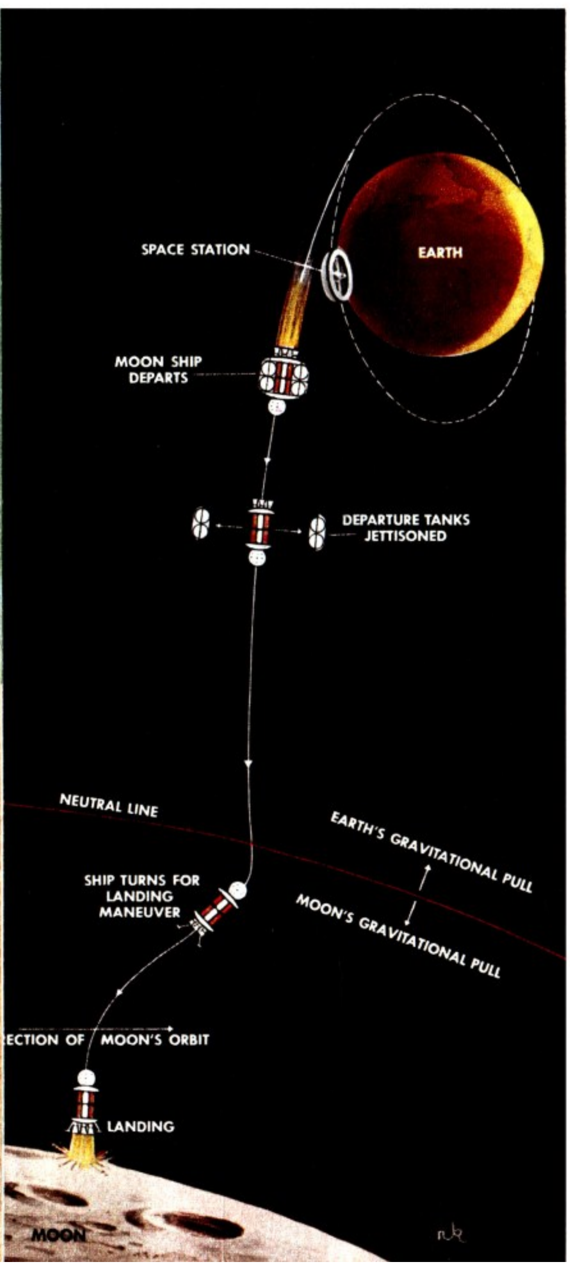


Diagram above shows flight paths to and from moon. Moving in elliptical course about globe every 27⅓ days, moon's position lines up with space station's orbit once every two weeks. Trips can be made only at this time. During expedition's six-week stay on lunar surface, moon will make 1½ revolutions around earth to reach correct position for return. Slight curves in flight track during landing and take-off are caused by moon's gravity. Drawing below, not in scale, shows moon-bound flight maneuvers in close-up



in. With a satisfactory site located, we start our detailed planning.

To save fuel and time, we want to take the shortest practical course. The moon moves around the earth in an elliptical path once every 27⅓ days. The space station, our point of departure, circles the earth once every two hours. Every two weeks, their paths are such that a rocket ship from the space station will intercept the moon in just five days. The best conditions for the return trip will occur two weeks later, and again two weeks after that. With their stay limited to multiples of two weeks, our scientists have set themselves a six-week limit for the first exploration of the moon—long enough to accomplish some constructive research, but not long enough to require a prohibitive supply of essentials like liquid oxygen, water and food.

Six months before our scheduled take-off, we begin piling up construction materials, supplies and equipment at the space station. This operation is a massive, impressive one, involving huge, shuttling cargo rocket ships, scores of hard-working handlers, and tremendous amounts of equipment. Twice a day, pairs of sleek rocket transports from the earth sweep into the satellite's orbit and swarms of workers unload the 36 tons of cargo each carries. With the arrival of the first shipment of material, work on the first of the three moon-going space craft gets under way, picking up intensity as more and more equipment arrives.

The supplies are not stacked inside the space station; they're just left floating in space. They don't have to be secured, and here's why: the satellite is traveling around the earth at 15,840 miles an hour; at that speed, it can't be affected by the earth's gravity, so it doesn't fall, and it never slows down because there's no air resistance. The same applies to any other object brought into the orbit at the same speed: to park beside the space station, a rocket ship merely adjusts its speed to 15,840 miles per hour; and it, too, becomes a satellite. Crates moved out of its hold are traveling at the same speed in relation to the earth, so they also are weightless satellites.

As the weeks pass and the unloading of cargo ships continues, the construction area covers several littered square miles. Tons of equipment lie about—aluminum girders, collapsed nylon-and-plastic fuel tanks, rocket motor units, turbopumps, bundles of thin aluminum plates, a great many nylon bags containing smaller parts. It's a bewildering scene, but not to the moon-ship builders. All construction parts are color-coded—with blue-tipped cross braces fitting into blue sockets, red joining members keyed to others of the same color, and so forth. Work proceeds swiftly.

In fact, the workers accomplish wonders, considering the obstacles confronting a man forced to struggle with unwieldy objects in space. The men move clumsily, hampered by bulky pressurized suits equipped with such necessities of space-life as air conditioning, oxygen tanks, walkie-talkie radios and tiny rocket motors for propulsion. The work is laborious, for although objects are weightless they still have inertia. A man who shoves a one-ton girder makes it move all right, but he makes himself move, too. As his inertia is less than the girder's, he shoots backward much farther than he pushes the big piece of metal forward.

The small personal rocket motors help the workers move some of the construction parts; the big stuff is hitched to space taxis, tiny pressurized rocket vehicles used for short trips outside the space station.

As the framework of the new rocket ships takes form, big, folded nylon-and-plastic bundles are brought over. They're the personnel cabins; pumped full of air, they become spherical, and plastic astrodomes are fitted to the top and sides of each. Other sacks are pumped full of propellant, and balloon into the shapes of globes and cylinders. Soon the three moon-going space ships begin to emerge in their final form. The two round-trip ships resemble an arrangement of hourglasses inside a metal framework; the one-way cargo carrier has much the same framework, but instead of hourglasses it has a central structure which looks like a great silo.

Dimensions of the Rocket Ships

Each ship is 160 feet long (nine feet more than the height of the Statue of Liberty) and about 110 feet wide. Each has at its base a battery of 30 rocket motors, and each is topped by the sphere which houses the crew members, scientists and technicians on five floors. Under the sphere are two long arms set on a circular track which enables them to rotate almost a full 360 degrees. These light booms, which fold against the vehicles during take-off and landing to avoid damage, carry two vital pieces of equipment: a radio antenna dish for short-wave communication and a solar mirror for generating power.

The solar mirror is a curved sheet of highly polished metal which concentrates the sun's rays on a mercury-filled pipe. The intense heat vaporizes the mercury, and the vapor drives a turbo-generator, producing 35 kilowatts of electric power—enough to run a small factory. Its work done, the vapor cools, returns to its liquid state and starts the cycle all over again.

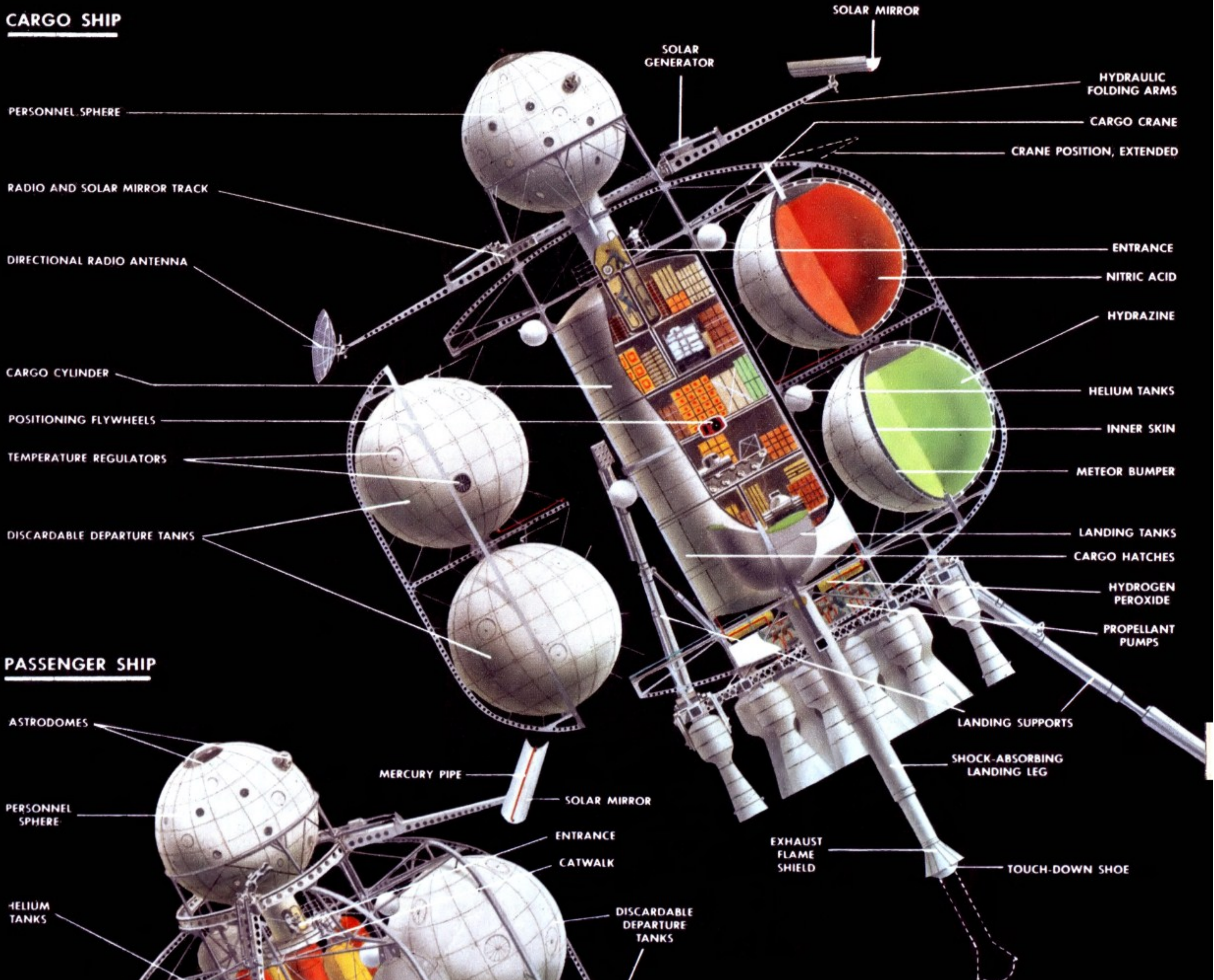
Under the radio and mirror booms of the passenger ships hang 18 propellant tanks carrying nearly 800,000 gallons of ammonialike hydrazine (our fuel) and oxygen-rich nitric acid (the combustion agent). Four of the 18 tanks are outsized spheres, more than 33 feet in diameter. They are attached to light frames on the outside of the rocket ship's structure. More than half our propellant supply—580,000 gallons—is in these large balls; that's the amount needed for take-off. As soon as it's exhausted, the big tanks will be jettisoned. Four other large tanks carry propellant for the landing; they will be left on the moon.

We also carry a supply of hydrogen peroxide

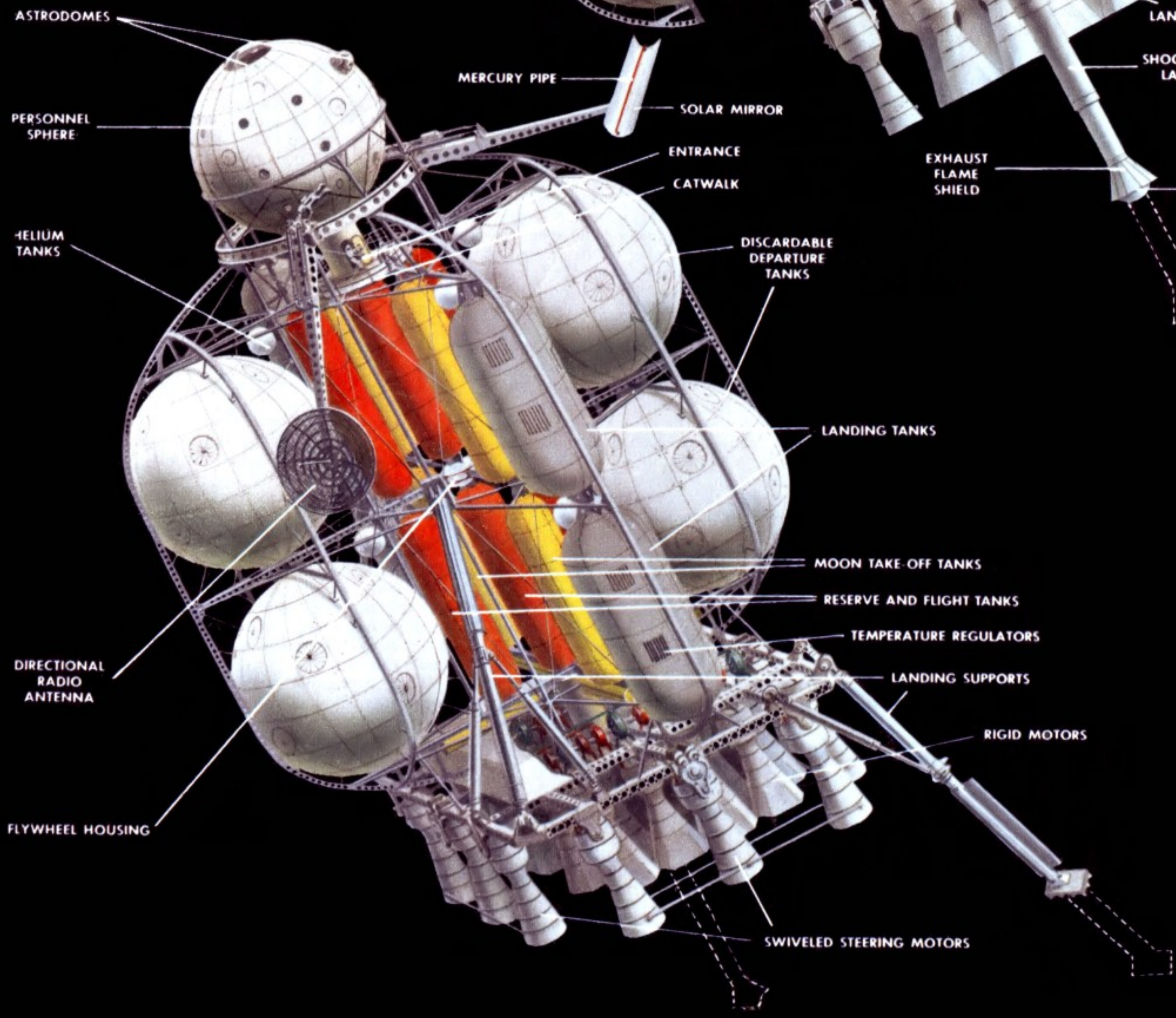
Vehicles, right, have same dimensions: 160 ft. long, 110 ft. wide; weigh 4,370 tons. Cargo ship carries 10 men, passenger ships 20 each

DRAWINGS BY ROLF KLEP

CARGO SHIP



PASSENGER SHIP



to run the turbopumps which force the propellant into the rocket motors. Besides the 14 cylindrical propellant tanks and the four spherical ones, eight small helium containers are strung throughout the framework. The lighter-than-air helium will be pumped into partly emptied fuel tanks to help them keep their shape under acceleration and to create pressure for the turbopumps.

The cost of the propellant required for this first trip to the moon, the bulk of it used for the supply ships during the build-up period, is enormous—about $300,000,000, roughly 60 per cent of the half-billion-dollar cost of the entire operation. (That doesn't count the $4,000,000,000 cost of erecting the space station, whose main purpose is strategic rather than scientific.)

The cargo ship carries only enough fuel for a one-way trip, so it has fewer tanks: four discardable spheres like those on the passenger craft, and four cylindrical containers with 162,000 gallons of propellant for the moon landing.

In one respect, the cargo carrier is the most interesting of the three space vehicles. Its big silo-like storage cabin, 75 feet long and 36 feet wide, was built to serve a double purpose. Once we reach the moon and the big cranes folded against the framework have swung out and unloaded the 285 tons of supplies in the cylinder, the silo will be detached from the rest of the rocket ship. The winch-driven cables slung from the cranes will then raise *half* of the cylinder, in sections, which it will deposit on trailers drawn by tractors. The tractors will take them to a protective crevice on the moon's surface, at the place chosen for our camp. Then the other lengthwise half will be similarly moved—giving us two ready-to-use Quonset huts.

Now that we have our space ships built and have provided ourselves with living quarters for our stay on the moon, a couple of important items remain: we must protect ourselves against two of the principal hazards of space travel, flying meteors and extreme temperatures.

For Protection Against Meteors

To guard against meteors, all vital parts of the three craft—propellant tanks, personnel spheres, cargo cabin—are given a thin covering of sheet metal, set on studs which leave at least a one-inch space between this outer shield and the inside wall. The covering, called a meteor bumper, will take the full impact of the flying particles (we don't expect to be struck by any meteors much larger than a grain of sand) and will cause them to disintegrate before they can do damage.

For protection against excessive heat, all parts of the three rocket ships are painted white, because white absorbs little of the sun's radiation. Then, to guard against cold, small black patches are scattered over the tanks and personnel spheres. The patches are covered by white blinds, automatically controlled by thermostats. When the blinds on the sunny side are open, the spots absorb heat and warm the cabins and tanks; when the blinds are closed, an all-white surface is exposed to the sun, permitting little heat to enter. When the blinds on the shaded side are open, the black spots radiate heat and the temperature drops.

Now we're ready to take off from the space station's orbit to the moon.

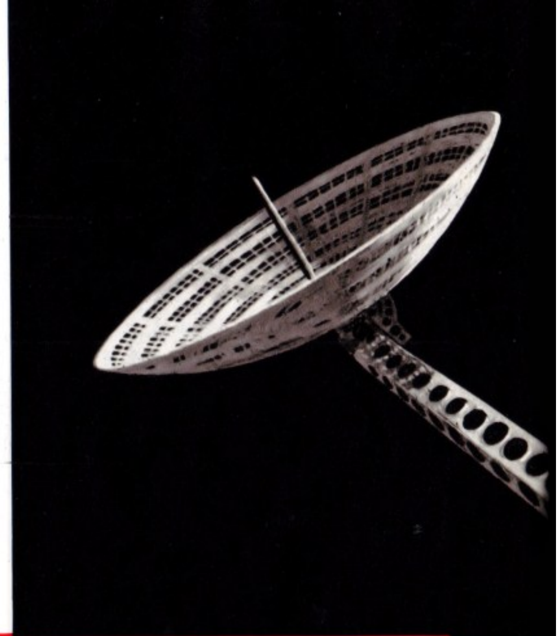
The bustle of our departure—hurrying space taxis, the nervous last-minute checks by engineers, the loading of late cargo and finally the take-off itself—will be watched by millions. Television cameras on the space station will transmit the scene to receivers all over the world. And people on the earth's dark side will be able to turn from their screens to catch a fleeting glimpse of light—high in the heavens—the combined flash of 90 rocket motors, looking from the earth like the sudden birth of a new, short-lived star.

Our departure is slow. The big rocket ships rise ponderously, one after the other, green flames streaming from their batteries of rockets, and then they pick up speed. Actually, we don't need to gain *much* speed. The velocity required to get us to our destination is 19,500 miles an hour, but we've had a running start; while "resting" in the space station's orbit, we were really streaking through space at 15,840 miles an hour. We need an additional 3,660 miles an hour.

Thirty-three minutes from take-off we have it. Now we cut off our motors; momentum and the moon's gravity will do the rest.

The moon itself is visible to us as we coast through space, but it's so far off to one side that it's hard to believe we won't miss it. In the five days of our journey, though, it will travel a great distance, and so will we; at the end of that time we shall reach the farthest point, or apogee, of our elliptical course, and the moon should be right in front of us.

The earth is visible, too—an enormous ball, most of it bulking pale black against the deeper black of space, but with a wide crescent of daylight where the sun strikes it. Within the crescent, the continents enjoying summer stand out as vast green terrain maps surrounded by the brilliant



Inside the Moon Ship

By WILLY LEY

ABOARD the moon ships, living is cramped, but not uncomfortable. Each of the two passenger vehicles holds 20 men en route to the moon, 25 on the return trip (the 10 men on the one-way cargo ship will split up coming back). For added safety, each passenger ship carries enough oxygen (three pounds per man per day), water (four pounds per man per day) and food for the *entire* expedition.

The top floor of the personnel sphere is the control deck. At the far left, an engineer keeps watch over fuel, temperature, pressure, oxygen and other gauges. Next to him, the radio operator maintains contact with the other two ships and the space station. At center, a member of the navigation staff, using a combination telescope-celestial camera, sights on a star. (When not in use, astrodomes are closed off by shutters to block the sun's blinding glare.)

To the right of his position is the rocket motor instrument panel and, underneath, the automatic pilot and the reels of tape which operate it during landing. The man at extreme right is the crew captain, strapped into a swivel seat which enables him to watch either the master controls, as he's doing now, or the motor instruments behind him (for comfort, all seats are contour seats; personnel must be strapped in so they won't float away in the weightless ship). A control board at the captain's position enables him to operate the rocket motors, and the intercom unit by his hand keeps him in communication with the rest of the ship.

The next floor down is primarily a navigation deck, although a sponge-bath stall (there are no showers, because the water won't fall properly) and extra bunks are also installed here. Next to the bathing stall, a navigator operates a mechanical computer. The chief navigator and two assistants are working at the dead-reckoning tracer, a device which automatically records the space ship's course. The clock on the wall shows elapsed time since departure, and the three screens at the right indicate the attitude of the ship, as determined by an artificial horizon mechanism in the astrodome at far right.

On the central, and largest, deck are the ship's living quarters. Bunks line the walls and hang from stanchions (the sleeping men are members of the off-duty watch), and a cooking-dining area occupies most of the floor space. At center is an automatic dining unit: table, short-wave food heater and dishwasher.

It works this way: the "cook" (background) has taken a packaged, precooked meal from the deep freeze and is placing it on a conveyer belt. It enters the short-wave heater and is deposited in a spring-lidded dish (so it won't float away). The dish is locked into one of the two outer conveyer tracks on the table (one for solids, the other for liquids) and the diner draws the food toward him along a slot. When he's finished, he slides his dish back to the third, or inner, track, which carries it to the dishwashing unit. Straps hold the diners in their seats, making their snap-equipped belts unnecessary. At far right is a snack dispenser for quick meals, particularly for crewmen standing watch.

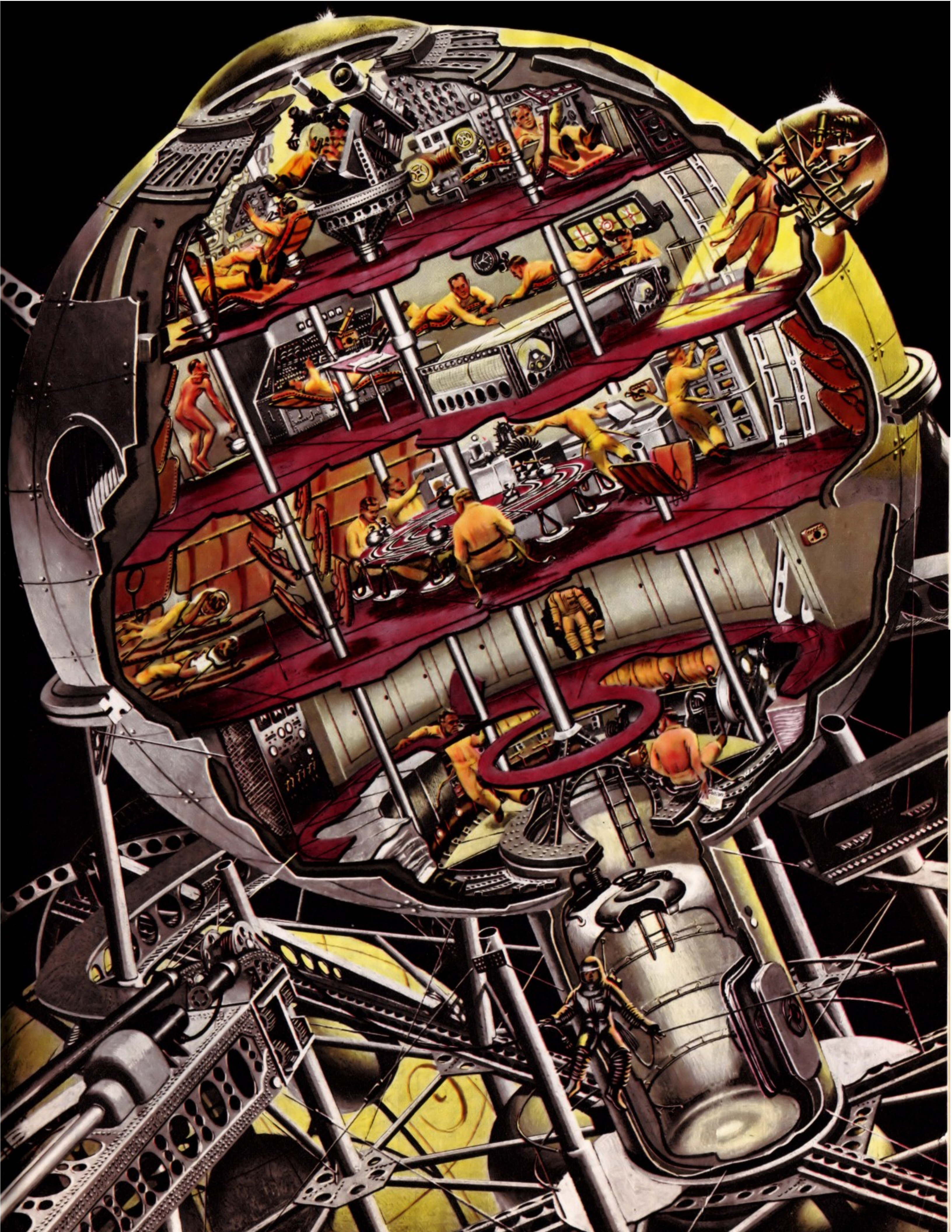
The fourth floor down, or stowage deck, houses the main electrical switchboard, storage cupboards and a washroom (next to the stairway).

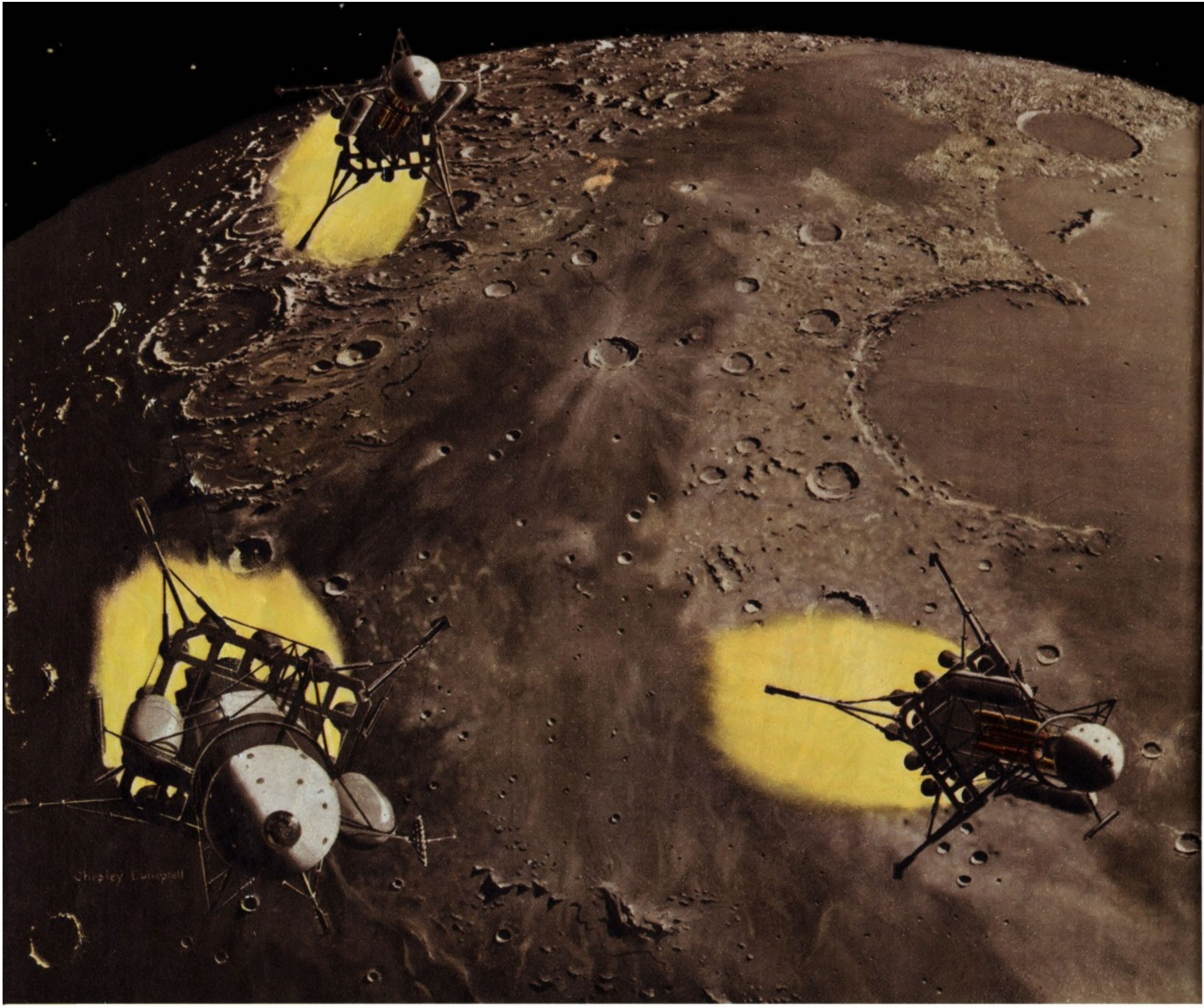
The engineering deck is at the bottom of the sphere. Lining the walls, directly below the ceiling, are water tanks (left), yellow oxygen tanks (center), air blower pump (behind the large gauges) and tanks for water recovered from the ship's atmosphere. Below this ring are the brown electric storage batteries and the ship's air-conditioning and water-cleansing systems. Sewage tanks are under the floor.

The space-suited engineer outside the ship's air lock holds the main power line, which connects with the power-producing solar mirror (off picture at lower left). He's about to plug the line into the black distributing box, shown on the catwalk between his feet, half hidden by the air-lock tower.

The sphere will be home to the voyagers not only for the five-day trip, but for several days after, while lunar quarters are being constructed. ▲▲▲

ILLUSTRATED BY FRED FREEMAN





Landing on the moon. Ten minutes before touchdown, rocket motors are switched on to slow down ships' high-speed fall caused by the moon's gravity. Vehicles are maneuvering 550 miles above landing area known as *Sinus Roris* (Dewy Bay), dark plain above cargo ship in lower left

blue of the oceans. Patches of white cloud obscure some of the detail; other white blobs are snow and ice on mountain ranges and polar areas.

Against the blackness of the earth's night side is a gleaming spot—the space station, reflecting the light of the sun.

Two hours and 54 minutes after departure, we are 17,750 miles from the earth's surface. Our speed has dropped sharply, to 10,500 miles an hour. Five hours and eight minutes en route, the earth is 32,950 miles away, and our speed is 8,000 miles an hour; after 20 hours, we're 132,000 miles from the earth, traveling at 4,300 miles an hour.

On this first day, we discard the empty departure tanks. Engineers in protective suits step outside the cabin, stand for a moment in space, then make their way down the girders to the big spheres. They pump any remaining propellant into reserve tanks, disconnect the useless containers, and give them a gentle shove. For a while the tanks drift along beside us; soon they float out of sight. Eventually they will crash on the moon.

There is no hazard for the engineers in this operation. As a precaution, they were secured to the ship by safety lines, but they could probably have done as well without them. There is no air in space to blow them away.

That's just one of the peculiarities of space to which we must adapt ourselves. Lacking a natural sequence of night and day, we live by an arbitrary time schedule. Because nothing has weight, cooking and eating are special problems. Kitchen utensils have magnetic strips or clamps so they won't float away. The heating of food is done on electronic ranges. They have many advantages: they're clean, easy to operate, and their short-wave rays don't burn up precious oxygen.

Difficulties of Dining in Space

We have no knives, spoons or forks. All solid food is precut; all liquids are served in plastic bottles and forced directly into the mouth by squeezing. Our mess kits have spring-operated covers; our only eating utensils are tonglike devices; if we open the covers carefully, we can grab a mouthful of food without getting it all over the cabin.

From the start of the trip, the ship's crew has been maintaining a round-the-clock schedule, standing eight-hour watches. Captains, navigators and radiomen spend most of their time checking and rechecking our flight track, ready to start up the rockets for a change in course if an error turns up. Technicians back up this operation with reports from the complex and delicate "electronic brains"—computers, gyroscopes, switchboards and other instruments—on the control deck. Other specialists keep watch over the air-conditioning, temperature, pressure and oxygen systems.

But the busiest crew members are the maintenance engineers and their assistants, tireless men who have been bustling back and forth between ships since shortly after the voyage started, anxiously checking propellant tanks, tubing, rocket motors, turbopumps and all other vital equipment. Excessive heat could cause dangerous hairline cracks in the rocket motors; unexpectedly large meteors could smash through the thin bumpers surrounding the propellant tanks; fittings could come loose. The engineers have to be careful.

We are still slowing down. At the start of the fourth day, our speed has dropped to 800

PAINTING BY CHESLEY BONESTELL

miles an hour, only slightly more than the speed of a conventional jet fighter. Ahead, the harsh surface features of the moon are clearly outlined. Behind, the blue-green ball of the earth appears to be barely a yard in diameter.

Our fleet of unpowered rocket ships is now passing the neutral point between the gravitational fields of the earth and the moon. Our momentum has dropped off to almost nothing—yet we're about to pick up speed. For now we begin falling toward the moon, about 23,600 miles away. With no atmosphere to slow us, we'll smash into the moon at 6,000 miles an hour unless we do something about it.

Rotating the Moon Ship

This is what we do: aboard each ship, near its center of gravity, is a positioning device consisting of three flywheels set at right angles to one another and operated by electric motors. One of the wheels heads in the same direction as our flight path—in other words, along the longitudinal axis of the vehicle, like the rear wheels of a car. Another parallels the latitudinal axis, like the steering wheel of an ocean vessel. The third lies along the horizontal axis, like the rear steering wheel of a hook-and-ladder truck. If we start any one of the wheels spinning, it causes our rocket ship to turn slowly in the other direction (pilots know this "torque" effect; as increased power causes a plane's propeller to spin more rapidly in one direction, the pilot has to fight his controls to keep the plane from rolling in the other direction).

The captain of our space ship orders the longitudinal flywheel set in motion. Slowly our craft begins to cartwheel; when it has turned half a revolution, it stops. We are going toward the moon tail-end-first, a position which will enable us to brake our fall with our rocket motors when the right time comes.

Tension increases aboard the three ships. The landing is tricky—so tricky that it will be done entirely by automatic pilot, to diminish the possibility of human error. Our scientists compute our rate of descent, the spot at which we expect to strike, the speed and direction of the moon (it's traveling at 2,280 miles an hour at right angles to our path). These and other essential statistics are fed into a tape. The tape, based on the same principle as the player-piano roll and the automatic business-machine card, will control the automatic pilot. (Actually, a number of tapes intended to provide for all eventualities will be fixed up long before the flight, but last-minute checks are necessary to see which tape to use—and to see whether a manual correction of our course is required before the autopilot takes over.)

Now we lower part of our landing gear—four spiderlike legs, hinged to the square rocket assembly, which have been folded against the framework.

As we near the end of our trip, the gravity of the moon, which is still to one side of us, begins to pull us off our elliptical course, and we turn the ship to conform to this change of direction. At an altitude of 550 miles, the rocket motors begin firing; we feel the shock of their blasts inside the personnel sphere and suddenly our weight returns. Objects which have not been secured beforehand tumble to the floor. The force of the rocket motors is such that we have about one third our normal earth weight.

The final 10 minutes are especially tense. The tape-guided automatic pilots are now in full control. We fall more and more slowly, floating over the landing area like descending helicopters. As we approach, the fifth leg of our landing gear—a big telescopic shock absorber which has been housed in the center of the rocket assembly—is lowered through the fiery blast of the motors. The long green rocket flames begin to splash against the baked lunar surface. Swirling clouds of brown-gray dust are thrown out sideways; they settle immediately, instead of hanging in air, as they would on the earth.

The broad round shoe of the telescopic landing leg digs into the soft volcanic ground. If it strikes too hard, an electronic mechanism inside it immediately calls on the rocket motors for more power to cushion the blow. For a few seconds, we balance on the single leg. Then the four outrigger legs slide out to help support the weight of the ship, and are locked into position. The whirring of machinery dies away. There is absolute silence. We have reached the moon.

Now we shall explore it. ▲▲▲

NEXT WEEK

The Exploration of the Moon

THE EXPLORATION

By Dr. FRED L. WHIPPLE and Dr. WERNHER von BRAUN

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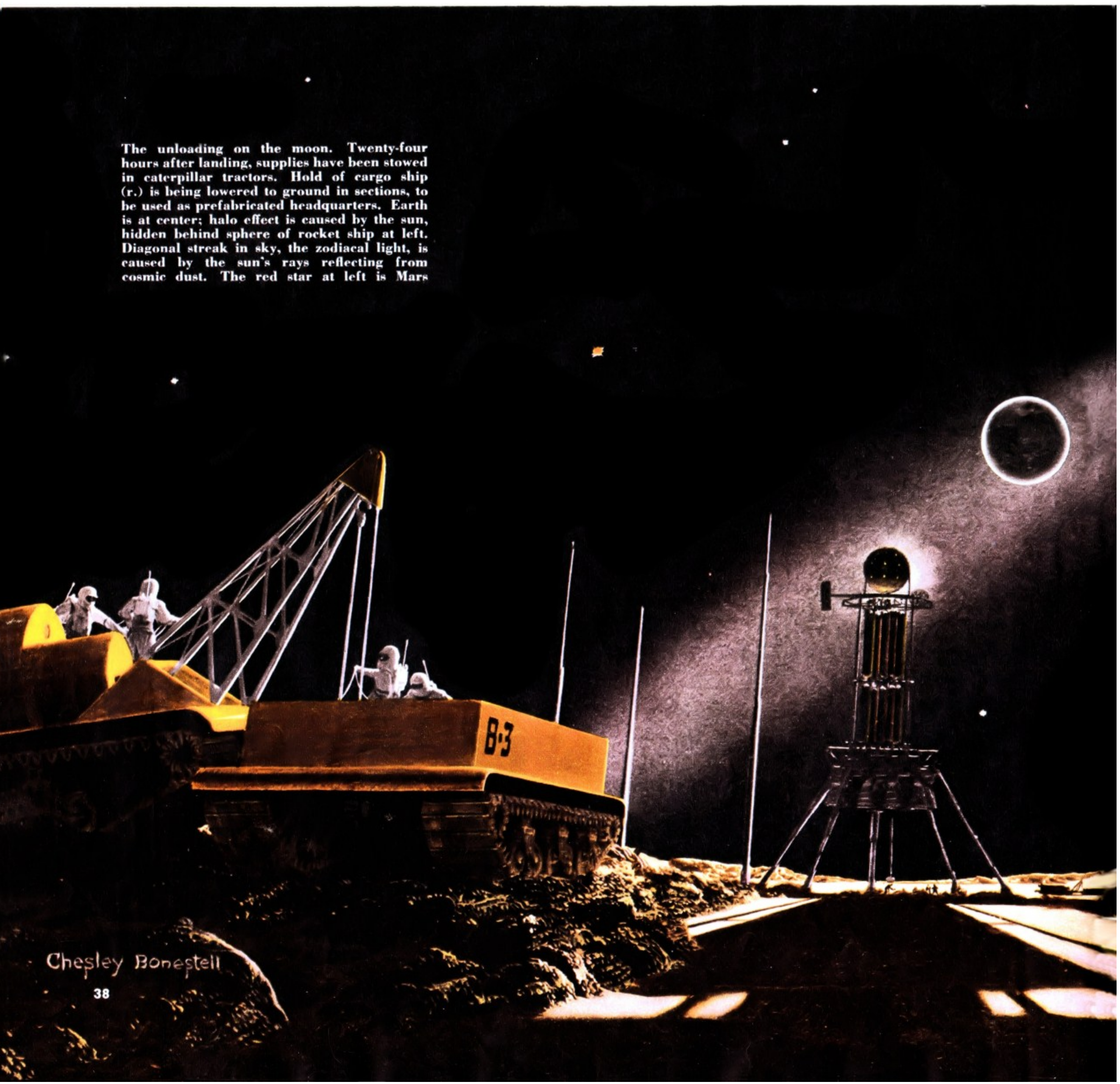
Our top scientists say we'll reach the moon in our lifetime. What do we find when we get there? What are the secrets of this ball of rock five times the size of the United States? Here's expert testimony



The unloading on the moon. Twenty-four hours after landing, supplies have been stowed in caterpillar tractors. Hold of cargo ship (r.) is being lowered to ground in sections, to be used as prefabricated headquarters. Earth is at center; halo effect is caused by the sun, hidden behind sphere of rocket ship at left. Diagonal streak in sky, the zodiacal light, is caused by the sun's rays reflecting from cosmic dust. The red star at left is Mars

THERE is danger on the moon—the danger of the unknown. Our first expedition, which can land there in the next 25 years, must be prepared. Tissue-damaging cosmic rays—invisible, deep-penetrating atom particles—unpredictably streak in from space, with no atmosphere to impede them. Meteorites, from microscopic grains to mountainous boulders, hurtle down. On the lunar surface, thin layers of crust might cover great crevasses, making travel perilous. Jagged rocks threaten the fabric of the pressurized, oxygen-equipped space suits essential to life.

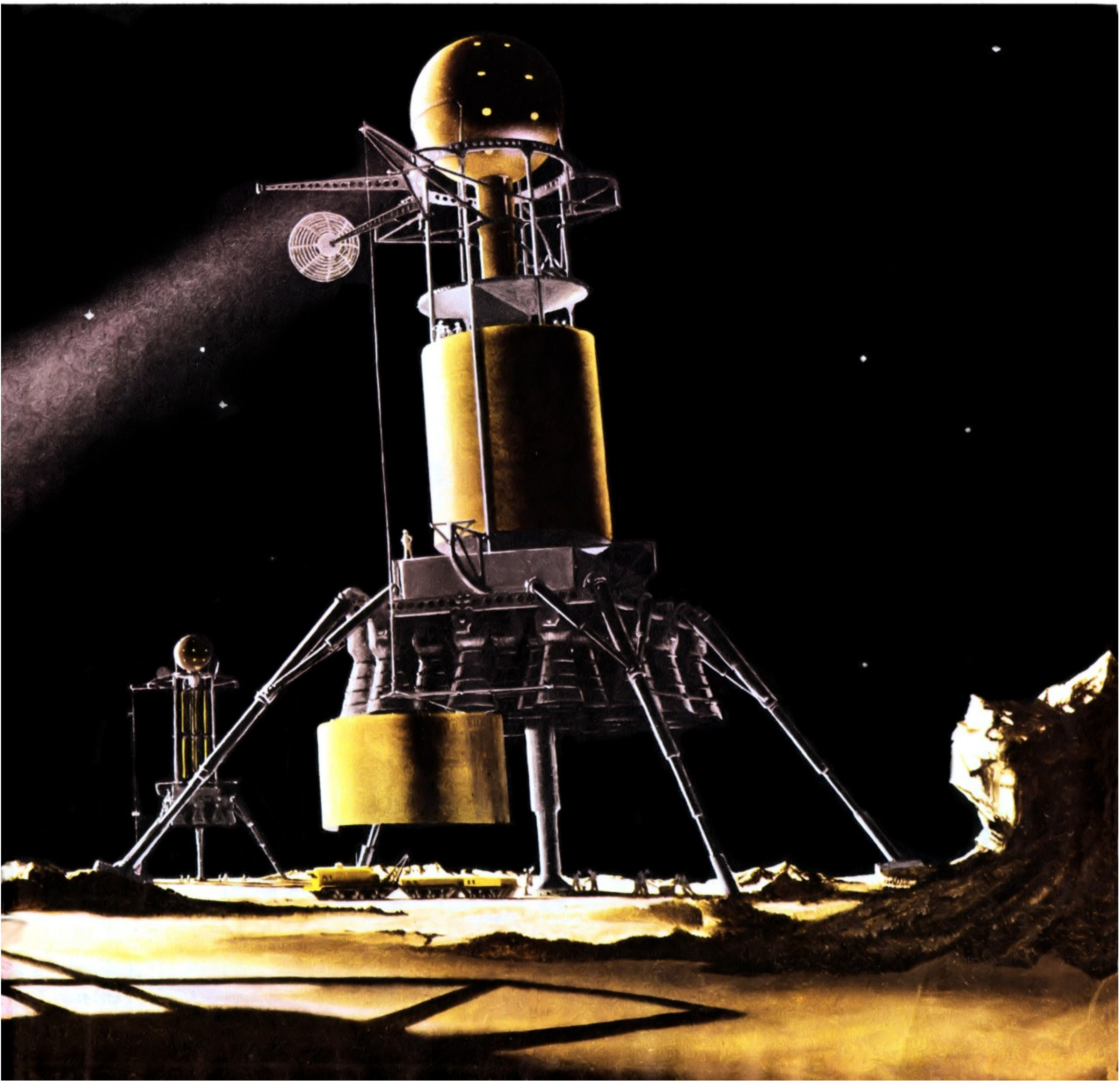
How great are the hazards? We don't know exactly, but we do know how to take precautions. Until we can measure the severity of the cosmic radiation, we shall stay under cover as much as possible. Our headquarters must be located in a deep crack in the surface, protected from both rays and meteorites. Brief exposure to cosmic radiation probably won't hurt us. Exposure to large meteorites will hurt us—but we don't expect to encounter them; the smaller meteorites will shatter against the two thicknesses of our space suits. The keen eyes of experienced geologists will guard us against break-throughs in the crust. Caution should be ample protection against rips in the precious space suits. We can explore the moon safely.

Our first step after arrival is to unload equipment and prepare for a six-week stay. Three awkward-looking but efficient rocket ships (none of them streamlined, because there is no air resistance in space) have carried us to the lunar surface from a man-made satellite 1,075 miles above the earth. On this voyage, two of the craft carried passengers and propellant for a return trip; the third, a one-way cargo vehicle, must be dismantled and converted into living and working quarters for the 50-man expedition.

We have arrived just at the beginning of the two weeks of sunlight that comprise the lunar day. From the catwalks of the ships, 130 feet above the moon's surface, the scene is dismal. The pitted surface of the landing area—a place known to scientists as *Sinus Roris,* or Dewy Bay, not far from the lunar north pole—stretches to the south like a vast, discolored expanse of broken ice.

On the other three sides, we are surrounded by towering mountains. The rays of the rising sun

CHESLEY BONESTELL



have painted the great mountain range a blinding white against the pitch blackness of the sky. But elsewhere, there is none of the brilliant color we are used to on earth—just dull, lifeless browns and grays. There is no cloud cover, no wind, no rain or snow—no weather of any kind. Overhead, pinpoint stars shine steadily; they don't twinkle, for there is no blurring atmosphere, as on earth.

Dust-covered, drab, silent, the panorama has the frozen stillness of a faded backdrop.

Within minutes after the landing, big cranes on the sides of the passenger ships swing out and start lowering expedition members to the ground. In our cumbersome space suits, we plod through the quarter-inch dust layer toward the cargo ship, whose crewmen are already starting the unloading operation. Our movements are restricted by the suits, yet we feel light. The moon's gravity is about one sixth that of the earth; a 180-pound man weighs only 30 pounds now. We wear weighted shoes to help pin us down.

The first equipment brought out of the cargo ship is one of our three surface vehicles, tanklike cars equipped with caterpillar treads for mobility over the moon's rough surface. The pressurized, cylindrical cabins hold seven men, two-way radio equipment, radar for measuring distances and depths, and a 12-hour supply of oxygen, food, water and fuel. Power is provided by an enclosed turbine driven by a combination of hydrogen peroxide and fuel oil (oxygen escaping from the hydrogen peroxide enables the fuel oil to ignite). The vehicle goes 25 miles an hour on flat ground.

As soon as the moon car has been set down and checked, a search party boards it to scout out a suitable crevice for the campsite. They drive off in a spray of dust which settles almost immediately, like the bow wave of a motorboat (there is no air to hold the dust suspended, as on earth).

The area around the cargo ship bustles with activity. Through our earphones, we can hear a stream of orders from the engineer in charge of unloading. All orders are addressed to numbers, rather than names; faces are not visible through the heavy antiglare glass of the helmets, and we wear numerals for identification.

By the time the search party returns, the ground around the cargo ship is littered with supplies: containers of water and liquid oxygen, canned and frozen food, scientific equipment, high explosives, rockets, the other two lunar cars and nine trailers (three per car) also track-equipped.

Ship's Hold Is Converted into Huts

In all, the huge cylindrical cargo hold, 75 feet long and 36 wide, has held 285 tons of supplies (less than 50 tons, moon-weight). But the silolike hold is itself part of the cargo, and must be unloaded from the framework of the ship. Its walls are laced with wiring, air-conditioning ducts, and water and sewage pipes; split lengthwise, the cargo cabin will become two buildings like Quonset huts, and the horizontal floors which separated it into compartments will be vertical partitions. We'll live in one hut; the other will be a laboratory.

Engineers direct the unbolting of the hold from the framework, and cranes lower the huge cylinder in sections onto trailers. Two of the lunar tractors hitch up to three trailers each, and the double convoy moves silently off for the headquarters site. A third convoy, loaded with supplies and personnel, brings up the rear.

The framework of the cargo ship now stands stripped and forlorn on the barren plain, only its personnel sphere left intact. We'll leave it there and use the sphere, with its expensive radio equipment and big disk antenna, as a station for communication with the earth—lonely, but essential, duty for the radio operators.

The crevice picked for the campsite by our search party is deep—we require a depth of 65 to 100 feet for safety—with almost vertical sides. Cranes attached to the rear of the lunar tractors lower an advance squad to the floor of the chasm. It's fairly level down there, but some big chunks of rock may have to be moved to clear the way for the two prefabricated huts; pickaxes and small explosive charges do most of the work, and the cranes do the rest. Now the sections are lowered.

The front ends of the tractors are firmly anchored to the moon's surface, and one by one the hut units are eased down the side of the gully. They are quickly assembled at the bottom; electrical circuits are joined, air conditioning, water and sewage pipes hooked up—and we're ready to move in. A power unit like those on the rocket ships—a solar mirror which heats mercury to produce vapor (like steam) for a turbogenerator—is set up at the lip of the chasm.

We have now been on the moon 48 hours. There has been little sleep for anybody, but the preparatory work is over. Supplies (including our store of high explosives) are now safely out of the way of vagrant meteorites; our living quarters and laboratory are ready to use—and we'll be ready to explore as soon as we've slept.

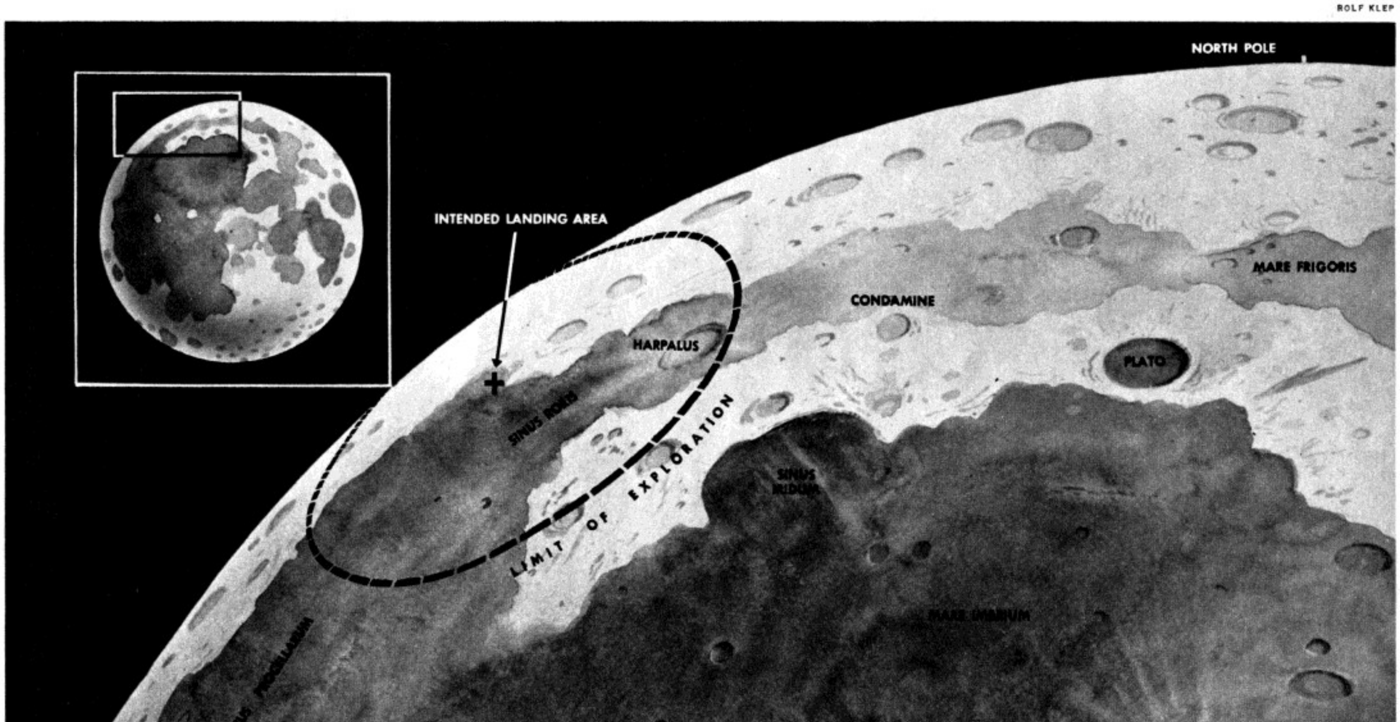
Sinus Roris, our landing area, was selected partly because of the opportunities it offers for exploration, partly because its temperature is livable—40 degrees Fahrenheit during the lunar daytime (at the lunar equator it hits a blistering 220 degrees), and 240 degrees below zero at night. That's mighty cold, but it's bearable on the airless, waterless moon, and we have heaters inside the huts.

From our headquarters site, we can explore any place within a range of 250 miles, and all the lunar features of interest to our scientists fall within that area. It may require some long trips, though—the region involved is approximately as large as the whole northeastern part of the United States, north of Washington, D.C.; in other words, the size of the six New England states, New York, Pennsylvania, New Jersey, Maryland and Delaware. Besides looking over selected sites on the side of the moon visible from the earth, we'll also be able to see a part of the unknown side—the part always turned away from the earth.

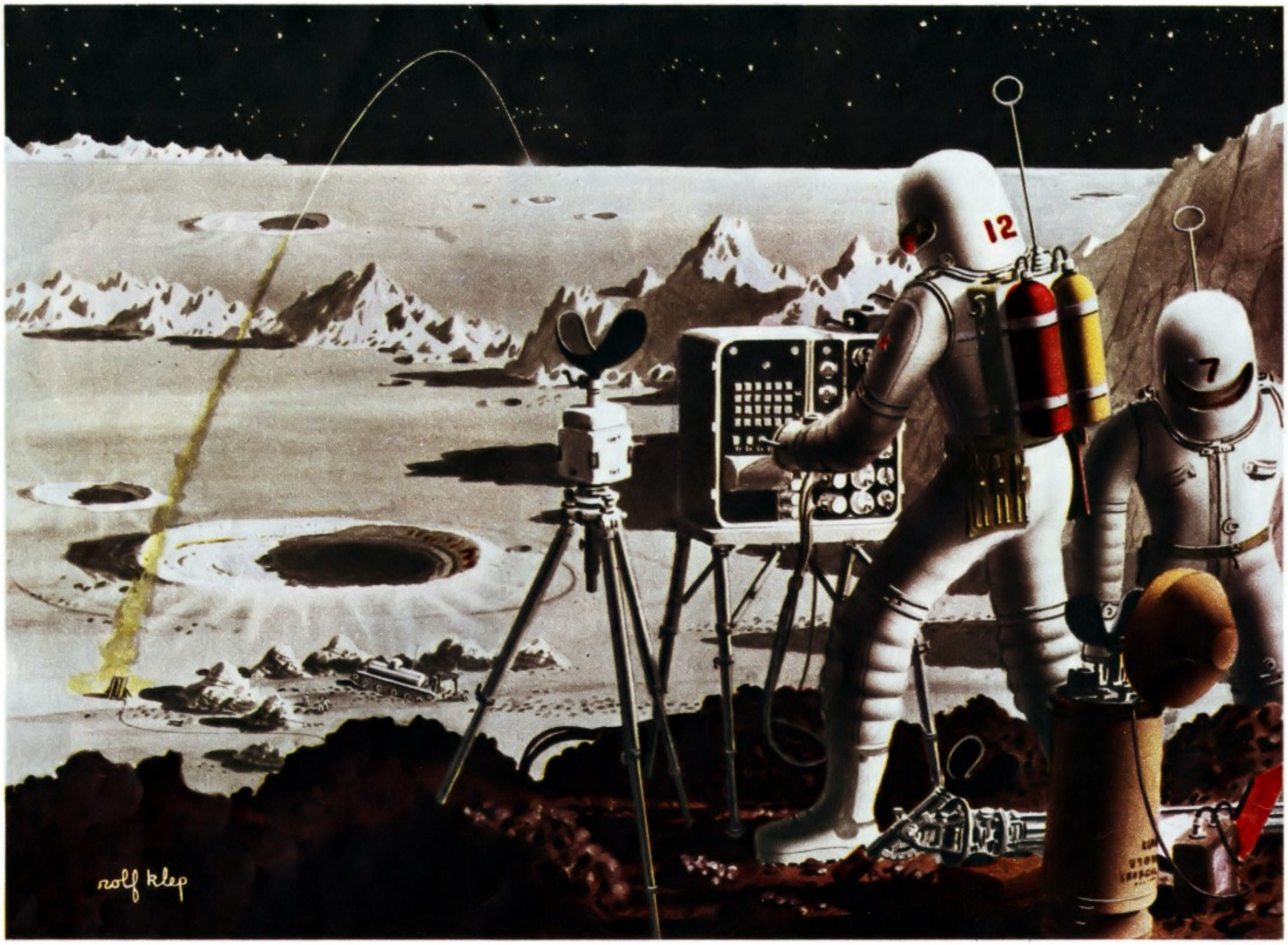
What will we be looking for?

To start with, our scientists want to know whether any faint traces of atmosphere are present, what minerals there are (maybe we'll find some rare, useful ones), whether the moon has a magnetic field like the earth and how the temperature varies beneath the lunar crust. Sheer curiosity suggests other questions and will play a large part in our explorations. We're the first people who've ever been here, the first ever to peer into the mys-

ROLF KLEP



Exploration area, within dotted line, covers 195,000 square miles, about equal to New England, New York, New Jersey, Maryland, Pennsylvania, Delaware. It lies in lunar northern hemisphere and can be seen by naked eye from earth at full moon (see inset, left)



ROLF KLEP

terious lunar valleys, the first to examine the mountains and craters of the moon close up. Who knows what we may find on this virgin ball of unexplored rock, about five times the size of the United States?

The possibilities are exciting. Suppose we turn up a great store of raw materials; maybe then we'll want to recommend setting up a permanent community. We can make it practically self-supporting, securely encased inside a great plastic dome with its own synthetic atmosphere. Such an establishment could serve as a superb scientific laboratory—especially for astronomy and for research work requiring a vacuum; as a springboard for further ventures into space (if we can manufacture our own fuel on the moon, which is a possibility, we can make tremendous savings in the launching of a space ship); perhaps as a military base (the moon would be fine for launching military rockets, but hard to hit from the earth).

But the principal aim of our expedition during this first lunar exploration will be strictly scientific—and very important. Our investigations will help us unravel the secret of the universe: how the moons and planets were born and what they're made of. Up to now, all our information on that subject has come from examination of the earth and from surveying the heavens from observatories. The moon will give us a new perspective: a different look at the astral bodies and the story of its own birth as a clue to the birth of other satellites, planets and stars.

We know that the moon didn't form in the Pacific Ocean and get hurled into space, as was generally believed 50 years ago. It *is* possible that it was an independent planet which came from outer space, fell into the earth's gravitational field, smashed into the Pacific and then ricocheted back into its present orbit. But the most likely explanation is that the moon originally consisted of a belt of gases and minerals that girdled the earth—much as Saturn's ring surrounds that planet today—and eventually fused into a solid mass.

That's the theory we'll check.

First, if there are faint traces of such heavy gases as xenon and krypton, we'll know the moon was never a completely molten, hot mass (for extreme heat would have dispelled *all* gases), and so could not have been an independent planet. We'll find out by using a rotary pump which will compress whatever gases may exist and capture them in a bottlelike container. It probably will take many days to accumulate enough of whatever gases there may be, but checking them will be fairly simple.

Does the Moon Have an Iron Core?

Then we'll look for a magnetic field. If we don't find it, we'll have another indication that the moon doesn't have an iron core, as an independent planet would. Compasslike magnetometers will do the trick for us; if the moon has magnetic poles as the earth has, they will show up (isolated iron deposits also will register, but they will be easily distinguishable from a core).

We'll also shake up the moon's surface a bit. Scientists have learned a lot about the earth from earthquakes. The vibration waves of a quake travel freely through solids, but some of them cannot pass through liquids—which is how we know that the center of the earth is molten iron. We can't count on having moonquakes, so we'll make some: we'll send off rockets with high-explosive war heads and

Causing moonquakes. Rockets with explosive war heads are fired off and scientists check vibration waves caused by distant blast, to determine interior composition of the moon. Seismograph in foreground is push-button controlled and surveying instrument to its left has cupped headpiece, to accommodate hand hooks and helmets of expedition members

then read the story of the waves from our seismographs. The explosions, occurring about 100 miles away, will show if the moon's core is molten (in which case, our waves will be stopped), solid (they'll go right through), or a jumble of rocks which never have been molten (muffled waves).

There is another clue to the moon's origin: the scars on its surface. The plains of the moon are rough and scored by fissures. Close examination will disclose whether these score marks are cracks or wrinkles. Wrinkles will indicate that the moon was molten at birth, and has cooled since. Cracks will be evidence that it was cool to begin with and has since been heated, perhaps by radioactivity. Fortunately, these lunar birthmarks have not been washed away by erosion, as has happened on earth.

So much for the moon's past. There are also some facts we want to learn about its present. One of the most important is the exact intensity of the cosmic rays which strike it. As soon as we're settled in our quarters, we set out instruments to measure the rays. Another is the frequency of meteorite hits. Careful measurements also will be kept of the surface temperature caused by the sun, and we'll want to measure the subsurface tempera-

At end of two-week-long lunar day, convoy of tractors, each pulling two of its three trailers, moves cautiously across rough terrain near plain

ture at varying depths (it may be considerably warmer than the surface, due to radioactivity).

For two weeks, we devote ourselves to research on these points, past and present. The expedition breaks up into teams, each with its own assignment. Most of the investigating during this period is done within a 10-mile radius of the base. It's difficult, dangerous work. We climb across meteor pits, into chasms, up great rock piles, struggling in our bulky suits, always fearful of snagging ourselves on sharp outcroppings, always nervous about stray meteorites and watchful for thin crust.

Because we'll never be really certain how safe we are on the moon, however long we stay, we keep up a chatter over our walkie-talkie radio transmitters, not to bolster our courage, but for a practical reason: if something happens to us, the people back at headquarters will have a record of our findings.

For the same reason, lunar headquarters maintains constant contact with the earth. Back there, a special panel of scientists remains in constant session, as it will all during our six-week stay. A dozen specialists in fields like astronomy, astrophysics, geophysics, mineralogy and geology follow our every move by radio (as, indeed, does the entire world), keeping track of our findings, suggesting new leads and occasionally asking for the repetition of an experiment. Television transmission is impractical, but every day dozens of photographs are radioed back to earth.

For those of us on the moon, the work is endless and fascinating. We collect samples of everything in sight—dust (where did it come from; what's it composed of?), mineral specimens, rock and lava fragments. Besides scouring the lunar surface, we make test drillings several hundred feet into the moon's ground, and collect more samples that way.

We work in almost frantic haste during these two weeks, trying to make the most of the brilliant sunlight. We eat and sleep in shifts, so that there will be no halt in the research, no break in the flow of information back to the earth.

But soon the sun begins to slip over the horizon. For a while, there's still plenty of light; work slows down, but not entirely. For several days after sunset, we live in a kind of twilight, with a cold, but fairly bright, illumination cast over us by the earth (it reflects about 60 times as much sunlight on the moon as the full moon reflects on the earth). The browns and grays of the lunar day take on a green tint; mountains throw long shadows; craters and chasms appear jet black. The light grows dimmer as the "full earth" becomes a "half earth."

Now comes an exciting moment: the start of our longest expedition. We've had to wait to make it, because all the vehicles have been in constant use for the vital explorations near the base; as a result, we'll have to travel outbound in comparative darkness. That's not desirable, but it's possible, and we have no alternative.

of *Sinus Roris* (Dewy Bay). Glare of mountain range to north is caused by setting sun. Remainder of scene is illuminated by greenish earth light

Our destination is a crater about 195 miles away as the rocket flies, but about 250 miles off by lunar tractor. This crater, called Harpalus, is the most interesting one within reach—24 miles across, with a surrounding ridge 3,100 feet high, and a depth of almost 11,000 feet from peak to bottom.

It must have taken a monstrous meteorite to smash into the moon with such force—or was it a meteorite? That's one of the questions we want answered. All we know before we start is that a meteorite *could* make such a crater—if it were the size of a small mountain, and traveling at a speed of thousands of miles an hour. Another mystery we can solve on this journey is the nature of the great white marks which radiate for tremendous distances from the most perfect (and perhaps the newest) craters. Maybe they're powdered dust, shot out by the impact of meteorite against moon; maybe their origin is volcanic. We'll soon know.

Our expedition consists of two tractors, hauling three trailers each. Ten men are making the trip, and we carry supplies and fuel enough to last about two weeks. The outbound trip should take a little less than five days, the return journey, made in sunlight, perhaps four; we also want to spend a day or two at the crater. That's 10 days. We carry an extra four days' emergency supplies.

The trip is slow and difficult. The two vehicles cautiously pick their way around great rocks and deep pits, making about two miles an hour over the rough ground. Powerful searchlights and radar probe for major obstacles; at suspicious places, a geologist hops out to scan the ground for thin crust and feel his way afoot. When, despite our precautions, one of the tractors gets stuck in a rut, the other hauls it out.

At selected points along our course, we stop and plant explosives—part of our vibration-wave experimentation—which technicians back at headquarters will fire later by remote control (the explosions will be visible from the earth through strong telescopes).

After four days, the perimeter ridge of Harpalus looms ahead. As we press on, the first rays of the sun—marking our second lunar day on the satellite—glare off the side of the ridge and the mountain range to our left. By the time we get to the base of the ridge, full sunlight pours down on us again.

From a few miles away, the crater rim is measured with surveying instruments and photographed with special cameras. As we move closer, lava samples are collected, and holes are drilled for additional specimens. Other members of the expedition take temperature readings, check for magnetism and gather dust specimens.

Scaling the crater wall is a hard job. In some places, where the ridge is rough, we can make slow progress with regular mountain-climbing equipment; elsewhere, steep walls compel us to shoot grappling hooks up the sides by means of rockets;

PAINTING BY CHESLEY BONESTELL

rope ladders then enable us to reach the rim. The party descends as far as it can into the mouth of the crater. When no further progress is possible, we lower one man by rope to examine the floor and gather lava specimens. It's tricky, dangerous work; despite the relatively slight gravitational pull, a tumble would be just as dangerous as on earth, for there's no atmosphere to retard a falling body.

We work swiftly, for our time is limited. After a day or two at the crater, we start back, making a detour to examine the mountain range to the northeast, where there are interesting rock and lava formations and cavelike holes of unknown origin. The trip home is faster than the journey to the crater; the vehicles are heavily laden with specimens, but there is light to drive by. In a few days, we're back at the headquarters crevice.

Now the six hectic weeks of exploration draw to a close. At the landing site, electronic engineers set up automatic recording instruments which will radio scientific observations to earth after we've taken off. These stations (not much larger than an office desk) house delicate instruments which record cosmic radiations, tremors caused by the impact of meteorites hitting the surface, temperature changes and other scientific data. They are connected by cables to the skeleton of the cargo ship, which we're leaving behind. The ship's solar mirror generates power for the instruments, and the dishlike antenna will flash the readings to earth. Unless these automatic stations are destroyed by meteorites, they will operate for years without human supervision.

Engineers and technicians clamber over the passenger ships, checking pumps, rocket motors and electrical connections. The day before take-off, specimens for later study, oxygen and any remaining food are loaded onto the trailers at the lunar base. The entrances to the two huts are left open, permitting the synthetic atmosphere to escape; all material in the living quarters and laboratory will now be preserved by the vacuum of space.

During the next few hours, the cranes of the two ships haul up supplies. Each lunar tractor, when finally unloaded, is parked beside the skeleton of the cargo ship, to remain until the next lunar expedition. At last the cranes complete the loading

INSIDE the LUNAR BASE

By WILLY LEY

NOTED ROCKET SCIENTIST AND AUTHOR

THE first visitors to the moon will travel 239,000 miles through space—and then go underground at their destination. For their six-week stay, their home will be in a deep chasm, for protection against meteorites and cosmic rays. The cylindrical hold of the cargo-carrying rocket ship is split into lengthwise halves, 75 feet long and 36 wide, and lowered in sections by the cranes of our lunar tractors. One of the halves becomes a laboratory; we live in the other.

In the picture at right, one tractor is seen at the lip of the crevasse, lowering scientific specimens from the surface. Expedition members may also use the crane to enter the chasm, or they may climb down the light extension ladder at the left. Between the ladder and the tractor is a power plant like those on the rocket ships: a solar mirror focuses the sun's rays on a mercury pipe, creating vapor which drives a turbogenerator.

Each of the two buildings has its own air-conditioning, oxygen and water-recovery systems (the latter captures and cleanses for re-use all the moisture in the synthetic atmosphere we have provided within the huts). The air-conditioning and water-recovery plants of the laboratory building (rear) are visible just behind the ladder, on the first floor. Next is the chemical analysis room, and, to its right, the photographic darkroom. The radio operator works in the compartment next door, keeping in constant touch with fieldworkers, and recording their reports on tape. (The tapes are passed on to the radio operator in the cargo ship for transmission to the earth.) The upper floor at this end of the building is used for supplies and water storage (note the cylindrical water tanks).

The central unit of the hut contains a two-story screen for viewing color photographs, slides and films made in the course of the scientific investigations. At the far side of the room is a physical laboratory; experiments to determine whether the moon has an atmosphere are made here, and mineral samples are checked for magnetism, radioactivity and so forth. The projection room is visible under the pipes; next to it, through the open door, is a small conference room. To the right of the conference room, behind the small ladder, is a dispensary. Records are kept on the balcony above it.

The entire right-hand section of the lab building is an entry chamber, with space suits suspended by pulleys overhead. To get in and out of the huts, we crawl through air locks. A man is shown entering the laboratory air lock; the spring-loaded outer hatch will clap shut behind him, and a twist of wheel will open the inner hatch. (The wheel can be seen in the air lock of the other building, through which a man is about to leave.)

An airtight pipe connects the two huts; in an emergency, it can carry either water or air from one building to the other.

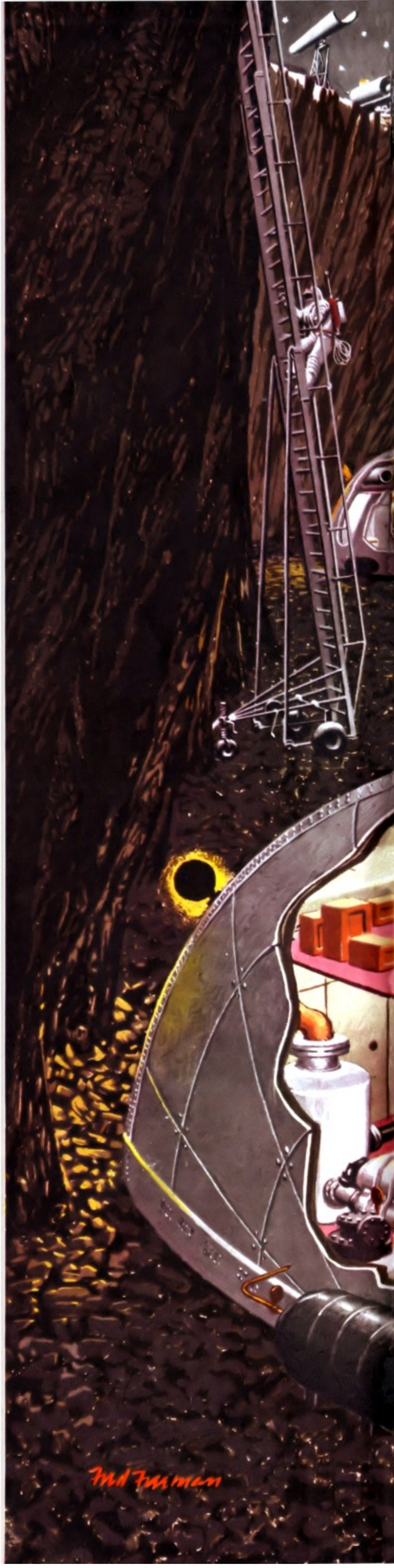
In the foreground of the hut used for living is a close-up view of the air-conditioning and water-recovery systems. The compartment behind it contains berths and lockers for most of the expedition members and, on the right, a washroom. (Bunks for the remaining personnel are on the second floor, which runs the length of the building and is otherwise used mainly for supplies.)

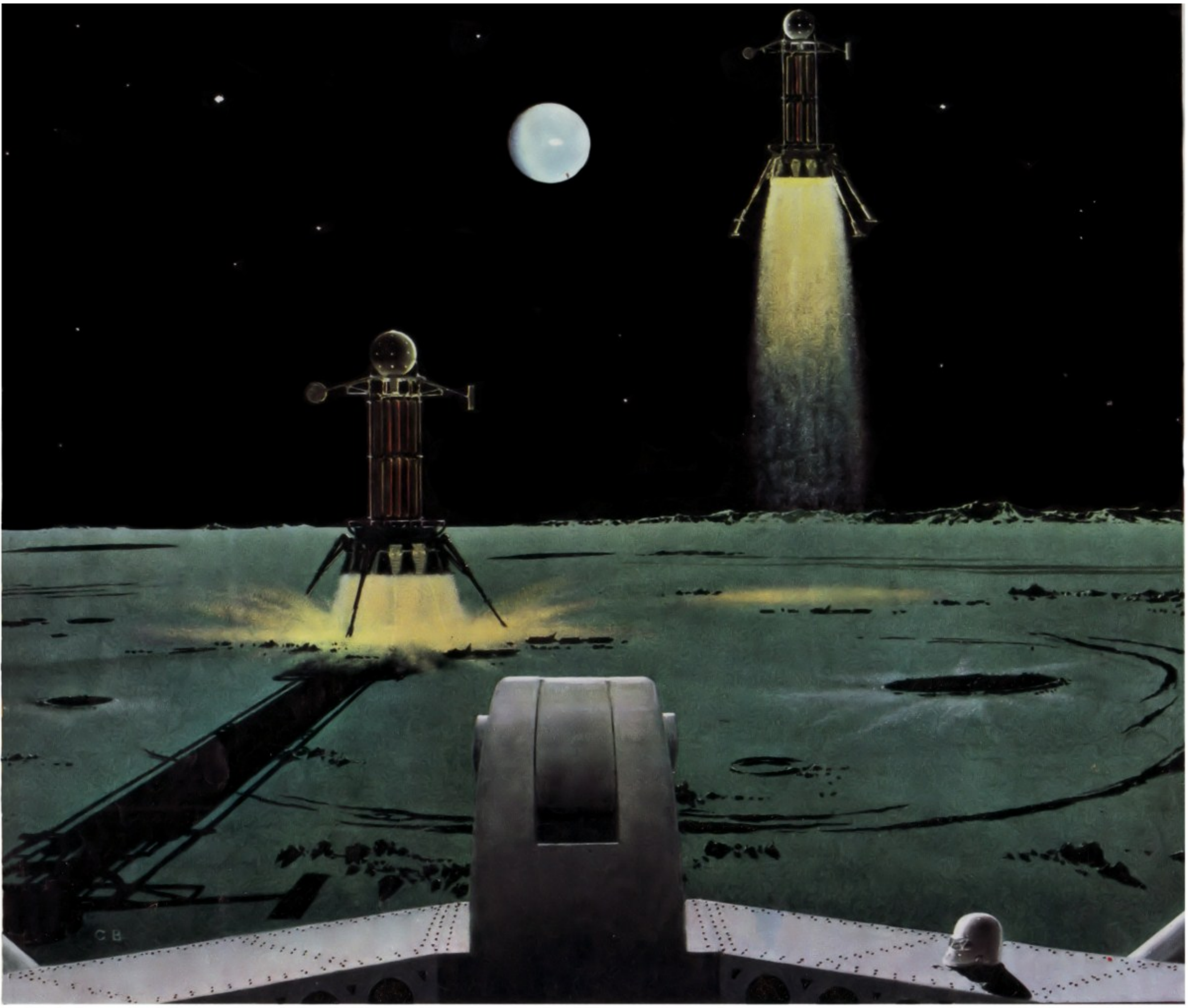
The large middle compartment has the expedition's kitchen and dining room. A dumb-waiter leads to the storehouse on the upper floor. The table-and-bench units in the dining area can be raised to the ceiling when not in use (one is shown in raised position). Against the right-hand wall of this section are washing machines, a hot-air drying room and a shower closet. The rearmost stalls on this wall are clothes lockers.

Oxygen supplies for both buildings are contained in the cylinders shown on the outside walls of the huts (they're placed there to save space). Also on the outer walls are floodlights to illuminate the dark interior of the chasm.

Here, 65 to 100 feet below the surface of the moon, the visitors from the earth spend most of their time during their lunar visit.

PAINTING BY FRED FREEMAN





CHESLEY BONESTELL

Seen from abandoned cargo ship with "full earth" shining in sky, passenger ships take off for return trip from the moon to space station's orbit

of equipment and start hoisting men up to the catwalks of the two rocket ships. Then the cranes are folded against the framework, ready for flight.

Through the intercom, the commander of the fleet counts off the seconds to take-off. At X minus 4 seconds, a thunderous rumble sounds in the passenger spheres: the rocket motors have been started. The turbopumps are switched on, forcing hydrazine and nitric acid into the motors.

One by one, the ships slowly lift from the surface. An automatic pilot performs the complicated take-off maneuvering which will set us precisely on course for the space station circling the earth 239,000 miles away. We have timed our departure so that we shall arrive at the space station at the precise moment when its orbit is lined up with the direction of our travel.

Immediately after leaving the ground, the ship's four spiderlike corner legs are jettisoned to save weight; soon afterward, the central shock-absorbing leg is burned away by the fierce heat of the rocket motors around it.

By now, our earth-weight has returned, and we feel astonishingly heavy. As the ship picks up speed, we are made heavier and heavier by the force of acceleration, until at an altitude of 40 miles from the moon, about 2½ minutes after take-off, we weigh 3½ times normal earth-weight.

We have reached maximum powered speed at this point: 4,200 miles an hour, sufficient to counteract the moon's gravitational pull and its 2,280-mile-an-hour speed in its course around the earth. We can now cut our motors; momentum will carry us beyond the moon's gravity, and from that point on we'll simply fall toward our destination. As the flame of the rocket motors dies away, we become weightless once again.

From here on, the flight is routine. The navigators keep constant check on our flight path (we can change course by using our rockets), fixing the position of the ships in relation to star constellations and the steadily growing globe of the earth. Far behind us, and to the right, the moon becomes correspondingly smaller.

Once past the neutral point between the gravitational fields of the moon and the earth, we start our fall, picking up speed constantly. At a distance of 131,000 miles from the space station's orbit with 20 hours of travel to go, we hit a speed of 4,300 miles an hour. Eighteen hours later, a little less than 17,000 miles from the orbit, our speed reaches 10,500 miles an hour, and we start to think about slowing down. We cartwheel our ship (by using a flywheel which, turning in one direction, causes the ship to turn in the other), so the rocket motors point toward the space station. Now we watch our speed carefully. Ahead, the man-made satellite, looking like a bright star, is traveling around the earth at 15,840 miles an hour. When our speed reaches 22,200 miles an hour, we turn on the motors. Because they point in the direction of our movement, they act as brakes.

Gradually we slow down. As we get closer, we cut the motors to half power. The needle of the speed indicator backs across the dial. When it hits 15,840, our motors are off. We are now a satellite of the earth, traveling in the 1,075-mile-high orbit at just the right speed to counteract the earth's gravity. A few miles away is the space station, endlessly circling the earth at the same speed.

We are back at our starting point. Man's first exploration of the moon has ended. Space taxis speed toward us from the station. Other men pour out of the satellite's air lock to greet us.

Our next trip will be a short one: two hours to the earth, aboard one of the sleek rockets parked nearby. There, the members of our scientific panel await us—and, without question, a great crowd of earthlings, come to see the first men ever to set foot on the ancient, mysterious soil of the earth's closest neighbor in the heavens. ▲▲▲

Collier's

FEBRUARY 28, 1953 • FIFTEEN CENTS

EXCLUSIVE

WORLD'S FIRST SPACE SUIT

How and Where We'll Use It

Man's Survival

We can build the rocket ships, but success depends on

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ILLUSTRATED BY CHESLEY BONESTELL, FRED FREEMAN AND ROLF KLEP

in Space

Edited by
CORNELIUS RYAN

the most complicated mechanism of all: the human body

WHO will fly tomorrow's rocket ships? Must the crews be limited to expert mathematicians, astronomers and physicists or can we use the caliber of men who fly today's jet planes? Will space travelers be tall, short, fat or thin?

We have the answers to these questions. Scientists, physicists and aero-medical doctors can specify the type of person suited for the job of conquering space and how the crews will be selected and trained. There's a good reason why our scientists can confidently make these estimates: they are hard at work at this moment to put man into space. So are certain branches of the Navy and Air Force.

While the government has not officially announced a space program, a score of the nation's colleges have quietly received U.S. contracts to investigate specific space flight problems. Some aircraft manufacturers are busily engaged in top-secret space research. One has the prototype of a space station on its drawing boards.

The Air Force and Navy are also vitally concerned with what kind of man we'll need for space flight. Today's jet fighters, bombers and experimental rocket-powered craft are flying faster and higher than ever before. They are speeding along the very borders of the upper atmosphere and, at these great altitudes and high speeds, crews are meeting virtually the same environmental hazards which exist in the void of space. In short, modern aviation is rapidly growing into space flight. We have been preparing for the inevitable.

Just as we protect man in atmospheric flight, so will we safeguard man in space. In the last few years, Air Force and Navy scientists and doctors, working together, have developed pressure suits which can be used in upper-altitude flight. We can use the Navy's version in space. The time has come to start thinking how we want the rocket ships built.

In the prejet age, airplanes were built with only performance in mind. Little thought was given to the men who had to fly them. Pilots and crews were expected to adjust automatically to the finished machines. Modern aviation medicine, as it becomes space medicine, has one rule of thumb concerning upper-altitude or space flight: man—human needs—must be considered before a single blueprint for an aircraft or rocket ship leaves the drawing board. Says Major General H. G. Armstrong, Air Force Surgeon General: "Physics and its allied sciences identify the specific physical hazards . . . Medicine determines the human reactions to these hazards . . . Engineering and its allied sciences design and develop the necessary protective equipment."

We must construct our rocket ships around the men who must fly them.

But who are they?

The story of the selection and training of the crews who will operate tomorrow's rocket ships begins on the following pages, as the first of a three-part series. So many branches of science are involved in discussing the human factor of space flight that Collier's asked a distinguished panel of aero-medical scientists, physicists, radiologists and engineers to contribute to the series. Because their fields of study interlock and overlap, their papers have been combined into one continuous narrative.

It is an important narrative. The success of any program to reach space depends on the machines, it is true. But even more largely it depends on the most delicate, most indispensable of all instruments—man himself.


VON BRAUN


MULLER


FLICKINGER


LEY


STRUGHOLD


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Picking the Men

Can ordinary, healthy people visit space? They can—the Navy's new space suit points the way—but we'll look for special qualities in the pioneers. The physical and psychiatric examinations will be so tough that of every 1,000 trainees who can meet the strict entrance requirements only five will make the grade. Here's how we'll choose

WE COULD send man into space right now, this year. And he *would* survive. Without any particular discomfort, either. He'd face hazards—from blood-draining acceleration to blood-boiling low pressure, from cosmic rays to extreme temperatures—but these are hazards we know we can beat.

Most, in fact, have been overcome by a single development, never before publicly disclosed: the completion of the Navy's new pressure suit, tailored for space travel. The Navy space suit, pictured on this week's cover and on the opposite page, carries its own atmosphere—oxygen, pressure, air conditioning. It can be worn for long periods, and permits complete freedom of movement. It was developed with space problems in mind.

You could wear it to the moon tomorrow.

We know that we can build the rocket ships to take us into space (Collier's, March 22, October 18 and 25, 1952), and we know we can protect their crews. All we have to do is find the right men—and women—to make the trip.

It would be foolish to solve all the mechanical problems and then run a risk of human error. So we must choose space crew members carefully—so carefully that Colonel Don Flickinger, the doctor who is one of the top Air Force experts on what the body must endure in flight, makes this rough estimate:

Of every 1,000 persons who can meet the initial rigid educational, physical and age requirements for space training, only five will ever enter space—just enough for one rocket-ship crew.

What are the standards those 1,000 must measure up to? And what are the problems that will wash out 995 of them?

An applicant for space training must be old enough to have mature judgment; whizzing through the blackness of space at speeds up to 18,000 miles an hour, facing situations men have never known before, he must make decisions fast—and right. But he must not be so old that he can't stand the rigors of space travel: catapultlike acceleration which may increase his weight ninefold, followed within minutes by complete weightlessness; tremendous demands on his endurance; the need for near-perfect reflexes and co-ordination.

Of the 11 scientists taking part in Collier's three-installment symposium, six contributed to the article Picking the Men: Drs. Heinz Haber, Donald W. Hastings, Hermann Muller and James A. Van Allen; Air Force Col. Don Flickinger and Navy Capt. James E. Sullivan

He must be well-educated, so he can absorb the fairly advanced scientific instruction that will equip him for rocket travel and life in space. As part of his training, he will receive a thorough grounding in both practical and theoretical engineering, medicine, astronomy and navigation.

He can't be too tall or too short and stout. Such people often have poor control of their blood circulation, which makes them more subject to fainting, and more susceptible to variations in temperature and other hazards of space.

The best prospective crew members will be between twenty-eight and thirty-five years old, and of medium build: five feet five to five feet eleven inches tall, and weighing perhaps 10 per cent less than the average for their height. And they will have college degrees, or the equivalent as measured by examination.

How about women? Chances are, they'll be sought after for some space crew jobs. Not as pilots, perhaps, but as radio and radar operators—jobs requiring a high degree of concentration under difficult circumstances. In industry, women have indicated that they can perform monotonous and tedious tasks hour after hour without undue loss of efficiency. We need people like that in space travel. The physical and educational qualifications will be about the same for women as for men, except that the women may be shorter and lighter.

Those are the applicants. Now they must be culled; the unfit must be ruthlessly eliminated to minimize the risk of personnel failure.

The first and most severe test will be a medical-psychiatric examination which will cut the original 1,000 down drastically. The physical exams, which will be in two parts, are expected to weed out no less than 880 of the starters, and the psychiatric test 60 more.

Why so tough? Because even minor organic or emotional defects will be tremendous handicaps; what we're looking for are people with specific physical attributes and unusually stable personalities.

The space crew members will not be supermen. But they will be well-adjusted individuals in excellent health, with a few special aptitudes to equip them for the special problems of space. Those special aptitudes are important; they explain why even men as carefully picked and well-trained as jet pilots probably wouldn't all make the grade as space pilots.

At altitudes above four miles, there's virtually no air; an unprotected man would swiftly suffocate. From eight to 12 miles up, the region of extreme low pressure starts; from that level on into infinity, the body fluids would boil if not protected (first the saliva bubbles, then the skin balloons in places, under the pressure of water vapor rising beneath it, and finally the blood starts to churn).

Then there's the temperature problem. A man speeding spaceward passes within moments through wild temperature variations—from moderate temperatures on the ground to 67 degrees below zero F. at an altitude of eight miles and then into a region where temperature as we know it no longer exists: a man exposed to the full blast of the sun's ultraviolet rays would roast in an instant, while objects hidden from the sun would lose heat until—if in the shadow long enough—their temperature would drop close to absolute zero.

In a region so unlike the environment we've always known, there's only one way to protect life: bring our environment with us. From the moment he enters space until the time he leaves it, man will

Like Navy, the Air Force has been thinking of space problems. This is Air Force emergency pressure suit, developed by Dr. James Henry, shown undergoing pressure-chamber test. Suit inflates automatically as cabin pressure drops, does not protect hands or feet. Main contractors were David Clark Co., Bendix Aviation Corp., and International Latex Corp.

PHOTOGRAPHS BY RALPH ROYLE

New Navy space suit is a one-piece affair, with helmet hinged to the shoulders. It has been tested to altitudes of 63,000 feet and still higher tests are under way. Many details of the suit are top secret

Suit permits great freedom of movement. It was designed by Carroll P. Krupp, of Findlay, O., 35-year-old self-taught Goodrich engineer, under the direction of U.S. Navy's technicians. It would work on the moon

A typical space crewman: not too tall, short or stout—and emotionally stable. For some

live inside a protective envelope of his own making, a high-pressure chamber, either within the sealed cabin of his rocket ship or living quarters, or within the sealed casing of his space suit. The new Navy suit—developed under the direction of Captain James Sullivan of the Navy Bureau of Aeronautics—will do the trick.

The Navy space uniform, which is being used experimentally under heavy guard at the National Air Matériel Center, Philadelphia, actually does more than solve the major problems which occur at extreme low pressure. It solves many of the bothersome minor problems, too.

How does a man move around when he's encased in a high-pressure balloon (which is what a space suit is)?

The natural tendency of a pressure-filled suit is to become rigid and unyielding; how can the wearer bend his arms and legs? How can he use his fingers? Turn his head?

The rubber Navy suit permits almost complete mobility by means of a variety of devices, most of them still top secret. Semirigid accordion pleats allow movement of the important body joints: shoulders, elbows, knees. Ingenious wrist joints permit rotation of the hands. Man in space will find that his fingers wriggle almost as freely as they might in a conventional thick glove—and with a sensitivity of touch that's almost completely lacking in normally gloved hands. The helmet is attached at the shoulders, and is so built that a man's head can move comfortably within it. The suit has special slide fasteners which seal the suit as they close.

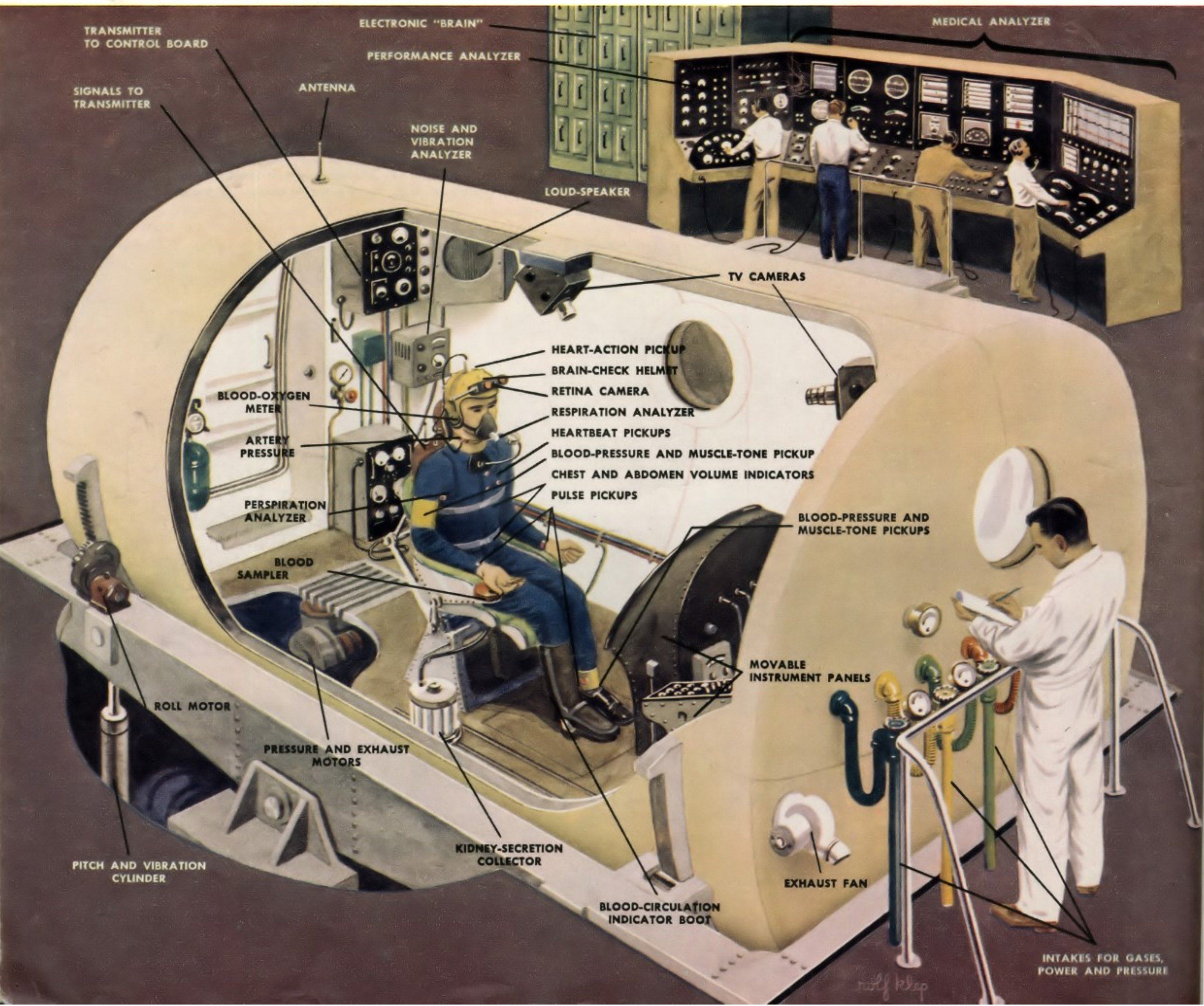
Refinements such as these explain, in part, why the suit cost about $225,000 to develop. (It was made by the B. F. Goodrich Company, using fabricating techniques developed by the David Clark Company and hardware by the Firewel Company and Bendix Aviation Corporation. In production—it will be made in three sizes—its price will drop to about $2,000 per suit.) But the real significance of the uniform is the near-perfect protection that it gives against the big hazards: lack of oxygen, blood-boiling low pressure and temperature variation.

If the crew member gets all that protection, why worry about special aptitudes? Couldn't any individual live comfortably in an artificial atmosphere almost identical to the earth's?

The answer is no. Some people simply can't endure man-made atmosphere. Scientists aren't sure why, although it seems certain that the reasons are largely psychological. Pressure-chamber and pressure-suit tests show that a certain percentage of any group will fold up under conditions which other people don't mind at all. And a few can take low pressures that would knock out almost anyone else.

Those are the few we want.

Suppose a rocket-ship cabin develops a leak. It's possible; no equipment is perfect. The crew members will be so well-versed in emergency procedures that the leak probably will be plugged in a few moments—but for those few moments all personnel aboard the ship will have to cope with an environ-



jobs, women may beat out men

ment far different from the earth's. It's then that our extreme care in the selection of crew members will pay off.

Obviously, we'll want to test all applicants in pressure chambers. We've been doing that for years with aircraft crews and trainees. But more than that, we'll check our 1,000 for certain physical properties. A person whose circulatory system is under excellent control will be far better equipped to exist for long periods on relatively little oxygen, and in the cramped quarters of a rocket ship, than one with unpredictable variations in blood pressure.

A crew member whose nervous and circulatory systems react swiftly and efficiently to outside temperature changes will be affected only slightly by variations which might incapacitate someone else.

Problems of a Space Vehicle's Crew

Before a space vehicle even leaves the 120-mile-high atmosphere which surrounds the earth, its crew members will have confronted all the problems of low pressure, plus a couple of others: cosmic radiation and ultraviolet radiation.

Ultraviolet radiation doesn't trouble us; it could be dangerous to an unprotected man, but our crew member will never lack the protection of cabin walls, space suit fabric and tinted glass.

Cosmic rays, the minute, ultrahigh-speed, radioactive particles which whiz constantly through the upper atmosphere and space, have been an object of dread for many years—principally because most people know so little about them.

Scientists know enough, however, to be pretty certain of two facts:

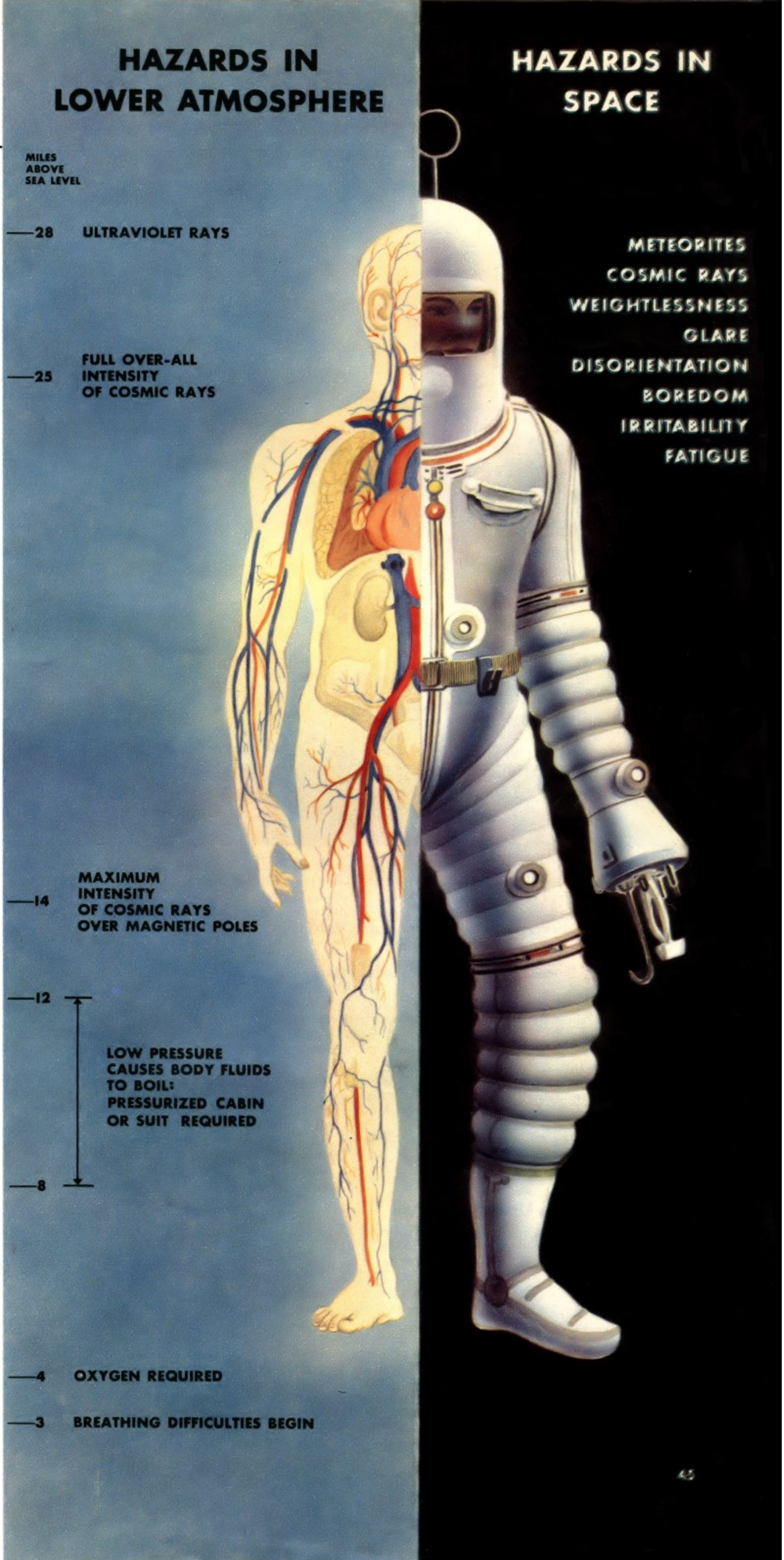
First, they aren't as bad as they've been described, not bad enough to constitute a real danger.

Second, their relative harmlessness is a source of vast satisfaction to space scientists, because there's no practical way of protecting space travelers from them. The reasons will be discussed later in this article.

Above the atmosphere, only one more physical hazard confronts the space traveler: meteorites. There again, there is no built-in safeguard in the human body. Medical men are counting on the engineers to provide sufficient protection. But there are other problems we must meet.

In aviation training, the greatest number of men are eliminated because of faulty reactions or poor judgment under actual flight conditions. It isn't easy to provide flight conditions in rocket-ship training; obviously, we can't send potential crew members into space in a multimillion-dollar space vehicle as part of our selection process. Yet it's much more important to weed out the unfit in a

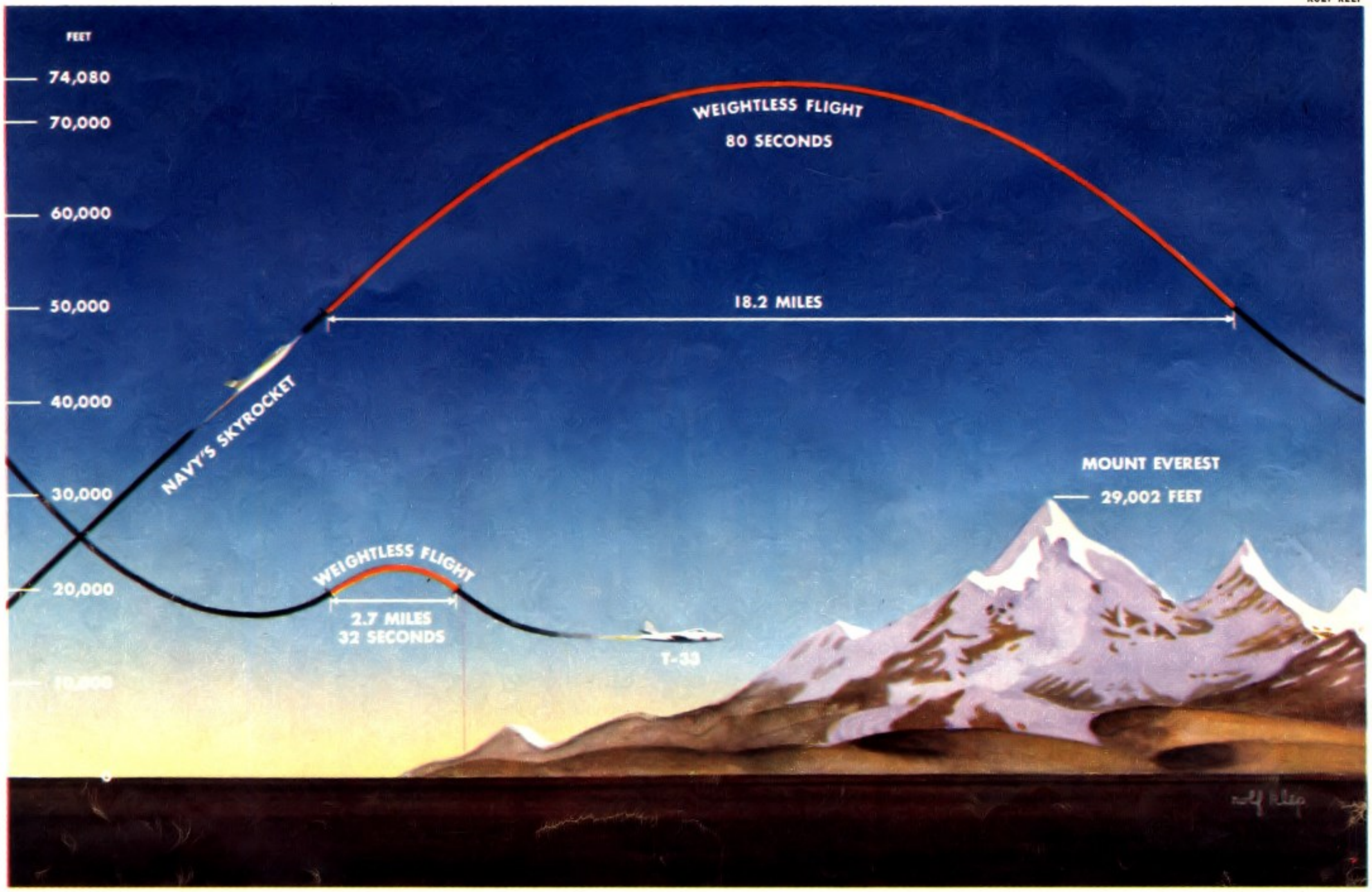
This device will test candidate's ability to take stresses of space. Roll motor and pitch cylinder will rock and shake chamber; noise will be piped in; pressure and composition of atmosphere will be varied. Prospective crew member will be required to solve problems set into instrument panels by remote control. As he works, electrodes, cardiographs and other instruments attached to his body will record how various organs function under the strain. The heart, brain, eyes, perspiration, blood, muscles all will be checked separately, and technicians and surgeons will see results on analyzer panels. One TV camera will be fixed on candidate, other on the instrument boards



In lower atmosphere, the hazards at left menace unprotected man. Even crewman in space wearing pressure suit will be subject to dangers noted on right. But none is a serious obstacle to an assault on space today

DRAWINGS BY ROLF KLEP

Science is breaking down the barriers. The Navy suit licks the low-pressure hazard;



This shows the method devised by Dr. Heinz Haber for achieving weightless flight in a modern high-velocity airplane. Plane dives to pick up speed, then pulls up and flies in humplike arc. Pilot is weightless while in arc. Bottom diagram shows flight path of T-33 jet trainer which made the first such flight, with crack Air Force test pilot Maj. Charles Yeager at the controls. Upper line indicates how our fastest rocket plane, the Douglas Skyrocket, flying above 10-mile altitude, can lengthen arc, almost triple period of weightlessness

space program than in aviation training. What can we do?

We can copy the stresses of rocket flight on the ground. In fact, we can do better: right now we can make the tests far more concrete than those used in aviation, which depend largely on personal observation and opinion.

The trainee will be seated within a small, elaborately instrumented, boilerlike chamber. The inside pressure can be lowered; the chemical composition of the atmosphere varied; the temperature adjusted. The testing flight surgeon can vibrate the whole contraption violently, pipe noises into it—or conduct any of the tests in combination.

Candidate Given Electronic Checkup

The candidate will, in effect, be wired for sound and radar. His suit will be the center of a network of wires. Television and X-ray cameras will hover over him. Electrodes, cardiographs and other electronic devices will check his pulse, blood pressure, breathing rate, skin temperature, internal temperature, perspiration and the oxygen content of his blood. Every section of his heart and brain will send out its own signals to a control board outside the chamber—so the surgeons will be able to check not only for malfunctioning of specific organs, but for the co-ordination of the physical machinery as a whole.

The air intake of the candidate's lungs and the chemical composition of the exhaled air will be analyzed to see how efficiently his lungs work at various pressures. The movement of blood through his body will be followed as a check on the contraction and relaxation of his blood vessels.

Outside the chamber, the watching doctors will see a picture story of the candidate's life processes in action. They will be able to evaluate the reports transmitted from the chamber, to see if some organs are working too hard, to see if integration between the brain, heart, lungs and circulation is all it should be.

By the time he steps out of the chamber, the candidate won't have a physical secret left; of the original 1,000 only 120 men and women will remain. And the chamber tests may disclose a few psychological secrets, too.

Psychology is an extremely important consideration in weighing a candidate's ability to cope with life in space. An individual living in the confinement of a rocket ship or space station experiences many emotional strains: the confusing absence of familiar guidepoints, like the horizon, to show him what position he's in (there's no vertical or horizontal in space); the tremendous monotony of empty scenery and cramped quarters; the irritating presence of the same few people over long periods; mental fatigue caused by the need for constant, unrelenting alertness to the problems of a completely new environment.

Can harassed modern man endure the additional mental stresses of space life?

He can, according to Dr. Donald W. Hastings,

U.S.A.F.

Maj. "Chuck" Yeager, first man to be weightless, found experience confusing

the top Air Force consultant on psychiatric problems. Some men will do better than others, though, and we'll want the best of the lot. We'll get them by putting each candidate through an exhaustive psychiatric check, probing into his subconscious (possibly with the aid of harmless drugs and hypnosis), and testing him for such characteristics as ingenuity, intelligence, judgment and courage.

When our psychiatrists and psychologists finish with the candidates, the 120 survivors of the physical tests will have been whittled down to 60.

Even so, no test psychologists can devise will measure adequately an individual's ability to adjust to the one remaining problem of space: weightlessness.

A space vehicle or space platform traveling around the earth at a certain distance and speed (1,075 miles and 15,840 miles an hour, for example) will exactly counterbalance the effect of the earth's gravity. Occupants of such craft will float in space. It's likely to be a disturbing experience; until crew members get used to it, they may suffer from dizziness and nausea.

Some people might never get used to it. How can we comb them out? We certainly can't simulate weightlessness on earth, can we?

No, but we can simulate at least one *effect* of weightlessness, and, using jet planes, at certain speeds we can achieve brief periods of weightlessness in the air.

Cosmic rays, X rays act alike. Normal flies like one above, heavily X-rayed, had freakish descendants below: tiny-eyed, yellow, short-winged, wingless, mottle-eyed or dark-bodied. But men won't find such heavy dosage in space

Zoologists know that when small iron filings replace the sand grains which are normally in the inner ear, or balancing organ, of a crayfish, and a magnet is held above the filings, the crayfish shows about the same kind of confusion humans can expect from weightlessness. His organ of equilibrium responds to the impulse of the magnetized filings with a wrong guess: up becomes down, and the crayfish flips onto its back. A similar experiment, both harmless and painless, might be tried on larger animals. We might learn a lot about weightlessness in humans from such research.

An Experiment in Defying Gravity

But obviously, the most effective way to judge the effect of weightlessness is to watch someone who's experiencing weightlessness. We're now able to do that, using a method devised by Dr. Heinz Haber, astronomer and physicist, who was formerly with the Air Force Department of Space Medicine. A number of men have already tried Haber's method, and have defied gravity for periods of up to 30 seconds. Here's how it's done:

A cannon shell is weightless from the moment it leaves the muzzle until the instant it strikes the target. Haber proposed imitating the arc of a shell with an airplane.

Air Force Major Charles Yeager tried it. Yeager, the first man to fly faster than sound, went up in a jet trainer and put it into a long dive, to pick up speed. Then he pulled up and pushed over into a roller-coaster arc, to simulate a shell's flight. From the moment he started the arcing trajectory, he was weightless. A pencil lying on the jet's instrument panel rose majestically into the air and hovered there, providing Yeager with a course indicator. (When the freely floating pencil rose too high, Yeager adjusted his flight to keep the pencil stationary; in that way, he was able to stay within the weightless arc.)

How did it feel?

Strange, Yeager reported. First there was a falling sensation, but that didn't bother him much, since he was securely fastened to his seat. But then his head began to "grow thick," and he had trouble orienting himself. A few seconds later, he had the impression that he was spinning around slowly; he couldn't say in what direction. It was, he said, like sitting on a big ball which was slowly rotating in all directions at once. After 15 seconds, thoroughly confused, he pulled out of the arc.

Several other men have tried the Haber method since Yeager's attempt. Some have been weightless for half a minute—and none have reported the effects that disturbed Yeager. Their solution: by staring at a fixed point on the plane's instrument panel, they keep a sense of balance and perspective. Additional flights, under controlled conditions, should supply more answers to the problem of weightlessness—especially if they're made in one of the latest experimental rocket models. If the Navy's rocket-propelled Douglas Skyrocket, our fastest plane, were used for such an experiment, weightlessness could be achieved for almost a minute and a half.

There's just one more possible psychological hazard to space travel: an unreasoning fear of cosmic radiation. The simplest answer is to give our space candidates a complete course in cosmic rays, to prove that they need not be afraid.

Theoretically, cosmic rays are capable of doing the same kind of delayed damage to humans as that done by X rays or radium or atomic-bomb rays: a person who absorbed too great a dosage might produce strange physical changes—or mutations—in his descendants.

But the damage is insignificant unless we absorb an overdose. About 25 years ago, massive doses of X rays were administered to a species of fruit fly which breeds so rapidly an entire generation can be produced in a few weeks. Within a short time, weird freaks turned up among certain of the descendants—some without eyes, others with strangely shaped wings and legs, or with legs where their feelers should be, or with unusual coloration. These mutations were passed on to later generations, proving that the damage had been permanent.

The fruit-fly tests were dramatic and, to many people, fearsome. They should not have been. It wasn't easy to produce the freakish insects. Of hundreds of flies subjected to massive X-ray doses, only a relative few passed on marked changes to their offspring, and it sometimes took generations of breeding to turn out a real monster. Even

PHOTOGRAPHS BY INDIANA UNIVERSITY

ROLF KLEP

One expert checked cosmic-ray intensity 53 miles up

genes which sustain a near-killing dose of radiation seldom produce outlandish abnormalities. Changes, yes; freaks, rarely. Dr. Hermann J. Muller, one of the world's outstanding authorities on the subject, puts it this way: If a human were exposed to all the radiation his system could stand, enormous numbers of his descendants would have to be closely examined before a single really abnormal person turned up.

How much cosmic radiation would a man absorb in space?

The Air Force is conducting experiments to help answer that question, sending fruit flies aloft in balloons to altitudes between 50,000 and 100,000 feet. But even now we know the answer in general terms. Last year, Dr. James A. Van Allen led an expedition to the waters off Greenland for the Office of Naval Research to measure the intensity of cosmic radiation over the polar area, where the earth's magnetism attracts an especially high concentration of the electrically charged particles. Small plastic balloons were sent aloft from the Coast Guard cutter Eastwind with slender rockets suspended beneath them. After 55 minutes, timing devices launched the rockets, and Geiger counters on each rocket measured cosmic intensity all the way up to 53 miles.

The greatest concentration—about 170 particles per second striking an area the size of a man's hand—was found at altitudes between 14 and 25 miles. There are sure to be more particles than that at a great distance from the earth, because the earth itself shielded Van Allen's Geiger counter from particles which might otherwise have struck from below. Van Allen estimates, on the basis of his findings, that a three-inch square 1,000 miles above the earth might be struck by about 700 cosmic particles a second.

Is that a dangerous intensity? Far from it. A man could absorb such a concentration for as long as six years in a row without appreciable harm. The X-ray doses used on the fruit flies were equivalent to millions of particles, administered all at once.

So, the 60 candidates now left of the original 1,000, armed with the facts on cosmic radiation, will know they have little to fear on that score.

But some tests lie ahead. The 60 are ready for training now—training in methods of withstanding acceleration shocks, training in group procedures within a sealed cabin, in navigation, and in personal locomotion in space. By the time the candidates have finished that instruction, there will be only five left.

U.S. NAVY PHOTO

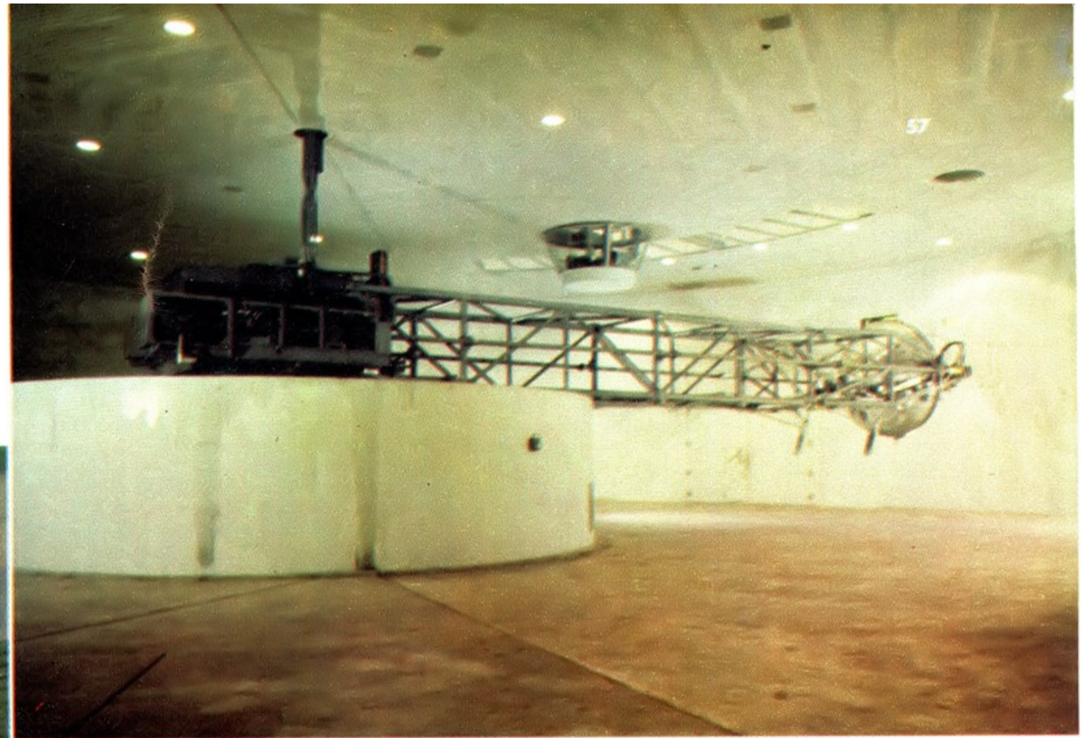
Left: high-altitude cosmic-ray tests were carried on from Coast Guard cutter Eastwind by launching balloons which set off rockets aloft. Above: preparing rocket-firing mechanism

Next Week **In a big hangar, a cage whirls around like a bucket on the end of a string; inside sits a man, his face sagging, his body under heavy pressure—but his mind working swiftly. In the next room, a space-suited figure is seated atop a slender pole with a gunlike instrument in his hand; as he pulls the trigger, he cartwheels, spins, gyrates crazily. What are they doing? They're training for the toughest assignments of their lives: the harsh, complicated, exacting duties of rocket crewmen preparing to conquer space**

Testing the Men

ROLF KLEP

Disaster is the penalty for an error in space. The pioneer rocket crews will practice for perfection on earth, aided by a gallery of wonderful machines



RALPH ROYLE

Navy centrifuge at Johnsville, Pa., one of several in use to simulate acceleration force

Eleven top experts contributed to the symposium, Man's Survival in Space. This part, the second of three, is based on papers done by Dr. Wernher von Braun, chief, Army Guided Missiles Laboratory; Dr. Hubertus Strughold, head, Air Force Dept. of Space Medicine; Dr. Fritz Haber of the same agency; Dr. Donald W. Hastings, national psychiatric consultant to the Air Force; Dr. James P. Henry, Air Force Aero Medical Laboratory; rocket expert Willy Ley. Collier's Cornelius Ryan assembled the material

HOW do you make a space man out of an earth man? The tests a human encounters in space, the tasks he is charged with in rocket flight, are like nothing he knew on solid ground: flattening acceleration pressures; brain-twisting navigational problems; nerve-racking confinement in cramped quarters; the problem of moving from one point to another when you're hovering 1,000 miles above the ground. No man experiences such difficulties on earth. How does he prepare to meet them in space?

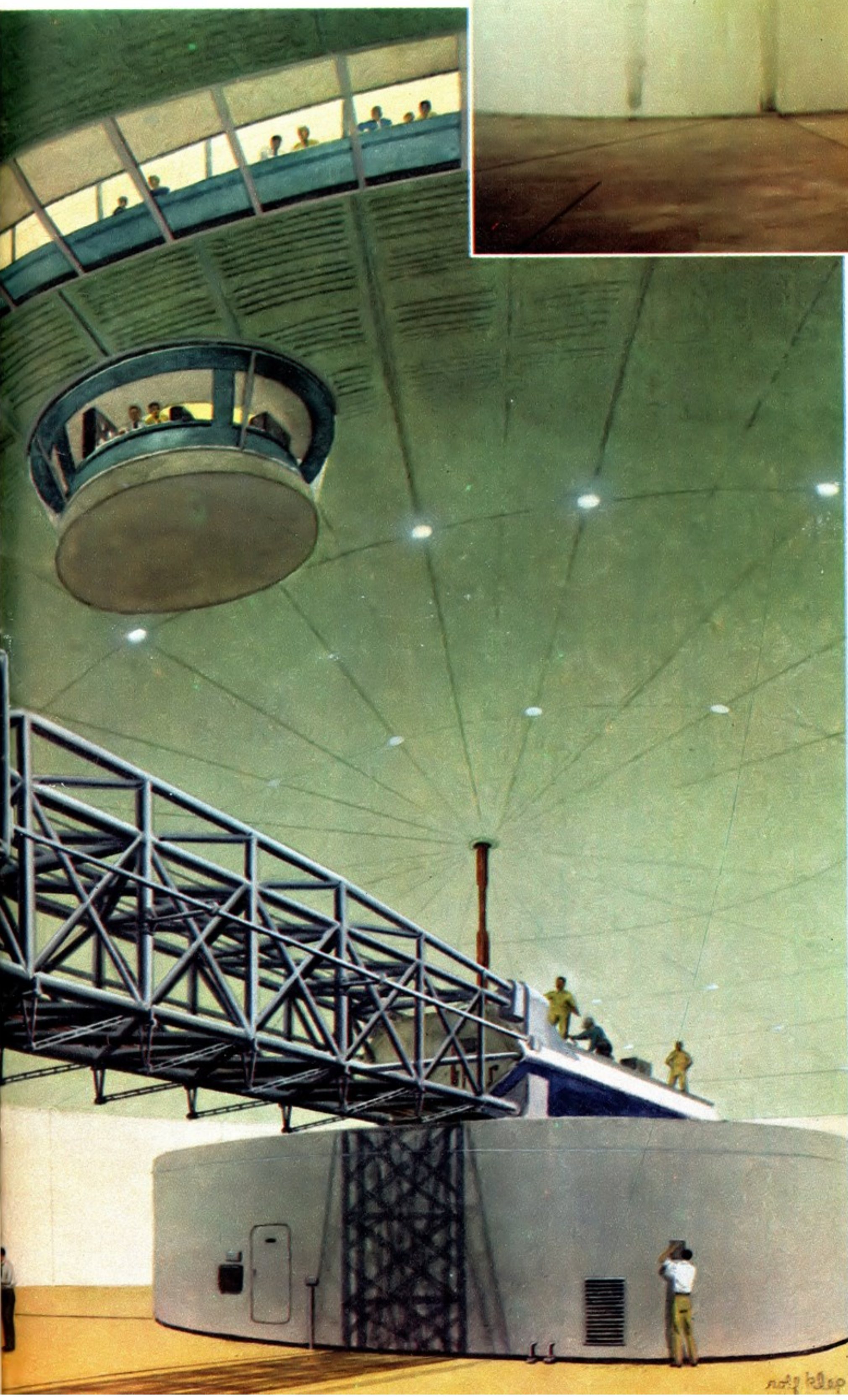
He must prepare on the ground. When he actually gets into space, it will be too late to start learning. Massive, dramatic machines are the teachers—and they already are roughly blueprinted.

One machine (you can see it at the left) will whirl crews around at speeds that reproduce the breath-taking, body-crushing pressures imposed by a fast-rising rocket ship. As the trainer rotates, problems will be fed into the cabin requiring split-second, co-ordinated action from the nearly immobilized crew.

A second machine will teach man to move around in the weightlessness of space. He'll spin, cartwheel, fly violently backward, roll and twist until he gets the hang of self-locomotion.

Trainees also will be jammed together for days in a sealed, boilerlike chamber—working, sleeping, eating, relaxing in a confined space and in a pressurized, synthetic atmosphere.

Navigators dare not be wrong in space; a fractional error may put a speeding vehicle thousands of miles off course. So navigators will have the



Crew centrifuge would expose five persons at once to g pressures, while instructors sent in problems requiring immediate solution. In action, cabin nose would swing down, bringing it into line with centrifuge arm. Operators suspended beneath ceiling could rotate cabin to simulate realistic emergency at launching

Numbing acceleration pressures almost immobilize rocketeers at launching—yet they

most complicated—and most striking—trainer of all: a huge globe which will simulate the vastness and stark beauty of space; sitting inside, the navigator-trainee will get most of the errors out of his system before they can do any harm.

Five Years' Hard Study for Trainees

Besides training in these simulators, most of them designed by Dr. Wernher von Braun, the world's top rocket engineer, the crews will get a tough classroom schedule, taking courses in rocket and instrument design, physics, astronomy, navigation (for all personnel) and basic medicine. The training will take five years, and each of the crew members who graduates will have the equivalent of a master's degree in at least one specialty.

How many will graduate? About five out of every 60 who start the training course. But even those 60 will have been carefully selected; so the graduates will be the cream of a carefully chosen group that once numbered hundreds.

We know we can build superbly engineered rockets to carry man into space; in picking our crews we must aim for the same degree of perfection. Before an applicant is accepted, he must meet rigid physical, educational and age requirements (Collier's, February 28, 1953). He must be between the ages of twenty-eight and thirty-five; he must have a college education; he must be of medium weight, and between five feet five and five feet eleven inches tall. (Exceptionally tall or short people tend to have poor blood-circulation control, which hampers them in adjusting to the stresses of space travel.)

Of every 1,000 applicants who meet those standards, 940 are expected to wash out during the stringent medical and psychiatric examinations which precede training. And now, in the training phase, we'll find that 55 of the remaining 60 students can't cope with the physical, emotional and educational demands of rocket flight.

Perhaps the toughest test will be the trainee's ability to function swiftly and efficiently during acceleration.

Flight into space will be made in three-stage rocket ships: vehicles built in three sections, each with a bank of powerful rocket motors. The first stage, or tail section, provides the tremendous power needed to get the rocket ship off the ground; at an altitude of 25 miles, the first stage is cast loose and the rockets of the second stage, or center section, start firing. At 40 miles, the center section is dropped, and the third stage, which contains the crew compartment, continues on into space. All during the ascent, the rocket ship is guided by an automatic pilot. The pilot is operated electronically by a magnetic tape into which precise instructions have been fed beforehand.

How Acceleration Affects the Crew

As each stage takes over the task of propulsion, there is a sharp drop in acceleration, followed by a sudden thrust forward as the new bank of rockets bursts into action. The crew members feel a numbing acceleration pressure, like the pressure you feel against your back when you step on the gas in an auto, but many, many times more powerful.

The first great acceleration shock comes shortly after launching: from a standing start, the rocket surges to a speed of 5,250 miles an hour in 84 seconds. The second stage propels the rocket for 124 seconds, building up to a speed of 14,364 miles an hour, and the third stage, which then takes over, requires another 84 seconds to hit top speed—18,468 miles an hour. At each spurt, the rocket passengers are crushed against their seats with enormous force.

At the two acceleration peaks (about 80 seconds and 300 seconds after launching), the pressure is equal to nine times a man's weight—that is, nine times the force normally exerted by gravity. Scientists call it nine gravities, or nine g's.

Position Governs Time of Blackout

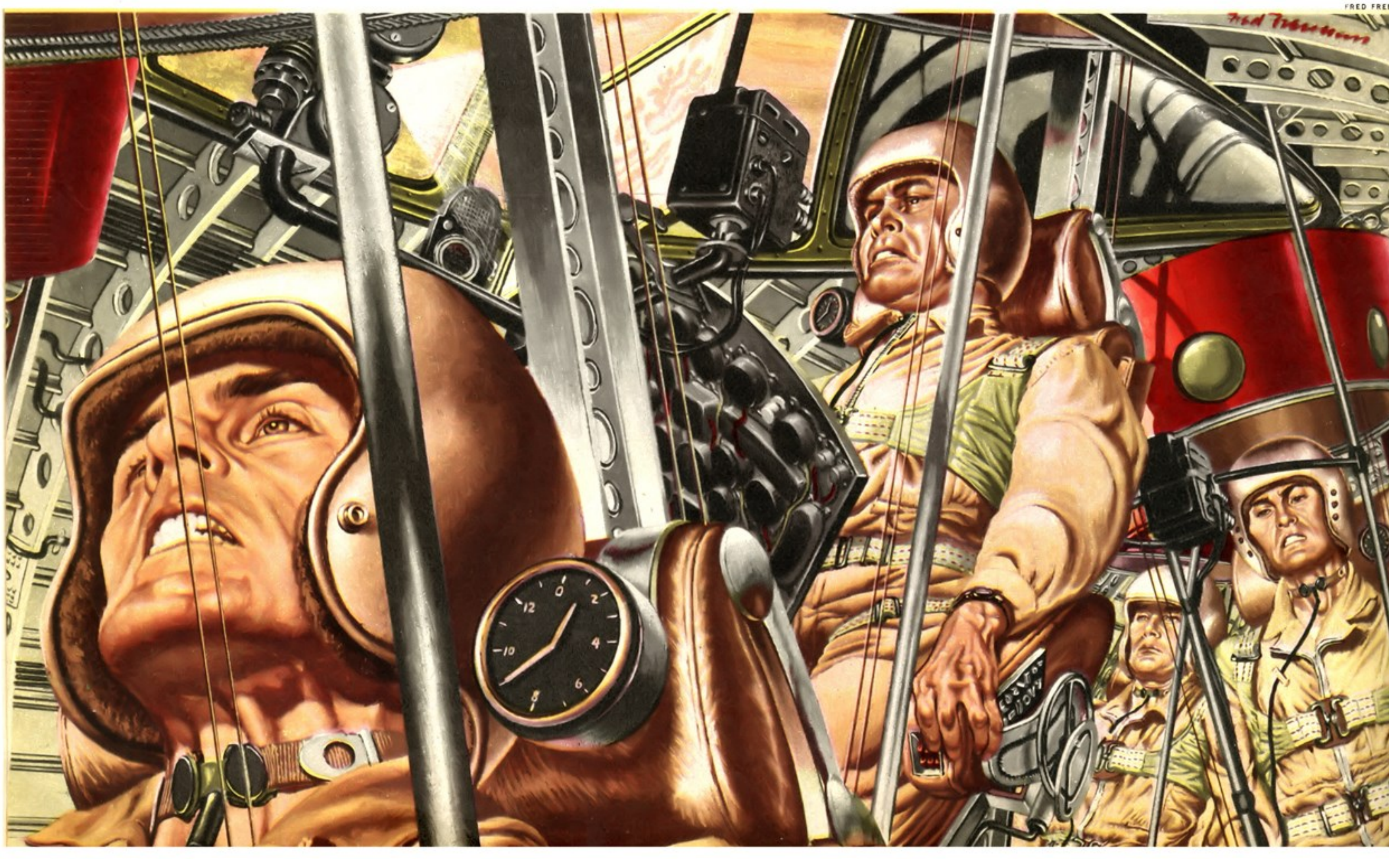
Can a man operate under such pressure? Yes, if he's sitting in the proper position. If the direction of the pressure is from his head to his feet, the blood drains from his brain, and he blacks out at only four or five g's. If the direction is from foot to head, the blood rushes in the other direction, and he can take barely 2½ g's. But if the pressure is from chest to back, some men can withstand as many as 17 g's without difficulty. How do we know? We have a machine that exposes men to g-forces, a centrifuge consisting of a cage on the end of a long arm, which whirls around like a bucket on the end of a string. Just as a stone in such a bucket will be pinned to the bottom, so a man in the centrifuge is pinned back against his seat. The faster the cage goes around, the more g pressure the man experiences.

Dr. James Henry, one of the Air Force's top physiologists, has found that men spun in the centrifuge at the Wright-Patterson Air Base in Dayton, Ohio, can take up to 10 g's, chest-to-back, and still move their arms and legs.

That's important. It means that if something goes wrong during the first five minutes of rocket

Within cabin of swiftly rotating centrifuge, crew is subjected to terrific strain like that of rocket acceleration. Force sustained equals nine times a man's weight, or nine g's. Problems calling for group action are fed into trainer; crew responds by using fingers to strike armrest buttons

FRED FREEMAN



must act fast in emergencies

flight, the crew will be capable of taking emergency action, up to as many g's as they're likely to experience.

But emergency action in a rocket ship calls for split-second co-ordination among several people. So we'll train our crews in a bigger, more complicated centrifuge; the cage will be a near replica of the cabin of a rocket ship. The crew members will sit in contour seats so adjusted that the simulated acceleration pressure will strike them from chest to back, and during the test runs they will be fed emergency problems by instructors on the outside. The training probably will go something like this:

The captain and crew strap themselves into their chairs. Ahead of them, projected on the frosted glass of the cabin canopy, they see a color film showing a blue sky dotted with white clouds.

After a last-minute instrument check, the captain presses a button on the armrest of his chair. The rockets of the first stage begin to mutter; a muffled rumble emerges from hidden loud-speakers in the cabin.

The instructor at the remote-control board outside now gives the captain the launching signal. A light flashes in the cabin, and the captain pushes another button, turning the motors on full power.

The noise from the loud-speakers grows to a roar. The centrifuge begins to spin, simulating the lift of the rocket ship. The sudden surge throws the crew members back hard into their seats. As the white clouds on the canopy race toward the ship and disappear, the faces of the occupants begin to strain under the mounting pressure.

The sky darkens quickly to a jet black that is broken only by stars, glinting cold and sharp directly ahead. As the centrifuge picks up speed, the breath is driven from the bodies of the crew members, and their muscles become almost powerless against the g pressure; yet they watch the orange-red illuminated dials which register a multitude of performance signals. If anything goes wrong, they must be ready to act.

And suddenly, as the peak pressure of 9 g's approaches, something does go wrong.

Danger from Jamming of Fuel Pumps

A high-pitched klaxon horn blasts over the motor roar, and a light flickers near one of the dials on the engineer's panel: one bank of fuel pumps has jammed, and the lines providing the pumps with pressure may burst. Squeezed almost immobile between the chair backs and the tremendous pressure bearing down on their chests, the crew members must act—decisively and quickly.

The engineer's thumb gropes for the interphone switch on his chair arm. "Engineer to captain. Series five pumps are stuck!" The captain must make a hasty decision. The rocket trouble is sure to affect the ship's flight path; yet in a few moments the troublesome first stage is due to be jettisoned. Should he try to keep going? Or should he plan a forced landing or escape procedure? In the last, he can either gain more altitude for safety's sake, or get rid of both the first and second stages immediately and head back for the earth. He decides to continue.

"Captain to navigator. Check flight path with ground station."

The radio operator, hearing the order, gives the navigator direct contact with the earth. The navigator speaks briefly, listens, then switches his set back to intercom with a movement of his finger. "Navigator to copilot. Tape 13."

The copilot turns his wrist until his hand is over a tape selector panel, then punches button 13.

The engineer, meanwhile, has applied a partial corrective for the faulty rockets. "Increasing the speed of remaining pumps," he announces, as soon as the intercom is open.

The navigator in turn prepares to call the ground for another heading, to compensate for the increased power put in by the engineer. The infor-

Here's what happens to a man subjected to head-to-foot g pressure, the kind an airplane pilot experiences in pull-out from a dive. Force drags facial muscles downward, drains blood from head, causing average man to black out at 5 g's. A rocket crew member would feel such force if he leaned forward during launching

Foot-to-head force pulls muscles upward, causes blood to rush to man's head. A normal man can take only about 2 g's in this direction before he experiences the condition called red-out. Aircraft pilots performing difficult outside loop know this feeling, as would a rocket crewman leaning too far back at acceleration peak

Problem of g force can be licked if direction of pressure is from chest to back. Men in centrifuge tests have endured up to 17 g's of this kind without blackout or red-out, and space vehicle crews will be seated so acceleration forces strike them this way. All of these photos were made in Navy and Air Force centrifuges

PHOTOGRAPHS FOR COLLIER'S BY RALPH ROYLE

Moving around in weightless space is tricky; you can spin, cartwheel, or tumble

mation he gets will affect the copilot, and the captain will have to take the actions of both into account in making further plans.

And all this time, the radio operator has been busy sending step-by-step reports back to the ground station, so the people there will know what happened in case the rocket ship crashes.

All this action has occurred in seconds. Inside the whirling cage, television cameras have caught the whole scene. Outside, instructors have watched TV screens and light panels, and have timed and recorded every move. By the time the first stage is cast loose, 84 seconds after launching, the emergency is over. Two more accelerations, as the second and then the third stage rockets open fire—and the centrifuge slows down and finally stops.

Many Wash Out in Centrifuge Training

There will be many centrifuge tests before a trainee steps into his first real rocket ship. Many of the students never will see the inside of a space vehicle, because they will wash out in centrifuge training.

Some people are more susceptible to g pressures than others; some will be able to take the pressures, but will falter when their judgment is tested in the spinning cage. They will be eliminated.

Still more will fail because they can't cope with the next machine, the personal-propulsion trainer.

What's so tricky about personal propulsion? The answer is almost everything—in space.

When a space vehicle circles the earth at the right distance and speed, it becomes a satellite, like the moon. A rocket ship 1,075 miles away, traveling 15,840 miles an hour, would circle the earth endlessly. Its speed at that distance would exactly counterbalance the earth's gravity. Once moving at the right speed, it wouldn't need power, because there's nothing in space to slow it down (as there is near the earth, where the atmosphere ultimately brakes the speed of any falling body). The ship would just stay up there, making one trip around the globe every two hours.

Suppose a man stepped out of the vehicle (protected by a space suit, of course). He, too, would be a satellite, spinning around the earth in the so-called two-hour orbit. He would remain in space, hovering near the rocket ship.

But suppose there were two rocket ships, and he wanted to move from one to the other. There's only one practical way for him to do it: each visitor to space will carry a small rocket motor in his hand. By firing it dead ahead, he'll make himself fly backward. When he wants to stop, he'll fire a short burst to one side. That will make him spin part way around. Two more pulls of the trigger—one to stop the spin, the other to halt his flight—and there he is.

It's complicated, and with a couple of hidden traps. What if he fires a trifle too high? He's apt to start tumbling end over end. If he holds his arm a little off to one side, he will spin like a top. If he fires sharply to the left or right, he may start cartwheeling. And it might be hard to stop.

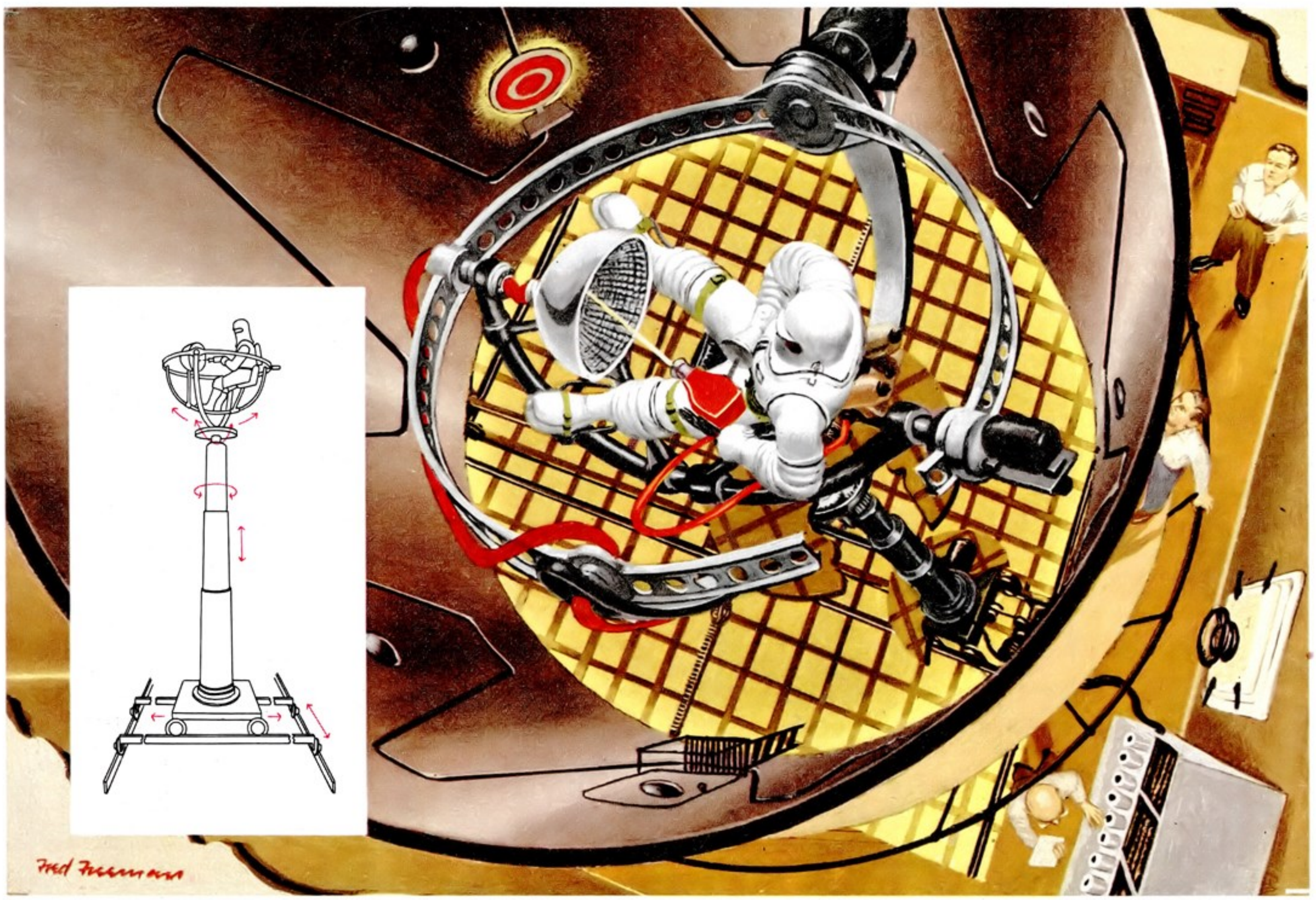
The way to prevent such mishaps is to train the crew members before they ever get into space. We can't duplicate the weightlessness man will experience as a satellite. But we can almost duplicate the spin, roll and pitch hazards of personal propulsion.

Instruction in Personal Propulsion

The student of personal-propulsion training, garbed in a bulky space suit, sits on a chair at the top of a slender telescoping pole. The chair is mounted within rings which enable it to roll sideways, or rock forward and backward. A system of rollers, elevators and gears also makes it possible to move directly backward and forward, or to either side; to go up and down, or to spin to right or left. In front of the student are concentric wire mesh screens studded with photoelectric cells which react to a light ray from the student's propulsion gun. The cells are connected to electric motors which set the chair in motion.

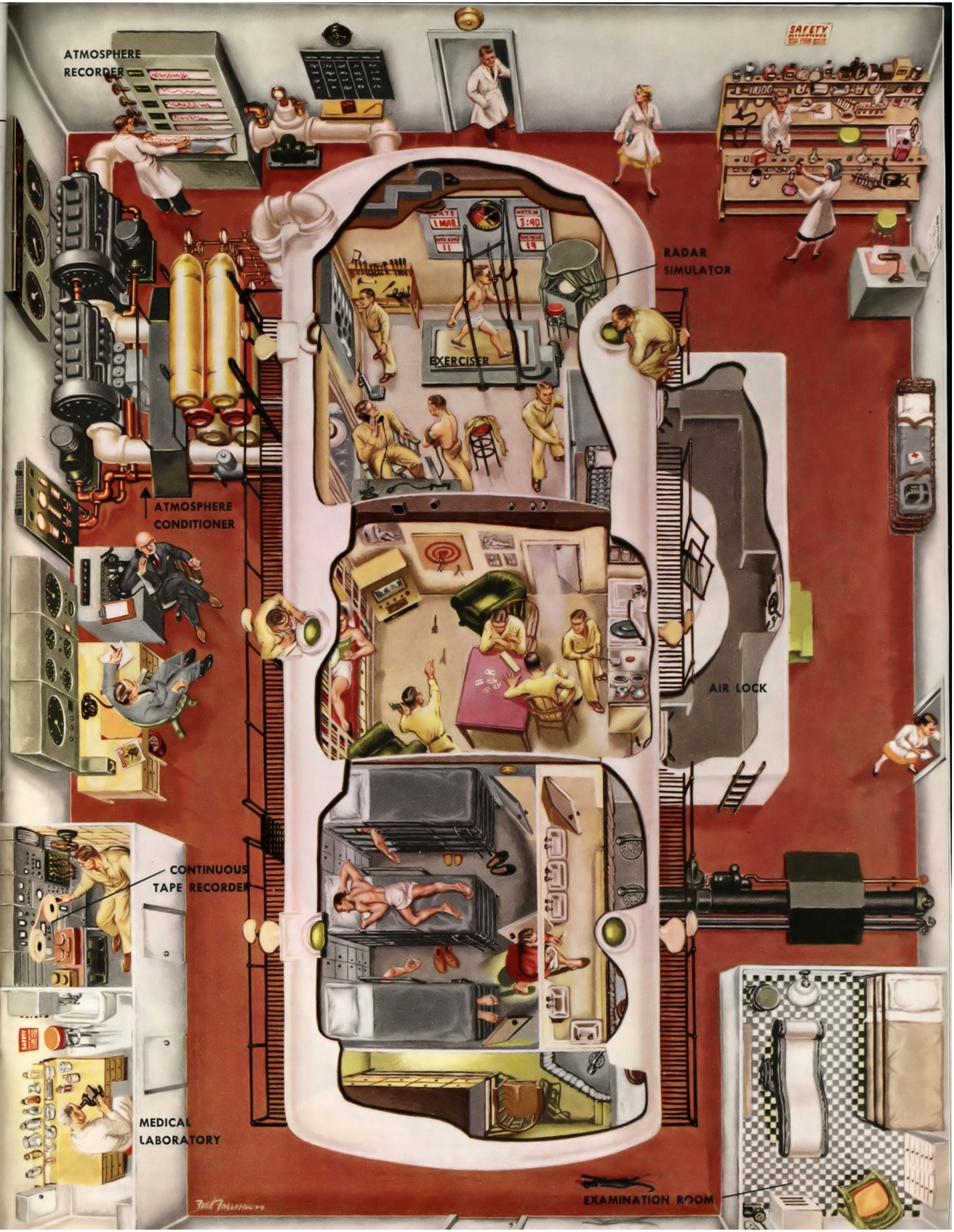
By firing directly in front of him, the student will propel himself backward. Any slight error in his

Crew trainees will stay for weeks on end in this sealed tank. Experts will observe how students react to each other—and to an air mixture of 40 per cent oxygen and 60 per cent helium (on earth, it's 20 oxygen, 80 nitrogen) ▶



Man wanting to go from one rocket ship to another in space will propel himself with rocket gun. This trainer teaches him to aim properly, avoid gyrations. To reach target, trainee shoots light ray—instead of rocket gun—at electric-eye dish. Bad aim makes him spin and roll

DRAWINGS BY FRED FREEMAN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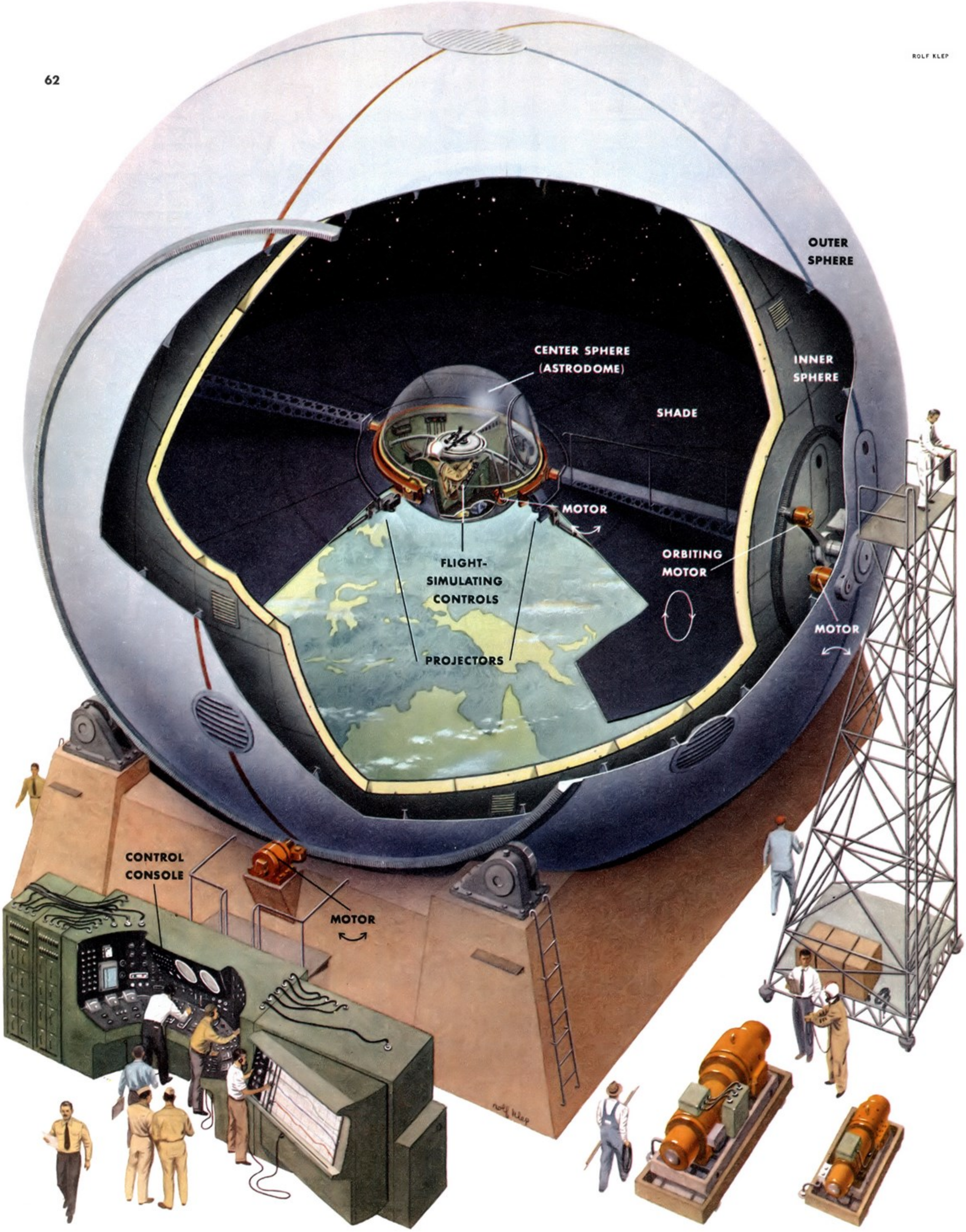

Navigator students will use this trainer—three concentric globes, all movable to simulate space flight. Trainee sits in center sphere, takes sights on stars and earth, which are depicted on inner sphere. Shade keeps light from the filmed earth picture from reflecting above aim will have the same effect as a comparable error in space: he'll spin, cartwheel or tumble.

There's one more aspect of personal propulsion which the simulator can't duplicate exactly. Suppose a man blasts himself backward and suddenly finds his gun is jammed or out of fuel. Unless other men become aware of the danger in time to rescue him, won't he go plummeting off into space with nothing to stop him? No, he'll wear a protective life line, tied to the rocket ship. Not only will it keep him from becoming lost; it also will extend his range, because he can use up the fuel in his gun, then float back to the ship with one tug on the line.

Personal propulsion is a problem space men and women encounter outside the rocket ship. They'll also have to adjust to life *inside* the vehicle, and another trainer will help prepare them for that.

What difficulties will they face? A much lower atmospheric pressure than they're used to; personality conflicts resulting from long periods spent in close quarters with the same few people; psychological reactions to a monotonous existence in a small area. Those are the main problems; there are also a few minor ones.

All of them (with the exception of weightlessness, which can't be reproduced on the ground) will be simulated in the next trainer, a crew pressure chamber. Ten to 15 men at a time will spend several consecutive weeks in the chamber, getting used to the cramped quarters—and to one another.

Why so long? A trip to the two-hour orbit, where we someday hope to build a permanent station, will take only about an hour. Why force the trainees to spend weeks together?

Because they probably will be the crews which—after the space station is built—will pioneer in interplanetary flight. A trip to Mars will take eight months, one way. The men of a crew will be under severe stress during such a trip, and we must know *now* which ones are able to take it.

Reasons for Ban on Women

Women, who may beat out men for certain crew jobs, won't go along on interplanetary journeys, where privacy will be lacking for long periods. So they'll take the chamber tests separately, and briefly, in preparation for the shorter flights that they will make.

The chamber will be like the interior of a rocket ship—functional, pressurized and cramped. Most of the pressure problems have been worked out by the physiologist-engineer team of Drs. Hubertus Strughold and Fritz Haber. The chamber's interior pressure will not be that of the earth at sea level, which is about 14½ pounds per square inch, because such pressure would impose too much of a strain on the junctions where pipes and tubes pass through the sides of a rocket-ship cabin. A pressure of about eight pounds will be used, equivalent to an altitude of 15,000 feet.

After a short adjustment period, most men can breathe comfortably at that altitude. Increasing the percentage of oxygen in our artificial atmosphere, from the 20 per cent a man is accustomed to on the ground to about 40 per cent, will make it easier.

There will be another change in the atmosphere, suggested by Willy Ley, noted rocket expert and writer. Instead of nitrogen, which makes up about 80 per cent of the earth's air, helium will be pumped in. Nitrogen in the blood tends to form bubbles when there is a rapid change in pressure (which might occur by accident in space), producing the painful—and possibly fatal—affliction known as the bends. Helium does not form bubbles in the blood as easily as nitrogen does, so it poses no problems.

The psychological problems of the sealed cabin are even more interesting than the physical. Men working under strain for long periods tend to become irritable and less efficient; in long-distance aircraft they generally start growling at one another after about eight hours, and show a marked loss of efficiency after about 15 hours. Some do better than others, and tests in the pressure chamber will enable us to pick the top men.

How about those who show signs of early strain, those who start sulking and finally lapse into an unsociable silence? Are they finished?

No, but special efforts will be required to match them to the proper crewmates. Psychologists have found that they can almost eliminate friction on aircraft crews by choosing men with like interests, background and education.

Cases of Claustrophobia Are Rare

Besides indicating their ability to work as a team, the trainees may display other psychological reactions to the chamber tests. A few rare cases of claustrophobia may develop, for example, although Dr. Donald W. Hastings, the Air Force's chief psychiatric consultant, expects such fear of confined space to be rare. The ability of the men to act in crisis situations may be tested again; if a man becomes sick, his fellow trainees will care for him (unless an emergency develops, of course). Temperature and atmosphere changes will be fed into the room to test the physical—and emotional—responses of the students. Routine flight problems will be passed to the trainees to keep them busy, and exercise machines will be available inside the chamber to keep them fit.

GEORGE WISLER

Air Force officers with model of new navigator-training plant, Wright Air Development Center, Dayton, O. Huge trainer is latest step in direction of navigation simulator on facing page

But no problems that a navigator solves in a pressure chamber will prepare him for those he encounters in flight. The fourth simulator is aimed primarily at him, although other crew members will use it.

The navigation simulator consists of three spheres: a large globe, 30 feet in diameter, with two concentric spheres inside. The smaller of the two inner spheres, measuring about six feet across, is the navigator's compartment, or astrodome. The larger, which fits just inside the exterior globe, is, in effect, a great picture of the universe, with the earth looming large below.

The inside of this middle sphere is pitted with small holes through which light shines, to simulate the constellations. The earth is depicted by color movie film, projected against the inner skin of the sphere.

The big picture-sphere makes a complete rotation every two hours, so that the student navigator gets the illusion of starting in the two-hour orbit.

For the navigator, rocket flight will differ from aircraft flight in several important respects.

First, he won't have the usual landmarks and radio aids; his only points of reference will be the earth below and the stars above.

Second, during the outward flight, the normal navigational problems have been solved in advance and worked into the automatic pilot; so almost all the navigator's work will occur just before and during the rocket ship's return earthward from space.

The homeward journey is begun by cutting the speed of the rocket ship, so it no longer is moving fast enough to continue as a weightless satellite; it then starts to fall out of the orbit, toward the earth. The speed is reduced by turning the vehicle tail-end-to, so that the rocket motors point in the direction of movement, and employing a short burst of power. The strength and duration of the rocket thrust—if properly aimed and timed—will put the vehicle precisely on course for its destination on the earth.

The navigator's main job is to make the aiming and timing as nearly accurate as possible; if that's done correctly, the rest of the homeward navigation will virtually take care of itself. If his initial calculations are wrong, there may be trouble, for the rocket carries very little fuel on the return trip and it may prove difficult to correct the course. Obviously, the departure timing depends on what part of the earth is opposite the vehicle; under certain conditions, the problem is so complicated that the navigator must wait for a better moment.

A Test in the Astrodrome

In training, the student navigator will take his seat within the astrodome, and instructors outside will set up a problem by moving the stars to a certain position and by selecting a specific picture of the earth to be screened below him.

From then on, the trainee operates the simulator. He determines his present attitude (*attitude*, not altitude) by taking sights on the stars and the earth. Then he decides on his desired attitude for time of departure, and aligns the ship properly, by pressing buttons on a control panel at his right. In a real rocket ship, the buttons would cause the ship to tilt to the desired position; in the simulator, the pictures of the stars and earth shift instead.

The navigator then checks his exact location in space by radioing to the ground, confirms his timing calculations—and is ready to go.

Every move that he makes will be charted on the panel outside. New problems and emergency situations may be posed by the instructors, and careful measurements will be kept of his position, to determine the degree of error in his calculations.

For most of the crew members, the navigation trainer will be an interesting machine whose main purpose will be to familiarize them with the kind of scenery they'll see in space. For the navigator trainee, fighting to keep from being eliminated, it will be a major obstacle. Some navigator students will wash out.

By the time all the trainees have passed through all the simulators, only five will be left of the 60 who started the course (and of the 1,000 who originally applied for it).

Now comes flight training.

Next Week **Disaster can strike in space, as it can anywhere else. How does a rocket crew save itself when its vehicle starts blowing up at a speed of 15,000 miles an hour, 1,000 miles from solid ground? Scientists tell the answers**

Collier's

MARCH 14, 1953 • FIFTEEN CENTS

Who Will Be THE NEXT POPE?

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How Man Will Meet EMERGENCY In Space Travel

•

What Is Your SEX IQ?

March 14, 1953

ARTICLES

FICTION

The characters in all stories and serials in this magazine are purely imaginary. No reference or allusion to any living person is intended.

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The Cover

Inbound from space, a fast-moving rocket ship noses down toward the earth, its crew alert—as always—for signs of danger. Disaster won't occur often in space, but rocketeers will be prepared: most of the paraphernalia shown in the cutaway sections of artist Fred Freeman's picture is emergency equipment. To see how it is used, turn to Emergency! on page 38.

Week's Mail

Survival in Space

EDITOR: Your article of February 28th on the dangers which human beings will encounter in flights at high altitudes (Man's Survival in Space) should go far to debunk the exaggerated fears prevalent in some quarters. Especially significant is the point that cosmic radiation, even at its worst, will not produce an important amount of damage to the hereditary constitution which later generations receive.

Unfortunately, however, the reason for this conclusion is stated in a misleading way. It is true, as your article states, that even a large amount of radiation would seldom produce striking abnormalities in the descendants of an exposed person. Yet this does not imply the absence of important damage. Even though the harmful changes resulting from a high exposure were hard to detect, they would be distributed over so many descendants that the total harm done would be very serious, and would usually include several premature deaths. That is why the present writer has always maintained that in the medical use of X rays more efforts should be exerted to keep the exposures as low as possible.

The real reason why the effects of cosmic radiation on heredity are not to be feared is because it would take so tremendous a time before a person could absorb any considerable amount of this radiation. An X-ray examination of the abdomen by a fluoroscope commonly delivers more radiation to the reproductive cells than six months' continuous exposure to cosmic radiation would give.

H. J. MULLER, Indiana University,
Bloomington, Ind.

In editing Dr. Muller's contribution to the Man in Space symposium, Collier's inadvertently omitted the words "in space" from his statement that a man exposed to radiation for a long time would rarely pass on marked changes to his descendants.

The Barrier of Language

EDITOR: Your editorial Barriers to Western Unity (Feb. 7th) is excellent and timely. The next to the last sentence in the article stands out: "They must cultivate friendly relations and mutual understanding."

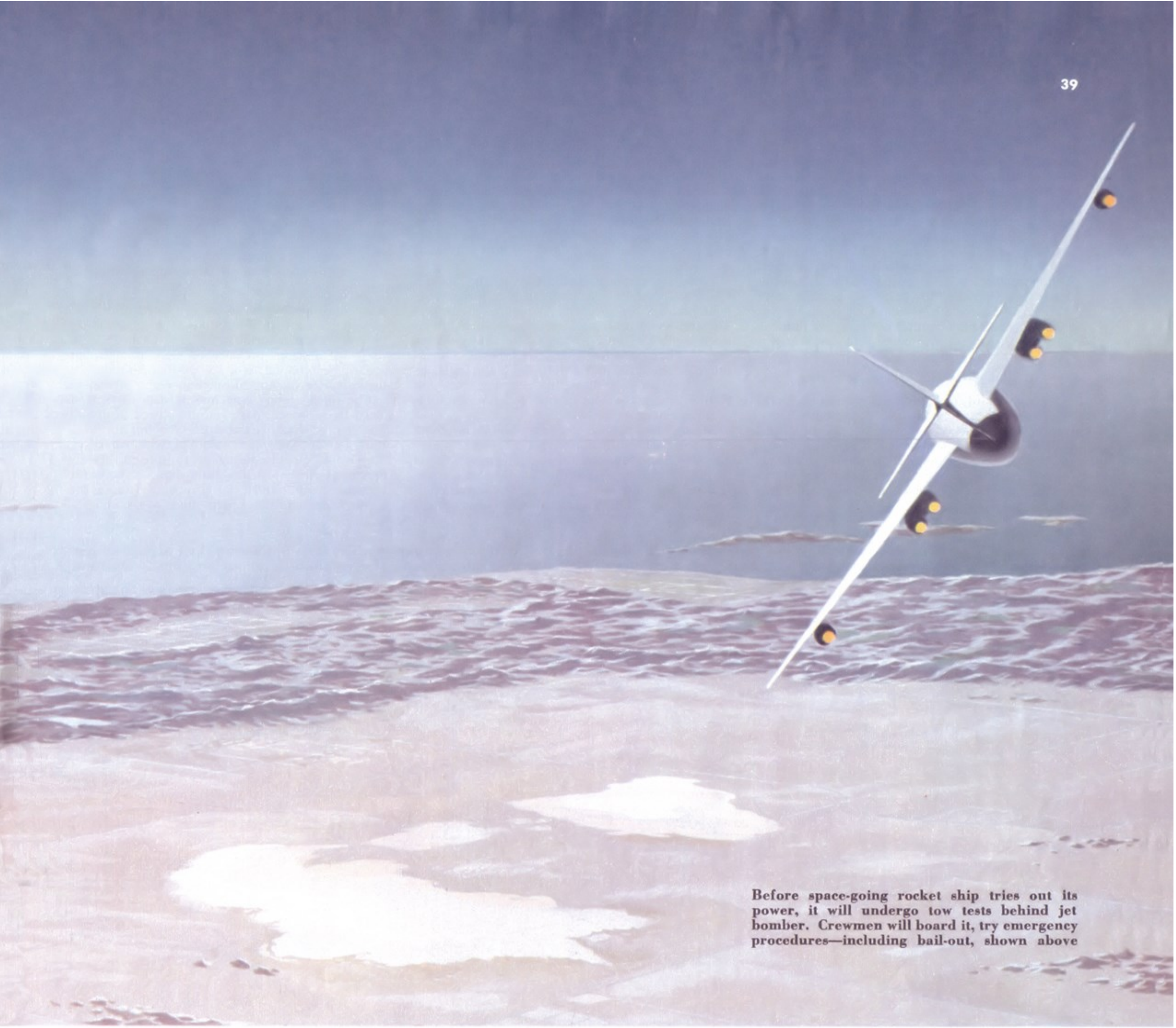
There seems to be one serious problem to uniting the West European nations. They will never cease being suspicious of one another as long as they cannot understand one another. They need a common, easily and quickly learned language that in itself would help bind them together.

Many will say this would take too long and that our present problems are

Man's Survival in Space

EMERGENCY!

Authorities whose papers were the basis for this article, last of a three-part series, are Dr. Wernher von Braun, chief of the Army Guided Missiles Laboratory; Dr. James P. Henry, of the Air Force Aero Medical Laboratory and rocket expert Willy Ley. Contributors to the other two parts included Col. Don Flickinger, Director of Human Factors at the Air Force Air Research and Development Command; Capt. James E. Sullivan, director, Airborne Equipment Division of the Navy Bureau of Aeronautics; and Drs. Hermann J. Muller of Indiana University; Hubertus Strughold, head of the Air Force Department of Space Medicine; Fritz Haber of the same agency; Donald W. Hastings, National Psychiatric Consultant to the Air Force; James Van Allen of the State University of Iowa; and Heinz Haber of the University of California. The material for the entire series was collected by Collier's Cornelius Ryan



Before space-going rocket ship tries out its power, it will undergo tow tests behind jet bomber. Crewmen will board it, try emergency procedures—including bail-out, shown above

What happens when disaster strikes in space? Can the crew of a 15,000-mile-an-hour rocket ship bail out or land their disabled craft? Here, for the first time, famous scientists disclose the answers

A ROCKET ship is cruising serenely through space at 15,000 miles an hour, its crew relaxing within the pressurized cabin. Suddenly the calm is shattered by an explosion: one of the double-paned portholes has blown out; in an instant the artificial atmosphere has vanished and the five men are exposed to the blood-boiling, suffocating vacuum of space. What can they do?

Or suppose the time is shortly after launching; the ship is picking up speed on a vertical flight path—and suddenly the fuel lines feeding the roaring bank of rocket motors burst into searing flame! Can the crewmen trapped inside bail out—or, perhaps, bring their multimillion-dollar vehicle in for a successful crash landing?

What can men do when disaster threatens their rocket ship during a supersonic dash through the atmosphere, or in the strange, airless environment of space?

If the crew is well trained, there are few emergency situations that can't be licked. The captain may have to make hair-trigger decisions; it may be necessary to throw away machinery and equipment that cost millions of dollars and years of work to develop; it may be necessary to take risks. There'll be plenty of excitement. But for almost all foreseeable crises, there will be an emergency procedure providing a good chance for safety. *If* the crew is well trained.

The first space crews will be more than well trained. They'll be selected with infinite care, superbly conditioned, educated in the special problems of space for five years. Every ground training device our scientists can conceive will give them the feel of space flight—and the problems of space flight—before they ever step into a rocket ship (Collier's, February 28, March 7, 1953).

But the big moment, and the best preparation for danger, will come when they get aboard a space vehicle and go roaring skyward.

There will be some preliminaries. Before they start space flights, the pilot and copilot, both jet-trained, will take many hours of transition flying in single- or double-seat supersonic rocket planes like the present Bell X-2 and Douglas Skyrocket.

Rocket flight is different from any other flight, and the important difference is that it's unpowered, except for a few minutes. (Three rocket blasts lasting a total of five minutes will carry a rocket ship beyond the earth's dense atmosphere; then it will simply coast the rest of the way to its destination.)

Flying in small rocket-powered aircraft, the crew captain and his copilot will learn to expect a sudden power cutoff after a brief burst—and will learn to make every landing glider-fashion, without power, as all rocket pilots must.

Then, with the rest of the crew, the two men

PAINTING BY CHESLEY BONESTELL

will climb aboard their new space-going rocket ship—but not for rocket-propelled flight.

The pioneer space crews and the first space ships will be developed together. All the time the men—and women; they'll probably be on rocket crews, too—are taking their training, engineers will be hard at work perfecting the vehicles. Crews and ships will be ready to undergo testing at about the same time. They'll do that together, too.

The vehicle that takes man into space will consist of three sections, or stages. Two of them will simply be power packages which will hurl the third section spaceward at a great speed and then be discarded. Only the third stage will actually enter space; it will carry the crew and cargo, and it will have wings and other control surfaces, like those of an airplane, necessary to make landings on earth.

A Start in Basic Escape Training

Since the third stage poses the greatest engineering problems, it will be the first section built. Once it's considered ready for flight, it will be towed aloft by a powerful jet bomber and put through a series of tests. The crew will board it at that time, to get used to it, to help the engineers perfect the internal layout, and—especially—to start basic escape training.

After each test is finished, the towrope will be cast loose and the two pilots will make the unpowered landing at the home base.

Finally, the day will come when the third stage and its crew are ready for a rocket launching. The ship will be set on a launching platform, tail down, nose pointing skyward. A few final checks, a moment's pressure on a button beside the captain's chair and the four main rocket motors will roar. The needle-nosed ship will rise slowly into the air, picking up speed rapidly until it hits 4,000 miles an hour.

From the moment the craft leaves the ground, the crew must be prepared for breakdowns, for malfunctions, for the early symptoms of danger. The trip—and each such third-stage flight thereafter—will last only about 20 minutes; there's barely enough fuel for a 300-mile trip, up to an altitude of about 30 miles. Into the few minutes of flying time on each flight, the crew members will cram an intense course in emergency procedures.

What emergencies?

Most of the troubles that can crop up in rocket flight are fairly easily handled. Instrument failure? The ship has double sets of instruments—two sets of flight instruments for the captain and copilot, and two of functional instruments for the engineer. Pump trouble may affect a space-bound rocket ship so that it can't make its destination; it will remain aloft long enough to burn up its heavy fuel load, then, light enough to land, it will return to base.

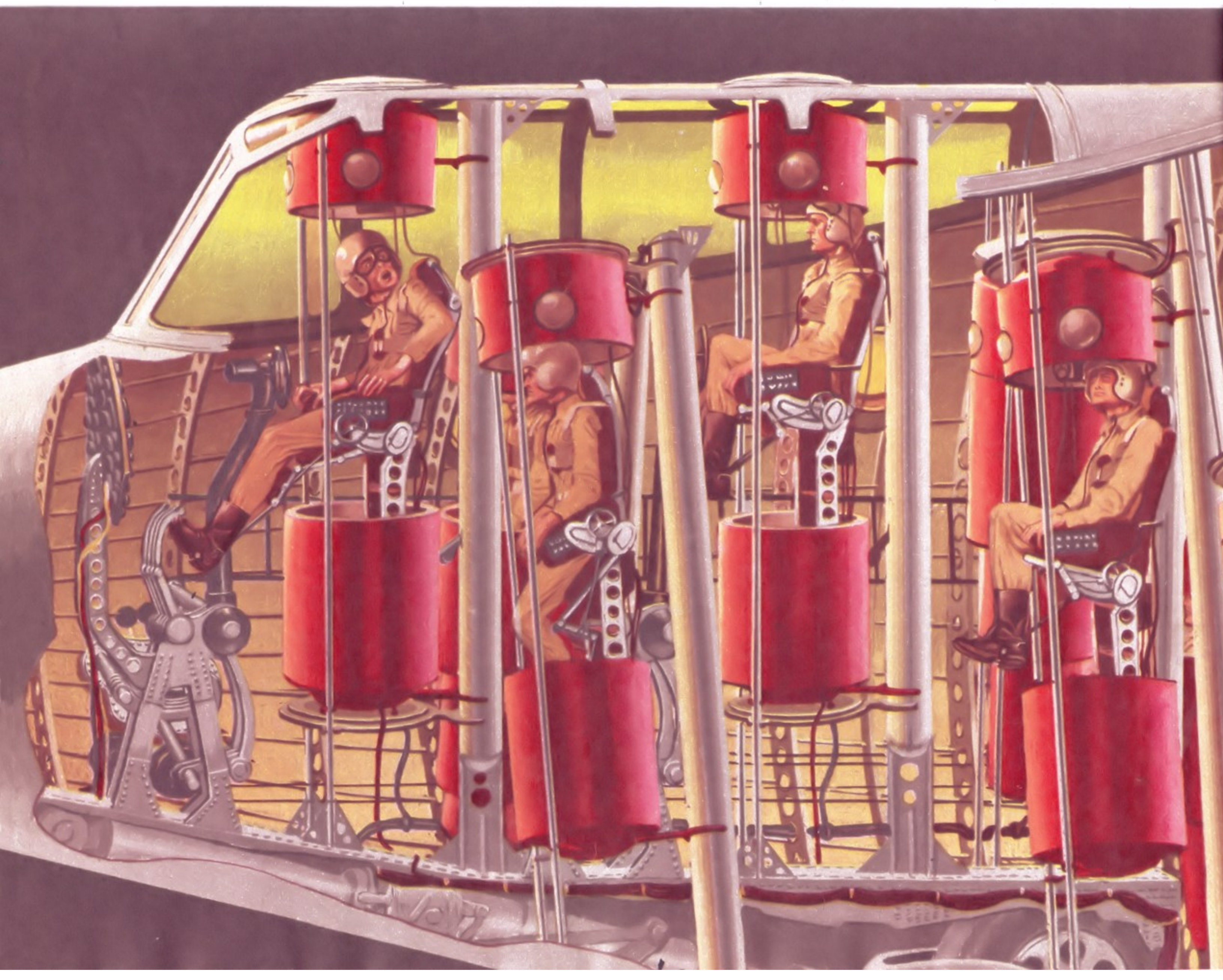
But four difficulties may spell real danger: mechanical trouble in the power plant or hull; failure of specific pieces of electrical equipment for which there are no duplicates; fire, and the sudden loss of cabin pressure. Fortunately, all such breakdowns should be rare.

Effects of Sudden Decompression

Swift decompression could be caused by the accidental opening of an escape hatch or by the sudden blowout of a porthole. It would subject the crew to an enormous pressure change: from the normal cabin pressure of eight pounds per square inch (equal to a 15,000-foot altitude) to the complete vacuum of outer space.

Can men stand such instant decompression? Tests have proved that carefully picked men can. The change would be uncomfortable but not fatal. But unless the crewmen could find swift protection, they would quickly die from exposure to the low pressure, which provides little or no oxygen for breathing, and which very quickly causes the blood, saliva and other body fluids to boil. Space

In emergency (as when broken porthole lets cabin pressure escape, as pictured), crewman and passengers press buttons on chair arms; contour seats straighten automatically, capsules clap shut, seal. Capsules are connected to cabin pressure system, also have own pressure for bail-out



suits? They'll be invaluable in space, to keep men supplied with pressure and oxygen outside their pressure cabins, but they won't be worn inside a rocket ship; they're too clumsy in such cramped quarters under conditions calling for fast movement. And they take a long time to put on.

The solution is a fast-closing personal pressure cabin for each man. Such a cabin already has been designed by Dr. Wernher von Braun, one of the world's foremost rocket engineers. The moment a crew member becomes aware of the cabin leak, he will press two buttons, one on each arm of his contour chair. One button would do, but two will force the crewman to pin both arms to his sides. That's important, because the instant the buttons are pressed, the chair will straighten slightly, and two metal cylinders will zip out of the floor and ceiling and snap shut around the man, encasing him completely in a sealed tube. The tube, called an emergency capsule, is connected to the ship's central air supply. It also has its own pressure-atmosphere system, if needed.

The capsule protects the crew member from the low outside pressure—but isn't he helpless?

Far from it. All the control switches he has been using to do his assigned job are located on the arms of the chair, and the chair arms are inside the capsule with him. Even before the cylinder clapped shut, the control wires were connected to the ship's electrical system through breakaway plugs at the bottom half of the capsule. Chances are good that, even encased within their capsules, the crew members can save the ship.

At the very least, the captain can start back for the earth; when the space craft descends below 20,000 feet, he and the other crew members can emerge from their metal shells and bring the ship in for a normal landing.

Landing May Be on Space Station

Suppose he has a destination in space. Once scientists have the first space-going ships in operation, they will start building a permanent station 1,075 miles from the earth, as a combined military observation point and astronomical observatory (Collier's, March 22, 1952). The station will circle the globe endlessly, once every two hours—an unpowered satellite, like the moon. If our decompressed rocket ship is on its way to the satellite, it might be wise to continue on course. After its arrival, the crew members in their capsules will be removed from the damaged vehicle by space-suited men from the satellite, and taken to the pressurized station. The rocket ship will be repaired before its return flight.

With proper emergency equipment, decompression can be licked fairly simply.

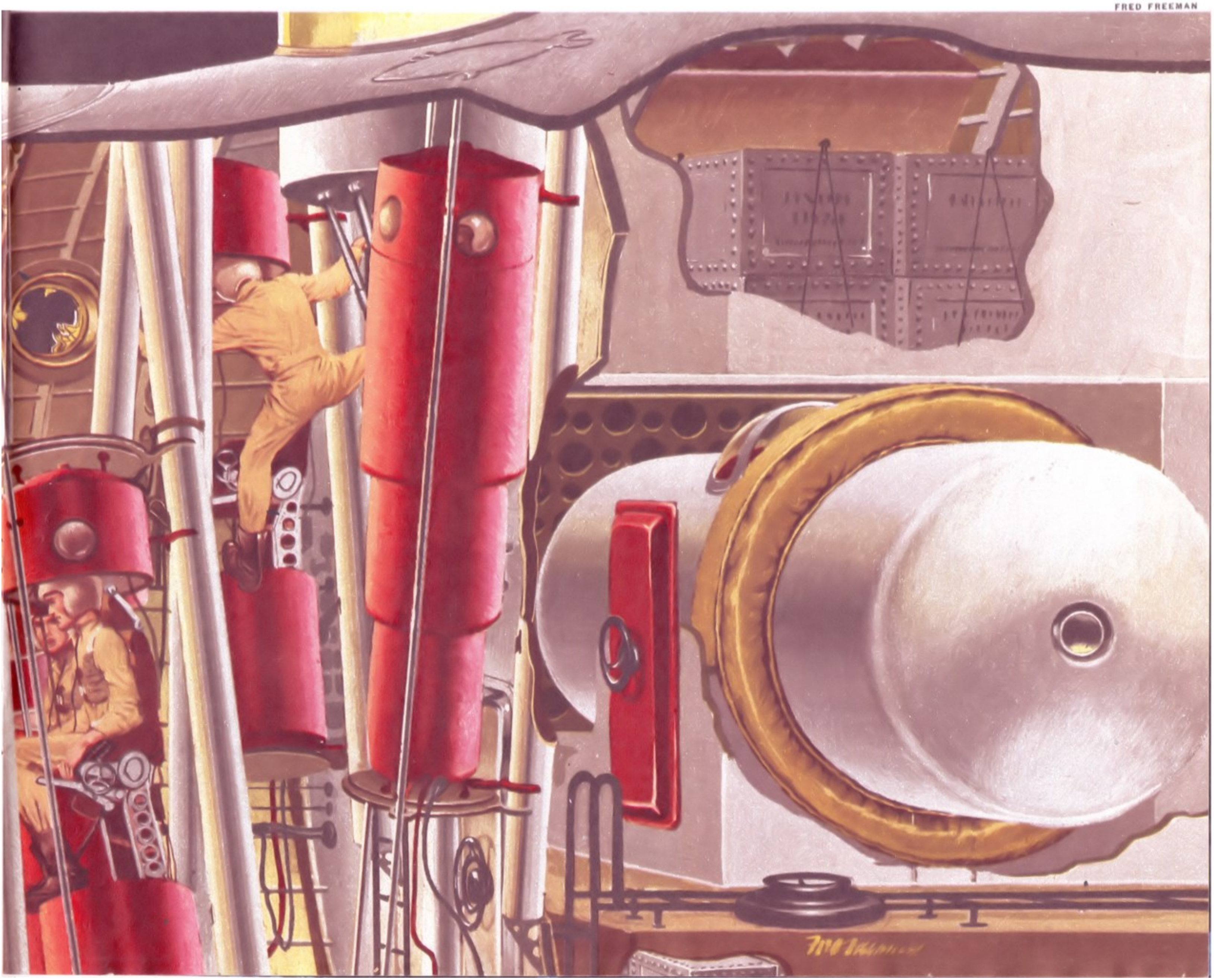
Fire is something else again. Suppose the turbine driving the fuel pump flies apart and a hot splinter rips through the fuel tanks. A stream of ammonialike hydrazine would engulf the motor and fuel systems in searing flame. What then?

It depends on where the fire is located, how bad it is, how bad it's likely to get—and where the rocket ship is in space. The ship starts its flight from the ground with three sets of rocket motors, mounted one behind another. The first part of each flight is over the ocean. The bottommost, or first, stage provides power until it runs out of fuel, then drops into the sea. The second stage takes over, to be discarded in turn two minutes later. If fire occurs in either of the first two stages, the pilot will immediately jettison it. If he works fast enough, that will end the danger. He will glide the third stage back to earth, after dumping most of its fuel.

But what if the blaze starts just after departure, with the ship only a few thousand feet off the ground? A jettisoned stage, especially if it's aflame, might wipe out the entire launching installation—and hundreds of men. For the rocket captain, it's a tough decision: if he waits too long, he and his crew (and their costly vehicle) might be lost; if

To abandon ship, men push another button. Capsules, guided by rails, are ejected by powder charge, drop safely into ocean with men inside. When possible, men will remain in ship, operating controls from within capsules, until they are close enough to the earth to land normally

FRED FREEMAN



Emergency capsule is ejected from rocket ship with crewman inside, drops into sea. Speed is slowed by metal chute, impact is cushioned by small rocket in capsule base. The picture shows radar-equipped plane, rescue vessels converging on area to pick up four crew members—one in sea, two being slowed by rockets, and one (foreground) still so high rocket hasn't blasted yet. Cutaway shows man in capsule, strapped to contour chair, with rocket and frozen air under feet. Metal arms on base guide capsule during ejection

An ingeniously engineered bail-out device gives the rocketeer his margin of safety

he acts too quickly, he may cause catastrophe on the ground. His best bet is to turn the rocket into a shallow flight path, and attempt to cast loose the burning section where it can do no harm.

Luckily, fires are likely to be rare. Most of the risk comes during launching, and for the five minutes after launching, when the motors are operating and quantities of fuel remain. How about an explosion? The two propellants, nitric acid and hydrazine, are in separate tanks; a hot fragment of metal wauld have to pass through both sets of tanks, causing the propellants to mix, before an explosion could occur. The fragment would have to be traveling at terrific speed.

Yet it *could* happen. If it did, there probably would be no emergency procedure: rocket ship and crew would be blasted to bits instantly.

If fire or explosion should occur, it will probably be on the way up, while the ship is still in the atmosphere—almost never in space, or in the atmosphere on the way back. First, after the ship has left the atmosphere outbound, there will be little fuel left to burn—just enough for brief maneuvering and to provide insurance against a bungled landing attempt on the return to earth. Second, there's no oxygen in space to kindle the flame. Third, the motors won't be running, which means no pumps to spray fuel out of a leaky connection, and no working parts to start a fire even if there is a flow of fuel.

If decompression and fire are both unlikely—and easily manageable when they do happen—what other dangers are there?

Helpless Without Electric Power

Electrical equipment can fail. If the equipment isn't duplicated on the rocket ship, the failure could cause serious trouble. Some of the navigator's most vital instruments are electrically operated, and could not be easily replaced in flight. If one of them suddenly broke down, the navigator might be almost totally unable to operate; he would have to depend on advice from the ground. But the radio is electrical, too. It could fail, halting all communication with the home base. Even under the most favorable circumstances, the navigator relies on some ground help for difficult computations; if he were deprived of this help, he could use only rough estimates for the exceedingly tricky navigational problems of space flight.

Or the electrically operated valves between fuel tanks and pumps could break down, stopping the motors.

Actually, motor trouble could be caused by many kinds of breakdown. Among the possible hazards of space flight, it falls in a major category of its own, posing problems something like those caused by fire.

If motor failure occurs during the first seconds after take-off—catastrophe. If it happens later during the ascent, the captain probably would jettison the stricken stage, pump out excess fuel and head in for a landing.

The most complicated situation occurs when the third stage is out in space and lacks the power to maneuver into a circular orbit around the earth. What happens then?

Eventually it would start back around the earth, pulled by gravity into a lopsided orbit, about 1,100 miles from the earth on one side and 60 on the other. On the low side of the orbit, the ship would drag briefly through the atmosphere, and that would slow it down slightly. After perhaps 24 hours, and a dozen round trips, it would be low enough so that the control surfaces would take hold in the denser air. The pilot might then be able to land the ship like an airplane.

During this long flight, the damage which caused the power failure could prove much greater than first believed, possibly bad enough to ruin any chance of landing. Other rocket ships would hurry to the rescue. They would be launched into the same orbit, their departures timed with scientific care to enable them to overtake the disabled vehicle. All the vehicles and their crews would be weightless in the uneven orbit, so it would be a fairly simple matter to transfer the men from the stricken craft to a rescue ship. Space-suited rescue crews would remove the crew members of the damaged rocket vehicle, capsules and all, through escape hatches, and would then carry the cylinders to the safety of the pressure cabins in their own craft.

But what if rescue is impossible? A rocket crew which found itself in a lopsided orbit would stay in the ship as long as possible, even if it began breaking up as it swept through the atmosphere. They would have little choice. Rocket expert Willy Ley estimates that crew members who bailed out would stay in the uneven orbit for almost three days; after the first half hour, they would be dead inside their capsules for lack of oxygen.

At best, bailing out of a disabled space vehicle is far more difficult than parachuting from an airplane. A man who jumped from a rocket ship at thousands of miles an hour would almost certainly collide with part of the vehicle. That would mean instant death. Suppose he was thrown free of the ship. At an extremely high altitude, he would die anyhow, and almost as fast—his lungs gasping for air, his body fluids set aboil by low pressure. Would a pressurized space suit save him? Only for the moment. Plummeting earthward, he would plunge into the dense atmosphere at terrific speed; the friction would toast him, scorch him and finally set his clothing furiously ablaze.

Then how would he bail out?

In the same emergency capsule he uses inside the cabin. A powder charge hurls him away from the speeding ship. As he tumbles through space, artificial atmosphere guards him from the dangers of low pressure. A light steel parachute steadies the

U. S. NAVY PHOTO

Ejection seat, similar in principle to escape capsule, being tested by Navy. Military services use ejection for bail-out from fast jet planes

Will the escape cylinder work in the upper altitudes? A similar capsule already has

capsule and brakes his speed as he enters the earth's envelope of air. Insulation keeps him cool. Just before he strikes the earth, a self-starting rocket jet cushions the landing. If he lands at sea, the capsule floats easily on the swells, and a radio signal beckons rescuers.

Suppose an earthbound third stage runs into serious difficulty at an altitude of about 50 miles, and it's impossible to land. The captain immediately slams the bail-out bell. Within seconds, the crew members have clapped shut their capsules. Once encased, they can operate the ejection buttons—and at a hasty signal from the captain, they do so. The powder charge hurls each cylinder free of the disabled ship, through a hatch. The opening is promptly sealed tight by a lid which closes automatically behind the departing capsule.

At the moment of bail-out, the rocket ship has been following a course which almost parallels the earth's curvature. The cylinders take the same course for several hundred miles before they start down, their progress slowed by a four-foot steel-mesh parachute.

As the capsule plows through the dense atmosphere, it begins to glow, and soon it becomes red hot. Inside, the crew member is protected by glass-wool insulation, and by lumps of solidified air, which has been frozen at a temperature of 363 degrees below zero F.

Approaching the earth's surface, the capsule falls at a rate of 150 feet per second. That's too fast; a man striking ground at that speed probably would be killed. But 150 feet off the ground, a proximity fuse sets off a small rocket in the foot of the capsule; the blast of the rocket slows the rate of fall, and the landing is fairly gentle. It's especially gentle if it occurs in the ocean, and rocket-ship captains who have the choice will attempt to bail their crews out over water.

Equipment in the bottom of the capsule serves as ballast and gives the cylinder stability in high seas. An automatic radio system guides rescue boats to the floating tube. A release catch opens the capsule's portholes, to let air in.

The emergency capsule will be used only rarely for escape. When they can, the crews will attempt to bring damaged ships back to land, and usually it will be perfectly practical to do so. Not only will emergency landings save many millions of dollars' worth of machinery and equipment—they will also protect the crew members from certain hazards of capsule bail-out.

For example, a man who ejects his capsule from a rocket ship which is speeding earthward at too steep an angle might be killed by the jarring impact of his collision with the atmosphere, or by the tremendous friction heat. Wherever possible, the captain will pull up his injured ship, so the crew members will be cast out at an angle which will permit them to enter the atmosphere gradually.

Then suppose the capsule, instead of landing in water, strikes down on solid ground. The touchdown will be gentle, but the man inside could be badly shaken up as the big tube flops over on its side. Or suppose it lands on a mountain, or on the roof of a house, and goes tumbling down the side?

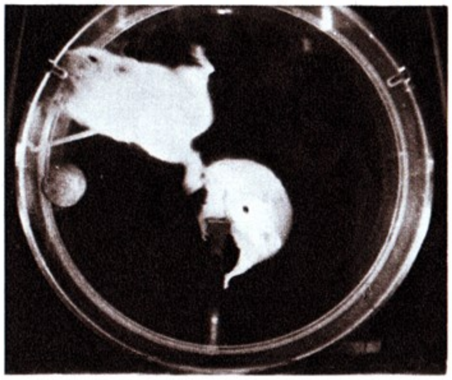
Those landing risks will be extremely slight, statistically. Yet they'll worry the crew members. So will the possibility of equipment failure within the capsule. So will almost everything else about the cylinder.

The mental hazard will be one of the most important deterrents to the use of the capsules for bail-out. They will be psychologically offensive: coffinlike, cramped, stuffy and uncomfortable. The men inside them, once ejected from the ship, will be completely helpless. It will be a horrible feeling.

RALPH ROYLE

Monkeys Pat and Mike (shown with Lt. Johnie Reeves and A/1c Marshal Ross) went to 35-mile altitude in rocket like one in photo, were safely ejected in capsule

Two mice traveled with monkeys in rocket, were photographed while experiencing weightlessness (below, left) and again as their weight returned on the way down



U. S. AIR FORCE PHOTOS

Saga of Two Monkeys—Pat and Mike

But the capsule *will* work when nothing else does. In fact, it has worked—at least, a capsule very much like it has.

Last May, two monkeys were sent to an altitude of 35 miles aboard an Air Force Aerobee rocket, at a speed of 2,000 miles an hour. The animals, named Pat and Mike, were seated in the projectile's nose, which was triggered to break away shortly after the rocket started back to earth. The nose capsule, with the monkeys slightly anesthetized to keep them from becoming excited, broke loose on schedule. It hit a peak speed of 1,000 miles an hour before a parachute (serving the same purpose as the steel-mesh umbrella on the man-sized capsule) broke the fall. The breaking impact was equal to about five times the monkeys' normal weight, but they were unharmed. They drifted safely back to earth, and are still alive and healthy (so healthy that they're too big to get into the capsule now).

The test, conducted by a team of biologists and engineers headed by Dr. James P. Henry, Air Force physiologist, proved the practicality of escape by capsule, and gave scientists other information about space travel as well. Both the monkeys and a couple of mice, who also were passengers in the capsule, experienced weightlessness for about two minutes, with no ill effects. They also endured an acceleration shock at launching far greater than that man will experience: they were flattened by a force 13 times their own weight, compared with the ninefold weight increase man can expect on his journeys spaceward, and the tenfold pressure he might feel as a capsule smashed into the atmosphere.

Pat and Mike were among the first living visitors to the extreme altitudes. The two creatures briefly experienced all the major difficulties of space travel—acceleration pressure, weightlessness, life in an artificial atmosphere. Nothing bothered them. Many more animals are sure to be rocketed into the earth's newest frontier.

After them will go the men.

Collier's

JUNE 27, 1953 • FIFTEEN CENTS

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A DOZEN LAUGHS WITH BASEBALL UMPIRES

Collier's

June 27, 1953

ARTICLES

FICTION

The Cover

Its curved mirrors reflecting the starlit blackness of space, man's first artificial satellite sweeps over the East Coast of the United States—Boston, New York and Philadelphia are all visible—busily sending scientific reports to the experts waiting below. Altitude: 200 miles; speed: 17,200 mph; duration of flight: 60 days. Those are the bare statistics; the exciting story starts on page 33.

BABY SPACE STATION

By Dr. WERNHER von BRAUN with CORNELIUS RYAN
Chief, Guided Missiles Development Division, Redstone Arsenal, Huntsville, Alabama

An unmanned rocket, whizzing around the earth 200 miles high, pouring vital facts back to ground stations . . . Scientists now know that's the first step in the conquest of space

WE ARE at the threshold today of our first bold venture into space. Scientists and engineers working toward man's exploration of the great new frontier know now that they are going to send aloft a robot laboratory as the first step—a baby space station which for 60 days will circle the earth at an altitude of 200 miles and a speed of 17,200 miles an hour, serving as scout for the human pioneers to follow.

We rocket engineers have learned a lot about space by shooting off the high-flying rockets now in existence—so much that right now we know how to build the rocket ships and the big space station we need to put man into space and keep him there comfortably. We know how to train space crews and how to protect them from the hazards which exist above our atmosphere. All that has been reported in previous issues of Collier's.

But the rockets which have gathered our data have stayed in space for only a few minutes at a time. The baby satellite will give us 60 days; we'll learn more in those two months than in 10 years of firing the present instrument rockets.

We can begin work on the new space vehicle immediately. The baby satellite will look like a 30-foot ice-cream cone, topped by a cross of curved mirrors which draw power from the sun. Its tapered casing will contain a complicated maze of measuring instruments, pressure gauges, thermometers, microphones and Geiger counters, all hooked up to a network of radio, radar and television transmitters which will keep watchers on earth informed about what's going on inside it.

Speeding 30 times faster than today's best jets, the little satellite will make one circuit around the earth every 91 minutes—nearly 16 round trips a day. At dawn and dusk it will be visible to the naked eye as a bright, unwinking star, reflecting the sun's rays and traveling from horizon to horizon in about seven minutes. Ninety-one minutes later, it completes the circuit—but if you look for it in the same place, it won't be there: it travels in a fixed orbit, while the earth, rotating on its own axis, moves under it. An hour and a half from the time you first sighted the speeding robot, it will pass over the earth hundreds of miles to the west. The cone will never be visible in the dark of night because it will be in the shadow of the earth.

If you live in Philadelphia, one morning you may see the satellite overhead just before sunup, moving on a southeasterly course. Ninety-one minutes later, as dawn breaks over Wichita, Kansas, people there will see it, and after another hour and a half it will be visible over Los Angeles—again, just before the break of dawn.

That evening, Philadelphians—and the people of Wichita and Los Angeles—will see the speeding satellite again, this time traveling in a northeasterly direction. The following morning, it will

CHESLEY BONESTELL

Ready for launching. Rocket is divided into three sections (separated by red bands), each with its own set of motors. Lower two will be cast off when their power is spent. Only the topmost cone—equipped with TV cameras, other instruments—will get to 200-mile orbit

Monkeys in the trail-blazing satellite will prepare the way for the men who follow

be in sight again over the same cities, at about the same time, a little farther to the west. After about ten days, it will no longer appear over those three cities, but will be visible over other areas. Thus, from any one site, it will be seen on successive occasions for about 20 days before disappearing below the western horizon. In another month or so, it will show up again in the east.

And while you're gazing at the little satellite, it will be peering steadily back, through a television camera in its pointed nose. The camera will give official viewers in stations scattered around the globe the first real panoramic picture of our world —a breath-taking view of the land masses, oceans and cities as seen from 200 miles up. More than likely, commercial TV stations will pick up the broadcasts and relay them to your home.

Three more cameras, located inside the cone, will transmit equally exciting pictures: the first sustained view of life in space.

Three rhesus monkeys—rhesus, because that species is small and highly intelligent—will live aboard the satellite in air-conditioned comfort, feeding from automatic food dispensers. Every move they make will be watched, through television, by the observers on earth.

As fast as the robot's recording instruments gather information, it will be flashed to the ground by the same method used now in rocket-flight experiments. The method is called telemetering, and it works this way: as many as 50 reporting devices are hooked to a single transmitter which sends out a jumble of tonal waves. A receiver on earth picks up the tangled signals, and a decoding machine unscrambles the tones and prints the information automatically on long strips of paper, as a series of spidery wavelike lines. Each line represents the findings of a particular instrument—cabin temperature, air pressure and so on. Together, they'll provide a complete story of the happenings inside and outside the baby space station.

What kind of scientific data do we hope to get? Confirmation of all space research to date and, most important, new information on weightlessness, cosmic radiation and meteoric dust.

At a high enough speed and a certain altitude, an object will travel in an orbit around the earth. It—and everything in it—will be weightless. Space scientists and engineers know that man can adjust to weightlessness, because pilots have simulated the condition briefly by flying a jet plane in a roller-coaster arc. But will sustained weightlessness raise problems we haven't foreseen? We must find out —and the monkeys on the satellite will tell us.

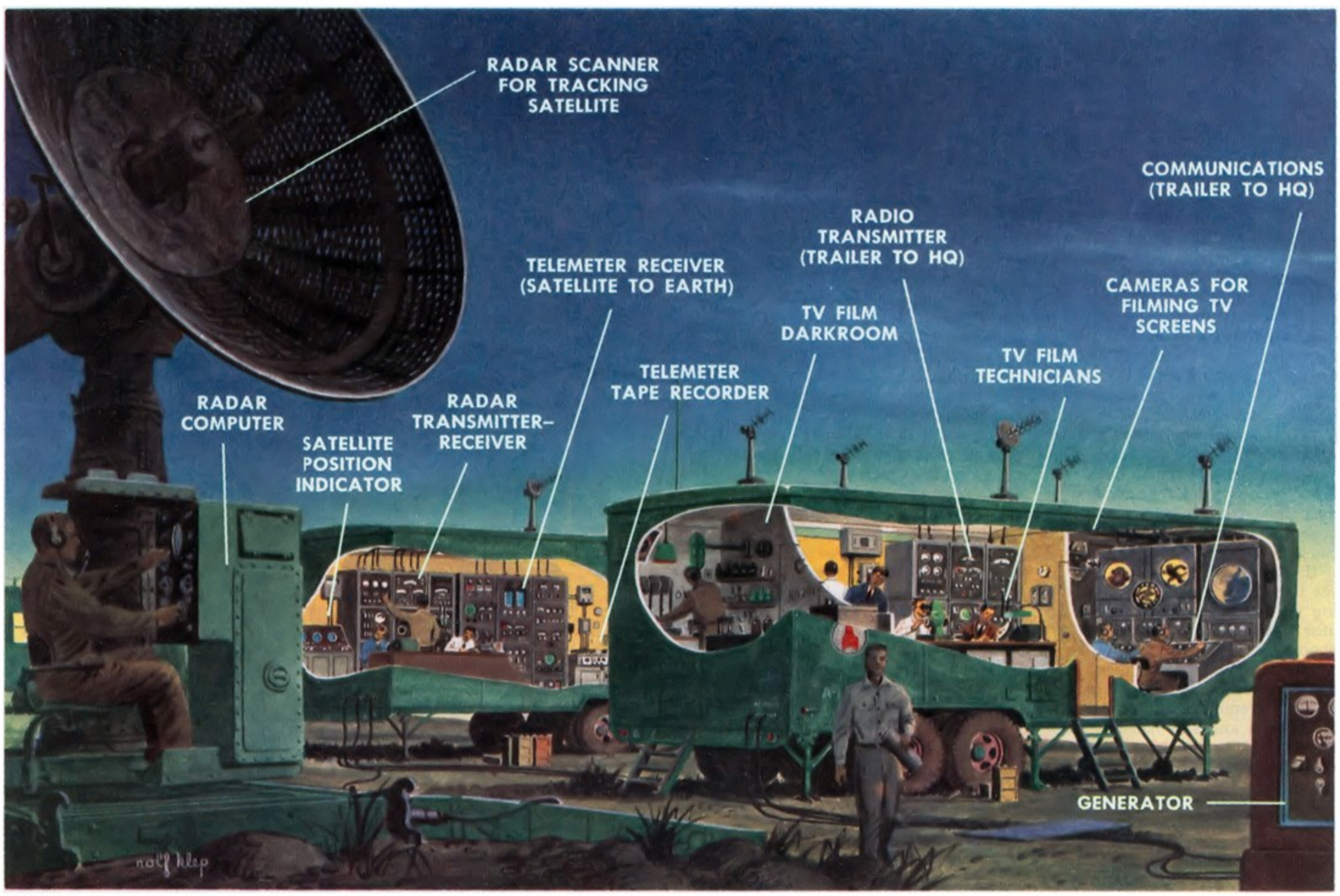
The monkeys will live in two chambers of the animal compartment. In the smaller section, one of the creatures will lie strapped to a seat throughout the two-month test. His hands and head will be free, so he can feed himself, but his body will be bound and covered with a jacket to keep him from freeing himself or from tampering with the measuring instruments taped painlessly to his body. The delicate recording devices will provide vital information—body temperature, breathing cycle, pulse rate, heartbeat, blood pressure and so forth.

The other two monkeys, separated from their pinioned companion so they won't turn him loose, will move about freely in the larger section. During the flight from earth, these two monkeys will be strapped to shock-absorbing rubber couches, under a mild anesthetic to spare them the discomfort of the acceleration pressure. By the time the anesthetic wears off, the robot will have settled in its circular path about the earth, and a simple timing device will release the two monkeys. Suddenly they'll float weightless, inside the cabin.

What will they do? Succumb to fright? Perhaps cower in a corner for two months and slowly starve to death? I don't think so. Chances are they'll adjust quickly to their new condition. We'll make it easier for them to get around by providing leather handholds along the walls, like subway straps, and by stringing a rope across the chamber.

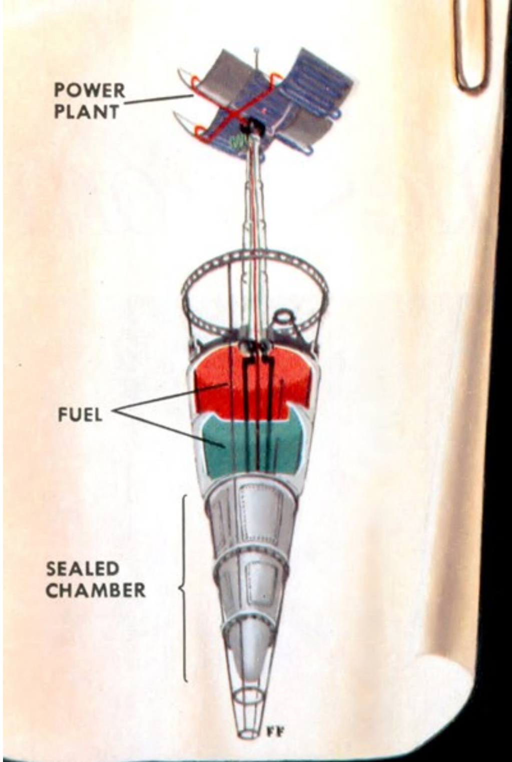
There's another problem for the three animals: to survive the 60 days they must eat and drink.

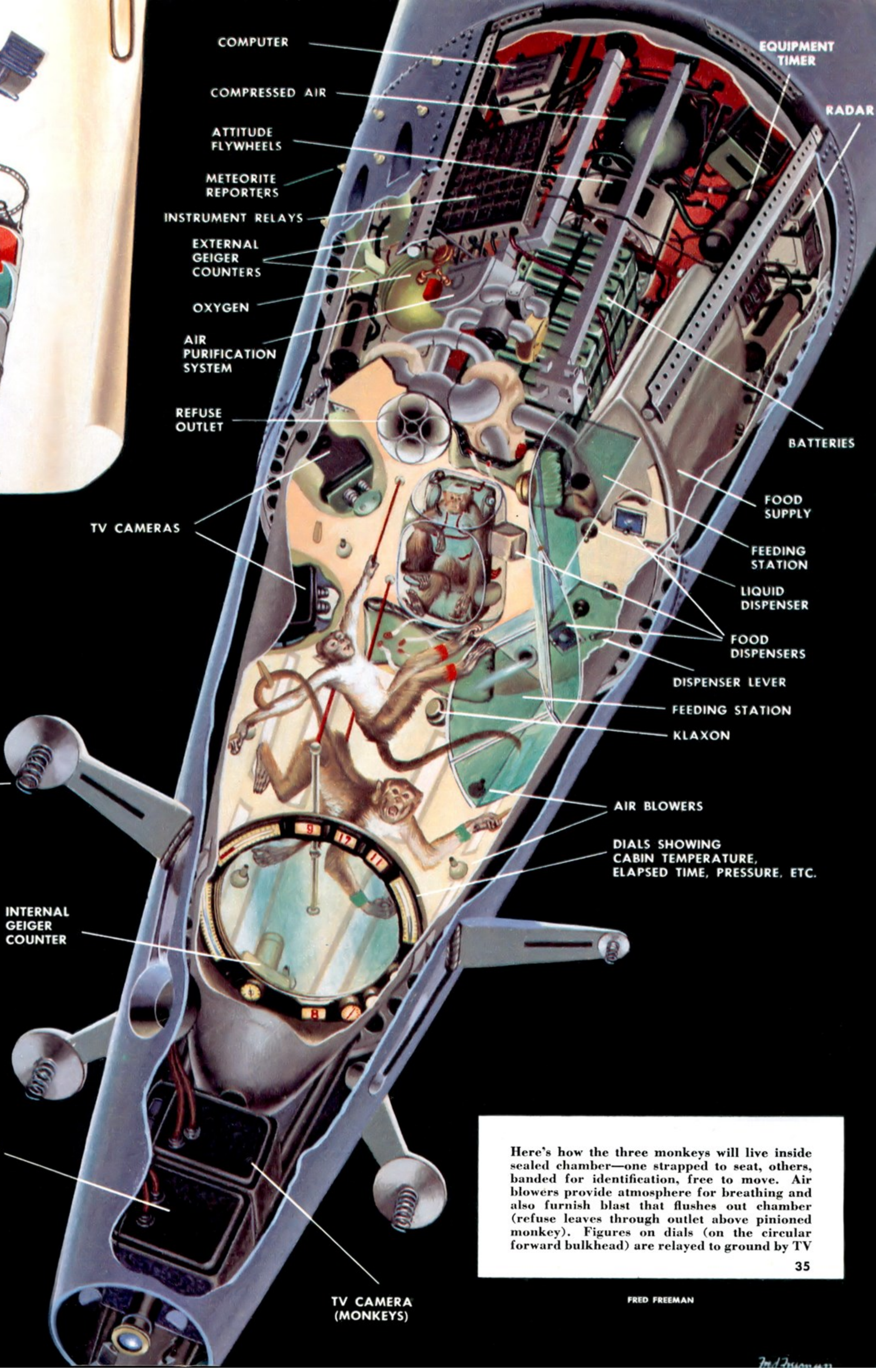
They'll prepare to cope with that problem on the ground. For months before they take off, the two unbound monkeys will live in a replica of the compartment they'll occupy in space, learning to operate food and liquid dispensers. In space, each of the two free animals will have his own feeding station. At specific intervals a klaxon horn will sound; the monkeys will respond by rushing to the feeding stations as they've been trained to do. Their movement will break an electric-eye beam, and clear plastic doors will snap shut behind them, sealing them off from their living quarters. Then, while they're eating, an air blower will flush out the living compartment—both for sanitary reasons



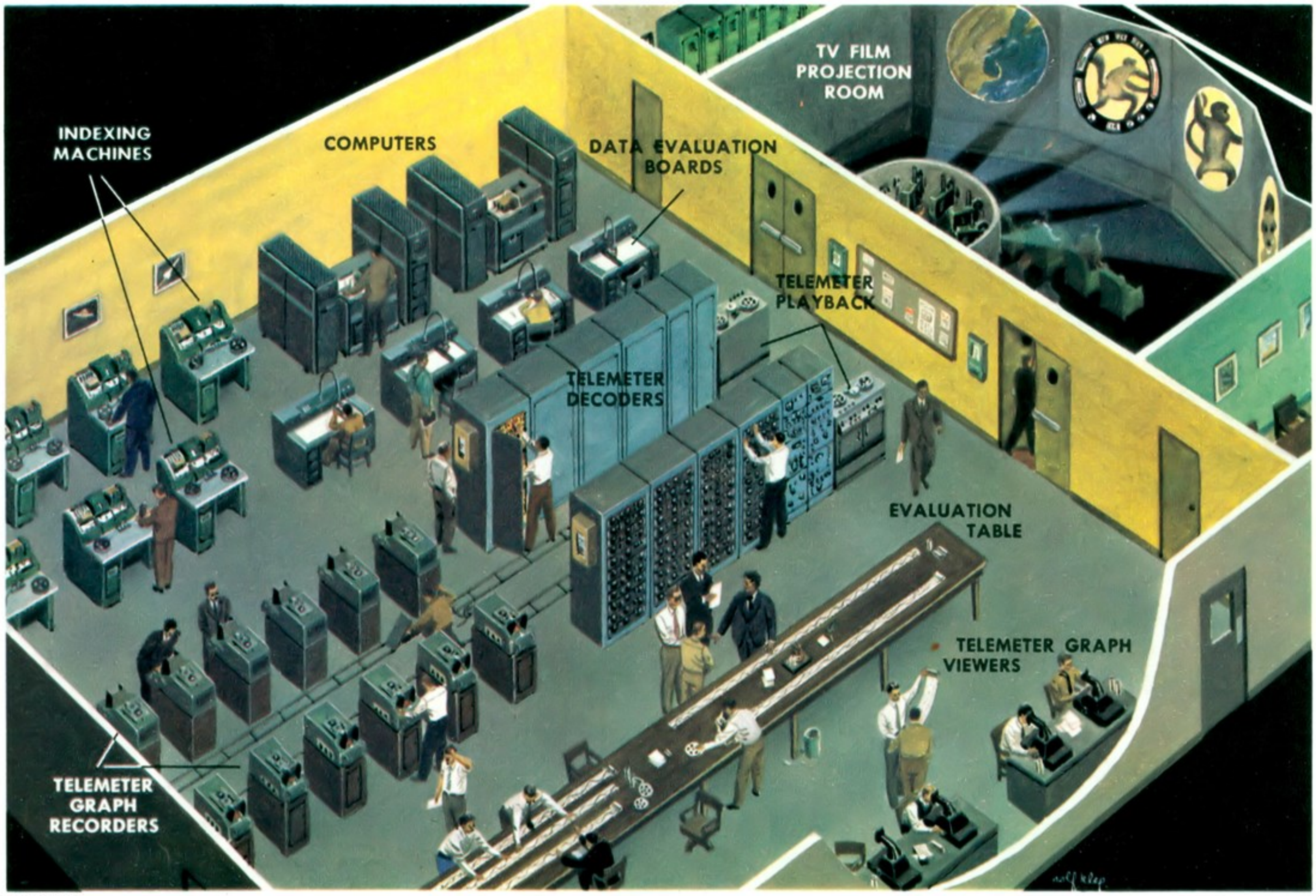
ROLF KLEP

One of the 20 field stations, scattered around the world, which will track the satellite and receive the reports it transmits by telemeter and TV. Information gathered here will be sent immediately to headquarters in the U.S.





Here's how the three monkeys will live inside sealed chamber—one strapped to seat, others, banded for identification, free to move. Air blowers provide atmosphere for breathing and also furnish blast that flushes out chamber (refuse leaves through outlet above pinioned monkey). Figures on dials (on the circular forward bulkhead) are relayed to ground by TV



ROLF KLEP

Main headquarters, where data transmitted by satellite—and relayed by field stations—will be decoded, interpreted and indexed for study

and to keep weightless refuse from blocking the television lenses. The plastic doors will spring open again when the housecleaning is finished.

The monkeys will drink by sucking plastic bottles. Liquid left free, without gravity to keep it in place, would hang in globules. To get solid food, each of the monkeys—again responding to their training—will press a lever on a dispenser much like a candy or cigarette machine. The lever will open a door, enabling the animals to reach in for their food. They'll get about half a pound of food a day—a biscuit made of wheat, soybean meal and bone meal, enriched with vitamins. The immobilized monkey will have the same food; his dispensers will be within easy reach.

For the two free monkeys, it will be a somewhat complicated life. The way they react to their ground training under the new conditions posed by lack of gravity will provide invaluable information on how weightlessness will affect them.

While the monkeys are providing physiologists with information on weightlessness, physicists will be learning more about cosmic rays, invisible high-speed atomic particles which act like deep-penetrating X rays and were once feared as the major hazard of space flight. Theoretically, in large enough doses cosmic rays could conceivably cause deep burns, damage the eyes, produce malignant growths and even upset the normal hereditary processes. They don't do much damage to us on earth because the atmosphere dissipates their full strength, but before much was known about the rays people worried about the dangers they might pose to man in space. From recent experiments scientists now know that the risk was mostly exaggerated—that even *beyond* the atmosphere a human can tolerate the rays for long periods without ill effects. Still, the best figures available have been obtained by high-altitude instrument rocket flights which were too brief to be conclusive. These spot checks must be augmented by a prolonged study, and the baby space station will make that possible.

The concentration of cosmic rays over the earth varies, being greatest over the north and south magnetic poles. The baby space station will follow a circular path that will carry it close to both poles within every hour and a half, so it can determine if cosmic-ray concentration varies that high up.

Geiger counters inside and outside the robot will measure the number of cosmic particle hits. The telemetering apparatus will signal the information to the ground—and for the first time physicists will have an accurate indication of the cosmic-ray concentration in space, above all parts of the globe.

Besides cosmic rays, the baby satellite will be hit by high-speed space bullets—tiny meteors, most of them smaller than a grain of sand, whizzing through space faster than 1,000 miles a minute.

When men enter space, they'll be protected against these pellets. Their rockets, the big space station, even their space suits, will have an outer skin called a meteor bumper, which will shatter the lightning-fast missiles on impact. But how many grainlike meteors must the bumpers absorb every 24 hours? That's what we space researchers want to know. So dime-sized microphones will be scattered over the robot's outer skin to record the number and location of the impacts as they occur.

In the process of unmasking the secrets of space, the baby satellite also will unravel a few riddles of our own earth.

For example, there are numerous islands whose precise position in the oceans has never been accurately established because there is no nearby land to use as a reference point. Some of them—one is Bouvet Island, lying south of the Cape of Good Hope—have been the subject of international disputes which could be quickly settled by fixing the islands' positions. By tracking the baby space station as it passes over these islands, we'll accurately pinpoint their locations for the first time.

The satellite will be even more important to meteorologists. The men who study the weather would like to know how much of the earth is covered with cloud in any given period. The robot's television camera will give them a clue—a start toward sketching in a comprehensive picture of the world's weather. Moreover, by studying the *pattern* of cloud movement, particularly over oceans, they may learn how to predict weather fronts with precision months in advance. Most of the weather research must await construction of a man-carrying space station, but the baby satellite will show what's needed.

To collect this information, of course, we must first establish the little robot in its 200-mile orbit. All the knowledge needed for its construction and operation is already available to experts in the fields of rocketry, television and telemetering.

Before take-off, the satellite vehicle will resemble one of today's high-altitude rockets, except that it will be about three times as big—150 feet tall, and 30 feet wide at the base. After take-off it will become progressively smaller, because it actually will consist of three rockets—or stages—one atop another, two of which will be cast away after delivering their full thrust. The vehicle will take off vertically and then tilt into a shallow path nearly parallel to the earth. Its course will be over water at first, so the first two stages won't fall on anyone after they're dropped, a few minutes after take-off.

When the third stage of the vehicle reaches an altitude of 60 miles and a speed of 17,700 miles an hour, the final bank of motors will shut off auto-

In one move we'll crack the secrets of cosmic rays, meteor bullets—even lost isles

matically. The conical nose section will coast unpowered to the 200-mile orbit, which it will reach at a speed of 17,100 miles an hour, 44 minutes later. The entire flight will take 48½ minutes.

After the satellite reaches its orbit, the automatic pilot will switch on the motors once again to boost the velocity to 17,200 miles an hour—the speed required to balance the earth's gravity at that altitude. Now the rocket becomes a satellite; it needs no more power but will travel steadily around the earth like a small moon for 60 days, until the slight air drag present at the 200-mile altitude slows it enough to drop.

Once the satellite enters its orbit, gyroscopically controlled flywheels cartwheel the nose until it points toward the earth. At the same time, five little antennas spring out from the cone's sides and a small explosive charge blasts off the nose cap which has guarded the TV lens during the ascent.

Finally, the satellite's power plant—a system of mirrors which catch the sun's rays and turn solar heat into electrical energy—rises into place at the broad end of the cone. A battery-operated electric timer starts a hydraulic pump, which pushes out a telescopic rod. At the end of the rod are the three curved mirrors. When the rod is fully extended, the mirrors unfold, side by side, and from the ends of the central mirror two extensions slip out. Mercury-filled pipes run along the five polished plates; the heated mercury will operate generators providing 12 kilowatts of power. Batteries will take over the power functions while the satellite is passing through the shadow of the earth.

With the power plant in operation, the baby space station buckles down to its 60-day assignment as man's first listening post in space.

At strategic points over the earth's surface, 20 or more receiving stations, most of them set up in big trailers, will track the robot by radar as it passes overhead, and record the television and telemetering broadcasts on tape and film. Because the satellite's radio waves travel in a straight line, the trailers can pick up broadcasts for just a few minutes at a time—only while the robot remains in sight as it zooms from horizon to horizon.

As the satellite passes out of range, the recorded data will be sent to a central station in the United States—some of it transmitted by radio, the rest shipped by plane. There, the information will be evaluated and integrated from day to day.

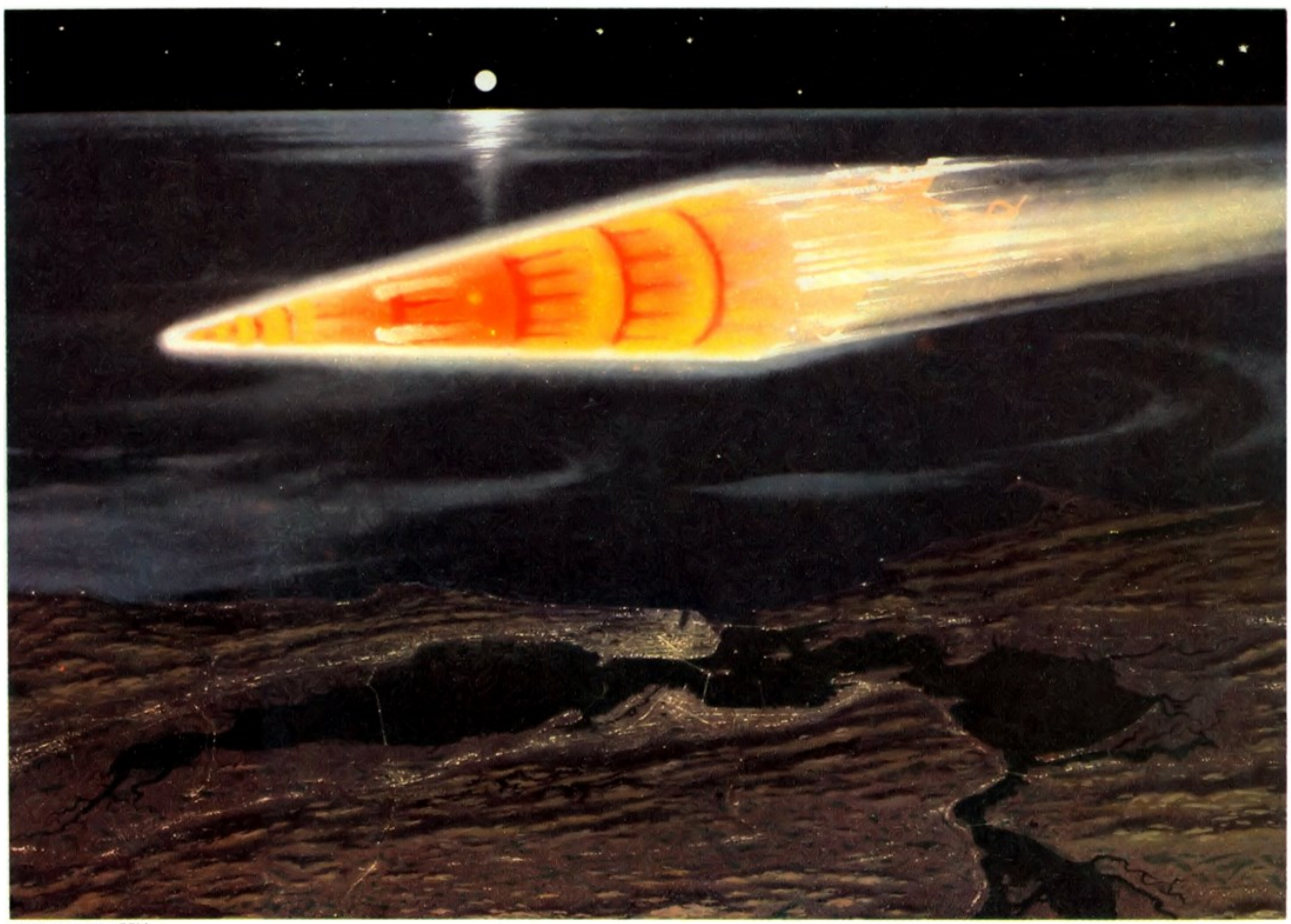
The monitoring posts will be set up inside the Arctic and Antarctic Circles and at points near the equator. In the polar areas, stations could be at Alaska, southern Greenland and Iceland; and in the south, Shetland Islands, Campbell Island and South Georgia Island. In the Pacific, possible sites are Baker Island, Christmas Island, Hawaii and the Galapagos Islands. The remaining monitors may be located in Puerto Rico, Bermuda, St. Helena, Liberia, South-West Africa, Ethiopia, Maldive Islands, the Malay Peninsula, the Philippines, northern Australia and New Zealand.

These points, all in friendly territory, would form a chain around the earth, catching the satellite's broadcasts at least once a day.

The monitor stations will be fairly costly, but they'll come in handy again later, when man is ready to launch the first crew-operated rocket ships for development of a big-manned space station, 1,075 miles from the earth.

The cost of the baby satellite project will be absorbed into the four-billion-dollar 10-year program to establish the bigger satellite. We scientists can have the baby rocket within five to seven years if we begin work now. Five years later, we could have the manned space station.

One of the monitoring posts will view the last moments of the baby space station. As the weeks pass, the satellite, dragging against the thin air, will drop lower and lower in its orbit. When it descends into fairly dense air, its skin will be heated by friction, causing the temperature to rise within the animal compartments. At last, a thermostat will set off an electric relay which triggers a capsule containing a quick-acting lethal gas. The monkeys will die instantly and painlessly. Soon afterward, the telemetering equipment will go silent, as the rush of air rips away the solar mirrors which provide power, and the baby space station will begin to glow cherry red. Then suddenly the satellite will disappear in a long white streak of brilliant light—marking the spectacular finish of man's first step in the conquest of space.



CHESLEY BONESTELL

Baby space station's last noments. With San Francisco Bay in background, satellite plunges into atmosphere in fiery windup to 60-day flight

Collier's

APRIL 30, 1954 • FIFTEEN CENTS

Can We Get to Mars?

Is There Life on Mars?

SPECIAL REPORT

How Your Town Can AVOID A Recession

• **8 Danger Signals To Watch For**

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Collier's

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THE COVER . . Chesley Bonestell

From an orbit around Mars, the first visitors from the earth prepare to land on the most intriguing of our neighbor planets. The winged rocket in the foreground is preparing for the descent; the ships that remain, all cargo carriers, will stay in the orbit. When will this visit occur—and what will it uncover? Leading scientists give the answers in a special nine-page report, starting on page 21

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COLLIER'S CREDITS..

GILLOON AGENCY

Wernher von Braun, Ryan

THE name Dr. Hubertus Strughold will ring a bell with readers who recall our symposium on Man's Survival in Space (Collier's, February 28, 1953), of which the doctor, head of the Department of Space Medicine at Randolph Field, Texas, was a member. We Credit him now because Dr. Wernher von Braun and staffer Cornelius Ryan found much relevant information in Dr. Strughold's book, The Green and Red Planet (University of New Mexico Press), when our writing team tackled the discussion of a 355,000,000-mile journey to Mars.

Dr. Strughold's thesis is perhaps more easily assimilated than Dr. Wernher von Braun's authoritative volume, The Mars Project (University of Illinois Press), because it does not contain such formulas as Dr. von Braun's

$$\dot{v} = \frac{F_1 + A_{e,1}(p_{e,1} - p_a) - c_D \cdot A_1 v^2 \gamma / 2g_0}{1/g_0 \, (W_{0,1} - \dot{W}_1 \cdot t)} - g_0 \cos \vartheta \quad (4.1)$$

for "the ascent track" of a space ship. But friend Wernher's scientific books are not particularly intended for your library or ours, and anyway that's where "Connie" Ryan comes in—to give you the facts in nontechnical verbiage.

The Mars story begins on page 21 and will comprise part of the third book on space travel that Cornelius Ryan has edited since Collier's began to explore the subject two years ago.

★ ★ ★

EFFORTS to improve American schooling long ago became a permanent agendum on our editorial calendar, which is why, when we were casting about for a quick and comparatively inexpensive answer to the current shortage of schoolroom facilities, we consulted The Architects Collaborative, of Cambridge, Massachusetts. This eight-member partnership is inspired by seventy-year-old Walter Gropius, whose architectural achievements cover every kind of service and design man can dream about. Well equipped by experience and imagination, the Collaboratives co-operated with Collier's in detailing the plans for the modern school plant we sponsor in this issue.

Credits to the hard-working team (identified below)—and a special one for Mr. Gropius for having recently received in Brazil the Grand Prix International d'Architecture (Premio São Paulo) from the hands of President Getulio Vargas in the presence of the diplomatic corps.

★ ★ ★

SPEAKING of schools, we have proud and selfish reasons for mentioning a Creditable new magazine called Omnibus. Vol. 1, No. 1 of this fat (53-page) periodical, jammed with articles, stories, drawings and advertisements, was produced on a duplicating machine by sixth-grade students in Oceanlake, Oregon. Preliminary work on the project included a thorough study of seven leading magazines by the editors, who finally "decided to use Collier's as a model because it has so many different kinds of features." The youthful staff regretted the lack of a Letters department, but explained logically that it was their first issue and no mail was at hand. Typical Omnibus cartoon: on the sidewalk one flea asks another, "Shall we walk or take a dog?" The last (editorial) page Omnibusly warned: "Let Collier's look to their laurels . . . There's only room at the top for one and we won't quit until we are there!" Respectful note to the Omnibus staff: Confronted by this spirit of competition, we shall indeed do as you advise. P.S. Perhaps this item will find a place in your indubitably now flourishing Letters column.

—GURNEY WILLIAMS

SAMUEL ROSENBERG

The designers of the Collier's school included this architectural team: Benjamin Thompson, Sarah Harkness, Norman Fletcher, Chester Nagel, Walter Gropius, Jean B. Fletcher, John C. Harkness, Louis A. McMillen

IS THERE LIFE ON MARS?

By Dr. FRED L. WHIPPLE

Chairman, Department of Astronomy, Harvard University

Astronomers—planning to give the great red planet its closest scrutiny in history this summer—are nearer than ever before to answering the most fascinating question of all

On JULY 2d, the planet Mars, swinging through its lopsided orbit around the sun, will be closer to the earth than at any time since 1941. All over the world, scientists will train batteries of telescopes and cameras on the big red sphere in history's greatest effort to unravel some of the mystery surrounding this most intriguing of the planets.

Next to Venus, Mars is our closest planetary neighbor. Even so, it will be 40,000,000 miles away as it passes by this summer (compared to 250,000,000 miles at its farthest point from the earth); on the most powerful of telescopes it will look no larger than a coffee saucer. Still, it will be close enough to provide astronomers important facts about its size, atmosphere and surface conditions—and the possibility that some kind of life exists there.

We already know a great deal.

Mars's diameter is roughly half the size of the earth. The Martian day is 24 hours, 37 minutes long, but its year is nearly twice as long as ours—670 Martian days. During daylight hours, the temperature on Mars shoots into the eighties, but at night a numbing cold grips the planet: the temperature drops suddenly to 95 below zero, Fahrenheit.

There is no evidence of oxygen in Mars's thin blue atmosphere. Moreover, its atmospheric pressure is so low that an earth man couldn't survive without a pressurized suit. If life of any kind does exist on Mars it must be extremely rugged.

Through the telescope, astronomers can clearly see Mars's great reddish deserts, blue-tinted cloud formations and—especially conspicuous—its distinctive polar caps.

The Martian polar caps cover about 4,000,000 square miles in the wintertime—an area roughly half the size of the North American continent. But as they melt in spring, strange blue-green areas develop near their retreating edges. Some months later these color patches, now covering great areas of the planet's surface, turn brownish. Finally in the deep of Martian winter they're a dark chocolate color. Do these seasonal color variations indicate some sort of plant or vegetable life? That's one of the riddles we'd like to solve.

There's another big question mark: Mars's so-called canals. Although most modern astronomers have long since discounted the once popular theory that the faint tracings seen by some on Mars are actually a network of waterways (and, therefore, perhaps constructed by intelligent beings), we still don't know what they are—or if they exist at all.

The "canals" have had a controversial history. They were first reported in 1877 by an Italian astronomer named Giovanni Schiaparelli who said he had seen delicate lines tracing a gridlike pattern over vast areas of the planet. He called them *canali*—"canals" or "channels."

Since Schiaparelli, many astronomers (especially Dr. Percival Lowell, who established an observatory for the primary purpose of studying Mars) have reported observing the delicate veinlike lines. Others, just as keen-sighted, have spent years studying the Martian face without once seeing the disputed markings.

This year we may get an opportunity to clear up the canal confusion once and for all. An American team, sponsored jointly by the National Geographic Society and Lowell Observatory, will photograph Mars from Bloemfontein, South Africa, where Mars will appear almost directly overhead nightly during early July. The U.S. team, using new photographic techniques and the latest in fast film emulsions, expects to get the most detailed photographs of the planet yet obtained.

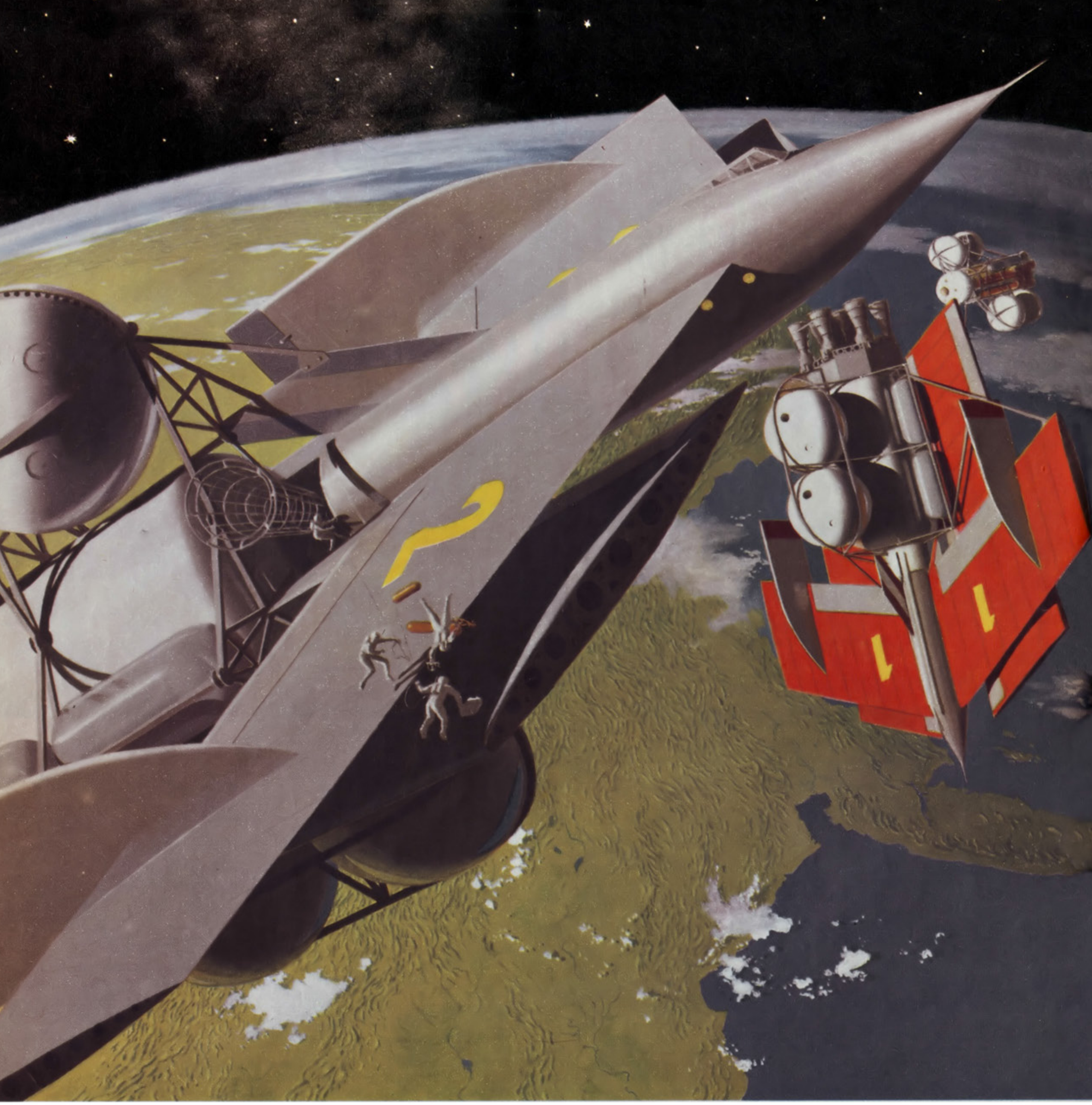
But great as the 1954 Mars observation program promises to be, it's only the curtain raiser for 1956, when Mars will approach to within 35,000,000 miles of the earth. Not for another 15 years, in 1971, will it be so close again.

When all the findings have been evaluated we may be able to make some intelligent guesses as to the possibility of life on Mars. Chances are that bacteria are the only type of animal life which could exist in the planet's oxygenless atmosphere. There also may be some sort of tough, primitive plant life—perhaps lichens or mosses which produce their own oxygen and water. Such plants might explain the changing colors of the Martian seasons.

There's one other possibility.

How can we say with absolute certainty that there isn't a *different* form of life existing on Mars—a kind of life that we know nothing about? We can't. There's only one way to find out for sure what is on Mars—and that's to go there. ▲▲▲

Rocket expert Dr. Wernher von Braun discusses the problems of a trip to Mars on the pages that follow ▶



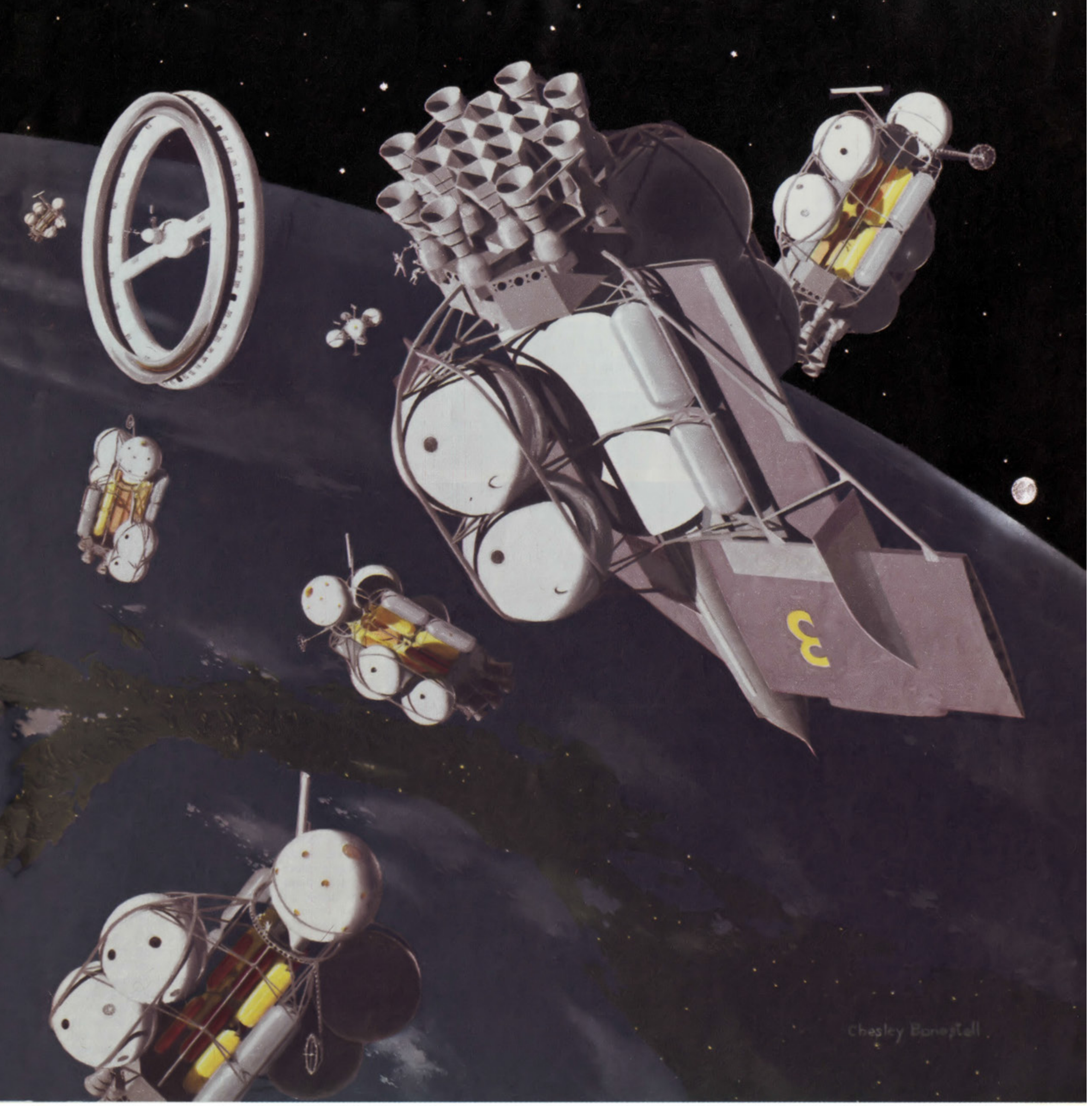
Near wheel-shaped space station 1,000 miles from the earth, built especially for assembly of the Mars expedition, weightless workers put togeth

Can We Get to MARS?

By DR. WERNHER von BRAUN with CORNELIUS RYAN

Chief, Guided Missile Development Division, Redstone Arsenal, Huntsville, Alabama

Man's trail-blazing journey to Mars will be a breath-taking experience—with problems to match



CHESLEY BONESTELL

the 10 rocket ships required for the flight. Three of the huge space craft have torpedo noses which convert to planes for landing on the planet

THE first men who set out for Mars had better make sure they leave everything at home in apple-pie order. They won't get back to earth for more than two and a half years.

The difficulties of a trip to Mars are formidable. The outbound journey, following a huge arc 355,000,000 miles long, will take eight months—even with rocket ships that travel many thousands of miles an hour. For more than a year, the explorers will have to live on the great red planet, waiting for it to swing into a favorable position for the return trip. Another eight months will pass before the 70 members of the pioneer expedition set foot on earth again. All during that time, they will be exposed to a multitude of dangers and strains, some of them impossible to foresee on the basis of today's knowledge.

Will man ever go to Mars? I am sure he will—but it will be a century or more before he's ready. In that time scientists and engineers will learn more about the physical and mental rigors of interplanetary flight—and about the unknown dangers of life on another planet. Some of that information may become available within the next 25 years or so, through the erection of a space station above the earth (where telescope viewings will not be blurred by the earth's atmosphere) and through the subsequent exploration of the moon, as described in previous issues of Collier's.

Even now science can detail the technical requirements for a Mars expedition down to the last ton of fuel. Our knowledge of the laws governing the solar system—so accurate that astronomers can predict an eclipse of the sun to within a fraction of a second—enables scientists to determine exactly the speed a space ship must have to reach Mars, the course that will intercept the planet's orbit at exactly the right moment, the methods to be used for the landing, take-off and other maneuvering. We know, from these calculations, that we already have chemical rocket fuels adequate for the trip.

Better propellants are almost certain to emerge during the next 100 years. In fact, scientific advances will undoubtedly make obsolete many of the engineering concepts on which this article, and the accompanying illustrations, are based. Nevertheless, it's possible to discuss the problems of a flight to Mars in terms of what is known today. We can assume, for example, that such an expedition will involve about 70 scientists and crew members. A force that size would require a flotilla of 10 massive space ships, each weighing more than 4,000 tons—not only because there's safety in numbers, but because of the tons of fuel, scientific equipment, rations, oxygen, water and the like necessary for the trip and for a stay of about 31 months away from earth.

All that information can be computed scientifically. But science can't apply a slide rule to man; he's the unknown quantity, the weak spot that makes a Mars expedition a project for the far distant, rather than the immediate, future. The 70 explorers will endure hazards and stresses the like of which no men before them have ever known. Some of these hardships must be eased—or at least better understood—before the long voyage becomes practical.

For months at a time, during the actual period of travel, the expedition members will be weightless. Can the human body stand prolonged weightlessness? The crews of rocket ships plying between the ground and the earth's space station about 1,000 miles away will soon grow accustomed to the absence of gravity—but they will experience this odd sensation for no more than a few hours at a time. Prolonged weightlessness will be a different story.

Over a period of months in outer space, muscles accustomed to fighting the pull of gravity could shrink from disuse—just as do the muscles of people who are bedridden or encased in plaster casts for a long time. The members of a Mars expedition might be seriously handicapped by such a disability. Faced with a rigorous work schedule on the unexplored planet, they will have to be strong and fit upon arrival.

The problem will have to be solved aboard the space vehicles. Some sort of elaborate spring exercisers may be the answer. Or perhaps synthetic gravity could be produced aboard the rocket ships by designing them to rotate as they coast through space, creating enough centrifugal force to act as a substitute for gravity.

Far worse than the risk of atrophied muscles is the hazard of cosmic rays. An overdose of these deep-penetrating atomic particles, which act like the invisible radiation of an atomic-bomb burst, can cause blindness, cell damage and possibly cancer.

Scientists have measured the intensity of cosmic radiation close to the earth. They have learned that the rays dissipate harmlessly in our atmosphere. They also have deduced that man can safely venture as far as the moon without risking an overdose of radiation. But that's a comparatively brief trip. What will happen to men who are exposed to the rays for months on end? There is no material that offers practical protection against cosmic rays—practical, that is, for space travel. Space engineers could provide a barrier by making the cabin walls of lead several feet thick —but that would add hundreds of tons to the weight of the space vehicle. A more realistic plan might be to surround the cabin with the fuel tanks, thus providing the added safeguard of a two- or three-foot thickness of liquid.

The best bet would seem to be a reliance on man's ingenuity: by the time an expedition from the earth is ready to take off for Mars, perhaps in the mid-2000s, it is quite likely that researchers will have perfected a drug which will enable men to endure radiation for comparatively long periods. Unmanned rockets, equipped with instruments which send information back to earth, probably will blaze the first trail to our sister planet, helping to clear up many mysteries of the journey.

FRED FREEMAN

Small Meteors Could Do Little Damage

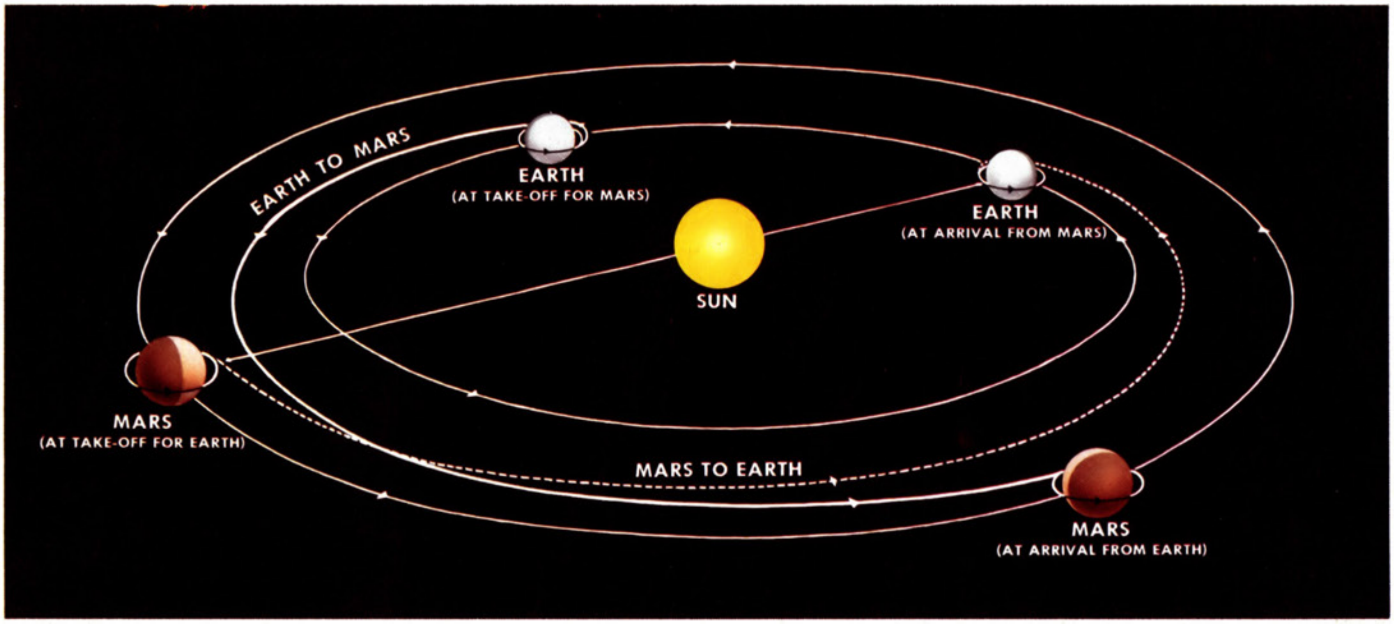
Meteors, for example. Many billions of these tiny bullets, most of them about the size of a grain of sand, speed wildly through space at speeds of more than 150,000 miles an hour. For short trips, we can protect space ships from these lightning-fast pellets by covering all vital areas—fuel tanks, rocket motors, cargo bins, cabins and the like—with light metal outer shields called meteor bumpers. The tiny meteors will explode against this outer shell, leaving the inner skin of the ship—and the occupants—unharmed.

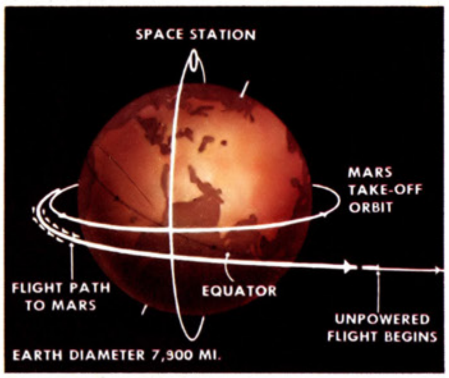
But in the 16 months of space travel required for a visit to Mars, much larger projectiles might be encountered. Scientists know that the density of large meteors is greater near the red planet than it is around the earth. If, by some chance, a rock the size of a baseball should plow through the thin shell of one of the rocket ships it could do terrible damage—especially if it struck a large, solid object inside. A meteor that size, traveling at terrific speed, could explode with the force of 100 pounds of TNT. In the cabin of a space vehicle, such an explosion would cause tremendous destruction.

Fortunately, meteors that size will be extremely rare, even near Mars.

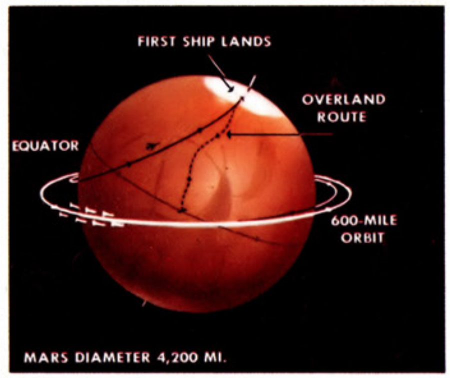
Dime-sized chunks are more likely to be encountered. They will be a danger, too, although not so bad as the larger rocks. They'll rip through the bumper and skin like machine-gun bullets. If they strike anything solid, they'll explode with some force. If not, they'll leave through the other side of the ship—but even then they may cause trouble. Holes will have to be plugged to maintain cabin pressure. The shock wave created by the meteors' extreme speed may hurt the ship's occupants: there will be a deafening report and a blinding flash; the friction created by their passage through the cabin atmosphere will create enough heat to singe the

Illustration shows how the landing planes are assembled in 600-mile Martian orbit. Pointed noses are removed from three of 10 ships that made trip from earth; wings and landing gear are fitted to them. Cutaway of plane in the foreground shows personnel, tractors in ship





Top diagram shows positions of earth and Mars at times of arrival and departure, and routes followed in both directions. Drawing at left depicts take-off maneuver from an orbit 1,000 miles above earth's equator (note polar orbit of original earth space station, which might be built within next 15 or 20 years). Mars vehicles cut power 5,700 miles from the earth and coast rest of the way through space. At right, fleet of 10 rocket ships approaches to within about 600 miles of Mars, establishes itself in orbit and launches first of three landing planes toward Martian polar area for snow landing. After landing, advance party abandons plane and travels on tractors 4,000 miles to equator, where it prepares a landing strip for expedition members in other planes



ROLF KLEP

eyebrows of a man standing close by. And, of course, a person in the direct path of a pebble-sized meteor could be severely injured. A fragile piece of machinery could be destroyed, and it's even possible that the entire rocket ship would have to be abandoned after sustaining one or more hits by space projectiles that size (astronomers estimate that one out of 10 ships on a 16-month voyage might be damaged badly, although even that is unlikely).

If one of the Mars-bound vehicles does suffer serious damage, the incident needn't be disastrous. In a pinch, a disabled space vehicle can be abandoned easily. All of the ships will carry small self-propelled craft—space taxis—which are easily built and easily maneuvered. They will be fully pressurized, and will be used for routine trips between the ships of the convoy, as well as for emergencies. If for some reason the space taxis aren't available to the occupants of a damaged ship, they will be able to don pressurized suits and step calmly out into space. Individual rocket guns, manually operated, will enable each of them to make his way to the nearest space ship in the convoy. Space-suited explorers will have no difficulty traveling between ships. There's no air to impede motion, no gravitational pull and no sense of speed. When they leave their ship the men will have to overcome only their own inertia. They'll be traveling through the solar system at more than 70,000 miles an hour, but they will be no more aware of it than we on earth are aware that every molecule of our bodies is moving at a speed of 66,600 miles an hour around the sun.

Science ultimately will solve the problems posed by cosmic rays, meteors and the other natural phenomena of space. But man will still face one great hazard: himself.

Man must breathe. He must guard himself against a great variety of illnesses and ailments. He must be entertained. And he must be protected from many psychological hazards, some of them still obscure.

How will science provide a synthetic atmosphere within the space-ship cabins and Martian dwellings for two and a half years? When men are locked into a confined, airtight area for only a few days or weeks oxygen can be replenished, and exhaled carbon dioxide and other impurities extracted, without difficulty. Submarine engineers solved the problem long ago. But a conventional submarine surfaces after a brief submersion and blows out its stale air. High-altitude pressurized aircraft have mechanisms which automatically introduce fresh air and expel contaminated air.

There's no breathable air in space or on Mars; the men who visit the red planet will have to carry with them enough oxygen to last many months.

When Men Live Too Close Together

During that time they will live, work and perform all bodily functions within the cramped confines of a rocket-ship cabin or a pressurized—and probably mobile—Martian dwelling. (I believe the first men to visit Mars will take along inflatable, spherical cabins, perhaps 30 feet across, which can be mounted atop tractor chassis.) Even with plenty of oxygen, the atmosphere in those living quarters is sure to pose a problem.

Within the small cabins, the expedition members will wash, perform personal functions, sweat, cough, cook, create garbage. Every one of those activities will feed poisons into the synthetic air—just as they do within the earth's atmosphere.

No less than 29 toxic agents are generated during the daily routine of the average American household. Some of them are body wastes, others come from cooking. When you fry an egg, the burned fat releases a potent irritant called acrolein. Its effect is negligible on earth because the amount is so small that it's almost instantly dissipated in the air. But that microscopic quantity of acrolein in the personnel quarters of a Mars expedition could prove dangerous; unless there was some way to remove it from the atmosphere it would be circulated again and again through the air-conditioning system.

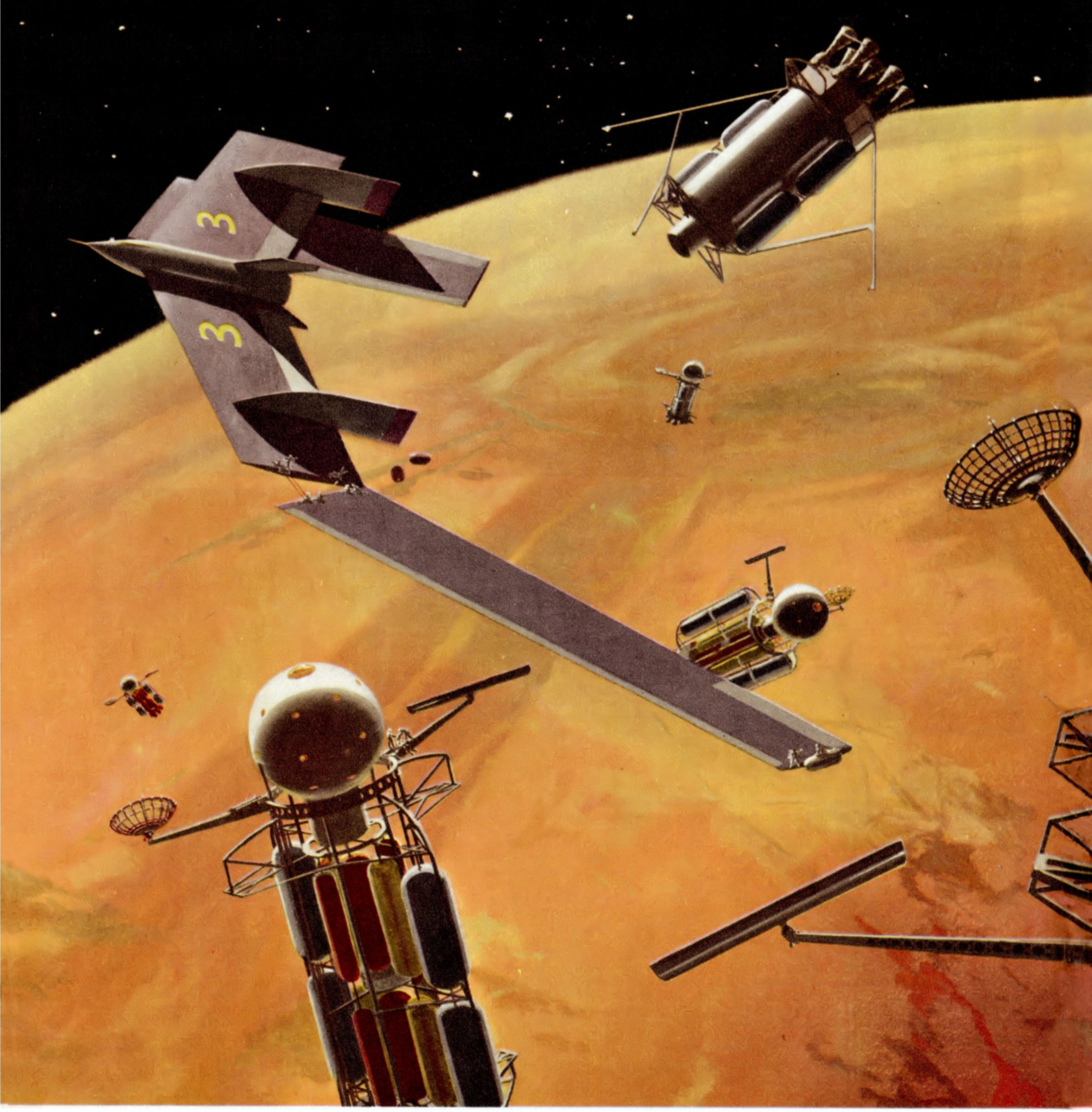
Besides the poisons resulting from cooking and the like, the engineering equipment—lubricants, hydraulic fluids, plastics, the metals in the vehicles—will give off vapors which could contaminate the atmosphere.

What can be done about this problem? No one has all the answers right now, but there's little doubt that by using chemical filters, and by cooling and washing the air as it passes through the air-conditioning apparatus, the synthetic atmosphere can be made safe to live in.

Besides removing the impurities from the man-made air, it may be necessary to add a few. Man has lived so long with the impurities in the earth's atmosphere that no one knows whether he can exist without them. By the time of the Mars expedition, the scientists may decide to add traces of dust, smoke and oil to the synthetic air—and possibly iodine and salt as well.

I am convinced that we have, or will acquire, the basic knowledge to solve all the physical problems of a flight to Mars. But how about the psychological problem? Can a man retain his sanity while cooped up with many other men in a crowded area, perhaps twice the length of your living room, for more than thirty months?

Share a small room with a dozen people completely cut off from the outside world. In a few weeks the irritations begin to pile up. At the end of



The first landing party takes off for Mars. Two other landing planes will wait until runway is prepared for them, and the remaining seven ships

a few months, particularly if the occupants of the room are chosen haphazardly, someone is likely to go berserk. Little mannerisms—the way a man cracks his knuckles, blows his nose, the way he grins, talks or gestures—create tension and hatred which could lead to murder.

Imagine yourself in a space ship millions of miles from earth. You see the same people every day. The earth, with all it means to you, is just another bright star in the heavens; you aren't sure you'll ever get back to it. Every noise about the rocket ship suggests a breakdown, every crash a meteor collision. If somebody does crack, you can't call off the expedition and return to earth. You'll have to take him with you.

The psychological problem probably will be at its worst during the two eight-month travel periods. On Mars, there will be plenty to do, plenty to see. To be sure, there will be certain problems on the planet, too. There will be considerable confinement. The scenery is likely to be grindingly monotonous. The threat of danger from some unknown source will hang over the explorers constantly. So will the knowledge that an extremely complicated process, subject to possible breakdown, will be required to get them started on their way back home. Still, Columbus' crew at sea faced much the same problems the explorers will face on Mars; the fifteenth-century sailors felt the psychological tension, but no one went mad.

But Columbus traveled only ten weeks to reach America; certainly his men would never have stood an eight-month voyage. The travelers to Mars will

CHESLEY BONESTELL

will stay in 600-mile orbit. Arms on cargo ships hold screenlike dish antennas (for communication), trough-shaped solar mirrors (for power)

have to, and psychologists undoubtedly will make careful plans to keep up the morale of the voyagers.

The fleet will be in constant radio communication with the earth (there probably will be no television transmission, owing to the great distance). Radio programs will help relieve the boredom, but it's possible that the broadcasts will be censored before transmission; there's no way of telling how a man might react, say, to the news that his home town was the center of a flood disaster. Knowing would do him no good—and it might cause him to crack.

Besides radio broadcasts, each ship will be able to receive (and send) radio pictures. There also will be films which can be circulated among the space ships. Reading matter will probably be carried in the form of microfilms to save space. These activities—plus frequent intership visiting, lectures and crew rotations—will help to relieve the monotony.

There is another possibility, seemingly fantastic, but worth mentioning briefly because experimentation already has indicated it may be practical. The nonworking members of a Mars expedition may actually hibernate during part of the long voyage. French doctors have induced a kind of artificial hibernation in certain patients for short periods, in connection with operations for which they will need all their strength (Collier's, December 11, 1953—Medicine's New Offensive Against Shock, by J. D. Ratcliff). The process involves a lowering of the body temperature, and the subsequent slowing down of all the normal physical processes. On a Mars expedition, such a procedure, over a longer period, would solve much of the psychological problem, would cut sharply into the amount of food required for the trip, and would, if successful, leave the expedition members in superb physical condition for the ordeal of exploring the planet.

Certainly if a Mars expedition were planned for the next 10 or 15 years no one would seriously consider hibernation as a solution for any of the problems of the trip. But we're talking of a voyage to be made 100 years from now; I believe that if the French experiments bear fruit, hibernation may actually be considered at that time.

Finally, there has been one engineering development which may also simplify both the psychological and physical problems of a Mars voyage. Scientists are on the track of a new fuel, useful only in the vacuum of space, which would be so economical that it would make possible far greater speeds for space journeys. It could be used to shorten the travel time, or to lighten the load of each space ship, or both. Obviously, a four- or six-month Mars flight would create far fewer psychological hazards than a trip lasting eight months.

In any case, it seems certain that the members of an expedition to Mars will have to be selected with great care. Scientists estimate that only one person in every 6,000 will be qualified, physically, mentally and emotionally, for routine space flight. But can 70 men be found who will have those qualities—and also the scientific background necessary to explore Mars? I'm sure of it.

One day a century or so from now, a fleet of rocket ships will take off for Mars. The trip could be made with 10 ships launched from an orbit, about 1,000 miles out in space, that girdles our globe at its equator. (It would take tremendous power and vast quantities of fuel to leave directly from the earth. Launching a Mars voyage from an orbit about 1,000 miles out, far from the earth's gravitational pull, will require relatively little fuel.) The Mars-bound vehicles, assembled in the orbit, will look like bulky bundles of girders, with propellant tanks hung on the outside and great passenger cabins perched on top. Three of them will have torpedo-shaped noses and massive wings—dismantled, but strapped to their sides for future use. Those bullet noses will be detached and will serve as landing craft, the only vehicles that will actually land on the neighbor planet. When the 10 ships are 5,700 miles from the earth, they will cut off their rocket motors; from there on, they will coast unpowered toward Mars.

After eight months they will swing into an orbit around Mars, about 600 miles up, and adjust speed to keep from hurtling into space again. The expedition will take this intermediate step, instead of proceeding directly to Mars, for two main reasons: first, the ships (except for the three detachable torpedo-shaped noses) will lack the streamlining required for flight in the Martian atmosphere; second, it will be more economical to avoid carrying all the fuel needed for the return to earth (which now comprises the bulk of the cargo) all the way down to Mars and then back up again.

Upon reaching the 600-mile orbit—and after some exploratory probings of Mars's atmosphere with unmanned rockets—the first of the three landing craft will be assembled. The torpedo nose will be unhooked, to become the fuselage of a rocket plane. The wings and a set of landing skis will be attached, and the plane launched toward the surface of Mars.

The landing of the first plane will be made on the planet's snow-covered polar cap—the only spot where there is any reasonable certainty of finding a smooth surface. Once down, the pioneer landing party will unload its tractors and supplies, inflate its balloonlike living quarters, and start on a 4,000-mile overland journey to the Martian equator, where the expedition's main base will be set up (it is the most livable part of the planet—well within the area that scientists want most to investigate). At the equator, the advance party will construct a landing strip for the other two rocket planes. (The first landing craft will be abandoned at the pole.)

In all, the expedition will remain on the planet 15 months. That's a long time—but it still will be too short to learn all that science would like to know about Mars.

When, at last, Mars and the earth begin to swing toward each other in the heavens, and it's time to go back, the two ships that landed on the equator will be stripped of their wings and landing gear, set on their tails and, at the proper moment, rocketed back to the 600-mile orbit on the first leg of the return journey.

What curious information will these first explorers carry back from Mars? Nobody knows—and it's extremely doubtful that anyone now living will ever know. All that can be said with certainty today is this: the trip can be made, and will be made . . . someday.

FRED FREEMAN

Advance party, after landing on Martian snow in ski-equipped plane, prepares for trip to equator. Men live in inflatable, pressurized spheres mounted on tractors, enter and leave through air locks in the central column. Sphere on tractor at rear center is just being blown up. Cutaway of tractor, foreground, shows closed-circuit engine, run by hydrogen peroxide, oil. Trailer cutaway shows fuel supply, cargo

After 15-month exploration, the Mars expedition prepares for return flight to earth. Two landing planes are set on tails, with wings and landing gear removed. They will rocket back to the 600-mile orbit on first leg of journey