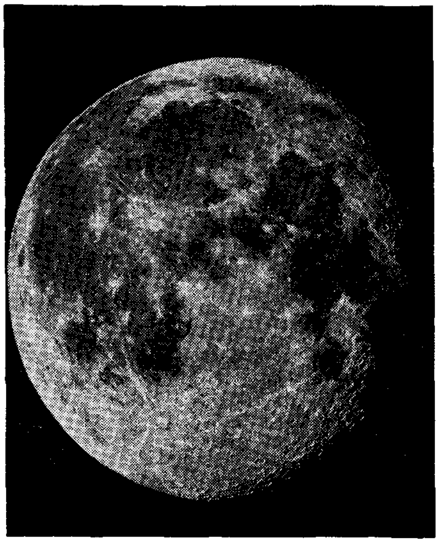

—From "The Measure of the Moon" (Baldwin).

Tycho's rays cradle The Moon.

pending on the astronomer making the estimate, Tycho's rays go out as far as 1140 or 1254 or 1440 miles from the crater rim. Nobelist Harold Urey has suggested that one of the rays, which crosses Mare Serenitatis, goes entirely around the moon. Because of its scintillating emanations, Tycho dominates the lunar landscape when the moon is full. At that time the disc takes on the appearance of a peeled orange, with Tycho at the navel.

The ray that stretches from Tycho to the lakebed where Ranger VII landed is approximately 625 miles long. Successive photographs snapped by the robot before it crashed explained the nature of the rays for the first time. They are chains of secondary and tertiary craters formed by ejection of debris during the formation of a primary crater. The fifty-foot-high hill on which Ranger VII crashed is a relic typical of the elongated dribbling that would have been expected from the fall of a curtain of rock. What probably happened can be compared to the shoveling of snow. When a shovelful is thrown onto snow accumulated roundabout, some of the shovel's burden will scoot onward from the point at which the shovel load strikes.

OF course I do not report the foregoing information on my own authority. It is derived from a daylong talk here in Tucson with Professor Gerard P. Kuiper, creator and moving force of the Lunar and Planetary Laboratory of the University of Arizona. Professor Kuiper is the chief scientific investigator of Ranger VII's findings on the moon. We sat down together at his desk on a Saturday morning, just after breakfast. We parted well after sundown. In the ten and a half intervening hours he allowed me to peer through his scientifically sophisticated eyes onto a new frontier of astronomy, the like of which has not opened up for four and a half centuries.

For a long while after the Italian Galileo in 1609 borrowed the Dutch idea (which some historians credit to Hans

PERSONALITY PORTRAIT—XCVIII

THE PORTABLE ASTRONOMER

Prof. Gerard P. Kuiper

"SUPPOSE there were people on planet Mars, and you were one of them. Suppose you had been watching planet earth for most of your life and thought of visiting the place. You would want to learn as much as you could about the safety of such a trip. You would study the earth through various instruments which you would invent for the purpose. You would confirm that planet earth had an atmosphere swimming around it. You would find signs of water vapor in the atmosphere. You would also discover that temperatures on the earth often fell low enough to cause the water vapor to freeze. Knowing that water was liquid, you would think of raindrops. Thinking of frozen drops, you might visualize hailstones. But would you predict a snowflake?"

After Professor Gerard P. Kuiper asks this question, he doesn't just sit and watch you looking goggle-eyed. He starts to answer the question.

"You probably would know about crystals, and you would suspect some interesting patterns in water crystals because of the offbeat way the two hydrogens and the one oxygen hook together. But would you predict a snowflake? If you had never seen a snowflake, would you dare to imagine such exquisite mathematical symmetries as snowflakes?"

The Professor doesn't offer to finish the answer, and in the unfinished nature of it lies his point. Science must always expect the unexpected. At the same time, it must try to reduce the unexpected to manageable proportions.

The Lunar and Planetary Laboratory which Professor Kuiper runs in a red brick building on the campus of the University of Arizona in Tucson is an effective example of this type of management. Into it he has gathered astronomers, physicists, chemists, geologists, communication engineers, and map-makers. Among the apparatus is a fat tube half as long as the building. In it gases are mixed in various proportions to simulate atmospheres. The mixtures are analyzed spectroscopically, and the resulting light patterns are matched against the patterns displayed by the atmospheres of the planets of the sun. Atmospheric pressures can be deduced by this process, and Professor Kuiper's lab team has in fact deduced the pressure of the atmosphere of Mars.

When the laboratory first announced this Martian finding, the pressure reported was so low that the National Aeronautics and Space Administration refused to accept it as an influence in planning exploration of Mars. However, the Kuiper reputation (he had served with distinction at Harvard and Yerkes

—Denis Milon, LPL.

for many years before coming to Arizona) encouraged other astronomers to zero in on Mars to check his observations. One by one they announced concurrence with his radically new appraisal. NASA could no longer afford to ignore the evidence, for the first NASA probes to Mars were supposed to drop instruments by parachute, and an atmosphere as flimsy as the one Professor Kuiper predicted would not hold a parachute open. The Mars probe being worked on now is of a different, hardier design.

Perhaps his birth in Holland, a country that has struggled for centuries to hold back the sea, has something to do with Professor Kuiper's ease in contemplating the grand environment of the universe. A strong genetic dose of far-sightedness must be built into him. Pure luck seldom accounts for sweeping changes in direction such as the one he undertook with the opening of the 1960 decade. Generally, successful practition-

Lippershey and others to Zacharias Janssen) of magnifying lenses to see across great distances, astronomers could make no more revealing searches through the telescope than could be accomplished with the unaided eye. As time passed, telescopes grew steadily bigger, and cameras were attached to their eyepieces for keener seeing. Yet men still could not penetrate the ultimate mystery of the lights and shadows on the moon's face. Now Ranger VII has proved that it is possible for robots to carry cameras directly to the lunar surface and there to discover thousands of geographical details in regions which look absolutely flat and bare in pictures taken through telescope lenses up to 200 inches across.

THE availability of such details is not, in and of itself, advantageous to scientific understanding. Details can confuse as well as clarify. The first task of science, therefore, is to determine criteria capable of establishing order in the midst of complexity. And Professor Kuiper has admirably performed this function in his analysis of the flood of data returned to earthly TV screens by Ranger VII. Tentatively, subject to the usual revision or contradiction by critical colleagues, he has found what appears to be a governing pattern in Ranger VII's close-up pictures of the moon. To his exquisitely trained eye there seems to be a direct proportion (at one point in our conversation he went so far as to call it a one-to-one correlation) between the degree of brightness of the lighted portions of lunar images in earthbound telescopes and the number of secondary craters like those forming the moon-circling ray which Ranger VII landed at the end of.

Saturday Review readers can check Professor Kuiper's principle of proportionality for themselves by examining the series of pictures reproduced on pages 41 to 43 of this issue of the magazine. They should not, however, jump to the conclusion that this discovery removes the long train of problems that lie between the crash-landing of a robot on the moon and the landing alive on the lunar surface of a man who is thereafter able to return alive to earth.

Ranger VII has placed an unexpected tool in the hands of astronomers. The tool seems applicable to the lunar garden plot that Ranger VII caught sight of at close range (for comparative dimensions, see photos on pages 35 and 41). But even in that small arena the real utility of the tool must be tested. There are, for example, extremely dark spots in the two overlapping lakebeds surrounding Ranger VII's landing site. Are these spots composed of lava, as many astronomers—Professor Kuiper included—suppose? Another Ranger could answer the question. Suppose the answer were positive; could we be certain that the correlation is not merely some trick of sunlight? Can the details in the Ranger VII photographs be extrapolated accurately across the entire face of the moon? Again the answer can be given by other Rangers. So much more information needs to be gathered that it seems reasonable to suggest dispatch of at least half a dozen more Rangers to the moon rather than depending on the necessarily localized findings of the two more now scheduled by the National Aeronautics and Space Administration.

Before the Ranger VII flight, the dangers of landing a man on the moon were purely speculative. Ranger VII proved that at least one danger is real. That danger is the risk of toppling the landing craft in a string of small and irregularly spaced craters. How many other equally unsuspected dangers may lurk in the countless unknowns of the lunar surface? Is it comforting to learn that Ranger VII crashed on a hill invisible

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ers of modern astronomy worked with telescope lenses 100 or 200 inches across. They hunted the farthest stars. Professor Kuiper turned his attention close to home, concentrating on the solar system.

The course he has followed may fairly be described as portable or bargain basement astronomy. The moon Rangers have revolutionized observation of the heavens; telescopes orbiting above earth's atmosphere will extend the revolution indefinitely, for they will operate around the clock instead of merely at night. If earth-based astronomy is to have a role in this mobile context, telescopes will have to be smaller and must be assigned more specialized objectives in order to cut costs. Professor Kuiper already is testing his belief that the volcano cones of the Hawaiian archipelago afford the clearest seeing on earth. And an electronic genius in his laboratory—Harold Johnson—has built one telescope on a peak in the Catalina mountains for little more than half a million dollars, and automated another to the point where high school students can drive it like a truck.

For the moment, at least, Professor Kuiper is quite content to let the Rangers explore the moon. He has no ambition to make the trip himself. His candidate for that job is one of his colleagues on the Ranger science advisory team, geologist Eugene Shoemaker (the other team members are Nobelist Harold Urey, Ewen Whitaker of the Kuiper lab, and Raymond L. Heacock of JPL). The Professor is much too happy growing evergreens around the patio behind the house he and his handsome wife, Sarah, their son Paul and daughter Lucy fill with banter, love, and laughter.

—WILL JONATHAN.

from earth? Is it reasonable to consider sending out a second generation of lunar exploring robots—the Surveyors, designed to descend slowly to the moon and there to sample the rocks of the countryside— when superficial scanning of the Surveyor blueprints reveals fuel tanks so placed as to explode on impact with uneven ground like the ground one often finds on hilltops? Would it not be saner to postpone Surveyor expeditions until the Rangers have made a thorough reconnaissance of all the contrasting major features of lunar terrain: the great, apparently flat lowland basins that occupy two-fifths of the moon's visible hemisphere (it is always the same hemisphere); the chains of circular mountains; the craters of all sizes, those with rays and those without?

THERE has been too much instant science in the American program for exploring the moon. To those unfamiliar with this new phenomenon, it can be explained that instant science is an intoxicating brew that drives respectable researchers to a fate worse than death. Instant science is concocted in the following manner. A competent and if possible eminent scientist is captured by granting him tax moneys to finance his favorite type of experiments. The scientist is then squeezed of his life juices periodically. He is called upon to report findings he is not yet certain of. Where necessary, hired writers state the uncertainties for him in such terms as to persuade unwitting Congressmen that the uncertainties are certain. If the captive scientist resists the squeezing, he is reminded sharply of his obligation to his country and to the well-being of his fellow scientists. If, on the other hand, he helps to stir the instant science, his reports become the basis for more generous appropriations by the Congress, the research he loves is supported more richly than ever, and he may even be invited to the White House to shake the hand of the President and answer politically loaded questions on which the future of the entire planet is professed to hang.

No amount of instant science could extinguish the genuinely brilliant achievement of Ranger VII. But enough of the heady stuff was brewed at strategic moments to pressure Congress into approving another extravagant budget for putting a man on the moon by 1970. Though Professor Kuiper won't discuss it, it is a matter of record that the Jet Propulsion Laboratory of California Institute of Technology, holder of the primary NASA contract for the nine scheduled Ranger missions, propelled the Professor onto a national TV network by inviting him to California for a press conference. The press was in the audience alright; so were millions of lay taxpayers; and when the Professor said he couldn't interpret Ranger VII's pictures to mean a deep layer of dust on the moon's surface, spokesmen for JPL and NASA turned this negative statement into a positive declaration that man could safely go to the moon as soon as a suitable vehicle was ready to carry him. When the Science and Astronautics Committee of the U.S. House of Representatives asked him to explain his observations under quieter circumstances in Washington later, the Professor scrupulously qualified his tentative interpretations to emphasize the doubts.

Professor Kuiper's remark about the dust did in one sense cheer moon travel enthusiasts. For lunar observations of various sorts—optical, radio, radar, thermal, photometric, spectrographic—had been widely read to signify the presence of a dust layer at least a few inches and perhaps a few miles deep. The last of Ranger VII's photos was taken only 1,000 feet off the moon; it showed primary craters as little as three feet in diameter and one foot deep. The outlines of those tiny craterlets registered as sharply as did the walls of the biggest craters. Such a correlation was not theoretically compatible with a deep dust layer, which presumably would swallow small crater-forming projectiles with little or no trace.

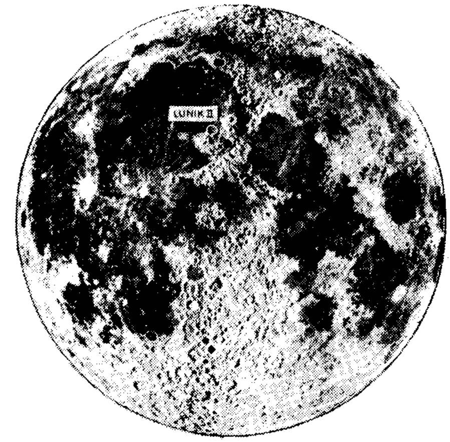
Now the supposed origin of the supposedly deep dust was the constant hail of meteorites to which the moon is almost certainly subject. The earth is pelted with a comparable showering, but these sometimes sizeable objects are reduced to powder by the friction of their passage through earth's atmosphere. The moon, being one quarter the size of the earth, is too small to possess sufficient gravitational attraction to hold any mass of gas around itself. Hence meteorites striking the moon would tend to strike as discrete objects and simultaneously pulverize the lunar surface and themselves.

SINCE the Ranger VII pictures appeared to deny the presence of a deep lunar dust layer, Professor Kuiper had to postulate an alternate fate for meteorites hitting the moon. What he came up with was a model of a sand-blasting operation. He now supposes that the meteorites, instead of shattering themselves and piling up dust on the moon's surface, must strike with such force in the lunar vacuum that either one of two events occurs:

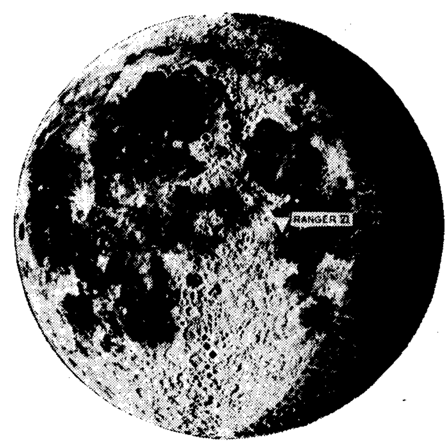
FIRST, the particles glance back into space, chipping off bits of the moon and driving those ahead, or

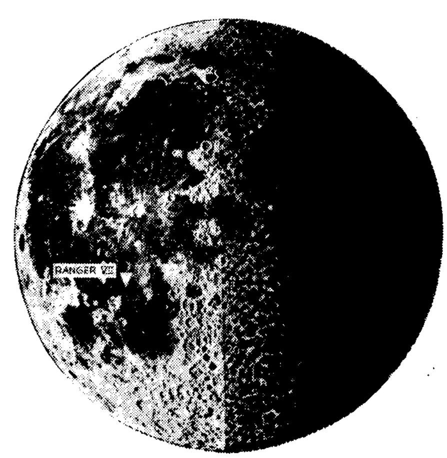
SECOND, the particles pierce the lunar surface and convert it into a kind of rocky sponge to uncertain depth.

Professor Kuiper did not arrive at the sand-blasting model through study of the Ranger VII photos alone. He matched the Ranger close-ups with telescopic pic-



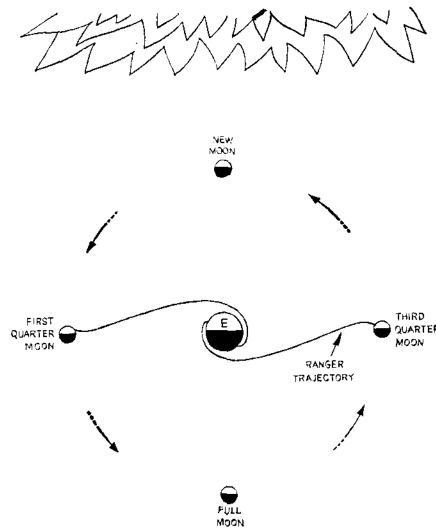
THE RUSSIAN LUNIK II was first to reach the moon. It made a direct flight in thirty-seven hours, landing on September 14, 1959. Its impact point is marked on the globe above. In the next month, Lunik III performed a spectacular maneuver that has not been duplicated since. Lunik III approached the moon while the earth-facing hemisphere was dark, and photographed the sunlit hemisphere on October 7, 1959, at a distance of 40,000 miles beyond the moon. Storing the pictures automatically, Lunik III then orbited out to an apogee 292,000 miles from earth, swung back to perigee at 29,000 miles and there transmitted its pictures to earth on October 18, 1959. Crash points of Ranger VI and VII are shown below.





The Log of Ranger VII

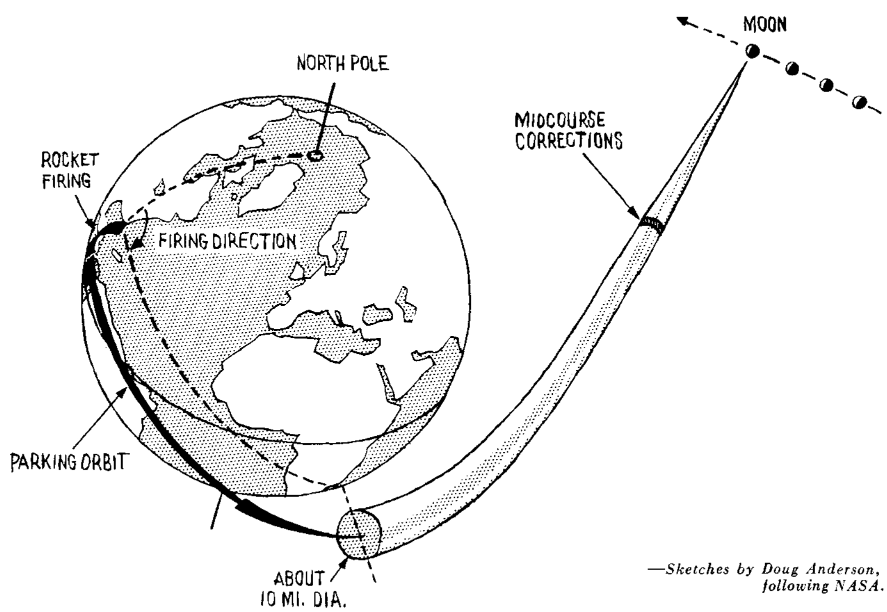
THE assignment was to photograph the earth-facing hemisphere of the moon close up and send the pictures back to earth on a TV screen. Since the pictures were to be gathered out of the sky by a big dish in the desert at Goldstone, California, and since TV signals can travel only over direct lines of sight, the mission required the moon to be somewhere above the Goldstone horizon at the time the pictures were snapped. The higher above the horizon the moon was, the less risk there would be of pictures blurred by electromagnetic noises originating on earth. When the moon was directly overhead, the risk would be lowest of all. It could not be a new moon, or a first quarter moon, or a full moon (see top sketch, this page); only a third quarter moon would do. Only then would the sun throw shadows at angles conducive to revealing photography while the moon was moving into Ranger VII's line of flight. All these conditions would be met at approximately half past five, Pacific Standard Time, on any morning of the week beginning with July 30, 1964.



At that time, the moon would be 238,000 miles over the Goldstone dish. But straight-line travel would tax available fuel capacity. A more economical scheme (see middle sketch, this page) would be to go into orbit 115 miles out from earth and then use the orbit as a rare-air springboard (magnifying the reaction to any given thrust) for the big jump onward. The elapsed time on such a trajectory would be sixty-eight and a half hours, allowing an hour for asking directions on the way. By counting backwards from the approximate Goldstone deadline of 5:30 A.M., the rocketeers computed the earliest launch from Cape Kennedy (nee Canaveral) in Florida for about noon, Eastern Standard Time, July 27.

Technicalities interfered on July 27. But on July 28, nine minutes and fifty-two seconds before noon, EST, Ranger VII took off.

The Atlas carrier rocket lifted the Agena B rocket on its nose over the West Indies. As the Atlas dropped behind, the Agena B fired and coasted over the Atlantic. Off Africa's western coast, the Agena B fired again and fell away after driving Ranger VII into a ten-mile-wide tunnel of sky which should pass through the space the moon would enter in the early hours of July 31 when the Goldstone dish was directly below.



—*Sketches by Doug Anderson, following NASA.*

The guidance motors aboard Ranger VII carried only a small amount of fuel to correct any skewing that might occur in the tunnel entry. If a large correction had to be made, it should be soon. While the remaining pathway was still several hundreds of thousands of miles long, any given change in the angle of direction would have a proportionally greater leverage. The first good chance for correction came five hours after launch, when enough readings of Ranger VII's position were in hand to give a sure result. Ranger VII's trajectory then was so close to the ideal that the correction was delayed for eleven more hours. Then a relatively small landing place could be chosen. The choice fell at 11 degrees south latitude, 21 degrees west longitude. Ranger VII landed at 10.7 degrees south, 20.7 degrees west. At Goldstone the time was 5:25:49 A.M., PST, July 31.

This stunning achievement should not be mistaken for a purely American exploit. There must be a great triangle of earthly observation points for any continuous watch on interplanetary space (see bottom sketch, this page). Ranger VII's triumph belongs to Africa and Australia as well as to the United States.