News of Science

Space Program Offered by Killian Advisory Committee

On 26 March President Eisenhower made public a report on outer space prepared by his Science Advisory Committee under the chairmanship of James R. Killian, Jr. The study set forth a research program leading through automated exploration of the moon and planets to manned space flight. Following are excerpts from "Introduction to Outer Space."

". . . It is useful to distinguish among four factors which give importance, urgency, and inevitability to the advancement of space technology.

"The first of these factors is the compelling urge of man to explore and to discover, the thrust of curiosity that leads men to try to go where no one has gone before. Most of the surface of the earth has now been explored and men now turn to the exploration of outer space as their next objective.

"Second, there is the defense objective for the development of space technology. We wish to be sure that space is not used to endanger our security. If space is to be used for military purposes, we must be prepared to use space to defend ourselves.

"Third, there is the factor of national prestige. To be strong and bold in space technology will enhance the prestige of the United States among the peoples of the world and create added confidence in our scientific, technological, industrial, and military strength.

"Fourth, space technology affords new opportunities for scientific observation and experiment which will add to our knowledge and understanding of the earth, the solar system, and the universe. . . .

"*The moon as a goal.* Moon exploration will involve three distinct levels of difficulty. The first would be a simple shot at the moon, ending either in a 'hard' landing or a circling of the moon. Next in difficulty would be a 'soft' landing. And most difficult of all would be a 'soft' landing followed by a safe return to earth.

"The payload for a simple moon shot might be a small instrument carrier similar to a satellite. For the more difficult 'soft' landing, the carrier would have to include, as part of its payload, a 'retro-rocket' (a decelerating rocket) to provide braking action, since the moon has no atmosphere that could serve as a cushion.

"To carry out the most difficult feat, a round trip to the moon, will require that the initial payload include not only 'retro-rockets' but rockets to take off again from the moon. Equipment will also be required aboard to get the payload through the atmosphere and safely back to earth. To land a man on the moon and get him home safely again will require a very big rocket engine indeed —one with a thrust in the neighborhood of one or two million pounds. While nuclear power may prove superior to chemical fuels in engines of multi-million-pound thrust, even the atom will provide no short cut to space exploration.

"Sending a small instrument carrier to Mars, although not requiring much more initial propulsion than a simple moon shot, would take a much longer travel time (eight months or more) and the problems of navigation and final guidance are formidable.

"*A message from Mars.* Fortunately, the exploration of the moon and nearby planets need not be held up for lack of rocket engines big enough to send men and instrument carriers out into space and home again. Much that scientists wish to learn from satellites and space voyages into the solar system can be gathered by instruments and transmitted back to earth. This transmission, it turns out, is relatively easy with today's rugged and tiny electronic equipment.

"For example, a transmitter with a power of just one or two watts can easily radio information from the moon to the earth. And messages from Mars, on the average some 50 million to 100 million miles away at the time the rocket would arrive, can be transmitted to earth with less power than that used by most commercial broadcasting stations. In some ways, indeed, it appears that it will be easier to send a clear radio message between Mars and earth than between New York and Tokyo.

"This all leads up to an important point about space exploration. The cost of transporting men and material through space will be extremely high, but the cost and difficulty of sending information through space will be comparatively low. . . .

"*The view from a satellite.* Here are some of the things that scientists say can be done with the new satellites and other space mechanisms. A satellite in orbit can do three things: (1) It can sample the strange new environment through which it moves; (2) it can look down and see the earth as it has never been seen before; and (3) it can look out into the universe and record information that can never reach the earth's surface because of the intervening atmosphere.

"The satellite's immediate environment at the edge of space is empty only by earthly standards. Actually, 'empty' space is rich in energy, radiation, and fast-moving particles of great variety. Here we will be exploring the active medium, a kind of electrified plasma, dominated by the sun, through which our earth moves. Scientists have indirect evidence that there are vast systems of magnetic fields and electric currents that are connected somehow with the outward flow of charged material from the sun. These fields and currents the satellites will be able to measure for the first time. Also for the first time, the satellites will give us a detailed three-dimensional picture of the earth's gravity and its magnetic field.

"Physicists are anxious to run one crucial and fairly simple gravity experiment as soon as possible. This experiment will test an important prediction made by Einstein's General Theory of Relativity, namely, that a clock will run faster as the gravitational field around it is reduced. If one of the fantastically accurate clocks, using atomic frequencies, were placed in a satellite and should run faster than its counterpart on earth, another of Einstein's great and daring predictions would be confirmed. (This is not the same as the prediction that any moving clock will appear to a stationary observer to lose time—a prediction that physicists already regard as well confirmed.)

"There are also some special questions about cosmic rays which can be settled only by detecting the rays before they shatter themselves against the earth's atmosphere. And, of course, animals carried in satellites will begin to answer the question: What is the effect of weightlessness on physiological and psychological functions? (Gravity is not felt inside a satellite because the earth's pull is precisely balanced by centrifugal force. This is just another way of saying that bodies inside a satellite behave exactly as they would inside a freely falling elevator.)

"The satellite that will turn its attention downward holds great promise for meteorology and the eventual improvement of weather forecasting. Present weather stations on land and sea can keep only 10 percent of the atmosphere under surveillance. Two or three weather satellites could make a cloud inventory of the whole globe every few hours. From this inventory meteorologists believe they could spot large storms (including hurricanes) in their early stages and chart their direction of movement with much more accuracy than at present. Other instruments in the satellites will measure for the first time how much solar energy is falling upon the earth's atmosphere and how much is reflected and radiated back into space by clouds, oceans, the continents, and by the great polar ice fields.

"It is not generally appreciated that the earth has to send back into space, over the long run, exactly as much heat energy as it receives from the sun. If this were not so the earth would either heat up or cool off. But there is an excess of income over outgo in the tropical regions, and an excess of outgo over income in the polar regions. This imbalance has to be continuously rectified by the activity of the earth's atmosphere which we call weather.

"By looking at the atmosphere from the outside, satellites will provide the first real accounting of the energy imbalances, and their consequent tensions, all around the globe. With the insight gained from such studies, meteorologists hope they may improve long-range forecasting of world weather trends.

"Finally, there are the satellites that will look not just around or down, but out into space. Carrying ordinary telescopes as well as special instruments for recording x-rays, ultraviolet, and other radiations, these satellites cannot fail to reveal new sights forever hidden from observers who are bound to the earth. What these sights will be, no one can tell. But scientists know that a large part of all stellar radiation lies in the ultraviolet region of the spectrum, and this is totally blocked by the earth's atmosphere. Also blocked are other very long wave lengths of 'light' of the kind usually referred to as radio waves. Some of these get through the so-called 'radio window' in the atmosphere and can be detected by radio telescopes, but scientists would like a look at the still longer waves that cannot penetrate to earth.

"Even those light signals that now reach the earth can be recorded with brilliant new clarity by satellite telescopes. All existing photographs of the moon and nearby planets are smeared by the same turbulence of the atmosphere that makes the stars twinkle. Up above the atmosphere the twinkling will stop and we should be able to see for the first time what Mars really looks like. And we shall want a really sharp view before launching the first rocket to Mars.

"*A close-up of the moon.* While these satellite observations are in progress, other rockets will be striking out for the moon with other kinds of instruments. Photographs of the back or hidden side of the moon may prove quite unexciting, or they may reveal some spectacular new feature now unguessed. Of greater scientific interest is the question whether or not the moon has a magnetic field. Since no one knows for sure why the earth has such a field, the presence or absence of one on the moon should throw some light on the mystery.

"But what scientists would most like to learn from a close-up study of the moon is something of its origin and history. Was it originally molten? Does it now have a fluid core, similar to earth's? And just what is the nature of the lunar surface? The answer to these and many other questions should shed light, directly or indirectly, on the surrounding solar system.

"While the moon is believed to be devoid of life, even the simplest and most primitive, this cannot be taken for granted. Some scientists have suggested that small particles with the properties of life—germs or spores—could exist in space and could have drifted on to the moon. If we are to test this intriguing hypothesis we must be careful not to contaminate the moon's surface, in the biological sense, beforehand. There are strong scientific reasons too, for avoiding radioactive contamination of the moon until its naturally acquired radioactivity can be measured.

"*And on to Mars.* The nearest planets to earth are Mars and Venus. We know quite enough about Mars to suspect that it may support some sort of life. To land instrument carriers on Mars and Venus will be easier, in one respect, than achieving a 'soft' landing on the moon. The reason is that both planets have atmospheres that can be used to cushion the final approach. These atmospheres might also be used to support balloons equipped to carry out both meteorological soundings and a general photo survey of surface features. The Venusian atmosphere, of course, consists of what appears to be a dense layer of clouds so that its surface has never been seen at all from earth.

"Remotely controlled scientific expeditions to the moon and nearby planets could absorb the energies of scientists for many decades. Since man is such an adventurous creature, there will undoubtedly come a time when he can no longer resist going out and seeing for himself. It would be foolish to try to predict today just when this moment will arrive. It might not arrive in this century, or it might come within one or two decades. So much will depend on how rapidly we want to expand and accelerate our program. According to one estimate it might require a total investment of about a couple of billion dollars, spent over a number of years to equip ourselves to land a man on the moon and to return him safely to earth.

"*The satellite radio network.* Meanwhile, back at earth, satellites will be entering into the everyday affairs of men. Not only will they be aiding the meteorologists, but they could surely—and rather quickly—be pressed into service for expanding worldwide communications, including intercontinental television.

"At present all trans-oceanic communication is by cable (which is costly to install) or by shortwave radio (which is easily disrupted by solar storms). Television cannot practically be beamed more than a few hundred miles because the wavelengths needed to carry it will not bend around the earth and will not bounce off the region of the atmosphere known as the ionosphere. To solve this knotty problem, satellites may be the thing, for they can serve as high-flying radio relay stations. Several suitably equipped and properly-spaced satellites would be able to receive TV signals from any point on the globe and to relay them directly—or perhaps via a second satellite—to any other point. Powered with solar batteries, these relay stations in space should be able to keep working for many years.

"*Military applications of technology.* The development of military rockets has provided the technological base for space exploration. It will probably continue to do so, because of the commanding military importance of the ballistic missile. The subject of ballistic missiles lies outside our present discussion. We ask instead, putting missiles aside, what other military applications of space technology can we see ahead?

"There are important, foreseeable military uses for space vehicles. These lie, broadly speaking, in the fields of communication and reconnaissance. To this we could add meteorology, for the possible advances in meteorological science which have already been described would have military implications. The use of satellites for radio relay links has also been described, and it does not take much imagination to foresee uses of such techniques in long range military operations.

"The reconnaissance capabilities of a satellite are due, of course, to its position high above the earth and the fact that its orbit carries it in a predictable way over much of the globe. Its disadvantage is its necessarily great distance, 200 miles or more, from the surface. A highly magni-

Table 1. Timetable of scientific and technical objectives.

Early
1. Physics
2. Geophysics
3. Meteorology
4. Minimal moon contact
5. Experimental communications
6. Space physiology
Later
1. Astronomy
2. Extensive communications
3. Biology
4. Scientific lunar investigation
5. Minimal planetary contact
6. Human flight in orbit
Still later
1. Automated lunar exploration
2. Automated planetary exploration
3. Human lunar exploration and return
And much later still
Human planetary exploration

fying camera or telescope is needed to picture the earth's surface in even moderate detail. To the human eye, from 200 miles away, a football stadium would be a barely distinguishable speck. A telescopic camera can do a good deal better depending on its size and complexity. It is certainly feasible to obtain reconnaissance information with a fairly elaborate instrument, information which could be relayed back to the earth by radio.

"Much has been written about space as a future theater of war, raising such suggestions as satellite bombers, military bases on the moon, and so on. For the most part, even the more sober proposals do not hold up well on close examination or appear to be achievable at an early date. Granted that they will become technologically possible, most of these schemes, nevertheless, appear to be clumsy and ineffective ways of doing a job. Take one example, the satellite as a bomb carrier. A satellite cannot simply drop a bomb. An object released from a satellite does not fall. So there is no special advantage in being over the target. Indeed, the only way to 'drop' a bomb directly down from a satellite is to carry out aboard the satellite a rocket launching of the magnitude required for an intercontinental missile. A better scheme is to give the weapon to be launched from the satellite a small push, after which it will spiral in gradually. But that means launching it from a moving platform halfway around the world, with every disadvantage compared to a missile base on the ground. In short, the earth would appear to be, after all, the best weapons carrier. . . ."

Scientific objectives. "The scientific opportunities are so numerous and so inviting that scientists from many countries will certainly want to participate. Perhaps the International Geophysical Year will suggest a model for the international exploration of space in the years and decades to come.

"The timetable [Table 1] . . . suggests the approximate order in which some of the scientific and technical objectives mentioned in this review may be obtained."

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Detection of Nuclear Explosions

American scientists have yet to reach agreement on the scientific question of whether a fool-proof monitoring system for nuclear weapon testing is possible. This first disagreement is at least partially responsible for a second—the policy question of whether the United States should enter into a pact with the Soviet Union to suspend tests. Thus, Edward Teller holds that "disarmament is a lost cause," while Harrison Brown, professor of geochemistry at the California Institute of Technology, charges that Teller is "willfully distorting the realities of the situation."

The scientific arguments in the disagreement have not been fully revealed, but in the March 1958 issue of the *Bulletin of the Atomic Scientists,* Jay Orear, who is assistant professor of physics at Columbia University, discusses four possible methods for detecting nuclear explosions. Orear has been a participant since 1957 in the Columbia Inspection Project, which is a private, unclassified study sponsored by the Columbia University Institute of War and Peace Studies. Orear says that since he has no access to classified material, he is "in the fortunate position of being free to say anything." Following are some excerpts from his discussion.

"An adequate inspection system for a test ban would require the establishment of monitoring stations at various locations deep inside the Soviet Union. About 25 such stations uniformly distributed throughout the Soviet Union should be sufficient. There is hope that such an inspection system would be acceptable to Russia, since it was Soviet delegate Valerian Zorin who proposed in the June 14, 1957 meeting of the U.N. Disarmament Subcommittee that the test-ban agreement 'be implemented by scientific control posts to be set up in the U.S., U.S.S.R., U.K., and Pacific Ocean areas.'

"The main techniques for detection of nuclear weapons testing are detection of: acoustic waves, seismic waves, electromagnetic radiation, radioactivity."

Acoustic waves. "Much of the radiation released in a nuclear explosion gets degraded by atomic processes to kinetic energy of the air molecules. Except in the immediate region of blast effects, this disturbance travels with the speed of sound and can be detected by sensitive microbarometers. This technique accurately gives the location and time of the test, and also gives a measure of the size of the explosion (yield in kilotons of TNT). The general feeling is that except for deep underground explosions, very high altitude tests, and tests of subnominal yield, nuclear tests can be detected at very large distances by this technique. Thus low-yield tests of just a few kilotons TNT equivalent would probably require monitoring stations inside the Soviet Union. Low-yield tests could probably be detected at distances up to a few hundred miles. If we require that every point in the Soviet Union be within 300 miles of a monitoring station, about 22 stations would be needed within the borders of the Soviet Union. This is assuming there are additional stations in the free nations bordering the U.S.S.R. A similar density of stations would be needed in other possible testing areas. In general, the microbarographic technique of detection is the most sensitive and would usually be the most relied upon."

Seismic waves. "In air and surface bursts, considerable blast energy is transferred to the ground. Thus, all tests whether underground or not, give rise to seismic waves which can be detected up