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THE ARTIFICIAL EARTH SATELLITE - PAST, PRESENT AND FUTURE

The beginning of the "space age" is unlikely to upset seriously a world which is by now thoroughly conditioned to the idea. The author discusses how satellite experiments lead to a better scientific understanding of our environment, which may have important consequences for our economy and way of life.

By S. FRED SINGER*

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* S. FRED SINGER, Associate Professor of Physics at the University of Maryland, is known mainly for his design of the small instrumented MOUSE satellite. He authored the resolutions concerning earth satellites adopted by international scientific bodies in 1954.

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Nearly 300 years ago Sir Isaac Newton formulated the laws of celestial mechanics to explain the motion of the earth and planets, and of the earth's natural satellite, the moon. Now after many centuries of watching these laws in operation we will give up our role as passive observers to test these very same laws on a man-made object, an artificial satellite.

Need for Satellites as Scientific Research Tool

The idea of an artificial earth satellite is many years old, although generally in the form of a manned space station. The concept of a small instrumented satellite to be used for scientific research developed only in recent years. Perhaps this is natural enough. The early thinking was done by men coming from the field of aeronautics, or by space flight enthusiasts; in all of these disciplines a manned vehicle seems to be the basis. Since the second world war, however, the rise in the science of radio, of electronic instrumentation, and the initiation of upper atmosphere explorations with rockets have focused attention also on an instrumented unmanned satellite. Again this is natural enough. While rockets provide the opportunity for carrying scientific equipment to extremely high altitudes, the total time spent in the upper atmosphere is only of the order of minutes, and they can explore only at a given location of the earth's surface at any one time. The idea of a satellite vehicle which would stay up for many days or months is a very appealing one to anyone who has gone through the effort of preparing a large number of instrument-carrying rockets, each as complicated as a modern television receiver, who has launched them at points stretching from the equator to the Artic, and who has watched them disappear forever after providing only a few minutes worth of data. Not only do we receive an extension in time of the data, but also a large geographic coverage. These considerations then formed the impetus in the thinking behind the small instru-

mented artificial satellites soon to be launched.

It was fortunate that a clear justification could be given for such a small "minimum" satellite because it represented also a project attainable with present rocket techniques. In other words, a satellite weighing a few pounds is technically feasible today while a manned space station is not.

The advantages of minimum satellites to various types of geophysical research became so apparent that during the summer of 1954 several international scientific bodies adopted resolutions endorsing the construction of an artificial satellite. The resolution of most immediate interest is the one adopted on October 4, 1954, by a Special Committee for the International Geophysical Year (CSAGI) which met in Rome. "In view of the great importance of observations during extended periods of time of extraterrestrial radiations and geophysical phenomena in the upper atmosphere, and in view of the advanced state of present rocket techniques, CSAGI recommends that thought be given to launching of small satellite vehicles, to their scientific instrumentation, and to the new problems associated with satellite experiments, such as power supply, telemetering, and orientation of the vehicle".

During the winter of 1954-55 preliminary study and planning was undertaken by an ad-hoc committee set up by the U. S. National Committee for the IGY. This committee on March 10, 1955, recommended the inclusion of satellite vehicles in the US effort for the International Geophysical Year of 1957-58, whereupon scientists from the National Academy of Sciences and the National Science Foundation submitted the proposal to the Government. The President's public endorsement of the program on July 29, 1955, signaled its actual adoption. The worldwide reaction was immediate, enthusiastic, and warm in its praise for the leadership taken by the United States in this scientific satellite project.

Project Vanguard

In the meantime Project Vanguard was born in the Department of Defense with the Navy acting as project manager. Project director is Dr. John P. Hagen of the Naval Research Laboratory. The Navy would provide the rocket vehicles, radio and tracking equipment, the Air Force its launching facilities at Patrick Air Force Base, Florida, and the Army observation bases; all of these are necessary to make the satellite undertaking a success. The National Academy would concern itself with the decisions involved in planning the scientific, non-secret satellite vehicles and their orbits. To carry out these latter functions, Prof. Joseph Kaplan, Chairman of the U. S. National Committee for the IGY, appointed a panel headed by Dr. Richard W. Porter, past president of the American Rocket Society.

Three-Stage Rocket

The problems are many. The satellite vehicle, even though it may weigh only little over 20 lbs requires a great deal of rocket propulsion to achieve the necessary velocity, about 5 miles per second. To provide this propulsion efficiently it must be applied in stages: first a large rocket booster lifts the assembly above the bulk of the atmosphere and maneuvers it into the proper direction with a speed of some 3000 mph; secondly an intermediate stage which brings the final stage and satellite into the proper horizontal trajectory with a speed of 11000 mph, and finally a third stage which at an altitude of 300 miles adds the last required amount of speed to give the satellite the necessary orbital velocity of nearly 18000 mph. The accuracy problems are severe. The velocity has to be kept within about one percent of the designed value and the angle from the horizontal must not exceed one to two degrees.

The overall contract for Project Vanguard has been awarded to the Glenn L. Martin Company of Baltimore, Maryland, the design of the first-stage rocket motor

to the General Electric Company, the second stage to the Aerojet-General Corporation of Azusa, California. The details of the third stage have not been announced; it is thought likely that it will be a solid-propellant rather than a liquid-fueled rocket. Because of the possibility of failures in any of the stages and because of the severe accuracy requirements, ten or more launchings are planned in the hope that they will lead to several successful satellites which will remain above the atmosphere for many orbits.

The designed launching altitude is approximately 300 miles although launching errors in velocity and angle will make the orbit elliptical and therefore of varying altitude. The limits 200 and 800 miles which have been announced in the press give essentially an estimate of the errors expected. At these altitudes the atmosphere, even though a better vacuum than we can ever achieve at sealevel, still contains a large number of molecules with which the satellite will collide and which will rob it of some of its energy. After a few days therefore, depending on the details of the orbit, the satellite will spiral in, reenter the atmosphere, disintegrate and burn up before reaching sealevel. In a perfect circular orbit at 300 miles it would "live" for about 100 days. Any large deviation from this orbit will shorten its life drastically.

Satellite Orbit

The details of the satellite itself are now being settled. The available rocket propulsion power limits the maximum weight of the satellite vehicle to something like 21½ lbs. Its dimensions will be small, of the order of 30 inches, in order to reduce the exposed area and therefore the atmospheric drag, but large enough to be trackable from the ground by optical and radio techniques. The satellite may even be visible to the naked eye under ideal viewing conditions at dawn and dusk. With the sky nearly dark it will then

shine by reflected sunlight and appear like a faint star which flashes across the sky in a few minutes.

The major problem revolves around the choice of orbit. Due consideration must be given to the available rocket propulsion power, the precision of the control system, the availability of a launching site and associated questions of range safety; even the cost and logistic problems of setting up a chain of world-wide tracking stations for observing and communicating with the satellite has to be considered. The orbit now chosen for the initial satellites is inclined about 40° to the earth's equator. The satellite can then be seen from latitudes 40° north to 40° south (from New York to Buenos Aires in the western hemisphere, from Madrid, Naples, Ankara, Peiping down through all of Africa and Australia). In all likelihood, however, future satellites will not be confined to the 40° inclination. From the point of view of many scientific experiments, mainly geophysical, a higher inclination would be more desirable; a 90° inclination would of course produce a polar orbit which can traverse every part of the globe. The satellite, being outside of the atmosphere, does not participate in the earth's rotation but stays fixed in space; during every orbit traversal it will therefore see a different portion of the earth's surface.

Scientific Space Laboratory

The question of what scientific equipment the satellite is to contain is being considered widely, and many scientific organizations have held special symposia to discuss just such problems, for example the Institute of Radio Engineers, the Institute of Aeronautical Sciences, the American Meteorological Society, the Upper Atmosphere Rocket Research Panel, and others. There is no lack of suggested experiments for the satellite. It seems that it can investigate many scientific phenomena in a very efficient manner. These include investigations of the

earth's interior, its magnetism and mass distribution, of the conditions of the lower and upper atmosphere, and range all the way out to the study of extra-terrestrial radiations, such as cosmic rays, interplanetary dust particles, and various radiations from the sun and stars. Even valuable checks of the Einstein theory of relativity can be performed by means of satellites.

Observatory in Space Revolutionizes Astronomy

It is perhaps not generally realized how restricted out earth-bound view of the universe really is. We see astronomical objects only in the visible part of the optical spectrum. Thanks to developments in the science of radio we can now also observe the objects in our galaxy and beyond, which emit radio waves. We have thus learned to extend the limited sensitivity of the human eye; the main obstacle now becomes our own atmosphere which absorbs most of the incident radiations and hides much of the universe from our view.

It is therefore not difficult to appreciate how even a small satellite will revolutionize observational astronomy and geophysics; much more so when larger and more elaborate satellites capable of carrying television cameras and telescopes become technically feasible.

We do not need to belabor this great scientific importance of artificial satellites further; it is a foregone conslusion.

Will it Revolutionize our Lives?

It is more interesting to speculate on the effects of this venture on our everyday lives. Now that man is taking his first, although indirect steps into space, now that our scientists and engineers are getting ready to start a new science - the science of experimental celestial mechanics, will the beginning of the space age change our mode of life suddenly or drastically?

Predictions are always risky, but I don't think we should anticipate any

violent changes. Unlike in the case of nuclear energy which hit us suddenly and forcefully, we have long been conditioned by science fiction, by countless magazine and newspaper accounts, and by TV to this coming age of space. No one will be particularly surprised when it officially begins; in fact a goodly number of people are already convinced of the existence of space ships and interplanetary travel.

It is reasonable to expect that most of us will remain earthbound, that we will conduct our business and live our lives with both feet on terra firma, and that our main concern will still be, as it always has been, - the weather.

Weather - A National Problem

This last remark is more than a figure of speech; living on the earth's surface we have a real earth-bound view, and regard what goes on in the lowest layers of the atmosphere as most important. Indeed, the importance of weather can hardly be overestimated. Every section of our economy and of our national life depends on it; not only agriculture, but meat packers, canners, agricultural implement manufacturers, the fuel oil industry, the building industry. The vagaries of weather affect hydroelectric plants, city water supplies, clothing manufacturers and resort operators. It is significant to watch the increasing extent to which airlines and other transportation companies, even insurance companies are employing meteorologists. There has been a tremendous rise in the business of weather consultants, firms which will forecast specific weather problems for a client, who may produce umbrellas and rainwear, sports equipment, fans or heaters. The list is endless; weather touches all of us earthlings.

Floods, hurricane damage, droughts, all these may be regional in extent but they have become of immense national concern. More and more therefore we must focus our attention on the problem of weather prediction, not only on a day-to-day (synoptic) basis but well in advance on a longer period basis: wet

spells, heat waves, droughts, frost in every-day language; the irregular motion of air masses, the formation of weather fronts and cyclonic systems, of "highs" and "lows", in the language of the meteorologist. The problem is to predict when and how these disturbances are formed and superimposed on the vast globe-girdling circulation of the atmosphere. The behavior of the atmosphere follows known physical laws and can in principle be described mathematically; in practice this description is exceedingly complicated. Nevertheless, remarkable success can be achieved in predicting the weather by numerical techniques using modern high-speed electronic computers. The main stumbling block is the lack of sufficient world-wide meteorological data based on observations.

It turns out, and indeed this is perhaps the main point of this article, that an artificial satellite carrying proper instruments, even though above the atmosphere, is in a surprisingly good position to tell us what is going on in the lower atmosphere. The main reason for this is that the satellite can view the earth whereas we cannot: it is too difficult and too expensive. In fact less than 5% of the earth's surface is under meteorological surveillance, with a heavy concentration of stations in the USA and wide gaps elsewhere. During the International Geophysical Year, meteorologists will try to fill some of the largest gaps, particularly in the Antarctic, but they cannot approach the continuous, hour-to-hour coverage of a satellite.

Solar Radiation is Source of Weather

The circulation of the atmosphere is caused by the unequal distribution of energy from the sun; more energy arrives at the equator than at the pole. The main job of the satellite is to measure the energy retained by the earth. This is an easy measurement: a simple photocell pointed downward can determine the fraction of sunlight reflected back into space (mainly by clouds); the

rest of the energy remains with the earth and the atmosphere and provides the driving force for the large-scale motions of the atmosphere.

Storm Tracking

A simple satellite as a tool of meteorology can do even better. By reporting on cloud patterns it allows us to recognize typical weather conditions, and track the development and motions of cyclonic storms, hurricanes, etc. Such a satellite may become a reality before the end of this decade. Soon thereafter with further developments in rocket propulsion it should become possible to launch the "ideal" meteorological satellite suggested by Dr. Harry Wexler of the US Weather Bureau, which carries a television camera and traverses the earth in a 4000 mile high pole-to-pole orbit. (As in the case of the small satellites the information would be stored, and relayed to ground receiving stations by radio transmissions.)

Control of Weather?

It seems that the beginning of the "space age" will not immediately call forth interplanetary travel, but rather an increase in man's understanding of the physical environment of his own planet, Earth. But man's ingenuity knows few bounds. Perhaps, as in the case of the atom, increased understanding and knowledge of the atmosphere will prove to be only the forerunners of man's control over his natural environment.