'Well,' said this officer, who also should not go unhonoured, 'we are grateful to you all the same. In a moment I shall tell you to leave. Take not this door but the one on the right. Go through. No one will ask you who you are or why you are there. You will walk straight on.'

Perhaps the main thing is as simple as that. Desmond Chute was essentially a Catholic priest, living a full life with wide spiritual sympathies extending alike to the dignities of a departing social order, to the intellectual subtleties of the Mozart *Concertante* or the *Anathemata* of David Jones, to the traditional workman and to all trades with their gear and tackle and trim, to the victims of war and the harried cats and dogs of Genoa. Of a piece with this are the instructions concerning his death, written in inimitable Italian but roughly to be translated thus: 'In reverence and love for the Sacred Liturgy, I desire that my requiem shall be sung with deacon and subdeacon; apart from this, let my funeral be like the funerals of the poor. Let me be buried in the habit of a Dominican Tertiary and in all the vestments of a priest. If I do not die in England, let my tombstone bear only the dates: birth, ordination, death; and the words: DESMOND MACREADY CHUTE: PULVIS ATTAMEN SACERDOS.'

# Survey

## FIVE YEARS OF SPACE

On October the 4th, 1957, the world was startled by the announcement that the Russians had put a satellite, Sputnik I, successfully into orbit. The launching, coupled with the relatively large size of the satellite, caused widespread alarm in the United States. The Americans had already announced their intention of launching a number of small satellites as part of their contribution to the International Geophysical Year, which began in July 1957. Practically the only hint that the Russians intended anything similar was given by an article in a Soviet magazine for Radio amateurs, which in July 1957 asked enthusiasts to prepare receiving systems in the 20 and 40 Megacycle Bands for satellite reception, laid down the form in which observations should be taken, and gave a telegraphic address, Moskva-Sputnik, to which they should be sent. This article passed unnoticed in the West.



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Five years later, with more than 100 successful launchings of satellites and space probes, it is possible to attempt some assessment of the scientific contribution made by these experiments. In some fields it has been very significant, in others disappointingly small, serving mainly to confirm what had already been inferred by indirect methods. The number of spectacular discoveries has been very small indeed.

Sputnik I was a sphere, about 23 inches across, and weighing 184 lbs. Its rocket carrier, weighing four tons, went into the same orbit. It carried two radio transmitters of fairly high power, which continued to transmit for about three weeks. As far as is known, it had no scientific instruments apart from those which monitored conditions inside the satellite, and the only scientific publications resulting from this flight have been those concerned with the satellite path, and the effects of atmospheric drag. Sputnik II, which went into orbit on November 3rd, was heavier and more sophisticated. Weighing 1,100 lbs, it carried a simple Cosmic ray counter, a spectrograph for observing ultra-violet and X-rays from the sun, and a mongrel dog called Laika. They were unlucky, with this satellite, not to discover the radiation belts. The orbit was rather elliptical, reaching an altitude of 1,000 miles at apogee, with a perigee altitude of 140 miles. At its highest point the vehicle must have passed into the inner radiation belt, but this occurred in the Southern Hemisphere, where no Russian tracking stations existed. Signals picked up by stations in Australia were not decodable, and the priority of discovery therefore went to an American satellite some months later. The impact of Sputnik II was lessened in Anglo-Saxon countries by indignation about the treatment of the dog, which died in orbit after about a week. The vehicle and its rocket re-entered the atmosphere in April 1958, apparently breaking up, since bright meteor-like tracks were seen by many observers in America and Europe over a period of about an hour. Although the cosmic ray detectors did not find the radiation belts, accurate measurements were made of the position of the earth's magnetic equator, and these results, published in 1961, confirmed the existence of anomalies which had been inferred from cosmic ray measurements at sea level and in aircraft.

Meanwhile the U.S. Navy had tried unsuccessfully on December 6th, to launch its first 'grapefruit' satellite, six inches in diameter, and weighing three lbs. Although very small, the first of them was equipped for measurements on meteors. By necessity, the American instrumentation was at this stage more sophisticated and far lighter than the Russian. Unfortunately the Vanguard rocket failed at launch, and burnt up on the pad. The first successful American launch was made on January 31st, 1958, when the U.S. Army put its Explorer I vehicle into an elliptical orbit which reached 1,570 miles at apogee and 224 miles at perigee. It was launched by a Redstone rocket first stage, followed by a group of eleven small Sergeant rockets as the second stage, with three Sergeant rockets as a third stage, followed finally by a single combined fourth stage rocket-satellite. The whole complicated device, which was developed by Von Braun's group at Huntsville, Alabama, depended on a signal which fired the



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second stage, and was controlled from the ground by hand. This extremely tricky operation was, however, successful at the first attempt, and Explorer I took into space the cosmic ray detector, built by Van Allen's group at the State University of Iowa, whose apparent failure led to one of the very few important and almost totally unexpected discoveries of the past five years, the radiation belts.

Spectroscopic observations of the aurora by Meinel and other workers, in 1950, had indicated the existence of some trapping mechanism outside the earth's atmosphere, by which charged particles on their flight from the sun were delayed. Studies of magnetic storms, cosmic ray variations and of radio interference following solar flares showed anomalies which are now explainable in terms of the Van Allen belts. At the international conference on Cosmic Radiation at Varenna in July 1957, a great deal of the discussion was devoted to these effects. None of the explanations offered were correct, and certainly no one at that meeting expected that the answer would be given so soon. The answer is not yet complete, and it seems clear that effects which were then thought to be associated must now be explained separately. In some ways the existence of the belts raises problems which are more difficult than those known previously, but their discovery remains a very significant advance.

At the further points of the Explorer I orbit, the signals from the cosmic ray counter, instead of levelling off to the steady value expected, stopped altogether, although on returning to lower altitudes counting began again at a normal rate. At first a failure was assumed, but it occurred to someone in Van Allen's group that this effect would also occur if the counter were paralysed by very intense radiation. Explorer II, which was launched on March 5th, 1958, carried a detector which was capable of responding to somewhat higher radiation intensities. This shot unfortunately failed, due to a last-stage breakdown, but Explorer III, on March 26th went into orbit successfully and showed that the radiation was indeed increasing outside the earth's atmosphere. Finally, Explorer IV, launched on July 26th, in an orbit which approached more closely to the poles than previously, was instrumented sufficiently well to plot the radiation contours of the belt out to 1,400 miles.

Meanwhile the U.S. Navy, having failed again on February 5th, succeeded on March 17th in putting their Vanguard grapefruit into a high and rather elliptical orbit, where it will remain for several hundred years. Powered by solar batteries, its transmitter is still working, and measurements have been made on the intensities of very small meteors.

On May 15th, the Russians launched Sputnik III, with a 1½ ton payload, which included cosmic ray and X-ray detectors, ion detectors, Atmospheric pressure and composition equipment, an ultra-violet spectrograph for solar radiation, and devices for measuring the earth's magnetic and electric fields. About ten papers have been published in scientific journals on results of measurements with this satellite, and a great deal of more detailed data circulated through the I.G.Y. publication services. Perhaps the most significant result was the



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observation of an anomaly at the edge of the Van Allen belt, which afterwards proved to be part of a separate outer belt. Observations were also made on the effects of a solar flare which occurred on July 7th, 1958.

After the first year, in which seven successful satellite launchings were made, a great deal of effort was put into mapping and detailed measurement of the radiation belts. The inner belt is a doughnut shaped region extending from about 600 miles to about 10,000 miles altitude, and covering the whole equatorial region of the earth from about latitude 50° North to 50° South. The outer belt is more crescent shaped in cross-section, curling towards the earth at high northern and southern latitudes and extending detectably out to about 40,000 miles. Both belts contain high energy protons and electrons, which spiral constantly, to and fro along the lines of force of the earth's magnetic field which traps them. They are slowly absorbed by the earth's atmosphere at the northern and southern ends of the belts, where they come to altitudes of only a few hundred miles. The energies of the particles are comparable with that produced by a cyclotron, and small by cosmic ray standards, but because their density is high, the radiation intensity in the whole region between 500 miles and forty thousand miles would be dangerously high for an unprotected animal or human being. A limited amount of shielding could be provided by a space capsule, but the belts would make it difficult to find a suitable orbit for a permanent manned observatory. The particles in the belts probably originate from the sun, from which they are ejected in bursts associated with solar flares. There are still considerable difficulties in explaining their intensity and constitution, and our understanding is only qualitative.

The next stage was the firing of deep space probes, the first of which was attempted unsuccessfully by the U.S. Air Force on August 17th, 1958. On August 24th, Explorer V failed, due to a freak accident when almost in orbit. After the upper section had separated, the booster rocket continued upwards, slightly faster, and hit it, knocking it off course. Eventually the Air Force had a semi-successful firing of a space and moon probe, called Pioneer I, which got out to 70,000 miles before failing, and falling back to earth. Some useful radiation measurements were made with this rocket, but it was followed by two more failures, one of which reached 63,000 miles.

1959 was a good year for the Russians. They fired three Moon rockets. Lunik II hit the moon after making valuable cosmic ray measurements in transit. They found no radiation belts associated with the moon, which implies no, or a very small magnetic field, and these results were confirmed by direct magnetic measurements. Lunik III circled the moon in October, taking television pictures of the far side, which cannot be seen from the earth. The surface features were similar to those on the visible side, and these flights shed little light on current controversies about its origin and composition, but were a considerable prestige success.

American work in 1959 and 1960 continued to measure more accurately the properties of the outer belt, using Pioneer IV, and the very successful Pioneer V,



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which in March 1960 made important measurements on particles and plasma ejected from the sun. These measurements form the basis of a current controversy on the mechanism by which charged particles are carried from solar flare events. Later in the year, between November 12th and 23rd, a complex group of solar flares occurred whilst one of the American Discoverer satellites, and Explorer VII, were in orbit. The Discoverer satellites could be recovered after re-entry, and nuclear emulsions carried by them examined in the laboratory. It was found after the November 1960 events that the capsules of the recovered satellites were faintly but detectably radio-active, due to the high radiation level encountered. Pieces of lead and iron could be examined to estimate the nature and intensity of the particles from the flare. (A difference of opinion developed at this stage between those who felt that pieces of recovered satellite, suitably polished and mounted, should be kept as souvenirs, and those who wanted them sawn into small bits for scientific examination.) The details of these events have not yet been completely assembled and analysed but sufficient information has been published to show that solar flare events are far more complex than had been believed.

During this period, the whole American rocket programme was reorganized, and its scientific research aspects came mainly under the control of N.A.S.A., the National Aeronautics and Space Administration, a new Government agency. The Tiros weather satellites, which carried television cameras to record cloud and storm movements, and the Transit navigational satellites, for accurate measurements of position and geodetic research, were also launched successfully.

In February 1961, the Russians launched a space probe towards Venus, which negotiated successfully the difficult early stages of going into an orbit about the earth and then being fired out again. This stopped transmitting unaccountably when far out towards the planet.

In April and May 1961, the first manned flights occurred, and public attention became centred on the space race. The very large rockets which the Russians have been developing since 1948 gave them a considerable advantage in this field, and the American reply, the Mercury project, was admittedly a makeshift affair. The scientific information obtained from the manned flights has been small. In general, instruments will do a better job in space than a man. Although the physiological and psychological data obtained were necessary for any development of manned space flight, a human observer is scientifically important only if completely new and unexpected phenomena occur. So far, none of any significance have.

The manned flights distracted attention from two important American experiments carried out at the same time, both by M.I.T. groups. Explorer X, launched into a highly elliptical orbit extending to 240,000 miles, measured velocities and densities of plasma, and established the existence of a solar 'wind', which complicates but adds to the interest of problems associated with solar flare particles. Explorer XI detected, for the first time, Gamma-rays in cosmic radiation. This discovery, made by Clark and Kraushaar of M.I.T., is of great



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significance in the problem of the origins of cosmic rays, and has a bearing, hotly disputed at present, on the two rival theories of cosmology, the evolutionary or 'expanding universe' model, and the steady state or 'continuous creation' model.

During 1961 also, the Echo satellites, large inflatable balloons used for studies of atmospheric drag and radiation pressure, were launched successfully. Two new types of military satellite, the Midas missile detection vehicle and the Samos reconnaissance satellite, came into operation. A number of classified launchings, made by the Americans in the past eighteen months, were probably concerned with these.

1962 seems to have seen no important discoveries in pure science, but considerable technical advance in manned flight, as well as the success of Telstar. The fate of the American Venus probe, which could give very important information on the planet, is still not certain. The Russians have again demonstrated their technical precision with the double manned flight, whose purpose is, however, not quite clear.

Over the past five years, the total achievement must be regarded scientifically as valuable, but not spectacular. Our knowledge of the earth and its environment has been extended from an altitude of about fifty miles to several thousand miles. A great deal of measurement must still be made; the unexpectedly long life of the new radiation belt set up by the American nuclear explosion in July shows that some of the data obtained previously on conditions at even a few hundred miles is unreliable.

It is significant that no outstanding figures have emerged in the past five years. Most of the important experiments have been done by groups which already had distinguished records in their fields before the satellites went up. They have simply taken the new technique and used it where ground level measurements, balloons, or small rockets were inadequate. Groups under Van Allen, Pomerantz, Rossi, Simpson, Yagoda, Vernov and Chudakov in cosmic rays, Meinel and Sedov in Astronomy, Chapman in geomagnetism, Schklovskii, Ginzburg, Gold and Spitzer in theoretical astrophysics, have done outstanding work with satellites as they did with other methods before. Even in fields where space vehicles seem to have an enormous advantage, the ground-based scientist can still sometimes produce important results first. In some fields, as for instance in ultra-high energy cosmic ray physics, it seems unlikely that the space techniques will compete with sea level and mountain experiments at all, because the earth's atmosphere is essential to the detection and identification of the highest energy particles. Moreover, quite a lot of useful information can be obtained by simply observing satellites, carefully and patiently, from the ground. The group at Farnborough under King-Hele has produced in collaboration with many other groups, important results on the variation of atmospheric pressure with altitude, based on observations of the changing orbits of many vehicles with time.

Over the past eighteen months, some misgivings have been voiced both by scientists, and by scientific journalists, over the whole space programme. The manned moon-flight project in particular has been very strongly criticized.



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Space experiments are expensive, and manned space experiments very expensive. It is difficult to make a realistic assessment, because practically the whole cost of an experiment is in the rockets, and military expenditure is inextricably bound up with pure scientific research. The incremental cost of a typical Explorer satellite experiment can be put at about three million dollars, about the cost of the Jodrell Bank radio-telescope, and more than half the cost of the University of California's Bevatron accelerator, which has made several fundamental discoveries in nuclear physics.

Meanwhile, the attack on the real problem of this century, that of providing food and the means of survival for a rapidly expanding world population, goes limping along for lack of funds and skilled technical manpower.

The sciences and techniques which are being developed most intensively at present are precisely those which will increase the standard of living and wealth of the industrialized countries, widening the gap between them and the rest of the world. There is a desperate need of money and people for applied research in agriculture, plant genetics, the utilization of solar power, cheaper and more efficient methods of producing electric power in small units, and all the other problems involved in economic development of the hungry two-thirds of the world.

It is easy to criticize the Americans and easy to forget that, whatever their policy on space and military expenditure, they are also the only nation in the world who have made any significant contribution to the economic development of the under-privileged countries. Nor are the problems solely those of money and manpower. The problem of feeding the African continent would be largely solved by damming the Congo River, creating two lakes which would cover most of the Congo and Chad, and using them to irrigate the Sahara. Even if money for the project were available it is difficult to imagine the new independent nations agreeing to it. A less ambitious, but still very important scheme, would be the diversion of the River Tsangpo in Tibet, and the construction of a hydroelectric station, which could produce a quarter of the present world electric power output. The chances that this relatively cheap project, which could revolutionize the economies of Southern China and Northern India, will ever be agreed, seem equally small.

These are, of course, problems of technology, rather than science, and many scientists believe that their only responsibility is the overall development of their subjects as pure disciplines in a balanced way, from which developments technology can draw what it needs. The question at present is whether any country, or any group within a society, can afford to stand aside from the problem, which threatens to be the largest ever faced by the human race as a whole, more serious even than the threat of nuclear war. Possibly some of the long term aims must be sacrificed for the short term problems. Whatever the answer, it seems certain that the expansion into space, the most remarkable achievement of our time, must, if the situation is faced rationally, have only small priority.

NEIL PORTER



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