

James C. Hagerty, Press Secretary to the President

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AND

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THE ARGUS EXPERIMENT

This report discusses the scientific results and implications of the Argus experiments. Because of the fact that many of the experiments performed in connection with these atomic bursts involved both the electron trapping phenomenon and the military effects phenomena, it was considered advisable to keep the results classified until a proper sorting of the information had been accomplished. Since reports on relevant military aspects have only become available within the last two weeks, it is regrettable that it is possible to release any of this information.

The scientific aspects of these experiments, involving flights at high altitude, small atomic bursts over the North Atlantic in August and September 1958, are regarded by many participants as one of the major achievements of the International Geophysical Year. The coordination of these experiments engaged the coordinated resources of large numbers of the scientific talent of the nation, and it was apparent that the success of the experiment, if successful, would be recorded by instruments of the far-flung international network of the IGY. The completion of the observational and interpretative contribution by the many participants will doubtless stand as a durable milestone in the development of our knowledge of the great natural phenomena of the earth's atmosphere which have engaged his study for many centuries.

The Christofilos Experiment

The underlying idea for the Argus experiments was conceived by Nicholas C. Christofilos, physicist at the Lawrence Radiation Laboratories of the University of California. In 1957 he called attention to the fascinating physical effects which might be expected from an atomic burst in the near-vacuum of outer space, high above the earth and its dense atmosphere. Of the various effects contemplated, the most interesting one promised to be the formation and trapping of ionospheric electrons at high altitudes in the magnetic field of the earth. In the event of the burst there would be thrown out many particles, including atoms of intermediate atomic weight. Most of these particles are well known to be radioactive and subsequently decay with the emission of alpha particles, electrons and gamma rays. Most of these decay processes are completed within minutes.

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The fission fragments themselves are electrically charged and move at high velocity. Hence, their paths in the near-vacuum of outer space would be controlled, in the main, by the earth's magnetic field and would be helical ones around magnetic lines of force. The electrons resulting from their decay would likewise move in helical paths in the magnetic field. In accordance with the theory of synchrotron motions, which has been known and demonstrated in a laboratory for many years, it could be expected that from high energy electrons

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would be trapped in the outer reaches of the earth's magnetic field and would only slowly "leak" down into the atmosphere and be destroyed by collisions with air molecules in the tenuous upper atmosphere. The trapping region would be in the form of a thin "magnetic shell" surrounding the earth and bounded by lines of force. Trapping times ranging from minutes to weeks were estimated for electrons whose helical paths ranged as close to the solid earth as 100 to 2000 miles, depending on their energy.

The proposal of Christofilos captured the imagination of many of other scientists and the idea was studied tentatively during the following months.

Meanwhile, the United States had succeeded in launching the first IGY satellite, Explorer I, which had as its primary purpose the study of cosmic radiation in the vicinity of the earth. The observations made by this satellite as well as those with Explorer II, launched a few months afterwards, led to the discovery of a surprising phenomenon, namely, the existence in the region around the earth of a belt of high intensity corpuscular radiation due to natural radioactive sources.

The first public report of the discovery and of its interpretation in terms of magnetic trapping was made on May 1, 1958, at a symposium of the National Academy of Sciences and the American Physical Society. The report was given by James A. Van Allen, with his colleagues of the State University of Iowa, who had originally carried out the experiments.

The existence of the natural corpuscular radiation served to provide all validation of the proposal of Christofilos. At the same time it raised the problem of whether observations of the effects of an artificial injection of electrons would be possible in the presence of the natural "background".

#### Initiation of Argus Experiment

The fate of the entire enterprise was held before the President's Science Advisory Committee since it was clear that the program involved a mixture of scientific and military interests. At the suggestion of the President's Science Advisory Committee, a group of representatives of the scientific community and the defense community was brought together to appraise all aspects of the matter. It was decided in latter April 1958 to proceed with the Argus experiment as a national undertaking. The operational and technological management of the project was vested in the new Air Force Research Program Office of the Department of Defense. In his capacity as Chief Scientist, Herbert York directed the program for the agency.

The Air Force Special Weapons Center undertook the development of a series of high altitude sounding balloons for the study of the fringes of the expected effect at altitudes of about 100 miles. The five-stage solid propellant rocket vehicle that had been developed by NASA. The Air Force Cambridge Research Center and the Air Force Research Institute developed, located and prepared the ground stations of equipment at suitable ground stations and also arranged for the launch. The difficult mission of delivering these balloons to high altitudes, high altitude and detonating them there in the upper atmosphere over the South Atlantic Ocean was undertaken by a Navy tank barge specially organized for the purpose.

EXPERIMENT IV

Meanwhile, the Academy's (ASA) group was planning to vigorously further studies of the Van Allen radiation belts revealed by Explorers I and III. To secure more detailed knowledge of the Van Allen radiation belts, and to observe any artificial phenomena from the proposed Argus experiment, instrumentation was being designed and developed at the State University of Iowa, together with rockets of the type developed by the Army Ballistic Missile Agency and the Jet Propulsion Laboratory of the California Institute of Technology had already been scheduled as satellite vehicles. The main objective of the program was the launching of Explorer IV.

Conduct of Argus Experiment

On July 26, 1958, Explorer IV was successfully launched from an orbit inclined at a 51° angle with the equator and with all equipment operating perfectly, immediately began transmitting valuable new information on the nature, intensity and distribution of the natural radiation belts. This inclination orbit proved to be a distinct advantage over the previously used 34° inclination orbits due to its much greater spatial coverage. Meanwhile, the new observing stations were being set up. The task force was enroute to the designated areas of the high latitude island. Preliminary sounding rocket flights were being conducted at Wallops Island in Virginia, Ramey Air Force Base in the Virgin Islands, and at the Air Force Base in Florida.

Bursts occurred on the 27th and 28th of August between 10:00 and 11:00 hours and on the 6th of September when they were coincident with a solar time. In order to produce an adequate quantity of data for analysis, it was desirable to minimize the local reflections to the atmosphere. Calculations showed that this could be done by putting the satellite in the shell between longitude zero and 90° west. This was done in view of the fact that the earth's magnetic axis is tilted and displaced relative to its rotational axis, so that the edges of the shell would intersect the surface at these longitudes. The burst data were fairly good.

Because of the small yields involved in the high latitude bursts, there was no fallout hazard.

A fascinating sequence of data was obtained from the initial flash of the burst was seen as a very faint aurora but the auroral luminescence in the atmosphere extending upwards along the magnetic line of force through the forest point. Simultaneously at the point where this line intersects the atmosphere in the northern hemisphere, a bright aurora was observed near the Azores islands, a bright aurora was observed from the aircraft previously mentioned. The event, and the complex series of events began, and the time in history measured geophysically, and the energies were being related to a quantitative measurement of the energies into the earth's magnetic field or the quantity of energy at the energies at a known position and time.

The diverse radiation instrument on Explorer IV was reported to ground stations the atmospheric intensity and position of the shell of high energy electrons or its passage through the atmosphere during the bursts. The satellite continued to orbit and for the duration of the

man-made shell of trapped radiation has a low velocity of drift. The physical shape and position of the shell were accurately plotted and the decay of intensity was observed. Moreover, the rapid distribution of the radiation was measured at each point. The shape of a selected magnetic shell of the earth's magnetic field was being plotted out for the first time by experimental means. In addition, excursions within this shell the trapped electrons were traveling great distances and were following the magnetic field patterns of the earth of over 4,000 miles. The rate of decay of electron density as a function of altitude provided new information on the density of the upper atmosphere since atmospheric scattering was the dominant cause for loss of particles. Moreover, continuing observation of the thickness of the shell served to answer the vital question as to the rate of loss of trapped particles transverse to the shell. All of these matters are of essential importance in a thorough understanding of the dynamics of the natural radiation and were now the subject of detailed study by means of the "labeled" electrons released on Argus.

Throughout the testing period a plan of series of flights at high altitude sounding rockets was carried out with full success and yielded valuable results in the lower fringes of the trapping region.

Explorer IV continued to observe the artificially injected electrons from the Argus tests, making some 15 transits of the shell, until exhaustion of its batteries in latter September, though by that time the intensity had become barely observable above the background of natural radiation at the altitudes covered by the orbit of Explorer IV.

It appears likely, however, that the deep space probe will have detected a small residuum of the Argus electrons at very high altitudes on December 6, 1958. But the effect appeared to have been an indication of before the flight of Pioneer I on November 1958.

The site of the Argus tests was selected to place the artificial injected radiation shell in a region where the intensity of the natural radiation had a relative minimum. If the bursts had been made at either higher or lower latitudes, the site would have been more difficult to detect, plot and follow.

The immense body of observations has been under active interpretation by a large number of persons for about seven months. At this time now are satisfactory accounts being given available from the ground to the scientists. From these observations we have learned, for example, the following examples:

There was no diffusion of electrons transverse to the electron shell since the thickness of the shell remained constant. Also, traces of the shell persisted for many days and possibly weeks.

Extrapolations of the earth's magnetic field into regions which have been based on satellite measurements, were confirmed by the experiment. The experiment has made it possible to predict the shape and intensity of the earth's field with considerable accuracy to distances of the order of several earth's radii.

The directness and clarity of the artificial injection test have provided a sound basis for interpretation of the natural radiation around the earth. It is likely that many other natural phenomena

continue to arise from the great diversity of geophysical observations being conducted by other countries participating in the International Geophysical Year.

The IGY group of the National Academy of Sciences plans, in conjunction with its other programs, to make the scientific results of Expedition 1957 available as rapidly as analytical procedures permitted. In view of the progress made by experimenters and analysts, the Academy has already more than a week ago to arrange for the presentation of summary reports at its annual meeting on April 22-25, 1957.