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THE WHITE HOUSE
WASHINGTON

November 3, 1958

MEMORANDUM FOR THE PRESIDENT

FROM: J. R. KILLIAN, JR.

SUBJECT: Preliminary Results of the ARGUS Experiment

Background and Summary

This historic experiment, probably the most spectacular ever conducted, provides the first verification of the existence of several phenomena of military importance when a nuclear explosion takes place in space above the earth's atmosphere. That these phenomena would result was first predicted by Nicholas Christofilos of the Livermore Radiation Laboratory. He pointed out that high energy electrons from the fission products generated by a suitably placed explosion would spread out into a broad belt around the earth covering the equatorial and temperate zones. These electrons might damage electronic equipment in space, render the space above the earth temporarily lethal to man, generate world-wide radio noise, especially in the HF and VHF bands, and produce strong localized disturbances of the ionosphere at great distances from the explosion.

These predictions were brought to the attention of the President's Science Advisory Committee in January 1958, and at its request a group of twenty outstanding physicists in the country was assembled at Livermore for an intensive two-week study of the subject. Their report, completed in March, confirmed and extended the theoretical findings of Christofilos.

This subject matter was presented to the National Security Council on March 6 by representatives of the President's Science Advisory Committee. The experiment itself, with the approval of the President, was planned during April and May under ARPA direction and was carried out by a team including elements of all three military services and the Armed Forces Special Weapons Project. W. H. Bradley of my staff has played an important coordinating role and has brought this information together. [redacted]

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The results yielded by the experiment verified and confirmed the earlier predictions. They affect the design requirements for the electronic and warhead components of intercontinental and intermediate range ballistic missiles, the design of ballistic missile and air defense radar equipment, and, especially, military short wave communication equipment.

The successful performance of the experiment was in itself an extraordinary accomplishment. Especially notable was the successful launching of a large solid-fuel rocket carrying a nuclear payload from the heaving deck of a ship in the squally South Atlantic. Scarcely less so is the fact that the whole experiment was planned and carried to a completely successful conclusion in less than five months, including arrangements for coordinated measurements utilizing Explorer IV.

Impressive, too, is the fact that no leaks have occurred despite the large number of civilian and military personnel involved in the planning, in the Navy task force, in the preparation of Explorer IV and the analysis of its data, and in subsequent scientific studies.

The Experiment

A| KT nuclear weapon, carried by a solid fuel rocket, was launched near 45° South Latitude in the Atlantic by the USS Norden Sound and exploded in space at an altitude of about 350 kilometers. The expanding, glowing bomb debris was confined and guided by the earth's magnetic field so that after the first few seconds, the material moved mainly along the magnetic field lines. The action of the field resembled that of the barrel of a recoilless rifle. Half of the material plunged immediately into the top of the atmosphere near the launching site causing a man-made Aurora. The other half arched up 4000 miles above the equator and returned to earth, still guided by the field lines, near the Azores where another Aurora and radar reflections from it were observed from the USS Albemarle.

Along the trajectory, high energy electrons were emitted by the flying fission products. It was mainly with these fission-decay electrons in mind that the experiment had been planned. Physical principles had indicated that the electrons should rebound rapidly from north to south along the magnetic field lines, meanwhile progressing more slowly in longitude, circling the earth in a few minutes. This zigzag motion should

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continue until the energy of the electrons was dissipated by collisions with other slower electrons and ions which normally inhabit the space above the earth.

The experiment bore out the theoretical predictions of Christofilos in a beautiful manner and provided scientific information of great value about conditions surrounding the earth. The electrons were observed by means of four counters in the satellite Explorer IV, which had been prepared with this experiment in mind. The counting rate was transmitted by radio to microlock and minitrack stations on the ground and recorded on tapes.

Many other observations in connection with the experiment were made near the launching site and also near the so-called "conjugate point" to determine the effect of the phenomenon on the ionosphere. Not all of these results are yet available. A significant check on the Explorer IV data was provided by sounding rockets carrying radiation measuring apparatus. Three shots in all were fired from the USS Norden Sound, separated by a few days. The first was apparently low in altitude but the other two were placed as planned. The best observations were obtained from shot III.

Military Significance

A nuclear explosion in space produces three kinds of effects of military importance. The high energy radiation including particles from the explosion produces effects in space; the whirling high energy electrons generate radio noise; and the delayed radiation from the fission products can affect radio transmission.

All of these effects are matters of degree, depending on yield, location and geometrical considerations.

All of the effects are bounded by about 70° magnetic N. latitude. It is doubtful if any long-lived effects can be produced nearer to the pole than this limit.

The effects are also limited by the tendency of the pressure of the products of the explosion to "burst" the earth's magnetic field. Too large a nuclear explosion would expel the bomb debris through a temporary "crack" in the field.

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1. a. Effect in Space. The effect in space itself is of importance to apparatus such as satellites and ballistic missiles exposed to this effect. The high energy electrons generate X-rays when they strike any material object; these X-rays are very penetrating and can damage electronic equipment. Of course, they are lethal to man in such quantities.

The experiment indicated that the KT bursts caused about one million electrons per second having energies greater than about 1 Mev to strike a square centimeter target for a period of several tens of hours. During the first few minutes, a much higher electron flux existed in the vicinity of the shot.

b. Duration. The duration of the effect is such that the electron counting rate decays two to one in about one day.

2. Radio Noise Effect. High energy electrons in a magnetic field radiate radio noise over a band extending from a lower limit below the broadcast band up to an upper limit typically in the region of one hundred megacycles.

The yield and altitude of the ARGUS experimental shot were so planned that the noise should not have been observed. The amount of noise is reliably predictable from the number of electrons of each energy and magnetic field orientation and therefore the experiment provides a basis for estimating the amount of noise produced by larger explosions.

3. Ionosphere Effects. Spots of greatly increased ionization several hundred kilometers across, at each end of the magnetic field lines passing through the shot, are formed at the top of the earth's atmosphere. These spots should exhibit radar reflections, intense auroral glow, and various effects on communications equipment. The experiment confirmed the existence of these effects and the data when fully utilized will permit an estimate of their military consequences.

Scientific Significance

The experiment provided a great deal of information of scientific importance. [redacted]

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1. From the decay rate of the electron count, the density of the atmosphere at great heights above the earth can be inferred. The results so far seem to confirm the predictions that the "exosphere" is somewhat denser than had formerly been supposed, confirming recent clues from satellite drag data.

2. The experiment provides the first extensive experimental evidence concerning the structure of the earth's magnetic field above a thousand miles or so. The fact that the electrons emitted by the shot remained mainly confined to a layer about one hundred miles thick for two weeks shows that even 4000 miles above the earth the magnetic field is not unduly turbulent as some scientists had suspected.

3. Comparison of the man-made aurorae of the ARGUS experiment with natural ones may throw considerable light on the mechanism of those perplexing phenomena.

J. R. Killian, Jr.

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