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OPERATION ARGUS

1958

United States Atmospheric Nuclear Weapons Tests
Nuclear Test Personnel Review

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In late August and early September of 1958, U.S. Navy Task Force 88, consisting of nine ships and approximately 4,500 men, secretly conducted three high-altitude nuclear tests in the South Atlantic. The code name of the operation was ARGUS. In each of these tests, the task force launched from the missile trials ship, USS Norton Sound (AVM-1), a specially modified X-17a three-stage ballistic missile carrying a low-yield nuclear warhead, which was detonated high in the Earth's upper atmosphere. Upon completion of these launchings on September 6, the task force departed the operating area (Con't)

20. ABSTRACT (Con't)

for Rio de Janeiro, Brazil, and thence to home ports in the United States. This report details Department of Defense personnel participation in these tests, with an emphasis on radiological safety.

FACT SHEET

ARGUS was the designation given to the three high-altitude nuclear test shots conducted by the United States in the South Atlantic Ocean in August and September 1958. The ARGUS shots were conducted to test the Christofilos theory, which argued that high-altitude nuclear detonations would create a radiation belt in the upper regions of the Earth's atmosphere. It was theorized that the radiation belt would have military implications, including degradation of radio and radar transmissions, damage or destruction of the arming and fuzing mechanisms of ICBM warheads, and endangering the crews of orbiting space vehicles that might enter the belt.

The tests were conducted in complete secrecy and were not announced until the following year. The organization conducting these tests was Task Force 88, a naval organization consisting of nine ships and approximately 4,500 men. A few specialists from the other services and the Atomic Energy Commission and their contractors were with the fleet. Coordinated measurement programs using satellite, rocket, aircraft, and surface stations were carried out by the services and other government agencies and contractors throughout the world. The ships of Task Force 88 were the antisubmarine carrier USS Tarawa (CVS-40), the destroyers USS Bearss (DD-654) and USS Warrington (DD-843), the destroyer escorts USS Courtney (DE-1021) and USS Hammerberg (DE-1015), the fleet oilers USS Neosho (AO-143) and USS Salamonie (AO-26), the missile trials ship, USS Norton Sound (AVM-1), and the seaplane tender USS Albemarle (AV-5).

The low-yield (1- to 2-KT) devices were lifted to about a 300-mile altitude by rockets fired from the Norton Sound. The detonations occurred at such distances above the Earth that there was no possibility of exposure of task force personnel to ionizing radiation.

Of the 264 radiation-detection film packets distributed to the task force, 21 had indications of radiation exposure, but the highest exposure recorded by an individual's packet was 0.010 roentgen (R), so low as to be negligible. The highest exposure recorded, 0.025 R, was by a control film packet. Control film packets were located in radiation-free areas within the ships. Even this reading was so low that it could have been spurious or the result of natural background radiation. In any event, both readings were below the accuracy limit of the film, developing system, and densitometers used.

The results of the ARGUS operation proved the validity of the Christofilos theory. The establishment of an electron shell derived from neutron and beta decay of fission products and ionization of device materials in the upper fringe of the atmosphere was demonstrated. The operation not only provided data on military considerations but also produced a great mass of geophysical data, pure scientific material of great value.

PREFACE

Between 1945 and 1962, the U.S. Atomic Energy Commission (AEC) conducted 235 atmospheric nuclear weapons tests at sites in the United States and in the Pacific and Atlantic oceans. In all, about 220,000 Department of Defense (DOD) participants, both military and civilian, were present at the tests. Of these, approximately 142,000 participated in the Pacific test series and approximately another 4,500 in the single Atlantic test series.

In 1977, 15 years after the last aboveground nuclear weapon test, the Center for Disease Control (CDC) of the U.S. Department of Health and Human Services noted more leukemia cases than would normally be expected among about 3,200 soldiers who had been present at shot SMOKY, a test of the 1957 PLUMBBOB Series. Since that initial report by the CDC, the Veterans Administration (VA) has received a number of claims for medical benefits from former military personnel who believe their health may have been affected by their participation in the weapons testing program.

In late 1977, the DOD began a study that provided data to both the CDC and the VA on potential exposures to ionizing radiation among the military and civilian personnel who participated in the atmospheric testing 15 to 32 years earlier. In early 1978, the DOD also organized a Nuclear Test Personnel Review (NTPR) to:

- Identify DOD personnel who had taken part in the atmospheric nuclear weapon tests
- Determine the extent of the participants' exposure to ionizing radiation
- Provide public disclosure of information concerning participation by DOD personnel in the atmospheric nuclear weapon tests.

This report on Operation ARGUS is one of many volumes that are the product of the NTPR. The DOD Defense Nuclear Agency (DNA), whose Director is the executive agent of the NTPR program, prepared the reports, which are based on military and technical documents reporting various aspects of each of the tests. Reports of the NTPR provide a public record of the activities and associated radiation exposures of DOD personnel for interested former participants and for use in public health research and Federal policy studies.

Information from which this report was compiled was primarily extracted from planning and after-action reports of Task Force 88 (TF 88) and its subordinate organizations. What was desired were documents that accurately placed personnel at the test sites so that their degree of exposure to the ionizing radiation resulting from the tests could be assessed. The search for this information was undertaken in archives and libraries of the Federal Government, in special collections supported by the Federal Government, and, where reasonable, by discussion or review with participants.

For ARGUS, the most important archival source is the Washington National Records Center in Suitland, Maryland. The record groups searched at the Records Center were those of DNA, Office of the Chief of Naval Operations, and the Naval Operating Forces. The Naval Operational Archives at the Washington Navy Yard also was helpful, as was the collection of documents assembled by the Air Force Weapons Laboratory (AFWL) Historian, the collection now being housed in the AFWL Technical Library at Kirtland Air Force Base, Albuquerque, New Mexico. Other archives searched were the Department of Energy archives at Germantown, Maryland, its Nevada Operations Office archives at Las Vegas, the archives of the Test Division of the Los Alamos National Laboratory, and the Eisenhower Library at Abilene, Kansas.

The major gap in the information sources for ARGUS is the documentation of the results of the exposure of the film badges that were actually used. Because of the nature of the operation and the remoteness of the detonations, the possibility of any exposure at all was extremely small, and only a very few film badges were even removed from storage for use. The various record collections consulted do not have documentation of the readings of the processed badges. The agency that provided and processed the badges, the U.S. Army Lexington Blue Grass Depot Activity has made repeated searches but has not found these records.

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INCEPTION OF OPERATION ARGUS

Introduction

In late August and early September of 1958, Navy Task Force 88 (TF 88), consisting of nine ships and approximately 4,500 men, secretly conducted three high-altitude nuclear tests in the South Atlantic. The operation was conducted under the code name ARGUS. In each of these tests, the task force launched from the missile trials ship USS Norton Sound, a specially modified X-17a three-stage ballistic missile carrying a low-yield nuclear warhead, which was detonated high in the Earth's upper atmosphere. Upon completion of these launchings on 6 September, the task force departed the operating area for Rio de Janeiro, Brazil, and then to home ports in the United States. Not until March 1959 did the United States Government acknowledge that TF 88 had been sent to sea to conduct those nuclear tests.

ARGUS was unique among U.S. atmospheric nuclear test operations in a number of respects. It was one of the most expeditiously planned and executed of all U.S. nuclear tests, requiring just 5 months from inception to execution, in contrast to the normal period of one or more years. It was the only clandestine test series conducted during the 17-year period of atmospheric testing. It was also the first shipboard launch of a ballistic missile with a nuclear warhead, and it was the only atmospheric nuclear test operation in the Atlantic Ocean. Most significant of all, the purpose of ARGUS did not fit the usual categories: the ARGUS shots, strictly speaking, involved neither diagnostic tests of a weapon design nor effects tests on military systems. The objective of ARGUS was to establish the practicability of a theory postulating that a very-high-altitude nuclear detonation of proper yield would produce phenomena of potentially significant military importance by interfering with communications and weapon performance. When the Eisenhower Administration officially announced the occurrence of the tests on 19 March 1959, the New York Times headlined ARGUS as the "Greatest Scientific Experiment Ever Conducted."

The ARGUS nuclear tests grew out of an experiment proposed by Nicholas Christofilos, a physicist working at the University of California Radiation Laboratory at Livermore (UCRL), California. In late 1957 and early 1958 Christofilos examined the possibility of creating an artificial radiation belt in the upper regions of the Earth's atmosphere with a nuclear detonation at an extremely high altitude. Naturally occurring belts of electrically charged particles trapped above the Earth had been discovered by Explorer I, the first satellite launched by the United States in early 1958, and had been named the Van Allen belts in honor of the man who directed the experiment that discovered them. The charged radiation in these belts consists of high-energy electrons and protons. The primary sources for these particles are the disturbances on the sun's surface. The particles are ejected from great flares and come toward the Earth where they are trapped by the geomagnetic field. The magnetic field bends the flight path of these particles because of their electric charge. Some of the particles are forced into a corkscrew-like motion along the north-south direction of the Earth's magnetic field.

Christofilos theorized that a nuclear detonation several hundred miles above the Earth acting as a source of beta particles (electrons originating from an atomic nucleus) would produce a shell of high-energy electrons (trapped radiation) in the upper atmosphere, oriented along the Earth's magnetic field like the naturally occurring Van Allen belts (Figure 1). The following paragraphs give a simplified description of the physical processes involved in trapped radiation.

A portion of the energy released in splitting, or fissioning, uranium or plutonium atoms and in the decay of the products of this splitting is in the form of beta particles. These are not so important a consideration in low-altitude atmospheric nuclear explosions as they cannot penetrate

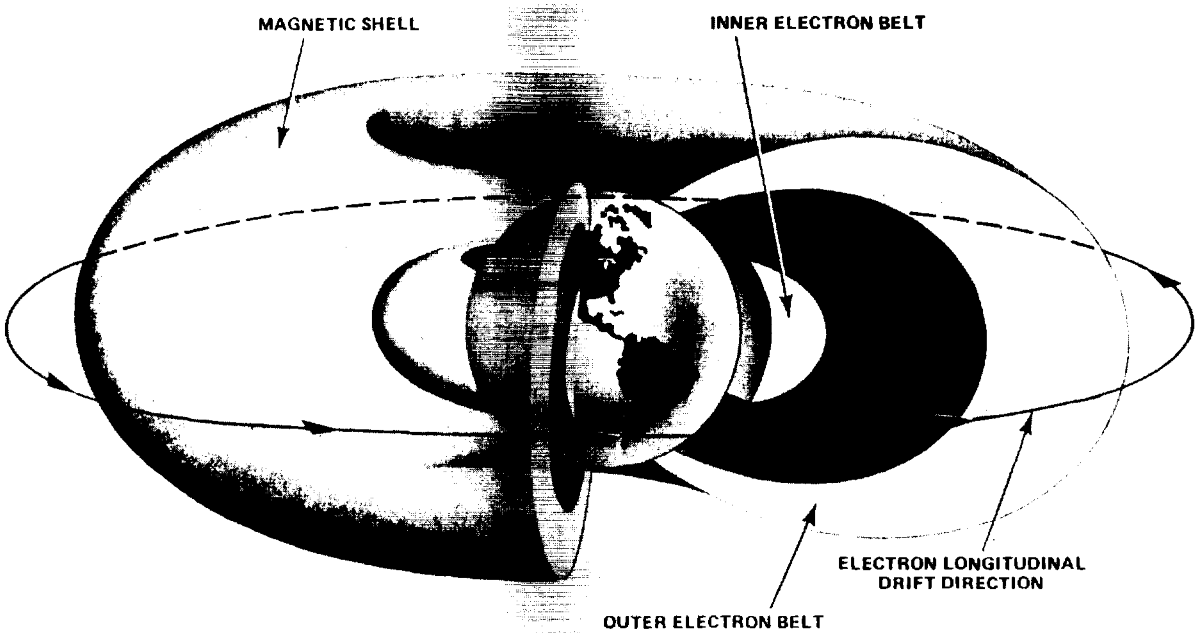

Figure 1. Van Allen belts.

more than a few meters of air before they lose their energy by interacting with air particles. Their contribution to the initial energy release in a nuclear explosion is comparable to the other forms of emission (gamma and neutron) in the processes of fission and fission-product decay.

The absence of many air particles surrounding a high-altitude nuclear explosion allows the beta particles, or electrons, a great freedom of movement without loss of energy, although their motion is guided by the presence of the Earth's magnetic field. At their birth, the beta particles have a velocity that depends on the kind of fission fragment that is decaying and a direction of motion that is the sum of the motion of the decaying fragment and the random emission direction from the fragment.

A beta particle moving in an east-west direction with regard to the north-south orientation of Earth's magnetic field will follow a circular path whose radius will depend on the energy of the particle and strength of the magnetic field at that point. The motion of most of the beta particles formed in a nuclear explosion will, however, form some angle other than an exact right angle with the magnetic field, and therefore the motion of the betas will be a corkscrew-like motion along the north-south orientation of the magnetic field.

The Earth's magnetic field emanates from the magnetic north and south poles and rises to great heights (several Earth radii) over the magnetic equator. This field is often represented by "lines of force" that are shown closely spaced in the polar regions and widely spaced over the magnetic equator (Figure 2). The closeness of these lines in these representations depicts the strength of the field, with closely packed lines at the poles indicating high field strength and widely spaced lines over the equator indicating lower field strength.

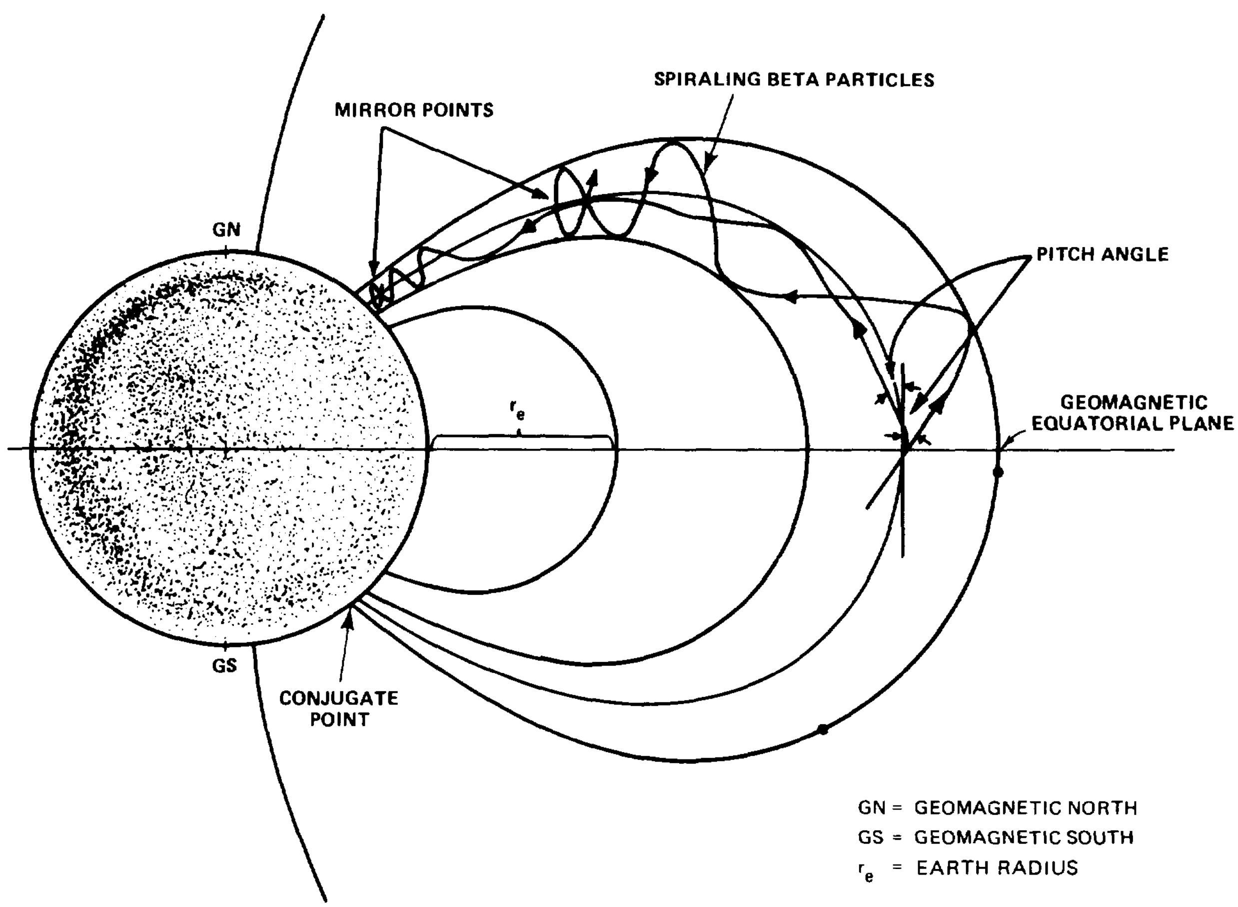

Figure 2. Trapped radiation diagram.

The beta particles spiral around these "lines." The size of their spiral depends on the beta particle energy and on the strength of the field. At the magnetic equator, where the field is weakest, the beta spirals are large, but as they move toward the poles the spirals tighten as the field strength grows. The spirals finally tighten to a point at which the particles are reflected back up the field line and spiral toward the other pole. The place at which a particle reflects is called a mirror point, and the mirror points at the north and south ends of the field line are often referred to as the conjugate points.

The conjugate point varies with the energy, or velocity, of the particles and their direction of motion and position in the magnetic field at the time of their release during the decay processes. For some betas, the mirror, or conjugate, point is within the atmosphere, and the betas collide with air particles, lose their energy, and do not spiral back up the field lines. Some of the energy given to the air particles in these collisions will cause them to give off light. These light displays are called auroras after the natural auroras visible in the polar regions that occur when electrically charged particles coming from the sun are trapped by the geomagnetic field and are guided down to low mirror points. If the mirror points are above the atmosphere the beta particles retain their energy and spiral back and forth with great rapidity. For example, a beta of typical fission decay energy mirroring at about 185 miles (298 km) above New York City will reflect to its conjugate point above the Earth's southern hemisphere and return about 10 times per second. It will corkscrew about the field line about one million times per second (Figure 2).

In addition to the motion of the charged particles along the field lines, there is a tendency for them to move across the lines wherever the magnetic field strength is not uniform. This results in an eastward (longitudinal) drift around the Earth superimposed on the back-and-forth spiral motion between regions near the conjugate points. Within a few hours after a high-altitude nuclear detonation, the beta particles form a shell completely around the Earth (Reference 1).

Christofilos' theory was of major interest to the U.S. Government, particularly the Department of Defense (DOD), because of the possible effects of an artificially created radiation belt on defense systems. For example, a sufficiently powerful electron source, such as a nuclear warhead of several megatons yield, if detonated high above the Earth might seriously degrade radio and radar transmission and reception in the 50- to 200-MHz band. Such a radiation belt might also damage or destroy the arming and fuzing mechanisms of an intercontinental ballistic missile passing through it. A third possibility was that the radiation belt might endanger crews of orbiting space vehicles that entered the belt.

To verify Christofilos' theory and the magnitude of its predicted effects required a nuclear test operation unlike any the United States had previously conducted. Both the operation itself and the effect predicted by Christofilos came to be known by the code name ARGUS.

The remainder of this chapter and Chapters 2 and 3 discuss Operation ARGUS from inception through execution, with special emphasis on the planning and conduct of radiological safety (radsafe) procedures. Appendix A summarizes and graphically presents ARGUS planning and operational milestones. Because of its unique characteristics, Operation ARGUS did not produce the detailed documentary record found with other oceanic nuclear tests. Much of the planning for the operation was done on a highly informal basis to ensure secrecy and to conserve time. TF 88, which carried out the actual tests, was organized solely to conduct this one operation. Once it completed its mission, the task force dissolved and its records were dispersed. Over time, some of these records have been either lost or destroyed. Careful and extensive research among repositories, archives, and libraries in the Washington, D.C., area and elsewhere in the United States resulted in recovery of many of the most important documents for understanding how Operation ARGUS was carried out. (The documentary sources consulted are presented in Appendix B.) One notable exception was the inability to locate ARGUS film badge records.

Planning

Soon after Christofilos published his findings, the military implications of his theory attracted the interest of the Chairman of the President's Science Advisory Committee (Reference 2). In February 1958, the Chairman convened a scientific working group at UCRL to investigate the theory and its potential military applications. The Pacific phase of Operation HARDTACK, scheduled for the summer of 1958, included a high-altitude, high-yield detonation, shot TEAK. The working group was especially interested in whether TEAK would cause the operational impairment of radar and radio systems effect predicted by Christofilos' theory. The working group concluded that TEAK would be able to demonstrate only limited effects on the systems in question.* The group also concluded, however, that severe electromagnetic disturbances in the radio and radar frequency ranges of concern might be produced by designing a weapon and burst height specifically to achieve these results. Thus, because of the lack of knowledge about the effects of nuclear detonations at high altitude, some uncertainties in Christofilos' predictions, and the likelihood that such detonations could seriously degrade strategic military systems, the working group recommended that a test of the theory be conducted as soon as possible (References 2 and 3).

During March and April, the decison was made, and planning proceeded, to mount a special nuclear test designed solely to determine the practicability of Christofilos' theory. The planning environment for the operation was unlike that of any previous nuclear test series. Shortage of time and tight security were the unique factors in planning for ARGUS (References 2 and 4).

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* TEAK did, in fact, cause communications impairment over a widespread area in the Pacific basin. This was not due to the Christofilos effect, however, but to the TEAK shot injection of a large quantity of fission debris into the ionosphere. The fission debris prevented normal ionospheric reflection of high-frequency (HF) radio waves back toward the Earth, which disrupted most long-distance HF radio communications.

One reason for speed in the planning and execution of the ARGUS operation was the possibility of an atmospheric nuclear test moratorium going into effect in the fall of 1958. The Commander, TF 88 (CTF 88), who was responsible for conducting the operation, described the planning environment in his final report (Reference 2), "A sense of urgency was injected into this planning due to the political climate then prevailing, which rendered the future of nuclear testing politically uncertain." Thus planners had to work within a very tight schedule, with a deadline of 1 September 1958 for completing the test. This date was selected because it coincided with the end of the Pacific phase of Operation HARDTACK (Reference 4). A unilateral testing moratorium was actually begun by the United States following the Nevada phase of HARDTACK on 1 November 1958.

Stringent security was required because the ARGUS effect would not remain localized. If an ARGUS detonation performed as predicted, it would produce worldwide disturbances in the upper atmosphere that could be monitored by any nation with properly emplaced instrumentation. Therefore, the most obvious way to prevent other nations from acquiring experimental data was to deny them accurate knowledge of the operation's timing and objectives (Reference 2).

The political sensitivity of the ARGUS test, combined with security requirements, led to a series of carefully designed cover plans. These plans were to conceal the true intentions of all phases of the ARGUS operation, not only from other nations but also from the majority of DOD personnel participating in the tests themselves (References 4 and 5).

An additional planning consideration was the geographic location of the operation. The high-latitude South Atlantic was chosen for several reasons related to the nature of the experiment. The first was the altitude capability of the launch vehicle. The X-17a missile was chosen because of its ready availability, but it had a limited altitude capability. To reach the altitude necessary to trap the beta particles on the desired magnetic field line with a launch from the Pacific Proving Ground at equatorial latitude would require a much greater capability than that of the X-17a. A launch with the detonation at the same altitude but nearer the poles would place the burst geomagnetically much higher (see Figure 2). The South Atlantic was chosen as it lay east of a dip in the magnetic field known as the Brazilian Anomaly. At this point the field swings unusually low, so that beta particles trapped on the lower field lines would collide with air particles, lose their energy, and be lost to the experiment. As the particles were expected to drift eastward from the detonation point, a detonation to the east of this anomaly would allow measurements to be made over most of the Earth's surface before this anomaly was encountered and the beta particles became lost.

All the foregoing considerations influenced the decision to conduct the ARGUS test as a sea-based operation in the South Atlantic at about 45° south magnetic latitude. A launch point in this vicinity placed the task force outside normal shipping lanes, which was desirable from the standpoint of safety and security. Furthermore, a launch in this region meant the magnetic conjugate point would appear near the latitude of the Azores, well within the range of U.S. military forces required for support of the scientific projects planned for ARGUS. These forces would be able to operate from the U.S. Air Force Base at Lajes in the Azores, as well as from bases in the continental United States and Puerto Rico (References 2 and 6).

Authorization

President Eisenhower approved testing the ARGUS concept on 6 March. As a result of action by the Armed Forces Policy Council on 11 March, UCRL was directed to undertake the necessary further theoretical work and to submit recommendations as to the nature of any nuclear test to be conducted. In order to effect close coordination between the DOD and the Atomic Energy Commission (AEC), the Deputy Secretary of Defense on 24 March designated the Armed Forces Special Weapons Project (AFSWP) as the responsible agency for the DOD, in coordination with the Advanced Research Projects Agency

(ARPA). In a memorandum of 4 April, the Deputy Secretary of Defense assigned the overall responsibility for the management of this research and development program to the Director, ARPA (Reference 2).

During March and April 1958, several conferences to develop a plan for the ARGUS experiments were conducted among representatives of ARPA, AFSWP, the three Services, and other participating agencies. For example, in a memorandum of 3 April, the Chief, AFSWP reported to the Assistant to Secretary of Defense (Atomic Energy) on the important scientific ties between HARDTACK and ARGUS. Citing a meeting of 2 April, he noted that the agencies involved in designing the ARGUS experiment were counting on the scientific data from the two HARDTACK high-altitude shots to assist their planning (Reference 7), "They are particularly interested in using such data as stepping stones in planning for the safety and instrumentation of the ARGUS experiment." He also stated that while ARGUS was to be completed before the end of the Pacific phase of HARDTACK, it could not usurp personnel and resources previously allocated for HARDTACK.

As a result of these March and April conferences, AFSWP reported to ARPA that it would be possible to conduct a definitive test of the Christofilos hypothesis, provided that specified problems received a timely resolution and that a shipboard launch of the warhead at about 45° geomagnetic latitude was feasible. AFSWP recommended that funds and priorities be established to conduct a test within 5 months (Reference 2).

The program outlined by AFSWP following the 2 April 1958 ARGUS conference consisted of the following elements (Reference 2):

1. Two missiles, with warheads of 300 to 500 pounds (136 to 227 kg), would be fired from a single location within a period of 1 month.
2. The first priority shot would be one at 200 to 1,000 miles altitude (322 to 1,609 km) at about 45° geomagnetic latitude. The lower priority shot would be at 2,000 to 4,000 miles (3,219 to 6,437 km) altitude near the geomagnetic equator. Four test flights would be required to check out the warhead-adaption kit.

3. Earth satellites carrying a payload of about 100 pounds (45.4 kg) would be placed in equatorial (up to 30^{o}) and polar (up to 70^{o}) orbits, with perigees of about 200 miles (322 km) and apogees of 1,800 miles (2,897 km) or greater.
4. Satellite instrumentation would measure electron density as a function of time with energy discrimination; would include a magnetometer, and possibly means for measuring radio noise; and would record background information prior to the shots as well as the postshot phenomena.
5. Sounding rockets, fired from appropriate ground locations, would carry instrumentation to make the same measurements as the satellites, except for radio noise. Ground stations would be used to study effects on radio astronomy and radar probing and to make auroral measurements.

The concurrent UCRL theoretical study completed on 15 April summarized the requirements for an ARGUS test shot as including a geomagnetic latitude of 30^{o} to 45^{o}, an altitude of 500 to 800 miles (805 to 1,287 km), and a yield of 2 to 10 KT. This study also recommended that the measurements be limited to those essential for determining the existence of the ARGUS effect because of the pressing time problem (Reference 2). The essential scientific elements of the proposed operation were decided upon at a conference held on 17 April. The Chief, AFSWP reported the results of this conference to the Chief of Naval Operations (CNO) in a memorandum dated 21 April. In this memorandum, CNO was alerted to the fact that the Norton Sound was the planned launching ship and that it should be accompanied by an aircraft carrier, at least three destroyers, and a fleet oiler. The memorandum requested the CNO to order a flag officer and an operational staff to duty with the Chief, AFSWP. As part of AFSWP, the admiral and his staff were to coordinate the activities of the agencies contributing to the ARGUS project. They were also to plan and conduct the tests themselves (Reference 7).

On the basis of the above planning, on 25 April 1958, the Deputy Secretary of Defense approved a nuclear test in the exosphere prior to the completion of Operation HARDTACK, subject to coordination with the AEC and the State Department, and the approval of the President. Such coordination was effected, and the President approved the operation on 1 May 1958. The Deputy Secretary of Defense specified that the test would be conducted by AFSWP, separate from the Pacific phase of Operation HARDTACK. The test was originally assigned the code name HARDTACK-ARGUS, and later FLORAL. For purposes of cover and security, it was later found desirable to assign another code name for the experiment as a whole, as well as several others for separate parts of the operation. The Deputy Secretary of Defense also officially directed the Joint Chiefs of Staff (JCS) to provide the necessary operational support (Reference 2). In a memorandum of 16 June 1958, JCS requested the Service chiefs to support the operation (Reference 8).

CONDUCT OF THE ARGUS SERIES

Scientific planning for the shots was already well advanced by the time the President approved Operation ARGUS on 1 May 1958. Indeed, the recommendation to the President to approve ARGUS was based on a series of scientific meetings dealing with the Christofilos theory (including the February UCRL session and the meetings held in March and April) that included the interested parties within the nuclear research community who would be the logical participants in any test of the theory.

Organizational Responsibilities

The plan enclosed with the Deputy Secretary of Defense memorandum of 25 April to the JCS to conduct the ARGUS experiment listed the following organizations and their responsibilities (Reference 2):

1.	Advanced Research Projects Agency (ARPA)	Overall responsibility; provide direction and funds to agencies involved
2.	Armed Forces Special Weapons Project (AFSWP)	Conduct the test and be the central coordinating agency for all other participants
3.	Army Ballistic Missile Agency (ABMA)	Satellite missiles, satellite instrumentation and receivers. (Project 7.1)
4.	Air Force Special Weapons Center (AFSWC)	Sounding rockets, if feasible, and receivers (Project 7.2)

5.	U.S. Navy	Warhead missile, launching and support ships (Project 7.4)
6.	Los Alamos Scientific Laboratory (LASL) and Sandia Corporation	Warhead and firing system
7.	Air Force Cambridge Research Center (AFCRC)	Ground instrumentation (Project 7.3)

ARPA Order 4-58, dated 28 April 1958, requested the Chief, AFSWP to proceed at once with the ARGUS experiments and made funds available to commence procurement of two warhead missiles, the responsibility for which was assigned to the Office of Naval Research (ONR). Other funds were to be made available after ARPA had approved the detailed project proposals to be submitted through AFSWP by the participating organizations. A small technical staff within AFSWP, augmented by a liaison officer for each project furnished by the cognizant service, coordinated the detailed planning among the participating organizations. By later amendments to ARPA Order 4-58, the total funds were increased to $9,023,000, and an additional project was added: the launching of small satellites into polar orbits from naval fighter aircraft under the cognizance of the Naval Ordnance Test Station (NOTS), Inyokern, California (Reference 2).

The most significant change in ARGUS planning took place during June and July 1958. In June the Chief, Special Weapons Test Project (SWTP) and CTF 88 suggested that the number of ARGUS shots be increased from two to three to enhance the chances of a successful experiment. Chief, AFSWP, approved this recommendation, and passed it on to the Division of Military Application (DMA) at the AEC. On 3 July, the DMA reported to the Chief AFSWP that the AEC would authorize the release of the additional warhead (References 4 and 9).

Creation of Task Force 88

The Chief, AFSWP, in letters dated 28 April requested the Army and Air Force to provide officers for duty on the technical staff of TF 88 (Reference 6). This staff would be involved in planning and in coordinating actions with various laboratories and contractors. Even though the staff of TF 88 was composed of scientific and technical officers from all three military services, most were naval officers on temporary duty from AFSWP, where they had occupied technical positions.

At the request of the Chief, AFSWP, the Navy designated the newly appointed Commander, Destroyer Flotilla Two, to plan and conduct the operational phase of the experiment. He reported to the Chief, AFSWP on 19 May 1958 in a dual capacity as Chief, SWTP, and Commander, TF 88 (Reference 2). Later, the technical and operational staffs were combined to form the SWTP within AFSWP. When the Commander-in-Chief, U.S. Atlantic Fleet (CINCLANTFLT) activated TF 88 for planning purposes on 2 June 1958, they became the TF 88 staff. On 14 July, TF 88 officially became an operational command when the naval officer chosen reported to the CNO that he had assumed command of the task force (Reference 10).

The operational section of the staff planned the naval phase of ARGUS and, with some augmentation from the technical section, became the staff of CTF 88 for operations at sea. The technical section coordinated the scientific programs and later became Task Group (TG) 88.6 (Headquarters Group), which remained at the Pentagon during the period that CTF 88 was at sea.

The temporary assignment of highly qualified officers from each Service to the staff of CTF 88 was of tremendous assistance in planning and conducting the ARGUS experiments in the short period of 3 months. Because of their permanent assignments, these officers had knowledge of and direct access to the responsible individuals in the participating organizations. Personal liaison was the key to the coordination of the various scientific programs and the expeditious solution of difficulties at all stages of the operation (References 2 and 9).

The need for secrecy placed special demands upon preparation of TF 88 units and their assembly in the South Atlantic. The designated missile-firing ship, the Norton Sound, was in San Francisco. All other designated

TF 88 ships had home ports on the east coast. The Norton Sound had to be modified to handle the X-17a missile chosen as the launch vehicle. The ship's personnel required training in assembling, maintaining, and launching the missile. AFSWP staff members made trips to California in April, May, and June to work with personnel of the Norton Sound and Lockheed Aircraft Corporation (the missile manufacturer), and to the San Francisco Naval Shipyard where modifications to the ship were underway. While Lockheed was modifying the X-17a missile to accomplish test objectives, the shipyard was investigating the possible need to reinforce the shipboard launching area on the Norton Sound and was making necessary ship alterations to accommodate the missile. Shipboard personnel practiced missile assembly and handling with a dummy missile to ferret out installation deficiencies (Reference 11).

The preparation of the Norton Sound and its preliminary operations were completely disassociated from Atlantic Fleet units and CTF 88 in order to maintain security. AFSWP liaison was maintained through CNO and ONR. Direct communications from ONR encouraged the idea that the Norton Sound was involved in special missile operations requiring preliminary tests on the Pacific Coast Point Mugu Missile Range before conducting a series of firings in a remote area of the Pacific Ocean (Reference 2).

TF 88 was identified as consisting of Atlantic Fleet units. This force ostensibly was established by CINCLANTFLT to conduct a series of tests of new equipment being introduced into the operating forces. These tests were to be conducted over a wide range of sea and climatic conditions, necessitating a prolonged period of operations at sea (Reference 2).

The seaplane tender, USS Albemarle, which was also to participate in ARGUS, was not named as part of the task force for security purposes. The Albemarle had just completed a yard overhaul period. It was plausible that the ship make a shakedown cruise in the mid-Atlantic. To round out the deception, the ship was also supposed to be providing routine services to the Air Force in connection with certain tests of long-range communications.

The Albemarle's type commander and ONR handled the necessary arrangements through direct liaison with AFCRC (Reference 2).

To lend authenticity to these cover stories, CTF 88 prepared a confidential operation order (Reference 12) that was promulgated as a Commander, Destroyer Flotilla Two document and distributed to all the Atlantic Fleet units assigned to the task force, except the Albemarle. This order directed the conduct of a series of evaluations of new equipment required by CINCLANTFLT and provided a rationale for meeting complex logistic, personnel, and equipment requirements before getting underway (Reference 2).

CTF 88 concurrently prepared a Top Secret, Restricted Data, Limited Distribution Operation Order 7-58 that set forth the complete scope and nature of the special test operations (Reference 13). To assure maximum secrecy, this document was not distributed until just before the departure of units to the test area and in some instances was delivered at sea to units in company (Reference 2).

Although the possibility of radiological exposure of participants during ARGUS was considered to be remote, Annex M of Operation Order 7-58 did provide for this contingency. The radiological safety program was not revealed to personnel of the task force but CTF 88, through AFSWP channels, procured 4,000 film badges from the Army Lexington Signal Depot. A total of only 264 of these was used during ARGUS.

The organization of the task group, as it was defined in Operation Order 7-58 (Reference 13), appears in Table 1 and Figure 3.

Assignments and Responsibilities

TF 88 essentially consisted of sea-going units, some of which had been specially modified to carry out the missile-launch and observation phases of the operation. The only exception was TG 88.6, the Headquarters Group, which remained in Headquarters, AFSWP, and participating scientific activities. In addition, a land-based scientific support operation existed outside of the formal TF 88 organization.

Table 1. Operation ARGUS, functions and complements, Task Force 88.

Task Group Number	Task Group Name	Component	Complement: Officer	Complement: Enlisted	Complement: Civilian	Functions
TG 88.1	Carrier Group	Tarawa (CVS-40) (Support Aircraft Carrier)	103	1,482	1	The commanding officer of the Tarawa served as task group commander. The Tarawa carried Air Force MSQ-1A radar and communications vans for missile tracking and gathering scientific data. VS-32 aircraft flew for search and security missions as well as scientific measurement, photographic, and observer missions for each shot. HS-5 provided intra-task-force transportation for personnel and cargo. The TG 88 headquarters staff, based on board the Tarawa, was in overall command of Operation ARGUS.
		Marine Detachment	2	44	0	
		VS-32: 19 S2F aircraft	56	268	0	
		HS-5: 8 HSS-1 helicopters	21	121	0	
		CTF 88 Staff	22	6	3	
TG 88.2	Destroyer Group	Warrington (DD-843) (Destroyer)	15	257	1	The commanding officer of the Warrington served as task group commander. The task group maintained a weather picket 250 nmi (463 km) west of the task force, provided a plane guard for the Tarawa during flight operations, and carried out other standard destroyer functions, such as escort of other task groups, surface security, and search and rescue missions. The Warrington also carried equipment for launching Loki-Dart rockets.
		Bearss (DD-654) (Destroyer)	13	244	0	
		Hammerberg (DE-1015) (Destroyer Escort)	11	150	0	
		Courtney (DE-1021) (Destroyer Escort)	10	149	0	
TG 88.3	Mobile Logistics Group	Neosho (AO-143) (Oiler)	16	269	0	The Neosho's commanding officer served as task group commander. The tankers refueled task force ships underway. The Salamonie returned to the United States upon arrival of the task force in the operating area, and did not participate in any shots. The Neosho assisted in tracking ARGUS shots with Air Force MSQ-1A radar vans mounted on its helicopter platform. Two Air Force officers may have been assigned to the vans.
		Salamonie (AO-26) (Oiler)				

(continued)

Table 1. Operation ARGUS, functions and complements, Task Force 88 (continued).

Task Group			Complement			
Number	Name	Component	Officer	Enlisted	Civilian	Functions
TG 88.4	Missile Group	Norton Sound (AVM-1) (Guided Missile Ship)	32	555	12	The Norton Sound was the launching platform for Pogo rockets and for the X-17a ARGUS launch vehicle. It also carried instrumentation and a 27-MHz COZI radar operated by Air Force Cambridge Research Center to monitor ARGUS effects.
TG 88.5	Scientific Support Group	Albemarle (AV-5) (Seaplane Tender)	30 (est.)	501	5	The Albemarle operated off the Azores serving as a platform for ARGUS effects measurements at the conjugate point. It mounted a 27-MHz COZI radar and other instrumentation to detect manmade ionization. The measurements were performed by Air Force Cambridge Research Center and Stanford Research Institute personnel.
TG 88.6	Headquarters Group	Armed Forces Special Weapons Project	5	N/A[a]	N/A	The headquarters group was located at the Pentagon and consisted of technical personnel who provided liaison among CTF 88, the Chief of Armed Forces Special Weapons Project, and scientific agencies concerned with ARGUS.

Note:

[a]N/A -- Not Available.

Source: Reference 13.

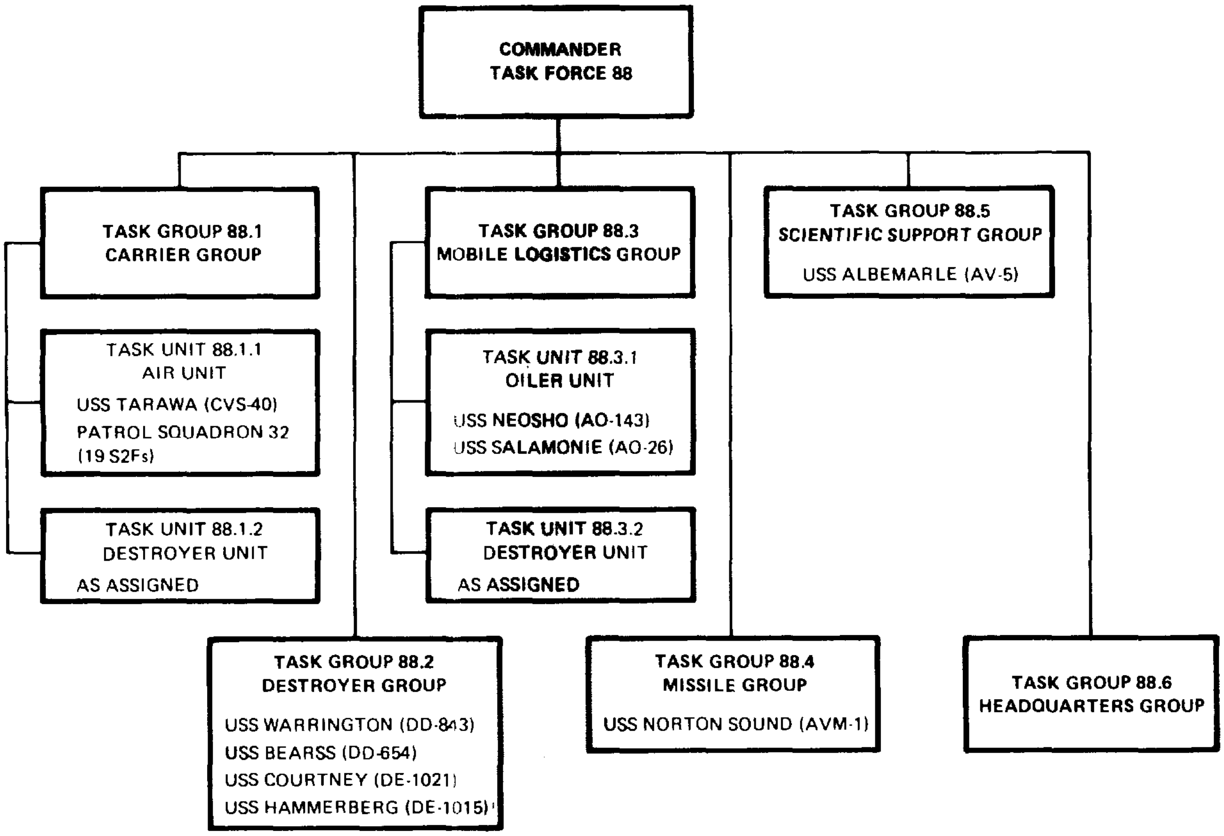

Figure 3. Organization of Task Force 88, ARGUS (source: Reference 13).

The sea-going elements of TF 88 and their assigned functions and complements are described in Table 1, and Table 2 lists the types and crew complements of TF 88 aircraft. Land-based scientific support activities are identified and their functions are described in a subsequent section (Scientific Program) of this chapter (page 37).

Execution

Preparation for the firing of the ARGUS warhead shots took place in two oceans. The event being planned was without precedent. It was the first known instance of an operable nuclear weapon being launched and fired from a vessel (Reference 6). Off the California coast, the Norton Sound, accompanied by the USS Floyd County (LST-762), completed four X-17a test firings in the Naval Air Missile Test Center Sea Test Range. These X-17a missiles were equipped with telemetry heads by the Sandia Corporation

Table 2. Task Force 88 aircraft types and crew complements, ARGUS.

Aircraft Type	Number	Task Force 88 Mission	Crew Size
Grumman S2F-1 & -2	19	Area surveillance; burst observation and sky-camera photography	4
Sikorsky HSS-1 Helicopter	8	Intra-task-force logistics	2
Boeing C-97	2	Airborne spectrophotometers and all-sky camera	NA[a]

Note:

[a] Three AFCRC personnel operated the scientific instrumentation in these aircraft, which were deployed in the conjugate area near the Azores.

Source: References 2 and 14.

(Reference 15). (The X-17a missile with the telemetry head was termed the Winder missile.) Figure 4 is a diagram of a Winder missile. As detailed below, two of the four test launches were successful.

The objectives of the Winder missile tests were to (Reference 15):

- Demonstrate the capability of the X-17a to reach the altitudes required for obtaining the desired data and determine the missile trajectory
- Verify the design of the timing and firing mechanism developed by the Sandia Corporation
- Demonstrate satisfactory missile handling and launching facilities and techniques on board the Norton Sound
- Confirm the ability to precalculate the forces (wind, roll, ship speed, etc.) acting upon the missile with the precision needed to establish the missile in a near vertical trajectory, when launched from aboard ship
- Demonstrate satisfactory tracking with shipborne Air Force MSQ-1A radar and the normal ship's radar, and train two Air Force crews in the proper tracking techniques.

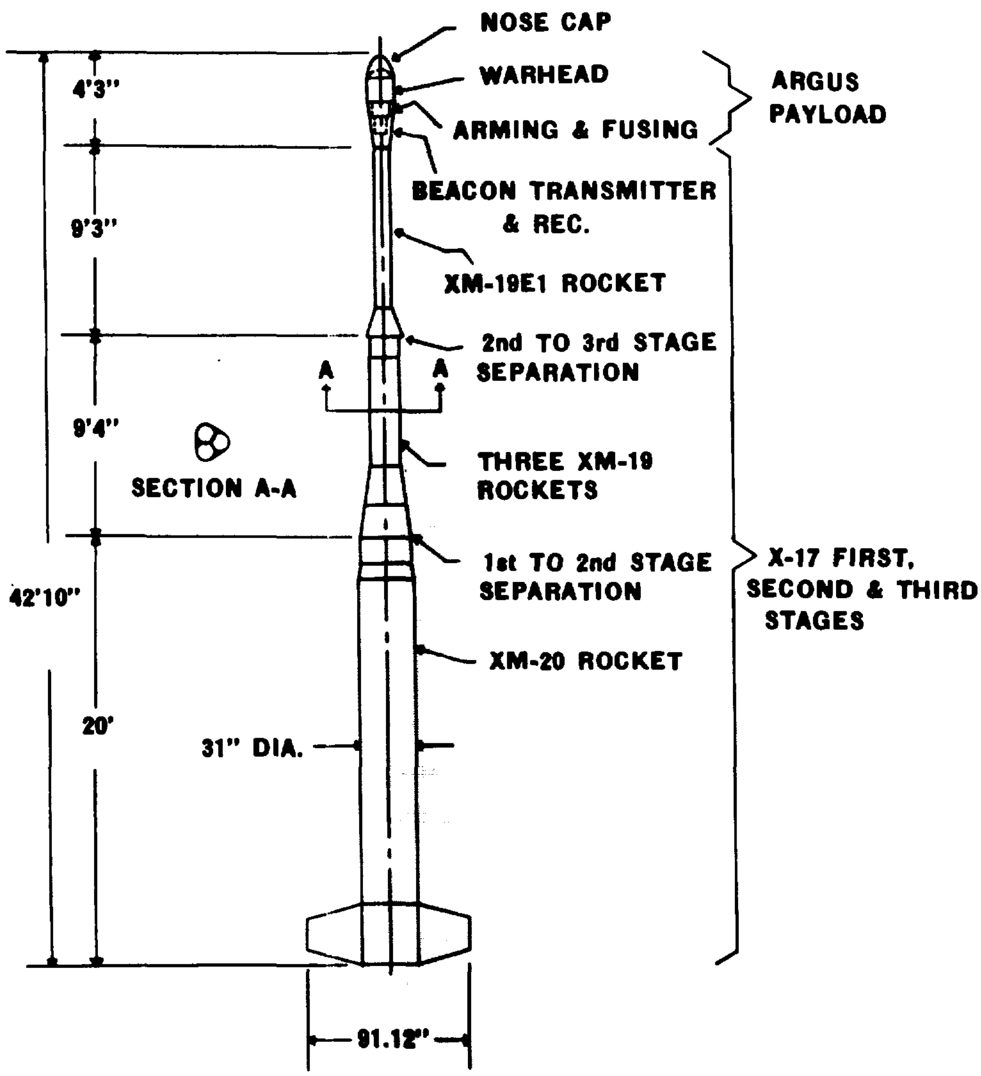

Figure 4. Diagram of Winder missile.

One objective of the tests was to demonstrate satisfactory missile tracking using nonstabilized radars aboard ship. It was also considered necessary to develop proper techniques for use by the Air Force crews, which were not familiar with the problems of shipboard operations. An Air Force MSQ-1A radar, similar to those being installed on the USS Neosho and USS Tarawa, was flown out from Orlando AFB and placed aboard the Floyd County. The two Air Force crews that would take part in later operations were also stationed aboard the Floyd County for training purposes (Reference 15).

The first Winder missile launch and flight were successful, with the third stage coasting after burnout to an altitude of 302 nmi (560 km).

The second Winder missile failed after 25 seconds of flight and the third Winder missile broke up within the first 3 seconds after launch. After a conference on 18 July 1958 about the possible cause of missile failures, a decision was made to remove the spin rockets and to reduce the first-stage spin cant on each of two fins (Reference 15). On 24 July, the fourth Winder launch was successful with a third-stage apogee of 363 nmi (672 km).

Despite the fact that by 24 July only two out of four Winder launches had been successful, the Norton Sound was scheduled to depart for the ARGUS operating area on 1 August. Thus, additional proof-testing of the X-17a was not practical. By working around the clock during the 7 days remaining before the Norton Sound's departure, technicians from Lockheed Missiles System Division were able to assemble the three remaining X-17a missiles at the Naval Construction Battalion Center, Port Hueneme, California. At 1530 on 1 August the last missile was on board, and at 1800 the Norton Sound was underway to its secret rendezvous in the South Atlantic (Reference 15).

During the voyage to the firing area, the Norton Sound conducted repeated missile-handling drills in erecting the missile under day and night conditions. Anticipating bad weather in the launch area, the ship concentrated on practicing during periods of bad weather en route with an objective of determining the weather limits of a successful launch. As a result of these experiments, it was concluded that the Norton Sound could launch the X-17a in winds up to 40 knots (74 km/hr) and swells up to 16 feet (5 meters). After intensive practice, the crew could roll out the missile on its trailer and rig it in its firing position in 45 minutes (Reference 15).

CTF 88, with TG 88.1, TG 88.2 and TG 88.3, departed east coast ports on 7 August 1958 for the test area (References 16, 17, 18, 19, 20, 21, and

22). The USS Albemarle departed Norfolk, Virginia, on 14 August 1958 to proceed via the Azores to its observation site (Reference 23). After fueling at Ponta Delgada in the Azores, the Albemarle made background measurements en route to the observation site (Reference 2). Figure 5 shows the routes taken by components of TF 88 to their operating areas.

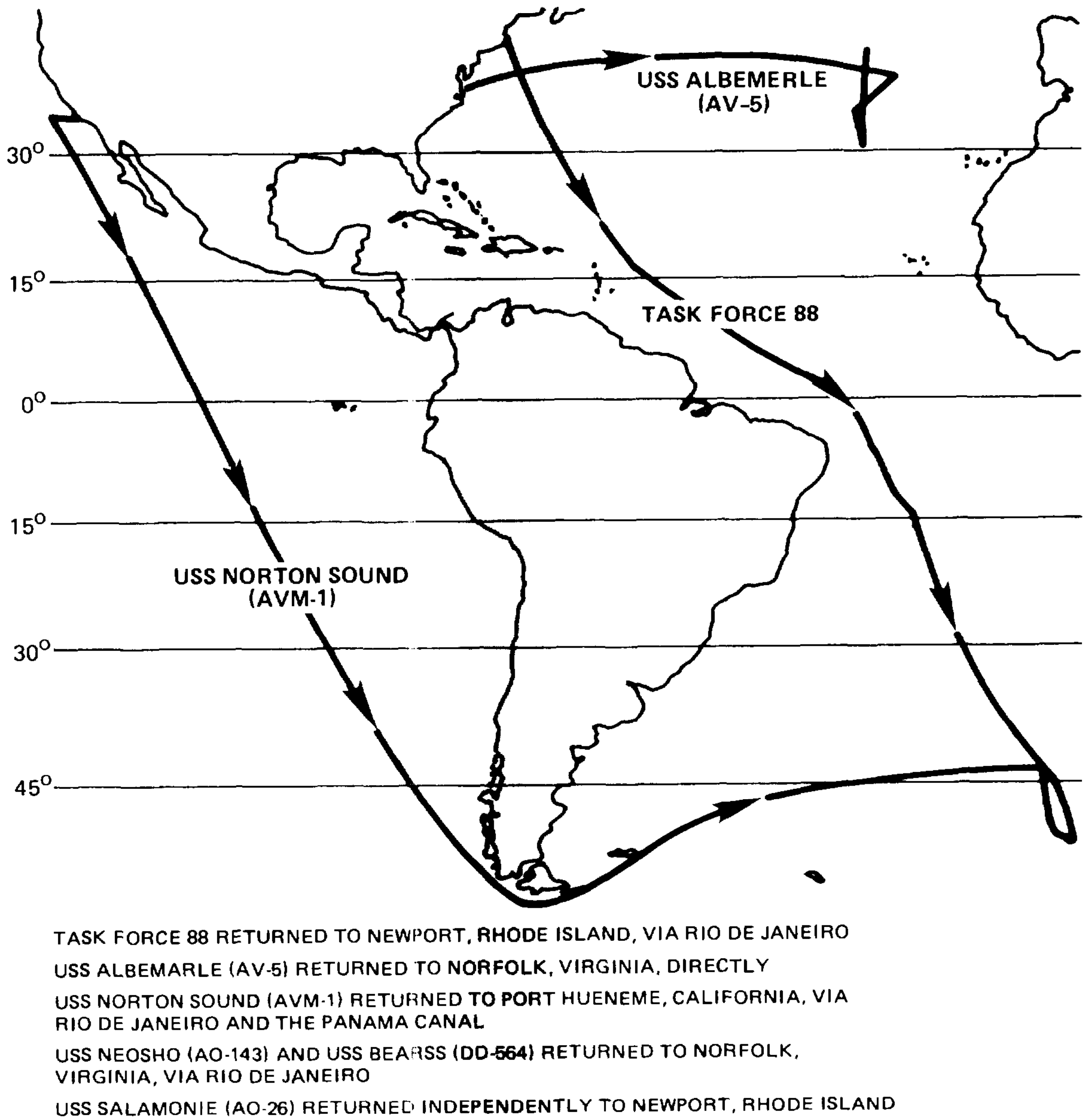

Figure 5. Task Force 88 track chart, 1 August to 6 September 1958, ARGUS (source: Reference 2).

As east coast units of TF 88 steamed toward the South Atlantic, they participated in countdown, launch, and missile-tracking drills using Loki/Dart high-altitude, antiaircraft rockets fired from the USS Warrington. The Loki rockets were modified to carry an AN/DPN-23 (XE-32) radio beacon (Reference 24). Fourteen Loki launches were conducted from 12 to 22 August, simulating the countdown procedures that later would be used for the ARGUS launches. These test firings enabled the task force to test equipment and procedures, and to train personnel in specialized assignments. These included stationing of ships, MSQ-1A radar tracking by the Neosho and the Tarawa, communications, positioning of sky-camera S2F aircraft, and area surveillance S2F aircraft (References 13 and 24).

When the Norton Sound joined TF 88 it was the first time the units had ever operated together. Separately, under great pressure and severe security limitations, these Navy operating units had developed and practiced procedures for a highly complex scientific experiment. At 1645 on 23 August 1958, the Norton Sound lookouts reported seeing the Tarawa. A message from the Norton Sound addressed to CTF 88 was sent (Reference 15), "Doctor Livingstone, I presume?" Four days later the Norton Sound would launch the first nuclear-tipped missile from a ship at sea.

The primary operational consideration in the test area was the successful launching of the X-17a missiles. Suitable weather conditions were sought on a day-to-day, hour-to-hour basis. The weather service unit in the Tarawa served as the task force weather center, providing two 24-hour forecasts daily to the task force. Besides the information available from radio weather broadcasts and local observations from the Tarawa, information was obtained from additional weather reporting units stationed to the west of the force while in the operating area. A destroyer escort was maintained on station bearing 270° true, 250 nmi (463 km) from the task force, and aircraft flew weather patrols on bearings of 240° and 300° true to a distance of 250 nmi (463 km) (Reference 2).

The greatest single aid in forecasting was the compilation of historical weather charts prepared by the weather bureau of the Union of South

Africa. This series of weather charts was valuable in showing various weather patterns that might be expected. By using this information with the limited data available from the weather broadcasts of South America and South Africa, the weather center in the Tarawa was able "to produce a gratifyingly accurate weather analysis" (Reference 2).

An attempt was made to listen to all weather broadcasts sent in international Morse code from Pretoria, Union of South Africa; Rio de Janeiro, Brazil; Buenos Aires, Argentina; and Port Stanley, Falkland Islands. These stations were generally low-power and atmospheric interference was frequent. Consequently, reception of the broadcasts was poor. It usually was not possible to understand weather broadcasts from South America and South Africa for the same weather chart. The result was that most weather charts prepared by the weather center contained data from few reporting stations (Reference 2).

The most important weather considerations concerned forecasting the days when conditions would permit firing and obtaining the surface wind data needed to compute a near vertical trajectory for the X-17a missiles (Reference 15). Since fallout was not a consideration for the expected high burst altitudes, there was no plan to determine and promulgate a radiation exclusion area based upon wind distribution of fallout.

Hourly weather reports from the weather picket ships were important in making a short-range forecast of weather conditions at firing time. It was determined that weather changes at the weather picket ship reached the Norton Sound about 7 hours later (Reference 15).

The most vital launch calculation was determining the surface wind. The force of the wind on the rocket was important only during the initial boost stage of the shot, and the most important wind levels were 0 to 100 feet (0 to 30 meters). The Norton Sound made course and speed corrections until the moment of missile release to compensate for surface wind changes (Reference 15).

As final preparation for the first ARGUS shot, the Norton Sound fired four modified Deacon rockets, code named Pogo. Three rockets were fired on 25 August and one on 26 August. The purpose was to simulate an ARGUS shot, permitting all units of TF 88 to rehearse their missions. During these rehearsals, ship and aircraft control procedures were tested and missile-tracking and observation techniques were refined (Reference 15).

Briefly summarized, the actual ARGUS tests took 11 days from start to finish. The Norton Sound launched the first X-17a missile on 27 August. After a delay of 2 days, during which TG 88.6 directed TF 88 to move farther south to enhance observations at the conjugate point in the Azores, the Norton Sound launched ARGUS 2 on 30 August. A more prolonged delay, caused by a combination of weather and mechanical problems with the third X-17a missile, resulted in ARGUS 3 being launched on 6 September 1958.

All three ARGUS shots were detonated at high altitudes -- 125 to 300 miles (201 to 483 km) above the Earth's surface (Reference 1). Due to the designed burst height of each of these shots, ARGUS planners were not concerned that the shots would produce any radiological exposure to personnel in the operating area. Nevertheless, the task force commander and his staff had laid out a series of precautionary radsafe measures to be followed in each stage of the operation (Reference 13). These radsafe measures were implemented as directed, notwithstanding the lack of any significant radiation exposure from the three shots (Reference 2).

The four scientific projects operational during ARGUS testing were successful. Their measurements confirmed that the detonation of a nuclear device at a sufficiently high altitude did produce a shell of electrons enveloping the Earth. Furthermore, this electron shell was seen to degrade both reception and transmission of radar signals (Reference 2).

During the missile launchings, the Albemarle operated in the vicinity of the Azores, recording phenomena produced by the three nuclear detonations at the conjugate point. Its station was changed during the operation, based upon the scientific data being obtained. The Albemarle departed the observation site on 11 September and arrived at Norfolk, Virginia, on 16 September (Reference 2).

The USS Salamonie departed the test area on 26 August, the day before the first ARGUS shot, and arrived at Newport, Rhode Island, on 10 September (Reference 20). The remainder of the force departed the area on 6 September and, after a 5-day visit to Rio de Janeiro, arrived in east coast ports on 30 September and 1 October 1958. The Norton Sound passed through the Panama Canal and arrived at Port Hueneme, California, on 11 October.

Scientific Program

Since the objectives of the ARGUS shots were to determine the existence of the ARGUS effect and to measure the principal characteristics of the associated phenomena, the organization of the scientific program differed fundamentally from other oceanic test series. For example, there was no agency within TF 88 analogous to the scientific task group in Pacific testing. Instead, the Headquarters task group (TG 88.6) provided overall liaison among CTF 88, AFSWP, ARPA, and the various organizations responsible for conducting the ARGUS experimental projects.

Non-Navy DOD military personnel, DOD civilian employees and contractors, and AEC organization personnel aboard TF 88 units are enumerated in Table 3. These men were involved in the execution of the ARGUS scientific program.

The discussion that follows summarizes each of these projects in terms of the participating agencies, project objectives, operations, and potential radiological exposure of the participants (Reference 25).

Project 7.1 -- Satellite Measurements

Agencies: Primary responsibility for conducting this project lay with ABMA. Additional agencies and organizations operating in a support role included those listed in Table 4.

Table 3. Non-Navy DOD and AEC personnel aboard Task Force 88 units, ARGUS.

	Norton Sound (AVM-1)	Albemarle (AV-5)	Tarawa (CVS-40)	Neosho (AO-26)	Warrington (DD-843)	C-97
USAF						
Lookout Mtn AF Station	1					
Home Station unknown				2		
DOD civilian employees						
Hydrographic Office			3			
Cambridge Research Center	2	2	1			3
AEC Organizations						
Sandia Corp.	3	1				
DOD Contractors						
Cooper Development					1	
Lockheed	6					
Stanford Research Institute	1	2				

Table 4. Supporting organizations, Project 7.1, ARGUS.

Agency	Function
State University of Iowa	Satellite instrumentation
Jet Propulsion Laboratory	Satellite telemetry instrumentation and power supply; microlock ground stations at Cape Canaveral, Florida, and Camp Irwin, California
Naval Research Laboratory	Circuitry and transmitters; operated Minitrack ground station network at required times
Army Signal Research and Development Laboratory	Supplied battery pack to State University of Iowa; operated Deal Ground Station at Ft. Monmouth, New Jersey
Office of Chief Signal Officer, U.S. Army	Operated ground tracking station, Van Buren, Maine
Smithsonian Astrophysical Laboratory	Operated optical tracking stations; final satellite ephemerides
Army Map Service	Provided tracking data from Pacific tracking stations
Ballistic Research Laboratories	Provided tracking data
Army Security Agency	Provided data prior to ARGUS shots for background calibration; telemetering data for 3 days following ARGUS shot

Objective: The principal objective of the project was to place two instrumented Earth satellites, Explorer IV and Explorer V, in orbits calculated to intersect the predicted artificial radiation belt created by the ARGUS shots. The instrumentation package to be employed contained radiation sensing and telemetry devices similar to those used in Explorer I and Explorer II, which had only recently determined the existence of natural radiation belts at altitudes above approximately 540 nmi (1,000 km). This instrumentation was designed to measure natural background radiation and several aspects of the ARGUS effect, permitting assessment of Christofilos' predictions about particle density, flux, trapping lifetime, and eastward drift (References 26, 27, and 28).

Operations: The launching date of the first satellite, Explorer IV, was established as 26 July 1958, plus or minus 2 days. The timing of this launch was crucial, because ARGUS could not be postponed. Explorer IV was to monitor natural background radiation, after which it would measure the effects of the two high-altitude shots in HARDTACK -- TEAK and ORANGE -- during August and then monitor the ARGUS effects in late August and September. The launch occurred on schedule. At 1000 EST on 26 July a Jupiter-C missile, fired at the Air Force Missile Test Center (AFMTC) at Cape Canaveral, placed Explorer IV into the desired orbit. Five days later, on 31 July, shot TEAK took place at Johnston Island in the North Pacific. The launch of Explorer V followed on 10 August, but the satellite failed to go into orbit. The next day, 11 August, shot ORANGE was detonated above Johnston Island. The failure of Explorer V did not jeopardize the project because Explorer IV continued to function and to supply adequate data during each phase of the operation. It recorded background radiation and detected a weak ARGUS effect during HARDTACK, and the effect during ARGUS. Over 40 ground stations located throughout the world tracked Explorer IV or monitored telemetry, with the result that experimental data confirmed the presence of the effects predicted by Christofilos (Reference 26).

Radiation Exposure Potential: No total figure is available for participants in this ARGUS project, nor is there an indication that any of the participants were badged for this portion of ARGUS activities. No precaution of this sort was necessary, since none of these participants could have been exposed to radiation from any of the ARGUS shots.

Project 7.2 -- Sounding Rocket Measurements (Project JASON)

Agencies: This project, under the code name JASON for security reasons, was conducted by AFSWC, operating through the JASON Division of the Research Directorate. Supporting organizations included (References 3, 29, 30, 31, and 32):

Aerolab Development Company
Lockheed Missile Systems Division
Pilotless Aircraft Research Station, Wallops Island, Virginia
Air Force Missile Test Center, Cape Canaveral, Florida
72nd Bomber Wing, Ramey AFB, Puerto Rico.

Objectives: The general aim of the project was to establish the existence of the ARGUS electron shell by measuring the distribution of beta particles emitted by an ARGUS shot that were subsequently trapped in the geomagnetic field. The project was planned to back up and supplement the data provided by the ABMA Explorer IV satellite. To achieve the project objective, rocket instrumentation was designed to measure high-energy electron flux as a function of five variables: magnetic latitude, altitude above sea level, electron energy, time after detonation, and angular distribution with respect to the magnetic field (References 30 and 33).

Operations: Project JASON launched missiles from three sites, selected because they bracketed the magnetic latitude of the calculated conjugate point. The locations chosen were: the Pilotless Aircraft Research Station, operated by the National Advisory Committee on Aeronautics (NACA) at Wallops Island, Virginia; Patrick AFB at Cape Canaveral, Florida; and Ramey AFB in Puerto Rico. These sites operated under the code names Whiskey, Papa, and Romeo, respectively (References 30 and 33).

The Aerolab Development Company modified the 5-stage, solid-fueled rockets used to carry the instrumentation package aloft. Lockheed Missile Systems Division assembled the instrumentation packages, which consisted of radiation-sensing systems and a data transmission link to ground receiving stations, and installed the package on the missiles. AFMTC at Cape Canaveral, the Pilotless Aircraft Research Station at Wallops Island, and the 72nd Bomber Wing at Ramey AFB each provided local support for missile launchings. AFMTC also provided command center facilities to Project JASON command (Reference 31).

Wallops Island personnel undertook three preliminary test launches to determine how well the system worked. The first two rockets failed, and the third was successful. Each site also launched a background, or calibration, shot. The first test launch at Patrick AFB on 15 August was successful. Those from Ramey AFB and Wallops Island on 20 August and 25 August both failed (Reference 29).

The project operated during only the first two ARGUS shots. On ARGUS 1, there were four rocket launches, two from Patrick AFB and two from Ramey AFB. The firings all took place on 27 August, the same day as the detonation. On ARGUS 2, detonated 30 August, a total of 12 launches occurred between 30 August and 2 September: 5 from Wallops, 4 from Patrick AFB, and 3 from Ramey AFB (Reference 34).

Radiation Exposure Potential: There is no total figure for all participants in Project JASON. One document, listing operational control within the project, provides 24 names, including three personnel each from Aerolab and Lockheed, and one individual from NACA. The rest were presumably AFSWC employees. There are no exposure records for any of these people, and it is highly unlikely any of them were badged for participation in ARGUS, since their great distance from all ARGUS effects precluded radiological exposure.

Project 7.3 -- Surface Measurements (Project MIDAS)

Agencies: This project, code-named MIDAS for security reasons, was conducted jointly by AFCRC and Stanford Research Institute (SRI). Supporting organizations included (Reference 14):

Lajes AFB
Torrejon AFB
Albemarle

Norton Sound

Tarawa

A number of other organizations, with detection equipment of various sorts located at stations throughout the world, were placed on alert to monitor with their equipment as a backup to AFCRC/SRI instrumentation at the conjugate and launch points. These agencies and the location of their instrumentation are listed in Table 5.

Table 5. Supporting organizations, Project 7.3, ARGUS.

Agency	Station Location
Stanford University, Radio Propagation Laboratory	Hawaii and Palo Alto, California
Air Force Cambridge Research Center	Plum Island, Massachusetts
Raytheon	South Dartmouth, Massachusetts, and Grand Bahama Island
National Bureau of Standards	Washington, D.C.
Office of Naval Research	Washington, D.C.
Massachusetts Institute of Technology, Lincoln Laboratory	Ipswich, Massachusetts, Sacramento Peak, New Mexico, and the Aleutian Islands
Army Signal Corps	Arizona, New Jersey, and Maine
Rome Air Development Center	Laredo, Texas

Source: Reference 14.

Objectives: The goal of the project was to study the effects of electrons emitted by the high-altitude bursts that entered the Earth's dense lower atmosphere rather than remaining trapped within the Earth's magnetic field. The predicted effects to be measured were: auroral phenomena at the conjugate and burst points, disturbances in the geomagnetic field, changes in the ionospheric layers, increased absorption of radio waves by the ionosphere, and Earth currents (References 14 and 28).

Operations: The principal site for project instrumentation was at the conjugate point, predicted to be within the vicinity of Lajes AFB. AFCRC personnel operated very-low-frequency (VLF) and extremely-low-frequency (ELF) radio receivers, ionospheric instruments, and magnetometers at Lajes AFB. Two Air Force C-97 aircraft, Nos. 8400 and 2596, operating from Lajes AFB, were equipped with ionospheric instruments for airborne detection of ionospheric disturbances (Reference 35). One of the C-97s also carried an all-sky camera and a set of spectrophotometers for optical measurements of auroral phenomena. Three AFCRC personnel were on board the C-97 airborne at shot time to run the project equipment. The Albemarle, positioned about 400 nmi (741 km) south of the Azores, carried high-frequency (HF) communications zone indicator (COZI) radar, an all-sky camera, spectrophotometers, and ionospheric instruments. Two project personnel, one from SRI and the other from AFCRC, were responsible for this equipment. At Torrejon, Spain, project personnel operated VLF receivers, ionospheric instruments, and a microlock receiver to monitor transmissions from the Explorer IV satellite. At the launch point, both the Norton Sound and the Tarawa mounted VLF wide-band receivers. The Norton Sound also had an HF COZI radar and an ionospheric instrument on board. A spectrophotometer was located on the Tarawa. Three AFCRC employees were responsible for this equipment. In addition, the S2F aircraft of Air Antisubmarine Squadron 32 (VS-32), based on board the Tarawa, carried magnetic airborne detectors and all-sky cameras (Reference 14).

Radiation Exposure Potential: The project operated on all three shots. Due to the altitude of the conjugate phenomena under investigation no personnel at the conjugate point were subject to radiological exposure during the series. The same is true of personnel at the launch point. It is not possible to determine from existing records whether any of the AFCRC or SRI personnel at the launch point carried one of the 264 badges distributed during the operation.

Project 7.4 -- Nuclear Weapon Launch Support

Agencies: Office of Naval Research
Atomic Energy Commission
Sandia Corporation

Objective: The objective of the ONR project was to provide personnel, equipment, and support to place a nuclear weapon at an exospheric altitude and provide tracking information to ascertain the actual height of burst. The vehicle chosen was the X-17a, a 3-stage, solid-fuel, unguided missile furnished by the Lockheed Missile Systems Division.

Operations: Four missiles were fired as instrumented test vehicles from the Norton Sound on the Point Mugu Test Range. Three were fired with live warheads in the South Atlantic in the general vicinity of $48^{\circ}S$, $8^{\circ}W$. Tracking was accomplished by MSA-1A radar systems, furnished with crews by the Air Force and installed in the Tarawa and the Neosho.

The AEC furnished four dummy warheads for the instrumented test vehicles and three live warheads for the actual firings. The Sandia Corporation, for the AEC, provided the arming and firing system and supervised the assembly of the warheads into the missiles. The warhead was selected for the ARGUS experiments because its yield was appropriate, it was compatible in size and weight with the X-17a, its safety aspects had been thoroughly explored by previous testing, and its yield could be predicted with confidence, again based on prior testing. The latter point was of importance since it was recognized that there was no possibility of measuring the yield under the conditions of the experiment as it was to be conducted.

Radiation Exposure Potential: No potential for exposure existed during the vehicle testing phase. The three Sandia Corporation and the Navy weapon-handling personnel could have been subjected to very small amounts of radiation escaping through the ARGUS weapon casings, but these personnel were badged and equipped with ten self-reading pocket dosimeters as well as alpha-detection equipment provided by the Sandia

Corporation (Reference 2). The highest badge exposure recorded by any individual in the task force was 0.010 R, low enough to have occurred from background radiation.

Project 7.5 -- Satellite Launching from Aircraft

Agencies: The conduct of this project was the sole responsibility of Naval Ordnance Test Station, Inyokern, California (Reference 25).

Objective: The objective of the project was to provide additional Earth satellite instrumentation as a backup to Explorer IV for measuring the ARGUS effect (Reference 25).

Operations: In pursuit of this objective, in the 5 months prior to ARGUS, NOTS personnel designed, fabricated, tested, and attempted to launch a new kind of satellite. The launch vehicle and satellite were to be carried aloft by a Navy F4D-1 aircraft that would then launch the rocket intended to place the satellite package in orbit. Each satellite instrument package contained radiation-sensing and -counting equipment, plus a transmitter. NOTS-designed microlock stations, manned by NOTS personnel, were shipped to New Zealand, Alaska, Greenland, the Azores, and Hawaii to track the satellites and to receive telemetered data (Reference 25).

At the Pacific Missile Range in late July and early August 1958, NOTS made three attempts to launch the satellite vehicle, containing a diagnostic payload instead of ARGUS instrumentation. In all three of these test launches, the first-stage ignition failed. On 25, 26, and 28 August NOTS attempted to launch the satellite with the radiation-counting payload on board. All three of these attempts also failed. Consequently, the NOTS project was not operational during any of the ARGUS shots. The NOTS microlock ground receiver stations, however, did assist in tracking Explorer IV and monitoring its telemetry signals (Reference 25).

Radiation Exposure Potential: None. Personnel participating in this project were not badged for ARGUS; their remoteness precluded the possibility of exposure.

Potential Radiation Exposures

The placement of the burst is a primary determinant in the effects of any nuclear detonation. Generally, burst placement is characterized as one of five types: subsurface, underwater, surface, air, or high-altitude. An airburst is defined as a detonation in which the fireball does not intersect the surface of the Earth, while a high-altitude detonation is conventionally and somewhat arbitrarily defined as a detonation occurring at altitudes of 100,000 feet (30.5 km) or above (Reference 1). In Operation ARGUS, all three shots were designed to take place in the Earth's exosphere, that is, in the highest, least dense region of the atmosphere. Shots at this altitude have no potential for radiological exposure of personnel either at the Earth's surface or aboard aircraft at normal operating altitudes in the Earth's lower atmosphere.

Personnel involved with nuclear testing could be exposed to ionizing radiation produced either at the time of the burst or for about 1 minute thereafter -- usually referred to as initial radiation -- or radiation emitted later by the weapon debris (residual radiation).

Initial radiation from an exospheric burst is attenuated and absorbed by the atmosphere long before it reaches the surface of the Earth. The altitudes at which the radiations are virtually stopped for the various classes of radiation are: X-rays, 35 to 55 miles (56 to 89 km); neutrons and gamma rays, 15 miles (24 km); and beta particles, 35 miles (56 km).

The possibility of exposure to early fallout after a high-altitude burst is also virtually nonexistent. A high-altitude detonation injects radioactive material into the stratosphere or above. The detonation altitude is above that at which weather might act as a precipitator of weapon debris. Consequently, there is no likelihood of the suspended radioactive material descending quickly enough to expose personnel in the vicinity of the burst point. In short, the major concern associated with radiation exposure potential from a high-altitude burst is delayed fallout (References 1 and 36).

In fact, residual weapon debris remains in the upper atmosphere about 6 months. During this period, most of the radionuclides produced by the detonation decay to low levels before they descend to Earth, with two notable exceptions. Isotopes of strontium (^{90}Sr) and cesium (^{137}Cs) have half-lives that are longer than the time required for their deposition. The production of these two radionuclides, which are major contributors to world-wide fallout, is dependent on the fission yield of the detonation, not its altitude.

The only real issues facing ARGUS radsafe planners were contingencies that might arise if a missile launch failed to go as planned. That is, they had to take into consideration the possibility that a missile launch failure might spread radioactive device components about the launch area, or that a warhead might detonate over the task force at an altitude lower than planned (Reference 37).

RADIOLOGICAL SAFETY

Radsafe Planning

Two considerations affected ARGUS radsafe planning. The first was the remote possibility of radiation exposure developing from a high-altitude shot (Reference 15). The second was the need to maintain secrecy. As CTF 88 noted in his final report of the operation (Reference 2), "Security aspects of the ARGUS experiments precluded the operation of the type of radiological safety program that is common to nuclear testing." The radsafe program plan developed by the commander and his staff was published as Annex M of Task Force 88 ARGUS Operation Order 7-58 (Reference 13). Chapter 8 of the commander's ARGUS final report (Reference 2) summarized radsafe planning and execution.

No organization within the task force was specifically chartered to implement the ARGUS radsafe program. Instead, the plan called for radsafe activities to be conducted through "normal command channels." If "outsiders [were] inadvertently exposed to the remote possibility of contamination" then action would "be ordered by the Task Force Commander as the situation indicates" (Reference 49).

Before the first shot, task force units were directed to develop "operational skill in all phases of radiological safety through training;" to fill their allowances of radsafe equipment; to maintain and calibrate their radiac equipment; and to establish decontamination facilities for personnel. They were also to institute "air and surface surveillance of the shot area . . . to insure against the presence of outsiders in the shot area" (Reference 13)

For the shot phase, all ships in the test area were directed to be prepared to set maximum conditions of watertight integrity, and immediately to close all Circle William fittings (to make the ships airtight) in event of a nuclear missile misfire. The Norton Sound was to set maximum conditions of watertight integrity and to close all Circle William fittings before handling warheads and before erecting or taking down the rocket with the warhead attached (Reference 13).

The radsafe plan required commanding officers of ships in the operating area to report to the commander any contamination of either personnel or equipment "as early as practicable following the shot or the occurrence of a nuclear incident" The report was to be by "visible message" (Reference 13). The means of communication thus could have been by flashing light, infrared signal, flaghoist, or semaphore. The message itself was to contain seven components fully detailing the radiological problem and specifying the measures taken to correct it (Reference 13).

The ARGUS radsafe program also instituted a film badging program. It specified that the commanding officers of all ships at the test site be furnished ten waterproof, numbered film badges prior to each shot. Since the Albemarle was located at the Azores conjugate point in the North Atlantic and the Salamonie was scheduled to depart from the operating area prior to the first shot, these ships were not participants in the badging program. The ten film badges were to be placed topside or on the ship's superstructure 6 hours before the shot and recovered 6 hours after the shot. No specific directions for film badge placements were given. An additional "control" film badge was to "be stored in a radiation-free area." Each ship was required to maintain records that indicated badge number and its location on the ship. After the operation was over, each ship's commanding officer, "upon arrival at the first port after the test," was to "submit all records in duplicate, film badges and 'CONTROL' packets to CTF 88" (Reference 13). None of these individual records has been located.

There was also to be an individual badging program "if CTF 88 directs film badges to be issued to individuals." These records were to be turned over at the first port, along with the other radsafe records. Individual radsafe records were to include the following data (Reference 13):

- Film badge number
- Full name of the individual
- Rank, rate, or title
- Organization
- Home station or agency
- Date of exposure and remarks.

Safety Criteria

The ARGUS Operation Plan is silent about maximum permissible levels of radiation exposure (Reference 13). It is clear from the discussion in Operation Plan 7-58 that no radiation exposure was anticipated provided that the detonations occurred as they did, at the high altitudes programmed (the exact burst altitudes have not been released). A concurrent nuclear test operation in the Pacific, HARDTACK, included two high-altitude shots, TEAK and ORANGE. For Operation HARDTACK, the maximum permissible routine exposure was 3.75 R for a 13-week period, or 5 R for the entire operation (Reference 38).

Safety guidelines established for TEAK and ORANGE were based on the premise that detonations above 90,000 feet (27.43 km) in the atmosphere posed no threat to individuals from ionizing radiation (Reference 37). Only thermal radiation caused some concern among ARGUS planners. The flash of the TEAK and ORANGE detonations was considered to be the major hazard to participants. Consequently, ARGUS planners sought expert advice in determining the likelihood of airborne observers during ARGUS shots being similarly exposed. The conclusion was that if the detonations occurred at the designed altitudes all observers would be far too distant for any risk of this sort (Reference 39).

The ARGUS radsafe plan did cover the contingency of a premature nuclear detonation. All observers aboard ship assigned to watch the missile during its early flight were to be equipped with high-density goggles. They were instructed to leave their goggles in place until 36 seconds after launch, when the missile was estimated to be above 100,000 feet (30.5 km). Pilots flying aircraft were directed not to focus their vision on the missile during flight. As a further safety precaution, one pilot in each aircraft was to wear goggles until 60 seconds after missile launch (Reference 13).

Pre-event Safety Measures

Notwithstanding the consensus that the ARGUS shots posed no danger to participants, badges and other monitoring devices were distributed during the tests, as directed by the radsafe plan. CTF 88, working through AFSWP, procured 4,000 film badges from the U.S. Army Lexington Signal Depot. This was a sufficient number of badges to distribute to all personnel in case the need arose (Reference 2).

Under this scheme, the seven ships in the operational area were to receive one control badge plus ten badges for each of three shots, which would account for 217 badges of the 264 issued during the operation. Operation Plan 7-58 required that the two pilots be badged in each of the four aircraft that were airborne for the three shots (Reference 13). This accounts for an additional 24 badges. Conversations with participants have revealed that a scientific observer was airborne in one of the aircraft for each of the shots. Presumably he also was badged. It is likely that the remaining 20 badges known to have been issued were for warhead handlers on the Norton Sound.

Table 6 details the assumed film badge issue based upon all available evidence. After the return of the task force to the United States, these film packets were processed at the Army Lexington Signal Depot, which reported the results to CTF 88 (Reference 2). This report has not been located. Appendix B details the search conducted for this documentation.

Table 6. Assumed film badge issue, ARGUS.

Unit	No. of Badges
USS Tarawa (CVS-40)	31
Aircrew pilots	24
Scientific observer	3
USS Norton Sound (AVM-1)	31
Warhead handlers	20
USS Warrington (DD-843)	31
USS Bearss (DD-654)	31
USS Courtney (DE-1021)	31
USS Hammerberg (DE-1015)	31
USS Neosho (AO-26)	31

Sources: References 2 and 13.

In addition to the planned badging, other pre-event radsafe measures were taken. Sandia Corporation had alpha-detectors on board the missile ship, the Norton Sound. The Navy supplied 12 self-reading pocket dosimeters. Ten of these dosimeters were carried by warhead handlers. The other two were carried by the airborne observer (Reference 2).

Despite the fact that no radiation exposure was postulated for normal test activity, consideration had to be given to possible transient shipping that could be placed at risk in the event of an errant missile launch or a detonation at an unprescribed altitude. The largest part of the solution to this potential problem was the selection of the South Atlantic as the test site. August is midwinter and cold in the South Atlantic. No routine activities, such as whaling, were likely to bring ships into the area at this season (Reference 6).

For reasons of secrecy and the seclusion afforded by the test site, no hazard zone was officially established (Reference 40). To assure that the test site was clear of transient shipping, however, a 300-nmi (556-km) radius air search was conducted around the Norton Sound. The surveillance aircraft were launched 14 hours before the scheduled rocket firing time and recovered 9 hours before the firing. Only four test observation aircraft were airborne during the test firings (Reference 13).

Undoubtedly the ship at greatest risk during missile firings was the test missile firing ship, the Norton Sound. Sensitivity to this risk and one step taken to ameliorate the consequences of an accident may be seen in this statement from the final operational report (Reference 15) of the Norton Sound's commanding officer:

> It was considered highly improbable that the NORTON SOUND would suffer from either radiation or physical damage during the FLORAL (ARGUS) tests. However, all topside personnel could remember vividly the failure of WINDER missile number three and the fact that the third stage and warhead container had landed within 300 feet from the ship on the starboard quarter. While it was true that the Lockheed engineers assured us that they had corrected the trouble and that a repetition of such a failure was not possible, only one test missile had been fired to demonstrate this important fact.
>
> It was decided that the ship should be made as gas tight as possible during the firings and the same precautions observed as for an atomic attack. The ship's normal water curtain was considered to be inadequate and additional hoses and lines were run so that the forward topside area could be subjected to a good spray if it were needed.

Postevent Activities

Chapter 8 of the final report of Operation ARGUS (Reference 2) indicates that ships' commanding officers complied with the directives of the radsafe plan, Annex M of Operation Order 7-58 (Reference 13). No instances of personnel or equipment contamination occurred during the operation. A radiation reading of 0.27 R/hr at one location on the Norton Sound's deck following snowfall about 7 hours after ARGUS 1 was deemed "spurious, or in any event not connected with TF 88 operations." The reasons for this conclusion were that "the detonation occurred at an altitude far above where weather is formed and the film packets in Norton Sound did not confirm this dose" (Reference 2). No additional documentation on this episode has been located.

Personnel Exposure Records

The following excerpt from the final report of CTF 88 (Reference 2) summarizes the results of the ARGUS radsafe program:

> Of the 264 film packets distributed, 21 contained indications of a radiation dose, according to the Lexington Signal Depot. Of these, the highest dose recorded was 0.025 rem, and this was on one of the control film packets. Another control indicated 0.020 rem. The highest dose recorded by an individual was 0.010 rem. The pocket dosimeters carried aloft by the observer indicated zero dose on all shots. It is concluded that no radiation dose was incurred by task force personnel as a result of the nuclear detonations.

The Lexington Signal Depot (now known as Lexington--Blue Grass Depot Activity) record does not indicate whether the individual's badge was worn by an aircraft crewmember or by someone aboard ship. By convention, the function of control packets, one each of which was scheduled to be placed in a radiation-free area of each ship, is to measure background or natural cosmic radiation reaching the Earth's surface. If more than one control packet is used to cover the same time period, their values are averaged and this value subtracted from individual badge values to determine the amount of radiation above the normal background an individual is exposed to as the result of a test operation at a particular location. These readings were below the accuracy limit of the film, developing system, and the densitometers used. The Depot cannot now locate the badging records of any ARGUS participant.

The shipboard film badges were to have been exposed for a total of 12 hours. Due to operational delays, this planned exposure cycle was undoubtedly interrupted for ARGUS 2 and ARGUS 3. Table 7 is a matrix of scheduled and rescheduled launch times and programmed badge placement and badge retrieval times. No documentation has been located to indicate what action, if any, was taken to retrieve and replace film packs when launch delays were encountered. The issue may have possible significance because of potential exposure of these badges to indigenous shipboard low-level radiation sources.

Annex M to Operation Plan 7-58 provided general guidance on where on each ship to place the ten waterproof film badges. The positions selected were to provide adequate coverage of the various parts of the ship (Reference 13). Personnel were to place badges topside on decks and other surfaces exposed to weather. They were also to place badges on the ship's superstructure. No records have been located that specify precisely where these film packs were placed. Such information is important because of the possibility of inadvertent placement of some badges in the vicinity of shipboard radiation sources. These may have included radioluminescent deck markers and sound-powered phone jacks that were marked with encapsulated luminescent radium (Reference 41). It is also possible that despite the injunction that some of the control film packets were to be stored in a radiation-free area (Reference 13) they were similarly exposed to shipboard radiation. These theories are advanced because of the virtual certainty that the film badges were not affected by any of the three ARGUS detonations. The exospheric detonation of all three ARGUS shots argues for this conclusion.

The reading of 0.27 R/hr at one place on the deck of the Norton Sound was taken following snowfall approximately 7 hours after ARGUS 1 (Reference 2). None of the film packets confirmed this reading, although if

Table 7. Shot times versus programmed film-badge placement and retrieval times, ARGUS.

	Scheduled Shot Time (GMT)[a]	Programmed Ship Badge Emplacement	Programmed Ship Badge Retrieval	Remarks
ARGUS 1	27 Aug 1958 0200Z	26 Aug 1958 2000Z	27 Aug 1958 0800Z	Actual launch was at 0220Z 27 Aug 1958.
ARGUS 2	29 Aug 1958 0140Z	28 Aug 1958 1940Z	29 Aug 1958 0740Z	Missile beacon failed during countdown, new launch time, 300310Z scheduled.
ARGUS 2	30 Aug 1958 0310Z	?	30 Aug 1958 0910Z	Launch was at 300310Z. It is not known whether or not the ship badges remained in place during this 26-hour delay.
ARGUS 3	1 Sep 1958 0025Z	31 Aug 1958 1825Z	1 Sep 1958 0625Z	Launch cancelled at minus 30 minutes due to high winds.
ARGUS 3	1 Sep 1958 2345Z	?	2 Sep 1958 0545Z	Launch cancelled at minus 180 minutes due to high winds.
ARGUS 3	2 Sep 1958 2345Z	?	3 Sep 1958 0545Z	At minus 90 minutes, launch cancelled to move to alternate launch site.
ARGUS 3	5 Sep 1958 2230Z	?	6 Sep 1958 0430Z	At zero time the launch failed due to a defective relay.
ARGUS 3	6 Sep 1958 2205Z	?	7 Sep 1958 0405Z	Launch was at 062205Z. It has not been determined whether or not ship badges remained in place during this 6-day delay.

Note:

[a]Because of its longitude, GMT was also local time for the task force.

Source: Reference 15.

their removal had been on schedule, they would have been recovered by the time the reading was taken. Perhaps the most important consideration is the fact that Reference 2 cites a reading at only one location on deck. No other readings are reported. There is no evidence to refute the conclusion in Reference 2 that the indication of radiation was spurious.

CHAPTER 2
SHOT CHRONOLOGY

ARGUS 1

Chronology of Events

Appendix I to Annex E of Reference 13 describes the TF 88 ARGUS firing procedure. The chronology of this chapter describes details of participants and exceptions to the standard procedure.

23 August, 0619: The USS Hammerberg arrived on a weather picket station, 180 nmi (334 km) west of TF 88. The ship remained on this assignment until relieved by the USS Courtney at 0818 on 29 August. The assignment was to make weather reports and to control S2F aircraft airborne on weather reconnaissance and area surveillance flights.

26 August, 0800: The USS Tarawa launched S2F aircraft 14 hours before the scheduled missile launch time to conduct weather reconnaissance and aerial search of a 300-nmi (556-km) radius circular area around the USS Norton Sound.

27 August, 0103: The Tarawa launched test photographic and observation aircraft.

27 August, 0220: ARGUS 1 was fired on schedule. Surface winds were 25 knots (46.3 km/hr) and the sea state was rough. The predicted trajectory was 90°, but the actual trajectory was less than this. It was suspected that one or more of the following factors caused the trajectory discrepancy: (1) last-minute variations in the surface wind, (2) high wind variability produced by a mild frontal passage, (3) the use of an improper trajectory correction

factor, or (4) excessive dispersion during first- and second-stage burning (Reference 15).

Scientific Objectives

The principal purpose of the test was to explore the lifetime and capture efficiency of electrons placed in the exosphere by a nuclear explosion. This was done in order to provide information for further studies of the effects of these electrons on radio and radar operation, and other more intense effects that had been postulated. These possibilities were of major concern for both immediate and longer-term developments in missile and space warfare (Reference 13).

The four specific active scientific projects for each of the three ARGUS events are described in Chapter 1, page 37.

Force Disposition

Generalized planned locations of surface and air units for the ARGUS series launches are shown in Figure 6. At the launch of ARGUS 1, the Tarawa was 11°T at 17.43 nmi (32.30 km) and the USS Neosho was 180°T at 17.13 nmi (31.75 km) from the Norton Sound. The Courtney and the USS Bearss were in company with the Tarawa acting as plane guards. The USS Warrington was stationed 60° on the port bow 1 nmi (1.85 km) ahead of the Norton Sound in order to take photographs of the missile launching. The Hammerberg was 200 nmi (371 km) west of the formation on a weather picket station (References 13, 16, 17, 18, 22, and 42). Distances from the burst position were calculated. These distances are given from the point in the ocean over which ARGUS 1 detonated and are not slant ranges, which would be significantly larger.

The estimated burst position of ARGUS 1 from the center of the task force was 330°T at 340 nmi (630 km) (Reference 2). The Hammerberg was approximately 300 nmi (556 km) from this burst location. The USS Salamonie had detached from the task force 10 hours before the ARGUS 1 event. Its courses and speeds after detachment placed it approximately 275 nmi

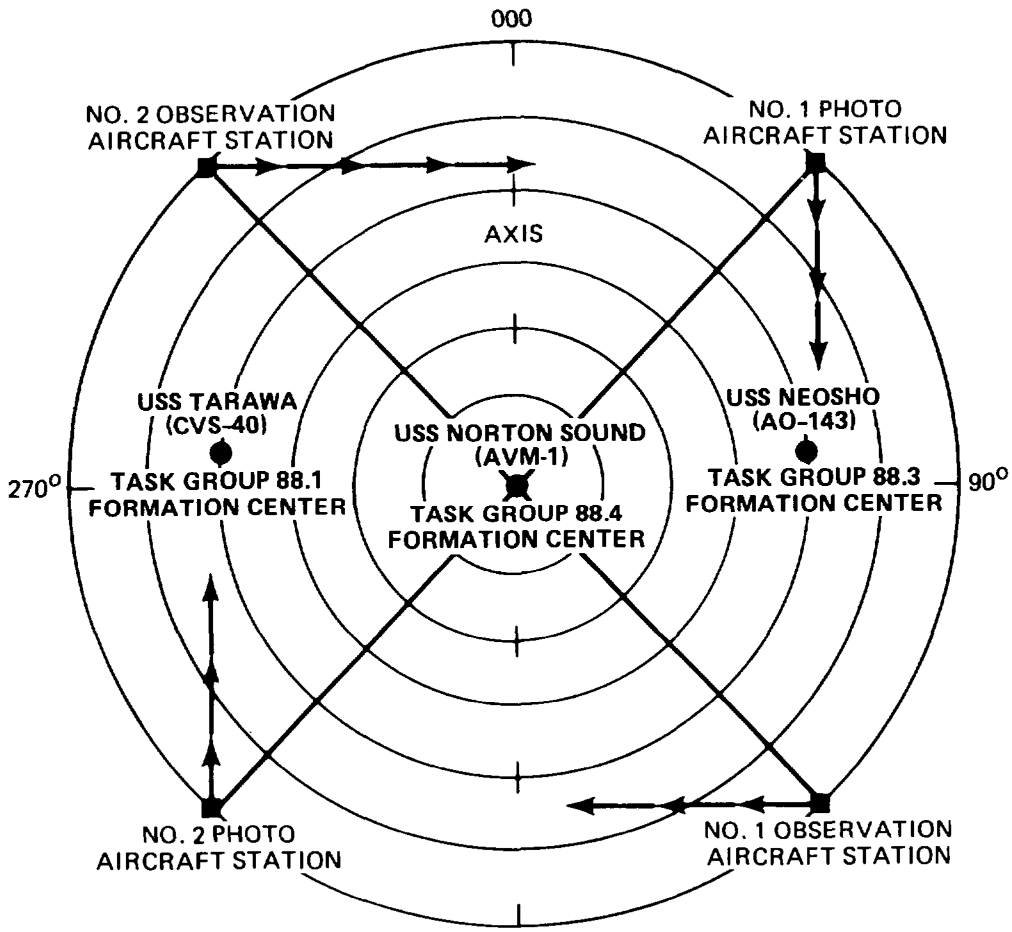

Figure 6. Generalized planned locations of surface and air units at launch time, ARGUS series (source: Reference 13).

(510 km) from the burst location (Reference 20). Since all three ARGUS shots were high-altitude detonations, all TF 88 units were removed from radiological exposure by both a significant vertical and horizontal separation. Figure 7 shows positions of TF 88 launch units at burst time for ARGUS 1. Figure 8 depicts the locations of TF 88 units in both hemispheres for ARGUS 1.

Radiological Considerations

Shipboard observers saw a horizon-wide flash brighten the cloud layer (Reference 6). The only S2F aircraft above the clouds was at 22,000 feet

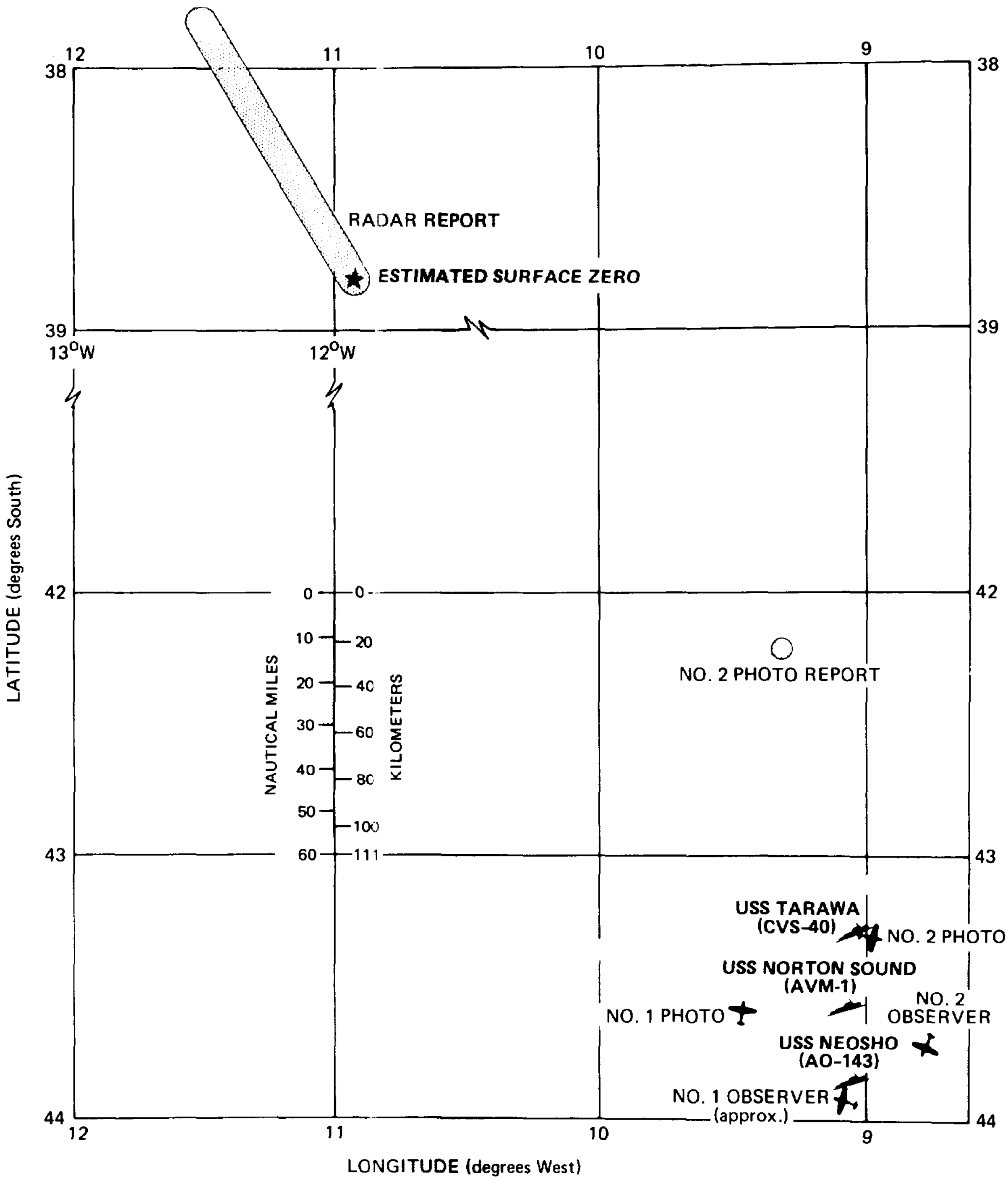

Figure 7. Positions of Task Force 88 units and reported burst, ARGUS 1 (source: Reference 2).

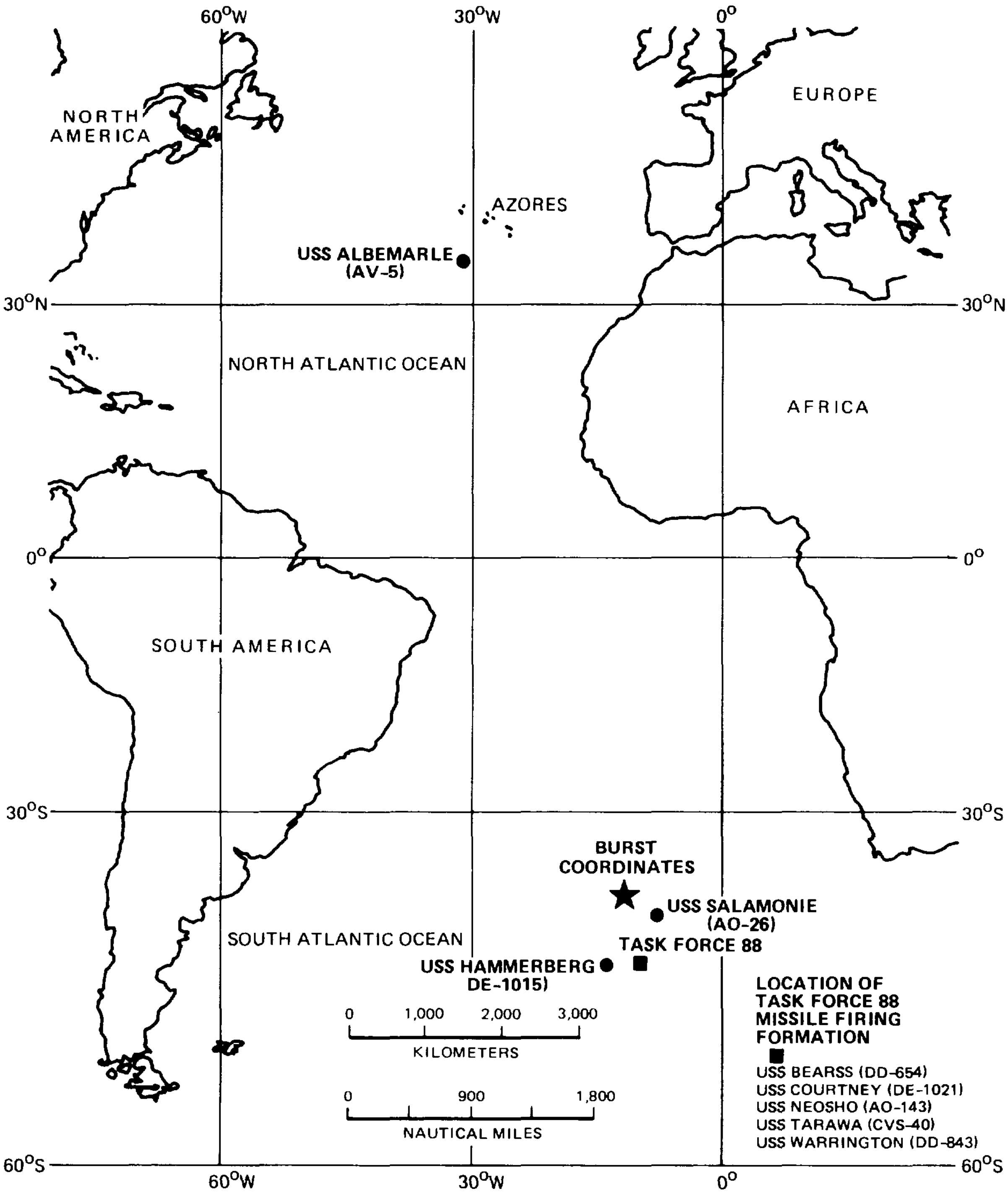

Figure 8. ARGUS 1, locations of ships at burst time.

(6.7 km) when ARGUS 1 detonated; the pilot reported a great luminous ball about 40^{o} above the horizon. For the next 30 minutes the aircrew observed and photographed an awesome auroral display as colors and shapes changed (Reference 2). More significantly, the satellite of Project 7.1 recorded the existence in the exosphere of increased electrons in the northern hemisphere that was later determined to have been the result of electron and geomagnetic behavior theorized by Christofilos (References 2 and 6). Detonating in the exosphere an estimated surface range of 340 nmi (630 km) away from most of the task force units and a surface range of 275 nmi (510 km) away from the closest unit, ARGUS 1 was too far removed to cause radiological exposure (Reference 2).

Results

The specific objective of Project 7.4 was to deliver and detonate a nuclear payload at a predetermined height above the Earth's surface. This objective was only partially achieved. ARGUS 1 was launched as scheduled, but an errant trajectory resulted in a detonation at a lower altitude than desired for experimental purposes. Nevertheless, reports from Project 7.1 (Explorer IV) indicated a band of increased particle count some 200 miles (322 km) thick and two to five times background in areas high above Haiti, Mexico, and Baja California (Reference 6). One of the Air Force Cambridge Research Center (AFCRC) C-97s reported an orange glow at 140^{o}T from Santa Maria in the Azores approximately 22 minutes after the detonation (Reference 14). The second C-97 was grounded because of engine trouble (Reference 35). The USS Albemarle, also involved in AFCRC's Project 7.3, reported receiving strong radar echoes, but did not receive any VLF radio signals, or indications on the riometers or photometers aboard (Reference 43). Because of the negative results from other projects, however, TG 88.6 headquarters concluded that a second shot was required. In order to put the conjugate point farther north so that observers would be in a more favorable position to get better measurements, the decision was made to move the launch point farther south (Reference 6).

Project 7.3 radars at both the launch and conjugate points received echoes. Project 7.2 sounding rockets failed to detect any ARGUS effect for the ARGUS 1 shot (Reference 2).

ARGUS 2

Chronology of Events

Normal aircraft support operations were conducted before the ARGUS 2 launch.

29 August, 0818: The Courtney was on a weather picket station approximately 250 nmi (463 km) west of the task force missile-firing formation.

29 August, 2215: The firing time was readjusted to 30 August at 0310 when the missile beacon system malfunctioned.

30 August, 0310: The missile was fired with a near-vertical trajectory. The surface wind was 22 knots (40.8 km/hr) and the sea state was rough.

Scientific Objectives

The scientific objectives remained the same for each of the three ARGUS launches. See statement of objectives and identification of scientific projects under ARGUS 1, this chapter, and Chapter 1. The launch and detonation points were shifted south for ARGUS 2 in an attempt to achieve conjugate point effects closer to where Project 7.3 units were arrayed.

Force Disposition

Figure 6 shows the generalized planned location of surface and air units. At the launch of ARGUS 2, the Tarawa was 223^{o}T at 16.4 nmi (30.4 km), and the Neosho was 42^{o}T at 17.5 nmi (32.4 km) from the Norton Sound (Reference 15). The Hammerberg and the Bearss were in company with the Tarawa acting as plane guards. Four S2F aircraft were airborne. The Warrington was stationed at 60^{o} on the port bow of the Norton Sound at a distance of 1 nmi (1.85 km) in order to photograph the missile launch. The

Courtney was 250 nmi (463 km) west of the task force missile-firing formation (Reference 13, 16, 17, 18, 22, and 42). The Albemarle was at 30°25'N, 30°03'W.

The estimated burst position of ARGUS 2 was 196°, 85 nmi (158 km) from the main body of the task force (Reference 2). The Courtney, on a weather picket station, was approximately 245 nmi (454 km) from the point under the burst. Figure 9 shows the position of TF 88 launching units for ARGUS 2. Figure 10 depicts the location of TF 88 units in both hemispheres for ARGUS 2.

Radiological Considerations

As in ARGUS 1, the radiological environment of ARGUS 2 was restricted to the exosphere. The weather at the shot site was overcast at the surface. The bright initial flash was visible from the ships. However, the tops of the low clouds were at about 3,000 feet (914 meters), so that observers in all four airborne aircraft had a clear view of the resulting changing phenomena of color and shape (Reference 2). Heavy clouds at the northern conjugate point prevented the Albemarle and observers at ground stations from seeing any significant visual effects (Reference 6).

Results

ARGUS 2 was launched with a good trajectory but, due to a possible third-stage failure, did not achieve the optimum desired burst altitude (Reference 2). The estimated position of the exospheric detonation was 85 nmi (158 km) from the task force launching formation (Reference 2). Following the detonation of ARGUS 2, Explorer IV data under Project 7.1 began to arrive from Huntsville, Alabama, reporting that a high-energy electron shell again had been established (Reference 6). Uncertainty about the findings, however, resulted in the decision to once again move the task force farther south for the launching of ARGUS 3 (Reference 6).

For the ARGUS 2 launch, the task force had been moved south of the ARGUS 1 launch point. This move was made in an attempt to move the anticipated conjugate point effects location farther north. Confusion arose

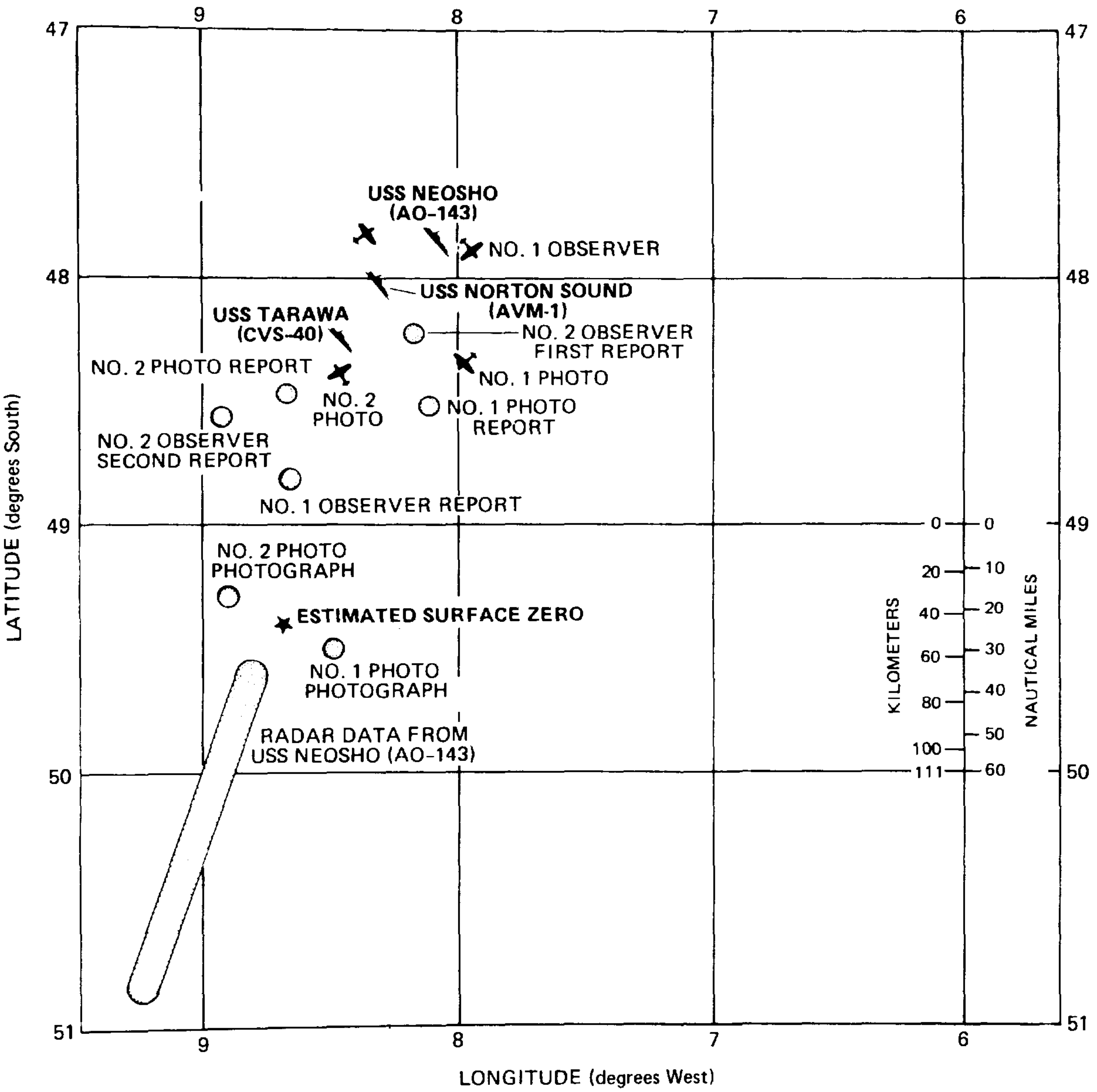

Figure 9. Positions of Task Force 88 units and reported burst, ARGUS 2 (source: Reference 2).

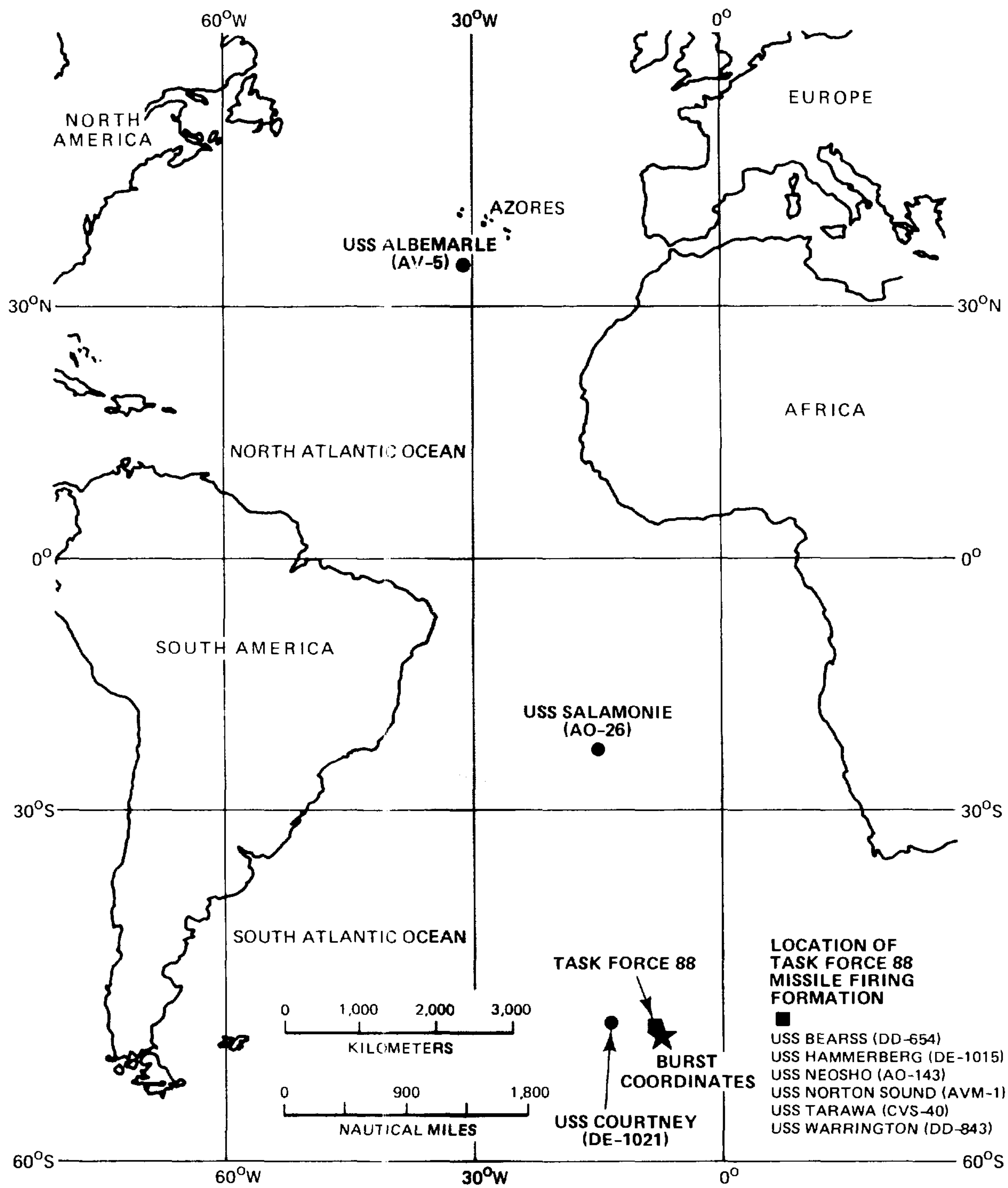

Figure 10. ARGUS 2, locations of ships at burst time.

when the conjugate point effects location plotted with Project 7.1 Explorer IV satellite data unexpectedly fell along the data line noted for ARGUS 1. This situation led to a closer scrutiny of the satellite reports. It was finally determined that the satellite had accumulated a position error in latitude amounting to almost 2 minutes since ARGUS 1. Correcting for this error moved the ARGUS 2 ground intercepts northward by some 500 nmi (927 km), the region where conjugate point effects had been anticipated (Reference 6). The sounding rockets of Project 7.2 recorded good results. Firings from all three rocket sites found a significant increase in electrons (Reference 2). Project 7.3 radars at the launch point received the anticipated echoes (Reference 2). No ARGUS 2 positive results were received by the Project 7.3 equipment aboard the Albemarle at the conjugate point (Reference 43). No ARGUS 2 results were detected by either of the Project 7.3 C-97 aircraft.

ARGUS 3

Chronology of Events

Normal aircraft support operations were conducted before each ARGUS 3 launch attempt.

1 September, 1958:	The first attempt to launch the third X-17a was cancelled due to high winds. TF 88 moved south to a new launch site.
4 September, 0656:	The Hammerberg was on a weather picket station approximately 250 nmi (463 km) west of the main task force.
5 September, 2230:	The missile failed to ignite upon actuation of its firing circuit.
6 September, 2205:	The missile fired with a near-vertical trajectory. The surface wind was 15 knots (27.8 km/hr); the sea state was moderate.

Scientific Objectives

The scientific objectives remained the same for each of the three ARGUS launches. See statement of objective and identification of scientific projects under ARGUS 1, this chapter, and Chapter 1.

After the position error for Explorer IV had been identified and a new launch site determined, the effects of ARGUS 3 in the northern hemisphere occurred where they were anticipated. The satellite again found high-energy electron zones in the exosphere. The ground intercepts defined a geomagnetic latitude line that fell very close to the one from ARGUS 2 and again conformed within reason to the contours originally calculated for this area (Reference 43).

Force Disposition

Figure 6 shows the generalized planned location of surface and air units. At the launch of ARGUS 3, the Tarawa was 291°T at 19.3 nmi (35.8 km), and the Neosho was 116°T at 18.5 nmi (34.3 km) from the Norton Sound (Reference 2). The Courtney and the Bearss were in company with the Tarawa acting as plane guards. The Warrington was stationed at 60° 1 nmi (1.85 km) off the port bow of the Norton Sound in order to photograph the missile launch. The Hammerberg was 250 nmi (463 km) west of the task force missile-firing formation on a weather picket station (References 13, 16, 17, 18, 22, and 42). Figure 11 indicates the location of TF 88 units at the launch site for ARGUS 3. Figure 12 depicts the positions of TF 88 units in both hemispheres for ARGUS 3.

The estimated surface position of the high-altitude burst position of ARGUS 3 was 286°T, 115 nmi (213 km) from the main body of the task force (Reference 2). The Hammerberg was approximately 145 nmi (269 km) from a point under the burst (Reference 18).

Radiological Considerations

As in ARGUS 1 and 2, the radiological environment of ARGUS 3 was restricted to the exosphere. At the launch site there were no clouds, and the flash of the detonation and resulting aurora display were visible to

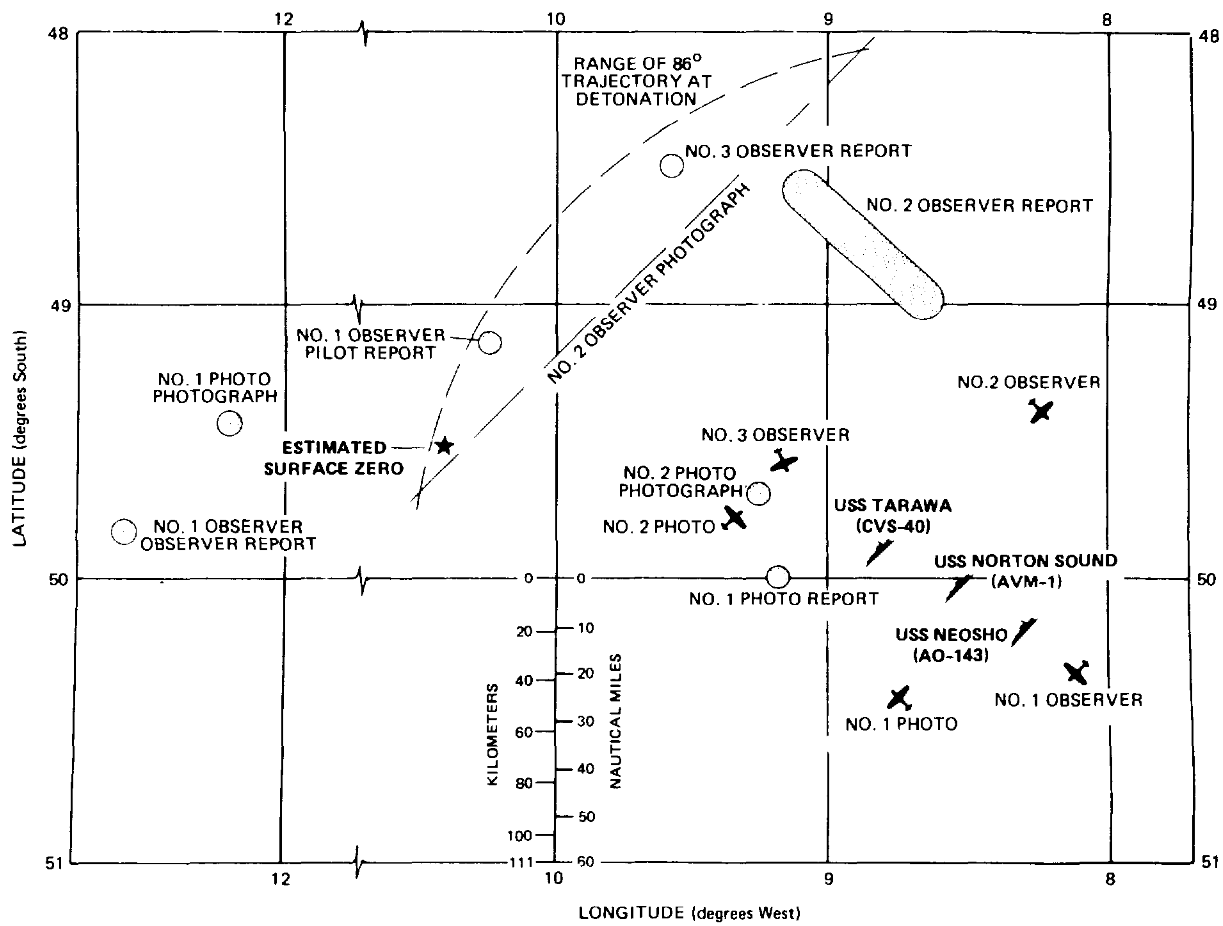

Figure 11. Positions of Task Force 88 units and reported burst, ARGUS 3 (source: Reference 2)

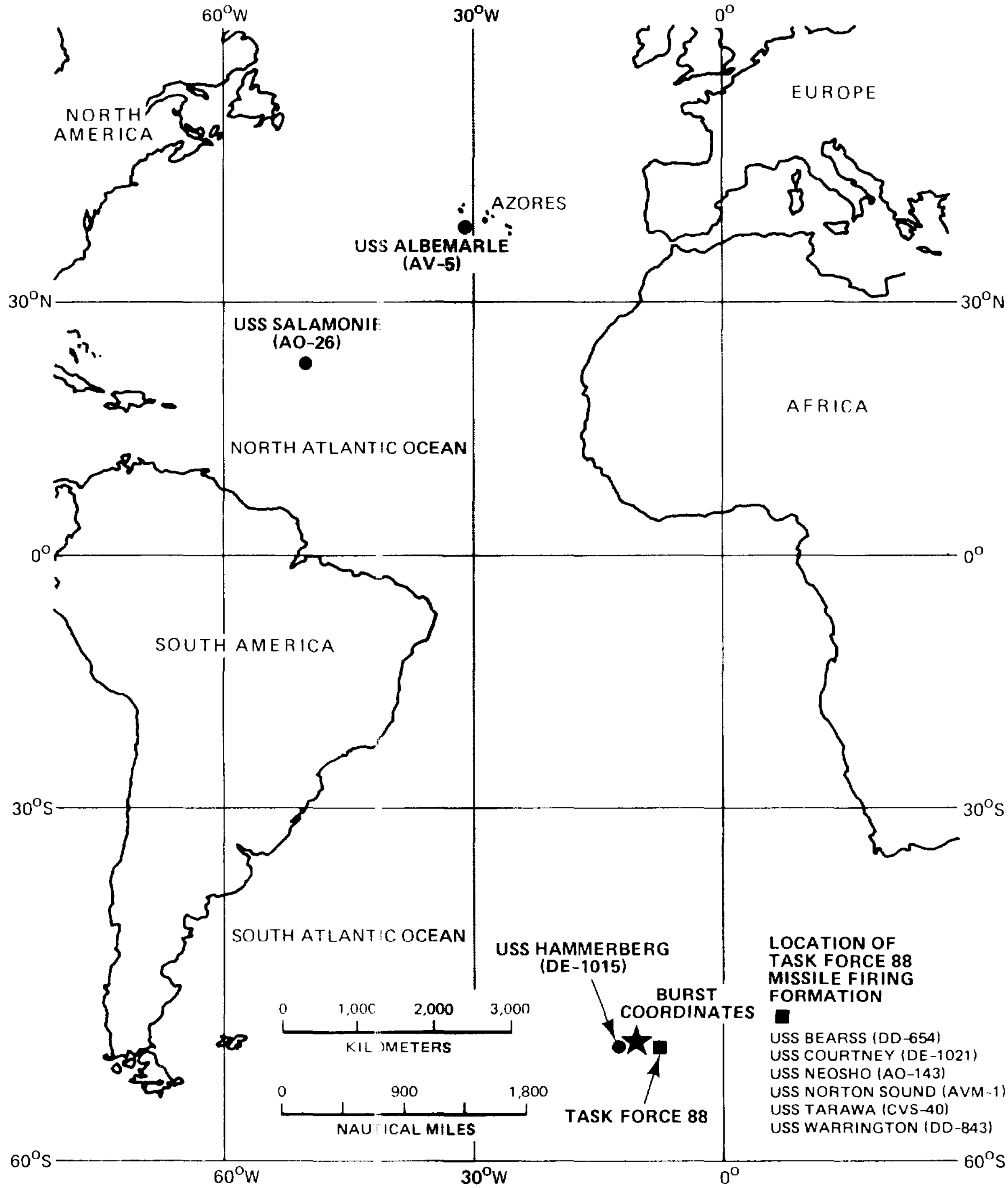

Figure 12. ARGUS 3, locations of ships at burst time.

observers in the task force as well as to those in the observation aircraft (References 2 and 6). This time the sky was also clear in the north and the Albemarle reported seeing a mild auroral glow (Reference 6).

Results

ARGUS 3 was launched with a good trajectory and achieved the desired burst altitude (Reference 2). This high-altitude detonation was approximately 115 nmi (213 km) from the main task force (Reference 2). The anticipated electron phenomena were detected by the Project 7.1 Explorer IV satellite and the radars at both the launch and conjugate points of Project 7.3 (References 2 and 6). Visual observations of an auroral glow were made from ships and aircraft at the launch site, and from the Albemarle at the conjugate point (Reference 14). One C-97 aircraft on the ground and an airborne C-97 noted sporadic ionospheric changes, but these were considered as only suggestive of the ARGUS 3 effect (Reference 14).

CHAPTER 3
TASK FORCE 88 UNIT HISTORIES

TASK GROUP 88.1 -- CARRIER GROUP

The aircraft carrier, the USS Tarawa, was the flagship of Commander, Task Force 88 (CTF 88) and carried two air units, Air Antisubmarine Squadron 32 (VS-32) and Helicopter Antisubmarine Squadron 5 (HS-5). Additionally, the Tarawa supported AFCRC's Project 7.3. Air Force MSQ-1A radar and communication vans for missile tracking and AFCRC optical and radio equipment for scientific measurements were carried aboard the Tarawa. The S2F aircraft of VS-32 were used in multiple support missions: weather reconnaissance, area search, and airborne photographic and observation platforms for rocket firings. The HSS-1 helicopters of HS-5 were used for intra-task-force movement of personnel, cargo, and mail (Reference 2). Certain crewmembers and observers of VS-32 aircraft were badged and carried self-reading pocket dosimeters on missile launch observation flights. The pocket dosimeters carried aloft indicated zero exposure on all shots (Reference 2).* Film packets were placed in selected topside locations of the Tarawa before each rocket launch. Table 8 summarizes information on the Tarawa's activity for all three ARGUS missile launches. Figure 13 shows Tarawa flight operations en route to the South Atlantic launch site.

TASK GROUP 88.2 -- DESTROYER GROUP

The Destroyer Group, TG 88.2, was composed of the destroyers, USS Warrington and USS Bearss, and the destroyer escorts, USS Courtney and USS Hammerberg. These units were involved in routine task force screening

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* Documentation has not been located that precisely identifies the recipients of the 264 film badges issued for the operation and the 21 badges of this group that subsequently recorded a radiological exposure. See the Radiological Safety section of Chapter 1 for a discussion of what is known on this subject. The maximum exposure recorded by an individual was 0.010 R (Reference 2).

Table 8. USS Tarawa (CVS-40) operational activities during ARGUS test series.

Departure from Point of Origin

On 7 August 1958 at 1406 departed Quonset Point, Rhode Island; beginning 9 August steamed in company with USS Hammerberg (DE-1015), USS Warrington (DD-843), USS Salamonie (AO-26), USS Neosho (AO-143), USS Bearss (DD-654), and USS Courtney (DE-1021); on 23 August at 1818 rendezvoused with USS Norton Sound (AVM-1)

Arrival in Operational Area

25 August

Departure from Operational Area

9 September

Arrival at Destination

15 September arrived at Rio de Janeiro, Brazil, for 5-day visit; arrived Quonset Point, Rhode Island, 1 October

Shot	Shot Date	Time of Det.	Ship Location/Activities: Preshot	Ship Location/Activities: At Shot Time	Ship Location/Activities: Postshot
ARGUS 1	27 Aug	0227	On 27 August steamed in company with other ships of Task Force 88; at 0054 launched four S2F airplanes; at 0130 sounded general quarters	Steaming on course in the South Atlantic between the following two points: 45°05'S, 09°29'W on 26 August at 2000 and 43°26'S, 07°58'W on 27 August at 0800	Steamed as before; at 0239 secured from general quarters; at 1730 ceased flight operations
ARGUS 2	30 Aug	0317	On 29 August steamed in South Atlantic Ocean in company with six other ships as part of Task Force 88; at 2131 began flight operations; ended flight operations at 0225; on 30 August at 0216 began flight operations; at 0240 sounded general quarters	Steamed in South Atlantic between the following points: 48°43'S, 09°13'W on 29 August at 2000, and 47°44'S, 09°33'W on 30 August at 0800	On 30 August at 0317 secured from general quarters; at 1525 ceased flight operations; on 31 August at 2133 began flight operations; on 1 September at 0110 ceased flight operations; On 3 September at 2215 observed hail and rain; on 4 September at 1755 observed snow
ARGUS 3	6 Sept	2212	On 5 September steamed in the South Atlantic in company with five ships, units of Task Force 88; on 6 September at 0834 began flight operations; at 1420 observed moderate snow; at 2135 went to general quarters	At 2205 observed test ECHO; ship in the South Atlantic between the following locations: 50°16'S, 07°55'W on 5 September at 2000 and 49°47'S, 08°02'W on 6 September at 0800	On 6 September at 2224 secured from general quarters; on 7 September at 1305 secured from flight quarters; at 0945 observed light snow; from 8 September until arrival at Rio de Janeiro on 15 September conducted flight operations daily

Source: Reference 21.

Figure 13. USS Tarawa (CVS-40) flight operations, 13 August 1958.

operations, weather pickets, and plane guard assignments for the carrier Tarawa.

The Warrington steamed on lifeguard station when the USS Norton Sound was rigging and preparing to launch X-17a missiles. Before missile launch, the Warrington moved up to 60° on the Norton Sound's port bow at a distance of 1 nmi (1.85 km) to photograph the launch.

The Hammerberg and Courtney rotated assignments as weather picket ship. The Warrington was specially equipped with a Loki/Dart rocket launcher and rehearsed units of the task force in simulated ARGUS countdown procedures, communications, and radar tracking (References 2 and 42).

As in the case of the Carrier Group, the TF 88 Operation Plan and TF 88 Final Report state that each of the Destroyer Group units was provided 10 film packets to be placed in above-deck positions for each ARGUS shot. Readings from these badges are not reported.

Tables 9, 10, 11 and 12 summarize operational activities during the ARGUS test series for Destroyer Group units.

TASK GROUP 88.3 -- MOBILE LOGISTICS GROUP

Mobile Logistics Group 88.3 was formed by the oilers, USS Neosho and USS Salamonie. The Salamonie replenished the Norton Sound on 24 August 1958 following that ship's voyage around South America. The aviation gasoline tanks of the Norton Sound had been converted to fuel oil tanks before its departure from California in order to permit it to reach the test area without the need to refuel. On 26 August 1958, the Salamonie refueled the Neosho. Following this transfer, the Salamonie detached from TF 88, steaming independently en route to Newport, Rhode Island (Reference 20). Following the Salamonie's departure, the Neosho had complete refueling responsibility for the task force.

The Neosho also participated in scientific program 7.3 with an Air Force MSQ-1A radar van manned by an Air Force crew aboard. The Neosho took station approximately 15 nmi (28 km) from the Norton Sound during launch operations and attempted to track the X-17a missile and detect burst phenomena (References 2 and 6).

The Neosho was issued film packets that were to be placed in above-deck or superstructure locations for each of the three ARGUS launches (References 2 and 6).*

Tables 13 and 14 summarize activities of the units of the Mobile Logistics Group during all three ARGUS launches.

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* No film badges were issued to the Salamonie as this ship detached from the task force 10 hours before the first scheduled ARGUS launch. Documentation has not been located that precisely identifies the recipients of the 264 film badges issued for the operation and the 21 badges of this group that subsequently recorded a radiation exposure. See the Radiological Safety section of Chapter 1 for a discussion of what is known on the subject. The maximum exposure recorded by an individual was 0.010 R (Reference 2).

Table 9. USS Bearss (DD-654) operational activities during ARGUS test series.

Departure from Point of Origin

On 7 August 1958 departed from Norfolk, Virginia, in company with USS Neosho (AO-143); rendezvoused at sea on 8 August with USS Salamonie (AO-26), USS Warrington (DD-843), USS Tarawa (CVS-40), USS Courtney (DE-1021), and USS Hammerberg (DE-1015)

Arrival in Operational Area

25 August

Departure from Operational Area

8 September in company with other ships of Task Force 88

Arrival at Destination

15 September, Rio de Janeiro, Brazil, for 5-day visit; arrived Norfolk, Virginia, 30 September

Shot	Shot Date	Time of Det.	Ship Location/Activities: Preshot	Ship Location/Activities: At Shot Time	Ship Location/Activities: Postshot
ARGUS 1	27 Aug	0227	27 August in company with the Tarawa and Courtney as Task Group 88.1; at 0055 took plane guard station 1	Steaming as before; missile fired at 0220; position of ship between following two points: 44°36.9'S, 11°35.3'W on 26 August at 2000 and 44°50.7'S, 09°45.5'W on 27 August at 0800	Continued maneuvering in formation with Tarawa and Norton Sound (AVM-1) as disposition guide; conducted flight operations from 1400 to 1416
ARGUS 2	30 Aug	0317	In plane guard station 1, in company with Tarawa and Warrington in plane guard station 2; Norton Sound formation guide bearing 047° 17 nmi (32 km) distant	Steaming as before; ship located between following two points: 48°23.1'S, 10°05.8'W on 29 August at 2000, and 48°55.0'S, 09°44.0'W on 30 August	Steaming as before, serving as Tarawa screen; left screen and between 0944 and 1020 took on fuel and provisions from Neosho; at 1030 returned to screen
ARGUS 3	6 Sept	2212	At 1817 on plane guard station 1 for Tarawa as Task Group 88.1	Steaming as before; on 6 September at 2201 missile fired; ship located between following points: 50°22.7'S, 07°51.0'W on 5 September at 2000, and 49°40.0'S, 08°32.1'W on 6 September at 0800	Between 2236 and 2253 flight operations underway; at 2305 maneuvering to take position in screen on Norton Sound; at at 0959 visibility began fluctuating between 500 and 4,000 yards (0.5 and and 3.7 km) due to snow

Source: Reference 16.

Table 10. USS Courtney (DE-1021) operational activities during ARGUS test series.

Departure from Point of Origin

On 7 August 1958 at 1248 underway from Newport, Rhode Island, en route to South Atlantic waters in company with USS Salamonie (AO-26); on 8 August rendezvoused with Task Force 88, composed of USS Neosho (AO-143), USS Bearss (DD-654), USS Tarawa (CVS-40), USS Warrington (DD-843), and USS Hammerberg (DE-1015); on 23 August at 1230 rendezvoused with Task Group 88.4: USS Norton Sound (AVM-1)

Arrival in Operational Area

25 August

Departure from Operational Area

8 September with other ships of Task Force 88

Arrival at Destination

15 September, Rio de Janeiro, Brazil, for 5-day visit; arrived Newport, Rhode Island, 1 October

Shot	Shot Date	Time of Det.	Ship Location/Activities: Preshot	At Shot Time	Postshot
ARGUS 1	27 Aug	0227	On 27 August at 0140 went to general quarters	Steaming as before; at 0229 observed flash from X-17a missile; ship located between following positions: 43°05'S, 09°50'W on on 26 August at 2000 and 45°26'S, 08°25'W on 27 August at 0800	At 0242 secured from general quarters; continued steaming as before
ARGUS 2	30 Aug	0317	Continued steaming as before; on 28 August at 0940 commenced refueling from Neosho; at 1750 detached from Task Group 88.1 and assumed command of Task Group 88.2.2, proceeded to relieve Commander Task Group 88.2.1 on weather picket station; on 30 August at midnight steamed independently 250 nmi (463 km) west of Task Force 88	Steaming as before; at 0319 observed flash; ship located between following points: 47°39'S, 13°44'W on 29 August at 2000 and 47°58'S, 14°11'W, on 30 August at 0800	Continued steaming as before; by 4 September steamed independently en route to Task Force 88; by 5 September rejoined Task Force 88; at 0810 Task Group 88.2 consisted of Warrington, Bearss, and Courtney detached to observe and photograph iceberg; at 1108 rejoined Task Force 88
ARGUS 3	6 Sept	2212	Steamed as before; on 6 September at 1550 commenced refueling and replenishing from Neosho; by 1607 refueling and replenishing completed; at 2145 went to general quarters; at 2204 set gas-tight envelope	Steaming as before; at 2206 Norton Sound fired one X-17a missile; ship located between following points: 50°23'S, 07°20'W on 5 September at 2000 and 49°59'S, 07°23'W on 6 September at 0800	At 2225 secured from general quarters; continued steaming as before; 9 September departed operating area with other ships of Task Force 88; on 15 September arrived at Rio de Janeiro

Source: Reference 17.

Table 11. USS Hammerberg (DE-1015) operational activities during ARGUS test series.

Departure from Point of Origin

On 7 August 1958 at 1252 departed Newport, Rhode Island, en route to operating area in company with other ships of Task Force 88, including USS Tarawa (CVS-40), USS Warrington (DD-843), USS Salamonie (AO-26), USS Bearss (DD-654), and USS Courtney (DE-1021)

Arrival in Operational Area

See preshot activities for Argus 1

Departure from Operational Area

8 September with other ships of Task Force 88

Arrival at Destination

15 September, Rio de Janeiro, Brazil, for 5-day visit; arrived Newport, Rhode Island, 1 October

Shot	Shot Date	Time of Det.	Ship Location/Activities: Preshot	At Shot Time	Postshot
ARGUS 1	27 Aug	0227	On 22 August at 1247 left formation and proceeded independently to weather picket station; on 27 August steaming independently on weather picket station, bearing 270, 200 nmi (371 km) from Task Force 88	Steaming independently on weather picket station; location of ship between following two points: 43°24'S, 12°46'W on 26 August at 2000, and 43°28.3'S, 13°04.8'W on 27 August at 0800	Continued steaming independently as weather for Task Force 88; on 29 August changed course to rejoin Task Force 88; relieved Courtney
ARGUS 2	30 Aug	0317	Steaming independently to rejoin Task Force 88; on 30 August at 0149 rejoined Task Force 88 and proceeded to plane guard station 2 for Tarawa	Steaming as before; location of ship between the following points: 47°56'S, 10°21'W on 29 August at 2000 and 47°44'S, 11°28'W on 30 August at 0800	Steaming in company with Task Force 88; on 4 September left for weather picket station
ARGUS 3	6 Sept	2212	On 4 September steamed independently en route to weather picket station; by 5 September station reached, bearing 270, 250 nmi (463 km) distant from Task Force 88	Steaming independently on weather picket station; location of ship between following two points: 50°14'S, 13°07'W on 5 September at 2000, and 50°05'S, 14°20'W on 6 September at 0800	On 6 September at 2235 departed weather picket station en route to rejoin Task Force 88; on 15 September arrived at Rio de Janeiro

Source: Reference 18.

Table 12. USS Warrington (DD-843) operational activities during ARGUS test series.

Departure from Point of Origin

On 7 August 1958 at 1301 departed Newport, Rhode Island; by 9 August steaming in company with USS Courtney (DE-1021), USS Hammerberg (DE-1015), USS Tarawa (CVS-40), USS Salamonie (AO-26), USS Neosho (AO-143), and USS Bearss (DD-654); on 23 August at 1611 made rendezvous with USS Norton Sound (AVM-1)

Arrival in Operational Area

25 August

Departure from Operational Area

9 September

Arrival at Destination

15 September at Rio de Janeiro for 5- day visit; arrived Newport, Rhode Island, 1 October

Shot	Shot Date	Time of Det.	Ship Location/Activities: Preshot	At Shot Time	Postshot
ARGUS 1	27 Aug	0227	Steamed in company with ships of Task Force 88; on 27 August served as lifeguard station for Norton Sound in company with other ships of Task Force 88	On 27 August at 0220 observed Norton Sound fire missile; ship located between following points: 43°08'S, 09°55'W on 26 August at at 2000 and 43°24'S, 08°25'W on 27 August at 0800	On 27 August steaming as before
ARGUS 2	30 Aug	0317	On 29 August steamed in company with Task Force 88; on 30 August at 0145 detached from plane guard duty, assumed station ahead of Norton Sound	At 0311 observed Norton Sound fire missile; ship located between following locations: 40°37'S, 09°07'W on 29 August at 2000, and 47°43'S, 09°30'W on 30 August at 0800	Detached from station to refuel from Neosho between 0750 and 0855; resumed former station; on 31 August between 2400-0400 observed snow and choppy seas
ARGUS 3	6 Sept	2212	On 5 September at 2227 observed rocket misfire on board Norton Sound, exercise cancelled; on 6 September at 1643 formation proceeded into missile firing formation; at 1730 on station bearing 340°, 2000 yards (1.8 km) off bow of Norton Sound	Steamed as before between following points: 50°30'S, 07°42'W on 5 September at 2000 and 49°50'S, 08°52'W on 6 September at 0800	Continued steaming as before with ships of Task Force 88

Source: Reference 22.

Table 13. USS Neosho (AO-143) operational activities during ARGUS test series.

Departure from Point of Origin

On 7 August 1958 at 1155 departed Norfolk, Virginia, en route to operations at sea in the South Atlantic; at 1443 rendezvoused with the USS Bearss (DD-654); on 8 August Task Group 88.3 activated, composed of USS Salamonie (AO-26), Bearss, USS Courtney (DE-1021), and Neosho; at 0900 joined Task Group 88.1 composed of USS Tarawa (CVS-40), USS Hammerberg (DE-1015), and USS Warrington (DD-843); during this cruise the Neosho replenished the ships of the task force as necessary

Arrival in Operational Area

25 August

Departure from Operational Area

9 September with other ships of Task Force 88

Arrival at Destination

15 September at Rio de Janeiro, Brazil, for 5-day visit; arrived Norfolk, Virginia, 30 September

Shot	Shot Date	Time of Det.	Ship Location/Activities: Preshot	Ship Location/Activities: At Shot Time	Ship Location/Activities: Postshot
ARGUS 1	27 Aug	0227	On 27 August at 0115 went to general quarters steamed in company with other ships of Task Force 88	Steaming as before; ship located between following points: 43°11'S, 10°57'W on 26 August at 2000, and 43°26'S, 09°22'W on 27 August at 0800	On 27 August at 0242 secured from general quarters; at 1228 helicopter over bow to deliver exposure suits; through 30 August continued steaming in company with other ships of Task Force 88
ARGUS 2	30 Aug	0317	Steamed as before; on 30 August at 0215 went to general quarters	Steaming as before; ship located between following points: 48°20'S, 09°02'W on 29 August at 2000, and 47°17'S, 09°38'W on 30 August at 0800	On 30 August, steaming as before; at 0320 secured from general quarters; through 6 September continued steaming in company with with ships of Task Force 88, providing replenishment of fuel and stores
ARGUS 3	6 Sep	2212	Steamed as before	Steaming as before; ship located between following points: 50°32'S, 05°11'W on 5 September at 2000, and 49°54'S, 08°14'W on 6 September at 0800	Steamed as before

Source: Reference 19.

Table 14. <u>USS Salamonie</u> (AO-26) operational activities during ARGUS test series.

<u>Departure from Point of Origin</u>

On 7 August 1958 at 1333 underway from Newport, Rhode Island; at 1455 rendezvoused with <u>USS Courtney</u> (DE-1021); on 8 August at 0910 rendezvoused with <u>USS Neosho</u> (AO-143), <u>USS Bearss</u> (DD-654), <u>USS Tarawa</u> (CVS-40), <u>USS Warrington</u> (DD-843), and <u>USS Hammerberg</u> (DE-1015)

<u>Arrival in Operational Area</u>

Detached prior to arrival

<u>Departure from Operational Area</u>

On 26 August at 1617 detached from Task Force 88, steamed independently en route to Newport, Rhode Island

<u>Arrival at Destination</u>

10 September at 1205 moored at Melville, Rhode Island

Shot	Shot Date	Time of Det.	Ship Location/Activities: Preshot	Ship Location/Activities: At Shot Time	Ship Location/Activities: Postshot
ARGUS 1	27 Aug	0227	Steamed independently en route to Newport, Rhode Island	Steaming independently to Newport, Rhode Island; ship between following points: 42°41'S, 19°35'W on 26 August at 2000, and 39°37'S, 07°25'W on 27 August at 0800	Continued steaming en route to Newport, Rhode Island
ARGUS 2	30 Aug	0317	Steamed independently to Newport, Rhode Island	Steamed as before, ship located between following positions: 22°37'S, 13°35'W on 29 August at 2000, and 19°50'S, 16°04'W on 30 August at 0800	Steamed en route to Newport, Rhode Island
ARGUS 3	6 Sept	2212	Steamed en route to Newport, Rhode Island	Steamed as before; location of ship between following points: 17°56'N, 45°09'W on 5 September at 2000, and and 20°46'N, 47°28'W on 6 September at 0800	Steamed as before

Source: Reference 20.

TASK GROUP 88.4 -- MISSILE GROUP

The Norton Sound was the key participant in the ARGUS operation. Selected because of its availability and capability to conduct test rocket and missile firing exercises, the ship and personnel required special preparation to participate in the ARGUS operation.

The ship lacked the usual fueling-at-sea installations. The necessary equipment for this procedure was installed during the brief Naval Shipyard availability period scheduled to modify the ship to handle and fire the X-17a missile (Reference 2). A practice fueling at sea and high-line transfer operations were conducted with the fleet tanker USS Tolovana (AO-64) off Long Beach, California, on 3 July 1958. None of the crewmembers had conducted helicopter operations with the Norton Sound. Because this would be an important logistics operation, practice exercises were arranged with the Naval Air Missile Test Center (NAMTC). These were conducted in conjunction with the four Winder (X-17a test missile with a telemetry payload) firings (Reference 15).

A 10-day training course on the X-17a missile was conducted by Lockheed Missiles System Division at Van Nuys, California, for Norton Sound personnel. Under supervision of Lockheed technicians, Norton Sound electronics and machinist personnel assembled the four Winder test missiles and the three X-17a ARGUS missiles to be fired in the South Atlantic. Thirteen enlisted personnel performed all the steps involved in the assembly and checkout of each component of the missile (Reference 2).

In June 1958 San Francisco Naval Shipyard personnel and the ship's company worked to convert the Norton Sound from a Terrier/Tartar missile test capability to an X-17a high-altitude missile launch capability. An X-5 dual-arm launcher on the port side of the launcher deck was removed and replaced with a vertical X-17 launcher. Additional modifications of the hangar provided storage for three X-17a missiles on their handling trailers. A shop in the hangar area was turned over to the Sandia Corporation for its use. Finally, to increase the cruising range of the

Norton Sound, the ship's aviation gasoline bunkers were converted to fuel-oil bunkers.

Between 2 and 24 July 1958, four Winder test missiles were fired in the Sea Test Range off Point Mugu, California. Although tests two and three were partial failures, the engineering solution devised for missile number four provided a successful launch, and the Norton Sound sailed on schedule with the three X-17a ARGUS missiles, which had been modified based upon the Winder test experience (References 2 and 15). Two views of the Norton Sound just after the successful launch of Winder missile number four are shown in Figures 14 and 15. Figure 14 is a high-angle shot of the ship showing the open deck area comprising the aft third of the ship, where the missile launches took place. Figure 15 is a low-angle view from the stern and shows the thin vertical arms that supported the Winder before launch.

Figure 14. Aerial view of the USS Norton Sound (AVM-1) after successful Winder missile launch, 24 July 1958.

Figure 15. View of the launch area, USS Norton Sound (AVM-1).

The Norton Sound rendezvoused with units of TF 88 23 days after departing California. On 25 and 26 August, the Norton Sound launched a total of four Pogo missiles. These exercises provided the first opportunity for all units of TF 88 to operate together and to rehearse the detailed procedures for an ARGUS launch (Reference 2, 15, and 44).

The ARGUS 1 launch went off on schedule on 27 August, followed by the ARGUS 2 launch on 30 August. This launch had been delayed by a beacon failure. To make repairs, the missile was removed from the launching deck to the hangar bay. The ARGUS 3 launch took place on 6 September. The first ARGUS 3 launch attempt on 1 September was aborted due to poor weather. ARGUS 3 was delayed again on 2 September, when a new launching point was designated and the task force moved south to it. On 5 September a defective relay in the firing circuit aborted the launch. Finally, on 6 September, ARGUS 3 was successfully launched (Reference 15).

Table 15 summarizes Norton Sound activities during the three ARGUS missile launches.

TASK GROUP 88.5 -- SCIENTIFIC SUPPORT GROUP

The USS Albemarle participated in Project 7.3 to record surface measurements of electromagnetic and optical effects of the ARGUS detonations from the geomagnetic conjugate point (Reference 14).

Radiological effects of the very-high-altitude ARGUS detonations were measured by the Explorer IV satellite. As noted in the surface measurements report (Reference 14):

> The satellite data shows very positive results from ARGUS I, II and III. The strength of the radiation is quite impressive at such a distance, being probably in excess of 1r/hr.

The Albemarle in the North Atlantic and the remainder of the task force units in the South Atlantic were hundreds of miles under this measured shell of trapped electrons.

Operation Order 7-58 (Reference 13) specified that each ship in the task force except the Albemarle and the Salamonie be furnished film badges. The Salamonie was an exception because it was scheduled to depart the South Atlantic operations area before the first scheduled ARGUS launch. The Albemarle was similarly excepted because of its isolation from any potential radiological exposure associated with the ARGUS launch operation. The position of the Albemarle for each of the three ARGUS launches was the conjugate point in the North Atlantic, near the Azores Islands (Reference 41).

Table 15. USS Norton Sound (AVM-1) operational activities during ARGUS test series.

Departure from Point of Origin

On 1 August 1958 at 1800 departed Port Hueneme, California, en route to special project firing area; on 23 August at 1345 rendezvoused with USS Courtney (DE-1021), USS Warrington (DD-843), and USS Tarawa (CVS-40); at 1735 Tarawa alongside, received telphone lines for command conference with Commander Task Force 88; on 24 August at 0851 rendezvoused with USS Salamonie (AO-26)

Arrival in Operational Area

25 August

Departure from Operational Area

9 September

Arrival at Destination

15 September at Rio de Janeiro, Brazil, for 5-day visit; arrived Port Hueneme, California, via Panama Canal on 11 October

Shot	Shot Date	Time of Det.	Ship Location/Activities: Preshot	Ship Location/Activities: At Shot Time	Ship Location/Activities: Postshot
ARGUS 1	**27 Aug**	**0227**	**On 27 August steamed in company with other ships of Task Force 88; at 0130 sounded general quarters**	**Steamed as before; at 0220 launched X-17a missile; ship located between following points: 43°13'S, 09°44'W on 26 August at 2000 and 43°36'S, 08°14'W on 27 August at 0800**	**At 0235 secured from general quarters, continued steaming as before**
ARGUS 2	30 Aug	0317	Steamed in Task Force 88; at 0100 sounded missile quarters; at 0250 sounded general quarters	Steamed as before; at 0310 fired X-17a missile; ship located between following positions: 48°28'S, 08°23'W on 29 August at 2000, and 47°29'S, on 30 August at 0800	At 0325 secured from general quarters; continued steaming as before; on 31 August at 2226 sounded missile quarters; at 2357 cancelled missile operations; on 2 September at 2145 sounded missile quarters; at 2210 secured from missile quarters; on 5 September at 2154 sounded general quarters; at 2234 X-17a missile misfired; at 2300 secured from general quarters
ARGUS 3	6 Sept	2212	On 6 September steamed in company with ships of Task Force 88; at 2007 sounded missile quarters; at 2010 commenced maneuvering on various courses and speeds to obtain correct winds for missile launch; at 2135 sounded general quarters	Steamed as before; at 2205 launched an X-17a missile; ship located between following positions: 50°30'S, 07°32'W on 5 September at 2000 and 49°59'S, 08°24'W on 6 September at 0800	At 2219 secured from general quarters; continued steaming as before

Source: Reference 44.

The *Albemarle* was specially manned and outfitted for its scientific assignment. Two civilians, one each from AFCRC and SRI, were responsible for the operation of the following specialized equipment (Reference 14):

- HF (27-MHz) communications zone indicator (COZI) radar
- An all-sky camera
- Spectrophotometers
- Riometers
- VLF receivers.

The auroral glow of ARGUS 3 was visually sighted from the *Albemarle*. Strong HF radar echoes were obtained after ARGUS 1 and ARGUS 3. Results from the all-sky camera and the spectrophotometers aboard the *Albemarle* could have been expected during ARGUS 3 except that the equipment was not turned on. No results were obtained from the network of riometers, devices designed to detect cosmic radio noise that the sky continuously emits. A riometer is a VHF receiver with a pen chart recorder that measures and records differences in this noise level. The VLF receiver aboard the *Albemarle* recorded effects from ARGUS 2 (Reference 14). Table 16 summarizes *Albemarle* activities for the three ARGUS missile launches. Figure 16 shows the *Albemarle* moored at Azores harbor before the start of the operation.

Table 16. USS Albemarle (AV-5) operational activities during ARGUS test series.

Departure from Point of Origin

On 14 August 1958 at 0602 departed Norfolk, Virginia, steaming independently; on 21 August refueled at Ponta Delgada, Azores; at 1628 underway for operating area

Arrival in Operational Area

On 23 August reached assigned operations area in the Azores

Departure from Operational Area

10 September

Arrival at Destination

On 16 September arrived at Norfolk, Virginia

Shot	Shot Date	Time of Det.	Ship Location/Activities: Preshot	Ship Location/Activities: At Shot Time	Ship Location/Activities: Postshot
ARGUS 1	27 Aug	0227	Steamed independently in assigned operating area, Azores	Steamed as before; ship located between following positions: 34°07'N, 31°17'W on 26 August at 2000,and 33°44'N, 30°57'W on 27 August at 0800	Continued steaming as before in Azores operating area; on 29 August at 2116 aerologists released radiosonde balloon
ARGUS 2	30 Aug	0317	Steamed in assigned operating area, Azores	Continued steaming as before; ship located between following positions: 39°08'N, 31°04'W on 29 August at 2000, and 33°57'N, 30°59'W on 30 August at 0800	Continued steaming as before, on 1 September at 0904 commenced simulated atomic attack; at 0907 set gas-tight envelope; at 1004 secured from from atomic attack drill; on 2 September commenced steaming en route to new operating area; arrived at new operating area at 0109; continued steaming as before
ARGUS 3	6 Sept	2212	Steamed in assigned operating area, Azores	Continued steaming as before; ship located between following positions: 34°00'N, 30°02'W on 5 September at 2000 and 37°06'N, 30°06'W on 6 September at 0800	Continued steaming as before; on 16 September arrived at Norfolk, Virginia

Source: Reference 23.

Figure 16. USS Albemarle (AV-5) moored at Ponta Delgada.

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An availability code appears at the end of many reference citations for those who wish to read or obtain copies. Availability status was correct at the time the reference list was prepared. Many documents indicated as unavailable will become available during the declassification review process. The Department of Energy Coordination and Information Center (DOE CIC) and the National Technical Information Service (NTIS) will be provided future DNA-WT documents bearing an "EX" after the report number.

Source documents with an availability code of DOE CIC may be reviewed at the following address:

Department of Energy
Coordination and Information Center
(Operated by Reynolds Electrical & Engineering Co., Inc)
ATTN: Mr. Richard V. Nutley
2753 S. Highland
P.O. Box 14100
Las Vegas, Nevada 89114
Telephone: (702) 734-3194; FTS: 598-3194.

Source documents bearing an NTIS availability code may be purchased at the following address:

National Technical Information Service
(Sales Office)
5285 Port Royal Road
Springfield, Virginia 22161
Telephone: (703) 787-4650.

When ordering by mail or phone, please include both the price code and the NTIS number. The price code appears in parentheses before the NTIS order number; e.g., (A07) AD 000 000.

Additional ordering information or assistance may be obtained by writing to the NTIS, Attention: Customer Service, or by calling (703) 487-4660.

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APPENDIX A
ARGUS PLANNING AND OPERATIONAL MILESTONES

Fall 1957	Christofilos theory proposes use of a plasma of electrons for military applications in space.
3 January 1958	Christofilos theory brought to attention of President's Science Advisory Committee (PSAC). PSAC requests a group of 20 outstanding physicists to meet at Livermore for an intensive 2-week study of the theory.
10 January 1958	Christofilos' concept published by University of California Radiation Laboratory, Livermore (UCRL).
10-21 February 1958	Working committee of scientists assemble at Livermore to study Christofilos' concept. It recommends a small-yield, high-altitude test shot.
6 March 1958	J. R. Killian, Jr. and Dr. Herbert York brief President Eisenhower on ARGUS concept. President approves testing the concept and directs that arrangements be made to orbit a satellite to measure the effects.
6 March 1958	National Security Council briefed on ARGUS by Dr. Herbert York, PSAC.
11 March 1958	Armed Forces Policy Council directs UCRL to undertake further theoretical work and make recommendations concerning nature of nuclear test to be conducted.

24 March 1958	Deputy Secretary of Defense designates the Armed Forces Special Weapons Project (AFSWP) the responsible agency in the Department of Defense, in coordination with the Advanced Research Projects Agency (ARPA).
March-April 1958	A number of conferences are conducted with representatives of ARPA, AFSWP, the three military services, and other agencies to develop a plan for the ARGUS experiments.
2 April 1958	Chief, AFSWP, recommends to Director, ARPA, the funding and priorities required to conduct a test within 5 months.
4 April 1958	Deputy Secretary of Defense assigns overall management of the ARGUS operation to Director, ARPA.
14 April 1958	Technical and operational ARGUS planning staffs are combined to form the Special Weapons Test Project (SWTP) within AFSWP.
15 April 1958	UCRL provides AFSWP the requirement for an ARGUS test shot.
25 April 1958	Deputy Secretary of Defense approves the proposed ARGUS test subject to coordination with the U.S. Atomic Energy Commission (AEC) and the Department of State, and the approval of the President.
28 April 1958	Chief, AFSWP, requests the Army and Air Force to provide officers for duty on the technical staff of Task Force 88 (TF 88).
28 April 1958	ARPA promulgates its Operation Order 4-58 directing AFSWP to proceed with ARGUS.

28 April 1958	Chief, AFSWP, informs the Norton Sound that it has been designated as the missile firing ship for ARGUS. Suggests a 2 May conference.
1 May 1958	President Eisenhower formally approves the ARGUS Operation.
19 May 1958	Rear Admiral Lloyd M. Mustin reports to Chief, AFSWP, to become Chief, SWTP and CTF 88.
19 May 1958	AEC states to Chief, AFSWP, its understanding of AEC participation in ARGUS.
20 May 1958	RADM Mustin briefs the Military Liaison Committee on Operation ARGUS.
2 June 1958	TF 88 activated by Commander-in-Chief, U.S. Atlantic Fleet (CINCLANTFLT), for planning purposes.
11 June 1958	The Joint Chiefs of Staff (JCS) promulgate SM-417-58, which lists DOD agency responsibilities for ARGUS and requests the chiefs of the military services to provide the necessary operational support.
18 June 1958	CTF 88 holds a briefing in Washington, D.C., for all TF 88 ships' commanding officers.
3 July 1958	The Chairman, Joint Committee on Atomic Energy, U.S. Congress, informed of ARGUS operation by the Assistant to the Secretary of Defense (Atomic Energy).
14 July 1958	TF 88 activated by CINCLANTFLT for operations.
19 July 1958	President Eisenhower approves transfer of warheads from AEC to DOD for use in Operation ARGUS.
1 August 1958	Norton Sound departs Port Hueneme, California.

7 August 1958	Neosho and Bearss depart Norfolk, Virginia.
7 August 1958	Salamonie, Warrington, Courtney, and Hammerberg depart Newport, Rhode Island.
7 August 1958	Tarawa departs Quonset Point, Rhode Island.
14 August 1958	Albemarle departs Norfolk, Virginia.
23 August 1958	Albemarle arrives in assigned operations area in the Azores.
25 August 1958	Neosho, Norton Sound, Tarawa, Warrington, Courtney, and Bearss arrive in operational area.
26 August 1958	Salamonie detached from task force.
August 27, 1958	ARGUS 1 shot.
August 29, 1958	Assistant to the Secretary of Defense (Atomic Energy) reports initial results of Operation ARGUS to the Chairman, Joint Committee on Atomic Energy.
30 August 1958	ARGUS 2 shot.
6 September 1958	ARGUS 3 shot.
8 September 1958	Bearss, Hammerberg, Courtney depart operational area.
9 September 1958	Neosho, Norton Sound, Tarawa, and Warrington depart operational area.
10 September 1958	Albemarle departs operational area.
September 10, 1958	Salamonie arrives Melville, Rhode Island.
16 September 1958	Albemarle arrives at Norfolk, Virginia.

30 September 1958	Neosho and Bearss arrive Norfolk, Virginia.
1 October 1958	Tarawa arrives Quonset Point, Rhode Island.
1 October 1958	Warrington, Courtney, and Hammerberg arrive Newport Rhode Island.
11 October 1958	Norton Sound arrives Port Hueneme, California.
3 November 1958	J. R. Killian, Jr. reports preliminary results of ARGUS to President Eisenhower.

APPENDIX B
SOURCES AND RESEARCH

Operation ARGUS was planned and conducted under extreme conditions of security and with an abbreviated planning and execution schedule unprecedented in United States oceanic nuclear testing. One result of the compressed schedule was that a larger than normal amount of the planning and coordination was done in person, without the usual amount of formal preplanning, agenda preparation, and position papers being written.

Almost all of the written documents originally were classified Top Secret. Research soon established that these highly classified documents were early candidates for destruction. A specific case in point concerns the search for Commander Task Force 88 Operation Order 7-58. The available Task Force 88 ARGUS final report provided a full citation of this critical document. Since the operation order would provide details concerning radiological planning along with other essential information required to document the ARGUS operation, a thorough search was made to locate it. When the document was not located in DNA ARGUS holdings at the Washington National Records Center, a determined effort was made to locate it in other feasible record groups.

Since ARGUS was predominantly a naval operation, Record Group 038, Office of the Chief of Naval Operations, was searched. Results were negative. Records Group 313, Naval Operating Forces, was considered next. A copy of a concurrent Confidential ARGUS operation order had been located in the Admiral Lloyd M. Mustin Papers at the Navy Operational Archives. The distribution list of this operation order helped direct a search of the Flag Files of a number of operational commands that would have had responsibilities for Operation ARGUS. Top Secret and Secret files for the Commander-in-Chief Atlantic Fleet and four other Atlantic major fleet commands were searched for the years 1958 and 1959. Some ARGUS material was discovered, but not Operation Order 7-58. A search of Department of

Energy files for the period established that the Atomic Energy Commission had received a copy of the operation order, but it had not survived the years of selective destruction of documents.

Searches were made in the records of the Office of the Secretary of Defense without success. Records management personnel of the Joint Chiefs of Staff and the Advanced Research Projects Agency responded to a retrieval request and reported negative results. A visit to the Dwight D. Eisenhower Library was made in the search. This turned up a number of very interesting ARGUS documents, but not the operation order. The search had a successful ending when researchers working on Operation HARDTACK discovered the operation order and other important ARGUS material filed securely within the HARDTACK material. Not surprisingly, when the first copy was located, a second source for the operation order was also identified.

Failure to locate the final report of film badge readings has been discussed previously. Medical records were searched for some of the pilots who flew on ARGUS missions. None of these provided any documentary evidence of badging or exposure readings.

With the large separations between the ARGUS burst points and the test participants, however, and the maximum recorded personnel film packet exposure of 0.010 R relative to a 0.025 R control packet exposure, there is no question that personnel radiation exposures resulting from these detonations were essentially nil.

APPENDIX C
TERMS, ABBREVIATIONS, AND ACRONYMS

Many of the definitions in this glossary relating to nuclear device and radiation phenomena have been quoted or extracted from The Effects of Nuclear Weapons (3rd edition), S. Glasstone and P.J. Dolan, 1977.

accelerometer. An instrument for determining the acceleration of the system with which it moves.

AEC. Atomic Energy Commission, Washington, D.C. Independent agency of the Federal government with statutory responsibilities for atomic energy matters. No longer exists; its functions have been assumed by the Department of Energy and the Nuclear Regulatory Commission.

AF. Store ship (Navy); also Air Force.

AFSWC. Air Force Special Weapons Center, Kirtland AFB, New Mexico.

AFSWP. Armed Forces Special Weapons Project.

AGC. Amphibious force flagship; now LCC.

airburst. The detonation of a nuclear device in the air at a height such that the expanding fireball does not touch the earth's surface when the luminosity (emission of light) is at a maximum.

air particle trajectory. The direction, velocity, and rate of descent of windblown radioactive particles.

AKA. Attack cargo ship; now LKA.

allowable dose. See MPE and MPL.

alpha emitter. A radionuclide that undergoes transformation by alpha-particle emission.

alpha particle. A charged particle emitted spontaneously from the nuclei of some radioactive elements. It is identical with a helium nucleus, having a mass of 4 units and an electric charge of 2 positive units. See also radioactivity.

alpha rays. A stream of alpha particles. Loosely, a synonym for alpha particles.

AN/PDR-39. An ion-chamber-type survey meter; this was the standard radsafe meter. Others in use included the Navy version, the AN/PDR-T1B, the AN/PDR-18A and -18B, and lower range Geiger-Mueller instruments (AN/PDR-27, Beckman MX-5, and Nuclear Corporation 2610).

AO. Oiler (Navy).

AOC. Air Operations Control Center.

AOG. Gasoline tanker.

AP. Transport ship.

APG. Aberdeen Proving Ground, Maryland.

apogee. The highest point (the greatest distance from the Earth) in the orbit of a satellite as opposed to the perigee.

arming. The changing of a nuclear device from a safe condition (that is, a condition in which it cannot be accidentally detonated) to a state of readiness for detonation.

ARS. Salvage ship.

ARSD. Salvage lifting ship.

ATF. Fleet ocean tug.

atomic bomb (or weapon). A term sometimes applied to a nuclear weapon utilizing fission energy only. See also fission, nuclear device.

atomic explosion. See nuclear explosion.

attenuation. The process by which radiation is reduced in intensity when passing through some material. It is due to absorption or scattering or both, but it excludes the decrease of intensity with distance from the source (inverse square law), which see.

aurora. Display of the effects of electrically charged particles from the sun guided by the Earth's magnetic field as they interact with the upper layers of the Earth's atmosphere in higher latitude and polar regions. See also trapped radiation.

background radiation. The radiation of man's natural environment, consisting of that which comes from cosmic rays and from the naturally radioactive elements of the Earth, including that from within man's body. The term may also mean radiation extraneous to an experiment.

becquerel (Bq). See curie (Ci).

beta burns. Beta particles that come into contact with the skin and remain for an appreciable time can cause a form of radiation injury sometimes referred to as "beta burn." In an area of extensive early fallout, the whole surface of the body may be exposed to beta particles.

beta emitter. A radionuclide that disintegrates by beta particle emission. All beta-active elements existing in nature expel negative particles, i.e., electrons or, more exactly, negatrons. Beta-emitting particles are harmful if inhaled or ingested.

beta particle (ray). A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Most (if not all) of the direct fission products emit (negative) beta particles. Physically, the beta particle is identical to an electron moving at high velocity.

blast. The detonation of a nuclear device, like the detonation of a high explosive such as TNT, results in the sudden formation of a pressure or shock wave, called a blast wave in the air and a shock wave when the energy is imparted to water or Earth.

blast wave. An air pulse in which the pressure increases sharply at the front accompanied by winds propagated from an explosion.

blast yield. That portion of the total energy of a nuclear explosion that manifests itself as blast and shock waves.

bomb debris. See weapon debris.

BRL. Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland (Army).

BuMed. Bureau of Medicine and Surgery (Navy).

burst. Explosion; or detonation. See also airburst, high-altitude burst, surface burst.

BuShips. Bureau of Ships (Navy).

cathode-ray tube. A vacuum tube in which cathode rays (electrons) are beamed upon a fluorescent screen to produce a luminous image. The character of this image is related to, and controlled by, one or more electrical signals applied to the cathode-ray beam as input information. The tubes are used in measuring instruments such as oscilloscopes and in radar and television displays.

cave. A heavily shielded enclosure in which radioactive materials can be remotely manipulated to avoid radiation exposure of personnel.

Ci; c. Abbreviation for curie, which see. Ci is preferred now but c was the abbreviation used in the 1950s.

Circle William fittings. The closing of certain closures, designated "Circle William" fittings, hinders the movement of outside air into the interior spaces of naval ships. This sealed state is also called Circle William condition.

closed area. The land areas of Bikini and Enewetak and the water areas within 3 miles of them that the United States closed to unauthorized persons.

cloud chamber effect. See Wilson cloud.

cloud column (funnel). The visible column of weapon debris (and possibly dust or water droplets) extending upward from the point of a nuclear burst.

cloud phenomena. See fallout, fireball, radioactive cloud.

CNO. Chief of Naval Operations.

collimate. To align nuclear weapon radiant outputs within an assigned solid angle through the use of baffles in order to enhance measurements.

Condition "Purple". See Purple conditions.

contamination. The deposit of radioactive material on the surfaces of structures, areas, objects, and personnel following a nuclear detonation. This material generally consists of fallout in which fission products and other device debris have become incorporated with particles of dust, vaporized components of device platforms, etc. Contamination can also arise from the radioactivity induced in certain substances by the action of neutrons from a nuclear explosion. See also decontamination, fallout, weapon debris.

CPM. Counts per minute; a measure of radioactive material disintegration.

crater. The depression formed in the surface of the Earth by a surface or underground explosion. Crater formation can occur by vaporization of the surface material, by the scouring effect of airblast, by throwout of disturbed material, or by subsidence.

C/S. Chief of Staff.

CTG. Commander, Task Group.

curie (Ci). A unit of radioactivity; it is the activity of a quantity of any radioactive species in which 3.700×10^{10} (37 billion) nuclear disintegrations occur per second (approximately the radioactivity of 1 gram of radium). The gamma curie is sometimes defined correspondingly as the activity of material in which this number of gamma-ray photons is emitted per second. This unit is being replaced by the becquerel (Bq), which is equal to one disintegration per second.

CVE. Escort aircraft carrier.

CW net. Carrier wave network. An organization of stations capable of direct radio communications on a common channel or frequency.

D-day. The term used to designate the unnamed day on which a test takes place. The equivalent rule applies to H-hour. Time in plans is indicated by a letter which shows the unit of time employed in figures, with a minus or plus sign to indicate the amount of time before or after the reference event, e.g., D+7 means 7 days after D-day, H+2 means 2 hours after H-hour.

DDE. Escort destroyer.

DE. Destroyer escort.

debris (radioactive). See weapon debris.

decay (radioactive). The decrease in activity of any radioactive material with the passage of time due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, sometimes accompanied by gamma radiation, or by gamma photons alone. Every decay process has a definite half-life.

decontamination. The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination; (2) letting the material stand so that the radioactivity is decreased as a result of natural decay; and (3) covering the contamination in order to attenuate the radiation emitted.

device. Nuclear fission and fusion materials, together with their arming, fuzing, firing, chemical-explosive, and effects-measuring components, that have not reached the development status of an operational weapon.

diagnostic measurements or experiments. Experiments whose purpose is to study the explosive disassembly of a nuclear device as opposed to effects measurements (which see).

DM. Minelayer destroyer. Converted destroyers designed to conduct high-speed minelaying operations.

DOD. Department of Defense. The Federal executive agency responsible for the defense of the United States. Includes the four services and special joint defense agencies. Reports to the President through the Secretary of Defense.

dose. A general term denoting the quantity of ionizing radiation absorbed. The unit of absorbed dose is the rad (which see). In soft body tissue the absorbed dose in rads is essentially equal to the exposure in roentgens. The biological dose (also called the RBE dose) in rems is a measure of biological effectiveness of the absorbed radiation. Dosage is used in older literature as well as exposure dose and simply exposure, and care should be exercised in their use. See also exposure.

dose rate. As a general rule, the amount of ionizing (or nuclear) radiation that an individual or material would receive per unit of time. It is usually expressed as rads (or rems) per hour or multiples or divisions of these units such as millirads per hour. The dose rate is commonly used to indicate the level of radioactivity in a contaminated area. See survey meter.

dosimeter. An instrument for measuring and registering the total accumulated dose of (or exposure to) ionizing radiation. Instruments worn or carried by individuals are called personnel dosimeters.

dosimetry. The measurement and recording of radiation doses and dose rates. It is concerned with the use of various types of radiation instruments with which measurements are made. See also dosimeter, survey meter.

DPM. Disintegrations per minute, a measure of radioactivity, literally atoms disintegrating per minute. Difficult to directly compare with roentgens per hour for mixtures of radionuclides.

DTMB. David Taylor Model Basin, Carderock, Maryland (Navy).

dynamic pressure. Air pressure that results from the mass air flow (or wind) behind the shock front of a blast wave.

effects measurements or experiments. Experiments whose purpose is to study what a nuclear explosion does to equipment and systems. Includes also measurement of the changes in the environment caused by the detonation such as increased air pressures (blast), thermal and nuclear radiation, cratering, water waves, etc.

EG&G. Edgerton, Germeshausen & Grier, Boston, Massachusetts (now EG&G, Inc.). An AEC contractor. Provided timing and firing electronics and technical film coverage.

electromagnetic radiation. Electromagnetic radiations range from X-rays and gamma rays of short wavelength (high frequency), through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wavelength.

electron. A particle of very small mass and electrically charged. As usually defined, the electron's charge is negative. The term negatron is also used for the negative electron and the positively charged form is called a positron. See also beta particles.

ETA. Estimated time of arrival.

ETD. Estimated time of departure.

exosphere. The outermost region of the Earth's atmosphere extending from about 300 statute miles (480 km) altitude to outer space.

exposure. A measure expressed in roentgens of the ionization produced by gamma rays (or X-rays) in air. The exposure rate is the exposure per unit time (e.g., roentgens per hour). See dose, dose rate, roentgen.

exposure rate contours. Lines joining points which have the same radiation intensity that define a fallout pattern, represented in terms of roentgens per hour.

fallout. The process or phenomenon of the descent to the Earth's surface of particles contaminated with radioactive material from the radioactive cloud. The term is also applied in a collective sense to the contaminated particulate matter itself. The early (or local) fallout is defined, somewhat arbitrarily, as particles reaching the Earth within 24 hours after a nuclear explosion. The delayed (or worldwide) fallout consists of the smaller particles, which ascend into the upper troposphere and stratosphere and are carried by winds to all parts of the Earth. The delayed fallout is brought to Earth, mainly by rain and snow, over extended periods ranging from months to years.

film badges. Used for the indirect measurement of ionizing radiation. Generally contain two or three pieces of film of different radiation sensitivities. They are wrapped in paper (or other thin material) that blocks light but is readily penetrated by gamma rays. The films are developed and the degree of fogging (or blackening) observed is a measure of the gamma-ray exposure, from which the absorbed dose is calculated. Film badges can also measure beta and neutron radiation.

fireball. The luminous sphere of hot gases that forms a few millionths of a second after a nuclear explosion as the result of the absorption by the surrounding medium of the thermal X-rays emitted by the extremely hot (several tens of millions of degrees) device residues. The exterior of the fireball in air is initially sharply defined by the luminous shock front and later by the limits of the hot gases themselves.

fission. The process of the nucleus of a particular heavy element splitting into two nuclei of lighter elements, with the release of substantial amounts of energy. The most important fissionable materials are uranium-235 and plutonium-239; fission is caused by the absorption of neutrons.

fission detectors. Radiation pulse detector of the proportional counter type in which a foil or film of fissionable materials is incorporated to make it respond to neutrons.

fission products. A general term for the complex mixture of substances produced as a result of nuclear fission. A distinction should be made between these and the direct fission products or fission fragments that are formed by the actual splitting of the heavy-element nuclei into nuclei of medium atomic weight. Approximately 80 different fission fragments result from roughly 40 different modes of fission of a given nuclear species (e.g., uranium-235 or plutonium-239). The fission fragments, being radioactive, immediately begin to decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains over 300 different radionuclides of 36 elements.

fixed alpha. Alpha radioactivity that cannot be easily removed as evidenced by no measured change in a swipe of a 100-cm^2 area.

fluorescence. The emission of light (electromagnetic radiation) by a material as a result of the absorption of energy from radiation. The term may refer to the radiation emitted, as well as to the emission process.

fusion. The combination of two light nuclei to form a heavier nucleus, with the release of the difference of the nuclear binding energy of the fusion products and the sum of the binding energies of the two light nuclei.

gamma rays. Electromagnetic radiations of high photon energy originating in atomic nuclei and accompanying many nuclear reactions (e.g., fission, radioactivity, and neutron capture). Physically, gamma rays are identical to X-rays of high energy; the only essential difference is that X-rays do not originate from atomic nuclei of high energy. Gamma rays can travel great distances through air and can penetrate considerable thickness of material, although they can neither be seen nor felt by human beings except at very high intensities, which cause an itching and tingling sensation of the skin. They can produce harmful effects even at a long distance from their source (The Effects of Nuclear Weapons, 3rd edition).

Geiger-Mueller counter. A gas discharge pulse counter for ionizing radiation. See also AN/PDR-39 and ion-chamber-type survey meter.

GMT. Greenwich Mean Time.

gray (Gy). A recently introduced ICRP term; 1 Gy equals 100 rad.

H-hour. Time zero, or time of detonation. When used in connection with planning operations it is the specific hour at which the operation event commences. See D-day.

half-life. The time required for a radioactive material to lose half of its radioactivity due to decay. Each radionuclide has a unique half-life.

HASL, NYKOPO. Atomic Energy Commission's Health and Safety Laboratory, New York Operations Office.

high-altitude burst. Defined, somewhat arbitrarily, as a detonation in or above the stratosphere. The distribution of the energy of the explosion between blast and thermal radiation changes appreciably with increasing altitude.

hodograph. A common hodograph in meteorology represents the speed and direction of winds at different altitude increments.

hot; hot spot. Commonly used colloquial term meaning a spot or area relatively more radioactive than some adjacent area.

ICRP. International Commission on Radiological Protection.

initial radiation. Also known as prompt radiation. Electromagnetic radiations of high energy emitted from both the fireball and the radioactive cloud within the first minute after a detonation. It includes neutrons and gamma rays given off almost instantaneously, as well as the gamma rays emitted by the fission products and other radioactive species in the rising cloud. Initial radiations from ground or near-ground bursts activate both Earth materials and device debris to create contamination.

inverse square law. The decrease in radiation intensity with distance from a single-point source is proportional to the square of the distance removed.

ion-chamber-type survey meter. A device for measuring the amount of ionizing radiation. Consists of a gas-filled chamber containing two electrodes (one of which may be the chamber wall) between which a potential difference is maintained. The radiation ionizes gas in the chamber and an instrument connected to one electrode measures the ionization current produced.

ionization. The process of adding electrons to, or knocking electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, and nuclear radiation can cause ionization.

ionizing radiation. Any particulate or electromagnetic radiation capable of producing ions, directly or indirectly, in its passage through matter. Alpha and beta particles produce ion pairs directly, while gamma rays and X-rays liberate electrons as they traverse matter, which in turn produce ionization in their paths.

ionosphere. The region of the atmosphere, extending from roughly 40 to 250 miles (64 to 400 km) above the Earth, in which there is appreciable ionization. The presence of charged particles in this region profoundly affects the propagation of radio and radar waves.

irradiation. Exposure of matter to radiation.

isodose lines. Dose or dose-rate contours. In fallout, contours plotted on a radiation field within which the dose rate or the total accumulated dose is the same.

isotope. Atoms with the same atomic number (same chemical element) but different atomic weight; i.e., the nuclei have the same number of protons but a different number of neutrons.

JCS. Joint Chiefs of Staff.

kinetic energy. Energy associated with the motion of matter.

LASL. Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

LCM. Landing craft, mechanized.

LML. Lookout Mountain Laboratory, Hollywood, California (Air Force).

Loran. Long-range aid to navigation system. Loran stations were maintained by the U.S. Coast Guard Station on Enewetak Island and Johnston Atoll.

magnetometer. An instrument for measuring changes in the geomagnetic field.

MATS. Military Air Transport Service; later, Military Airlift Command (joint Air Force).

megaton (energy). Approximately the amount of energy that would be released by the explosion of one million tons of TNT.

microcurie. One-millionth of a curie.

micron. One-millionth of a meter (i.e., 10^{-6} meter or 10^{-4} centimeter); it is roughly four one-hundred-thousandths (4×10^{-5}) of an inch.

milliroentgen. One-thousandth of a roentgen.

MINSY. Mare Island Naval Ship Yard, California.

MPE. Maximum Permissible Exposure (rule dose). That exposure to ionizing radiation that is established by authorities as the maximum over certain periods without resulting in undue risk to human health.

MPL. Maximum Permissible Limit. That amount of radioactive material in air, water, foodstuffs, etc. that is established by authorities as the maximum that would not create undue risk to human health.

mR; mr. Abbreviation for milliroentgen.

MSTS. Military Sea Transportation Service, (Navy).

mushroom cap. Top of the cloud formed from the fireball of a nuclear detonation.

MV. Motor vessel.

NAS. Naval Air Station.

NBS. National Bureau of Standards.

NCRP. National Committee on Radiation Protection and Measurements. Before 1956 simply the National Committee on Radiation Protection.

neutron. A neutral elementary particle (i.e., with neutral electrical charge) of approximately unit mass (i.e., the mass of a proton) that is present in all atomic nuclei, except those of ordinary (light) hydrogen. Neutrons are required to initiate the fission process, and large numbers of neutrons are produced by both fission and fusion reactions in nuclear explosions.

neutron flux. The intensity of neutron radiation. It is expressed as the number of neutrons passing through 1 cm^2 in 1 second.

NPG. Nevada Proving Ground, now the Nevada Test Site (NTS).

NRDL. Naval Radiological Defense Laboratory.

NRL. Naval Research Laboratory.

NTPR. Nuclear Test Personnel Review.

NTS. Nevada Test Site.

nuclear cloud. See radioactive cloud.

nuclear device (or weapon or bomb). Any device in which the explosion results from the energy released by reactions involving atomic nuclei, either fission or fusion, or both. Thus, the A- (or atomic) bomb and the H- (or hydrogen) bomb are both nuclear weapons. It would be equally true to call them atomic weapons, since the energy of atomic nuclei is involved in each case. However, it has become more or less customary, although it is not strictly accurate, to refer to weapons in which all the energy results from fission as A-bombs. In order to make a distinction, those weapons in which part of the energy results from thermonuclear (fusion) reactions of the isotopes of hydrogen have been called H-bombs or hydrogen bombs.

nuclear explosion. Explosive release of energy due to the splitting, or joining, of atoms. The explosion is observable by a violent emission of ultraviolet, visible, and infrared (heat) radiation, gamma rays, neutrons, and other particles. This is accompanied by the formation of a fireball. A large part of the energy from the explosion is emitted as blast and shock waves when detonated at the Earth's surface or in the atmosphere. The fireball produces a mushroom-shaped mass of hot gases and debris, the top of which rises rapidly. See also radiation, gamma rays, fireball, nuclear device, fission, fusion, blast.

nuclear fusion. See thermonuclear fusion.

nuclear radiation. Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from the weapons standpoint, are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, but the reverse is not true; X-rays, for example, are included among ionizing radiations, but they are not nuclear radiations since they do not originate from atomic nuclei.

nuclear tests. Tests carried out to supply information required for the design and improvement of nuclear weapons and to study the phenomena and effects associated with nuclear explosions.

nuclide. Any species of atom that exists for a measurable length of time. The term nuclide is used to describe any atomic species distinguished by the composition of its nucleus; i.e., by the number of protons and the number of neutrons. Isotopes of a given element are nuclides having the normal number of protons but different numbers of neutrons in this nuclei. A radionuclide is a radioactive nuclide.

off-scale. Radiation (or other physical phenomena) greater than the capacity of a measuring device to measure.

ONR. Office of Naval Research, Washington, D.C.

OPNAV. Office of the Chief of Naval Operations.

ORNL. Oak Ridge National Laboratory, Tennessee.

oscilloscope. The name generally applied to a cathode-ray device.

overpressure. The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock (or blast) wave from an explosion.

peak overpressure. The maximum value of the overpressure (which see) at a given location.

perigee. The lowest point (the shortest distance from the Earth) in the orbit of a satellite, as opposed to the apogee.

permissible contamination or dose. That dose of ionizing radiation that is not expected to cause appreciable bodily injury to a person at any time during his lifetime.

phantom. A volume of material closely approximating the density and effective atomic number of tissue. The phantom absorbs ionizing radiation in the same manner as tissue, thus radiation dose measurements made within the phantom provide a means of approximating the radiation dose within a human or animal body under similar exposure conditions. Materials commonly used for phantoms are water, masonite, pressed wood, and beeswax.

pig. A heavily shielded container (usually lead) used to ship or store radioactive materials.

prompt radiation. See initial radiation.

proton. A particle carrying a positive charge and physically identical to the nucleus of the ordinary hydrogen atom.

Purple conditions. A shipboard warning system used in radiological defense. Various numbered conditions were sounded when radioactive fallout was encountered. Responses to the sounded warnings included closing of various hatches and fittings, turning off parts of the ventilation system, and removing personnel from a ship's open decks. The higher the Purple condition number, the more severe the radiological situation.

R; r. Symbol for roentgen.

Ra. Chemical symbol for radium.

rad. Radiation absorbed dose. A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of ionizing radiation per gram (or 0.01 J/kg) of absorbing material, such as body tissue. This unit is presently being replaced in scientific literature by the Gray (Gy), numerically equal to the absorption of 1 joule of energy per kilogram of matter.

RadDefense. Radiological defense. Defense against the effects of radioactivity from atomic weapons. It includes the detection and measurement of radioactivity, the protection of persons from radioactivity, and decontamination of areas, places, and equipment. See also radsafe.

radex area. Radiological exclusion area. Following each detonation there were areas of surface radiological contamination and areas of air radiological contamination. These areas were designated as radex areas. Radex areas were used to chart actual or predicted fallout and also used for control of entry and exit.

radiation. The emission of any rays, electromagnetic waves, or particles (e.g., gamma rays, alpha particles, beta particles, neutrons) from a source.

radiation decay. See decay (radioactive).

radiation detectors. Any of a wide variety of materials or instruments that provide a signal when stimulated by the passage of ionizing radiation; the sensitive element in radiation detection instruments. The most widely used media for the detection of ionizing radiation are photographic film and ionization of gases in detectors (e.g., Geiger counters), followed by materials in which radiation induces scintillation.

radiation exposure. Exposure to radiation may be described and modified by a number of terms. The type of radiation is important: alpha and beta particles, neutrons, gamma rays and X-rays, and cosmic radiation. Radiation exposure may be from an external radiation source, such as gamma rays, X-rays, or neutrons, or it may be from radionuclides retained within the body emitting alpha, beta, or gamma radiation. The exposure may result from penetrating or nonpenetrating radiation in relation to its ability to enter and pass through matter -- alpha and beta particles being considered as nonpenetrating and other types of radiation as penetrating. Exposure may be related to a part of the body or to the whole body. See also whole-body irradiation.

radiation intensity. Degree of radiation. Measured and reported in roentgens (R), rads, rems, and rep, multiples and divisions of these units, and multiples and divisions of these units as a function of exposure rate (per hour, day, etc.).

radioactive (or nuclear) cloud. An all-inclusive term for the cloud of hot gases, smoke, dust, and other particulate matter from the weapon itself and from the environment, which is carried aloft in conjunction with the rising fireball produced by the detonation of a nuclear weapon.

radioactive nuclide. See radionuclide.

radioactive particles. See radioactivity.

radioactive pool. A disk-like pool of radioactive water near the surface formed by a water-surface or subsurface detonation. The pool gradually expands into an annular form, then reverts to a larger irregular disk shape at later times with a corresponding attenuation of radioactivity.

radioactivity. The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an (unstable) nuclide. As a result of this emission the radioactive nuclide is converted (decays) into the isotope of a different (daughter) element, which may (or may not) also be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (nonradioactive) end product is formed.

radiological survey. The directed effort to determine the distribution and dose rate of radiation in an area.

radionuclide. A radioactive nuclide (or radioactive atomic species).

radiosonde. A balloon-borne instrument for the simultaneous measurement and transmission of meteorological data, consisting of transducers for the measurement of pressure, temperature, and humidity; a modulator for the conversion of the output of the transducers to a quantity that controls a property of the radiofrequency signal; a selector switch, which determines the sequence in which the parameters are to be transmitted; and a transmitter, which generates the radiofrequency carrier.

radiosonde balloon. A balloon used to carry a radiosonde aloft. These balloons have daytime bursting altitudes of about 80,000 feet (25 km) above sea level. The balloon measures about 5 feet (1.5 meters) in diameter when first inflated and may expand to 20 feet (6 meters) or more before bursting at high altitude.

radium. A radioactive element with the atomic number 88 and an atomic weight of 226. In nature, radium is found associated with uranium, which decays to radium by a series of alpha and beta emissions. Radium is used as a radiation source for instrument calibration.

radops. Radiological safety operations.

radsafe. Radiological safety. General term used to cover the training, operations, and equipment used to protect personnel from potential overexposures to nuclear radiation during nuclear tests.

rainout. Removal of radioactive particles from a nuclear cloud by rain.

rawin. Radar wind sounding tests that determine the winds aloft patterns by radar observation of a balloon.

rawinsonde. Radar wind sounding and radiosonde (combined).

RBE. Relative biological effectiveness. A factor used to compare the biological effectiveness of absorbed radiation doses (i.e., rads) due to different types of ionizing radiation. For radiation protection the term has been superseded by Quality Factor.

rem. A special unit of biological radiation dose equivalent; the name is derived from the initial letters of the term "roentgen equivalent man (or mammal)." The number of rems of radiation is equal to the number of rads absorbed multiplied by the RBE of the given radiation (for a specified effect). The rem is also the unit of dose equivalent, which is equal to the product of the number of rads absorbed multiplied by the "quality factor" and distribution factor for the radiation. The unit is presently being replaced by the sievert (Sv).

rep. An obsolete special unit of absorbed dose.

residual nuclear radiation. Nuclear radiation, chiefly beta particles and gamma rays, that persists for a time following a nuclear explosion. The radiation is emitted mainly by the fission products and other bomb residues in the fallout, and to some extent by Earth and water constituents, and other materials, in which radioactivity has been induced by the capture of neutrons.

riometer. Relative Ionospheric Opacity Meter; an instrument that measures the absorption of cosmic noise in the ionosphere.

roentgen (R; r). A special unit of exposure to gamma (or X-) radiation. It is defined precisely as the quantity of gamma (or X-) rays that will produce electrons (in ion pairs) with a total charge of 2.58 x 10^{-4} coulomb in 1 kilogram of dry air under standard conditions. An exposure of 1 roentgen results in the deposition of about 94 ergs of energy in 1 gram of soft body tissue. Hence, an exposure of 1 roentgen is approximately equivalent to an absorbed dose of 1 rad in soft tissue.

RTTY. Radio teletype.

SC. Sandia Corporation, Albuquerque, New Mexico.

scattering. The diversion of radiation (thermal, electromagnetic and nuclear) from its original path as a result of interactions (or collisions) with atoms, molecules, or larger particles in the atmosphere or other media between the source of the radiations (e.g., a nuclear explosion) and a point some distance away. As a result of scattering, radiations (especially gamma rays and neutrons) will be received at such a point from many directions instead of only from the direction of the source.

scintillation. A flash of light produced by ionizing radiation in a fluor or a phosphor, which may be crystal, plastic, gas, or liquid.

shear (wind). Refers to differences in direction (directional shear) of wind at different altitudes.

shielding. Any material or obstruction that absorbs (or attenuates) radiation and thus tends to protect personnel or equipment from the effects of a nuclear explosion. A moderately thick layer of any opaque material will provide satisfactory shielding from thermal radiation, but a considerable thickness of material of high density may be needed for gamma radiation shielding. See also attenuation.

shock. Term used to describe a destructive force moving in air, water, or Earth caused by detonation of a nuclear detonation.

shock wave. A continuously propagated pressure pulse (or wave) in the surrounding medium, which may be air, water, or Earth, initiated by the expansion of the hot gases produced in an explosion.

sievert (Sv). A recently introduced ICRP measure of "dose equivalent" that takes into account the "quality factor" of different sources of ionizing radiation. One sievert equals 100 rem.

slant range. The straight-line distance of an aircraft at any altitude from ground zero or the distance from an airburst to a location on the ground.

SRI. Stanford Research Institute, Stanford, California.

stratosphere. Upper portion of the atmosphere, approximately 7 to 40 miles (11 to 64 km) above the Earth's surface, in which temperature changes but little with altitude and cloud formations are rare.

streamline. In meteorology, the direction of the wind at any given time.

surface burst. A nuclear explosion on the land surface, an island surface or reef, or on a barge.

survey meters. Portable radiation detection instruments especially adapted for surveying or inspecting an area to establish the existence and amount of radiation present, usually from the standpoint of radiological protection. Survey instruments are customarily powered by self-contained batteries and are designed to respond quickly and to indicate directly the exposure rate conditions at the point of interest. See AN/PDR-39, Geiger-Mueller counter, and ion-chamber-type survey meter.

survey, radiation. Evaluation of the radiation hazards associated with radioactive materials.

TDY. Temporary duty assignment.

thermal radiation. Electromagnetic radiation emitted in two pulses from a surface or airburst from the fireball as a consequence of its very high temperature; it consists essentially of ultraviolet, visible, and infrared radiation. In the first pulse, when the temperature of the fireball is extremely high, ultraviolet radiation predominates; in the second pulse, the temperatures are lower and most of the thermal radiation lies in the visible and infrared regions of the spectrum.

thermonuclear fusion. Refers to the processes in which very high temperatures are used to bring about the fusion of light nuclei, such as those of the hydrogen isotopes (deuterium and tritium), with the accompanying liberation of energy. The high temperatures required to initiate the fusion reaction are obtained by means of a fission explosion. See also fusion.

TNT equivalent. A measure of the energy released as the result of the detonation of a nuclear device or weapon, expressed in terms of the mass of TNT that would release the same amount of energy when exploded. The TNT equivalent is usually stated in kilotons (1,000 tons) or megatons (1 million tons). The basis of the TNT equivalence is that the explosion of 1 ton of TNT is assumed to release 1 billion calories of energy. See also megaton, yield.

trapped radiation. Electrically charged particles moving back and forth in spirals along the north-south orientation of the Earth's magnetic field between mirror points, called conjugate points. Negatively charged particles drift eastward as they bounce between northern and southern conjugate points and positively charged particles drift westward, thus forming shells or belts of radiation above the Earth. The source of the charged particles may be natural, from solar activity (often called Van Allen belts), or artifical, resulting from high-altitude nuclear detonations.

tropopause. The boundary dividing the stratosphere from the lower part of the atmosphere, the troposphere. The tropopause normally occurs at an altitude of about 25,000 to 45,000 feet (7.6 to 13.7 km) in polar and temperate zones, and at 55,000 feet (16.8 km) in the tropics. See also stratosphere, troposphere.

troposphere. The region of the atmosphere, immediately above the Earth's surface and up to the tropopause, in which the temperature falls fairly regularly with increasing altitude, clouds form, convection is active, and mixing is continuous and more or less complete.

type commander. The officer or agency having cognizance over all Navy ships of a given type. This is in addition to the particular ship's assignment in a task force, fleet, or other tactical subdivision.

UCLA. University of California, Los Angeles.

UCRL. University of California Radiation Laboratory, Livermore, California.

UHF. Ultra-high frequency.

ultraviolet. Electromagnetic radiation of wavelengths between the shortest visible violet (about 3,850 angstroms) and soft X-rays (about 100 angstroms).

USNS. United States Navy Ship; vessels of this designation are manned by civilian crews.

warhead. The portion of the missile or bomb containing the nuclear device.

weapon debris. The radioactive residue of a nuclear device after it has been detonated, consisting of fission products, various products of neutron capture, weapon casing and other components, and uranium or plutonium that has escaped fission.

whole-body irradiation. Exposure of the body to ionizing radiation from external radiation sources. Critical organs for the whole body are the lens of the eye, the gonads, and the red-blood-forming marrow. As little as only 1 cm^3 of bone marrow constitutes a whole-body exposure. Thus, the entire body need not be exposed to be classed as a whole-body exposure.

Wilson cloud. A mist or fog of minute water droplets that temporarily surrounds a fireball following a nuclear detonation in a humid atmosphere. This is caused by a sudden lowering of the pressure (and temperature) after the passing of the shock wave (cloud chamber effect) and quickly dissipates as temperatures and pressures return to normal.

worldwide fallout. Consists of the smaller radioactive nuclear detonation particles that ascend into the upper troposphere and the stratosphere and are carried by winds to all parts of the Earth. The delayed (or worldwide) fallout is brought to Earth, mainly by rain and snow, over extended periods ranging from months to years.

WT. Prefix of Weapon Test (WT) report identification numbers. These reports were prepared to record the results of scientific experiments.

yield. The total effective energy released in a nuclear detonation. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested as nuclear radiation (including residual radiation), thermal radiation, and blast and shock energy, the actual distribution depending upon the medium in which the explosion occurs and also upon the type of weapon. See TNT equivalent.

yield (blast). That portion of the total energy of a nuclear detonation that is identified as the blast or shock wave.

yield (fission). That portion of the total explosive yield attributable to nuclear fission, as opposed to fusion. The interest in fission yield stems from the interest in fission product formation and its relationship to radioactive fallout.

APPENDIX D

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Exec Ofc of The President
Management & Budget Off Lib
ATTN: Librn

Library of Congress
ATTN: Library Service Division
ATTN: Science & Technology Div
ATTN: Serial & Govt Publication

National Atomic Museum
ATTN: Historian

Department of Commerce
National Bureau of Standards
ATTN: Librn

Occupational Safety & Health Admin
ATTN: Library

Office of Health & Disability (ASPER)
ATTN: R. Copeland

Ofc of Workers Compensation Program
Department of Labor
ATTN: R. Larson

U.S. Coast Guard Academy Library
ATTN: Librn

U.S. House of Representatives
2 cy ATTN: Committee on Armed Svcs

U.S. House of Representatives
Committee on Interstate & Foreign Commerce
ATTN: Subcommittee on Health & Envir

U.S. Military Academy
ATTN: Director of Libraries

U.S. Senate
Committee on Armed Services
ATTN: Committee on Veterans Affairs

U.S. Senate
ATTN: Committee on Veterans Affairs

Veterans Administration-RO
Providence, RI
ATTN: Director

Veterans Administration-RO
Montgomery, AL
ATTN: Director

Veterans Administration-RO
Anchorage, AK
ATTN: Director

Veterans Administration-RO
Phoenix, AZ
ATTN: Director

Veterans Administration-RO
Little Rock, AR
ATTN: Director

Veterans Administration-RO
Los Angeles, CA
ATTN: Director

Veterans Administration-RO
San Francisco, CA
ATTN: Director

Veterans Administration-RO
Denver, CO
ATTN: Director

Veterans Administration-RO
Hartford, CT
ATTN: Director

Veterans Administration-RO
Wilmington, DE
ATTN: Director

Veterans Administration-OFC Central
Washington, D. C.
ATTN: Dept Veterans Benefit, Central Ofc
ATTN: Director
ATTN: Board of Veteran Appeal

Veterans Administration-RO
St. Petersburg, FL
ATTN: Director

Veterans Administration-RO
Atlanta, GA
ATTN: Director

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration-RO
Honolulu, HI
ATTN: Director

Veterans Administration-RO
Chicago, IL
ATTN: Director

Veterans Administration-RO
Seattle, WA
ATTN: Director

Veterans Administration-RO
Indianapolis, IN
ATTN: Director

Veterans Administration-RO
Des Moines, IA
ATTN: Director

Veterans Administration-RO
Wichita, KS
ATTN: Director

Veterans Administration-RO
Louisville, KY
ATTN: Director

Veterans Administration-RO
New Orleans, LA
ATTN: Director

Veterans Administration-RO
Togus, ME
ATTN: Director

Veterans Administration-RO
Baltimore, MD
ATTN: Director

Veterans Administration-RO
Boston, MA
ATTN: Director

Veterans Administration-RO
St. Paul, MN
ATTN: Director

Veterans Administration-RO
Jackson, MS
ATTN: Director

Veterans Administration-RO
Huntington, WV
ATTN: Director

Veterans Administration-RO
St. Louis, MO
ATTN: Director

Veterans Administration-RO
Ft. Harrison, MT
ATTN: Director

National Archives
ATTN: Librn

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration-RO
Lincoln, NE
ATTN: Director

Veterans Administration-RO
Reno, NV
ATTN: Director

Veterans Administration-RO
Manchester, NH
ATTN: Director

Veterans Administration-RO
Newark, NJ
ATTN: Director

Veterans Administration-RO
Milwaukee, WI
ATTN: Director

Veterans Administration-RO
Albuquerque, NM
ATTN: Director

Veterans Administration-RO
Buffalo, NY
ATTN: Director

Veterans Administration-RO
New York, NY
ATTN: Director

Veterans Administration-RO
Winston-Salem, NC
ATTN: Director

Veterans Administration-RO
Fargo, ND
ATTN: Director

Veterans Administration-RO
Cleveland, OH
ATTN: Director

Veterans Administration-RO
Muskogee, OK
ATTN: Director

Veterans Administration-RO
Portland, OR
ATTN: Director

Veterans Administration-RO
Pittsburgh, PA
ATTN: Director

Veterans Administration-RO
Philadelphia, PA
ATTN: Director

Veterans Administration-RO
San Francisco, CA
ATTN: Director

Veterans Administration-RO
San Juan, Puerto Rico
ATTN: Director

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration-RO
Columbia, SC
ATTN: Director

Veterans Administration-RO
Sioux Falls, SD
ATTN: Director

Veterans Administration-RO
Houston, TX
ATTN: Director

Veterans Administration-RO
Waco, TX
ATTN: Director

Veterans Administration-RO
Salt Lake City, UT
ATTN: Director

Veterans Administraiton-RO
White River Junction, VT
ATTN: Director

Veterans Administration-RO
Roanoke, VA
ATTN: Director

Veterans Administration-RO
Cheyenne, WY
ATTN: Director

Veterans Administration-RO
San Diego, CA
ATTN: Director

Veterans Administration-RO
Boise, ID
ATTN: Director

Veterans Administration-RO
Detroit, MI
ATTN: Director

Veterans Administration-RO
Nashville, TN
ATTN: Director

The White House
ATTN: Domestic Policy Staff

DEPARTMENT OF ENERGY CONTRACTORS

Lawrence Livermore National Lab
ATTN: Tech Info Dept Library

Los Alamos National Lab
ATTN: Library
2 cy ATTN: ADPA MMS 195

Sandia National Lab
ATTN: W. Hereford
ATTN: Central Library

Reynolds Electrical & Engr Co., Inc
ATTN: CIC
ATTN: W. Brady

OTHER

Adams State College
ATTN: Librn

Akron Public Library
ATTN: Librn

Alabama State Dept of Archives & History
ATTN: Military Records Div

University of Alabama
ATTN: Reference Dept/Docs

University of Alaska Library at Anchorage
ATTN: Librn

University of Alaska
ATTN: Dir of Libraries

Albany Public Library
ATTN: Librn

Alexander City State Jr College
ATTN: Librn

Allegheny College
ATTN: Librn

Allen County Public Library
ATTN: Librn

Altoona Area Public Library
ATTN: Librn

American Statistics Index
Congressional Info Service, Inc
ATTN: Cathy Jarvey

Anaheim Public Library
ATTN: Librn

College of Wooster
ATTN: Gov Docs

Angelo State University Library
ATTN: Librn

Angelo Iacoboni Public Library
ATTN: Librn

Anoka County Library
ATTN: Librn

Appalachian State University
ATTN: Library Docs

Arizona State University Library
ATTN: Librn

University of Arizona
ATTN: Gov Doc Dept/C. Bower

Arkansas College Library
ATTN: Library

Brooklyn College
ATTN: Doc Div

OTHER (Continued)

Arkansas Library Comm
ATTN: Library

Arkansas State University
ATTN: Library

University of Arkansas
ATTN: Gov Docs Div

Austin College
ATTN: Librn

Atlanta Public Library
ATTN: Ivan Allen Dept

Atlanta University
ATTN: Librn

Auburn University Library at Mongomery (Reg)
ATTN: Librn

C. W. Post Ctr Long Island University
ATTN: Librn

Bangor Public Library
ATTN: Librn

Bates College Library
ATTN: Librn

Baylor University Library
ATTN: Docs Dept

Beloit College Libraries
ATTN: Serials Docs Dept

Bemidji State College
ATTN: Library

State University College
ATTN: Gov Docs

Akron University
ATTN: Gov Docs

Boston Public Library (Reg)
ATTN: Docs Dept

Bowdoin College
ATTN: Librn

Bowling Green State University
ATTN: Lib Gov Docs Services

Bradley University
ATTN: Librn

Brandeis University Library
ATTN: Docs Section

Brigham Young University
ATTN: Librn

Brigham Young University
ATTN: Docs Collection

Brookhaven National Laboratory
ATTN: Tech Library

OTHER (Continued)

Broward County Library Sys
ATTN: Librn

Brown University
ATTN: Librn

Bucknell University
ATTN: Reference Dept

Buffalo & Erie Co Public Library
ATTN: Librn

State University Library of California at Fresno
ATTN: Library

University Library of California at Los Angeles
ATTN: Pub Affairs Serv U.S. Docs

University of California at San Diego
ATTN: Docs Dept

State College Library of California at Stanislaus
ATTN: Library

California State Polytechnic University Library
ATTN: Librn

California State University at Northridge
ATTN: Gov Doc

California State Library (Reg)
ATTN: Librn

California State University at Long Beach Library
ATTN: Librn

California State University
ATTN: Librn

California State University
ATTN: Librn

California University Library
ATTN: Gov Pub Dept

California University Library
ATTN: Librn

California University Library
ATTN: Gov Docs Dept

California University Library
ATTN: Docs Sec

University of California
ATTN: Gov Docs Dept

Calvin College Library
ATTN: Librn

Kearney State College
ATTN: Gov Docs Dept

Carleton College Library
ATTN: Librn

OTHER (Continued)

Carnegie Library of Pittsburgh
ATTN: Librn

Carnegie Mellon University
ATTN: Dir of Libraries

Carson Regional Library
ATTN: Gov Pubs Unit

Case Western Reserve University
ATTN: Librn

University of Richmond
ATTN: Library

University of Central Florida
ATTN: Library Docs Dept

Central Michigan University
ATTN: Library Docs Sec

Central Missouri State Univ
ATTN: Gov Docs

Central State University
ATTN: Lib Docs Dept

Central Washington University
ATTN: Lib Docs Sec

Central Wyoming College Library
ATTN: Librn

Charleston County Library
ATTN: Librn

Charlotte & Mechlenburg County Public Library
ATTN: E. Correll

Chattanooga Hamilton County, Bicentennial Library
ATTN: Librn

Chesapeake Public Library System
ATTN: Librn

Chicago Public Library
ATTN: Gov Pubs Dept

State University of Chicago
ATTN: Librn

Chicago University Library
ATTN: Dir of Libraries
ATTN: Docs Processing

Cincinnati University Library
ATTN: Librn

Claremont Colleges Libraries
ATTN: Doc Collection

Clemson University
ATTN: Dir of Libraries

OTHER (Continued)

Cleveland Public Library
ATTN: Docs Collection

Cleveland State University Library
ATTN: Librn

Coe Library
ATTN: Docs Div

Colgate University Library
ATTN: Ref Lib

Colorado State University Libraries
ATTN: Librn

University of Colorado Libraries
ATTN: Dir of Libraries

Columbia University Library
ATTN: Docs Svc Ctr

Columbus & Franklin Cty Public Library
ATTN: Gen Rec Div

Compton Library
ATTN: Librn

Connecticut State Library (Reg)
ATTN: Librn

University of Connecticut
ATTN: Gov't of Connecticut

University of Connecticut
ATTN: Dir of Libraries

Cornell University Library
ATTN: Librn

Corpus Christi State University Library
ATTN: Librn

Culver City Library
ATTN: Librn

Curry College Library
ATTN: Librn

Dallas County Public Library
ATTN: Librn

Dallas Public Library
ATTN: Librn

Dalton Junior College Library
ATTN: Librn

Dartmouth College
ATTN: Librn

Davenport Public Library
ATTN: Librn

Davidson College
ATTN: Librn

OTHER (Continued)

Dayton & Montgomery City Public Library
ATTN: Librn

University of Dayton
ATTN: Librn

Decatur Public Library
ATTN: Librn

Dekalb Community College So Cpus
ATTN: Librn

Delaware Pauw University
ATTN: Librn

University of Delaware
ATTN: Librn

Delta College Library
ATTN: Librn

Delta State University
ATTN: Librn

Denison University Library
ATTN: Librn

Denver Public Library (Reg)
ATTN: Docs Div

Dept of Library & Archives (Reg)
ATTN: Librn

Detroit Public Library
ATTN: Librn

Burlington Library
ATTN: Librn

Dickinson State College
ATTN: Librn

Alabama Agricultural Mechanical University & Coll
ATTN: Librn

Drake University
ATTN: Cowles Library

Drew University
ATTN: Librn

Duke University
ATTN: Pub Docs Dept

Duluth Public Library
ATTN: Docs Sec

East Carolina University
ATTN: Lib Docs Dept

East Central University
ATTN: Librn

East Islip Public Library
ATTN: Librn

OTHER (Continued)

East Orange Public Library
ATTN: U.S. Gov't Depository

East Tennessee State University Sherrod Library
ATTN: Docs Dept

East Texas State University
ATTN: Library

Monmouth County Library Eastern Branch
ATTN: Librn

Eastern Illinois University
ATTN: Librn

Eastern Kentucky University
ATTN: Librn

Eastern Michigan University Library
ATTN: Library

Eastern Montana College Library
ATTN: Docs Dept

Eastern New Mexico University
ATTN: Librn

Eastern Oregon College Library
ATTN: Librn

Eastern Washington University
ATTN: Librn

El Paso Public Library
ATTN: Docs & Geneology Dept

Elko County Library
ATTN: Librn

Elmira College
ATTN: Librn

Elon College Library
ATTN: Librn

Enoch Pratt Free Library
ATTN: Docs Ofc

Emory University
ATTN: Librn

Evansville & Vanderburgh Cty Public Library
ATTN: Librn

Everett Public Library
ATTN: Librn

Fairleigh Dickinson University
ATTN: Depository Dept

Florida A & M University
ATTN: Librn

Florida Atlantic University Library
ATTN: Div of Pub Docs

OTHER (Continued)

Florida Institute of Technology
ATTN: Library

Florida International University Library
ATTN: Docs Sec

Florida State Library
ATTN: Docs Sec

Florida State University
ATTN: Librn

University of Florida
ATTN: Docs Dept

Fond Du Lac Public Library
ATTN: Librn

Ft Hays State University
Ft Hays Kansas State College
ATTN: Librn

Ft Worth Public Library
ATTN: Librn

Free Public Library of Elizabeth
ATTN: Librn

Free Public Library
ATTN: Librn

Freeport Public Library
ATTN: Librn

Fresno Cty Free Library
ATTN: Librn

Gadsden Public Library
ATTN: Librn

Garden Public Library
ATTN: Librn

Gardner Webb College
ATTN: Docs Library

Gary Public Library
ATTN: Librn

Georgetown University Library
ATTN: Gov Docs Room

Georgia Institute of Technology
ATTN: Librn

Georgia Southern College
ATTN: Librn

Georgia Southwestern College
ATTN: Dir of Libraries

Georgia State University Library
ATTN: Librn

OTHER (Continued)

University of Georgia
ATTN: Dir of Libraries (Reg)

Glassboro State College
ATTN: Librn

Gleeson Library
ATTN: Librn

Graceland College
ATTN: Librn

Grand Forks Public City-County Library
ATTN: Librn

Grand Rapids Public Library
ATTN: Dir of Lib

Greenville County Library
ATTN: Librn

Guam RFK Memorial University Library
ATTN: Fed Depository Coll

University of Guam
ATTN: Librn

Gustavus Adolphus College
ATTN: Librn

South Dakota University
ATTN: Librn

Hardin-Simmons University Library
ATTN: Librn

Hartford Public Library
ATTN: Librn

Harvard College Library
ATTN: Dir of Lib

Harvard College Library
ATTN: Serials Rec Div

University of Hawaii Library
ATTN: Gov Docs Coll

Hawaii State Library
ATTN: Fed Docs Unit

University of Hawaii at Monoa
ATTN: Dir of Libraries (Reg)

University of Hawaii
Hilo Campus Library
ATTN: Librn

Haydon Burns Library
ATTN: Librn

Hennepin County Library
ATTN: Gov Docs

Henry Ford Community College Library
ATTN: Librn

OTHER (Continued)

Herbert H. Lehman College
ATTN: Lib Docs Div

Hofstra University Library
ATTN: Docs Dept

Hollins College
ATTN: Librn

Hopkinsville Community College
ATTN: Librn

Wagner College
ATTN: Librn

University of Houston Library
ATTN: Docs Div

Houston Public Library
ATTN: Librn

Tulane University
ATTN: Docs Dept

Hoyt Public Library
ATTN: Librn

Humboldt State College Library
ATTN: Docs Dept

Huntington Park Library
ATTN: Librn

Hutchinson Public Library
ATTN: Librn

Idaho Public Library & Information Center
ATTN: Librn

Idaho State Library
ATTN: Librn

Idaho State University Library
ATTN: Docs Dept

University of Idaho
ATTN: Dir of Libraries (Reg)
ATTN: Docs Sec

University of Illinois Library
ATTN: Docs Sec

Illinois State Library (Reg)
ATTN: Gov Docs Br

Illinois University at Urbana-Champaign
ATTN: P. Watson Docs Lib

Illinois Valley Community College
ATTN: Library

Illinois State University
ATTN: Librn

Indiana State Library (Reg)
ATTN: Serial Sec

Indiana State University
ATTN: Docs Library

OTHER (Continued)

Indiana University Library
ATTN: Docs Dept

Indianapolis Marion County Public Library
ATTN: Social Science Div

Iowa State University Library
ATTN: Gov Docs Dept

Iowa University Library
ATTN: Gov Docs Dept

Butler University
ATTN: Librn

Isaac Delchdo College
ATTN: Librn

James Madison University
ATTN: Librn

Jefferson County Public Library
Lakewood Regional Library
ATTN: Librn

Jersey City State College
ATTN: F. A. Irwin Library Periodicals Doc Sec

Johns Hopkins University
ATTN: Docs Library

La Roche College
ATTN: Librn

Johnson Free Public Library
ATTN: Librn

Kalamazoo Public Library
ATTN: Librn

Kansas City Public Library
ATTN: Docs Div

Kansas State Library
ATTN: Librn

Kansas State University Library
ATTN: Docs Dept

University of Kansas
ATTN: Dir of Library (Reg)

University of Texas
ATTN: Lyndon B. Johnson School of Public Affairs Library

Maine Maritime Academy
ATTN: Librn

University of Maine
ATTN: Librn

OTHER (Continued)

Kent State University Library
ATTN: Docs Div

Kentucky Dept of Library & Archives
ATTN: Docs Sec

University of Kentucky
ATTN: Gov Pub Dept
ATTN: Dir of Lib (Reg)

Kenyon College Library
ATTN: Librn

Lake Forest College
ATTN: Librn

Lake Sumter Community College Library
ATTN: Librn

Lakeland Public Library
ATTN: Librn

Lancaster Regional Library
ATTN: Librn

Lawrence University
ATTN: Docs Dept

Brigham Young University
ATTN: Docs & Map Sec

Library and Statutory Dist & Svc
2 cy ATTN: Librn

Earlham College
ATTN: Librn

Little Rock Public Library
ATTN: Librn

Long Beach Public Library
ATTN: Librn

Los Angeles Public Library
ATTN: Serials Div U.S. Docs

Louisiana State University
ATTN: Gov Doc Dept
ATTN: Dir of Libraries (Reg)

Louisville Free Public Library
ATTN: Librn

Louisville University Library
ATTN: Librn

Hoover Institution
ATTN: J. Bingham

OTHER (Continued)

Manchester City Library
ATTN: Librn

Mankato State College
ATTN: Gov Pubs

University of Maine at Farmington
ATTN: Dir of Libraries

Marathon County Public Library
ATTN: Librn

Principia College
ATTN: Librn

University of Maryland
ATTN: McKeldin Library Docs Div

University of Maryland
ATTN: Librn

University of Massachusetts
ATTN: Gov Docs Coll

Maui Public Library
Kahului Branch
ATTN: Librn

McNeese State University
ATTN: Librn

Memphis & Shelby County Public Library & Information Center
ATTN: Librn

Memphis State University
ATTN: Librn

Mercer University
ATTN: Librn

Mesa County Public Library
ATTN: Librn

Miami Dade Community College
ATTN: Librn

University of Miami Library
ATTN: Gov Pubs

Miami Public Library
ATTN: Docs Div

Miami University Library
ATTN: Docs Dept

University of Santa Clara
ATTN: Docs Div

Michigan State Library
ATTN: Librn

Michigan State University Library
ATTN: Librn

Murray State University Library
ATTN; Lib

OTHER (Continued)

Michigan Tech University
ATTN: Lib Docs Dept

University of Michigan
ATTN: Acq Sec Docs Unit

Middlebury College Library
ATTN: Librn

Millersville State College
ATTN: Librn

State University of New York
ATTN: Docs Librn

Milwaukee Public Library
ATTN: Librn

Minneapolis Public Library
ATTN: Librn

University of Minnesota
ATTN: Dir of Libraries (Reg)

Minot State College
ATTN: Librn

Mississippi State University
ATTN: Librn

University of Mississippi
ATTN: Dir of Libraries

Missouri University at Kansas City General
ATTN: Librn

University of Missouri Library
ATTN: Gov Docs

M.I.T. Libraries
ATTN: Librn

Mobile Public Library
ATTN: Gov Info Div

Midwestern University
ATTN: Librn

Montana State Library
ATTN: Librn

Montana State University Library
ATTN: Librn

University of Montana
ATTN: Dir of Libraries (Reg)

Montebello Library
ATTN: Librn

Moorhead State College
ATTN: Library

Mt Prospect Public Library
ATTN: Gov't Info Ctr

OTHER (Continued)

Nassau Library System
ATTN: Librn

Natrona County Public Library
ATTN: Librn

Nebraska Library Community
Nebraska Public Clearinghouse
ATTN: Librn

University of Nebraska at Omaha
ATTN: Univ Lib Docs

Nebraska Western College Library
ATTN: Librn

University of Nebraska
ATTN: Dir of Libraries (Reg)

University of Nebraska Library
ATTN: Acquisitions Dept

University of Nevada Library
ATTN: Gov Pubs Dept

University of Nevada at Las Vegas
ATTN: Dir of Libraries

New Hampshire University Library
ATTN: Librn

New Hanover County Public Library
ATTN: Librn

New Mexico State Library
ATTN: Librn

New Mexico State University
ATTN: Lib Docs Div

University of New Mexico
ATTN: Dir of Libraries (Reg)

University of New Orleans Library
ATTN: Gov Docs Div

New Orleans Public Library
ATTN: Librn

New York Public Library
ATTN: Librn

New York State Library
ATTN: Docs Control Cultural Ed Ctr

State University of New York at Stony Brook
ATTN: Main Lib Docs Sec

State University of New York Col Memorial Lib at Cortland
ATTN: Librn

State University of New York
ATTN: Lib Docs Sec

North Texas State University Library
ATTN: Librn

OTHER (Continued)

State University of New York
ATTN: Librn

New York State University
ATTN: Docs Ctr

State University of New York
ATTN: Docs Dept

New York University Library
ATTN: Docs Dept

Newark Free Library
ATTN: Librn

Newark Public Library
ATTN: Librn

Niagara Falls Public Library
ATTN: Librn

Nicholls State University Library
ATTN: Docs Div

Nieves M. Flores Memorial Library
ATTN: Librn

Norfolk Public Library
ATTN: R. Parker

North Carolina Agricultural & Tech State University
ATTN: Librn

University of North Carolina at Charlotte
ATTN: Atkins Lib Doc Dept

University Library of North Carolina at Greensboro
ATTN: Librn

University of North Carolina at Wilmington
ATTN: Librn

North Carolina Central University
ATTN: Librn

North Carolina State University
ATTN: Librn

University of North Carolina
ATTN: BA SS Div Docs

North Dakota State University Library
ATTN: Docs Librn

University of North Dakota
ATTN: Librn

North Georgia College
ATTN: Librn

Minnesota Div of Emergency Svcs
ATTN: Librn

Northeast Missouri State University
ATTN: Librn

Northeastern Oklahoma State University
ATTN: Librn

Northeastern University
ATTN: Dodge Library

Northern Arizona University Library
ATTN: Gov Docs Dept

Northern Illinois University
ATTN: Librn

Northern Michigan University
ATTN: Docs

Northern Montana College Library
ATTN: Librn

Northwestern Michigan College
ATTN: Librn

Northwestern State University
ATTN: Librn

Northwestern State University Library
ATTN: Librn

Northwestern University Library
ATTN: Gov Pubs Dept

Norwalk Public Library
ATTN: Librn

Northeastern Illinois University
ATTN: Library

University of Notre Dame
ATTN: Doc Ctr

Oakland Community College
ATTN: Librn

Oakland Public Library
ATTN: Librn

Oberlin College Library
ATTN: Librn

Ocean County College
ATTN: Librn

Ohio State Library
ATTN: Librn

Ohio State University
ATTN: Lib Docs Div

Ohio University Library
ATTN: Docs Dept

Oklahoma City University Library
ATTN: Librn

Oklahoma City University Library
ATTN: Librn

OTHER (Continued)

Oklahoma Department of Libraries
ATTN: U.S. Gov Docs

University of Oklahoma
ATTN: Docs Div

Old Dominion University
ATTN: Doc Dept Univ Lib

Olivet College Library
ATTN: Librn

Omaha Public Library Clark Branch
ATTN: Librn

Onondaga County Public Library
ATTN: Gov Docs Sec

Oregon State Library
ATTN: Librn

University of Oregon
ATTN: Docs Sec

Ouachita Baptist University
ATTN: Librn

Pan American University Library
ATTN: Librn

Passaic Public Library
ATTN: Librn

Queens College
ATTN: Docs Dept

Pennsylvania State Library
ATTN: Gov Pubs Sec

Pennsylvania State University
ATTN: Lib Doc Sec

University of Pennsylvania
ATTN: Dir of Libraries

University of Denver
ATTN: Penrose Library

Peoria Public Library
ATTN: Business, Science & Tech Dept

Free Library of Philadelphia
ATTN: Gov Pubs Dept

Philipsburg Free Public Library
ATTN: Library

Phoenix Public Library
ATTN: Librn

University of Pittsburgh
ATTN: Docs Office, G8

Plainfield Public Library
ATTN: Librn

OTHER (Continued)

Popular Creek Public Library District
ATTN: Librn

Association of Portland Library
ATTN: Librn

Portland Public Library
ATTN: Librn

Portland State University Library
ATTN: Librn

Pratt Institute Library
ATTN: Librn

Louisiana Tech University
ATTN: Librn

Princeton University Library
ATTN: Docs Div

Providence College
ATTN: Librn

Providence Public Library
ATTN: Librn

Public Library Cincinnati & Hamilton County
ATTN: Librn

Public Library of Nashville and Davidson County
ATTN: Librn

University of Puerto Rico
ATTN: Doc & Maps Room

Purdue University Library
ATTN: Librn

Quinebaug Valley Community College
ATTN: Librn

Auburn University
ATTN: Microforms & Docs Dept

Rapid City Public Library
ATTN: Librn

Reading Public Library
ATTN: Librn

Reed College Library
ATTN: Librn

Augusta College
ATTN: Librn

University of Rhode Island Library
ATTN: Gov Pubs Ofc

University of Rhode Island
ATTN: Dir of Libraries

Rice University
ATTN: Dir of Libraries

Louisiana College
ATTN: Librn

OTHER (Continued)

Richland County Public Library
ATTN: Librn

Riverside Public Library
ATTN: Librn

University of Rochester Library
ATTN: Docs Sec

University of Rutgers Camden Library
ATTN: Librn

State University of Rutgers
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