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STATEMENT OF
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BEFORE THE
SENATE COMMITTEE
ON
VETERANS' AFFAIRS

Mr. Chairman and Members of the Committee:

We appreciate the opportunity to be here today to discuss our recently issued report entitled Operation Crossroads: Personnel Radiation Exposure Estimates Should Be Improved.[1] At the request of the Committee's Ranking Minority Member, we evaluated selected aspects of radiation safety at a nuclear weapons test conducted in the Pacific Ocean during the summer of 1946--a test referred to as Operation Crossroads. This operation represented the first and largest--in terms of participants--of any of the post-World War II atmospheric nuclear tests conducted by the United States. It involved two nuclear detonations and approximately 240 naval ships, 80 of which were used as targets for the detonations. After the detonations, according to the Defense Nuclear Agency (DNA), approximately 17,100 of the 42,000 person task force were in frequent contact with contaminated naval vessels as they performed such tasks as reboarding the target ships to evaluate the damage and to determine the radiation intensity on the target ships.

[1]Operation Crossroads: Personnel Radiation Exposure Estimates Should Be Improved, GAO/RCED-86-15, dated November 8, 1985.

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The Ranking Minority Member asked GAO to specifically evaluate the following three aspects of Operation Crossroads:

--reliability of the personnel film badges used to measure radiation;

--adequacy of the personnel decontamination procedures; and

--accuracy of radiation dose reconstruction in cases where film badges were not worn or were incapable of measuring the type of radiation present.

In summary, our review showed that the calculation of exposure estimates for each of four radiation types to which personnel were exposed at Operation Crossroads--internal alpha, internal and external beta, and external gamma radiation (each of which is discussed in detail in an attachment to this statement)--needs improvement. The primary reasons we believe such improvement is necessary is because certain factors have not been appropriately considered in the DNA's exposure estimates. For example, the principal device worn to measure radiation at Operation Crossroads--the film badge--was not reliable for measuring both external gamma and beta radiation, as intended, and was not worn by all Crossroads participants. In addition, personnel decontamination procedures did not offer adequate protection for Crossroads personnel throughout the operation. Furthermore, DNA's dose reconstruction analysis for internal alpha

and beta radiation has not properly estimated the possible personnel exposure from three potential pathways--inhalation, ingestion, and open wounds.

We have recommended that the Secretary of Defense direct DNA to adjust where feasible, the Crossroads participants exposure estimates by appropriately recognizing such matters as (1) the inaccuracies associated with the film badges in measuring external gamma and beta radiation exposure, (2) the likelihood that personnel received additional radiation exposure from a lack or violation of comprehensive personnel decontamination procedures, and (3) the internal alpha and beta radiation dose possible from all three potential exposure pathways. In addition, where any of the preceding actions have been determined not to be feasible, we recommended that the Secretary of Defense require DNA to document the reasons for each such determination so that the military services can provide this information to the Veterans Administration (VA) and the affected veterans.

In commenting on our report, VA provided a favorable response and indicated that the report's recommendations should also be applied to all other atmospheric nuclear tests. Conversely, DOD provided us extensive comments substantially disagreeing with the report. In evaluating those comments, we found no new relevant information that had not been previously considered in preparing the report and thus, made no changes to our findings, conclusions, and recommendations. We continue to believe that DOD can and should improve radiation exposure estimates for Crossroads personnel by effectively addressing and implementing our recommendations.

I would like now to elaborate on each of the topics I have briefly touched on--beginning with an overview of Operation Crossroads.

OPERATION CROSSROADS

Following the end of World War II, questions remained among American military experts regarding the best ways to use the nuclear bomb, if necessary, in another war. These experts reasoned that only by testing the nuclear bomb under simulated war conditions could these questions be answered. With this in mind, the United States initiated nuclear weapons testing in the Pacific Ocean during 1946. Operation Crossroads was the first such test. It consisted of two nuclear detonations in the Bikini Atoll--an island chain in the northern part of the Marshall Islands. One test was made above the water's surface on July 1, 1946, and the other underwater on July 25, 1946.

This operation involved more participants--almost 42,000 Army and Navy personnel and civilian scientists--than any other atmospheric nuclear weapons test conducted by the United States. It lasted from July 1 to August 10, 1946, when efforts by participating personnel to board and decontaminate the approximately 80 unmanned naval ships used as targets for the two bomb tests were officially terminated because plutonium contamination was discovered on the target ships. If deposited in the body, a microscopic amount of plutonium could prove lethal.

DNA--under direction from the Department of Defense--issued a report on Operation Crossroads in 1984 and has also developed radiation exposure estimates on personnel who participated in that

operation. These estimates are a combination of exposure readings from film badges worn by about 15 percent of the Crossroads participants and a computer model exposure reconstruction for those times no film badge was worn and for internal radiation that film badges were incapable of measuring. Because the VA has used these estimates in adjudicating former Crossroads participants' radiation-related disability claims, the Ranking Minority Member of this Committee asked us to specifically evaluate selected aspects of radiation safety at Operation Crossroads.

PRINCIPAL FINDINGS

Film Badge Accuracy

A film badge consists of a small piece of film usually encased in a metal or plastic container that can be pinned to clothing. The film, which is similar to photographic film, is wrapped in paper or other material to prevent light from exposing it. In addition, the container may be sealed or placed in a plastic bag to protect it from water.

The film in the badge reacts to radiation in much the same manner as ordinary photographic film reacts to light. As the radiation is absorbed by the film, it produces a chemical change that causes the film to blacken. The extent of the blackening of the developed film is a measure of the total amount of radiation to which it has been exposed. To determine the recorded radiation dosage, an instrument called a densitometer is used to compare the blackening with that of film of the same type that has been exposed to known amounts of radiation.

According to technical literature on film badges, there are inaccuracies associated with their use. These inaccuracies typically exist because of a variance in quality that occurs during film manufacturing and errors that can and do occur during film processing--unless processing conditions are carefully controlled.

We found, however, that DNA's radiation exposure estimates for Crossroads personnel have made no allowance for film badge inaccuracy. This was not done even though DNA has acknowledged that if the people involved in reading film badges at Operation Crossroads had conducted the film badge processing activities perfectly and without error, then the recorded film badge readings would have had an overall inaccuracy of approximately ± 30 percent. If, on the other hand, the film badge processing activities had not been conducted correctly and errors occurred there, we found that the overall inaccuracy of the recorded Crossroads film badge readings could be greater, and possibly much greater, than the inaccuracy of just the film.

Because data on Crossroads film badges is generally not available, we could not determine whether errors actually occurred during Crossroads film badge processing. We believe, however, that a sense of the range of inaccuracies that could have occurred could be obtained by analyzing the accuracy of film badge processing under controlled laboratory conditions.

In this regard, we found that a considerable amount of information has been developed on the ability of laboratories across the United States to properly process and read film

badges. For instance, the U.S. National Bureau of Standards tested several laboratories in the mid-1950's and found that, under controlled laboratory conditions, their processing and reading of film badges were often inaccurate by as much as ± 100 percent. It is unlikely, in our view, that the film badge readings made under harsh field conditions at Operation Crossroads would have been any more accurate than those in laboratories.

Further, Crossroads film badges were also intended to measure external beta radiation. According to DNA, the film badges overestimated the exposure dose for this radiation type because the portion of the film intended for measuring this dose was actually affected by external gamma radiation as well. We found cases, however, in which external beta radiation exposure may have been underestimated or not estimated at all. For instance, we observed that during the month of August 1946, only 21 out of 6,664 film badges worn were recorded as having been exposed to external beta radiation. In assessing this situation, we reviewed one film badge ledger containing entries for about 1,300 film badges. We found that the people reading and processing these Crossroads film badges identified exposure on most of the 1,300 badges and recorded that exposure in the ledger, but did not make an additional entry in the ledger as to the external beta radiation dose associated with that exposure. Consequently, absent a dose estimate in the ledger, such Operation Crossroads personnel who had worn these badges with exposures on them were incorrectly assigned a zero external beta radiation dose.

Personnel Decontamination Procedures

Personnel working in radioactive areas sometimes pick up radioactive particles on their bodies and their clothes.

Recognizing this, personnel decontamination procedures are usually instituted that will minimize both the spread of this radioactivity and the potential personnel exposure to it. Such procedures normally include (1) reporting to a central change station to obtain and put on proper clothing before entering a radioactive area, (2) carrying radiation monitoring equipment into the radioactive area to provide a record of exposure and a means of detecting and avoiding high radiation areas; and (3) upon leaving the radioactive area, returning to the central change station to shower and put on clean clothing.

Because DNA believes adequate personnel decontamination procedures existed from the beginning at Operation Crossroads, its radiation exposure estimates do not recognize the possibility that personnel may have retained radioactivity on their bodies and clothes after working on contaminated target ships. However, we believe this possibility exists because decontamination procedures at Crossroads evolved from very simplistic radiation protection measures to more comprehensive ones. For example, the earliest evidence that we found of personnel being required to shower or change clothes after returning from contaminated target ships was in procedures issued on July 31, 1946, 6 days after the second detonation. Further, even after comprehensive personnel decontamination procedures were instituted--about 3 weeks after detonation--some violations were reported, such as crews continuing to wear contaminated clothing. Thus Crossroads participants were probably exposed to more radiation than accounted for by DNA.

Internal Radiation Dose Reconstruction

Regarding the third area we were asked to review, we found that internal radiation exposure was not measured at Operation Crossroads because, according to DNA, film badges were incapable of detecting this and radiation instruments intended for this measurement failed due to the influence of humidity and mishandling. Thus, DNA has reconstructed an internal alpha and beta radiation exposure dose for Crossroads personnel in a draft report entitled Internal Dose Assessment--Operation Crossroads. In that report, DNA assumed that Crossroads participants could receive internal radiation exposure only by inhaling, or breathing in, radioactive materials. This analysis estimated alpha radiation, as from plutonium contamination, by using certain information contained in a September 20, 1946, Crossroads memorandum that suggested that a constant ratio existed between this radiation type and beta and gamma radiation. However, subsequent information contained in a November 21, 1946, Crossroads memorandum, and our conversations with the author of this memorandum and a radiochemist at the Department of Energy's Hanford Operations Office, indicate that the alpha-beta-gamma ratio at Operation Crossroads was not constant and that use of a constant ratio may underestimate alpha radiation by a factor of 5 or even 10.

Further, we found evidence that internal radiation exposure could also have occurred through ingestion-as from eating contaminated food or drinking contaminated water-or from cuts or open wounds caused by contaminated objects. When we brought this

to the attention of DNA, that agency's assistant nuclear test personnel review manager told us that internal radiation exposure through ingestion was a possibility because personnel--during the course of their decontamination work--were permitted, for a period of time, to eat their meals on board contaminated target ships. This same DNA official added that internal radiation exposure from cuts or open wounds was a possibility but said that this was not discussed in the internal dose assessment report because it is unknown how to calculate for it.

RECOMMENDATIONS

To correct the problems identifed in our review, we recommended that the Secretary of Defense direct DNA to adjust, where feasible, the Crossroads participants' exposure estimates in the following manner:

--Develop a range for each film badge reading that recognizes film and film processing inaccuracies; reassess the accuracy of the external beta radiation dose information for those who wore film badges and, because not all Crossroads participants wore film badges, perform a dose reconstruction for external beta radiation;

--Estimate the extent to which personnel received radiation exposure from a lack or violation of comprehensive decontamination procedures;

--Reevaluate and disclose the possible errors or uncertainties associated with its analysis of internal radiation exposure by inhalation and analyze possible internal radiation exposure through ingestion or open wounds.

In addition, as stated earlier, where any of the preceding actions has been determined not to be feasible, we recommended that the Secretary of Defense require DNA to document the reasons for each such determination so that the military services can provide this information to the VA and the affected veterans.

AGENCY COMMENTS

VA stated that it does appear that service personnel were exposed to more radiation during Operation Crossroads and the subsequent cleanup than they would have been after safety precautions were better developed and used as in subsequent nuclear tests. VA also indicated that our recommended actions for calculating radiation doses for Crossroads participants should be applied to participants in all atmospheric nuclear tests. These new calculations, VA stated, would almost certainly result in reports of higher levels of radiation exposure and could require a reevaluation of previously-denied claims. In this regard, VA stated that it is imperative that any new calculated dose assessment be reported to the VA if dose information had previously been reported in connection with a claim for veteran's benefits.

VA also stated it could not be certain whether changes in radiation dose estimates resulting from our recommendations would require reversal of VA decisions regarding service-connected disabilities allegedly resulting from radiation exposure. For example, even a two- or three-fold increase in an initially small radiation dose estimate would likely be of little significance in the VA's adjudication of a claim dependent upon that estimate.

Increases of such a magnitude could have greater importance where a substantial radiation dose was initially estimated.

DOD generally disagreed with the report's findings, conclusions, and recommendations. Further, according to DOD, even if it implemented all of our recomendations, exposure estimates would increase only 10 percent over its total average calculated dose for Crossroads personnel.

However, in analyzing DOD's comments, we found that DOD (1) provided incorrect or unsupported statements, (2) misinterpreted certain Crossroads-related documents, or (3) presented information inconsistent with DNA's historical report on Operation Crossroads and other material. We believe providing a couple of examples of these conditions would be helpful to the Committee in appreciating why we did not change our report based on DOD's extensive comments.

For example, regarding its statement that implementing all of our recommendations would increase exposure estimates only 10 percent over its total average calculated dose for Crossroads personnel, DOD provided us information that seemingly contradicts this statement. Specifically, in support of its comments, DOD provided us a calculation that showed wearing contaminated clothing for a day could have resulted in a radiation exposure dose which is 18 percent of its total average calculated dose. In as much as instructions requiring Crossroads personnel to change clothing were not instituted until 6 days after the second nuclear test, and personnel began boarding contaminated target ships immediately after both nuclear tests, wearing contaminated

clothing on several different days could have occurred. Consequently, this one element could have resulted in a larger overall dose increase than suggested by DOD.

In addition, DOD said that teams initially boarding target ships, including radiation monitors, wore protective clothing in the performance of their work. However, a picture which appeared on page 106 of DNA's historical report does not support this contention. The picture shows a radiation monitor on the target ship USS Hughes which on that day--3 days after the second Crossroads nuclear test--was being prepared for towing. The picture shows the radiation monitor standing beside a welder, wearing a T-shirt, no protective rubber gloves, no protective rubber boots, no protective breathing device and smoking a cigarette--which would have increased his risk for internal radiation exposure.

In summary, for the above reasons, we did not change our report based on the comments received and we continue to believe that DOD can improve personnel radiation exposure estimates for Crossroads personnel by effectively addressing and implementing our recommendations.

In addition, let me point out that, during the course of our review and in analyzing DOD's commments, we had technical and medical experts assist us in formulating the positions taken in this report.

Let me additionally point out that we did not look into the feasibility of doing an epidemiological study of former Crossroads personnel. Congress assigned the task of evaluating the feasibility of undertaking an epidemiological study of atmospheric nuclear weapons testing participants to the VA.

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That concludes my prepared statement. We will be pleased to respond to any questions at this time.

RADIATION TYPES EXISTING AT OPERATION CROSSROADS

Alpha Radiation

Alpha radiation is difficult to detect and its effect is lasting for years. It has a range of only 1 or 2 inches in the air and is incapable of penetrating clothing or even the outer layer of unbroken skin. However, alpha-emitting particles are a primary hazard when absorbed internally.

Once inside, alpha particles are distributed by the body in a manner similar to that of calcium. They are carried to the bones, liver, kidneys, and other parts of the body and deposited. These alpha deposits bombard the tissue surrounding them, causing irritation that is not given an opportunity to heal and thus may lead to malignancy.

Beta Radiation

Beta radiation may travel several feet in the air before being absorbed. In more dense material, such as body tissue, some beta radiation may travel up to half an inch. Clothing normally provides adequate protection from beta radiation. Therefore, beta radiation is a hazard only when beta-emitting particles are either in direct contact with the skin or absorbed internally.

A large quantity of these particles concentrated on the skin will cause irritations much like burns. In addition, beta particles of high energy can be hazardous to the skin and those body organs and glands close to the outer skin layer such as the eyes and gonads. Beta-emitting substances taken into the body have two consequences-irritation of the walls in the intestial tract and the destruction of white blood cells, which decreases resistance to infection.

Gamma Radiation

In general, gamma rays have ranges of hundreds of feet in the air, and they can readily penetrate living and nonliving matter. Because they are highly penetrating, gamma rays pose a significant external exposure hazard. Dense materials, such as lead and steel, are often used as shields against gamma radiation.

Inside the body the ionizing properties of gamma radiation destroy the body cells and upset the normal functions of the body. A high dose of gamma radiation may cause loss of hair. Higher doses may cause nausea and aplastic anemia. As the dosage becomes greater, the bone marrow, spleen, and lymph nodes are affected. The mechanisms that manufacture red and white blood cells are also destroyed. Red and white blood cells not destroyed by gamma radiation are depleted through the

ATTACHMENT

Gamma Radiation cont.	normal functioning of the body. If these cells cannot be replaced, the natural medium of conveying nourishment and oxygen to the body cells (red corpuscles) and of combating infection (white corpuscles) is lost, producing anemia and reducing the body's defense against disease.

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