THE UNDER SECRETARY OF DEFENSE

WASHINGTON, DC 20301

ACQUISITION



3 AUG 1987

Mr. Frank C. Conahan
Assistant Comptroller General
National Security and
International Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Conahan:

This letter and enclosures are the Department of Defense (DoD) response to the General Accounting Office (GAO) Draft Report, "NUCLEAR HEALTH AND SAFETY: Radiation Exposure Estimates For Cloud Sampling Personnel Are Understated," dated May 11, 1987 (GAO Code 301726/OSD Case 7299).

The DoD concurs with most of the GAO findings and one of the GAO recommendations. The DoD has, as a matter of fact, been correcting errors in the film badge exposure records since 1979. The Department plans to continue this effort and appreciates the GAO pointing out areas that need particular focus.

With respect to the second GAO recommendation, it continues to be the Department's position that the film badges worn by each cloud sampler are a better representation of the dose to the individual than the integron. The DoD view is supported by the five scientists involved in the project at the time and who were contacted by the GAO for this study. Also, the current President of the National Council for Radiation Protection and Measurements (NCRP) reviewed the GAO report (at the GAO request), and he independently arrived at the same conclusion. All six statements are provided (see enclosures 2 through 7). Also attached to enclosure 7 is the statement by the former head of the International Commission on Radiation Units (ICRU). Another statement by a distinguished radiologist and film badge expert is provided at enclosure 8. Since the DoD does not agree with this GAO recommendation, the GAO may want to consider submitting the analysis that forms the basis of the second recommendation for independent review, such as to the Office of Technology Assessment.



HRE-0638

There are uncertainties in measuring any radiation exposure, but these uncertainties do not affect the conclusion that the dose received by most cloud sampling personnel was low. Moreover, the GAO draft report suggests that the dose was overstated as well as understated. It is, therefore, the DoD position (along with the President of the NCRP) that it is misleading to conclude the doses are understated.

One of the original GAO objectives was to ascertain if the cloud sampling personnel were experiencing adverse health effects as a result of their radiation exposure. For various reasons, the GAO could not undertake this analysis. The DoD regards this issue as important, and intends to ask the National Academy of Sciences to conduct a mortality study of the men in the cloud sampling, tracking and penetration units.

The detailed DoD comments on the findings and recommendations are provided in enclosure 1. Thank you for the opportunity to comment on the draft report.

Sincerely,

Robert R. Barker

for

Richard P. Godwin

Enclosures
As stated

GAO DRAFT REPORT - DATED MAY 11, 1987
(GAO CODE 301726) OSD CASE 7299

"NUCLEAR HEALTH AND SAFETY: RADIATION EXPOSURE ESTIMATES FOR CLOUD SAMPLING PERSONNEL ARE UNDERSTATED"

DEPARTMENT OF DEFENSE COMMENTS

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FINDINGS

- FINDING A: Manned Nuclear Cloud Sampling. The GAO reported Department of Defense (DoD) estimates that between 1945 and 1962, nearly 200,000 Americans participated in the atmospheric nuclear weapons testing program, with more than half receiving some radiation exposure. The GAO observed that a principal activity at these tests was to confirm efficiency and nuclear yield by cloud sampling. The GAO noted that, whereas in the 1940s this was done by drone aircraft, in 1951 manned aircraft were assigned to this task. During the period 1951 through 1962, approximately 4,000 personnel (DoD estimate) were involved in manning or decontaminating the aircraft. The GAO explained that during sampling flights a monitoring device (either a dosimeter or an integron) warned when crew exposure was reaching certain limits. The GAO further explained that after the flight, ground crews removed radioactive samples and decontaminated the aircraft. The GAO referenced a November 1985 report, Experimental Irradiation of Air Force Personnel During OPERATION REDWING, by the Environmental Policy Institute, which indicated radiation exposure to personnel manning these aircraft may have been understated. Because of this, the Senate Committee on Veterans' Affairs and the House Committee on Energy and Commerce, Subcommittee on Energy Conservation and Power, asked the GAO to determine how many personnel were involved in nuclear cloud sampling work at three operations--TUMBLER-SNAPPER (1952), REDWING (1956), and DOMINIC I (1961)--and how much radiation was received. (p. 2, pp. 8-15/GAO Draft Report)

  DoD Position: Partially Concur. The DoD estimate of 4,000 men was for all the men in the units that had responsibility for cloud penetration, sampling and tracking from 1951-1962. Of this 4,000 total, only a limited number were involved in flying and decontaminating aircraft, while a large number were involved in maintenance, administration, meteorology and the other aircraft squadrons support functions.

ENCLOSURE 1

- FINDING B: OPERATIONS TUMBLER-SNAPPER, REDWING, And DOMINIC I. The GAO reported that Operation TUMBLER-SNAPPER consisted of eight low-to-intermediate-yield detonations conducted at the Nevada Proving Ground in the Spring of 1952, and cloud sampling was carried out by 270 Air Force personnel, about 80 of whom flew through nuclear clouds. The GAO found that the Atomic Energy Commission and the DoD established a limit of 3.0 rem of radiation exposure per 13 weeks, except for aircrews who were authorized to receive up to 3.9 rem. The GAO noted that, according to the DoD, the aircrews received an average of 1.13 rem and the entire test group averaged .55 rem. The GAO further reported that OPERATION REDWING took place in the Spring and Summer of 1956, at the Pacific Proving Ground and, of 205 Air Force personnel in the cloud sampling group, about 35 flew through nuclear clouds. The GAO found that in this case, 3.9 rem was established as the 13-week limit, except for aircrews who were authorized to receive up to 20 rem. (The GAO observed that in 1956, the annual exposure limit recommended by the National Council on Radiation Protection and Measurement was 15 rem.) The GAO further reported that, according to the DoD, the aircrews received an average radiation exposure of 6.85 rem and the entire test group averaged 4.05 rem. In addition, the GAO reported that OPERATION DOMINIC I was conducted from April to November 1962, near Christmas and Johnston Islands, and cloud sampling involved 330 Air Force personnel, about 85 of whom flew through nuclear clouds. For this operation, the GAO found the limits were set at 3.0 rem for 13 weeks, and 12 rem annually, except for aircrews who were allowed 20 rem for the operation. The GAO reported that, again according to the DoD, these aircrews received an average of 5.68 rem and the entire group averaged .68 rem. (pp. 16-19/GAO Draft Report)

  DoD Position: Concur.

- FINDING C: Responsibilities Of The Defense Nuclear Agency. The GAO reported that in December 1977, in response to various test participants' claims to the Veterans Administration (VA) for radiation-related disability compensation, the DoD assigned responsibility for a program of wide-ranging actions to the Defense Nuclear Agency (DNA). The GAO found that, in turn, the DNA established a nuclear test personnel review program, which has included:

  - compiling a roster of the American military personnel and civilians involved in the atmospheric nuclear test;

- developing a historical report of each atmospheric nuclear test that involved American military personnel and civilians;

- providing estimates of atmospheric test radiation doses (both as a comparison with film badge readings and as a substitute for them in cases where badges were not worn or readings were not recorded); and

- providing assistance to veterans, the VA and others by researching and providing as complete data as possible on individual participation and radiation doses.

The GAO observed that with its October 1984 report on OPERATION CROSSROADS, the DNA completed its publication of a historical report on each of the 20 atmospheric nuclear weapons test operations. According to the GAO, each report (including those on OPERATIONS TUMBLER-SNAPPER, REDWING, and DOMINIC I) provides an overview of the operation, an identification of the principal organizations and branches of the Military Service involved, a description of the radiological safety procedures in place, and a summary of personnel exposures to external radiation. The GAO observed that these reports usually discuss specific personnel exposure to external radiation in terms of exposure to gamma radiation, in rems as measured by film badges (or where these were not worn or were lost--by dose reconstruction). The GAO noted that, in addition, the DNA is currently in the process of estimating possible personnel exposure to internal alpha and beta radiation. The GAO explained that both are hazards if the material is absorbed internally, and materials emitting beta radiation are a hazard if in contact with the skin. The GAO found that the current schedule calls for the DNA to publish its report on internal exposure by the Summer of 1987. (pp. 19-20/GAO Draft Report)

**DoD Position:** Partially Concur. It was not until 1980 that the DoD began an investigation of internal dose from alpha, beta and gamma. In the summer of 1987, the DNA will release its report on internal dose to DoD personnel who witnessed atmospheric nuclear tests in the continental United States. The internal dose report for tests in the Marshall Islands and the other oceanic tests will be released at a later date.

- **FINDING D: Reported Underestimates Of Exposure.** The GAO observed that, according to the report of the Environmental Policy Institute, the OPERATION REDWING early cloud penetration report admitted that film badges of aircrew members registered readings lower than actual exposure (in some cases by a factor of two and a half). The GAO examined the preliminary draft and final DNA reports, Early Cloud Penetration Report--OPERATION REDWING. The GAO observed the preliminary draft report discussed a radiation monitoring device called a P-meter installed on the nose of the aircraft that indicated radiation doses two and a half times higher than did film badges worn by aircrews. The GAO found the final report showed tests of the P-meter by the Air Force and the National Bureau of Standards indicated that the P-meter, at the extremely cold temperatures encountered in the nose of the aircraft, read two and a half times too high. The GAO reported it had contacted a radiation expert at the National Bureau of Standards, who confirmed this phenomena. (pp. 22-24/GAO Draft Report)

  **DoD Position:** Concur. These findings are consistent with what the DoD reported to the Congress in November 1985.

- **FINDING E: Gamma Radiation--Problems With Film Badges.** The GAO found that film badges were the official record of gamma radiation exposure for those who participated in the atmospheric nuclear weapons testing program. The GAO observed, however, that certain inaccuracy problems--beyond the inherent inaccuracies associated with all film badges--were known or are known to have existed with the film badges used at OPERATIONs TUMBLER-SNAPPER AND REDWING. For instance, the GAO reported that, at those two operations, it is acknowledged problems existed in the badge ability to effectively measure gamma radiation over particular radiation ranges. The GAO noted that, according to a film badge expert used by the DNA in preparing a 1985 report on film badges used during the atmospheric nuclear tests, the TUMBLER-SNAPPER film badge--in the range between 10 and 15 rem--had an inaccuracy of plus 60 to minus 30 percent; and the REDWING film badge--in the range between 10 and 15 rem--had an inaccuracy of plus 40 to minus 20 percent. Because of such inaccuracies, the GAO concluded that uncertainties exist in the amount of gamma radiation measured. (pp. 29-33, pp. 57-58/GAO Draft Report)

**DoD Position:** Partially Concur. The Department agrees that the inaccuracy of the film badges is greater in the area of overlap (10 - 15 rem) between the two badges in the film packet. It should be noted, however, that although the information provided by the GAO was correctly applied to the example given for OPERATION TUMBLER-SNAPPER, it was incorrectly applied for the example given for OPERATION REDWING. This incorrect interpretation of the statement was also used to calculate and report incorrect film badge inaccuracy ranges on page 33 of the report. These errors should be corrected.

In addition, even though the badges used in the operations cited did have some additional error in this range, it should be clarified that no VA claim has been filed in which a single film badge fell in the overlap range. This is true for all operations that used this type of film badge packet. If a VA claim should be forwarded that involves a single film badge reading in the overlap range, the DoD will certainly bring this error variation to the attention of the VA. It should also be noted that individuals with recorded exposures in this range are already part of the over-5-rem medical follow-up program and were informed of the potential hazards that might be associated with their exposure.

- **FINDING F: Film Badge Exposure Records Contained Errors.** The GAO reported that, beyond the need to accurately measure radiation exposure, there is the equal need to maintain an accurate, cumulative record of each film badge worn. The GAO, however, found errors in about 26 percent and 13 percent of the records used to tabulate the readings from all film badges worn by personnel at OPERATIONS REDWING and DOMINIC I, respectively. For example, at OPERATION REDWING, an estimated 2 to 3.5 rem of radiation fell on islands housing cloud sampling personnel, but this radiation was not added to about 8 percent of the individual cumulative exposure totals. In other instances, a film badge was lost or not turned in, and no radiation dose was credited to the particular individual's exposure record. Also, the GAO found arithmetical mistakes in about 6 percent of the REDWING individual exposure records--most being understatements of less than 1 rem, but one understatement was over 8 rem. The GAO concluded that the net effect of these and other errors identified during its review generally was an understatement of gamma radiation exposure

dose, and that these errors should be corrected. The GAO further concluded that, given the frequency of the identified errors, a review should be made to identify similar errors in each Air Force film badge exposure record for each individual who participated in the atmospheric nuclear weapons testing program. (p. 4, pp. 33-42, p. 58/GAO Draft Report)

DoD Position: Partially Concur. Since 1979, the DoD has been aware that some source documents have arithmetic errors, and that reconstructions are necessary for periods when badges were lost or not issued. For VA claims, it is the DoD policy to conduct individual analyses of the records before responding to the VA, and will continue to conduct these rigorous analyses. The DoD has also corrected errors in the records for selected operations and will continue this effort until those source documents have been checked.

The DoD nonconcurs, however, with the GAO presumption that if REDWING film badges were not turned in at four week intervals, then the badges were lost. There are, in fact, records of issue and turn-in dates for the badges that show badges were not lost, but were worn more than four weeks (at REDWING, this would result in an overestimated dose). Moreover, at REDWING, there was an organized system to account for all badges, and any lost badges should have been noted on the source documents.

- FINDING G: Monitoring Devices Read Higher Levels Of Radiation Than Anticipated Compared To The Film Badges Worn By The Aircrew. The GAO reported that for personnel who flew aircraft through nuclear clouds, exposure to gamma radiation was not only monitored by film badges worn on or inside their clothing, but also by other devices positioned within the aircraft cockpit itself. The GAO noted that one device, the integron, was used at each of the three operations included in its review and was capable of providing both an immediate measure of gamma radiation and a check against the radiation readings on the film badges worn by the crew. The GAO found that at TUMBLER-SNAPPER, the integron and the film badges worn provided comparable readings. The GAO reported that, because of this and other experiences with the use of the integron, prior to OPERATION REDWING in 1956, a ratio of 1.25 between the readings measured by the integron and the film badges worn under a lead vest was known to exist. The GAO review of both REDWING and DOMINIC I, however, showed that in a large

percentage of the missions flown, the integron readings exceeded the 1.25 ratio. The GAO noted that several different explanations were offered as to why the integron may have read measurably higher, including integron malfunction or improper calibration with a radiation source. The GAO concluded, however, that none of these explanations seemed to adequately account for these higher readings. The GAO also concluded that, if indeed accurate, the integron readings suggest that the film badges had read low and that cloud sampling personnel received a larger amount of gamma radiation exposure than has been officially recorded and, therefore, a reexamination of integron readings should be made. (pp. 43-49, p. 59/GAO Draft Report)

DoD Position: Nonconcur. The ratio of 1.25 plus or minus 25 percent between the integron and the film badge measurements may be valid for the earlier tests, but is not applicable to REDWING or DOMINIC I. In OPERATION REDWING, both the B-57 and the F-84 aircraft were used. The ratio of the integron to film badge measurements for the B-57 at REDWING was 1.23 plus or minus 13 percent. The ratio for the F-84 aircraft at REDWING was 1.61 plus or minus 30 percent. The higher ratio for the F-84 aircraft does not indicate that the film badge measurements were inaccurate, but does indicate that the relative shielding afforded the integron by the B-57 aircraft at REDWING was higher, thus bringing down the ratio between the integron and the film badges worn by the crew.

In OPERATION DOMINIC, where only B-57 aircraft were used, the ratio between the integron and the personnel film badge measurements was 1.39 plus or minus 30 percent. The reason for the increase over the previously established ratio of 1.25 was a change in the relative radiation environments, not errors in film badge measurements.

At DOMINIC, a film badge was also placed on the ion chamber of the integron where it would be exposed to the same radiation environment as the integron. These film badges exposed to the same radiation environment as the integron gave slightly higher readings on the average than the integron. The correlation between the film badge on the integron and the integron was close: 0.97 plus or minus 30 percent. This data demonstrate that the difference in readings between the integron and the film badges worn by personnel was due to differences in the radiation environment they were exposed to and not errors in either the integron or the film badges, and confirms that the film badge provided an accurate indication of radiation exposure.

Because the DoD conclusion that the radiation environment varied with location in the aircraft is in conflict with the GAO statement that "radiation in the cockpit was fairly uniform and positioning should not alter the integron and the crew's film badge readings by more than a few percent," the DoD contacted the five scientists interviewed by the GAO and asked them to review the DoD analysis of the data. All five scientists concurred in the DoD analysis of the data. Their statements are provided as enclosures 2 through 6.

- FINDING H: Gamma Radiation--Film Badges Worn Under A Lead Vest. The GAO reported that in 1952, the military began using protective barriers to reduce the crew radiation exposure, and that lead-lined vests were introduced with later operations. The GAO noted that a 1978 report by the National Council on Radiation Protection and Measurements stated that if a lead-lined apron is worn and only one film badge is used, the film badge should be worn underneath the apron to estimate the radiation exposure to the person's whole body. The GAO observed that the report also noted greater face and neck exposure and, therefore, that recorded doses should be increased to express thyroid and/or eye lens doses. The GAO found that, according to the DNA assistant nuclear test personnel review program manager, the DNA has not done this. The GAO observed that the lead vest covered only a small portion of the cloud sampling person's body. The GAO concluded, therefore, that the gamma radiation exposure, which affected the unshielded portion of the person's body, including the thyroid, eye lens, and area possibly below the abdomen, could lie somewhere between the readings recorded on the integron and the film badges shielded by the lead vest. The GAO further concluded that, as part of the DNA reexamination of integron readings, an analysis should also be made of each person's total gamma radiation exposure based on film badges worn underneath a lead vest. (pp. 14-15, pp. 46-47, pp. 59-60/GAO Draft Report)

DoD Position: Partially Concur. The DoD agrees that lead vests were used during OPERATIONS TUMBLER-SNAPPER and REDWING, but not OPERATION DOMINIC I.

The DoD provides the VA with a whole body dose, not an organ dose. According to the assistant scientific director for cloud sampling at REDWING, the lead vest covered the front

of the body from the shoulders down to and including the bladder and gonads. According to a 1957 study of cloud samplers, the vest reduced the level of radiation by 6 percent. Based on a 1962 study of cloud samplers at DOMINIC I, the pilot's seat offered at least as much shielding from radiation as a lead vest would have provided.

Thus, a pilot at REDWING was shielded by both the vest and seat. With the exception of the eye, this shielding effectively covered what the National Council on Radiation Protection and Measurements (NCRP) calls the "whole body." The NCRP defines whole body exposure as that to the blood forming organs, gonads, and the lens of the eye.

Since the vest and seat shielded the gonads and more than 80 percent of the blood forming organs, the only uncovered area was the eye lens (which the VA does not regard as a site for radiogenic illness). Consequently, the film badge worn under the lead vest reflects the whole body dose as defined by the NCRP. If the VA submits a request for dose information on a case involving thyroid cancer or some eye lens disability, and the man wore a lead vest with a film badge under it (which has not occurred to date), the DoD will inform the VA that the dose to the eye or thyroid could be 6 percent higher.

- **FINDING I: Internal Radiation.** The GAO observed that, in addition to gamma radiation, cloud sampling personnel were subject to alpha and beta radiation, resulting in possible internal radiation exposure. The GAO found, however, that OPERATION DOMINIC I air and ground crew personnel were fully protected from such exposure. For instance, where airborne radioactive particles were possibly present, ground crews wore respirators. The GAO also found that at OPERATIONS TUMBLER-SNAPPER and REDWING, it appeared that necessary precautions to preclude internal radiation exposure were generally followed by aircrews. The GAO concluded, however, that respiratory protection devices were not consistently worn by ground crews at these two operations. The GAO further concluded that the lack of consistency in wearing such devices during the various test operations should be recognized by the DNA in its internal radiation exposure evaluation. The GAO also concluded that this evaluation should include estimating the internal radiation exposure received by REDWING cloud sampling personnel exposed to

fallout from one of the test shots and possibly breathing in radioactive materials, or swimming in Bikini lagoon and possibly swallowing radioactive materials. (The GAO noted that the DNA is generally aware of the possibilities for internal radiation exposure and currently in the process of estimating such exposure for cloud sampling personnel participating at all atmospheric nuclear weapons tests.) (pp. 50-52, pp. 55, p. 60/GAO Draft Report)

**DoD Position:** Partially concur. The DNA dose reconstruction methodology has been, and continues to be, fully consistent with this GAO finding. Respiratory protective devices, although available, were not consistently worn by ground crews at certain nuclear testing operations. The devices were on hand and the decision to wear them was up to the radiation safety officer who supervised the work. The DNA modifies internal dose estimates by protection factors attributed to respiratory protective devices when there is evidence concerning the thorough testing and use of the devices and the magnitude of the protection offered. Otherwise, internal doses are high-sided by the presumption that no respiratory protection was used. In so doing, the DNA overstates the dose to personnel who wore respiratory protective devices, but never underestimates the dose to those who did not.

The GAO discusses a person who was swimming in Bikini Lagoon, even though he lived at Enewetak Atoll. It is noted that Bikini Lagoon is not adjacent to Enewetak Atoll, but some 190 miles away. Notwithstanding, the individual would have received a lower dose while swimming than if he had been on land where his film badge would have been.

- **FINDING J: Testing For Internal Radiation.** The GAO reported that internal exposures, which can occur through three pathways--inhalation, ingestion, or cuts or open wounds--cannot be measured by an integron or a film badge. The GAO found that no personnel at OPERATION TUMBLER-SNAPPER and only a few personnel at OPERATION REDWING were monitored for internal radiation exposure, and the limited monitoring that was done may not have been reliable. The GAO noted, for example, that to test REDWING personnel for plutonium, only one 24-hour urine sample was taken after possible exposure. The GAO reported that, according to four health

physicists it (the GAO) contacted, it is now recognized that repeated urine samples should be collected over several days to accurately estimate plutonium exposure. The GAO concluded that, as part of its internal radiation exposure assessment, the DNA should recognize the protective breathing devices were not consistently worn for cloud sampling ground personnel at OPERATIONs TUMBLER-SNAPPER and REDWING. The GAO noted that Public Law 98-542, The Veterans Dioxin and Radiation Exposure Compensation Standards Act, requested the Secretary of Health and Human Services to prepare a report on the reliability and accuracy of urinary or other bioessay testing techniques in determining previous radiation exposure. The GAO concluded that, to the extent the Secretary of Health and Human Services reports back to the Congress that such techniques can reliably and accurately determine previous radiation exposure, then possible testing of TUMBLER-SNAPPER and REDWING ground crew personnel may be more prudent than estimating the internal radiation exposure doses they received. (pp. 6-7, p. 50, pp. 53-55, p. 60/GAO Draft Report.)

- DoD Position: Partially Concur. The monitoring conducted at REDWING was reliable for determining if any significant exposure occurred. While additional tests might have refined low dose estimates--it would not have changed a low dose to a high dose. Therefore, there is no reason to disagree with the REDWING Early Cloud Penetration report (WT 1320), which states as follows:

  "1. No internal radiation hazards (sic) arises from flights through thermonuclear clouds, regardless of the oxygen control setting. Urine samples showed no significant amounts of gamma-emitting fission product, beta-emitting fission products, or unfissioned plutonium.

  "2. Flight through thermonuclear clouds may lead to some external fission-product contamination, but the amount is not significant from the standpoint of radiation hazard.

  "3. Individuals who participate in nuclear test operations, but who do not fly through thermonuclear clouds, do not exhibit internal activity which is significantly different from the ordinary population."

  The DoD concurs that the HHS investigation of possible bioassay techniques for determining previous radiation exposure is worthwhile and would welcome the application of any reliable technique to TUMBLER-SNAPPER and REDWING cloud sampling and decontamination personnel.

## RECOMMENDATIONS

- RECOMMENDATION 1: The GAO recommended that the Secretary of Defense direct the DNA to correct the GAO-identified errors in the film badge exposure records of cloud sampling personnel participating in OPERATIONs REDWING and DOMINIC I and, given the frequency of such errors identified, review for similar errors each Air Force individual film badge exposure record. (p. 61/GAO Draft Report)

  DoD Position: Concur, but this recommendation is essentially moot. Since 1979, the DoD has been carrying out error correction. To date, source document errors have been corrected for about two thirds of the test series. The DoD will continue to work on the remaining records and anticipates that this project will be completed in another four years.

  In addition, it is (and has been) DoD policy to check the source documents before responding to VA requests for doses. To make sure this policy has been followed, the DoD recently conducted an internal review of VA cases. Moreover, the DNA will assume the responsiblities of the Services to ensure consistency and sustain the effort required for this task. (The Navy and Marine Corps responsibilities have already been assumed by the DNA; the Army and Air Force responsibilities will be assumed in October 1987.)

- RECOMMENDATION 2: The GAO recommended that the Secretary of Defense direct the DNA to reexamine, for all atmospheric nuclear weapons tests including OPERATIONS REDWING and DOMINIC I, the radiation readings measured by the integron in comparison to film badges worn and adjust, as necessary, the radiation doses assigned to cloud sampling aircrew personnel. (p. 61/GAO Draft Report)

  DoD Position: Nonconcur. The data cited by the GAO not only fail to indicate that there were possible errors in the film badge measurements as opposed to those of the integron, but the GAO data actually confirm the accuracy of film badge measurements (see DoD response to Finding G).

MEMORANDUM FOR THE RECORD

SUBJECT: DoD Response to FINDING G in GAO Draft Report "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated"

I have reviewed the DoD response to FINDING G of the GAO Draft Report, "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated" and agree with the attached DoD response.

Ken Street

Dr. Ken Street

June 5, 1987

ENCLOSURE 2

Los Alamos
Los Alamos National Laboratory
Los Alamos New Mexico 87545

June 8, 1987

MEMORANDUM FOR THE RECORD

SUBJECT: DoD Response to FINDING G in GAO Draft Report "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated"

I have reviewed the DoD response to FINDING G of the GAO Draft Report, "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated" and agree with the attached DoD responses.

Paul R. Guthals

ENCLOSURE 3

5 June 1987

MEMORANDUM FOR THE RECORD

SUBJECT: DoD Response to FINDING G in GAO Draft Report "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated"

I have reviewed the DoD response to FINDING G of the GAO Draft Report, "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated" and agree with the attached DoD response.

Harry G. Hicks

Dr. Harry Hicks

ENCLOSURE 4

June 9, 1987

MEMORANDUM FOR THE RECORD

SUBJECT: DoD Response to FINDING G in GAO Draft Report "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated"

I have reviewed the DoD response to FINDING G of the GAO Draft Report, "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated" and agree with the attached DoD response.

I would add further that a comparison should be made of the readings of the film badges on the integrons with the readings of the film badges worn by the crew members. Since the readings of the film badges on the interons correlated well with the integron readings themselves, lower readings of the film badges worn by the crew compared to those of the film badges on the integrons (apples compared to apples) would clearly indicate that the former were a more accurate indicator of dose to the crew members than were the integrons.

Edward H. Fleming

Dr. Edward H. Fleming

ENCLOSURE 5

MEMORANDUM FOR THE RECORD

SUBJECT: DoD Response to FINDING G in GAO Draft Report "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated"

I have reviewed the DoD response to FINDING G of the GAO Draft Report, "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated" and agree with the attached DoD response.

Harold Plank

Dr. Harold Plank

6-24-87

National Council on Radiation Protection and Measurements

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WARREN K SINCLAIR PhD President
S JAMES ADELSTEIN M D Vice President
W ROGER NEY J D Executive Director

June 5, 1987

J. Dexter Peach
Assistant Comptroller General
U.S. General Accounting Office
Wasington, D.C. 20548

Dear Mr. Peach:

Thank you for the opportunity to review the draft report of the GAO on "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated".

I have made a number of comments and suggestions that I hope will be helpful. However, I think the main point is that there is very probably a rational explanation for the integron readings to be higher than film badges on the body and that the latter readings are not invalidated as a result. In my view therefore, even the words "are understated", in the title, are inappropriate. I trust the GAO will find it possible to revise its approach in the light of this important point.

Dr. Harold Wyckoff, Scientific Councellor to the ICRU and former Chairman of the ICRU, has also made some comments at my request, mainly dealing with the lack of rigor in some of the terminology used. I enclose his comments. While it is not noted in his comments, in discussion with me, Dr. Wyckoff has stated that he agrees with my explanation for the difference in integron/film badge readings.

Dr. Ted Webster, physicist at Massachusetts General Hospital, a member of the NCRP and an expert on film badge dosimetry, has also made comments, which are being sent to you separately. Again, in discussion he agrees with my explanation for the difference in integron/film badge readings and I think his comments will reflect that.

I hope these reviews will be helpful to the GAO in its work. If there are any questions or I can be of further assistance, please contact me.

Yours sincerely,

Warren K. Sinclair
President

ENCLOSURE 7

Comments on GAO Draft Report:
Nuclear Health and Safety:
Radiation Exposure Estimates for Cloud
Sampling Personnel are Understated

Warren K. Sinclair
May 1987

I think the title is misleading. I would delete "are understated". I think this is not proven. "May be understated" could be true but its implications are unnecessary. I recommend deleting "are understated".

Executive Summary

Page 3, Results in Brief, Line 8. "is understated" is too strong. This is not proven later. It may be understated at most and probably isn't.

Page 4, Paragraph 1, Lines 9-10. "... could not effectively measure radiation between 4 to 9 rem." I don't understand why this would be and I hope it gets explained later (unless the film pack included one film with a maximum of four rem and another with a minimum of nine rem). However, in any event at Tumbler-Snapper among 1,803 badged personnel, 48 had doses between 3 and 5 and 10 only above 5. Thus, the impact is not large.

Page 4, Paragraph 2. Not mentioned here is that in the Dominic operation, about 5% had arithmetical errors, of which understatements and overstatements were about equal (page 42). This fairer statement could have been quoted as well.

Page 5, Paragraph 1, Line 4. I don't know who this individual would be. According to the list supplied to me the maximum individual exposure was 16.4 rem.

Page 5, Paragraph 2. There is a possible explanation for the differences and the variability in integron vs film badge readings. Granted that film badges have many inaccuracies they have usually been agreed to be the record of choice and they probably still are the best measure of what the wearer actually received (see later).

Pages 6-7. Of course, it would be desirable to establish what can be said (even at this late date) about internal exposure.

Page 7, Recommendations. The first one on correcting identified arithmetic and other errors is, of course, sound and sensible. On the face of it, there seems to be more of these than one would expect but fortunately the individual errors seem mainly to be small.

Second. Assuming there is more information available somewhere to reexamine, a reexamination of the film badge/integron readings may well be worth doing, with the aim of throwing more light on the probable physical explanation for the difference in integron vs film badge readings. However, the second portion of this recommendation "adjust, as necessary, the radiation doses assigned to cloud sampling aircrew personnel." seems to have the implication of revising the film badge readings upward according to the integron readings. If my explanation is correct there is no need to do this (see below, re pages 43-49). The film badge has its limitations as is well known. These are noted specifically in the NAS* report which includes a positive bias of up to 40% for up to 100 mr and of the order of ±30 to ±40% for random errors in higher exposures, but these limitations may be no worse in these circumstances than in many other occupational circumstances.

*Review of the Methods Used to Assign Radiation Doses to Service Personnel at Nuclear Weapons Tests. NAS 1985.

Page 37, Paragraph 2. "... the 10 mission badges did not record all radiation received." Not necessarily, the 10 mission badges may have recorded all the missions he actually undertook. I doubt this can be established one way or the other, now.

Pages 39 and 40. Since the permanent badge record extended to 22 and 23 of July, except for the matter of swimming, it could have included the fallout dose. Thus, it is difficult to assert that the mission total is strictly too low, since it is substantially higher than the permanent record, probably including fallout.

Page 42. Certainly the absence of a record on an issued film badge is of concern. How to allow for that now? If the highest previous exposure were added to the record it would rise from 2.4 to 3.3 rem. Neither dose is large.

Pages 43-49. The differences between the integron and the film badge worn on the body is probably quite real and has a physical explanation. Any instrument (integron ion chamber or film badge) placed in a radiation field which may be isotropic or approximately so (i.e., radiation coming in equally from all directions) will read a certain dose (kerma) value depending on how it was calibrated. Presumably, the integron, apart from a few pieces of surrounding matter, mainly cockpit and etc., is essentially or at least approximately, "free in air" and receives radiation from a $4\pi$ solid angle. However, the film badge on the body has the solid angle of radiation reduced from $4\pi$ by the presence of the body, especially from the back. This will reduce the apparent reading by an amount probably less than a factor of two but very likely of the order of 1.2 to 1.6 or so. Evidence for this explanation is available from three sources:

1) it is noted, page 48-49, that two film badges <u>situated in the cockpit like the integron but not on the pilot, read slightly higher than the integron</u>! This strongly supports this explanation.
2) In the Redwing series DNA gives information on ratios of integron to film badge and finds it different for two different aircraft. It is about 1.25 for B-57 and about 1.6 for the F84. Presumably, the configuration of the integron vis-a-vis the pilot in the two cockpits is different. One would <u>guess</u> that the integron on the F84 had less material around it and was perhaps further from the pilot.
3) Variations in the integron/film badge ratio are considerable and this would be expected if the radiation field itself were not constant. Even the size of the pilot could make a difference, so also would the configuration of the radiation field, (whether fully isotropic or not, whether the airplane was at the edge of the cloud or in the center, etc.) and the energy of the radiation field.

In view of the above, I see no reason not to assume that the film badge on the wearer's body is not as good (or as poor) a record of his exposure as for other occupational circumstances when film badges are used. In my opinion, the GAO should revise its text to take account of this very likely explanation. Thus, statements like, page 48, paragraph 1, line 6 "... should have been about the same." are incorrect, they should have been different.

Another point that should be made is that the composition of the radiation field at different points in the cloud (and at different flight times after the burst) might be quite variable. It might include not only gammas, betas, alphas, some fission products and possibly neutrons and the energies may cover a broad range. The response of both the film badge and the integron may be primarily to gammas, but possibly other particles could influence one or the other reading and perhaps differently. Much more would need to be known about the circumstances, which have probably varied in individual cases. Again this probably accounts for some of the variation seen, but does not indicate, without further information, any preference for the integron over the film badge.

Another relevant matter is just exactly how the integron and for that matter, the film badge, was calibrated. It seems unlikely that an isotopic field would be used for this purpose. Then the angular response of the integron and of the film badge both become highly relevant. It would have been very helpful if the integron itself and the method of calibration had been much more fully described.

Indeed this problem of the aircrew doses touches on an interesting general question on what doses should be specified in occupational circumstances? Choices might be, 1) the free field kerma into which a person may be put (the integron reading may approximate this), 2) the dose at the surface of the body in the field, the film badge presumably approximates this, 3) a dose to a specified organ(s) in the body such as bone marrow [this will usually be substantially less than (1) or (2)], or 4) an average dose throughout the body which may be less or more than (3) or about the same depending on the organ considered in (3). It will be less than (1) or (2).

In current occupational practice, the dose at the surface of the body as measured by the film badge on the body, is the dose that is measured and recorded. Pending a different approach to the specification of occupational doses by authoritative bodies, such as ICRU, ICRP and NCRP, it would seem that the film badge reading in this case of these aircrews is as likely to be correct as in other occupational circumstances.

Page 45, Footnote. This clearly shows that the lead vests were essentially irrelevant and at most 15% reduction. Thus the dose to the bladder, to the eye and the thyroid could only be 15% higher at most and perhaps not at all if allowance is made for the depth of the critical tissue in the body (even the lens is 1 cm or so deep).

In Summary

I have made a number of suggestions for improvement in this draft report (starting with the title) which I hope will be found helpful.

On the recommendations, first, I think the GAO report correctly recommends that arithmetic and like errors be corrected.

Second, a reexamination of the integron vs film badge readings could be very useful, assuming there is more material to examine, in order to throw more light on the probable fact that there is a real physical explanation for the integron (in "free air") to read higher than the film badge on the body.

However, given this fact, the integron readings do not invalidate the film badge readings on the body, which presumably therefore, are as true a record of the exposures of the aircrews as film badges are for other occupational circumstances.

Subject: Comments on "Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel are Understated"

Comments are keyed to the page, paragraph and sentence or line in that paragraph.

8, 3 and 9, 1. Before attempting to compare numerical values obtained for different measurements, it is necessary first to see whether or not the two measurements are of the same quantity. In an attempt to understand what quantities might be considered in this document for measurement, the Section labeled "Glossary" was next consulted. Difficulty arose when attempting to understand the meaning of "calibrating" in the present context.

When one determines the calibration of a given instrument for a specified physical quantity, one determines the instrument response in terms of the magnitude of the desired quantity. Here, "magnitude" represents the numerical value as well as the unit. There is difficulty in saying how one can associate calibration for the radiations of interest in this document with the definition of "calibrating" given in this glossary. One can imagine a requirement for the calibration of an instrument to measure the absorbed dose in a specified material and for a given geometry when the instrument traverses a cloud containing a concentration of radioactive material. One can also imagine the requirement for the determination of the absorbed dose under specified conditions from radionuclides deposits upon the aircraft during its traversal of the cloud. It is difficult to understand how either of these could "measure...radiation emitted from a particular radiation source." The sources in the cloud and those deposited on the aircraft provide a radiation field that may be expressed in terms of its variation with location in the cloud or distance from a contaminated aircraft. Such determinations can be in

terms of fluence, energy fluence or their rates. However, for the purposes here, one would desire a numerical value for the absorbed dose in body tissue for specified geometrical conditions. Thus, the determination of interest here cannot be the radiation emitted from a source but must be measured in terms of the energy deposited per unit mass under specified conditions in tissue-like material. Thus, the term in the glossary labeled "calibrating" is not of much use in the present context.

The term labeled "integron" in the glossary is not adequate for the present purposes. The quantity of interest here is not the "gamma radiation present" but the energy per unit mass that this radiation might deposit in specified locations.

The definition for "ion chamber" also seems to be strange. Usually this term is a synonym for "ionization chamber." However, an ionization chamber is not necessarily one with a "positively charged wire strung through the center." Depending primarily upon the electric field, such a chamber may be used under conditions whereby the ions collected are just those produced by the incoming radiation. Alternatively, the field may be increased so that it accelerates ions and produces additional ones. Because of the apparent requirement in this definition for a nonuniform electric field, this may be the type of instrument considered here. Such instruments may be used in the so-called "proportional region" whereby the number of ions is proportional to the number of incident radiation particles or it may be used as a "Geiger" counter where each entering charged particle produces approximately the same number of charged particles by multiplication. Thus, it can be seen that this definition is not of much use in the present context.

It is not clear, under the definition of "rem" what is meant by the first sentence. How can a unit "express biological effects" and what does it mean? The "dose equivalent" is the quantity of interest for such determinations. Here the dose equivalent is the product of the average absorbed dose in a given organ and the relative biological effectiveness for the radiation type and energy delivering the absorbed dose. In view of the apparent lack of understanding of the physical principles involved, it is firmly recommended that this document in its present format not be disseminated.

Several other impressions of this document reinforce the idea that this document should not be disseminated.

29, last paragraph. Here it is indicated that the "radiation monitoring devices" (should one infer from this that the radiation monitoring devices are "integrons") are located at various positions in the cockpit ("either on the instrument panel in front of the pilot or behind the pilot's seat). As the reading of the instrument depends upon its location because of possible differences in attenuation from the outside of the aircraft to the location of the instrument, the readings for locations may not be comparable.

31, 2. According to Enclosure 1, (Tumbler-Snapper Operation) page 7, the number of badges with doses indicating greater than 5 rem is 10. At least for these badges the two badge readings for each aircraft as well as comparison with the integron should be given. Do these data support opinion (4-9 rem) or (10-15 rem)?

31, Footnote 1. This comment needs to be answered.

33, 3. If the Dominic badge was prone to environmental damage, how can comparisons of the results of badge and integron readings have any meaning?

44, last paragraph and 45, 1. Should one interpret the words here to mean that the radiation sensing device is located on the cockpit floor but the meter indicating the reading was on the instrument panel? In the next paragraph, it is indicated that the integron was relocated to a "chest-level position" in the cockpit but it doesn't indicate the geometry of possible attenuating or scattering material in the vicinity.

44, 3. What are "box-like dimensions"?

45, Footnote 11. The rationale for the 2.25 value is not understood.

46, 2. According to Enclosure 5, the distribution of ratios is very large and is different for the two types of aircraft. The median value for the F-84 is in the range from 1.51 to 1.75. However, for the B-57 the median is between 1.01 and 1.25. How can one say that the ratio should be above a certain number in view of the range of the distribution for the two aircraft? If there is a rationale for this magic number, it is not apparent here.

46, last paragraph and 47, 1. ICRP Publication 26, paragraph 105, indicates the radiosensitivity for a number of the organs, including thyroid. There it appears that thyroid is about one tenth as sensitive as the whole body. Also, if one considers the lens of the eye equally sensitive, small differences in absorbed dose for these organs should be relatively unimportant.

47, 4. With the small amount of attenuation by the vests and the large uncertainty in absorbed dose, why is the wearing of a vest important?

48, last line of text. Having seen the wide range in the distributions of dose, the "slightly higher" is not sufficiently specific.

48, Footnote 15. In the present context, it is not understood why "speeds" of radiation are important. Actually the radiation penetrating the skin of the aircraft must result from either photons or, perhaps, neutrons. Up to this point in the document there is no mention of possible neutron exposure.

49, 3. This statement is suspect on at least two theses. The "fairly uniform" is not quantified and the responsé is an untested opinion.

58, 1. According to Enclosure 1 on Tumbler-Snapper tests, there were only 10 gamma ray exposures of greater than 5 roentgens out of a total of 1,684. Also, in Enclosure 1 from DNA, only 12 of 14,643 badges at Redwing had received more than 10 rem. With this small number involved, it might be worthwhile to spend a little more time trying to understand whether or not the current estimates are reasonable.

59, 2, first four lines. There is a statement for Section 3.1.4 from a letter of Plank indicating that the ratio of the integron reading to that under the lead vest was 1.25 prior to Operation Redwing. If this is true, one needs to know why the distribution is so large in the ratio table of Enclosure 5.

60, last paragraph. This is not clear. Does it mean that a current test of the concentrations of internal radionuclides could be used to indicate the concentrations some decades ago?

May 28, 1987 Harold O. Wyckoff

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June 5, 1987

Mr. J. Dexter Peach
Assistant Comptroller General
U. S. General Accounting Office
Resources, Community and Economic
Development Division
Washington, DC 20548

Subject: Draft Report on
Nuclear Health and Safety

Dear Mr. Peach,

Dr. Warren Sinclair, President of the NCRP, has asked me to assist in the review of the above draft report. I have discussed the principal findings of my review with him and we are in general agreement on them. At the suggestion of Dr. Sinclair I am enclosing herewith my suggestions for revision plus detailed comments on specific items.

My review has been facilitated by receiving from Dr. Sinclair copies of several other relevant documents as follows:

1. DNA Fact Sheet on Operation Tumbler-Snapper

2. DNA Fact Sheet on Operation Redwing

3. DNA Fact Sheet on Operation Dominic I

4. A letter from Dr. David Auton of the DNA to Dr. Sinclair dated Feb. 12, 1987, with several enclosures as follows:

5. A memorandum from R. H. Goeke on Film Dosimetry Procedures employed at Redwing dated July 23, 1957.

6. A copy of Paragraph 3.1.4 of a letter from Dr. H. Plank dated April 16, 1956 on Cloud Sampling Mission Plans for Redwing.

7. A comparison of Integron-to-Film-Badge Ratios for F-84 and B-57 aircraft for Operation Redwing.

ENCLOSURE 8

8. 32CFR218 on guidance for dose determination and reporting by DNA, DOD (Federal Register 10/21/85, pp. 42520-25).

9. Review of DNA dose assignment methods. National Research Council, 1985.

For your information I am a member of the Board of Directors, NCRP, and was Chairman of the NCRP Committee #7 which prepared Report 57 "Instrumentation and Monitoring Methods for Radiation Protection" (1978).

Yours sincerely,

E. W. Webster, Ph.D.
Professor

EWW/bh
Enc.

cc: W. K. Sinclair, Ph.D.
D. R. Auton, Ph.D.

Comments on GAO Draft Report
Nuclear Health and Safety: Radiation Exposure Estimates for Cloud Sampling Personnel

by Edward W. Webster, Ph.D.

A. General Comments. The most important finding in this review concerns the large emphasis placed in the draft on the elevation of the dose ratio between the integron and film badge readings (I/FB). The validity of the conclusion that the integron readings should be preferred over the film badge readings, and that on this account the current personnel doses are understated, is seriously questioned. There are good physical reasons why the I/FB ratio is greater than 1.0 and in general this ratio should, in the opinion of this reviewer, be greater than 1.25 (see later). On the other hand the errors of omission and arithmetic in the dose record should be remedied and appear to be the major reason for any "understatement." Conversely, no attention is given in the report to the opinion of the National Research Council Committee and to the DNA Fact Sheets (particularly Dominic I) which suggest that doses are overstated.

Probably the most significant finding in the report is that on page 48 which notes that film badges mounted in the cockpit independently of the pilot (i.e., not on his person) read the same as, or slightly higher than the integron. The significance of this is that a film badge worn on the body surface (with or without a lead vest) records considerably lower doses than a film badge "in free air," as would be expected for good physical reasons in a "cloud" of radiation. The fact that in free air the film badge reads higher than the presumably "energy independent" integron confirms the opinion of the NRC Committee that the film badge (which is "energy dependent") probably overestimates the personnel dose.

Figure 1 (attached) suggests the principal reason why the film badge on the body will read lower than the integron in an omni-directional radiation field; and Table I gives the approximate values of I/FB ratios for several different gamma ray energies, with and without a lead vest (assumed equal to 0.5 mm thick). It is evident that a ratio of 1.6 for fission product irradiation (Cs-137, I-131) would be expected when the lead vest is worn. [In Table 1 the backscatter factor is applied to the frontal exposure and an estimate of the mean Tissue-Air-Ratio (T-A-R) is applied to the rear exposure. (Brit. Jour. Rad. Suppl. Ii 1972). The shielding effect of 0.5 mm lead is taken from NCRP Report 49.] It is of interest that none of the advisers (p. 48) noted this basic difference in response.

The I/FB ratio according to DNA data appears to vary widely with a standard deviation of $\pm$ 0.25 between various sampling flights. Moreover the elevated ratios appear to correlate with the use of the F-84 plane rather than the B-57 in the Redwing

series. This suggests that the position of the integron may affect its reading - particularly its closeness to the pilot. The closer to the pilot, the greater the shielding of the device by the pilot and the lower the ratio.

The National Research Council Report on page 12 (3rd para.) suggests that with about 10% of the radiation having energies below 0.2 MeV, the film badges in use in early atomic tests (about 1952) overestimated personnel dose by 30 to 40%. We assume that the integron reading was energy independent. The recorded I/FB ratio would then be too low by 30 to 50%.

A 1.25 ratio would therefore correspond to 1.625 to 1.75 in terms of true roentgens of exposure. If in later tests the badge filters were changed to reduce the amount of over-response at low energies, the I/FB ratio would rise , but probably only to the 1.4 level recorded for Dominic I (see next paragraph) which is in line with the estimates made in Table 1 for unshielded badges for Cs-137 and I-131 with an admixture of low energy (< 0.2 MeV) gamma rays. The 1.4 estimate in Table 1 assumes that the film badge is not energy dependent.

On Page 47 (last paragraph) it is noted that the integron reading exceeded the "expected" 1.25 ratio in about 72% of the Dominic I missions. This suggests that the mean ratio at Dominic was about 1.4 (i.e., 50% below, 50% above). This lines up reasonably well with the values expected (Table I) for missions without a lead vest.

This reviewer therefore concludes that there is no reason to suspect that the film badge readings "understate" the skin dose received by the sampling crews because of the Integron readings, and that the substitution of the higher integron values would be inappropriate. Specifically the suggestions in the examples in Appendix II that the integron readings show a higher "hypothetical" dose are presumptions since a ratio of 2 (as in example C) could be explained through considerations of gamma energy and/or directionality of the incident radiation.

B. Review of Recommendations (pp. 7-8), (p. 61). This reviewer believes that the errors of arithmetic and omission should be corrected for all Air Force participants in the atmospheric nuclear weapons tests.

The second recommendation is not entirely justified by the discussion in the draft report. The fourth line should be modified to read as follows ". . . badges worn, and reconsider, if necessary, the radiation doses . . . ". (The sentence as presently written appears to conclude that indeed an upward adjustment will be necessary when the Integron/film badge ratio exceeds some nominal value, such as 1.25.)

C. Specific Comments (by page).

Title: The present title is biassed and assumes the conclusions of the present report are unchallengeable. Either

omit "are understated" or change as follows: Nuclear Health and Safety: Some Radiation Exposure Estimates for Cloud Sampling Personnel are Too Low or Too High".

Page 3, Line 17: Amend as follows: ..... Dominic I is either understated or overstated and ....

Page 5, Last Para.: The 1.25 figure would appear to be too low if, as noted above, the film badge reads too high for low gamma ray energies. Improvements in the badges used for Redwing or Dominic regarding energy response (if so), would increase the I/FB ratio.

Page 6, Para. 1: Changes in film badge energy response or in energy spectrum could account for an increase in I/FB ratio so that reached the predicted values of about 1.6 (Redwing) and 1.4 (Dominic).

Page 7, Para. 1: It would be nice to know whether the urine samples which were measured (particularly if taken from personnel considered to be more likely exposed) were negative or very low. This would give some reassurances that Pu inhalation was not a problem.

Page 22, Line 16: The word "actual" is biassed - it assumes without proof that the integron reading is the correct measure of personnel dose. My Table 1 indicates that the ratio I/FB can cover a wide range, particularly if the badge is shielded by lead and gamma energy is low.

Page 28, Para. 2: This completely omits any suggestion that the personnel doses may have been overstated because of: a) energy response problems of the film badge; or b) the effect of environmental conditions - heat, light, and humidity - on the badge densities, as claimed vigorously by DNA for the Dominic I tests. [98% of all badges with density above 0.4 as noted in the DNA Fact Sheet, Page 3, with one-third of higher exposures most probably zero.]

Page 29, Lines 12-14: It should be indicated how the personnel selected for whole body counting were selected. The results should be reviewed before hasty conclusions are drawn.

Page 29, Last 4 Lines: The integron argument is ambiguous and may not "show that exposure is understated." The film badge actually on the person is probably the best final arbiter of dose.

Page 30, Line 13: Processing conditions do not have to be "carefully controlled" if known standard exposures with film badges (calibration films) are measured with each new batch of badges.

Page 31, Last 6 Lines: The significance of a "gap" between 10 and 15 rem seems small if the maximum recorded dose was 7.6 rem with only two readings > 5 rem according to the DNA History at Tumbler-Snapper.

Page 37, Lines 10-14: The arguments are not bolstered by known facts. How long would a person be working around a particular cloud sample, and how fast does the sample exposure rate decay with time over the first few days? What were typical exposure rates to personnel removing the samples (mR/hr)?

Page 40, Figure 2.2: It could be that the 4095 mR permanent badge included both July missions (since 1 badge could read less than two single badges, especially if there were environmental background effects). Probably the only missing data in the total is the 725 mrem from 7/22 to 7/23.

Page 43, Last Para.: Should be reconsidered in view of the "lack of holiness" of the 1.25 value for the I/FB ratio discussed above.

Page 47, 3rd Para.: A diagram of the lead vest would be useful. "Three square feet wide" does not make sense. Does the vest have a front and a back? If the width was 1.5' and the length was 2', the bladder would be covered.

Page 48, top. The I/FB ratio average of about 1.4 would not be surprising if the film badge over-reading at low energies had been corrected. 1.4 is an expected value based on the "body-shielding" effect.

Page 57, 3rd para. Delete first four words. Start with "Other information .....". Change last two lines to ".....could result in a few cases in an increase in a particular individual's recorded dose to a level in excess ....."

Suggest add another paragraph to precede this which reads roughly "Physical considerations indicate that the higher readings of the monitors are to be expected and by themselves do not justify any upward adjustment of the personnel doses recorded by film badges".

Page 58, after 3rd para. Add a new para which indicates the "overstatements" due to environmental fogging, particularly at Dominic Such as: "On the other hand, particularly at Dominic I the high incidence (98%) of environmental fogging of the film badges resulted in a considerable overstatement of personnel dose such that one-third of the badges showing higher doses should actually read zero. The impact of this on personnel recorded with the highest doses (above 5 rem) is not yet defined and should be further explored."

Page 59, 2nd Para. Too much is made of the difference between the older 1.25 ratio (average) and the later 1.4 to 1.6. First the 1.25 (5th line) should be 1.25 $\pm$ 0.25. Second, add "This factor could well be 1.5 $\pm$ 0.3 if account were taken of the over-reading of the low energy component of gamma rays." Third, also add "In Redwing it is evident that this ratio was dependent on the aircraft type, possibly due to different placement of the integron relative to the pilot."

Page 59 (cont) Also delete last sentence of para 2 "Upon examination ..... readings." Add new sentence: "The integron did not read higher however compared with film badge readings on badges in the cockpit in free space -- not on personnel. This suggests that the increase in the ratio was basically related to the location of the badge on the torso of the pilot and under a lead vest, both of which would shield the film and reduce the dose to the film badge, but not affect the validity of the skin dose measurement."

Page 59, 3rd Para. Delete. Substitute in place:
"It seems likely therefore that the film badge readings are the most reliable measure of the surface dose received by the pilots".

Page 60 1st Para. OK, but a small point. The organs principally at risk are mainly under the vest -- most of the active bone marrow, the lungs, GI tract, GU tract, liver. The thyroid has a low weighting factor because of the low mortality from radiation-induced thyroid cancer.

Enclosures. Table 1, Figure 1

E N D

## Table 1

Estimated I/FB Ratios
(Elliptical section 20 cm thick)

| Energy | Film Badge | | I | I/FB |
|---|---|---|---|---|
| High 1.2 MeV Co-60 Backscatter 1.06 | Dose from front | 1.06 | 1.0 | |
| | Dose from rear | 0.39 | 1.0 | |
| | Total | 1.45 | 2.0 | 1.38 |
| | Total with 97% transm.* | 1.41 | 2.0 | 1.42 |
| High 0.66 MeV Cs-137 Backscatter 1.07 | Dose from front | 1.07 | 1.0 | |
| | Dose from rear | 0.30 | 1.0 | |
| | Total | 1.37 | 2.0 | 1.46 |
| | Total with 93% transm.* | 1.27 | 2.0 | 1.57 |
| Intermediate 0.36 MeV I-131 Backscatter 1.15 | Dose from front | 1.15 | 1.0 | |
| | Dose from rear | 0.25 | 1.0 | |
| | Total | 1.40 | 2.0 | 1.43 |
| | Total with 88% transm.* | 1.23 | 2.0 | 1.62 |
| Low < 0.2 MeV** Backscatter 1.34 | Dose from front | 1.34 | 1.0 | |
| | Dose from rear | 0.18 | 1.0 | |
| | Total | 1.52 | 2.0 | 1.31 |
| | Total with 50% transm.* | 0.76 | 2.0 | 2.63! |

Integron dose 4π exposure

* 0.5 mm Pb. body shield (vest)

** Well-filtered 200 kV x rays
T-A-R = tissue/air ratio

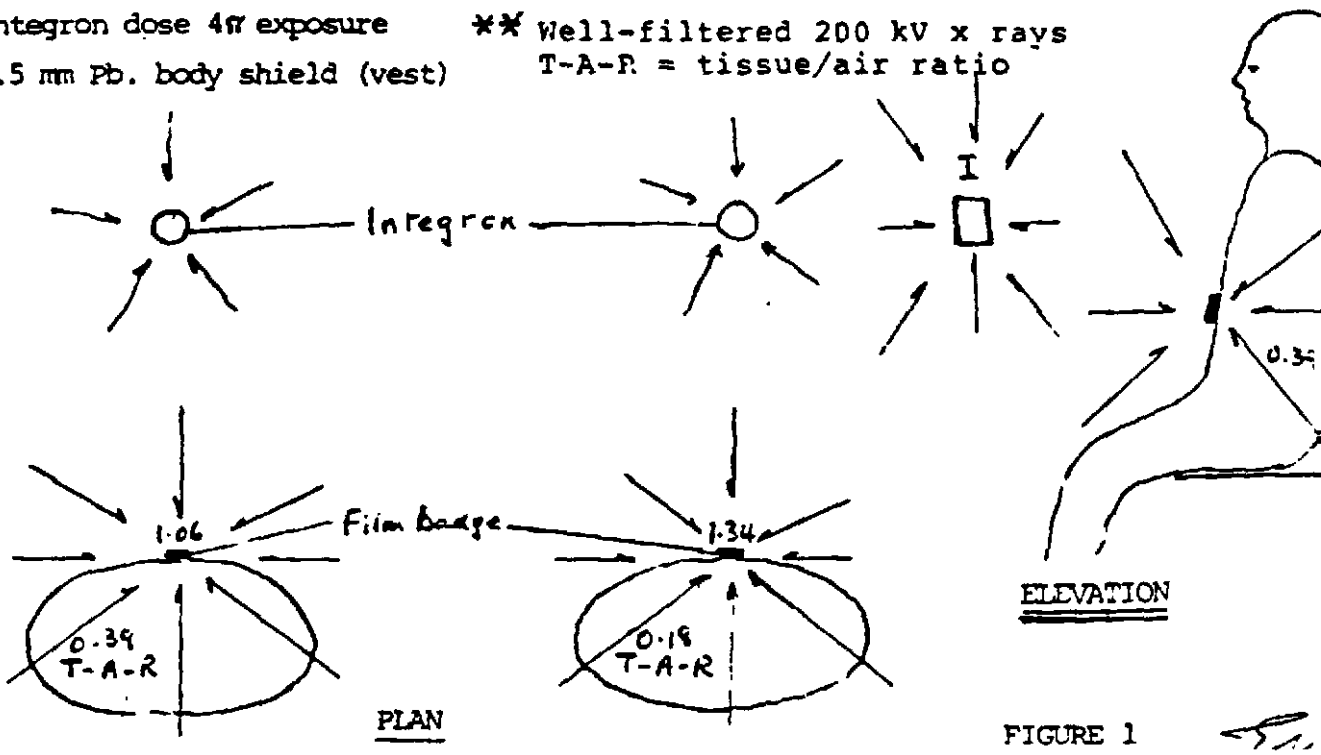


FIGURE 1