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Defense Nuclear Agency
Washington, D.C. 20305-1000

MAR 14 1988

MEMORANDUM FOR THE UNDER SECRETARY OF DEFENSE (ACQUISITION)
THROUGH: THE ASSISTANT TO THE SECRETARY OF DEFENSE (ATOMIC ENERGY)

SUBJECT: General Accounting Office (GAO) Final Report GAO/RCED-87-134, "NUCLEAR HEALTH AND SAFETY: Radiation Exposures for Some Cloud-Sampling Personnel Need to Be Reexamined," Dated September 29, 1987 (GAO Code 301726), OSD Case 7299--PREPARATION OF PROPOSED RESPONSE TO GAO FINAL REPORT

1. By letter of February 11, 1988, the Inspector General, Department of Defense forwarded the subject report and established the Office of the Assistant to the Secretary of Defense (Atomic Energy) as the primary action office and also set up dual collateral action offices to prepare a response on behalf of the Secretary of Defense. The collateral action offices appointed were the Director, Defense Nuclear Agency (DNA) and the Secretary of the Air Force.

2. The ATSD(AE) central points of contact, MAJ Wayne Anderson (X73098), and Dr. Dale Tuggle, LANL, (505) 667-4526 have been working with the Defense Nuclear Agency and a representative from the Air Force to prepare this joint response on behalf of both DNA and the Secretary of the Air Force.

3. Enclosed is a proposed draft response to the GAO, addressing their rebuttals to the previous DoD inputs partially printed in the already published Final Report. This response has been coordinated with the Air Force.

Enclosure
as stated

J. T. PARKER
Vice Admiral, USN
Director

HRE-903

THE UNDER SECRETARY OF DEFENSE

WASHINGTON, DC 20301

ACQUISITION

DRAFT

MAR 28 1988

Mr. J. Dexter Peach
Assistant Comptroller General
Resources, Community, and Economic Development Division
United States General Accounting Office
411 G Street N. W.
Washington, D. C. 20548

Dear Mr. Peach:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) Final Report GAO/RCED-87-134, "NUCLEAR HEALTH AND SAFETY: Radiation Exposures for Some Cloud-Sampling Personnel Need to be Reexamined", dated September 29, 1987 (GAO Code 301276/OSD Case 7299).

The Department of Defense nonconcurs with the GAO position regarding the accuracy of the film badges. The DoD also nonconcurs with the GAO recommendation that integron radiation readings be used in conjunction with film badge readings to better define the doses received by cloud-sampling personnel. In this regard, and in general, the GAO report misrepresented the data. The GAO report also includes findings not supported by facts and selectively edits the DoD comments on the draft report. It is the DoD position that the report is less than fairly and accurately presented.

The detailed DoD responses to the GAO rebuttal comments are provided in enclosure 1. There is no basis for the GAO finding that problems with film badges might have led to understatements of the external gamma doses. While problems were discussed in various historical documents, in all but one case the problems were that the film badges were either reading high or were showing a radiation exposure when none had occurred. Excerpts from several of these reports are provided in enclosure 2. The only reported problem that might have resulted in an understatement of the radiation dose by film badges was a decrease in the accuracy for a film badge reported to be exposed in the range of 10 to 15 rem. (This anomaly is addressed later in enclosure 1, the DoD response to the GAO rebuttals.)

As previously stated, the DoD nonconcurs with the recommendation that the integron readings be used in conjunction with the film badge readings to define radiation doses. The integron readings are not appropriate for determining individual dose, not because of an inherent inaccuracy in the instrument, but because the integron was located some distance from the crew members. The film badges, on the other hand, were worn by the crew members directly

on their bodies. As effectively stated by Dr. Warren K. Sinclair, the President of the National Council on Radiation Protection and Measurements (NCRP):

> "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 [the International Commission on Radiation Units and Measurements] (ICRU), [the International Commission on Radiological Protection] (ICRP), and (NCRP), it would seem that the film badge reading in this case of these aircrews is likely to be correct as in other occupational circumstances".

The radiation environment in the cockpit was not uniform. The variation of radiation intensity with location in the cockpit was known at the time of these operations. An excerpt (provided at enclosure 3) from a memo written by a Los Alamos Scientific Advisor, during the planning of OPERATION REDWING, includes a discussion of this variation and the probable causes for it. Also, an excerpt from the final report on early cloud-sampling at OPERATION REDWING discussing the variation of radiation intensity with location, is provided at enclosure 4.

The integron data can be used to identify cases where apparent discrepancies between the film badge and integron readings exist. There is no basis, however, for the GAO assumption that, where there are discrepancies "...either the pilot's film badge reading or the observer's film badge reading is incorrect." Four examples were cited by the GAO in its rebuttals to the DoD comments on the draft report. All four of these examples have been examined by the DoD. The GAO did not use the complete film badge documents which had more accurate and comprehensive data on each individual dose and, therefore, reached incorrect conclusions. A more thorough analysis of the source data by the GAO would have shown that differences were not explained by film badge inaccuracy and that personnel records reflect the highest value recorded on the mission.

The DoD strongly objects to the fact that GAO did not print all of the expert comments that were submitted with, and were an intrinsic part of, the DoD response to the draft report. Copies of these important materials are enclosed again and expressly incorporated into this response.

- On May 28, 1987, the former head of the International Commission on Radiation Units and Measurements (ICRU) (as provided at enclosure 5) expressed concerns about technical errors in the glossary, expressed his confusion regarding the rationale used by the GAO in reviewing the ratio between integron and film badge readings and explained the relative insensitivity of certain organs, such as the thyroid and the lens of the

eye. Moreover, he supported the DoD comments on the effect of location on the radiation exposures measured.

- Dr. Edward E. Webster, one of the country's leading experts on film badge dosimetry from the Harvard Medical School, provided extensive comments in his attached letter of June 5, 1987 (provided at enclosure 6). Dr. Webster pointed out:

  "The fact that in free air the film badge records 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."

  He further concluded 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." He also pointed out that "...the increase in ratio was basically related to the location of the badge on the torso of the pilot and under a lead vest, both of which shield the film and reduce the dose to the film badge, but not affect the validity of the skin dose". The GAO omission of such important comments is inexcusable.

Furthermore, the GAO did not include comments from the five scientists who are most knowledgeable about the integron and who established policy regarding its use at the tests cited by the GAO. The attached memoranda for the record (provided at enclosures 7 through 11) from all five scientists, indicate agreement with the DoD position.

In conclusion, there is an unfortunate lack of objectivity shown in the GAO report. The available evidence strongly supports the DoD position that film badge measurements did not underestimate the external gamma radiation doses. The GAO finding to the contrary is clearly in error. So is the related GAO recommendation. In determining that integron data should be used to check for film badge errors, the GAO ignored the fact that multiple film badges were carried by personnel on missions as a check against film badge errors, although the experts' opinions clearly pointed this out. The selective reading of history and data, coupled with the refusal to even print significant portions of the DoD comments on the draft report, raises serious questions about the integrity of the GAO audit process in this instance. In light of the lack of objectivity and completeness of the report, the DoD strongly recommends that this report be withdrawn until it can be formally reviewed and corrected by a scientific body, such as the Office of Technology Assessment.

The statements of several experts that were part of the original DoD response to the draft report, but were not included in the

report, are again provided at enclosures 5 through 11. In addition, enclosures 12 and 13 are more recent letters from Dr. WarrenK. Sinclair and Dr. Harold O. Wyckoff that provide additional comments on the GAO report. It is unfortunate that all relevant information was not incorporated into the final printed report.

13 Enclosures:

1. DoD Responses to the GAO Rebuttal Comments set forth in Appendix III of the Final Report
2. Excerpts from several reports
3. Los Alamos scientific advisor memo written during the planning of REDWING, April 16, 1956
4. Excerpt from REDWING Final Report on Early Cloud Sampling regarding variation of radiation intensity with location
5. Dr. Harold W. Wyckoff May 28, 1987 comments provided as an enclosure to Dr. Warren Sinclair June 5, 1987 letter
6. Dr. Edward W. Webster June 5, 1987 letter to Mr. Peach, GAO
7. Dr. Paul R. Guthals June 8, 1987 response
8. Dr. Harry Hicks June 5, 1987 response
9. Dr. Edward H. Flemming June 9, 1987 response
10. Dr. Harold Plank June 5, 1987 response
11. Dr. Ken Street June 5, 1987 response
12. Dr. Warren K. Sinclair November 12, 1987 letter
13. Dr. Harold O. Wyckoff November 24, 1987 letter

GAO FINAL REPORT GAO/RCED-87-134 - DATED SEPTEMBER 29, 1987
(GAO Code 301726) - OSD Case 7299

"NUCLEAR HEALTH AND SAFETY: RADIATION EXPOSURES
FOR SOME-CLOUD SAMPLING PERSONNEL
NEED TO BE REEXAMINED"

DEPARTMENT OF DEFENSE COMMENTS ON
GAO REBUTTALS AND RECOMMENDATIONS
IN THE FINAL REPORT

- GAO REBUTTAL 1: Radiation Exposure Estimates for Cloud-Sampling Personnel are Understated. In response to the DoD position (as supported by expert opinions) that the GAO draft report was misleading in concluding the doses were understated, the GAO noted it redirected the final report towards the need to reexamine the exposures. The GAO stated, however, that based on its review, 26 percent of OPERATION REDWING and 13 percent of OPERATION DOMINIC I exposure levels were in error, nearly all understatements. The GAO reiterated its position that far more radiation estimates assigned to cloud-sampling personnel are understated than overstated. In addition, the GAO reviewed two documents mentioned by the President, National Council on Radiation Protection and Measurements (NCRP). The GAO reported that the first, a 1979-80 reevaluation of approximately 1,350 DOMINIC I film badges, showed nearly half involved environmentally-damaged film badges worn by Navy personnel stationed on ships, whereas DOMINIC I cloud-sampling personnel were stationed on an island and wore their film badges for shorter periods. The GAO observed that the environmental differences and shorter periods when badges were worn would have made these badges susceptible to less environmental damage and, therefore, less likely to overstate dosages. The GAO also reported that the National Academy of Sciences 1985 report, "Review of the Methods Used to Assign Radiation Doses to Service Personnel at Nuclear Weapons Tests," indicated film badges, under laboratory conditions and with the radiation source perpendicular to the badges, overstated dosage by 40 percent. The GAO questioned this data relevance, since cloud-sampling personnel did not wear film badges under laboratory conditions or in a radiation environment essentially perpendicular to their film badges. The GAO noted that the DoD, recognizing the lack of direct relevance, had contracted with the National Academy of Sciences to examine the film badge accuracy, and the results are due near the end of 1988. (p.68, pp. 82-83/GAO Final Report)

- DoD RESPONSE: Nonconcur. The GAO statement that the integron readings need to be used in conjunction with film badge readings "in view of the problems known to exist with film badges" is incorrect unless it refers to overestimates of doses. The GAO assumption that doses are understated is

not supported by any of the evidence presented in the report nor in the GAO rebuttal, including the four examples cited in Table III.1 of the GAO rebuttal.

The film badge is designed to indicate the dose to the wearer in an omnidirectional field. The DoD recognizes that differences in exposure geometry will cause the film badge to read differently than in a free-field environment. These differences are known and have been quantified--radiation solely from the front will cause the badge to read high, while that from the rear will cause a chest-worn badge to read low. In an omnidirectional source environment, such as for a crewmember of a cloud-penetrating aircraft, the badge is considered by all authoritative bodies to be a measure of the dose to the blood-forming organs of the body. Nonetheless, the DoD has asked the National Academy of Sciences to examine individual personnel dosage in order to determine the validity of exposures assigned, The DoD does not regard the GAO report as a technically accurate assessment.

A DoD review of the GAO examples found none of the apparent discrepancies that the GAO alleges to be caused by problems with the film badges.

- In the first example the pilot should have worn three film badges, two mission badges and his permanent badge. The two identical mission badges which read 0.330 rem document how well film badges can agree in the same environment. No error resulted in the total dose assignment because the dose recorded by the permanent badge was used in calculating this pilot's total radiation exposure.

- In the second example the GAO apparently only relied upon the information on the integron data sheet and did not verify the observer dose by looking on the individual radiation exposure record, which is the official record of dose. The integron data sheet only showed the observer's task group number (i.e., 7.1) which was not his dose in millirem. The individual radiation exposure record showed that the observer had two mission badges for that day which averaged 2.118 rem.

- In the third example, the GAO incorrectly reported the observer dose as zero. Again, the source records for that individual showed he had two mission badges for that day reading 0.87 rem and 0.94 rem, averaging 0.91 rem. The reproducibility of the two mission badges is excellent and they compare closely with the two mission badges that both read 1.0 rem (1000 mrem) for the pilot.

- In the fourth example, the GAO again misinterpreted the records. The observer film badge read 1.650 rem and not

0 rem, as the GAO cited. In this case there is only a 0.050 rem difference between the observer and the pilot film badge readings. The use of film badges for estimating whole body gamma radiation exposure is more appropriate than use of the integron readings because the film badges were worn next to individual bodies, while the integrons were mounted in the cockpits some distance away from the crew members. When the aircraft were actually in the bomb clouds, the radiation intensities were assumed to be uniform throughout the cockpits, but on the the return flight to the base, the cockpit radiation levels caused by contamination of the surfaces of the aircraft by radioactive debris were not uniform because the amounts of contamination and its distribution on the aircraft were variable. In the April 16, 1956 memo cited by the GAO (provided at enclosure 3), the Los Alamos Scientific Advisor stated:

> "The radiation background to which crew personnel are exposed after departing the cloud arises from the disposition of radioactive debris on the exterior surface, ducts, and engines of the aircraft. Since the retention of debris by these areas varies from aircraft to aircraft of the same type and from shot to shot, variation in the background acquired will be experienced."

In his May 5, 1955 memorandum, the same scientific advisor discussed the variation of the radiation intensity in the cockpit of a B-57A aircraft flown on a cloud sampling mission during OPERATION TEAPOT. On this mission the pilot received a total radiation dose of 0.460 rem, while the observer received a total dose of only 0.365 rem. He stated:

> "The difference between the two exposures in the B-57A appears to be similar to the difference observed in the featherweight B-36, No. 1086, during OPERATION CASTLE, between the total exposure for the forward compartment and that for the rear scanner. The ratio of the scanner to forward crew total exposure was about 1.3, the increment in exposure for the forward compartment being 0.4 and that calculated for the scanners about 0.8. In this case it is believed that the higher increment for the scanners was the result of a greater disposition of radioactive cloud debris on the protruding scanning blisters and supporting surfaces which gave a higher background radiation rate near them during return to base than in the forward compartment. The pilot's canopy on the B-57A and the scanner's blisters in the B-36 fuselage extend into the streamline airflow around the fuselage in the same way in the two airplanes. The difference in return increments for the two positions in the B-57A, therefore, appear to be real and to be a function of the canopy configuration."

This variation in both the amount and the distribution of radioactive debris once again attests to the importance of the location of the measuring device.

Because film badge readings provide a more accurate indication of the whole body external gamma dose than the integron and the only film badge problems identified resulted in overestimates of the doses, there is no need to use the integron readings.

- GAO REBUTTAL 2: Monitoring Devices Read Higher Levels of Radiation Than Anticipated Compared to Film Badges Worn by the Aircrew. The DoD did not agree with the GAO position that earlier readings by film badge and a radiation measuring device--the integron, carried in cloud-sampling aircraft cockpits--established a known ratio between the two readings, and that no satisfactory explanation had been provided for this ratio being higher in OPERATION REDWING and DOMINIC I. The DoD also disagreed with the GAO recommendation that integron readings should, therefore, be reexamined for all atmospheric nuclear tests (including OPERATIONs REDWING and DOMINIC I) and used to adjust the radiation doses assigned to cloud-sampling aircrew personnel. (The experts also rejected any suggestion that film badge readings were cast into question by integron readings.) The GAO took issue with the DoD response, as follows:

> "It is not our belief nor our report's position that integron readings should be used in lieu of film badge readings in assigning radiation exposure estimates to cloud-sampling aircrew personnel. Rather, we believe--in view of the problems known to exist with film badges--that integron readings used in conjunction with film badge readings can be helpful in better defining cloud-sampling aircrew personnel dose. This position, in our view, has an adequate scientific and analytical basis."

The GAO also cited language in NCRP Report 57, Instrumentation and Monitoring Methods for Radiation Protection, indicating that, unless radiation was uniformly distributed, a measurement at one point could not strictly determine the "whole body dose," and that at levels near the maximum permissible dose, careful evaluation and correction factors should be applied. The GAO concluded:

> "Given...there is no certainty that cloud-sampling aircrews were subjected to a uniform distribution of dose, use of integron readings in conjunction with film badge readings to better define aircrew dose would seem advisable."

Citing two instances were the pilot and observer film badges recorded very different levels, the GAO further concluded that the integron reading could arbitrate which was correct.

In addition, the GAO noted an April 16, 1956, memorandum in which a Los Alamos cloud-sampling scientific advisor identified a 1.25 integron-to-film badge ratio, based on observed differences in readings by these devices at earlier atmospheric nuclear tests.

OPERATION REDWING: The GAO stated that in 1955 it had independently compared ratios of readings for OPERATION TEAPOT, (1.24), as well as for 61 OPERATION REDWING missions in which the F-84 aircraft was used (1.64). The GAO also noted the April 16 memorandum stipulation that the 1.25 ratio was based on film badges worn underneath a lead vest. The GAO concluded that this change in ratio in identical aircraft indicated a need for further examination of integron and film badge readings.

OPERATION DOMINIC I: The GAO observed that lead vests were not worn in OPERATION DOMINIC I and, therefore, film badge and integron readings should be closer than the 1.25 ratio. The GAO concluded that, since the DoD had calculated the ratio was higher than 1.25 at OPERATION DOMINIC I, a further examination of, and comparison of, integron and film badge readings seemed warranted. The GAO further observed:

> "Though DoD said the increase in ratio was caused by a change in the relative radiation environments, it could offer us no proof that this caused the increase. Until that proof is developed, it cannot be ruled out that the increase in ratio was not caused by errors in film badge measurements."

The GAO further reported, with respect to the experts, the following:

> "In finalizing this report, we met with Drs. Sinclair, Wyckoff, and Webster to clarify our position on the integron reading issue. We indicated...our position that because problems were or are known to exist with the film badges, the integron readings can be used in conjunction with the film badge readings to better define cloud-sampling aircrew personnel dose. Each of the three NCRP individuals agreed there was merit to using the integron readings to confirm or deny, in general terms, the readings made by the film badge."

The GAO also reported that it had asked the Office of Technology Assessment to review a draft of the report, and that office informally expressed support for the findings, conclusions, and recommendations in the draft report. (pp. 67-70, p. 83/GAO Final Report)

- DoD RESPONSE: Nonconcur. The variation of the film badge to integron ratio was known at the time of these operations. The value of 1.25 was only an average that was valid when the aircraft were actually in the radiation clouds and the radiation flux in the cockpit was uniform. After penetrating the cloud, the contamination on the aircraft was not uniform and thus neither was the radiation flux in the cockpit. This variation in radiation flux due to contamination on various

parts of the aircraft was discussed (by the Los Alamos scientist cited by the GAO) in a memorandum of May 3, 1955. During OPERATION TEAPOT, the total dose to the pilot of a B-57A was 30 percent higher than the dose to the observer. The reason given for this difference was a higher background radiation rate for the pilot. In the memo of April 16, 1956 cited by the GAO, the Los Alamos scientist states:

> "The radiation background to which crew personnel are exposed after departing the cloud arises from the deposition of radioactive debris on the external surface, ducts, and engines of the aircraft. Since the retention of this debris varies from aircraft to aircraft of the same type and from shot to shot, variation in the background acquired will be experienced."

Because of the variation in the cockpit background, the ratio of the integron to film badge readings for total exposure also varies.

While the GAO claimed that the NCRP scientists supported their position, what was actualy said is reflected in enclosures 12 and 13. Specifically, Dr. Sinclair stated, "I do not believe (a) that integron readings should be used in lieu of film badge readings, but (b) I do believe they could be helpful in cases where the film badge is suspect." As discussed above, however, the GAO has failed to provide genuine examples in which the correct dose cannot be ascertained from the full set of historical film badge records. The GAO addressed only selective portions of these documents. The other scientist, Dr. Wyckoff, said the GAO statement was ambiguous and added, "Furthermore a value of 1.25 obtained from the film badge and integron readings <u>should not</u> be used to correct the film badge reading." Lastly, the Office of Technology Assessment was not given the opportunity to review the DoD comments to the draft GAO report prior to making its <u>informal</u> comments.

It would appear that the GAO has been selective in its use of data and as a result has attempted to draw scientific conclusions not supported by experts in the field.

- GAO REBUTTAL 3: Claim Involving 10 to 15 Rem Range Gamma Radiation. The DoD noted that film badges worn in OPERATION TUMBLER-SNAPPER and OPERATION REDWING had some additional error in measuring gamma radiation between 10 and 15 rem. The DoD pointed out, however, that no claim involving a badge falling into this range had been filed with the Veterans Administration (VA). According to the GAO, however:

  > "Contrary to DoD's statement, there has been at least one VA claim for radiation-related disability compensation in which the claimant had a film badge reading...in the overlap range. The claimant participated in early cloud penetration work at OPERATION REDWING. His total assigned dose was 15.8 rem, which included a single cloud penetration mission dose of 14.8 rem. Interestingly, we observed that this individual's film badge record included an arithmetical understatement of 8.62 rem, bringing his correct total dose to over 23 rem. This individual claimed compensation for varicose veins, defective hearing, hemmorhoids, heart disease, and degenerative spine, none of which is considered radiation-related. Thus, it is uncertain whether his claim for radiation-related disability compensation would have been granted even if his correct total dose had been reported to the VA." ("Comment 6" p.69/GAO Final Report)

- DoD RESPONSE: Nonconcur. The DoD has found that the REDWING cloud sampler reported by GAO, with a 14.8 rem mission badge for one day, was not, as GAO stated, a VA claimant. He has no known illnesses and has never filed a VA claim. As DoD stated in its comments to the draft report, any individual filing a VA claim with a single badge in the 10-15 rem range will be provided the full information.

  Furthermore, an analysis of the actual film badge at Reynolds and Electrical and Engineering Company (REECO) by DoD revealed that the low component portion of the permanent badge was incorrectly recorded as 8.62 rem. That particular film was so dark that the density was well above the 10.0 rem range, representing an unreadable density. It was realized, at the time, that it could not be relied upon to determine a dose. Instead, the film badge processor relied upon the dose recorded on the high component portion of the mission badge in assigning the dose of 14.8 rem. The GAO is correct in its concern that the 15.08 rem dose (determined by the two mission badges of 14.8 rem and 0.280 rem) does not fully reflect the individual's full dose. This kind of error is being resolved by the systematic review of the source documents currently ongoing. With modern dose reconstruction techniques, it is now possible to provide an additional dose based on contribution from island fallout. For this individual, an additional estimated dose of 2.767 rem takes

into account his exposure from July 1 until August 6, 1956, when he departed. This also includes the fallout contribution from Shot TEWA. Current DoD procedures will assign him the 15.08 rem total from his mission badges and an additional estimated dose of 2.767 rem (covering the period that his permanent film badge would have recorded) for a total of 17.847 rem, not the 23.7 rem proposed by the GAO. The addition of the mission badges and the incorrectly reported permanent badge reading, as used in the GAO computation, is not the proper method to resolve this particular individual's full dose potential.

- GAO REBUTTAL 4: Badge Issue and Turn-in Dates. The DoD advised that, for OPERATION REDWING, there are issue and turn-in date records showing the badges were not lost, but were worn more than four weeks (at REDWING, this would result in an overestimated dose). The DoD also advised that there was an organized system to account for all badges at REDWING, and any lost badge should have been noted on the source documents. The GAO reported, however, that its review of available records confirmed 18 REDWING cloud-sampling personnel film badges were issued and not turned in, and the film badge records did not note the missing badges. The GAO also questioned whether a film badge worn for more than 4 weeks would result in an overestimated dose. According to the GAO, (1) 3 REDWING cloud-sampling personnel apparently wore particular film badges for more than six weeks, (2) Under the environmental conditions present at OPERATION REDWING--about 80 degrees Fahrenheit temperature and about 80 percent relative humidity--several scientific publications suggest film badges tend to fade or underestimate dose, and (3) a 1963 article, "Accuracy and Sensitivity of Film Measurements of Gamma Radiation - Part III," in Health Physics, [states:] decreases in film badge radiation readings as low as 50 percent were found in all experiments at 80 degrees Fahrenheit temperature as relative humidity increased above 60-70 percent. ("Comment 7" pp. 69-70, GAO Final Report)

- DoD RESPONSE: Nonconcur. The loss of a permanent badge does not mean that no radiation exposures were recorded for that period of time. Once again, the GAO has approached the problem as though only one film badge had been worn by cloud samplers. The GAO should acknowledge that multiple dosimetry aided proper dose determination, even when a badge may have been lost or flawed. Specifically, for cloud samplers, mission badges were issued for each mission and these would have recorded any radiation exposures received during missions flown. The only radiation exposure not recorded would be that received from background on the islands. These background levels have been calculated and are shown as cumulative doses in the table at the end of this response. For any time periods when permanent film badge data is not recorded, data from this table is used to estimate background doses.

  The problem with badges worn more than six weeks at OPERATION REDWING was that water spots were darkening the film. In a letter to his division leader, a Los Alamos scientist discussed this problem.

  > "We are still having some difficulties with the permanent film badges. Those worn more than six weeks are showing what looks like water marks. Apparently the cellulose acetate is sufficiently permeable" [so that] "the water vapor is getting through. Then it condenses during the night and does produce some spots. Approximately one percent of a relatively small sample

checked are badly water spotted to the point that they cannot be truly read with either the Shaler or Ansco densitometers. However any reading will be on the safe side."

The article cited by the GAO does not address this problem. Nor does the article conclude, as maintained by the GAO, that radiation readings taken under the environmental conditions present at OPERATION REDWING would cause film badges to read as low as 50 percent. It concluded, instead, that the response of unprotected film packets exposed to radiation was decreased by the presence of water vapor at temperatures up to 80 degrees Fahrenheit. As an effort to monitor this problem closely at REDWING, calibration badges were exposed to a known amount of radiation and processed along with badges worn by test personnel, i.e., monitoring badges. An accurate reading on the calibration film served to confirm the validity of the film badge processing procedures. A variation in response, though, would only effect dose assignments "if calibration films are exposed to warmer or dryer atmospheres than those to which the monitoring films are exposed." At Operation REDWING, the calibration films were exposed to cooler temperatures and to the same water vapor as the monitoring films. Thus, the response of the monitoring films would have been higher than that of the calibration films and radiation doses would be overstated, not understated.

Operation REDWING
Table 4a. Cumulative Film Badge Dose for Personnel Assigned to Parry Island, Enewetak Atoll (July 1956 - August 1956)
(Average Dose for Personnel Working Outside)

Date (1956)		Dose (rem)	Date (1956)		Dose (rem)
July	1	0.001	August	1	2.676
	2	0.002		2	2.698
	3	0.039		3	2.717
	4	0.061		4	2.735
	5	0.072		5	2.752
	6	0.078		6	2.767
	7	0.083		7	2.780
	8	0.087		8	2.795
	9	0.090		9	2.807
	10	0.100		10	2.819
	11	0.107		11	2.830
	12	0.111		12	2.840
	13	0.114		13	2.850
	14	0.117		14	2.860
	15	0.119		15	2.867
	16	0.121		16	2.877
	17	0.123		17	2.886
	18	0.124		18	2.894
	19	0.126		19	2.901
	20	0.127		20	2.909
	21	0.388		21	2.916
	22	1.494		22	2.923
	23	1.915		23	2.929
	24	2.167		24	2.936
	25	2.349		25	2.942
	26	2.471		26	2.948
	27	2.524		27	2.953
	28	2.564		28	2.959
	29	2.597		29	2.964
	30	2.627		20	2.970
	31	2.653		31	2.974

- GAO REBUTTAL 5: Different Film Badge and Integron Readings. The DoD advised that, at OPERATION DOMINIC I, a film badge placed on the integron ion chamber (where it would be 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 reading was close: 0.97 plus or minus 30 percent.) The DoD pointed out that these data demonstrate the integron and film badge readings were due to radiation environment differences, not to errors in either integron or the film badges, and confirm that the film badge provided an accurate indication of radiation exposure. The GAO asserted, however:

  "In reviewing our draft report, an NCRP distinguished radiologist and film badge expert prepared a series of calculations that illustrated why the integron and the film badge worn by the aircraft crew may read differently even when both devices operated as intended. Those calculations showed, in part, that because each crew member's body was shielding some of the radiation from reaching the film badge worn on the chest, the film badge could conceivably read only one-half of the amount of radiation present in the surrounding environment."

  "Those calculations, we believe, seriously challenge DoD's assertion that the film badge provided an accurate indication of radiation exposure. At minimum, the film badge would not have accurately recorded the radiation that was absorbed by the crew member's body and shielded from reaching the film badge. In view of those calculations, our report recommends that DoD use integron readings in conjunction with film badge readings to better define cloud-sampling aircrew dose." ("Comment 10" pp. 70-71, GAO Final Report)

- DoD RESPONSE: Nonconcur. The GAO has seriously misquoted the information provided by the NCRP distinguished radiologist and film badge expert. He provided an explanation for differences, and concluded there was no reason to suspect that film badges underestimated the dose. His calculations demonstrated that free-in-air measurements of radiation levels are higher than measurements made at the body surface because of shielding by the torso, He also made it clear that, for determining the whole body radiation exposure, the body surface measurements should be used. He specifically stated the following:

  "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 sub-

stitution of the higher integron values would be inappropriate..." He goes on, "The film badge actually on the person is probably the best arbiter of dose."

In a more recent letter of November 12, 1987 (provided at enclosure 12), Dr. Warren Sinclair stated, "I do not believe (a) that integron readings should be used in lieu of film badge readings, but (b) I do believe they would be helpful in cases where the film badge is suspect. (Note the integron could be suspect too and is unlikely to have a better performance than film badges.)"

Also, Dr. Harold O. Wyckoff, the former Head of the International Commission on Radiological Protection in a November 24, 1987 letter stated: (provided at enclosure 13)

> "Furthermore, a value of 1.25 obtained from film badge and integron readings should not be used to correct the film badge reading."

Dr. Wyckoff also provided information on the effect of integron placement in relation to pilot and observer. In closing, he stated:

> "I am still of the opinion that the GAO report should not be published."

- GAO REBUTTAL 6: Experts Reviews of DoD Analysis. The DoD advised that, because its conclusion conflicted with the GAO statement--"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"--it contacted the five scientists interviewed by the GAO and asked them to review the DoD analysis. The GAO noted that all five scientists concurred in the DoD analysis. According to the GAO, however, the DoD provided the scientific advisors an analysis of REDWING integron-to-film badge comparisons separately for the F-84 single seat and B-57 double seat cloud-sampling aircraft. The GAO noted that the DoD ratio for the F-84 aircraft was 1.61 and for the B-57 aircraft was 1.23. The GAO observed that, because the integron was not similarly positioned in both aircraft at OPERATION REDWING, the DoD concluded that positioning accounted for the difference in average ratio for each aircraft, and the five scientific advisors agreed. The GAO, on the other hand, asserted the following:

  > "If DoD had also provided these advisors with a similar analysis of data for Operation Teapot, held in 1955 (the year before Operation Redwing), the analysis would have shown that the average integron-to-film badge ratio for the F-84 aircraft was 1.24 and for the B-57 aircraft was 1.35. Whereas, at Operation Redwing, the integron-to-film badge ratio was higher in the F-84 as opposed to the B-57 aircraft, at Operation Teapot the reverse was true. Thus, historical review of other test operations would not support DoD's conclusion that differences in radiation readings can simply be explained on the basis of the type of aircraft used." ("Comment 11" p. 71/GAO Final Report)

- DoD RESPONSE: Nonconcur. The DoD has pointed out previously that many factors play a role in determining the ratio of integron to film badge readings. The attempt to draw correlations between the ratio of integron to film badge from test-to-test or aircraft-to-aircraft is not relevant to the assignment of individual dose. This only proves that the film badge worn on the body is still the best indicator of dose to the individual.

- GAO REBUTTAL 7: Effects of Lead Vests. The DoD advised that, according to the assistant scientific director for cloud-sampling at REDWING, the lead vest covered the front of the body from the shoulder down to and including the bladder and gonads. The DoD pointed out that, according to a 1957 study of cloud samplers, the vest reduced the radiation level by six percent, and based on a 1962 study of cloud samplers at DOMINIC I, the pilot seat offered at least as much shielding from radiation as a lead vest would have provided. A pilot at REDWING was shielded by both the vest and seat. The GAO responded:

  > "In preparing our report, different opinions were provided to us on the area of the body covered by the lead vest. Figure III.1 of cloud-sampling personnel at Operation Plumbbob (1957) shows that the lead vest extended from the shoulders down to just below the waist but did not cover the bladder or gonads. REDWING cloud-sampling pilots whom we contacted indicated that the lead vest used at that operation was of similar design and provided similar protection, and did not cover the bladder or gonads." ("Comment 13" p. 71/GAO Final Report)

- DoD RESPONSE: Nonconcur. Information from the consultants, who knew most about the use of the lead vest (i.e., those responses provided at enclosures 3 through 8), indicates that when a pilot sits in the seat of an aircraft, the heavy lead vest falls down over the pelvis and effectively shields the gonads, the bladder and pelvic bone structure. In addition, the heavy seat provides significant additional shielding to this region of the body.

- GAO REBUTTAL 8: Whole Body Exposure. The DoD advised that the vest and seat shielded the gonads and more than 80 percent of the blood forming organs, and the only uncovered area was the eye lens (which the VA does not regard as a site for radiogenic illness). Consequently, the DoD concluded that the film badge worn under the lead vest reflects the whole body dose as defined by the NCRP. In response, the GAO contended:

  > "The NCRP (National Council on Radiation Protection and Measurements) defines whole body exposures as exposure to the blood forming organs, or specifically the red bone marrow, gonads, and to the lens of the eye. According to a NCRP distinguished radiologist and film badge expert, 50 percent of a person's red bone marrow lies below the waist. To the extent that the lead vest extended from the shoulders down to only just below the waist, the film badges worn underneath the lead vest would not reflect the radiation dose to about 50 percent of the red bone marrow (lying below the waist), the gonads, or the lens of the eye." ("Comment 14" p. 72/GAO Final Report)

- DoD RESPONSE: Nonconcur. As noted in the response to the GAO Rebuttal 7 above, the lead vest afforded much more protection than the GAO implied (i.e., the GAO stated that the film badge worn beneath the lead vest would not reflect the radiation dose to about 50% of red bone marrow). DoD believes the lead vest was effective in reducing exposure to much of the red bone marrow in the pelvic region, which includes 36% of the body red bone marrow. The additional effect of tissue shielding and the shielding of the seat would mean the film badge still over-estimated the dose actually received by the pelvis, gonads and red bone marrow.

- GAO REBUTTAL 9: Thyroid Cancer or Eye Lens Disability. The DoD advised that, 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 six percent higher. In response, the GAO contended:

  > "According to the early cloud penetration report for Operation Teapot (1955), the lead vest worn during that operation reduced the level of radiation exposure to the chest by about 15 percent. Thus, DoD may want to review the available information on the effectiveness provided by the lead vest for the various atmospheric nuclear weapons testing operations before it reports any adjusted dose to the bladder, eye, or thyroid to the VA." ("Comment 15" p. 72/GAO Final Report)

- DoD RESPONSE: Concur. Based on materials presented in the GAO rebuttal, 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 as much as 15 percent higher.

* * * * * *

RECOMMENDATIONS

- RECOMMENDATION 1: The GAO recommended that the Secretary of Defense direct the Defense Nuclear Agency (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. 5/GAO Final Report)

- DoD Response: Concur. This recommendation is essentially moot, however. 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 responsibilities of the Services to ensure consistency and sustain the effort required for this task. (The Air Force, Navy, Marine Corps and Army responsibilities have already been assumed by the DNA.

- RECOMMENDATION 2: The GAO recommended that the Secretary of Defense direct the Defense Nuclear Agency to use integron readings, in conjunction with film badge readings, to better define the radiation dose received by cloud-sampling personnel for all atmospheric nuclear weapons test, including OPERATIONs REDWING and DOMINIC I. (p. 5/GAO Final Report)

- DoD Response: Nonconcur. The personnel doses are not better defined by using integron readings in conjunction with film badge readings. The integron readings are considered less accurate than the film badge readings in measuring the radiation doses received by the crews. This was effectively stated by Dr. Warren K. Sinclair, the President of the National Council on Radiation Protection and Measurements, as follows:

  > "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 likely to be correct as in other occupational circumstances."

26 May 1956

Dr. Thomas L. Shipman
Box 1663
Los Alamos, New Mexico

Dear Tom,

This seems like a better way to get news to you. Last letter was written by me on Saturday, then it was Monday before I could get written and cleared and off to you.

The past week since the shot Monday has been relatively quiet. There was only nominal contamination on Bikini Atoll, for reasons which I'm sure you have heard. We had traces of fall-out both here and on Bikini the morning of the 23rd. It was pegged here as between 0300 and 0500, seems to have come during showers and lasted only a few minutes. The maximum reading was of the order of 0.5 mr/hr. Beta plus gamma on surfaces. The Eberline air monitors are in shape and running now. On the 24th and 25th we picked up several peaks. The maximum intensity occurred at 1930 the 24th, lasting approximately 10 minutes, and peaking at 3000 d/m/ft^3.

We are still having some difficulties with the permanent film badges. Those worn six weeks are showing what looks like water marks. Apparently the cellulose acetate is sufficiently permeable the water vapor is getting through. Then it condenses during the night and does produce some spots. Approximately one percent of a reatively small sample checked are badly spotted to the point that they cannot be truly read with either the Shlaer or Ansco densitometers. However, any reading made will err on the safe side. We are presently trying coatings of crylon and ceresin wax, at Si's suggestion, to see if we can keep the water vapor out. We are also trying a tumbling experiment to determine wheither shaking of the packet inside the plastic can wear the paper at the packet edges enough to cause light leaks. We are having some flashing along the edges, not enough to affect the area of the badge we normally read. I have a feeling the edge leaks are caused more by the water vapor, loosening the glue holding the packet together. We'll see.

That's about all the news. We are almost to the state of dual capability and are hoping for weather which will allow us to fire both barrels.

Stopi and Vay Shelton promoted a trip to Ponape yesterday, due back today. I understand Bradbury and Carson Mark were also in the party.

Yours truly,

ENCL 2

[redacted]

ANNEX A

TO APPENDIX A OF ENCLOSURE N

PHOTODOSIMETRY

1. Film Badges: The film badge program was designed to provide a dosage indicating device to all personnel in the Task Force in order that complete dosage information could be maintained on everyone entering the Christmas and Johnston Islands area during the Operation. Film badges were issued to all individuals upon their arrival at these locations, with instructions that the badge would be worn at all times, and would be turned in on recall by Radsafe Branch, upon exit from any contaminated area, return from a cloud sampling mission, or upon departure from the test area. The badge consisted of the DuPont 556 film packet (508 component 0-10r range and 834 component 0-1000r range) dipped in ceresin wax and then packaged in a rigid polyvinly chloride (PVC)case. The purpose of the wax dip and the PVC case was to make the film packet impervious to moisture in order that it might be worn for several months without deturioration. Based upon extensive experience, and a check of overall efficiency of the packaging of similar badges used during Operation HARDTACK (JTF 7), it was not expected that any significant failure in packaging would occur. However, near the end of the operation when certain film lots were being processed, it was observed that higher-than-expected dosage readings were being obtained. An immediate check of the rosters revealed that the individuals who had worn the badges could hardly have received such dosages, since they had not participated in any operation which would have subjected them to such an exposure. A subsequent analysis of the film indicated that the film pack suffered deterioration due to environmental conditions. This deterioration was sufficient to cause an erroneous reading of the film. Careful examination of the film base fog revealed the pattern observed to be that characteristically associated with environmental damage such as heat, light,and humidity, and not that of ionizing radiation. The wax dip was suspected of being inadequate, rendering the film packet vulnerable to seal failure with resultant light damage.

2. Film Badge Processing and Record Posting:

a. Two dosimetry sections were required for the Pacific Test Area. One was established at Christmas Island and the other in Honolulu, Hawaii. The Christmas Island section handled all film badge dosimetry for the Christmas Island operations, using the Honolulu installation as a back-up. The Honolulu installation performed all dosimetry for Johnston Island the Barbers Point personnel of the Task Force.

b. During the period 1 April - 1 November 1962, 43,000 film badges

 [redacted]

[redacted]

were issued, processed, and the information recorded. Records were maintained on approximately 30,000 individuals. Film was processed using standard techniques. Density shown on film was then read using the Eberline densitometer and converted into dosage using a standard calibration dosage curve. The calibration curve was established under the normal process of exposing unused film against a known radiation source strnegth for specified periods of time.

c. The dose records cards (5 x 8 cards) were prepared in the Honolulu section, utilizing four to six female clerks hired locally. Approximately 20,000 five-by-eight data cards were typed and initial dosages posted.

d. Film badges worn by sampler aircraft crews were collected immediately after each event and returned to Radsafe Branch Dosimetry Section for expeditious processing (6 hrs) of dosage information to successive sampler crews. A photodosimetry trailer on loan from the USAF, operated by JTF 8 radsafe personnel, was located in the JOC area. This trailer contained the necessary equipment for developing and drying film. Subsequently, film was read in the FS-3 densitometer manufactured by the Eberline Instrument Corporation. Two such instruments with auxilliary punch card readout, together with an addressograph machine, were situated in the building next to the trailor. This completely air conditioned building housed the dosimetry section and the TU 8.5.1 radsafe office on one end, the JTG 8.4 instrument repair section on the other end, and provided utilities service to the photodosimetry trailer.

e. Near the end of the Christmas Island test series, the dosimetry operation at Christmas Island was relocated in Honolulu, Hawaii.

f. On 1 November 1962 the Honolulu dosimetry operations were terminated and preparations were initiated to transfer all processed film, film requiring processing, and records and materials to the Nevada Test Site (NTS), Mercury, Nevada. Reynolds Electrical and Engineering Company (REECo), located at NTS had agreed to do the final portion of the film badge processing and prepare a final IBM listing with the assistance of several selected JTF 8 radsafe personnel. Four of the original JTF 8 radsafe personnel arrived at NTS on 7 November 1962, and the remaining three arrived during the period 17-20 November 1962. The equipment and associated materials began to arrive at NTS between 14-17 November 1962.

g. Approximately 10,000 film badge packets were opened by JTF 8 radsafe personnel and sent to the REECo dosimetry laboratory for processing. Approximately 1,000 additional five by eight data cards, NAVMED forms (Naval Medical Forms indicating U.S. Navy issue), and approximately 30,000 listings were posted, finalized and coded for IBM key punching during the period 17 November 1962 - 11 January 1963.

 [redacted]

[redacted]

h. In order to utilize the IBM system for listing final rosters, organization codes were established by groups in the quantities indicated below:

GROUP	NUMBER OF SEPARATE CODES
HQ JTF 8	10
U.S. Army	92
U.S. Navy	162
U.S. Air Force	400
Civilians	85
Total:	749

i. Interim listings were furnished by the IBM division of REECo, and after the final review, all dose cards were sorted and the final listings were prepared in the quantities as follows:

TYPE	NUMBER OF LISTINGS
Alphabetical	12
Alphabetical-Organization	12
Service-Alphabetical	4
Service-Organization	4
Numerical-Non-Returned Badges	4
Alphabetical-Non-Returned Badges	4
Unassigned Badges	4

j. All copies of the final rosters were delivered to Hq, JTF 8, Washington, D. C. by the NCOIC, JTF 8 Radsafe Branch. The reports were then separated and sent to the proper cognizant agency: Surgeons General, U.S. Army, U.S. Air Force; Chief, Bureau of Medicine and Surgery, Navy Department; Chief Medical Officer, U.S. Coast Guard; and the Division of Operational Safety, USAEC.

k. Four JTF 8 radsafe personnel remained at NTS for the final roll-up which included assembling all final data records and processing film into acceptable order for proper storage at NTS by REECo. Upon completion of all dosimetry work for Operation DOMINIC, with the exception of unreceived film badges, the JTF 8 Radsafe Branch Dosimetry Section was dissolved and all personnel returned to their home station.

3. Pocket Dosimeters: Pocket dosimeters, Bendix Model No. 611, 0-5 r range, were also used as a means of obtaining quick information on aircraft crew dosage.

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AD A995161

ENCLOSURE N

TO THE
REPORT BY

COMMANDER
JOINT TASK FORCE EIGHT

ON THE

1962 PACIFIC NUCLEAR TESTS
(OPERATION DOMINIC)

★

RADSAFE

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2.1.2 Contamination.

2.1.2.1 Cockpit Radiation Background After Penetration. The radiation background to which crew personnel are exposed after departing the cloud arises from the deposition of radioactive debris on the exterior surface, ducts, and engines of the aircraft. Since the retention of debris by these areas varies from aircraft to aircraft of the same type and from shot to shot, variation in the background acquired will be experienced. Other factors such as airspeed and air density may also affect the amount of contamination acquired but will not be discussed here. For practical purposes it can be assumed that on the average the radiation rate in r/hr in the cockpit of the F-84G airplane will be approximately equal to the integrated radiation exposure in roentgens acquired in the cloud, when the airplane samples between 25,000 and 40,000 feet. In the case of the B-57B airplane, the radiation rate in the cockpit should be approximately one-half (0.5) of the integrated exposure because of its different air duct-engine configuration. These ratios apply to clean, acid brightened and grease-free aircraft. The presence of grease, dried gunk, mud from a bomb-cloud, or other "sticky" material near the crew compartment will greatly increase the cockpit background rate in proportion to the radiation exposure acquired within the cloud.

2.1.2.2 Radiation Exposure Received During Return to Base. The fractional increase in radiation exposure received by crew personnel while returning to base after a cloud penetration will be determined by the initial magnitude of the cockpit radiation rate, its rate of decrease, and how long the crew are exposed. Naturally, the variation between aircraft mentioned above will cause considerable variation in the fractional increment to be experienced. Assuming that shots fired at Eniwetok will require one-half of the time for the sampling aircraft to land as those fired at Bikini, and making use of past data averaged for many shots and aircraft, the values assumed for the fractional increase in radiation exposure for REDWING are given in Table 2.0.

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HEADQUARTERS
TASK GROUP 7.1
Joint Task Force SEVEN
APO 437, Box 1
San Francisco, California

1174-JPE (DEL) 16 April 1956

SUBJECT: Program 11's Standard Cloud Sampling Mission Plans for REDWING

RESTRICTED DATA
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TO: Distribution

1.0 INTRODUCTION

1.1 The size of samples which can be collected by sampler aircraft from clouds of radioactive bomb debris is directly proportional to the radiation exposure received by crew personnel while in the cloud, the length of time after burst, the indicated airspeed at which penetration of the cloud is performed and the airflow developed through the filter unit carried by the aircraft. There is also a direct dependence of sample size upon the square root of the ambient air density which will cause larger samples to be collected at lower altitudes because of the higher air density. When the size of sample required is known, it is possible to specify values for these parameters which will enable the aircraft to collect the quantity of debris required.

1.2 The choice of values for these parameters in specifying a mission plan for bomb cloud sampling must be consistent with the characteristics of both the sampling aircraft used and the bomb cloud to be sampled, and with the limitation imposed upon crew radiation exposure. Reconciliation of these factors must in turn incorporate an assumption of the effects caused by probable wind and weather conditions. It should include an estimate of the effect which deviations from the weather picture assumed will have on the sample collection capability afforded by the basic plan. The characteristics of the aircraft, bomb clouds, weather and collection capability assumed are given in the following pages. These data are included for reference by the operational director of the actual sampling missions and will support the requirements of the mission plans described herein.

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PACIFIC PROVING GROUNDS

May - July 1956

Project 2.66a

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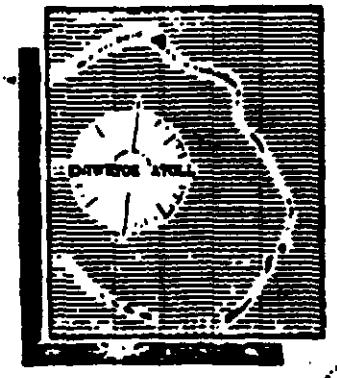

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after detonation for devices.

Considering Table 3.3 and Figure 3.3, it may be concluded that one may fly through the cloud from any yield 100-percent-fission weapon in a high-performance aircraft at an altitude of 45,000 feet at 20 minutes after detonation for an expected radiation dose of 25 r. Under the same conditions, one may fly through the cloud (stem) at 30,000 to 40,000 feet as early as 10 minutes after detonation for a radiation dose of 15 r or less.

TABLE 3.3 AVERAGE RADIATION DOSE RATE IN DIAMETER OF, AND RADIATION DOSAGE IN TRANSIT OF, RADIOACTIVE CLOUDS FROM MEGATON-YIELD WEAPONS AT VARIOUS ALTITUDES AT 20 MINUTES AFTER DETONATION

Assumptions: (1) 100-percent-fission-yield detonation; (2) aircraft speed of 420 knots; (3) tropopause at 55,000 feet; and (4) water-surface or air burst.

Altitude	Yield			Yield		
	Cloud Diameter	Radiation Dose Rate	Transit Dose	Cloud Diameter	Radiation Dose Rate	Transit Dose
$\times 10^3$	miles	r/min	r	miles	r/min	r
[illegible]	5	0.5	0.4	7	0.5	0.5
[illegible]	7	0.8	0.8	10	0.8	1.2
[illegible]	10	2.5	4	15	2.5	5
45	15	12	25	20	8	25
50	20	10	30	35	15	75
55	0	—	—	40	—	—

3.6 CONTAMINATION FACTOR

The contamination factor was defined and discussed in Section 2.3.9. Values given in Table 3.1 are from computations made using each of the methods of calculation which were described. The average contamination factor for B-57B aircraft is 0.6 ± 0.2 percent per minute. Both methods of calculation gave about the same value. With a contamination factor of this magnitude, a return to base flight of several hours duration after an early penetration of a radioactive cloud would result in a radiation dose to the crew, during the return flight, of about 25 percent of the total dose. One extremely high contamination factor computed for a penetration of the Shot Apache cloud at 20,000 feet is discussed in Section 3.8.

The contamination factor for any particular type of aircraft is a function of the distance between the crew compartment and the residual contamination on the aircraft. In general, the engines are the most highly contaminated portion of the aircraft after flight through a radioactive cloud. Project 2.8 of Operation Teapot measured contamination factors on several different types of aircraft and concluded the contamination factor to be higher for those aircraft where the crew compartment was close to the engine or engines (see Reference 8).

3.7 DECAY OF CONTAMINATION ON THE AIRCRAFT

The two methods used to measure the rate of decay of gamma radiation in the cockpit because of contamination on the aircraft gave essentially similar results, as shown in

TABLE 3.1 CONTINUED

Due to difficulties in instrumentation, the P meter readings are not considered to be as accurate as other monitoring techniques.

Item	Total Integrated Radiation Dose Received on Flight, r						Integrated Radiation Dose Received During Transit of the Cloud, r			Integrated Radiation Dose Received on Flight to Base After Exit from Cloud, r				Total Dose Received After Cloud Exit, pct		Decay Function of Contamination on Aircraft, Negative Exponent of Time	
	P Meter	Biocel	Sigma-tron	Quartz-Fiber Dosimeter	NBS Film	Rad-Safe Film	P Meter	Biocel	Sigma-tron	P Meter	Biocel	Sigma-tron	TIB	P Meter	TIB Film	In Flight (P Meter)	On Ground (TIB)
1	0.17	0.3	—	—	0.3	0.3	0.2	0.3	—	—	—	—	0.02	—	—	—	1.34
2	—	—	—	—	0.2	0.2	—	—	—	—	—	—	0.05	—	—	—	1.50
3	0.33	—	—	—	0.2	0.2	0.1	0.1	—	—	—	—	0.04	—	—	—	1.55
4	3.2	0.8	2.0	1.0	1.2	1.2	3.2	0.8	—	—	—	—	0.16	—	15	—	1.54
5	2.7	3.5	3.0	1.8	1.8	2.1	2.1	2.4	1.5	0.6	1.1	0.5	0.34	22	19	1.6	1.64
6	2.4	2.4	2.5	2.1	1.9	1.5	1.9	1.9	1.5	0.4	—	1.0	0.42	19	22	—	1.62
7, 8	—	—	—	—	1.8	1.5	—	—	—	—	—	—	0.46	—	—	—	1.54
9	5.3	5.7	—	5.4	4.8	3.3	4.3	4.2	—	0.8	1.5	—	1.03	16	21	1.7	1.54
10	—	—	6.8	3.4	4.1	3.0	—	—	4.0	—	—	2.0	1.34	—	32	—	1.61
11	6.4	8.8	9.5	8.0	7.2	7.6	5.6	7.5	7.5	0.8	1.3	2.0	0.76	12	11	1.8	1.52
12	3.3	5.2	3.2	2.2	2.6	2.2	2.9	4.6	3.0	0.4	0.6	0.2	0.34	12	13	1.7	1.40
13	0.3	0.4	—	—	0.3	0.3	0.3	0.4	—	—	—	—	0.03	—	—	—	1.70
14	0.1	0.1	—	—	0.2	0.2	0.1	0.1	0.2	—	—	—	0.02	—	—	—	1.21
15	4.8	5.0	7.5	6.0	5.7	5.4	4.4	4.6	6.0	0.3	0.4	1.5	0.70	7	12	1.9	1.37
16	20.5	18.0	—	15.0	15.0	16.0	19.4	16.0	—	1.4	2.0	—	1.20	7	8	1.7	1.45
17	18.6	—	—	—	—	—	17.6	18.0	18.0	0.8	—	—	—	3	—	—	—
18	1.9	12.0	17.0	17.0	17.0	14.0	1.8	1.8	1.2	0.2	—	—	—	9	—	—	1.50
19	7.2	—	—	—	—	—	0.1	0.1	0.2	7.1	—	—	—	99	—	—	—
20	22.2	—	20.0	17.0	16.0	15.0	21.1	—	18.0	1.1	—	1.2	1.10	5	7	1.5	1.39
21	4.4	5.0	7.5	5.1	5.7	4.7	4.1	4.6	7.0	0.3	0.4	0.5	0.44	6	8	1.8	1.44
22	1.4	1.3	—	—	1.3	1.3	1.1	1.1	—	—	—	—	0.20	—	15	—	1.12
23	1.1	1.7	2.5	—	1.8	—	1.1	1.6	2.2	—	—	0.3	0.15	—	8	—	1.13
24	1.3	—	2.3	—	1.4	1.3	1.2	—	2.0	—	—	0.3	0.10	—	7	—	0.95
25	—	—	—	—	—	—	0.3	0.4	0.5	—	—	—	—	—	—	—	—
26	0.4	—	—	—	0.7	0.6	0.06	0.1	0.2	—	—	—	0.06	—	9	—	0.95
27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 3.1 SUMMARY OF CLOUD PENETRATION DATA

Due to difficulties in instrumentation, the P meter readings are not considered to be as accurate as other monitoring techniques.

Item	Shot	Time of Penetration Min After Detonation	Indicated Altitude of Penetration	Length of Time in Cloud	Maximum Dose Rate in Cloud r/min		Average Dose Rate in Cloud, r/min			Dose Rate in Cockpit After Cloud Exit mr/min		Contamination Factor of Aircraft, pct/min	
					P Meter	Biocal	P Meter	Biocal	NBS Film	P Meter	TIB	From P Meter	From TIB and Film
			$R \times 10^3$	min									
1	Cherokee	75	42	4.2	0.13	0.14	0.04	0.07	0.06	—	0.0	—	0.3
2		68*	40	2.0	—	—	—	—	0.10	—	0.0	—	—
3		59*	39	2.6	0.09	0.12	0.04	0.06	0.06	—	2.0	—	1.2
4	Zuni	70*	46	3.9	1.9	0.33	0.03	0.20	0.25	18	5.0	0.6	0.5
5		60*	44	3.9	1.00	1.03	0.56	0.62	0.37	21	10.0	1.0	0.7
6		52*	41	3.4	0.9	0.92	0.56	0.63	0.44	10	15.0	0.0	1.0
7	Flathead	65	47	2.4	—	—	—	—	0.56	—	10.0	—	0.7
8		70	34										
9		49*	46	2.1	4.4	3.7	2.1	1.9	1.0	32	20.0	0.0	0.7
10		56	44	1.5	—	—	—	—	2.2	—	45.0	—	1.3
11	Dakota	42	40	3.1	3.7	5.0	1.8	2.4	1.9	27	30.0	0.5	0.5
12		38	45	2.0	2.1	3.3	1.0	1.6	0.74	12	15.0	0.4	0.7
13		34	41	3.2	0.16	0.25	0.06	0.12	0.09	—	1.3	—	0.5
14		28	35	1.1	0.33	0.23	0.11	0.06	0.14	—	0.0	—	0.5
15	Apache	44	42	7.0	1.2	1.4	0.03	0.05	0.72	21	29.0	0.4	0.0
16		35	47	5.0	7.7	6.7	3.5	3.3	3.0	77	62.0	0.0	0.5
17		34	45	5.0	7.0	6.7	2.0	2.0	—	94	—	0.5	—
18		45	33	3.1	1.3	0.8	0.61	0.58	—	17	—	0.0	—
19		53	30	0.3	0.22	—	0.22	0.33	—	222	—	300	—
20		28	40	6.2	7.7	—	4.0	—	2.7	65	60.0	0.3	0.5
21		20	41	3.0	3.2	3.3	1.1	1.2	1.5	27	41.0	0.7	0.0
22	Navajo	30	49	4.9	0.67	0.6	0.20	0.25	0.32	—	0.3	—	0.6
23		27	47	4.0	0.67	0.9	0.20	0.42	0.41	—	0.0	—	0.4
24		25	45	4.0	0.94	—	0.39	—	0.32	—	3.2	—	0.3
25		22	40	3.4	0.10	0.25	0.06	0.12	—	—	—	—	—
26		27	37	1.0	0.07	0.00	0.02	0.03	—	—	2.3	—	—
27		33	30	0.7	0.02	0.03	0.01	0.02	—	—	—	—	—

* Indicates 180 degree turn penetration.

SANITIZED

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 response 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

HUSETTS GENERAL HOSPITAL ◆ HARVARD MEDICAL SCHOO

ARTMENT OF RADIOLOGY
ision of Radiological
ciences and Technology
Director:
EDWARD W WEBSTER, Ph.D.
Professor of Radiology (Physics)

Mailing Address:
Massachusetts General Hospit
Boston, Massachusetts 02114
(617) 726-8326/3078

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.

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 ± 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" betwee 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 typica exposure rates to personnel removing the samples (mR/hr)?

Page 40, Figure 2.2: It could be that the 4095 mR permaner 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 tota 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 discusse 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 leng 2', the bladder would be covered.

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

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

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

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

Page 59, 2nd Para. Too much is made of the difference betw the older 1.25 ratio (average) and the later 1.4 to 1.6. First t 1.25 (5th line) should be 1.25± 0.25. Second, add "This factor c well be 1.5 ± 0.3 if account were taken of the over-reading of th energy component of gamma rays." Third, also add "In Re ing it evident that this ratio was dependent on the aircraft [illegible] due to different [illegible]

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

This copy made at U.S. Government expense.

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	2.631

Integron dose 4π exposure
* 0.5 mm Pb. body shield (vest)
** Well-filtered 200 kV x rays
T-A-R = tissue/air ratio

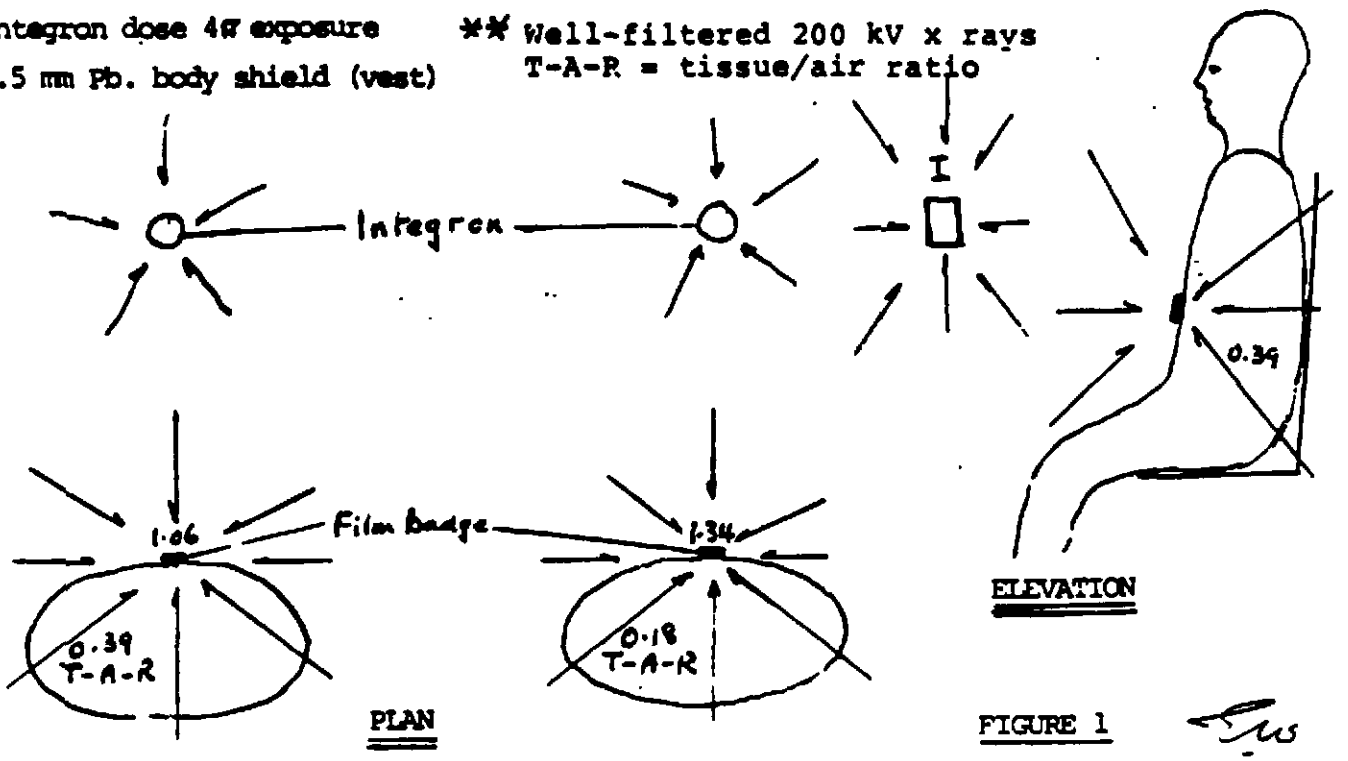

FIGURE 1

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 Guthals

Paul R. Guthals

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ENCL 7

5 June 1987

MEMORANDUM FOR THE RECORD

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Harry G. Hicks

Dr. Harry Hicks

ENCL 8

June 9, 1987

MEMORANDUM FOR THE RECORD

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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

ENCL 9

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"

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Harold Plank

Dr. Harold Plank

6-24-87

ENCL 10

FINDING G: Monitoring Devices Read Higher Levels of Radiation than Anticipated Compared to the Film Badges Worn by the Aircrews. 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 noted that several different explanations were offered 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 re-examination of integron readings should be made. (pp. 43-49, p. 59/GAO Draft Report)

DoD Position: DoD nonconcurs. The ratio of 1.25 plus or minus 25% between the integron and the film badge measurements for Operation TUMBLER-SNAPPER is valid only for the B-57 aircraft. 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 15%. The ratio for the F-84 aircraft at REDWING was 1.61 plus or minus 30%. 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 film badge measurements was 1.39 plus or minus 30%. 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.

FINDING G: (Continued)

At DOMINIC, a film badge was placed on top 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 very close: 0.97 plus or minus 30%. This data demonstrates that the difference in readings between the integron and the film badges worn by personnel were due to differences in the radiation environment that they were exposed to and not errors in either the integron or the film badges, and confirms that the film badge provided an accurate measure of radiation exposure.

Because the DoD conclusion that the radiation environment varied with location in the aircraft was 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.

Engineering-Science
Associates

2454 W. Bayshore Rd., #10
Palo Alto, CA 94303
(415) 856-2187

ANSWERS TO GAO QUESTIONS

1. a) Within the probable error for film badges they are an accurate measure of radiation exposure. At Stanford University Medical Center,where radiation is used for various types of cancer therapy, Dr. Roland Finston. Head of Health Physics, has told me that film badge error might be as much as ±20%. He was thinking of uncontrolled, haphazard kind of use without well trained personnel in film badge evaluation. In our case we had first rate people responsible for processing and evaluating exposed badges. In the field operating environment our potential problem with badges lay in the possibility that they could be contaminated on surfaces by radioactivity in post-shot handling and therefore give erroneously high readings. We, of course, took prudent measures to avoid this possibility. Two badges were used per pilot and the average of the two exposures was recorded.

1. b) Within a bomb cloud the median energy of fission product and neutron-activated sources of gamma radiation energy is approxmately 1 Mev. The process of multiple scattering by air molecules converts 25% of the total gamma radiation energy into 70 Kev radiation. Radiation of this energy is completely absorbed by very little lead shielding. Accordingly, in order to reduce pilot mission exposures, lead vests and thin lead shielding on the back and seat of the ejection seat assembly were devised. The pilot's vest and the seat shielding protected the trunk and thighs of the main body including the gonads. Because only arms, lower legs, neck and head were not so protected, I believe that the film gadge evaluation represents a fair measure of whole body exposure, taking account high badge readings that could arise from radioactive contamination. The protection afforded by the pilot shielding is similar to the protection used in dental and certain medical X-ray procedures.

2. a) The integron had the envelope and dimensions of an altimeter and was based on integrating ion chamber principles. Like an altimeter this instrument was mounted in the instrument panel in front of the pilot in a single crew aircraft like the F-84G. In a two crew-member aircraft seated in tandem as in the B-57B it was mounted in the instrument panel in front of the rear cockpit. In either of these position it indicated the exposuure that would be representative of the crew unshielded.

2. b) The integron was an accurate indicator of unshielded exposure at its position. It was impervious to cockpit pressure changes while in flight. Its response was flat across the gamma radiation energy spectrum. The instrument was developed and made in-house at the Los Alamos Scientific Laboratory. In the field it was routinely calibrated using a one curie radium source.

3. a) As discussed above the integron was not shielded. Therefore, it included the 25% of the gamma radiation energy at 70 Kev and the ratio of its exposure to film badge was 1.25.

3. b) As mentioned in paragraph 1. a), because of the possibility that film badges could be in error in a contaminated environment situation, we did routinely check this ratio. Results largely confirmed the 1.25 ratio. The observed ratio also occasionally alerted operations to badge surface radioactive contamination from whatever source. For example, if the ratio were found to be 0.625, it would indicate that the badge(s) had received surface contamination some where: inflight, postshot handling, or in developing. Our concern was to determine, as well as possible, what in fact our pilots exposure was on a particular mission. In the hypothesized example the film badge(s) would have been in error by a factor of two high. In such a case the integron exposure multiplied by 0.80 would give a good estimate of the proper film badge exposure. We worked with a guideline that 3.9 R per quarter was biologically acceptable and scheduled exposures to that limit or less as required.

4. a) As we moved from B-29 and B-50D aircraft to fighter type aircraft (T-33, F-84G) we found that their pressurization systems blew contaminated air across the pilot's head. So, in late 1951 into 1952 we devised pressurization filters to eliminate this problem. Of course, during post-flight decontamination, this radioactivity was detected immediately and removed. In larger aircraft like the B-57B with much larger volume and without direct air flow to the head we considered the problem to be less significant. But, you will note that we suggested for other reasons that pressurization filters be installed in the B-57BD.

4. b) Very high altitude aircraft like the B-57B maintain cockpit pressure at about 2.5 psi above ambient outside pressure. For example at an altitude of 50,000 ft. the cockpit pressure altitude would be equivalent to 35,000 ft. Standard preflight procedure required 10 to 15 minutes spent on 100% oxygen before take-off to denitrogenate the blood in order to avoid bends on climb out to sampling altitudes. As I recall, the aircraft had oxygen systems that used "pressure breathing" starting at a certain cockpit pressure altitude; above this altitude system automatically supplied 100% OXYGEN. Accordingly, the crews chances for inhaling radioactive materials would have been negligible if pressurization filters were not used.

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2454 W. Bayshore Rd., #10
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5. a) Am not certain just when 100% oxygen first was in effect before formally adopted in Operation Castle. As discussed in paragraph 4. b), the oxygen breathing system in the aircraft could automatically do the same thing.

5. b) In view of the above discussion the question is rather moot. Our crews were not operating in a "shirt sleeve" environment. Pressurization flow rate would have to be known required to maintain a cockpit pressure of 2.5 psi above ambient as well as the hold up of radioactivity in the delivery duct work system estimated. In my opinion the crews' chances for increased inhalation under the circumstances were negligble or only slightly higher if 100% Oxygen were not used.

H. F. P.

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

March 4, 1987

Dr. Harold F. Plank
2454 West Bayshore Road
Palo Alto, California 94303

Dear Dr. Plank:

My agency, the U.S. General Accounting Office (GAO), is an investigative arm of Congress. At the request of both the Senate Committee on Veterans' Affairs and the House Committee on Energy and Commerce, Subcommittee on Energy Conservation and Power, GAO has been asked to gather information on the radiation doses received by nuclear cloud sampling personnel during the atmospheric nuclear weapons testing program.

The reason for the Committees' interest centers around information regarding one of the tests--Operation Redwing in 1956--indicating there were devices installed on the cloud sampling aircraft that measured different radiation levels than was recorded on the film badges worn by the aircrews. Thus, both Committees asked us to specifically look at cloud sampling activities at Operation Redwing and at two other test operations arbitrarily selected subject to their approval. The two other operations selected have been Operations Tumbler-Snapper (1952) and Dominic I (1962).

Knowing that you played a key role in nuclear cloud sampling activities during the earlier atmospheric nuclear tests, I thought you might be able to help answer some of the questions we are trying to address. Those questions have been listed in enclosure 1. If you wish to know more about our work or discuss aspects about nuclear cloud sampling not touched on in those questions, please feel free to call me at (301) 353-5185. Otherwise, let me thank you in advance for your help. We feel your input is essential for us having a proper understanding of nuclear cloud sampling.

Sincerely,

Robert J. Baney

Robert J. Baney
Management Analyst

Enclosures - 4

ENCLOSURE 1

GAO QUESTIONS

1. The radiation film badge was and is used now as the official record of cloud sampling crews' gamma radiation exposure.

   a. To what extent was the film badge an accurate indicator of exposure?

   b. At certain tests, Operation Redwing in particular, the crews wore their film badges underneath a lead vest which covered only a portion of their bodies. In such cases, did the reading on the film badge provide a representative indication of whole body exposure?

2. For test operations, commencing with Operation Tumbler-Snapper in 1952, a device called the integron--an electronic total gamma dosage instrument--was apparently used to operationally control cloud sampling crews' exposures.

   a. Where was the integron generally positioned in relation to the aircraft crew?

   b. To what extent was the integron an accurate indicator of exposure?

3. Your April 16, 1956 memo on the subject of "Program 11's Standard Cloud Sampling Mission Plans for Redwing" (see enclosure 2) indicates that a constant ratio of 1.25 existed between the exposure on the integron to that on the film badges worn by the crew.

a. For what reason did the integron read higher by this ratio?

b. The memo also indicates that a routine check of this ratio was necessary in order to apparently assure accurate film badge results. Was this, in fact, done and what were the results?

4. Your January 24, 1957 letter to the Commander of the 4950th Test Group (see enclosure 3) indicates that pressurization filters were not used on the B-57B sampling planes at Redwing.

a. When, if ever, did it become a standard practice to use pressurization filters on sampling planes during the atmospheric nuclear weapons testing program?

b. To the extent that pressurization filters were not used, how did this increase the crews' chances for inhalation of radioactive materials?

5. The History of Air Force Atomic Cloud Sampling (see enclosure 4, pp. 102-103) states that for Operation Castle (1954), yet more precautions were taken for sampling pilots: "when the sampling pilot flew into the atomic cloud, he went on 100 percent oxygen and remained on it for the duration of the mission."

a. Did this practice of sampling pilots using 100 percent oxygen commence with Operation Castle? If not, when?

b. To the extent that 100 percent oxygen was not used, how did this increase the crews' chances for inhalation of radioactive materials?

ENCLOSURE 2

TITLE:

Program 11's Standard Cloud Sampling Mission Plans for Redwing, dated 4/16/56.

EXTRACT:

Pt. 3.1.4 "Radiation exposures are given in terms of film badge readings. Two each such badges should be worn by sampler aircraft personnel and the values averaged if in reasonable agreement. Comparison with the integrating dosimeter (integron) should be made routinely to detect possible errors in film badge exposures due to contamination during post-flight handling or other causes. The integrating dosimeter is used operationally to control film badge exposures. The ratio between its exposure and that of the film badges under the vest has been 1.25 in the past. A routine check of this ratio from shot to shot is necessary in order to assure good control of the film badge exposures specified.

NOTE: A copy of the complete memo could not be provided as it remains classified (SECRET/RESTRICTED DATA) as of this date. This part of the memo has, however, been declassified.

UNIVERSITY OF CALIFORNIA
LOS ALAMOS SCIENTIFIC LABORATORY
(Contract W-7405-Eng-36)
P. O. Box 1663
LOS ALAMOS, NEW MEXICO

J11-169 24 January 1957

Commander
4950th Test Group (Nuclear)
Air Force Special Weapons Center
Kirtland Air Force Base, N. Mex.
Attn: Lt. Col. Richard J. Hynes, Dir. of Opns.

Dear Col. Hynes:

I am replying to your recent letter which requested a detailed list of modifications and special equipment required by us to be incorporated in the future RB57D sampling aircraft. The detailed modifications and special equipment which are required in these aircraft are extremely well described in the Glenn L. Martin Co. report "A Proposal For An Air Sampling Version Of The RB57D," ER 7621P, October 1955 (SECRET), SWC 5512445-1/5, 5-RDZ-8054-5. These requirements were jointly agreed to between personnel of the Glenn L. Martin Co., AFSWC and LASL. This report describes the way the particulate filter units should be installed on the airplane, alternative installations for a gas sampling system, and the special radiation, communication, and navigation instrumentation required for both sampling and ferry missions. In addition, valuable aircraft performance data are included, such as climb and descent rates, turn radii, and typical ferry and sampling mission profiles in standard temperate and tropical atmospheres.

The requirements described in this report were based upon provisions then planned for the B-57B sampling aircraft. As might be expected, a few differences exist between what is shown in the report and the way the B-57B aircraft were actually instrumented. For your information, I would like to indicate which of the general provisions are still suitable and which should be brought into conformation with the existing instrumentation in the B-57B.

a. REDWING experience with operating the B-57B airplane at maximum altitude confirmed the requirement that the B-57D airplane should be flown with a crew of two as shown in Figure 2, page 4.

b. Installation of the forward filtering part of the existing B-57B wing tank filter unit on a nacelle-type structure as illustrated in Figure 1, page 3, Figure 32, page 51, Figure 33, page 54 and as described in Part IV, starting on page 49, is still preferred by reason of distance from crew compartment and ground clearance. The filter unit part of this structure will of course be furnished by LASL. It is assumed that design and fabrication of the nacelle and strengthening of the local wing area, as discussed on page 25, is to be accomplished through USAF resources in accordance with Dr. N. E. Bradbury's letter to Brig. Gen. W. M. Canterbury, December 23, 1955, reference DIR-1112, SECRET RD.

c. With the exception of the AN/ASN-6 Ground Position Indicator, which was found to be unsatisfactory, radiation, navigation, and communication instrumentation as provided in the B-57B airplane is required for the RB-57D sampler.

Ltr fm H. F. Plank to LtCol R. J. Rynes, Serial No. J11-469, dtd 24 January 1957 (Cont'd)

It should be noted that the layout of these items in Figure 19, page 32, is not as installed in the B-57B airplane. For uniformity we would prefer that the layouts in the two types of aircraft be the same. The navigation and communications requirements described in Section 6, page 61, were jointly formulated by AFSWC and LASL to support both the sampling mission and ferrying the aircraft to Eniwetok. It is understood that a replacement for the ASN-6 in the B-57B aircraft is being considered. It would appear that this replacement should also be installed in the RB-57D airplane.

d. As mentioned in Section E, paragraph 1 on page 30, the cabin pressurization system must be filtered to remove particulate contaminating debris. Experience during REDWING, in which such pressurization filters were not used in the B-57B, indicates that contamination admitted to the cockpit during sampling contaminates the film badges and can lead to errors of a factor of two in the apparent radiation exposure of the crew.

e. Although it does not appear to havebeen included in ER 7621P, installation of 1/32 or 1/16 inch lead sheet in the seats of the aircraft is required to afford protection of the crew against 70 kilovolt gamma radiation within the bomb cloud. The 1/16 inch sheet should be used if consistent with permissable weight for ejection.

f. The power requirements described in Section VIII, starting on page 67, are assumed to include power required for the operation of four gas sampling compressors. A modest 13 watts, 28V DC and 25 watts, 110V, 400 cycle AC of power for the Wing Tank Ion Chamber should have been included in Table 2, page 68. Wiring and power between rear cockpit and filter units like that in the sampling B-57B's must be provided.

g. LASL does not have a direct requirement for the equipment described in Section V, starting on page 55. It is suggested, therefore, that AFSWC query Mr. Walter Singlevich and Dr. Roger E. Batzel as to which of the alternative installations is to be used.

In general, dimensioned drawings or detailed circuit diagrams for the required modifications are not included in ER7621P. It should be possible, however, to secure suitable drawings and diagrams based on the B-57B sampling aircraft either from WRAMA, AFSWC or LASL. To illustrate the details of B-57B filter unit systems, I am enclosing herewith Century Engineers Inc., Drawing No. 106552 entitled "General Arrangement B-57B Wing Tank Filter Unit."

1 Incl:
Century Drwg 106552

Very truly yours,

Hal Plank

HAROLD F. PLANK

HFP/wm

DISTRIBUTION:
1 - Cdr, AFSWC, attn DCS/O w/Incl
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1 - Cdr, 4926th Test Squadron (Sampling) AFSWC
1 - Walter Singlevich, Hqs, USAF
1 - Roger E. Batzel, UCRL
1 - A. C. Graves
2 - Mail and Records
1 - H. F. Plank, J-11

V

immediately after the exercise for repairs. Also, the RB-36 sampler controller aircraft turned up some communications failures which needed correcting before operations started. By mid-December 1953, the USS ESTES had undergone work in San Diego and was ready for another test. General Estes, therefore, sent six F-84 samplers to San Diego to run a communications check and to give the pilots some additional practice on ground control interception. During this test, communications equipment worked satisfactorily aboard the ESTES.[19]

The value of a lead vest to protect pilots from radiation was demonstrated during Operation IVY. In August 1953, pilots of the sampler squadron worked out a new design for the vest. This consisted of a nylon, sleeveless vest which buttoned around the neck with fiberglass-lead shielding attached by four buttons. The fiberglass with lead woven into it was a quilted pattern and pliable. When the first copy of the new design arrived at Kirtland Air Force Base, the 4926th pilots took it to the swimming pool for safety tests. Escape from the vest, while in water, was found satisfactory. Dr. Plank suggested that the fiberglass-lead shielding be widened a bit to protect better and with this modification the vest weighed six pounds. The vest was manufactured for use during CASTLE.

Further precautions found the seats of the F-84G samplers covered with sheets of lead.[20] In addition, the pressurization system of the aircraft contained filters to keep out radiation. Yet more precautions were taken. When the sampler pilot flew into the atomic cloud, he went

on 100 per cent oxygen and remained on this for the duration of the mission. When the sampler pilot landed, a platform mounted on a fork lift removed the pilot, thus preventing him from coming into contact with the contaminated skin of the aircraft.[21]

Joint Task Force SEVEN limited personnel again to 3.9 roentgens exposure. Some personnel, conducting special experiments, had been exempted from this restriction and included were the cloud sampler pilots who were limited to 12 roentgens. This would allow the pilots to fly three or four missions. But pilots who were expecting to fly on future tests were restricted to 7.5 roentgens for CASTLE.[22]

Sampling CASTLE Shots

After the training program had been drastically delayed, General Estes arranged to have the sailing date of the aircraft carrier, USS BAIROKO, delayed so the pilots could have more time for this purpose. Scientific personnel opposed because the carrier was taking some aircraft to the islands which were required immediately. The advanced echelon of Task Group 7.4 arrived on Eniwetok 2 January 1954, and began preparing for the main party which arrived on 27 January. As noted above, the sampler people began an intensive flying program. Flights were made to check time schedules and communications. These were followed on 16 February 1954, with a full-scaled rehearsal of the Air Task Group units, and, 23 February 1954, with all participating units.[23]

CASTLE was to have seven shots, [redacted] However, one was cancelled and another changed so the

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Ken Street

Dr. Ken Street

June 5, 1987

ENCL 11

Lawrence Livermore National Laboratory

Excerpts of meeting notes with Dr. Edward Fleming and Dr. Kenneth Street, Oct. 16, 1986.

Notes taken by Paul T. Schafer of LLNL

Interviewers: Robert Baney and Robert Lilly of GAO.

Baney: We have reviewed data which shows in some cases integron readings which do not match with recorded film badge exposures on early cloud penetration tests. In fact in some cases integron readings double those of film badges were not uncommon. What do you feel is the more accurate reading?

Street: I have always endorsed film badge readings as those which best reflect radiation exposure to the body. Integron readings registered radiation doses at different points in the aircraft.

Fleming: Concurred with Street and noted that integrons were often a part of an experimental program of radiation measurements and would not necessarily reflect body dosages received.

Baney: Do you think that matching of this type of information is a reasonable thing to do? You know when you have an integron reading of 7 rads and film badge reading of 3 rads --

Fleming: I don't find a factor of 2 surprising. I would still rely on the film badge for measurements of body dosage.

Street: Concurred

Baney: How about on two or three flights when you compare this data in a cumulative nature.

Fleming: Not surprising.

Street: Not surprising. Those instruments don't provide an absolute measurement of dose.

Fleming: I thought of another possible reason why integron readings might be higher than those of film badges. I'm not sure of when they removed the instrument from the aircraft. If the integron meter remained in the aircraft after the pilots and observers were out of the aircraft, radiation readings would continue to increase.

Baney: Changing the subject slightly, what do you know about pilot exposure through inhalation? Our contacts with the military indicated that it was the pilots choice to use pure oxygen or go on automix. (mixture of outside air and oxygen).

Fleming: I find that hard to believe, unless it was only prior to cloud penetration. In every single flight in which I was associated we all breathed 100% oxygen, not only prior to and during cloud penetration, but also during the flight back to the landing strip and until we left the aircraft.

Street: Concurs

Baney: Did you ever run out of oxygen and or switch to automix?

Fleming: Never. The capacity of the oxygen system provided about 5 - 6 hours on pure oxygen. We were never exposed that long.

These statements are a faithful representation of the notes taken by me during the interview on 10/16/86.

Paul T. Schafer
6/2/87

These statements reflect my responses to questions raised in the interview, and I continue to endorse them.

Edward H. Fleming
6/2/87

(Dr. Street has since retired from the Laboratory and is not present to comment).

NCRP

National Council on Radiation Protection and Measurements

7910 WOODMONT AVENUE, SUITE 1016, BETHESDA, MARYLAND, 20814-3095 AREA CODE (301) 657-2652

WARREN K. SINCLAIR, Ph.D., *President*
S. JAMES ADELSTEIN, M.D., *Vice President*
W. ROGER NEY, J.D., *Executive Director*

November 12, 1987

Commander R.T. Bell, MSC, USN
Program Manager
Nuclear Test Personnel Review
Defense Nuclear Agency
Washington, D.C. 20305-1000

Dear Commander Bell:

Thank you for your letter received on November 12.

I have not previously had the opportunity to review the final version of the GAO report and all the comments associated with it. To do so in detail would take considerable time and you need a response soon.

I have scanned the material quickly and find some of the GAO statements ambiguous and at times obscure. Thus, it is not too clear what the GAO did accept about my previous comments. Some of them obviously.

My chief point would still be that I only partially concur with GAO recommendation two on page 5.

I do not believe (a) that integron readings should be used in lieu of film badge readings, but (b) I do believe they could be helpful in cases where the film badge is suspect. (Note the integron could be suspect too and is unlikely to have a better performance than film badges).

With regard to (a) GAO states on page 67 that they don't believe the integron should replace the film badge either. However, that is exactly what they do in the hypothetical records on pages 50 and 51. Furthermore, in item 10 on page 70 they imply that Dr. Webster's analysis indicates the film badge is in error. This need not be the case at all depending on the calibration. Calibration details are significantly lacking for both the film badge and the integron.

With regard to B, the examples GAO quotes at the foot of page 67 may be an instance in which the integron can be helpful. In the Redwing example 1, for instance, the integron would suggest the observers reading may be correct and in example 2 that the pilots reading may be correct. Assuming in both cases that the observer and the pilot badge are expected to read the same. Thus the integron could be useful in some suspect cases. These may be isolated examples however.

You ask specifically about (a) item 10 page 70 and I have dealt with that above and (b) item 14 page 72. (b) It is true that 50% of the red marrow may be in the lower part of the body and might only be partially shielded by the lead vest. However, this is really splitting hairs since the lead vest accounted for only about 15% reduction anyway and the true dose to the bone marrow in the lower half of the body is less than to the film badge because of tissue shielding which may be of the order of 30% - 40%.

In both cases, item 10 and item 14 exactly what Dr. Webster said is not cited. I think if Dr. Webster were consulted he might not care for these interpretations of his statements.

Regarding page 49, in paragraph 3, sentence 2, in spite of the tortuous language used here, it is evident that Sinclair, Wyckoff and Webster did not agree with replacing the film badge readings by the integron reading.

In the last paragraph page 49 and on page 83 it is also clear that we thought the integron could provide general confirmation of film badge readings (and we would generally expect it to read higher!) and indeed it seems to do so.

Regarding the second paragraph on page 82, I find this paragraph especially confusing. As far as I am aware the GAO did not previously (in the report itself) refer to these circumstances in which possible over statement of the dose occurs. I merely felt that a balanced account should be presented rather than one with a clear bias. That is still my view. However, I would say that the GAO has toned down their comments considerably since the first version.

I hope this answers your questions.

Yours sincerely,

Warren K. Sinclair

Warren K. Sinclair
President

P.S. I note the comment made in the letter by the Under Secretary of Defense that GAO's second recommendation might be submitted to independent review such as the Office of Technology Assessment. I agree with an independent peer review. It must surely be more sensible to have technical people deal with the technical issues involved and their review is likely to have more meaning.

cc: Dr. Wyckoff
Dr. Webster

WKS/clo

HAROLD O. WYCKOFF
4108 MONTPELIER ROAD ■ ROCKVILLE, MARYLAND 20853
Phone: (301) 460-1277

November 24, 1987

Cdr. R.T. Bell, MSC, USN
Program Manager
Nuclear Test Personnel Review
Defense Nuclear Agency
Washington, D.C. 20305

Dear Cdr. Bell:

I appreciate very much receiving a copy of the GAO report entitled, "Radiation Exposures for Some Cloud-Sampling Personnel Need to be Re-examined" together with comments on an earlier draft of the report. The GAO draft and their present report came after the DoD analysis of radiation exposure received by approximately 300 air force personnel involved with sampling bomb debris clouds. The exposure information resulted from film badges mostly worn by personnel and a device called a "integron" that was located in each plane's cockpit during the operations. In your transmitting letter of 10 November 1987, you asked that I review the present report and, if called for, provide you with additional comments. One finding of GAO was that there were some errors in copying from original data or in arithmetic. If, indeed, there were such errors, proper correction needs to be made. This is an area where the GAO personnel should be experts and DoD should review this finding and make proper adjustments. According to the letter from Barker of DoD to Conahan of GAO, DoD concurs.

The GAO comment starting on the last paragraph of page 67 of the GAO report doesn't seem to accept the comments of Sinclair and Webster with regard to the interpretation of the differences observed between values recorded from the film badges and the integron for a given flight. One must say "doesn't seem" because this paragraph indicates that the "integron reading could be used to arbitrate which film badge reading is correct." This is at variance with the contents of Item 10 on pages 70 and 71 on this topic. Item 2 (page 75) raises questions about the value for the integron and whether the value has zero uncertainty (with a large range of values that provide the 1.25 average given there, one must object to the arbitrary selection of such an average as applying to all situations. Furthermore, a value of 1.25 obtained from film badge and integron readings should not be used to correct the film badge reading). In addition, the last sentence on page 83 with regard to my agreement that integron readings could be used "to confirm or deny, in general terms, the reading made by the film badge" is ambiguous. Perhaps, GAO didn't understand the implications of the material supplied in some detail by Webster. This may not be surprising because GAO personnel have no background

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that would provide them an understanding of the meaning and importance of radiation attenuation for such measurements. It may be helpful to point out some estimated approximate relationships between the three readings for various locations and orientations of the plane. For convenience the relative values will be for a fixed location and orientation of the plane and for the same time increment for all situations. A common increment permits me to deal in terms of dose equivalent and not dose equivalent rate.

Prior to about 1977, it was usually assumed that a badge (either photographic film or other indicator) when properly calibrated and located on the front of the trunk of a person gave an adequate measure of the risk to the wearer. For such an interpretation, it was assumed that the radiation was incident primarily on the front of the trunk and the radiation attenuation in the trunk of the body was negligible. To more precisely estimate the value of a quantity that would take into account the difference in radiation sensitivity of the various organs of the body and the attenuation of the radiation by the body, the concept of effective dose equivalent (H_E) was developed and presented in Publication 26 of the International Commission on Radiological Protection in 1977.

In 1985 the International Commission on Radiation Units and Measurements (ICRU) produced a report on the relationship between what was called the "ambient dose equivalent" (H^*) and H_E (see Figure 1 of that report) when the incident radiation was defined in terms of (a) monodirectional radiation incident upon the front of the trunk of the body, (b) monodirectional radiation incident upon the back of the trunk of the body, (c) radiation incident normal to the long axis of the body when the body was slowly rotated about its axis and (d) radiation isotropically incident upon the body for various photon energies. For photon energies below 1 or 2 MeV and the usual range of times after detonation that would be of interest here--see, for example, "US-Japan Joint Reassessment of Atomic Bomb Radiation Dosimetry in Hiroshima and Nagasaki," published by the "Radiation Effects Research Foundation" in 1987, page 67--the value of H_E/H^* is about 0.9 for geometry a, 0.8 for geometry b, 0.7 for geometry c and 0.6 for geometry d. One may infer from these data that a lateral irradiation of the body would result in ratios of less than 0.7. In a report to be published by ICRU next year, there will be further information for other geometries.

With such information and a few additional geometry assumptions, one may make estimates of the badge readings for the pilot, observer, and for the "integron." It is assumed that the "observer" (when present) is immediately behind the pilot, that the "integron" is isotropically sensitive, that the value of H^* is the same for all locations in the cockpit except those possibly shielded by the wings and when the pilot and observer are not present. The attenuation of the radiation by the trunk of the pilot or observer is assumed to be about a factor of 2. The location of the aircraft is said to be "far"

from the fireball when the distance is many times the diameter of the cylindrical part of the cloud and that passes are made through or near the edge of this cylinder. Let us now consider estimates of H_E for four plane locations and directions.

The plane location is far from the cloud but is pointed towards the cloud. In this situation the pilot's dosimeter reading is not influenced by the radiation attenuation by the pilot. However, the reading of the observers dosimeter results after an attenuation of about a factor of about 2 by the pilot. For this situation the integron reads approximately 10% more than H_E for the pilot and within about 10% of the reading of the pilot's dosimeter if both dosimeter and integron read correctly. However, the reading of the observer's dosimeter will be about 2 times smaller than that of either the pilot's dosimeter or the integron. However, the H_E for the observer may be somewhat higher than that of his badge reading but still less than that for the pilot if the lineup of observer, pilot and center of the fireball is not exact.

Assume that the plane location is far from the cloud but pointed away from the cloud. If the center of the observer, center of the pilot and the integron are on a line to the center of the cloud, the reading on the observer's badge will be about 1/2 of the value of the incident dose on him. and the reading of the pilot's dosimeter will be about 1/4 of this incident dose. for H^* and the integron will read approximately the same as the pilot's badge. Note that the H_E will be approximately 0.8 (see Figure 1) of 1/2 and 1/4. Of course, if the observer is not present, then the attenuation factors for him and for the integron will be about a factor of 2 larger. Note for this case that the film badges, as well as the integron, read too small if one wishes to obtain an approximation to the effective dose equivalent.

Now let us consider the plane in the center of the cylindrical cloud so that the radiation without the pilot and observer being present is approximately isotropically incident on the cockpit. If the integron is on the dash of the plane, it will read an approximation to H^*. It is an approximation because the solid angle subtended by the pilot will attenuate a portion of the radiation which is assumed to be isotropic when the pilot and observer are not there. This reduction in attenuation will be somewhat less than a factor of 2. The pilot's badge will read approximately a factor of 2 less than that of H^* and, thus, will give a reading approximating H_E. However, if the integron is placed immediately under the pilot, the radiation incident on the integron from the upper 2π solid angle will be attenuated by the pilot's body, thus, the integron in this location might read approximately half as large as an integron on the dash. For such a location, the integron will, thus, read approximately the same as the pilot's film badge.

Now consider a horizontal plane path outside of, but close to, the cylindrical cloud. We will focus on the incremental readings when the plane is closesh to the cloud and assume that the attenuation of the wing will affect all readings equally. The contribution to H_E will be less than 0.7 of the incident dose for lateral irradiation. However, the film badges of both pilot and observer will be larger than half of the integron reading. Thus, the H_E for the pilot and observer will be about 0.7 of the reading of the integron.

Thus, for different locations and orientations, the pilot's badge may read from something approximately equal to H_E down to approximately 1/2 of H_E if no observer is present to 1/4 of H_E if an observer is present. Also, for various locations and orientations of the plane, the observer's badge may read from approximately 1/2 to 1/4 of H_E. Of course, the actual reading of each of the badges and the integron for a mission will depend upon the time spent in each of the locations and orientations. One should note that the reading increment per unit of time will be larger in the cloud than in the other locations. Thus, for a given mission, the pilot's badge reading should approach H_E provided the integron is placed immediately under the pilot's seat or behind the pilot's seat if there is no observer. However, because of the range of possible H_E to badge or integron readings, "corrections" of original badge or integron data should not be considered unless they differ by a factor of 2 (or perhaps 4 if one considers the uncertainty of both film badge and integron reading).

In addition to the foregoing, I have a few other comments on the comments of GAO.

Page 68, second paragraph. It is not clear what is meant by "informally expressed support." Is this to be inferred from the reproduction on page 75? I have reservations about the use of 1.25.

Page 69, fourth paragraph. It is not clear what the GAO is disagreeing with. One must assume that a value of 23 rem can be justified and that this, indeed, is the same as the effective dose equivalent for the person wearing this badge. The chances of his later developing an effect which could be considered to be radiation induced from this dose is only about 0.2%! Thus, this could not have been the fact which GAO disagrees with. The fact that some badges were not turned in does not mean that these are automatically ones which would indicate an excessive reading if they had been read. It is also not clear whether or not the 13 Redwing cloud sampling personnel if they wore their badges for six weeks, would give excessive readings even if the reading value was multiplied by a factor of 2.

Page 70, third full paragraph. It is not clear how this paragraph helps the interpretation. The ratio of 1.25 is an average value from a large number

of individuals' exposures. With the wide range of these individual ratios, how can one "see" a perturbation which might amount to, perhaps, 15% due to the wearing of the vest?

Page 70, paragraph labeled "10." See my earlier comments.

Page 71, second paragraph. One must ask whether or not the "scientific advisors" actually performed experiments to justify the difference or if these are merely opinions. Without such experimental verification, these are still only opinions and one should not be swayed by their expression.

Page 71, paragraphs labeled 12 and 13 and page 72, paragraph labeled 15. In view of the large uncertainty of the readings, a correction of 15% might be questioned as to whether it is warranted or not.

Page 72, paragraph labeled 14. The assumption was made that the whole body was more or less uniformly exposed and, I believe, indicated the organs of highest radiosensitivity as being the ones of most importance for uniform whole body exposure.

I am still of the opinion that the GAO report should not be published. I have no objection to modifying the exposure records if there are, indeed, copying or arithmetical errors involved. However, I do object to the interpretation of the data which appears only to be for the purpose of increasing the value of the primary recorded data. Such an increase should only be considered when it can be shown from auxiliary experiments that they are justified. Certainly changes should not be made by groups not knowledgeable in radiation protection assessment. Please let me know if you don't understand any of this.

Sincerely yours,

Harold Wyckoff

Harold O. Wyckoff

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