DEFENSE NUCLEAR AGENCY
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Subject: Fact Sheet - Enewetak Operation

In April 1980 the Department of Defense (DoD) will return Enewetak Atoll to its People. This event will mark the end of the largest radiological cleanup operation ever conducted and will fulfill a moral obligation incurred by the United States thirty-three years ago. This paper summarizes these events from the perspective of DoD.

Enewetak is the northwestern atoll in the Marshall Islands--which themselves are one of the major island groups in Micronesia and in the Trust Territory of the Pacific Islands (TTPI). Enewetak lies some 2400 nautical miles west-southwest of Honolulu. The atoll is formed by a coral reef, oval in shape, which surrounds a lagoon stretching some 23 miles in a general north-south direction and 17 miles east-west. Rising from the reef at intervals along its circumference are some 40 low, sandy islands--most of them quite small.

The People of Enewetak--who have lived on the atoll for centuries, and who are different in many ways from other Marshall Islanders--subdivide into two groups: the dri-Enewetak, whose home is the largest southern island of the atoll (Enewetak); and the dri-Enjebi, whose home is the largest island in the north (Enjebi).

Enewetak's role in the nuclear age began shortly after World War II, when the imperatives of national security required the establishment of several proving grounds for the testing of nuclear weapons. Enewetak was one of the principal sites selected for this testing, particularly for the higher-yield thermonuclear devices that were then in the conceptual stage. The People of Enewetak--then numbering about 150--were relocated in 1947 to a much smaller atoll, Ujelang, some 125 miles to the southwest. A large scientific and military task force, under the joint direction of the Atomic Energy Commission (AEC--now the Department of Energy (DoE)) and DoD, established its headquarters on the southern islands of Enewetak Atoll. Between 1948 and 1958, 43 nuclear tests were carried out on the atoll. The great majority were conducted in the northeastern quadrant, to keep the base camps in the south free of contamination. Some of the "ground zeros" were on the islands themselves, some were on the reef, some were in the lagoon, and one was in the ocean nearby. The tests were detonated in the air, on towers, on the surface of islands and reefs, on barges, and underwater. The nuclear weapons developed through this decade-long test program have been major elements in the mechanism of deterrence which has ensured the security of the free world and the absence of nuclear war for succeeding decades.

In 1958 the U.S. ceased nuclear testing on Enewetak, in response to a trilateral US-UK-USSR testing moratorium. However, radioactive debris and fission products from the detonations and the resulting fallout contaminated most of the northern islands to varying degrees. The southern islands, which had been used as a base for the scientific task force, remained relatively uncontaminated.

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From 1958 until 1976 DoD retained custody of the atoll, and a small caretaker force remained on Enewetak Island in the south. The atoll was occasionally used for DoD programs not involving nuclear testing. During this period, in 1972, the U.S. Government decided that future national requirements in this part of the world could be met without use of Enewetak; and Ambassador Franklin Haydn Williams announced that the atoll would be returned to the TTPI Government, for subsequent return to the people--who by this time had not seen their homeland for 25 years. The announcement also committed the U.S. Government to cleanup and rehabilitation of Enewetak.

Planning for the radiological cleanup and rehabilitation programs was intensive and complex. It extended from 1972 until 1977, and involved major actions by numerous departments and agencies in the Executive Branch, by the Congress, and by the People of Enewetak. The hallmark of the entire effort was total involvement by the People of Enewetak in all major decisions.

The major milestones of the planning effort--each of which required many months or even years of work--were: conduct of a detailed radiological survey of the atoll, its islands, and the lagoon by the AEC; conduct of a comprehensive engineering survey of the structures and debris on the atoll by the Defense Nuclear Agency (DNA); preliminary planning of resettlement options with the People of Enewetak; development and study of cleanup options, and selection of a preferred course of action, by an AEC Task Group; assignment of responsibilities to Executive Branch Departments, as follows: AEC for radiological characterization, DoD for radiological cleanup and operational support, and Department of the Interior (DoI) for rehabilitation and resettlement; development of a detailed Master Plan for rehabilitation and resettlement by the People of Enewetak, assisted by DoI, DoD, and AEC; development, issuance, and resulting action on an Environmental Impact Statement (EIS); development of disposal/containment options for radioactive soil and debris, and selection or a preferred plan; presentation of issues to the Congress, and ultimate Congressional authorization and appropriation; development by DNA of a Concept Plan (CONPLAN) governing the cleanup, and its approval by the Joint Chiefs of Staff; assignment of individual responsibilities to Army, Navy, and Air Force; and development by DNA of a detailed Operation Plan (OPLAN) governing all facets of the cleanup operation.

At an early juncture in this planning process the Defense Nuclear Agency was designated the DoD Project Manager for the Enewetak operation.

A key decision in this process was that operations would be concurrent rather than sequential. The normal, conservative approach would have been to conduct the operation in three sequential phases: first, the detailed on-site radiological characterization by AEC (DoE); second, the cleanup by DoD, based upon the radiological characterization developed in the first phase; and third, the rehabilitation (homebuilding, crop planting, etc.) and resettlement by DoI, once the DoD cleanup had been completed. To save time and money, the planners decided on a much riskier concurrent approach, in which all three phases would be carried out simultaneously. Because support costs are a dominant portion of overall expense,

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this approach shortened the project by several years and saved tens of millions of dollars.

Because of the isolation and lack of facilities at Enewetak, any productive effort in any of the three phases required establishment and maintenance on the atoll of such supporting infrastructure as: an electrical power generation and distribution system; a fresh water distillation, storage, and distribution system; a complete airhead for air transportation; cargo-handling piers; regular sealift and airlift to and from the atoll; a tank farm for receipt, storage, and distribution of various types of fuel; living and messing accommodations for about 1,000 individuals; large-capacity refrigeration facilities for storage of food; extensive medical facilities up to the operating-room level; satellite and high-frequency long-haul communications; an inter-island communication network; an extensive fleet of Navy landing craft and boats for inter-island water transportation, backed up by major boat maintenance facilities; vehicles for land transportation; helicopters and associated maintenance facilities for medical evacuation and other emergency use; underwater demolition and ordnance disposal capabilities; a large maintenance and repair facility for heavy construction equipment (bulldozers, graders, rock crushers, frontloaders, trucks, backhoes, cranes, etc.); a postal system; austere recreation facilities; etc.

Many of the early planning decisions addressed the problems of radiological contamination. It was recognized that a distinction had to be made between two types of soil contamination, "transuranics" and "suburanics." Transuranics are elements above uranium in the atomic table, such as plutonium. They typically have very long half-lives, e.g., 24,000 years in the case of plutonium. Suburanics, such as strontium-90 and cesium-137, have much shorter half-lives. These two, for example, are 28 and 30 years, respectively. The AEC's radiological survey had disclosed that, except on the island of Runit, most high transuranic concentrations were in the top few centimeters of soil. This was not the case with suburanics, which, because of their water solubility, were distributed to considerable depth. Since the near-surface transuranics had the greatest potential for ingestion or inhalation through resuspension, and since their threat was long-term, it was recognized that the cleanup would have to deal with them. Excision of soil contaminated with suburanics, however, was simply not practicable. To do so would require such extensive soil removal as to render the island useless for habitation or subsistence agriculture. However, by the same token, cleanup of suburanics was less essential because contamination levels were declining measurably year by year. Thus it was determined that, insofar as contaminated soil was concerned, the radiological cleanup would address transuranics.

Another key decision concerned the method for disposing of, or containing, contaminated debris and soil. Various options were developed and analyzed: lagoon-dumping, ocean-dumping, spreading over the surface of Runit, etc. The method selected--after extensive debate on the EIS--incorporated the following elements:

o All contaminated debris and soil on all islands would be transported by boat to the island of Runit.

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o The contaminated soil would be mixed with cement and formed into a concrete matrix, which would fill the crater on the north end of Runit formed by the "Cactus" nuclear detonation.

o The contaminated debris would be encapsulated in this concrete matrix.

o The dome-like mound formed over Cactus crater would be covered with a concrete cap to remove any resuspension and inhalation threat.

o Since the entire island of Runit would remain quarantined indefinitely because of residual sub-surface contamination in its soil, presence of the capped, encapsulated contamination at the north end of the island should pose no future problems for the People of Enewetak.

In 1975 the Congress authorized the Enewetak Radiological Cleanup and Rehabilitation Project, and funds were appropriated in 1976. Congressional guidance was as follows:

o The radiological cleanup was to be accomplished by the Military Services.

o A total of $20 million was appropriated in FY 1977 Military Construction (MilCon) funds.

o DoD was directed to draw other needed resources, without reimbursement, from the Military Services' construction and support forces, their subsistence, equipment, material, supplies, and transportation.

o DoD was further directed to employ all feasible economies in the project, consistent with meeting radiation standards established by AEC (DoE).

o The People of Enewetak were required to agree that appropriation of the $20 million MilCon funds would constitute the total commitment of the U.S. Government for the cleanup of Enewetak Atoll.

During development of the Master Plan with the People of Enewetak, probably the most important decision involved choice of residence islands. Since residence islands would be the site of most subsistence agriculture, as well as living and sleeping quarters and community centers, great care had to be taken to ensure that the living patterns and locations selected would not permit the people to accumulate lifetime body burdens of radioactivity at levels thought by medical science to cause any significant increase in the risk of adverse health effects. From the start it was clear that the dri-Enewetak could return safely to their home island of Enewetak in the south. The three large southern islands of Enewetak, Medren, and Japtan, which had been the base camp for the 4,000-man scientific task force during the test period, had remained essentially uncontaminated by the testing and had served as headquarters for the caretaker force subsequently. The

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level of residual contamination on these islands was generally less than that of most locations in the United States. At the outset it was hoped that the dri-Enjebi could return to their home island of Enjebi in the north. However, upon analyzing the results of the radiological survey, AEC (DoE) decided in 1974 that residual levels of suburanics in the soil of Enjebi would be such that the lifetime body burden accumulated by people eating crops grown in the Enjebi soil might exceed levels then considered acceptable. Accordingly, the Master Plan developed by the People of Enewetak and the U.S. Government in 1975 called for both the dri-Enewetak and the dri-Enjebi--then numbering about 450 in total--to reside on Enewetak, Medren, and Japtan in the south. Because of the relatively short half-lives of the principal suburanics in the north, it was recognized that eventual return to Enjebi would be possible.

In addition to identifying the three large southern islands as the location for residence and subsistence agriculture, the Master Plan also outlined virtually all other major aspects of the future life-style of the People of Enewetak after return to their atoll. For example, in it the people set forth their property boundaries, the desired location of each family's home, the house designs they had selected, the location and configuration of the community centers, their decision not to have electrical power in their homes, their option for individual water catchment systems rather than a distillation plant, etc.

The planning documents identified the desired utilization of each island as either residential, agricultural, or food-gathering. The acceptability of each island for the desired use depended upon the residual radiation levels, as follows:

o Islands whose soil met the tightest standard for amount of residual transuranics could be used for residence (including subsistence agriculture), provided suburanic levels were acceptable.

o Islands whose soil met an intermediate standard of residual transuranics could be used for agriculture (e.g., coconut trees for copra production).

o Islands whose soil met a lesser, but still acceptable, standard for residual transuranic contamination could safely be visited for food-gathering (fishing, bird's egg gathering, etc.).

o Only one island of the 40, Runit, had such extensive sub-surface contamination that cleanup to meet any of the three standards was not feasible. With the agreement of the People of Enewetak, Runit was to be quarantined indefinitely.

o The lagoon was safe for all purposes, including fishing, for which the People of Enewetak would normally use it.

The radiological cleanup itself consisted of three phases spanning 35 months. Phase I, Mobilization, commenced on-atoll on 15 May 1977 and lasted six months, completing on 15 November 1977. Phase II, Cleanup, was scheduled for 22 months,

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terminating on 15 September 1979. Phase III, Demobilization, was scheduled for seven months, completing on 15 April 1980. DoI's rehabilitation effort was to start subsequent to DoD's Mobilization Phase, but was scheduled to complete concurrently with DoD on 15 April 1980. These schedules were established in 1976, during preliminary planning, and the entire project has remained on schedule all the way through to completion.

Mobilization began in the spring of 1977. The base camp on Enewetak Island, which had served as the home of the caretaker force for many years, was expanded manyfold to accommodate the support forces, the cleanup forces who would clear the southern islands of uncontaminated debris, and the DoI contractor who would carry out the rehabilitation effort. An advance camp was constructed on the island of Lojwa in the northeastern chain. Residual radiation levels on Lojwa were very low, and the island was of adequate size to accommodate the cleanup force of about 400 men who would clear the northern islands of uncontaminated debris, contaminated debris, and soil with the highest levels of transuranic contamination. Lojwa also served as the base for the sizeable force which carried out containment operations for contaminated material on the island of Runit.

Throughout the summer and fall of 1977 on-atoll personnel levels rose and construction activity increased, until by the end of the Mobilization Phase on 15 November 1977 the camps on Enewetak and Lojwa were completed and the on-atoll force numbered about 900.

During the planning stages it had been recognized that the People of Enewetak--then exiled from their homeland for 25 years--longed to return to their atoll as soon as possible; yet the cleanup and rehabilitation efforts would keep them away for three more years. To accommodate their desires to the maximum extent possible, an "early return" program was established whereby some 50-60 of the people could return at the start of the Mobilization Phase and live on Japtan, one of the uncontaminated islands in the south. The people selected those who would first return to Japtan (generally the older individuals, some of whom might not survive for three more years), and the U.S. Government established austere temporary housing facilities. The results were highly successful, in that it meant a great deal to the people (who rotated residents between Japtan and Ujelang every few months), and it created no problems for cleanup and rehabilitation forces which could not be worked out.

The complexity of the radiological environment on Enewetak Atoll required DoE to employ highly sophisticated methods in its soil characterization efforts. A laboratory complex was established on the atoll, incorporating modern equipment and methods for the rapid analysis of many thousands of samples. This made possible the timely use of laboratory results in day-to-day planning. Noteworthy was the method employed by DoE to identify the plutonium content of soil. Plutonium is an emitter of alpha particles, a form of radiation that is not penetrating. For example, alpha radiation can be stopped by a few inches of air, or a sheet of paper, or tiny particles of soil. Thus it was entirely impractical to measure directly for plutonium in the soil by attempting to detect alpha radiation.

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Instead, DoE measured the gamma radiation emitted by americium--a daughter product of plutonium. Americium results from radioactive decay of plutonium, and its gamma emissions are sufficiently energetic to penetrate several inches of soil. To accomplish this measurement in the difficult environment on Enewetak, DoE designed and built special tracked vehicles which could operate in the soft sands, equipped them with boom-mounted, highly sensitive germanium detectors (cooled by liquid nitrogen), and installed analysis and counting equipment in the vehicle. The vehicle itself was air conditioned to provide a controlled environment for this delicate equipment. These mobile measuring systems measured the intensity of gamma radiation in the energy spectrum characteristic of americium. Readings were taken at every intersection of a 50-meter grid surveyed on each island which coarser aerial and in-situ surveys had shown to have significant transuranic contamination. At each location of van readings, soil samples from several depths were obtained and were analyzed for plutonium-americium ratio by the radiological laboratories. In areas of higher or irregular contamination, additional van readings and soil samples were taken at intervals of 25, 12½, or 6¼ meters. Sophisticated computer programs were developed to produce radiation contour maps of plutonium contamination, which were then used by cleanup teams to guide soil excision. After each removal of soil, the area was re-surveyed, new van readings and new soil samples were taken, until residual plutonium contamination had reached acceptable limits.

The U.S. forces which accomplished the radiological cleanup and rehabilitation throughout 1978 and 1979 typically were present in about the following groups and strengths:

Joint Task Group Staff (DNA)	35
Army Element	430
Navy Element	115
Air Force Element	75
Support Contractor	165
Army & Air Force Exchange System	5
DoE	5
Rad-Lab Contractors	10
Mid-Pacific Research Laboratory	10
DoI and TTPI	5
Rehabilitation Contractor	100
Micronesian Labor	10
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The U.S. military forces performed with great effectiveness in this difficult environment. Tour lengths on-atoll were about six months for most personnel, one year for key individuals. Some were volunteers, but because of the specialized nature of most tasks, the majority were assigned from units world-wide having the necessary skills. It was arduous, rigorous work in a harsh environment, with potentially hazardous conditions always present. The planned workweek was 60 hours, with many individuals working much more. Temperatures and humidities were always high, and for those working in confining anti-contamination clothing, short shift lengths had to be established. Living conditions were austere, and recreational facilities were extremely limited (and even here there was potential for danger). In all, over 4,000 U.S. servicemen served on-atoll in the Enewetak radiological cleanup; and six lost their lives (two in industrial accidents, two in a recreational accident, and two unrelated to the environment).

The Army element, which was the largest of the Service contingents, came principally from the 84th Engineer Battalion in Hawaii. These Army engineers performed the bulk of the actual cleanup work, and provided the maintenance capability for the heavy construction equipment. The Army also supplied the helicopter detachment for medical evacuation, search and rescue, and other emergency use.

The Navy element, which drew large numbers of its personnel from Assault Craft Unit One of the Pacific Fleet, provided all inter-island water transport--a task which required some 30 Navy landing craft and boats and extensive maintenance facilities for their support. The Navy also provided the Underwater Demolition Teams, the Explosives Ordnance Disposal Teams, and some of the technicians for DoE's radiological laboratories.

The Air Force element, whose personnel came from force-wide units, provided a myriad of support functions: Field Radiation Support Teams for on-site radiological safety supervision, communications team, staff for the medical facilities, POL (fuels) team, airhead detachment, some laboratory technicians, and postal workers.

Despite the rigorous and austere nature of the assignment, personnel problems were few. Individuals understood and supported the important objectives of the radiological cleanup and its national and international significance. In recognition of their unselfish and highly effective efforts, the Secretary of Defense awarded the DoD Humanitarian Service Medal to members of all Services for meritorious participation on-atoll in the Enewetak radiological cleanup.

Throughout every step of planning and every day of execution, the most important consideration in the cleanup operation was the radiological safety of individuals involved in the operation. In planning, each aspect of the operation was designed to minimize the potential for exposure of individuals to ionizing radiation. In execution, each operation involving possible radiation exposure was directly supervised and closely reviewed by teams or organizations whose sole function was radiological safety (radsafe). Radiation exposure standards were set conservatively

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to begin with; and the guiding philosophy was for operations to be conducted so as to assure that radiation exposure of individuals was limited to the lowest levels practicable within these standards. The goal has been to ensure that any actual exposures are so much lower than today's standards that they should not be a cause for concern even if future Federal exposure standards were to be tightened by a factor of ten or more.

The standard operating procedures for the radiological safety program were developed by experts from DoE, Sandia Laboratories, Lawrence Livermore Laboratory, and DNA. The program was implemented in the field by a specially qualified group of Air Force personnel organized into Field Radiation Support Teams. These teams were under the supervision of trained radiation safety personnel in the Radia tion Control Division of the Joint Task Group (JTG) staff on the atoll. Overseeing these organizations and monitoring the overall radiological safety program was an on-atoll Radiation Control Committee, which included the JTG Deputy Commander, a medical doctor, a DoE representative, and a representative from each of the Service elements. Finally, an independent "Radiation Safety Audit and Inspection Team" of experts headed by the Director, Armed Forces Radiobiology Research Institute (AFRRI), and including representatives from DoE and the three Services, visited the atoll frequently during the project to ensure the radsafe policies and procedures were sound and that actual practices in effect at the work sites were effective.

Personnel assigned to Enewetak Atoll were briefed on the known and potential radiological risks involved in the operation. Upon arrival, all personnel received an initial orientation covering the operation and the potential hazards--not only those involving radiation, but also sunburn, coral, swimming, fish, and others. A sizeable percentage of the servicemen assigned to Enewetak--those who lived and worked on the southern islands--had no potential for exposure to radiation. The others--those who were engaged in cleanup of radioactive debris and soil--underwent additional training covering operations in controlled areas, potential risks, and radiological safety procedures. Written standard operating procedures outlined the conduct of all operations.

The most fundamental procedure employed to keep exposure to a minimum was rigid control of access to contaminated islands. Extensive knowledge of the radiological environment was available before the cleanup began. Reports of the nuclear tests were reviewed to ascertain exactly where each test occurred, and the patterns of known or expected radioactive contamination that resulted from it. Helicopter surveys were then made to define the existing radiation situation in more detail. Finally, DoE conducted a detailed island-by-island survey to identify precise radiological contamination contours before the removal of soil and debris began. Travel to controlled (contaminated) islands was permitted only for cleanup-related purposes, and individuals were logged in and out on each occasion. Personnel working on these islands were under supervision of the Radiation Control Division and under constant surveillance of a Field Radiation Support Team. This

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team monitored the local radiation environment, sampled the air for airborne activity, determined the level of protective equipment needed, and monitored personnel for contamination.

The low gamma radiation levels found at Enewetak Atoll would not normally require a full-scale dosimetry program, however such a program was established. All personnel who worked on, or visited, the contaminated northern islands were issued film badges on a monthly basis. Because film badges frequently were adversely affected by climatic conditions, a supplemental dosimetry system making use of thermoluminescent dosimeters (TLDs) was established for personnel working on contaminated islands. TLDs had the additional advantage that they could be read on-atoll. Self-reading ionization chambers (pocket dosimeters) were also issued, as required, to provide backup dosimetry before TLDs were acquired.

When earth-moving operations were conducted in contaminated areas, water sprinklers were normally rigged to minimize resuspension of the soil. Personnel were trained (and directed on-site) habitually to remain upwind of any dust-producing operation. Air samplers were set up downwind to monitor for any airborne hazard. These power-operated samplers forced air through filters, which were monitored and changed at two-hour intervals, and subjected to laboratory analysis. During transit, trucks containing soil were wet down and covered with tarpaulins. Personnel involved in earth-moving operations wore appropriate safety gear for the conditions (respirators, protective clothing, etc.). Bioassay procedures (nose swipes, fecal analysis, urine analysis) were established on the atoll and used as required. Urine samples from personnel who worked for extended periods on controlled islands were collected at end of tour and analyzed.

The effectiveness of this conservative approach toward sampling the radiological environment, and controlling and measuring exposure to it, is borne out by the very low radiological exposures that were experienced.

Exposures to gamma radiation were extremely low level. Of some 12,000 film badge readings, about 83% show zero exposure, and the highest valid reading is about 0.07 rem.*

The probability of there having been any internal (inhaled) contamination is similarly very low, as shown by the facts that:

(1) More than 5,000 filters from air samplers were collected during the operation, and about one million cubic meters of air were sampled. Over half the filters showed no traces of transuranic element activity, over 95% showed less than one percent of the maximum permissible concentration (MPC), and none showed more than 10% of MPC.

*The current Federal guideline for allowable exposure for radiation workers is 3 rem per quarter, or 12 rem per year (reduced to 5 rem per year when certain age-exposure limits have been reached).

(2) Assays of urine samples of some 2,000 individuals were carried out, with no indication of any contamination attributable to activities on the atoll.

Finally, extensive permanent documentation of individuals involved, their assignments, operations, protection levels, exposures, etc., has been carried out. In summary, it would be difficult to identify additional radsafe precautions that could have been taken. The measured results bear out the effectiveness of the program.

During the course of the three-year cleanup operation, numerous changes and setbacks occurred which added significantly to the scope of work and the amount of effort required. Four of the more significant are summarized below:

o Throughout the years of planning and into the actual Cleanup Phase, all soil-removal estimates had been based upon plutonium-239 and -240 being the only significant transuranics present in the soil. In early 1978, as more detailed soil characterizations became available, DoE identified that significant amounts of plutonium-238 and americium-241 were also present, and recommended that the cleanup be based upon "total transuranic" concentrations. DNA accepted this recommendation, which significantly improved final island conditions, although it correspondingly increased the quantity of soil to be removed.

o In the planning process, the guidelines for soil cleanup which DoE provided to DNA were as follows:

(1) Residence islands were to be cleaned to a level of 40 picocuries of plutonium-239/240 per gram of soil (pCi/gm);

(2) plutonium-239/240 concentrations greater than 400 pCi/gm were to be excised wherever found; and

(3) case-by-case decisions were to be made by DNA for cleanup of plutonium-239/240 concentrations between 40 and 400 pCi/gm.

In 1978 DoE provided new and expanded radiological guidance to DNA, as follows:

(1) Residence islands were to be cleaned to the same numerical standard as before--40 pCi/gm--but now based on total transuranics;

(2) agriculture islands were to be cleaned to a transuranic level of 80 pCi/gm; and

(3) food-gathering islands were to be cleaned to a transuranic level of 160 pCi/gm.

These more detailed standards permitted soil removal decisions to be based more directly on cost-benefit considerations; however, because they were much tighter standards, they greatly increased the amount of soil-removal work required.

o The original plan did not include cleanup of contaminated soil from the large island of Enjebi in the north, even though this was the ancestral homeland of the dri-Enjebi, and although the transuranic levels in the soil were known to be in excess of the standards for a residence island. This situation was not a planning

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oversight. It had long been considered that the massive effort which would be required to improve the transuranic condition of Enjebi would be disproportionate to the end result, considering that the levels of suburanics remaining after the cleanup were still estimated to be excessive for immediate residential use of the island. In 1978, however, as more detailed information became available on the overall scope of the soil removal work, it became apparent that significant improvement of Enjebi was not beyond reach. DNA made the decision to attempt the Enjebi soil cleanup--for if the transuranic condition of the island were not now improved it might never be habitable, even after the passage of several half-lives of the shorter-lived suburanics. Initially an intermediate goal was set, but as the work progressed major innovations were developed in soil measuring, mapping, and removal techniques. The residential criterion for transuranics was met, thereby making possible the eventual resettlement of the dri-Enjebi to their home. Enjebi soil removal was the single most massive effort of the cleanup, and potentially the most significant to the returning people.

o During the three-year duration of the radiological cleanup project, four major typhoons and tropical storms hit Enewetak Atoll, causing extensive destruction. In particular, two of them did such damage to boats and landing craft that extensive repair and replacement efforts were required, and cleanup work was slowed for many months. One typhoon required complete evacuation of the atoll.

In terms of results achieved, the three-year radiological cleanup was a striking success. The Enewetak forces met all cleanup objectives and exceeded many. The following subparagraphs discuss some of the accomplishments:

o Over 215,000 cubic yards of uncontaminated debris were removed from islands and reef areas and disposed of at designated dump sites in the lagoon and in shoreline protection. Before any piece of debris could be touched, it had to be screened by radiation monitors for several types of possible contamination, and then marked as contaminated or uncontaminated. In many cases (e.g., blockhouses and bunkers) extensive demolition of uncontaminated structures was required. For debris in the reef areas, Navy Underwater Demolition Teams often worked in 10 or 20 feet of water clearing sunken landing craft and other objects. Repeated post-cleanup inspections of each of the 40 islands verified them to be completely clear of even the smallest scraps of residual debris from World War II and the test period.

o About 16,000 items of World War II ordnance (e.g., unexploded artillery projectiles, mortar shells, hand grenades, small arms and ammunition) were located by detectors, dug up, and disposed of by Navy Explosive Ordnance Disposal Teams.

o Some 6,000 cubic yards of radiologically contaminated debris were identified, transported by landing craft to Runit, and immobilized in concrete in Cactus crater.

o All former dumps, crypts, and burial sites for contaminated debris and soil during the test period, to which reference could be found, were excavated and the contents were encapsulated in Cactus crater. One major crypt on Aomon island was so extensive and difficult it required over a year to plan and carry out its excavation.

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o About 105,000 cubic yards of soil contaminated with transuranics, principally isotopes of plutonium and americium, were identified, excised, transported by landing craft to Runit, and mixed with cement to form concrete with which Cactus crater was filled. This crater in the reef is about 350 feet in diameter and some 30 feet deep. The crater volume below sea level was filled by the tremie method, in which a concrete slurry is pumped by large hose and pipe to the crater floor, and progressively built up. Above the waterline, a soil-cement mixture was formed from the contaminated soil. A thick concrete keywall was constructed around the circumference, and a dome-shaped concrete cap covered the entire crater.

o At the completion of the cleanup, of the 40 islands of Enewetak Atoll: 30 qualified as residential and subsistence agriculture islands in terms of residual transuranic contamination; seven qualified as agriculture islands; two qualified as food-gathering islands; and the last one, Runit, had all identified high-level concentrations of transuranics removed. It remains quarantined because of residual sub-surface contamination. Every island designated in planning documents for a particular end-use by the people was cleaned at least to the level corresponding to that use; and for many islands--including, most significantly, Enjebi--the cleanup exceeded the planning goals.

Costs have remained remarkably constant for the duration of the project. The effort has been completed within the $20 million MilCon funds originally appropriated for the task. When Congressional direction was received to accomplish the cleanup project with military forces without reimbursement, the first estimate of total project cost was developed by DNA during the Mobilization Phase and was presented to Congress in the spring of 1978. At that time DoD costs were estimated at $80 million (including MilCon), DoI costs at $12 million, and DoE costs at $4 million, for an overall total of $96 million. Despite inflation, major increases in project scope, unforeseen difficulties, and damage and delay from four severe typhoons, current estimates today, more than two years later (and within a few weeks of project completion) are: DoD $86 million; DoI $14 million; DoE $4 million; for a total of $104 million. While this amount represents "value received" by the People of Enewetak in terms of cleanup effort, "out of pocket" cost for U.S. taxpayers is substandially less, because many of the DoD expenses would have accrued had there been no Enewetak cleanup (e.g., pay and subsistence for personnel, fuel and spare parts for vehicles). DNA estimates that the cost to the taxpayers of the Enewetak cleanup and rehabilitation program has been approximately: DoD $49 million (including MilCon); DoI $14 million; DoE $4 million; for a total of $67 million.

DoI's rehabilitation program has involved the construction of 116 homes for the people on the three southern islands of Enewetak, Medren, and Japtan, along

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with community centers, piers, and other life support elements. Subsistence agriculture (breadfruit, pandanus, dwarf coconuts, etc.) has been planted on the three southern islands, and some 31,000 coconut trees for commercial and subsistence purposes have been planted throughout the atoll (20,000 in the south, 11,000 on the lesser contaminated islands in the northeastern chain).

As mentioned earlier, a continuing hallmark of the Enewetak cleanup and rehabilitation project has been the total and continuing involvement of the People of Enewetak in the process. Frequent inspection visits and planning conferences by the Enewetak leadership have been held on the atoll, with the Enewetak hereditary leaders, the Magistrate, the Planning Council, and others traveling from Ujelang to Enewetak for periods of days or weeks. This continuing interaction has resulted not only in a feeling of deep involvement by the People of Enewetak, but also in accomplishment of the cleanup and rehabilitation in accordance with their desires.

The issue of when the dri-Enjebi may be able to return to their ancestral home island of Enjebi in the north is still unresolved. As noted previously, all planning and project execution to date--with the agreement of the People of Enewetak--has been based upon the dri-Enjebi residing initially in the south, and this is where their homes have been constructed. One of the remaining responsibilities of the U.S. Government is to advise the dri-Enjebi when it will be safe to return to their home island. To provide this advice, DoE, DoI, and TTPI have collected extensive data on residual suburanic soil contamination in the north, on radionuclide uptake by crops, on alternative living and subsistence patterns in the north, on the rate of accumulation of radionuclides in the body, and on estimated health effects from this accumulation. These data have been analyzed in-depth and combined into dose assessments. Separately, the People of Enewetak have engaged their own team of eminent scientists and authorities to provide them with independent estimates of the above factors and the resulting dose assessments. Based upon extensive review of the data provided by both sources, the People of Enewetak have expressed their desire for the dri-Enjebi to return at once to their home island. The U.S. Government has this request under consideration at the time of this writing.

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level of residual contamination on these islands was generally less than that of most locations in the United States. At the outset it was hoped that the dri-Enjebi could return to their home island of Enjebi in the north. However, upon analyzing the results of the radiological survey, AEC (DoE) decided in 1974 that residual levels of suburanics in the soil of Enjebi would be such that the lifetime body burden accumulated by people eating crops grown in the Enjebi soil might exceed levels then considered acceptable. Accordingly, the Master Plan developed by the People of Enewetak and the U.S. Government in 1975 called for both the dri-Enewetak and the dri-Enjebi--then numbering about 450 in total--to reside on Enewetak, Medren, and Japtan in the south. Because of the relatively short half-lives of the principal suburanics in the north, it was recognized that eventual return to Enjebi would be possible.

In addition to identifying the three large southern islands as the location for residence and subsistence agriculture, the Master Plan also outlined virtually all other major aspects of the future life-style of the People of Enewetak after return to their atoll. For example, in it the people set forth their property boundaries, the desired location of each family's home, the house designs they had selected, the location and configuration of the community centers, their decision not to have electrical power in their homes, their option for individual water catchment systems rather than a distillation plant, etc.

The planning documents identified the desired utilization of each island as either residential, agricultural, or food-gathering. The acceptability of each island for the desired use depended upon the residual radiation levels, as follows:

o Islands whose soil met the tightest standard for amount of residual transuranics could be used for residence (including subsistence agriculture), provided suburanic levels were acceptable.

o Islands whose soil met an intermediate standard of residual transuranics could be used for agriculture (e.g., coconut trees for copra production).

o Islands whose soil met a lesser, but still acceptable, standard for residual transuranic contamination could safely be visited for food-gathering (fishing, bird's egg gathering, etc.).

o Only one island of the 40, Runit, had such extensive sub-surface contamination that cleanup to meet any of the three standards was not feasible. With the agreement of the People of Enewetak, Runit was to be quarantined indefinitely.

o The lagoon was safe for all purposes, including fishing, for which the People of Enewetak would normally use it.

The radiological cleanup itself consisted of three phases spanning 35 months. Phase I, Mobilization, commenced on-atoll on 15 May 1977 and lasted six months, completing on 15 November 1977. Phase II, Cleanup, was scheduled for 22 months,

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terminating on 15 September 1979. Phase III, Demobilization, was scheduled for seven months, completing on 15 April 1980. DoI's rehabilitation effort was to start subsequent to DoD's Mobilization Phase, but was scheduled to complete concurrently with DoD on 15 April 1980. These schedules were established in 1976, during preliminary planning, and the entire project has remained on schedule all the way through to completion.

Mobilization began in the spring of 1977. The base camp on Enewetak Island, which had served as the home of the caretaker force for many years, was expanded manyfold to accommodate the support forces, the cleanup forces who would clear the southern islands of uncontaminated debris, and the DoI contractor who would carry out the rehabilitation effort. An advance camp was constructed on the island of Lojwa in the northeastern chain. Residual radiation levels on Lojwa were very low, and the island was of adequate size to accommodate the cleanup force of about 400 men who would clear the northern islands of uncontaminated debris, contaminated debris, and soil with the highest levels of transuranic contamination. Lojwa also served as the base for the sizeable force which carried out containment operations for contaminated material on the island of Runit.

Throughout the summer and fall of 1977 on-atoll personnel levels rose and construction activity increased, until by the end of the Mobilization Phase on 15 November 1977 the camps on Enewetak and Lojwa were completed and the on-atoll force numbered about 900.

During the planning stages it had been recognized that the People of Enewetak--then exiled from their homeland for 25 years--longed to return to their atoll as soon as possible; yet the cleanup and rehabilitation efforts would keep them away for three more years. To accommodate their desires to the maximum extent possible, an "early return" program was established whereby some 50-60 of the people could return at the start of the Mobilization Phase and live on Japtan, one of the uncontaminated islands in the south. The people selected those who would first return to Japtan (generally the older individuals, some of whom might not survive for three more years), and the U.S. Government established austere temporary housing facilities. The results were highly successful, in that it meant a great deal to the people (who rotated residents between Japtan and Ujelang every few months), and it created no problems for cleanup and rehabilitation forces which could not be worked out.

The complexity of the radiological environment on Enewetak Atoll required DoE to employ highly sophisticated methods in its soil characterization efforts. A laboratory complex was established on the atoll, incorporating modern equipment and methods for the rapid analysis of many thousands of samples. This made possible the timely use of laboratory results in day-to-day planning. Noteworthy was the method employed by DoE to identify the plutonium content of soil. Plutonium is an emitter of alpha particles, a form of radiation that is not penetrating. For example, alpha radiation can be stopped by a few inches of air, or a sheet of paper, or tiny particles of soil. Thus it was entirely impractical to measure directly for plutonium in the soil by attempting to detect alpha radiation.

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Instead, DoE measured the gamma radiation emitted by americium--a daughter product of plutonium. Americium results from radioactive decay of plutonium, and its gamma emissions are sufficiently energetic to penetrate several inches of soil. To accomplish this measurement in the difficult environment on Enewetak, DoE designed and built special tracked vehicles which could operate in the soft sands, equipped them with boom-mounted, highly sensitive germanium detectors (cooled by liquid nitrogen), and installed analysis and counting equipment in the vehicle. The vehicle itself was air conditioned to provide a controlled environment for this delicate equipment. These mobile measuring systems measured the intensity of gamma radiation in the energy spectrum characteristic of americium. Readings were taken at every intersection of a 50-meter grid surveyed on each island which coarser aerial and in-situ surveys had shown to have significant transuranic contamination. At each location of van readings, soil samples from several depths were obtained and were analyzed for plutonium-americium ratio by the radiological laboratories. In areas of higher or irregular contamination, additional van readings and soil samples were taken at intervals of 25, 12½, or 6¼ meters. Sophisticated computer programs were developed to produce radiation contour maps of plutonium contamination, which were then used by cleanup teams to guide soil excision. After each removal of soil, the area was re-surveyed, new van readings and new soil samples were taken, until residual plutonium contamination had reached acceptable limits.

The U.S. forces which accomplished the radiological cleanup and rehabilitation throughout 1978 and 1979 typically were present in about the following groups and strengths:

Joint Task Group Staff (DNA)	35
Army Element	430
Navy Element	115
Air Force Element	75
Support Contractor	165
Army & Air Force Exchange System	5
DoE	5
Rad-Lab Contractors	10
Mid-Pacific Research Laboratory	10
DoI and TTPI	5
Rehabilitation Contractor	100
Micronesian Labor	10
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The U.S. military forces performed with great effectiveness in this difficult environment. Tour lengths on-atoll were about six months for most personnel, one year for key individuals. Some were volunteers, but because of the specialized nature of most tasks, the majority were assigned from units world-wide having the necessary skills. It was arduous, rigorous work in a harsh environment, with potentially hazardous conditions always present. The planned workweek was 60 hours, with many individuals working much more. Temperatures and humidities were always high, and for those working in confining anti-contamination clothing, short shift lengths had to be established. Living conditions were austere, and recreational facilities were extremely limited (and even here there was potential for danger). In all, over 4,000 U.S. servicemen served on-atoll in the Enewetak radiological cleanup; and six lost their lives (two in industrial accidents, two in a recreational accident, and two unrelated to the environment).

The Army element, which was the largest of the Service contingents, came principally from the 84th Engineer Battalion in Hawaii. These Army engineers performed the bulk of the actual cleanup work, and provided the maintenance capability for the heavy construction equipment. The Army also supplied the helicopter detachment for medical evacuation, search and rescue, and other emergency use.

The Navy element, which drew large numbers of its personnel from Assault Craft Unit One of the Pacific Fleet, provided all inter-island water transport--a task which required some 30 Navy landing craft and boats and extensive maintenance facilities for their support. The Navy also provided the Underwater Demolition Teams, the Explosives Ordnance Disposal Teams, and some of the technicians for DoE's radiological laboratories.

The Air Force element, whose personnel came from force-wide units, provided a myriad of support functions: Field Radiation Support Teams for on-site radiological safety supervision, communications team, staff for the medical facilities, POL (fuels) team, airhead detachment, some laboratory technicians, and postal workers.

Despite the rigorous and austere nature of the assignment, personnel problems were few. Individuals understood and supported the important objectives of the radiological cleanup and its national and international significance. In recognition of their unselfish and highly effective efforts, the Secretary of Defense awarded the DoD Humanitarian Service Medal to members of all Services for meritorious participation on-atoll in the Enewetak radiological cleanup.

Throughout every step of planning and every day of execution, the most important consideration in the cleanup operation was the radiological safety of individuals involved in the operation. In planning, each aspect of the operation was designed to minimize the potential for exposure of individuals to ionizing radiation. In execution, each operation involving possible radiation exposure was directly supervised and closely reviewed by teams or organizations whose sole function was radiological safety (radsafe). Radiation exposure standards were set conservatively to begin with; and the guiding philosophy was for operations to be conducted so as to assure that radiation exposure of individuals was limited to the lowest levels practicable within these standards. The goal has been to ensure that any actual exposures are so much lower than today's standards that they should not be a cause for concern even if future Federal exposure standards were to be tightened by a factor of ten or more.

The standard operating procedures for the radiological safety program were developed by experts from DoE, Sandia Laboratories, Lawrence Livermore Laboratory, and DNA. The program was implemented in the field by a specially qualified group of Air Force personnel organized into Field Radiation Support Teams. These teams were under the supervision of trained radiation safety personnel in the Radia tion Control Division of the Joint Task Group (JTG) staff on the atoll. Overseeing these organizations and monitoring the overall radiological safety program was an on-atoll Radiation Control Committee, which included the JTG Deputy Commander, a medical doctor, a DoE representative, and a representative from each of the Service elements. Finally, an independent "Radiation Safety Audit and Inspection Team" of experts headed by the Director, Armed Forces Radiobiology Research Institute (AFRRI), and including representatives from DoE and the three Services, visited the atoll frequently during the project to ensure the radsafe policies and procedures were sound and that actual practices in effect at the work sites were effective.

Personnel assigned to Enewetak Atoll were briefed on the known and potential radiological risks involved in the operation. Upon arrival, all personnel received an initial orientation covering the operation and the potential hazards--not only those involving radiation, but also sunburn, coral, swimming, fish, and others. A sizeable percentage of the servicemen assigned to Enewetak--those who lived and worked on the southern islands--had no potential for exposure to radiation. The others--those who were engaged in cleanup of radioactive debris and soil--underwent additional training covering operations in controlled areas, potential risks, and radiological safety procedures. Written standard operating procedures outlined the conduct of all operations.

The most fundamental procedure employed to keep exposure to a minimum was rigid control of access to contaminated islands. Extensive knowledge of the radiological environment was available before the cleanup began. Reports of the nuclear tests were reviewed to ascertain exactly where each test occurred, and the patterns of known or expected radioactive contamination that resulted from it. Helicopter surveys were then made to define the existing radiation situation in more detail. Finally, DoE conducted a detailed island-by-island survey to identify precise radiological contamination contours before the removal of soil and debris began. Travel to controlled (contaminated) islands was permitted only for cleanup-related purposes, and individuals were logged in and out on each occasion. Personnel working on these islands were under supervision of the Radiation Control Division and under constant surveillance of a Field Radiation Support Team. This

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team monitored the local radiation environment, sampled the air for airborne activity, determined the level of protective equipment needed, and monitored personnel for contamination.

The low gamma radiation levels found at Enewetak Atoll would not normally require a full-scale dosimetry program, however such a program was established. All personnel who worked on, or visited, the contaminated northern islands were issued film badges on a monthly basis. Because film badges frequently were adversely affected by climatic conditions, a supplemental dosimetry system making use of thermoluminescent dosimeters (TLDs) was established for personnel working on contaminated islands. TLDs had the additional advantage that they could be read on-atoll. Self-reading ionization chambers (pocket dosimeters) were also issued, as required, to provide backup dosimetry before TLDs were acquired.

When earth-moving operations were conducted in contaminated areas, water sprinklers were normally rigged to minimize resuspension of the soil. Personnel were trained (and directed on-site) habitually to remain upwind of any dust-producing operation. Air samplers were set up downwind to monitor for any airborne hazard. These power-operated samplers forced air through filters, which were monitored and changed at two-hour intervals, and subjected to laboratory analysis. During transit, trucks containing soil were wet down and covered with tarpaulins. Personnel involved in earth-moving operations wore appropriate safety gear for the conditions (respirators, protective clothing, etc.). Bioassay procedures (nose swipes, fecal analysis, urine analysis) were established on the atoll and used as required. Urine samples from personnel who worked for extended periods on controlled islands were collected at end of tour and analyzed.

The effectiveness of this conservative approach toward sampling the radiological environment, and controlling and measuring exposure to it, is borne out by the very low radiological exposures that were experienced.

Exposures to gamma radiation were extremely low level. Of some 12,000 film badge readings, about 83% show zero exposure, and the highest valid reading is about 0.07 rem.*

The probability of there having been any internal (inhaled) contamination is similarly very low, as shown by the facts that:

(1) More than 5,000 filters from air samplers were collected during the operation, and about one million cubic meters of air were sampled. Over half the filters showed no traces of transuranic element activity, over 95% showed less than one percent of the maximum permissible concentration (MPC), and none showed more than 10% of MPC.

*The current Federal guideline for allowable exposure for radiation workers is 3 rem per quarter, or 12 rem per year (reduced to 5 rem per year when certain age-exposure limits have been reached).

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(2) Assays of urine samples of some 2,000 individuals were carried out, with no indication of any contamination attributable to activities on the atoll.

Finally, extensive permanent documentation of individuals involved, their assignments, operations, protection levels, exposures, etc., has been carried out. In summary, it would be difficult to identify additional radsafe precautions that could have been taken. The measured results bear out the effectiveness of the program.

During the course of the three-year cleanup operation, numerous changes and setbacks occurred which added significantly to the scope of work and the amount of effort required. Four of the more significant are summarized below:

o Throughout the years of planning and into the actual Cleanup Phase, all soil-removal estimates had been based upon plutonium-239 and -240 being the only significant transuranics present in the soil. In early 1978, as more detailed soil characterizations became available, DoE identified that significant amounts of plutonium-238 and americium-241 were also present, and recommended that the cleanup be based upon "total transuranic" concentrations. DNA accepted this recommendation, which significantly improved final island conditions, although it correspondingly increased the quantity of soil to be removed.

o In the planning process, the guidelines for soil cleanup which DoE provided to DNA were as follows:

(1) Residence islands were to be cleaned to a level of 40 picocuries of plutonium-239/240 per gram of soil (pCi/gm);

(2) plutonium-239/240 concentrations greater than 400 pCi/gm were to be excised wherever found; and

(3) case-by-case decisions were to be made by DNA for cleanup of plutonium-239/240 concentrations between 40 and 400 pCi/gm.

In 1978 DoE provided new and expanded radiological guidance to DNA, as follows:

(1) Residence islands were to be cleaned to the same numerical standard as before--40 pCi/gm--but now based on total transuranics;

(2) agriculture islands were to be cleaned to a transuranic level of 80 pCi/gm; and

(3) food-gathering islands were to be cleaned to a transuranic level of 160 pCi/gm.

These more detailed standards permitted soil removal decisions to be based more directly on cost-benefit considerations; however, because they were much tighter standards, they greatly increased the amount of soil-removal work required.

o The original plan did not include cleanup of contaminated soil from the large island of Enjebi in the north, even though this was the ancestral homeland of the dri-Enjebi, and although the transuranic levels in the soil were known to be in excess of the standards for a residence island. This situation was not a planning

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oversight. It had long been considered that the massive effort which would be required to improve the transuranic condition of Enjebi would be disproportionate to the end result, considering that the levels of suburanics remaining after the cleanup were still estimated to be excessive for immediate residential use of the island. In 1978, however, as more detailed information became available on the overall scope of the soil removal work, it became apparent that significant improvement of Enjebi was not beyond reach. DNA made the decision to attempt the Enjebi soil cleanup--for if the transuranic condition of the island were not now improved it might never be habitable, even after the passage of several half-lives of the shorter-lived suburanics. Initially an intermediate goal was set, but as the work progressed major innovations were developed in soil measuring, mapping, and removal techniques. The residential criterion for transuranics was met, thereby making possible the eventual resettlement of the dri-Enjebi to their home. Enjebi soil removal was the single most massive effort of the cleanup, and potentially the most significant to the returning people.

o During the three-year duration of the radiological cleanup project, four major typhoons and tropical storms hit Enewetak Atoll, causing extensive destruction. In particular, two of them did such damage to boats and landing craft that extensive repair and replacement efforts were required, and cleanup work was slowed for many months. One typhoon required complete evacuation of the atoll.

In terms of results achieved, the three-year radiological cleanup was a striking success. The Enewetak forces met all cleanup objectives and exceeded many. The following subparagraphs discuss some of the accomplishments:

o Over 215,000 cubic yards of uncontaminated debris were removed from islands and reef areas and disposed of at designated dump sites in the lagoon and in shoreline protection. Before any piece of debris could be touched, it had to be screened by radiation monitors for several types of possible contamination, and then marked as contaminated or uncontaminated. In many cases (e.g., blockhouses and bunkers) extensive demolition of uncontaminated structures was required. For debris in the reef areas, Navy Underwater Demolition Teams often worked in 10 or 20 feet of water clearing sunken landing craft and other objects. Repeated post-cleanup inspections of each of the 40 islands verified them to be completely clear of even the smallest scraps of residual debris from World War II and the test period.

o About 16,000 items of World War II ordnance (e.g., unexploded artillery projectiles, mortar shells, hand grenades, small arms and ammunition) were located by detectors, dug up, and disposed of by Navy Explosive Ordnance Disposal Teams.

o Some 6,000 cubic yards of radiologically contaminated debris were identified, transported by landing craft to Runit, and immobilized in concrete in Cactus crater.

o All former dumps, crypts, and burial sites for contaminated debris and soil during the test period, to which reference could be found, were excavated and the contents were encapsulated in Cactus crater. One major crypt on Aomon island was so extensive and difficult it required over a year to plan and carry out its excavation.

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o About 105,000 cubic yards of soil contaminated with transuranics, principally isotopes of plutonium and americium, were identified, excised, transported by landing craft to Runit, and mixed with cement to form concrete with which Cactus crater was filled. This crater in the reef is about 350 feet in diameter and some 30 feet deep. The crater volume below sea level was filled by the tremie method, in which a concrete slurry is pumped by large hose and pipe to the crater floor, and progressively built up. Above the waterline, a soil-cement mixture was formed from the contaminated soil. A thick concrete keywall was constructed around the circumference, and a dome-shaped concrete cap covered the entire crater.

o At the completion of the cleanup, of the 40 islands of Enewetak Atoll: 30 qualified as residential and subsistence agriculture islands in terms of residual transuranic contamination; seven qualified as agriculture islands; two qualified as food-gathering islands; and the last one, Runit, had all identified high-level concentrations of transuranics removed. It remains quarantined because of residual sub-surface contamination. Every island designated in planning documents for a particular end-use by the people was cleaned at least to the level corresponding to that use; and for many islands--including, most significantly, Enjebi--the cleanup exceeded the planning goals.

Costs have remained remarkably constant for the duration of the project. The effort has been completed within the $20 million MilCon funds originally appropriated for the task. When Congressional direction was received to accomplish the cleanup project with military forces without reimbursement, the first estimate of total project cost was developed by DNA during the Mobilization Phase and was presented to Congress in the spring of 1978. At that time DoD costs were estimated at $80 million (including MilCon), DoI costs at $12 million, and DoE costs at $4 million, for an overall total of $96 million. Despite inflation, major increases in project scope, unforeseen difficulties, and damage and delay from four severe typhoons, current estimates today, more than two years later (and within a few weeks of project completion) are: DoD $86 million; DoI $14 million; DoE $4 million; for a total of $104 million. While this amount represents "value received" by the People of Enewetak in terms of cleanup effort, "out of pocket" cost for U.S. taxpayers is substandially less, because many of the DoD expenses would have accrued had there been no Enewetak cleanup (e.g., pay and subsistence for personnel, fuel and spare parts for vehicles). DNA estimates that the cost to the taxpayers of the Enewetak cleanup and rehabilitation program has been approximately: DoD $49 million (including MilCon); DoI $14 million; DoE $4 million; for a total of $67 million.

DoI's rehabilitation program has involved the construction of 116 homes for the people on the three southern islands of Enewetak, Medren, and Japtan, along

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with community centers, piers, and other life support elements. Subsistence agriculture (breadfruit, pandanus, dwarf coconuts, etc.) has been planted on the three southern islands, and some 31,000 coconut trees for commercial and subsistence purposes have been planted throughout the atoll (20,000 in the south, 11,000 on the lesser contaminated islands in the northeastern chain).

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