The History of the US Department of Defense Programs for the Testing, Evaluation, and Storage of Tactical Herbicides

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Submitted by
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for

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14. ABSTRACT

Early in 2006, the Department of Veterans Affairs (DVA) requested that the Department of Defense (DoD) provide: “an official compilation of locations and dates outside of Vietnam where the Department used herbicide agents, including Agent Orange, as well as locations and dates where DoD personnel were likely exposed to these agents.” The intent of this request was to obtain information that may be important in evaluating the merits of many veterans’ disability claims. Various estimates have circulated on the Internet as to the number of sites where veterans may have been exposed to Agent Orange and “other herbicides” used in Vietnam. There is, however, significant confusion by veterans and by the Department of Veterans Affairs as to the distinction between “commercial herbicides” used by the DoD and “tactical herbicides” used by the DoD. The belief that commercially available herbicides were simply purchased from the chemical companies and deployed directly to Vietnam is incorrect and contrary to historical records. Tactical Herbicides were herbicides developed specifically by the United States Department of Defense to be used in “combat operations.” The history of the military development and use of tactical herbicides dates to World War II. During the Korean Conflict, the DoD developed the first major tactical herbicide, Herbicide Purple, although never deployed. Subsequently, for Vietnam the DoD developed, tested, evaluated, and deployed five additional tactical herbicides, Herbicide Pink, Herbicide Green, Herbicide Blue, Herbicide Orange, and Herbicide White. This report discusses the history of the development of the tactical herbicides, how they differed from commercial herbicides, and where they were tested, evaluated, stored, used (in the case of Korea in 1968) OUTSIDE of Vietnam. Additionally, the report discusses the final disposition of Herbicide Orange after Vietnam. The report contains 32 leaflets identifying different locations or multiple locations involved in same projects (e.g., Leaflet 19 identifies 5 locations in Texas), or the multiple use of a specific location (e.g. Eglin Air Force

Base, Florida). A total of 40 distinctly different locations are identified. For each leaflet, a description of the activity is given, an assessment is made of the activity and the individuals involved in the project, and sources of the information are documented.

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ABSTRACT

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The History of the Development of Tactical Herbicides

INTRODUCTION

The period of use of tactical herbicides in the Vietnam War, 8 January 1961 – 7 January 1971, is a story that begins many years before Vietnam, and it is really a history of the Department of the Defense's efforts to develop vegetation control methods that would have military applications. In 1943, the Department of the Army contracted the University of Chicago to study the effects of a new series of organic compounds, especially 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-triclorophenoxyacetic acid (2,4,5-T) on cereal grains and broadleaf crops. From that research came the concept of military applications of small quantities of such compounds to destroy enemy crops. Subsequently, in early 1945, the Army tested 2,4-D and 2,4,5-T formulations at the Bushnell Army Air Field in Florida. That site is now a FUDS (**F**ormerly **U**sed **D**efense **S**ite) location for the Department of Defense. Although not used in World War II, the concept of vegetation control was not forgotten. In 1952, the Department of Army's Chemical Corps Biological Laboratories at Camp Detrick, Maryland, initiated a major program to develop both the aerial spray equipment and herbicide formulations for potential deployment in the Korean Conflict. Again, although not used in the Korean Conflict, the equipment that had been developed and tested, and the formulated chemicals were both stored on the Island of Guam until the end of the Conflict, after which the equipment was sent to Utah and the drums of herbicide were sent to Camp Detrick. Camp Detrick (now Fort Detrick) continued working on developing deployment systems and herbicidal materials through the 1950s.

The Period from 1945 to 1959: Supporting the Initial Deployment of Herbicides for the Early Years of the Vietnam War

The Tactical Herbicide Spray Systems (fixed-wing, helicopter, and herbicides) developed during this period were available to be tested in Vietnam in 1961. Their successful use during the period from 8 October 1961 through 18 March 1965 (the Initial Program Development Phase) resulted in the United States Department of Defense approving a major combat role for Tactical Herbicides from 29 March 1965 to 7 January 1971 (the Operational Phase). As noted above, the Initial Program Development Phase depended heavily on the limited research into both aerial spray systems and tactical herbicides that the United Army Chemical Corps had carried out from the end of World War II (1945) through 1959. The Leaflet Series from Site 1 to Site 9 provide both the history and successes of these research projects. For each site, an "**Activity Description**" is given to place in context what was occurring at the time and the intent of the project. The "**Assessment**" section of each Leaflet is intended to provide details about the human element, including who was involved and what they did with respect to the herbicides

being evaluated, i.e. potential exposures. The section on "**Sources**" provided the information that was described and assessed.

The Period from 1963 to 1967: Developing the Spray Systems and Multiple Herbicides for Supporting Combat Operations in Vietnam

The second period was the period in which new spray equipment and new formulations of tactical herbicides were developed and thoroughly tested in different geographical locations that were applicable to the subtropical and tropical conditions encountered in Vietnam. This research supported the "Operational Phase" of the Army Chemical Corps and the Air Force Operation RANCH HAND deployment of tactical herbicides in the combat environment of Vietnam. The Leaflet Series from Site 10 through Site 21 describe the development of various aerial spray systems at Eglin Air Force Base, Florida, and the Dugway Proving Ground, Utah, for the Army Chemical Corps (helicopters and a proposed fixed-wing Defoliant System), and the Air Force C-123U modifications for RANCH HAND combat spray missions. In addition, this series of Leaflets describes the continual efforts of the Army Chemical Corps Laboratories at Fort Detrick to develop and test new tactical herbicides, including fine-tuning the rates of applications required to control the vegetation encountered in Vietnam and throughout Southeast Asia.

The Use of Tactical Herbicides in Korea in 1968, and the "Camille" Incident in Mississippi in 1969

The only "military use" of tactical herbicides "outside" of Southeast Asia was in 1968 when the Korean and US Governments agreed to provide Herbicide Orange and Herbicide Blue for vegetation control adjacent to the Demilitarized Zone in Korea. Leaflet 22 describes this activity and the involvement of Korean and US military personnel. Leaflet 23 describes the incident in August 1969 at Gulfport, Mississippi where hundreds of drums of Herbicide Orange and Herbicide Blue were destroyed or lost due to the damaging winds of Hurricane "Camille." This Leaflet also assesses the involvement of personnel from the Army Corps of Engineers and the Air Force Logistics Command in the cleanup operations.

The Period from April 1972 – March 1977: Disposal Options for the Surplus Herbicide Orange Remaining After the Vietnam War

This time period was the period in which the military evaluated various options for the destruction of the surplus Herbicide Orange that was returned to the United States in April 1972 from Vietnam (Operation PACER IVY), or was in storage at the Naval Construction Battalion Center (NCBC), Gulfport, Mississippi in 1969. In August 1966, the United States Air Force Logistics Command took over the responsibility for managing the growing and continued procurement requirements for tactical herbicides in Southeast Asia. With the abrupt cessation of the use of Herbicide Orange in Vietnam in April 1970, the 7th Air Force in Vietnam was given the task of consolidating the remaining Herbicide Orange stocks in Vietnam (Operation PACER IVY), and

transferring those stocks to Johnston Island, Central Pacific Ocean. The responsibility for maintaining those "surplus" stocks of Herbicide Orange and disposing of them in an environmentally and publicly acceptable manner was given to the Air Force Logistics Command. Leaflet Series 24 to 30 describe the many options for the final disposition of Herbicide Orange. The importance of identifying these options, and hence the preparation of the Leaflets, was because of the active involvement of Active Duty military personnel. Moreover, the Leaflets provide a unique view of the history of the disposal of Herbicide Orange.

The Period From May 1977 to December 2004: Operation PACER HO and Site Monitoring and Reclamation of the Storage Sites at NCBC and Johnston Island

After reviewing the technical and scientific data obtained from the studies of the various options for the disposition of Herbicide Orange, and weighing of the costs in both economic and environmental terms, the Department of Defense made the decision to destroy all of the remaining stocks of Herbicide Orange by at-sea incineration. The operation to dispose of the "surplus" Herbicide Orange at the Naval Construction Battalion Center, Gulfport, Mississippi, and Johnston Island, Central Pacific Ocean was named Operation PACER HO. The Air Force Logistics Command used the term "PACER" to describe the operational movement of materiel. The "HO" referred to "Herbicide Orange". Leaflets 31 and 32 describe Operation PACER HO for both the inventories at the NCBC and at Johnston Island. The importance of documenting this military operation is because hundreds of Active Duty military personnel were involved in the activity. With the completion of the removal of the drums of Herbicide Orange at the NCBC and Johnston Island, the responsibility for monitoring the residues and environmental impacts of those toxic residues was done by Active Duty military. In February 1989 and December 2004, final corrective measures at the NCBC and Johnston Island, respectively, were completed under the Department of Defense Environmental Restoration Program.

The Distinction Between Tactical and Commercially Approved Herbicides Used in the Vietnam War

There exists significant confusion as to how herbicides were selected by the military to be used in the defoliation program in the Vietnam War The belief that commercially available herbicides were simply purchased from the chemical companies and deployed directly to Vietnam is incorrect and contrary to historical records.

The Military Development and Deployment of Tactical Herbicides

Tactical Herbicides were herbicides developed specifically by the United States Department of Defense to be used in "combat operations". The history of the military development and evaluation of tactical herbicides was described in the previous section. The testing of large volume aerial systems in 1952 and 1953 using Air Force B-29, B-50, and C-119 aircraft, and spraying a mixture of 2,4-D and 2,4,5-T, proved that military aircraft and tactical herbicides could be potentially used in a combat environment. The mission to develop additional tactical herbicides and new delivery technology was assigned to the US Army Chemical Corps, and specifically to the Crops Division of the Biological Warfare Laboratories (subsequently, the Plant Sciences Laboratories) at Fort Detrick, Maryland. The program involved the evaluation of thousands of compounds for herbicidal activity. In addition, the US Army with the active participation of the Air Force and Navy continued engineering development of delivery technology. When the Air Force accomplished prove-out and acceptance testing of the large-capacity (1,000 gallons) spray system (known as the MC-1 or Hour-glass Spray System) it was immediately sent to Guam, along with 5,000 drums of a concentrated mixture of technical butyl esters of 2,4-D and 2,4,5-T called "Purple", although neither the Spray Systems or the herbicides were used. After the close of the Korean Conflict, Fort Detrick scientists were involved in 1957 with tests showing the herbicidal activity of cacodylic acid (an organic arsenical) on rice and grasses, and with the evaluation of aerial application tests with mixtures of 2,4-D and 2,4,5-T at Fort Ritchie, Maryland (1956), Dugway, Utah (1959), and Fort Drum, New York (1959) (see Leaflets 6, 7, and 8).

In early 1961, the US military initiated Project AGILE, a project designed to provide technical information on the chemical means of controlling vegetation that could be applied to military operations in South Vietnam. The tactical problem to which research was directed was the development of chemicals that could rapidly control a broad range of botanical species. Once again the Department of the Army's Plant Sciences Laboratories at Fort Detrick, Maryland was given the responsibility, but this time the goal was to determine the technical feasibility of defoliating jungle vegetation in South Vietnam.

In late 1961, a test program for evaluating tactical herbicides for vegetation control in South Vietnam was approved for the Air Force. With the full concurrence and support of the Republic of Vietnam and the Vietnamese Air Force, a project under the code name operation RANCH HAND was initiated. Operation RANCH HAND was the USAF operation responsible for the tactical fixed-wing aerial application of herbicides from UC-123 Aircraft. Operation RANCH HAND began 7 January 1962, and terminated 7 January 1971, exactly nine years to the day from the arrival of the first RANCH HAND aircraft at Tan Son Nhut airport. The military justification, and hence the mission for the deployment of tactical herbicides by RANCH HAND, was to improve combat visibility in enemy controlled or contested jungle areas in order to expose infiltration routes, base camps, weapon placements, and storage sites of the Viet Cong and the regular Armed Forces of the Democratic Republic of Viet Nam. Tactical herbicides were also used along lines of communication, riverine transportation routes, around base perimeters, and also for crop destruction.

The first tactical herbicides selected for evaluation in Vietnam were Purple, the 2,4,5-T formulations of Pink and Green, and the powder form of cacodylic acid identified as "Blue". None of these products were commercially available; thus, following the publication of "military specifications", for the formulation, packaging, labeling of drums (including a 10-inch colored band around the center of the drum identifying the tactical herbicide), and shipment, these herbicides were purchased by the Defense Federal Supply Center (later the Defense Supply Agency), Richmond, Virginia via competitive bids. The United States Air Force Logistics Command took responsibility for the arrangements of the shipment of these tactical herbicides to the Republic of Vietnam.

Recognizing the continuing mission in Vietnam for tactical herbicides, the Plant Sciences Laboratories maintained an active program of testing and evaluating chemicals for potential use in Vietnam. Three major "Defoliation Conferences" (1963, 1964, and 1965) were sponsored by Fort Detrick. Plant Sciences Laboratory personnel simultaneously conducted field tests in Puerto Rico, Thailand, New Brunswick, and in the States of Alabama, Arkansas, Florida, Georgia, Hawaii, Maryland, and Texas. With the exception of Texas and Puerto Rico, only personnel from the United States Department of Agriculture (USDA) identified and visited the test sites, the responsibility for the testing protocol and spray operations rested with US Army or US Air Force personnel. The USDA had no regulatory authority over the selection or use of herbicide formulations developed by the Department of the Army. These field tests resulted in the selection of a liquid formulation of cacodylic acid (Herbicide Blue), a picloram-2,4-D formulation (Herbicide White), and a 50:50 mixture of an n-butyl formulation of 2,4-D and 2,4,5-T (Herbicide Orange). Following publication of "Military Specifications", these new "Tactical Herbicides" were purchased directly by the Department of Defense for use in Vietnam. These new tactical herbicides had a 3-inch colored band around the center of the drum, in addition to a brief description, the Transportation Control Number (TCN) and final destination in Vietnam.

Operation RANCH HAND involved modifications of standard military aircraft and development of sophisticated aerial spray equipment. It also required a military cadre of

highly trained air and ground-support crews. The training of aircrews, development of the interface between the aircraft and the spray equipment, and test and evaluation of the aerial spray systems were the responsibilities of the USAF Air Development Test Center and the Air Force Armament Laboratory, Eglin AFB, Florida.

The Air Force Armament Laboratory at Eglin AFB, Florida, the Air Force Environmental Health Laboratory, at McClelland AFB, California, the Air Force Occupational and Environmental Health Laboratory, Kelly AFB, Texas, the Plant Sciences Laboratory at Fort Detrick, and the United States Army Environmental Hygiene Agency, Aberdeen, Maryland, were responsible for determining physical properties, efficacy, toxicology, safe handling procedures, and actions to be taken for spills, environmental contamination, and disposal for all of the tactical herbicides.

Helicopters were used in the test phases of the tactical herbicide spray operations (1961 –1965), and were owned and operated by the Vietnamese Air Force. In September 1961, the Air Force Special Air Warfare Center, Eglin AFB, Florida, provided Army H-34 helicopters, spray systems, and aircrew training to the Vietnamese Air Force for tactical herbicide operations. Later the US Army and Marines used specially designed equipment developed by the US Navy at the Medical Field Research Laboratory, Camp LeJeune North Carolina, that could temporarily be attached to UH-1 helicopters for conducting spray projects around base perimeters and in other limited areas. The Department of the Army assigned a Chemical Office (J3-09) to the Military Assistance Command, Vietnam (MACV) to coordinate "operational aspects and plans" involving the use of the tactical herbicides by US and Vietnamese military units. In 1966, the US Army deployed the first (of 22) Army Chemical Corps units to South Vietnam. These units were responsible for the storage, handling, mixing, and application of riot control agents (tear gas), burning agents, and herbicides by the US Army. Men serving in these units performed duties associated with storage, preparation, and the ground and helicopter applications of vegetation control chemicals, as well as equipment cleaning and maintenance. The training of the Army Chemical Corps personnel to handle herbicides was the responsibility of the Army Chemical Corps Training Center at Fort Leonard Wood, Missouri.

The Defense Supply Agency (DSA) procured all tactical herbicides. DSA provided the 55-gallon drums and arranged for all transportation (primarily by rail) of the drums from the chemical companies manufacturing the herbicides to the port of embarkation. The chemical companies were selected on the basis of competitive bids and DSA provided the specifications (developed by the Army Chemical Corps) required to be met by the manufacturer.

Summary

The Herbicide Purple, Herbicide Pink, Herbicide Green, Herbicide Orange, Herbicide Blue, and Herbicide White were developed as "Tactical Herbicides". The United States Army's Plant Sciences Laboratories at Fort Detrick, Maryland, were responsible for the spraying, testing, and evaluating of tactical herbicide candidate formulations at numerous

sites throughout the United States, and in Puerto Rico, Canada, and Thailand. The Plant Sciences Laboratories were also responsible for establishing the "Military Specifications" for those herbicides selected to be used as "Tactical Herbicides". The ground and aerial spray equipment were developed by the Department of Defense to support tactical combat military operations in Southeast Asia. The Department of Defense provided the training for the Air Force aircrews, ground based personnel, and the Army Chemical Corps personnel that had responsibility for handling and spraying of the tactical herbicides. The selection and use of the tactical herbicides were exempt from USDA regulatory oversight, or from the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

The Role of the Armed Forces Pest Management Board

On 17 November 1956, Department of Defense Directive 5154.12 established the Armed Forces Pest Control Board (AFPCB) [subsequently The Armed Forces Pest Management Board (AFPMB)]. The purpose for establishing the AFPCB was to provide oversight of the DoD's pest management programs on its more than 600 world wide military installations. At the time the Board was established, the Department was using millions of pounds of commercial pesticides on these installations. The DoD Directive required that the Board be composed of members from the Army, Navy, Air Force and selected Defense Agencies (a total of 20 members). The Board was also to have 24 liaison members and 25 non-DoD Agency representatives. The Board established 8 Standing Committees: Environmental Impact, Equipment, Quarantine, Medical Entomology, Pesticides, Real Property Protection, Stored Products, and Training, Certification, and Manpower. In August 1961, the Department of Defense, via a Memorandum of Understanding, established with the USDA a support program that among other responsibilities provided the research, recommendations, and specifications of pesticides that were suitable and met the need for DoD use.

The Armed Forces Pest Control Board required all DoD agencies to use pesticide formulations that had "Federal Specifications", with the labeling and use directions approved by the Pesticides Regulation Branch of USDA (now EPA), and in full compliance with the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). As previously noted the "Tactical Herbicides" were required to meet "Military Specifications". There are four distinct "types of specifications". These are: (1) Purchase descriptions; (2) Army, Navy, and Air Force Specifications; (3) Military Specifications; and; (4) Federal Specifications. Purchase descriptions are merely descriptions of the material desired and are used for filling small needs or for materials that are needed on an emergency basis. They are issued by all government agencies and are of a temporary nature. Army, Navy, and Air Force Specification cover items specific to one of these military services (e.g., a biocide for ship hulls). Military Specifications are complete documents and are used when the need for the material is confined to a specific military operation (e.g., the Tactical Herbicides used in combat operations in Vietnam). The AFPCB adopted the policy for the Department of Defense to recommend that any pesticide formulation that has uses in civilian agencies be issued as a "Federal Specification". These types of pesticide are to be issued by the General Services

Administration (Tactical Herbicides were the responsibility of the Defense Supply Agency).

By 1966, the AFPCB strictly controlled the kinds and forms of pesticides available under "Federal Specifications" and on the military supply list. New pesticides, before being considered by the Board, had to be recommended by the US Department of Agriculture, the Fish and Wildlife Service, or the Public Health Service, and the proposed use had to have been approved by all three of these organizations. In February 1967, the Federal Committee on Pest Control (FCPC) was established. All Federal pest control activities were placed within the purview of the Committee. The Committee was composed of two members from each of the Departments of Agriculture; Defense; Health; Education, and Welfare; and Interior. Before a pesticide was approved for use in the United States, or by a Federal Agency, it had to be reviewed by the FCPC. The DoD's "Tactical Herbicides" were exempt from this approval and oversight process. However, all other herbicides used by the Department of Defense were required to meet this approval process. The significance of this action was that herbicides used in 1967 to 1970 on the more than 600 military installations managed by the Department of Defense required approval by both the AFPCB and the FCPC (after 1970, the registration and oversight of commercially available pesticides was the responsibility of EPA). This requirement applied to herbicides used in Vietnam that were NOT TACTICAL HERBICIDES. Thus, herbicides used on Allied Bases in Vietnam around buildings, in equipment storage sites, and along interior roads came under the requirements of the AFPCB. The responsibility for the purchase and application of commercial pesticides on these installations was the Base Civil Engineer, NOT the Army Chemical Corps. Tactical Herbicides were NOT approved for these uses. The insecticides used in Operation FLYSWATTER (the aerial application of insecticides to control mosquitoes in Vietnam) were under the Military's Disease Prevention Program and were approved by the AFPCB.

With the establishment and functioning of the AFPCB, anytime a DoD Military Base, e.g., Eglin AFB, Florida, Andersen AFB, Guam, or Osan AB, Korea, requested the use of a herbicide to control plant pests, the selection of the herbicide must have been approved by the Board. Locally purchased pesticides were to be approved by the Command Entomologist. Moreover, the application of the herbicide had to be done by a Board "certified" (trained) applicator, and with equipment that had been approved by the USDA, and under the supervision of the Base Civil Engineer. The Department of Agriculture's Agricultural Research Service (ARS), and the Cooperative State Research Service (CSRS) provided critical support to the development of pesticides that were subsequently recommended and approved for use by the AFPCB. The Board DID NOT work with the chemical companies manufacturing the pesticides, rather, these materials were evaluated by ARS, the various State University Experiment Stations, and the State and Federal Extension Services. In addition, AFPCB depended upon CSRS and its University-based research and extension system to prepare and publish manuals on pesticide use, plans for certification of pesticide applicators, and the disposal of old pesticides and pesticide containers. The final statements on safety and environment precautions on the use of herbicides commercially available to the military were

determined by the agencies of the Public Health Service, and when necessary by the United States Army Environmental Hygiene Agency.

To ensure that military installations were identifying and controlling pests detrimental to military personnel, property, projects, and programs, the AFPCB had a cadre of military and civilian personnel via supporting Agencies and Laboratories (e.g., the Epidemiology Division of the School of Aerospace, Brooks AFB, Texas; USAF Occupational and Environmental Health Laboratory, Kelly AFB, Texas; and the Public Health Service) that routinely conducted Pest Surveys, Staff Visits, Training Programs, and Conferences on identifying and controlling pests. Reports of these visits, programs, and conferences were published by the Board and widely circulated to other military installations.

Summary

Under the Directives 5154.12 and 4150.7, the Department of Defense gave the Armed Forces Pest Control Board/Armed Forces Pest Management Board the authority to set pest management policy *"applicable for all Department of Defense pest management activities in any unit, at any time, in any place, even when conducted by contract operations."* The significance of this Directive is that any herbicides used after 1961 on DoD's more than 600 installations must have been approved by the Board, and must have met USDA's regulatory requirements, and all the requirements of FIFRA. The exception to these Directives was the development of the "Tactical Herbicides" sprayed in combat military operations in Vietnam, or by Department of State approval as used in Korea adjacent to the Demilitarized Zone in 1968.

Implications

Herbicides used in Operation RANCH HAND for defoliation and crop destruction projects, and by the US Army Chemical Corps for vegetation control on perimeters, cache sites, and similar militarily-important targets were classified as "Tactical Herbicides" and were formulated, tested, evaluated, and assigned "Military Specifications" by the Department of Defense. They were not subject to regulatory oversight by the Department of Agriculture, the Armed Force Pest Control Board, or the Federal Committee on Pest Control. However, the insecticides used in Operation Flyswatter were subject to the AFPCB, as were all other pesticides used for control of pests within the boundaries of the military installations in Vietnam.

There were no documents that indicated the herbicides used in Guam, or CONUS military installations were "tactical herbicides", rather, the available documents confirmed that all pesticides use in these locations and other US Department of Defense installations world wide were those commercially available and approved by AFPCB.

Supporting Literature

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28175 USDA Pesticide Situations for 1964-1965 (1965)

35132 Federal Committee on Pest Control (FCPC, 1967)

37972 Non Standard Herbicides (1967)

40103 Report of Staff Visit to Japan and Korea (1968)

40234 How Agriculture Stretches Your Defense Dollar (1967)

40654 Restriction on 2,4,5-T to SEA (1967)

42605 USDA Moves to Tighten Pesticide Labeling Regulations (1963)

44355 Pesticides and Pest Control Equipment (1968)

50641 Herbicides, Pest Control, Agents, and Disinfectants (1969)

57235 Interim Guidelines for Disposal of Surplus Herbicide and Containers (1970)

57625 Insecticide Dispersal Equipment for Navy and Marine Corps Aircraft (1971)

61764 Statement on Use and Disposition of Pesticides (1971)

65134 Tactical Employment of Herbicides (1969)

72229 Pesticide Monitoring of Water, USAF Environ. Lab., McClellan AFB, CA (1969)

80358 History of the Armed Forces Control Board (1974)

96815 DoD Certification of Pesticide Applicators (1977)

118307 Medical Pest Management Survey, Korea, USAF OEHL (1983)

123220 Military Handbook on Design of Pest Management Facilities (1984)

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165110 Pesticide Usage in DoD, 1994

168230 Contingency Pest Management Pocket Guide (1986)

171960 Military Pest Management Training Manual (1999)

Tactical Herbicides Deployed in Vietnam/Southeast Asia

DESCRIPTION

Herbicide Purple, 1962 – 1965: Purple was first formulated by the Army Chemical Corps at Fort Detrick, Frederick, Maryland in the mid-1950s time period. It was first used in the Camp Drum, New York defoliation tests in 1959 (*see Leaflet Site 8*). The formulation was a brown liquid soluble in diesel fuel and organic solvents but insoluble in water. One gallon of Purple contained 8.6 pounds active ingredient (acid equivalents) of 2,4-D and 2,4,5-T. The percentages of the Purple formulation were:

n-butyl 2,4-D	50%
n-butyl 2,4,5-T	30%
iso-butyl 2,4,5-T	20%

Herbicide Green, 1962: Green was a single component formulation consisting of the n-butyl ester of 2,4,5-T. It was used in limited quantities in 1962. The formulation was a light brown liquid soluble in diesel fuel but insoluble in water. One gallon of Green contained 8.16 pounds active ingredient of 2,4,5-T.

Herbicide Pink, 1962 –1964: Pink was a formulation of 2,4,5-T used extensively in the early RANCH HAND operations and in the defoliation test program in Thailand in 1964 (*see Leaflet Site 13*). One gallon of Pink contained 8.16 pound active ingredient 2,4,5-T. The percentages of the Pink formulation were:

n-butyl 2,4,5-T	60%
iso-butyl 2,4,5-T	40%

Herbicide Orange, 1965 – 1970: Orange was a reddish-brown to tan colored liquid soluble in diesel fuel and organic solvents but insoluble in water. The first shipment of Herbicide Orange arrived in Vietnam in March 1965. One gallon of Orange contained 8.62 pounds of the active ingredient 2,4-D (4.21 pounds) and 2,4,5-T (4.41 pounds). The percentages of the Orange formulation were:

n-butyl 2,4-D	50%
n-butyl 2,4,5-T	50%

Herbicide Orange II, 1967-1968: The same as Orange but with the substitution of the isooctyl ester of 2,4,5-T for the n-butyl ester of 2,4,5-T.

Herbicide Blue (Liquid), 1966 – 1971: In 1961, the first Blue (95 drums) that was shipped to Vietnam was a powdered formulation that required water. In February 1966, the first Liquid Blue arrived in Vietnam. Herbicide Blue was a clear yellowish-tan liquid that was soluble in water, but insoluble in diesel fuel. One gallon of Blue contained 3.1 pounds of the active ingredient cacodylic acid. Blue contained both the cacodylic acid as the free acid and the sodium salt of cacodylic acid. The percentages of the formulation were:

cacodylic acid	4.7%
sodium cacodylate	26.4%
surfactant	3.4%
sodium chloride	5.5%
water	59.5%
antifoam agent	0.5%

Herbicide White, 1966 – 1970: White was a dark brown viscous liquid that was soluble in water but insoluble in diesel fuel or organic solvents. Herbicide White first arrived in Vietnam in January 1966. One gallon of White contained 0.54 pounds of the active ingredient 4-amino-3,5,6-trichloropicolinic acid (picloram) and 2.00 pounds of the active ingredient of 2,4-D. White was formulated to contain a 1:4 mixture of the triisopropanol-amine salts of picloram and 2,4-D. The percentages of the formulation were:

triisopropanolamine salt of picloram	10.2%
triisopropanolamine salt of 2,4-D	39.6%
inert ingredient (primarily the solvent, triisopropanolamine)	50.2%

The studies reported in the Leaflets describe how the tactical herbicides and the spray equipment were developed, tested, evaluated for use in Vietnam. The outcome of this process was that the tactical herbicides were sprayed at the rate of 3 gallons per acre in Vietnam. These were formulations and concentrations that greatly exceeded how the commercial components of these tactical herbicides (2,4-D; 2,4,5-T; picloram; and, cacodylic acid) were formulated and used in the United States in brush and weed control, and in forestry management.

Search Strategy for Historical Documents on Tactical Herbicides

SOURCES

The Department of Army research on tactical herbicides was conducted primarily by the Army Chemical Corps' Plant Sciences Laboratory, Fort Detrick, Frederick, Maryland and it predecessors. A search was conducted of more than a thousand documents of the Army Chemical Corps at the National Archives in Greenbelt, Maryland.

The United States Armed Services Center for Unit Records Research (CURR), The Department of Army, Springfield, Virginia was contacted with the assistance of the Deployment Health Support Directorate, Deputy Under Secretary of Defense (Installations and Environment), Department of Defense, Washington, DC. CURR provided numerous leads on important documents.

The Defense Technical Information Center (DTCI), Fort Belvoir, Virginia, is the "premier provider of DoD technical information." DTIC is the repository of the documents submitted by the military to its predecessor, the Defense Documentation Center (DDC). A DTIC search resulted in the identification and acquisition of numerous DDC documents.

The Armed Forces Pest Management Board's Defense Pest Management Information Analysis Center, and Literature Retrieval System, Forest Glen Section, Walter Reed Army Medical Center, Washington, DC. The Literature Retrieval System is an online collection of scientific papers comprising more than 102,000 documents in searchable PDF format for research purposes only. The Literature Retrieval System was an excellent source of information.

The Alvin L. Young Collection on Agent Orange, Specially Collections, The National Agricultural Library, Beltsville, Maryland, This is a collection of more than 7,000 documents collected by Dr. Alvin L. Young from 1969 – 1987 on the issues associated with the use of herbicides in Vietnam and Southeast Asia. Many of the documents are technical reports of research conducted by the military on the use and disposal of tactical herbicides. Included are technical reports by Dr. Young on the fate of the tactical herbicides in the environment. Approximately 1,600 documents are retrieval in a searchable PDF format.

The Office of Air Force History, Bolling Air Force Base, Washington DC, and the Office of History, Air Force Logistics Command, Wright-Patterson Air Force Base Ohio were additional sources for information on tactical herbicides, Operation RANCH HAND Operations Operation PACER IVY and Operation PACER HO.

DOD TACTICAL HERBICIDE SITES

Site 1

Location: Bushnell Army Air Field, Florida

Dates⟶ February – April 1945

Activity Description: The purpose of this research was to determine means of accomplishing defoliation of tropical vegetation by application of a chemical agent. The herbicidal agents evaluated included the acids of 2,4-D and 2,4,5-T as 2% formulations in tributyl phosphate and diesel fuel. A total area of 382 acres (155 ha) was aerially sprayed, some areas receiving multiple applications.

Assessment: During the three-month period, a team (five military officers) from Camp Detrick, Frederick, Maryland, conducted preliminary screening of tropical plants obtained from the Plant Introduction Garden, Coconut Grove, Florida. Following the initial evaluations, aerial spray tests were conducted on "grids" of the natural vegetation adjacent to the runways on the Bushnell Army Air Field. Observations were made over the three-month period. The herbicides were formulated at Camp Detrick and transported to Bushnell Army Air Field.

Sources: Carpenter, JB (June 1945): The Effects of VXA and VKS on Natural Vegetation: Preliminary Trials. Special Reports No. 23 & No. 14, Special Projects Division, Chemical Warfare Service, Camp Detrick, MD, 17 June 1945. *The document declassified 30 Oct 1961, but subject to export control*

Norman, AG, Taylor DL, Weaver RJ, Page RM, Carpenter JB, Newman AS (May 1945): Marking and Defoliation of Forest Vegetation, Special Report No. 13 Camp Detrick, Maryland. *The document declassified 6 Oct 1967 but subject to export control*

DOD TACTICAL HERBICIDE SITES

Site 2

Location: USDA Station, Brawley, California

Dates ⟶ July—August 1951

Activity Description: By the early 1950's, the herbicides 2,4-D and 2,4,5-T were being extensively evaluated by the United States Department of Agriculture (USDA) for their weed control properties. However, much of this work provided evidence that these same herbicides were detrimental to broadleaf crops, i.e., beans, soybeans, peppers, tomatoes, etc. Hence, the US Army Chemical Corps' Biological Laboratories at Camp Detrick, Frederick, Maryland, initiated studies to determine application rates that could be used in tactical operations as anti-crop agents. Formulations of 2,4,D and 2,4,5-T were evaluated on small field plots of various agronomic crops in an effort to evaluate the anti-crop effectiveness of small droplet sprays of these herbicides.

Assessment: The Army Chemical Corps established a project agreement with Division of Weed Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, USDA, to conduct studies on the toxicity to agronomic crops of various 2,4-D and 2,4,5-T formulations. The rates varied from 0.5 pounds (lbs) of active ingredient of the herbicide per acre (A) to 8 lbs/A. USDA personnel at the USDA Research Station at Brawley, California conducted all of the studies. Camp Detrick personnel provided project oversight and the formulations to be tested.

Source: Weintraub RL, Minarik, CE (1952): Field Plot Experiments with Plant Inhibitors, the 1950–51 Crop Season. Special Report No. 156, Chemical Corps, Biological Laboratories, Camp Detrick, Frederick, Maryland, August 25, 1952. *The Document declassified 17 April 1962 but subject to export control*.

DOD TACTICAL HERBICIDE SITES

Site 3

Location: Eglin Air Force Base, Florida (Test Ranges 52 and 57)

Dates ⟶ November – December 1952, March – April 1953

Activity Description: In preparation for the potential use of tactical herbicides for use as anti-crop agents, the Air Force Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, tasked the Air Force Armament Center, Eglin Air Force Base, Florida, with the requirements for the design and procurement of a Large Capacity Spray System to used in the B-29, B-50, and C-119 bomber aircraft.

Assessment: In late 1952, a mixture of technical butyl 2,4-D (50%) and technical butyl 2,4,5-T (30%) and technical isobutyl 2,4,5-T (20%) was aerially sprayed from altitudes of 100-1000 feet at an airspeed of 200 mph. Tank size varied between 125-640 gallons. Spray systems were tested for B-29, B-50, and C-119 aircraft. The total spray area was 8,700 acres. This is first documented use of the Purple formulation. In the 1953 tests, the ester formulation was aerially sprayed from a B-29 and a C-119 aircraft from altitudes of 1,000-2,000 feet. Tank size was 1,000 gallons in both aircraft. 8,500 gallons of herbicide were released at a rate of 0.34 lbs/A on 8,000 acres of both test areas. A small number of Air Force, Army, and contractor personnel were involved in the operations. The formulation was furnished by the US Army Chemical Corps, Camp Detrich, Frederick, Maryland.

Source: Acker RM, Hartmeyer RW, Heatherly JE, and Bullard WE (1953): Anticrop Aerial Spray Trials, Phase III. Special Report No. 184, US Army Chemical Corps' Biological Laboratories, Camp Detrick, Frederick, Maryland, February 15, 1953. *The document declassified 4 November 1954 but subject to export control. Available from the Defense Documentation Center, Accession Number AD49572*

Ward JF (August 1953): Evaluation of Production Model of Large Capacity Spray System for B-29 and C-119 Aircraft. Technical Report No. 53-33, Air Force Armament Center, Eglin AFB, Florida. *The document declassified 4 November 1954 but subject to export control. Available from the Defense Documentation Center, Accession Number AD17563*

DOD TACTICAL HERBICIDE SITES

Site 4

Location: USDA Experimental Fields, Gallatin Valley, Bozeman, Montana

Dates⟶ July – August 1953

Activity Description: In 1951, the US Army Chemical Corps evaluated the phytotoxicity of 2,4-D and 2,4,5-T on broadleaf crops. The question remained as to whether the phenoxy herbicides were equally phytotoxic to narrow leaf grain crops. Thus, a preliminary series of field evaluations were conduced of various 2,4-D and 2,4,5-T formulations as anti-crop agents against wheat. The tests were conducted at the United States Department of Agriculture (USDA) Research Center in the Gallatin Valley near Bozeman, Montana.

Assessment: The objective of these experiments conducted on wheat was to determine the feasibility of applying very small amounts of candidate anti-crop agents from a spray boom mounted on a light aircraft. The tests took place in July 1953 on 139 acres of hard red spring wheat. Four chemical agents were formulated by the Crop Division's Biological Laboratories, Camp Detrick, Maryland, and consisted of various mixtures of n-butyl, isobutyl and amyl formulations of 2,4-D and 2,4,5-T. The mixture of concentrated butyl 2,4-D and 2,4,5-T [50% butyl 2,4-D, 25% butyl 2,4,5-T, and 25% isobutyl 2,4,5-T – Herbicide Purple] was applied at rates from 0.03 to 4.18 lbs/A in four replications of plots within the 139 acres of wheat. The mixtures were sprayed from an altitude of 30 feet. Total quantity for all formulations of 2,4-D and 2,4,5-T was less than 55 gallons. Personnel involved were from either the USDA or from Camp Detrick.

Source: Acker RM, Hartmeyer RW, Bullard WE, and Heatherly JE (February 1954): Field Development of Chemical Anticrop Agents. Special Report No. 200, Crops Division, US Army Chemical Corps' Biological Laboratories, Camp Detrick, Maryland. *The document declassified 4 November 1954 but subject to export control. Available from the Defense Documentation Center, Accession Number AD49571.*

DOD TACTICAL HERBICIDE SITES

Site 5

Location: Area B, Fort Detrick, Frederick, Maryland

Dates ⟶ June – July 1953

Activity Description: Experiments were conducted on field grown crops to determine the feasibility of using an experimental spray tower mounted on a pickup truck to simulate aerial spray applications of chemical anti-crop agents. In addition, since anti-crop agents were to be deployed from a bomber aircraft, it was essential to obtain crop yield data when sprays were applied under simulated tactical operational conditions.

Assessment: The tests were conducted on Area B, Camp Detrick, Maryland, The Purple mixture of technical butyls of 2,4-D/2,4,5-T was applied to 1-acre plots of soybeans and sweet potatoes at a rate of 0.05 lbs/A. The chemical mixture was sprayed from a 20-foot tower mounted on a pickup truck. The agent was applied in the evening under inversion conditions, and with a wind velocity between 2 and 3 mph and a direction parallel to the crop rows. Chemical Corps personnel were responsible for both the spray operations and the preparation and handling of the tactical herbicide.

Source: Acker RM, Hartmeyer RW, Bullard WE, and Johnson WB (January 15, 1954): Field Development of Chemical Anticrop Agents, Series 2, Response of Field Grown Crops to Chemical Anticrop Agents Released from an Experimental Spray Tower. Special Report No. 201, Chemical Corps, Biological Laboratories, Camp Detrick, Frederick, Maryland. *Document declassified 4 November 1954 but subject to export control. Available from the Defense Documentation Center, Accession Number AD49420.*

DOD TACTICAL HERBICIDE SITES

Site 6

Location: Fort Ritchie, Cascade, Maryland

Dates⟶ April 1956 – September 1957

Activity Description: In 1956 and 1957, 577 chemicals were screened for the best available tactical defoliants, desiccants, and vegetation control agents. Selection of suitable agents was determined by evaluating environmental conditions, spray techniques, and formulations that increased the effectiveness of the defoliants and desiccants.

Assessment: Selected coniferous and deciduous trees native to the Fort Ritchie Reservation, Cascade, Maryland, were selected for treatment with 5, 60, 500, and 1,000 parts-per-million (ppm) applications of various 2,4-D and 2,4,5-T formulations. All applications were done by hand application. Sprays with the technical butyl esters of 2,4-D and 2,4,5-T were found to be most effective as defoliants. The applications of the tactical herbicides and the preparation of the formulations were the responsible of the personnel from the Biological Warfare Laboratories, Fort Detrick, Maryland.

Source: Preston WH, Downing CR, Hess CE (July 1959): Defoliation and Desiccation. Biological Warfare Laboratory Technical Report Number 16, Crops Division, Director of Biological Research, Army Chemical Corps Research and Development Command, US Army Biological Warfare Laboratories, Fort Detrick, Frederick, Maryland. *The document declassified July 1971 but subject to export control. Available from the Defense Documentation Center, Accession Number AD31980.*

DOD TACTICAL HERBICIDE SITES

Site 7

Location: Dugway, Utah

Dates ⟶ May 1951 – March 1959

Activity Description: Ten projects of chemical anti-crop agents were conducted on the Dugway Proving Ground, including tests with formulations of 2,4-D and 2,4,5-T, between 7 May 1951 and 23 March 1959.

Assessment: The series of tests were all conducted from a variety of platforms, including balloons, an experimental spray tower, light aircraft, and jet aircraft, and with a range of volumes from low volume to large capacity spray tank volumes. Studies were conducted on the effects of altitude and airspeed on the droplet behavior of chemical anti-crop agents. The formulations, including the butyl ester formulations of 2,4-D and 2,4,5-T, were prepared by the US Army Chemical Corps, Fort Detrick, Frederick, Maryland. Personnel were from the Chemical Corps or on detail from the United States Air Force.

Sources: King DW, Ward RM (1961): Summary and Evaluation of Chemical Spray Trials, Technical Report 61-1B, Volume 2, Bibliography, C-E-I-R, Inc., Dugway Field Operations, Dugway, Utah, 31 August 1961. *Document declassified 19 October 1964.* (Summaries included for Special Report 149, 7 May 1951; Special Report 151, 20 December 1951; Special Report 184, 15 February 1953; Special Report 201, 15 January 1954; Special Report 200, February 1954; Special Report 225, November 1954; Special Report 227, 14 January 1955; Special Report 232, June 1955; Summary Report E-47-2, 2 December 1957; Summary Report E-47-3, 23 March 1959). *All documents subject to export control. Summary document available from the Defense Documentation Center, Accession Number AD354205.*

DOD TACTICAL HERBICIDE SITES

Site 8

Location: Fort Drum, New York

Dates → May – October 1959

Activity Description: The basic consideration in aerial applications of liquid sprays for vegetation control is to secure maximum deposition of the delivered agent on the selected target. In the summer of 1959, a 2,4-D/2,4,5-T formulation was evaluated for its operational use in defoliating or killing trees growing in an area of about four square miles in an impact zone (an area receiving explosive ordnance) at Camp Drum, New York.

Assessment: Thirteen drums (715 gallons) of the concentrated butyl esters of 2,4,D and 2,4,5-T (Herbicide Purple formulation) were aerially applied by helicopter over 2,560 acres of Fort Drum's deciduous forested area in the summer of 1959. The area selected for treatment was an area isolated from combat maneuvers. The tests were conducted by US Army Chemical Corps personnel, and the Purple Herbicide formulation was surplus herbicide from an inventory manufactured in 1953-1954 period for potential use in the Korean Conflict. The rates of deposition and the flow rate calculations were instrumental in subsequent defoliation tests in both the Continental United States and in Southeast Asia.

Sources: Brown JW (1962): Section VI. Vegetation Control, Camp Drum, New York. IN: Vegetational Spray Tests in South Vietnam. US Army Biological Laboratories, Fort Detrick, Frederick, Maryland. *The document unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0476961*.

Minarik CE (1964): Crops Division Defoliation Program. IN Proceedings of the First Defoliation Conference, 29-30 July 1963. United States Army Biological Laboratories, Fort Detrick, Frederick, Maryland. *The document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0427874.*

DOD TACTICAL HERBICIDE SITES

Site 9

Location: Eglin AFB, Florida, Test Area C-52A and Hardstand 7

Dates⟶ March 1962 – January 1971

Activity Description: The training of the aircrews, the development of the interface between the aircraft and the spray equipment, and the test and evaluation of the entire aerial spray system were the responsibilities of United States Air Force's Air Development Test Center (ADTC), at Eglin Air Force Base (AFB). For ten years (1961-1971), the Air Force Armament Laboratory at Eglin AFB provided the scientific, engineering, and technical support for Operation RANCH HAND in Vietnam. One of the most important aspects in the development of aerial spray systems was testing of the equipment under the most realistic conditions possible. An array of test grids was developed where the aircraft and equipment could be monitored and evaluated using the actual herbicides that were deployed for use in Vietnam. The goal was not to test the effectiveness of the herbicides, but rather the effectiveness of the aircraft and spray equipment in disseminating a concentration of herbicide that would be effective in defoliating jungle vegetation.

Assessment: During the 10-year period, four test grids, each uniquely arrayed to match the needs of either fixed-wing, helicopter, or high performance jet aircraft, were established and operated within the boundary of Test Area C-52A. During the years of its operation, an area of less than 1 square mile of the Test Area received 15,455 gallons of Herbicide Purple (281 drums) and 18,975 gallons of Herbicide Orange (345 drums), 4,400 gallons of Herbicide Blue (80 drums). Spray equipment tests and evaluations of the more than 400 missions over the Test Area were generally scheduled and conducted with environmental conditions optimal for spray operations. The total estimated flight time spent dispensing herbicides over the four test arrays was 235 hours.

The program terminated in the spring of 1971, and Test Area C-52A was set-a-side as a unique research site for the environmental impacts of tactical herbicides and the associated dioxin. In 1978, following the conclusion of many ecological and environmental studies, the entire area was fenced and restricted from public access. The decision by the ADTC to allow natural attenuation to clean the ecosystem of chemical residues prevented a major reclamation operation of an area of more 400 acres.

In support of the test and evaluation programs on Test Area C-52A, ADTC established a herbicide storage and aircraft loading site at Hardstand 7, an asphalt and concrete aircraft parking area located west of the North-South Runway on the main Eglin AFB Airdrome. Hardstand 7 was the herbicide-loading site for the approximately 400 aerial missions in support of the aircraft and spray equipment tested on the Test Area. In 1974, 130 drums of Herbicide Orange were removed from the Hardstand to the Naval Construction Battalion Center, Gulfport, MS for final disposition

In the first years of the tests programs on Test Area C-52A, numerous US Army Chemical Corps personnel were involved in the operations. By 1963, Air Force Armament Laboratory military, civilian, and contractor personnel were involved in the handling and test operations. Hundreds of military and civilian personnel were involved in the Eglin AFB Test Programs, and subsequent ecological studies over the years from 1963 to 1983.

Sources: More than 25 technical reports on test operations and ecological studies involving Test Area C-52A and Hardstand 7 are available in the Special Collection on Agent Orange at the National Agricultural Library, Beltsville, MD.

Young AL, Thalken CE, Ward WE (1975): Studies of the Ecological Impact of Repetitive Aerial Applications of Herbicides on the Ecosystem of Test Area C-52 A, Eglin AFB, Florida. *Available from the Defense Documentation Center, Accession Number AD-A032773*.

Two recent articles have been published that summarize the test programs and ecological studies on Test Area C-52A and Hardstand:

Young AL, Newton M (2004): Long Overlooked Historical Information on Agent Orange and TCDD Following Massive Applications of 2,4,5-T-Containing Herbicides, Eglin Air Force Base, Florida. *Environ Sci & Pollut Res* 11(4): 209-221.

Vasquez AP, Regens JL, Gunter JT (2004): Environmental Persistence of 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin in Soil Around Hardstand 7 at Eglin Air Force Base, Florida. *J Soils and Sediments* 4(3): 151-156.

DOD TACTICAL HERBICIDE SITES

Site 10

Location: Fort Ritchie, Fort Meade, Maryland

Date → 1963 – 1964

Activity Description: The search for effective defoliants prior to Vietnam focused primarily on the effectiveness of the phenoxy herbicides 2,4-D and 2,4,5-T. Thus Herbicide Purple was the earliest formulation that was considered appropriate for use in Vietnam. However, the Crops Division of the US Army Biological Laboratories continued its search for other potential defoliants that could be used in Vietnam. This effort was both an in-house program at Fort Detrick, and a contractual program managed by Fort Detrick. By the early 1960s, the knowledge and experience in synthesizing and evaluating various chemicals with herbicidal properties was located primarily with the Chemical Companies that were developing new pesticides for agricultural use. Thus, in 1963, the Army Chemical Corps sponsored the first of three "Defoliation Conferences". The First Defoliation Conference was held at Fort Detrick on 29-30 July 1963. At this Conference, the major pesticide producers in the United States were invited to participate. The concept was that the companies through contractual agreements would synthesize new potential compounds and that Fort Detrick would screen these compounds for the necessarily biological activity.

The screening program by Fort Detrick was carried out in three phases: primary screening on 14 day-old Black Valentine beans at 0.1 and 1.0 pounds per acre (lbs/A); secondary screening of the most promising chemicals sprayed in the greenhouse at 1, 5, and 10 lbs/A on maple, spruce, pine, locust, privet, pin oak, hemlock, and elm seedlings; and, the third phase consisted of field screening. Some initial field screening occurred at Fort Detrick. Subsequent field screening was conducted at Fort Ritchie and Fort Meade in Maryland, geographically not far from Fort Detrick, but on Military Reservations sufficiently large to permit spraying individual trees or small plots in areas isolated and restricted from public access. The field screening was used to answer the question: "At what rate are certain compounds effective, if not effective at 5 or 10 lbs/A?"

Assessment: The 1963 tests at Fort Ritchee consisted of spraying various rates of picloram, 2,4-D, Herbicide Orange, diquat, endothal, and combinations of each of these on 108 individual trees consisting of ash, elm, and locust. The 1963 field tests at Fort Meade consisted of spraying 24 plots, each 225 square feet, with cacodylic acid, Dowco 173, and butynediol at 10, 25, 40, 55, 70, 85, and 100 lbs/A on 15 species of trees, including scrub pine, maples, oaks, American chestnut, sweet gum, tulip poplar, quaking

aspen, and vaccinium. The 1963 tests confirmed the selectivity and effectiveness of a combination of picloram-2, 4-D (subsequently later labeled Herbicide White), and a water-soluble sodium formulation of cacodylic acid (subsequently later labeled Herbicide Blue). The 1964 field trials continued the evaluation of various "new" compounds that were sprayed on 105 plots, each 225 square feet, with 52 different compounds and formulations at 5 and 10 lbs/A.

Because the trees and plots at Fort Ritchie and Fort Meade were spread over a considerable area, and the terrain was frequently very rough, the spray system consisted of 3-gallon tank sprayer with a 20-foot hose and a 9-foot stainless steel wand having a 20-inch boom with three No.2 Whirljet nozzles. The compounds and formulations were carefully weighed to the desired rates in the laboratory at Fort Detrick, and then poured into the tank sprayer with just enough diluent to cover a plot or an individual tree. The sprayers were outfitted with pressure gauges so that each tree could be sprayed at 30 lbs pressure. Spraying was done from a large tank truck so that the spray was directed down on the foliage to more closely simulate aerial spraying. All personnel involved in the handling and spraying of the chemicals were military and civilians assigned at Fort Detrick.

Sources: Mattie VZ (1964): Proceedings of the First Defoliation Conference, 29-30 July 1963. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0427874*.

Darrow RA, Mattie VZ (1965): Proceedings of the Second Defoliation Conference, 5-6 August 1964. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0329567*.

Mattie VZ, Darrow RA (1966): Proceedings of the Third Defoliation Conference, 10-11 August 1965. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD898001*.

DOD TACTICAL HERBICIDE SITES

Site 11

Location: Dugway Proving Ground, Dugway, Utah

Date ⟶ September – October 1964

Activity Description: The objectives of the tests conducted on the Dugway Proving Ground during September and October 1965 were to determine the performance reliability, maintenance requirements, and suitability of the Army Interim Defoliant System for the US Army OV-1 (MOHAWK) aircraft.

Assessment: Six dissemination trials of the E44 Interim Defoliant System were conducted using two E44 spray tanks mounted under the wings of a US Army OV-1 (MOHAWK) aircraft. For each trial, Herbicide Orange was released at the deposition rate of 3 gallons/acre over an area of approximately 17 acres. In six trials, 935 gallons (17 drums) of Orange were disseminated on the test area. The trials were conducted by the US Army Chemical Corps' Biological Laboratories, Fort Detrick, Maryland, under an agreement with the US Army Test and Evaluation Command. The US Army Chemical Corps and the Dugway Proving Grounds provided all the personnel and tactical herbicides for the tests and evaluations.

Sources: US Army Test and Evaluation Command (1965): Integrated Engineering/Service Test of an Interim Defoliant System. Part I. Service Test, USATECOM Project No 5-4-3001-02. US Army Aviation Test Board, Fort Rucker, Alabama. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD466566*.

McIntyre WC, Sloane HS, Johnson KR, Taylor WS (1965): Final Report of Integrated Engineering/Service Test of an Interim Defoliant System. US Army Test and Evaluation Command, Dugway Proving Ground, Dugway, Utah. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD363013*.

DOD TACTICAL HERBICIDE SITES

Site 12

Location: Georgia Power Company Right-of-Way, and Tennessee Valley Authority Power Line Right-of-Way

Date → May 1964 – October 1965

Activity Description: The successful screening of candidate defoliants at Fort Ritchie and Fort Meade prompted Fort Detrick personnel to seek additional sites where a more extensive evaluation could be conducted on Herbicide Orange, Picloram-2,4-D (Herbicide White formulation), and with various combinations of the commercial herbicides diquat and dicamba. The objective of the field tests was to evaluate these formulations under field conditions against the standard tactical herbicide "Purple".

The Crops Division arranged with Georgia Power Company and Tennessee Valley Authority for the use of 65 acres of right-of-way through the swamps of Georgia, and additional 65 acres of right-of-way in the mountains of Tennessee. The test sites selected in Georgia were characterized by swamp forest vegetation with a long, hot, growing season and ample water available for active growth. Typically, the level of water in the swamp was between 6 and 24 inches. Sections of the right-of-ways for the Valdosta-Thomasville Power Line and the Bonaire Power Line near Macon were selected for treatment. In Tennessee, a section of the 200-foot right-of-way provided by the Tennessee Valley Authority was in a mountainous area and on a power line between Hiwassee Dam, North Carolina, and Coker Creek, Tennessee.

Assessment: The aerial spray tests conducted on these transmission line right-of-ways were by helicopter. In Georgia, six plots, each 60 by 2,640 feet, were treated on the Valdosta-Thomasville line, which had a 60-foot right-of-way. On the Bonaire line, with 200-foot wide right-of-way, seven plots were established each 200 feet wide and 700 feet long. At both locations, Herbicides Orange and Purple were applied at 10 lbs/A. The proposed Herbicide White formulation was applied at 4 lbs/A picloram and 11 lbs/A 2,4-D. In the aerial tests in Tennessee, the plots were difficult to mark because of the mountainous terrain, and thus the right-of-way (approximately 3 acres between adjacent powerline towers), served as the tests plots. The Orange and Purple Herbicides were applied at 4, 8, and 33 lbs/A. The proposed White formulation was sprayed at rates of 6.25, 11.50, 19.10, and 25.5 lbs/A. The plots in Georgia were sprayed on 20-23 May 1964. The plots in Tennessee were sprayed 17 June and 2-3 July 1964.

The Bell G-3 helicopter used in all tests was equipped with two 60-gallon saddle tanks and a 24-foot boom rigged amidship. Twenty-four D-8 nozzles without swirl plates were placed on 1-foot centers along the boom. The helicopter sprayed a 50-foot swath at an altitude of approximately 60 feet above the ground. All applications were made either just after sunrise or just before sunset when wind velocities were between 0 and 3 mph. Observations on all the plots in both Georgia and Tennessee were made over a period of one year. The Companies provided the helicopter and operators. The herbicide formulations and on-site personnel were provided by Fort Detrick.

Sources: Darrow RA, Mattie VZ (1965): Proceedings of the Second Defoliation Conference, 5-6 August 1964. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *The document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0329567*.

Mattie VZ, Darrow RA (1966): Proceedings of the Third Defoliation Conference, 10-11 August 1965. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Maryland. *The document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD898001*.

DOD TACTICAL HERBICIDE SITES

Site 13

Location: Pranburi Military Reservation, Thailand

Date ⟶ April 1964 – April 1965

Activity Description: The objectives of the Thailand tests were to (1) determine minimal rates and volumes of Herbicide Purple, component 2,4,5-T butyl and isobutyl esters (Herbicide Pink), Dinoxol (31.6% butoxyethanol ester of 2,4-D and 30.3% butoxyethanol ester of 2,4,5-T), and Herbicide Blue applied at different seasons of the year for effective defoliation; and, (2) evaluate the effectiveness of other selected defoliants, desiccants, and herbicides applied singly or in combination mixtures at different seasons of the year on representative vegetation of Southeast Asia.

Assessment: The test site locations were established on the Pranburi Military Reservation. Arrangements were made with Thai governmental authorities to use the facilities of the Ministry of Communications Airport at Hua Hin (25 miles from the test site) as a base of operations for the twin engine Beechcraft (C-45) used for test applications. Survey and preparations of two test sites were initiated in August 1963. Lanes were cleared to mark boundaries of a series of 10-acre test plots for a total of 1450 and 2000 acres of treatment at the two test sites, respectively. The trials began on 2 April 1964 and continued through 8 September 1964 with duplicate 10-acre plots treated with each chemical mixture using three 100-foot swaths per plot flown at a height of 30 to 50 feet above treetops. Evaluations of vegetative responses to chemical treatments were made at periodic intervals, and primarily by photographic techniques. Observations continued for one year after treatment.

During the period from April through September 1964, approximately 115 gallons of Herbicide Purple, 46 gallons of Herbicide Pink, 21 gallons of Dinoxol and 15 gallons of Herbicide Blue were aerially sprayed on 170 acres of Pranburi Military Reservation, Thailand. Five civilians and 5 military personnel from Fort Detrick, Maryland, conducted the spray operations and subsequent research. Approximately 25 Thai civilian workers were involved in the preparation of the test sites, and 4 US civilian workers were involved in evaluating the results of the spraying through the end of September 1964. The names of the US personnel are listed in the source document.

Source: Darrow RA (1965) OCONUS Defoliation Test Program, Semiannual Report, 1 April – 30 September 1964. ARPA Order No. 423, US Army Biological Laboratories, Fort Detrick, Maryland. *Document declassified October 1977, but subject to export control. Available from the Defense Documentation Center, Ascension Number AD360646*.

DOD TACTICAL HERBICIDE SITES

Site 14

Location: Aberdeen Proving Ground, Maryland

Date → May 1965 – May 1966

Activity Description: Scientists at Fort Detrick were concerned about the equipment they were using to simulate aerial applications to forest vegetation. The studies at Aberdeen Proving Ground, Maryland, were designed to evaluate a new spraying apparatus. A truck was outfitted with a "cherry-picker basket" having two booms, each 20 feet long. The upper and lower booms were able to rotate 110 and 90 degrees, respectively; both booms would then rotate horizontally 410 degrees. Controls for operating the booms were in both the basket and truck. The actual spray equipment consisted of a one gallon pressurized container connected to an air supply, and a 5-foot spray boom with three No.5 Whirl-jet nozzles. The lift was positioned over the area to be sprayed and by rotating the lift the spray system closely simulated helicopter applications.

Assessment: The research at the Aberdeen Proving Ground was conducted in two different areas on the Proving Ground, but both locations were isolated from public access. The predominant species at both locations were sweetgum, black willow, persimmon, black gum, white oak, pin oak, and sumac. In the first location, 314 plots (each 225 square feet) were sprayed with 70 compounds applied alone or in combination between May and September 1965. At the second location, 75 plots were used to test the seasonal variations of five different formulations of proposed tactical herbicides, including Herbicides Orange and Purple, picloram, and cacodylic acid. They were sprayed at proposed tactical operational rates in May, June, July, August, and September 1965. All formulations were prepared and sprayed by civilian and military personnel affiliated with the Fort Detrick's Biological Laboratories, Frederick, Maryland.

Source: Mattie VZ, Darrow RA (1966): Proceedings of the Third Defoliation Conference, 10-11 August 1965. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Maryland. *The document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD898001.*

DOD TACTICAL HERBICIDE SITES

Site 15

Location: Middleport, New York

Date ⟶ May – September 1965, July 1966

Activity Description: Under a January 1965 contract with the US Army Biological Laboratories, Fort Detrick, Maryland, FMC Corporation conducted studies in an attempt to improve the herbicidal properties of the Herbicide Purple and Herbicide Orange formulations. Field plots of "several acres" were identified near the Niagara Chemical Division, FMC Corporation Facilities in Middleport, New York.

Assessment: Various esters (n-butyl, iso-butyl, iso-octyl) formulations of 2,4-D and 2,4,5-T were mixed in "suspensions " with auxiliary herbicides (e.g., dalapon,diuron, atrazine, ammonium thiocyanate, aminotriazole, and cacoylic acid) and evaluated for stability and phytotoxicity. Individual plots, dominated by deciduous brush, were seven feet square and a specified volumes equal to rates of 1 to 3 gallons per acre were administered by use of a spray gun. Five replications of each rate was tested, and observations taken throughout the seasons in 1965 and 1966. The two tactical herbicides Purple and Orange were provided by the Army Biological Laboratories, Fort Detrick, while the auxiliary herbicides were obtained from commercial sources. The researchers involved in the mixing of formulations and in the various tests were employees of the FMC Corporation.

Source: Willard JR (1967): Herbicidal Formulations of Enhanced Efficacy for Defoliation: Final Report. Prepared for the US Army Biological Laboratories, Fort Detrick, Frederick, Maryland, by the Niagara Chemical Division, FMC Corporation, Middleport, New York.

DOD TACTICAL HERBICIDE SITES

Site 16

Location: Preston, Maryland

Date ⟶ October 1967

Activity Description: Under a contract with the Air Force Armament Laboratory, Eglin Air Force Base, Florida, the Tidewater AG Systems Company was tasked with developing new spray nozzles for the UC-123B Internal Modular Spray System. The purpose of the visit to the Tidewater AG Systems Facilities in Preston, Maryland, was to evaluate the new spray nozzle for potential use on the A/A 45Y-1 Spray System used in Operation RANCH HAND.

Assessment: A crop dusting aircraft was outfitted with the AG nozzles and flown at an altitude of approximately 20 feet above ground level, and at an estimated 95 mph air speed. The Orange Herbicide was mixed with kerosene and was sprayed over a line of kromekote cards spaced at two-foot intervals for two hundred feet. The droplet size was estimated to be 100 microns. The evaluation was observed on-site by the military and civilian representatives to the Defoliant/Anticrop Subcommittee of the JTCG Technical Coordinating Group. Three employees of the Tidewater AG Systems Company participated in the test and evaluation.

Source: Reynard KA (9 October 1967): Trip Report, Preston, Maryland and Fort Detrick, Maryland. Biological Branch, Bio-Chemical Division, Air Force Armament Laboratory, Eglin AFB, Florida.

DOD TACTICAL HERBICIDE SITES

Site 17

Location: Base Gagetown, New Brunswick, Canada

Date ⟶ June 14-17, 1966 and June 21-24, 1967

Activity Description: The successful screening of tactical herbicides in Arkansas, Georgia, Tennessee, Florida, and Maryland prompted the Fort Detrick personnel to seek a site outside the Continental United States to evaluate a selection of tactical and commercial herbicides on a mixed hardwood-conifer forest. Following discussions with Canadian Military Forces, a decision was made to evaluate an array of herbicides on vegetation of the Canadian Forces Base Gagetown, New Brunswick, Canada. Base Gagetown contained 427 square miles, of which 80% was heavily forested. The site for the 1966 trials was located in the western portion of Base Gagetown between Broad Road and Blissville Road. The test site was an undisturbed forest consisting of a mixture of conifers (fir, spruce, and pine) and broadleaf deciduous species (maple, alder, and beach) ranging in height from about 20 to 75 feet. It was approximately 4 miles long by 1,200 feet wide. Because of terrain and surrounding swamp, only tracked vehicles were able to navigate through the mud and mire to the test site. The base of operation was the Blissville Air Strip, located approximately 4 miles from the test site.

The test area for the 1967 field trials was located approximately 10 miles from the nearest border of the military reservation. Specifically, the test site was located on Rippon Road and east of Broad Road, and consisted of a densely wooded area dominated by broadleaf deciduous species and fir, spruce, and pines. Fifty plots, each 200 by 660 feet (3 acres) with a 200-foot buffer zone between adjacent plots, were laid out on both sides of Rippon Road. As in 1966, the base of operation was the Blissville Air Strip, located approximately 4 miles from the test site.

Assessment For 1966 Field Trials: A total of 116 plots, each 200 by 600-feet with a 100-foot buffer strip between plots, were marked off along both sides of an east-west oriented trail through the forested area. The corners of each plot were delineated by strips of colored surveyor's tape, and were marked with a 6-inch-square aluminum plate identifying the plot. A US Army helicopter equipped with a HIDAL spraying system consisting of a 200-gallon fiberglass tank, an electrically driven centrifugal pump, and two booms, each approximately 25 feet long. The booms were fitted with 15 check values on 6-inch spacing with each value fitted with a Teejet nozzle tip. The helicopter was flown at treetop level at 65 knots airspeed during the three days of spray operation. Plots were flagged for the pilot with telescopic fiberglass poles that

extended to a height of 50 feet with fluorescent orange flags attached. The compounds were applied at rates of 1, 2, 3, or 4 gallons per acre on duplicate plots. Because the HIDAL system was calibrated to deliver 1 gallon per acre, the pilot had to fly over the same area two to four times to deliver the higher rates. Spraying began on 14 June 1966 when new leaves were fully expanded and the trees actively growing. Spraying was done during a stationary low pressure atmospheric condition when there was little or no wind so that spraying was continuous from daylight to dark for 3 successive days, thereby completing 107 plots in about 30 hours actual flying time. The remaining nine plots were left as check plots.

Of the nine compounds tested, four contained 2,4,5-T. They were described as Orange (50:50 mixture of n-butyl esters of 2,4-D and 2,4,5-T), Purple (50% n-butyl ester 2,4-D, 30% n-butyl ester of 2,4,5-T, and 20% isobutyl ester of 2,4,5-T), 70:30 Mixture (70-30 mixture of n-butyl esters of 2,4-D and 2,4,5-T), and M-2993 (1:4 mixture of isooctyl ester of picloram + propylene glycol butyl ether ester of 2,4,5-T).

Of the 107 plots receiving herbicides, 46 plots received 2,4,5-T at varying rates. Thus for the entire experiment, 55 gallons (1 drum) of Orange were sprayed on 14 plots (38.5 acres), 55 gallons of Purple (1 drum) were sprayed on 14 plots (38.5 acres), 50 gallons of 70:30 Mixture were sprayed on 12 plots (33 acres), and 12 gallons of M-2993 on 6 plots (16.5 acres). The 46 plots received a total of 172 gallons of 2,4,5-T containing herbicide, or approximately 800 pounds of 2,4,5-T as the butyl ester or butyl ether ester sprayed on 126.5 acres which equates to approximately 6 pounds of 2,4,5-T per acre aerially applied at tree-top level.

The authors acknowledged the two men who piloted the helicopter, and a Canadian Major who assisted the two researchers in the field as a Range Officer. They also acknowledged the "enlisted men" of the Royal Canadian Army Service, the Royal Canadian Horse Artillery, and the Air Observation Post. Presumably the enlisted men may have been involved in the logistical operations of receiving and transport of the herbicide to the airfield and in assisting the loading of the aircraft. The isolation of the site and how the operation was conducted suggested that few men outside of the Fort Detrick Research Team would have been involved in the actual spraying of the herbicides.

1966 Sources: Demaree KD and Creager RA (1968): Defoliation Tests in 1966 at Base Gagetown, New Brunswick, Canada. Technical Memorandum 141, Department of the Army, Fort Detrick, Frederick, Maryland. *Document unclassified but subject to special export control. Available from the Defense Documentation Center, Accession Number AD 843989.*

Minarik, CE (1966): Trip Report – Evaluation of Defoliation Tests at Canadian Forces Base Gagetown, New Brunswick, Canada. Crops Division, Fort Detrick, Frederick, Maryland.

Assessment for the 1967 Field Trials: The plots were sprayed by a Bell G-2 helicopter fitted with two 40-gallon saddle tanks and a 24-foot boom with nozzle

spacing every 6 inches along the boom. The system was calibrated to deliver 3 gallons per acre at an altitude of 10 to 15 feet above the tops of the trees while flying at 40 knots indicated air speed. The resultant spray swath was 50 feet. Fifteen herbicides were applied by helicopter on duplicate 3-acre plots at a volume of 3 gallons per acre. The original plan was to spray duplicate plots at 3, 6, and 10 gallons per acre, but due to unfavorable weather conditions only treatments at 3 gallons per acre were applied. Of the 15 herbicides used in this experiment, only 2 contained 2,4,5-T herbicide; Orange and a material labeled as HCA + T (hexachloroacteone + 2,4,5-T, formulated to contain 2 pounds HCA and 2 pounds 2,4,5-T per gallon). One of the other materials sprayed on duplicate plots was pentachlorophenol, although not containing 2,4,5-T it was likely contaminated with dioxin and furan congeners.

Orange was sprayed on a total of 6 acres at a rate of 3 gallons per acre for a total quantity of 18 gallons of herbicide, or approximately 90 pounds of 2,4,5-T, or 15 pounds of n-butyl 2,4,5-T/acre. HCA + T was also sprayed on 6 acres for a total of 24 pounds of 2,4,5-T or 4 pounds of 2,4,5-T/acre. The pentachlorophenol was applied at 12 pounds/acre. All of the other herbicides were commercial products, but not containing 2,4,5-T. The flagging to identify individual plots by the helicopter pilots was done by the use of telescopic fiberglass poles that extended to a height of 50 feet with fluorescent orange flags attached. These were fixed and not held by ground crew.

Because the treatment plots were located on both sides of Rippon Road, access to the plots was easier than in the 1966 studies. The authors acknowledged the cooperation of Base Gagetown Commanding Officer, the Range Officer, and the assistance of enlisted personnel.

1967 Sources: Demaree, KD and AR Haws (1968): Chemical Defoliation of Northern Tree Species. Technical Memorandum 145, Department of the Army, Fort Detrick, Frederick, Maryland. *Document unclassified but subject to special export control. Available from the Defense Documentation Center, Accession Number AD 842825.*

Darrow RA, Frank JR, Martin JW, Demaree, KD, Creager RA (1971): Field Evaluation of Desiccants and Herbicide Mixtures as Rapid Defoliants. Technical Report 114, Plant Sciences Laboratories, Fort Detrick, Frederick, Maryland. *Document unclassified but subject to special export control. Available from the Defense Documentation Center, Accession Number AD 880685.*

DOD TACTICAL HERBICIDE SITES

Sites 18

Location: Kauai, Hawaii

Date → 1 May 1967 – 30 June 1968

Activity Description: During the period December 1966 to October 1967, the newly named "Plant Science Laboratories" at Fort Detrick initiated a comprehensive short-term project to evaluate desiccants and herbicidal mixtures as rapid-acting defoliants. The objectives of these studies were to evaluate rapid-acting desiccants as defoliants and to assess the defoliation response of woody vegetation to mixtures of herbicides and/or desiccants. The criteria for assessment was based principally on rapidity of action, but included other features such as safety and ease of handling, compatibility with dissemination systems, and low toxicity to man and wildlife. The Kauai Branch Station of the Hawaii Agricultural Experiment Station was selected as the site to evaluate tactical and commercial herbicides on tropical woody and forest vegetation.

This research was conducted by the Department of Agronomy and Soils of the University of Hawaii with oversight provided by the Plant Sciences Laboratory, Fort Detrick, Maryland. The primary purpose of the research was to evaluate a series of tactical herbicide formulations on tropical vegetation. It was conducted on the Island of Kauai at the Kauai Branch Station of the Hawaii Agricultural Experiment Station, at Kapaa, Hawaii. Four experimental sites (series) were selected for the evaluation of the herbicides. Three of the sites were in tropical vegetation within five miles of the experiment station and were located on the Wailua Game Refuge, Bauxite Reclamation Project, or the Department of Land and Natural Resources, respectively. The fourth site was located at Moalepe in the Wailua Game Refuge.

Assessment: As noted, the main objective of this research was to evaluate the rapidity of action and the degree and duration of defoliation and damage on trees and shrubs of Hawaii to aerial applications of selected chemicals and chemical mixtures. The investigations were divided into four categories or series of tests. The experimental plots ranged from 2-acre plots for Series I and II, to 5-acre plots in Series III, and 6-acre plots in Series IV. The 2,4,5-T related materials included Silvex, M-3140 formulation (picloram + 2,4,5-T), Orange Herbicide, Hexachloroacetone + 2,4,5-T, and M-3190 (picloram + 2,4,5-T + dalapon). Both Blue (Phytar 560G) and White (Tordon 101) were also evaluated in the series of tests.

Approximately 111 acres of replicated plots out of 232 acres were treated with 2,4,5-T (51 gallons), Silvex (35.5 gallons), or Orange Herbicide (92.5 gallons) during the period from 24 July through 21 December 1967 (or approximately 1.7 gallons of active ingredient 2,4,5-T per acre). Blue was applied at 2, 4, or 6 gallons per acre (180 gallons), while White (tactical formulation M2628) was applied at 3 and 6 gallons per acre (54 gallons). All applications were done by a fixed-wing commercial applicator (Murryair, Ltd.) capable of applying a 40-foot swath and delivering either 3 or 6 gallons of formulation per acre. The vegetation in the various plots ranged in height from 3-6 feet for Lantana (*Lantana camara*) to more than 60 feet for Silveroak (*Grevillea robusta*). Although the plots were accessible by ground vehicles, they were in areas isolated from public access. The investigators reported that some drift did occur from the plots, especially those sprayed in the late fall. However, the drift was in the opposite direction of any private or commercial agricultural fields. All locations received heavy rainfalls within the first and second months following applications. Observations and vegetative-injury ratings of the plots were obtained 1, 2, 3, and 4 weeks following application, and on a monthly basis thereafter.

In all tests, precautions were taken in handing of chemicals. Each person was required to wear gloves, goggles, respirators, and aprons or coveralls. Aircraft props were cut-off during loading to ensure safety from chemical backwash and carelessness. The report did not state whether the flagman were required to wear the same safety gear. All excess herbicide in the aircraft tank and spray system was collected, transferred to steel 55-gallon drums, and buried. Empty containers were also buried immediately following completion of the spraying. The locations were not specified. The aircraft tank and spray system was rinsed once with diesel fuel (which was also collected and buried) and followed with a thorough washing. The exterior of the aircraft was also washed. All of the herbicidal chemicals were provided by the Department of the Army, Fort Detrick, Maryland. Three investigators from the University of Hawaii, one investigator from USDA, the pilot, and Experiment Station support personnel were involved in the tests and subsequent evaluations.

Sources: Suchisa RH, Saiki DF, Younge OR, Plucknett DL (1968): Defoliation of Tropical Jungle Vegetation in Hawaii. Final Report, May 1, 1967 to June 30, 1968, Department of Agronomy and Soil Science, University of Hawaii, Honolulu, Hawaii, and the Department of the Army, Fort Detrick, Frederick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD 839968*.

Darrow RA, Frank JR, Martin JW, Demaree, KD, Creager RA (1971): Field Evaluation of Desiccants and Herbicide Mixtures as Rapid Defoliants. Technical Report 114, Plant Sciences Laboratories, Fort Detrick, Frederick, Maryland. *Document unclassified but subject to special export control. Available from the Defense Documentation Center, Accession Number AD 880685.*

DOD TACTICAL HERBICIDE SITES

Site 19

Location: Five Locations in Texas, including Llano, Refugio, Victoria, Carlos, and Livingston

Date → March 1963 – June 1967

Activity Description: Because of its large area and extreme variations in environmental conditions, Texas has a rich flora. Many of these species are represented, either by genus or species, in Southeast Asia, and other tropical areas. The forest components of Texas, as in other temperate regions, may be broadly classed as conifers or softwoods, and broadleaf or hardwoods. The brush vegetation on rangeland in Texas was considered analogous to thorn thicket of tropical regions. Several genera, and even species that occurred in Texas, were also found in Southeast Asia. These included mesquite, huisache, and other species of *Acacia*, retama, and Macartney rose. It was concluded by Department of Army personnel at Fort Detrick, Frederick, Maryland that research on tactical and commercial herbicides in Texas would contribute to the understanding and use of such herbicides in Southeast Asia.

The research in Texas on the use of tactical and commercial herbicides was sponsored the Advanced Research Projects Agency (ARPA), Department of Defense. Reports of the research were reported at all three of the Defoliation Conferences (1963, 1964, and 1965). Personnel of the Agricultural Research Service, United States Department of Agriculture, were responsible for the conduct of the research. The objectives of the research were to "discover and evaluate new herbicides and principles for killing trees, brush, and other vegetation; develop methods for evaluating herbicides on different species of woody vegetation; develop methods and principles for improved application techniques; and, determine effects of environment on behavior and effectiveness of promising herbicides."

The treatments in Texas were made at five locations on a variety of woody species. The species were selected because previous work had shown them to relatively resistant to phenoxy herbicides. In addition, they represented many plant families and genera so that a broad array of taxonomic entities was involved. Research sites in Texas were located at Llano (on the Edwards Plateau), Refugio (on the Gulf prairie), Victoria (in a post oak savannah), Carlos (in piney woods), and Livingston (in piney woods). The sites were lands leased from private landowners, and varied from approximately 45 to 60 acres.

Assessment: The treatments at all five locations in 1963 through 1964 were initially applied with a contourmatic boom sprayer mounted on a ¾-ton truck. The boom had three sections, each of which could be positioned hydraulically from controls on the truck. The research sites where the contourmatic boom sprayer was used were selected on the basis of brush and density and growth low enough to permit treatment. Truck mobility on the research sites was aided by bulldozing lanes through the brush. Plots were then established on each side of the lanes. A plot width of 22 feet was used for all treatments because that width could be effectively treated with the two end sections of the boom. Most of the plots were 95 feet long, but some were as much as 200 feet long. Beginning in May 1964 through 1966, plots in most locations were also established for aerial applications. For these aerial applications a fixed-wing aircraft was used. Generally, the plots were either 5-acre plots 160 feet wide and 1,320 feet long, permitting four 40-foot swaths for each plot, or 4-acre plots 200 feet wide and 840 feet long permitting five swaths on each plot. Two replications in a randomized block design were treated with the fixed-wing aircraft flying about 10 feet above the vegetation.

Multiple plots were sprayed at all locations over a period of four years, 1963 –1966. For example at Llano, Texas:

Test No. 1, Llano: Fourteen herbicides at various rates were applied to whitebrush on July 30, 1963. A volume of 10 gallons per acre was applied on two plots for each treatment. Herbicides included Orange @ 4, 8, and 12 lbs/A; 2,4,5-T ester @4, 8, and 12 lbs/A; and, 2,4,5-T: dicamba (1:1) @ 8 lbs/A.

Test No. 2, Llano: Whitebrush was treated with 11 herbicides on October 1, 1963. Various herbicidal rates were evaluated but volume was constant at 5 gallon/A. Two plots were sprayed for each treatment (plot size: 22 x 95 or 22 x 200 feet). Herbicides included 2,4,5-T @1, 4, 8 lbs/A; and 2,4,5-T:diquat (1:1) @8 lbs/A.

Test No. 3, Llano: Replicated plots of whitebrush were treated with 12 herbicides on May 11, 1964. A volume of 10 gal/A was used and included Orange @ 4 and 8 lbs/A; 2,4,5-T @ 1, 4, 8 lb/A; and, 2,4,5-T: paraquat (1:1) @ 8 lbs/A.

Test No.4, Llano: Nine herbicides were applied on replicated plots of whitebrush on October 7, 1964. A volume of 10 gal/A was used and included Orange @ 4 lbs/A; MCPA: 2,4,5-T (1:1) @ 1 lbs/A; and, MCPA: 2,4,5-T (2:1) @ 1.5 lbs/A.

Test No. 5, Llano: Fourteen herbicides were applied to replicated plots of whitebrush on May 11, 1965. A volume of 10 gal/A was used and included Orange @ 8 lbs/A; MCPA: 2,4,5-T (2:1) @1.5 lbs/A; MCPA: 2,4,5-T (4:1)@ 2.5 lbs/A; 2,4,5-T @ 0.5 lbs/A; 2,4,5-T: ammonium thiocyanate (1:1) @1 lbs/A; and, picloram: 2,4,5-T (4:1) @ 2.5 lb/A.

Test No. 6, Llano: Five herbicides were applied at various rates to whitebrush on October 11, 1965. Two plots per treatment at a constant rate of 10 gal/A containing various formulations of picloram from 0.5 to 4 lbs/A.

Test No. 7, Llano: The last foliage treatment to whitebrush was on May 20, 1966, and compared Orange to paraquat, picloram and M-2993 (1:4 mixture of isooctyl ester of picloram + propylene glycol butyl ether ester of 2,4,5-T). Treatments were applied at 6 gallons/acre. Orange was evaluated at 12, 24, and 48 lbs/A while M-2993 was evaluated at 7.5, 15, and 30 lbs/A.

Seven tests were also conducted at Refugio, Victoria, Carlos, and Livingston from October 3, 1963 through June 15, 1966 with similar herbicides and rates. Twelve scientists with the Agricultural Research Service were responsibly for designing, conducting, and evaluating the research plots. Additional personnel from the Agricultural Research Service provided the support for the treatments and mixing of the herbicides. The two tactical herbicides, Herbicide Orange and Herbicide White (picloram-2,4-D), were provided by Fort Detrick, Frederick, Maryland.

Sources: Mattie VZ (1964): Proceedings of the First Defoliation Conference, 29-30 July 1963. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0427874*.

Darrow RA, Mattie VZ (1965): Proceedings of the Second Defoliation Conference, 5-6 August 1964. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0329567*.

Mattie VZ, Darrow RA (1966): Proceedings of the Third Defoliation Conference, 10-11 August 1965. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD898001*.

Bovey RW, Davis FS, Morton HL (1968): Herbicide Combinations for Woody Plant Control. *Weed Science* 16 (3): 332-335.

Tschirley FH (1968): Research Report…Response of Tropical and Subtropical Woody Plants to Chemical Treatments. Report Number CR-13-67. Agricultural Research Service, US Department of Agriculture Under ARPA Order No. 424, Advanced Research Projects Agency, US Department of Defense.

Dowler CC, Tschirley FH, Bovey RW, Morton HL (1971): Effects of Aerially-Applied Herbicides on Texas and Puerto Rico Forests. *Weed Science* 18 (1): 164-168.

DOD TACTICAL HERBICIDE SITES

Site 20

Location: Seven Locations in Puerto Rico, including Mayaguez, Maricao, Guajataca, Guanica, Toro Negro, El Verde, and Jimenez

Date → June 1963 – October 1967

Activity Description: The importance of obscuring vegetation is particularly important in tropical areas. The Luquillo National Forest of Northeastern Puerto Rico resembled the evergreen forests of Southeast Asia. Precipitation is high and the constant high humidity and abundant soil moisture contribute to the development of lush plant growth. Numerous short trees, slender vines, and stout lianes obstruct horizontal visibility. Heavy foliage in the contiguous crowns of top story hampers vertical visibility. Vegetation in swamps or marshlands is a characteristic feature that was similar in Puerto Rico and Southeast Asia. Another feature of the vegetation in Puerto Rico and Southeast Asia was the contrast between lowland and mountain flora. The Department of Army personnel at Fort Detrick, Frederick, Maryland recognized that defoliation of such tropical vegetation similar to that found in Southeast Asia would reduce the amount of obscuring vegetation. Thus, in Southeast Asia the possibility of ambush would be reduced, and the movement of enemy equipment and personnel could be more easily observed. It was concluded that research on tactical and commercial herbicides in Puerto Rico would contribute to the understanding and use of such herbicides in Southeast Asia.

The research in Puerto Rico on the use of tactical and commercial herbicides was sponsored the Advanced Research Projects Agency (ARPA), Department of Defense. Reports of the research were reported at all three of the Defoliation Conferences (1963, 1964, and 1965). Personnel of the Agricultural Research Service, United States Department of Agriculture, were responsible for the conduct of the research. The objectives of the research in Puerto Rico were to "conduct advanced evaluation of promising herbicides for tropical and subtropical killing vegetation; and, determine optimum times and rates of application, distribution parameters, formulations and mixtures for most effective use of herbicides."

The treatments and studies in Puerto Rico were conducted at seven locations providing a wide spectrum of vegetative and environmental variability. The site at Mayaguez represented a moist coastal forest habitat; the site at Maricao was in the Lower Cordillea Forest habitat; the Guajataca site was located in a most limestone forest habitat; the Guanica site was on the southern, dry side of Puerto Rico and excluded many of the tree

species found on the north side of Puerto Rico; the Toro Negro site was located in the Upper Cordillera Forest and was characterized by lower temperatures and higher rainfall than the Lower Cordillera Forests; the El Verde and Jimenez sites were in the Luquillo National Forests in areas that represented the best developed forests in Puerto Rico. The lands were the sites were located were provided by either private individuals, companies, the Federal Experiment Station in Puerto Rico, or the Commonwealth Division of Forestry of the Commonwealth of Puerto Rico.

Assessment: Herbicides treatments were made by two different methods. Ground applications were made with a telescoping pole sprayer designed to cover a 40-foot diameter circle. The sprayer was calibrated to spray 10 gallons of liquid per acre. Aerial applications were accomplished with a Hughes 300 helicopter delivering 1.5 or 3.0 gallons per acre in a 35-foot swath at 45 miles per hour. All applications were made near tree-top level. The herbicides applied in the various Puerto Rico sites included the isooctyl esters of picloram (Fort Detrick formulation M-3142); a 2:2:1 mixture of the isooctyl esters of 2,4-D:2,4,5-T:picloram (Fort Detrick formulation M-3140); a 4:1 mixture of 2,4,5-T:picloram (Fort Detrick formulation M-2993); and the tactical herbicides Orange, Purple, and White. In addition to Herbicide Blue, three other contact herbicides were evaluated, monosodium methanearsonate (MSMA), paraquat, and diquat. The rates varied from 3 lbs/A (White), to 6 lbs/A (Blue), and up to 24 lbs/A (Orange).

A randomized block design with one or two replications was used in each test site. Land availability, topography, number of treatments, and application equipment determined the number of replications and plot size. For aerial applications, two replications of 1-acre plots (175 by 249 feet) were treated with a helicopter calibrated for delivering 10 gallons of liquid per acre; thus rate calculations were based upon that volume. Ester formulations were sprayed in diesel oil, while amine and sodium salt formulations were sprayed in water.

Twelve scientists with the Agricultural Research Service were responsibly for designing, conducting, and evaluating the research plots. Additional personnel from the Agricultural Research Service provided the support for the treatments and mixing of the herbicides. The three tactical herbicides, Herbicides Orange, White, and Blue and the proposed candidates M-2993, M-3140, and M-3142 were provided by Fort Detrick, Frederick Maryland.

Sources: Mattie VZ (1964): Proceedings of the First Defoliation Conference, 29-30 July 1963. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Technical Information Center, Accession Number AD0427874*.

Darrow RA, Mattie VZ (1965): Proceedings of the Second Defoliation Conference, 5-6 August 1964. United States Army Chemical Corps' Biological Laboratories, Fort Detrick, Frederick, Maryland. *Document is unclassified but subject to export control. Available from the Defense Documentation Center, Accession Number AD0329567*.

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Bovey RW, Davis FS, Morton HL (1968): Herbicide Combinations for Woody Plant Control. *Weed Science* 16 (3): 332-335.

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Bovey RW, Dowler CC, and Diaz-Colon JD (1969): Response of Tropical Vegetation to Herbicides. *Weed Science* 17 (3): 285-290.

Dowler CC, Tschirley FH, Bovey RW, Morton HL (1970): Effects of Aerially-Applied Herbicides on Texas and Puerto Rico Forests. *Weed Science* 18 (1): 164-168.

DOD TACTICAL HERBICIDE SITES

Site 21

Location: Fort Gordon, Augusta, Georgia
Fort Chaffee, Fort Smith, Arkansas
Apalachicola National Forest, Sopchoppy, Florida

Date → July 1967 – October 1967

Activity Description: During the period December 1966 to October 1967, the newly named "Plant Science Laboratories" at Fort Detrick initiated a comprehensive short-term project to evaluate desiccants and herbicidal mixtures as rapid-acting defoliants. The objectives of this study were to evaluate rapid-acting desiccants as defoliants and to assess the defoliation response of woody vegetation to mixtures of herbicides and/or desiccants. The criteria for assessment was based principally on rapidity of action, but included other features such as safety and ease of handling, compatibility with dissemination systems, and low toxicity to man and wildlife.

The approach to the objective of an improved rapid-acting defoliant involved three phases: (1) evaluation of commercially available rapid desiccants or contact herbicides; (2) evaluation of improved formulations of rapid desiccants developed under industry contacts and by in-house effort; (3) development and evaluation of desiccant-herbicide mixtures containing the rapid defoliant characteristics with the sustained long-term effects of Orange and other Tactical Herbicides. The project required an immediate access to a diversity of woody vegetation. Accordingly, Fort Detrick arranged for test locations at Fort Gordon near Augusta, Georgia; Fort Chaffee near Fort Smith, Arkansas, and Apalachicola National Forest near Sopchoppy, Florida.

The Georgia site was described as a warm temperate, humid, moderate rainfall climate with deep, well-drained sands in rolling topography. The vegetation type was an oak-hickory-pine forest. The Arkansas site was described as a temperate continental, moderate rainfall climate with fine sandy loam soils in rolling topography. The vegetation type was an oak-hickory forest. The Apalachicola National Forest site was described as a subtropical, humid, moderate precipitation climate with sandy soils in a flat poorly drained topography. The vegetation type was described as a Southern mixed forest. All sites were selected because of their isolation from any local human populations, e.g., in Florida, the site was a ridge located in a swamp forest.

Assessment: The desiccants selected for evaluation included Herbicide Blue (a tactical herbicide), and the commercial desiccants diquat, paraquat, dinitrobutylphenol

(DNBP), pentachlorophenol (PCP), hexachloroacetone (HCA), and monosodium methanearsonate (MSMA), pentachloro-pentenoic acid (AP-20), endothall, and various mixed formulations of these desiccants. The systemic herbicides included the two tactical herbicides Orange and White; the potassium salt, triisopropanolamine salts, and the isooctyl ester of picloram; and, a ethylhexyl ester of 2,4,5-T mixed with HCA. Mixtures of propanil, nitrophenol, linuron, and silvex were also evaluated. All chemicals were furnished by Fort Detrick.

Aerial application at these three sites were made with a Bell G-2 helicopter equipped with two 40-gallon tanks and a 26-foot boom with 6-inch nozzle positions adaptable for volume deliveries of 3, 6, or 10 gallons per acre in a 50-foot swath. Spray equipment, pilot, and support were furnished under contract with Allied Helicopter Service of Tulsa, Oklahoma. Aerial applications were made on duplicate 3-acre plots, 200 by 660 feet in dimension. A sampling and evaluation trail was established in each plot on a diagonal beginning at 100 feet from one corner. Major species were marked along 500 feet of this transect and individual plants were identified by combinations of colored plastic ribbons. A minimum of 10 individuals of each species was marked unless fewer were present. Evaluations were made at 1-, 5-, 10-, 30-, and 60-day intervals by experienced Fort Detrick personnel. At each evaluation period the identical marked individuals of the major species were rated for defoliation and desiccation. At each location, approximately 475 gallons (~10 drums) of Herbicide Blue, 95 gallons (~2 drums) of Herbicide Orange, and 6 gallons of Herbicide White were expended.

The assistance of Department of Army forestry personnel at Fort Gordon, Fort Chaffee, and the 3rd and 4th Army Headquarters were acknowledged in the report for their support in the selection and preparation of sites in Georgia and Arkansas. The land and facilities for the Florida tests were provided by the Supervisor, Apalachicola National Forest, Tallahassee, Florida. Personnel from the Physical Sciences Division, Fort Detrick assisted in the development of formulations and preparations of field test mixtures. They also provided the data on the physical characteristics of the candidate tactical defoliants and mixtures.

Sources: Darrow RA, Frank JR, Martin JW, Demaree, KD, Creager RA (1971): Field Evaluation of Desiccants and Herbicide Mixtures as Rapid Defoliants. Technical Report 114, Plant Sciences Laboratories, Fort Detrick, Frederick, Maryland. *Document unclassified but subject to special export control. Available from the Defense Documentation Center, Accession Number AD 880685.*

DOD TACTICAL HERBICIDE SITES

Site 22

Location: Adjacent to the Demilitarized Zone, Korea

Date → 20 March 1968 – 1 July 1968

Activity Description: In early 1967, as part of a general review of the Demilitarized Zone (DMZ) defenses, the United Nations Command (UNC) and the United States Forces Korea (USFK) found that dense vegetation within the DMZ and contiguous areas provided cover for North Korean infiltration or raiding parties. The vegetation in these areas had grown unencumbered since the Armistice and was an important part of the DMZ defensive problem. In March 1967, representatives of the Plant Sciences Laboratory, US Army Biological Laboratories, Fort Detrick, Maryland visited Korea and inspected typical vegetation growth in selected areas contiguous to the DMZ. Based upon this evaluation, the Plant Sciences Laboratory recommended the use of tactical herbicides, specifically Herbicides Orange and Blue, and a commercially available soil applied herbicide (Monuron UROX 22) to control general and specific vegetation growth adjacent to the DMZ.

The decision to use tactical herbicides required obtaining approval of the United States Department of State. Numerous messages were dispatched during the period May through September 1967. In early September, the US Secretary of State authorized discussion of the program with the Republic of Korea (ROK) Government. These discussions provided the acceptance of the program by the ROK Prime Minister and on 20 September 1967 both governments (ROK and US) granted permission for the use of the tactical herbicides to be sprayed in the area between the DMZ South tape and the Civilian Control Line.

Following a series of planning conferences a comprehensive vegetation control program was developed. On 4 March 1968, the Commander, US Forces in Korea (COMUKOREA) was authorized to deploy tactical herbicides as part of the vegetation control program in Korea. To preclude the possibility of unfavorable propaganda and to ensure that defoliants would be properly employed with a margin of safety, the following constraints were placed upon the vegetation control program: (a) Defoliants were not be employed North of the Southern boundary of the DMZ; (b) During application, care was to be taken to ensure that there was neither run-off nor spray drift into areas North of the Southern boundary of the DMZ; (c) Defoliants would not be applied during precipitation or when rain was expected within 12 hours after application; (d) Extreme caution was to be exercised to avoid damage to food crops; (e) Defoliants would note be dispensed from aircraft of any kind; and (f) a Korean Military Assistance Group (KMAG) Representative

(a Chemical Corps Officer assigned to this subordinate element of the Eighth US Army) would be physically present whenever defoliants were deployed. By 20 March 1968, the first herbicide (Monuron) and equipment arrived in country. On 31 March, implementation of the Vegetation Control Program CY 68 (for Calendar Year 1968) was ordered to begin on or about 15 April 1968. On 10 April 1968 supplies of Herbicides Orange and Blue were on-hand in forward locations near the DMZ.

Assessment: Soldiers from the First Republic of Korea Army (FROKA) were assigned the task of applying the herbicides. Monuron UROX 22 was spread by hand or mechanical broadcast beginning on 15 April 1968 and through 28 April 1968. The usual technique involved dividing a selected area into several lanes and each soldier walked along his assigned lane spreading the Monuron pellets along an area of 5 meters on each side of his marked lane. Supplies of Monuron were spotted throughout the area to facilitate individual re-supply along assigned lanes. In this manner, approximately 7,800 drums (397,800 pounds) of palletized herbicide were applied on 1,560 acres or at a rate of 255 lbs/A.

Applications of the tactical herbicides Orange and Blue began on 15 May 1968 upon the emergence of foliage, and terminated on 15 July 1968, The Orange herbicide was mixed with diesel oil at a ratio of 3 gallons of Orange to 50 gallons of diesel. Since many application areas selected for spraying with Orange were relatively inaccessible for use of the modified M8A2 Decontamination Trailer, 22 liquid defoliant spray sets were employed. These units were insecticide sprayers commonly used in Engineer Entomological Services and consisted of a portable lightweight hypro-type pump with a standard gasoline engine. The Republic of Korea Army (ROKA) also had available ten M106 “Mitey Mite” dispensers that were used to supplement liquid spray capabilities. The M106 was a commercial, backpack sprayer that consisted of a compact two-cycle gasoline engine that dispersed the herbicide through a 6-foot hose. The tank contained 3 gallons of liquid. The modified M8A2 Decontamination Trailers were used for spraying both Orange and Blue. The unit consisted of a 200 gallon capacity tank and a 25 HP GED pump mounted on a 1 ½ ton trailer. A single hose reel allowed the operator to move approximately 50 feet from the trailer and direct a liquid spray through the adjustable Beam type spray gun at a rate of 20 gallons per minute.

Approximately 380 drums of Orange (20,900 gallons) were applied on 6,966 acres (3 gallons/acre). Herbicide Blue was applied as a liquid spray mixed with water at a ratio of 3 gallons of Blue to 50 gallons of water for application on one acre. Approximately 625 drums of Blue (34,375 gallons) were applied on 11,458 acres (3 gallons/acre). As noted, all applications were done by ground-based spray systems. The use of masks and handling precautions were mandatory. The report noted that 3,345 FROKA soldiers were involved in the actual spray operations. No US military personnel were used to spray the tactical herbicides, or were involved in any of the spray operations, e.g., mixing of the herbicides and diluents. US military personnel (Chemical Corps Officers) were used to monitor and report on the activities of the ROKA Forces.

Sources: Buckner JE (2 January 1969): Final Report, Vegetation Control Plan CY 68. United States Army Advisory Group, Korea, APO San Francisco 96302. *Document 203-C69, Declassified from Confidential, source or date not legible*.

Sypko T (2004): Korea DMZ Vets & Agent Orange. VFW Magazine, January 2004, page 44.

Additional Comment: The Sypko article noted that Agent Orange was used from April 1968 through July 1969. The Buckner Report confirmed only that Orange and Blue were used from 15 May through 15 July 1968 (three months). There was no record found of the use of Orange or Blue Herbicides being applied in CY 1969. The Sypko article confirmed correctly that **all of the defoliants were applied by South Korean Troops**. The Buckner Report noted that all ROKA personnel who participated in the project were well trained, prepared, and that the operation was adequately organized and followed the planned schedule in an orderly manner.

DOD TACTICAL HERBICIDE SITES

Site 23

Location: The Outport, Gulfport, Mississippi

Date → 17 August – 7 November 1969

Activity Description: In August 1966, the United States Department of the Air Force consolidated the responsibility for the management of all tactical herbicides (used in Vietnam) under the Directorate of Air Force Aerospace Fuels, San Antonio Air Materiel Area (SAAMA), San Antonio, Texas. One action that resulted from this consolidation was the selection of the Port of Mobile, Mobile, Alabama for the port of embarkation of all tactical herbicides procured and shipped to Vietnam. Thus, all of the producers of Herbicide Orange, Herbicide White, and Herbicide Blue were instructed by the Defense Supply Agency (the procuring agency) to ship the tactical herbicides in 55-gallon drums and by rail to the Port of Mobile. As the tactical herbicide inventory began to build up in Vietnam (primarily at the Air Bases at Bien Hoa and Da Nang) in 1968, SAAMA temporarily discontinued shipment from the Port of Mobile in order "to avoid exposing large quantities of herbicides to possible damage by enemy action." Since the Port of Mobile was routinely used as the port of embarkation, SAAMA arranged for the tactical herbicides to be temporarily placed in storage at the Port. However, it was recognized that additional temporary shortage would be needed.

On 26 June 1968, SAAMA negotiated with the Naval Construction Battalion Center (NCBC), Gulfport, Mississippi to receive and store additional drums of tactical herbicides, Moreover, the NCBC outside storage area was about two miles from the Gulfport Outport Docks. By December 1968, 66,700 drums had been moved to NCBC. Over the next eight months (in 1969) drums were again being shipped to Vietnam out of both the Outport at Gulfport and from the Port of Mobile. On 17 August 1969, Hurricane "Camille" hit the Gulfport, Mississippi area with winds in excess of 200 miles per hour. There were 17 railroad cars on the Gulfport Docks containing 1,700 drums of herbicide that were withdrawn to NCBC area before the storm hit. However, there were 1,466 drums of Orange and Blue in the berthing area awaiting loading and shipment to Vietnam. These drums were scattered throughout the port area and into the water by the hurricane.

Assessment: Of the 1,466 drums, 412 were recovered and shipped to Vietnam. The remainder were dredged from the Gulf by the personnel of the Army Corps of Engineers and piled in the Commercial Port Area at Gulfport. On 2 October 1969, the Air Force Logistics Command directed the Eastern Area Military Traffic Management and

Terminal Services to furnish labor, hoses, and heavy equipment for the redrumming of the remaining inventory. SAAMA furnished new drums, marking and shipping instructions. The Army Corps of Engineers (Gulf Detachment) disposed of the contaminated soil and empty damaged drums.

The redrumming operations were completed on 7 November 1969. Contaminated soil and the damaged drums that had been flattened were hauled to a Hurricane Camille "dumping area" where they were plowed underground. Salvaged drums were placed on pallets and delivered to the Gulfport Docks for loading and shipment to Vietnam. After the completion of the operation, Port Officials and Air Force Logistic Command personnel determined that 171 drums of Herbicide Blue and 74 drums of Herbicide Orange/Orange II were missing from the inventory and despite recovery efforts, they were never found. The issue of these "lost drums" was the subject of a Freedom of Information Request to the Air Force Logistics Command, Wright-Patterson Air Force Base, Ohio, and a subsequent newspaper article in The Sun/The Daily Herald, Biloxi, Mississippi, 11 March 1985.

Sources: Craig DA (1975): Use of Herbicides in Southeast Asia. A History Prepared for the Directorate of Energy Management, San Antonio Air Logistics Center, Kelly Air Force Base, Texas.

Miller RA, Shafts PA, Stieritz SF, Termena BJ (1980): The Disposal of Herbicide Orange, 1971-1979. Office of History, Air Force Logistics Command, Wright-Patterson Air Force Base, Ohio.

Rose C (1985): Freedom of Information Act, Case 85-325. Headquarters United States Air Force, Department of the Air Force, Washington, DC. (dated 9 April 1985)

DOD TACTICAL HERBICIDE SITES

Site 24

Location: Soil Biodegradation Studies of Herbicide Orange, in Five Locations- Florida, Kansas, Utah, Oregon, and Washington

Date → April 1972 – March 1979

Activity Description: One method selected for the potential disposal of the surplus 2.3 million gallons of Herbicide Orange remaining after the Vietnam War was subsurface injection or soil incorporation of the herbicide at massive concentrations. The premise for such studies was that high concentrations of the herbicides and TCDD would be degraded to innocuous products by the combined action of soil microorganism and soil hydrolysis. In order to field test this concept, biodegradation plots were established in five climatically and environmentally different areas of the United States: Northwest Florida at Eglin Air Force Base (AFB); Western Kansas at the Kansas State University Experimental Station, Garden City; Northwestern Utah on the Air Force Logistics Command (AFLC) Test Range Complex near the Dugway Proving Grounds; A Pesticide Waste Disposal Site established by the Department of Entomology, Oregon State University in Eastern Oregon; and the Agronomy Farm, Washington State University, Pullman, Washington. The project was initiated in April 1972. Drums of Herbicide Orange were available at Eglin AFB for the plots established on Test Area C-52A of the Eglin Reservation. However for the other locations drums of Herbicide Orange were shipped from the Naval Construction Battalion Center, Gulfport, Mississippi to Garden City, Kansas (one 55-gallon drum), Dugway Proving Ground, Utah (two 55-gallon drums), Department of Entomology, Oregon State University (one 55-gallon drum), and Department of Agronomy and Soils, Washington State University (one 55-gallon drum).

Assessment: The amount of Herbicide Orange incorporated into field plots varied by location. On Test Area C-52A, Eglin AFB, Florida, the herbicide was placed (simulated subsurface injection) in 5 replicated 10 x 10-foot plots, 6 inches below the soil surface at concentrations of 4,000 pounds per acre (initial concentration in 6-inch profile was 5,000 parts-per-million). The 10 plots were periodically samples over a period of six years (Apirl 1972 – April 1978). At the Garden City Kansas Experiment Station, Herbicide Orange was pre-plant incorporated into one-acre plots via a rototiller at concentrations of 2,000 and 4,000 pounds per acre. The site was sampled and monitored for three years (June 1972 – June 1975). At the AFLC Test Range Complex, Herbicide Orange was placed (simulated subsurface injection) into replicated 10 x 15-foot plots, 6 inches below the soil surface at concentrations of 1,000, 2,000 and 4,000 pounds per acre. The site was

sampled and monitored for six years (May 1972 – May 1977). At the Pesticide Waste Disposal Site in Eastern Oregon, herbicide was subsurface injected at 1,000 pounds per area (on one acre). At the Agronomy Farm at Washington State University, Herbicide Orange was incorporated into 42 field lysimeters at concentrations of either 1,000 or 5,000 pounds per acre. The lysimeters were established in December 1976 and were terminated in March 1979.

At Eglin AFB, Florida, 2 civilians and 2 military officers were involved in the treatment and monitoring of the plots. At Garden City Kansas, one civilian with the Kansas State Experiment Station was involved in the sampling and monitoring of the plots. At the AFLC Test Range, 2 military officers were involved in the sampling and monitoring of the plots. At the Pesticide Waste Disposal site in Eastern Oregon, personnel from the Department of Entomology were involved in sampling and monitoring. At Washington State University, the research was the focus of a Ph.D. Thesis, and thus a graduate student and his Major Professor were involved in the project.

The United States Air Force Scientific Advisory Board's Ad Hoc Committee for the Disposal of Herbicide Orange felt that this method was promising, but that more data and evidence were needed to ensure environmental safety. Moreover, the permission to use Federal lands for this disposal option would require not only an appropriate Environmental Impact Statement, but also the approval of State and Federal Authorities, with likely many legal challenges.

Sources: Young AL, Thalken CE, Arnold EL, Cupello JM, Cockerham LG (1976): Fate of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in the Environment: Summary and Decontamination Recommendations. Technical Report USAFA-TR-76-18, Department of Chemistry and Biological Sciences, United States Air Force Academy, Colorado.

Stark HE, McBride JK, Orr GF (1975): Soil Incorporation/Biodegradation of Herbicide Orange. Volume I. Microbial and Baseline Ecological Study of the US Air Force Logistics Command Test Range, Hill AFB, Utah. Document No. DPG-FR-C615, US Army Dugway Proving Ground, Dugway, Utah. *Unclassified*, *limited to US Government Agencies only*.

Tanigughi G (1975): Soil Incorporation/Biodegradation of Herbicide Orange. Volume II. Meteorological and Chemical Studies of a Proposed Test Site on the AFLC Test Range, Hill AFB, Utah. Document No. TECOM-5-CO-213-000-015, US Army Dugway Proving Ground, Dugway, Utah. *Unclassified, limited to US Government Agencies only*.

Goulding RL (1973): Waste Pesticide Management. Final Narrative Report. US Environmental Protection Agency Demonstration Grant No. 5-G06-EC-00222, Department of Entomology, Oregon State University, Corvallis, Oregon.

Majka JT, Cheng HH, Muzik TJ (1982): Dissipation of Massive Quantities of 2,4-D and 2,4,5-T n-Butyl Esters in Field Mini-Lysimeters. J Environ Qual 11 (4): 645-649.

Majka JT, Cheng HH, McNeal BL (1982): Mobility of 2,4-D and 2,4,5-T n-Butyl Esters in Soils Following Massive Applications to Field Mini-Lysimeters. J Environ Qual 11 (4): 650-655.

SAIC (1989): Final Decision Document for Herbicide Orange Test Area, Utah Test and Training Range, North Range, Utah. US Air Force Installation Restoration Program, Hill Air Force Base, Utah. Prepared Under Interagency Agreement No 40-1760-86 by Science Applications International Corporation, McLean, Virginia. Submitted to US Air Force Logistics Command, Wright-Patterson AFB, Ohio. *Unclassified, available for public distribution.*

DOD TACTICAL HERBICIDE SITES

Site 25

Location: Reformulation of Herbicide Orange for Domestic or Foreign Use, Bound-Brook, New Jersey

Date → April 1972 – January 1973

Activity Description: One method selected for the potential disposal of the surplus 2.3 million gallons of Herbicide Orange remaining after the Vietnam War was the option of donating or selling the herbicide to private industry, or to another United States Government Agency. For example, a significant portion of the total land area of the United States was used for pasture and grazing purposes, and weeds and brush presented a major problem on these lands. Various species of undesirable brush and trees and numerous noxious (foreign) weeds dominated some 320 million acres of US rangeland and pastures, and the application of phenoxy herbicides, such as found in Herbicide Orange, could be an economical method of increasing the quality and grazing capacity of these lands. Moreover, in April 1972 representatives from the Blue Spruce Company, Bound-Brook, New Jersey and from the International Research Institute, a Rockefeller Foundation affiliate, contacted the Air Force Logistics Command proposing to reformulate Herbicide Orange and sell or donate it to a number of South American Governments, including Brazil, Colombia, Venezuela, and Surinam. The basic plan was to have the Air Force donate the herbicide for use to improve rangelands in the upper Amazon Basins of South America. The Herbicide Orange would be reformulated (diluted) and repackaged for ground application under controlled conditions. AFLC advised the Blue Spruce Company that "*it had no objection, but recommended that the proposed governments that would be involved would employ Blue Spruce Company to reformulate and repackage the Herbicide Orange*." From May 1972 through January 1973, 121 drums (6,655) gallons of Herbicide Orange were shipped to the Blue Spruce Company.

Assessment: As a "Tactical Herbicide", Herbicide Orange was not an EPA (US Environmental Protection Agency) registered pesticide, and as such could not be domestically used or sold. However, the 2.3 million gallons of surplus represented a resource of considerable monetary value. Beginning in May 1972 the Blue Spruce Company experimented on reformulating and diluting the Herbicide Orange. Simultaneously, the Company (with the assistance of the International Research Institute) initiated discussions with the Brazilian Government and with the US EPA. After more than one year negotiating with US and South American Government Agencies, letters of support for the proposal were not forthcoming. Accordingly, after a great deal of

discussion, the United States Air Force Scientific Advisory Board's Ad Hoc Committee on the Disposal of Herbicide Orange rejected this alternative for the following reasons: "*Once sold or donated, the United States could not assure that the herbicide would be handled with the proper technical and environmental controls. In addition, the widespread publicity on the use of the herbicide in Southeast Asia had created an "anti-people" image for the material that would probably result in adverse public opinion and political reactions in the event the herbicide was sold to another country. In view of these considerations, the Board felt that the herbicide's sale or donation to a foreign country would be against the best interests of the United States*."

No record could be found of how the Blue Spruce Company disposed of the reformulated herbicide. The use of 2,4,5-T herbicide was not formally suspended until 1978.

Sources: Department of the Air Force (1974): Final Environmental Statement on the Disposition of Orange Herbicide by Incineration. November 1974, Department of the Air Force, Washington, DC, *Unclassified, available for public distribution*

Air Force Logistics Command (1976): Historical Records – Project on the Disposition of Herbicide Orange. Office of History, Air Force Logistics Command Archives, Wright-Patterson Air Force Base, Ohio, *Unclassified*

DOD TACTICAL HERBICIDE SITES

Site 26

Location: Destruction of Herbicide Orange by Chlorinolysis, Painsville, Ohio

Date → September 1972 – July 1974

Activity Description: One method selected for the potential disposal of the surplus 2.3 million gallons of Herbicide Orange remaining after the Vietnam War was the option of chlorinolysis. From the theoretical engineering point of view, chlorinolysis offered an efficient, controlled, and safe method for the disposal of Herbicide Orange. The concept was that the chlorinolysis process would breakdown the molecules of herbicides and add a chlorine molecule to produce carbon tetrachloride, phosgene, and anhydrous hydrogen chloride, each of which had established commercial value. In July 1972, discussions and correspondence with the US Environmental Protection Agency (EPA) committed the Air Force Logistics Command (AFLC) to pursue the testing and research necessary to determine the feasibility of converting Herbicide Orange to salable products by chlorinolysis. In September 1972 a Memorandum of Agreement between the EPA and AFLC was initiated. The objective of the agreement was the development of a laboratory program to evaluate the practicality of the application of chlorinolysis for the disposal of Herbicide Orange. It was agreed that the EPA would manage the research and provide a report containing all data collected, together with conclusions and recommendations. AFLC agreed to fund the research. Three drums (165 gallons) of Herbicide Orange containing 14 ppm TCDD were provided to the Diamond Shamrock Corporation Laboratory in Painsville, Ohio.

Assessment: Chlorinolysis as a means to dispose of Herbicide Orange was evaluated over a period of almost two years. Reports received in early 1973 confirmed that no dioxin was detected (sensitivity level of 10 parts-per-trillion). Moreover, the 2,4-D that was fractionally distilled from Herbicide Orange by the Diamond Shamrock laboratory contained less than 1 part-per-billion dioxin. The material remaining after distillation was predominantly the dioxin-contaminated 2,4,5-T herbicide, which was then subjected to the chlorinolyis process. EPA estimated that to convert 26.5 millions pounds of Herbicide Orange to carbon tetrachloride, phosgene, and hydrogen chloride would require about 170 million pounds of chlorine. To undertake such a large industrial operation, Diamond Shamrock estimated that it would take from 36 to 90 months to build and evaluate a plant large enough to handle the volume of Herbicide Orange available. In the Final EPA Report, the Diamond Shamrock scientists concluded that chlorinolysis could be an effective means of disposing of the surplus Herbicide Orange. Destruction of the dioxin

(TCDD) was complete, and preliminary toxicology tests of the recovered carbon tetrachloride on rabbits show no evidence of TCDD contamination, i.e., the rabbit ear test for chloracne was negative.

Owing to the uncertainties associated with developing this technique to a full-scale plant capable of safely processing 2.3 million gallons of Herbicide Orange in a timely and economic manner, chlorinolysis was not accepted as the method of disposal even though it was shown to be satisfactory from an environmental point of view. The EPA Final Report did not provide any information on the personnel involved in the laboratory research, nor on the fate of any remaining Herbicide Orange or subsequent products from the chlorinolysis process.

Sources: US Environmental Protection Agency (1974): Study of Feasibility of Herbicide Orange Chlorinolysis. Technical Report EPA-600/2-74-006, July 1974, US Environmental Protection Agency, Washington, DC. *Unclassified, available for public distribution*.

Department of the Air Force (1974): Final Environmental Statement on the Disposition of Orange Herbicide by Incineration. November 1974, Department of the Air Force, Washington, DC. *Unclassified, available for public distribution.*

Miller RA, Shafts PA, Stieritz SF, Termena BJ (1980): The Disposal of Herbicide Orange, 1971-1979. Office of History, Air Force Logistics Command, Wright-Patterson Air Force Base, Ohio.

DOD TACTICAL HERBICIDE SITES

Site 27

Location: Fractionation of Herbicide Orange for Commercial Use, Jacksonville, Arkansas

Date →14 March 1972 – January 1973

Activity Description: One method selected for the potential disposal of the surplus 2.3 million gallons of Herbicide Orange remaining after the Vietnam War was the option of fractionation (chemical distillation). Fractionation was the proposed process of converting Herbicide Orange into its acid ingredients by means of high temperature distillation. The concept was to separate the normal butyl esters of 2,4-D and 2,4,5-T herbicides from the dioxin (TCDD) contaminant. The 2,4-D and 2,4,5-T was then to be reformulated for commercial use. The dioxin (TCDD) would then be destroyed by chemical, biological, or incineration techniques. Actual distillation efficiencies theoretically could approach 90% to 95%. In February 1972, Transvaal, Inc., a chemical company in Jacksonville, Arkansas approached the Air Force Logistic Command (AFLC) with a proposal to dispose of Herbicide Orange through a process of fractional distillation. On 3 March 1972, a team of Bio-environmental Engineers from the AFLC's United States Air Force Environmental Health Laboratory, Kelly Air Force Base, Texas visited the Transvaal Facilities in Jacksonville, Arkansas. On 14 March 1972, AFLC shipped one drum (55 gallons) of Herbicide Orange from the inventory at the Naval Construction Battalion Center, Gulfport, Mississippi to the Transvaal Inc. laboratory in Jacksonville, Arkansas.

Assessment: Immediately after the visit by personnel from Kelly AFB, Transvaal, Inc. undertook a small-scale feasibility study funded by AFLC and with the Herbicide Orange from Gulfport. The Kelly AFB personnel had informed Transvaal that their Herbicide Orange disposal option must contain a feasible monitoring capability that would establish what concentrations of 2,4-D and 2,4,5-T esters, and the TCDD contaminant would be released to the environment during the re-distillation process. Although the Transvaal research laboratory was very limited in instrumentation, they were able to separate Herbicide Orange into its original ingredients. The Transvaal Engineers stated that the TCDD residue would be isolated and destroyed during the fractionation process. However, subsequent research did not demonstrate adequately the fate of the TCDD. In addition, standards to control and monitor vapor and fluid emissions into the environment were not adequately identified. In January 1973, the Air Force Scientific Advisory Board recommended that further research into fractionation not be supported, and that this option not be considered for the disposal of Herbicide Orange.

No records could be found of how the Transvaal, Incorporated disposed of the separated and reformulated herbicides, nor of any remaining Herbicide Orange. The use of 2,4,5-T herbicide was not formally suspended by EPA until 1978.

Sources: Callahan RA (1972): Trip Report to Transvaal Inc., Jacksonville, Arkansas. Prepared for the Commander, USAF Environmental Health Laboratory, Kelly Air Force Base, Texas (copy in the Alvin L. Young Agent Orange Collection, National Agricultural Library – see Sources Page).

Department of the Air Force (1974): Final Environmental Statement on the Disposition of Orange Herbicide by Incineration. November 1974, Department of the Air Force, Washington, DC. *Unclassified, available for public distribution.*

Miller RA, Shafts PA, Stieritz SF, Termena BJ (1980): The Disposal of Herbicide Orange, 1971-1979. Office of History, Air Force Logistics Command, Wright-Patterson Air Force Base, Ohio.

DOD TACTICAL HERBICIDE SITES

Site 28

Location: Reforestation Tests in Western Oregon

Date → 15 May 1973 – 1 June 1974

Activity Description: One method selected for the potential disposal of the surplus 2.3 million gallons of Herbicide Orange remaining after the Vietnam War was the option using it in reforestation programs in the Western United States. Forest surveys taken in 1972 indicated that there were some 4.7 million acres of commercial forest lands in Western Oregon and Washington that were either non-stocked or poorly stocked with conifers (e.g., Douglas fir). Virtually all such lands were occupied by vegetation whose presence precluded reestablishment of conifers. Concepts of selective brush control had been developed for reforestation with the aid of commercial formulations of 2,4-D and 2,4,5-T. In 1972, more than 100,000 acres were being treated each year with various formulations of these materials, all as low-volatile esters. Success had been good, especially in "release" operations where the newly planted conifer species would have the opportunity of out-growing the brush species that had been treated with the herbicides. There were three general approaches to the use of phenoxy brushkillers in reforestation, with the differences tied to season of application. Dormant sprays were applied in spring, between the onset of plant growth activity in early spring and conifer bud busting. Summer and fall foliage sprays were used when brush species were typically resistant to dormant treatment. Summer treatments were the least selective in a Douglas fir community, but tended to have the greatest systemic activity on sensitive species.

In May 1972, a Professor of Forestry with the Oregon State School of Forestry, Corvallis, Oregon submitted a proposal to the Air Force Logistics Command (AFLC) titled: "Field Tests of Herbicide Orange for Brushfield Rehabilitation and Conifer Release." The objectives of this proposed research were: (1) to evaluate the impact of high-volatile brushkiller on brush-dominated forest ecosystems, (2) to determine whether Herbicide Orange could be used effectively in the re-establishment of conifers in Western Oregon brushfields, (3) to evaluate the difficulties of using a technical grade ester without adjuvants for field use, and, (4) to obtain a crude estimate of whether drift problems from the high-volatile butyl esters were manageable. On 20 October 1972, after reviewing the proposal with other Federal agencies, AFLC authorized the shipping of 5 drums of Herbicide Orange from the inventory at the Naval Construction Battalion Center, Gulfport, Mississippi to the School of Forestry, Oregon State University, Corvallis, Oregon.

Assessment: A total of 358 acres of test plots in Western Oregon were treated with Herbicide Orange on 10-11 May 1973. The plots on which Herbicide Orange was applied were selected among sites available on the ownership of three industrial cooperators, all of whom had on-going chemical brush control programs. The cooperators provided the cost of application by helicopter and secured application permits from the Oregon State Forestry Department. Tall brush plots were treated with 4.3 pounds per acre acid equivalent (one-half gallon of Orange in 15 total gallons of diesel fuel), while low brush plots received 2.1 pounds per acre acid equivalent (one quart per acre in ten gallons total spray). The treatments were made by a commercial applicator. Oregon State University School of Forestry personnel conducted the field flagging, field observations, and evaluations of the effectiveness of Herbicide Orange.

Although the brush control and conifer release with Herbicide Orange was excellent, the resulting negative publicity, and concerns expressed by the US Environmental Protection Agency over the transport and use of a non-registered pesticide caused AFLC to reject this method of disposing of the surplus Herbicide Orange. The remaining Herbicide Orange (2 drums) was subsequently returned to the Naval Construction Battalion Center.

Sources: Newton M (October 1972): Field Tests of Herbicide Orange for Brushfield Rehabilitation and Conifer Release. Oregon State University School of Forestry Research Project F882A. Submitted to Air Force Logistics Command, Wright-Patterson Air Force Base, Ohio.

Gazette Telegraph (1973): Weed Killer Banned in Vietnam Being Tested in Five States. Sunday, June 10, 1973, Colorado Springs, Colorado.

Newton M (1975): Environmental Impact of "Agent Orange" Used in Reforestation Tests in Western Oregon. Abstract 144, pages 52-53, Proceedings of the Weed Science Society of America, 1975 Annual Meeting held in Washington, DC.

DOD TACTICAL HERBICIDE SITES

Site 29

Location: Incineration Tests on Herbicide Orange, Van Nuys, California

Date → October 1973 – April 1974

Activity Description: One method selected for the potential disposal of the surplus 2.3 million gallons of Herbicide Orange remaining after the Vietnam War was the option of destroying the herbicide in a land-based commercial incinerator. Personnel from the United States Air Force (USAF) Environmental Health Laboratory (EHL), Kelly Air Force Base, San Antonio, Texas were directed in August 1971 by the Air Force Logistics Command (AFLC) to prepare a statement of work for the disposal of Herbicide Orange by incineration. The tasks involved first conducting in-house bench-sized incinerations tests to determine feasibility of monitoring the emissions of incinerators burning Herbicide Orange, and secondly, in identifying an appropriate commercial incinerator capable of destroying the large quantity of surplus herbicide. The in-house tests were augmented by studies conducted at Mississippi State University and at the Rocket Propulsion Laboratory at Edwards Air Force Base, California. The EHL personnel made trips to Monsanto Company's Krummrich Plant, Sauget, Illinois; and to the Rollins Purle Commercial Incinerator near Philadelphia, Pennsylvania. The outcome of these trips was the recognition that additional engineering studies were required to fully understand the requirements that a commercial incinerator would need to undertake the project. In 1973, AFLC contracted with the Air Force-Marquardt Jet Laboratory, at Van Nuys, California to conduct the required tests. Twenty-eight drums (1,540 gallons) were shipped from the Herbicide Orange Inventory at the Naval Construction Battalion Center, Gulfport, Mississippi to the Marquardt Company in Van Nuys, California. The mean concentration of the dioxin (TCDD) in the Herbicide Orange was 13.3 ppm (parts-per-million).

The tests objectives were to: (1) determine the capability of an incinerator system to destruct the Herbicide Orange over a range of selected incinerator conditions; (2) obtain the necessary engineering data to adequately monitor, control, and document the incinerator operation during the project; (3) evaluate the test burns' effects and project the long-term effects of the combustion gases on the material of the incinerator unit; and, (4) determine the combustion gas, scrubbed effluent gas, and "spent" scrubber water discharge mass rates of herbicide constituents and any other organic compounds that may be detected.

Assessment: On 8 October 1973, tests were initiated with the Marquardt incinerator system to evaluate the incineration of Herbicide Orange in a commercial incinerator over a range of selected conditions. Particular emphasis was placed on the ability of the incinerator to destroy the parts-per-million quantities (11-16 mg/kg) of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) present in the herbicide. A total of 30.5 hours of burn time on undiluted Herbicide Orange fuel was accumulated during eight record burn periods. Test data demonstrated that the incineration system operated very satisfactorily using undiluted "Orange" Herbicide as a fuel and that the herbicide and TCDD was effectively and safely destroyed in the combustion process.

The tests were accomplished between 8 October 1973 and 21 December 1973 at the Air Force-Marquardt Jet Laboratory, Van Nuys, California. During the conduct of the tests, twelve military personnel from the USAF Environmental Health Laboratories at Kelly Air Force Base, Texas and McClellan Air Force Base, California performed the gas sampling, scrubber water sampling, biomonitoring, noise testing, drum cleaning experiments, and the combustion and scrubbed effluent gas monitoring.

With the success of the Marquardt studies, the Under Secretary of the Air Force (Installations and Environment) recommended that the site location for a commerical incinerator was probably the most important factor for the disposal of Herbicide Orange. In 1976, the Air Force selected at-sea incineration aboard the *M/T Vulcanus*, a Dutch-owned incinerator ship, to destroy the herbicide in Operation PACER HO (to be described in the leaflets for the Naval Construction Battalion Center, Gulfport, Mississippi, and Johnston Island, Central Pacific Ocean).

Sources: Department of the Air Force (1974): Final Environmental Statement on the Disposition of Orange Herbicide by Incineration. November 1974, Department of the Air Force, Washington, DC. *Unclassified, available for public distribution.*

Air Force Logistics Command (1976): Historical Records – Project on the Disposition of Herbicide Orange. Office of History, Air Force Logistics Command Archives, Wright-Patterson Air Force Base, Ohio.

Miller RA, Shafts PA, Stieritz SF, Termena BJ (1980): The Disposal of Herbicide Orange, 1971-1979. Office of History, Air Force Logistics Command, Wright-Patterson Air Force Base, Ohio.

DOD TACTICAL HERBICIDE SITES

Site 30

Location: Reprocessing of Herbicide Orange, Gulfport, Mississippi

Date → May 1975 – March 1977

Activity Description: In December 1974, the Department of the Air Force filed a final environmental impact statement with the Council on Environmental Quality on the disposition of Herbicide Orange by destruction aboard a specially designed incinerator ship in a remote area of the Central Pacific Ocean west of Johnston Island. The US Environmental Protection Agency (EPA) held a public meeting in February 1975 to consider the Air Force's request for a permit for ocean incineration of Herbicide Orange. During that meeting, public testimony was presented that suggested that Herbicide Orange could indeed be reprocessed and the material commercially used. The EPA requested that the Air Force Logistics Command (AFLC) again investigate the feasibility of reprocessing the herbicide as a means of disposition prior to making a decision on the permit of ocean incineration. In March 1975, a private company, Agent Chemical Inc., (ACI) submitted a proposal to AFLC proposing that a new process had been developed to remove the TCDD from the herbicide, thus making it available to be reformulated, registered with EPA, and sold in commercial channels.

From May 1975 to March 1977, ACI, the Defense Supply Agency, and AFLC worked on tests and pilot plant research to determine if the reprocessing of the Herbicide Orange stocks could be preformed safely. During the period, the Defense Supply Agency took the lead in managing the reprocessing program. The AFLC's Occupational and Environmental Health Laboratory at Brooks Air Force Base, Texas provided the technical expertise. AFLC retained responsibility for all project and environmental safety programs. In August 1975, ACI received permission from the Mississippi Air and Water Pollution Control Commission to construct a pilot reprocessing plant at the Naval Construction Battalion Center (NCBC) in Gulfport, Mississippi. The NCBC was the storage site for 860,000 gallons of Herbicide Orange. The Naval authorities worked closely with AFLC and the Defense Supply Agency in their reprocessing efforts. If the pilot plant proved successful, NCBC would be the site for the reprocessing operation.

Assessment: In October 1975, ACI received a permit to construct and operate the pilot plant. The plans called for reprocessing the herbicide at both Gulfport and Johnston Island. The process consisted of heating the herbicide and then passing it through carbon absorption cylinders to remove the TCDD. To reprocess all of the Herbicide Orange

would require about 1,000 steel cylinders, each 10 feet long and 30 inches in diameter, 642 tons of activated charcoal. In a series of tests, ACI processed 354 gallons (6.5 drums) of Herbicide Orange (taken from the NCBC Inventory). On 7 July 1976 ACI submitted its report to EPA, the Defense Supply Agency, Under Secretary of Defense for Installations and Environment, Air Force Logistics Command, and to the Occupational and Environmental Health Laboratory. ACI's process was judged successful, and the Defense Supply Agency began negotiating a contract. Complications subsequently emerged related to disposal of the TCDD-loaded steel cartridges, and with concerns by the Navy over the construction of a major facility at NCBC, and from Environmental Groups over the reprocessing of the 2,4,5-T herbicide. In March 1977, the Department of Defense recommended that all reprocessing efforts be discontinued in favor of incineration at sea. Since the incinerator ship *MT Vulcanus* was expected to be available in April 1977, DoD requested EPA immediately grant the permit for the at-sea incineration of the entire Herbicide Inventories at NCBC and Johnston Island.

Active duty Air Force personnel with the Occupational and Environmental Health Laboratory, Brooks Air Force Base, Texas were intimately involved in all phases of the pilot plant construction, the handling of the Herbicide Orange, the on-site environmental monitoring, the oversight of the pilot plant operations, and the health and environmental safety programs. In addition, active duty Navy personnel with the Naval Construction Battalion Center provided additional oversight of the activities occurring on the Naval installation.

Sources: Department of the Air Force (1974): Final Environmental Statement on the Disposition of Orange Herbicide by Incineration. November 1974, Department of the Air Force, Washington, DC. *Unclassified, available for public distribution.*

Air Force Logistics Command (1976): Historical Records – Project on the Disposition of Herbicide Orange. Office of History, Air Force Logistics Command Archives, Wright-Patterson Air Force Base, Ohio.

Hightower D (1976): Report of Plant Operation and Proposed Reprocessing of Herbicide Orange, 24 May—8 July 1976. Agent Chemical Company, Houstong, Texas.

Miller RA, Shafts PA, Stieritz SF, Termena BJ (1980): The Disposal of Herbicide Orange, 1971-1979. Office of History, Air Force Logistics Command, Wright-Patterson Air Force Base, Ohio.

DOD TACTICAL HERBICIDE SITES

Site 31

Location: Storage and Operation PACER HO, Naval Construction Battalion Center, Gulfport, Mississippi

Date → December 1968 – February 1989

Activity Description: After August 1966, the Port of Embarkation for the "Tactical Herbicides Orange, White, and Blue" was the Port of Mobile, Mobile, Alabama. As the tactical herbicide inventory began to build up in Vietnam in 1968, the San Antonio Air Materiel Area (SAAMA), a component of the Air Force Logistics Command (AFLC), temporarily discontinued shipment from the Port of Mobile Outport in order "to avoid exposing large quantities of herbicides to possible damage by enemy action." Since the Port of Mobile was routinely used as the port of embarkation, SAAMA arranged for the excess tactical herbicides to be temporarily placed in storage at the Naval Construction Battalion Center (NCBC), Gulfport, Mississippi. About 10 out of every 10,000 drums received at the Outports during 1968 were damaged or defective. Most of the leakage occurred as a result of punctures (from forklifts) or split seams. Thus, when NCBC agreed to temporarily store the herbicide, it required SAAMA to provide funds and 17 personnel (civilian, contract) to perform storage and warehousing functions associated with the herbicide program.

The NCBC outside storage area was about two miles from the Gulfport Outport Docks, with convenient access to the railroad. It was fenced and isolated from public traffic. The NCBC provided surveillance as well as controlled access. The outside storage was planned and set up for long-term storage. To provide good drainage, 2 x 6-inch dunnage (creosoted lumber) was laid on a hard surface and drums, positioned horizontally with the bung closure point outward, were stacked in double rows, three high, in pyramidal fashion. With the decrease use of tactical herbicides in Vietnam in 1969, the inventory of Herbicide Orange at NCBC began to increase. On 4 November 1969, the Assistant Secretary of Defense placed a restriction on the use of Herbicide Orange in Vietnam. However, all Herbicide Blue and Herbicide White continued to be sent to Vietnam. On 15 April 1970, the Department of Defense issued a total suspension of the use of Herbicide Orange in all military operations in Southeast Asia. These actions left approximately 832,000 gallons of Herbicide Orange in storage at the NCBC that had to

be continually maintained while the Air Force sought a final solution for the disposition of the surplus.

After 1970, the Herbicide Orange inventory at NCBC was augmented by receipt of shipment of surplus Herbicide Orange that had been in temporary storage at Eglin Air Force Base, Florida, and by receipt of shipment of surplus Herbicide Pink (n-butyl 2,4,5-T) that had been in storage at Kelly Air Force Base, Texas. The research efforts to develop a viable option for the disposal of Herbicide Orange expended approximately 180 drums of herbicide, leaving the inventory in April 1977 at 15,470 drums (850,850 gallons). Immediately after the US Environmental Protection Agency issued the permit for the at-sea incineration of Herbicide Orange, Operation PACER HO (pacer an Air Force term for movement, and HO for Herbicide Orange) was implemented at NCBC on 29 April 1977.

Assessment: Operation PACER HO required the dedication and coordination of military and civilian personnel from numerous state and federal agencies and from the military installations in Texas, Mississippi, Alabama, Florida, Ohio, Hawaii, Utah, Georgia, Oklahoma, and California. The Programming Plan detailed requirements for (1) de-drumming operations at Gulfport, Mississippi and Johnston Island; (2) environmental monitoring at Gulfport and Johnston Island; and (3) disposal by at-sea incineration in a remote area off Johnston Island. The plan also included personnel requirements, medical and environmental surveillance, emergency protocols, public relations coordination, and technical guidance for all of the engineering and transportation requirements. The active duty military at the AFLC Occupational and Environmental Laboratory, Brooks Air Force Base, Texas played key roles in the oversight of all activities during Operation PACER HO. The physical operation for PACER HO commenced on 2 May 1977 at NCBC. The schedule called for all actions to be completed at Gulfport within 38 days at which time the operation would shift to Johnston Island, with final activities including at-sea incineration to be completed by day 123 (5 September 1977).

The need for Operation PACER HO personnel for the NCBC portion of the operation was met by issuing a call for active duty military volunteers from the Air Force Logistics Command's five Combat Logistics Support Squadrons (CLSS). More than 200 men volunteered from Robins Air Force Base Georgia (the 2955th CLSS), Hill Air Force Base, Utah (the 2952nd CLSS), Kelly Air Force Base, Texas (the 2954th CLSS), Tinker Air Force Base, Oklahoma (2953rd CLSS) and McClellan Air Force Base, California (2951st CLSS). Additional civilian and military personnel came from Andrews Air Force Base, Maryland, Wright-Patterson Air Force Base, Ohio, and the United States Air Force Academy, Colorado.

The members of CLSS teams were responsible for carrying out all phases of PACER HO including empting drums, loading tank cars, pumping the herbicide onboard the *M/T Vulcanus* at the Gulfport Outport Dock, and crushing and stacking the emptied 55-gallon drums. The uniform of the day for all CLSS members in the processing of the herbicide included protective clothing, masks with respirators and goggles, and personal monitoring devices that were checked at regular intervals. The medical staff from the

Aerospace Medical Division at Brooks Air Force Base, Texas provided pre- and post-exposure physical examinations to all active duty members of the CLSS units and other active duty military participating in PACER HO. The operation was completed at NCBC on 10 June 1977.

Following the completion of Operation PACER HO at NCBC, military from the Occupational and Environmental Health Laboratory, Brooks Air Force, Texas supervised the initial clean up of the NCBC storage site including disposal of dunnage, contaminated protective clothing, and other waste materials. These were subsequently disposed of in an approved landfill at the National Space and Technology Laboratory in Bay Saint Louis, Mississippi. The crushed 55-gallon drums were sold to a smelter. In August 1977, a soil, sediment, and biological monitor program was put into place to track the fate of TCDD and residues of Herbicide Orange in the NCBC environment. This monitoring program was conducted by Active duty Air Force officers from the Occupational and Environmental Health Laboratory, San Antonio, TX and from the Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, conducted the monitoring program. In February 1989, the Air Force in accordance with the Defense Environmental Restoration Program completed a final site cleanup at NCBC by incinerating all remaining TCDD-contaminated soil.

Sources: Department of the Air Force (1974): Final Environmental Statement on the Disposition of Orange Herbicide by Incineration. November 1974, Department of the Air Force, Washington, DC. *Unclassified, available for public distribution.*

Young AL, Calcagni JA, Thalken CE, Tremblay JW (1978): The Toxicology, Environmental Fate, and Human Risk of Herbicide Orange and Its Associated Dioxin. Technical Report OEHL-TR-92, USAF Occupational and Environmental Health Laboratory, Aerospace Medical Division, Brooks Air Force Base, Texas. *Approved for public release, distribution unlimited.*

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DOD TACTICAL HERBICIDE SITES

Site 32

Location: Storage and Operation PACER HO, Johnston Island, Central Pacific Ocean

Date → April 1972 – June 2004

Activity Description: On 15 April 1970, the Assistant Secretary of the Defense suspended the use of Herbicide Orange in Vietnam. The suspension lasted from 15 April 1970 to 13 September 1971. On 13 September 1971, the Secretary of Defense directed the Chairman, Joint Chiefs of Staff that "*all stocks of Herbicide Orange in Vietnam will be returned to the Continental United States as quickly as practicable for disposition. A Joint State/Defense message has been prepared requesting the US Embassy negotiate with the Government of Vietnam for the return to US control of all stocks of Herbicide Orange in the Republic of Vietnam*." Based on this directive, the 7th Air Force in Vietnam initiated Operation PACER IVY, the removal of all Herbicide Orange in Vietnam to Johnston Island. In mid-April 1972, the cargo ship, the *M/T TransPacific*, arrived at Johnston Island, Central Pacific Ocean, and off-loaded 25,200 55-gallon drums (1,386,000 gallons) of Herbicide Orange. From mid-April 1972 until mid-July when Operation PACER HO commenced, the Johnston inventory of Herbicide Orange required continual maintenance because of the deteriorating condition of the drums. The Pacific Test Division of Holmes and Narver, Inc., a civilian contractor, was responsible for the maintenance of the storage site and drums.

Assessment: When the Herbicide Orange stocks arrived at Johnston Island, the entire inventory was placed in the northwest corner of the Island and immediately fenced to restrict access to the storage area by civilians and Army personnel stationed on the Island, i.e., the inventory storage area was identified as an area "off limits" to military and civilian employees. The location of the storage area was important because it was located in an area where the prevailing winds would blow any vapors (and hence odor) away from the Island and away from where the temporary personnel or semi-permanent residents were quartered and messed.

The Johnston Island component of Operation PACER HO required the dedication and coordination of military and civilian personnel from State and Federal agencies and from many military installations. The Programming Plan detailed requirements for (1) de-

drumming operations at the Naval Construction Battalion Center (NCBC), Gulfport, Mississippi and Johnston Island; (2) environmental monitoring at Gulfport and Johnston Island; and (3) disposal by at-sea incineration in a remote area off Johnston Island. The plan also included personnel requirements, medical and environmental surveillance, emergency protocols, public relations coordination, and technical guidance for all of the engineering and transportation requirements. The active duty military at the AFLC Occupational and Environmental Laboratory (OEHL), Brooks Air Force Base, Texas played key roles in the oversight of all activities during Operation PACER HO. The physical operation for PACER HO at Johnston Island commenced on 27 July 1977.

On Johnston Island civilian employees were hired by a contractor to perform the de-drumming operations. USAF officers from OEHL monitored all operations. Two 10-hour shifts of approximately 50 men each were used. All workers were provided daily changes of freshly laundered work cloths, and men working within the de-drum facility wore protective clothing consisting of cartridge respirators, face shields, rubber aprons, gloves, and boots. Men on each crew remained in the same job through the de-drumming and transfer operations. A requirement for employment was pre- and post-operational physical examinations similar to those given to the active during military at NCBC.

In the actual de-drumming operation, the drums were handled using techniques similar to those at the NCBC. The herbicide and rinsing liquids from the drums were pumped into modified fuel tankers and transported to the Johnston Island Dock where the material was pumped aboard the *M/T Vulcanus*. A total of 24,795 drums of Herbicide Orange were processed between 27 July and 23 August 1977. Both environmental and occupational monitoring was accomplished on land and aboard the *M/T Vulcanus*. All sampling on Johnston Island was conducted by Battelle Columbus Laboratories, Columbus, Ohio. Personnel from TRW, Inc., Redondo Beach, California, and military officers from OEHL did the shipboard sampling.

Following the completion of Operation PACER HO at Johnston Island, military personnel from OEHL supervised the initial clean up of the storage site including disposal of dunnage, contaminated protective clothing, and other waste materials. These were subsequently disposed of in an approved burn site on the island. Afterward the residue was buried, and the remaining 36,000-plus crushed 55-gallon drums were sold to a smelter. In August 1977, a soil, sediment, and biological monitor program was put into place to track the fate of TCDD and residues of Herbicide Orange in the Johnston Island environment. This monitoring program was conducted by active duty Air Force officers from OEHL, the Department of Chemistry and Biological Sciences at the United States Air Force Academy, and from the Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida. In February 1989, the Air Force, in accordance with the Defense Environmental Restoration Program, completed a final site cleanup at Johnston Island by destroying all remaining TCDD-contaminated soil by the use of an on-site thermal desorption system employing low-temperature thermal desorption technology. The site was covered by approximately 6 inches of topsoil and planted with vegetative species native to the region.

Sources: Department of the Air Force (1974): Final Environmental Statement on the Disposition of Orange Herbicide by Incineration. November 1974, Department of the Air Force, Washington, DC. *Unclassified, available for public distribution.*

Young AL, Calcagni JA, Thalken CE, Tremblay JW (1978): The Toxicology, Environmental Fate, and Human Risk of Herbicide Orange and Its Associated Dioxin. Technical Report OEHL-TR-92, USAF Occupational and Environmental Health Laboratory, Aerospace Medical Division, Brooks Air Force Base, Texas. *Approved for public release, distribution unlimited*.

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Summary of Assessment of Site Exposure

The issue of "meaningful exposure" to Tactical Herbicides is a subject of debate in the scientific literature. The most reliable information has shown that the esters of the herbicides, 2,4-D and 2,4,5-T, that made up Herbicide Orange, and its associated dioxin contaminant (2,3,7,8-tetrachlorodibenzo-p-dioxin, TCDD) rapidly dried within minutes of being sprayed on vegetation, rendering them unavailable for absorption. The process of drying involved the chemicals being absorbed within the waxy layer of the plant cuticle, where they were not readily dislodged [1]. Studies of Herbicide Orange and the associated TCDD on both leaf and soil surface demonstrated that photolysis rapidly decreased the concentration of TCDD (within hours), and this process even continued in shade [2]. Studies of 'dislodgeable foliar residues' (the fraction of a substance that is available for cutaneous uptake from the plant leaves) showed that only 8% of were present 1 hour after application. This dropped to 1% 24 hours after application [3]. Moreover, studies in human volunteers confirmed that after 2 hours of saturated contact with bare skin, only 0.15-0.46% of 2,4,5-T entered the body and was eliminated in the urine [4]. The implications of these studies and observations are that individuals who entered a sprayed area one day after application of Herbicide Purple, Herbicide Green, Herbicide Pink and Herbicide Orange received essentially no "meaningful exposure." These are important findings because military and civilian personnel from Fort Detrick, United States Department of Agriculture (in Puerto Rico and Texas), and the Air Force Logistics Command that participated in the evaluation of the spray and monitoring operations were not likely to have been exposed. Certainly, any local civilians who entered the spray area days after spraying were at no risk of exposure.

What is meant by a "measurable" human exposure to Tactical Herbicides is difficult to estimate for personnel who were not monitored by non-evasive blood or urine techniques. In the years before and during Vietnam, these techniques were not available [5]. The components of the Tactical Herbicides, 2,4-D, 2,4,5-T, cacodylic acid and picloram can now be measured in the urine. The excellent studies by Lavy [5] and Hood [6] have provided convincing evidence that in forestry and brush control programs mixers and applicators of the phenoxy herbicides, picloram or cacodylic acid would have had "measurable", albeit generally very low, levels in their urine. However, these studies also indicated that individuals who walked through the sprayed areas even 2 hours after application did NOT have measurable levels of herbicides in their urine. Thus, it was unlikely that either short term or prolonged time spent in sprayed areas 24 hours after spraying would have resulted in any "measurable" levels of exposure.

Testing of serum dioxin levels has been widely regarded as the gold standard for epidemiological studies of TCDD from Herbicide Orange since its development in the late 1980s [7]. Studies conducted on the men that actually handled the liquid Herbicide Orange showed measurable levels of TCDD in their blood serum [8,9]. Moreover, the major industrial studies since the 1980's have relied upon it to validate estimation of exposure [7]. The significance of these studies and observations is that those Active Duty military personnel who mixed, loaded, and participated in the actual spray programs during the development of the tactical phenoxy-related herbicides and spray equipment,

and those who participated in Operation PACER HO, may have received a "measureable exposure" to TCDD. This was most likely true even though participants were generally instructed to use face shields or respirators, rubber gloves, and aprons. Many of these studies were conducted in subtropical and tropical climates; the wearing of protective clothing was very uncomfortable. In Operation PACER HO great care was taken to monitor the safety of the hundreds of men who participated in the de-drumming and transfer of the liquid Herbicide Orange and rinse, but the process was not free of minor spills and accidents.

Although most of the studies on the disposal options for Herbicide Orange involved Active Duty military, the use of safety protocols was an important part of the studies, and they were less likely to be exposed to the liquid Herbicide Orange. Safety protocols were also required in the site monitoring and remediation programs that followed PACER HO at the Naval Construction and Battalion Center and at Johnston Island. Active Duty military personnel handled contaminated soil. Studies of the binding of TCDD to soil particles likely minimized the cutaneous availability to naked skin (e.g., hands) and to many biological organisms associated with that soil [10,11]. Moreover, The handling of these soils generally occurred many months to years after the soil had been contaminated and most the residues would have been degraded by chemical and biological mechanisms [12]. Nevertheless, it cannot be concluded that "no measurable exposure" occurred. Indeed, three of the individuals who had participated in these monitoring programs did have analyses of their adipose tissue performed in 1978, and levels of 5-7 parts-per-trillion (ppt) TCDD were measured [10]. RANCH HAND personnel who handled the liquid Herbicide Orange a decade before the above individuals still had in 1986 levels that were orders of magnitude greater than those involved in the monitoring programs [8].

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