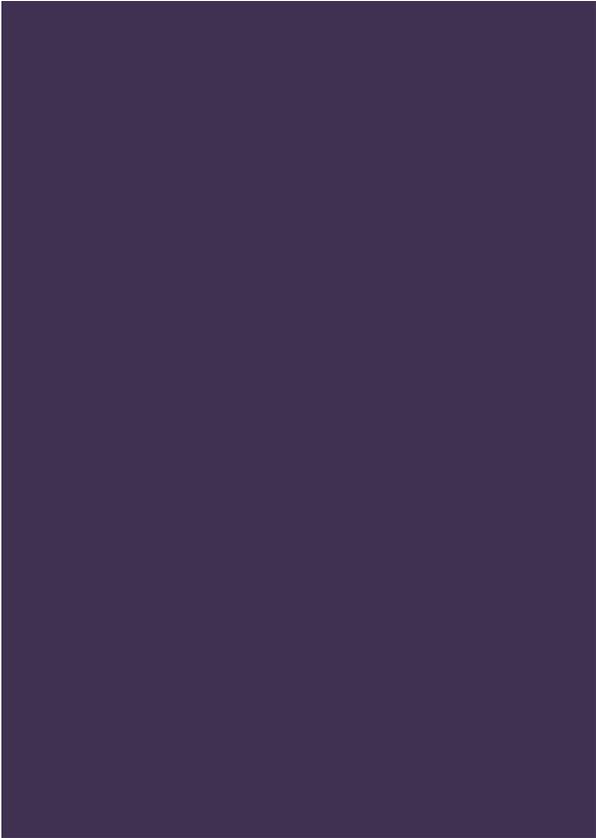




November
2023



Final

Description of Proposed Action and Alternatives

For the Environmental Assessment Addressing Test Activities and Infrastructure Improvements at the Conventional High Explosive Simulated Nuclear Test Site and Joint Use Area on Kirtland Air Force Base, New Mexico

*United States Air Force
Kirtland Air Force Base
Air Force Research Laboratory*



ACRONYMS AND ABBREVIATIONS

ABW	Air Base Wing
AFB	Air Force Base
AFRL	Air Force Research Laboratory
AFSC	Air Force Systems Command
AFWL	Air Force Weapons Laboratory
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CHESTNUT	Conventional High Explosive Simulated Nuclear Test
CZ	clear zone
DE	directed energy
DoD	Department of Defense
DOE	US Department of Energy
DOPAA	Description of Proposed Action and Alternatives
DTRA	Defense Threat Reduction Agency
EA	Environmental Assessment
EIAP	Environmental Impact Analysis Process
EO	Executive Order
EOD	Explosive Ordnance Disposal
FONSI	Finding of No Significant Impact
g	grams
GZ	Ground Zero
HE	high explosive
HEL	high energy laser
HPEM	high power electromagnetic
kg	kilogram
Lb.	pound
LEC	Laser Effect Compound
LIDAR	Light Detection and Ranging
MSG	Mission Support Group
N.E.W.	net explosive weight
NEPA	National Environmental Policy Act
NOA	Notice of Availability
PEA	Programmatic Environmental Assessment
RD	Directed Energy Directorate
RDT&E	research, development, test, and evaluation
RMO	Range Management Office
RV	Space Vehicle Directorate
SHPO	State Historic Preservation Officer
T&F	timing and firing
USAF	US Air Force
USC	United States Code
USFWS	US Fish and Wildlife Service
USSF	US Space Force
WMD	weapons of mass destruction
WSMR	White Sands Missile Range

COVER SHEET

**FINAL
DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES FOR THE
ENVIRONMENTAL ASSESSMENT ADDRESSING TEST ACTIVITIES AND
INFRASTRUCTURE IMPROVEMENTS AT THE CONVENTIONAL HIGH EXPLOSIVE
SIMULATED NUCLEAR TEST SITE AND JOINT USE AREA ON KIRTLAND AIR FORCE
BASE, NEW MEXICO**

Responsible Agencies: US Air Force (USAF), Kirtland Air Force Base (AFB), Air Force Research Laboratory (AFRL).

Affected Location: Kirtland AFB, New Mexico.

Proposed Action: Test Activities and Infrastructure Improvements at the Conventional High Explosive Simulated Nuclear Test (CHESTNUT) Site and Joint Use Area on Kirtland AFB.

Report Designation: Final Description of Proposed Action and Alternatives (DOPAA).

Abstract: This DOPAA was developed in compliance with the USAF's *Environmental Impact Analysis Process*. It supports a proposal by AFRL for the USAF, US Space Force (USSF), and Defense Threat Reduction Agency (DTRA) to continue conducting current test activities and implement future test activities, as well as construct, operate, maintain, and remove supporting infrastructure at the CHESTNUT Site and Joint Use Area on Kirtland AFB, New Mexico.

The Proposed Action includes current and proposed future test activities conducted by the USAF, USSF, and DTRA at the CHESTNUT Site and Joint Use Area (collectively hereafter referred to as "the Range"). Under the Proposed Action, AFRL/Directed Energy Directorate (RD) would continue to integrate directed energy (DE) technology into warfighter vehicles and evaluate DE weapon systems effectiveness on the Range. DE devices, such as high energy laser (HEL) and high power electromagnetics (HPEM), would be set up on the Range to evaluate the effects resulting from HEL and HPEM engagements on various targets to include explosives, munitions, electronics, small unmanned aircraft systems, and unmanned aerial vehicles. AFRL/RD would also continue to evaluate radar systems to be used in the detection and tracking of potential threat small unmanned aerial systems. The AFRL Space Vehicle Directorate proposes to begin conducting vaporization experiments on the Range. DTRA would continue to analyze the impacts of its research, development, test, and evaluation activities to counter, deter, and defeat weapons of mass destruction and improvised explosive device testing conducted on the Range. Additionally, DTRA proposes to begin conducting cloud simulation tests on the Range. The 377th Mission Support Group/Explosive Ordnance Disposal would continue to use the Range for suspicious package destruction.

In addition to the test activities, the Proposed Action includes the construction, operation, maintenance, and removal of supporting infrastructure as well as routine range construction, site preparation, and maintenance. Examples of supporting infrastructure projects that could be included in the Proposed Action consist of replacing outdated project timing and firing trailers, installing permanent pneumatic mast setups, replacing or installing up to 25,000 feet of underground cables a year, installing and removing up to 20 test structures/concrete pads/dirt berms to be used for test activities a year, and conducting general clean-up activities on the Range.

Given the length of time that has elapsed since the original 1987 *Environmental Assessment and Finding of No Significant Impact for the Civil Engineering, Research Facility Test Site, Kirtland AFB, New Mexico* and the proposed future test activities, USAF has determined that an update to the Environmental Assessment is appropriate.

PRIVACY ADVISORY

The EA will be provided for public comment in accordance with the National Environmental Policy Act, Council on Environmental Quality regulations for implementing the National Environmental Policy Act (Title 40 Code of Federal Regulations Parts 1500–1508, as amended by 87 Federal Register 23453–23470), and 32 Code of Federal Regulations Part 989, *Environmental Impact Analysis Process*.

The Environmental Impact Analysis Process provides an opportunity for public input on USAF decision making, allows the public to offer input, and solicits comments on USAF's analysis of environmental impacts. Public commenting allows USAF to make better-informed decisions. Letters or other written or oral comments provided may be published in the EA. As required by law, comments provided will be addressed in the EA and made available to the public. Providing personal information is voluntary. Private addresses may be compiled to develop a mailing list for those requesting copies of the EA. Only the names of the individuals making comments and specific comments will be disclosed in the EA. Personal information, home addresses, telephone numbers, and email addresses will not be published in the EA.

This document is compliant with Section 508 of the Rehabilitation Act. This allows assistive technology to be used to obtain the available information from the document. Due to the nature of graphics, figures, tables, and images occurring in the document, accessibility is limited to a descriptive title for each item.

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TABLE OF CONTENTS

Acronyms and Abbreviations.....Inside Front Cover

1.0	PURPOSE AND NEED FOR THE PROPOSED ACTION	1-1
1.1	INTRODUCTION.....	1-1
1.2	BACKGROUND.....	1-4
1.2.1	AFRL Operations.....	1-4
1.2.2	DTRA Operations.....	1-5
1.2.3	377 MSG/EOD Operations.....	1-5
1.3	PURPOSE OF THE PROPOSED ACTION.....	1-5
1.4	NEED FOR THE PROPOSED ACTION.....	1-6
1.5	DECISION TO BE MADE.....	1-6
1.6	INTERGOVERNMENTAL COORDINATION AND CONSULTATIONS.....	1-6
1.6.1	Interagency and Intergovernmental Coordination and Consultations.....	1-6
1.6.2	Government to Government Coordination and Consultations.....	1-7
1.7	PUBLIC AND AGENCY REVIEW OF DRAFT EA.....	1-7
2.0	DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES	2-1
2.1	PROPOSED ACTION.....	2-1
2.2	SELECTION STANDARDS.....	2-1
2.3	DETAILED DESCRIPTION OF THE ALTERNATIVES.....	2-1
2.3.1	Proposed Action.....	2-1
2.3.2	No Action Alternative.....	2-7
2.4	ALTERNATIVES CONSIDERED BUT ELIMINATED FROM FURTHER CONSIDERATION.....	2-8
2.4.1	White Sands Missile Range.....	2-8
2.4.2	Cannon AFB and Melrose Range.....	2-8

LIST OF FIGURES

Figure 1-1.	Kirtland AFB Vicinity Map.....	1-2
Figure 1-2.	CHESTNUT Site and Joint Use Area Overview.....	1-3
Figure 2-1.	Location of GZ-1, GZ-2, and LEC Test Areas.....	2-4

LIST OF TABLES

Table 2-1.	Proposed Small-, Medium-, and Large-Scale Testing Activity.....	2-5
Table 2-2.	Test Preparation Construction Equipment.....	2-7

1

APPENDICES

2

A. Interagency and Intergovernmental Coordination for Environmental Planning and Public Involvement Materials

3

4

B. Periodic Table of Elements

1.0 PURPOSE AND NEED FOR THE PROPOSED ACTION

1.1 INTRODUCTION

Kirtland Air Force Base (AFB), located southeast of the city of Albuquerque, New Mexico (see **Figure 1-1**), is home to the 377th Air Base Wing (ABW) of the Air Force Global Strike Command. The installation is a center for research, development, and testing of nonconventional weapons, space and missile technology, and directed energy (DE) systems. The 377 ABW ensures readiness and training of airmen for worldwide duty and prepares personnel to deploy worldwide on a moment's notice. The installation encompasses 51,585 acres, of which 44,052 acres are under US Air Force (USAF) control.

The **C**onventional **H**igh **E**xplosive **S**imula**T**ed **N**uclear **T**est (CHESTNUT) Site and Joint Use Area on Kirtland AFB (collectively hereafter referred to as "the Range") is an 800-acre range located in the southwest portion of the installation (see **Figure 1-2**) with 300-acres being an approved explosive range rated for up to 2,000-pounds (lbs) Net Explosive Weight (N.E.W.). The Range is bordered by Mesa del Sol to the west, the Pueblo of Isleta to the south, US Department of Energy (DOE) land to the north, and USAF property to the east. The area was established in 1987 through *The Civil Engineering Research Facility Test Site Environmental Assessment (EA)*, hereafter referred to as the 1987 EA, and has been in continuous operation since. Potential users of the Range could include the Air Force Research Laboratory (AFRL)/Directed Energy Directorate (RD), AFRL/Space Vehicle Directorate (RV), Defense Threat Reduction Agency (DTRA), and 377th Mission Support Group (MSG)/Explosive Ordnance Disposal (EOD), among others. Approximately 50 acres of the Joint Use Area north of CHESTNUT is an approved site for explosive tests. On CHESTNUT proper, AFRL/RD fires high energy lasers (HEL) and high power electromagnetics (HPEM) toward the east, which is the Joint Use Area. The remaining Joint Use Area (approximately 500 acres) provides a buffer between the DOE Thunder Range and CHESTNUT Site (see **Figure 1-2**).

The Proposed Action includes current and proposed future test activities conducted by the USAF, US Space Force (USSF), and Defense Threat Reduction Agency (DTRA) on the Range. Under the Proposed Action, AFRL/RD would continue to integrate DE technology into warfighter vehicles and evaluate DE weapon systems effectiveness on the Range. DE devices, such as HEL and HPEM, would be set up on the Range to evaluate the effects resulting from HEL and HPEM engagements on various targets to include explosives, munitions, electronics, small unmanned aircraft systems, and unmanned aerial vehicles. AFRL/RD would also continue to evaluate radar systems to be used in the detection and tracking of potential threat small unmanned aerial systems. AFRL/RV, of the USSF, proposes to begin conducting vaporization experiments on the Range. DTRA would continue to analyze the impacts of its research, development, test, and evaluation (RDT&E) activities to counter, deter, and defeat weapons of mass destruction (WMD) and improvised explosive device testing conducted on the Range. Additionally, DTRA proposes to begin conducting cloud simulation tests on the Range. The 377th Mission Support Group (MSG)/Explosive Ordnance Disposal (EOD) would continue to use the Range for suspicious package destruction.

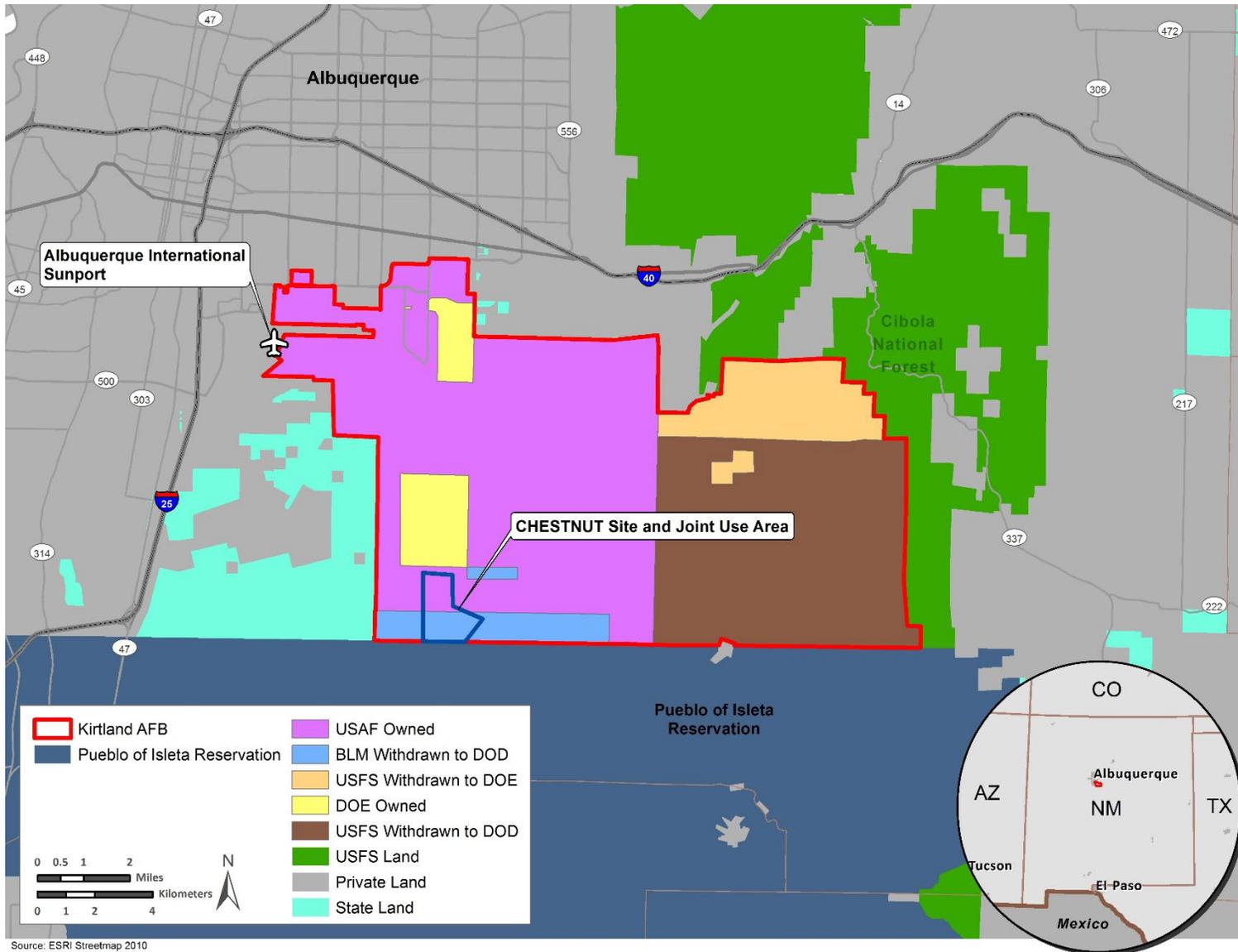


Figure 1-1. Kirtland AFB Vicinity Map

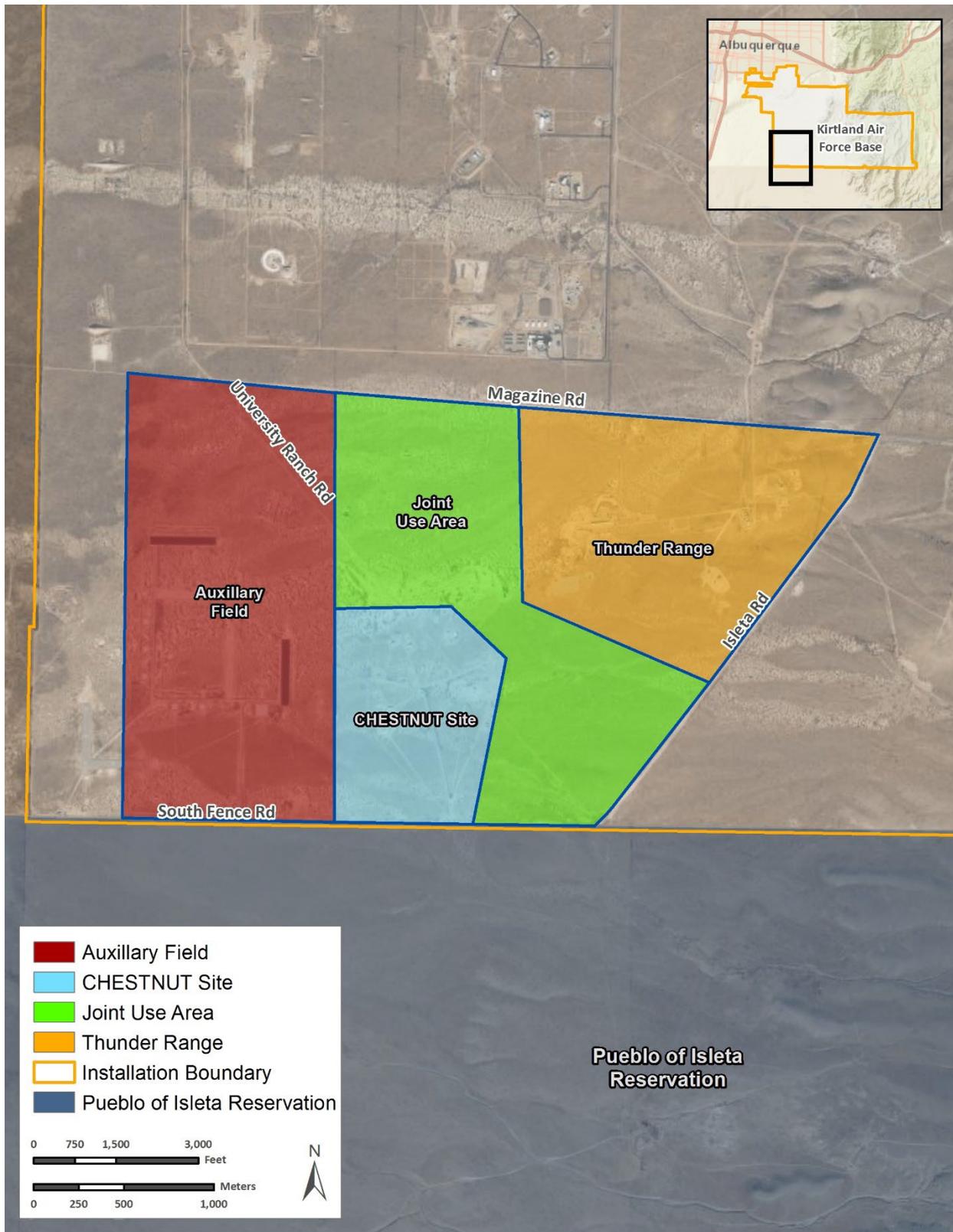


Figure 1-2. CHESTNUT Site and Joint Use Area Overview

DOPAA for EA Addressing Test Activities and Infrastructure Improvements at the CHESTNUT Site and Joint Use Area on Kirtland AFB, NM
 November 2023

In addition to the test activities, the Proposed Action also includes the construction, operation, maintenance, and removal of supporting infrastructure as well as routine range construction, site preparation, and maintenance. Examples of supporting infrastructure projects that could be included in the Proposed Action consist of replacing outdated project timing and firing (T&F) trailers, installing permanent pneumatic mast setups, replacing or installing up to 25,000 feet of underground cables (e.g., fiber optic cables, power lines, etc.) a year, installing and removing up to 20 test structures/concrete pads/dirt berms to be used for test activities a year, and conducting general clean-up activities on the Range (e.g., weed and brush removal, grading and leveling areas for explosive tests, weather proofing, and removing rodents/rodent waste from structures and bunkers). Given the length of time that has elapsed since the 1987 EA and the proposed future test activities, USAF has determined that an update to the EA is appropriate.

This Description of Proposed Action and Alternatives (DOPAA) lays the framework for the EA, detailing the proposed activities under the Proposed Action. The EA is a planning and decision-making tool that will be used to guide the USAF in implementing the Proposed Action in a manner that complies with all applicable federal, state, and local environmental laws and regulations and is consistent with USAF standards for environmental stewardship. This DOPAA supports a proposal by the USAF, Kirtland AFB, and AFRL to conduct a range of test activities on the Range as well as construct, operate, maintain, and remove supporting infrastructure.

1.2 BACKGROUND

The Department of Defense (DoD) Armed Services perform research and development to support the discovery of technologies to meet increasing threats and challenges encountered by the military under Title 10 of the United States Code (USC) Chapter 139. In 1949, the USAF established its own Special Weapons Center and test laboratory at Kirtland Field near Sandia, which eventually became the Air Force Weapons Laboratory (AFWL) in 1963 under the Air Force Systems Command (AFSC). AFWL conducted scientific research on weapons and their effects, as well as explored the military uses of nuclear power, weapons, and support equipment seeking to reduce the vulnerability of United States systems to enemy weapons. In the 1960s, AFWL's work moved toward laser research with the establishment of the Airborne Laser Laboratory program in the 1970s. DE's heritage has been strengthened over the years because of the shift from nuclear WMD to DE weapons which provide increased capabilities for surgical strikes.

In 1990, AFSC reorganized 13 laboratories across the country into four super laboratories and AFWL became Phillips Laboratory at Kirtland AFB, devoted to space and missiles research and development. Then in 1997, the laboratories were reorganized again and named the AFRL, as it is known today. Two directorates of AFRL remained at Kirtland AFB to continue research in space (RV) and directed energy (RD). All current training activities and facilities are situated on lands owned by USAF or on lands withdrawn from public use, by the Bureau of Land Management or the US Forest Service, and given to USAF for military research, testing, and development activities.

1.2.1 AFRL Operations

1.2.1.1 AFRL/RD Operations

The AFRL/RD mission is to, "Lead the discovery, development and delivery of directed energy science and technology for National Security." The research originally conducted by AFWL evolved into weapons that are very precise, can focus energy, cause minimal damage to surrounding personnel, and can counter threats employed by adversaries. Today AFRL/RD

develops DE weapons to counter electronic systems, attack improvised explosive devices or other munitions, and disable other targets. As this technology develops, scientists and engineers expand the concepts to ensure they can work for the warfighter.

AFRL/RD specializes in HPEM and HEL technology development. These areas of research offer the warfighter innovative technologies that enable a variety non-traditional counter electronic and thermal effects that can be either lethal or non-lethal. HPEM systems enable low collateral damage methods to disturb, deny, or damage electronics contained in adversary systems or buildings. HEL systems enable pinpoint accurate methods to degrade or destroy adversary systems. Both technologies operate by emitting high bursts of photons, but the damage mechanisms vary depending on the photon energies emitted. This vision of modern DE warfare is enabled by recent revolutionary advances and additional anticipated advances.

1.2.1.2 AFRL/RV Operations

AFRL/RV served as the USAF's center of excellence for space technology research and development until it was reorganized under the USSF in 2020. The directorate develops and transitions space technologies to provide space-based capabilities. Primary mission activities include space-based intelligence, surveillance and reconnaissance; space domain awareness; space communications, position, navigation and timing; and defensive space control (protecting space assets from man-made and natural effects). AFRL/RV leverages commercial, civil, and other government resources to stay one step ahead in space and to ensure the United States' advantage.

1.2.2 DTRA Operations

DTRA is the DoD's official Combat Support Agency for countering WMD. Personnel at DTRA address the entire spectrum of chemical, biological, radiological, nuclear, and high yield explosive threats. DTRA's programs include basic science research and development, operational support to warfighters on the front line, and an in-house WMD think tank that aims to anticipate and mitigate future threats long before they have a chance to cause harm. DTRA works with the military services, other elements of the US Government, and countries across the world on counterproliferation, nonproliferation, and WMD reduction issues with one goal in mind – making the world safer.

1.2.3 377 MSG/EOD Operations

The 377 MSG/EOD began using the Joint Use Area for training when the Open Detonation Treatment Facility on Kirtland AFB was shut down in 2010. Today, 377 MSG/EOD uses the Range for monthly proficiency training and emergency operations, as necessary. 377 MSG/EOD and AFRL/RD explosive handlers require routine training events to ensure personnel stay qualified and current with safety and proficiency standards. 377 MSG/EOD must remain qualified to support any potential munition/explosive emergency that may occur on Kirtland AFB or in locations required by their mission. They must be able to rapidly respond to ensure potential hazards are neutralized with minimum disturbance to personnel, property, and the surrounding environment.

1.3 PURPOSE OF THE PROPOSED ACTION

The purpose of the Proposed Action is for the USAF, USSF, and DTRA users to continue conducting current test activities and implement future test activities, as well as construct, operate,

maintain, and remove supporting infrastructure for all DoD agencies conducting Research, Development, Test, and Evaluation (RDT&E) activities on the Range on Kirtland AFB. The Range would continue to be shared by multiple DoD agencies, including but not limited to (1) AFRL/RD for testing and training with explosives, HPEM and HEL systems, and drones; (2) AFRL/RV for optimizing canister system designs to generate metallic vapor for the study of plasma effects in the ionosphere; (3) DTRA for research into the deterrence of WMD and improvised explosive devices; and (4) 377 MSG/EOD for explosive handling and emergency operations.

1.4 NEED FOR THE PROPOSED ACTION

The need for the Proposed Action is to allow USAF, USSF, and DTRA current and future users the ability to test concepts in need of an open-air (outdoor) environment to improve the technology discussed in **Sections 1.2.1** through **1.2.4**. Such tests detailed above are needed to determine the survivability and vulnerability of structures and targets for national security. In turn, these tests allow for the delivery of innovative and affordable weapons, materials, and methods to the warfighter in time to meet their mission demands. Because of ever-changing threat scenarios, the RDT&E and training conducted by these agencies is a critical element in the development of new capabilities for the nation's security, and it provides an important component of the United States' global leadership in safety, science, and technology.

1.5 DECISION TO BE MADE

The EA will evaluate whether the Proposed Action would result in significant impacts on the environment. If significant impacts are identified, USAF would undertake mitigation measures to reduce impacts to below the level of significance, undertake the preparation of an Environmental Impact Statement addressing the Proposed Action, or abandon the Proposed Action. If significant impacts are not identified, then the EA would be finalized and a Finding of No Significant Impact (FONSI) would be signed. The decision would be made by the approving official and could incorporate the Proposed Action, its alternatives, or any combination of the Proposed Action and alternatives. The EA will be prepared in accordance with the National Environmental Policy Act (NEPA) of 1969 (42 USC §§ 4331 et seq.), the regulations of the President's Council on Environmental Quality (CEQ) that implement NEPA procedures (40 Code of Federal Regulations [CFR] Parts 1500–1508), and the USAF Environmental Impact Analysis Process (EIAP) Regulations at 32 CFR Part 989.

1.6 INTERGOVERNMENTAL COORDINATION AND CONSULTATIONS

1.6.1 Interagency and Intergovernmental Coordination and Consultations

Executive Order (EO) 12372, *Intergovernmental Review of Federal Programs*, as amended by EO 12416, requires federal agencies to provide opportunities for consultation by elected officials of state and local governments that would be directly affected by a federal proposal. In compliance with NEPA, Kirtland AFB will notify relevant stakeholders about the Proposed Action and alternatives (see **Appendix A** for all stakeholder coordination materials). The notification process will provide these stakeholders the opportunity to cooperate with Kirtland AFB and provide comments on the Proposed Action and alternatives.

Per the requirements of Section 106 of the National Historic Preservation Act and implementing regulations (36 CFR Part 800), Section 7 of the Endangered Species Act and implementing regulations (50 CFR Part 17) including the Migratory Bird Treaty Act, findings of effect and a request for concurrence will be transmitted to the State Historic Preservation Officer (SHPO) and

the US Fish and Wildlife Service (USFWS). A brief summary of comments received will be included in the EA. All correspondence with SHPO and USFWS will be included in **Appendix A**. Correspondence regarding the findings, concurrence, and resolution of any adverse effect will also be included in **Appendix A**.

1.6.2 Government to Government Coordination and Consultations

EO 13175, *Consultation and Coordination with Indian Tribal Governments*, directs federal agencies to coordinate and consult with Native American tribal governments whose interests may be directly and substantially affected by activities on federally administered lands. To comply with legal mandates, federally recognized tribes that are historically affiliated with the geographic region will be invited to consult on all proposed undertakings that have a potential to affect properties of cultural, historical, or religious significance to the tribes (see **Appendix A** for all tribal coordination materials).

Scoping letters will be provided to Native American tribes whose ancestors were historically affiliated with the land underlying Kirtland AFB, inviting them to consult on the proposed undertakings outlined within the EA.

1.7 PUBLIC AND AGENCY REVIEW OF DRAFT EA

A Notice of Availability (NOA) for the Draft EA will be published in *The Albuquerque Journal* announcing the availability of the Draft EA. Letters will be provided to relevant federal, state, and local agencies and Native American tribal governments informing them that the Draft EA is available for review. The publication of the NOA will initiate a 30-day comment period. A copy of the Draft EA will be made available for review at the San Pedro Public Library, 5600 Trumbull Avenue SE, Albuquerque, New Mexico. A copy of the Draft EA will also be made available for review online at <http://www.kirtland.af.mil> under the Environment Information tab. At the closing of the public review period, applicable comments from the general public and interagency and intergovernmental coordination and consultation will be incorporated into the analysis of potential environmental impacts performed as part of the EA, where applicable, and included in **Appendix A** of the Final EA.

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2.0 DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

2.1 PROPOSED ACTION

The USAF proposes that the USAF, USSF, and DTRA would continue to conduct current test activities and implement future test activities, as well as construct, operate, maintain, and remove supporting infrastructure on the Range on Kirtland AFB, New Mexico.

2.2 SELECTION STANDARDS

Selection standards were developed to assist the USAF in determining reasonable alternatives and the basis for eliminating any of them. The following selection standards were used to determine the feasibility of each alternative and to determine which of the alternatives would be the best fit to meet the needs of the project:

- The alternative(s) must meet the purpose of and need for the Proposed Action (see **Sections 1.3** and **1.4**) The alternatives must allow the USAF, USSF, and DTRA current and future users the ability to test concepts in need of an open-air (outdoor) environment to improve the technology discussed in **Sections 1.2.1** through **1.2.4**.
- The alternative(s) must comply with all applicable USAF, federal, and state requirements.
- The alternative(s) must avoid and/or mitigate direct and indirect, adverse impacts on safety, cultural or natural resources, or other environmental constraints, such as impacts on an environmental restoration site.
- The alternative site(s) must accommodate a 2000-lb N.E.W. capability with enough land to ensure safe clear zones (CZs).
- The alternative site(s) must accommodate DE devices and weapon system testing. This includes spectrum authorization for propagation of HPEM radio frequencies and airspace with terrain backstop within 3 miles.
- The alternative site(s) must have airspace to accommodate drone flying, testing, and training.
- The alternative site(s) must be available and provide access for USAF, USSF, and DTRA current and future users to perform RDT&E mission activities. The site needs to be a remote location that is available for up to 22 days per month.

2.3 DETAILED DESCRIPTION OF THE ALTERNATIVES

2.3.1 Proposed Action

2.3.1.1 Test and Training Activities

The Proposed Action includes current and proposed future test activities conducted by the USAF, USSF, and DTRA on the Range. Under the Proposed Action, these DoD agencies would continue to use the Range to develop DE weapon systems and test new methods and explosive materials. This includes the evaluation of new concepts, tests of new HEL and HPEM system configurations, training of personnel to maintain explosive handling qualifications, and pilot proficiency training

with drones. These efforts and systems would be staged on the Range with the intent to expand knowledge to further develop and enhance system capabilities. The USAF, USSF, and DTRA current and future users would focus their efforts on:

- DE and material effects,
- System performance and reliability,
- Integration of radar and command and control systems with DE demonstrators,
- HEL and HPEM target interaction,
- New explosives and detonation techniques,
- The use of explosives to create shock and blast waves,
- Training with explosives and drone platforms to maintain proficiency, and
- Testing with drones or other targets of interest.

AFRL/RD currently manages the Range and shares it with other DoD agencies. The schedule for the Range is sporadic and depends on the mission needs of each organization. However, all test and training events are scheduled well in advance with the 377 ABW/Range Management Office (RMO). AFRL/RD and 377 ABW/RMO evaluate requests to use the Range from other interested DoD agencies to ensure the proposed activities fall within the scope of land use and meet all safety and environmental requirements. Explosive operations are authorized for up to 2,000-lbs N.E.W. at the northern portion of the Range and 55-lbs N.E.W. at the southern portion of the Range. Explosive quantities are increased as operations move from south to north to ensure safe distance and CZs meet or exceed minimum requirements in accordance with DoD Explosive Safety Regulation 6055.09 Air Force Manual 91-201, *Explosives Safety Standards*. The overall limitations and rules for explosive operations are defined and authorized by the DoD Explosive Safety Board Siting.

Less than 10 people would be on site daily during test preparation when instrumentation, equipment, and temporary structures are in place. The number of personnel on the Range during a test can be as many as 30, including up to 12 personal vehicles. All vehicles and personnel are required to stay on existing dirt roads as much as possible and at appropriate, safe distances during test events. When drones are defeated, personnel search the area and recover the assets. In 2021, the Range was used for test events a total of 123 days, with 33 of those days being dual use days in which two organizations conducted test events on different locations on the Range. In 2022, the Range was used a total of 108 days with only 3 of those days being dual use days. Additional schedules would be added for the AFRL/RV vaporization tests and any other future tests to be performed. Activities performed on the Range would continue to be deconflicted with surrounding operations by scheduling and briefing other Kirtland AFB organizations at the monthly 377 ABW/RMO meeting.

The following sections provide example test and training activities for current and future USAF, USSF, and DTRA users. For the purposes of this analysis, the following activities are not agency specific but could potentially be performed by any DoD agency at the approved locations on the Range. Additionally, the following sections detail activities that could occur but also would allow for additional similar activities to occur in the future that are a result of new technology. Any new proposed activities would be required to undergo the Kirtland AFB environmental review process.

2.3.1.1.1 AFRL Activities

2.3.1.1.1.1 AFRL/RD Activities

AFRL/RD activities are focused on research and development of DE, HEL, and HPEM devices and weapons, that provide the warfighter with precision offensive and defensive engagement of target threats. DE weapons are fundamentally different from conventional kinetic weapons by offering the following advantages: (1) speed of light delivery, (2) graduated effects (deny, disrupt, degrade, damage, and/or destroy), (3) minimal collateral damage, and (4) low operational costs.

DE weapons perform tests with targets by staging equipment on the Range to orient and limit beam propagation to safer airspace regions. Targets of interest are drones, cased munitions (such as mortars, shells, domes, and missiles), electronics (such as computers), and other components associated with threats. DE weapons are directional and can be focused to specific areas, all efforts are made to minimize impacts to overhead assets and use surrounding terrain as a backstop when testing. Targets are placed on a concrete pad, with overhead dog-house structures, and constrained to prohibit launching off site. A small transformer provides electrical power at the Laser Effect Compound (LEC) for tests conducted in this area. However, when the transformer is not available or cannot provide enough power, AFRL/RD brings temporary portable generators to the Range. AFRL/RD routinely uses three test locations on the Range (Ground Zero [GZ]-1, GZ-2, and the LEC) (see **Figure 2-1**) to position DE devices. Drones can be launched and flown anywhere on the Range within the Federal Aviation Administration approved Certificate of Waiver or Authorization.

AFRL/RD also routinely conducts open-air (outdoor) tests of HPEM systems on the Range. These tests involve transporting the HPEM system to an approved site on the Range and radiating electromagnetic energy toward a target or sensing device. While the HPEM systems are commonly placed near a location on the Range with 480-volt AC shore power, the systems can also be powered by a portable generator and therefore, be located anywhere on the Range for deconfliction with other tests. HPEM systems can be large or small, aboard a trailer, placed directly on the ground, or potentially in the air. Similarly, targets can be large or small, on the ground or in the air. HPEM tests are used to verify system performance in field conditions and can last several months depending on system performance and range schedule.

2.3.1.1.1.2 AFRL/RV Activities

AFRL/RV tests would be performed to optimize canister system designs for generating metallic vapor to study plasma effects in the ionosphere, a part of the space environment that has significant impacts on communications. Vaporization experiments would be conducted by looking at a range of materials to determine which combinations of materials would provide the best plasma. Diagnostics and models would be developed for further tests in space where the metal vapor could form a temporary plasma. Tests would consist of small (100–200 grams [g] of total material), medium (1 kilogram [kg] of total material), and large scale (7 kg of total material) tests. Materials to be used include most of the first two columns of the periodic table (see **Appendix B**) - alkali metals (lithium, sodium, potassium, rubidium, and cesium), alkali earth metals (magnesium, calcium, strontium, and barium), third row transition metals (scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, and zinc), and lanthanide metals (lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, holmium, erbium, thulium, ytterbium, and lutetium). Heat reaction sources to be used would include titanium, boron, cesium nitrate, potassium nitrate, sodium nitrate, and tungsten(VI) oxide.



Basemap: Bing Maps Aerial

Figure 2-1. Location of GZ-1, GZ-2, and LEC Test Areas

AFRL/RV would be required to submit an AF Form 813 for evaluation if any new metal/metal molecule and/or heat reaction source is proposed for use beyond what is listed above.

The releases happen very quickly (lasting less than 1 second) and results in plumes of approximately 20, 50, and 80 feet into the air for the small-, medium-, and large-scale tests, respectively. The quantity of metals listed above that would be released during these tests are comparable to the quantity of metals released by common fireworks, ranging from that of a “roman candle” for the small scale, to about the size of a single shell commonly employed in a large firework show for the large-scale tests. The total amount of material released in 1 year would be roughly equivalent to five or six firework shells from a typical Fourth of July fireworks show. The location being considered for this testing is an existing concrete pad near GZ-2 (see Figure 2-1). The amount of testing proposed per year is shown in Table 2-1.

Table 2-1. Proposed Small-, Medium-, and Large-Scale Testing Activity

	Small-Scale	Medium-Scale	Large-Scale
Tests per year	50	12	1
Range time needed per test	1/2 day	1 day	2 days

2.3.1.1.2 DTRA Activities

Most of the DTRA tests conducted on the Range involve the design, analysis, and testing of temporary structures, new equipment, and explosives. The types of temporary structures involved may include personnel protective structures, missile silos, bunkers, aircraft hangars, antennas, and tunnels. Most test structures are scaled versions and DTRA removes all structures at the end of test requirements.

Scaled high explosive (HE) field testing is an effective, real- world method of evaluating the accuracy of scientific calculations and theories related to the blast and shock environment and impacts on hardened, protective structures and equipment. This testing provides a reference point for, and validation of, both pre- and post-test predictions. Taken together, several tests provide a database against which future calculations, designs, and assessments of similar structures, equipment, and geological settings are evaluated. The following paragraphs provide a brief description of various types tests DTRA conducts on the Range.

Scaled and Non-scaled Building Tests. These tests measure the impact of explosives on scaled buildings or full-size building sections. The data collected from these survivability tests support improvements to military and civilian facility designs. Buried and aboveground structures are evaluated using aboveground, ground-level, and buried explosives.

Development and Testing of New Explosives. These tests determine the detonation characteristics of proposed new HE types, charge configurations, or new detonation techniques. New explosive mixtures or detonators are tested for explosive power, safety, and reliability. This testing may be done in an open area, within a structure, or buried. Initial tests usually use less than 10 lbs. of explosive but may be increased during a test program. The maximum surface charge is equivalent to 2000-lbs N.E.W.

Explosives to Create Shock and Blast Waves. Shock and blast waves check the ability of equipment or sensors to withstand explosive blasts or to obtain basic blast and shock impact

measurements (i.e., air blast, crater, ejecta, and/or ground motion from either surface or buried charges).

Instrumentation Development Tests. These tests use explosives to evaluate new instrumentation techniques for measuring blast and shock parameters (e.g., soil stress, particle motions, air blast peak, strains of structural models, and environmental impacts). Explosives are used to launch dust, water particles, or a non-active biological simulant into the air to create a cloud for new sensor testing.

Non-Explosive Tests. These tests are used to provide structural strength (before or after an explosive test) and to develop or test non-blast-related sensors. The sensors may collect air samples, measure various parts of the non-visual spectrum (e.g., infrared/ultraviolet), or measure other, non-blast-related characteristics. Most of the sensors are non-emitting, passive instruments; and some are hung from balloons to provide a vertical collection system.

Cloud Simulation Tests. These tests would use a disseminator to loft water, sands, and/or other possible nonhazardous materials to create “simulant clouds.” The other possible nonhazardous materials include oleic acid, cocoa powder, volcanic ash, urea, potassium chloride, dust, wheat/pizza flour, powdered sugar, Portland cement, or soybean meal. No explosives or hazardous materials are involved. The disseminator contains a heater, a blower, and dispersal injectors. DTRA may test equipment modifications during these efforts. Long-range sensors such as a Light Detection and Ranging (LiDAR) and long-wave infrared hyperspectral imaging systems would measure the cloud formation. Small unmanned aerial vehicles may also be deployed during test events. The LiDAR might contain non-eye safe lasers; all remaining systems are eye safe.

2.3.1.1.3 377 MSG/EOD Activities

377 MSG/EOD would continue to use the Range primarily for training as evaluated in the *2016 Programmatic EA (PEA) Addressing the Development, Use, and Maintenance of Military Training Areas at Kirtland AFB, New Mexico*, hereafter referred to as the 2016 PEA. GZ-2, just north of CHESTNUT (see **Figure 2-1**), was originally established by AFRL/RD in 2001 for HE tests. Environmental impacts associated with these activities were evaluated in the 2016 PEA and no significant impacts were found to be associated. A FONSI was signed for the PEA in September 2016. EOD uses GZ-2 for monthly proficiency training and emergency operations as necessary. Activities performed at GZ-2 are limited to 2,000-lbs N.E.W. All munitions are transported to GZ-2 using approved vehicles, containers, and designated routes. Monthly proficiency training consists of up to four shots, which typically last up to 6 hours and involve as many as 15 personnel. Additionally, the gated area behind GZ-2 is periodically used by 377 MSG/EOD to practice using tools for their operations.

2.3.1.1.4 Test Site Preparation

All development activities would stay within the boundaries of the Range. The location of all tests and experiments would meet DoD explosive safety distance requirements and would consider all environmental resources prior to placement on the Range to ensure adverse impacts are avoided. Equipment used in site development activities are identified in **Table 2-2**. These vehicles would be parked within previously disturbed areas or the proposed training areas to avoid disturbing more ground than necessary. Access to the Range would remain the same and no new improved roadways would be developed. No permanent storage for fuel or lubricants would occur on the Range. All necessary fuels or additional equipment would be provided by the using agency as needed for test efforts.

Table 2-2. Test Preparation Construction Equipment

Construction Equipment Type	Expected Use (days per year)	Fuel
bulldozer	10	Diesel
forklift	20	Diesel
backhoe	20	Diesel
dump truck	10	Gas
concrete truck delivery	10	Diesel
front-end loaders	150	Diesel
crane	3	Diesel
pickup truck	365	Gas
5-kilowatt generator	100	Gas
60-kilowatt generator	100	Diesel

Potential temporary structures that could be constructed for test activities include towers (free standing or guywire supported); buildings (typically concrete, steel frame); mobile structures, trailers, conex(s) (freight containers, typically 8 feet by 8.5 feet tall and 20 feet long); earthen structures (such as berms, pits, or trenches); and barriers or other safety/security devices.

Operational Risk Management is conducted for each test event to minimize fire, dust, and safety hazards. Dry vegetation near the DE target or explosives is removed, and water is transported to the Range for individual test events to use for any potential fires. When occupied, Fire Station 4, located within a 2-minute drive from the southwest corner of Kirtland AFB, is available to respond to fires. Additionally, wind and weather conditions would be monitored to ensure noise, sound pressures, and vibrations generated by test activities would not affect other facilities or locations on or off Kirtland AFB, including the Isleta Pueblo Indian Reservation.

2.3.1.2 Infrastructure Projects

Under the Proposed Action, the USAF, USSF, and DTRA current and future users would also construct, operate, maintain, and remove supporting infrastructure as well as conduct routine range construction, site preparation, and maintenance. Examples of infrastructure projects that could be included in the Proposed Action consist of replacing outdated project T&F trailers, installing permanent pneumatic mast setups, replacing/installing up to 25,000 feet of underground cables (e.g., fiber optic cables, power lines, etc.) a year, installing and removing up to 20 test structures/concrete pads/dirt berms to be used for test activities a year, and conducting general clean-up activities on the range (e.g., weed and brush removal, grading and leveling areas for explosive tests, weather proofing, and removing rodents/rodent waste from structures and bunkers).

2.3.2 No Action Alternative

Under the No Action Alternative, operations would continue as usual for the already authorized users of the Range, as consistent with mission and management plans. Planned efforts would not increase over current operating levels and would not deviate from DE research and development, explosives, and drone tests/training already approved. No new test and/or training activities would occur; this includes any expanded RDT&E operations and AFRL/RV or DTRA experiments that would pose new impacts on environmental resources. Additionally, no new support infrastructure would be constructed, operated, maintained, or demolished on the Range. The USAF EIAP (32 CFR § 989.8[d]) requires consideration of the No Action Alternative. Therefore, this alternative will be carried forward for detailed analysis in the EA. However, the No

Action Alternative would not meet the purpose of or need for the Proposed Action as described in **Sections 1.3** and **1.4**.

2.4 ALTERNATIVES CONSIDERED BUT ELIMINATED FROM FURTHER CONSIDERATION

The following alternatives were eliminated from further consideration based on the selection standards outlined in **Section 2.2** and other reasons as explained below.

2.4.1 White Sands Missile Range

White Sands Missile Range (WSMR) is located south of Albuquerque, New Mexico, approximately 129 miles from the northern boundary of the Range and approximately 242 miles from the southern boundary of the Range. WSMR is managed by the US Army and has an Environmental Impact Statement that covers range activities. WSMR is DoD's largest, fully instrumented, open-air (outdoor) range and provides the United States' Armed Forces, allies, partners, and defense technology innovators with the world's premiere RDT&E, experimentation, and training facilities to ensure our nation's defense readiness. All proposed actions in **Section 2.3.1** were considered at WSMR.

However, although WSMR could provide the land and airspace for the Proposed Action, the scheduling and availability of the range extremely limits the ability of the USAF, USSF, and DTRA current and future users to accomplish mission tasks. This alternative would also require the construction and/or relocation of temporary structures to WSMR, resulting in environmental impacts greater than those associated with the Range. Therefore, this potential alternative was considered but eliminated from further analysis.

2.4.2 Cannon AFB and Melrose Range

Cannon AFB is located 196 miles east of Albuquerque, New Mexico, encompassing 3,789 acres of land but most testing occurs on the Melrose Air Force Range (Melrose). The Melrose training area is located 25 miles west of Cannon AFB and is comprised of approximately 70,000 acres. Operations on Melrose also cover an area of 2,500 square miles of airspace. The primary focus for activities on Melrose is training, supporting daily air-to-ground and electronic combat training for approximately 3,400 F-16 wing sorties annually. Melrose is also used by the New Mexico Air National Guard, based at Kirtland AFB, and other United States and allied aircrew accounting for an additional 1,400 sorties annually. The Proposed Action was considered at Melrose.

However, the usage of Melrose would limit several proposed activities. Further, the configuration of the site severely limits how the range could be used and does not provide the ability to conduct both HEL and HPEM test activities in conjunction with targets and drones to the extent needed for the AFRL/RD RDT&E mission. Additionally, Melrose would require the construction of temporary structures and additional access and availability, restricting the ability of DTRA to accomplish mission objectives. This alternative does not meet the selection standard for scheduling or for accommodating HEL, HPEM, and DTRA explosive operations. Therefore, this potential alternative was considered but eliminated from further analysis.

APPENDIX A

**INTERAGENCY AND INTERGOVERNMENTAL COORDINATION
FOR ENVIRONMENTAL PLANNING AND
PUBLIC INVOLVEMENT MATERIALS**

Appendix A

Interagency and Intergovernmental Coordination for Environmental Planning and Public Involvement Materials

Federal, State, and Local Agencies – Scoping Letter Distribution List

Mr. Matt Wunder, Chief
Ecological & Environmental Planning
New Mexico Department of Game and Fish
PO Box 25112
Santa Fe NM 87504

Ms. Patricia Mattingly
Acting Regional Director and Regional
Environmental Specialist
Bureau of Indian Affairs
Southwest Region Regional Office
1001 Indian School Road NW
Albuquerque NM 87104

Ms. Sabrina Flores, District Manager
Bureau of Land Management
Albuquerque District Office
100 Sun Avenue NE, Pan American
Building, Suite 330
Albuquerque NM 87109-4676

Ms. Rebecca Collins
Regional Environmental Officer
Office of Environmental Policy and
Compliance, US Department of the Interior
1001 Indian School Road NW, Suite 348
Albuquerque NM 87104

Mr. Rob Lowe, Regional Administrator
Federal Aviation Administration
Southwest Region
10101 Hillwood Parkway
Fort Worth TX 76177

Mr. Nikolas Goodman
District Conservationist
Natural Resources Conservation Service
Albuquerque Service Center
100 Sun Avenue NE, Suite 160
Albuquerque NM 87109

Ms. Danielle Galloway, Chief
Environmental Resources Section
US Army Corps of Engineers -
Albuquerque District
4101 Jefferson Plaza NE
Albuquerque NM 87109

Dr. Earthea Nance, Regional Administrator
US Environmental Protection Agency
Region 6
1201 Elm Street, Suite 500
Dallas TX 75270

Ms. Cheryl Prewitt
Regional Environmental Coordinator
US Forest Service, Southwestern Region
333 Broadway Boulevard SE
Albuquerque NM 87102

Board of Directors
Mid-Region Council of Governments
809 Copper Avenue NW
Albuquerque NM 87102

Mr. Jeff M. Witte, Director/Secretary
New Mexico Department of Agriculture
MSC 3189, Box 30005
Las Cruces NM 88003

Mr. Bruce Baizel, Legal Director
Office of General Counsel & Environmental
Policy
New Mexico Environment Department
PO Box 5469
Santa Fe NM 87502-5469

Ms. Julie Morgas Baca
Bernalillo County Manager
Bernalillo County Manager's Office
415 Silver SW, 8th Floor
Albuquerque NM 87102

Dr. Adria Bodour, PhD
NEPA Compliance Officer
Department of Energy
National Nuclear Security Administration
Sandia Field Office
PO Box 5400
Albuquerque NM 87187

Mr. Jim Sanderson
Department of Energy
National Nuclear Security Administration
Headquarters General Council (NA-GC-10)
1000 Independence Avenue SW
Washington DC 20585

Dr. Linda Tello, PhD
Alternative NEPA Compliance Officer
Department of Energy
National Nuclear Security Administration
Sandia Field Office
PO Box 5400
Albuquerque NM 87187

Ms. Kelly Bowles, NEPA Program Manager
Sandia National Laboratories, New Mexico
PO Box 5800, MS 0915
Albuquerque NM 87185

The Honorable Martin Heinrich
Senator
United States Senate
303 Hart Senate Office Building
Washington DC 20510

The Honorable Ben Ray Luján
Senator
United States Senate
498 Russell Senate Office Building
Washington DC 20510

The Honorable Gabe Velasquez
Representative
United States House of Representatives
1517 Longworth House Office Building
Washington DC 20515

The Honorable Melanie Stansbury
Representative
United States House of Representatives
1421 Longworth House Office Building
Washington DC 20515

The Honorable Teresa Leger Fernandez
Representative
United States House of Representatives
1432 Longworth House Office Building
Washington DC 20515

Ms. Stephanie Garcia Richard
Commissioner of Public Lands
New Mexico State Land Office
310 Old Santa Fe Trail
Santa Fe NM 87501

Ms. Sarah Cottrell Propst,
Cabinet Secretary
New Mexico Energy, Minerals and Natural
Resources Department
Wendell Chino Building
1220 South St. Francis Drive
Santa Fe NM 87505

Commissioners
Bernalillo County Board of Commissioners
One Civic Plaza NW, 10th Floor
Albuquerque NM 87102

Councilmember
Albuquerque City Councilmembers
PO Box 1293
Albuquerque NM 87103

Joint Land Use Study Memorandum of Understanding – Scoping Letter Distribution List

Mr. Jim Bordegaray, Director
Commercial Resources Division
New Mexico State Land Office
PO Box 1148
Santa Fe NM 87504

Ms. Catherine VerEecke
Development Manager/Department Director
Bernalillo County Planning Section
111 Union Square SE, Suite 100
Albuquerque NM 87102

State Historical Preservation Office – Scoping Letter Distribution List

Dr. Jeff Pappas, PhD
State Historic Preservation Officer and Director
New Mexico Historic Preservation Division
Department of Cultural Affairs
Bataan Memorial Building
407 Galisteo Street Suite 236
Santa Fe NM 87501

Native American Tribes – Scoping Letter Distribution List

Governor Randall Vicente
Pueblo of Acoma
PO Box 309
Acoma Pueblo NM 87034

President Buu Nygren
Navajo Nation
PO Box 7440
Window Rock AZ 86515

Governor Pete Herrera
Pueblo of Cochiti
PO Box 70
Cochiti Pueblo NM 87072

Governor Larry Phillips
Ohkay Owingeh
PO Box 1099
San Juan Pueblo NM 87566

Chairman Timothy L. Nuvangyaoma
The Hopi Tribe
PO Box 123
Kykotsmovi AZ 86039

Governor Craig Quanchello
Pueblo of Picuris
PO Box 127
Peñasco NM 87553

Governor Max Zuni
Pueblo of Isleta
PO Box 1270
Isleta NM 87022

Governor Jenelle Roybal
Pueblo of Pojoaque
78 Cities of Gold Road
Santa Fe NM 87506

Governor Dominic Gachupin
Pueblo of Jemez
PO Box 100
Jemez Pueblo NM 87024

Governor Stuart Paisano
Pueblo of Sandia
481 Sandia Loop
Bernalillo NM 87004

President Edward Velarde
Jicarilla Apache Nation
PO Box 507
Dulce NM 87528

Governor Carl Valencia
Pueblo of San Felipe
PO Box 4339
San Felipe Pueblo NM 87001

Governor Wilfred Herrera
Pueblo of Laguna
PO Box 194
Laguna NM 87026

Governor Christopher Moquino
Pueblo of San Ildefonso
02 Tunyo Po
Santa Fe NM 87506

President Eddy Martinez
Mescalero Apache Tribe
PO Box 227
Mescalero NM 88340

Governor Nathan Garcia
Pueblo of Santa Ana
2 Dove Road
Santa Ana Pueblo NM 87004

Governor Nathaniel Porter
Pueblo of Nambe
15A NP102 West
Santa Fe NM 87506

Governor J. Michael Chavarria
Pueblo of Santa Clara
PO Box 580
Española NM 87532

Governor Esquipla Tenorio
Pueblo of Santo Domingo
PO Box 99
Santo Domingo Pueblo NM 87052

Chairman Lawrence SpottedBird
Kiowa Tribe of Oklahoma
PO Box 369
Carnegie OK 73015

Governor Gary Lujan
Pueblo of Taos
PO Box 1846
Taos NM 87571

Chairman Mark Woommavovah
Comanche Nation of Oklahoma
PO Box 908
Lawton OK 73502

Governor Milton Herrera
Pueblo of Tesuque
Route 42 Box 360-T
Santa Fe NM 87506

President Walter Echo-Hawk Pawnee
Nation of Oklahoma
PO Box 470
Pawnee OK 74058

Chairwoman Kasey Velasquez
White Mountain Apache Tribe
PO Box 700
Whiteriver AZ 85941

Chairman Terry Rambler
San Carlos Apache Tribe
PO Box 0
San Carlos AZ 85550

Governor E. Michael Silvas
Ysleta del Sur Pueblo
P119 S. Old Pueblo Road
Ysleta del Sur TX 79917

Chairman Melvin J. Baker
Southern Ute Indian Tribe
PO Box 737
Ignacio CO 81137

Governor Valentino Pino
Pueblo of Zia
135 Capitol Square Drive
Zia Pueblo NM 87053

Chairman Mark Mitchell
All Pueblo Council of Governors
2401 12th Street NW
Albuquerque NM 87103

Governor Arden Kucate
Pueblo of Zuni
PO Box 339
Zuni NM 87327

Executive Director Joshua Madalena
Five Sandoval Indian Pueblos
4321-B Fulcrum Way NE
Rio Rancho NM 87144

Chairman Manual Heart
Ute Mountain Ute Tribe
PO Box JJ
Towaoc CO 81334

Executive Director Gilbert Vigil
Eight Northern Indian Pueblos Council
327 Eagle Drive
Ohkay Owingeh NM 87566

Chairwoman Lori Gooday-Ware
Fort Sill Apache Tribe of Oklahoma
Rt 2, Box 121
Apache OK 73006

Honorable Crystalyne Curley, Speaker of the
Navajo Nation
25th Navajo Nation Council
PO Box 3390
Window Rock AZ 86515

Chairman Durell Cooper
Apache Tribe of Oklahoma
PO Box 1330
Anadarko OK 73005

US Fish and Wildlife Service - Scoping Letter Distribution List

Ms. Amy Leuders, Regional Director
US Fish and Wildlife Service, Southwest Regional Office
500 Gold Ave. SW
Albuquerque NM 87102

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APPENDIX B

PERIODIC TABLE OF ELEMENTS

Periodic table of the elements

group 1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
lanthanoid series 6		58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu		
actinoid series 7		90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr		

*Numbering system adopted by the International Union of Pure and Applied Chemistry (IUPAC). © Encyclopædia Britannica, Inc.

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