PROJECT JACK RABBIT: FIELD TESTS

CSAC 11-006

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U.S. Department of Homeland Security
Science & Technology

Chemical Security Analysis Center

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Project Jack Rabbit: Field Tests

EXECUTIVE SUMMARY

The Jack Rabbit Project, sponsored by the United States (U.S) Department of Homeland Security (DHS) Transportation Security Administration (TSA), was a study designed to improve the understanding of rapid, large-scale releases of pressurized, liquefied toxic inhalation hazard (TIH) gases. The project involved outdoor release trials of 1- and 2-ton quantities of chorine and anhydrous ammonia in 10 successful trials occurring in April and May of 2010. The project was managed by the Chemical Security Analysis Center (CSAC), part of the DHS Science and Technology (S&T) directorate, and executed at Dugway Proving Ground (DPG), a U.S. Army testing installation in Utah.

The objectives of the Jack Rabbit Project follow:

1. Execute a reduced-scale test of each of two chemicals (chlorine and anhydrous ammonia) to identify potential vulnerabilities before full test conduct.

2. Develop and evaluate a mechanism for the controlled, rapid release of liquefied, pressurized gases from containment to approximate the conditions hypothesized to generate a persistent vapor-aerosol cloud in a 90-ton railcar release.

3. Characterize the vapor/aerosol cloud movement, behavior, and physiochemical characteristics and compare those characteristics with known observations and testing of large-scale releases of the testing materials.

4. Determine if anhydrous ammonia can potentially act as less expensive and less dangerous dense gas for studying the component phenomena of large scale releases of dense gas TIH materials.

5. Field and evaluate instrumentation that can be used for the study of the large-scale release of the testing materials, and develop and evaluate testing methodology for future additional and potentially larger-scale tests.

Detection instrumentation was deployed out to a range of 500 meters, with some point detection MiniRAE instruments recording data at multiple heights, including 1-m, 3-m, and 6-m. Additionally, data was recorded from several stand-off instruments and video stations to capture the behavior of the cloud as it dispersed downwind. During the tests, meteorological, FTIR and UV optical, paper detection, thermal couple, and bubble sampling data were collected. The release trials were also recorded on digital video. Comprehensive studies and analyses of the data will be conducted through additional follow-on tasks in FY 2011 when all datasets have been collected, qualified, and made available.

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1.0 INTRODUCTION

1.1 Background

The United States (U.S.) Department of Homeland Security (DHS) and the Transportation Security Administration (TSA) tasked Edgewood Chemical and Biological Center (ECBC), with the support of the Chemical Security Analysis Center (CSAC), part of the DHS Science and Technology (S&T) Directorate, to study and improve the understanding of rapid large-scale releases of pressurized, liquefied toxic inhalation hazard (TIH) gases. DHS is concerned by the risk that an accidental or intentional release of a TIH material poses to our population. Millions of tons of TIH materials, such as chlorine and anhydrous ammonia, are transported annually in the U.S. by rail, road, water, and pipeline as pressurized, liquefied gases, frequently through highly populated areas. DHS has a critical need to improve the understanding and modeling of large-scale releases, and to provide better guidance to emergency responders and planners and mitigate the potential threat.

Currently, the expected behavior of large-scale releases of many toxic industrial chemicals (TICs) is extrapolated from experiments involving other gases, using different (non-validated) scaling, or with objectives that differ from the current needs of TSA. Therefore, TSA is funding experimental TIC field release studies to improve understanding of the behavior and associated phenomena. Several areas of the large-scale release phenomenology have been identified as requiring study and improved understanding:

1. *Scaling*. The amount of energy required to completely vaporize 60 to 90 tons of a liquefied, pressurized gas overwhelms the energy, which is available via superheat and the environment near the release site. This consideration, and others, needs to be investigated to understand how the behavior of well-understood, smaller puff releases scale to a railcar release.
2. *The Vapor/Aerosol (Mist) Cloud*. When a liquefied, pressurized gas is released from containment at small scales, there is enough air and energy entrained into the escaping jet to vaporize all the liquid. However, at the scale of a rapid railcar release, the available energy is not sufficient to vaporize the liquid, resulting in a vapor/aerosol cloud that is colder, denser, and more persistent than a vapor puff. This phenomenon, and the conditions by which it occurs, needs to be studied and compared with hypothesized calculations and models to determine if the current understanding and modeling methodologies need to be revised.
3. *Aerosol Characteristics*. The nature of the aerosol generated in a large-scale release needs characterization. In particular, the evolution of the vapor to aerosol mass ratio is

unknown for the desired large-scale release conditions of the testing materials, as is the aerosol droplet size and its distribution.

4. *Rainout*. The factors affecting droplet aggregation and precipitation, and the extent to which this occurs, is unknown for large-scale releases, and significantly affects the amount of material available in a cloud and its behavior.

5. *Deposition and Off-gassing*. At the small scale, a TIH released into the environment will have a small amount of interaction with surfaces surrounding the release site, as it is quickly moved and dissipated by the wind. However, at the scale of a railcar release, it is anticipated that the additional and persistent material will experience much more interaction with the surrounding surfaces. The extent to which the material will deposit or permeate into porous surfaces and the subsequent off-gassing rate at the large-scale is unknown.

Although the planning and resources currently do not exist to conduct full-scale 60- or 90-ton releases of the materials of interest, the ECBC/CSAC team planned field test releases for the TSA in the range of one to two tons, configured in such a way as to approximate some of the release conditions and parameters hypothesized to exist at the large scale. Two test gases were used: chlorine and anhydrous ammonia. Chlorine is a TIH of critical concern to TSA, but is difficult to field test in large amounts because of its toxicity, release restrictions, and overall testing costs. Anhydrous ammonia is also a TIH of concern for TSA, but is less problematic to use for large-scale field testing.

A release mechanism was developed for testing to enable the rapid release of the material, consistent with what may be expected during a release from a railcar. Two tons of each material was released in four separate trials into a saucer-shaped containment area. The reason for this configuration was to contain the material in a fixed location during release, thereby limiting the air entrainment rate and energy available to levels consistent with what is expected for large-scale releases. The depression also limited the initial spread of the cloud, additionally reducing the air-entrainment rate and energy influx, and provided a focal area for concentrating instruments to study the initial persistent behavior of the source cloud.

Most trials were conducted under low-wind conditions, with a stable or neutral atmosphere to limit additional turbulence-induced air entrainment and complications. The testing grid contained an array of chemical, physical, and meteorological instrumentation to characterize the various aspects of the releases and gather the data necessary to begin addressing the identified gaps and improving the understanding of the release phenomena.

1.2 Objectives

The objectives of the Jack Rabbit Project Field Tests (Jack Rabbit) were:

1. Execute a reduced-scale test of each of two chemicals (chlorine and anhydrous ammonia) to identify potential vulnerabilities before full test conduct.
2. Develop and evaluate a mechanism for the controlled, rapid release of liquefied, pressurized gases from containment to approximate the conditions hypothesized to generate a persistent vapor-aerosol cloud in a 90-ton railcar release.
3. Characterize the vapor/aerosol cloud movement, behavior, and physiochemical characteristics and compare those characteristics with known observations and testing of large-scale releases of the testing materials.
4. Determine if anhydrous ammonia can potentially act as less expensive and less dangerous dense gas for studying the component phenomena of large scale releases of dense gas TIH materials.
5. Field and evaluate instrumentation that can be used for the study of the large-scale release of the testing materials, and develop and evaluate testing methodology for future additional and potentially larger-scale tests.

1.3 Testing Authority

On 5 November 2009, the U.S. Army Developmental Test Command (DTC), Aberdeen Proving Ground (APG), Maryland, issued a test directive (Appendix A) through the U.S. Army Test and Evaluation Command (ATEC) Decision Support System (ADSS) authorizing West Desert Test Center (WDTC), U.S. Army Dugway Proving Ground (DPG), Utah, to conduct the Jack Rabbit Project, ATEC Project Number 2010-DT-DPG-SNIMT-E5835.[1, 2]

1.4 Test Overview

1.4.1 Basic Design

The design concept of Jack Rabbit was to release large quantities of chlorine and anhydrous ammonia (separate trials) in a depression to satisfy specific test objectives. Chemical, photonic, and meteorological measurements were sampled outside of the depression, and certain measurements were collected within the depression. Full descriptions of the instrumentation are provided in Appendix B.

1.4.2 Scope

The Jack Rabbit was conducted at WDTC, DPG under the direction of the WDTC Meteorology Division with assistance from other WDTC divisions. CSAC provided oversight for the Jack Rabbit.

1.4.3 Relevance

An accidental or intentional release of a TIH material, while in transport via road, rail, water or pipeline, poses a great risk to the life and health of the American public. Through Jack Rabbit, DHS seeks to improve the understanding and modeling of large-scale releases. The vast amount of data collected will provide the foundation for key studies of the cloud source, characteristics, behavior, and movement for years to come. The resulting improvements in emergency response, planning, mitigation, and modeling will ultimately contribute significantly to reducing the risk from large-scale TIH releases in the U.S.

1.4.4 Test Description

Jack Rabbit was conducted at WDTC on the Insensitive Munitions (IM) Test Grid first pilot trial conducted on 07 April 2010 and the last record trial conducted on 21 May 2010. The center of the IM test grid is located at 40.20661577 latitude/-113.2657215 longitude. A 2-m deep depression with a 25-m radius was the focal point of the test. Concentric rings with radii of 50-m, 100-m, 150-m, 200-m, 250-m, 500-m, 1250-m, and 2500-m also had instrumentation deployment. The safety standoff distance was set at 2500-m, and the control point (CP) for test operations was approximately 2835-m from grid center.

Either anhydrous ammonia or chlorine was disseminated during each trial. A single pilot test for each chemical was conducted on 07 and 08 April 2010. These pilot tests consisted of 1-ton disseminations. Upon completion of the pilot trial, adjustments or modifications were made to the instrumentation or testing techniques to obtain the best results during test conduct. Four record trials of each chemical were conducted for a total of eight record trials. Each record trial consisted of a 2-ton release.

WDTC provided meteorological, photonic, and chemical detection instrumentation. Along with the test instrumentation, WDTC designed and constructed a dissemination system, prepared the test site, and procured the chemicals and materials necessary for test conduct.

1.4.5 Test Conduct vs. Objectives Summary

The objectives of the Jack Rabbit are detailed in Section 1.2 of this report. The objectives were addressed as follows:

> **Objective 1** – Satisfied by WDTC successfully executing 10 trials for the Project Jack Rabbit field tests. Two disseminations were 1-ton pilot trials, and eight disseminations were 2-ton record trials.

Objective 2 – Satisfied with the successful design, construction, and operation of a dissemination system built by WDTC. The dissemination system simulated, on a smaller scale, the type of release expected when a 90-ton TIC tanker car is breached. During the trials, the contents of the disseminator evacuated within 60 seconds, as requested by the ECBC/CSAC team.

Objective 3 – Successfully addressed through the deployment of a wide range of instrumentation types to characterize the vapor/aerosol cloud movement, behavior, and physiochemical characteristics. Appendix B, Section 3 of this report discusses the observed chemical clouds from the Jack Rabbit disseminations. Although this section is not intended to be an exhaustive review or analysis of the collected datasets, it satisfies objective stated in Section 1.2.c of this report. The comparison of the data and findings from Jack Rabbit to known observations and testing of large-scale releases will also be performed in follow-on studies in FY 2011 when all datasets have been collected and made available.

Objective 4 – Addressed by conducting the four chlorine and four anhydrous ammonia trials under controlled conditions, allowing a comparison between anhydrous ammonia and chlorine. Additionally, the 1-ton chlorine and anhydrous ammonia pilot tests were conducted on days with nearly identical meteorological conditions. As a result of the field tests, it was determined that utilizing anhydrous ammonia as a surrogate for chlorine in experimentation is complicated by many observed differences in behavior. However, there are individual cloud characteristics of anhydrous ammonia that would allow it to serve as a surrogate for chorine in some cases. Detailed discussion is further continued in Appendix B, Section 3.

Objective 5 – Satisfied by the deployment of many types of photonic, meteorological, and chemical detection instrumentation during the field tests. In some cases, instrumentation was damaged or destroyed because of exposure to high concentrations of chemicals. A better understanding of instrumentation limitations and survivability was achieved through the trials, and improvements in fielding procedures and instrument utilization was documented.

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2.0 TEST DESCRIPTION

2.1 Detailed Test Description

During each trial, chemical releases of chlorine or anhydrous ammonia were made from an elevated disseminator deployed within a 2-m deep and 50-m diameter depression. Point and standoff chemical detection occurred at concentric rings around the dissemination location. Extensive meteorological measurements documented the boundary layer structure over the test grid and surface conditions within the test grid during the trials.

Measurements were taken within the dissemination depression to meet the test objectives of characterizing the vapor/aerosol physiochemical properties of a high concentration chemical release within a semi-confined area. Complete instrumentation descriptions are provided in Appendix C.

Data collection and quality control (QC) of all datasets were the responsibility of the test participant gathering the respective data. WDTC provided the ECBC/CSAC team with pre-test and post-test reports and datasets as described in Table 1.

Table 1. Pre-test and Post-test Reports for the Jack Rabbit Project

TIME FRAME	REPORT/DATASET	PROPOSED DATE
Pre-test	Data Requirements Plan	27 October 2009
	Instrumentation Plan	06 January 2010
	Safety Plan	21 January 2010
	Test Execution Plan (Operations Plan)	28 January 2010
	Climatological Datasets	04 February 2010
	Master Detailed Test Plan	17 March 2010
Post-test	Dissemination Summary	06 June 2010
	DPG[a] Point Detector Datasets	13 June 2010
	DPG Standoff Detector Datasets	13 June 2010
	Meteorological Datasets	13 June 2010
	Photonic Datasets	15 July 2010
	Dense Gas Behavior Assessment Report	15 July 2010
	Field Test Initial Report	15 July 2010
	Downwind Effects Assessment Report	24 July 2010
	Instrumentation Performance Assessment Report	24 July 2010
	Lessons Learned Report	24 July 2010
	Draft Field Test Final Report	24 July 2010
	Field Test Final Report	31 July 2010

[a] U.S. Army Dugway Proving Ground, Utah.

2.1.1 Test Management

Jack Rabbit was conducted at WDTC under the overall direction of the WDTC Meteorology Division, which has extensive experience in conducting field dispersion studies for the Department of Defense (DoD), Washington, DC. WDTC assembled a test team comprised of technical lead personnel from various WDTC divisions and branches. The ECBC/CSAC team was assigned overall program oversight of the Jack Rabbit Project by DHS/TSA.

2.1.2 Data Management

The WDTC Data Sciences Division served as the lead organization for data management and ensured that a quality dataset was collected and permanently archived. The Data Sciences Division assigned a data manager who was responsible for all data time synchronization, QC of datasets, and dataset packaging.

2.1.2.1 Data Collection

Most Jack Rabbit datasets were collected and temporarily archived in real-time. However, several datasets were not accessible in real-time and required data retrieval on a daily basis. The non real-time datasets were collected, reviewed, and temporarily archived every 24 hours. If data collection was terminated on any instrument(s), it was the responsibility of the WDTC test officer (TO) to determine whether that test should continue in the absence of the dataset.

2.1.2.2 Time Stamps

All datasets have a time stamp for each record collected. Time coordinates for all datasets are recorded in Coordinated Universal Time (UTC). Time synchronization was accomplished via global positioning system (GPS) receivers and/or a computer time server whenever possible. If manual time synchronization was necessary, it was done the morning of every test day on every piece of equipment requiring the manual process.

2.1.2.3 QC

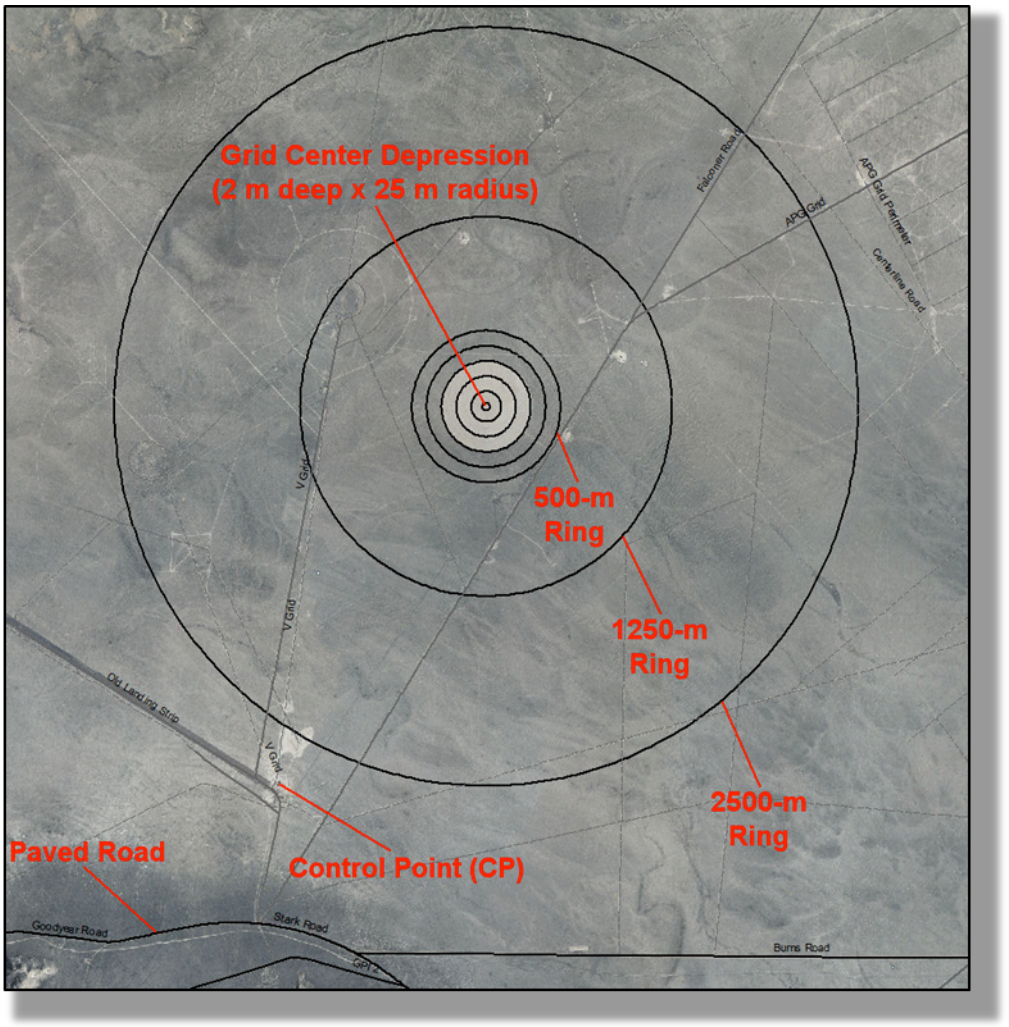
It was the responsibility of the test participants managing their instrumentation to ensure the quality of the collected dataset. Post-test data analysis included error checking and a process to flag bad or suspect data.

2.1.2.4 Data Submission

It was the responsibility of the test participants managing their instrumentation to submit a quality dataset to the TO and data manager as soon as possible after the testing ended. DPG provided ECBC/CSAC with a QC dataset of DPG-collected data on 14 June 2010.

2.1.3 Test Grid

The test grid was located at the WDTC IM Test Grid, which is positioned at 40.20661577 latitude/-113.2657215 longitude. The CP was approximately 2835-m to the south-southwest of grid center. An illustration of the general test area is provided in Figure 1.



NOTE: The dimensions provided for the concentric rings are the radius of the ring, which is also the standoff distance from grid center.

Figure 1. General Area for Jack Rabbit Project Field Tests

The center area of the Jack Rabbit grid was excavated to a depth of 2-m and a radius of 25-m. A technique of "cut and fill" was used for the excavation, which created a berm around the perimeter of the excavated depression. The depression basin had a slope of 1:7 inside the depression and a slope of 1:9 outside the depression. A graphic illustration of the excavated depression is provided in Figure 2.

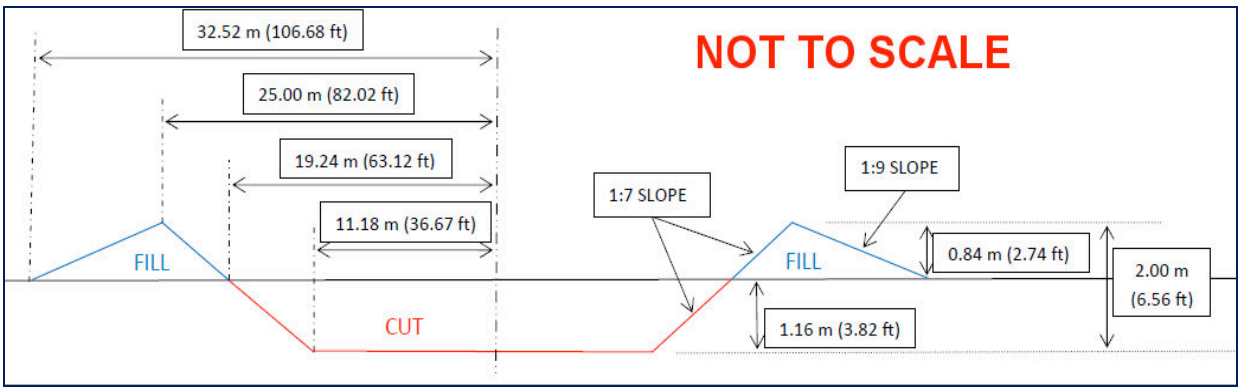


Figure 2. Graphical Depression Depiction of Project Jack Rabbit Project Field Tests

The WDTC Meteorology Division collected meteorological data from the test site over the course of several months. Multi-year climatology from the area surrounding the test site was combined with the test site data to optimize instrument placement and configuration. It was intended that the Jack Rabbit trials be configured to allow for careful study of the release source. The sheltered and low-wind conditions prevalent at the selected site facilitated this, and a 360-degree deployment strategy of the instrumentation was determined to be optimal rigorously interrogate the source and allow testing to proceed regardless wind direction.

Analyses of the testing location additionally confirmed that the best time of day for the desired meteorological conditions was sunrise.

2.1.4 Pre-test Setup

The WDTC Meteorology Division was the lead organization for pre-test setup and ensured that all required documentation and procurement actions were completed and that the test grid was set up in preparation for testing to begin on 07 April 2010. The Test Officer (TO), Mr. Donald Storwold, was responsible for the pre-test setup, either directly or through delegation of duties.

2.1.5 Pre-test Procedures

The following requirements were necessary in advance of the testing in order to proceed with the project: 1) Preparation of National Environmental Policy Act (NEPA) documentation; 2) Operations Security (OPSEC) documentation; 3) preparation of the WDTC Safety Procedures and Risk Assessment, and 4) preparation a WDTC letter of instruction (LOI) for the dissemination system operation.

The TO was responsible for coordinating all activity relating to the Jack Rabbit. This responsibility included notification of the intended test through ADSS and participation in the initial command review (ICR) to inform the WDTC Command of the test project. The TO coordinated scheduling through the WDTC master scheduler and also secured a CP location.

The TO coordinated with the WDTC Safety Office to conduct a pre-operational safety survey (POSS) before testing. Also, before Jack Rabbit testing began, a final command review (FCR) and operational readiness inspection (ORI) were conducted. Before allowing access to the test site, the TO conducted a test orientation and range safety briefing for all test participants.

The TO served as the interface between ECBC/CSAC, the WDTC and DPG Commands, and the Jack Rabbit Test Team. This tasking included the coordination of meetings such as the disseminator preliminary design review (PDR), critical design review (CDR), test readiness review (TRR), instrumentation meetings, and all other test-related meetings.

The TO was responsible for the procurement of all test-related items, including:

1. **Contracts**. WDTC has a contract in place with Jacobs Dugway Team (Dugway, Utah) for test support augmentation. In support of the Jack Rabbit Project field tests, Jacobs provided instrumentation support (mainly bubbler operation/processing), photonic support, data analysis, and portable toilet service at the test site. The TO coordinated with the WDTC contracting officer's representative (COR) for these services.

2. **Supplies**. The project sponsor provided sufficient quantities of the chemicals (chlorine, and anhydrous ammonia) for both the pilot and record test conduct. Additional items included Tyvek® (E.I. du Pont de Nemours and Company, Wilmington, Delaware) protective clothing, sampler tubing, and other miscellaneous test-related items.

3. **Equipment**. Custom disseminator systems were designed and constructed for the Jack Rabbit Project. Purchases for these disseminators included the tanks, valves, and materials for the construction of the stand to mount the disseminator. Other Jack Rabbit Project purchases included bubbler pumps, some communication equipment, personal toxic gas monitors, and Level-B protective clothing for the dissemination crew.

2.1.6 Test Grid Setup

The TO and/or test control officer (TCO) were responsible for the test grid setup, including the following:

1. A metals sweep of the test grid that was conducted before excavation. WDTC surveyed the test grid before and during excavation to ensure proper dimensions of the depression. The test site depression was excavated to the specifications shown in Figure 2.

2. All key test grid points were surveyed, such as photonic support locations, standoff chemical detection locations, point detection locations, and all meteorological locations.

3. WDTC instrumentation: visual spectrum high-definition (HD) cameras, infrared (IR) cameras, Fourier-transform infrared (FTIR) spectrometer, bubblers, Cerex Ultraviolet (UV) Sentry [Cerex Monitoring Solutions, Limited Liability Corporation (LLC), Atlanta, Georgia], Cerex UV Canary [Cerex Monitoring Solutions], Portable Weather Information and Display System (PWIDS), thermocouple array, ultrasonic anemometers, 32-m meteorological towers, 10-m camera towers, and other instrumentation (Appendix B).

4. WDTC provided general test oversight for visiting participants. WDTC also provided oversight for the installation of visiting participant data collection systems. These systems are explained in Table 2.

Table 2. Non-U.S. Army Dugway Proving Ground Participating Organizations and Systems Deployed for the Project Jack Rabbit Field Test

ORGANIZATION	ORGANIZATION LOCATION	DEPLOYED SYSTEM	MANUFACTURER
Signature Science, Limited Liability Corporation (SSLLC)	Austin, Texas	Jaz ultraviolet visible (UV-VIS) sensor	Ocean Optics Inc.; Dunedin, Florida
Center for Toxicology and Environmental Health (CTEH)	Little Rock, Arkansas	AreaRAE (CTEH-owned) and miniRAE (DPG-owned)	RAE® Systems; San Jose, California
SAFER Systems	Camarillo, California	Chemical risk management software	SAFER Systems; Camarillo, California
Air Force Research Laboratory (AFRL)	Tyndall Air Force Base (AFB); Panama City, Florida	Soil core sampling	NA[a]
Naval Surface Warfare Center (NSWC) - Dahlgren	Dahlgren, Virginia	Electronics sampling	NA
METSS Corporation	Westerville, Ohio	Coupon sampling	NA
NSWC - Dahlgren	Dahlgren, Virginia	Hazard prediction modeling	NA
Norwegian Defense Research Establishment	Oslo, Norway	Computational fluid dynamics (CFD) modeling	NA

[a] NA = not applicable

2.1.7 Post-test Procedures

The WDTC Meteorology Division was the lead organization for posttest retrograde. The WDTC TO was responsible for Jack Rabbit post-test retrograde, either directly or through delegation of duties. The following activities occurred at the conclusion of the release trials:

1. *Test Grid.* All Jack Rabbit instrumentation was removed from the test grid. If post-test calibration was necessary for any particular equipment, it was conducted within 48 hours of test conduct completion. All wire, stakes, trash, etc., were removed from the test grid, and the site was restored to its original state as much as possible, except that the WDTC Command decided to leave the depression intact without filling it to its original state.

2. *Test Residue.* All items used in Jack Rabbit Testing were turned in or appropriately disposed of in accordance with (IAW) applicable DPG regulations and permits, as well as federal and state laws. The disseminators used for test conduct were destroyed with high explosive to eliminate the concerns associated with storing hazardous waste.

3. *Shipments.* Test participants requiring shipment of equipment/supplies coordinated this activity through the TO. All shipments occurred within 2 weeks from the time of test completion.

4. *Chemicals.* All leased chemical tanks and cylinders were returned upon the completion of the test. Chemicals were entirely consumed so no unused chemicals needed to be returned to the vendor. This activity was coordinated through the TO.

5. *Control.* Upon completion of all retrograde activities previously outlined, the TO notified the WDTC Command Group and relinquished control of the IM Test Grid area.

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3.0 JACK RABBIT PILOT TEST

3.1 Objective

The objective of the Jack Rabbit pilot tests was to successfully execute a reduced-scale test of two test chemicals (chlorine and anhydrous ammonia) to identify issues and improvements in methodology to be incorporated into test procedures before execution of the full-scale trials.

3.2 Responsibility

The WDTC Meteorology Division was the lead organization for the Jack Rabbit Pilot Test. The TO was responsible for execution of the pilot test, either directly or through delegation of duties (i.e., TCO assignment). All final decisions relating to pilot test execution were the responsibility of the TO.

3.3 Data Analysis/Procedures

The pilot test data were collected and delivered to the ECBC/CSAC team. The end product of the pilot test was photonic, chemical, and meteorological datasets to be used in preparation for the Jack Rabbit Test. Upon review of the datasets, adjustments were made to the instrumentation placement and/or proposed procedure for test conduct.

3.4 Test Procedures

Two trial types were conducted during the pilot test; one chlorine trial and one anhydrous ammonia trial. During the pilot test phase, 1-ton of chlorine and 1-ton of anhydrous ammonia were released in separate trials.

The chlorine disseminator was a modified 500-gal propane tank with a remotely controlled 3-in ball valve assembly mounted to the bottom of the tank. The anhydrous ammonia disseminator was a modified 1,000-gal propane tank with a remotely controlled 4-in ball valve assembly mounted to the bottom of the tank. Both disseminators had an appropriately sized manual knife gate valve mounted between the tank and the remotely controlled valve as a safety precaution.

All disseminations occurred within a 2-m deep × 25-m radius depression located at 40.20661577 latitude/-113.2657215 longitude. The disseminator was mounted on a large metal stand with the outlet of the remotely controlled valve placed at a distance of 2-m above the floor of the depression basin, directed downward. The jet from the disseminator impinged against a 12-ft × 8-ft × 1-in steel plate, which served as the base for the metal disseminator stand.

The order in which the pilot disseminations occurred was the anhydrous ammonia dissemination first (Trial 01-PA), followed by the chlorine dissemination (Trial 02-PC). The dissemination matrix is provided in Table 3.

Table 3. Dissemination Matrix for Jack Rabbit Project Field Test

TEST PHASE	TRIAL NAME[a]	CHEMICAL	QUANTITY	DATE	TIME (UTC)
Pilot Test	01-PA	Anhydrous Ammonia	1 ton	07 April 2010	1400
	02-PC	Chlorine	1 ton	08 April 2010	1345
Record Test	03-RA	Anhydrous Ammonia	2 tons	27 April 2010	1315
	04-RA	Anhydrous Ammonia	2 tons	01 May 2010	1420
	05-RC	Chlorine	2 tons	03 May 2010	1320
	06-RC	Chlorine	2 tons	04 May 2010	1340
	07-RC	Chlorine	2 tons	05 May 2010	1405
	08-RC	Chlorine	2 tons	07 May 2010	1250
	09-RA	Anhydrous Ammonia	2 tons	20 May 2010	1245
	10-RA	Anhydrous Ammonia	2 tons	21 May 2010	1250

[a] Trial names are identified as follows: the first two digits are the trial sequence number, the first letter is the trial type (P = pilot, R = record; the second letter is the chemical type (A = anhydrous ammonia, C = chlorine).

The first pilot test was conducted on 07 April 2010 (anhydrous ammonia pilot test) and the second pilot test (chlorine) was conducted on the following day, 08 April 2010. Operational hours spanned across three different meteorological regimes. The night regime is defined as sunset plus 2 hours to sunrise plus 1 hour, which is approximately 0400 to 1420 UTC [2200 to 0820 Mountain Daylight Time (MDT)]. Morning is defined as sunrise plus 1 hour to sunrise plus 4 hours, which is approximately 1420 to 1720 UTC (0820 to 1120 MDT). Afternoon is defined as sunrise plus 4 hours to sunset minus 1 hour, which is 1720 to 0100 UTC (1120 to 1900 MDT). Disseminations were conducted during the night regime and trial data were collected throughout the morning regime.

Disseminations occurred as close to sunrise as possible because of the meteorological conditions that exist at that time of day. In most cases, wind speeds at the time of dissemination were calm or light with neutral or stable atmospheric conditions. As meteorological regimes cross from one regime to another, calm or light winds often occur, and this phenomenon was used during the test conduct. Disseminating at sunrise provided the daylight needed to record video coverage.

3.5 Data Required

The types of data gathered during the Jack Rabbit pilot test are described in Table 4.

Table 4. Project Jack Rabbit Pilot Test Requirements

ITEM NUMBER	DATA REQUIRED
1	Test control officer (TCO) log
2	Infrared (IR) and visible (VIS) camera data for 3 Dimensional Cloud Analysis and Visualization systems (3DCAV)
3	10-m tower camera data (real time)
4	Berm camera data (real time)
5	Bubbler data collected at the end of the trial (chlorine trials only)
6	Ultraviolet (UV) Canary data [hertz (Hz)] collected at the end of each trial
7	UV Sentry data (chlorine trials only)
8	Fourier-transform infrared (FTIR) data (anhydrous ammonia trials only)
9	Disseminator data (pressure, temperature, valve status, valve inlet pressure, and valve outlet pressure)
10	Thermocouple data (Hz) collected from six heights (real time)
11	Portable Weather Information and Display System (PWIDS) data (real time)
12	Ultrasonic Anemometer data (Hz) collected at the end of the trial

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4.0 JACK RABBIT RECORD TEST

4.1 Objectives

The objectives of the record tests are to execute release trials for each of two chemicals (chlorine and anhydrous ammonia) to accomplish the following objectives:

1. Develop and evaluate a mechanism for the controlled, rapid release of liquefied, pressurized gases from containment to approximate the conditions hypothesized to generate a persistent vapor-aerosol cloud in a 90-ton railcar release.

2. Characterize the vapor/aerosol cloud movement, behavior, and physiochemical characteristics and compare those characteristics with known observations and testing of large-scale releases of the testing materials.

3. Determine if anhydrous ammonia can potentially act as less expensive and less dangerous dense gas for studying the component phenomena of large scale releases of dense gas TIH materials.

4. Field and evaluate instrumentation that can be used for the study of the large-scale release of the testing materials, and develop and evaluate testing methodology for future additional and potentially larger-scale tests.

4.2 Responsibility

The WDTC Meteorology Division was the lead organization for the Record Test. The TO was responsible for the test execution, either directly or through delegation of duties, such as a TCO assignment. All final decisions relating to test conduct were the responsibility of the TO.

4.3 Data Analysis/Procedures

Data were collected and given to the customer for analysis. However, the end product of the Jack Rabbit Record Test was photonic, chemical, and meteorological datasets to be used in the development and evaluation of testing methodologies for future and potentially larger-scale TIC test projects, and in the development and evaluations of algorithms describing TIH behavior.

4.4 Test Procedures

Two trial types were conducted during the record test: four 2-ton chlorine trials and four 2-ton anhydrous ammonia trials. During the record test 8 tons of chlorine and 8 tons of anhydrous ammonia were released in eight separate 2-ton trials.

The chlorine disseminator was a modified 500-gal propane tank with a remotely controlled 3-in ball valve assembly mounted to the bottom of the tank. The anhydrous ammonia disseminator was a modified

1,000-gal propane tank with a remotely controlled 4-in ball valve assembly mounted to the bottom of the tank. Both disseminators had an appropriately sized manual knife gate valve mounted between the tank and the remotely controlled valve as a safety precaution.

All disseminations occurred within a 2-m deep × 25-m radius depression located at 40.20661577 latitude/-113.2657215 longitude. The disseminator was mounted on a large metal stand, with the outlet of the remotely controlled valve placed at a distance of
2-m above the depression basin. The outlet from the remotely controlled valve was 2-m above the depression basin and directed in a downward direction. The jet from the disseminator impinged against a 12-ft × 8-ft × 1-in steel plate, which served as the base for the metal disseminator stand.

The original intent with the dissemination schedule was to conduct the four anhydrous ammonia trials in the first week of testing and then conduct the four chlorine trials in the following week. Inclement weather significantly altered the original plan, so that two anhydrous ammonia trials were conducted, followed by four chlorine trials, and finally, the last two anhydrous ammonia record trials. The resulting dissemination matrix is provided in Table 3.

The record tests began on 27 April 2010 and continued through 21 May 2010. Operational hours spanned across three different meteorological regimes. The night regime is defined as sunset plus 2 hours to sunrise plus 1 hour, which is approximately 0435 to 1320 UTC (2235 to 0720 MDT). Morning is defined as sunrise plus 1 hour to sunrise plus 4 hours, which is approximately 1320 to 1620 UTC (0720 to 1020 MDT). Afternoon is defined as sunrise plus 4 hours to sunset minus 1 hour, which is approximately 1620 to 0135 UTC (1020 to 1935 MDT). Five disseminations occurred in the night regime and three were conducted in the morning regime. However, all of the disseminations were conducted during a period that could be considered a transitional phase, which occurs between regimes.

Disseminations occurred as close to sunrise as possible because of the meteorological conditions that exist at that time of day. In most cases, wind speeds at the time of dissemination were calm or light with neutral or stable atmospheric conditions. As meteorological regimes cross from one regime to another, calm or light winds often occur and this phenomenon was used during the test conduct. Disseminating at sunrise provided the daylight needed to record video coverage.

4.5 Data Required

The types of data gathered during the Jack Rabbit record trials are described in Table 5.

Table 5. Jack Rabbit Project Record Test Requirements

ITEM NUMBER	DATA REQUIRED
1	Test control officer (TCO) log
2	Infrared (IR) and visible (VIS) camera data for 3 Dimensional Cloud Analysis and Visualization systems (3DCAV)
3	10-m tower camera data (real time)
4	Berm camera data (real time)
5	Bubbler data collected at the end of the trial (chlorine trials only)
6	Ultraviolet (UV) Canary data [hertz (Hz)] collected at the end of each trial
7	UV Sentry data (chlorine trials only)
8	Fourier-transform infrared (FTIR) data (anhydrous ammonia trials only)
9	Disseminator data (pressure, temperature, valve status, valve inlet pressure, and valve outlet pressure)
10	Thermocouple data (Hz) collected from six heights (real time)
11	Portable Weather Information and Display System (PWIDS) data (real time)
12	Ultrasonic Anemometer data (Hz) collected at the end of the trial
13	Jaz UV Visible (UV-VIS) data (Hz) recorded in Microsoft® Excel spreadsheet

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5.0 JACK RABBIT DATA

The Jack Rabbit dataset consists of data collected from photonic, chemical, and meteorological instrumentation. Data described within this report pertains to information collected and compiled by DPG only. All other test participant datasets are not addressed in this report.

WDTC manages data collection and distribution with seven levels of data defined.[1] A brief description of the various data categories as follows:

> **Level 1**: Raw data—data in their original form. These are results of field trials, just as recorded.
>
> **Level 2**: Reduced data—data taken from the raw form and consolidated. Invalid or unnecessary data points identified as such with supporting rationale.
>
> **Level 3**: Ordered data—data which have been checked for accuracy and arranged in convenient order for handling. Operations limited to counting and elementary arithmetic.
>
> **Level 4**: Findings or summary statistics—data which have been summarized by elementary mathematical operations. Operations limited to descriptive summaries without judgments or inferences. Does not go beyond what was observed in the test.
>
> **Level 5**: Analysis or inferential statistics—data resulting from statistical test of hypothesis or interval estimation. Execution of planned analysis data includes both comparisons and statistical significance level. Judgments limited to analyst's selection of techniques and significant levels.
>
> **Level 6**: Extended analysis or operations—data resulting from further analytic treatment going beyond primary statistical analysis, combination of analytic results from different sources, or exercise of simulation or models. Judgment limited to analysts' choices only.
>
> **Level 7**: Conclusions or evaluation—data conclusions resulting from applying evaluative military judgments to analytic results.

Data from Jack Rabbit are archived in numerous forms and levels. All data delivered to the customer have passed through a QC process to ensure data integrity. Level 1 data will not be released outside of the WDTC.

The Jack Rabbit dataset continues to grow in size because of ongoing reporting and data compilation efforts. In some cases, the datasets or subsets will elevate in the established levels because of the work being done with the data.

5.1 Trial/Disseminator Information

All Jack Rabbit trial names follow a predetermined format. This format was used in most datasets and will be referred to in future publications and reports relating to the project. The following illustration (Figure 3) provides an explanation of this naming convention.

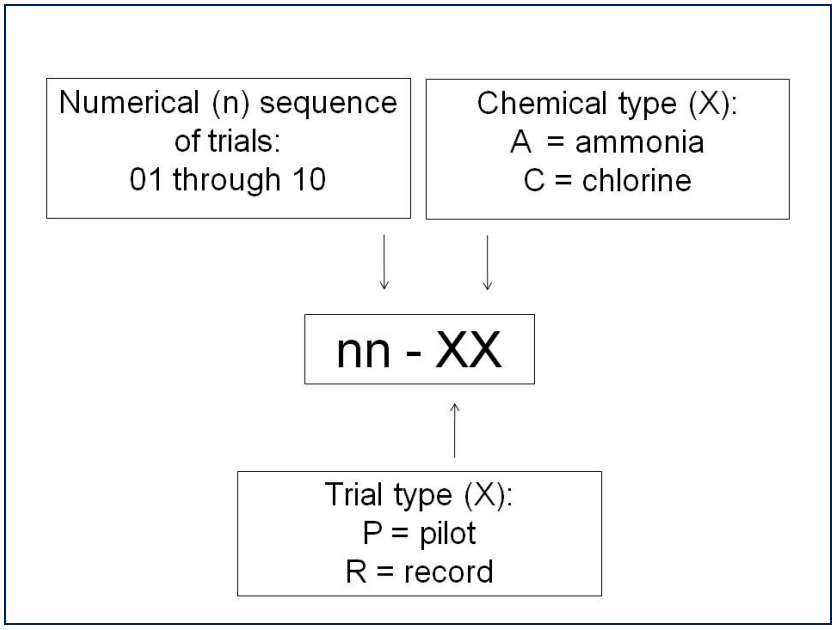

Figure 3. Jack Rabbit Project Field Test File Naming Convention

An example of the Jack Rabbit file naming convention is that "03-RA" represents the third trial, which is a record anhydrous ammonia trial. Trial data collected and/or processed from the field tests are summarized in Table 6.

Table 6. Data Summary for the Jack Rabbit Project

TRIAL NAME[a]	NUMBER OF DATA FILES	NUMBER OF VIDEO FILES	TOTAL NUMBER OF FILES	DATA DATASET SIZE (MB[b])	VIDEO DATASET SIZE (MB)	TOTAL SIZE OF ALL DATASETS (MB)
01-PA	67	199	266	140	200,922	201,062
02-PC	88	150	238	190	260,482	260,672
03-RA	108	246	354	382	37,446	37,828
04-RA	112	444	556	423	86,363	86,786
05-RC	110	172	282	348	155,476	155,824
06-RC	109	207	316	334	146,546	146,880
07-RC	111	237	348	348	243,778	244,126
08-RC	111	285	396	367	304,340	304,707
09-RA	96	350	446	302	450,927	451,229
10-RA	95	300	395	297	381,443	381,740

[a] Trial names are identified as follows: the first two digits are the trial sequence number, the first letter is the trial type (P = pilot, R = record; the second letter is the chemical type (A = anhydrous ammonia, C = chlorine).
[b] Megabyte

In addition to the data displayed in Table 6, there were 2,094 still photograph files created during the field tests for a total of 3.7 gigabytes of data.

Dissemination information from the field tests is summarized in Tables 7 through 16. In these tables, the meteorological data were a 10-second average of all of the 16 tripod-mounted PWIDS on the test grid for the time given. The tank information represents a 5 percent subset of the actual dissemination dataset.

It should be noted that during Trial 10-RA, the disseminator intermittently started and stopped several times at the beginning of the release. The problem did not persist beyond 5 seconds into the dissemination.

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