

Jack Rabbit II

Clorosur Technical Seminar &
WCC Safety Workshop

November 16-18, 2016

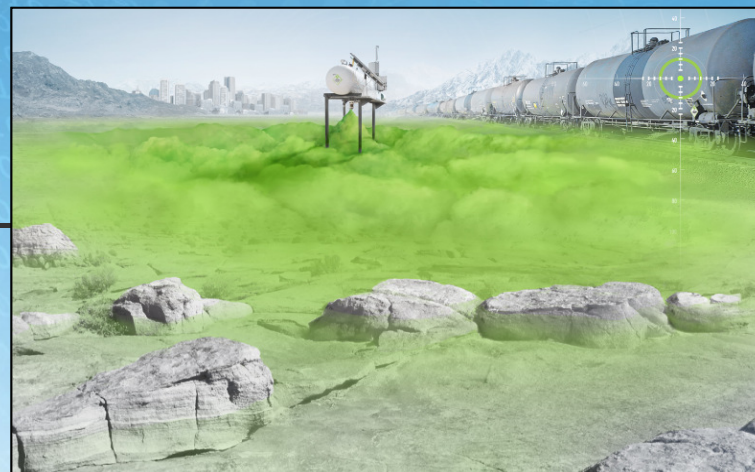


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Canada



Shannon B. Fox, PhD

Jack Rabbit II Program Manager
Chemical Security Analysis Center
DHS Science & Technology Directorate

Jack Rabbit II Program Sponsors

DHS S&T Chemical
Security Analysis Center
(CSAC)



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Defense Threat Reduction
Agency (DTRA)



Transport Canada /
DRDC



Transport
Canada

DEFENCE



DÉFENSE

Additional Performers, Participants and Contributors

- **Dugway Proving Ground:** Primary performer for test execution
- **DHS S&T CSAC**
- **DTRA:** Direct funding and support for field experiments. Over 20 staff directly participating in planning, field trials, and analysis
- **Transport Canada and DRDC:** Direct funding and staff directly participating in planning, field trials, and analysis
- **Chlorine Institute and Member Companies:** CHLOREP team conducting all chlorine handling operations. Contribution of chlorine, equipment.
- **Department of Transportation – PHMSA:** Sponsoring indoor studies
- **Lawrence Berkeley National Laboratory –** Indoor building and vehicle infiltration experiment
- **Utah Valley University:** Along with **FEMA, U.S. Fire Administration, IAFC, IAB** - Led team of partners fielding emergency response vehicles and several important experiments relevant to first responders

Additional Contributors

- **TSA:** Jack Rabbit I Sponsor, JR II partner and sponsor of Scientific Advisory Group
- **Singapore – DSO National Laboratories**
 - UV Camera – image capture in ultraviolet spectrum
 - VNIR Camera – Image capture within the visible, near infra-red spectrum
 - IR Camera – Image capture within the infra-red spectrum
 - Doppler LIDAR – Wind profile measurement
- **France – ARIA**
- **UK – Dstl, HSL**
- **Spectral Sensor Solutions (S³) – LIDAR**
- Aberdeen Test Center
- Naval Surface Warfare Center
 - Carderock
 - Dahlgren
- University of Arkansas
- Texas A&M University
- Clarkson University
- Signature Science

Jack Rabbit Program

- **Problem:** DHS and its partners and stakeholders in the HSE must better understand behavior and consequences of large-scale chlorine releases.

- Millions of tons of chlorine, a potent toxic inhalation hazard (TIH), are shipped annually through highly-populated areas
- Transported in bulk as a pressurized, liquefied gas via road, water, rail
- An accidental or intentional release can rapidly generate a lethal vapor cloud



-
- Hazard prediction models *are not consistent* with the evidence, data, and observations from previous fatal chlorine disasters
 - Rapid Cl₂ releases have never been tested at operationally-relevant scales
 - Critical knowledge and data gaps exist for source terms and other phenomena relevant to modeling and emergency response
 - There is insufficient understanding, knowledge, and documentation of large-scale chlorine releases to properly inform, train and prepare emergency responders
 - 2010 Jack Rabbit 1-2 ton chlorine trials identified phenomena and scaling factors that required additional testing.

Highest Priority TIHs – 2009 Gap Analysis

The most widely-shipped toxic inhalation hazard (TIH) chemicals in US, by route.

Chemical	Road	Rail	Water	Total	% of Total	
Ammonia (NH ₃)	5,793,000	3,470,592	1,718,974	10,982,566	52.8%	
Chlorine (Cl ₂)	724,000	3,750,372	137,202	4,611,574	22.2%	~75%
Sulfuric Acid (H ₂ SO ₄)	257,000	207,560	2,057,721	2,522,281	12.1%	
Acrylonitrile (C ₃ H ₃ N)	29,000	277,200	671,474	977,674	4.7%	
Ethylene Oxide (C ₂ H ₄ O)	106,000	671,260	1,132	778,392	3.7%	~95%
Hydrogen Fluoride (HF)	29,000	264,560		293,560	1.4%	
Sulfur Dioxide (SO ₂)	72,000	172,480	361	244,841	1.2%	
Hydrogen Chloride (HCl)	2,000	8,400	166,027	176,427	0.8%	
Hydrogen Cyanide (HCN)	33,000	31,600		64,600	0.3%	~99%
Bromine (Br ₂)	61,000			61,000	0.3%	
Nitric Acid (HNO ₃)	3,000	35,800	44	38,844	0.2%	

- Ammonia and chlorine dominate volume shipped
- Consideration of chlorine's much greater toxicity: Chlorine is TIH of greatest concern in transport

Recent Chlorine Releases

- Festus, MO, 2002
 - Ruptured 1-inch Cl₂ fill line
- Macdona, TX, 2004
- Graniteville, SC, 2005
- Iraq Chlorine Attacks, 2007-2008
 - Chlorine 1-ton containers and cylinders
 - Approximately 15 attacks
- Syria, N. Iraq Conflicts 2014-2015
 - Chlorine 1-ton containers
 - Chlorine “Barrel Bombs”

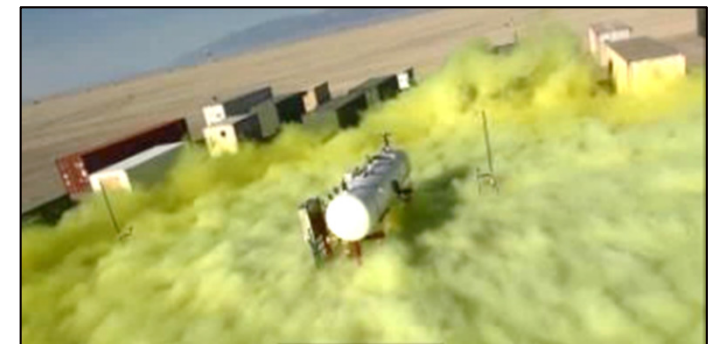
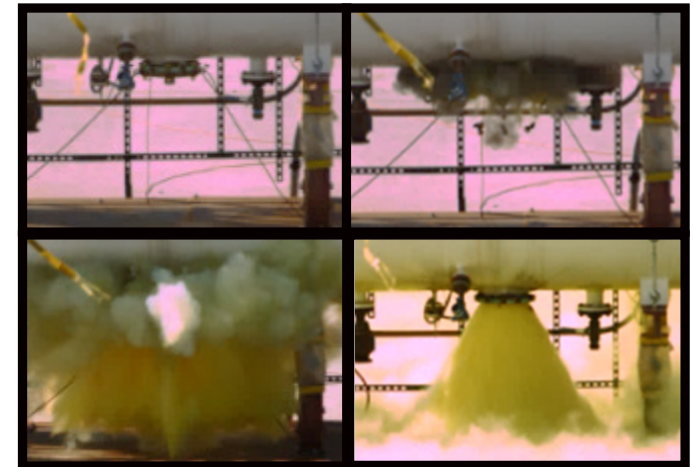


Jack Rabbit II – Objectives and Impact

- Primary Objective: Conduct a series of unprecedented large-scale chlorine release field trials to fill critical data and knowledge gaps for improved modeling and emergency response.
 - Execute multiple chlorine release trials greater than 1 to 20 tons.
 - Track and quantify downwind plume movement and concentration to at least 7 mi.
 - Measure key source term parameters for each trial, including mass flux, tank pressure and temperature dynamics, and phase distribution.
 - Measure dynamic cloud chlorine concentrations up to 100,000 ppm near-source.
 - Determine effects of obstacles and structures on cloud movement and behavior.
 - Examine effect of chlorine exposure on emergency response equipment and vehicles.
 - Examine chlorine reactivity with soil, vegetation, and common urban materials.
- Impact: Knowledge products that are required for improved capabilities and efficiencies in planning, response and mitigation
 - Experimentally-validated source terms, dispersion data, and modeling
 - Resiliency – better informed planning, emergency response, and policy
 - Vulnerability and impact reduction – hazard and risk mitigation

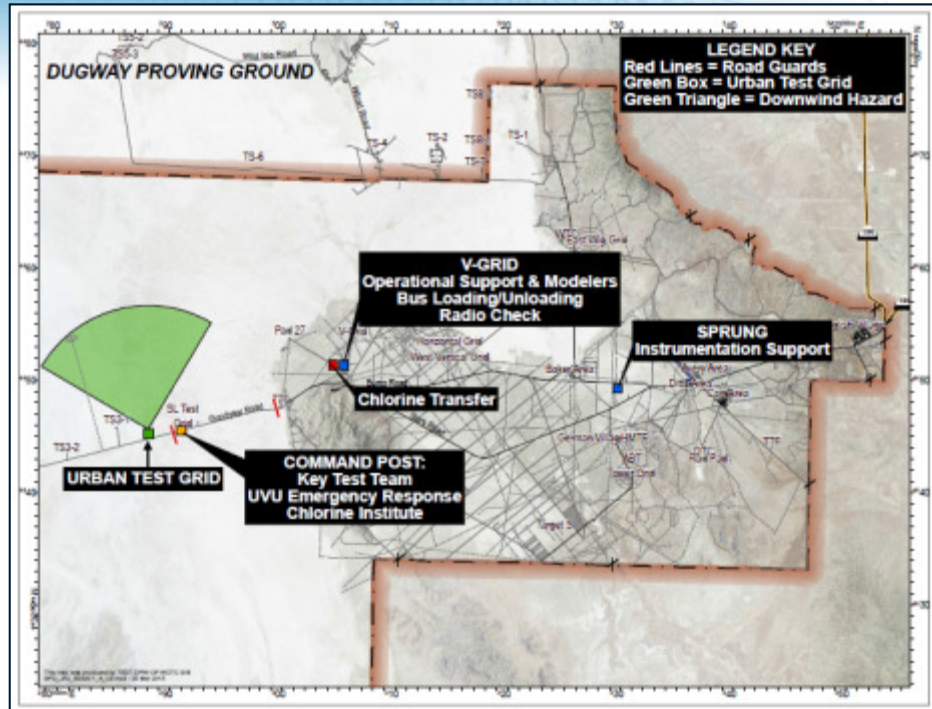
Jack Rabbit II – 2015 Trials

- 5 successful trials in 2015: 5-9 tons Cl_2
- Tracking downwind cloud and concentration to 7+ miles
- Quantifying source term parameters
- Simulated urban test grid to study effect of buildings
- Building infiltration and shelter-in-place studies
- Emergency vehicles and equipment exposure testing
- Studies of Cl_2 reactions with environment and surfaces



Test Site – Dugway Proving Ground

- U.S. Army’s Dugway Proving Ground, UT selected as test site and performer
- Extremely remote, unpopulated test range in barren desert salt-flats
- Unique and well-understood reproducible weather in July-September – 2yr study
- Successfully secured multiple levels of Federal and State approval:
 - Utah Title V Permit >10 tons Cl₂
 - Environmental Assessment / NEPA
 - CWC Treaty Compliance
 - Clean Air Act
 - Migratory Bird Act
 - UXO and Cultural Public Hearings

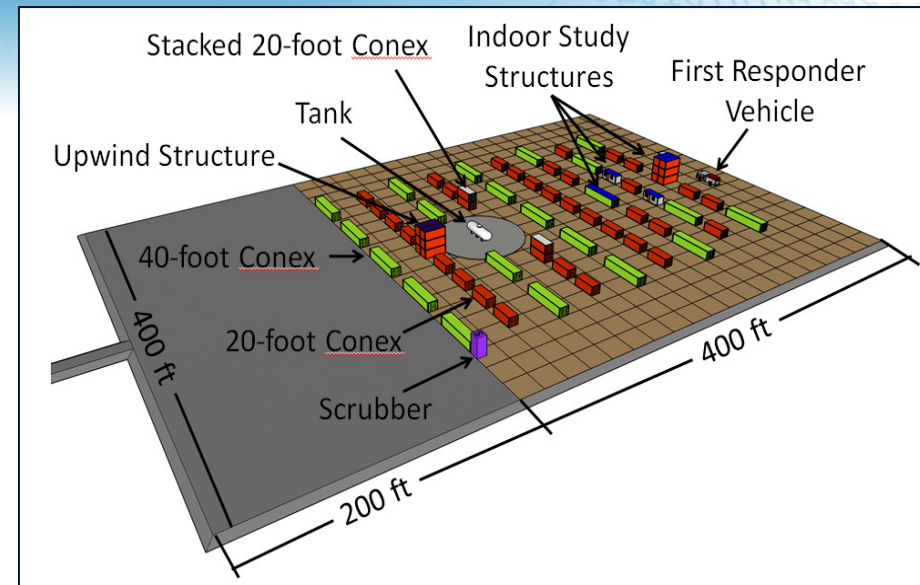


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Urban Test Grid (UTG)

- “UTG” constructed with over 80 Conex containers and mobile structures to simulate buildings and obstacles
- Release tank positioned in the middle of UTG on circular concrete pad
- Instrumentation deployed at stations throughout UTG to capture key data:
 - UV Jaz, Canary, MiniRAE – Concentration
 - Thermocouples, IR Cameras - Temperature
 - Guided Wave Radar (GWR) Liquid Depth
 - PWIDS, SODAR, SAMS Towers - Meteorology



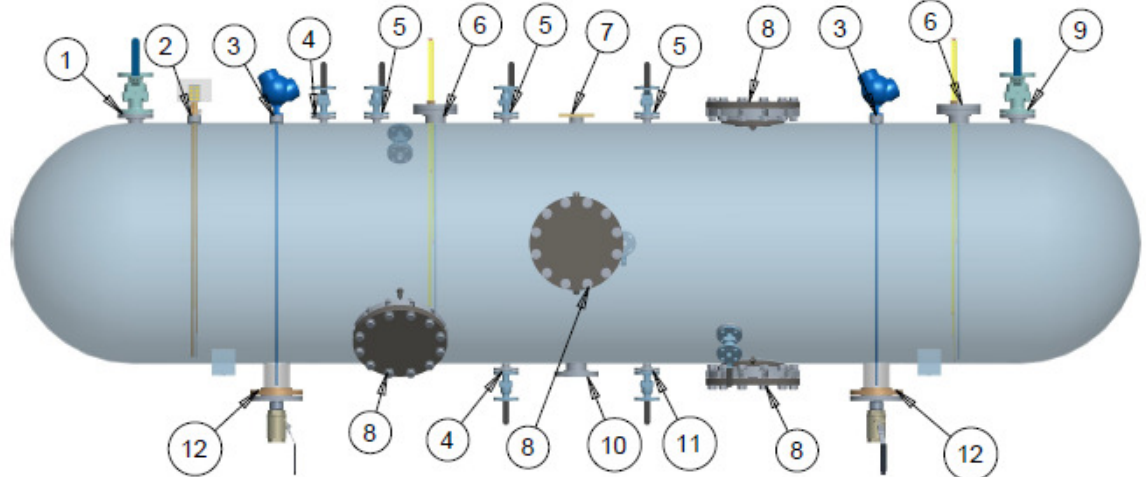
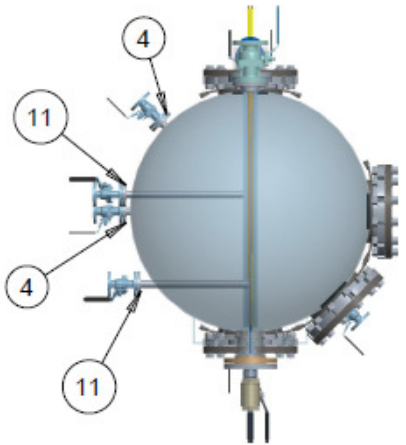
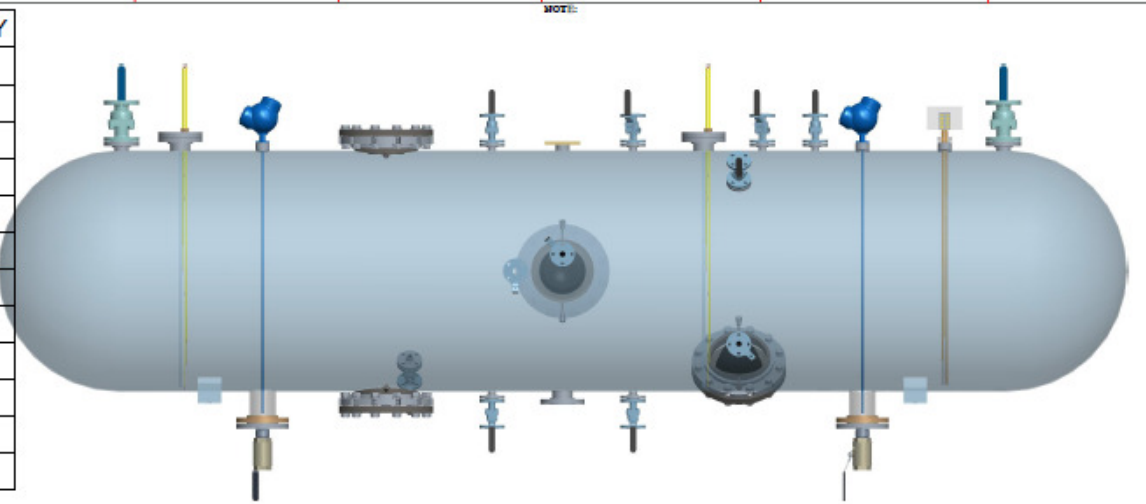
Urban Test Grid (UTG)

- JR II Cloud, Trial 5, looking toward south (upwind) 0.5 sec after release starts



Dissemination Tank

ITEM	DESCRIPTION	QTY
1	VENT PORT	1
2	THERMOWELL	1
3	GUIDED WAVE RADAR	2
4	ABSOLUTE PRESSURE	4
5	DIFFERENTIAL PRESSURE, LOW	3
6	THERMOCOUPLES	2
7	PRESSURE RELIEF VALVE	1
8	DISPERSION PORT	4
9	FILL PORT	1
10	DRAIN PORT	1
11	DIFFERENTIAL PRESSURE, HIGH	3
12	GUIDED WAVE RADAR EXTENDED PORT	2



DISIGNED BY S. STW	DRAWN BY S. STW	CHECKED BY	APPROVED BY	FILE NAME CHLORINE-VESSEL-STON-ASM	DATE Feb-04-15	SCALE DO NOT SCALE
DUGWAY PROVING GROUND DUGWAY, UTAH 84022 DPW-TSE				PART DESCRIPTION CHLORINE VESSEL ASSEMBLY (5 TONS)		
				DRAWING NUMBER JR-CH-V: 000000	REV. 1	SHEET 1/1

Chlorine Handling Operations

- Chlorine Institute's CHLOREP team performed all chlorine handling operations
 - Delivery of Cl₂ to Dugway
 - Transfer of Cl₂ delivery to 20-ton tanker truck
 - Transfer of Cl₂ from truck to dissemination tank
 - Resealing the dissemination tank after release – attaching new flange to 6-inch exit port
 - Reconditioning the tank after each release trial in preparation for next test

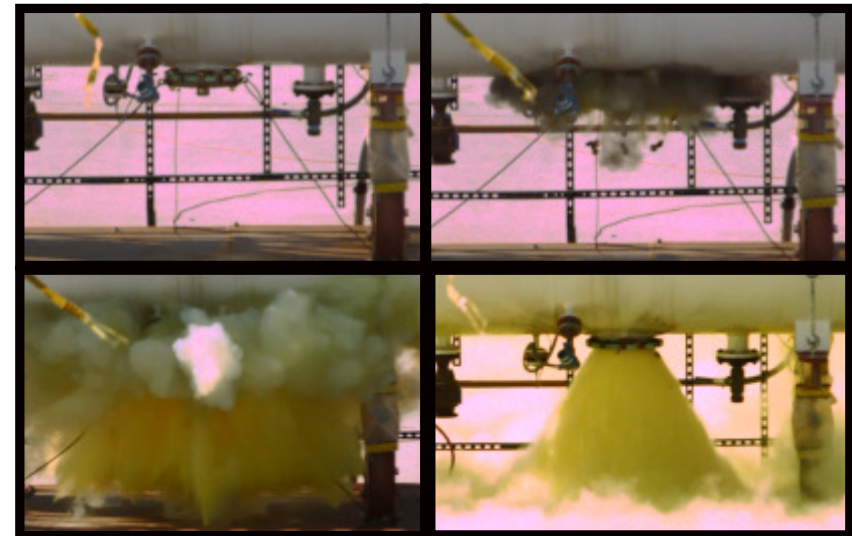


Dissemination

- 5 successful Cl₂ release trials in 2015:

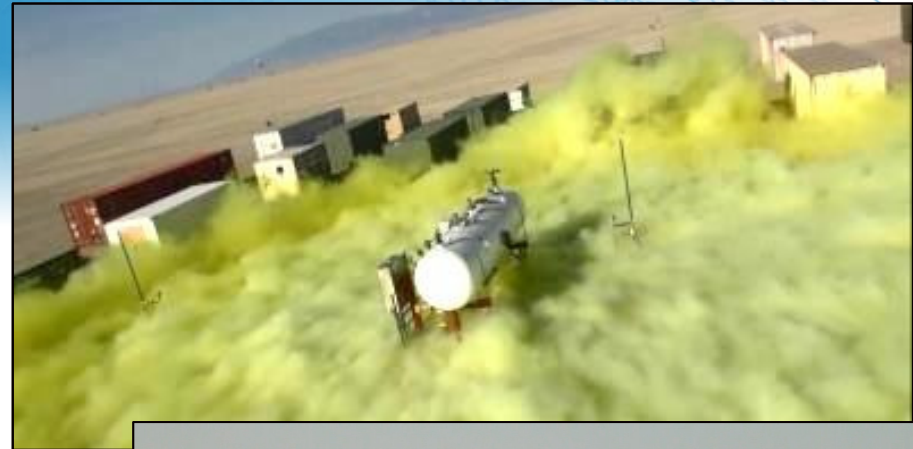
	Date	Time (MDT)	Mass Cl ₂
1	24-AUG-15	7:35:45 AM	5.0 Tons
2	28-AUG-15	9:24:21 AM	9.0 Tons
3	29-AUG-15	7:56:55 AM	5.0 Tons
4	01-SEP-15	8:38:50 AM	7.5 Tons
5	03-SEP-15	7:28:19 AM	9.5 Tons

- Time of day and year precisely selected in order to achieve required “go” criteria:
 - 2-6 m/s wind
 - Temp. Inversion
 - 90° wedge NNW
 - Atmos. Stability
- Reengineered 10-ton propane tank
- Explosive bolts released blind flange to expose 6-inch hole in bottom of tank
- Tank instruments measured key source-terms:
 - Temperature
 - Pressure
 - Mass Flux
 - Vapor Void Space
 - Liquid Volume
 - Liquid Depth



2015 Phase I Trials - Source Term and Near Field Experiments

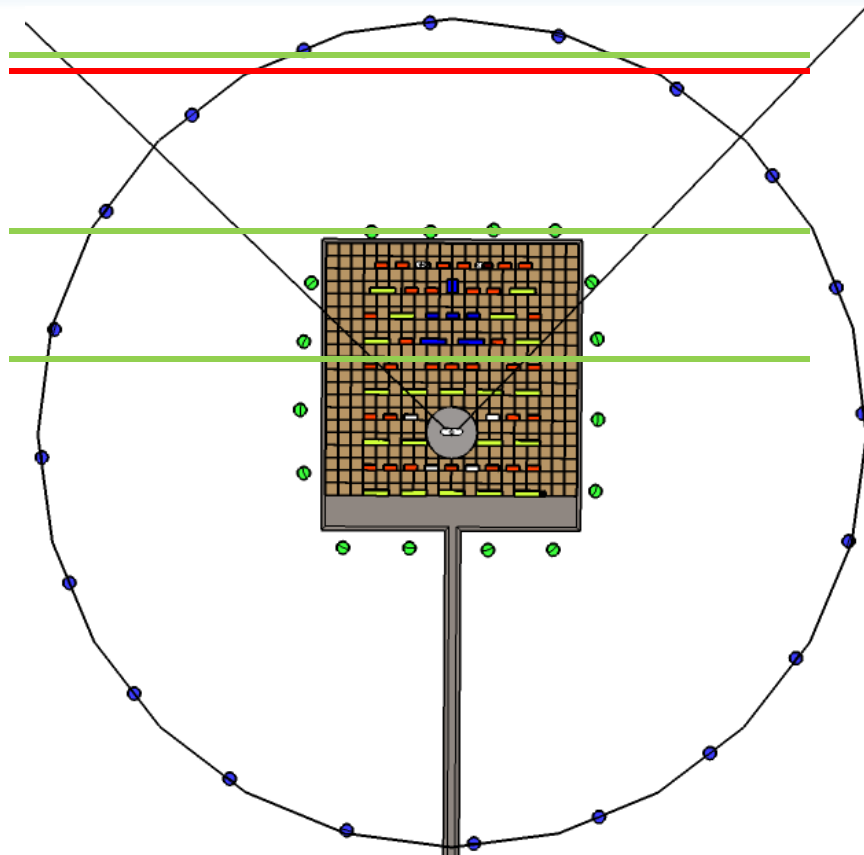
- Upwind Drift
- Liquid pooling
- Secondary evaporation
- Some (but not much) movement over 1 story structures (no cloud movement over 2 and 3 story structures)
- Channeling around structures
- Initial release concentrations over 100,000 ppm
- Concentration decreases rapidly with height
- Rapid Phase Transitions not observed



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Near Field Testing Grid



- 16 UV/Vis Jaz instruments measure Cl_2 in the near-field
- Upwind “retrograde” cloud flow, monitored at 200-m ring
- Indoor Study areas, and effect of buildings
 - UV Canary
 - - Jaz Unit
 - UV Sentry Line of Sight
 - Midac OP-FTIR Line of Sight

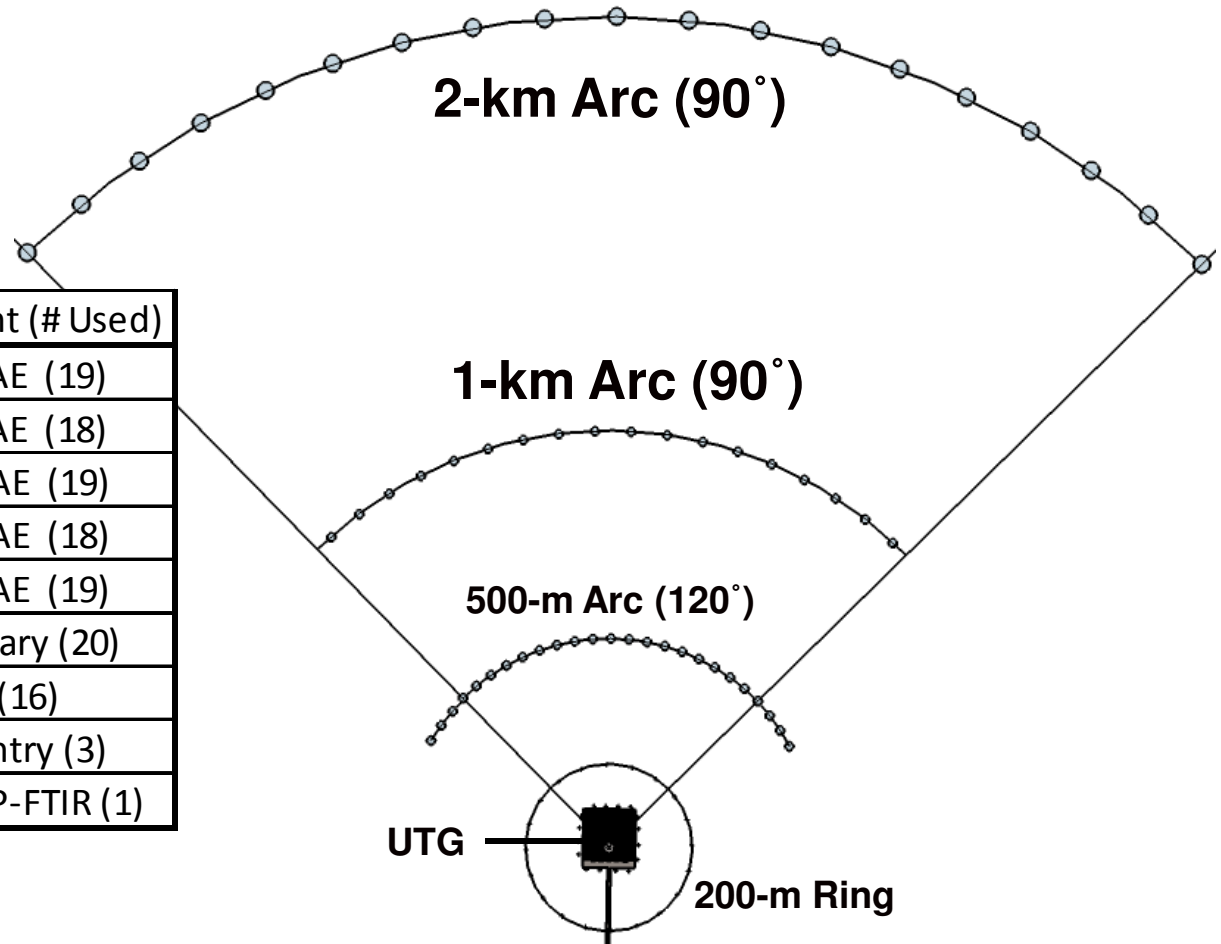


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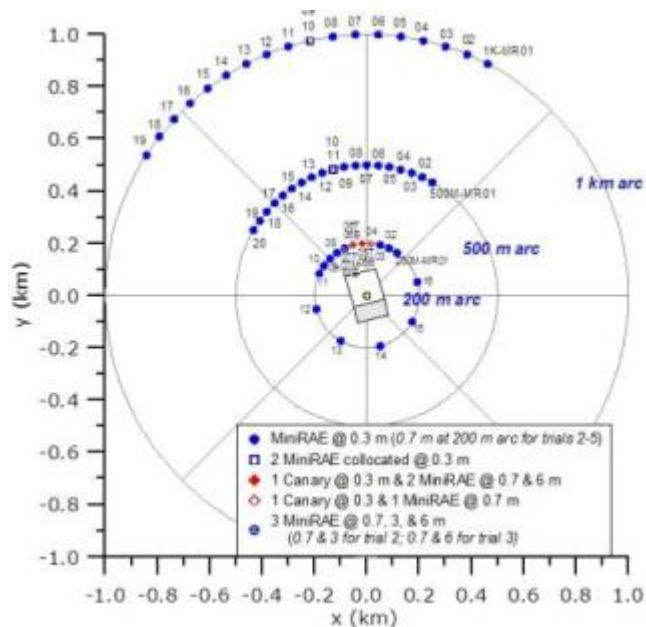
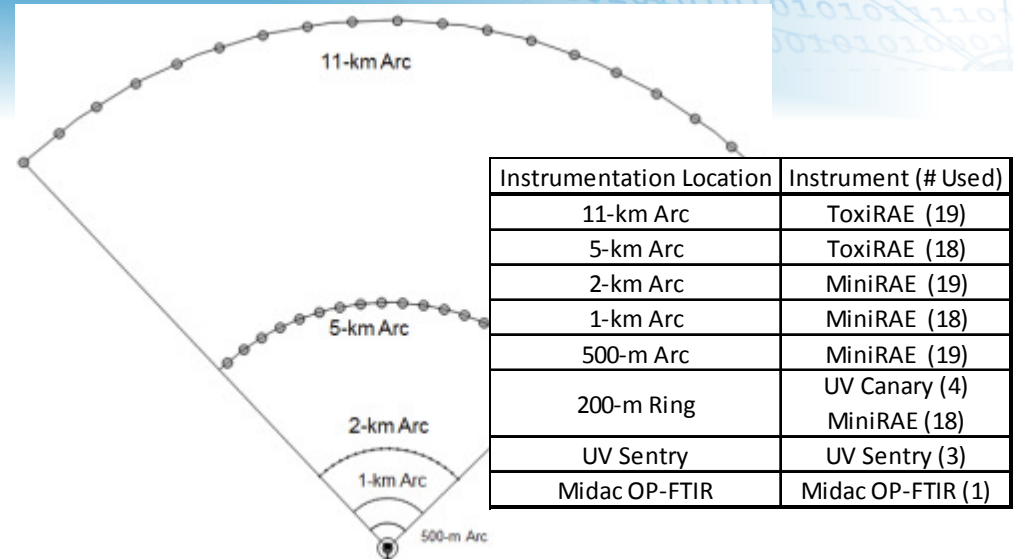
Mid-Range Test Grid

Instrumentation Location	Instrument (# Used)
11-km Arc	ToxiRAE (19)
5-km Arc	ToxiRAE (18)
2-km Arc	MiniRAE (19)
1-km Arc	MiniRAE (18)
500-m Arc	MiniRAE (19)
200-m Ring	UV Canary (20)
100-m Ring	Jaz (16)
UV Sentry	UV Sentry (3)
Midac OP-FTIR	Midac OP-FTIR (1)



Extended Test Grid

- Beyond UTG, instrument stations positioned on arcs at 200m, 500m, 1km, 2km, 5km, and 11km
- Plume tracked to 11km and beyond via 3 LIDAR stations:
 - 2 UV Differential Absorption LIDAR (DIAL)
 - 1 Mie-Scatter LIDAR (Aerosol)



UV-Dial LIDAR

Emergency Responder Experiments

- Deployed Emergency Response Vehicles, Equipment 100m from release
 - 3 fire trucks, 2 ambulances, cars (windows up, running, AC variable)
 - No vehicles stalled on any trial
 - Significant corrosion to all metal surfaces
- Exposure / Effect on Common Materials and Surfaces
 - Creosote soaked items such as poles and rail road ties
 - Asphalt Shingles, Wood, Hay, Grass
 - Rail Ballast
- Studies providing key data and findings to improve ER safety and operations:
 - Survivability in vehicles
 - Immediate and long-term operability of ER vehicles and equipment
 - Determination of vertical concentration gradient impacting vehicles
 - Validation of CP and Isolation Zones

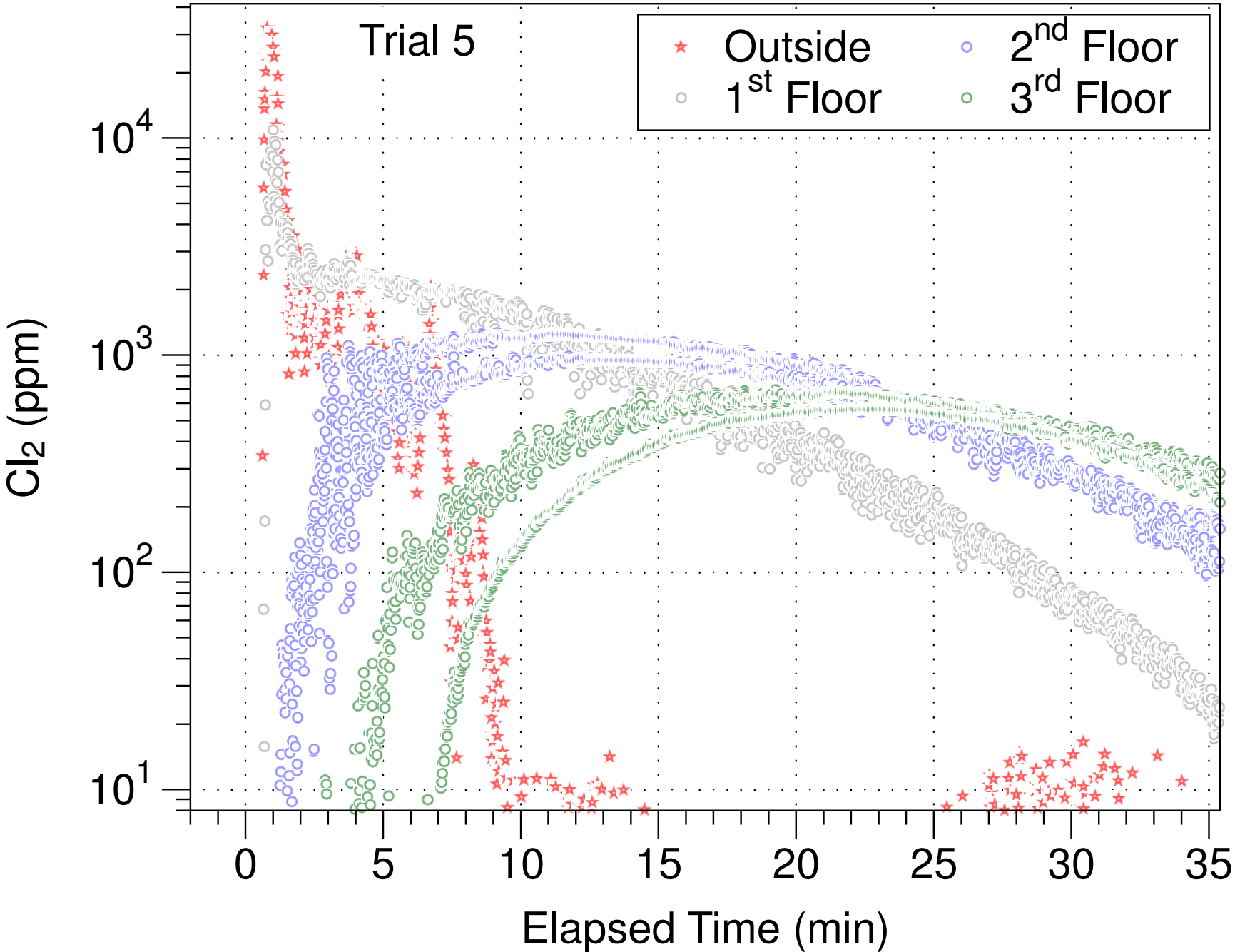


Indoor Infiltration Experiments and Studies

- DOD DTRA-funded, led by Dr. Mike Sohn, LBL
- Total of 6 large mobile trailers configured to mimic residential and office structures
- Additional Conex containers configured and equipped with interior and exterior sensors to record concentration of cloud and ingested Cl_2
- Studies are investigating and will reveal:
 - Indoor concentration profile generated by outdoor cloud
 - Effect of varying conditions including HVAC operation, windows, air exchange rates, materials
 - Examination of shelter-in-place procedures and guidance
 - Indoor exposure profiles – will lead to improved consequence assessment



Stacked CONEX



Toxic Load (TL)

$$TL = C^n \times T$$

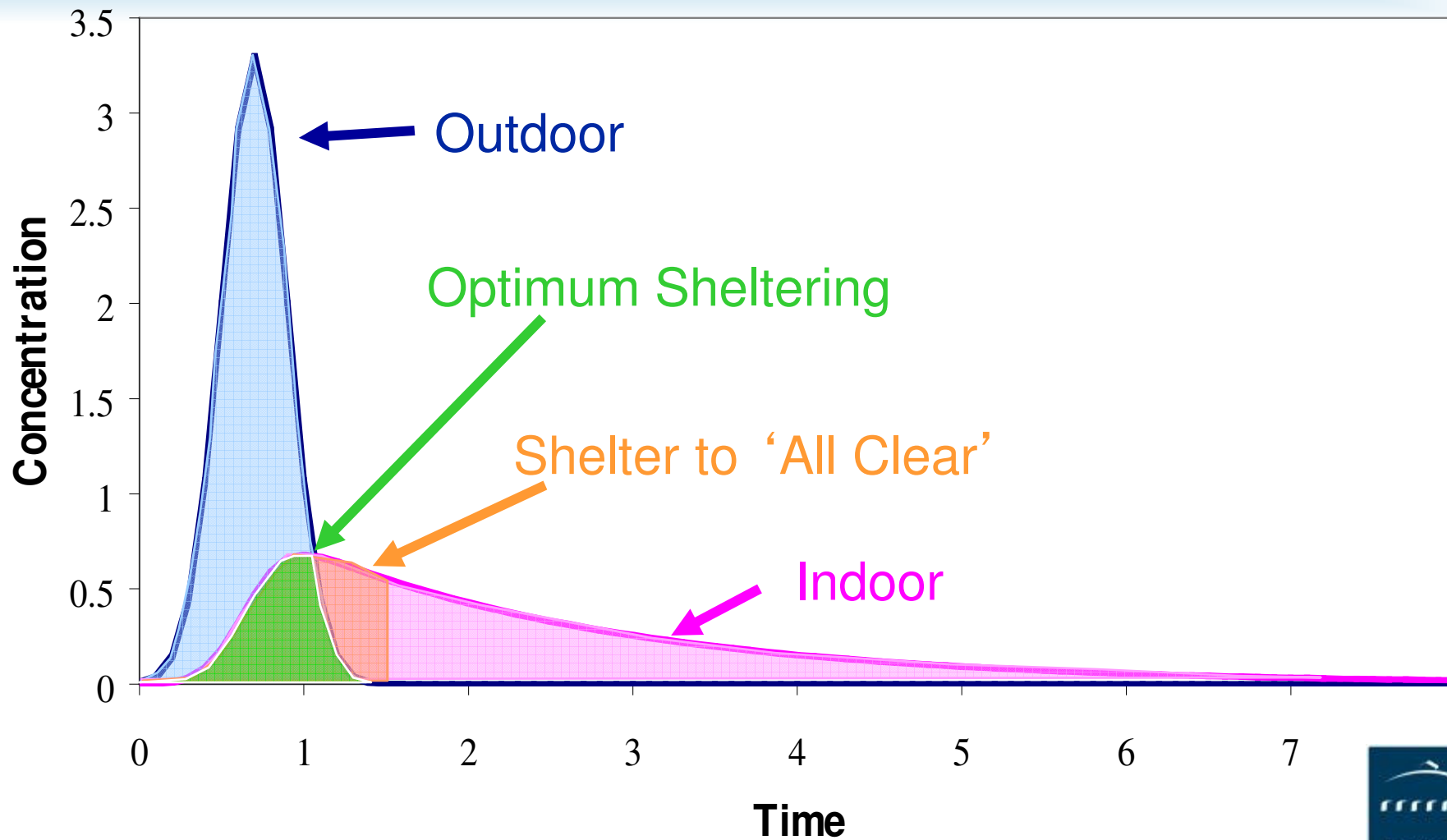
$$TL = \int_0^T C(t)^n dt$$



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Impact: Theoretical Strategy for Sheltering in Place



Jack Rabbit II – Phase 2 – 2016

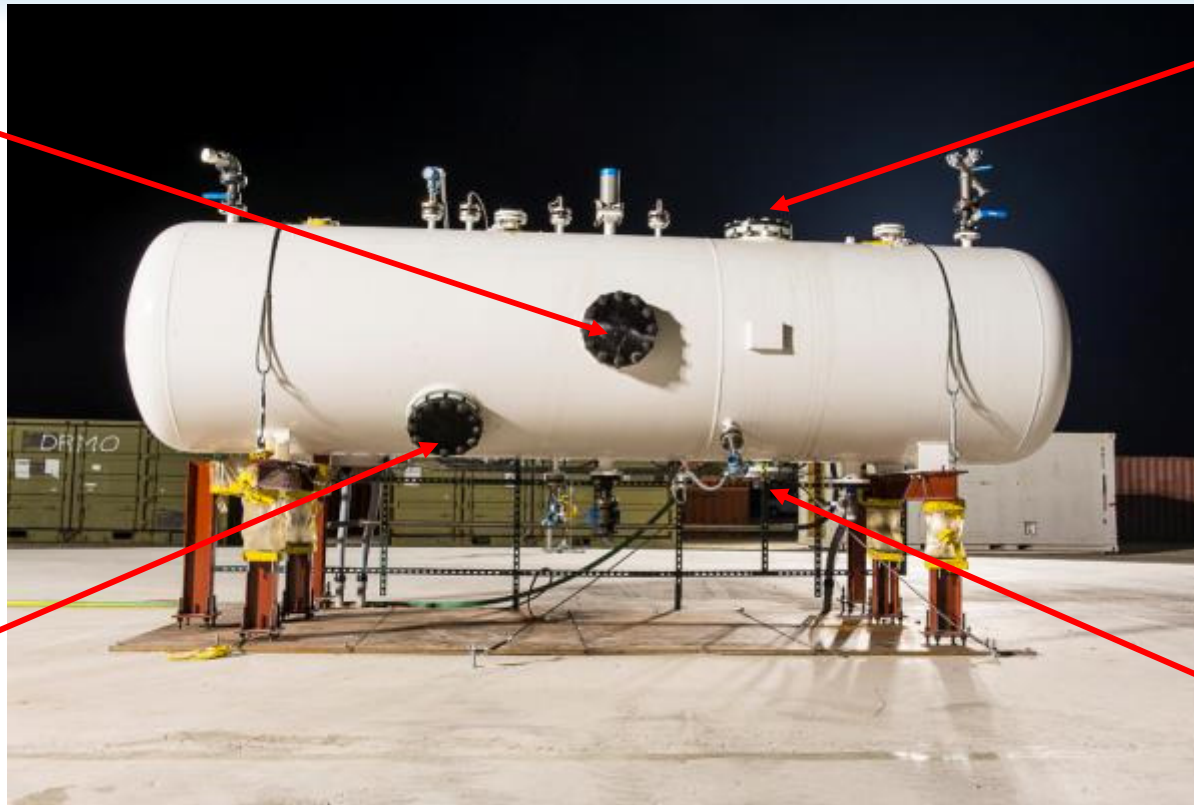
- 4 successful chlorine release trials from 10- and 20-ton tanks
- Release trials conducted **August 29th** through **September 17th**.
- Releases from tank using different release angles:
 - 0° (straight up)
 - ~~90° (horizontal)~~
 - 135° (45° angle from ground)
 - 180° (downward)
- 1 release trial from 20-ton tank
 - 180° (downward)
 - 20-ton tanker truck vessel used as release tank
 - Explosively breached
- Structures / Conex containers removed for Phase 2 trials, except:
 - 2 mobile buildings remaining for follow-up work for LBNL indoor experiments
 - 2 Emergency Response vehicles per trial



JR II 2016 – Dissemination

90 deg,
horizontal

0 deg, up



135 deg

180 deg,
down

JR II Disseminator: Purpose-Built 2,000 gal Tank



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JR II 2016 – Dissemination

- 20-ton tanker truck release was the final JR II release trial
- Explosive breach mechanism generated 6-inch hole on bottom of tank
- Designed and tested by Aberdeen Test Center and Naval Surface Warfare Center – Carderock



2016 Test Site Layout



- Trailer
- Conex
- Camera Towers
- Aerosols
- 10t Tank

**Command Post
2 miles**



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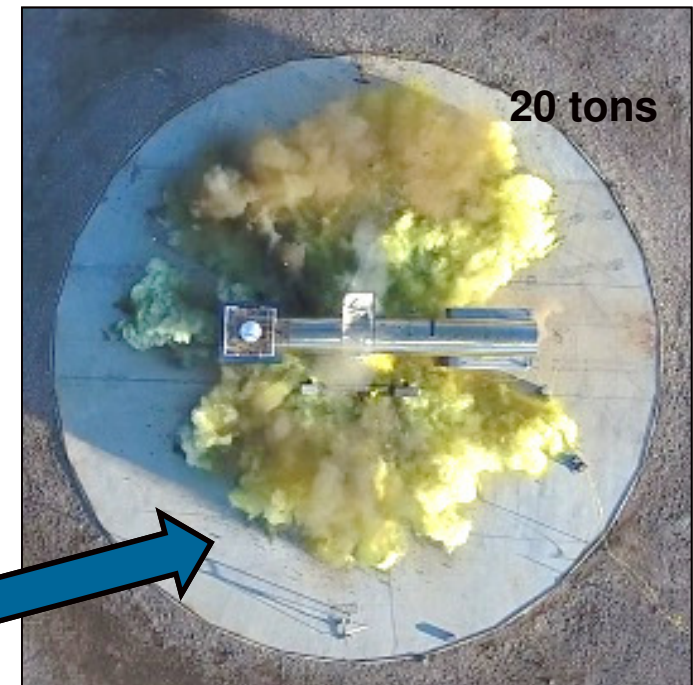
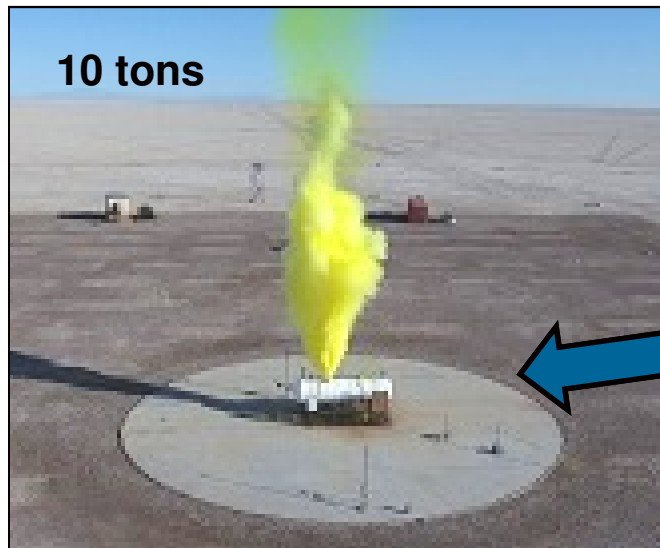
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JR II 2016 – Phase 2: 4 Successful Trials

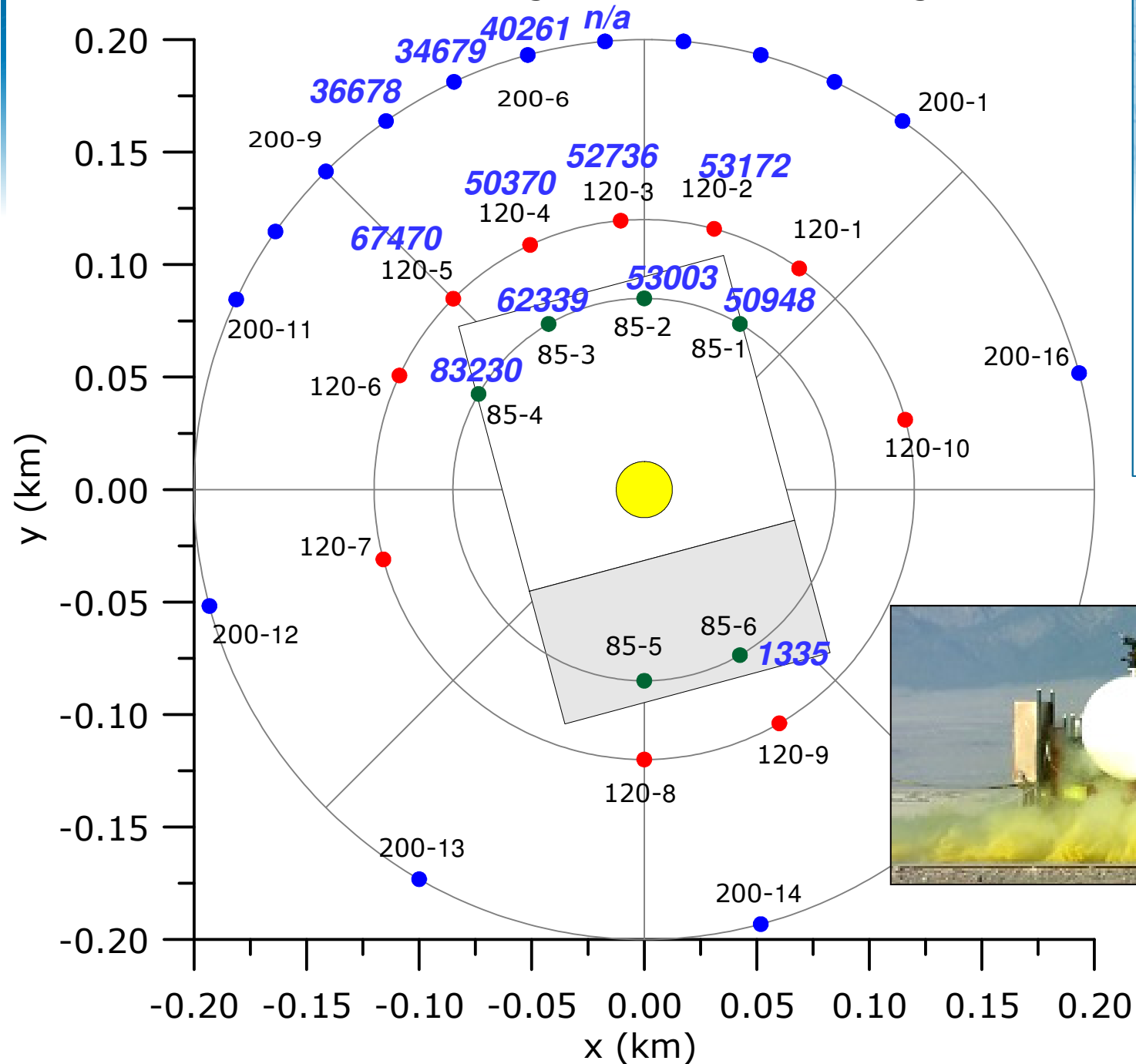


Release trials :

- ~~× August 29~~
- ✓ August 31 [180°-down]
- ✓ September 02 [135°-down]
- ~~× September 07~~
- ~~× September 09~~
- ✓ September 11 [0°-up]
- ~~× September 14~~
- ✓ September 17 [180°-down]



Azimuth of grid centerline: 345 deg



Trial 01
180° Release
Downward
10 Tons Cl₂

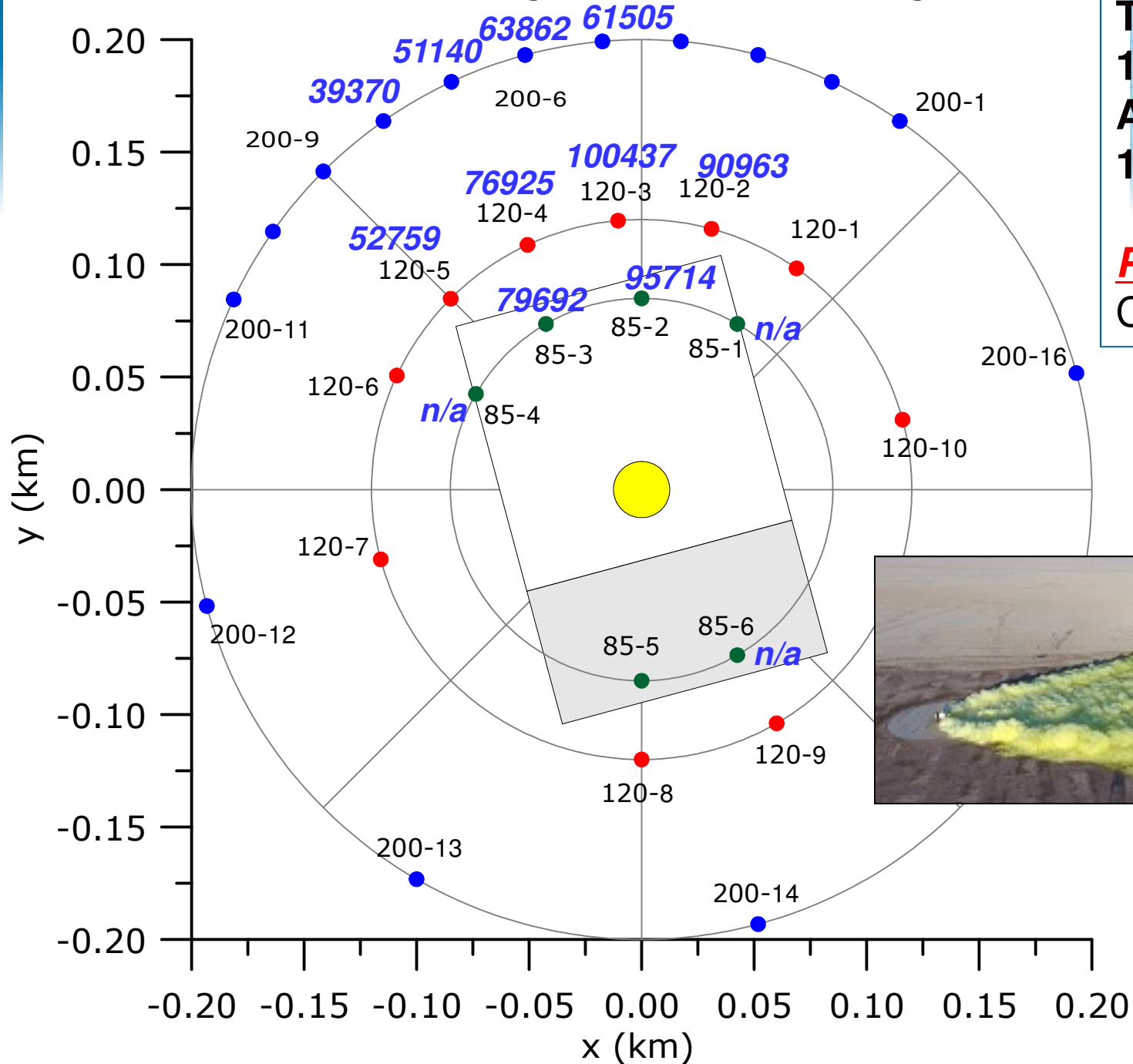
Preliminary
Max Conc.
Detected



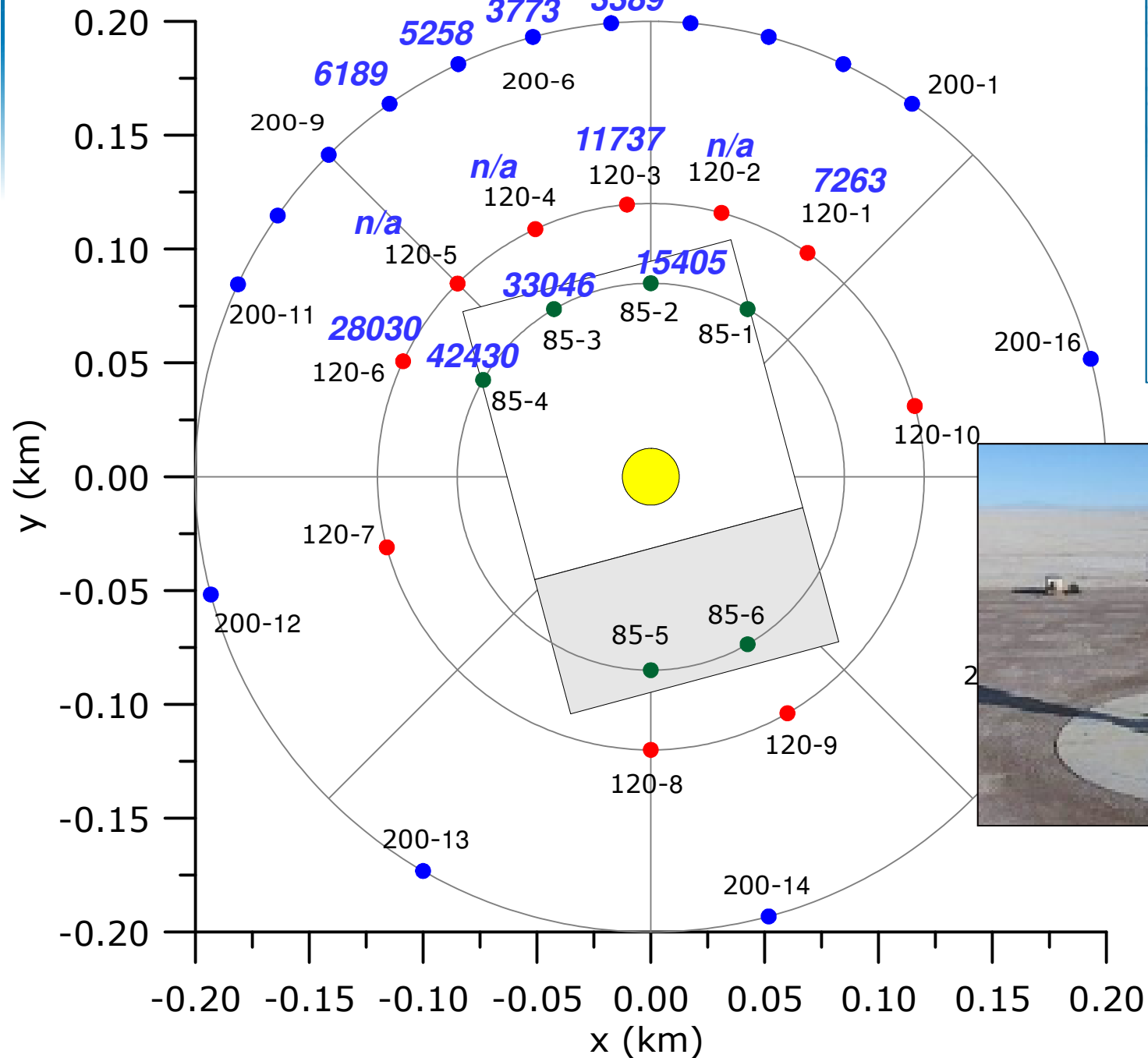
Azimuth of grid centerline: 345 deg

Trial 02
135° Release
Angled (Downward)
10 Tons Cl₂

Preliminary Max
Conc. Detected



Azimuth of grid centerline: 345 deg

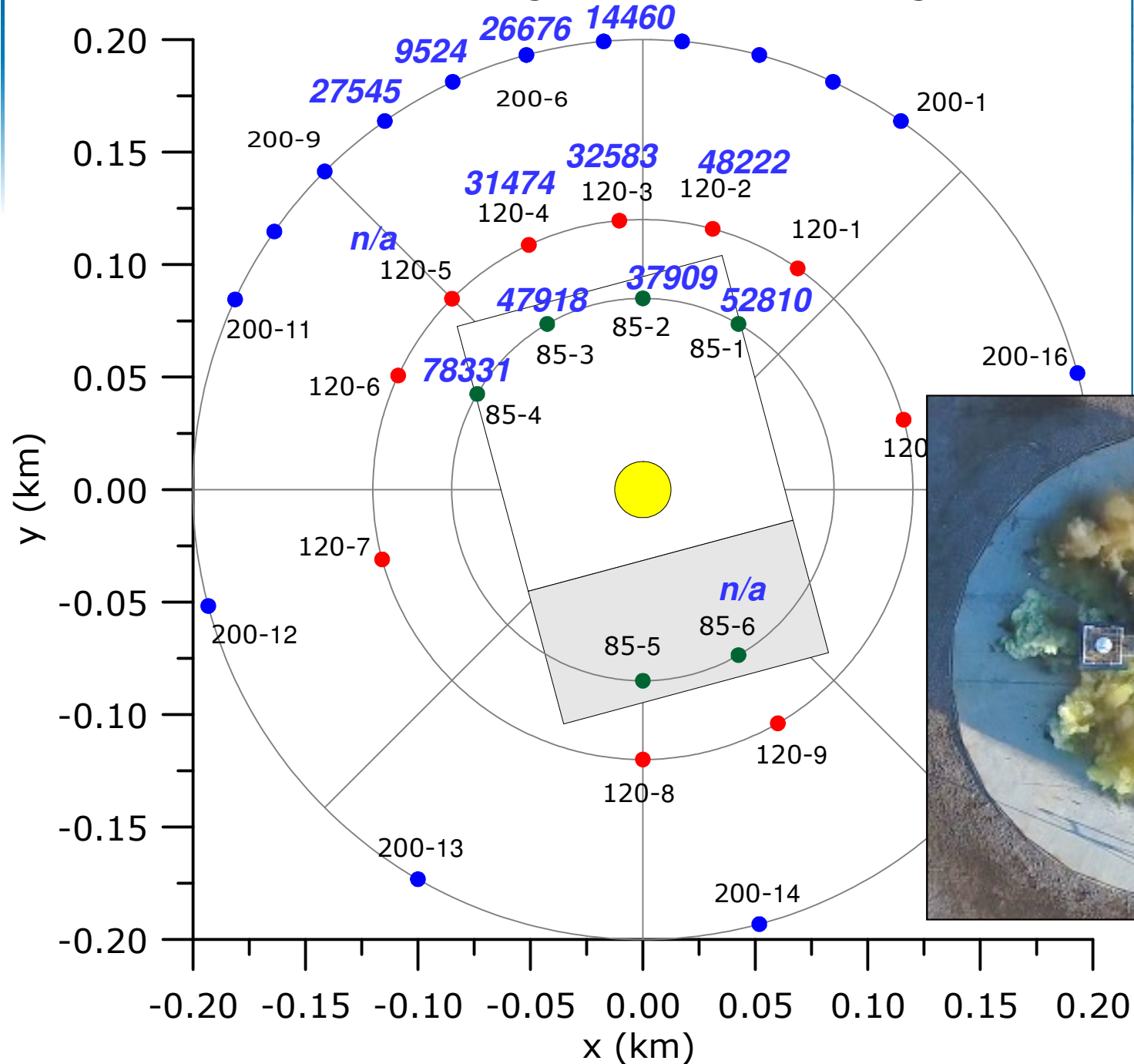


Trial 03
0° Release
Upward
10 Tons Cl₂

Preliminary
Max Conc.
Detected

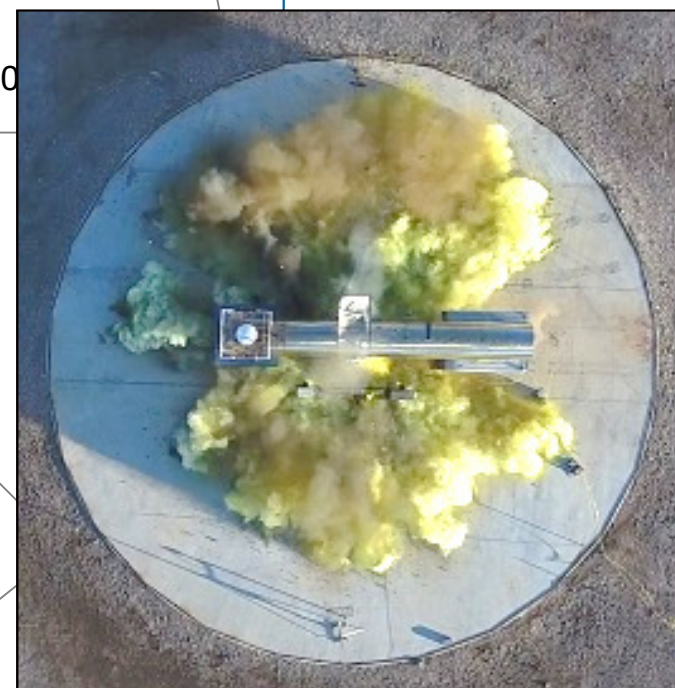


Azimuth of grid centerline: 345 deg

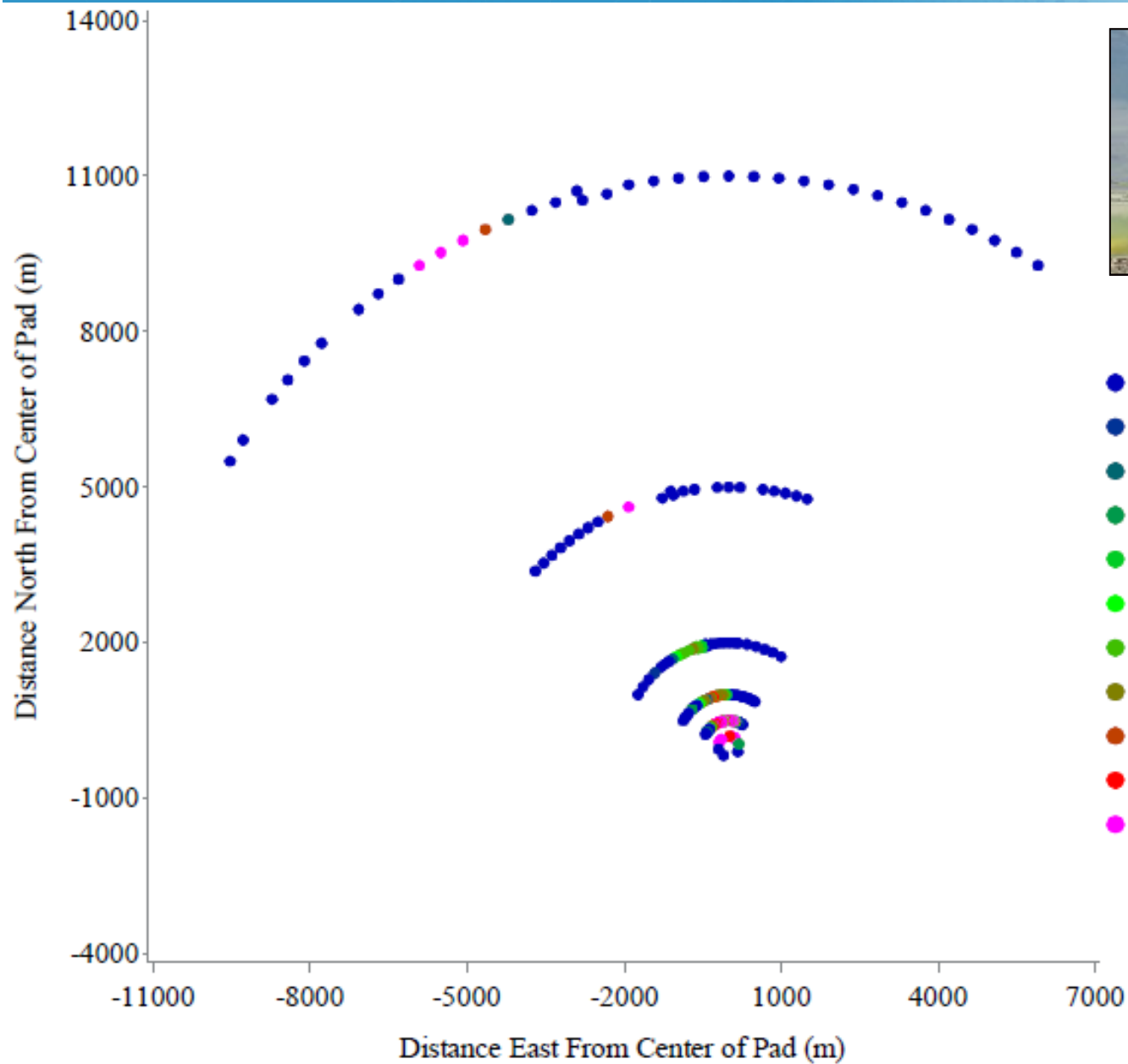


Trial 04
180° Release
Downward
20 Tons Cl₂

Preliminary
Max Conc.
Detected

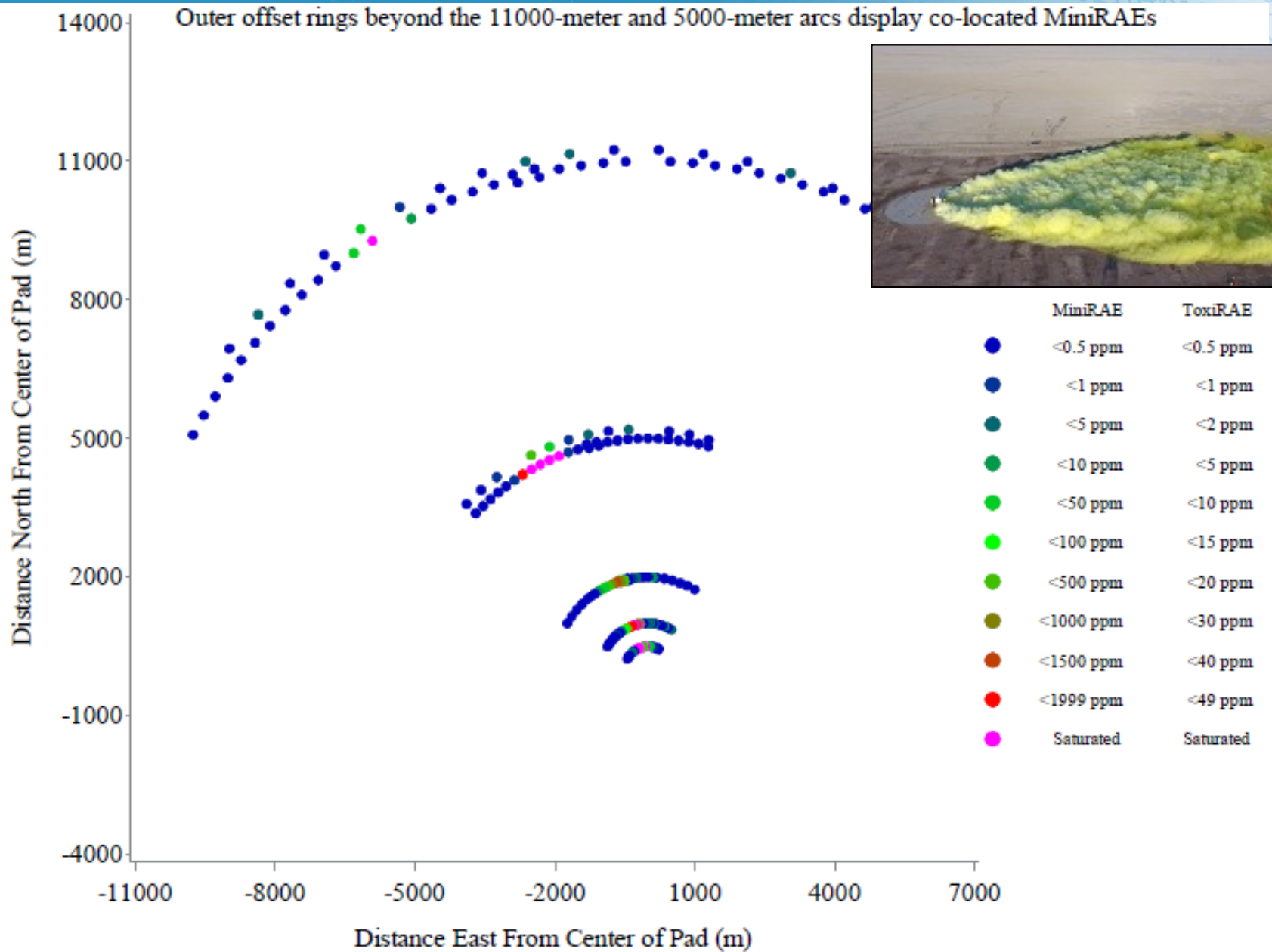


Trial 01 – Downwind Prelim. Max Conc.

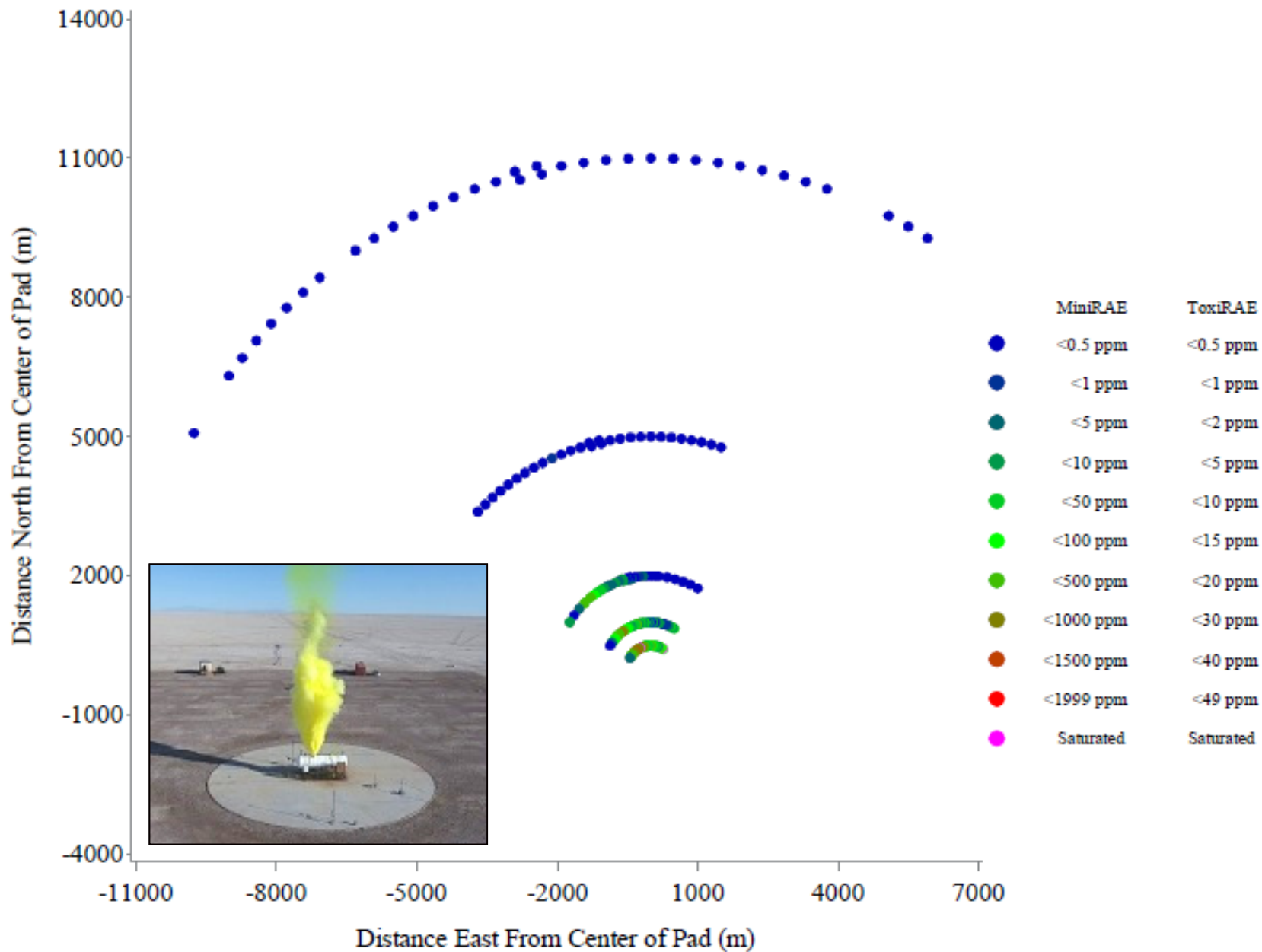


	MiniRAE	ToxiRAE
●	<0.5 ppm	<0.5 ppm
●	<1 ppm	<1 ppm
●	<5 ppm	<2 ppm
●	<10 ppm	<5 ppm
●	<50 ppm	<10 ppm
●	<100 ppm	<15 ppm
●	<500 ppm	<20 ppm
●	<1000 ppm	<30 ppm
●	<1500 ppm	<40 ppm
●	<1999 ppm	<49 ppm
●	Saturated	Saturated

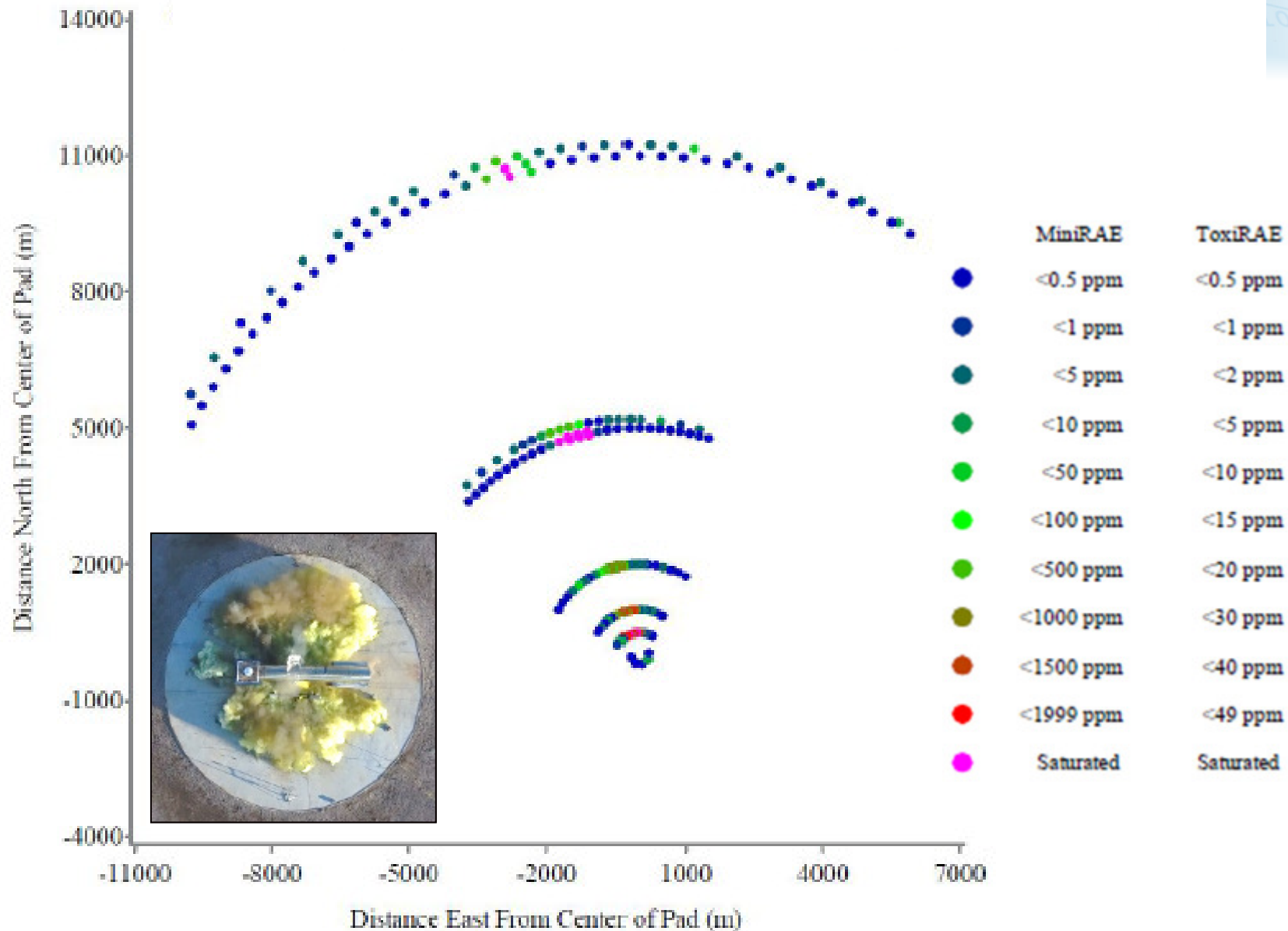
Trial 02 – Downwind Prelim. Max Conc.



Trial 03 – Downwind Prelim. Max Conc.



Trial 04 – Downwind Prelim. Max Conc.



Data and Video Transition

- Data Transition Portal for Jack Rabbit II is hosted on the Homeland Security Information Network (HSIN) and is being used to share data with stakeholders

<https://hsin.dhs.gov/Pages/Home.aspx>

- To request access, send email to: Jack.Rabbit@st.dhs.gov
- After being nominated and approved, access will be granted to the Jack Rabbit II HSIN Site:

<https://hsin.dhs.gov/ci/chm/jrwg/Pages/default.aspx>

- DHS S&T CSAC Point of Contact:

Shannon Fox: Shannon.Fox@st.dhs.gov

Program Manager, Jack Rabbit II

Utah Valley University Emergency Services

- <https://www.uvu.edu/esa/jackrabbit/>

The screenshot shows the website for the Jack Rabbit Project. At the top, there is a navigation bar with the UVU logo and 'EMERGENCY SERVICES ADMINISTRATION'. A search bar and links for 'A-Z Index', 'Contacts', and 'Find People' are also present. Below this is a secondary navigation bar with 'UNIVERSITY LINKS' and 'COLLEGES & SCHOOLS'. A third navigation bar lists various categories: 'ACADEMICS', 'AFFILIATES', 'CONTACT US', 'GALLERY', 'ADVISORY COMMITTEE', 'STATISTICS', 'JACK RABBIT', 'INTERNSHIPS', and 'TRANSFER CREDIT'. The main content area features a green header with the 'JACK RABBIT PROJECT' logo. Below the header, there is a paragraph of text describing the project's history and objectives. Further down, there are three tabs for 'Jack Rabbit I (2010)', '2015 Jack Rabbit II (Phase I)', and '2016 Jack Rabbit II (Phase II)'. A 'GALLERY' section is visible at the bottom, containing a large image of a silver tanker truck and a grid of smaller images showing various scenes from the project, including personnel in protective gear and chemical releases.

UTAH VALLEY UNIVERSITY
EMERGENCY SERVICES ADMINISTRATION

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JACK RABBIT PROJECT

In April, 2010, The Transportation Security Administration (TSA) of the Department of Homeland Security (DHS) collaborated with the Chemical Security Analysis Center (CSAC) and sponsored a series of atmospheric releases of Toxic Inhalation Hazard (TIH) materials, specifically Chlorine and Ammonia. These tests, called the "Jack Rabbit Project", were conducted in order to determine the Nation's vulnerability to TIH's in transport near sensitive populations and areas. The testing was conducted at Dugway Proving Ground in Utah.

These tests continued in 2015 using Chlorine only and were dubbed "Jack Rabbit II" (JRII). In the JRII tests, 7-9 tons of liquid Chlorine were released onto an urban test grid simulating a worst case situation in order to meet the objectives of the tests. This site is a repository of some of the results of these tests and meets the goal of the DHS in that the Nation's first responders are provided the information so that planning and operations may be adjusted to meet the challenges of a catastrophic release of a TIH in their communities.

Jack Rabbit I (2010) | 2015 Jack Rabbit II (Phase I) | 2016 Jack Rabbit II (Phase II)

GALLERY



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