DHS SCIENCE AND TECHNOLOGY

Jack Rabbit II – Update and Impacts

Homeland Security
Science and Technology

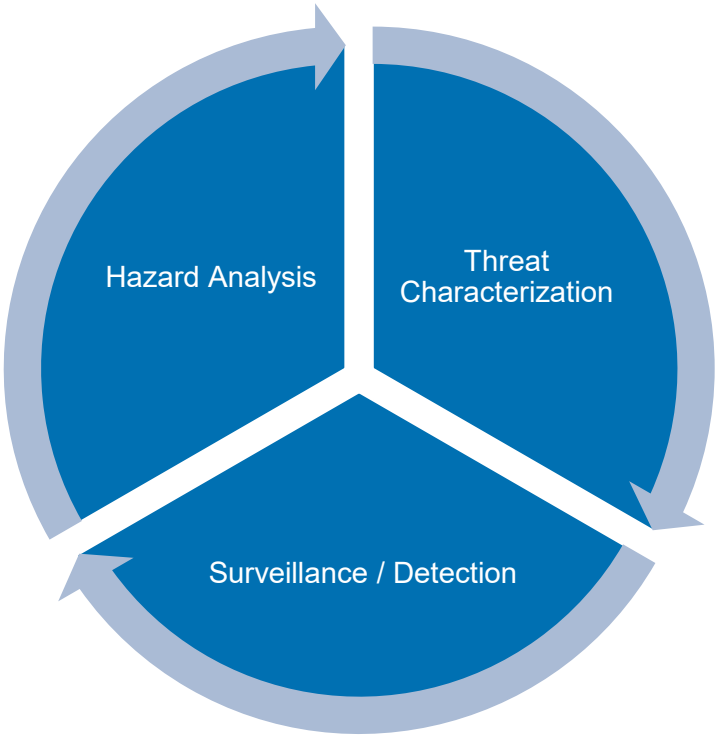
July 17, 2019

Shannon Fox
Director
Chemical Security Analysis Center (CSAC)
Science and Technology Directorate

Mission

S&T CSAC is the nation's only federal studies, analysis, and knowledge management center for assessing the threat and hazard associated with an accidental or intentional large-scale chemical event or chemical terrorism event in the U.S.

S&T CSAC is built on an Integrated Capability platform with a foundation in Modeling & Simulation and Core Subject Matter Expertise.



Chemical Hazard Analysis

- S&T-based Technical Assistance 24/7
- Bulletins
- Daily Reports / Weekly Reports
- Chemical Agent Reactions Database (CARD)
- ChemInformatics, including interagency Non Traditional Agent Library

Chemical Threat Characterization

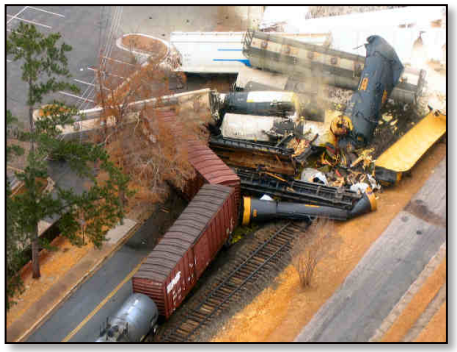
- Chemical Assessment – tailored assessments
- Chemical Characterization – assess the threat posed by the intentional use of high-consequence chemicals

Chemical Emergency Surveillance and Response – chemical detection subject matter expertise and knowledge products

Jack Rabbit Program

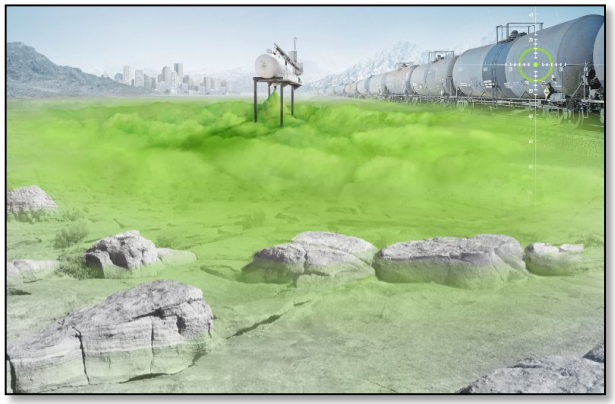
Problem: DHS and its partners and stakeholders in the HSE must better understand behavior and consequences of large-scale chlorine releases.

- 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 were not consistent with the evidence, data, and observations from previous fatal chlorine disasters
- Rapid Cl_2 releases never before tested at operationally-relevant scales
- Critical knowledge and data gaps for source terms and other phenomena relevant to modeling and emergency response
- Insufficient understanding, knowledge, and documentation of large-scale Cl_2 releases to train and prepare emergency responders

Jack Rabbit Program



Goal: Conduct a series of unprecedented large-scale chlorine release field trials to fill critical data and knowledge gaps for improved modeling and emergency response.

Objectives:

- ✓ Execute multiple chlorine release trials greater than 5 to 20 tons.
- ✓ Track and quantify downwind plume movement and concentration to 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 Cl_2 exposure on emergency response equipment and vehicles.
- ✓ Examine chlorine reactivity with soil, vegetation, and common urban materials.

Jack Rabbit II Program Sponsors

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DHS S&T Chemical Security Analysis Center (CSAC)

DoD Defense Threat Reduction Agency (DTRA)

Transport Canada and

Defence Research & Development Canada

Transport Canada

DEFENCE DÉFENSE

Federal Interagency Partners

- **DHS – S&T:** Primary program lead, sponsor, and integrator/performer
- **DHS – TSA:** JR II partner and sponsor of Scientific Advisory Group
- **DHS – CISA:** Program coordination and planning through GCC
- **DHS – FEMA**: Team of partners fielding emergency response vehicles and several important experiments relevant to first responders
- **DoD – U.S. Army Dugway Proving Ground:** Primary performer and site for test execution
- **DoD – DTRA:** Sponsor, lead scientific advisory group, onsite performer
- **DOT – PHMSA**: Sponsored indoor studies
  - **DOE – Lawrence Berkeley National Laboratory** – Indoor building and vehicle infiltration experiments

Private Sector Partners

- **Chlorine Institute and Member Companies**
  - CHLOREP team conducted all Jack Rabbit II chlorine handling operations
  - Contribution of chlorine, equipment, SMEs, and test planning
  - Volunteer participants from chlor-alkali industry member companies
- **Association of American Railroads (AAR)**
  - Volunteer participants from AAR and Rail industry member companies
- **American Chemistry Council (ACC)**
  - Coordinator and host Rabbit II Stakeholder Meetings
  - Sponsorship of onsite VIP live test observation days at DPG
- **Multiple Additional Commercial Participants and Contributors**
  - Honeywell Analytics (RAE Systems) – Sensors, Instrumentation
  - Spectral Sensor Solutions (S^3) – LIDAR
  - Signature Science

International Partners

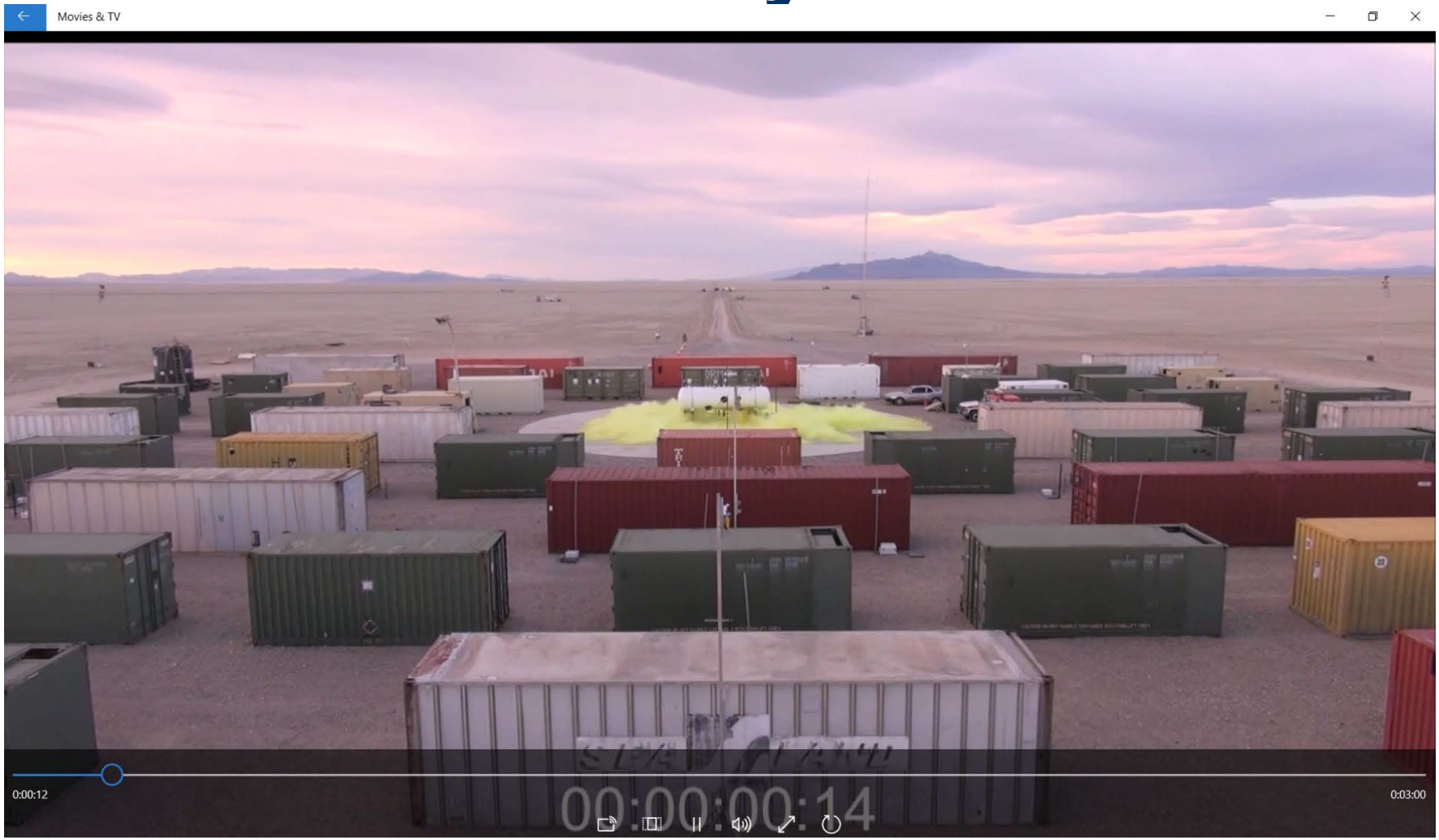
- **Singapore – DSO National Laboratories**
  - UV Camera – image capture in ultraviolet spectrum
  - VNIR Camera – Image capture within the visible, near infra-red spectrum
  - IR Camera – Image capture within the infra-red spectrum
  - Doppler LIDAR – Wind profile measurement
- **France – ARIA**
- **UK – Dstl, Health and Safety Laboratory (HSL)**
- **International Modeling Working Group**
  - 10+ Countries
  - Sponsored and led by DoD DTRA

Academia Partners

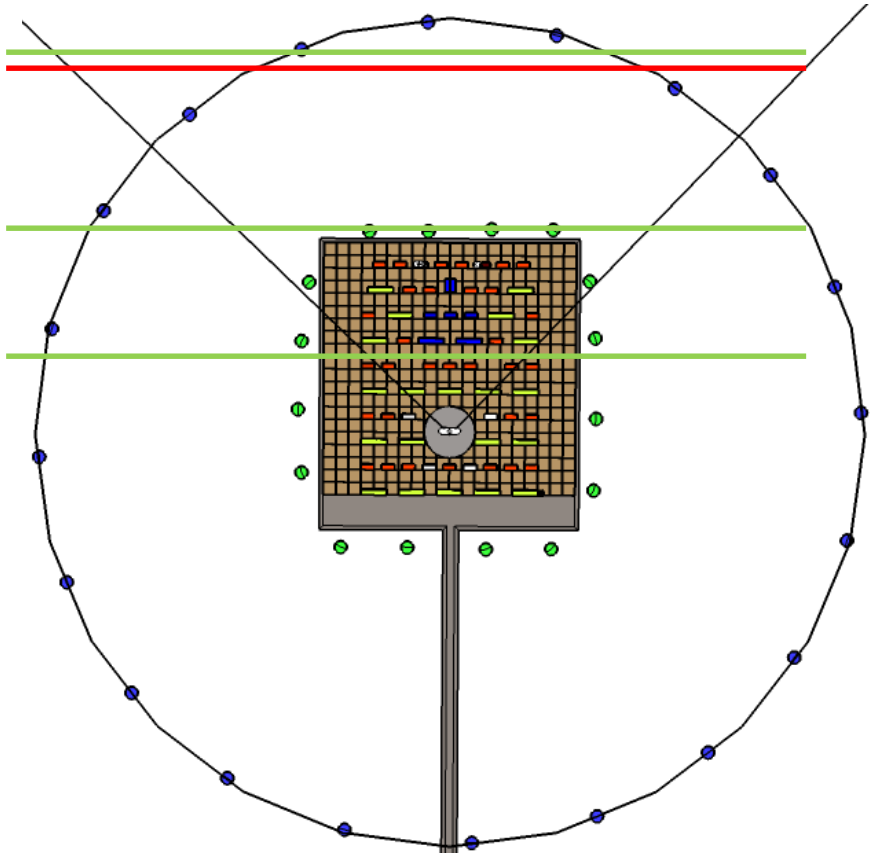
- **Utah Valley University**
  - Led team of partners fielding emergency response vehicles and several important experiments relevant to first responders
- **University of Arkansas**
  - Design of chlorine tanks, sensor payloads
  - Design of chlorine release mechanism
- **Texas A&M University**
  - Multiple field test participants
  - Deployment of sensors, data collection
- **Clarkson University**

2016 Test Site Layout

2015 Test Site Layout



Near Field Testing Grid

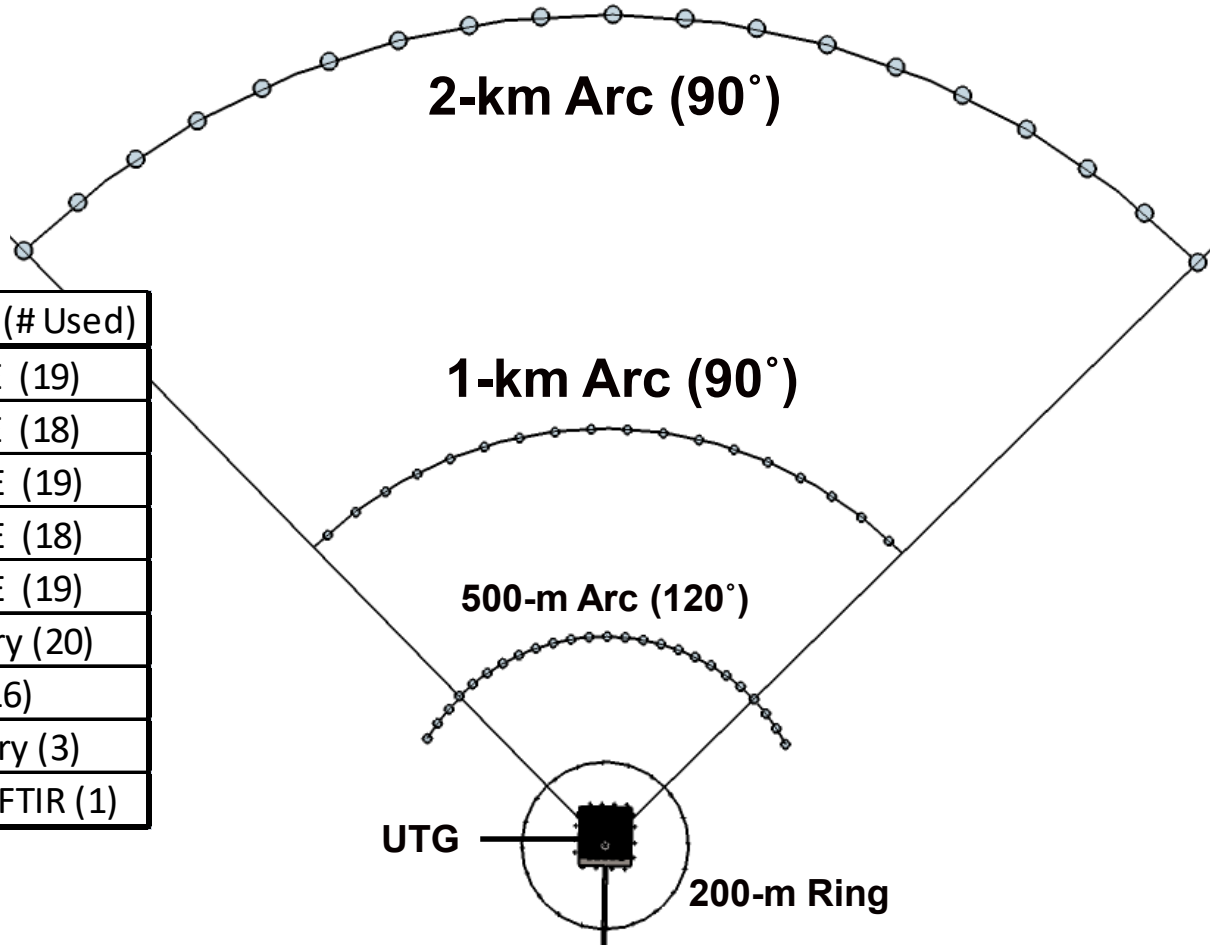


- 16 UV/Vis Jaz instruments measure Cl_2 in the near-field
- Upwind "retrograde" cloud flow, monitored at 200-m ring
- Indoor Study areas, and effect of buildings

-UV Canary
-Jaz Unit
-UV Sentry Line of Sight
-Midac OP-FTIR Line of Sight

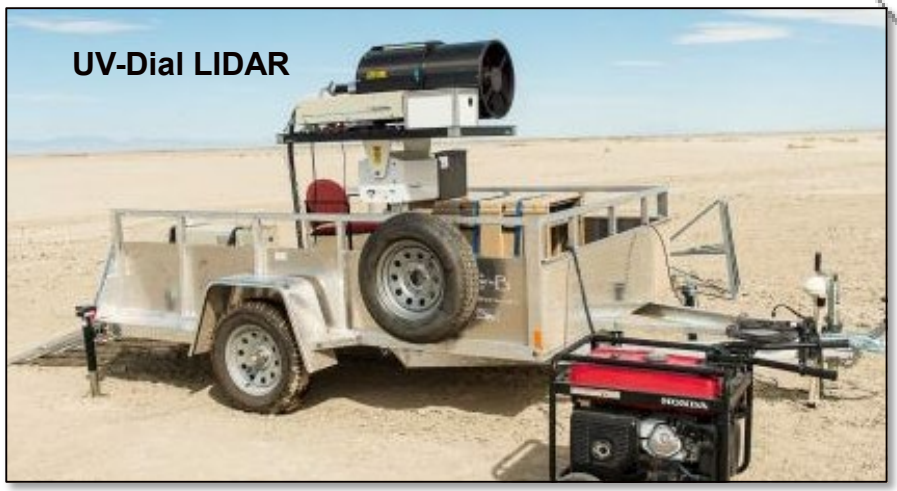
Mid-Range Test Grid

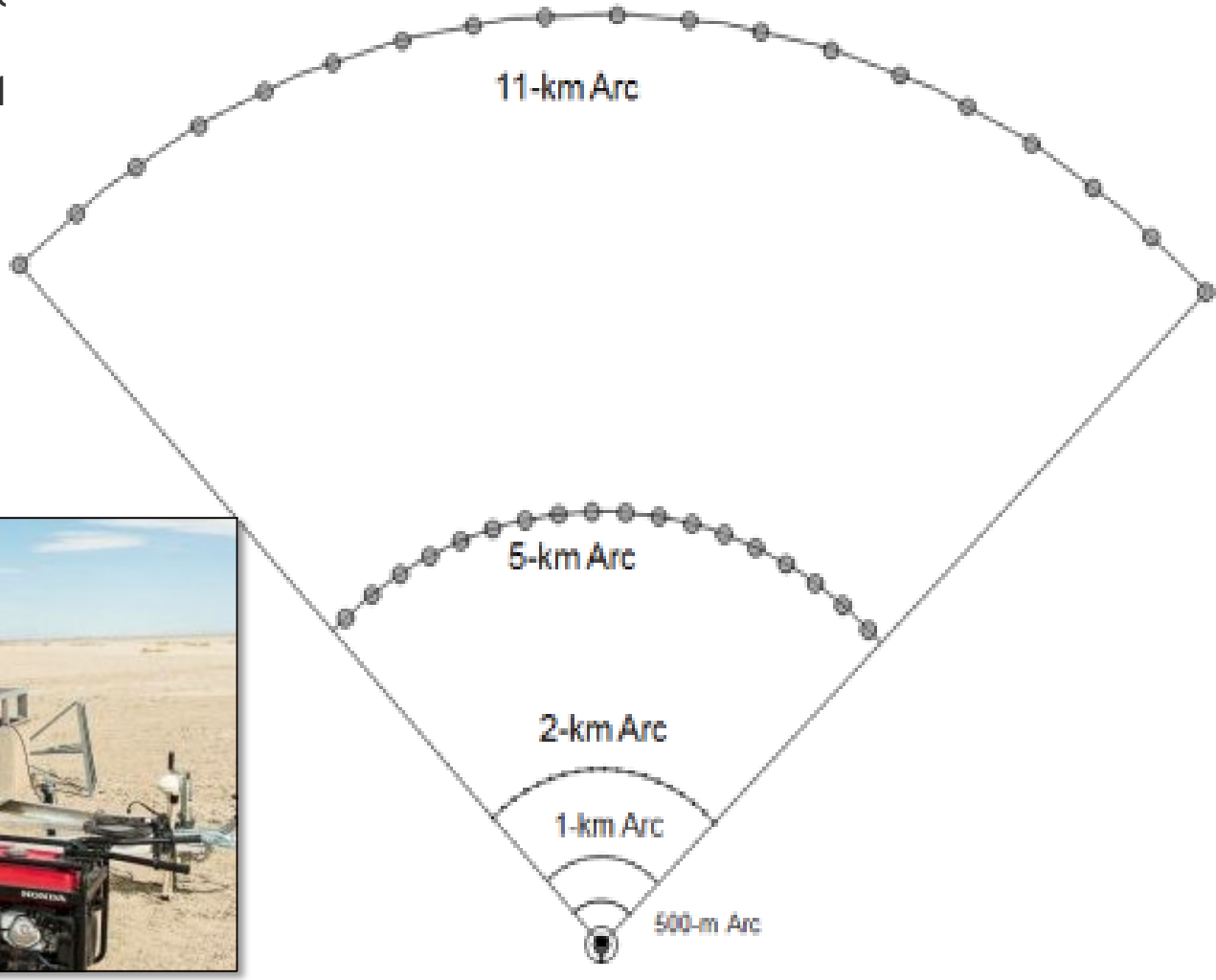
Instrumentation Location	Instrument (# Used)
11-km Arc	ToxiRAE (19)
5-km Arc	ToxiRAE (18)
2-km Arc	MiniRAE (19)
1-km Arc	MiniRAE (18)
500-m Arc	MiniRAE (19)
200-m Ring	UV Canary (20)
100-m Ring	Jaz (16)
UV Sentry	UV Sentry (3)
Midac OP-FTIR	Midac OP-FTIR (1)



Extended Test Grid

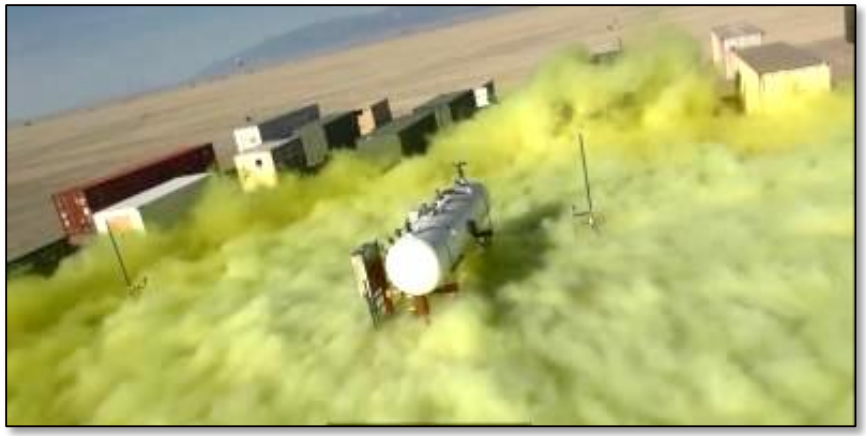
- Beyond UTG, instrument stati[illegible] positioned on arcs at 200m, 500m, 1km, 2km, 5km, and 11
- Plume tracked to 11km and beyond via 3 LIDAR stations:
  - 2 UV LIDAR (DIAL)
  - 1 Mie-Scatter LIDAR (Aerosol)





Jack Rabbit II – 2015 Testing

- 5 successful release trials from 5 to 10 tons
- Simulated urban test grid to study effect of buildings on cloud movement
- Building infiltration and shelter-in-place studies on indoor chlorine concentration
- Emergency vehicles and equipment exposure testing
- Studies of Cl_2 reactions with environment and surfaces



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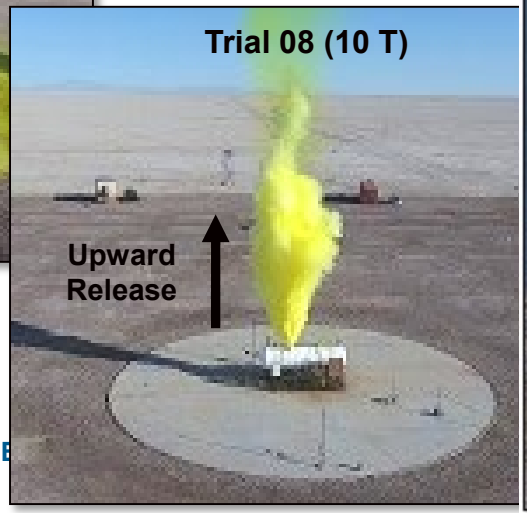
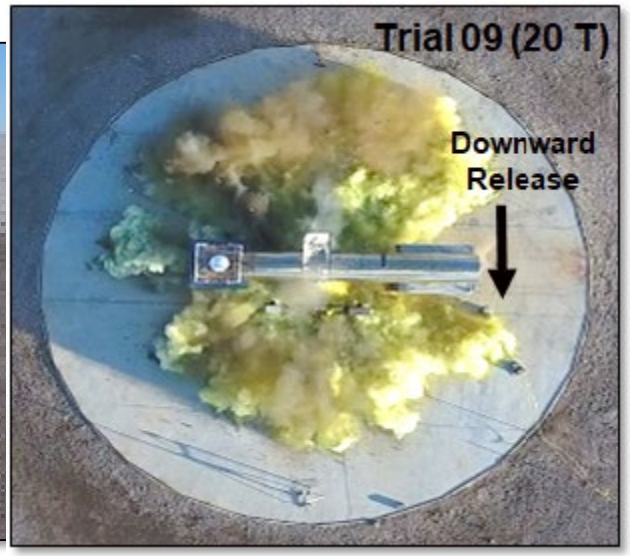
Jack Rabbit II – 2016 Testing

- 4 successful trials from 10 to 20 tons
- Measured key source term parameters
- Near-source, dynamic cloud chlorine concentrations up to 100,000 ppm
- Moderate Upwind Drift (0 to ~50 m)
- Tracked and quantify downwind plume movement and concentration to 7+ mi.

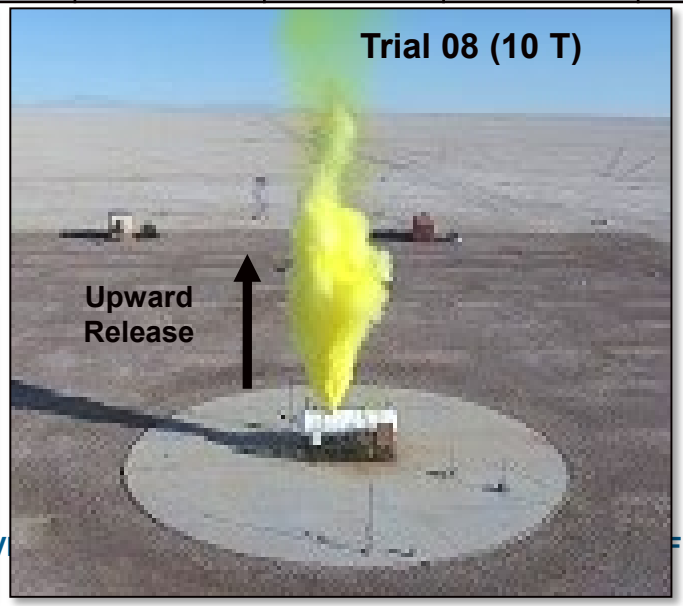


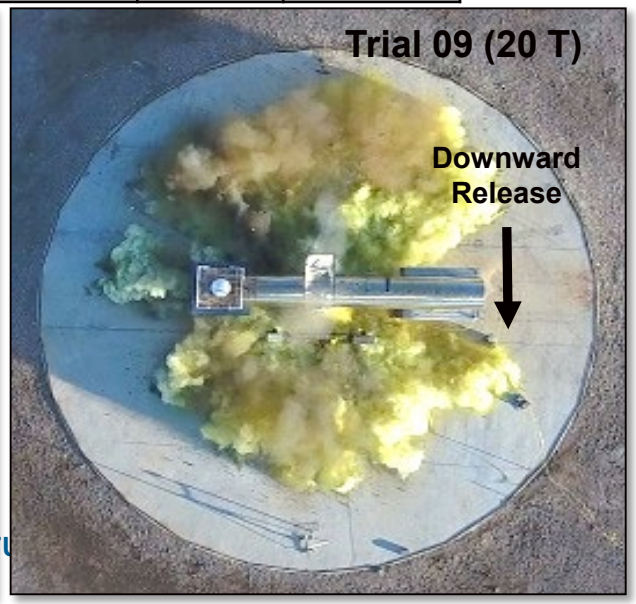


Jack Rabbit II – 2016 Testing

Maximum Downwind Cl_2 Concentration Observed

Trial	Cl_2	Angle	85 m	200 m	1 km	2 km	5 km	11 km
06	10 Tons	0º	65,000	44,000	1,900	630	> 50	> 50
07	10 Tons	135º	> 100 K	70,000	> 2,000	1,200	340	50
08	10 Tons	180º	34,000	5,000	500	200	ND	ND
09	20 Tons	0º	61,000	29,000	1,900	1,300	300	100





Emergency Response 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
  - 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
  - Command Post and and Isolation Zones

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Indoor Infiltration Experiments

- 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

Jack Rabbit II – 2016 Testing
CRADA – DHS S&T CSAC and CI

- Cooperative Research and Development Agreement (CRADA) between S&T CSAC and Chlorine Institute (CI)
- S&T CSAC utilizing new data and findings from Jack Rabbit II (JR II) program to conduct updated modeling for Pamphlet 74 scenarios
- Modeling and subject matter experts (SMEs) Working Group advised and supported new modeling for the Pamphlet 74 scenarios.
    - S&T CSAC
    - DOD DTRA Reachback
    - Chlorine Institute and Chlor-Alkali Industry Members
    - Others (EPA, University of Arkansas, IDA)
- Modeling for Pamphlet 74 utilized Department of Defense's (DoD) Threat Reduction Agency's (DTRA) Hazard Prediction and Assessment Capability (HPAC)

Chlorine Institute Pamphlet 74

- Intent of the pamphlet is to provide a simplified document to:
  - Assist chlorine producers / users, local emergency planning committees, fire departments, and municipalities
  - Estimate the area affected by a chlorine release
  - Inform emergency planning and hazard assessment activities
  - Provide a general understanding of the expectations of chlorine cloud release scenarios

Worst-Case Scenarios

150 lbs. cylinder
1-ton container
17-ton tank
90-ton Rail Car tank

Alternate Scenarios

1-Inch Pipe Failure (gas & liquid)
1-Ton Manifold (gas)
1-Ton Valve Failure (gas & liquid)
¼-Inch Tube Failure (gas & liquid)
½-Inch Tube Failure (gas & liquid)
17 Ton Valve Failure (gas/liquid)
90 Ton Relief Valve (gas/liquid)
Acid Reaction
Calcium Hypochlorite - Decomposition
150 lb. Valve Failure (gas/liquid)

Jack Rabbit II – 2016 Testing

Modeling: SME and Peer-Review Working Group

- Department of Defense – DTRA Reachback is funding several HPAC modeling and subject matter experts (SMEs) to advise and support in the new modeling for the Pamphlet 74 scenarios.
- DTRA-sponsored:
  - Ron Meris (DTRA Lead)
  - Tom Mazzola (Reachback Lead)
  - Scott Bradley (Reachback Lead)
  - Steven Simpson (Reachback, HPAC)
  - Steven Hanna (Modeling SME)
  - Joseph Chang (Modeling SME)
- S&T CSAC-sponsored:
  - Shannon Fox (S&T CSAC Lead)
  - Ray Jablonski (S&T CSAC Modeling Lead)
  - Dennis Howell (S&T CSAC Modeler)
  - Thomas Spicer (Univ. Ark. SME)
- Chlorine Institute/Industry
  - Robyn Brooks (CI)
  - Scott Wallace, Olin
  - Monica Hernandez, Formosa
  - Glenn Millner, CTEH
  - Scott Etzel, Dow
  - Neil Maxson, Covestro
  - Amy Gay/Barbara Alkis, Oxy
- Others
  - Jim Belke, EPA
  - Ian Skyes, Xator
  - Nathan Platt, IDA

Jack Rabbit II – 2016 Testing
Key Factors and Parameters Affecting Modeling

- Modeling and sensitivities studies were conducted to determine the key factors and parameters that have the greatest impact on the modeling results
- Parameters updated based upon new Jack Rabbit II field trial results and findings:
  - Source Term Definition
  - Chlorine Reactivity / Dry Deposition
- Parameters being updated based on Environmental Protection Agency (EPA) guidance and modeling Subject Matter Expert discussions
  - Use of Emergency Response Planning Guidelines (ERPGs) criteria, but with 10 minute averaging time

Argonne National Laboratory Chlorine Deposition Experiments

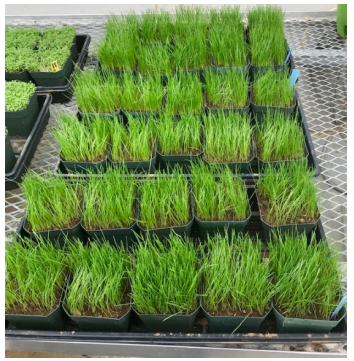
- In 2016, Argonne National Laboratory completed study and analysis of chlorine reactivity experiments
- Sponsored by DOT – PHMSA
- Initial maximum chlorine concentration set to 50 ppm due to limit of analytical instruments
- Several species of vegetation and mixtures of soils were exposed to chlorine in reaction chambers
- Analysis of this data has determined the maximum capacity of soil and plant species to react with chlorine
- Maximum capacity ranged from 600 to 5000 mg/m^2 depending on ground surface type
- Estimation of reactivity “cut-off” allows more much more realistic and accurate accounting for deposition in modeling

Current Experimental Program

Experiments at multiple velocities (0.25, 0.5, and 1 m/s) with initial chlorine concentration of 1000 ppm

Test Materials

- Bare soil (single moisture)
- Clover in soil
- Rye grass in soil
- Spruce (PVDF mount)
- Maple leaves (PVDF mount)



- Chlorine gas phase concentrations measured with JAZ instrument (Jack Rabbit II tests).
- Chloride concentrations in test materials measured using ion chromatography.

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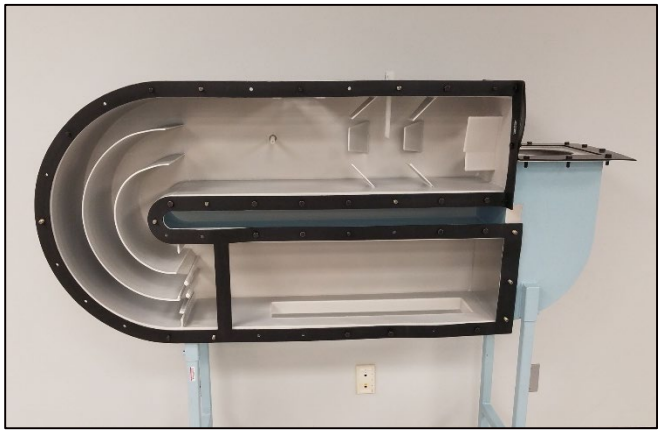
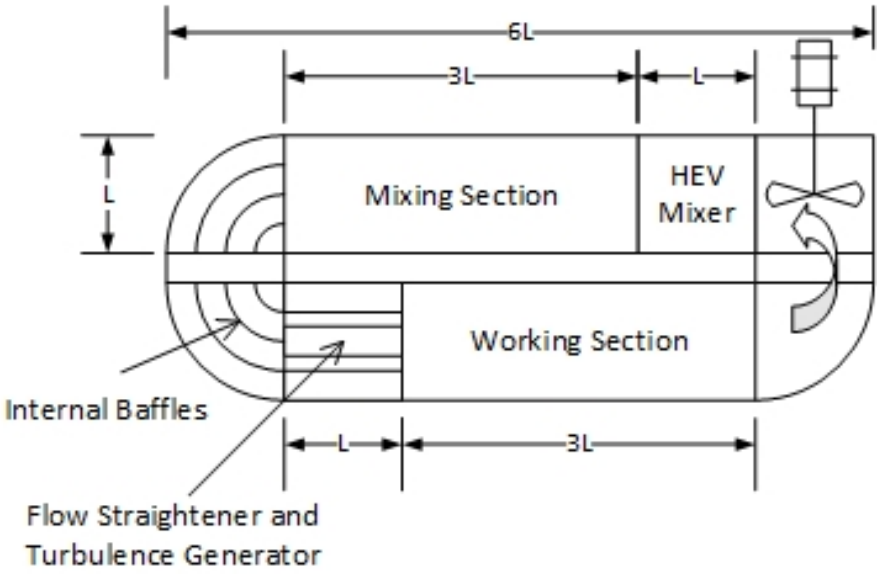
New Chlorine Reactivity Study Recirculating Test Chamber





- Working section is 75 cm long with 25 cm x 25 cm cross section.
- Apparatus internals coated with Kynar.
- Peroxide cured EDPM gasket.
- Kynar injection quills, tubing, and fittings.
- JAZ instruments for gas phase concentration

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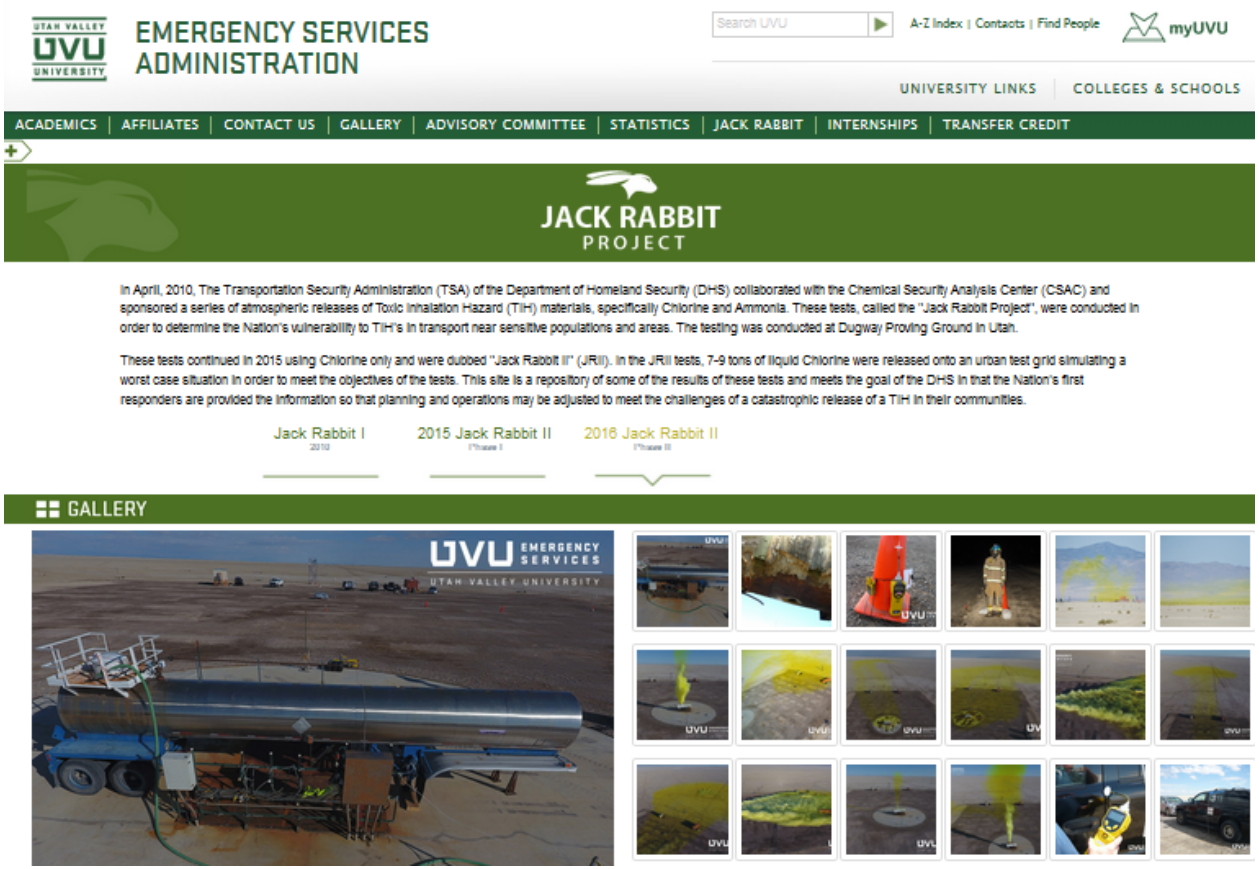
Utah Valley University Emergency Services

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



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DIVERSE PERSPECTIVES + SHARED GOALS = POWERFUL SOLUTIONS