2021
CHEMICAL SECURITY SEMINARS

December 1, 2021

#ChemicalSecurity

CHEMICAL SECURITY SEMINARS

Jack Rabbit III Program Updates

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U.S. Department of Homeland Security

SCIENCE AND TECHNOLOGY DIRECTORATE

Jack Rabbit III Update

Science and Technology

Jack Rabbit (JR) III Team
Chemical Security Analysis Center (CSAC)/Office of National Laboratories (ONL)

December 1, 2021

Jack Rabbit:

Filling critical hazard prediction data gaps in ATD modeling for emergency planning and response to toxic inhalation hazard chemical releases

Ammonia Basin Release

Chlorine Basin Release

JR III update: Agenda

- Goal and Objectives
- Jack Rabbit III Timeline
- Research & Development Activities
  - Ammonia hazard laboratory experiments
  - Wind tunnel study
  - Small-scale outdoor ammonia release (SOAR) field trials
- Jack Rabbit III Strategic Approaches
  - Scientific advisory group
  - Partnering opportunities
- Summary and Path Forward
- Acknowledgements

JR III goals and objectives

Characterize threat, analyze critical gaps, conduct studies, execute experiments to improve the accuracy of ATD software models, and develop more realistic hazard plume modeling for operational emergency management providing situational awareness and data driven guidance in all phases of emergency response to chemical supply chain incidents

Assess

To identify and decompose toxic industrial chemical modeling gaps and design and conduct a series of field experiments at scales representative of threats posed by anhydrous ammonia surface transportation and collect a suite of comprehensive field data using state of the art instrumentation.

Prepare

To introduce better planning mechanisms of integrating plume models in all phases of emergency response and provide emergency response professionals with unique and improved training capabilities relating to the chemical supply chain thereby enhancing on-scene situational awareness.

Respond

To equip professionals with advanced multifunctional sensing and surveillance technologies and a scientific understanding of hazards. Introduce novel capabilities to protect emergency responders, first responders, and civilians present in affected areas.

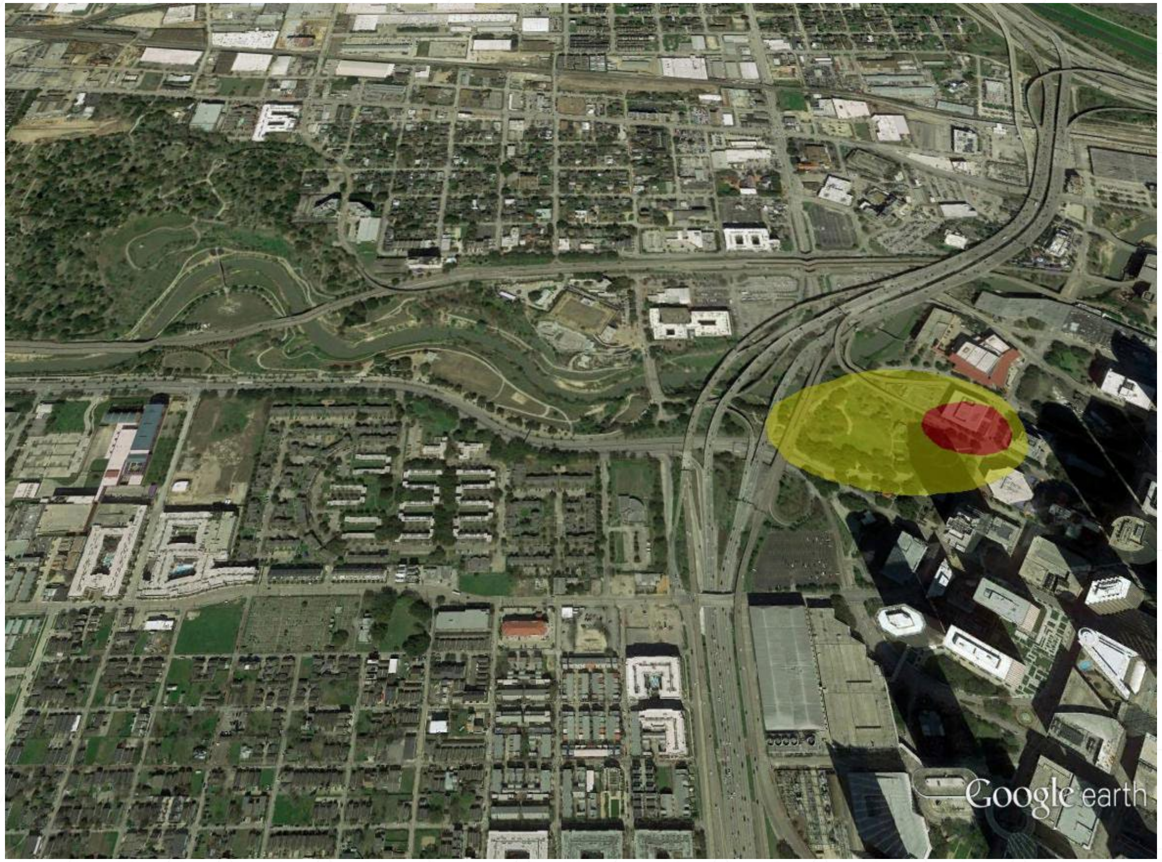
Recover

To develop strategies for countermeasures and recommend efficient decontamination solutions to expedite recovery from accidental or intentional chemical releases and minimize effects of incidents minimizing human casualties and disruption of commodity flow in critical supply chains.

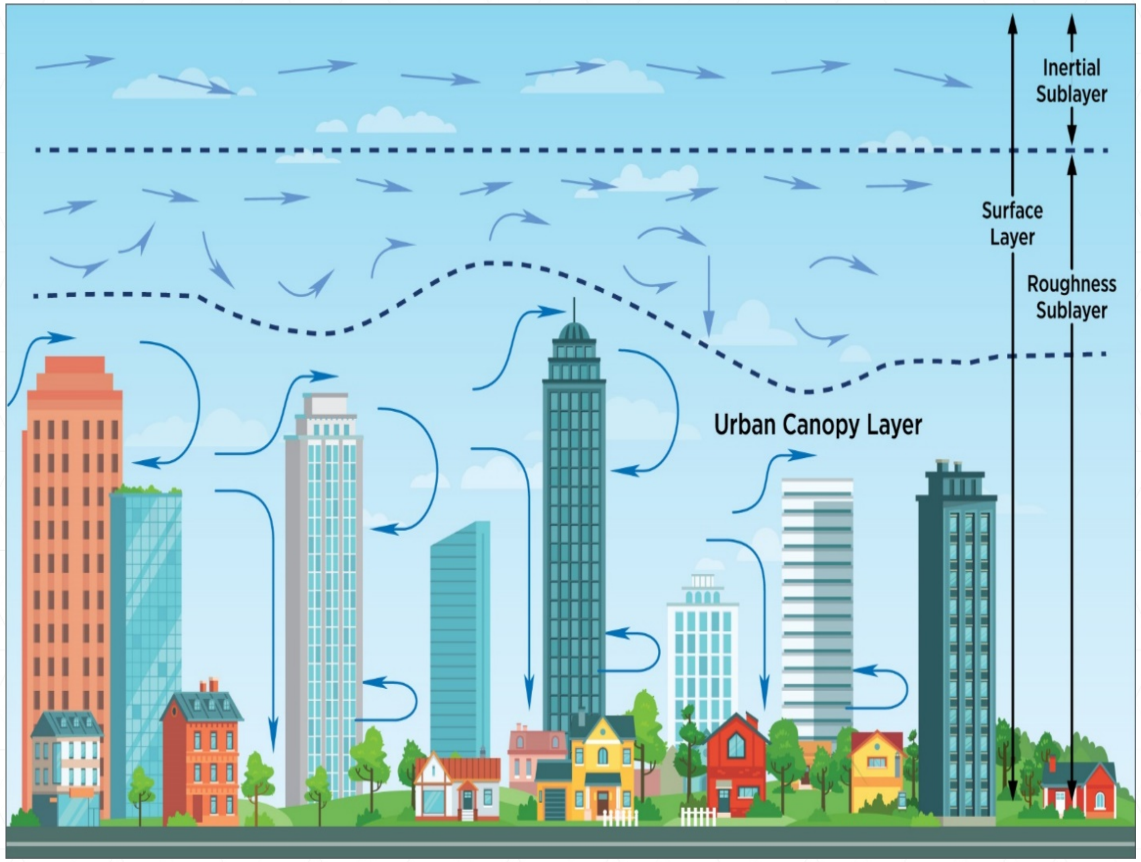
Sustain

To identify the needs of critical chemical infrastructures that synthesize, store, package, and distribute chemicals via all transportation modes for consumers from the perspective of regulatory agencies, manufacturing facilities, trade associations, and emergency services.

ASSESS: Improve hazard prediction and chemical dispersion modeling



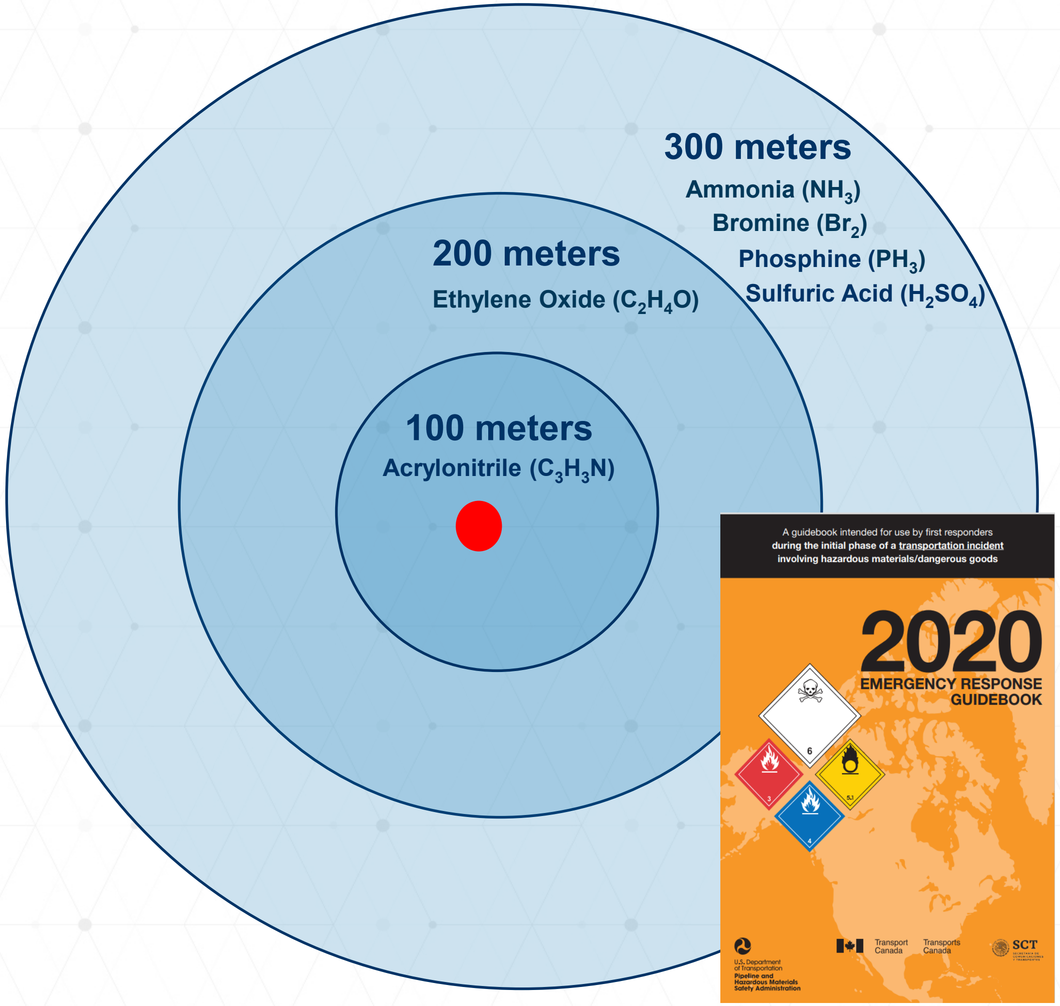
Modeling 50-ton ammonia release as atmospheric gas cloud



Schematic of flow through and over an urban area

PREPARE: Provide emergency planning, tabletop exercises, and increased public awareness

Initial Isolation Distance for Large Spills

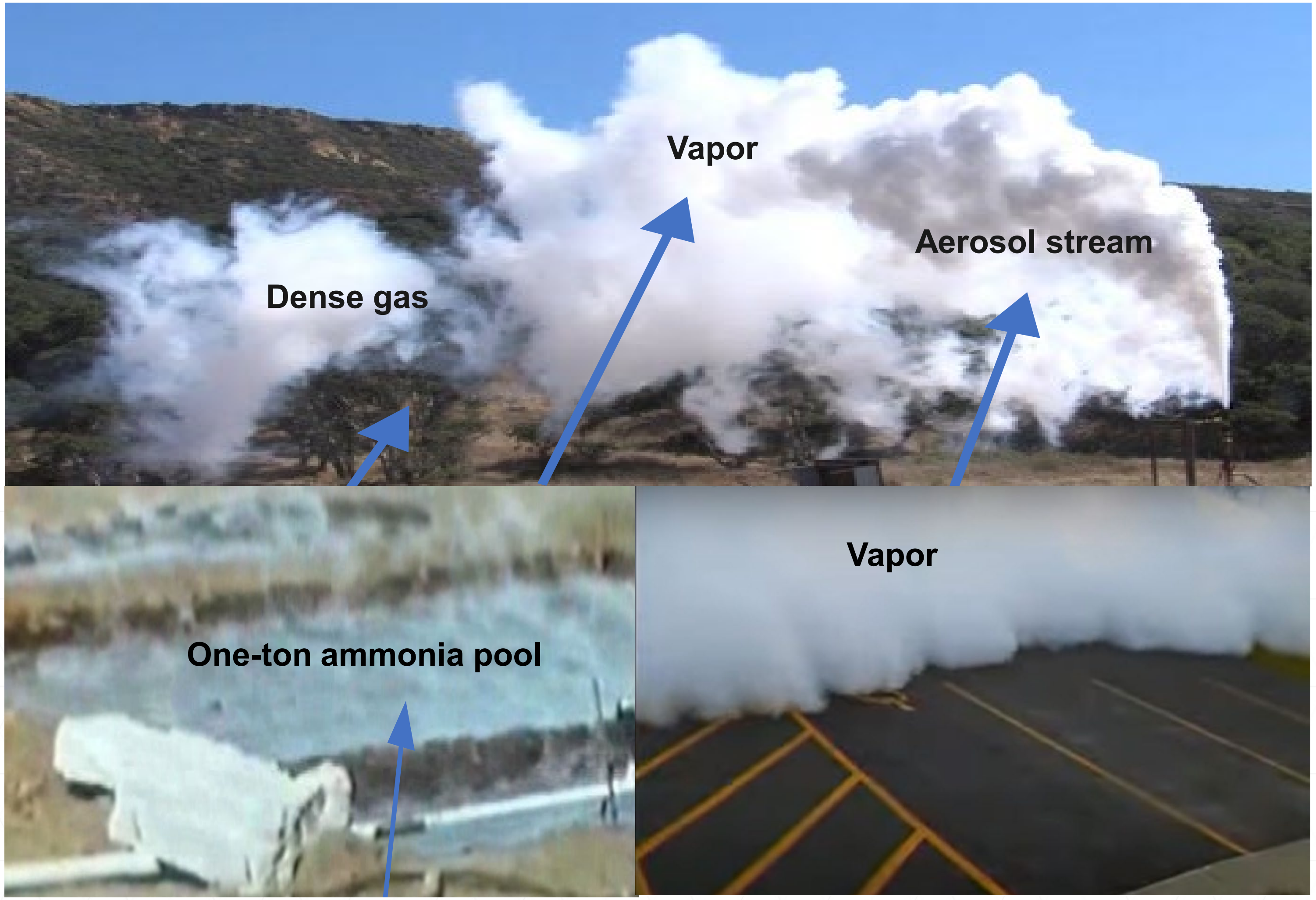


Health effect	Anhydrous Ammonia Concentration (ppm)						
	1	10	100	1,000	10,000	100,000	1,000,000
Mild irritation to upper respiratory track: pungent odor threshold (> 5 ppm)			Odor				
Moderate irritation to eyes, nose, throat, and chest: OSHA PEL: 8-hr TWA			50 ppm				
Serious, irreversible effects: ERPG-2 (1 hour)				150 ppm			
Life-threatening effects, intense irritation, excessive lacrimation: NIOSH IDLH				300 ppm			
Serious lung damage, death if not treated: emergency entry with level A & B PPE level						1,000 ppm < Level A or B PPE	
Burning, blistering of skin: emergency entry with level C PPE				300 ppm < Level C			
Flammability threat: fire and explosion hazard (NOTE: threshold will be lower if mixed with oil)						15-28%	
Immediately fatal to humans: pure anhydrous ammonia gas							<100%

RESPOND: Advance detection and protective equipment technologies

- DHS FEMA IMAAC: Rapid response (< 30 minutes)
- DHS FEMA ChemResponder: Networked information sharing operational tool for incident data collection and management during an emergency
- DTRA R&D: Dynamic plume modeling
- EPA Aerial spectral photometric environmental collection technology (ASPECT) – Fully operational 24/7/365 readiness
  - Infrared line imager
  - High-speed infrared spectrometer
  - High-resolution digital aerial cameras
  - Broadband satellite data system
  - Gamma-ray spectrometer
- DHS CSAC 24/7 Technical Assistance

RECOVER: Develop countermeasures and cultivate decontamination strategies



SUSTAIN: Safeguard critical infrastructure and devise hazard mitigation strategies

Jack Rabbit III program update

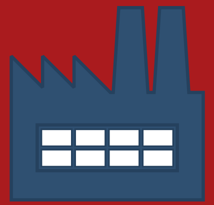
	4Q FY21 – 3Q FY22	4Q FY22 – 3Q FY23	4Q FY23 – 3Q FY24	4Q FY24 – 3Q FY25	4Q FY25 – 3Q FY26
Requirements	Official Requirements				
Chemical Threat Characterization	Toxic Gas Hazard Mapping Interview Fertilizer Industry & First Responders				
Collaboration	Official Endorsement of Collaboration Agreements Scientific Advisory Group and Working Groups: Testable Requirement & Solution Development & Transition Cooperative Research and Development Agreement				
Laboratory Experiments	Chemical Reactivity Study Laboratory Experimentation Ammonia Surface Deposition Study			Laboratory Experimentation	
Field Trials	Field Trial Small Scale	Test Site Facility Survey	Middle Scale Release Test Report of Mid-Scale & Test Plan for Large Scale Outdoor Release	Field Trials Large Scale Release Field JR III Report: Technology & Capability Transfer	

Industrial safety and security of ammonia production, transportation, and emergency response readiness

- **First Responders**
- **Fertilizer Industry**
- **Ammonia Industry Trade Association**
  - **The Fertilizer Institute**
  - **Ammonia Energy Association**
  - **Association of American Railroads**
  - **IIAR**
  - **Global Cold Chain Alliance**
  - **National Tank Truck Carrier**
- **Ammonia Hazmat/Safety Oranization**
  - **TRANSCAER**
  - **CTECH**
  - **Safety Training Institute**
- **Ammonia Supply Chain Actors**
  - **GRAMMER**
  - **Airgas**
  - **KIRBY**

Emergency Response (2020 Survey)

- Photoionization detectors/gas monitors are favored
- Wireless connectivity is highly valued
- Drones, temporary tent shelters, and ChemResponder can be useful for large-scale ammonia leaks but needs to be at state-level hazmat teams
- Drone technology may be more valuable for search/rescue/damage assessment application



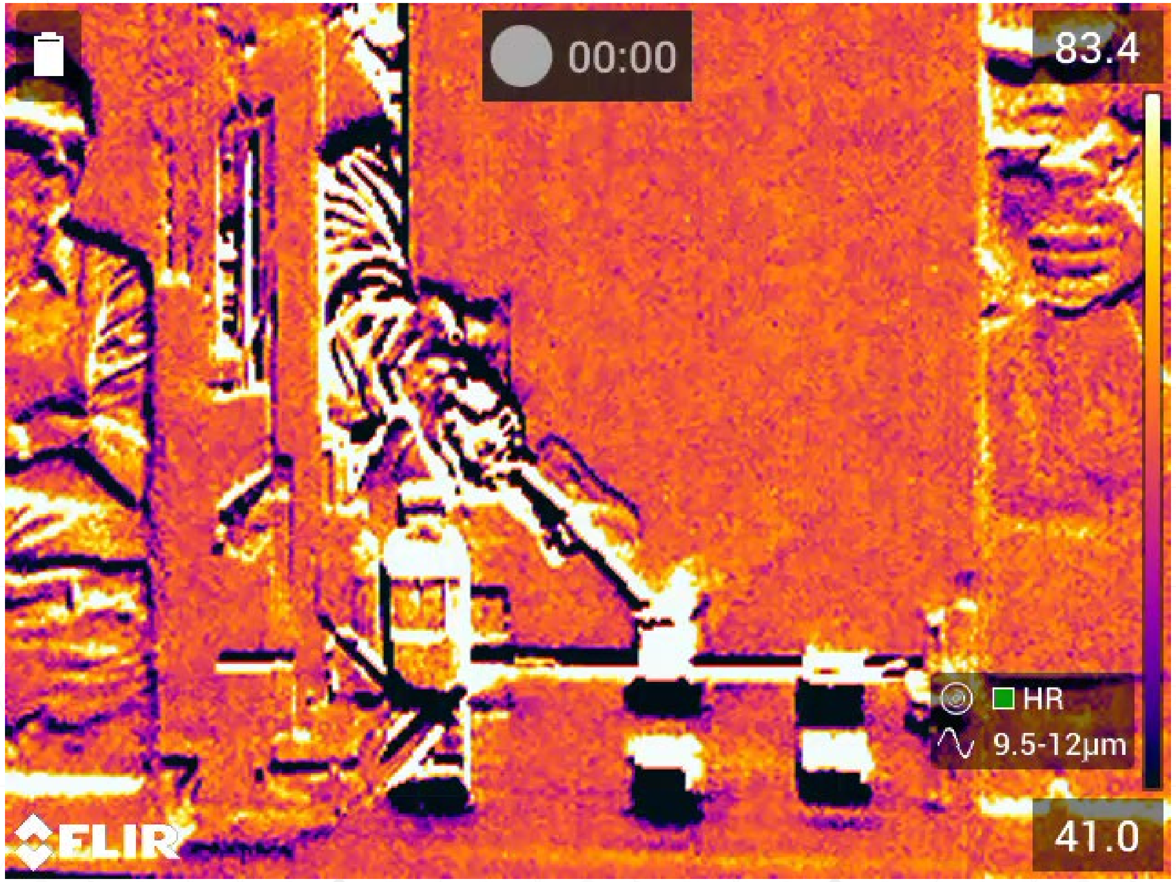
Technology

- Inadequate PPE for first responders
- Need innovative miniaturized sensors (interfaced with drones, mounted on unmanned platforms, wireless remote sensors)

Capability

- Lack of hazard mitigation strategies, chemical countermeasures, and decontamination capability
- Poor public awareness of anhydrous ammonia hazards

Laboratory-scale liquified anhydrous ammonia releases and detection technologies



An infrared detector is used to visualize the resulting plume after liquid ammonia is poured into a beaker containing 4% ammonia in water (left) and poured onto a concrete coupon (right)

Wind tunnel model

Jack Rabbit II field trial 1

Flow visualization of the physical scaled model

Overview of small-scale field trial

The SOAR trials were a multi-agency effort to demonstrate advanced technologies and prove concepts to build a collaborative framework of sound technologies for the JR III large-scale, two-phase ammonia release.

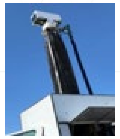
The focus of this demonstration was to evaluate the latest technologies that could potentially improve emergency response capabilities and to maximize utilization of hazard prediction models and live data feed detection systems on a common information sharing platform.

- **JR III advanced technology demonstration included:**
  - **Gas Cloud Imaging (GCI) System**
  - **ASPECT: Infrared Line Scanner (IRLS) and Versatile Spectroradiometer (VSR)**
  - **ChemResponder: Real-time display of sensor data and atmospheric hazard plume modeling**
- **Test grid layout of ammonia release**
- **Summary of trials and conclusions**
- **Recommendations by emergency responders**

Test grid and referee system layout

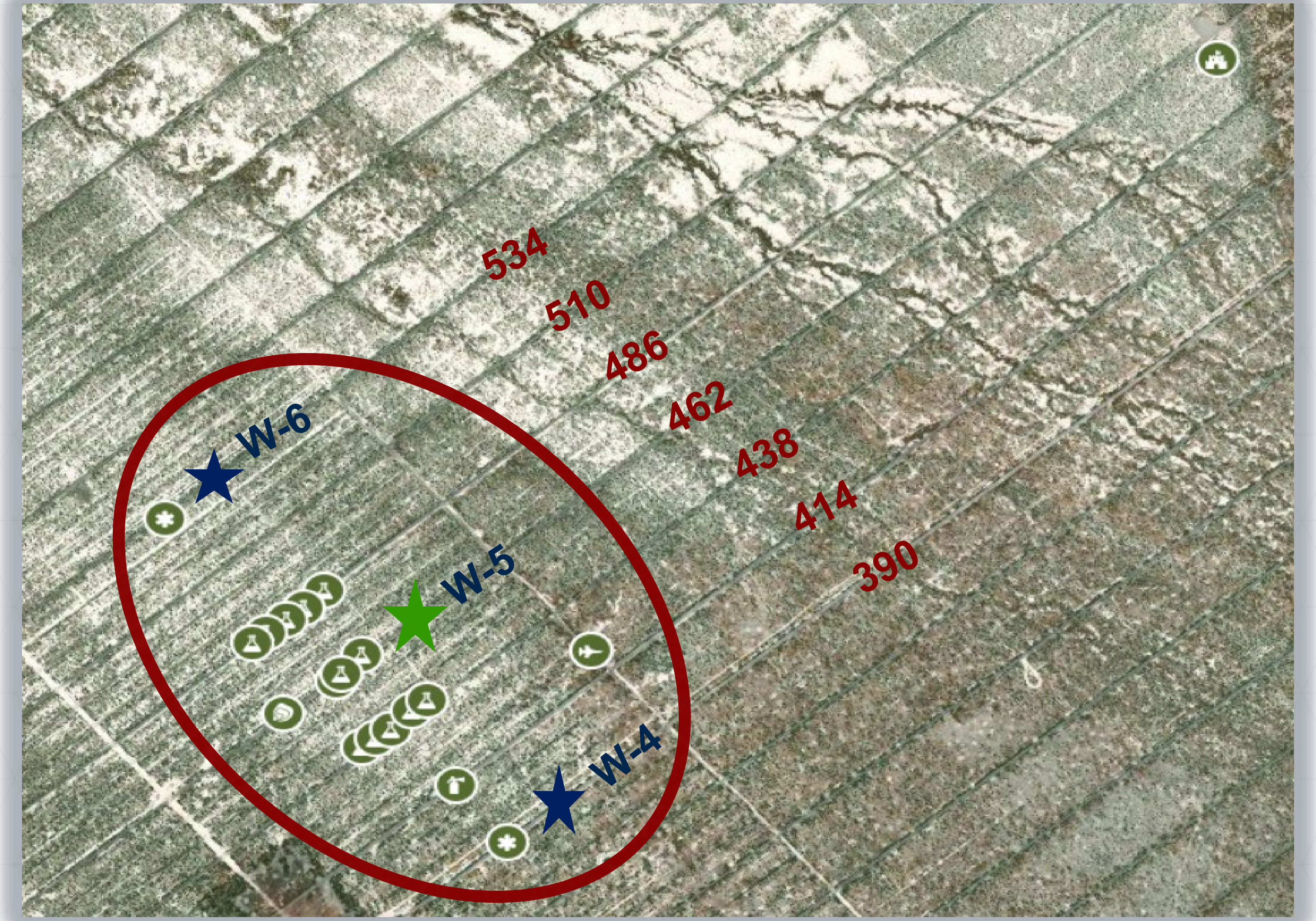
Gasmet™ DX-4000

MiniRAE/ RAELink



Gas Cloud Imaging

Ammonia Cylinder



Command Post

ASPECT

Anemometer

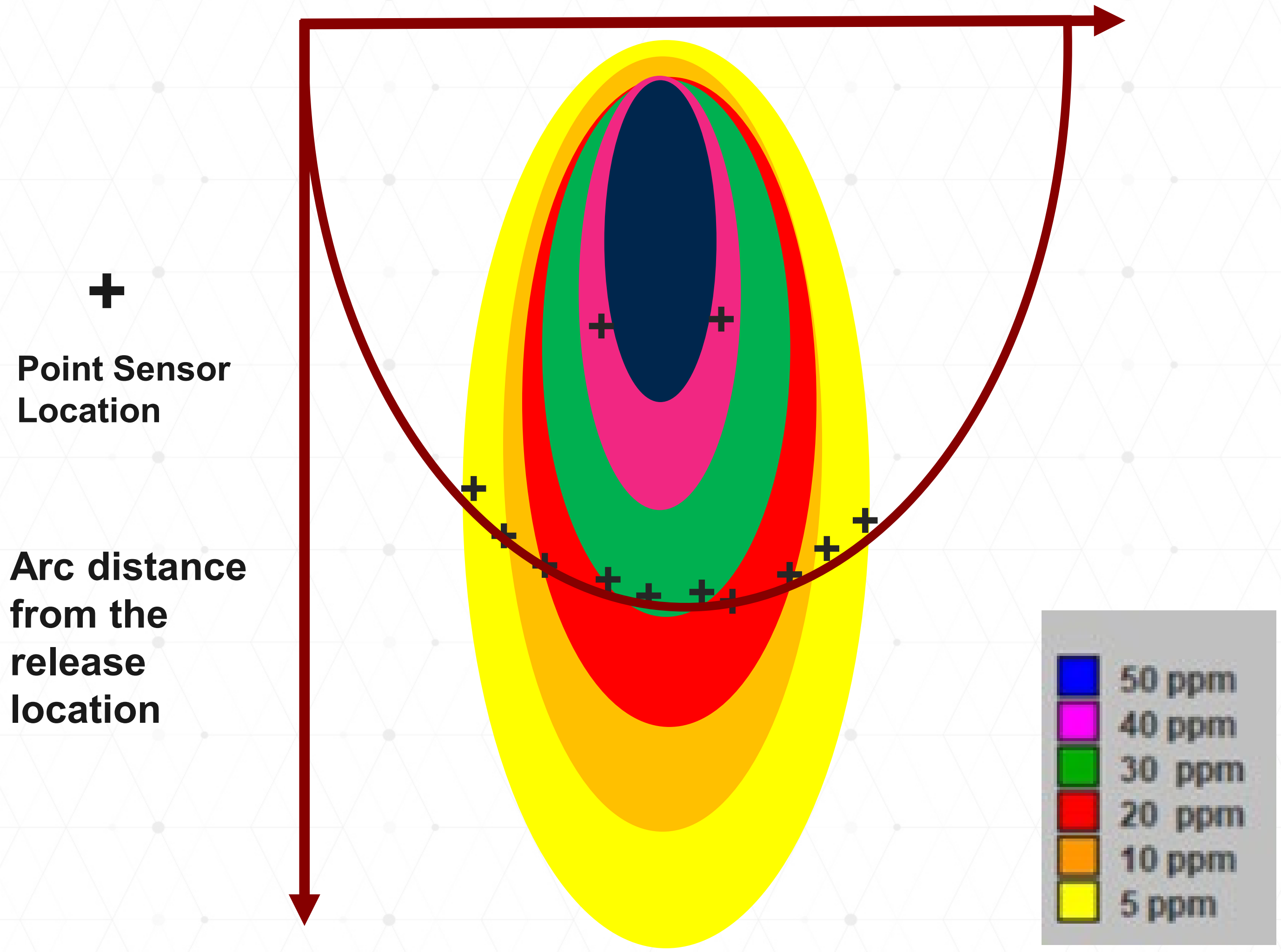
PWIDS

Anhydrous ammonia release

Event	Trial Period* 3:21-3:36 MDT (09:21-09:36 UTC) on October 6, 2021.
Cylinder Dissemination Started	3:25 AM MDT (09:25 UTC)
Cylinder Reported Empty	3:30 AM MDT (09:30 UTC)
Ammonia Release Location	324416 E 443609 N (Latitude: 40.06073253, Longitude: -113.0583859)
Ammonia Release Amount	45 pounds (3 cylinders)
Release Height	83 inches
Wind Direction and Speed Temperature Relative Humidity Pressure	145° (SE) at 3.91 m/s 13.72 °C 78.3 % 868 mb

* Pre- and post-background collection periods were included by the testing agency

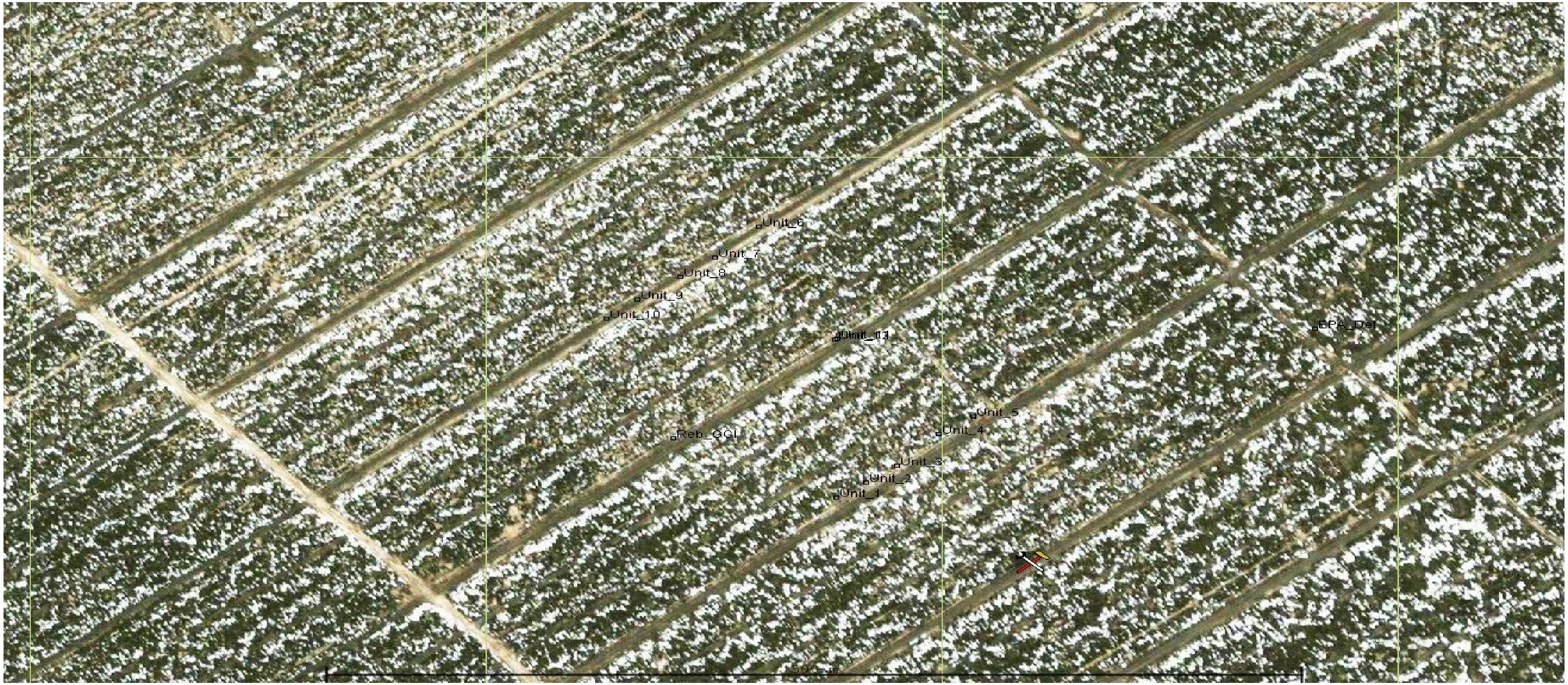
JR III SOAR planned sensor placement using concentration contour profile



Required Release Site Inputs

- Chemical data
- Source data: release duration, tank volume, and total amount released
- Atmospheric data: wind, ground roughness, stability class

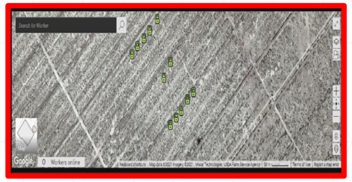
Actual SOAR modeling output



Standoff Detection:
Honeywell Rebellion gas cloud imaging system

Wireless sensor network detection

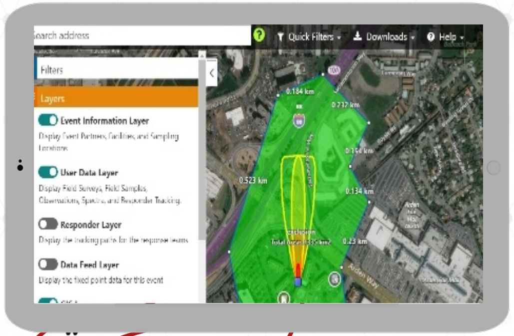
Safety Suite



Antenna

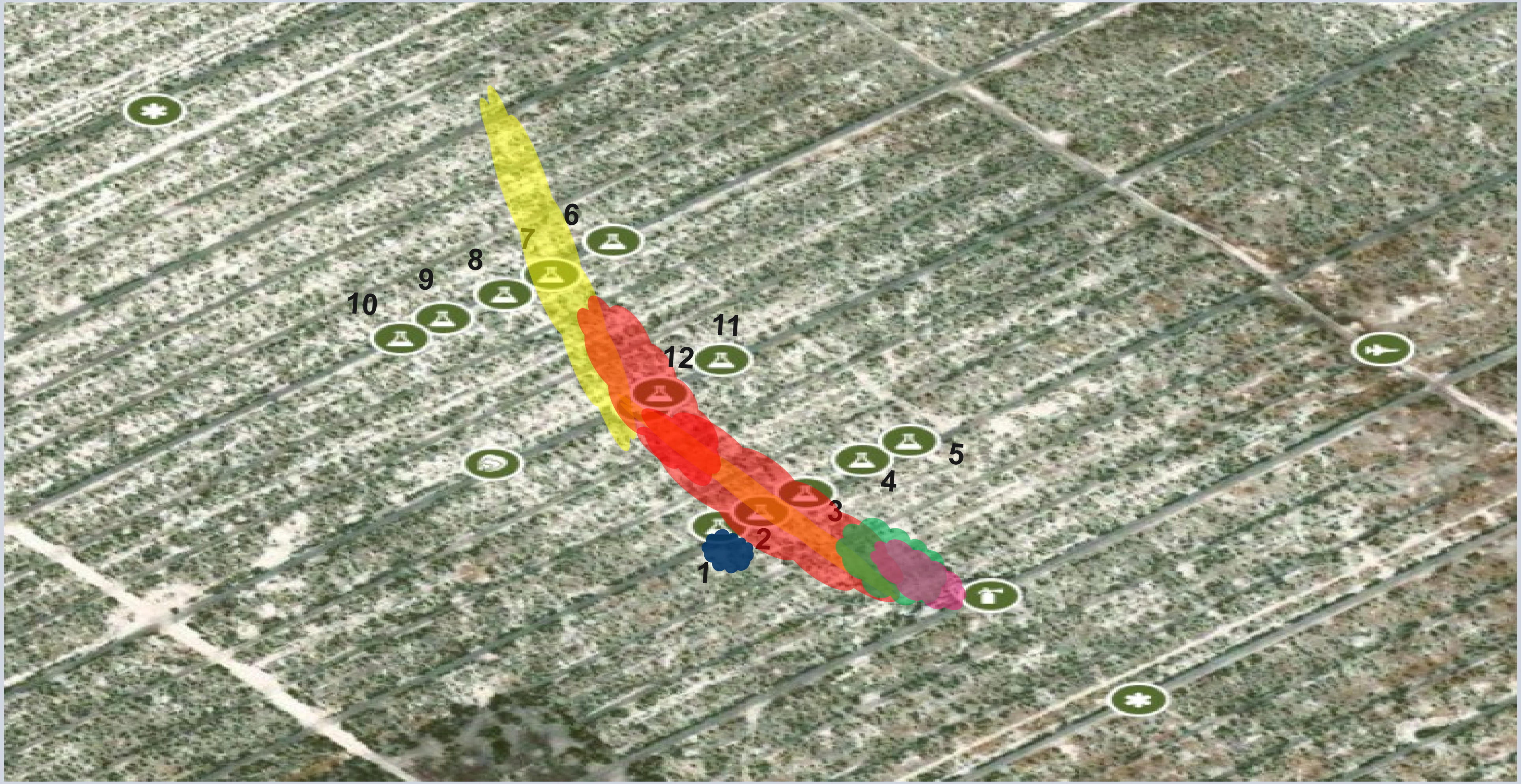
MiniRAE

ChemResponder



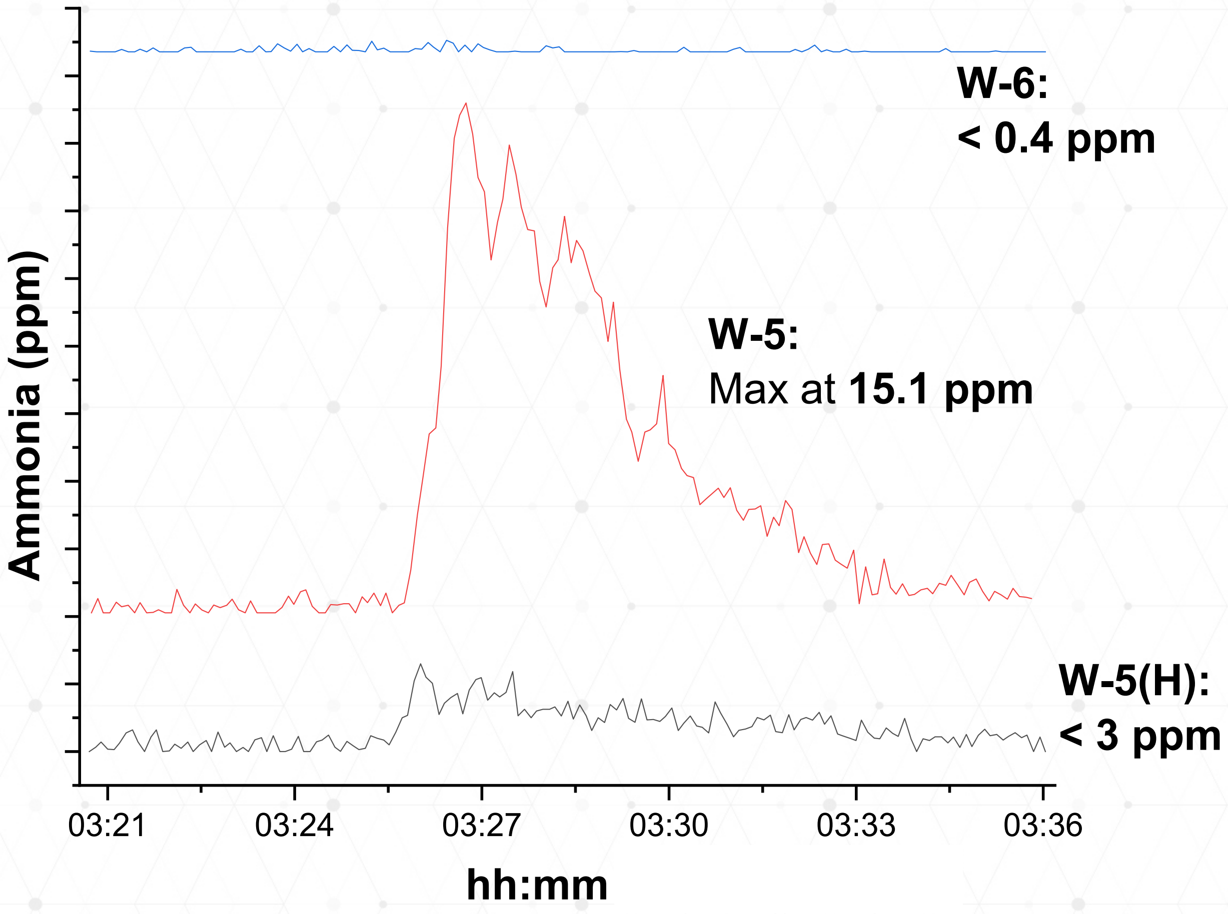
Real-time observation of the ammonia release
(MiniRAE data transfer from Safety Suite to ChemResponder through API)

Unit # (downfield distance from the release)	Ammonia Con. at 3:30 AM (Maximum Con.)
1 (0.1 km)	0.8 (0.8) ppm
2 (0.1 km)	9.9 (9.9) ppm
3 (0.1 km)	5.2 (7.7) ppm
4 (0.1 km)	1.0 (1.1) ppm
5 (0.1 km)	0.5 (0.6) ppm
6 (0.3 km)	0.4 (0.5) ppm
7 (0.3 km)	1.7 (2.4) ppm
8 (0.3 km)	0.6 (0.6) ppm
9 (0.3 km)	0.2 (0.3) ppm
10 (0.3 km)	0.2 (0.3) ppm
11 (0.2 km)	0.5 (0.5) ppm
12 (0.2 km)	8.4(13.1) ppm

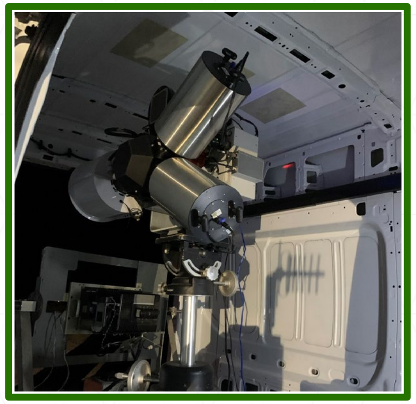


Point Detection: The Gasmet™ DX-4000 Fourier-transform infrared spectrometers

Unit # (distance from the release)	Ammonia Con. at 3:30 AM (Maximum Con.)
W-6 (0.5 km)	0.1 (<0.4) ppm
W-5 (0.2 km)	7.0 (15.1) ppm
W-5(H) (0.2 km)	1.3 (<3) ppm
W-4 (0.1 km up field)	No Data Collection



Standoff Detection: ASPECT
Fourier transform infrared spectrometer and IRLS



Summary of JR III SOAR findings: Advanced technologies demonstration

Technology	Technology Objectives
Rebellion Standard GCI System-Hyperspectral Imager	Determined Rebellion gas imager's minimum detection level for anhydrous ammonia is as low as 0.0001 kg/m^2.
ASPECT – Raytheon RS800 IRLS	No detectable chemical plume image downwind.
ASPECT – VSR	Provided remote chemical detection and quantified approximately 20 ppm*m.
Advanced Model Application	Demonstrated the feasibility of sensor requirements and placement from plume model analysis using the advanced DTRA climatology data.
Real-Time Remote Data Network-ChemResponder display of sensor data	Acquired data from point detection equipment wirelessly using the Safety Suite software. Live data was transmitted to ChemResponder network through the ChemResponder API.
Plume Model Display: ChemResponder display of plume model output and GIS data	Displayed DTRA GIS files on the ChemResponder event map: Maps and GIS data were pre-loaded for specific locations for viewing.

Further utilization of ChemResponder for emergency responders

Live data feed of chemical sensors in ChemResponder supports emergency response decision-making

- **Emergency response deployment considerations and observations:**
  - Preparation: detector types, quantities, locations, certified operators for deployment
  - Operation: legacy detection system requires additional RAELink modem to transfer data and GPS coordinates wirelessly
  - Function: data is transmitted to the point detector’s software which relays the data to ChemResponder
  - Multiple features and complex menus on ChemResponder are not optimal for initial responders’ use
- **Recommendations from SOAR emergency response users:**
  - Initial responder needs simplified menus for source data entry such as type of release, time, date, wind speed, direction, etc.
  - Source data from the contaminated area may be captured by unmanned aerial system
  - Tools should be able to work without internet connectivity
  - Simplifying all-for-one ChemResponder menus into two-phase approaches: Planner and Responder
  - Real-time sensor data feed to ChemResponder should be only visible when the sensor is in use

JR III strategic approaches

- Wind tunnel test and modeling
- Intermediate laboratory and field testing
- Large-scale modeling tests

Scaled Experiments

- **Conduct lab tests to improve models**
- **Define experimental uncertainty**
- **Identify critical parameters**
- **Investigate novel measurement techniques**

Modeling and Simulation

- **Planning: optimize layout, sensor placement**
- **Ingest complex test data to improve modeling & simulation capabilities**
- **Sensitivity and parametric analysis**
- **Recommend and inform next steps**
- **Develop operational procedures**

- Field test phase I: a series of 1 to 2-ton toxic industrial chemical releases
- Field test phase II: large-scale tests involving up to 20-ton releases

Realistic Field Tests

- **Define large-scale test parameters**
- **Build large-scale test bed with diagnostics**
- **Qualify operational response models**
- **Determine accuracy, precision, and experimental uncertainty for large tests**

Better tools, improved capabilities for operational support

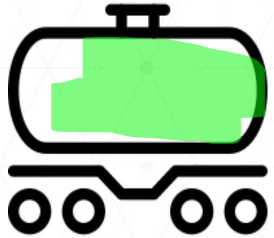
Addressing modeling gaps through experiments

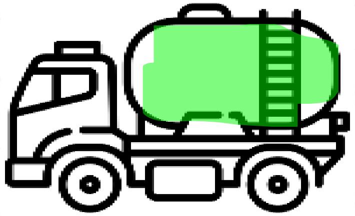
Major issues in ATD modeling of uncontrolled releases of ammonia to the atmosphere

- ATD modeling input parameters differ for emergency planning, operational response, and research applications
- Initial ammonia plume behavior for a refrigerated release (buoyant gas) differs from a pressurized liquefied gas release (dense two-phase mixture)
- Effects of ambient stability and inversions
- Interactions of plume with ambient water vapor and/or fog droplets
- Toxic gas removal by chemical reactions and deposition
- Plume behavior after buoyancy effects become insignificant
- Influence of variations in underlying surface and topography

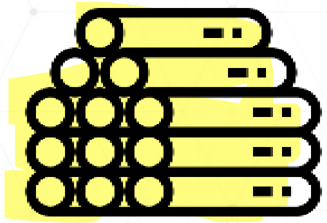
Scenarios and approaches addressing gaps in ammonia release emergency response

- Release from a pressurized tank
  - Source term emission models
  - Health risk models
  - Effects from obstacles, terrain, meteorological conditions
  - Ground types: organic or inorganic soils, asphalt, concrete

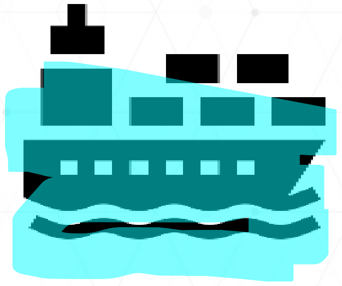




- Release from a pressurized pipeline
  - Leak at a valve or above ground, small and large amounts
  - Source term emission models
  - Data ensembles



- Release from a refrigerated barge
  - Source term of non-pressurized cold ammonia release
  - Proportion of downwind over-the-water dispersion versus underwater release
  - Waterborne transport hazards



DHS S&T CSAC JR III

Scientific Advisory Group (SAG)

JR III Working Groups

- Data Quality Working Group (DQWG)
- Modeling Working Group (MWG)
- Deposition & Surface Reactivity Working Group (DSRWG)
- Source Working Group (SWG)
- Instrumentation Working Group (IWG)
- Emergency Response Working Group (ERWG)
- Health & Human Effects Working Group (HHEWG)

- DHS (CISA, FEMA,TSA, CWMD, USCG)
- DoD (DTRA, U.S. Army)
EPA CMAD
DOT PHMSA
- IAFC, IAFF, IAB, IACP
- LBNL, LLNL, ANL, LANL, PNNL
- TFI, IIAR, ASTI, AAR, Honeywell
- UVU, U of Ark
- DRDC & TC, Canada
HSE, UK
MSIT & ADD, ROK

JR III Working Groups

Data Quality	Collaborate with experimental teams to establish and review quality control procedures, limits of detection, uncertainty management
Modeling	Advise test matrices and measurement challenges for all modeling considered
Instrumentation	Identify and suggest instrumentation options to meet the desired measurement requirements coming from other groups
Emergency Response	Synchronize first responder interests and objectives with SAG science objectives
Source Term	Provide for controlled and instrumented releases such that sources and uncertainties are quantified
Deposition & Surface Reactivity	Coordinate on objectives for deposition/reactivity and how to address this in lab facilities as well as in the field
Health & Human Effects	Understand the health and human effects models for ammonia

Acronyms

- °C: Degrees Celsius
- AAR: American Association of Railroads
- ADD, ROK: Agency for Defense Development, Republic of Korea
- ATD: Atmospheric transport and dispersion
- AM: Ante Meridiem
- ANL: Argonne National Laboratory
- API: Application Programming Interface
- ASTI: Ammonia Safety and Training Institute
- Con.: Concentration
- CISA: Cybersecurity and Infrastructure Security Agency
- CMAD: Consequence Management Advisory Division
- CWMD: Combating Weapons of Mass Destruction
- DHS: Department of Homeland Security
- DoD: Department of Defense
- DOT PHMSA: Departments of Transportation Pipeline and Hazardous Materials Safety Administration
- DRDC & TC: Defence Research and Development/Transport Canada
- DTRA: Defense Threat Reduction Agency
- EPA: U.S. Environmental Protection Agency
- ERPG: Emergency Response Planning Guidelines
- FEMA: Federal Emergency Management Agency
- FOV: Field of Vision
- FY: Fiscal year
- GIS: Geographic Information System
- GPS: Global Positioning System
- HSE, UK: Health & Safety Executive Science & Research Center, United Kingdom
- IAB: InterAgency Board for Emergency Preparedness and Response
- IACP: International Association of Chiefs of Police
- IAFC: International Association of Fire Chiefs
- IAFF: International Association of Fire Fighters
- IDLH: Immediate Danger to Life and Health
- IIAR: International Institute of Ammonia Refrigeration
- IMAAC: Interagency Modeling and Atmospheric Assessment Center
- kg/m^2: Kilograms per meter squared
- km: kilometers
- LANL: Los Alamos National Laboratory
- LBNL: Lawrence Berkeley National Laboratory
- LLNL: Lawrence Livermore National Laboratory
- m/s: meters per second
- mb: millibar
- MDT: Mountain Daylight Time

Acronyms (Continued)

- MSIT: The Ministry of Science and Information Communication Technology of The Republic of Korea
- NIOSH: National Institute for Occupational Safety and Health
- OSHA: Occupational Safety and Health Administration
- PEL: Permissible Exposure Level
- PNNL: Pacific Northwest National Laboratory
- PPE: Personal protective equipment
- ppm: Parts per million
- ppm*m - parts per million times meters (concentration times path length)
- PWIDS: Portable Weather Information Display System
- R&D: Research and Development
- SAG: Scientific Advisory Group
- TFI: The Fertilizer Institute
- TRANSCAER: Transportation Community Awareness and Emergency Response
- TSA: Transportation Security Administration
- TWA: Time-Weighted Average
- U.S.: United States
- U of Ark: University of Arkansas
- USCG: United States Coast Guard
- UVU: Utah Valley University
- UTC: Coordinated Universal Time

Acknowledgements

- DHS S&T Technology Transfer Office for Partnership Intermediary Agreements for surveying first responders and interviewing ammonia industry partners.
- DHS Federal Emergency Management Agency Chemical, Biological, Radiological and Nuclear Office's ChemResponder program team
- DTRA Research & Development-Digital Battlespace Management Division, Department of Defense Chemical, Biological, Radiological and Nuclear Consequence Management Advisory Division, United States Environmental Protection Agency
- Utah Valley University-Emergency Response Service
- Honeywell Analytics team Business Development Manager for Federal Government/Department of Defense/Maritime
- Honeywell Gas Analysis & Safety-Gas Cloud Imaging team
- United States Army Combat Capabilities Development Command Chemical Biological Center

Homeland Security

Science and Technology