Jack Rabbit III Initiatives:

Chemical Threat Characterization through Experimentation for Strengthening Safety and Security of Critical Infrastructure

Homeland Security

Science and Technology

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Science and Technology Directorate (S&T)

Overview

- Jack Rabbit III Initiatives
- Goal and Objectives
- Jack Rabbit III Timeline
- Highlights of the Department of Homeland Security (DHS) S&T Research & Development Activities
  - Threat Assessments - Chemical Down Selection for outdoor Release
  - Technical survey of first responders/Interviewing Industry partners/consequence Assessment Modeling and Research Gaps
  - Filling critical data gaps in small scale experiments and through computations modeling
  - Innovative Technology solutions
- Stakeholder Engagements and Partnering Opportunities
- Summary and Path forward
- Acknowledgements

Jack Rabbit (JR) III Initiatives

A new series of open-air toxic chemical release trials in a multi-agency effort, building upon the measure of success from Jack Rabbit I and Jack Rabbit II

JR I-Cl_2 & NH_3Basin Release

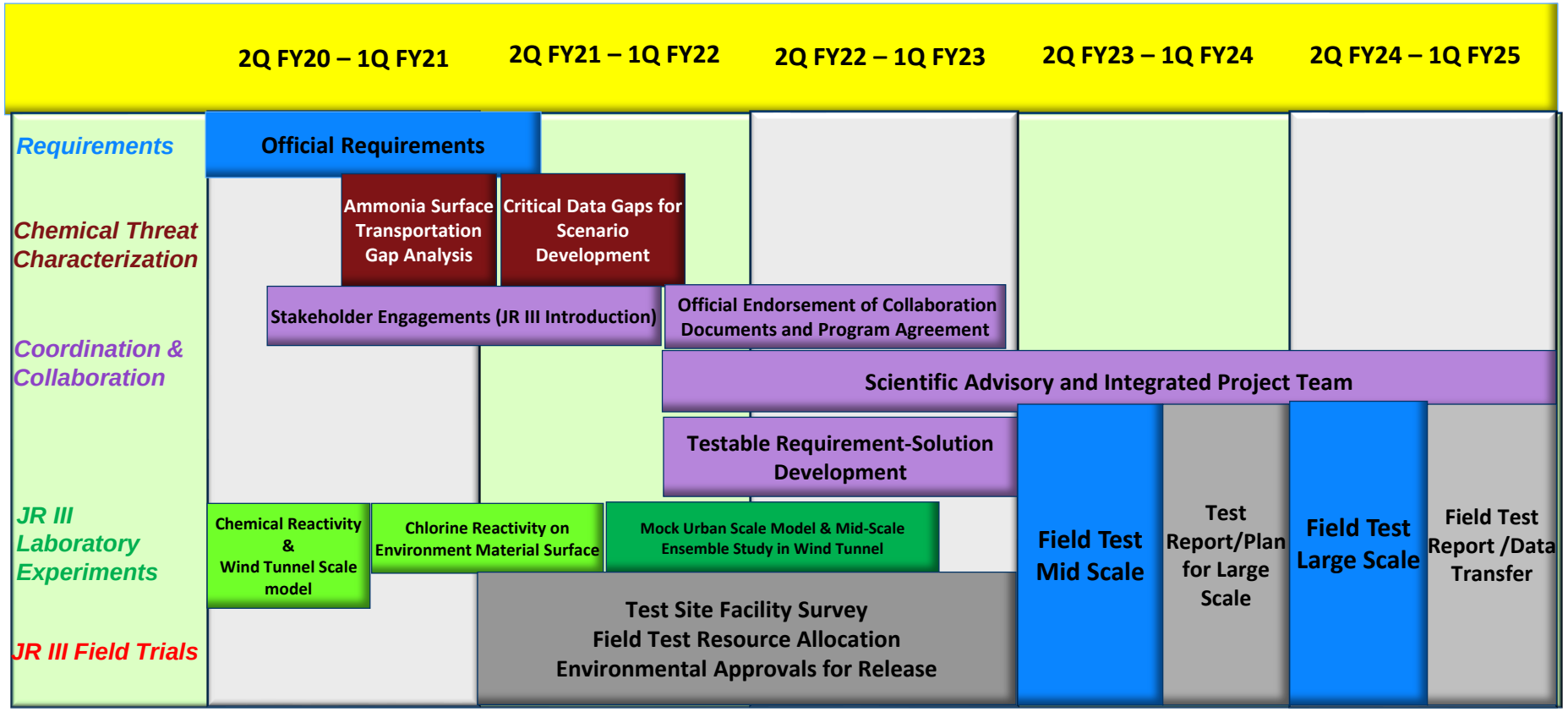
JR II-Cl_2 Mock Urban Area Release

JR III Goal and Objectives

Goal: Conduct studies and experiments needed to fill critical knowledge and data gaps and transfer technologies to safeguard the nation from chemical threats

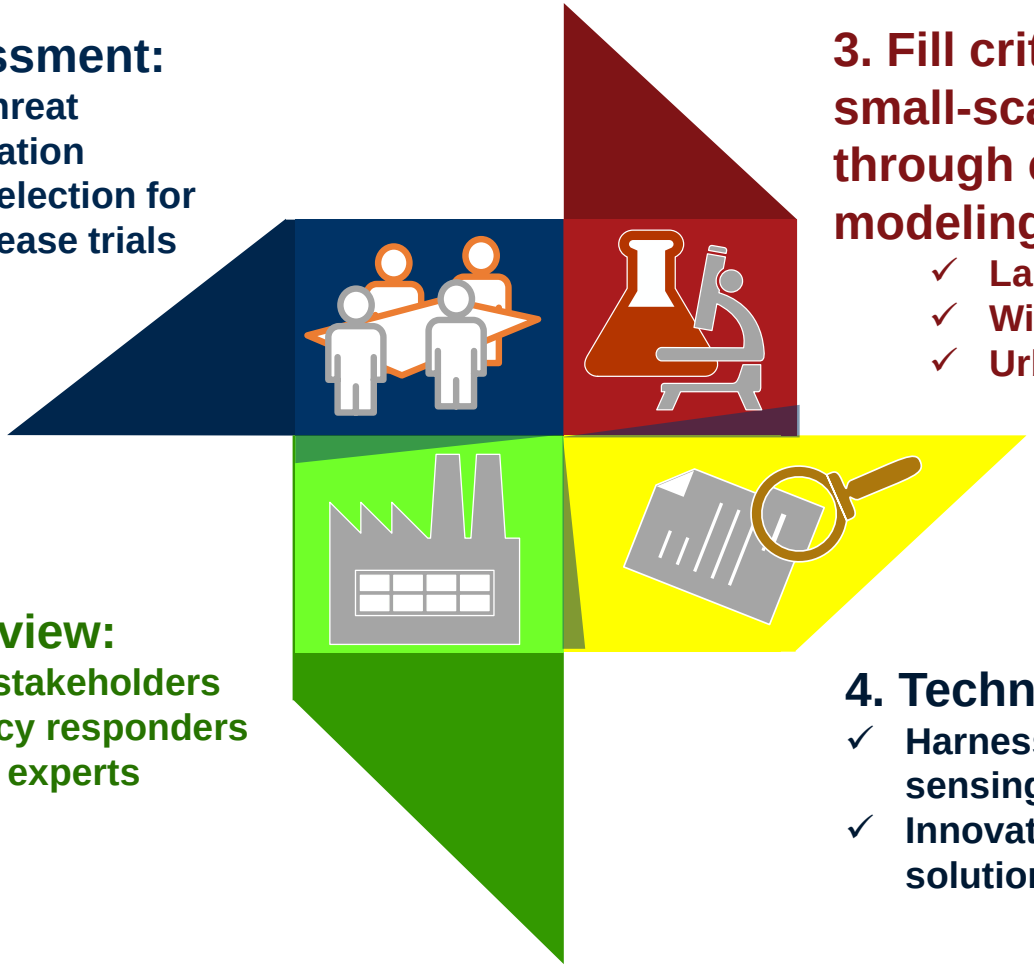
Assess	Prepare	Respond	Recover	Uphold
Advance Hazard Prediction and Chemical Dispersion Modeling	Enhance Emergency Response and provide opportunities for Training and National Level Exercises	Provide technologies to Advance Detection and Protective Equipment to Reduce Casualty	Develop Countermeasure Cultivate Decontamination Strategies	Safeguard Critical infrastructure and support critical function Devise Hazard Mitigation Approaches

Jack Rabbit III Timeline



Jack Rabbit III during COVID-19 Pandemic: Virtual Collaboration & Cooperation

1. **Threat assessment:**
   - ✓ Chemical threat characterization
   - ✓ Chemical selection for outdoor release trials



3. Fill critical data gaps in small-scale experiments & through computational modeling:
- ✓ Laboratory experiments
- ✓ Wind tunnel experiments
- ✓ Urban dispersion modeling

2. Survey/Interview:
- ✓ Industry stakeholders
- ✓ Emergency responders
- ✓ Modeling experts

4. Technology scouting:
- ✓ Harnessing state of the art sensing instrumentation
- ✓ Innovative technology solutions capabilities needed

1. Chemical Threat Assessment: JR III Chemical Selection Tool

Anhydrous Ammonia is the most reasonable choice for large-scale release based on the comprehensive consequences/likelihood/hazard Index Assessments

Consequences

Injuries, Accidents, and Property Damage Cost

Data Source: Risk Management Plan Database, U.S. EPA (2020)

Likelihood

Chemical Supply Chain Transportation Volume

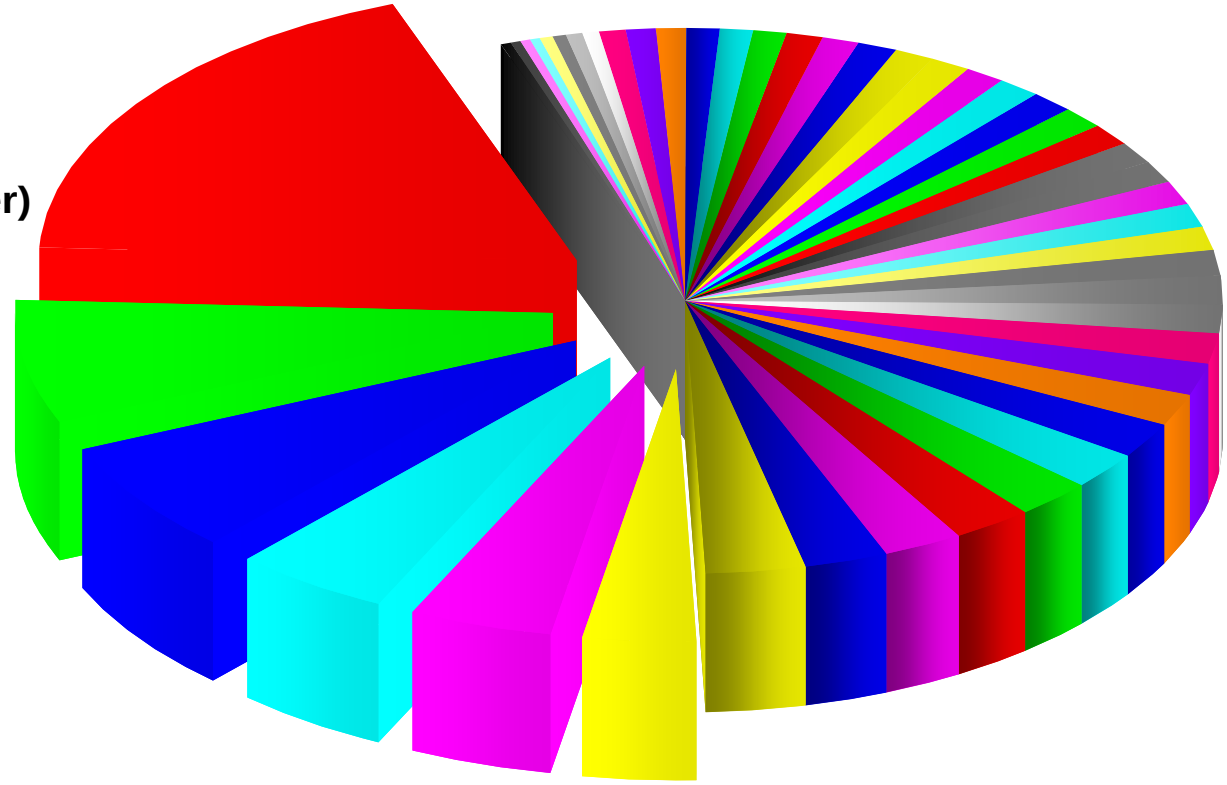
Data Source: CSAC Chemical Risk Assessment-Chemical Transportation Amounts (2017)

Toxicity (Acute Exposure Guideline Level), Vapor Pressure, Emergency Response Guidebook (Isolation Distance), and Flammability

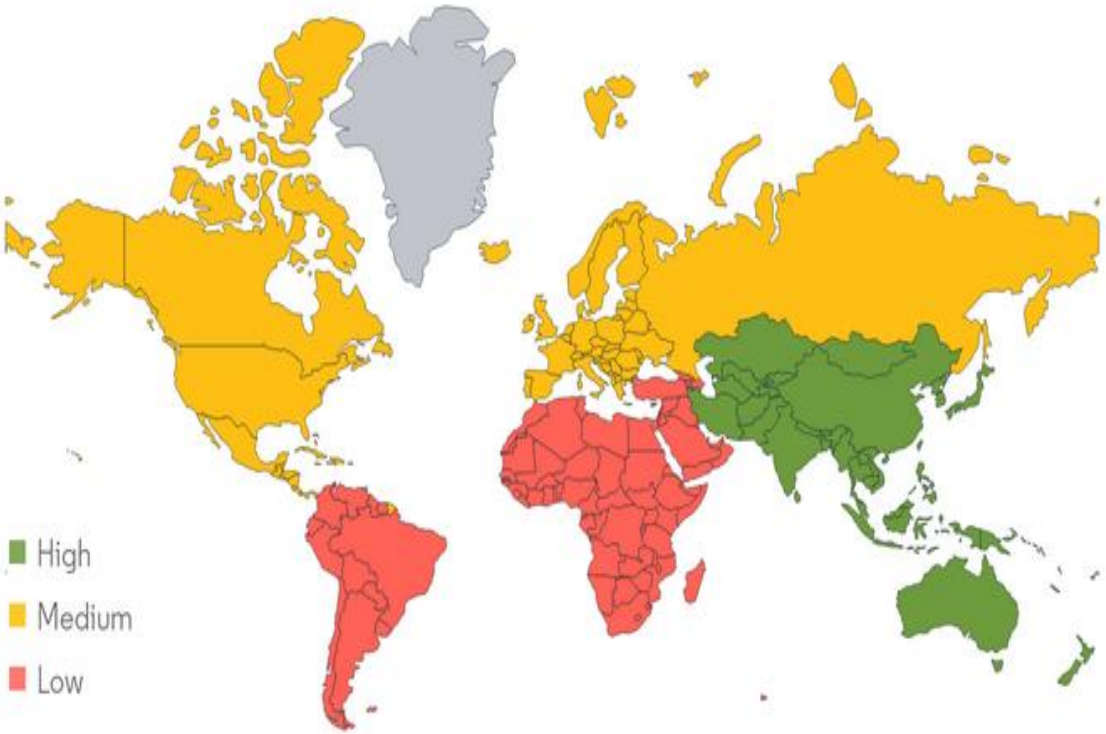
1. Chemical Selection: Threat Assessment of Chemical Supply Chain Chemicals

- 19% Ammonia (Anhydrous)
- 7% Hydrogen Sulfide
- 7% Chlorine (Anhydrous)
- 5% Hydrogen Cyanide
- 4% Hydrogen Selenide
- 3% Ammonia (conc. 20% or greater)

The Mean Probability of Anhydrous Ammonia Selection is 19%, which is far greater than 48 initial toxic industrial chemicals dominantly transported through chemical supply chain: this is 76 times greater than the least likely choice.



1. Growing Ammonia Market by Region and Forecast (2019-2024)



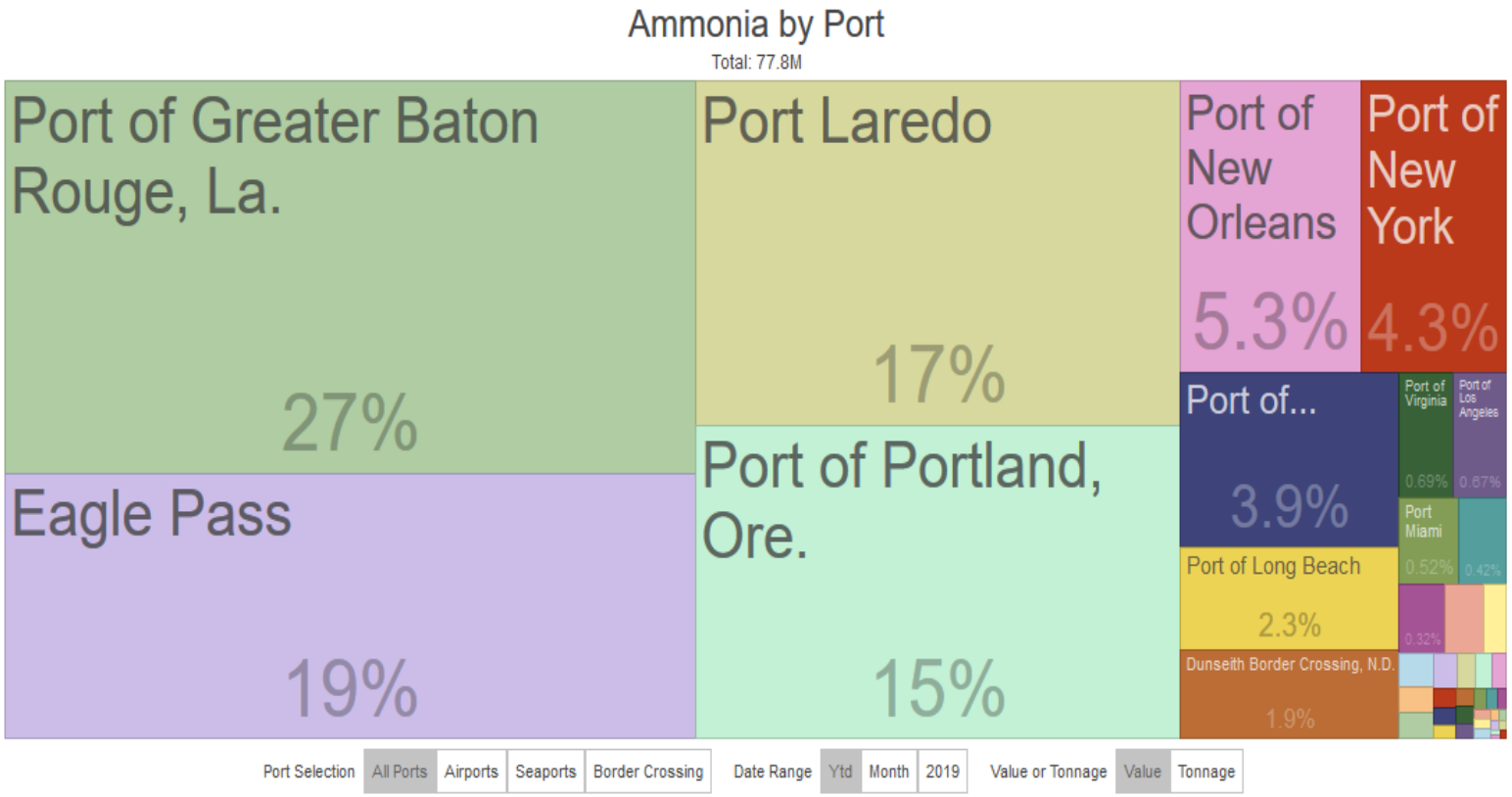
Source : Mordor Intelligence

Market Revenue by Application

- Fertilizers (80%)
- Refrigerants
- Pharmaceutical
- Textile processing
- Mining
- Household products
- Manufacturing plastics & rubber
- Metal treating
- Water treatment
- Green energy

1. U.S. Exports of Ammonia by Seaports, Airports, Border Crossing in 2020

U.S. Exports of Ammonia increased by 14.75 % ($78 million) from Jan to Aug of 2020



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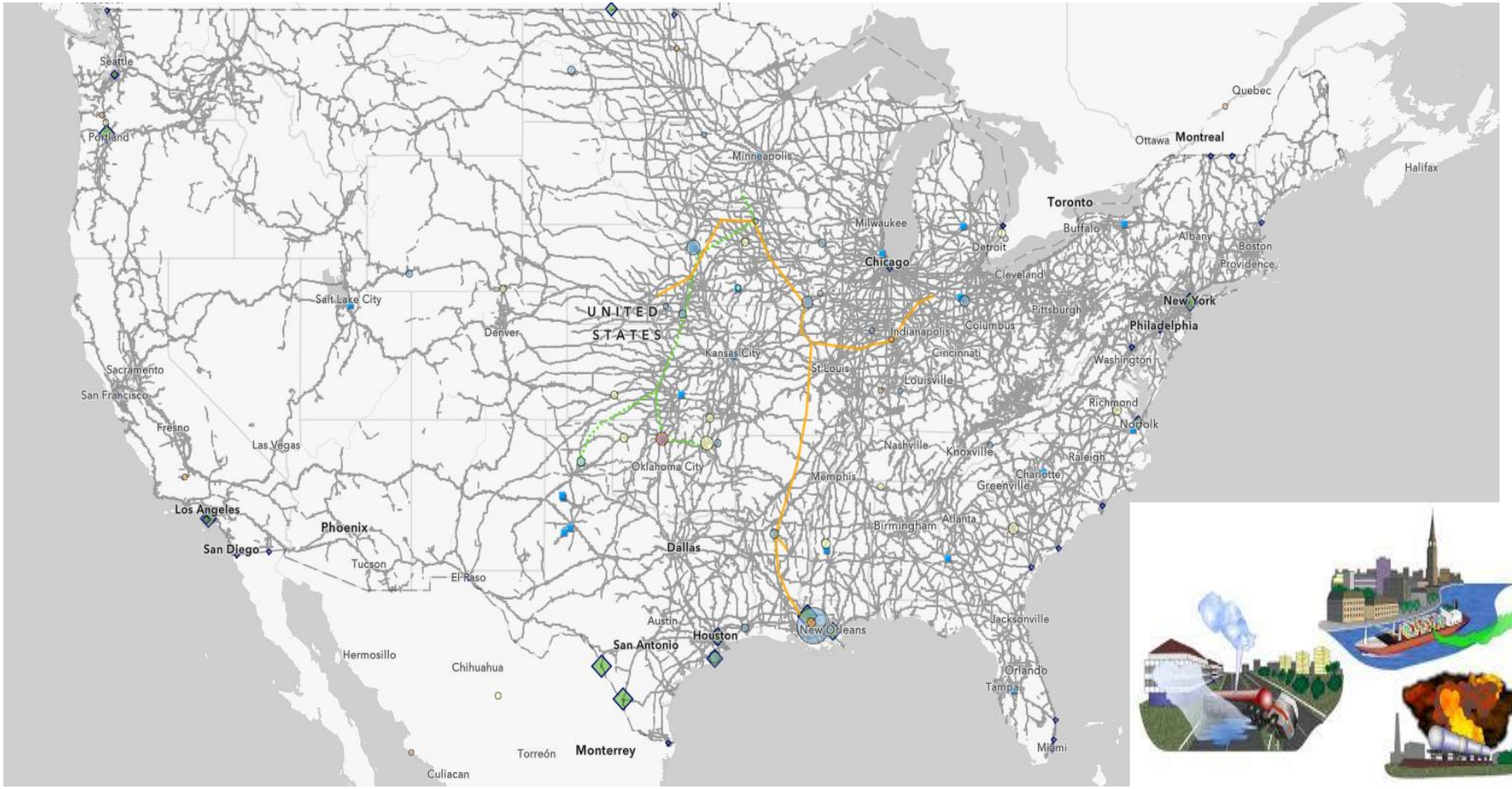
1. Anhydrous Ammonia Distribution via Railways, Waterways, Highways, and Pipeline



1. Accidental Anhydrous Ammonia Release: Opportunity to Chemical Terrorism

From the Chicago Tribune article about the incident dated April 25, 2019.

Pamela Burnett tried to avoid it but ended up driving through the plume. "It wasn't smoke," she said. "I thought to myself this is some kind of chemical. The next thing I knew, I couldn't breathe. It was such a strong smell. I thought to myself, 'Lord this is it. I'm done now.'

Roswell, NM (2020) Ammonia tanker overturned

San Antonio River, TX (2020), Nearly 5,500 Fish area dead due to leak in the refrigeration system

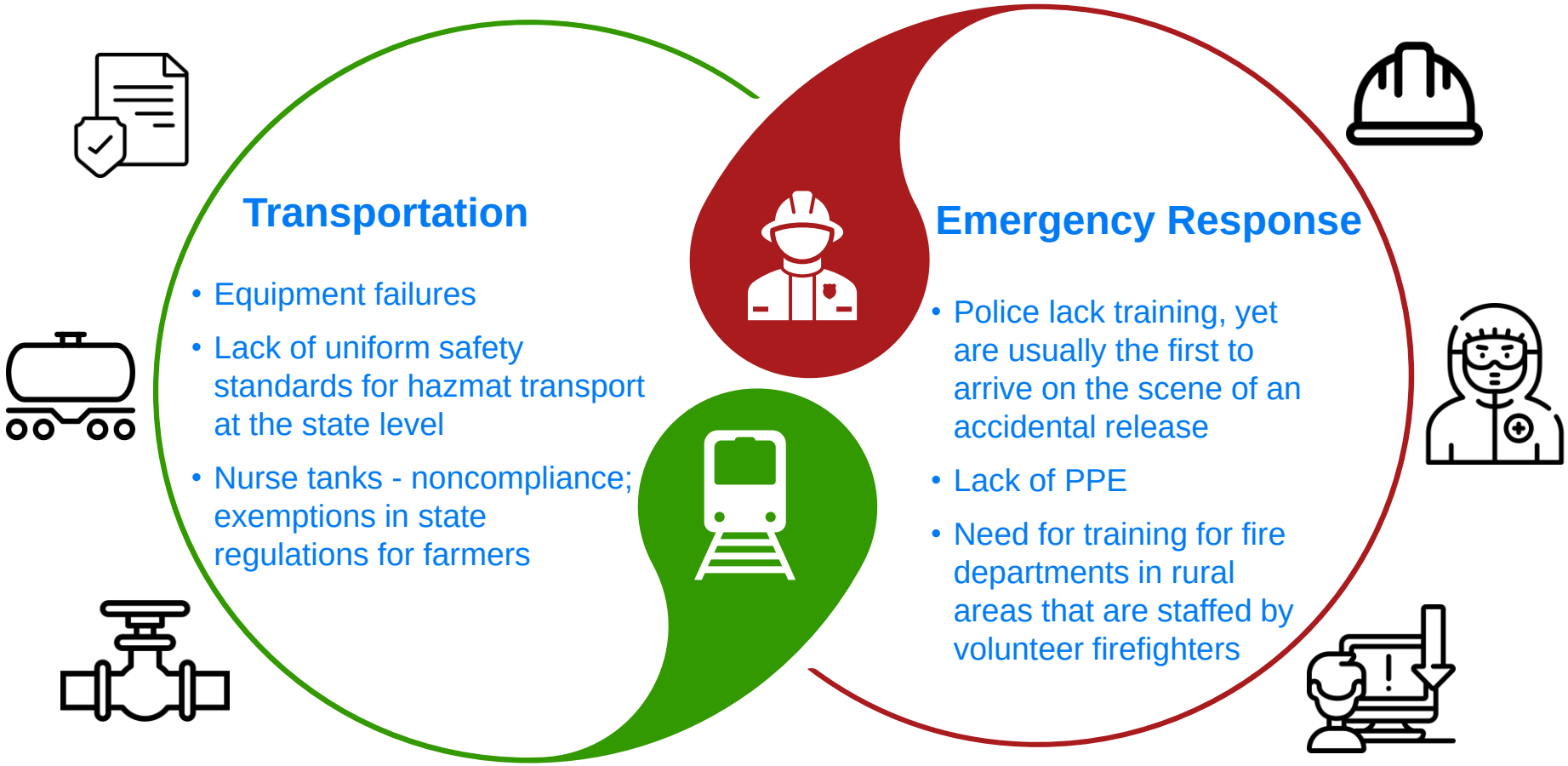
2. Safety and Security Risks Identified by Private Sector

Ammonia Industry Trade Association

Ammonia Hazmat/Safety Organization

Ammonia Supply Chain Actors

2. Safety: Transportation and Emergency Response Emerged as the Biggest Safety Concerns



2. Security: The Use of Ammonia for the Illicit Production of Meth Is a Significant Security Concern, as Are Handoff Points

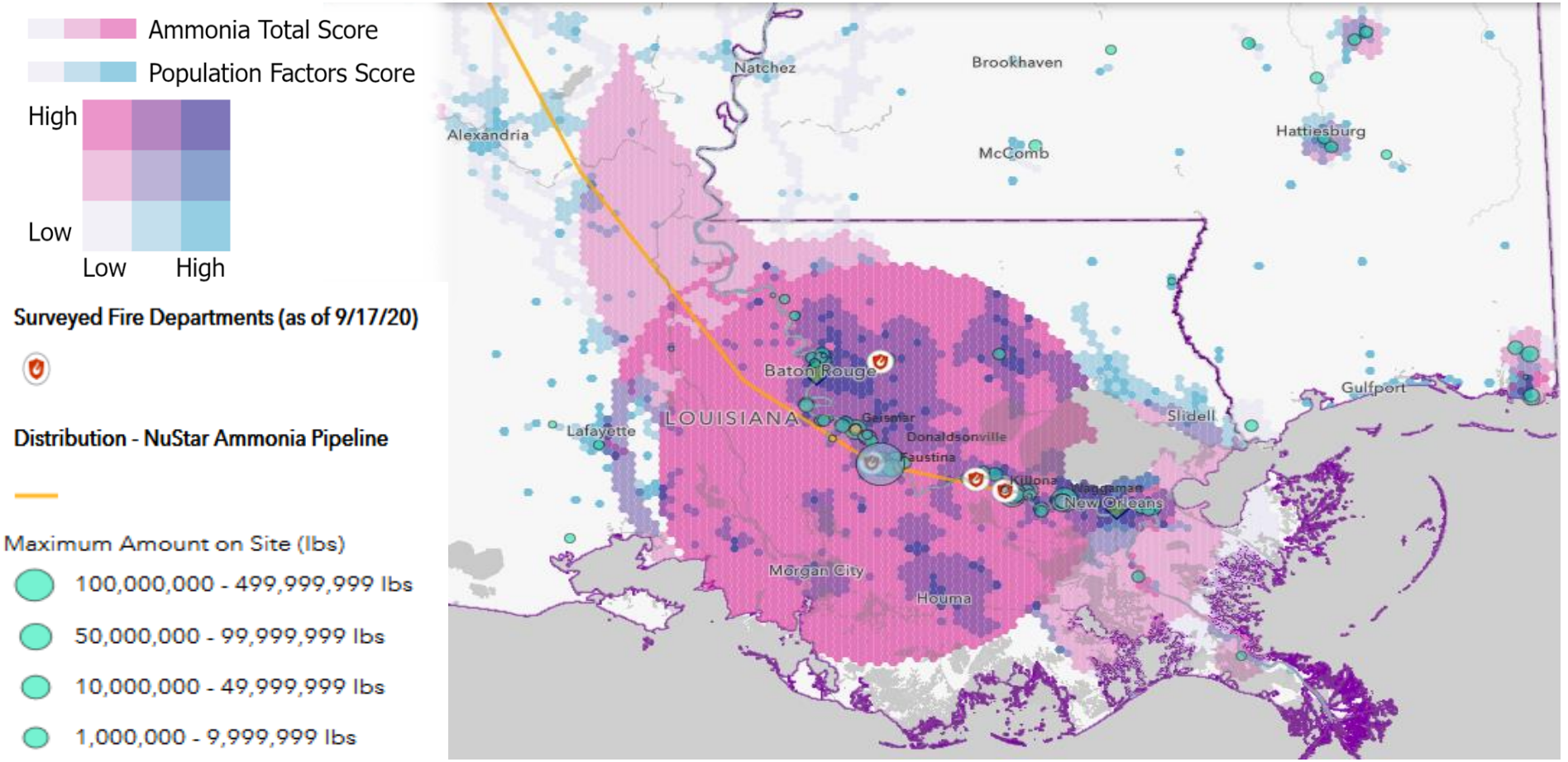
Ammonia and the Production of Methamphetamine

- Nurse tanks are a common target for the siphoning of ammonia
- Those looking to tap into tank cars typically use a makeshift hose and transfer it into a storage container

Handoff Points, Rest Stops, Long Dwell Time

- Potential terrorists would be looking for immediate transfer points
- Rail cars are less of a target than highway transportation tankers and nurse tanks

2. Anhydrous Ammonia Geographic Analysis: First Responder Survey Site Identification Using the Interactive Mapping Tool



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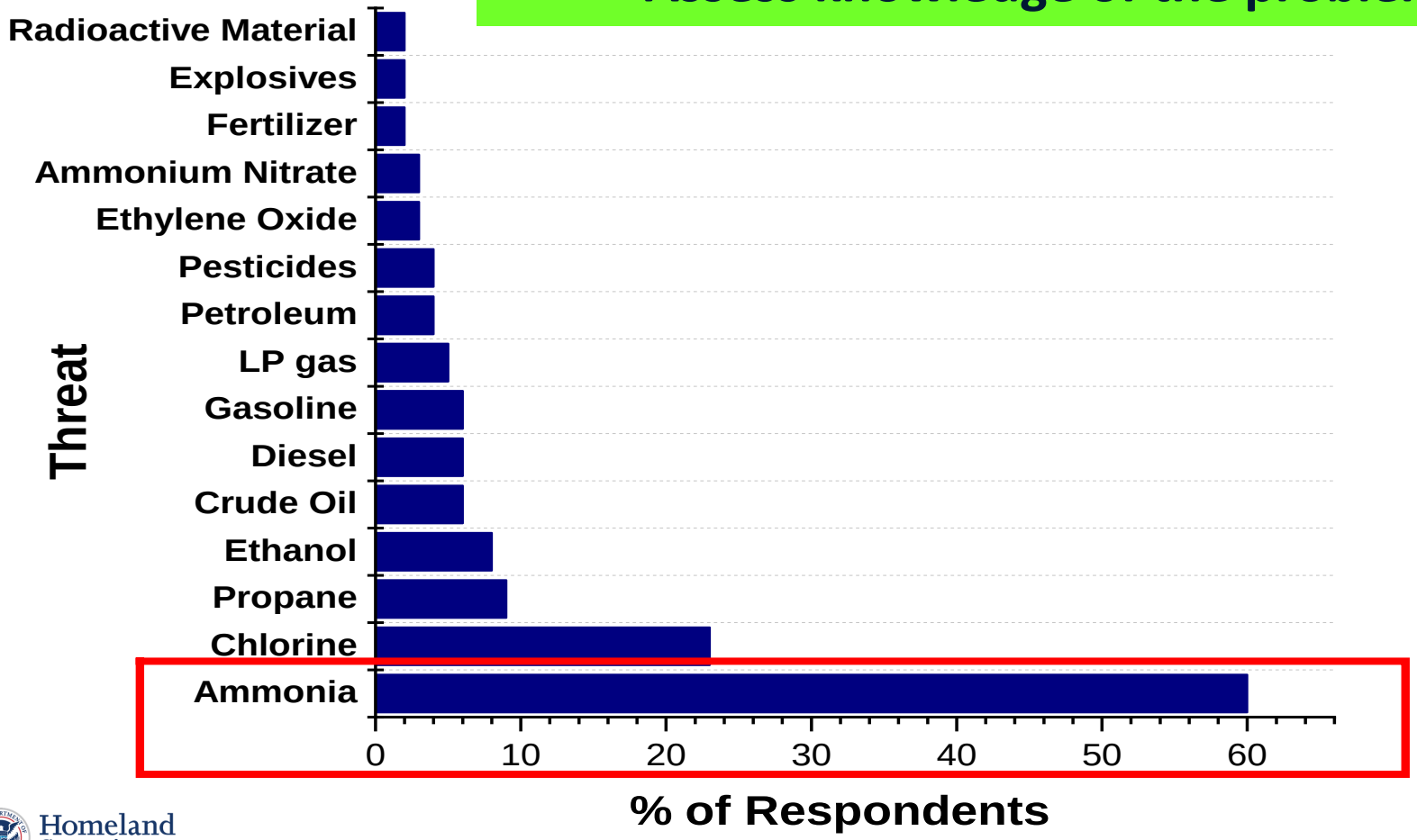
2. What Are the Most Serious Hazardous Material Threats in Your Community?

Assess knowledge of the problem



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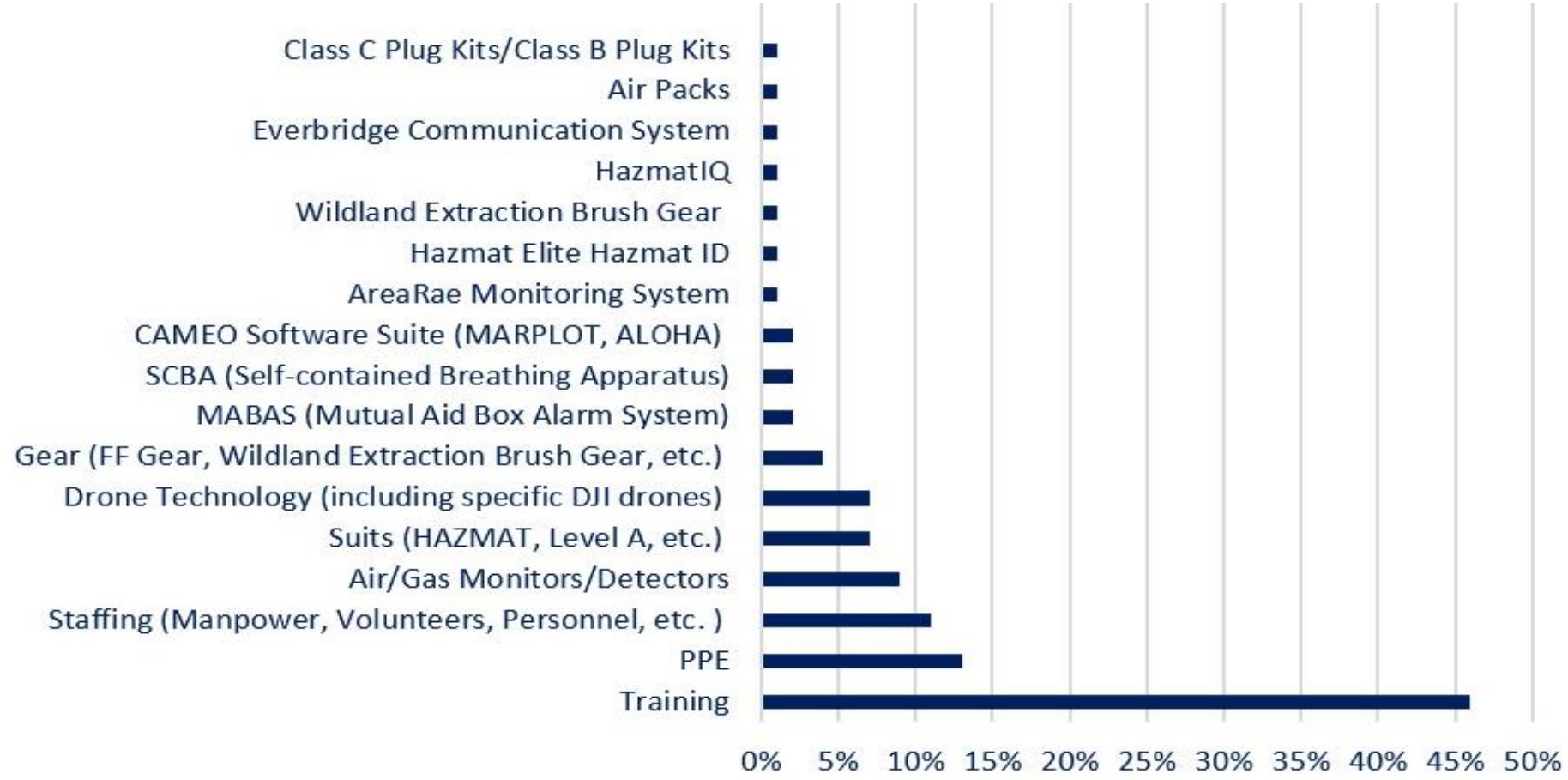
2. As a First Responder, What Gaps Do You See in the Security of Anhydrous Ammonia Transportation That Could Be Exploited by Those Intent on Causing Harm?

Self-identified gaps in security preparedness

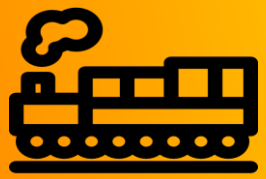
2. Is There Anything That You Feel Would Help You and/or Your Department's Ability to Effectively Deal With Anhydrous Ammonia or Other HAZMAT Emergencies?



2. Anhydrous Ammonia Modes of Transportation and Distribution: Potential Incident Release Volume Derived From Pressurized Vessel Capacity

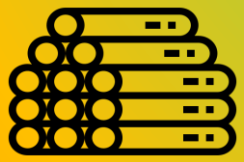
Nurse Tank
<2,000 gallons

Railcars
34,500 gallons per Tank Car



Tank Truck
6,000-12,600 gallons

Pipeline
Million tons annually
(570,000 gallons*)



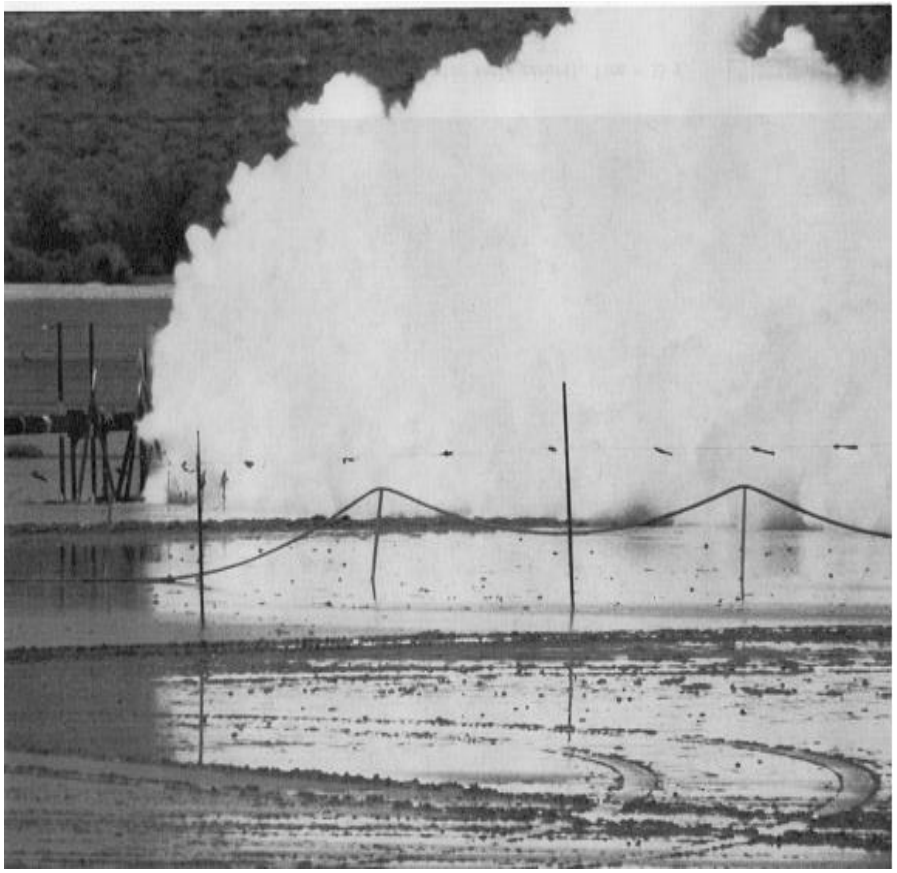
Refrigerated Barge
875,000 gallons / vessel

Storage
0-60,000,000 gallons

*** Assuming 95,000gallons/hour pipeline volumetric flow and an incident duration equivalent to 6 hours of release**

3. Recent efforts to identify Modeling Gaps

- Simon Gant (Health and Safety Executive, UK) *"Knowledge Gaps and Research Priorities in Atmospheric Dispersion Relevant to Acute Toxic Hazards-Survey of European Union SMEs in 2020"*
- Hanna Sep 2020 draft paper, "Gaps in Toxic Industrial Chemical (TIC) Model Systems - 2008 Versus 2020"
- "Modeling Large-Scale Toxic Chemical Transport Releases Gap Analysis," prepared by Science Applications International Corporation for DHS S&T CSAC, 2010
- Hanna and Chang, "Gaps in Toxic Industrial Chemical (TIC) Model Systems," 2008



3. Modeling Gaps That Can Be Addressed Through Field Trials (JR III)

- **Uncertainties in the state-of-the-art of source (term) emission models**
  - Characteristics of the flashing jet: two-phase jet release and flashing jet expansion
  - Liquid rainout & liquid evaporation of the rained-out pool
- **Inadequate transport and dispersion model algorithms**
  - Momentum jets encountering obstacles
  - Formation of a persistent shallow dense cloud in light wind conditions
  - Effects of local terrain
- **Vapor removal from atmosphere due to:**
  - Gravitational settling
  - Dry deposition
  - Chemical reactions (effect from moisture/humidity)
- **Infiltration of TICs into buildings/structures**

3. Chemical Reactivity With Environmental Materials Accounting for Boundary Layer and Maximum Deposition Effects

Clean Environment

Toxic Gas

- Conduct quantitative analysis & Kinetic Measurements using the recirculating toxic gas exposure apparatus
- Understand reactivity of environmental surfaces with chlorine for proper hazard assessment
- Determine deposition velocity and maximum deposition amounts that can be implemented for modeling prediction
- Quantitative determination of cloud removal via reactivity with atmosphere, soil, vegetation, metals, urban surfaces
- Assess chlorine reaction rates with environmental materials
- Assist emergency responder staging and respond to impact zone
- Develop mitigation strategies

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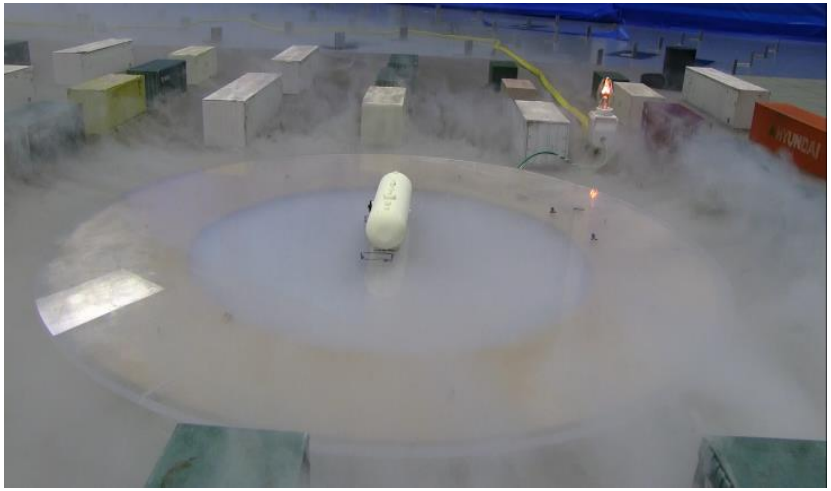
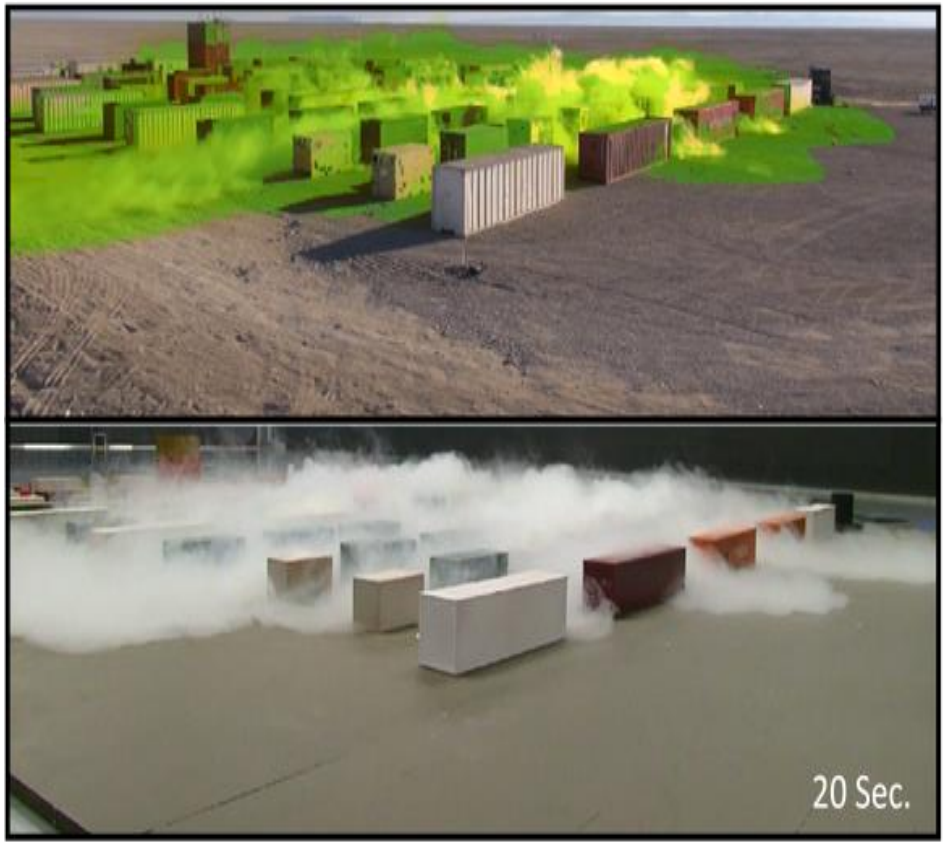
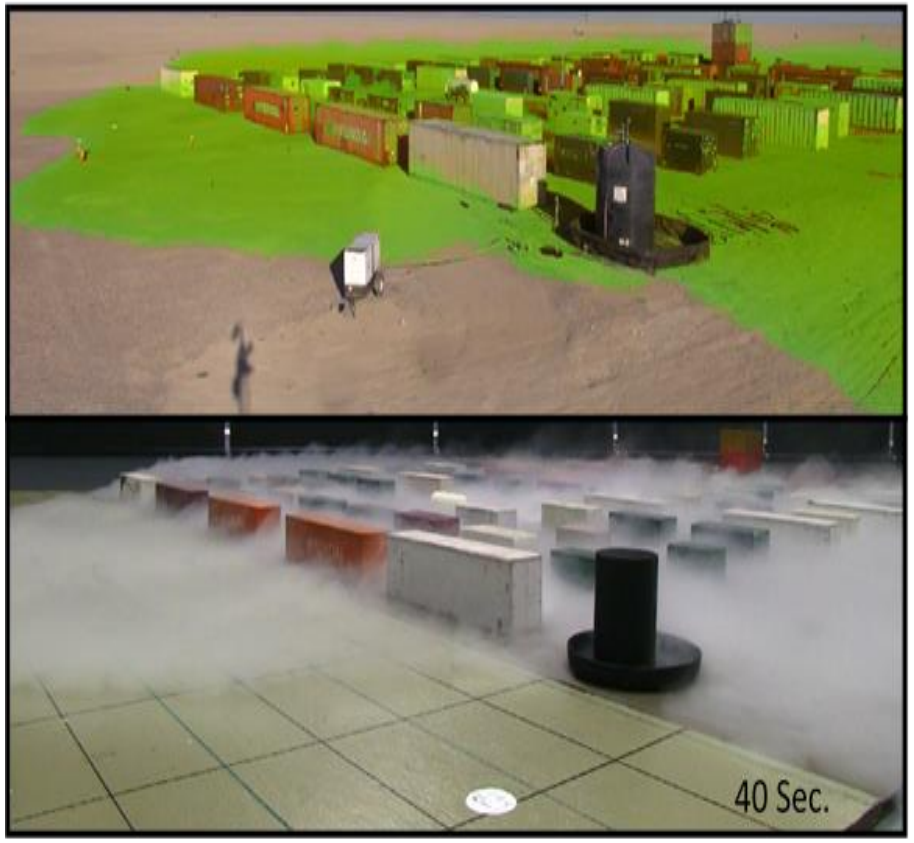
3. Wind Tunnel Experiments & Modeling: Source Term Characterization



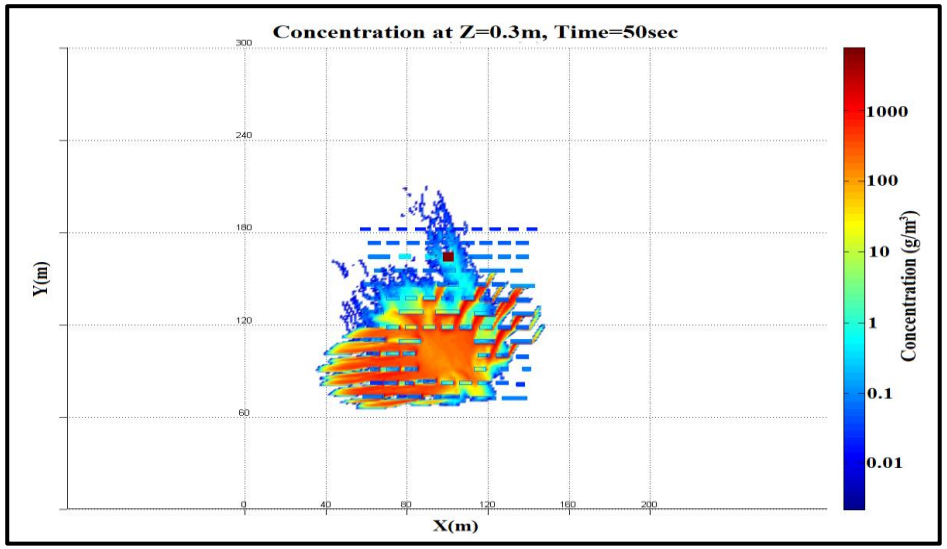
- Model atmospheric flows replicating the atmospheric conditions present and expansion phase of the two-phase chemical releases
- Construct an appropriately scaled model of the JR II Mock Urban areas and validate the physical model
- Develop computational source models from physical model simulations to help define source terms
- Estimate the extent of liquid rainout and air entrainment by toxic gas cloud over the concrete pad
- Study thermodynamic behavior of aerosol evaporation

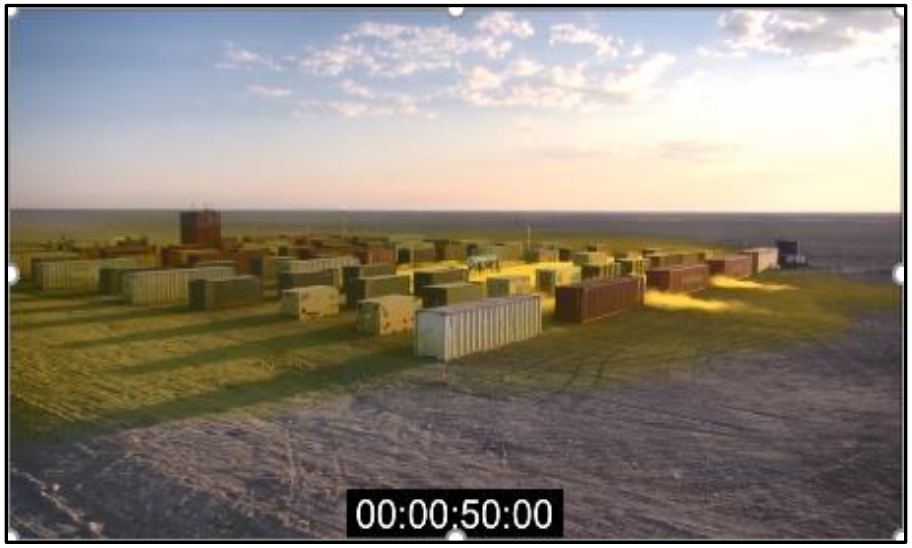
3. Wind Tunnel Experimentation: Flow Visualization of the Validated Physical Scaled Model





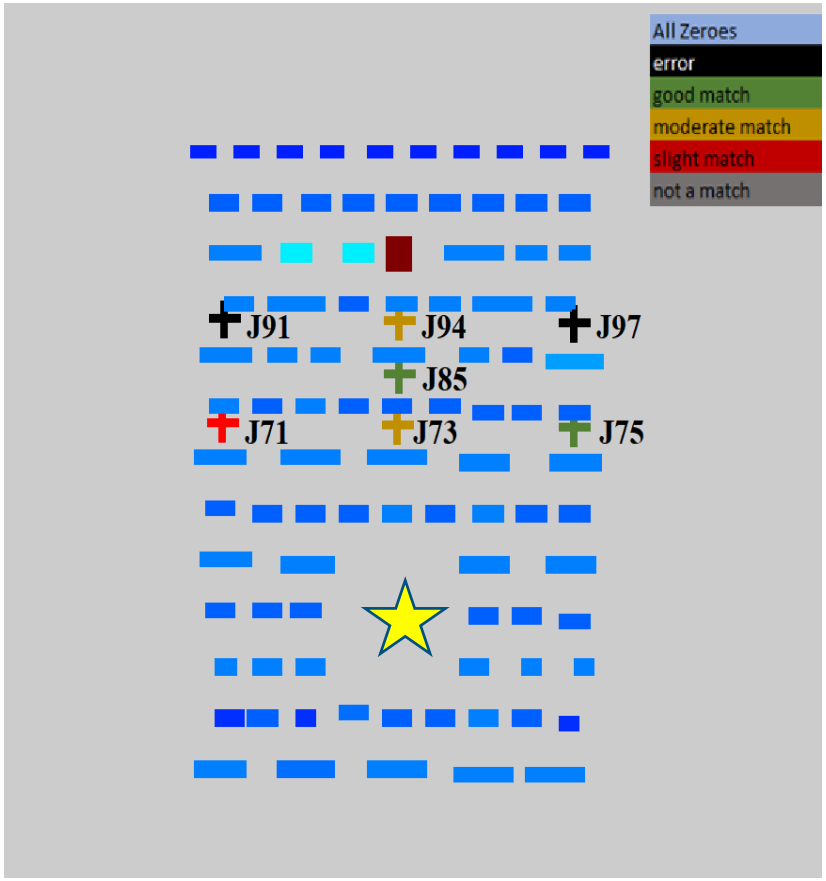
3. Quick Urban & Industrial Complex (QUIC) Modeling Study: Results Comparison at 50 Seconds





- Simulate JR II urban releases
- Compare model results to JR II sensor data on the general path of the plume
- Compare model results with sensor data within the urban array
- QUIC will be used for JR III Planning to determine general downwind plume behavior in an urban environment setting
- QUIC modeling can assist potential urban layout designs and building configurations

3. QUIC/JR Near Field Sensor Locations



- QUIC Output data tends to match maximum magnitude fairly well but do not match the timings
- Sensor data contains a lot of noise making direct comparisons hard:
  - Sensors J85/J75 are good match
  - Sensors J73/J94 moderate match
  - Sensor J71 is a slight match
  - Sensor locations J91 and J97 did not have readable sensor data

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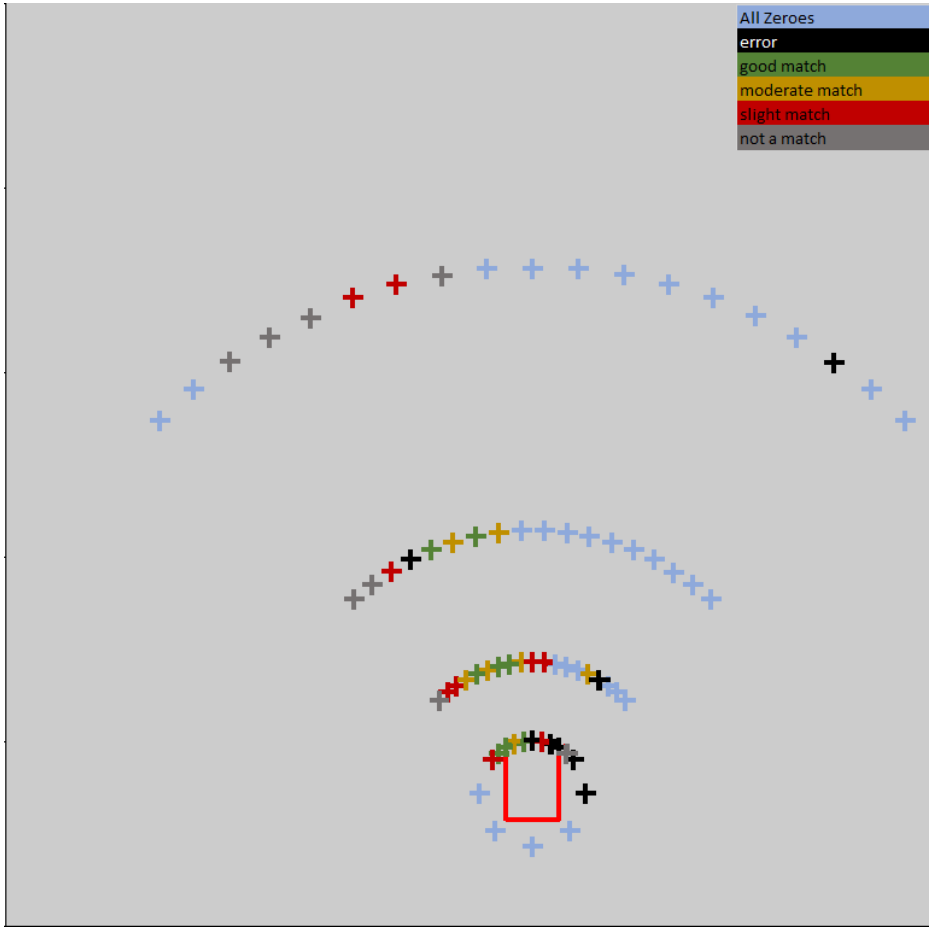
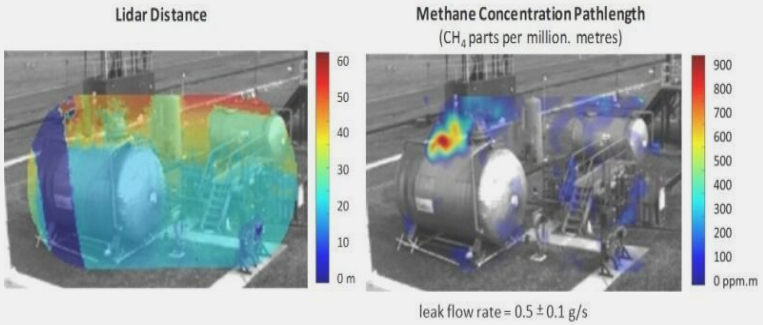
3. QUIC/JR Outer Arc Comparison

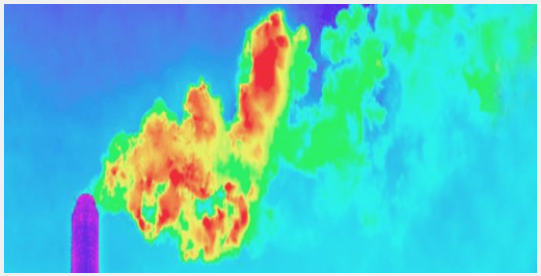


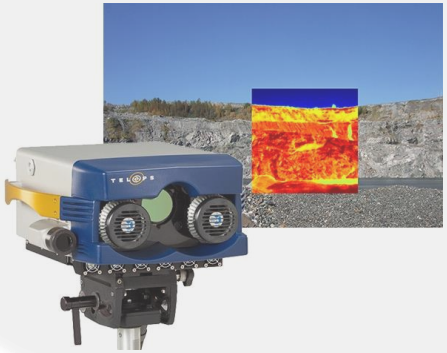
- QUIC seems to agree on the general path of the plume suggested by the JR II sensor data
- Sensor data suggests that the plume is wider downwind than what QUIC predicts. This may be due to source geometry assumptions or incomplete/incorrect atmospheric data
- QUIC tended to predict a faster plume and tended to underpredict downwind concentrations

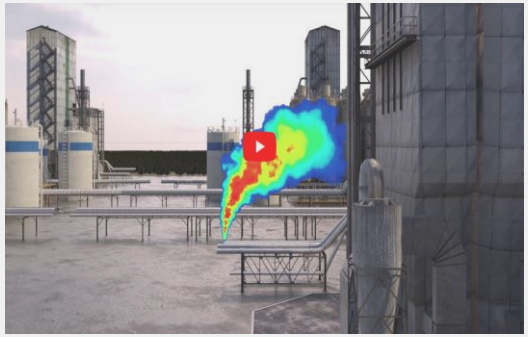
4. JR III Technology Scouting: Harnessing State of the Art Sensing Instrumentation

Hyperspectral Imaging technologies







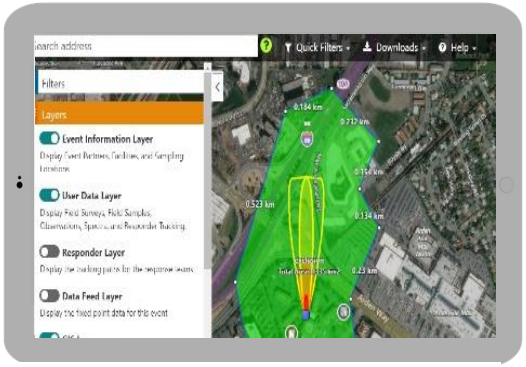


4. JR III Technology Scouting: Harnessing State-of-the-art Sensing Instrumentation

High-definition video recording equipment

Drones/Unmanned Aerial Systems

4. Innovative Technology Solutions



ChemResponder

NFPA Approved Blauer Multi-Threat Suit
The GORE® CHEMPAK® ADVANTAGE

Chameleon® Chemical Detection Armband

SafeAir® Chemical Detection Badges

BioHarness: Real Time Portable Physiological Monitory

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JR III Potential Collaboration Partners and Stakeholders

Large-Scale Toxic Chemical Transport Releases

DHS: S&T, CISA, FEMA, TSA, CWMD, USCG

Government	Private Sector	Academia National Labs	First Responder
Defense Threat Reduction Agency (DTRA)-Research & Development Directorate	The Fertilizer Institute	University of Arkansas	The International Association of Fire Chiefs
Environmental Protection Agency (EPA)-National Homeland Security Research Center (NHSRC)	International Institute of Ammonia Refrigeration	Utah Valley University	The International Association of Fire Fighters
EPA-CBRN Consequence Management Advisory Division	Ammonia Safety & Training Institute	Lawrence Livermore National Laboratory	InterAgency Board for Emergency Preparedness and Response
Department of Transportation-Pipeline and Hazardous Materials Safety (PHMSA)	American Chemistry Council		International Association of Chiefs of Police
	Association of American Railroads		
	The Chlorine Institute		

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JR III Summary

- Assessed current chemical threats and identified safety/security gaps through technical survey and interview
- Continued to fill critical knowledge gaps through modeling, wind tunnel chamber study, and laboratory experimentation
- Conducted Wind Tunnel Study to further support JR III Planning for Large Scale Open Field Release of Toxic Inhalation Hazard Chemicals
- Demonstrated QUIC modeling result will be able to guide determining appropriate sensor locations with the understating that some source behavior cannot be accounted for
- Identified innovative ammonia sensing: remote sensing, point sensing, high-definition video recording equipment, and drones/UAS for JR III Field Trials

JR III Path Forward

- ❑ Continue S&T Research & Development Activities to plan for JR III large scale outdoor release trials
- ❑ Complete the ammonia surface transportation gap analysis
- ❑ Connect with industry partners for cooperative research and development agreements and engage the emergency responders and atmospheric transportation and dispersion modelers to refine the gaps and prioritize the gaps
- ❑ Seeks to support Cybersecurity and Infrastructure Security Agency (CISA), Federal Emergency Management Agency (FEMA), Transportation Security Administration, Countering Weapons of Mass Destruction, United States Coast Guard and other relevant stakeholders in identifying data gaps, prioritize capability needs, and soliciting requirements
- ❑ Gather Requirements to start official Stakeholder Meetings/ Workshops/ Webinars
- ❑ Leverage the findings of the Jack Rabbit chemical field tests and new laboratory research to support enhanced industrial chemical safety
- ❑ Seek Collaboration Partners to discuss plans for the Jack Rabbit III

Acknowledgements

- Ms. Nohemi Zerbi and Ms. Custrina Reeves from DHS CISA
- Mr. Dante Steller from DHS FEMA
- Dr. Ronald Meris and DTRA Reachback Team for Jack Rabbit III International Modeling Data Comparisons
- Dr. Steven Hanna for Analyzing gaps in Toxic Industrial chemical model systems from Jack Rabbit I for Jack Rabbit III
- Dr. Simon Gant for knowledge gaps and research priorities in atmospheric dispersion relevant to acute toxic hazards from European modeling experts
- Dr. Tom Spicer for executing chlorine reactivity laboratory study and wind tunnel experiments
- MilTech for interviewing relevant private sector entities, conducting the survey of first responders, and scouting technologies under DHS S&T Partnership Intermediary Agreement

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