


Emergency Management of Tomorrow Research: Eliciting Stakeholder Input

Summary Reports of Interviews, Focus Groups, and Roundtables

May 2024

Science and Technology

Contents

Task 3A. Current State of Practice: Emergency Management Information Sharing

Pacific Northwest
NATIONAL LABORATORY

PNNL-35727

Emergency Management of Tomorrow Research – Task 3A Current State of Practice: Information Sharing

Eliciting Emergency Management Stakeholder Input

May 2024

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U.S. DEPARTMENT OF ENERGY

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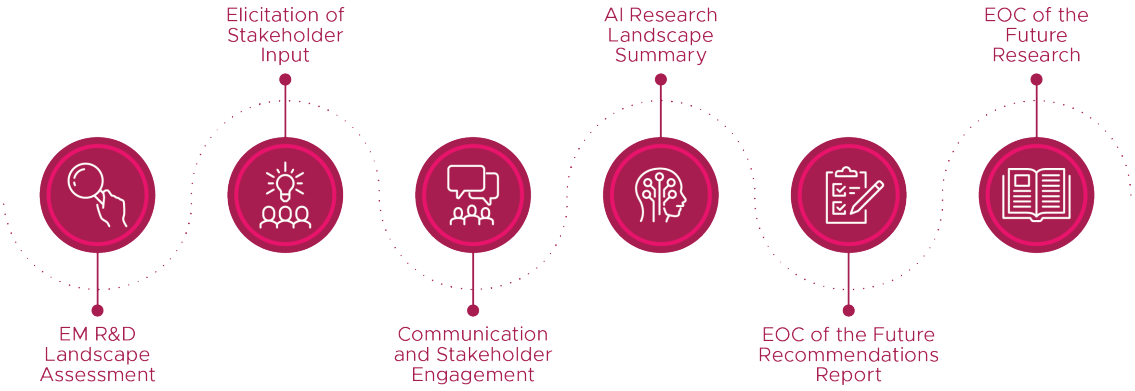
About the Emergency Management of Tomorrow Research

With support from the Department of Homeland Security (DHS) Science and Technology Directorate (S&T), Pacific Northwest National Laboratory (PNNL) is executing the Emergency Management of Tomorrow Research (EMOTR) Program to identify current EM research, elicit capability needs from EM practitioners, and identify where technology, such as artificial intelligence (AI), may benefit the future of EM and emergency operations centers. The project is delivering a phased and iterative approach to inform future research, development, and investments for the EM community.

This report details the methodology, analysis, and insights of interviews conducted as part of the task to elicit stakeholder input. Feedback from this task will help shape future EMOTR research, analysis, and recommendations. To learn more about this task or others within the EMOTR scope, contact emotr@pnnl.gov.



Summary

As a foundational component of the EMOTR program, PNNL conducted interviews with emergency managers to enhance understanding of the current state of practice and impediments to information sharing in EM. PNNL developed an interview protocol to provide a structured framework for consistent information gathering, maintaining alignment with the overall project while allowing for in-depth exploration of relevant topics. Key information sharing needs and opportunities identified.

- **Improving Resource Management and Situational Awareness:**
  - Establishing reliable validation and vetting processes for information.
  - Developing platforms for identifying and allocating just-in-time resources (material, training, responders, etc.).
  - Creating protocols for moving information within and across government entities.
  - Building a common operating picture for consistent situational awareness.
  - Improving public information dissemination and reducing social media interference.
- **Overcoming Policy, Trust, and Operational Gaps and Barriers:**
  - Overcoming barriers of funding limitations, political pressures, and proprietary systems.
  - Navigating organizational or jurisdictional policy constraints in AI use for EM.
  - Enhancing trust of systems, perceived ease of use, and flow of information.
  - Balancing human-machine interactions to address human capacity limitations and task saturation.
  - Tackling challenges related to data mining—extracting valuable information from large datasets (e.g., social media, sensor data, surveillance imagery).
- **Utilizing and Enhancing Existing Technology:**
  - Assessing technologies for information-sharing platforms and tools.
  - Optimizing WebEOC functionalities and their customizability.
  - Expanding real-time uploading of information into situational awareness platforms.
  - Improving integration and interoperability of solutions.
- **Exploring AI and Innovative Solutions:**
  - Investigating AI for planning, real-world scenarios, and resource management.
  - Implementing AI to assess the overwhelming amount of incoming information to assist with decision-making and minimize decision fatigue.
  - Developing AI for data analysis, incident summarization, and modeling for real-time disaster monitoring.
  - Communicate market research of existing AI solutions to inform procurement decisions.
- **Enabling Adaptable Emergency Operations Centers (EOCs) of the Future:**
  - Defining best practices and capabilities for future EOCs.
  - Exploring the concept of a geographic coordination center or shared EOCs.
  - Enhancing virtual EOC capabilities for improved information sharing, resilience, and record-keeping.

These priorities emerged repeatedly during discussions, highlighting their significance in EM and information sharing. This report summarizes PNNL's overall approach, outcomes, and analysis of the interviews. This information aims to assist DHS S&T in making informed decisions, emphasizing the importance of these priorities in EM and information sharing.

Acronyms and Abbreviations

AI	Artificial Intelligence
DHS	Department of Homeland Security
DOE	Department of Energy
EM	Emergency Management
EMOTR	Emergency Management of Tomorrow Research
EMS	Emergency Medical Services
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
LTE	Long-Term Evolution
ML	Machine Learning
PNNL	Pacific Northwest National Laboratory
PR	Project Responder
R&D	Research and Development
S&T	Science and Technology

Contents

1.0 Introduction

As part of the Emergency Management of Tomorrow Research Program (EMOTR), sponsored by the Department of Homeland Security (DHS) Science and Technology Directorate (S&T), Pacific Northwest National Laboratory (PNNL) is leading a three-part task to elicit input from the EM stakeholder and research community in a collaborative and interactive way. The task comprises a series of structured engagements (i.e., interviews, roundtables, surveys, and focus groups) designed to elicit stakeholder feedback on EM-related technologies and operations, discuss how they are evolving, and gather operational and researcher perspective on how they might impact the homeland security enterprise. Engagements are guided by previous and concurrent tasks conducted as part of the EMOTR mission to assess current research in the field of EM, elicit capability needs from EM practitioners, and identify where technology, such as artificial intelligence (AI), may benefit the future of EM and emergency operations centers (EOCs).

This report summarizes the subtask to elicit stakeholder input regarding "Current State of Practice: EM Information Sharing." This effort sought to collect individual stakeholder input via interviews to develop a baseline understanding of the current state of practice and impediments to information sharing. The interviews sought to validate findings from PNNL's landscape assessment[1] of EM research and elicit technology gaps and capability needs from the EM community in a collaborative and interactive manner. This report summarizes the stakeholder input, including capability gaps, barriers, and suggestions for future research and development (R&D). This process was the first of three tasks to elicit stakeholder input—subsequent tasks will analyze and summarize EM R&D needs and priorities as defined by EM practitioners, followed by a proposal for areas of research underrepresented in the current research ecosystem that are fit for EM community coordination.

2.0 Methodology

PNNL leveraged best practices from its First Responder Roadmap Project where the team developed a formal methodology for stakeholder engagement, and experience in leading first responder technology visioning to elicit feedback from EM stakeholders regarding information sharing. The goal of this inquiry is to build a baseline understanding of the current state of practice, capability needs and impediments, and validation of annotated bibliography findings related to EM information sharing.

2.1 Definition

Currently, no standard definition exists for information sharing within the field of EM. For the purposes of EMOTR, information sharing in EM is defined as follows, drawing on definitions from DHS[2] and FEMA[3]:

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[1] Sleiman, C., Thomas, K., Gray, J. Schroeder, J., Disney, M., Alsabagh, H., Ortega, S., Bartholomew, R., Lesperance, A. (2024). "Emergency Management of Tomorrow Research Landscape Assessment." Pacific Northwest National Laboratory. PNNL-35649

[2] DHS Management Directorate. (2017). "Instruction Manual 262-12-001-01 DHS Lexicon Terms and Definitions." https://www.dhs.gov/sites/default/files/publications/18_0116_MGMT_DHS-Lexicon.pdf

[3] FEMA. (2023). "Information Sharing Guide for Private-Public Partnerships." https://www.fema.gov/sites/default/files/documents/fema_information-sharing_guide.pdf

Information sharing in EM involves exchanging critical data, insights, and resources among various stakeholders before, during, and after emergencies or disasters. It encompasses the transfer of essential information—such as situational updates, resource availability, risk assessments, and response strategies—among government agencies, emergency responders, non-governmental organizations, and the public. Effective information sharing is pivotal for informed decision-making, enabling swift and coordinated responses, optimizing resource allocation, and enhancing public safety and resilience during crises.

2.2 Protocol

PNNL defined a suite of questions targeting the current practices, gaps, and barriers to information sharing; validation of information sharing capability gaps and priorities identified in the landscape assessment; and potential research areas warranting further consideration. The interview protocol and questions are available in Appendix A.

Interviews were conducted via teleconference with the EM interviewee, PNNL task lead, and support staff to document the feedback. Interview feedback is summarized in this report without attribution to facilitate a more open conversation.

2.3 Stakeholders

Interviews both re-engaged existing contacts and initiated new connections to develop a baseline understanding of current practices and impediments to information sharing. To identify diverse interviewees in discipline and jurisdiction, PNNL leveraged existing contacts from previous EM engagements and elicited grassroots suggestions to build new contacts. Ultimately, PNNL identified eight stakeholders and practitioners engaged in EM information sharing at the state and local level, dispersed throughout the nation (see Figure 1). The number of participants was limited per the statement of work.

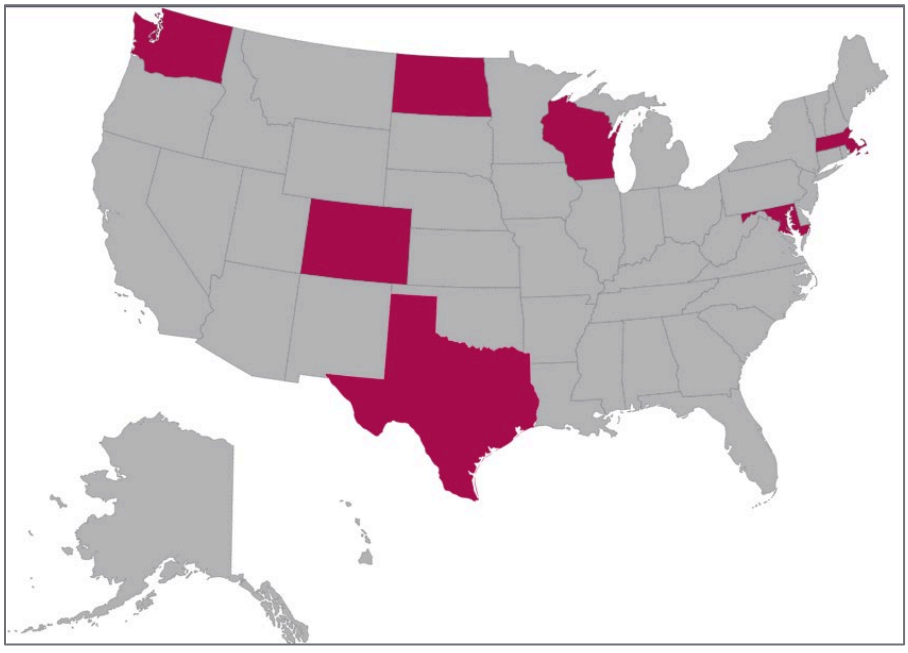

Figure 1. PNNL interviewed EM personnel from across the nation to better understand the current state of practice, capability needs, and impediments to information sharing.

2.4 Limitations

Interviews were limited to no more than eight stakeholders and practitioners engaged in EM information sharing at the state and local level. Interviews focused on information sharing in EM, a priority capability need identified in previous EM research and outreach. Furthermore, the purpose of the interviews was not consensus from stakeholders but rather broad elicitation to inform future research and investment. Lastly, interviews were scheduled for 30 minutes to make best use of participants' valuable time and limited availability.

3.0 Key Insights

3.1 Defining Information Sharing

While information sharing is often cited as a challenge in EM, conflicting definitions and its multidisciplinary and multijurisdictional nature make it a complex topic to address. To understand the current state of practice of information sharing and views of interviewees, interviews began with an inquiry to define information sharing. Stakeholders were asked to share how they defined or perceived information sharing in their field. Collective feedback reflected information sharing as:

- Vertical and horizontal, spanning layers of an organization as well as state and local level authorities and the public.
- Tiered, prioritized, and summarized for different audiences or end users (public, political, and first responder).
- Integrative, bringing together disparate data, intelligence, and other information from multitude of sources to make actionable decisions, inform policy, and guide operational and tactical direction.
- Varied by role and level, as information needs and decision-making capacity vary (i.e., emergency manager vs. policy maker vs. resource manager).

Participants' individual descriptions of information sharing are available in Appendix B.

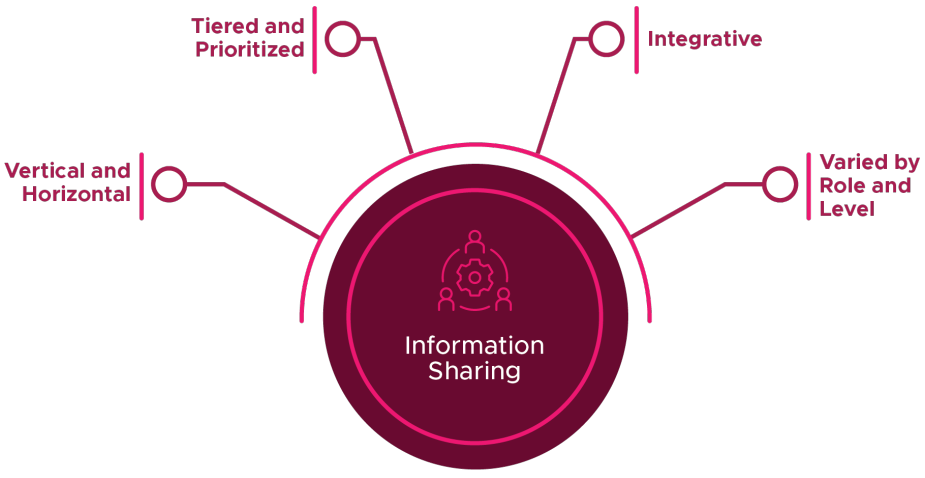

Figure 2. Definitions of Information Sharing

3.2 Current State of Practice

Based on collective feedback from interviewees, the current state of information sharing among EM personnel reflects a mixed landscape. While the integration of advanced technologies and communication platforms has led to significant progress, challenges continue to impede seamless information exchange, both internal and external to an organization. From pen and paper planning to internet- and cloud-based platforms, interviewees cited several examples of advances over the years. Most notably, the rapid transition to virtual operations during the COVID-19 pandemic accelerated the shift to virtual collaboration tools like Microsoft Teams and SharePoint. Furthermore, the adoption of cutting-edge technologies such as Geographic Information Systems and social media monitoring tools revolutionized situational awareness and decision-making processes during crises. Despite these advances, participants emphasized that challenges persist, such as issues with data standardization, privacy concerns, and the need for seamless integration among and between various stakeholders.

As the field continues to evolve, EM personnel are actively exploring innovative solutions and best practices to improve the overall effectiveness of information sharing, enabling a more resilient and coordinated response to disaster management. While advancements in R&D support these efforts, EM personnel continue to employ a human-centric approach for information sharing by leveraging their professional networks and orchestrating group discussions via conference calls during emergencies. The favored practice of information sharing through conference calls underscores the importance of personal connections and effective communication in navigating the complexities of EM.

3.3 Capability Needs

The following are information sharing challenges and opportunities identified by EM personnel during interviews. Participants shared where existing technologies or operations fall short in achieving effective information sharing, most commonly for decision-making, resource management, and situational awareness. Key challenges and opportunities for improvement include the following:

- Vetting, validating, analyzing, and synthesizing information, particularly in real time
- Analysis of sensor data (addressing incoming feeds from multitude of sensors)
- Automation for verifying information
- AI to synthesize and summarize incident information
- AI for resource management
- Managing alerts (messaging, frequency, outreach)
- Mis/disinformation propagated via social media
- Insider threats to information sharing systems
- Comprehensive national approaches for assessing technologies
- Researched and easily accessible guidance in technology investments
- Solutions that overcome limitations of current tools like WebEOC
- Solutions for ransomware, deep fakes, mis/dis-information

- Public information gaps on social media
- Human factor for discerning misinformation
- Contingency planning for alternative communications
- Information hub of lessons learned and after-action information.

3.4 Barriers to Improvement

EM personnel cited several barriers to effective information sharing within EM:

- **Trust** – Trust was the most cited barrier to information sharing, particularly trust in accuracy of information, sources of information (i.e., social media) and in the use of AI without a human in the loop. In addition to hesitance over accuracy, a fear persists that sharing information may result in retaliation, proposing an opportunity where automation could help reduce reliance on people in a positive way.
- **Funding and policies** – Securing funding and restrictive policies were persistently noted as the most difficult to advocate to change. Policy also hinders synergy across organizations and may affect the implementation of AI solutions (i.e., organizations or states that prohibit its use).
- **Interoperability** – Apart from WebEOC, EOCs are home to disparate and numerous technology solutions. No comprehensive approach exists for integrating capabilities for information sharing in EM. Proprietary systems, permissions-based access, and privacy concerns further limit opportunities for interoperability.
- **Time and resource constraints** – Implementing improved solutions is often labor intensive and cost prohibitive to evaluate and implement.
- **Ease of use** – New technology takes time to vet, implement, maintain, and train EM personnel—often a perishable skillset if the technology is not used regularly. Of existing tools mentioned, in person conversation, phone calls, and group text messages were preferred for their simplicity and reliability.
- **Political pressures** – Some participants cited the challenge of political pressures and ramifications to act with immediacy and share information versus vetting and validating first. Additionally, there is a lack of prioritization (and therefore funding and support) for innovation.
- **Accuracy and quality of data** – Information sharing platforms are only as good as the inputs they are given. Users should be trained in best practices for inputting useful information. There were numerous mentions of the potential for AI to assist with writing tasks, such as summaries for situational reports and grant proposals.

3.5 Vetting of the Landscape Assessment

A key thrust of the elicitation was to validate findings from PNNL's landscape assessment of EM research being conducted at academic institutions, U.S. national laboratories, and other research institutions. Participants were presented a list of leading capability needs captured in the bibliography and invited to share what critical gaps exist in the assessment that, if filled, could steer future research and investment in a more informed and impactful direction. Responses are summarized in Table 1, followed proposed gaps or alternative priority focus areas summarized in section 3.5.1.

Table 1. Landscape Assessment Validation

Research Area	Feedback from EM Personnel
Social Media Data - leverages platforms for information dissemination, situational awareness, and public peer-to-peer communications. Additionally, the public platforms provide real-time information for emergency managers and affected populations during large- and small-scale emergencies.	• Social media and use of handheld devices has taken over what used to be broadcast media sharing of information. • Challenges persist with trust and validity. Validating accuracy can take human labor and focus. • Furthermore, what can be considered trusted information sharing from a social media perspective?
Machine Learning Models - reduces the need for human intervention in data management and data mining to support decision-making. Such techniques allow the automatic detection, identification, and categorization of information by leveraging a computers ability to mimic human learning and analyze large datasets.	• Real-time makes all the difference, particularly with geospatial information. Investments in near-real-time modeling for flooding, hurricanes, etc. Gave example of flood modeling over 72 hours to a week on an ESRI-based product to see where the water is going to be and what infrastructure will be impacted (compared to National Weather Service forecasts every two weeks). • Innovation in this space remains a challenge. How do we innovate when no one wants to spend money on innovation? Suggested DHS grant program for innovation at state and local level. • Suggested this is the only topic of the five that can be looked at independently, but also may have overlap regarding data from wireless sensor challenge. • Emphasized hesitance regarding potential to jump too quickly into not fully understood AI solutions.
Optimization of Technology / Processes - feeds into the EM platforms. Examples are data integration, cross-sector coordination, communications, and information sharing.	• This task may seem easy to get to, but likely to go individual state by state, depending on what products they pick. • Consider how the data is coming in. Wireless connectivity issues highlight long-term evolution (LTE) challenge.
Wireless Sensors - enable real-time data collection, early warning systems, and rapid response. Advancements in the technology include energy efficiency, data analytics, and interoperability.	• This presents an area of opportunity. How can we maximize sensors? How do they communicate sensor data back? • Each sensor is different such that integration becomes localized versus large-scale. • Internet of Things is cited as a reflection of the LTE/5G challenge.
LTE Communications - enables emergency responders to communicate seamlessly with each other, regardless of their location or the type of device they are using. This enables critical information to be shared promptly, enabling a more coordinated and efficient response.	• This topic elicited the most questions regarding its scope and definition. What about 5G and beyond? Suggested focus area more encompassing of the future of cellular communications. • Gave example of state with multitude of sensors deployed where mesh network might make more sense in some contexts.

3.5.1 Gaps Identified

While participants generally concurred with the relevance of the proposed focus areas, they also identified what they perceived as gaps or additional opportunities for focus:

- **Resource management**. What platforms or capabilities could be applicable for soliciting, distributing, and tracking just-in-time resources? How do you manage the information of vendors and maintain accurate resource lists? How do you maintain relevancy in the resource management space? How do large-scale operations manage it (i.e., Amazon)?
- **Trust**. Trust and verification transcended all the focus areas suggested. How do we determine verifiable sources? Trust varies by disaster conditions. For example, a health/biological incident will focus on medical surveillance and accuracy of tracking of patient accountability, whereas a terrorist attack will focus on intelligence and surveillance.
- **Human interaction**. Beyond just the role of a human in the loop with AI, what about social capital, social networks, and human intelligence? Studies show the broader your network, the broader decision-making you will make (i.e., in a hurricane, people with more bridging ties [known neighbors, etc.] evacuated earlier than those with only bonding ties [limited personal contacts]).

3.6 Suggestions for Research to Enhance Information Sharing

Participants were invited to share thoughts or suggestions for research that could be applied to enhance information sharing (e.g., technological, policy). Suggested focus areas included the following:

- Use of satellite imagery, sensing, and communication
- Near-real-time forecasting for flooding, hurricanes, wildfires, etc.
- Automation for relevant tasks
- Navigating the nexus of human interaction, AI, and resource management
  - AI for planning, real-world scenarios, and training for realistic experience.
  - AI for saturation effect – AI to sort through the noise (i.e., data mining), reducing human decision fatigue of trying to get the right information.
  - Resource management planning for just-in-time resources.
  - Trust in AI – AI can help with data crunch but how do we do that in a trusted platform?
- As we increase information flow and capacity, consider the implications and opportunities:
  - What are the critical missions an EOC of the future must do?
  - What is the bandwidth of the human ability to receive information, process it, operate it, push it out, and start over?
  - How long can EM personnel effectively process large amounts of information and what is the diminishing return?
- The structure of the EOC of Tomorrow will be varied. Each will have different infrastructure capabilities and information will take on different challenges.
  - Is it fixed?

  - Tactical?
  - Mobile?
- Social sciences of how EM personnel really exchange information.
  - What are the protocols?
  - How do we make sure the right people have it?
- Building a common operating picture.
  - How do we build a system, framework, structure, and means of displaying information that will truly give us a national-level common operating picture applicable all the way to the granular local level?
- Market research and guidance for emergency managers when buying a platform, considerations for investments, best practices from across U.S.
  - Where and what technology is being utilized to best effect?

3.7 Sources of Information

The state of information sharing extends beyond the walls of an EOC to include how EM personnel commonly seek out information to inform their EOC operations and best practices. To that end, interviewees were asked where they most commonly look for research and practitioner news in their field. The most common response was peer networks and professional organizations, including the following:

- National Emergency Management Association
- Peers in other states (personal networks)
- Conferences
- Online repositories such as the Harvard Global Crisis & Resilience Forum, Social Research Science Network, ResearchGate, and Qeios.

4.0 Discussion

Collectively, EM personnel interviewed identified the following capability challenges and opportunities facing information sharing and EM:

- Vetting and validating incoming information. The most cited challenge was vetting and validating incoming information. Information may be raw or partially analyzed, but immediacy is key for building a timely understanding of the emerging situation. Human-machine interaction was cited as beneficial for handling information surges and enhancing decision-making; however, trust for technology in decision-making remains a barrier.
- Resource management and situational awareness. Two information sharing tasks suggested for potential improvement through AI, automation, or enhanced technology included resource management and situational awareness, to include synthesizing and summarizing information for distribution.
- Trust. Trust remains a persistently cited barrier to the use of AI, and the human interaction is essential for managing mis/dis-information. Trust of public information is further undermined

by the misuse of social media by trolls and bad actors, who disseminate misinformation that mute official messages.

- Integration and interoperability. Integration and interoperability issues persist because of the numerous, disparate tools in place across agencies and jurisdictions that lack cross-organizational coordination (whether due to technical, policy, or other constraints). While WebEOC is common in the industry, users noted that each instantiation differs, and it is unfeasible to replace at this time due to costs and adoption challenges. Several interviewees encouraged that customization could improve its usability, but ultimately, they desire a transition to more robust, cloud-based system.
- Market research. There was a repeated emphasis on the need for research to inform technology evaluation and investment. EM personnel need actionable, easy to use research to guide investment decisions. EM personnel often lack the time and resources to lead such in-depth market research. Additionally, the results of such evaluations should be broadly shared with and easily accessible to the EM community.

Ultimately, with disasters increasing in frequency and intensity, interviewees emphasized that the future EOC most importantly needs to be adaptable—a mix of physical spaces, formats (in person, virtual, hybrid), and capabilities. Ongoing research and outreach are critical for informed technology evaluation and investment decisions to identify, vet, and implement solutions that fit tomorrow's challenges.

5.0 Next Steps

This task sought to elicit stakeholder input to better understand current practice of and impediments to information sharing. Figure 3 highlights key priorities and needs for improving information sharing as was discussed in eight interviews with EM personnel. The goal of this inquiry was not to build consensus but rather broad exploration of the current state of practice, capability needs and barriers to implementation, and validation of annotated bibliography findings related to EM information sharing.

Insights from this task will guide future EMOTR outreach and elicitation efforts to further refine priorities, technology gaps, and capability needs. Next steps include outreach to EM R&D practitioners to review ongoing research programs, assess their effectiveness, identify gaps, and connect with EM R&D stakeholders to foster community coordination around research needs underrepresented in the current research ecosystem. The combined outputs of this guided elicitation will help DHS S&T inform future research and investments.

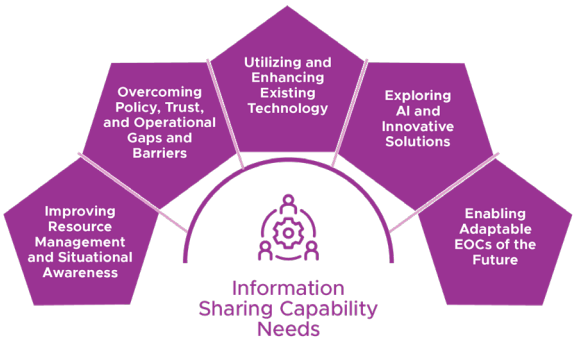

Figure 3. Information Sharing Capability Needs

Appendix A– Interview Questions

Interview overview:

- 30 minutes
- Two people; one to lead discussion; other to capture and summarize interview input.

Interview Start: Provide a high-level summary of EMOTR and the overall objectives/outcomes of the project and how this interview will fit into the greater context of the project.

Interview Questions:

1. Can you briefly describe your current role and how long you have been working in emergency management?

2. For your role, how would you define information sharing?
    - What kind of information is needed in real-time vs. what information is needed for post-event reporting?

3. How is information shared – including both formal and informal channels?
    - Is the information best shared raw or would it benefit from some processing?
    - Who do you get information to and how? Do you have a process in place? Or not?
    - Once received – what the next step? (Tailor these questions – EM vs. Watch Center)
    - Lack of process?
    - Lack of means of sharing (impediments for logistics to provide information to others?)

4. What capability gaps hinder your organization from information sharing?
    - Do you see ways that tools or technologies might mitigate these issues?

5. What have you seen that works to establish effective, cross-jurisdictional, inter-organizational, and cross platform linkages for information sharing and internal coordination?

6. Can you talk about the interplay between information sharing and decision-making?
    - pre-, during, and post-event?
    - Are there specific capability needs in one (i.e., pre-) that you don't have in other parts of the event (i.e., post)?

Mid-Interview/Transition to Bibliography: Provide a short, couple of minute summary of the annotated bibliography from a high level. Highlight the Clusters of Research below:

Publication counts per cluster.
- Social Media Data
- Machine Learning Models
- Optimization
- Wireless Sensors
- LTE

7. **Validation Question:** From what we've captured in the bibliography, what critical gaps exist in our current research assessment that, if filled, could steer future research and

investment in a more informed and impactful direction?

8. What are your thoughts/suggestions for research that could be applied to enhance information sharing – this could be technological, policy, or human factors?

If time permits:

9. What sources do you receive your information from? Is there a specific Journal?

Appendix B– Information Sharing Definitions

The following are EM personnel's descriptions of "information sharing" shared during interviews:

- Information sharing is bi-directional, with emergency managers receiving information from the first responders, funneled up to state operations center, or bi-directional through Joint information Center. Information flows down to local emergency managers and horizontally out to the state and private sector citizens. Responders report known details to the best of their ability in as real time as possible (i.e., attack vector, how many people, what resources are on scene, are there causalities).
- Information sharing is the data, information, and intelligence to make actionable decisions, craft policy and strategic intent, and guide operational and tactical direction.
- Information sharing is making sure whoever needs the information gets it. Protocols facilitate movement of information between and across government, and recipients use information to build a common operating picture.
- Information sharing is creating situational awareness in whatever form that comes in (voice, data, video).
- Information sharing at the state level is situational awareness, trying to get good and actionable information. Multiple levels of things are going on at the state level be clear on incident support (local level, operational), give situational awareness to elected leaders and Public Information Officers, coordinating resources, and talking to elected officials (i.e., declarations).
- Information sharing is tiered (public, political, and first responder) and relies on timely, accurate, actionable information to make good decisions, along with intuitive capabilities of the emergency manager who understands their jurisdiction (based on after-action reviews, etc.).
- Information sharing for an emergency manager is a daily task of situational awareness. They are the point-person to put information out to key staff who need to be informed for decision-making and action. Make sure everyone involved in whatever scenario has information to make operational and policy-level decisions. For a policy advisor, it is meeting with directors and other leadership, and keeping them updated on trends and risks to mitigate, react, and recover from situations.
- Information sharing is horizontal and vertical—horizontal within an organization, such as a peer to peer, and vertical, such as between management agencies (FEMA, local disaster managers).

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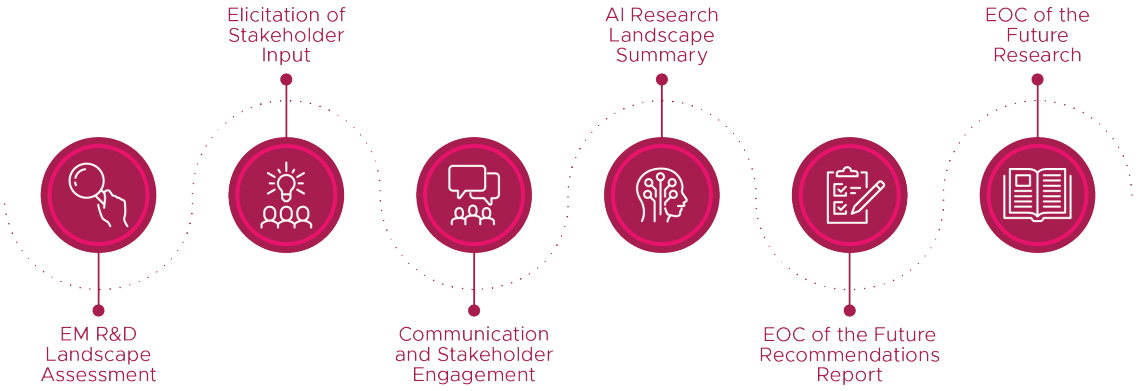
About the Emergency Management of Tomorrow Research

The Department of Homeland Security (DHS) Science and Technology Directorate (S&T) is partnering with Pacific Northwest National Laboratory (PNNL) to execute the Emergency Management (EM) of Tomorrow Research (EMOTR) program to identify current EM research, elicit capability needs from EM practitioners, and identify where technology, such as artificial intelligence (AI), may benefit the future of EM and emergency operations centers. The project is delivering a phased and iterative approach to inform future research, development, and investments for the EM community.

This report details the methodology, analysis, and insights of interviews and focus groups conducted as part of the task to elicit stakeholder input. Feedback from this task will help shape future EMOTR research, analysis, and recommendations. To learn more about this task or others within the EMOTR scope, contact emotr@pnnl.gov.



Summary

As a foundational component of the EMOTR program, PNNL conducted outreach to the EM research and development community to establish a comprehensive understanding of ongoing initiatives, existing capability gaps, unaddressed research endeavors, and the efficacy of research in addressing EM needs. PNNL conducted interviews and focus groups connecting with EM researchers and operational personnel nationwide. The following is a summary of themes that emerged, highlighting the interdisciplinary nature of crisis informatics research, the importance of addressing gaps in information dissemination and technology implementation, and the need for human-centric approaches in EM.

Challenges

- Mis/disinformation on social media and information equity, agility, and integrity.
- Data integrity and network security concerns regarding AI/machine learning (ML) applications for emergency responders.
- Gaps in human-centric research and needs of emergency response personnel.

Artificial Intelligence

- Need for AI and ML analysis for detecting a crisis and improving communication.
- Further exploration of AI applications in security, spectrum analysis, and network access.
- Need for human-in-the-loop systems and trust networks involving AI agents.
- Lack of access to and availability of data is a hindrance in using AI in EM, particularly in the private sector where data access is tightly controlled, limiting the ability to leverage AI for response efforts.

Emergency Operations Center Evolutions

- Need to integrate social media analytics and AI for crisis detection and response.
- Emphasis on expanding common operating pictures, zero trust architecture, and cloud solutions.
- Need to integrate a blend of in-person, virtual, and hybrid operations to be adaptable to diverse disaster scenarios and enhance response effectiveness.

Future Trends and Opportunities

- Further exploration is needed of emerging technologies such as AI/ML, cloud solutions, and unmanned aerial systems for emergency response.
- Importance placed on the integration of cybersecurity in emerging systems.
- Need for improved testing mechanisms, particularly in real emergency scenarios.

These themes emerged repeatedly during discussions, highlighting their significance in the EM R&D community. This report summarizes PNNL's overall approach, outcomes, and analysis of the interviews. This information aims to assist DHS S&T in making informed decisions for future EM R&D.

Acronyms and Abbreviations

AI	Artificial Intelligence
DHS	Department of Homeland Security
DOE	Department of Energy
EM	Emergency Management
EMOTR	Emergency Management of Tomorrow Research
EMS	Emergency Medical Services
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
ML	Machine Learning
NASA	National Aeronautics and Space Administration
OEM	Office of Emergency Management
PNNL	Pacific Northwest National Laboratory
PR	Project Responder
R&D	Research and Development
S&T	Science and Technology

Contents

1.0 Introduction

As part of the Emergency Management (EM) of Tomorrow Research Program (EMOTR), sponsored by the Department of Homeland Security (DHS) Science and Technology Directorate (S&T), Pacific Northwest National Laboratory (PNNL) is leading a three-part task to elicit input from both the EM stakeholder and research and development (R&D) communities in a collaborative and interactive way. Task 3, " Elicit Emergency Management Stakeholder Input," comprises three sub-tasks implementing structured engagements:

- Task 3A, "Current State of Practice: Emergency Management Information Sharing," developed a baseline understanding of current practice and impediments to information sharing.
- Task 3B, "Emergency Management Research and Development Community Awareness," conducted outreach to the EM R&D community to establish a comprehensive understanding of ongoing initiatives, existing capability gaps, unaddressed research endeavors, and the efficacy of research in addressing EM needs.
- Task 3C, "Emergency Management Research and Development Community Coordination," fostered a dialogue with EM R&D stakeholders to encourage collaboration, increase transparency, reduce overlaps, and increase overall efficiency of research investments in EM.

Figure 4. EMOTR Task 3B engages the EM R&D community to build awareness of and better understand capability needs in key aspects of technology development, including interoperability, standards, enterprise architecture, and transition impediments.

Task 3 engagements took the form of interviews, roundtables, and focus groups. These engagements were guided by previous and concurrent EMOTR tasks designed to assess current research in EM, elicit capability needs from EM practitioners, and identify where technology, such as artificial intelligence (AI), may benefit the future of EM and emergency operations centers (EOCs). Together, EMOTR outreach tasks are eliciting, analyzing, and summarizing EM R&D needs and priorities as defined by EM practitioners and will be followed by suggestions for areas of research underrepresented in the current research ecosystem that are fit for EM community awareness.

This report summarizes Task 3B, "Emergency Management Research and Development Community Awareness." The results of tasks 3A and 3C are available in separate reports available by request to emotr@pnnl.gov.

Task 3B sought to collect individual stakeholder input via interviews and focus groups (in-person and

virtual) to develop a baseline understanding of the ongoing research efforts within the EM R&D community. This task sought to validate findings from the EMOTR Task 2 Landscape Assessment[1] of EM research and elicit technology gaps and capability needs from the EM community using a structured elicitation approach. Stakeholders for this task included EM R&D personnel representing government and academic research institutions and operational personnel from private and public EM organizations This report summarizes the stakeholder input, including capability gaps, barriers, and suggestions for future R&D, in the areas of interoperability, standards, enterprise architecture, and transition impediments (Figure 1).

2.0 Methodology

PNNL leveraged best practices from its First Responder Roadmap Project,[2] where the team developed a formal methodology for stakeholder engagement and expert elicitation. PNNL led technology visioning exercises to elicit feedback from the EM R&D community regarding the current state of EM research programs and their effectiveness.

The goal of connecting with the EM R&D community was to build a baseline understanding of the current efforts of the research community, identify capability needs, and validate previous EMOTR findings. PNNL leveraged the EMOTR Task 2 Landscape Assessment to identify existing research programs and identify experts whose research aligned with EMOTR areas of interest.

2.1 Protocol

PNNL developed an interview protocol to provide a structured framework for consistent information gathering, maintaining alignment with the overall project objectives while allowing for in-depth exploration of relevant topics. The interview protocol consisted of a suite of questions targeting the effectiveness of current research programs, assessing their effectiveness, and identifying gaps and potential research areas warranting further consideration (See Protocol in Appendix A). One-on-one interviews with technical researchers were crucial to gaining an in-depth understanding of their research within the context of EM. Using a structured set of questions, these interviews provided valuable insights into the theoretical frameworks, methodologies, and potential applications of their work in real-world emergency scenarios. Additionally, conducting focus groups with operational practitioners served to validate and contextualize the findings from the interviews. By involving those directly serving in EM operations, the interviews and focus groups explored how identified research efforts align with practical needs and can effectively address challenges faced in the field. This comprehensive approach identified gaps in current research and made practitioners aware of the current state of EM research, which can ultimately lead to more effective EM strategies and solutions.

Interviews were conducted via teleconference with the EM R&D interviewee, PNNL EMOTR task lead, and PNNL note-taker. Interview content is summarized in this report without attribution to facilitate a more open conversation.

[1] Sleiman, C., Thomas, K., Gray, J. Schroeder, J., Disney, M., Alsabagh, H., Ortega, S., Bartholomew, R., Lesperance, A. (2024). “Emergency Management of Tomorrow Research Landscape Assessment.” Pacific Northwest National Laboratory. PNNL-35649

[2] Funded by DHS S&T in fiscal year 2024, the First Responder Capability Roadmap connected with first responders nationwide to understand their capability needs and create an actionable framework for strengthening capabilities and technology.

Additionally, PNNL conducted two focus groups in February 2024 with representatives from city, county, state, and private EM organizations:

- An in-person focus group convened in Boulder, Colorado. The event facilitated face-to-face interactions with structured discussions moderated by experienced facilitators and fostered a conducive environment for open dialogue.
- A virtual focus group leveraged online platforms and video conferencing tools to enable remote participation from geographically dispersed stakeholders. The virtual session maintained a similar level of engagement and interaction as in-person meetings, with participants joining from various locations via their electronic devices.

Each focus group was asked to respond to eight questions, covering the EMOTR themes of interoperability, standards, systems architecture, and transition challenges. Detailed protocols for the in-person and virtual focus groups are in Appendix B and Appendix C, respectively.

2.2 Stakeholders

With a clear focus on engaging stakeholders from diverse geographical areas, PNNL orchestrated targeted outreach efforts for both a local and national audience. Stakeholders for this task included EM R&D personnel such as representatives from government and academic research institutions and city, county, state, and private EM organizations across the United States. Leveraging relationships cultivated over time along with new partnerships established at conferences or through grassroots connections made during previous EMOTR tasks, PNNL reached out to key stakeholders to disseminate information about the focus group, inviting participation from individuals and organizations invested in the local and national EM community.

2.2.1 EM R&D Interviewees

A guiding source for PNNL's outreach to the EM R&D community was the EMOTR Task 2 Landscape Assessment, which is available separately from this report.[1] Analysis of the assessment findings allowed PNNL to identify current research initiatives and EM R&D researchers relevant to the EM mission and of potential interest for this elicitation task. The research clusters derived from the Task 2 Landscape Assessment (Figure 2) informed the strategic selection of participants whose research aligned closely with these predominant categories. This approach facilitated a targeted identification of experts whose work intersected with the areas of interest relevant to the EM mission.

[1] Sleiman, C., Thomas, K., Gray, J. Schroeder, J., Disney, M., Alsabagh, H., Ortega, S., Bartholomew, R., Lesperance, A. (2024). "Emergency Management of Tomorrow Research Landscape Assessment." Pacific Northwest National Laboratory. PNNL-35649

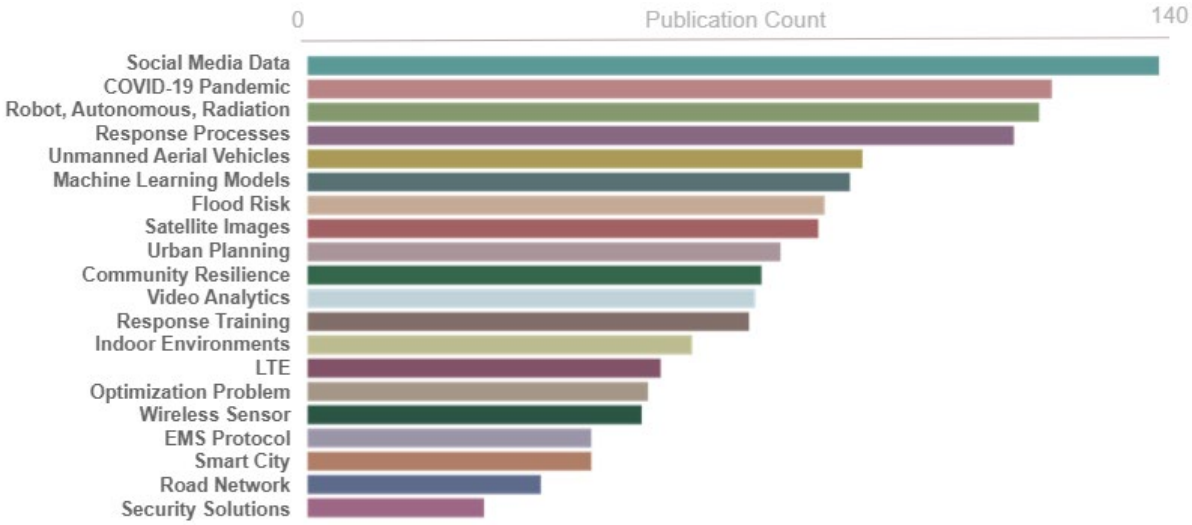


Figure 5. Top Research Clusters from EMOTR Landscape Assessment

2.2.2 Focus Group Participants

To identify focus group participants, PNNL leveraged long-standing relationships with the EM community via previous research and outreach efforts for DHS S&T collaborations and via the Northwest Regional Technology Center.[1] PNNL strategically leveraged attendance at conferences such as the International Association of Emergency Managers and the National Homeland Security Conference to establish connections within the EM space. Ultimately, PNNL identified 23 operational stakeholders within academia, the public sector, and the private sector dispersed throughout the nation.

2.2.3 Nationwide Outreach

Together, interviewees and focus group participants (in person and virtual) hailed from the following universities and research organizations across the nation (Figure 3):

Universities:
- Carnegie Mellon University
- George Mason University
- Indiana University
- Kansas State University
- University of Colorado Office of EM (OEM)
- University of Florida
- University of Wisconsin – Madison
- Vanderbilt University – Institute for Software Integrated Systems

Federal Government:
- Idaho National Laboratory
- National Aeronautics and Space Administration (NASA)

Private Corporations:
- Cascadia Region Earthquake Workgroup
- Moderna

Cities:
- Arvada, CO

[1] PNNL stewards the Northwest Regional Technology Center, a virtual center enabling homeland security solutions through outreach to emergency responder communities, federal, state, and local agencies, and private sector stakeholders. Learn more at http://www.pnnl.gover/projects/nwrtc.

- Broomfield, CO
- Boulder, CO
- Denver, CO
- Seattle, WA
- Thornton, CO

Counties:
- Arapahoe County, CO
- Boulder County, CO
- Hamilton County, OH
- Larimer County, CO
- Sacramento County, CA
- Weld County, CO

State Organizations:
- California Governor's Office of Emergency Services
- Colorado Department of Transportation EM
- Colorado OEM
- Colorado State Fire Chiefs Association
- North Central Region Healthcare Coalition EM Program

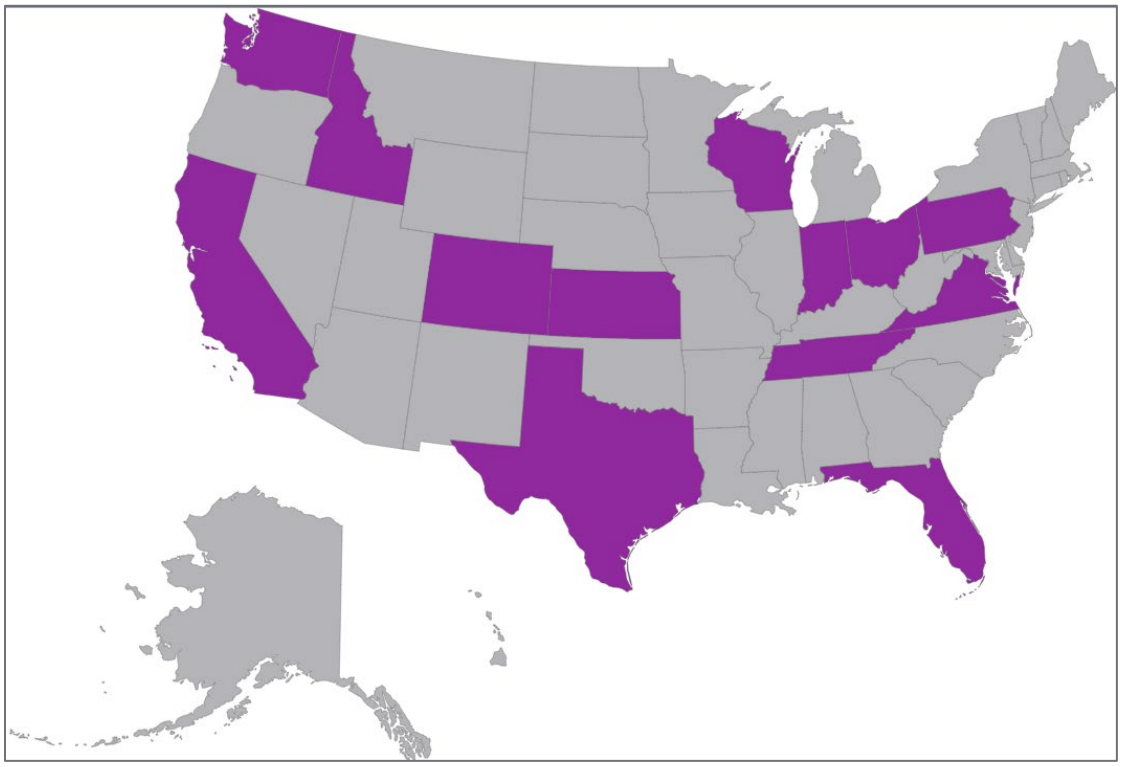


Figure 6. PNNL interviewed EM R&D stakeholders from across the nation in a series of structured interviews and focus groups.

PNNL's outreach approach combined targeted engagement with broader dissemination efforts, pursuing inclusivity and diversity. By harnessing the power of conferences and long-standing connections, PNNL effectively facilitated dialogue and collaboration among stakeholders, ultimately enriching the research process and driving meaningful outcomes.

2.3 Definitions

Four focus areas—transition impediments, system architectures, interoperability, and standards—were outlined as priorities for input by DHS S&T to guide EMOTR outreach and maintain consistency across discussions, PNNL utilized DHS S&T's existing resources to establish definitions for the key terms:

- **Transition Impediments:** Encompasses the challenges and barriers associated with deploying new technology and arising from the integration of new systems or platforms, leading to compatibility issues or disruptions to the current infrastructure.
- **System Architectures:** Outlines the organizational structure, relationships, and workflows to effectively align resources and capabilities through integrated, multidisciplinary analysis focused on improving interoperability, promoting industry standards, and minimizing the impacts of transition impediments.
- **Interoperability:** Highlights the capability of systems, technologies, and processes to seamlessly communicate, share information, and integrate into existing infrastructure for effective collaboration across diverse entities and platforms.
- **Standards:** Encompasses established formal and vetted protocols and guidelines that enable consistency and interoperability across various EM and response aspects.

2.4 Limitations

To maintain compliance with the Paperwork Reduction Act[1] to minimize the burden from the collection of information, interviews were limited to no more than nine stakeholders engaging in EM R&D. Furthermore, the interviews were not meant to achieve consensus from stakeholders but rather to elicit feedback from a broad array of EM R&D personnel to inform future research and investment.

To allow for engagement by a geographically distributed group of stakeholders, PNNL also held a virtual focus group in addition to the in-person focus group in Boulder, Colorado. While the virtual option may have presented limitations to engagement due to potential technological barriers and the lack of face-to-face interaction, it ultimately allowed PNNL to reach a broader audience. By eliminating geographical constraints and accommodating the busy schedules of stakeholders, the virtual format facilitated participation from individuals who might have otherwise been unable to attend in person. Despite the challenges, the virtual approach expanded the scope of outreach, enabling the team to gather insights from a diverse range of EM R&D stakeholders. Lastly, interviews were scheduled for 30 minutes to make the best use of participants' valuable time and limited availability.

3.0 Summary of Interviews

The following section provides a summary of insights from the outreach conducted to the EM R&D community. Inputs and analyses are included without attribution of individuals to maintain anonymity.

3.1 Research and Development Activities: Feedback from Researchers

The following is a summary of key insights garnered from interviews with researchers conducting EM R&D at leading research institutions with relevance to the EMOTR mission

[1] DHS. 2022. Paperwork Reduction Act Burden Reduction Initiative. https://www.dhs.gov/sites/default/files/2022-05/Burden_Reduction_Initiative_Memo_Final%20PDF%20CIO%20signed.pdf

space. PNNL selected researchers based on relevance in the EMOTR Task 2 Landscape Assessment findings and via grassroots networking during other EMOTR outreach.

3.1.1 Idaho National Laboratory

The current research focuses on wireless communications, with a particular emphasis on 5G technology, millimeter wave applications, and communications security. Key trends identified include the prioritization of maximizing coverage and security for first responders, as well as the encouragement of open systems at the national level. Research endeavors aim to enhance communications and security for emergency responders, with a specific focus on addressing gaps in securely utilizing 5G. AI and machine learning (ML) are being explored to reinforce security measures and optimize spectrum usage, potentially aiding in identifying and mitigating network interference. Key research priorities for the next decade include enhancing communications systems for first responders, conducting applied research for security, and anticipating and addressing emerging threats through scenario-based approaches.

3.1.2 National Aeronautics and Space Administration

As a government agency operating under the jurisdiction of the U.S. federal government, NASA plays a role in advancing scientific knowledge, technological innovation, and space exploration for the benefit of the public and the advancement of society. PNNL interviewed EM practitioners from NASA to gain insights into their contributions to EM R&D. Below are key focus areas of the discussion:

- NASA is adapting its technology to support emergency response efforts and aims to facilitate operational testing of its innovations.
- They fund small businesses working on applicable technologies through Small Business Innovation Research programs and collaborate with public and private entities.
- Operating within the Technology Readiness Level 4-6 range, NASA conducts nationwide workshops, addressing cascading disasters as future challenges.
- The "valley of death" between research and operational use, cybersecurity concerns, and data integration issues persist.
- They are working on projects like Open Data Integration and Advanced Capabilities for Emergency Response Operations to integrate data and guide aircraft usage during emergencies, focusing initially on wildfires and subsequently on hurricanes and other hazards.

3.1.3 Carnegie Mellon University

Researchers in the Carnegie Melon University Software Engineering Institute within the Computer Engineering Response Team Division's Monitoring and Response Directorate apply architecture-centric approaches to systems-of-systems to analyze and identify potential risks to improve their cybersecurity posture. The group manages situational awareness within the division, emphasizing security aspects of zero trust and designing systems to identify concerns and enhance risk assessments. Trends highlighted included zero trust and cloud technology, while research gaps focused on behavior analytics and trust in change, specifically the integration of AI in security strategies and cloud environments.

3.1.4 George Mason University

PNNL engaged with the Humanitarian Informatics Lab within the Department of Information Sciences and Technology at George Mason University, a research institution at the forefront of exploring various aspects of EM, including data integration, public education, risk perception, and the application of emerging technology. Below are key focus areas of the discussion:

- The researchers are focused on AI/ML pipelines to filter social media information and improve accessibility to relevant data.
- The identified gaps include policy issues, public perception challenges, and social-technical hurdles surrounding AI/ML applications, with a notable disconnect between social/behavioral research and data integration efforts in EM.
- The research aims to close gaps in understanding public behavior and perception of risk while leveraging technology to enhance decision support systems.
- The recommendations include enhancing community connections, fostering partnerships, and bridging the gap between research and operations.
- The priorities for future research include data integration, early warning systems, and understanding the dynamics of emerging threats.
- The research aims to contribute to more effective and informed EM strategies through interdisciplinary collaboration, technology integration, and community engagement.

3.1.5 Indiana University

Discussions with the University of Indiana's Crisis Technologies Innovation Laboratory unveiled a notable disparity between the advanced technological tools utilized in informatics work and the resources accessible within EOCs. From these conversations, key themes emerged, emphasizing the critical requirement for customizable information and automation tools to aid emergency managers in streamlining data organization. Moreover, discussions highlighted significant challenges in information management within EOCs, underscoring the critical necessity for intermediary systems. These systems are essential to facilitate the smooth dissemination of vital information across all phases of EM, ensuring that relevant data reaches decision-makers promptly and accurately. Below are key focus areas of the discussion:

- Evaluate options for innovative designs for EOCs, considering how technology and infrastructure can be optimized to enhance operational effectiveness.
- Optimize redundancy strategies, such that backup systems and processes are robust and reliable, thereby minimizing the risk of failure during critical moments.
- Develop comprehensive training programs tailored for emergency managers. These programs should equip them with the skills and knowledge to navigate traditional and emerging threats, enabling a proactive and effective response to any crisis.

3.1.6 University of Florida

Discussions with the University of Florida's Department of Urban and Regional Planning primarily focused on urban resilience and crisis informatics to understand the current R&D initiatives in EM. The department's work delves into integrating risk and crisis communication within EM, employing a bottom-up approach by analyzing online user responses to disasters and emergencies reported on social media platforms such as Twitter. This interdisciplinary

research aims to develop simulations, ML predictions, and culturally relevant risk communication strategies. Identified trends in research include urban resilience, crisis informatics, and ongoing efforts to combat misinformation on social media during crises. Gaps in information equity, agility, and integrity emphasize the need for improved warning and risk information delivery formats and content to reduce misinformation. Additionally, challenges in testing concepts were mentioned, highlighting the need for pilot platforms such as tabletop exercises to test EM strategies. Regarding future research priorities, enhancing information equity, agility, and integrity remain a key focus, along with exploring emerging trends such as augmented reality/virtual reality for risk communication and scenario simulation for emergency response preparedness.

3.1.7 University of Wisconsin – Madison

The discussion with the University of Wisconsin–Madison emphasized the importance of human-centric research in understanding the needs of emergency response personnel. Collaborating with professionals in the field emerged as a vital approach to developing or enhancing technologies for EM. Ongoing projects focus on the future of work in AI and integrating new technologies into emergency response scenarios. Areas for future research include human performance under extreme conditions and human-centered AI training for emergency responders. Challenges in seamlessly integrating humans with technology, particularly in high-stress environments like EOCs, were highlighted. Additionally, understanding human-AI interactions and trust dynamics within emergency response teams emerged as critical areas for future research. Overall, the conversation emphasized the multidisciplinary nature of EM research and the need to address the human-centric approach alongside technological advancements.

3.1.8 Vanderbilt University

The discussion with Vanderbilt University highlighted the importance of leveraging AI to enhance EM, particularly in the context of 9-1-1 and 3-1-1 phone calls. The School of Engineering aims to address various challenges in labor shortages, mental health support during emergency calls, and efficient resource allocation. Projects include automating non-emergency 3-1-1 calls and assisting call takers in dispatch decisions. They are also interested in integrating AI into emergency communication workflows and improving situational awareness through technologies like drones. Research in generative AI is also a priority for enhancing EOCs by leveraging large language models for prediction tasks. Generative AI models, such as GPT (Generative Pre-trained Transformer), have demonstrated remarkable capabilities in understanding and generating human-like text based on input prompts. In an EOC setting, these models can analyze vast amounts of textual data, including incident reports, social media updates, and news articles, to generate predictive insights regarding potential hazards, resource needs, and community response frameworks. By training these models on historical data and continuously updating them with real-time information, EOCs can improve their situational awareness, anticipate emerging threats, and make more informed decisions. Moreover, generative AI can assist in automating routine tasks, such as drafting incident reports or updating stakeholders, allowing emergency responders to focus on critical decision-making and resource allocation.

3.1.9 Kansas State University

Discussions with Kansas State University's National Agricultural Biosecurity Center highlighted challenges emergency managers face in response to agricultural disasters and animal disease

outbreaks. Unlike traditional rapid-response scenarios, these emergencies unfold over longer time scales, requiring a shift in preparedness and response strategies. Key challenges include resource management, continuity of business operations, and managing routes for animal movement during crises. Bridging the gap between traditional emergency responders and agricultural personnel is essential, highlighting the importance of education and training initiatives that integrate Incident Command System principles with farming practices. However, access to crucial data remains a significant barrier, particularly in industries like poultry farming, hindering efforts to leverage AI for emergency response. Future research priorities include improving biological threat surveillance systems, understanding the impact of natural disasters, and enhancing response capabilities for emerging threats in cyberbiosecurity.

In exploring diverse research initiatives across various institutions, several key themes and approaches have emerged, underscoring the dynamic landscape of EM and the multifaceted challenges it entails. From leveraging cutting-edge technologies like AI to addressing labor shortages and enhancing situational awareness in emergency communication workflows, to the imperative need for customizable information and automation tools within EOCs, the interviews reflected a comprehensive effort to enhance preparedness and response capabilities. Novel approaches such as integrating risk communication within social media platforms and employing generative AI models for predictive analytics demonstrate a forward-looking approach to addressing emerging threats and enabling resilient crisis management frameworks. Furthermore, the emphasis on interdisciplinary collaboration, community engagement, and bridging the gap between research and operational personnel underscores a holistic approach to the future of EM. As emergency managers continue to navigate the evolving risk landscapes and increasingly complex scenarios, these concerted efforts reflect a commitment to innovation, adaptability, and resilience that forms the foundation of effective EM strategies.

3.2 Effectiveness of Technology: Feedback from Emergency Managers and Operators

The following is a summary of the focus groups conducted with EM operational personnel. PNNL conducted two focus groups, one in person in Boulder, Colorado, with more than 15 participants from cities, counties, and the state of Colorado, and the other virtual, conducted via Microsoft Teams, with seven participants from private organizations, cities, and states from throughout the country. Both focus groups leveraged in-person and virtual collaboration tools that offered advantages in terms of accessibility and inclusivity, allowing a diverse range of stakeholders to contribute to the discussion and provide valuable insights on research strategies and potential solutions for enhancing EM capabilities (Figure 4). EM personnel participated in a guided, collaborative discussion that sought to determine the effectiveness of current research in closing EM capability gaps in consideration of interoperability, standards, enterprise architecture, and transition impediments.

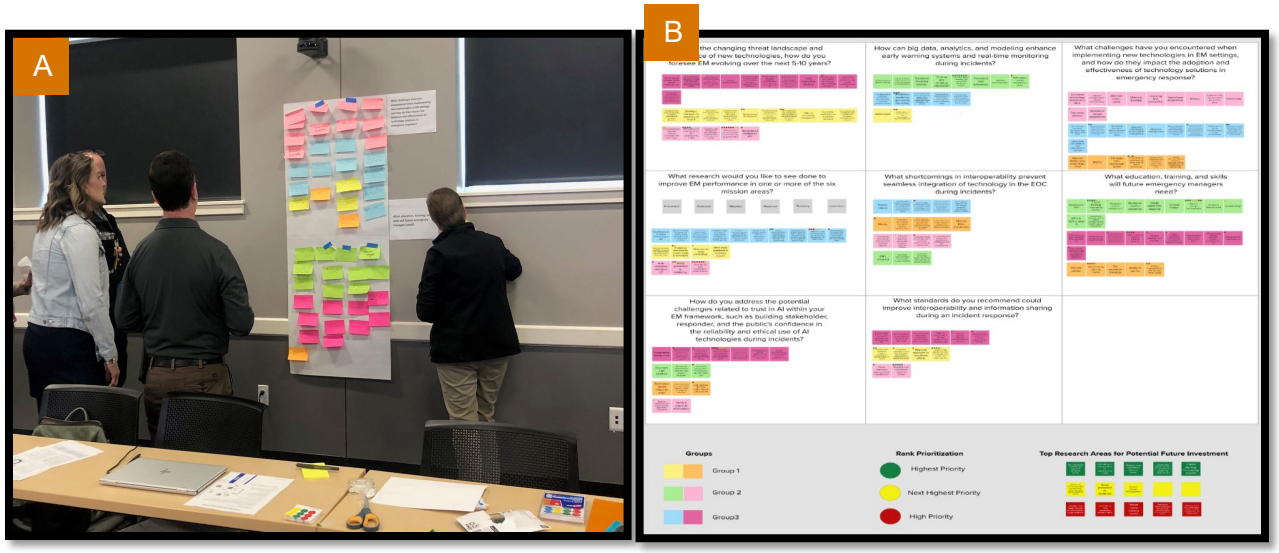


Figure 7. Representative activities from both the in-person (A) and virtual (B) focus groups. Figure 4A highlights participant interaction at the in-person focus group held in Boulder, Colorado. Figure 4B highlights Mural, an online collaboration tool that PNNL used to capture input and facilitate discussion during the virtual focus group.

3.2.1 In-Person Focus Group

In Boulder, Colorado, PNNL co-hosted an in-person focus group with the Office of Disaster Management for the City of Boulder and Boulder County for operational EM personnel to evaluate the efficacy of existing research in addressing capability gaps within EM. Throughout four rounds of guided collaboration, participants in each group discussed their contributions to the questions addressing interoperability, standards, enterprise architecture, and transition impediments. Following each discussion, the large group collectively reviewed and discussed the key takeaways such that insights were captured and understood. Key points from each round of collaboration are summarized in Tables 1-4. Detailed in-person focus group protocols are available in Appendix B.

Table 1. Key Takeaways from Focus Group Round One

Focus Group Round One Takeaways	
Debate on Standardization	Participants were divided regarding the necessity of standardization, with some advocating for it while others opposed it.
Technology Interoperability	Despite the abundance of available technology, focus group participants cited persistent issues with interoperability, cost, and licensing.
Concerns about Technology Overload	Participants cited concern that technology can overwhelm operations, leading to the creation of an "Office of Everything."
Stand-alone Cyber Capability	EOCs should have stand-alone cyber capabilities rather than relying solely on an Emergency Manager.

Table 2. Key Takeaways from Focus Group Round Two

Focus Group Round Two Takeaways	
Low-Orbit Satellite Imagery	Participants suggested the use of low-orbit/low-satellite imagery in EM to aid in disaster assessment, search and rescue operations, evacuation route monitoring, damage assessment, early warning systems, and environmental monitoring.
Trust Challenges	Trust issues persist regarding emerging technology, specifically AI, and the necessity for policies and products to address it while also considering potential misuse by bad actors.
Integration Challenges	Participants highlighted the difficulty of integrating software with existing tools and emphasized the importance of password management and future skills development.
Importance of Standards and Regional Approaches	Increased advocacy is needed for developing standards for interoperability and adopting a regional, county-wide approach for data-sharing and AI agreements.

Table 3. Key Takeaways from Focus Group Round Three

Focus Group Round Three Takeaways	
EOC Constraints	EM is stretched thin, with EOCs often managing multiple simultaneous responses and recoveries.
Technology Impact on EOCs	Implementing new technology may push EOCs beyond their intended capacities.
Innovative Training Methods	Creative training methods can be explored for EOC personnel, such as utilizing holograms for historical fire training.
Call for Increased Federal Investment	Increased federal investment could enable the development, testing, and deployment of technology solutions at the local level.

Table 4. Key Takeaways Regarding Applications for AI (Rounds One, Two, and Three)

Applications for AI (Rounds One, Two, and Three) Takeaways	
Situation Reports	AI can aid in planning by generating situation reports.
Exercise Development	AI can assist in building exercises and injects for training scenarios.
Predictive Analytics	AI has potential applications in predictive analytics for emergency response planning.

3.2.2 Virtual Focus Group

In addition to the in-person focus group, PNNL organized a virtual focus group with operational EM personnel to assess the effectiveness of current research in addressing EM capability gaps, focusing on interoperability, standards, enterprise architecture, and transition impediments. Detailed virtual focus group protocols are available in Appendix C. Table 1 summarizes key areas and opportunities identified during the virtual focus group.

Table 2. Key Takeaways from the Virtual Focus Group

Virtual Focus Group Takeaways	
Emphasis on Social Science in EM	• Participants emphasized the importance of understanding human-centric approaches in EM. • Validating AI was discussed regarding understanding and predicting human behavior during emergencies.
Utilization of AI in EM	• Participants discussed various applications of AI in EM, including emergency communications, providing information to first responders, deconfliction of documents, and reconciling data. • AI could be a tool to bridge the gap between technological advancements and practical application in emergencies.
Challenges and Opportunities in Integrating Technology	• Challenges included policy, privacy concerns, integration, and interoperability issues. • Better collaboration between researchers, operators, and funding sources could benefit the effective integration of new technologies.
Improving Adoption of New Technology	• Suggestions included reducing repetitive tasks, showcasing data to demonstrate value, providing adequate training, and building trust in new technologies among the public.
Interoperability Challenges and Solutions	• Difficulties in interoperability during response and recovery were highlighted, such as translation issues and disconnect between stakeholders. • Recommendations included using open standards and licensing to improve interoperability and information sharing.
Future Directions in EM Research	• Research areas discussed included community resilience, social/behavioral influences, risk modeling, and improving communication and data integration. • Participants expressed a need for continued focus on understanding human behavior, improving technology integration, and enhancing public trust in emergency information.

3.2.3 Focus Group Prioritization

Following the in-person and virtual focus group sessions, participants engaged in providing real-time feedback, prioritizing key areas of research for future investment and exploration. The top-ranked research areas identified during these discussions encompassed a wide range of critical topics, including:

- **Different Model for EOC Management (All Mission Areas)** - Participants emphasized the need for a departure from conventional command and control methodologies toward more innovative models capable of addressing all mission areas effectively. This transition aligns with broader efforts to enhance the resilience and adaptability of EM systems.
- **Change from Surge Concept to Core Division of Government** – Participants concurred regarding the need to transform the surge concept into an integral component of governmental divisions. This transition underscores the importance of embedding resilience and preparedness measures as fundamental elements within government structures.
- **Augmented Reality/Virtual Reality Capabilities** - The exploration of augmented reality and virtual reality technologies emerged as a priority for enhancing emergency response capabilities. Integrating augmented reality and virtual reality into training programs and operational procedures can provide immersive, realistic simulations to facilitate better decision-making and preparedness.

- **Systems Integration (Systems-of-Systems)** - Addressing the complexities of modern emergencies requires a comprehensive approach to systems integration. Participants stressed the importance of developing interconnected systems-of-systems to streamline information sharing, coordination, and resource allocation across various response agencies and stakeholders.
- **Low-Orbit Space Satellites** - Participants highlighted the potential of low-orbit space satellites for enhancing communication and situational awareness during emergencies. Moving away from reliance on terrestrial towers can improve resilience and coverage, especially in remote or disaster-affected areas.
- **EM Staffing, IT Core Group for AI/Cybersecurity in EM** - Recognizing the evolving nature of emergencies and technology, participants underscored the importance of staffing EM agencies with dedicated IT core groups focusing on AI and cybersecurity. This ensures proactive measures to address emerging threats and leverage technological advancements effectively.
- **Develop New Operational Planning Model** - Participants advocated for the development of innovative operational planning models tailored to contemporary EM challenges. This includes incorporating dynamic factors such as cascading events, critical thinking, and ethical considerations into planning processes.
- **County-wide Agreement with Municipalities, Private, and Public Sectors** - Establishing county-wide agreements encompassing municipalities, private entities, and public sectors emerged as a critical priority. Such agreements facilitate seamless coordination, resource sharing, and collaboration across jurisdictional boundaries during emergencies.
- **Redefine the National Preparedness Goal's 32 Core Capabilities**[1] - Participants suggested revisiting and redefining the existing core capabilities framework to better align with evolving EM paradigms and challenges. This entails identifying and prioritizing capabilities essential for modern emergency response and preparedness.
- **Address Ethical Challenges and Standards Driving AI Policy and Processes** - Acknowledging the growing role of AI in EM, participants emphasized the need to address ethical challenges and establish standards guiding AI usage. This supports responsible and ethical deployment of AI technologies in decision-making processes.
- **System Design Management** - Enhancing system design management emerged as crucial for optimizing the efficiency and effectiveness of EM systems. This includes designing systems that are adaptable, resilient, and capable of addressing evolving threats and challenges.

By prioritizing these research areas and suggestions, stakeholders hope to influence the advancement of the capabilities and resilience of EM systems, ensuring better preparedness and response to future crises. Additionally, participants unanimously agreed that the efficacy of ongoing research efforts is not the primary concern. Instead, the prevailing challenge lies in enabling accessibility and awareness of the research community's findings to facilitate the development of practical tools applicable in real-world scenarios rather than remaining solely theoretical. The top categories outlined in the Task 2 Landscape Assessment received concurrence among operational personnel, aligning with the key areas they prioritize for future research endeavors.

[1] FEMA. Mission Areas and Core Capabilities. https://www.fema.gov/emergency-managers/national-preparedness/mission-core-capabilities

4.0 Key Insights

Collectively, research and operational personnel interviewed and who participated in the in-person and virtual focus groups identified the following potential opportunities for future R&D efforts:

- **Integration of Emerging Technology** - Technology advancements, particularly in AI, data analytics, and remote sensing, offer promising avenues for enhancing decision-making workflows during emergencies. Developing AI-driven decision support systems tailored to specific contexts can provide real-time insights, enabling practitioners to make more informed and timely decisions in dynamic crises. Furthermore, the integration of AI and emerging technologies such as drones, Internet-of-Things sensors, and satellite imagery can significantly improve situational awareness and facilitate rapid assessment of disaster impacts, thus improving response coordination and resource allocation.
- **Update Frameworks and Protocols** - Refining interdisciplinary frameworks and legacy protocols to promote collaboration among diverse stakeholders, including government agencies, nonprofit organizations, private sector entities, and local communities. Legacy EM protocols require updating due to evolving societal dynamics, technological advancements, and emerging threats. The traditional one-size-fits-all approach may not adequately address the complexities of modern hazards, such as cyberattacks, climate change-induced disasters, and pandemics.
- **Focus on Scalability and Adaptability** - Potential research endeavors should prioritize the development of adaptable and scalable EM strategies to be responsive to evolving threats, demographic shifts, and climate change impacts. This involves conducting scenario-based planning exercises, modeling complex systems dynamics, and integrating scenario forecasting techniques to anticipate emerging risks and vulnerabilities.
- **Enable Human-Centric Approaches** - The human-centric approach of emergency managers during emergencies should investigate the psychological impacts of high-stress situations, including decision-making under pressure and coping mechanisms, while examining the role of communication, leadership styles, and organizational dynamics in effective crisis management. Additionally, research should explore the influence of external pressures, such as political considerations, public expectations, and the importance of diversity, equity, and inclusion in EM leadership. By addressing these areas, researchers can provide valuable insights into the complexities of EM decision-making and develop evidence-based strategies to enhance the resilience and effectiveness of emergency response efforts.

5.0 Conclusion

Across the EMOTR Task 3B interviews and in-person and virtual focus groups, research and operational personnel engaged in discussions regarding the effectiveness of current research and explored future opportunities to close the EM capability gaps, with a focus on interoperability, standards, enterprise architecture, and transition impediments. Key insights, priorities, and recommendations from their feedback are as follows:

- **Transition Impediments** - To overcome technology transition impediments when implementing new technologies such as AI, data analytics, and remote sensing in EM, comprehensive training and education programs should be required for personnel. These programs help emergency managers and responders build the necessary skills to use the

technology in dynamic crises. Pilot programs and testing before full-scale deployment allow for potential issues to arise early on, enabling adjustments to better align with operational needs. Collaboration with technology developers, research institutions, and stakeholders provides valuable resources and expertise, facilitating successful integration. Flexibility and adaptability are crucial as technology evolves rapidly, requiring emergency managers to remain open to new advancements and adjust strategies accordingly. Additionally, community engagement, transparent communication, and federal support concerning the benefits and usage of technologies foster trust and acceptance among stakeholders.

- **Enterprise Architecture** - Future R&D efforts in enterprise architecture for EM can explore several avenues to address capability gaps and enhance response capabilities. Integrating emerging technologies such as cloud computing, Internet of Things, and big data analytics into the architecture framework can facilitate real-time data collection, analysis, and decision-making processes. Additionally, research is needed to inform interoperable standards that promote seamless integration and communication among diverse systems and stakeholders. Exploring the application of AI/ML algorithms within the architecture can enhance predictive capabilities, optimize resource allocation, and improve overall response coordination.
- **Interoperability** - Future R&D efforts focused on interoperability for EM hold significant promise in addressing capability gaps and enhancing overall response effectiveness. One key area of exploration involves advancing interoperable communication systems and data exchange platforms tailored to the dynamic needs of emergency responders. Developing standardized protocols and technologies that enable seamless information sharing among diverse agencies and jurisdictions can facilitate more efficient coordination and decision-making during crises. Additionally, research is needed into interoperable Geographic Information Systems tools, which can integrate spatial data from multiple sources to provide comprehensive situational awareness and support resource allocation efforts. Finally, exploring innovative training programs and exercises designed to enhance interoperability among multidisciplinary response teams can help refine operational procedures and foster a culture of collaboration.
- **Standards** - Future R&D of standards holds immense potential for addressing capability gaps in EM. One critical area for exploration is the integration of emerging technologies, such as AI, ML, and unmanned aerial vehicles, into existing emergency response systems. Research can focus on developing standardized protocols for using these technologies in various aspects of EM, including rapid situational assessment, resource allocation, and decision support. Standards can promote interoperability among diverse response agencies and jurisdictions, enabling seamless communication and data sharing during crises. Standardized protocols for information sharing help relevant information reach the right stakeholders promptly, enhancing situational awareness and enabling more informed decision-making during emergencies. By establishing clear guidelines for data exchange and communication, these standards can help optimize resource allocation and improve response efficiency.

5.1 Next Steps

This task sought to elicit stakeholder input from interviews and in-person and virtual focus group input to understand the effectiveness of current research in closing EM capability gaps in consideration of interoperability, standards, enterprise architecture, and transition impediments. Figure 5 Figure 5 highlights key priorities and areas of research for improving EM functions, as was discussed in nine interviews and two focus groups with EM R&D personnel.

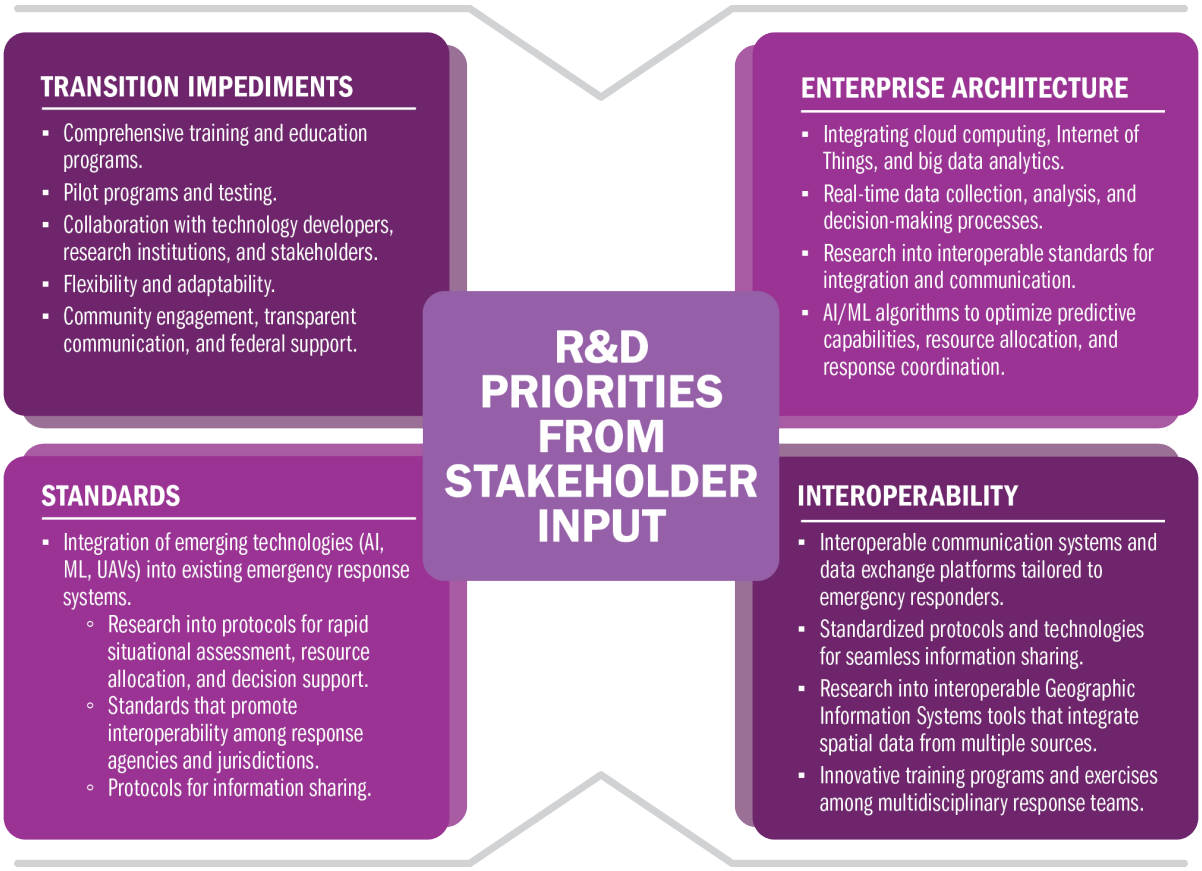


Figure 8. EMOTR interviews and focus group discussions identified key priorities and areas of research for addressing capability gaps in consideration of interoperability, standards, enterprise architecture, and transition impediments.

Insights from this task will guide future EMOTR outreach and elicitation efforts. These efforts will further refine priority technology gaps and capability needs to include outreach to EM operational personnel to review ongoing research programs, assess their effectiveness, identify gaps, and connect with EM R&D stakeholders to foster community coordination around research needs underrepresented in the current research ecosystem. The combined outputs of this guided elicitation will help DHS S&T inform future research and investments.

Appendix A– EM Researcher Interview Questions

EM Researcher Interviews
Interview overview:

- 30 minutes
- 2 people; one to lead discussion; other to capture and summarize interview input.

To better understand the research needs in the emergency management community, Pacific Northwest National Laboratory (PNNL), with support from the Department of Homeland Security (DHS) Science and Technology Directorate (S&T), is conducting interviews to understand **how research impacts operational functions**. The objective is to gain insight into the current research landscape and identify and review ongoing research initiatives to assess their effectiveness and identify persisting gaps.

Interview Questions

1. Can you provide a brief overview of your current research, highlighting the specific areas or topics you are investigating relevant to emergency management?

2. Regarding your research, how do you ensure that your work is applicable and beneficial for practitioners and policymakers involved in emergency management?

3. How has the integration of technology, such as artificial intelligence or data analytics, influenced the way emergency management tools are researched and implemented?

4. What role do interdisciplinary collaborations (life sciences, engineering, social sciences, policy, etc.) play in advancing our understanding of effective emergency management strategies?

5. What do you see as the top research priorities in emergency management for the next decade? Within those priorities are there any specific research efforts you see as promising? How do these align with the evolving landscape of risks and threats?

6. Considering the dynamic nature of emerging threats, such as bioterrorism or cyber threats, where do you see gaps in research that hinder our ability to anticipate and respond effectively to these evolving challenges?

7. In your opinion, what emerging trends or developments in the field of emergency management are not adequately addressed by current research, and where do you see opportunities for future exploration?

8. How has the increasing frequency and intensity of natural disasters impacted the direction and emphasis of emergency management research, and what implications does this have for future preparedness efforts?

9. Are there specific cultural or social factors that are recognized as significant influencers in the success or failure of emergency management initiatives? If so, how does this shape research agendas?

Appendix B– In-Person Focus Group Protocol

Goals

- To validate the Emergency Management of Tomorrow Research (EMOTR) landscape assessment and elicit new or previously unidentified technology gaps and needs from the emergency management community in a collaborative and interactive manner.

- The project's scope is unclassified and is not anticipated to impinge on any classified areas; however, there is the potential that some input may possibly need to be marked FOUO once conversations have occurred, so we just want everyone to be cognizant of that as we work through this process.

Protocol – 2.5 Hours Total

To foster a comprehensive discussion, PNNL formulated questions targeting the key areas of interoperability, standards, enterprise architecture, and transition impediments, as outlined in the statement of work. Employing a "gallery walk" format, participants moved through the conversation, providing insights and feedback in real time. PNNL gathered input from participants by separating the larger group into three smaller groups and employed flip charts to record their thoughts and ideas as they navigated through each question within the "gallery." For efficiency and structured engagement, participants were given a time limit of 10 minutes to respond to each question and an additional 3 minutes for providing a readout to the group. After completing all four stations with two questions each, participants were given 15 minutes to review answers from their colleagues and prioritize them using green, yellow, and red dots. In this scale, green dots indicated participants' highest priority for near-term research. To facilitate continuous engagement and updates, post-event, the PNNL team utilized the Mural virtual whiteboard platform, allowing participants to contribute and review information seamlessly. This approach enabled the team to gather diverse perspectives and valuable input from frontline EM practitioners, enhancing our understanding of the practical challenges and opportunities in bridging capability gaps within the field.

Preparation – 40 minutes

Background/Objective **– 15 minutes**

- Background/Context Information – 10 minutes
- Goals of Workshop – 5 minutes
    - Describe the desired outcomes of the engagement.
        - To validate the EMOTR Task 2 Landscape Assessment and elicit new or previously unidentified technology gaps and needs from the emergency management community.

Icebreaker/Introductions **– 25 minutes**

- What is your favorite tool in your emergency management toolbox?

Main Topic Review – 80 minutes

Gallery Walk **– 80 minutes**

- **Gallery Walk**: Split the 18 participants into three groups of six and direct each group to a different station; four stations with two questions each. Upon arriving at the station, each team writes comments for the question posed at the station – *10*

minutes per question; 3 minutes to review the question; 5 minutes to answer the question; 2 minutes to report out.

- **Rotate to New Station and Add Content**: The group then rotates, clockwise, to the next station. At the new station the group adds new comments with their assigned colored post-it notes – *10 minutes per station; 3 minutes to review the question; 5 minutes to answer the question; 2 minutes to report out*.

Questions

The Future of Emergency Management

1. Given the changing threat landscape and influence of new technologies, how do you foresee EM evolving over the next 5-10 years?
2. How can big data, analytics, and modeling enhance early warning systems and real-time monitoring during incidents?

Current State of Emergency Management Research

1. What research would you like to see done to improve EM performance in one or more of the five mission areas?

    - Prevention
    - Protection
    - Mitigation
    - Response
    - Recovery

2. What education, training, and skills will future emergency managers need?

Operational Challenges

1. What challenges have you encountered when implementing new technologies in EM settings, and how do they impact the adoption and effectiveness of technology solutions in emergency response?
2. How do you address the potential challenges related to trust in AI within your EM framework, such as building stakeholder, responder, and the public's confidence in the reliability and ethical use of AI technologies during incidents?

System Architecture, Interoperability, Standards

1. What shortcomings in interoperability prevent seamless integration of technology in the EOC during incidents?
2. What standards do you recommend could improve interoperability and information sharing during an incident response?

Prioritization/Next Steps – 30 minutes

Prioritization – 20 minutes

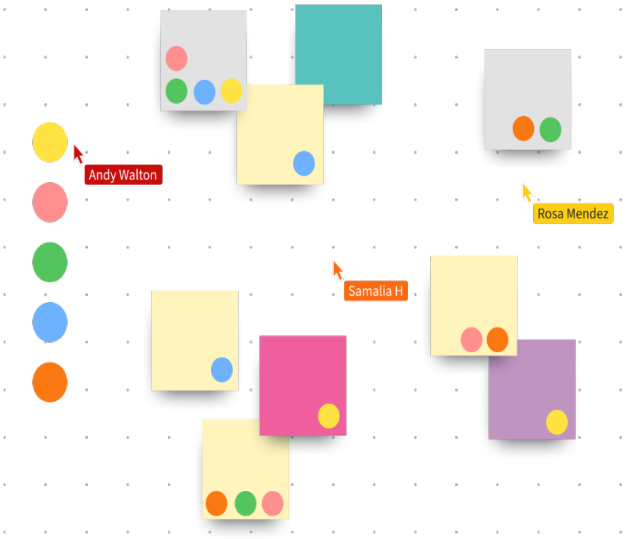
Each question set will be displayed on the wall. Then, participants are given a few dot stickers or varying colors (green, yellow, red) to place on the idea(s) or options they want to highlight as being a top priority. The discussion points with the most dots next to it is ranked high priority, based on the dot color scheme. It allows participants to voice a preference for multiple options, which can then be analyzed on the back end by the PNNL team.

1. Give each participant a set of dot stickers

Each participant will receive three green, three yellow, and three red dots – the colors correlate to the prioritization level of each participant.

2. Clarify voting constraints

Before prioritization, explain that we are holding a vote to prioritize the topics to help DHS S&T identify and provide research insights in emergency management requirements.



3. Prioritization

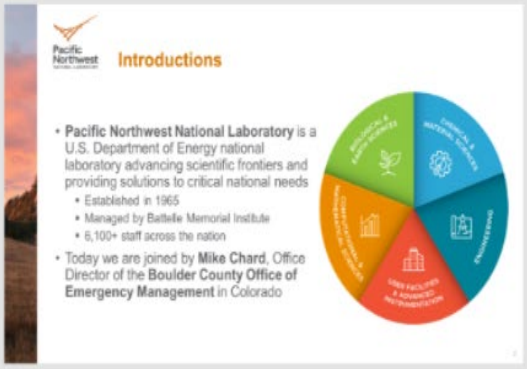
Each person sticks their dots on one or more options – the PNNL team will then analyze these on the back end and map them to the four areas highlighted by DHS S&T.

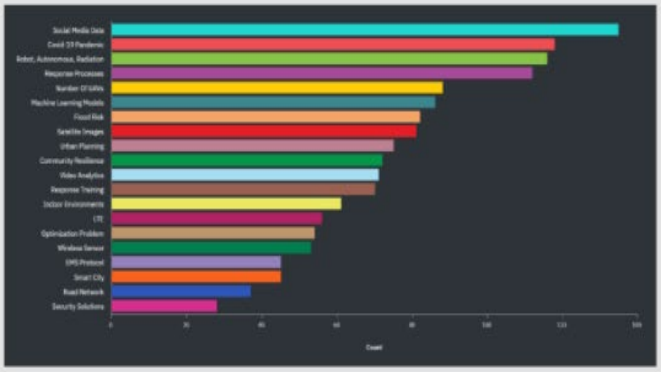
Closing/Next Steps – 10 minutes

Below are screen captures of the Mural board the PNNL team used for the virtual focus group. Mural is a digital workspace platform that facilitates remote collaboration and visual thinking. It provides a virtual canvas where teams can brainstorm, plan, and work together in real time, utilizing various tools, templates, and integrations. Access to the final EMOTR Mural board is available upon request to emotr@pnnl.gov.

Boulder, Colorado EMOTR Focus Group

What is your favorite tool in your emergency management toolbox?





Appendix C– Virtual Focus Group Protocol

Goals

- To validate the Emergency Management of Tomorrow Research (EMOTR) landscape assessment and elicit new or previously unidentified technology gaps and needs from the emergency management community in a collaborative and interactive manner.

- The project's scope is unclassified and is not anticipated to impinge on any classified areas; however, there is the potential that some input may possibly need to be marked FOUO once conversations have occurred, so we just want everyone to be cognizant of that as we work through this process.

Protocol – 2.5 Hours Total

To foster a comprehensive discussion, PNNL formulated questions targeting the key areas of interoperability, standards, enterprise architecture, and transition impediments, as outlined in the statement of work. Leveraging operational personnel's expertise, asking about challenges faced, examples encountered, current approaches, and envisioned improvements in each area, ensured comprehensive insights for filling capability gaps effectively. These questions were designed to elicit specific, actionable feedback from operational personnel, enabling PNNL to pinpoint key issues and develop tailored solutions aligned with operational realities. With targeted questions to cover the four focus areas, PNNL facilitated the discussion using its proven Innovation Foundry virtual ideation approach, allowing participants to contribute insights and feedback in real time. Using the Mural online virtual whiteboard platform, PNNL facilitated continuous engagement and allowed participants to update information seamlessly. This approach provided valuable perspectives from frontline practitioners, enhancing understanding of the practical challenges and opportunities in closing capability gaps within EM.

Preparation – 40 minutes

Background/Objective **– 15 minutes**

- Background/Context Information – 10 minutes
- Goals of Workshop – 5 minutes
    - Describe the desired outcomes of the engagement.
        - To validate the EMOTR Task 2 Landscape Assessment and elicit new or previously unidentified technology gaps and needs from the emergency management community.

Icebreaker/Introductions **– 25 minutes**

- What is your favorite tool in your emergency management toolbox?

Main Topic Review – **100 minutes**

- Question Review – 1 hour 20 minutes (10 minutes per Question)
- Mural Introduction and Orientation (5 minutes)

Questions

The Future of Emergency Management

1. Given the changing threat landscape and influence of new technologies, how do you foresee EM evolving over the next 5-10 years?
2. How can emerging technologies like AI and machine learning revolutionize emergency management?

Current State of Emergency Management Research

3. What current or future technologies enhance effectiveness over 1 or more of the 5 mission areas?

    - Prevention
    - Protection
    - Mitigation
    - Response
    - Recovery

4. What research would you like to see done to improve EM performance in one or more of the five mission areas?

    - Prevention
    - Protection
    - Mitigation
    - Response
    - Recovery

Operational Challenges

5. What challenges have you encountered when implementing new technologies in EM settings, and how do they impact the adoption and effectiveness of technology solutions in emergency response?
6. How do we improve adoption of new technology for EM?

System Architecture, Interoperability, Standards

7. Can you highlight examples where interoperability has been difficult during response and recovery?
8. What standards do you recommend could improve interoperability and information sharing during an incident response?

Closing/Next Steps – 5 minutes

Below are screen captures of the Mural board the PNNL team used for the virtual focus group. Mural is a digital workspace platform that facilitates remote collaboration and visual thinking. It provides a virtual canvas where teams can brainstorm, plan, and work together in real time, utilizing various tools, templates, and integrations. Access to the final EMOTR Mural board is available upon request to emotr@pnnl.gov.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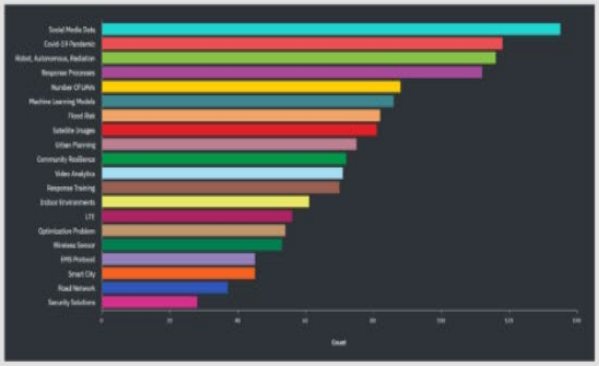
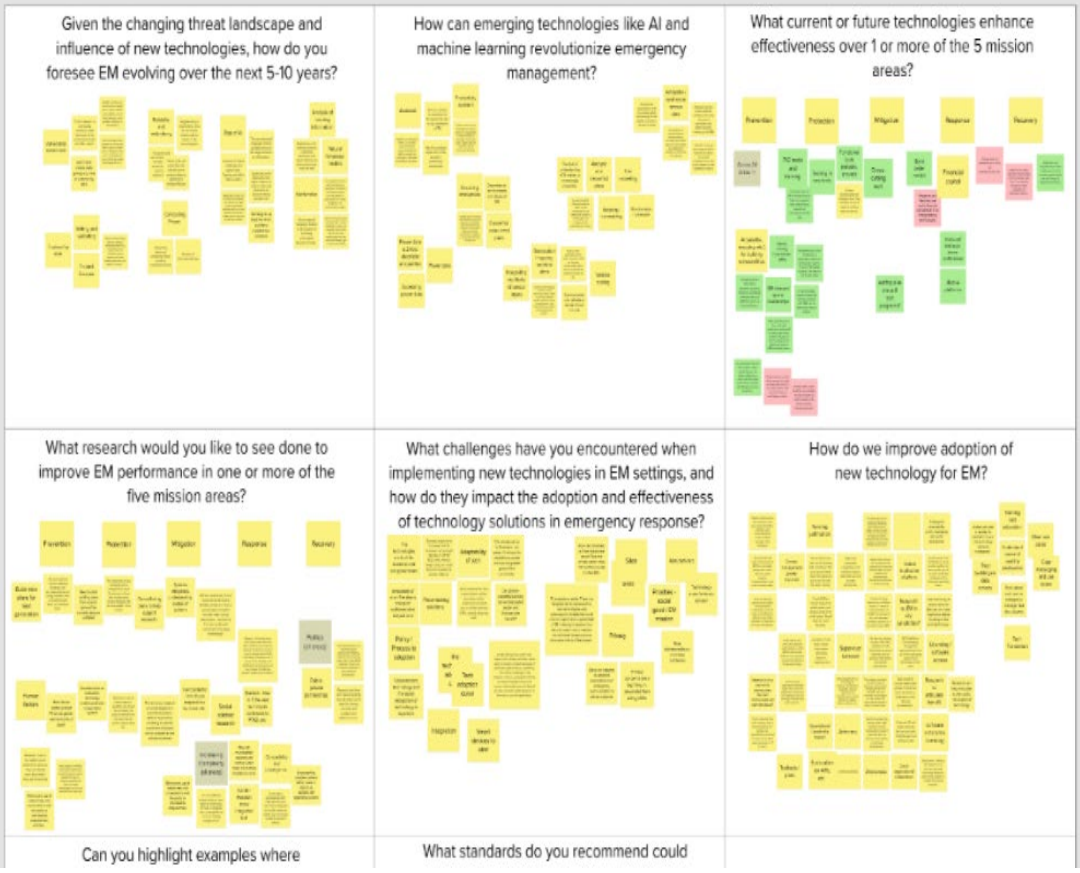
Emergency Management of Tomorrow Research
Project Breakdown:
• EM R&D Landscape Assessment
• Elicit EM Stakeholder Input
• Communications
• AI Research Landscape Summary
• EOC of the Future Recommendations Report
EMERGENCY OPERATIONS CENTER OF THE FUTURE
COORDINATION
FUTURE OF EMERGENCY MANAGEMENT
APPLIED RESEARCH
FUTURE THREATS RESEARCH

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How do we improve adoption of new technology for EM?
Can you highlight examples where
What standards do you recommend could

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Task 3C. Emergency Management Research and Development Community Coordination

Pacific Northwest
NATIONAL LABORATORY

PNNL-35996

Emergency Management of Tomorrow Research – Task 3C Emergency Management Research and Development Community Coordination

Eliciting Emergency Management Stakeholder Input

May 2024

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U.S. DEPARTMENT OF ENERGY

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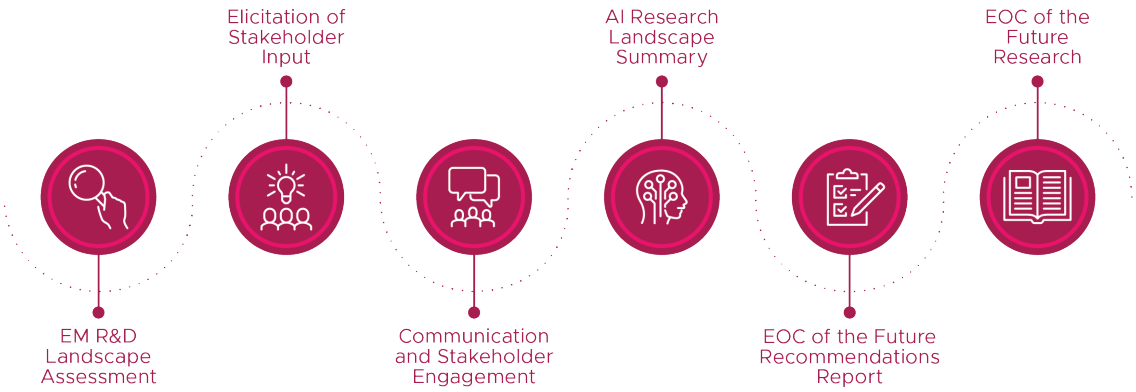
About the Emergency Management of Tomorrow Research

The Department of Homeland Security (DHS) Science and Technology Directorate (S&T) is partnering with Pacific Northwest National Laboratory (PNNL) to execute the Emergency Management (EM) of Tomorrow Research (EMOTR) program to identify current EM research, elicit capability needs from EM practitioners, and identify where technology, such as artificial intelligence (AI), may benefit the future of EM and emergency operations centers (EOCs). The project is delivering a phased and iterative approach to inform future research and development (R&D) and investments for the EM community.

This report details the methodology, analysis, and insights of a roundtable launched to foster a dialogue with EM R&D stakeholders to encourage collaboration, increase transparency, reduce duplication, and increase overall efficacy of research investments in EM. Feedback from this task will help shape future EMOTR research, analysis, and recommendations. To learn more about this task or others within the EMOTR scope, contact emotr@pnnl.gov.



Summary

As a foundational component of the EMOTR program, PNNL conducted outreach to the EM R&D community to establish a comprehensive understanding of ongoing initiatives, existing capability gaps, unaddressed research endeavors, and the efficacy of research in addressing EM needs. As part of this endeavor, PNNL initiated a monthly EMOTR roundtable discussion series to foster a dialogue with the EM R&D community. This series aimed to encourage collaboration, increase transparency, reduce duplication, and enhance the efficacy of research investments in EM by bringing together emergency managers and researchers from academia and government who conduct R&D in EM.

By convening the EM R&D community, the EMOTR roundtable series elicited input on current EM research areas of the academic, national laboratory, and other research communities, with a focus on:

- Identifying general areas and categories of research.
- Noting areas of research overlap and inefficiency due to lack of coordination.
- Identifying research needs based on previous literature (i.e., Project Responder 6), previous EMOTR research and outreach, and other resources, that are underrepresented in the current research ecosystem.

From January to May 2024, the EMOTR program hosted four roundtables (with one to follow the publication of this report). Presentations highlighted lessons learned and recommendations for EOC designs, an EM-centered safety framework advancing emerging operational concepts for emergency response, research on technology applications aiding individuals under stress within emergency response contexts, and research and tools to advance the field of crisis response. Guest speakers and presentation topics were selected based on previous EMOTR tasks and stakeholder outreach to identify potential R&D areas of need.

Potential areas of research for future consideration identified during the roundtables include:

- EOC infrastructure enhancements
- Technology integration
- Human augmentation technologies
- Data management
- Human-centric research
- AI for risk management and decision support.

This report summarizes the roundtable discussions regarding EM research, including general areas of need, overlap, and inefficiency as well as underrepresented avenues in the current research ecosystem as identified by roundtable participants. This information will inform future EMOTR research and outreach, which ultimately aims to assist DHS S&T in making informed decisions for future EM R&D.

Acronyms and Abbreviations

AI	Artificial Intelligence
DHS S&T	Department of Homeland Security Science and Technology Directorate
EM	Emergency Management
EMOTR	Emergency Management of Tomorrow Research Program
EOC	Emergency Operations Center
NASA	National Aeronautics and Space Administration
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development

Contents

1.0 Introduction

As part of the Emergency Management (EM) of Tomorrow Research Program (EMOTR), sponsored by the Department of Homeland Security (DHS) Science and Technology Directorate (S&T), Pacific Northwest National Laboratory (PNNL) is leading a three-part task to elicit input from the EM stakeholder and research and development (R&D) community in a collaborative and interactive way. Task 3, "Elicit Emergency Management Stakeholder Input," comprises three subtasks implementing structured engagements (i.e., interviews, focus groups, roundtables) to elicit stakeholder feedback:

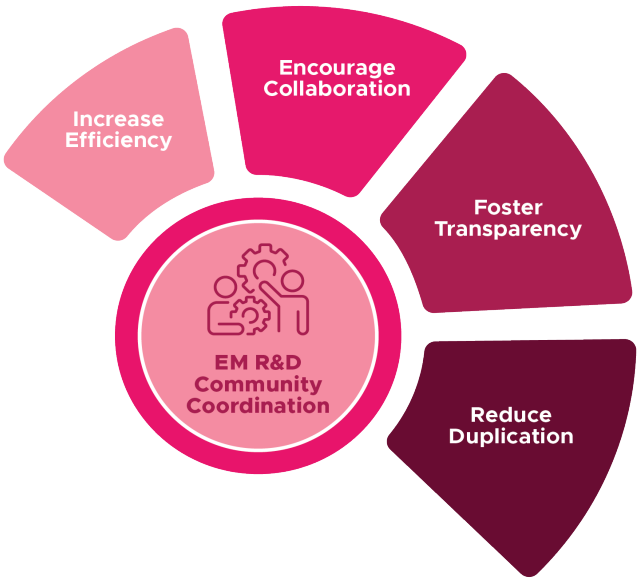


Figure 9. The EMOTR roundtable series sought to foster dialogue with the EM R&D community.

- Task 3A, "Current State of Practice: Emergency Management Information Sharing," developed a baseline understanding of current practice and impediments to information sharing. This task featured eight interviews that collected individual stakeholder input at the state and local levels to develop a baseline understanding of current practices and impediments to information sharing.
- Task 3B, "Emergency Management Research and Development Community Awareness," conducted outreach to the EM R&D community to establish a comprehensive understanding of ongoing initiatives, existing capability gaps, unaddressed research endeavors, and the efficacy of research in addressing EM needs. This task conducted nine interviews with stakeholders conducting R&D on EM topics to advance a common baseline of understanding of active work among the community. Additionally, this task facilitated two focus groups with EM operational personnel to provide insights on research strategies and potential solutions for enhancing EM capabilities.
- Task 3C, "Emergency Management Research and Development Community Coordination," initiated a community initiative to foster a dialogue with EM R&D stakeholders focused on priority research needs. The resulting EMOTR roundtable discussions and identified research areas are outlined in detail in this report.

Engagements were guided by previous and concurrent EMOTR tasks designed to assess current research in EM, elicit capability needs from EM practitioners, and identify where technology, such as artificial intelligence (AI), may benefit the future of EM and emergency operations centers (EOCs). Together, EMOTR outreach tasks elicited, analyzed, and summarized EM R&D needs and priorities as defined by EM practitioners and will be followed by recommendations for areas of research underrepresented in the current research ecosystem that are fit for EM community coordination. The results of Task 3A and 3B outreach activities are summarized in separate reports and available by request to emotr@pnnl.gov.

This report summarizes Task 3C, “Emergency Management Research and Development Community Coordination,” in which PNNL launched a monthly EMOTR roundtable to serve as a professional community for advancing EM-focused research (Figure 1). The roundtable sought to foster a dialogue with the EM R&D community to encourage collaboration, increase transparency, reduce overlaps, and identify areas of priority research needs based on Project Responder 6, previous EMOTR research and outreach, and other resources underrepresented in the current research ecosystem to increase the overall efficacy of EM research investments. The EMOTR roundtable served as a pilot initiative to evaluate the potential value and benefits of fostering collaboration between operational emergency managers and researchers from academia and government.

2.0 Methodology

PNNL applied its technical facilitation expertise to host a recurring roundtable discussion series designed to foster a dialogue among the EM R&D community on desired EM R&D efficiencies and potential opportunities to transition developed science and technology to operational use. The goal of convening the EM R&D community was to elicit input on current EM research areas of the academic, national laboratory, and other research communities, with a focus on:

- Identifying general areas and categories of research.
- Noting areas of research overlap and inefficiency due to lack of coordination.
- Identifying areas of priority research needs based on previous literature (i.e., Project Responder 6), previous EMOTR research and outreach, and other resources, that are underrepresented in the current research ecosystem.

Adhering to the methodology used for EMOTR Tasks 3A and 3B, PNNL leveraged best practices from its First Responder Roadmap Project (funded by DHS S&T in fiscal year 2024), where the team developed a formal methodology for stakeholder engagement. PNNL led first responder technology visioning exercises with key stakeholders to elicit feedback from the EM R&D community regarding the current state of EM research programs and their effectiveness. Vision exercises in EM serve as a strategic tool for analyzing the current state and effectiveness of the research landscape while preparing for future challenges. Through this exercise, participants envision potential scenarios, technologies, and threat landscapes, providing a framework for evaluating existing research efforts. Integrating insights from the vision exercise into the current research landscape enables participants to identify priorities, allocate resources effectively, and develop strategies to address emerging threats by aligning research efforts with future needs and priorities in EM.

The roundtable coordination also leveraged previous EMOTR tasks and outreach to identify focus areas and stakeholders for participation, as outlined below.

2.1 Protocol

PNNL defined a virtual roundtable protocol to efficiently convene the EM R&D community for open dialogue around EMOTR topics of interest. A draft agenda is available in Appendix A. Each one-hour session began with a summary of and highlight from the EMOTR program, providing context for the roundtable series. Next, a guest speaker shared a brief highlight aligned to the EMOTR community coordination objectives. During discussions, participants were encouraged to discuss what they envisioned as research gaps and challenges for the future of

EM. Each roundtable concluded with time to discuss capability needs and research opportunities related to the session's guest speaker presentation and overall EMOTR objectives. Key takeaways from the discussions were summarized after the event and are available in section 3.0.

2.2 Roundtable Participants

To engage an audience from diverse geographical areas, PNNL targeted outreach to both a local and national audience. Stakeholders for this task included EM R&D personnel such as representatives from government and academic research institutions and city, county, state, and private EM organizations across the United States. Leveraging relationships cultivated over time along with new partnerships established at conferences or through grassroots connections made during EMOTR tasks, PNNL disseminated information about the roundtable, inviting individuals and organizations invested in the local and national EM community.

To identify roundtable participants diverse in discipline and location, PNNL leveraged existing contacts from previous EM engagements and elicited grassroots suggestions to build new contacts. This outreach initiated new connections, identified in part through the EMOTR Task 2 Landscape Assessment report,[1] to advance a common baseline understanding of active work among the EM R&D community. The landscape assessment reviewed EM-related R&D and aided PNNL in identifying current research initiatives and EM R&D researchers relevant to the EM mission and of potential interest for this elicitation task. PNNL also leveraged long-standing relationships with the EM community via previous research and outreach efforts for DHS S&T collaborations and via the Northwest Regional Technology Center.[2] PNNL also leveraged attendance at conferences such as the International Association of Emergency Managers and the National Homeland Security Conference to establish connections within the EM space.

Together, roundtable participants hailed from universities and research organizations across the nation (Figure 2):

- California Office of Emergency Services
- City of Kirkland EM
- College of Engineering, University of Wisconsin – Madison
- Emergency Services Department, Idaho State University
- Harris County, TX, Homeland Security and EM
- Humanitarian Informatics Lab, George Mason University
- International Association of Emergency Managers
- King County, WA, EM
- NASA Ames Research Center
- National Agricultural Biosecurity Center, Kansas State University
- North Dakota Department of Homeland Security
- Ohio EM Agency
- Pennsylvania EM Agency
- Software Engineering Institute, Carnegie Mellon University
- Stanford University
- Town of Chapel Hill, NC, Emergency Preparedness and Risk Management
- Institute for Software Integrated Systems, Vanderbilt University.

[1] Sleiman, C., Thomas, K., Gray, J. Schroeder, J., Disney, M., Alsabagh, H., Ortega, S., Bartholomew, R., Lesperance, A. (2024). "Emergency Management of Tomorrow Research Landscape Assessment." Pacific Northwest National Laboratory. PNNL-35649

[2] PNNL stewards the Northwest Regional Technology Center, a virtual center enabling homeland security solutions through outreach to emergency responder communities, federal, state, and local agencies, and private sector stakeholders. Learn more at http://www.pnnl.gover/projects/nwrtc.

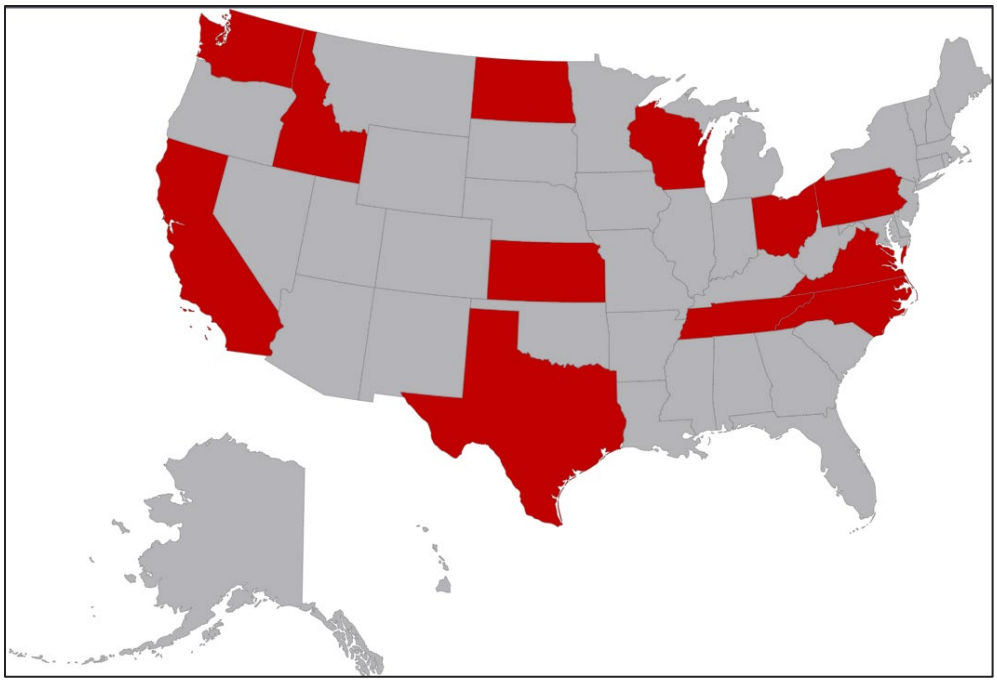


Figure 10. The EMOTR community coordination effort convened EM R&D stakeholders from across the nation in a series of roundtable discussions.

2.3 Guest Speakers and Presentations

PNNL leveraged findings from previous EMOTR tasks and stakeholder outreach to identify potential discussion R&D projects aligned with the EMOTR community coordination objectives in Task 3C. For example, PNNL leveraged the EMOTR Task 2 Landscape Assessment[1] to identify potential R&D projects and collaborations for inclusion, particularly those that address capability needs and technology gaps identified by participants as part of EMOTR outreach for other project tasks. The roundtable discussions were selectively tailored to the research community, such that each session provided insightful exchanges and valuable insights for advancing technical knowledge. Sessions included the following presentations and guest speakers:

- "Lessons Learned: Nationwide EOC Tour," presented by Mark Sloan, Homeland Security and EM Coordinator, Harris County.
  - Mr. Sloan is Coordinator for Homeland Security and EM for Harris County, Texas, an area serving more than 4.8 million residents spanning more than 1,770 square miles. Because of Harris County's large population, port operations, transportation infrastructure, and concentration of petrochemical plants, DHS identified Harris County as a Tier 1 region. To meet the growing expectations of EM, Mr. Sloan is streamlining regional emergency response coordination using automated flood warning systems, traffic management systems, broadcast media capabilities, first responder and community alerting, GIS mapping systems, and regional interoperable communications.

[1] Sleiman, C., Thomas, K., Gray, J. Schroeder, J., Disney, M., Alsabagh, H., Ortega, S., Bartholomew, R., Lesperance, A. (2024). "Emergency Management of Tomorrow Research Landscape Assessment." Pacific Northwest National Laboratory. PNNL-35649

- “NASA’s EM-Centered Safety Demonstrator Series,” presented by Dr. Hannah Walsh, Subproject Manager, NASA Ames Research Center.
  - Dr. Walsh is a computer engineer in the Intelligent Systems Division of NASA Ames Research Center. She earned her PhD and MS in mechanical engineering with emphasis in design from Oregon State University in 2020 and 2018, respectively, and her BS with a double major in aerospace science and engineering and mechanical engineering from the University of California, Davis in 2016. Her research interests include the application of AI to the design process with a particular emphasis on improving safety in complex systems. Her presentation focused on a safety framework for emergency response operations.
- “Human Augmentation Technologies,” presented by Dr. Ranjana Mehta, NeuroErgonomics Lab, University of Wisconsin-Madison College of Engineering.
  - Dr. Mehta’s research examines the mind-motor-machine nexus using a novel neuroergonomics approach to understand, monitor, and predict human performance under fatigue and stress. With these predictions, research in her laboratory focuses on developing closed-loop human augmentation technologies (sensory, neural, physiological) for safety-critical applications (emergency response, space exploration, and oil and gas). Efforts are funded by numerous agencies and industries and include user-centered and equitable design and evaluation of adaptive interfaces, wearable technologies, human-robotic interactions, and brain-computer interfaces to facilitate effective human-technology partnerships.
- “Human-AI Collaboration for Virtual Capacity Building in EOCs to Monitor Online Social Data at Scale,” presented by Dr. Hemant Purohit, Humanitarian Informatics Lab, School of Computing, George Mason University.
  - Dr. Purohit is an associate professor in the Department of Information Sciences and Technology and the director of the Humanitarian Informatics Lab. He researches the design of interactive intelligent systems to support and augment human work capabilities for real-time processing and management of non-traditional data sources (social media, web, Internet-of-Things) at emergency services and humanitarian organizations. He develops new methods in social computing using data mining, semantic computing with natural language processing, and human-centered computing with machine learning while taking inspiration from social-psychological theories for understanding human behavior. He obtained a PhD in computer science and engineering from Wright State University under Professor Amit Sheth.

An additional roundtable to be held after publication of this report is tentatively scheduled with Ma Meiyi of Vanderbilt University and will focus on integration of AI into Nashville's emergency operations, expanding beyond public safety communications to include police and fire departments.

2.4 Limitations

PNNL implemented a structured approach to the roundtable sessions, restricting them to one hour to accommodate presentations, questions and answers, and discussions. Using virtual sessions facilitated accessibility for participants across various locations, although it acknowledged potential challenges in engagement due to the absence of face-to-face interaction. Nevertheless, this approach broadened the audience base, overcoming geographical barriers and allowing participation from individuals unable to attend in person.

Further strategic planning involved limiting group sizes to fewer than 20 participants, fostering intimate discussions, and facilitating active engagement from all attendees while considering the challenges posed by the size of the group and the diverse disciplines represented. Additionally, efforts were made to address the challenges of bringing together operational and research personnel, which included accommodating different discourses, timeframes, and levels of operational knowledge among participants. This smaller group dynamic also streamlined decision-making processes, enhancing the likelihood of actionable insights and tangible outcomes from the roundtable discussions.

3.0 Roundtable Summaries

The following section summarizes insights from roundtable sessions held with the EM R&D community. Inputs and analyses are included without attribution of individual participants to maintain anonymity and encourage open dialogue. Presentation slides are available in Appendixes B and C.

3.1 Roundtable One – EOC Lessons Learned

The first roundtable featured “Lessons Learned: Nationwide EOC Tour,” presented by Mark Sloan, Homeland Security and EM Coordinator in Harris County, Texas. He highlighted lessons learned and solutions to improve EOCs based on the EOC model in place at Harris County, Texas, and those Mr. Sloan observed elsewhere. Proposed infrastructure upgrades encompassed:

- Adding breakout rooms
- Enhancing communication capabilities through secure networks
- Modular design for flexibility and scalability
- Emphasizing integrated communication systems.

Suggestions for optimizing room design included:

- Adaptable features like rollable screens
- Sound-reduction mechanisms
- Multi-functional setups to cater to diverse crises and team interactions.

3.1.1 Resources

No documents were shared during the presentation.

3.1.2 Discussion

The discussion emphasized that the EOC should maintain functionality for daily operations while remaining adaptable for crises such as homelessness or pandemics. The discussion also explored implementing user-friendly technology solutions to enable all staff to activate the EOC independently, focusing on simplicity and continuity without reliance on IT assistance. Lastly, most participants voiced a preference against fully virtual EOCs due to limitations in conveying urgency and understanding non-verbal cues, with physical centers deemed more effective tools for crisis management.

In addition to EOC enhancements, the discussion focused on various aspects of EM and the role of AI. Topics included AI's potential in the following areas:

- Emergency preparedness
- Translation services
- Broadcasting in multiple languages
- Social media monitoring and management during crises
- Tools and analytics for flood prediction, automation of administrative tasks, and risk management.

3.1.3 Recommendations

Across all the organizational and physical EOC recommendations addressed, a need persists for flexibility and managing uncertainty within emergency response systems. EOCs need to be easily activated—by all staff if possible and without an assist from an IT team. An EOC's physical structures need to be physically and mentally conducive to the fast-pace, high-stress EOC operations. Considerations for ergonomics, including comfort, and environmental factors like temperature control, lighting, and sound insulation, were highlighted as crucial for fostering a conducive working environment. In addition to physical comforts, structures such as sleeping quarters, outdoor break spaces, and medical services on-site can aid in EOC personnel's mental health. Furthermore, resource optimization strategies were recommended, advocating for cost-effective solutions such as dry-erase walls for versatile use in training exercises and crises, alongside adaptable infrastructure to justify budgets and cater to diverse needs.

3.2 Roundtable Two – EM-Centered Safety Framework for Emergency Response

The second roundtable featured Dr. Hannah Walsh, a computer engineer at the NASA Ames Research Center, Dr. Walsh highlighted NASA's Safety Demonstrator series, which outlines a safety framework for emergency response operations. The framework presented incorporates the In-Time Aviation Safety Management System, particularly in scenarios such as wildfire response. This series offers a structured approach to detect elevated risk states, which may arise from the convergence of multiple factors, and provides recommendations for mitigation actions.

3.2.1 Resources

Resources shared during the roundtable included the following:

- NASA. 2022. "NASA System-Wide Safety Wildland Firefighting Operations Workshop Report." https://hsi.arc.nasa.gov/awards_pubs/publication_view.php?publication_id=3013
- Ames Research Center. 2023. "Safety Demonstrator Series for an In-Time Aviation Safety Management System." https://ntrs.nasa.gov/citations/20230000834
- Ames Research Center. 2023. "In-time Safety Management Capabilities for Wildland Fire Management Aircraft Operations - A Gap Assessment." https://ntrs.nasa.gov/citations/20230006212

3.2.2 Discussion

Participants raised questions regarding the trust and accuracy of AI, integration of disparate data streams, and cybersecurity of the proposed framework. They also inquired how NASA's Demonstrator Series is giving consideration to cultural challenges of working with external partners and agencies regarding safety and how emerging challenges like climate change impact the research in this area.

3.2.3 Recommendations

The presentation and discussion among participants emphasized the importance of integrating various data sources, including social media and lessons learned documentation, to enhance situational awareness and decision-making processes during emergencies. Employing a framework such as that demonstrated during this presentation may help enable emerging operational concepts for emergency response, including capabilities to detect elevated risk states, those brought on by the convergence of multiple states, and recommend mitigation actions from operators or automated mitigation steps.

3.2.4 Funding Sources

- NASA's Aeronautics Research Mission Directorate

3.3 Roundtable Three – Human Augmentation Technologies

The third roundtable featured Dr. Ranjana Mehta from the University of Wisconsin – Madison NeuroErgonomics Lab, who presented **"**Human Augmentation Technologies," focusing on technology applications in aiding individuals under stress, particularly within emergency response contexts. Dr. Mehta led a discussion on stress's impact on human-system interaction and trust, drawing from studies on fatigue among disaster responders. Their research showcased the potential of technologies like transcranial direct stimulation to alleviate fatigue, demonstrating comparable efficacy to caffeine but with sustained effects. Efforts were also directed toward developing adaptive training systems for emergency responders, leveraging immersive technologies such as augmented reality.

3.3.1 Resources

Presentation slides are available in Appendix B. Resources shared included:

- Peres, S. C., R. K. Mehta, and R. R. Murphy. 2023. "Water, Lava, and Wind: Lessons Learned for Field Robotics and Human Factors Research During Real World Disasters." *Interaction Studies* 24 (3): 335-361. https://doi.org/https://doi.org/10.1075/is.22048.per.
- NeuroErgonomics. 2023. "LEARNER Minimum Viable Product Evaluation - July 2023." https://www.youtube.com/watch?v=MFJHP6XvpNg

3.3.2 Discussion

Participants discussed the significance of understanding stress's role in high-risk environments and managing fatigue through innovative technologies and adaptive training systems. Participants inquired about how challenges in data management and trust in AI—particularly trust dynamics within AI and human-machine teaming in decision-making—vary across genders and generations.

3.3.3 Recommendations

Recommendations include fostering collaboration with jurisdictions post-disaster and analyzing after-action reports for enhanced EM. Discussions highlighted the importance of operational feedback, access to testbeds, and partnerships with EM personnel and first responders. Suggestions for collaboration were directed to jurisdictions inclined toward post-disaster innovation, where researchers aimed to glean both positive and negative insights from past events for future technology integration. Technology must be well integrated both technically and operationally—garnering operational input from users in the field, those with tech-agnostic or "pre-tech" experience, as well as from EOCs directly or via after-action reports—can reduce resistance to technology by eliciting solutions informed by and aligned to end users.

3.3.4 Funding Sources

- Center for Offshore Safety
- Defense Advanced Research Projects Agency
- NASA
- National Institute for Occupational Safety and Health
- National Institutes of Health
- National Science Foundation
- SecureAmerica Institute
- The National Academies of Sciences, Engineering, Medicine
- U.S. Department of Transportation

3.4 Roundtable Four – Human-AI Collaboration for Virtual Capacity Building in EOCs

The fourth roundtable discussion featured Dr. Hemant Purohit from the George Mason University Humanitarian Informatics Lab and focused on research to advance the field of crisis response. Dr. Purohit's research focuses on developing systems that prioritize human needs and interactions across various crisis domains, including natural disasters, social upheavals, and cyber emergencies. Leveraging Dr. Purohit's extensive background in social computing for emergency response, George Mason's Humanitarian Informatics Lab seeks to address critical gaps in current EM practices. These gaps are being identified by examination of decision support and communication needs within EOCs.

3.4.1 Resources

Presentation slides are available in Appendix C. The presentation highlighted AI tools for virtual capacity building in EOCs to monitor online social data, including:

- DisasterKG (Disaster Knowledge Graph) – unifying semantic representation.
- CitizenHelper Tool – real-time data analytics platform for response and training.

3.4.2 Discussion

Discussion following the presentation inquired about how AI can assist in balancing EOC personnel's varying levels of training and expertise in synthesizing and analyzing information, how solutions address the potential for bad actors and misinformation in incoming information streams, and if the tools discussed are available. It was noted that despite the promise of AI-driven solutions, inherent challenges persist, including:

- Enhancing the accuracy and reliability of AI models
- Aligning AI systems with human operators
- Facilitating seamless collaboration and decision-making.

3.4.3 Recommendations

The discussion highlighted challenges such as resource constraints and limited capabilities for monitoring and analyzing open data streams, which are vital for effective crisis response. Overcoming these challenges requires innovative solutions around human-centric design principles. One such solution is a Social-EOC framework, which employs real-time analytics to prioritize and rank incoming calls for assistance. Additionally, Citizen-AI collaboration wherein AI technologies augment social media monitoring efforts, enhancing situational awareness and response capabilities.

The discussion also addressed the intricacies of social listening and communication within crisis contexts. It advocates for a shift from traditional, unidirectional communication models to bidirectional ones, enabling more effective interaction between authorities, citizens, and other stakeholders. This shift necessitates the development of specialized systems tailored to different types of interactions, such as authority-to-citizen, citizen-to-authority, and citizen-to-citizen communication channels.

3.4.4 Funding Sources

- Commonwealth Cyber Initiative
- National Science Foundation
- Office of Naval Research
- The Research Council of Norway

4.0 Discussion

The EMOTR Task 3C roundtable discussions highlighted several potential EM research areas of need or opportunity for future community coordination, outlined below and in Figure 3

- EOC infrastructure enhancements are crucial, encompassing not only physical upgrades like improved communication networks and adaptable room designs but also considerations for daily usability and ergonomic factors to optimize the EOC functionality.
- The pivotal role of technology integration emphasizes user-friendly solutions, empowering all staff members to efficiently utilize EOC resources alongside AI applications ranging from preparedness to risk management and decision support. However,

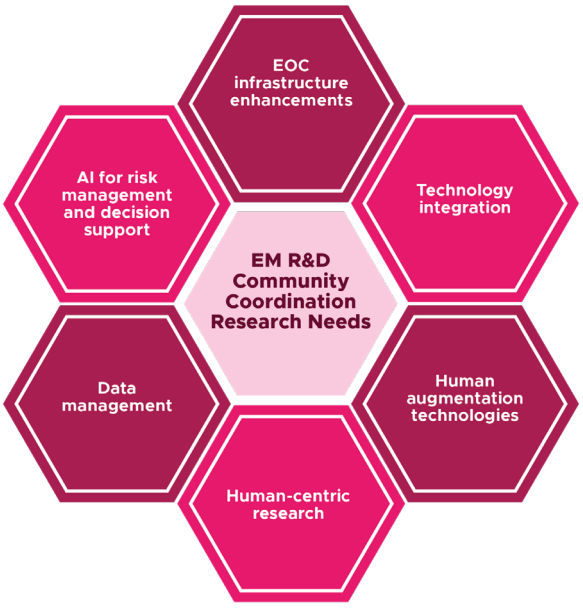


Figure 11. EM Areas of Research Needs

skepticism remains regarding the effectiveness of virtual EOCs and AI-driven solutions compared to physical centers, suggesting a need for further exploration and validation.

- The intersection of data management, AI integration, and cybersecurity presents a complex landscape. Integrating diverse data sources, including social media and lessons learned documentation, enhances situational awareness and decision-making processes during emergencies. Challenges such as maintaining data integrity, fostering trust in AI algorithms, and navigating cultural considerations in collaborative efforts with external partners pose significant hurdles requiring interdisciplinary collaboration and innovative solutions.
- Human augmentation technologies highlight an underrepresented area of research within EM—specifically, the enhancement of individual capabilities under stress conditions. The research landscape underscores the importance of understanding stress's impact on human-system interaction and trust, offering promising avenues for technology-driven interventions like transcranial direct stimulation to mitigate fatigue among disaster responders, emphasizing the need for continued exploration of human-centric approaches to augmenting emergency response capabilities and addressing gaps in current research, which predominantly focuses on infrastructure and technological solutions.

The findings from the roundtables align with the research priorities outlined in the EMOTR Task 2 Landscape Assessment as well as priorities identified in Task 3A, “Current State of Practice: Emergency Management Information Sharing,” and Task 3B, “Emergency Management Research and Development Community Awareness.” The discussions affirmed the multidimensional scope of EM research to encompass infrastructure enhancement, technology integration, data management, and human augmentation. Inefficiencies arise from the lack of coordination between these areas, hindering the development of comprehensive solutions.

Addressing these inefficiencies necessitates interdisciplinary collaboration, increased emphasis on human-centric research, and bridging the gap between technological innovation and practical implementation. Integrating these insights enriches the discourse on EM research, emphasizing the evolving landscape of technology and nuanced understanding of the crisis landscape to develop effective and resilient crisis response systems prioritizing individual and community well-being and safety. As highlighted in Table 1, identifying future research needs is crucial for advancing EM strategies and enabling the continual evolution of comprehensive solutions.

Table 3. Research Needs Identified in the Roundtables

Identified Research Needs	
Type of Research	**Research Focus**
Citizen-AI Collaboration	Build a Citizen-AI collaboration network as virtual capacity for different emergency support function-related services. Sequence tasks for data annotation to monitor and provide human feedback to update an AI model. Create a system interface for facilitating human feedback while assisting human users in the Citizen-AI collaboration.

Sensing Technologies	Leverage unmanned aerial systems in EM to advance sensor payloads to enhance detection, monitoring, and situational awareness during disaster response scenarios.
AI for Call and Resource Management	Build an AI solution to transform emergency response from the moment a call comes through dispatch to optimize scheduling and resource allocation.
Information Equity	A method to enhance communication by tailoring messages to diverse audiences' comprehension levels and circumstances. For example, providing hurricane warnings customized for coastal residents versus those in central Florida, considering factors like language proficiency and literacy levels to enable equitable access to critical information. This involves employing varied modalities and formats for improved inclusivity and effectiveness.
Information Agility	Develop a robust EM system capable of swiftly disseminating critical information in real-time, enhancing response agility during crises; this involves implementing advanced technologies and protocols to enable timely messaging across various channels to relevant stakeholders, facilitating effective decision-making and coordination.
Information Integrity	Develop protocols and systems to maintain the accuracy and reliability of information disseminated during emergencies, combating misinformation and disinformation through real-time monitoring, fact-checking, and transparent communication channels; this includes implementing robust verification processes, leveraging technology for rapid response to false narratives, and fostering partnerships with credible sources to maintain public trust and safety.
EOC of the Future	Develop an innovative EOC designed as a sandbox environment, allowing emergency managers to experiment with novel technologies and methodologies, serving as a pilot platform to test their effectiveness in real-world emergency scenarios.

5.0 Strategies for Future Engagement

To sustain a discussion series to assist DHS S&T in fostering dialogue among the EM R&D community, several strategies should be considered and are outlined below and in Figure 4.

- Creating a roundtable that maintains relevance to the EM mission requires evaluating the EM R&D landscape to identify, refine, and prioritize research gaps in EM. The EMOTR methodology, outlined in section 2.3, used structured review of the EM R&D landscape (Task 2, “Emergency Management Research and Development Landscape Assessment”), in combination with phased stakeholder elicitation (Task 3A, “Current State of Practice: Emergency Management Information Sharing” and Task 3B, “Emergency Management Research and Development Community Awareness”), to efficiently identify, vet, and

prioritize existing R&D initiatives aligned with the EM mission. These tasks pinpointed relevant research areas, technology gaps, and R&D initiatives culminating in strategic roundtable sessions to prioritize research needs and guide future investments (Task 3C, “Emergency Management Research and Development Community Coordination”).

- It is crucial for each meeting to have a clear agenda and purpose to achieve informed and actionable results. Each session should concentrate on topics relevant to EM R&D, such as emerging technologies, best practices, and current challenges. Underpinning each discussion with a defined objective will encourage participants to engage meaningfully and contribute valuable insights, thus ensuring that the agenda ties back to EMOTR priorities to inform future tasks and research priorities.
- Cultivating a diverse and inclusive participant pool is essential for promoting collaboration and minimizing redundancies. Inviting stakeholders from various backgrounds, including government agencies, academia, industry, and nonprofit organizations welcomes a diversity of perspectives, leads to innovative solutions, and fosters cross-sector partnerships. Additionally, incorporating opportunities for smaller breakout sessions or networking events within the roundtable can facilitate deeper discussions and build relationships among participants. Broaden the roundtable to convene a mix of researchers and practitioners to include academic researchers, EOC operators, DHS S&T leaders, technology providers, and more. Integrating and balancing researcher, operator, and other perspectives will better identify, vet, and validate research gaps and capability needs to guide future R&D and investments.
- Maintaining transparency and accountability throughout the series is crucial for establishing trust and optimizing research investments. This can be achieved by regularly sharing meeting summaries, progress reports, and plans with participants. Encouraging open dialogue and feedback mechanisms can also help identify areas for improvement and keep the roundtable responsive to the evolving needs of the EM R&D community. To foster productive roundtables, all participants should communicate effectively using a common discourse. For example, feedback gathered from EMOTR roundtables highlighted a consistent hurdle in bridging the gap between research findings and operational practices in the field. This challenge has been echoed in past EMOTR outreach efforts, where emergency managers are offered numerous innovative solutions but face obstacles in their implementation due to financial constraints, policy restrictions, trust issues, and interoperability barriers. A well-structured roundtable series, informed by research and practical insights, can serve as a collaborative platform for researchers and emergency

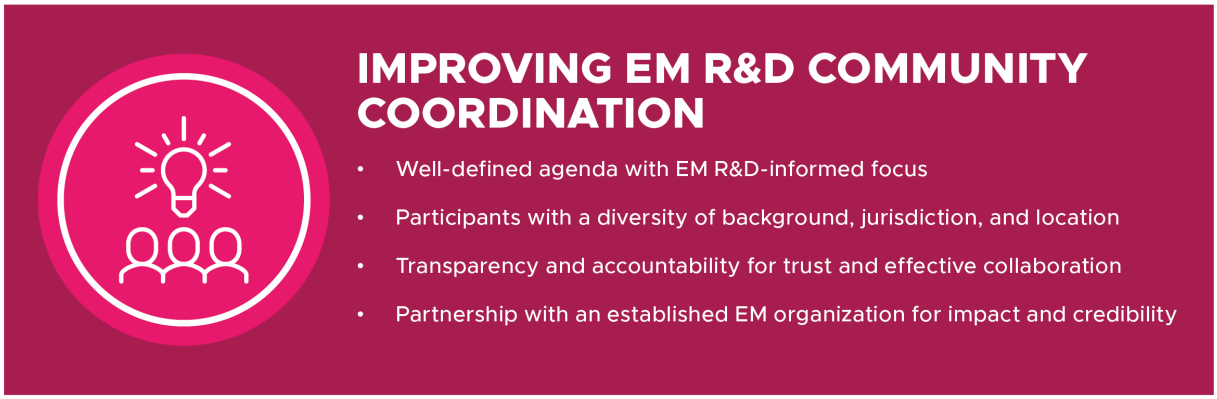


Figure 12. Recommendations for Continuous Improvement

managers. By facilitating meaningful conversations, roundtables can significantly enhance the translation of research into operational strategies and vice versa.

- To enhance the involvement of emergency managers in roundtable discussions, proactive measures are essential. This includes actively seeking their participation by reaching out to EM agencies, professional associations, and other pertinent stakeholders. Additionally, creating platforms for networking and collaboration between researchers and emergency managers fosters knowledge exchange and partnership building—a recurring theme previous EMOTR discussions. Simultaneously, it is crucial to proactively review presentation materials, agendas, and relevant documents to maintain clarity, conciseness, and accessibility for all participants. Identifying and addressing potential barriers to comprehension, such as technical jargon or disciplinary-specific terminology, is imperative. Encouraging plain language and providing context for complex concepts further enhances understanding among diverse audiences. This comprehensive approach maintains that research efforts are firmly rooted in real-world experience and aligned with the practical needs of EM practitioners.
- Hosting the roundtable in partnership with an established organization or agencies like the International Association of Emergency Managers, National Emergency Managers Association, Naval Postgraduate School, and the Federal Emergency Management Agency's National Advisory Council. EM-related professional organizations, like those contacted during EMOTR outreach, have expressed interest in looking at the future of EM and technology. Leveraging these existing community partners presents several advantages for advancing engagement, outreach, and sustainability within the EM R&D community:
  - **Enhanced Credibility**: Partnering with a reputable organization lends credibility to the roundtable, as it signals endorsement and support from a respected organization in the field. This can attract more participants and stakeholders who trust an existing organization's expertise and reputation.
  - **Expanded Reach**: Leveraging existing networks allows for broader outreach to professionals, researchers, policymakers, and practitioners in EM. This increases the likelihood of attracting a diverse range of perspectives and expertise to the roundtable discussions.
  - **Access to Resources**: Professional organizations likely have resources, such as communication channels, marketing platforms, and logistical support, that can facilitate the organization and promotion of the roundtable. This can save time and effort in planning and execution.
  - **Long-Term Engagement**: Collaborating with existing, sustained organizations promotes sustained engagement within the EM community beyond the roundtable event. It opens avenues for continued collaboration, knowledge sharing, and partnership on future initiatives and projects.
  - **Alignment of Efforts**: By aligning with existing organizations' objectives and initiatives, the roundtable can tap into ongoing efforts within the organization, fostering synergy and coherence in addressing key challenges and opportunities in EM R&D.

By implementing these strategies, the monthly roundtable discussion series can serve as a valuable platform for community coordination focused on collaboration, knowledge sharing, and collective problem-solving in EM.

6.0 Conclusion

Key areas of research needs identified in the roundtables included EOC infrastructure enhancements, technology integration, human augmentation technologies, data management, human-centric research, and AI for risk management and decision support. These outputs in combination with results from Task 3A and 3B, will inform future EMOTR tasks and recommendations to inform future DHS S&T investments.

Recommended best practices to maintain the roundtable series or a similar community engagement in the future include:

- **Identify Potential Research Needs and Capability Gaps:** Implement a structured roundtable discussion series to engage the EM R&D community in identifying research areas, addressing inefficiencies, and prioritizing research needs. Utilize the EMOTR methodology based on stakeholder engagement best practices, including landscape assessments and visioning exercises, to analyze the current research landscape, align efforts with future needs, and develop strategies to address emerging threats in emergency management.
- **Establish Clear EM-Relevant Objectives and Structured Agenda:** Clearly define the objectives of the roundtable series, emphasizing collaboration, transparency, reducing overlaps, and increasing efficiency in EM research investments.
- **Develop a Structured Agenda:** Develop a structured agenda for each roundtable session, focusing on topics relevant to the advancement of EM. Leverage existing resources such as the EMOTR findings (i.e., gaps and opportunities identified in the landscape assessment, interviews, and focus groups) to identify topics of interest. Allocate specific sessions every two months to include operational personnel, ensuring that findings from the research community are communicated to those in the field.
- **Identify Key Stakeholders:** Identify key stakeholders in the research and operational communities who would benefit from participating in the roundtable discussions. These may include researchers, emergency responders, and other relevant parties. Leverage existing networks, such as those established from previous EMOTR or other first responder and emergency manager outreach, PNNL's Northwest Regional Technology Center, researchers identified as conducting relevant work in the EMOTR Task 2 Landscape Assessment, and contacts at EM professional organizations or agencies.
- **Select Participants:** Carefully select participants for each session, convening a diverse range of expertise and perspectives. Consider inviting individuals who are champions within their respective communities and who can contribute meaningfully to the discussions.
- **Facilitate Engaging Discussions:** Assign experienced facilitators to lead the discussions such that all participants can contribute their insights and perspectives. Encourage open dialogue and the exchange of ideas. Prepare questions in advance to ensure discussion align to EMOTR objectives to identify prioritized EM research needs.
- **Document Findings and Action Items:** Document key findings, insights, and action items from each roundtable session. Create a repository of resources and best practices to support ongoing collaboration and information sharing.
- **Establish Follow-up Mechanisms:** Establish mechanisms for follow-up after each session, including follow-up emails, surveys, or working groups to further explore specific topics or initiatives identified during the discussions.

- **Evaluate and Iterate:** Regularly evaluate the effectiveness of the roundtable series in achieving its objectives. Solicit feedback from participants on the format, topics, or structure as needed to improve outcomes.
- **Promote Visibility and Outreach:** Promote the roundtable series through various channels (e.g., LinkedIn, websites, distribution lists) to increase awareness and participation. Engage with relevant professional organizations, government agencies, and other stakeholders to expand the reach of the series.

By following these steps, a successful roundtable series can foster collaboration, transparency, and efficiency in EM R&D efforts.

6.1 Next Steps

Ultimately, feedback and research needs identified through EMOTR outreach (Tasks 3A, B, and C) is being considered and further explored in EMOTR Task 5, “Artificial Intelligence Research Landscape Summary and Research Recommendations,” and Task 6, “Emergency Operations Center of the Future Recommendations Report.” Together, these tasks are vetting and validating EMOTR findings and exploring where AI and other research and technology might benefit EM operations and EOCs of the future. Findings from the EMOTR tasks will be provided in a recommendations report to inform future research and investment considerations. Recommendations will consider options such as fully virtual EOCs and virtual capacity scaling, the role of autonomous decision-making by AI tools, maintaining situational awareness through advanced communications and geospatial information technologies, advanced display technologies, and other emerging technologies that can dramatically increase EOC effectiveness and efficiencies.

Appendix A– Roundtable Agenda

Emergency Management of Tomorrow Research Roundtable

Date: TBD
Time: [1 hour]
Virtual: Microsoft Teams

AGENDA

TIME (PT/ET)	TOPIC	PARTICIPANTS
10:00 – 10:15 am PT / 1:00 – 1:15 pm ET	Introductions i. Updates on EMOTR	Task Lead, PNNL
10:15 – 10:45 am PT / 1:15 – 1:45 pm ET	Guest Speaker ii. Presentation iii. Q&A	Guest Speaker Name, Title, Organization
10:45 am – 11:00 am PT / 1:45 pm – 2:00 pm ET	Discussion iv. Capability Needs and Research Opportunities	All

Appendix B– Segment Three Presentation

1

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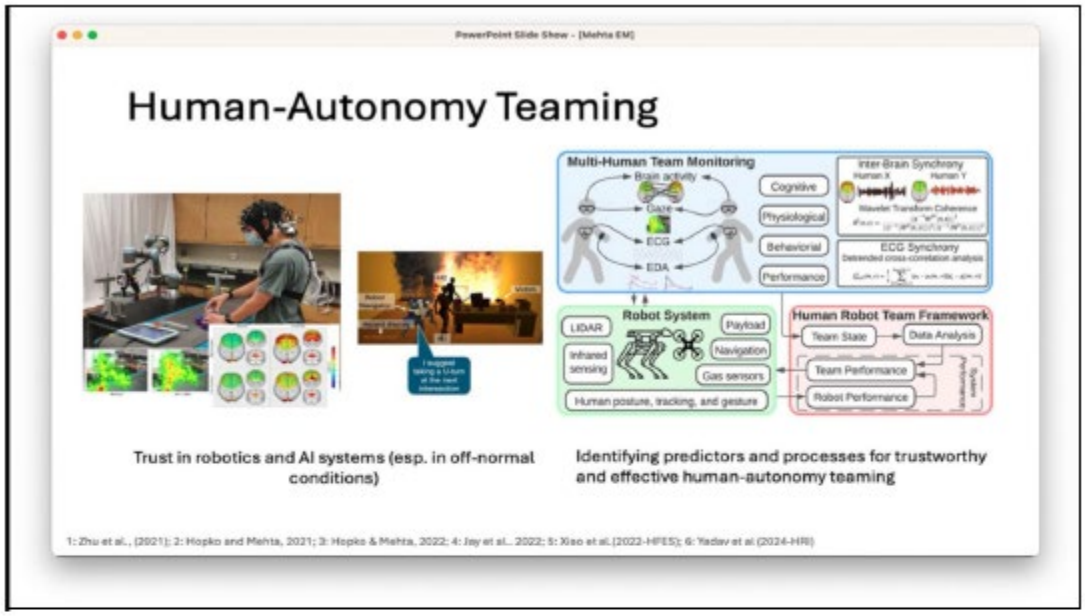
PowerPoint Slide Show - [Mehta EM]
NeuroErgonomics Laboratory
Fatigue Mechanisms
Predictive Fatigue Monitoring
Human-Autonomy Teaming
Adaptive Interfaces
Neurotechnology @ Work
NASA
NIH
DARPA
SecureAmerica Institute

3


PowerPoint Slide Show - [Mehta EM]
Human-Autonomy Teaming
Hurricane Harvey, 2017
Hawaii's Kilauea volcano, 2018
Hurricane Michael, 2018

4


PowerPoint Slide Show - [Mehta EM]
Human-Autonomy Teaming
Multi-Human Team Monitoring
Brain activity
Gaze
ECG
EDA
Cognitive
Physiological
Behavioral
Performance
Inter-Brain Synchrony
Human X
Human Y
Wavelet Transform Coherence
ECG Synchrony
Robot System
LIDAR
Infrared sensing
Payload
Navigation
Gas sensors
Human posture, tracking, and gesture
Human Robot Team Framework
Team State
Data Analysis
Team Performance
Robot Performance
Trust in robotics and AI systems (esp. in off-normal conditions)
Identifying predictors and processes for trustworthy and effective human-autonomy teaming
1: Zhu et al., (2021); 2: Hopko and Mehta, 2021; 3: Hopko & Mehta, 2022; 4: Jay et al., 2022; 5: Xiao et al.(2022-HFES); 6: Yadav et al.(2024-HRI)

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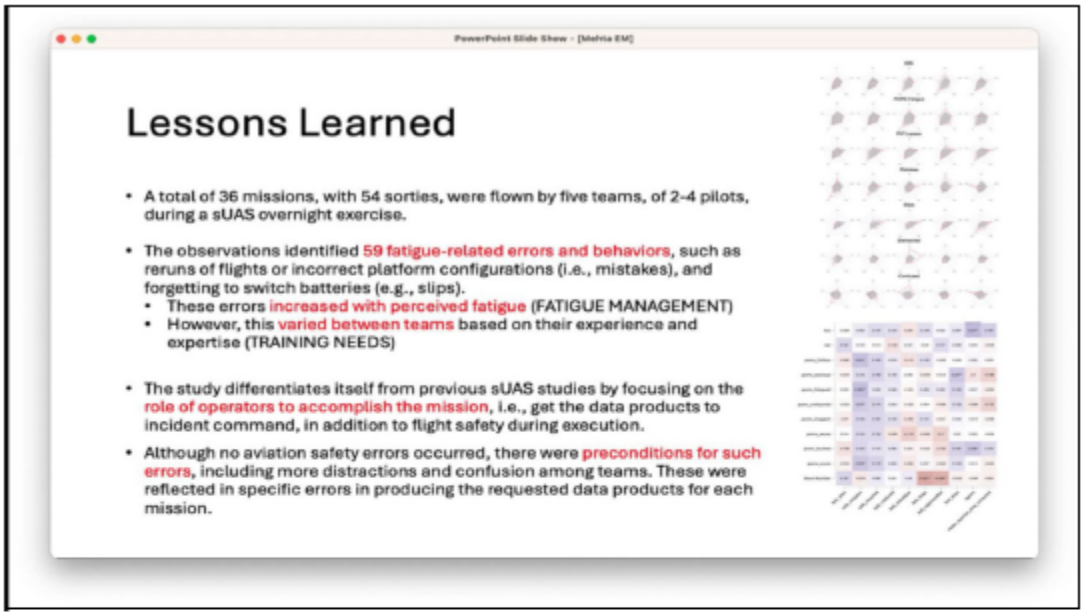
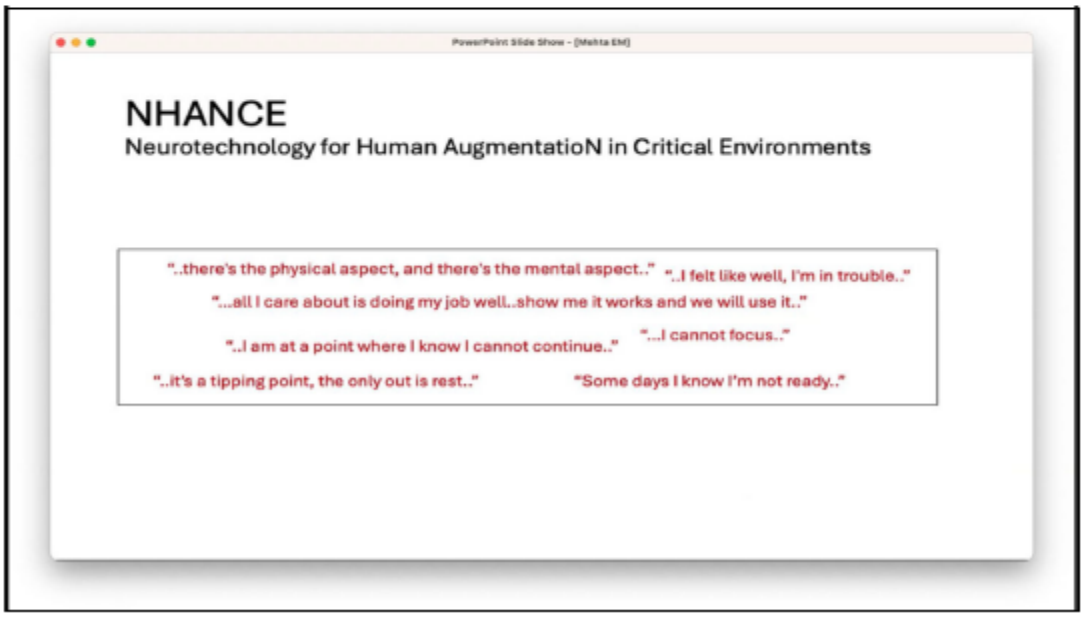
PowerPoint Slide Show - [Mehta EM]
Human-Autonomy Teaming
Overnight Training on HRI during Disasters
Phase 1
Phase 2
Phase 3
Phase 4
Phase 5
Time
All teams part of Hurricane Ian sUAS response
Day/night/fatigue/time pressure
Teams of 2 or 3: pilot, visual observer/safety officer
1: Mehta et al.(2024-HFES)

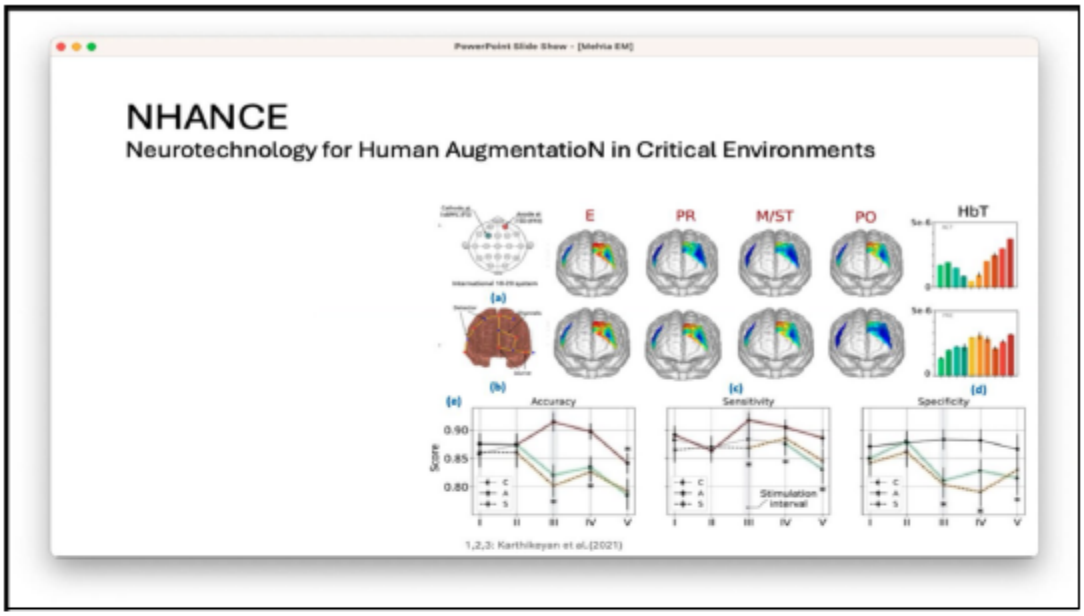
6


Lessons Learned
• A total of 36 missions, with 54 sorties, were flown by five teams, of 2-4 pilots, during a sUAS overnight exercise.
• The observations identified 59 fatigue-related errors and behaviors, such as reruns of flights or incorrect platform configurations (i.e., mistakes), and forgetting to switch batteries (e.g., slips).
• These errors increased with perceived fatigue (FATIGUE MANAGEMENT)
• However, this varied between teams based on their experience and expertise (TRAINING NEEDS)
• The study differentiates itself from previous sUAS studies by focusing on the role of operators to accomplish the mission, i.e., get the data products to incident command, in addition to flight safety during execution.
• Although no aviation safety errors occurred, there were preconditions for such errors, including more distractions and confusion among teams. These were reflected in specific errors in producing the requested data products for each mission.

7


NHANCE
Neurotechnology for Human AugmentatioN in Critical Environments
"..there's the physical aspect, and there's the mental aspect.."
"...I felt like well, I'm in trouble.."
"...all I care about is doing my job well..show me it works and we will use it.."
"...I cannot focus.."
"..I am at a point where I know I cannot continue.."
"..it's a tipping point, the only out is rest.."
"Some days I know I'm not ready.."

8


NHANCE
Neurotechnology for Human AugmentatioN in Critical Environments
E
PR
M/ST
PO
HbT
(a)
(b)
(c)
(d)
(e)
Accuracy
Sensitivity
Specificity
Score
0.90
0.85
0.80
Stimulation interval
1,2,3: Karthikeyan et al.(2021)

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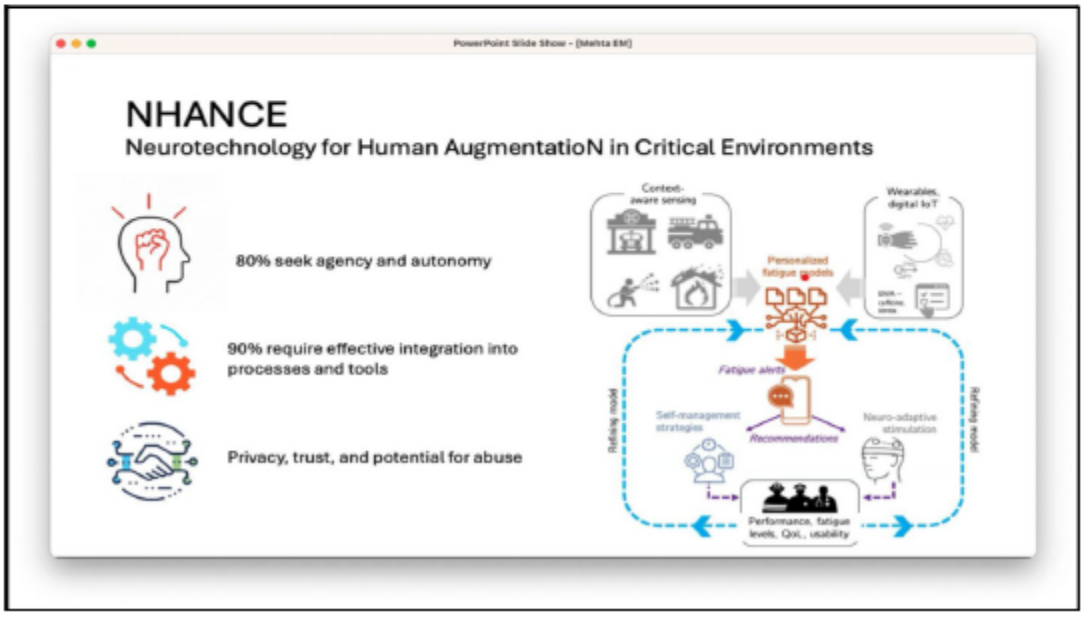
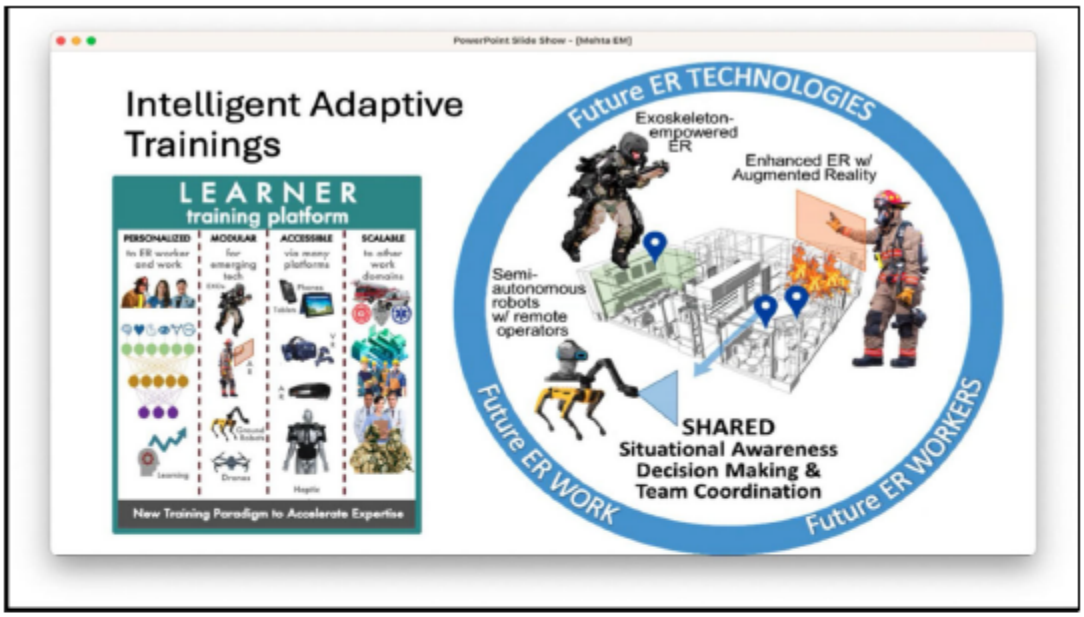

NHANCE
Neurotechnology for Human AugmentatioN in Critical Environments
80% seek agency and autonomy
90% require effective integration into processes and tools
Privacy, trust, and potential for abuse
Context-aware sensing
Wearables, digital IoT
Personalized fatigue models
Fatigue alerts
Self-management strategies
Recommendations
Neuro-adaptive stimulation
Performance, fatigue levels, QoL, usability
Refining model
Refining model

10


Intelligent Adaptive Trainings
LEARNER
training platform
PERSONALIZED
MODULAR
ACCESSIBLE
SCALABLE
New Training Paradigm to Accelerate Expertise
Future ER TECHNOLOGIES
Exoskeleton-empowered ER
Enhanced ER w/ Augmented Reality
Semi-autonomous robots w/ remote operators
SHARED
Situational Awareness
Decision Making &
Team Coordination
Future ER WORK
Future ER WORKERS

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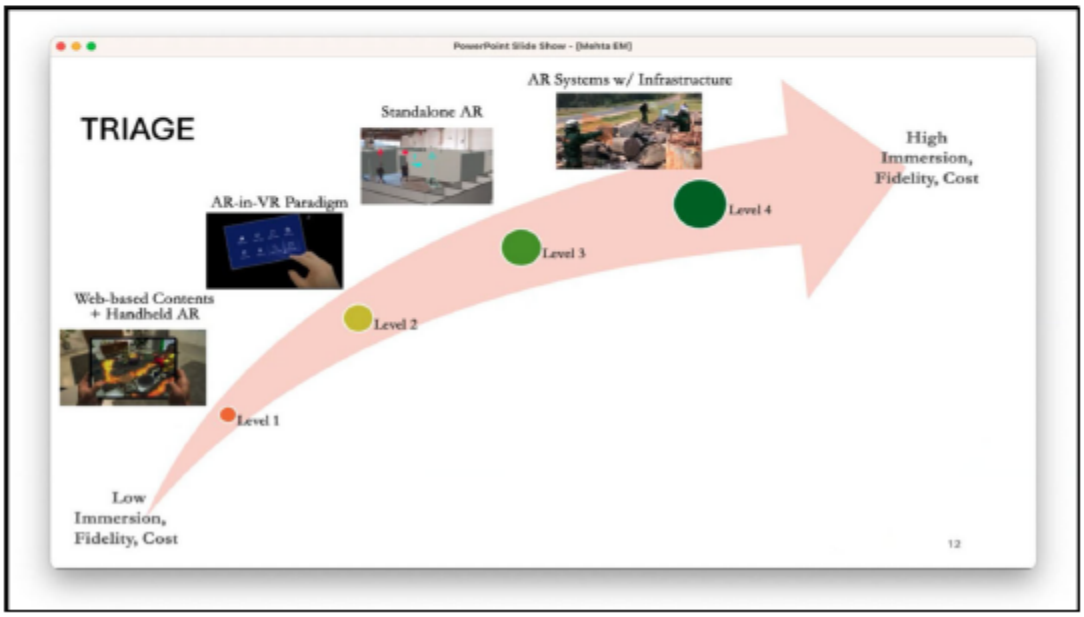
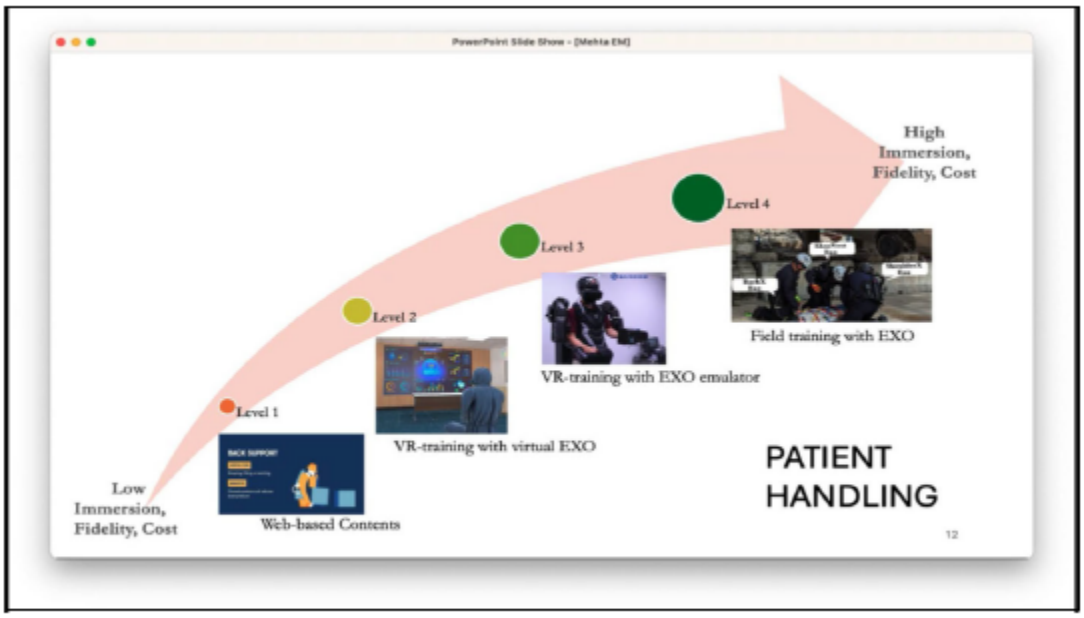

TRIAGE
AR Systems w/ Infrastructure
Standalone AR
AR-in-VR Paradigm
Web-based Contents + Handheld AR
Level 1
Level 2
Level 3
Level 4
High Immersion, Fidelity, Cost
Low Immersion, Fidelity, Cost
12

12


High
Immersion,
Fidelity, Cost
Level 4
Level 3
Level 2
Level 1
Field training with EXO
VR-training with EXO emulator
VR-training with virtual EXO
Low
Immersion,
Fidelity, Cost
Web-based Contents
PATIENT
HANDLING
12

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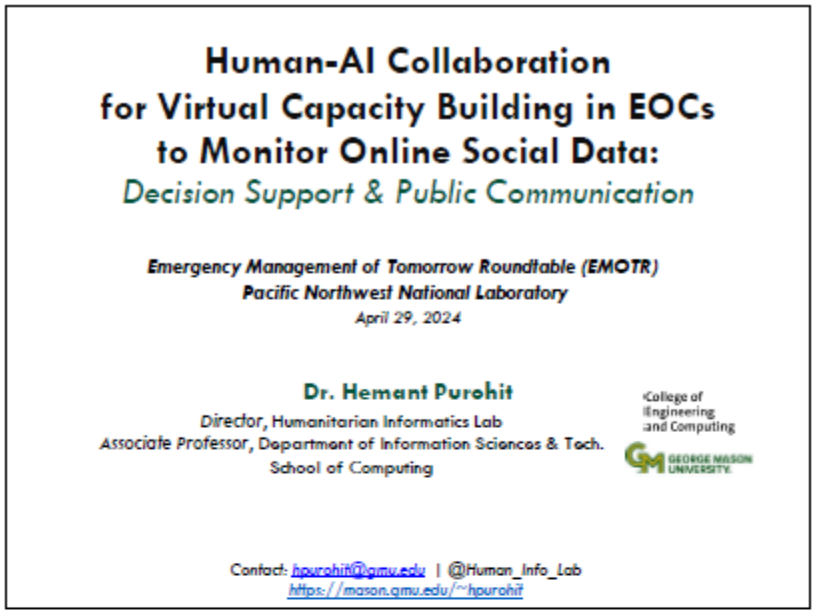
Appendix C– Segment Four Presentation



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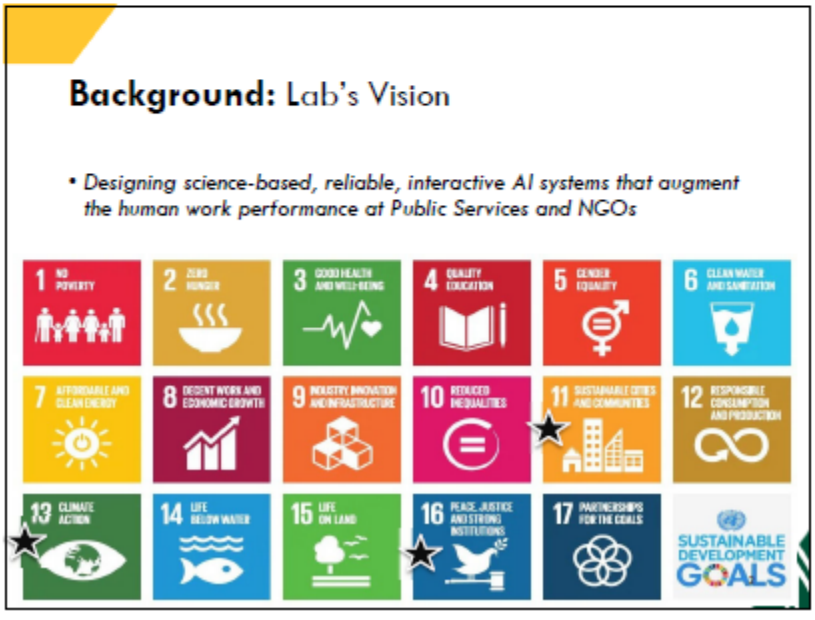

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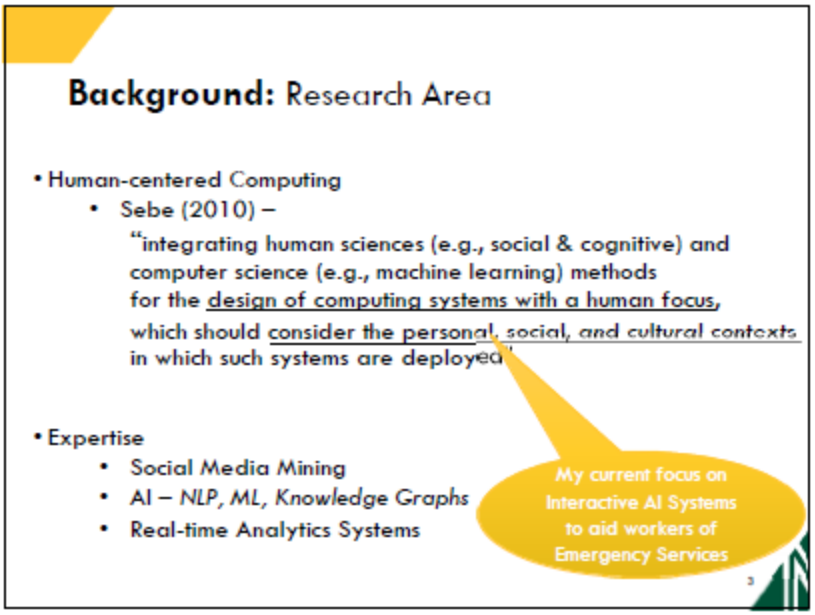
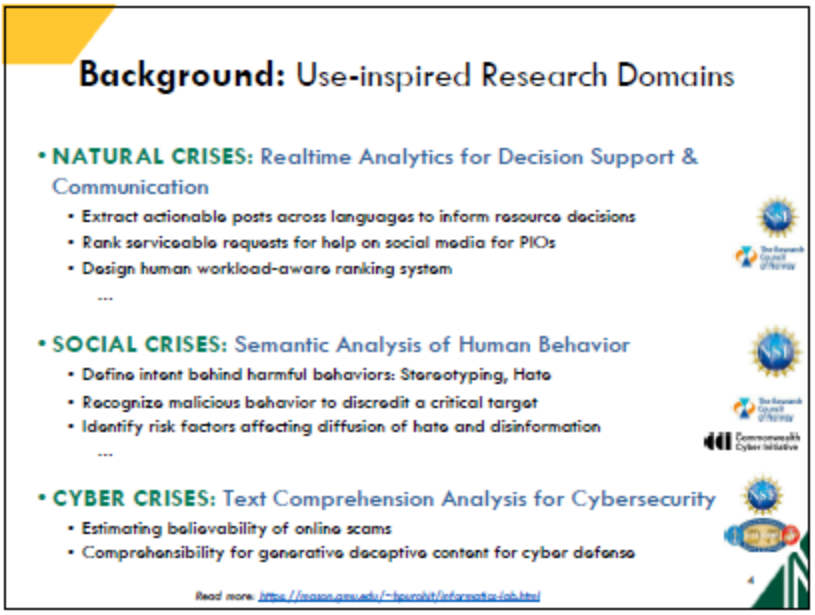

Background: Research Area
• Human-centered Computing
• Sebe (2010) –
"integrating human sciences (e.g., social & cognitive) and computer science (e.g., machine learning) methods for the design of computing systems with a human focus, which should consider the personal, social, and cultural contexts in which such systems are deployed"
• Expertise
• Social Media Mining
• AI – NLP, ML, Knowledge Graphs
• Real-time Analytics Systems
My current focus on Interactive AI Systems to aid workers of Emergency Services
3

3


Background: Use-inspired Research Domains
• NATURAL CRISES: Realtime Analytics for Decision Support & Communication
• Extract actionable posts across languages to inform resource decisions
• Rank serviceable requests for help on social media for PIOs
• Design human workload-aware ranking system
...
• SOCIAL CRISES: Semantic Analysis of Human Behavior
• Define intent behind harmful behaviors: Stereotyping, Hate
• Recognize malicious behavior to discredit a critical target
• Identify risk factors affecting diffusion of hate and disinformation
...
• CYBER CRISES: Text Comprehension Analysis for Cybersecurity
• Estimating believability of online scams
• Comprehensibility for generative deceptive content for cyber defense
Read more: https://psaas.psu.edu/~hpurohit/informatics-lab.html
4

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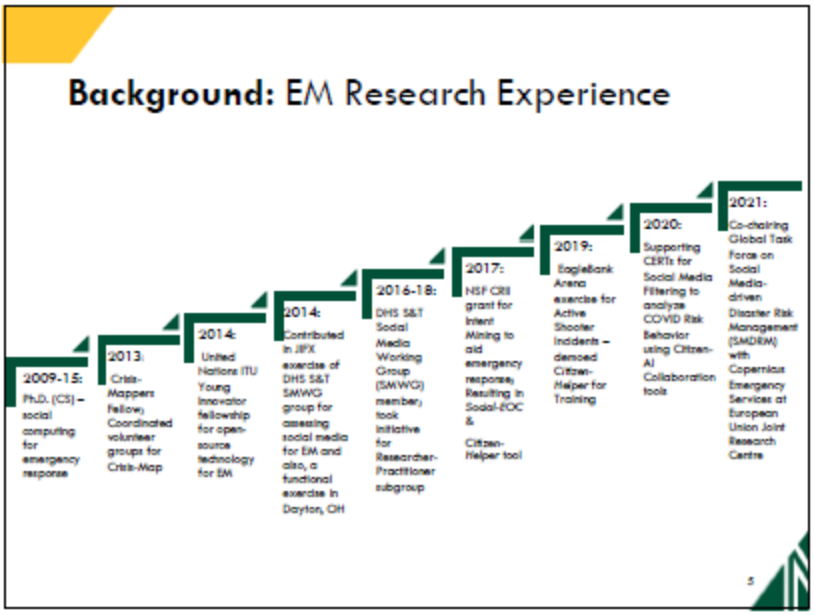
Background: EM Research Experience
2009-15:
Ph.D. (CS) – social computing for emergency response
2013:
Crisis-Mappers Fellow; Coordinated volunteer groups for Crisis-Map
2014:
United Nations ITU Young Innovator fellowship for open-source technology for EM
2014:
Contributed in JIFX exercise of DHS S&T SMWG group for assessing social media for EM and also, a functional exercise in Dayton, OH
2016-18:
DHS S&T Social Media Working Group (SMWG) member; took initiative for Researcher-Practitioner subgroup
2017:
NSF CRII grant for Intent Mining to aid emergency response; Resulting in Social-EOC & Citizen-Helper tool
2019:
EagleBank Arena exercise for Active Shooter Incidents – demoed Citizen-Helper for Training
2020:
Supporting CERTs for Social Media Filtering to analyze COVID Risk Behavior using Citizen-AI Collaboration tools
2021:
Co-chairing Global Task Force on Social Media-driven Disaster Risk Management (SMDRM) with Copernicus Emergency Services at European Union Joint Research Centre
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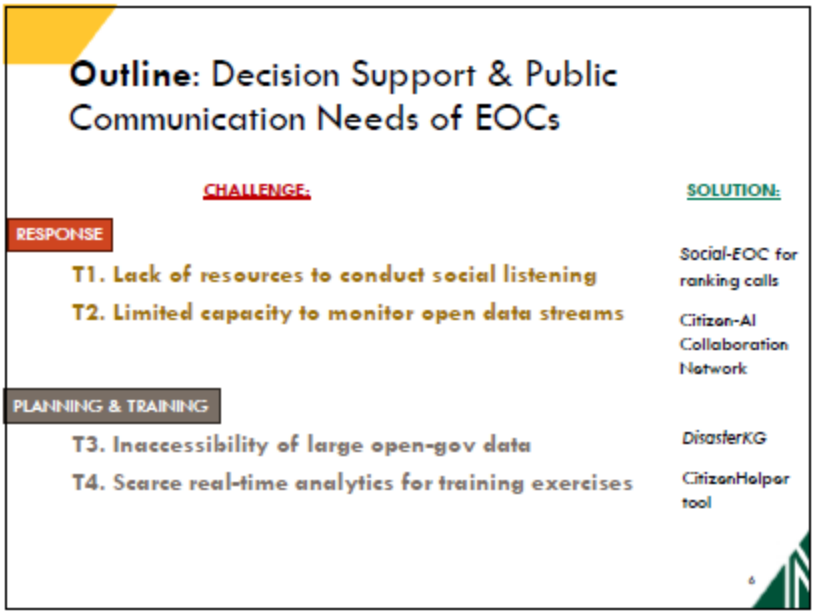
Outline: Decision Support & Public Communication Needs of EOCs
CHALLENGE:
SOLUTION:
RESPONSE
T1. Lack of resources to conduct social listening
T2. Limited capacity to monitor open data streams
Social-EOC for ranking calls
Citizen-AI Collaboration Network
PLANNING & TRAINING
T3. Inaccessibility of large open-gov data
T4. Scarce real-time analytics for training exercises
DisasterKG
CitizenHelper tool
6

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Outline

CHALLENGE:

SOLUTION:

RESPONSE

T1. Lack of resources to conduct social listening

Social-EOC for ranking calls

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T1. Social Listening: Why?

Uni-directional communication
(TO people)

Web 2.0 media

Bi-directional
(BY people, TO people)

Citizens as Sensors!

Real-time Access to Public Behavior Observations

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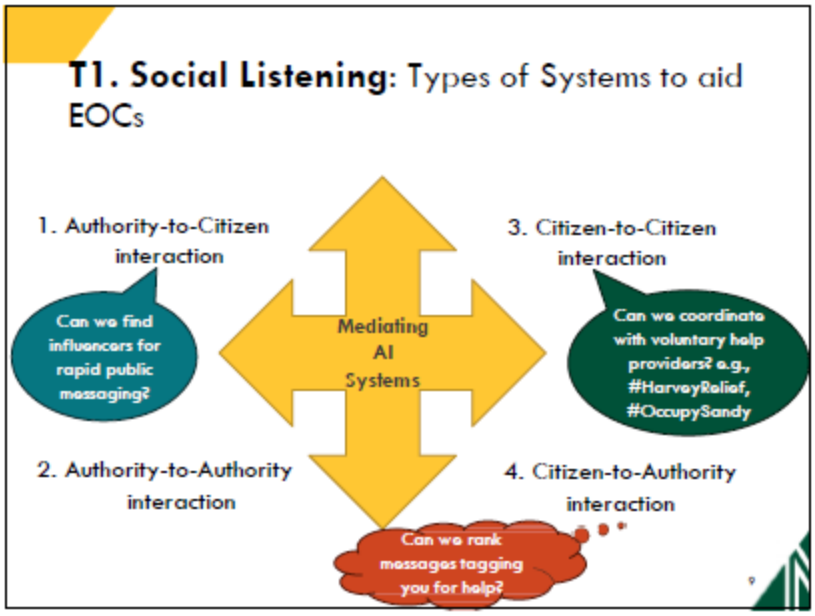
T1. Social Listening: Types of Systems to aid EOCs
1. Authority-to-Citizen interaction
Can we find influencers for rapid public messaging?
3. Citizen-to-Citizen interaction
Can we coordinate with voluntary help providers? e.g., #HarveyRelief, #OccupySandy
Mediating AI Systems
2. Authority-to-Authority interaction
4. Citizen-to-Authority interaction
Can we rank messages tagging you for help?
9

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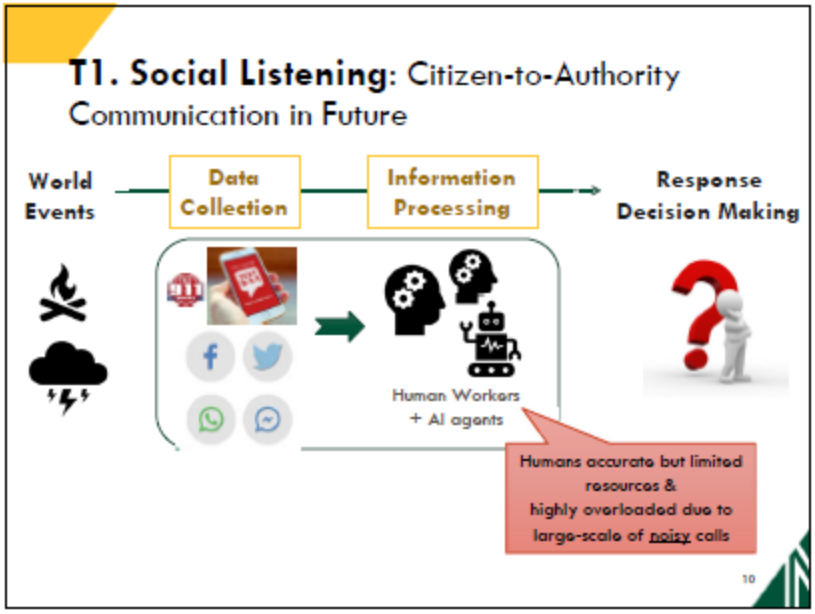
T1. Social Listening: Citizen-to-Authority Communication in Future
World Events
Data Collection
Information Processing
Response Decision Making
Human Workers + AI agents
Humans accurate but limited resources & highly overloaded due to large-scale of noisy calls
10

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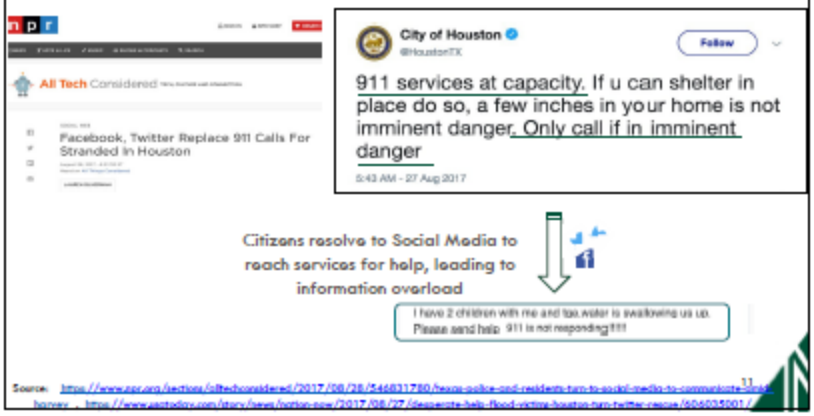
T1. Social Listening: Motivation to automatically analyze online calls for help



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T1. *Social-EOC:* Model the Serviceability of Calls

Can we filter, prioritize, and organize serviceable social media requests for city emergency services at scale?

Social Media
(Extendable to: NG911, 211,..)

Study Scope:
- Study user requests directly sent to the accounts of services
- Analyze the requests during a disaster response period

[Purohit et al., ASONAM'18, SNAM'20]

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T1. *Social-EOC:* Application for Reducing Time to Attend Critical Calls/Messages for Help

Image Source: https://blog.bufferapp.com/twitter-timeline-algorithm

RANKED TWEETS

5 hours ago

1 hour ago

3 hours ago

BEYOND TIME,
Rank by
Serviceability
&
Browse
Semantically

CURRENT

FUTURE

[Purohit et al., ASONAM'18, SNAM'20]

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T1. *Social-EOC:* Ranking & Relevancy Challenges

(Anonymized) Message	Operational Serviceability Degree
@_USER_ I am 9 ft above current water levels, why am I told to evacuate Grand Lakes now? Plz advise.	serviceable
@_USER_ If there has been no rain since yesterday, why is water not draining?	serviceable but lacks details
@_USER_ Thank God you are working on this.	not serviceable

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T1. *Social-EOC:* Modeling Requirement

- Objective: identify the quantifiable characteristics of a serviceable request post

  ➔ *Need: Service professionals care about explanation & reasoning*

  ➔ *Approach: Discussion with service professionals using FEMA training guidelines for Public Information Officers*

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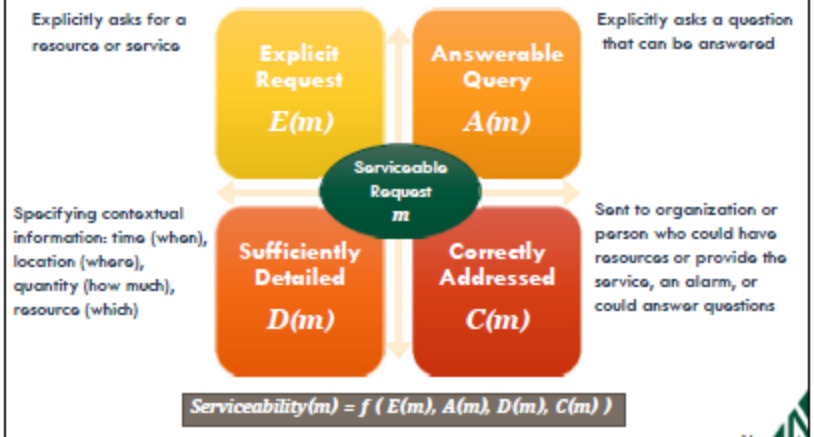
T1. *Social-EOC*: Explanatory Serviceability Model



[Purohit et al., ASONAM'18, SNAM'20]

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T1. *Social-EOC*: Serviceability Characteristics Ratings Examples

Illustration Table: Average scores of Likert ratings after crowdsourced annotations

(Anonymized) Message	Explicit	Answer-able	Addressed	Detailed
@account1 please, governor, post a phone # for specific info in our local areas	4.3	4.3	3.3	3.7
@account2 is thr parking at McMahon for volunteer?	4.0	5.0	5.0	5.0
@account3 how can I help	1.3	4.3	4.3	1.0
@account4 Plz pray for these families	1.7	1.0	1.0	1.0
@account5 been working in #LAFlood shelter, we actively monitor SM for feedback	1.0	1.0	2.0	2.0
"@account7 No matter where in the world ur followers live, you can donate from link Plz RT	1.0	1.0	1.0	1.0

[Purohit et al., ASONAM'18, SNAM'20]

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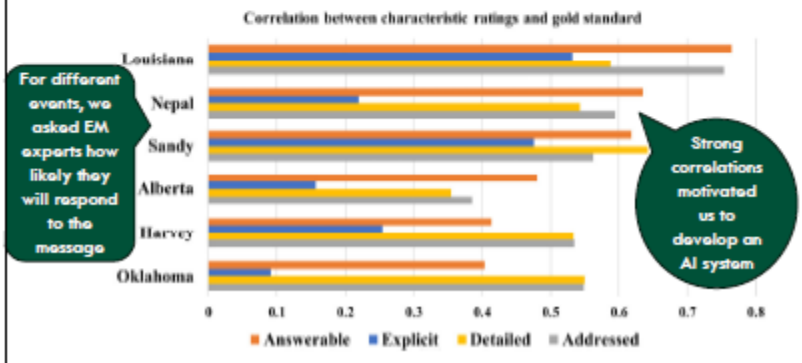
T1. *Social-EOC*: Ratings of Serviceability Characteristics vs. Relevance Perceived by EM Experts



[Purohit et al., ASONAM'18, SNAM'20]

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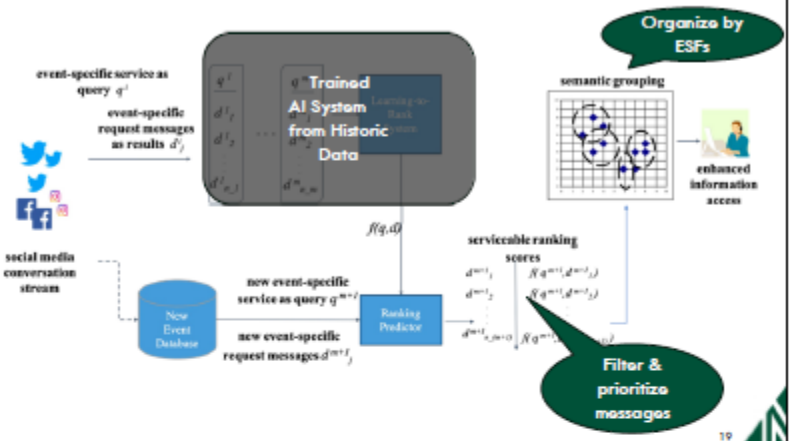
T1. *Social-EOC*: Using Serviceability Model to train an AI System (Supervised Learning-to-Rank)



[Purohit et al., ASONAM'18, SNAM'20]

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T1. *Social-EOC*: Examples of Ranked Calls by the AI System

TOP [Sandy]	- @_USER_ Queens trains aren't being addressed at all. When can v expect any service updates for the NQR trains?
BOTTOM [Sandy]	- @_USER_ HILARIOUS! That's much needed laughter, I am sure.
TOP [Alberta]	- @_USER_ can you tell me if sanitary pumps are running yet in elbow park? #yycflood
BOTTOM [Alberta]	- @_USER_ thank u calgary police

Ranked Messages by T (text)+I (Inferred) Modeling Scheme

[Purohit et al., ASONAM'18, SNAM'20]

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T1. *Social-EOC*: Extension directions

- Optimal top-K request alerts to respond while accounting for human workload *[Purohit et al., Web Intelligence(WI) '18]*
- Semantic grouping of requests using DBpedia knowledge graph *[Purohit et al., SNAM'20]*
- Models for unsupervised domain adaptation in new crises *[Krishnan et al., ASONAM'20]*
- Models that can process calls in multiple languages *[IEEE BigData'22; Vitiugin & Purohit, ICWSM 2024]*

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T1. *Social-EOC*: Extension Example for Human Workload-aware Ranking

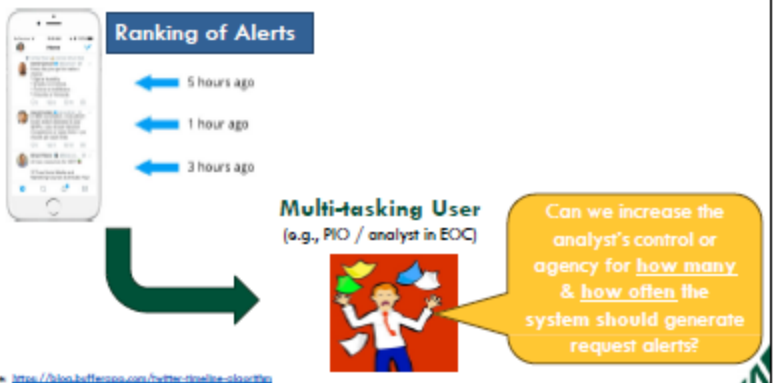

Image: https://blog.bufferapp.com/twitter-timeline-algorithm

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Outline

CHALLENGE:

SOLUTION:

RESPONSE

T1. Lack of resources to conduct social listening

T2. Limited capacity to monitor open data streams

Citizen-AI Collaboration Network

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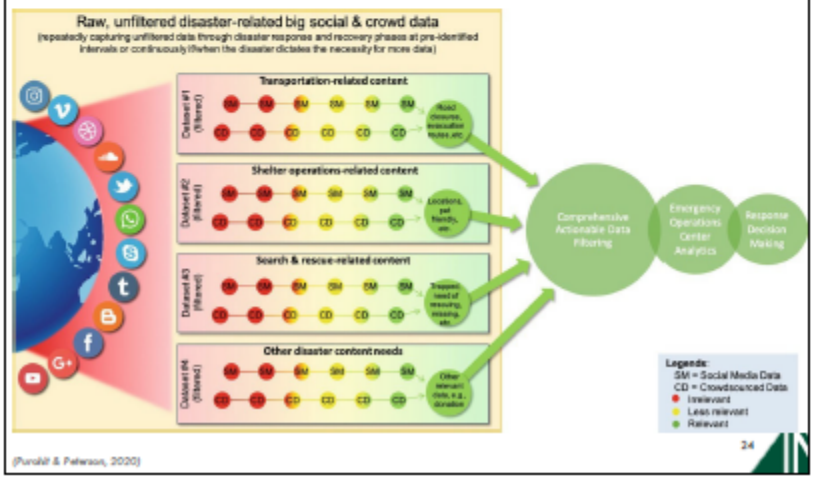
T2. Social Media Monitoring: Situational Awareness for Decision Support at Scale



(Purohit & Peterson, 2020)

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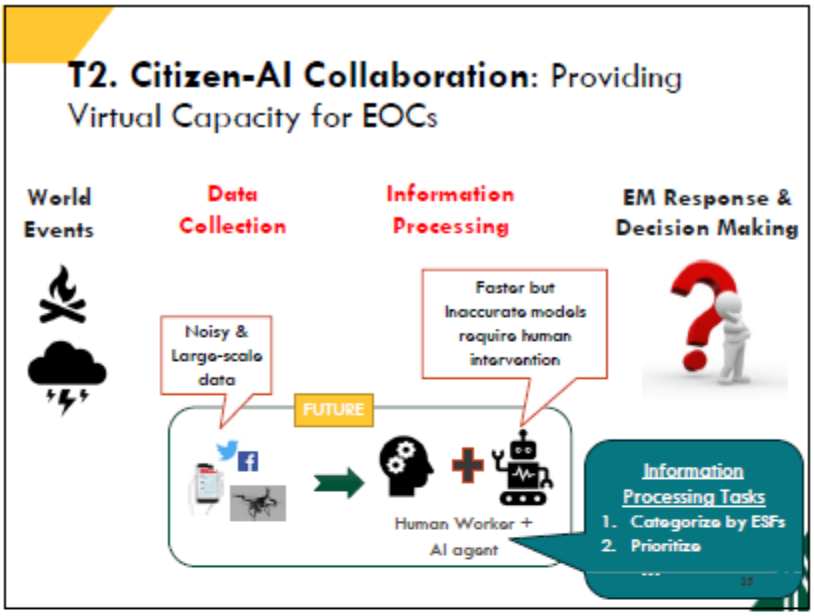
T2. Citizen-AI Collaboration: Providing Virtual Capacity for EOCs
World Events
Data Collection
Information Processing
EM Response & Decision Making
Noisy & Large-scale data
Faster but Inaccurate models require human intervention
FUTURE
Human Worker + AI agent
Information Processing Tasks
1. Categorize by ESFs
2. Prioritize

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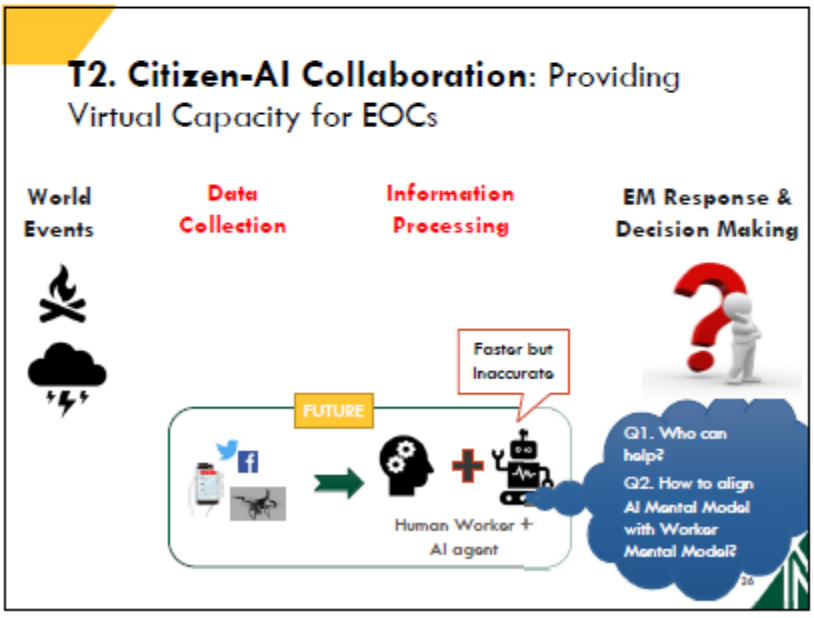
T2. Citizen-AI Collaboration: Providing Virtual Capacity for EOCs
World Events
Data Collection
Information Processing
EM Response & Decision Making
Faster but Inaccurate
FUTURE
Human Worker + AI agent
Q1. Who can help?
Q2. How to align AI Mental Model with Worker Mental Model?

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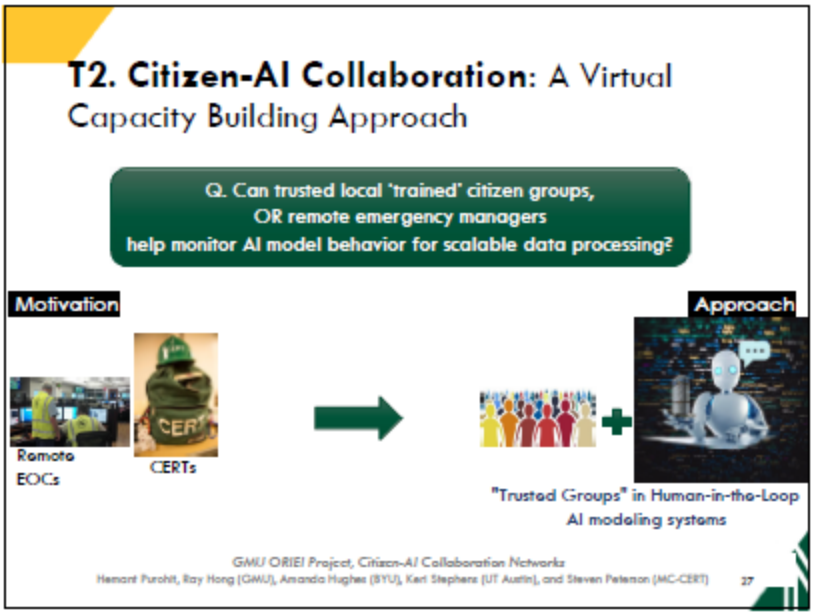
T2. Citizen-AI Collaboration: A Virtual Capacity Building Approach
Q. Can trusted local 'trained' citizen groups, OR remote emergency managers help monitor AI model behavior for scalable data processing?
Motivation
Approach
Remote EOCs
CERTs
"Trusted Groups" in Human-in-the-Loop AI modeling systems
GMU ORIEI Project, Citizen-AI Collaboration Network
Hemant Purohit, Ray Hong (GMU), Amanda Hughes (BYU), Kent Stephens (UT Austin), and Steven Peterson (MC-CERT)
27

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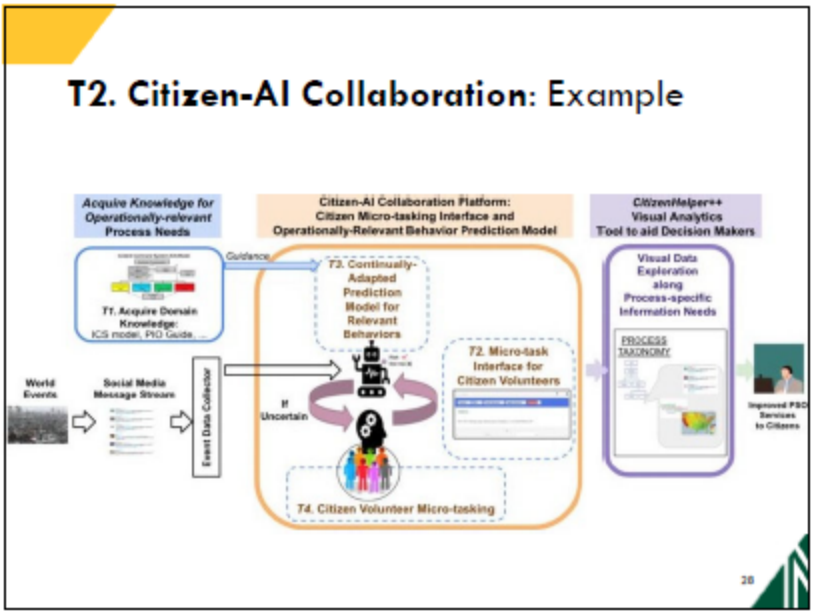
T2. Citizen-AI Collaboration: Example
Acquire Knowledge for Operationally-relevant Process Needs
Citizen-AI Collaboration Platform: Citizen Micro-tasking Interface and Operationally-Relevant Behavior Prediction Model
CitizenHelper++ Visual Analytics Tool to aid Decision Makers
T1. Acquire Domain Knowledge:
ICS model, PIO Guide
Guidance
T3. Continually-Adapted Prediction Model for Relevant Behaviors
T2. Micro-task Interface for Citizen Volunteers
Visual Data Exploration along Process-specific Information Needs
PROCESS TAXONOMY
World Events
Social Media Message Stream
Event Data Collector
If Uncertain
T4. Citizen Volunteer Micro-tasking
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T2. Citizen-AI Collaboration: Research Needs

- Key Questions:
  - **How to sequence the tasks for data annotation to monitor and provide human feedback to update an AI model continually while also mitigating human errors?** *(Pandey et al. ASONAM'2019; IJHCS'2022)*
  - How to create system interface for facilitating the human feedback while assisting human users in the Citizen-AI Collaboration Network? *(Ara et al., ACM Intelligent User Interfaces'2024)*

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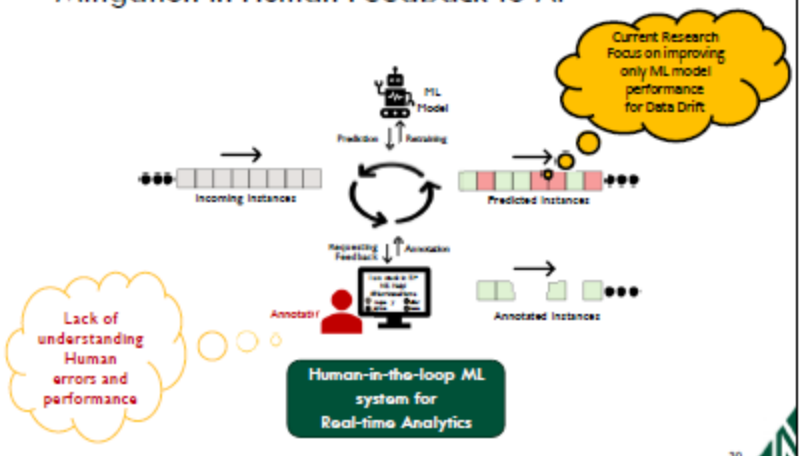
T2. Citizen-AI Collaboration: Task on Error Mitigation in Human Feedback to AI



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[Pandey and Purohit, ASONAM'2018; Pandey et al. ASONAM'2019; Pandey et al. IJHCS'2022]

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T2. Citizen-AI Collaboration: Task on Error Mitigation in Human Feedback to AI

- Proposed Human Error Framework for HITL-ML Systems
  - Inspiration: Psychology research on human memory & causes of errors (Reason, 2000; Norman, 1981; Loftus, 1985; Zhang et al, 2004)
  - *Slips*
    - Error in presence of correct and complete knowledge
  - *Mistakes*
    - Error due to incorrect or incomplete knowledge
- developed an Error-avoidance sampling algorithm to create reliable systems

Figure The effect of memory decay studied in Psychology (Baddeley, 1976) over time in learning or retaining conceptual knowledge.

Pandey et al. ASONAM'2018; Pandey et al. IJHCS'2022

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T2. Citizen-AI Collaboration: Research Needs

- Key Questions:
  - How to sequence the tasks for data annotation to monitor and provide human feedback to update an AI model continually while also mitigating human errors? (Pandey et al. ASONAM'2019; IJHCS'2022)
  - How to create system interface for facilitating the human feedback while assisting human users in the Citizen-AI Collaboration Network? (Ara et al., ACM Intelligent User Interfaces'2024)

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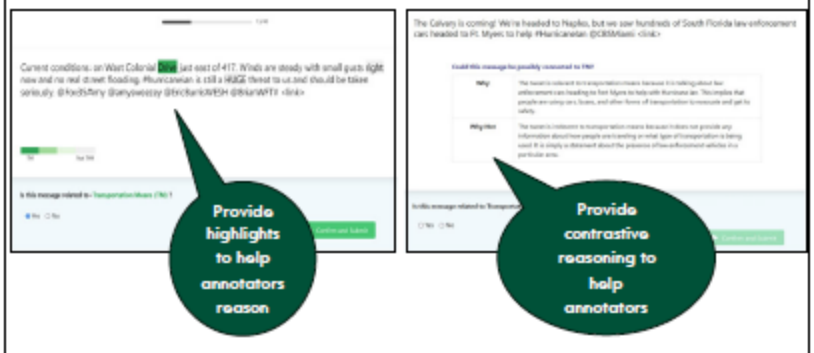
T2. Citizen-AI Collaboration: Task on Creating Effective Annotation Interface to Seek Human Feedback



Designing Different Interfaces to help Annotators using AI methods

[Senarath et al. (Disaster Handbook 2023); Ara et al. IUI 2024]

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Outline: Decision Support & Public Communication Needs of EOCs

CHALLENGE:	SOLUTION:
RESPONSE	
T1. Lack of resources to conduct social listening	
T2. Limited capacity to monitor open data streams	
PLANNING & TRAINING	
T3. Inaccessibility of large open-gov data	DisasterKG

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T3. *DisasterKG*: Disaster Knowledge Graph

- **Problem**
  - How can an emergency manager find information about critical resources and past events in a geographic region, their impacts, and also experts to collaborate for training and response planning?

KGs: core AI technology of Knowledge Representation and Reasoning to provide seamless, interoperable access to human and machine-interpretable data at scale

- **Research Task**
  - Address Heterogeneity of data sources, Inconsistency of vocabularies, Incompleteness of information across sources for an interoperable *DisasterKG*

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T3. *DisasterKG*: Motivation

- Illustrative graph for aviation safety and risk analysis

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T3. *DisasterKG*: Unifying Semantic Representation

- EDXL: Emergency Data Exchange Language ontology
  - Used in legacy disaster information systems
  - Extend with the complementary entity attributes from open data

CRITICAL RESOURCE:
e.g.,
Hospital entity

EDXL-HAVE concepts:
- *Hospital*
- *TraumaCenterServices*
- ...

AVAILABLE INFORMATION SOURCES:
with varied metadata

DATA.GOV

OpenStreetMap

[Purohit et al., ICSC'19]

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Outline: Decision Support & Public Communication Needs of EOCs

	CHALLENGE:	SOLUTION:
RESPONSE	T1. Lack of resources to conduct social listening	
	T2. Limited capacity to monitor open data streams	
PREPAREDNESS	T3. Inaccessibility of large open-gov data	
	T4. Scarce real-time analytics for response and training exercises	CitizenHelper tool

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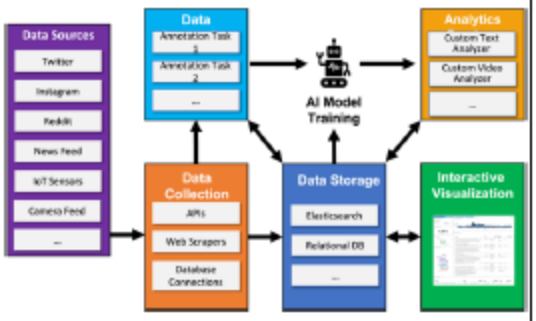
T4. *CitizenHelper tool*: Real-time data analytics platform for Response & Training

- Ingests multimodal data streams from heterogenous sources for Risk Analysis, Social Listening, Event Monitoring, ..
- Deployed for CERTs in DMV region for a NSF RAPID grant & First Responder Training



https://Citizenhelper.orc.gmu.edu

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(Karuna et al. (IC'WSM'17), Pandey & Purohit (ASONAM'20), Pandey et al. (ISCRAM'20), Senarath et al. (Disaster Handbook 2023))

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T4. *CitizenHelper tool:* Analytics for Response

Assisting regional CERT organizations for rapid social media filtering for COVID-19

- *NSF RAPID project:* with Steve Peterson (MC CERT), Kori Stephens (UT Austin), Amanda Hughes (Brigham Young U.)

Applications:

- Real-time situational awareness (e.g., Jurisdictional receptiveness -- risk, sentiment)
- Risk mitigation (e.g., COVID-19 trending risk topics)
- PIO tool (Proactive communications)

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(Senarath et al., Disaster Handbook 2023)

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T4. *CitizenHelper tool:* Analytics for Training

Training exercise

- Current practice to collect data for observing behaviors and interactions of trainees [Barnes et al., 2019]
  - Direct human observation
  - Radio-based audio communication
- Challenges
  - Missing observations
  - Cognitive load for human observer

[Pandey et al. ISCRAM 2020; Purohit et al., 2019]

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T4. *CitizenHelper tool:* Analytics for Training

- Feasible to collect multimodal data through IoT, wearables, video-based, audio-based, and social/citizen sensing [Dubrow et al.,2017; Feese et al.,2013; Kranzfelder et al.,2011]

Training exercise

Redundant, Complementary, Multimodal Sensing Data Streams

Enhanced Debriefing & Ability to 'Replay' Events

[Pandey et al. ISCRAM 2020]

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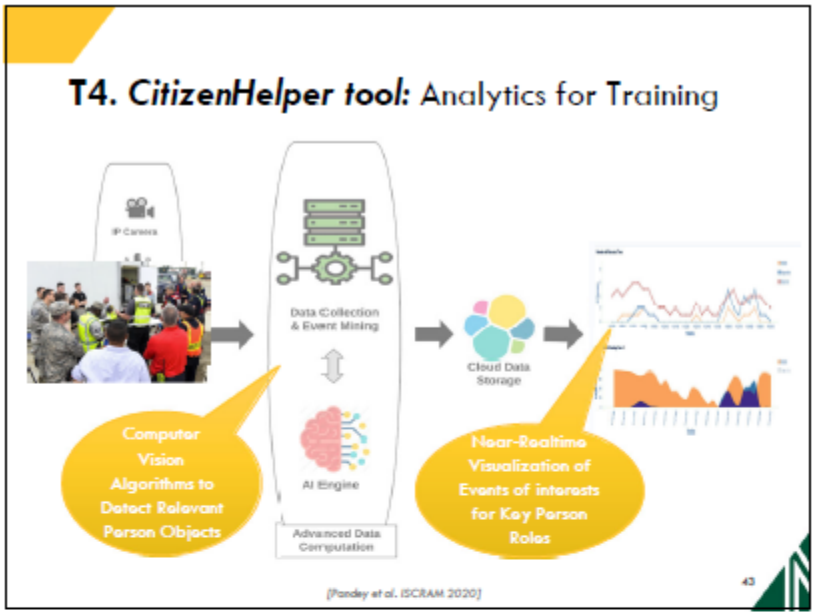
T4. CitizenHelper tool: Analytics for Training
IP Camera
Data Collection & Event Mining
AI Engine
Advanced Data Computation
Cloud Data Storage
Computer Vision Algorithms to Detect Relevant Person Objects
Near-Realtime Visualization of Events of interests for Key Person Roles
[Pandey et al. ISCRAM 2020]
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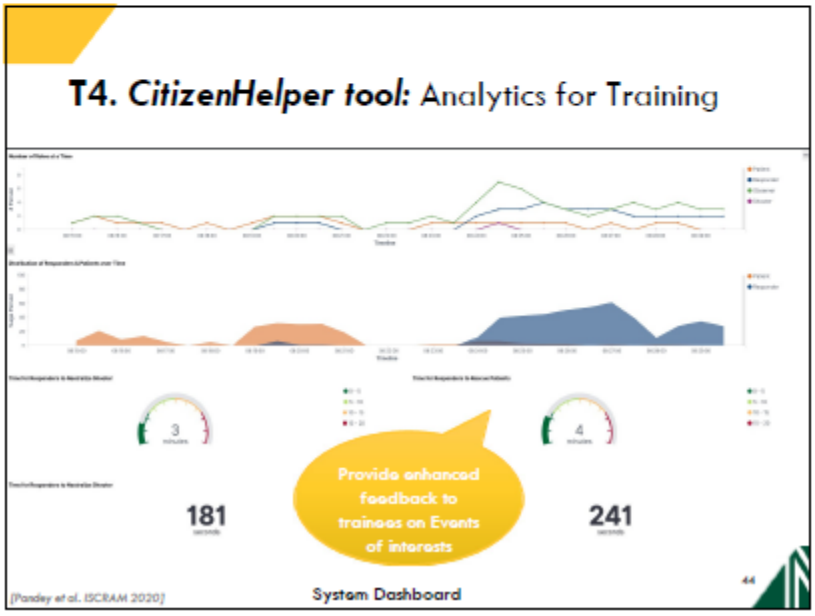
T4. CitizenHelper tool: Analytics for Training
3
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Provide enhanced feedback to trainees on Events of interests
[Pandey et al. ISCRAM 2020]
System Dashboard
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Conclusion

- Possible to deploy AI solutions in future EOCs to:
  - reduce the information overload
  - scale data processing across multiple modalities and languages
  - Build virtual capacity for resource-constrained local EOCs
- Need for human-centered AI system designs
  - Reliable and explanatory
  - Interactive for human control

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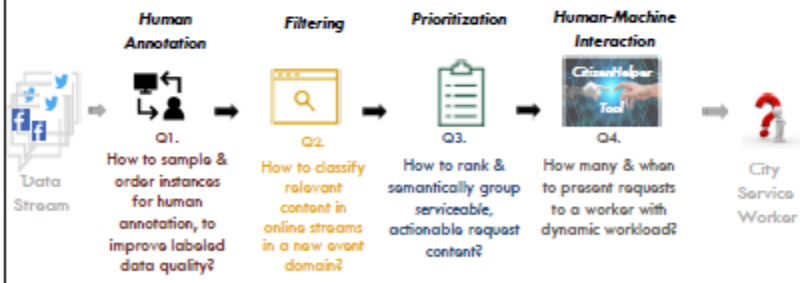
Future Work: Build Citizen-AI Collaboration Network as Virtual Capacity for Different ESF-related Services



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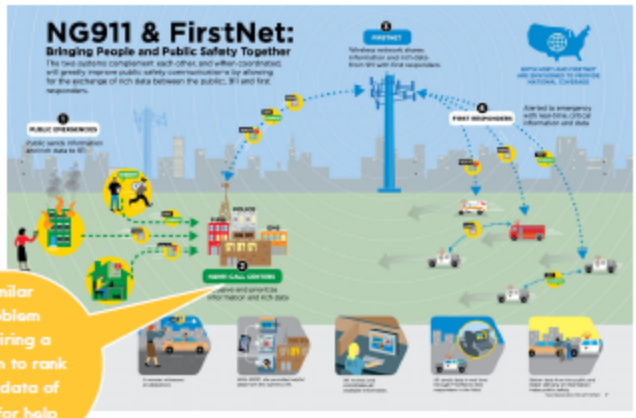
T1. Social-EOC: Application for NG911



Similar problem requiring a solution to rank noisy data of calls for help to respond

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Ongoing Projects: AI for Emergency Management Domain

- Summarizing multiple sources of data streams for situational awareness using LLMs for role-based summaries *[Saleemi et al., TREC'23]*
- LLM-assisted data annotation interfaces to support annotators for Human-AI Collaboration *[Aro et al., IUI'24]*
- Code-switching and cross-lingual message processing to support Multilingual Social Listening *[Saleemi et al., ISCRAM'23, Krishnan et al., IEEE Big Data 2022; Vitiugin & Purohit, ICWSM'24]*
- Human-centered AI tool for incident detection from crowdsourced data *[Senarath et al., ACM Digital Government'24; Senarath et al., ICDM'21]*
- Consistent reasoning of LLMs for fixing hallucinations in predictions
- Survey of EM practitioners from US and Europe for changing usage of social media platforms

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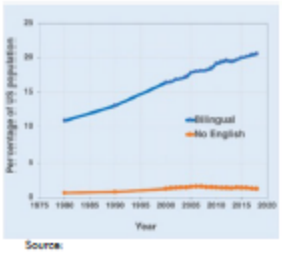
Ongoing Projects: Illustration of an Inclusive AI-assisted System for Social Media Monitoring

- Not everyone speaks English!
- Non-native speakers can use Transliteration and code-mixing, e.g.,

translated → transliterated

ENGLISH	SPANISH	ROMANIZED SPANISH
Flood in my village, today the rain created a storm :(	Inundación en mi pueblo, hoy la lluvia generó una tormenta :(	flood in mi bilage, hoy la lluvia generó una tormenta :(

Code-mixing for English & Spanish: flood in my village, hoy la lluvia generó una tormenta :(



Source: https://www.psychologytoday.com/us/blog/life-bilingual/201809/the-growing-rise-bilingualism-in-the-united-states

Can AI models account for diverse cultural nuances and social context?

[Krishnan et al., IEEE Big Data 2022, Saleem et al., ISCRAM 2023]

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Questions?

More about our research:
https://mason.gmu.edu/~hpurohit/informatics-lab.html

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