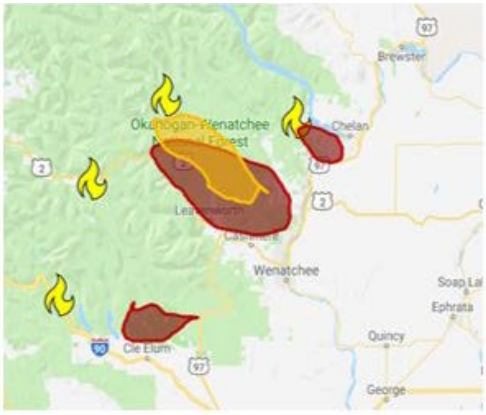




Wildland Urban Interface Fire Operational Requirements and Capability Analysis

Report of Findings

May 31, 2019

Homeland Security
Science and Technology

U.S. Fire Administration

FEMA

Wildland Urban Interface (WUI) Operational Requirements and Capability Analysis Project:

This report represents the collective efforts of an Integrated Project Team (IPT). Below are the organizational points of contact for this report:

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Table of Contents

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Executive Summary

In December of 2017, the Federal Emergency Management Agency (FEMA) Administrator requested the Department of Homeland Security DHS) Science and Technology (S&T) research new and emerging technology that could be applied to wildland fire incident response, given the loss of life that occurred in California during the fall of 2017 in Santa Rosa and Ventura.

In response to the request, DHS S&T—in collaboration with FEMA, the U.S. Fire Administration (USFA), and other key stakeholder experts—determined wildland urban interface (WUI) incidents and life-saving functions as the optimal areas for DHS S&T to explore technology innovation. As a result, S&T formed an Integrated Project Team (IPT) and initiated the WUI Fire Operational Requirements and Technology Capability Analysis Project. Over the course of the project, the IPT identified areas of innovation in wildland fire incident relating to wildland fire preparedness and mitigation and enhanced wildland fire suppression practices, including resistant infrastructure planning, building materials, and building codes. To meet the Administrator's request, however, the IPT focused its efforts on requirements for improving operational capabilities and incident response to save lives in WUI fires.

In doing so, the interagency IPT planned and conducted a series of consultative tabletop exercises (TTXs) and subject matter expert (SME) engagements to assess opportunities to enable life-saving activities during WUI fires. These activities elicited information requirements and capability gaps from expert firefighters, fire behaviorists, command staff, emergency management officials, and other key stakeholders. The IPT then identified potential solutions to meet these requirements and fill associated capability gaps, convening a panel of interdisciplinary SMEs to review and assess candidate solutions.

The project team identified three overarching conclusions that represent consistent themes captured throughout the course of the TTXs and expert engagements. These conclusions framed the development of key findings and more detailed analysis across the mission space of WUI fire response:

1. **Time Criticality of WUI Fire Incidents**: WUI fire incidents require immediate protective and response actions to save lives. The conflagration created when a wildland fire enters populated areas is unpredictable and can rapidly devastate these areas, threatening lives. Interventions and solutions that improve decision making and response in the initial minutes of a WUI fire are vital.
2. **Available Technology Solutions Exist:** There exist available technologies (both government and commercial), which—if implemented—could immediately help emergency responders reduce the number of lives lost during WUI fire incidents. In particular, these technologies could immediately support ignition detection, fire tracking, public information and warning, evacuation, and responder safety. Improving capabilities in other elements of the WUI response (i.e. preparedness and critical infrastructure) may require investing in adaptable or developable solutions that are not immediately available.
3. **Public Education and Preparedness Measures are Vital:** Public education and preparedness are essential to reducing the number of lives lost to WUI fire incidents. There is no solution more effective than preventing an ignition in the first place and ensuring the at-risk communities are prepared at the grassroots level to face wildland fire dangers.

The principal conclusions of this project are distilled into a set of seven key findings (**Table 1**). These key findings describe lines of effort addressing priority capability gaps that, if implemented, could substantially improve immediate life-saving efforts during WUI fire incidents. The key findings listed below are considered equally important to this objective and are not listed in any priority order.

Table 1: Summary of Key Findings

1	**Implement and scale the use of state-of-the-art remote sensing assets** to provide state and local stakeholders real-time, accurate, low-cost ignition detection and tracking information—especially fire perimeter using a mix of in situ, aerial, and space-based systems.
2	**Improve the ability of available and adaptable public alert and warning technologies** to deliver more targeted and effective message across the whole community, particularly to individuals with disabilities and others with Access and Functional Needs (AFN).
3	**Improve use of key public and private social media and internet resources and capabilities** to appropriately share data and adapt existing applications to enable more efficient and effective evacuation—e.g., expand and accelerate public-private partnerships through Integrated Public Alert and Warnings System (IPAWS) to include WUI incident-related evacuations, warning, and alerting.
4	**Support broader use of existing fire modeling and forecasting tools** for pre-incident planning; while also advancing efforts to create high-confidence, timely WUI fire-specific models that can be used to inform response tactics during extreme conditions.
5	**Increase infrastructure resilience**, especially critical infrastructure lifelines and support functions for wildland fire response—e.g., improve the resilience, interoperability, and reliability of communications, power utilities, digital links, and data center infrastructure.
6	**Integrate private, open, and crowdsourced data, resources, and capabilities** to improve public safety situational awareness of WUI fire ignition detection and tracking.
7	**Support wide-scale adoption of interoperable, low-cost blue-force tracking technologies** that feed near real-time situational awareness across key stakeholders, missions, and operations.

DHS S&T and its partners recognized that technology solutions do not exist in a vacuum. Improving capabilities requires a holistic, integrated suite of solutions which include technology as well as critical measures relating to policy, plans, organizational relationships, grants, public education, mitigation activities, training and exercises, and other non-technology components of preparedness. Some relevant lines of effort that should be considered as part of any solution implementation include:

- **Support efforts to educate the public** on WUI fire risks and integrate existing education programs into broader disaster education efforts.
- **Support a systematic approach to address the needs of the AFN population** to include tailored information, warning, and evacuation support before and during WUI fire incidents by sharing practices, establishing standards, creating regulation, etc. in conjunction with Key Finding #2.
- **Design and socialize standards to create uniform national evacuation doctrine** to propagate consistent evacuation terminology, authorities, and thresholds.
- **Expand training and exercise programs** to improve interagency and cross-disciplinary coordination in support of wildfire operations.
- **Encourage broader adoption of physical mitigation measures** (e.g., building codes) through grant investment, continued education of best practices and risks, and retrofitting.
- **Increase infrastructure resilience**, especially critical infrastructure lifelines and support functions.
- **Disseminate best management practices** on utilizing new technologies by sponsoring conferences and workshops and issuing best practice guidance and lessons learned from pilot programs, successful case studies, and proven implementations across various jurisdictions and agencies.

While the IPT endeavored to comprehensively assess requirements, gaps, and candidate solutions, both technology and the nature of the threat will continue to change. As a result, efforts to improve WUI fire response capabilities must stay at the forefront of innovation and technology development.

Key Findings

The WUI Fire Requirements and Technology Capability Analysis Project identified information requirements and capability gaps through an extensive literature review, tabletop exercises, and SME engagements. Gaps identified through this process were aggregated into key findings with technology solutions or implementation considerations for improving preparedness in a WUI incident. **Key findings represent lines of effort that, if implemented, have the potential to save a significant number of lives in future WUI fire incidents.** These lines of effort involve applied technology that could be integrated with relevant public safety and community plans, policies, procedures, training, doctrine, and existing capabilities. These key findings focus on available and adaptable technology solutions that require minimal changes or development to be applied into the existing operational environment and standard operating procedures (SOPs).

The tables below contain the key findings, the elements of the WUI firefighting mission it pertains to, the associated gaps (denoted in parenthesis by the letter "G" and a number), and a brief overview of potential solution considerations. For more information on the associated gaps, including a longer description and the associated requirements, refer to **Section III. Complete Findings**.

Key Finding 1: Implement and scale the use of state-of-the-art remote sensing assets to provide state and local stakeholders real-time, accurate, low-cost ignition detection and tracking information—especially fire perimeter using a mix of in situ, aerial, and space-based systems.

Mission Elements: Detection, Tracking

Associated Gaps:

- **Status of Available Resources** (G5): Lack of inventory of available resources from response partners hinders operations
- **Ignition Detection** (G11): Detection of WUI fire ignitions is not accurate or fast enough
- **Ignition Data Dissemination** (G12): Insufficient dissemination of ignition detection data to all response partners
- **Perimeter Tracking** (G13): Real-time perimeter tracking is often unavailable
- **Fire Characteristics** (G14): Lack of tracking data on a fire's parameters to include speed, crowning, spotting, and wind

Solution Considerations:

There exist low-cost and high-impact, available technologies that address WUI Detection and Tracking gaps (e.g., **Descartes Lab Platform, WIFIRE, Dunami, IRWIN, Hawkeye, ATAK, Tanka, CAWFE, LANCE**).

Key Finding 2: Improve the ability of available and adaptable public alert and warning technologies to deliver more targeted and effective message across the whole community, particularly to individuals with disabilities and others with Access and Functional Needs (AFN).

Mission Elements: Public Information and Warning

Associated Gaps:

- **Geographically Targeted Warnings** (G20): Lack of systems and procedures that deliver notifications and warnings to a targeted geographic area
- **Tailored AFN Warning**[1] (G21): Information and warning systems currently lack tailored communications to meet the specific needs of the AFN community
- **Social Media Warning Dissemination** (G23): Insufficient dedicated public information officers to disseminate warnings through social media during a WUI event
- **Carrier Limitations** (G25): Public information and warning is hindered by telecommunication carrier limitations
- **Warning Lexicon** (G28): Lack of consistently applied warning terminology across jurisdictions and types of disasters

Solution Considerations:

There are many available and adaptable solutions to improve geographic targeting and access to public alerting and warning technologies that are affordable with high impact for life safety (e.g., **CodeRed, Rumblr, SAVE, Hootsuite**).

Key Finding 3: Improve use of key public and private social media and internet resources and capabilities to appropriately share data and adapt existing applications to enable more efficient and effective evacuation—e.g., expand and accelerate public-private partnerships through IPAWS to include WUI incident-related evacuations, warning, and alerting.

Mission Element(s): Evacuation, Tracking, Preparedness

Associated Gaps

- **Access and Function Needs Data** (G5): AFN[2] population data are unreliable and/or dated
- **Crowdsourced Information** (G15): Non-traditional, crowdsourced information and communications (e.g., social media) are not frequently incorporated into the WUI fire common operating picture
- **Evacuation Status** (G31): Inability to track the status of evacuation routes, safety zones, evacuated buildings, and survivors
- **Public-Private Partnerships** (G32): Insufficient public-private partnerships to support evacuation efforts

Solution Considerations

There exist low-cost, available technologies that allow the real-time tracking of evacuation status through social media (e.g., **Dunami, LexisNexis Social Media Monitoring**).

[1] AFN populations may require additional assistance or resources with emergency notification, evacuation, sheltering, and transportation. WUI Fire solutions should consider impacts and effects the solution will have on the AFN community.

[2] Access and Function Needs (AFN) refers to individuals who are or have: physical, developmental, or intellectual disabilities; chronic conditions or injuries; limited English proficiency; older adults; children; low income, homeless and/or transportation disadvantaged (e.g., dependent on public transit); pregnant women.

Key Finding 4: Support broader use of existing fire modeling and forecasting tools for pre-incident planning; while also advancing efforts to create high-confidence, timely WUI fire-specific models that can be used to inform response tactics during extreme conditions.

Mission Elements: Forecasting, Preparedness

Associated Gaps

- **Pre-Incident Modeling** (G4): Lack of modeling capability for scenario-based pre-incident planning to understand fire behaviors in localities and assist in planning for major WUI incidents.
- **Fire Modeling Accuracy** (G18): Fire modeling often cannot consistently and accurately predict fire behavior
- **Fire Modeling Timeliness** (G19): Fire modeling and critical information dissemination are not timely enough to support effective decision making for emergency managers

Solution Considerations

There are developable and available technologies that incorporate modeling inputs more frequently to keep pace with WUI conditions (e.g., **WIFIRE, LANDFIRE, Intterra, CAWFE**) that are affordable.

Key Finding 5: Increase infrastructure resilience, especially critical infrastructure lifelines and support functions for wildland fire response—e.g., improve the resilience, interoperability, and reliability of communications, power utilities, digital links, and data center infrastructure.

Mission Elements: Critical Infrastructure, Responder Safety, Preparedness, Tracking

Associated Gaps:

- **Data Standards** (G6): Lack of widely-accepted interoperable data standards
- **Dispatch Centers** (G17): Public Safety Answering Point (PSAP) design and methods are not integrated with the Incident Command System (ICS)
- **Connectivity for First Responders** (G42): Lack of robust systems to ensure a common operating picture and last mile connectivity
- **Cross Discipline Integration** (G43): Lack of integration between law enforcement and emergency medical services into fire response
- **Resilient Communication** (G44): Lack of resilient communication systems (e.g., hardening cell towers)
- **Power Companies/Utilities** (G45): Inability to maintain power connectivity throughout response and access to proprietary data (e.g., affected power grid information)

Solution Considerations:

There are several medium and high-impact, yet low-cost and available technology solutions that address interoperability, resiliency and reliability of communications (e.g., **Intterra, FiResponse**).

Key Finding 6: Integrate private, open, and crowdsourced data, resources, and capabilities to improve public safety situational awareness of WUI fire ignition detection and tracking.

Mission Elements: Detection, Tracking, Critical Infrastructure

Associated Gaps:

- **Ignition Detection** (G11): Detection of WUI fire ignitions is not accurate or fast enough
- **Ignition Data Dissemination** (G12): Insufficient dissemination of ignition detection data to all response partners
- **Perimeter Tracking** (G13): Real-time perimeter tracking is often unavailable
- **Fire Characteristics** (G14): Lack of tracking data on a fire's parameters to include speed, crowning, spotting, and wind
- **Crowdsourced Information** (G15): Non-traditional, crowdsourced information and communications (e.g., social media) are not frequently incorporated into the WUI fire common operating picture
- **Power Companies/Utilities** (G44): Inability to maintain power connectivity throughout response and access proprietary data (e.g., affected power grid information)

Solution Considerations:

There exist low-cost, high-impact, available technologies that address crowdsourcing and integrating data sets (e.g., **Tanka, WIFIRE, Dunami, IRWIN, Hawkeye, ATAK, Tanka, CAWFE, LANCE**).

Key Finding 7: Support wide-scale adoption of interoperable, low-cost blue-force tracking technologies that feed near real-time situational awareness across key stakeholders, missions, and operations.

Mission Element(s): Responder Safety, Tracking, Preparedness

Associated Gaps

- **Status of Available Resources** (G4): Lack of inventory of available resources from response partners hinders operations
- **Common Operating Picture** (G16): Insufficient information sharing with all disciplines and jurisdictions to create a common operating picture
- **Position Awareness for Fire Responders** (G41): Fire services lack precise "blue-force" or GPS-enabled personnel tracking capabilities

Solution Considerations

There exist low-cost, available technologies that allow for the tracking of resources and personnel to create a common operating picture (e.g., **ATAK**).

Next Steps

The key findings listed in this report offer clear lines of effort to provide technologies to emergency responders that fulfill information requirements to inform decision-making during WUI fire incidents. The key findings have potential to lay a path forward for DHS S&T and partners to collaboratively develop resource-informed recommendations and solutions. From those resource-informed recommendations, DHS S&T and partners will develop recommended courses of action to present to the FEMA Administrator.

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I. Introduction

In December of 2017, the FEMA Administrator requested the Department of Homeland Security (DHS) Science and Technology Directorate (S&T) research new and emerging technology that could be applied to wildland fire incident response, given the loss of life that occurred in California during the fall of 2017 in Santa Rosa and Ventura.

Fires in the wildland urban interface (WUI) are a rapidly growing threat to lives and property. More than 46 million residences in 70,000 communities in the United States are at risk for WUI fires, and the WUI area continues to grow by approximately two million acres per year. In addition, over the last hundred years, some of the deadliest fires have occurred in the WUI.

Key Definition

The Wildland Urban Interface (WUI) is the area where houses and wildland vegetation meet or overlap, posing an increased risk for wildfires due to human-caused ignitions and a greater risk posed to lives and property where wildfire problems are most pronounced.

In recent years, WUI fires have resulted in extensive damage and loss of life. Of the 20 most destructive wildfires in California's history, eight occurred in either 2017 or 2018. The 2018 Camp Fire and the 2017 Tubbs Fire resulted in a combined 108 deaths and the destruction of more than 24,000 structures and 190,000 acres. The devastation caused by the 2018 fires underscored the importance of the Administrator's request and the urgent need to reduce the number of lives lost in WUI fire incidents.

WUI fires are the amalgamation where structures and human development meet with undeveloped vegetative fuels and are differentiated from structure[3] and wildland[4] fires. WUI fires create unique challenges for emergency responders. In 2016, wildfires in Tennessee's Great Smoky Mountains National Park, City of Gatlinburg, and Sevier County rapidly spread into local communities. High winds and heavy smoke hindered operational communication and limited situational awareness. The speed with which these fires grow and threaten large populations strain both resources and operational coordination and require critical decisions at the earliest stages of response. In the recent incidents with loss of life, the conflagration created by a wildland fire crossing the WUI was exacerbated by extreme weather conditions, particularly high winds.

In response to the request, DHS S&T—in collaboration with FEMA, the USFA and other key stakeholder experts—determined WUI and life-saving functions as the optimal areas to explore technology innovation. As a result, DHS S&T formed an IPT and initiated the WUI Fire Operational Requirements and Technology Capability Analysis Project. Over the course of the project, the IPT identified areas of innovation in wildland fire incident relating to wildland fire preparedness and mitigation and enhanced wildland fire suppression practices, including resistant infrastructure planning, building materials, and building codes. To meet the Administrator's request, however, the IPT focused its efforts on requirements for improving operational capabilities and incident response to save lives in WUI fires.

The project focused on understanding the essential elements of information for operational decision-making. As part of this process, the IPT examined lessons learned and reports from recent WUI fire incidents. However, this project is not intended to serve as an after-action or evaluation of recent incidents. **Figure 1** provides an overview of the WUI Fire Operational Requirements and Technology Capability Analysis Project.

[3] Structure Fire: Fire originating in and burning any part or all of any building, shelter, or other structure.
[4] Wildland Fire: Any non-structure fire, other than prescribed fire, that occurs in the wildland.

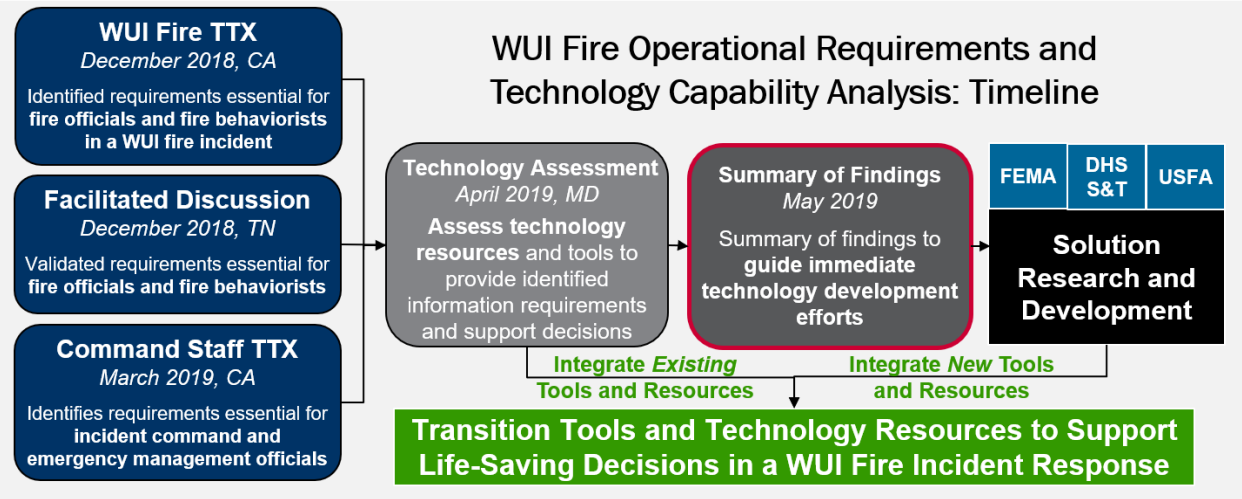


Figure 1: Objective of the WUI Fire Operational Requirements and Technology Capability Analysis Project is to understand what information is needed to support decisions that keep citizens and responders safe in a WUI fire incident.

II. Methodology

DHS S&T—in collaboration with FEMA and USFA—implemented a five-step process to assess the current state of technology capabilities to enable emergency responders to save lives during fires in the WUI. **Figure 2** below highlights this process. The following sections describe in detail each of these steps.

Figure 2: DHS S&T—in collaboration with FEMA and USFA—implemented a five-step process to recommended solutions for life-saving technology in a WUI Fire incident.

1. Define Mission Elements

The IPT conducted a literature review of relevant real-world events to identify mission elements through lessons learned and critical gaps. The literature review included recent After-Action Reports (AARs)—such as the 2017 North Bay, Southern California Fires AAR and Chimney Tops 2 Wildfire Gatlinburg AAR, academic literature, and federal reports. For more information, please refer to the **References** section. In addition to the literature review, the IPT reviewed situation reports from ongoing fires across the Nation, such as the 2018 Camp Fire, as well as media reports to identify trends, key findings, and lessons learned.

Based on the literature review and consultation with SMEs, the IPT organized information requirements into eight mission elements:

1. **Preparedness**: Information required to understand the status and maturity of all pre-ignition measures, such as public education, plans, pre-staged resources;
2. **Detection**: Information required to identify the ignition location and cause of a fire;
3. **Tracking**: Information required to assess the location, direction, and intensity of a fire in real time;
4. **Forecasting**: Information required to model and anticipate the fires future actions including movement, impacts, and spread;
5. **Public Information and Warning**: Information required to deliver emergency information, alerts, warnings, and notifications to the whole community prior to and during a fire incident;
6. **Evacuation**: Information required to enable survivors to leave or shelter in areas affected by the fire;
7. **Responder Safety**: Information required to ensure the protection of the health and safety of emergency responders; and
8. **Critical Infrastructure**: Information required to assess and stabilize human-created elements of the environment (e.g., power, water, chemicals, transportation, healthcare).

2. Elicit Requirements and Identify Gaps

Based on a review of real-world events and lessons learned, the IPT convened a series of consultative table-top exercises (TTXs) to solicit key information requirements and understand life-saving decisions during a WUI fire response. The following objectives guided each exercise:

1. Identify the essential elements of information for firefighters and fire behaviorists to effectively detect, assess, track, and model fire impacts.
2. Identify information requirements for command staff and other emergency management officials to take actions to provide prompt warning or evacuation orders to affected citizens.

3. Identify information requirements for other decision makers to take actions to save lives.

A facilitator guided structured group discussions during three consultative events:

- **WUI Fire TTX (December 5-6, 2018; Sacramento, California):** Firefighters and fire officials attended a two-day exercise, held in Sacramento, California. Participants provided an initial list of information requirements needed to inform decisions to save lives during a WUI fire. The TTX also provided participants an opportunity to highlight priority issues that firefighters face.
- **Facilitated Discussion (December 20, 2018; Sevierville, Tennessee):** Firefighters and fire officials attended a one-day structured discussion to discuss additional information requirements, validate information requirements from the California TTX, and raise pressing issues relevant to a WUI fire.
- **Command Staff TTX (March 6-7, 2019; Sacramento, California):** Emergency managers, emergency medical services, and law enforcement officers attended a two-day exercise, held in Sacramento, California. Participants provided a list of information requirements needed to inform decisions to save lives during a WUI fire. The TTX provided participants an opportunity to highlight priority issues that command staff faces.

Scenario Overview

The TTX scenario consisted of a progression of increasingly complex WUI fire impact modules. These modules elicited information requirements needed to support time-sensitive decisions that keep citizens and emergency responders safe in the immediate response to a representative WUI fire incident. The scenario incorporated a mix of elements experienced across WUI environments, including hazardous meteorological conditions, limited transportation critical infrastructure, communities with disabilities and others with access and functional needs, as well as involvement of state, local, and tribal governments. The selection of the scenario location—a representative location in Washington state—encouraged participants to consider information requirements and decisions outside of their current operating environment or jurisdiction. **Figure 3** shows a sample of information shown during each of the three modules and a map used in the scenario.

Module I. Ignition
Day 1, 1000 PST
Flames reported in areas across Chelan, Kittitas, and Okanogan Counties.

Module II. Localized Impacts
Day 1, 1100 – 1600 PST
Fire rapidly grows and pushes downhill towards city resulting in evacuation orders. Fire progresses, pushes into several neighborhoods, jumping highway, grounds small aircraft, and reducing visibility.

Module III. Multi-Jurisdiction Fire
Day 2, 0800 – 1700 PST
Spot fires have been reported across the state. The fire rapidly grows and has completely destroyed one town and threatens additional communities. Fiber-optic cables are melted and cell towers knocked out. Multiple fires across several jurisdictions threaten at-risk and AFN populations. Power outages complicate response efforts. The Governor requests a FMAG declaration.

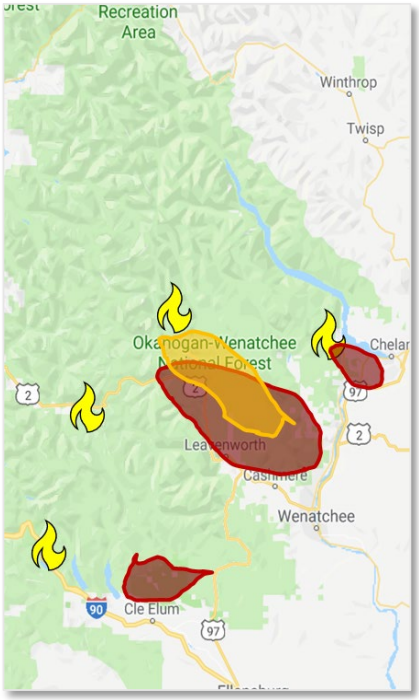


Figure 3: Escalating WUI Fire Scenario in Washington State

The IPT identified and validated information requirements through the course of the consultative TTX series and targeted follow-up engagement. Emergency responders with recent, first-hand experience fighting major WUI fires generated and validated information requirements that enable effective decisions to execute life-saving tasks, as well as pressing issues that impede emergency responders' ability to fight WUI fires.

Gap and Requirement Refinement

Based on the results of the first TTX, the IPT developed initial lists of requirements and gaps using the following definitions:

- **Requirements** – the information needed to make life-saving decisions
- **Gaps** – the delta between requirements and current capability

The IPT iteratively elaborated on these lists through the course of subsequent TTXs, targeted engagements, and follow-up literature reviews. In each subsequent TTX, the facilitator guided discussion through each mission element to elicit requirements and discuss gaps and validated the findings from previous engagements. After the third tabletop exercise, the IPT developed a near-finalized draft list of gaps and requirements.

A facilitator guided a structured group discussion with USFA SMEs to perform final validation and refinements on the gap statements and classify them based on the likely type of solutions needed to resolve the gap:

- **Capability Gap Review (March 14, 2019; Emmitsburg, Maryland):** USFA SMEs attended a one-day workshop which presented the gap statements for validation, refinement, and classification. SMEs were also encouraged to assess potential to save lives for each gap and recommend possible technology solutions.

The IPT created a database to count, track, and align the gaps, requirements, and technologies. The IPT used the database throughout the project to align solutions to gaps and requirements and perform analysis.

Table 2 shows the resulting totals of gaps and requirements identified through the course of the WUI Fire Initiative.

Table 2: Total Gaps and Requirements Identified

Outcomes	Number
Total Gaps Identified	48
Technology Gaps Identified	29
Total Requirements Identified	66
Technology Requirements Identified	40

For more information on how the requirements were applied, refer to **Section III. Complete Findings** and for a complete list of gaps and requirements refer to **Appendixes D and E** respectively. The IPT used the requirements to begin identifying and assessing candidate solutions.

3. Identify and Assess Potential Solutions

Following the complete list of identified requirements and gaps, DHS S&T conducted a technology scouting analysis. Technology scouting is a process of identifying, locating, and evaluating existing or developing technologies, products, services and emerging tools. This approach allows faster development and increases partnership opportunities and resources to assist the development of current or future WUI fire systems and needs. Once the technology scouting concluded, the IPT performed a technology assessment and requirements prioritization to determine the most critical gaps to resolve. Error! Reference source not found., on the right, shows the breakdown of gaps with and without technology solutions. There were several requirements identified that did not have a technology scouting analysis (Technology Gaps Not Assessed for Solutions), however, the IPT determined that these requirements may still be resolved with technology. The sum of the three categories exceeds the total number of gaps identified because many gaps were classified as both non-technology and technology.

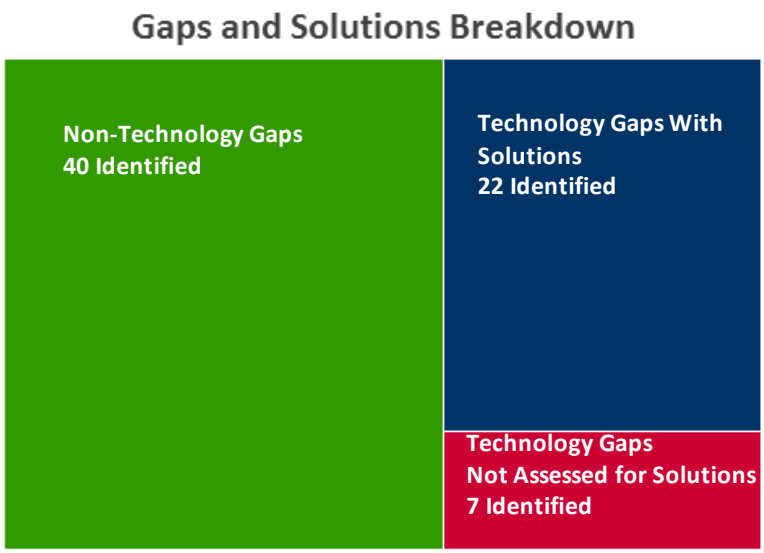


Figure 4: Tree map showing the distribution of gaps to identified solutions

The IPT assessed the Feasibility, Affordability, Usability, Alignment, and Impact of technology solutions identified through technology scouting analysis.

Feasibility

Definition: Timeliness of implementing the solution to address the particular requirement.

Scoring: Rated each solution regarding its ability to be implemented in a timely fashion.

Rating	Value	Description
Available (Commercial/ Government off-the-shelf [COTS/ GOTS] <2 years)	1	An available rating (1) means the technology is already in use and/ or deployed to a WUI use case.
Adaptable (COTS/ GOTS 2-4 years)	2	An adaptable rating (2) means the technology is deployed in an adjacent industry, would require some customization to meet the emergency responder use case. For example, risk maps and models deployed by private insurers can be adapted to develop risk levels for critical infrastructure but require further customization.
Developable (>4 years)	3	A developable rating (3) means the technology has an extremely low Technical Readiness Level (TRL) and would require significant research and development.

Affordability

Definition: Resources required to implement the solution to address the particular requirement.

Scoring: Rated each solution regarding the anticipated material, personnel, and financial resources needed to implement the solution.

Rating	Value	Value Description
Low Cost (within existing program resources)	1	A low rating (1) means the technology is inexpensive and is assigned to existing government products or solutions currently in use by major U.S. agencies. These solutions could be easily accessible with minimum cost (e.g., access existing National Weather Service satellite images).
Medium Cost (resources available through application of current funding mechanisms)	2	A medium rating (2) means the technology or solution is offered by the private sector and would have additional cost considerations and/or resource impacts.
High Cost (available through legislation or establishment of new programs)	3	A high rating (3) means the technology may have extensive development and/or implementation costs.

Usability

Definition: Degree of difficulty to incorporate the solution into current field operations in order to address the particular requirement

Scoring: Rated each solution regarding the anticipated ease or difficulty with which the technology could be adopted by emergency responders. Examples of a difficult technology include substantial training needs, security concerns, does not integrate with existing systems, etc.

Rating	Value	Description
Easy (can be picked up and used immediately)	1	A low rating (1) means the technology is intuitive and requires minimal implementation expenditure
Moderate (can be incorporated following minor implementation efforts)	2	A medium rating (2) means additional technologies, programs and/or system updates may be required; the specific technology may require organization-specific tailoring or trainings.
Difficult (requires major implementation efforts to integrate)	3	A high rating (3) means numerous technologies, programs and/or system updates may be required for integration. The technology will need to satisfy a significant use case with many dependencies.

Impact

Definition: Potential to save lives if the solution is implemented to address the particular requirement.

Scoring: Rated each solution regarding the anticipated impact it would have if the solution was implemented.

Rating	Value	Description
Low (incremental effect on decreasing lives lost)	3	A low rating (3) indicates a solution that, if implemented, would have a secondary relationship to saving lives during an incident (e.g., smoke modeling or risk maps).
Medium (continuous evolutionary effect on decreasing lives lost)	2	A medium rating (2) indicates a solution that, if implemented, would have a direct relationship to saving lives during an incident (e.g., wind modeling).
High (transformational capability that will significantly decrease lives lost)	1	A high rating (1) indicates a solution that, if implemented, would proactively reduce mass loss of life (e.g., mitigate large fires or effectively alert the public to seek safety).

Note: the values for ***Impact*** scale in opposite direction compared to the other criteria (i.e., High is the ideal rating, whereas in the other criteria Low is the ideal rating).

Alignment

Definition: Alignment to multiple requirements.

Scoring: Rated each solution regarding the ability to address multiple requirements in order to determine efficiencies in certain solutions. The technology that addressed the highest number of requirements was given the best value (1); technologies that addressed only one requirement were given the worst value (3); all technologies in between were assigned a rating proportional to the number of requirements addressed.

4. Analyze and Prioritize Solutions

DHS S&T Technology Scouting assigned an initial value for each technology solution across the five assessment criteria. This initial scoring was designed to serve only as a placeholder until experts could assign more accurate values. At the Technology Assessment TTX (April 18, 2019, Emmitsburg, Maryland), WUI subject matter experts attended a one-day technology assessment to validate findings, adjust scores, suggest alternative technology solutions, and establish weights. Following the Technology Assessment TTX, each solution identified by the technology scouting effort and each new solution proposed throughout the process was assigned a score for each first four criteria—Feasibility, Affordability, Usability, and Impact—and the Technology Alignment value was calculated.

Establishing Relative Criteria Weights

In order to assess the relative importance of the five assessment criteria, DHS S&T had the fire technology SMEs perform a series pairwise comparisons. The nine comparisons prompted the SMEs to determine which of two criteria was more important and the degree to which they differed. **Figure 5** below shows an example of one such pairwise comparison.

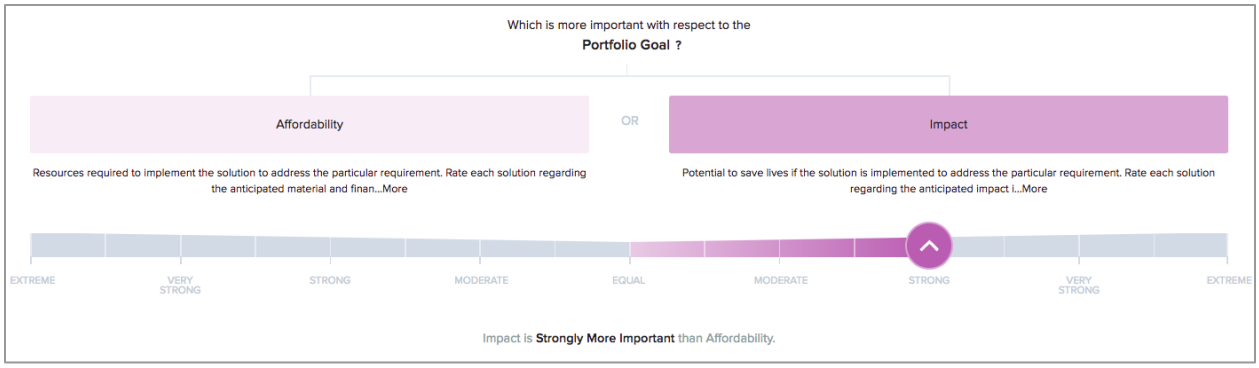


Figure 5: Example Pairwise Comparison Performed by Technology Assessment Participants

Table 3, below, shows the results of the pairwise comparisons. SMEs determined impact was the most important criteria by a substantial margin; nearly equaling the combined weights of the other four. Feasibility was the second most important, with agreement that it should be given greater weight than the remaining three criteria, but not to same extent as Impact. Finally, Technology Alignment, Usability, and Affordability were given somewhat equal ratings at roughly 10 percent

Table 3: Final Weights Based on the Pairwise Comparison

Criteria	Final Weight
Impact	47.91%
Feasibility	20.58%
Technology Alignment	12.1%
Usability	9.98%
Affordability	9.44%

Scoring Algorithm

DHS S&T developed a scoring algorithm to evaluate technology solutions and then defined how those scores can be used to assess associated requirements and gaps. Below is a description for how each score is determined and its meaning.

Technology Score – A solution's technology score is found by multiplying the value of each assessment criteria (e.g., Impact is Medium, therefore the value is two) by the criteria weight (Impact's weight is 47.91%). The sum of the five weighted criteria scores is the technology score.

The technology score is an indicator of the overall value of that technology as a solution using the five assessment criteria.

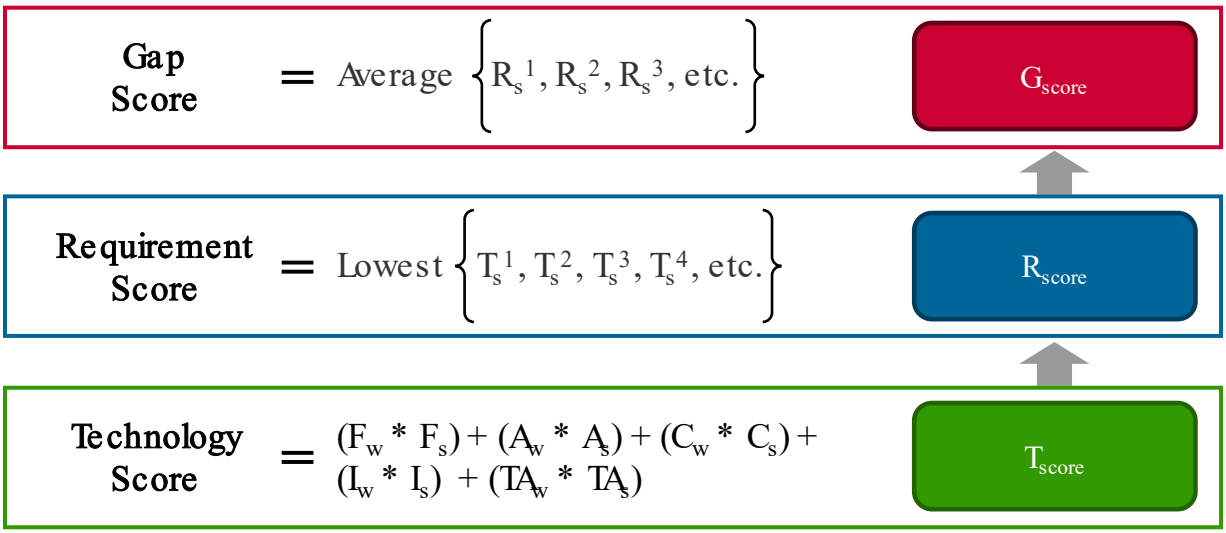
Requirement Score – A requirement score is found by selecting the lowest technology score which addresses that requirement. For example, if a requirement has two technologies with scores of five and eight; five would become the requirement score.

The requirement score is an indicator of the degree to which assessed technologies can fulfill the requirement.

Gap Score – A gap score is found by averaging the requirement scores of all available requirements.

A gap score is an approximate indicator to the degree to which assessed technologies can address the gap.

Figure 6, below, shows the equation for each of the three scores.



F = Feasibility A = Affordability C = Complexity I = Impact TA = Technology Alignment
w = weight s = score T = Technology R = Requirement

Figure 6: Analysis and Prioritization Algorithm

DHS S&T used the gap, requirement and technology scores to inform the following prioritization.

Prioritization Results

The following five tables show the results of the prioritization. Each table demonstrates the top solutions using different criteria. Criteria includes overall technology score, number of requirements addressed by the technology solution, requirements score, gap score, and average scores across all applicable criteria. All highest-ranked gaps and requirements are represented in the key findings. For a full list of all gaps, requirements, and technologies, refer to **Appendices D, E, and F**, respectively.

Table 4 shows the highest-scored solutions using the technology score equation.

Table 4: Top 10 Unique Solutions

Rank	Solution Name	Value Score[5]	Requirement Addressed[6]
1	WIFIRE	5	R17
2	Android Team Awareness Kit (ATAK)	5.4	R25
3	FASMEE	5.7	R27
4	Team Connect	6	R25
5	Fire Family Plus	6.2	R29
6	LANDFIRE (LF) Data Distribution	6.2	R29
7	WAZE	6.2	R46
8	Hawkeye	6.3	R15
9	CO-FPS	6.6	R28
10	Pathfinder	6.6	R52

Table 5 shows the top ten solutions based on how many requirements that solution addresses.

Table 5: Top 10 Solutions in Terms of Requirements Addressed

Rank	Solution Name	Number of Requirements Addressed	Requirements Addressed[7]
1	WIFIRE	7	R17, R21, R27, R28, R30, R58, R59
2	Intterra	5	R25, R57, R27, R41, R58
3	Android Team Awareness Kit (ATAK)	5	R9, R56, R16, R21, R24
4	Coupled Atmospheric-Wildland Fire Environment (CAWFE)	4	R17, R28, R30, R59
5	Land, Atmosphere Near Real-time Capability for EOS (LANCE)	4	R22, R17, R30, R59
6	Dunami	3	R18, R24, R54

[5] Scores range from 5 to 15. The best possible score is 5.
[6] Refers to the requirement addressed in which it receives the highest score. Many solutions address additional requirements beyond what is listed in this table. See below for more information.
[7] These requirement index numbers can be matched with the requirements in Section III. See Complete Findings or Appendix F. Requirements Index for the complete description.

Rank	Solution Name	Number of Requirements Addressed	Requirements Addressed[7]
7	LexisNexis Social Media Monitoring	3	R18, R24, R54
8	Integrated Reporting of Wildland-Fire Information (IRWIN)	3	R19, R41, R25
9	Hawkeye	3	R19, R15, R21
10	WFRAS (Wildland Fire Risk Assessment System)	2	R7, R12

Table 6 shows the ten highest-ranked requirements based on the requirement score.

Table 6: Top 10 Requirements

Rank	Requirement Number	Title	Highest Value Solution
1	R17	Need integrated data for baseline risk factors (e.g., weather, fuel, topography, fire history) with real-time updates	WIFIRE
2	R9	Need a catalog of local, state, and federal WUI firefighting resources	Android Team Awareness Kit (ATAK)
3	R16	Need widespread, automatic dissemination of detection data	Android Team Awareness Kit (ATAK)
4	R24	Need to exploit all source information to inform WUI Fire tracking	Android Team Awareness Kit (ATAK)
5	R56	Need "blue-force tracking" for emergency responders in a WUI incident —including location with verified time of arrival	Android Team Awareness Kit (ATAK)
6	R21	Need real-time and continuously updated tracking of fire perimeter	WIFIRE
7	R58	Need timely information to allow for en route incident briefing and planning	WIFIRE
8	R59	Need continuous hazard assessment that is distributed to emergency responders in the field	WIFIRE
9	R27	Need WUI Fire modeling that generates actionable and reliable data outputs	FASMEE
10	R25	Need inter-agency and inter-jurisdictional emergency responder data integration	Team Connect

Table 7 shows the ten highest-ranked gaps based on gap score.

Table 7: Top 10 Gaps

Rank	Gap Number	Topic	Associated Requirements	Mission Element
1	G15	Crowdsourced Information	R24	Tracking
2	G3	Status of Available Resources	R9	Preparedness
3	G41	Positional Awareness for Emergency Responders	R56, R59	Responder Safety
4	G43	Cross Discipline Integration	R58	Responder Safety
5	G16	Common Operating Picture	R16	Tracking
6	G31	Evacuation Status	R31	Evacuation
7	G18	Fire Modeling Accuracy	R27, R30	Forecasting
8	G12	Ignition Data Dissemination	R16, R19, R20	Detection
9	G32	Public-Private Partnerships	R46	Evacuation
10	G19	Fire Modeling Timeliness	R28, R29	Forecasting

Table 8 shows the average technology scores.

Table 8: Average Technology Score by Mission Element

Mission Element	Number of Requirements	Number of Solutions Assessed	Average Technology Score
Preparedness	14	7	8
Detection	6	12	8
Tracking	6	16	6
Forecasting	4	12	7.6
Public Information and Warning	13	15	8.7
Evacuation	12	8	7.8
Responder Safety	4	9	7
Critical Infrastructure	7	N/A	N/A

5. Develop Key Findings to Inform Next Steps

Based on solution prioritization, TTX participant input, and subject matter gap prioritization, DHS S&T and its partners aggregated multiple gaps into key findings, as demonstrated in **Figure 7**. First, participants at the TTXs were asked to identify the top issues they faced, or will face, with WUI fires. The responses were tallied and ranked to provide a local and state perspective to key findings. During the Capability Gap Review, USFA stakeholders determined gaps with the highest impact to provide a national perspective on WUI fires. Finally, technology solutions were prioritized based on Feasibility, Affordability, Usability, Impact, and Alignment. This technology solution prioritization was then used to rank gaps based on the algorithm in Step 4 of the methodology. The three aggregated efforts, accounting for the themes from the overarching takeaways, were then used to develop key findings.

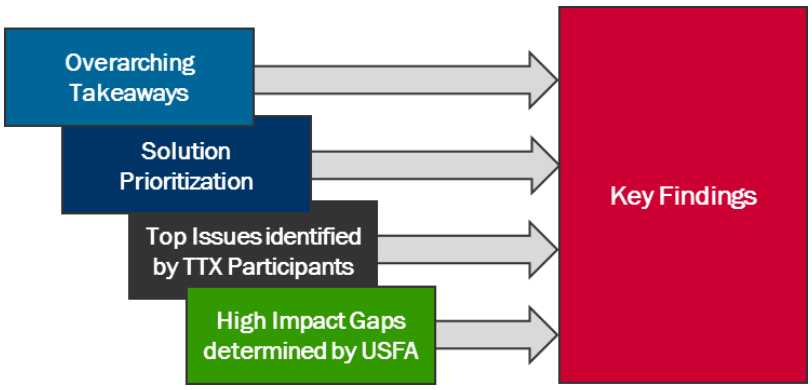


Figure 7: Key Findings Inputs

Key findings represent lines of effort that, if implemented, have the potential to save a significant number of lives in future WUI fire incidents through employed technology into the fire communities

plans, policies, procedures, training and doctrine. Key findings focus on available and adaptable technology solutions,that require minimal changes or development into existing standard operating procedures.

Figure 8 demonstrates the relationship between solutions, requirements, gaps, and key findings. At the bottom of the matrix, solutions are comprised of technology and non-technology identified solutions to WUI fire requirements. Some requirements may have many solutions, while others only have one or two. Requirements address gaps that were identified by TTX participants and those experience with WUI fires in the field. Gaps may be made up of several requirements. Key findings are at the top of the matrix, encompass gaps, requirements, and solutions identified in the respective tier.

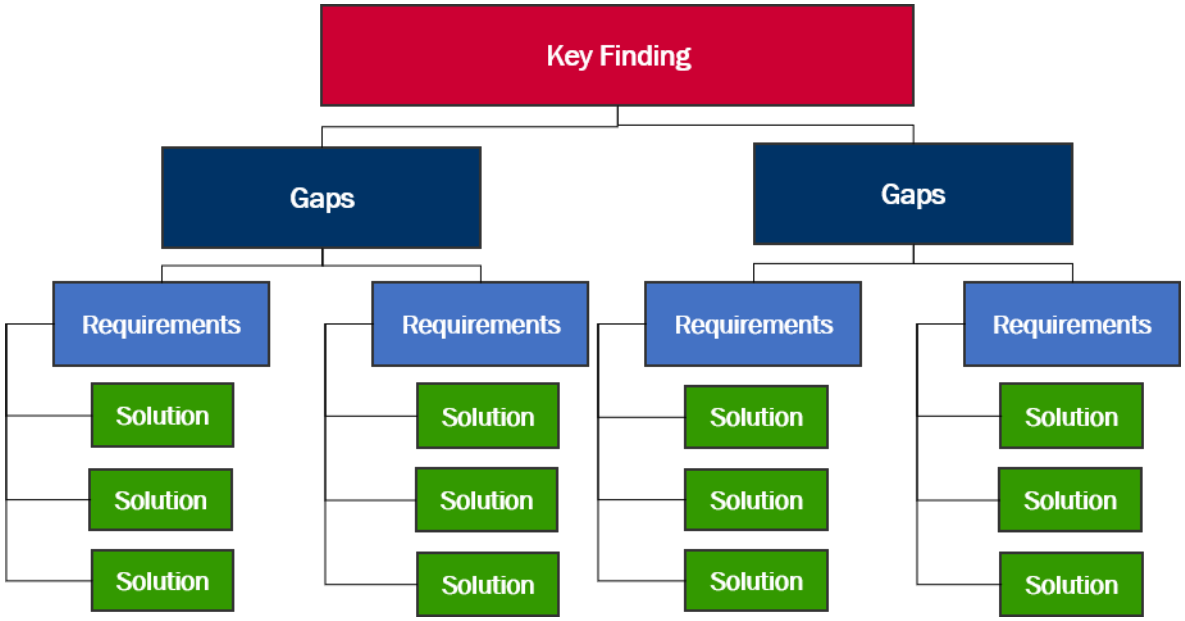


Figure 8: Relationship between Key Findings, Gaps, Requirements, and Solutions

6. Next Steps

The requirements methodology and findings will be socialized with the broader fire and emergency response communities. This process has already begun at workshops such as the interagency Federal Fire Working Group and the Smart Firefighter International Conference.

Following receipt of this report, FEMA, USFA, and DHS S&T leadership will work collaboratively to use the identified key findings to develop resource-informed courses of action to the present to the Administrator.

Once an agreed upon approach is selected, DHS S&T will work with FEMA and USFA project sponsors using its matrixed organization and operating model. **Figure 9** demonstrates the DHS S&T Operating Model which will drive DHS S&T support to selected WUI courses of action. DHS S&T stands ready to support FEMA and USFA through the acquisition lifecycle with technology requirement development, operational experimentation, testing and evaluating, solution development and adaptation, solution execution and assessment, and solution delivery.

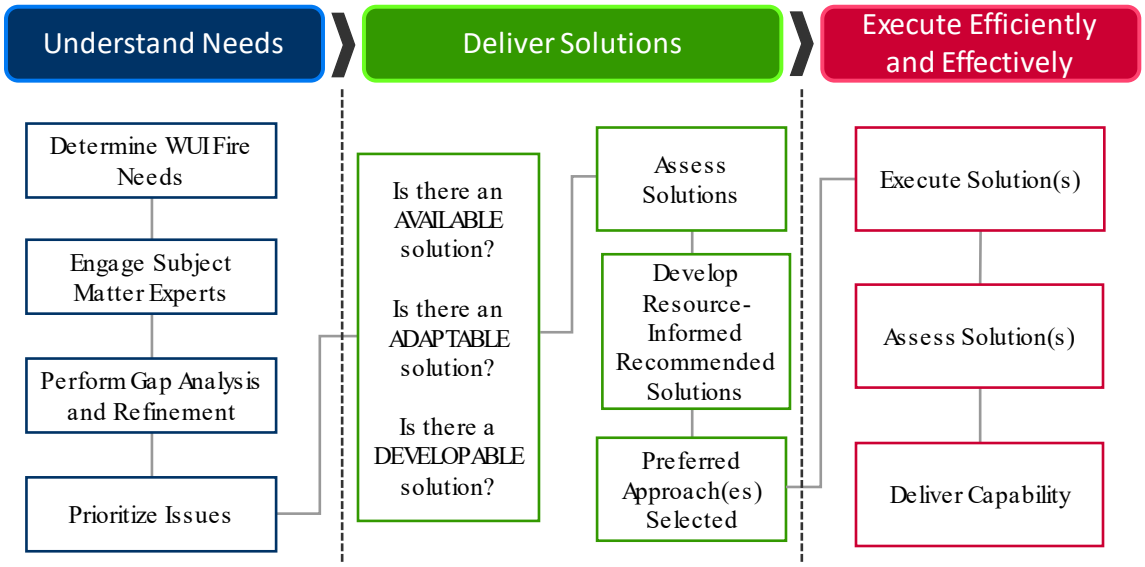


Figure 9: DHS S&T Operating Model Applied to the WUI Fire Operational Requirements and Technology Capability Analysis Project

III. Complete Findings

The following section provides the full list of gaps, requirements and an assessment of solutions that the IPT identified during the WUI Fire Operational Requirements and Technology Capability Analysis Project. The purpose of this section is to provide a complete record of all major issues uncovered throughout the project. Each of the issues in this section, whether technology related or not, could possibly be addressed to impact life-saving operations during WUI fire incidents.

Each finding is organized by mission element according to the following structure:

Title: A shortened version of the gap for ease of reference
Gap: States the problem that needs to be addressed; a gap is the delta between requirements and current capability;
Requirements: Identifies the necessary aspects of the solution to fully address the gap;
Description: Provides additional context, explanation, and justification for the gap statement to include specific examples heard from TTX participants;
Current Capability: Notes the existing abilities of the fire community as it relates to the gap; and
Technology Solution Assessment: Offers context on candidate solutions based initial technology assessment.

Furthermore, each finding is organized by whether they have technology solutions or not. All findings with potential technology solutions appear first within each mission element, even if no candidate solutions were identified. All findings that the IPT assessed have no technology solutions are listed second.

The Fire Community

In this report, the "fire community" is used as an all-encompassing term that refers to all components and disciplines which respond to a fire incident including firefighters, emergency management personnel, emergency medical service, and law enforcement.

The findings in this section are distinct from the key findings in this report's front matter. Each finding contains only one gap, the associated requirements, current capabilities and solution assessments. Key findings represent lines of effort that span multiple gaps and fulfill numerous requirements.

Preparedness

The WUI Fire Operational Requirements and Technology Capability Analysis Project defines preparedness as information required to understand the status and maturity of all pre-ignition measures, such as public education, plans, pre-staged resources. This section provides a list of gaps and recommended solutions categorized into the preparedness mission elements. **Table 9** below provides a summary of preparedness mission element findings.

Table 9: Summary of Preparedness Findings

Gap Title	Specific Gap	Index Number	Identified Solutions?
Technology (May Include Non-Technology Considerations)			
Physical Fire Mitigation	Lack of mitigation efforts for WUI fire-specific risks including defensible space, building codes, and fuel mapping/ testing.	G1	Yes
Critical Infrastructure Location Planning	Insufficient location planning for critical infrastructure to account for WUI fire threat (e.g., cell towers and emergency operations centers).	G2	Yes

Gap Title	Specific Gap	Index Number	Identified Solutions?
Status of Available Resources	Lack of inventory of available resources from response partners hinders life-saving efforts.	G3	Yes
Pre-Incident Modeling	Lack of pre-incident, scenario-based modeling to understand risks and hazards and provide off-the-shelf products during major WUI incidents.	G4	No
Access and Functional Needs Data	Individuals with disabilities and others with access and functional Needs (AFN) population data are frequently unreliable and/or dated.	G5	No
Non-Technology			
Data Standards	Lack of widely-accepted data standards hinder effective operations.	G6	
Public Education	Public information programs have insufficiently educated the whole community.	G7	
WUI Fire Doctrine	WUI fire threat and challenges have been insufficiently addressed in doctrine, policy, and training.	G8	
Coordinated Regional Plans	Current plans are insufficiently integrated with nearby jurisdictions and interagency response partner plans.	G9	
Common Lexicon	WUI fire terminology and concepts are not sufficiently understood by response partners and the public.	G10	

Technology Findings

1	Physical Fire Mitigation

Gap: Lack of mitigation efforts for WUI fire-specific risks including defensible space, building codes, and fuel mapping/testing

Description: Best practices of fire mitigation efforts for communities in a WUI area include the following: 1) Defensible space—a buffer zone between a building and fuel (grass, trees, leaves, etc.) that helps decrease the risk that a home will ignite as well as assist firefighters who are protecting the structure. 2). Building and maintenance codes to include an ignition resistant exterior, noncombustible decking and stairs, and tile or metal roofing; and 3). Fuel mapping and condition testing to ensure fire behaviorists understand the location of high-risk areas due to the type and extent of fuel in the area.

Current Capability: The fire community understands the importance of physical fire mitigation, but it is not fully implemented – often due to reasons out of their control (i.e. politics)

Requirements:

- R5 – Need mitigation measures (status of building and maintenance codes, other forms of hardening, and defensible/green space)
- R12 – Need to track highest-risk WUI areas based on fire, weather history, and fuel type (live and dead) and current conditions.

Technology Solution Assessment:

WUI fire models cannot identify precise highest-risk WUI areas, however they are able to identify broad areas where defensible space would be particularly beneficial. More accurate and exact locations would allow for the physical fire mitigation to mirror the level of risk.

Best Assessed Candidate Solution(s)					
R12.	**WFRAS (Wildland Fire Risk Assessment)**				
Description	WFRAS is a robust suite of wildfire risk assessment methods and software tools. WFRAS has been deployed at regional and local planning departments, providing a repeatable, consistent, and comparable approach for assessing current wildfire risk. WFRAS also includes tools to quantify the risk to areas of concern, such as communities in the WUI. It produces threat assessment maps by combining historical fire ignitions, weather observations, surface fuels, canopy characteristics, and other input data with robust fire science. In addition, by integrating census and assessor data, WFRAS can quantify potential impacts of fires, including estimates for economic and social impacts such as the dollar value of exposed structures, commodity agriculture, plantations, etc.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Medium	Medium	Low	2

2	Critical infrastructure Location Planning
Gap: Insufficient location planning for critical infrastructure to account for WUI fire threat (e.g., cell towers and emergency operations centers)	
Description: Participants reported radio and cell towers are often placed on top of mountains to receive the best service, however because of their location, they often melt or stop working because of a WUI fire. This hinders emergency responder's ability to communicate with one another, as well as the public's ability to receive warning message via cellphones. Emergency operation centers (EOC) have sustained fire damage in previous WUI fires. One participant noted their EOC used to reside at the foothill of a mountain and has since been relocated deeper into the city to avoid fire damage. ***Current Capability:*** Infrastructure that is critical to response (e.g., cell towers and radio towers) are often situated in hazardous locations which makes them susceptible to damage from a WUI fire.	***Requirements:*** ▪ R7 – Need to identify risk to and from critical infrastructure and plan accordingly (e.g. site communications appropriately)
Technology Solution Assessment: Models exist that can identify a broad area of risk, however critical infrastructures remain, and continue to be built, in these areas. More accurate models would allow for infrastructures to be prioritized for relocation and/or hardening. Best Assessed Candidate Solution(s)	

R7.	Dispatchr				
Description	Dispatchr is a software platform that leverages big data and AI to prevent disasters for the leading utility providers. They specialize in preventing both wildfires and power outages caused by extreme weather or equipment failure. They've worked with utility providers in the past to cover a 70,000 square mile area to prevent over a dozen wildfires and other power outages, that would have left millions without power. Their fire management program includes a database of all utility equipment, easy dispatching to potential fire events and real-time utility crew location tracking.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Medium	Low	Low	1

3	Status of Available Resources

Gap: Lack of inventory of available resources from response partners hinders live-saving efforts.

Description: Participants reported it would be beneficial to have an up-to-date inventory of all available resources in one repository. Because WUI fires often require partnerships with multiple agencies and jurisdiction, ensuring everyone knows what tools are available to them would greatly aid the process and decrease the chance of delays.

Current Capability: Local, state, and federal government; NGO; and private entities all have resources that would aid in a WUI fire, but response leadership is not always aware that they are available, particularly during severe and fast-paced incidents.

Requirements:

- R9 – Need a catalog of local, state, and federal WUI firefighting resources

Technology Solution Assessment:

Technologies exist to ensure multiple different agencies and jurisdictions are able to share data and maintain situational awareness, however integrating the necessary technologies to create a database used among local, state, and federal WUI firefighters to provide an up-to-date inventory of available resources needs more attention to become useable and widespread.

R9.	Android Team Awareness Kit (ATAK)
Description	ATAK is a government-off-the-shelf situational awareness app for Android smartphones. The app uses GPS and maps to give the user a real-time view of the area of operations. The capability includes "Blue-Force Tracking" to see where team members are (which helps with coordinating movements), as well as terrain, weather, and other topographical elements. Additionally, the app enables multiple types of encrypted data communication such as text and file sharing (including photos and video). These communications can be set for user-to-user, user-to-select teams, user-to-command post or user-to-entire force (even if they are from different agencies).

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	5

4	Pre-Incident Modeling
Gap: Lack of modeling capability for scenario-based pre-incident planning to understand fire behaviors in localities and assist in planning for major WUI incidents.	
Description: Participants indicated a pressing need for accurate modeling of fire behavior in WUI conditions. However, subject matter experts in fire behavior stated that current fire models do not account for extreme wind and weather conditions nor structure fires and may not produce accurate results (see Finding 17: Fire Modeling Accuracy). Participants indicated that the proper use for current fire models was to assess the most likely fire behavior in a given locality in WUI fire conditions in a planning capacity prior to any incidents. ***Current Capability:*** There are a number of fire models used for risk assessment. There is no standard usage or methodology, nor are these models validated for WUI planning.	***Requirements:*** ▪ R – 14 Need fire behavior modeling to ensure sufficient scenario-based pre-incident planning

5	Access and Functional Needs Data
Gap: Individuals with disabilities and others with access and functional needs (AFN) population data are frequently unreliable and/or dated.	
Description: Participants reported that there are no reliable systems that track data on the AFN population such as their requirements, their location, and other important information. This data are vital for emergency responders who need to assess, locate, and support the AFN population in a WUI fire. ***Current Capability:*** The fire community is becoming more aware of the extra attention needed for the AFN population, but there are no common systems that track AFN population data, such as their communication and medical needs, and mobility requirements or location.	***Requirements:*** ▪ R4 – Need the location of at-risk communities (including AFN population) in relation to highest risk areas and need planned and resourced procedures for each community

Non-Technology Findings

6	Data Standards
Gap: Lack of widely-accepted data standards hinder effective operations.	
Description: Participants reported difficulty sending and receiving data to other agencies and jurisdictions due to differences in communication system format. If a fire starts in one jurisdiction but moves into another and their systems are not interoperable, the handoff can be unnecessarily difficult (e.g. GPS coordinates format). ***Current Capability:*** Agencies have important data, but it is difficult to send and receive data to other agencies and jurisdictions due to differences in communication system formats.	***Requirements:*** ▪ R1 – Need widely-accepted interoperable data standards

7	Public Education
Gap: Public information programs have insufficiently educated the whole community.	
Description: Current public education programs (e.g., Ready, Set, Go) have not resulted in marked changes in behavior and have not effectively integrated with similar programs for other types of disasters. ***Current Capability:*** The fire community strives to educate the public, but current programs have not resulted in substantial changes in behavior and have not effectively integrated with similar programs for other types of disasters.	***Requirements:*** ▪ R2 – Need pre-incident public education, including understanding of actions associated with notifications and warnings ▪ R10 – Need the public to have more realistic expectations for protection in high-risk areas

8	WUI Fire Doctrine
Gap: WUI fire threat and challenges have been insufficiently addressed in doctrine, policy, and training.	
Description: Participants reported the fire community has not sufficiently adapted to threats associated with WUI fires. Meanwhile, the frequency and breadth of WUI fires has steadily increased with no sign of the threat reducing. For example, emergency responders highlighted that current wildland firefighting doctrine of morning briefings is insufficient for the information needs for fighting WUI fires; emergency responders need more frequent briefings to match the volatility of WUI fires	***Requirements:*** ▪ R3 – Need pre-incident fire community preparedness (e.g., emergency responder knowledge of local risk factors and training and exercising)

Current Capability: The fire community is becoming more aware of the WUI fire threat, but they have not sufficiently adapted to the rapid pace, shifting conditions, and high potential for loss of life associated with extreme WUI fires.	▪ R11 – Need pre-incident formalized communications between firefighters and the public to ensure public preparedness.

9	Coordinated Regional Plans
Gap: Current plans are insufficiently integrated with nearby jurisdictions and interagency response partner plans	
Description: Participants reported instances of neighboring regions evacuating into each other, having failed to communicate or exercise plans. AFN facilities, including hospitals, prove successful at evacuating people from the building, but struggle to evacuate out of the danger zone as existing transportation services are either unable to meet evacuation needs or are working to evacuate other facilities. ***Current Capability:*** Jurisdictions have plans in case of emergency, but neighboring counties, cities, and towns do not always communicate plans with one another, leading to evacuation into each other or insufficient resources (i.e. transport vehicles for AFN).	***Requirements:*** ▪ R6 – Need multi-jurisdictional and interagency integration (i.e. regional planning and pre-identified evacuation routes) ▪ R13 – Need pre-established relationships with partners so that information is automatically disseminated during an incident

10	Common Lexicon
Gap: WUI fire terminology and concepts are not sufficiently understood by response partners and the public	
Description: Participants reported a two-pronged problem with lexicon. Command staff does not always understand terms used by firefighters (e.g., “crowing” and “rollouts.”) which requires interpretation and creates subsequent delays and/ or confusion. The public does not always understand the terms either, or they vary amongst jurisdictions, potentially leading to overestimating or underestimating the threat a WUI fire poses to them. ***Current Capability:*** A growing knowledge of WUI fires necessitates a new lexicon, but command staff, various disciplines, and the public do not always understand terms used by firefighters.	***Requirements:*** ▪ R8 – Need commonly understood terminology and concepts for response partners and public

Detection

The WUI Fire Operational Requirements and Technology Capability Analysis Project defines detection as information required to identify the ignition location and cause of a fire. This section provides a list of gaps and recommended solutions categorized into the detection mission elements. **Table 10** below provides a summary of detection mission element findings.

Table 10: Summary of Detection Findings

Gap Title	Specific Gap	Index Number	Identified Solutions?
Technology (May Include Non-Technology Considerations)			
Ignition Detection	Detection of WUI fire ignitions is not accurate or fast enough.	G11	Yes
Ignition Data Dissemination	Insufficient dissemination of ignition detection data to all response partners.	G12	Yes

Technology Findings

11	Ignition Detection
Gap: Detection of WUI fire ignitions is not accurate or fast enough.	
Description: Participants from Tennessee and Northern California reported that the sooner they can detect an ignition, the sooner they can adopt appropriate mitigation and response actions for the fire. If an ignition is detected immediately, it can be extinguished with little expended resources or loss of life. Emergency responders with crowdsourced detection systems—such as high population areas in Southern California—worry less about hastening ignition detection. ***Current Capability:*** The fire community tries to detect ignitions as fast as possible, but current capabilities lack the speed and accuracy to detect and quickly extinguish a fire, especially in more rural areas.	***Requirements:*** ▪ R15 – Need real-time and continuous identification of heat sources and smoke to detect ignition location ▪ R17 – Need integrated data for baseline risk factors (e.g., weather, fuel, topography, fire history) with real-time updates ▪ R18 – Need to exploit all source information (e.g., social media) for ignition detection
Technology Solution Assessment: Existing Commercial/Government off-the-shelf (COTS/GOTS) satellite imagery generally cannot provide the necessary high-resolution data to deliver precise locations for WUI fire ignitions. Ground-based detection systems generally are able to more quickly detect ignitions but are more expensive. Classified assets are operational and detect thermal anomalies with latitude, longitude, date, time, and degree of confidence. Technology solutions offering near real-time ignition detection are not good enough for WUI fires. The breadth of social media for crowdsourcing ignition detection is underutilized and could be used when evaluating false-positive thermal abnormalities.	

Best Assessed Candidate Solution(s)					
R15.	**Hawkeye**				
Description	The Hawkeye Fire Detection and Reporting System is a program using airborne and spaceborne remote sensing assets to rapidly detect and report new fire starts within the continental United States. Detected fire starts are relayed to the Ignition Point Database (IgPoint) operated and managed by the Forest Service. The format is simple: Latitude/ Longitude, date/ time, level of confidence (low, moderate and high). Once the alert arrives in the IgPoint Database, anomaly detections are queried and retrieved to the appropriate response authority (e.g., The Enterprise Geospatial Portal or EGP). Local dispatch offices using the EGP view newly reported detections within a few minutes of reporting and allow the local authorities to determine the appropriate response based on local conditions – weather, fuel conditions, and proximity to assets at risk.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Medium	High	3
R17.	**WIFIRE**				
Description	The WIFIRE Firemap merges a robust array of sensor data with computational techniques like signal processing, data assimilation, modeling, and visualization to monitor environmental conditions and predict where and how fast a wildfire will spread. The Firemap enables analysis of various fire scenarios and the development of real-time forecasts by leveraging the UCSD Supercomputer Center.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	7
R18.	**LexisNexis Social Media Monitoring**				
Description	LexisNexis offers a Social Analytics product built for law enforcement to provide situational awareness before, during, and after emergency situations. While the system traditionally uses social media data to locate suspects, discover criminal activity, and prevent crime; it could also be applied to enhance situational awareness. The product monitors feeds from more than 10 social media networks, in 187 languages.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Medium	Low	Low	3

12	Ignition Data Dissemination

Gap: Insufficient dissemination of ignition detection data to all response partners.

Description: Participants reported the need to automatically receive relevant ignition data from all responding agencies and jurisdictions. Currently, many agencies and jurisdiction need to separately request the data which causes unnecessary delays. Many agencies are not aware of this data.

Current Capability: Due to the multi-jurisdictional nature of WUI fires, often multiple agencies respond to an event, but many agencies and jurisdictions are unaware of ignitions in adjacent areas. Agencies currently need to separately request ignition data instead of it automatically being distributed.

Requirements:

- R16 – Need widespread, automatic dissemination of detection data
- R19 – Need to deconflict and process ignition data into actionable information
- R20 – Need standardized format for ignitions that can be easily distributed and understood by emergency responders

Technology Solution Assessment:

Ignition detection technologies work best when multiple sensor systems can validate and confirm findings. However, there are challenges with integrating ignition detection data to compare, due to divergent efforts going on nationally. The lack of knowledge and/or experience with database systems and applications from other national and state agencies leads to insufficient information sharing and data dissemination of ignition detection data. There are common operating picture tools that require connectivity to function, but can disseminate data successfully across platforms, database systems, and application.

Best Assessed Candidate Solution(s)

R16.	Android Team Awareness Kit (ATAK)
Description	ATAK is a government-off-the-shelf situational awareness app for Android smartphones. The app uses GPS and maps to give the user a real-time view of the area of operations. The capability includes "Blue-Force Tracking" to see where team members are (which helps with coordinating movements), as well as terrain, weather, and other topographical elements. Additionally, the app enables multiple types of encrypted data communication such as text and file sharing (including photos and video). These communications can be set for user-to-user, user-to-select teams, user-to-command post or user-to-entire force (even if they are from different agencies).

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	5

R19.	Integrated Reporting of Wildland-Fire Information (IRWIN)				
Description	IRWIN is a Wildland Fire Information and Technology (WFIT) affiliated investment, intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage wildland fire incident data. IRWIN is focused on reducing redundant data entry, identifying authoritative Inputs, and improving the consistency, accuracy, and availability of operational data.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Medium	Medium	High	3

Tracking

The WUI Fire Operational Requirements and Technology Capability Analysis Project defines tracking as information required to assess the location, direction, and intensity of a fire in real time. This section provides a list of gaps and recommended solutions categorized into the tracking mission elements. **Table 11** below provides a summary of tracking mission element findings.

Table 11: Summary of Tracking Findings

Gap Title	Specific Gap	Index Number	Identified Solutions?
Technology (May Include Non-Technology Considerations)			
Perimeter Tracking	Real-time perimeter tracking is often unavailable.	G13	Yes
Fire Characteristics	Lack of tracking data on a fire's parameters to include speed, crowning, spotting, and wind.	G14	Yes
Crowdsourced Information	Non-traditional, crowdsourced information and communications (e.g., social media) are not frequently incorporated into the WUI fire common operating picture.	G15	Yes
Common Operating Picture	Insufficient information sharing with all disciplines and jurisdictions to create a common operating picture.	G16	Yes
Dispatch Centers	Public Safety Answering Point (PSAP) design and methods are not integrated with ICS.	G17	No

Technology Findings

13	Perimeter Tracking
Gap: Real-time perimeter tracking is often unavailable.	
Description: Participants reported real-time perimeter tracking would greatly aid in maintaining situational awareness, improving decision making about priorities (e.g., life, property, wildland protection), and allocating resources. Current systems are too infrequent, such as ad hoc drone flyovers, or too inaccurate, such as 911 calls. ***Current Capability:*** The fire community has many tools to track the perimeter of a fire, including drone or fixed wing flyovers, but current systems are not frequent or accurate enough to relay the real-time fire perimeter. Current capabilities may not penetrate through smoke cover, giving an inaccurate picture of the WUI fire perimeter.	***Requirements:*** ▪ R21 – Need real-time and continuously updated tracking of fire perimeter ▪ R26 – Need tracking capabilities able to penetrate smoke cover and other WUI fire conditions
Technology Solution Assessment: Perimeter tracking technologies can be adapted to include classified source detection information into existing platforms that combine data from multiple sources. Advancements in plume modeling in similar disciplines (e.g., hazmat management tools) may be incorporated into WUI Fire modeling and perimeter tracking technologies. Further exploration of when to deploy manned planes, high-	

altitude unmanned aerial vehicles (UAVs), and commercial low-altitude UAVs for perimeter tracking

Best Assessed Candidate Solution(s)

R21.	**WIFIRE**				
Description	The WIFIRE Firemap merges a robust array of sensor data with computational techniques like signal processing, data assimilation, modeling, and visualization to monitor environmental conditions and predict where and how fast a wildfire will spread. The Firemap enables analysis of various fire scenarios and the development of real-time forecasts by leveraging the UCSD Supercomputer Center.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Medium	High	7
R26.	**Areal Locations of Hazardous Atmosphere (ALOHA)-CAMEO**				
Description	ALOHA (Areal Locations of Hazardous Atmospheres) is a computer program designed to model chemical releases for emergency responders and planners. ALOHA can estimate how a toxic cloud might disperse after a chemical release - as well as several fires and explosions scenarios. CAMEO can access, store, and evaluate information critical for developing emergency plans.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	Medium	1

14	Fire Characteristics
Gap: Lack of tracking data on a fire's parameters to include speed, crowning, spotting, and wind.	
Description: Participants reported insufficient information on fire characteristics that would be beneficial to their plan of attack and/or understanding of the fire's future behavior. While the fire perimeter is the most important for real-time tracking and quick decision making, data on fire behavior provides vital information on next-steps. These characteristics are in addition to the fire perimeter and are needed for forecasting fire behavior. ***Current Capability:*** The fire community strives to obtain data on a fire's characteristics, but due to the fast-paced nature of WUI fires and technological limitations, it is quite difficult.	***Requirements:*** ▪ R22 – Need real-time and continuously updated tracking of fire characteristics (e.g. intensity, spotting, crowning, spread)
Technology Solution Assessment: Technology solutions that track fire characteristics and parameters require further development and longer-term investment. Tracking systems such as Firefly offer data that is too coarse to determine	

critical information such as flame length and fire intensity. Many wildfire models attempt to recreate fire characteristics and require an operator to manually enter inputs, but that does not adequately account for the threatened or burning landscape and is an inefficient use of time. No known automatic technology solutions track and account for fire characteristics in WUI Fire modeling.

Best Assessed Candidate Solution(s)

R22.	High-Altitude UAS				
Description	Designated MQ-9 Reaper® by its U.S. Air Force and Royal Air Force customers, the turboprop-powered, multi-mission Predator® B Remotely Piloted Aircraft (RPA) was developed with GA-ASI funding and provides significantly greater capabilities than Predator. The MQ-9 Reaper has become a key asset in California firefighting, including during the Carr and Mendocino Complex Fires.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	High	Low	High	1

15	Crowdsourced Information

Gap: Non-traditional, crowdsourced information and communications (e.g., social media) are not frequently incorporated into the WUI fire common operating picture.

Description: Social media posts, pictures, and videos provide up-to-date information that often contain important details. However, these are often not combined with other pieces of information given to the emergency responders which could serve to advance the common operating picture. Participants reported fusion centers would be helpful in this endeavor.

Current Capability: Social media posts, pictures, and videos provide important information for modeling, but there is not a clear, repeatable process to analyze and disseminate the information in a way which emergency responders in the field can easy utilize.

Requirements:

- R24 – Need to exploit all source information to inform WUI Fire tracking

Technology Solution Assessment:

Social media data can be useful in detecting and tracking WUI fires by cross-referencing social media hits with low-confidence notifications. Some technology solutions integrate social media into a common operating picture with other relevant information. However, there are only a few solutions that focus solely on collecting and analyzing social media information that are calibrated for WUI fires.

Best Assessed Candidate Solution(s)

R24.	ATAK
Description	ATAK is a government-off-the-shelf situational awareness app for Android smartphones. The app uses GPS and maps to give the user a real-time view of the area of operations. The capability includes "Blue-Force Tracking" to see where team

	members are (which helps with coordinating movements), as well as terrain, weather, and other topographical elements. Additionally, the app enables multiple types of encrypted data communication such as text and file sharing (including photos and video). These communications can be set for user-to-user, user-to-select teams, user-to-command post or user-to-entire force (even if they are from different agencies).

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	5

16	Common Operating Picture

Gap: Insufficient information sharing with all disciplines and jurisdictions to create a common operating picture.

Description: Participants reported an incomplete common operating picture due to agencies and neighboring counties failing to share vital information with one another. This is partially due to inherent siloed responsibilities, but also due to the different systems and programs that cannot communicate with one another, as well as the complex problem of protecting proprietary data.

Current Capability: Emergency responders have vital information but often fail or are unable to share data with other agencies and jurisdictions.

Requirements:

- R25 – Need inter-agency and inter-jurisdictional emergency responder data integration

Technology Solution Assessment:

There are several existing technology solutions that collect and disseminate information to stakeholders by creating a common operating picture (e.g., ATAK, Team Connect, IRWIN, existing FEMA tools).

Best Assessed Candidate Solution(s)

R25.	Team Connect
Description	Team Connect is a cloud-native server application that facilitates exchange of situational awareness (SA) data. The Team Connect solution brokers communication and collaboration of information to multiple end user clients. As an information broker, the Team Connect application does not perform Situational Awareness (SA) information processing but does provide bridging adapters to inject and export SA data securely in real time. Team Connect uses a commercially available database to store the SA information that flows through it.

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	2

17	Dispatch Centers
Gap: Public Safety Answering Point (PSAP) design and methods are not integrated with ICS.	
Description: Participants reported dispatch centers do not have a connection between the early incident command centers and communication centers, which can result in missing information. Participants emphasized the information's source is not important during response, only how it may influence response decisions. Furthermore, many dispatch centers are currently unable to integrate information coming from sources beyond 911 calls. ***Current Capability:*** PSAPs and incident command centers assist with dispatch during WUI events, but a lack of integration among these entities results in missing information.	***Requirements:*** ▪ R23 – Need public-safety answering points that are integrated with Incident Command (IC)

Forecasting

The WUI Fire Operational Requirements and Technology Capability Analysis Project defines forecasting as information required to model and anticipate the fires future actions including movement, impacts, and spread. This section provides a list of gaps and recommended solutions categorized into the forecasting mission elements. **Table 12** below provides a summary of forecasting mission element findings.

Table 12: Summary of Forecasting Findings

Gap Title	Specific Gap	Index Number	Identified Solutions?
Technology (May Include Non-Technology Considerations)			
Fire Modeling Accuracy	Fire modeling often cannot consistently and accurately predict fire behavior.	G18	Yes
Fire Modeling Timeliness	Fire modeling and critical information dissemination are not timely enough to support effective decision making for emergency managers.	G19	Yes

Technology Findings

18	Fire Modeling Accuracy
Gap: Fire modeling often cannot consistently and accurately predict fire behavior.	
Description: Fire models also do not always match fire behavior on the ground due to challenges predicting WUI fires. Existing models do not accurately forecast fires when certain factors are involved, such as fire-induced winds and multiple structures serving as fuel. Participants reported often needing to apply ad hoc improvisations to models for them to match observed conditions (e.g., change true fuel conditions to dry brush). ***Current Capability:*** Many fire models exist, but they do not accurately forecast WUI fires nor always match fire behavior on the ground.	***Requirements:*** ▪ R27 – Need WUI Fire modeling that generates actionable and reliable data outputs ▪ R30 – Need WUI Fire modeling that matches specific WUI conditions
Technology Solution Assessment: Fire models do not currently account for the unique nature of WUI fires; Fire models do not account for ignitions of structures and urban fuels across the WUI or extreme weather. Existing fire models have known and unknown limitations and are not consistent or accurate in predicting WUI fires, resulting in uncertainty in where the models will fail. As such, current fire modeling is only used as a supportive tool. Continued development to improve accuracy and consistency is required.	

Best Assessed Candidate Solution(s)					
R27.	**FASMEE**				
Description	FASMEE is a multi-agency effort to provide advanced measurements necessary to evaluate and advance operationally-used fire and smoke modeling systems and their underlying scientific models. The field campaign will be conducted on large operational prescribed fires targeting heavy fuel loads and burned to produce high-intensity fires with developed plumes in the southeastern and western United States.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	1
R30.	**WIFIRE**				
Description	The WIFIRE Firemap merges a robust array of sensor data with computational techniques like signal processing, data assimilation, modeling, and visualization to monitor environmental conditions and predict where and how fast a wildfire will spread. The Firemap enables analysis of various fire scenarios and the development of real-time forecasts by leveraging the UCSD Supercomputer Center.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Developable	Low	Medium	High	7

19	Fire Modeling Timeliness

Gap: Fire modeling and critical information dissemination are not timely enough to support effective decision making for emergency managers.

Description: Participants reported that it is difficult to gather sufficient data in time to create a model that is accurate and up-to-date. Participants reported that modeling results do not arrive in time to impact decision making—modeling can take upwards of eight hours to receive results. WUI fires evolve too quickly for such long turnaround times. (e.g., automatically distributed localized weather reports)

Current Capability: Many fire models exist, but it is difficult to gather sufficient data in time to create a model that is accurate and up-to-date.

Requirements:

- R28 – Need timely fire behavior modeling (i.e. updated hourly or less)
- R29 – Need to acquire WUI Fire modeling inputs (e.g., fuel, meteorological conditions, wind)

Technology Solution Assessment:

The first four hours of a WUI fire are critical; fire models take too long and are not accurate enough to impact critical decision making. As such, modeling predictive fire behavior algorithms need to be improved and updated, as they are from the 1970s. Improving fire models requires better data

inputs through refining data and automatic dissemination of data. Untimely data inputs hinder the speed required to model a WUI fire.

Best Assessed Candidate Solution(s)

R28.	**WIFIRE**				
Description	The WIFIRE Firemap merges a robust array of sensor data with computational techniques like signal processing, data assimilation, modeling, and visualization to monitor environmental conditions and predict where and how fast a wildfire will spread. The Firemap enables analysis of various fire scenarios and the development of real-time forecasts by leveraging the UCSD Supercomputer Center.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Adaptable	Low	Medium	High	7
R29.	**Fire Family Plus**				
Description	Fire Family Plus is a software package used to calculate fuel moistures and indices from the US National Fire Danger Rating System (NFDRS) using hourly or daily fire weather observations primarily from Remote Authomated Weather Stations (RAWS).				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	1

Public Information and Warning

The WUI Fire Operational Requirements and Technology Capability Analysis Project defines public information and warning as information required to deliver emergency information, alerts, warnings, and notifications to the whole community prior to and during a fire incident. This section provides a list of gaps and recommended solutions categorized into the public information and warning mission elements. **Table 13** below provides a summary of public information and warning mission element findings.

Table 13: Summary of Public Information and Warning Findings

Gap Title	Specific Gap	Index Number	Identified Solutions?
Technology (May Include Non-Technology Considerations)			
Geographically Targeted Warnings	Lack of systems and procedures that deliver notifications and warnings to a targeted geographic area	G20	Yes
Tailored AFN Warning	Information and warning systems currently lack tailored communications to meet the specific needs of the AFN community.	G21	Yes
Human Factor Delays Warning	Insufficient systems for monitoring smoke and air quality to warn emergency responders and the public.	G22	Yes
Social Media Dissemination	Insufficient dedicated public information officers to disseminate warnings through social media during a WUI event.	G23	Yes
Smoke Monitoring and Warning	Insufficient systems for monitoring smoke and air quality to warn emergency responders and the public.	G24	Yes
Carrier Limitations	Public information and warning are hindered by telecommunication carrier limitations.	G25	No
Non-Technology			
Warning Authorities	Inconsistent authorities on who orders an evacuation.	G26	
Warning Thresholds	Lack of consistently applied thresholds for notification and warning across agencies and jurisdictions	G27	
Warning Lexicon	Lack of consistently applied warning terminology across jurisdictions and types of disasters	G28	
Hazardous Conditions Warning	Hazardous condition warnings (e.g., the red flag system) are not integrated with fire departments and emergency manager's assessment of risk	G29	
Warning Tradeoffs	Tradeoffs between “warning fatigue” and the need for public awareness have not been sufficiently evaluated	G30	

Technology Findings

<table>
<tr><th colspan="6">20 Geographically Targeted Warnings</th></tr>
<tr><td colspan="6">Gap: Lack of systems and procedures that deliver notifications and warnings to a targeted geographic area</td></tr>
<tr><td colspan="4">Description: Participants cited a high rate of delivery failure due to hang ups, lack of landline/ cell, telecommunications network down, and other factors which all contributed to messaging not arriving to the intended recipient. Respondents noted the need for messaging across a wide variety of platforms to improve delivery rate.

Current Capability: Fire services, law enforcement, and emergency managers are able to mass message populations with warnings, and some can geotarget their alerts, but wireless service providers often do now allow resolution beyond a county or other arbitrary boundary.</td><td colspan="2">Requirements:
▪ R3 1 – Need geographically targeted notification and warning to specific areas</td></tr>
<tr><td colspan="6">Technology Solution Assessment:

There are technology solutions in the market that deliver notifications and warnings to targeted geographic areas (e.g., Everbridge). However, technology solutions must ensure critical messaging is distributed and arrives to the intended recipient, including a variety of messaging platforms, contingency messaging plans for downed networks or loss of landlines, and messaging accommodations for the AFN population.

Best Assessed Candidate Solution(s)</td></tr>
<tr><td>R3 1.</td><td colspan="5">Wide-Area Mass Notification</td></tr>
<tr><td>Description</td><td colspan="5">Eaton offers a Wide-Area Mass Notification system that can include a combination of audible and visual messages to an impacted area during an emergency in real-time. Their WAVES product broadcasts voice messages, tones, and sirens to large outdoor areas. This Giant Voice system can be mobile, allowing emergency responders to spread the message to communities in danger through vehicles or drones. WAVES' visual devices include strobe lights and LED signs for mass alerts.</td></tr>
<tr><td rowspan="2">Preliminary Assessment</td><td>Feasibility</td><td>Affordability</td><td>Usability</td><td>Impact</td><td>Technology Alignment</td></tr>
<tr><td>Available</td><td>Medium</td><td>Medium</td><td>High</td><td>1</td></tr>
</table>

21	Tailored AFN Warning

Gap: Information and warning systems currently lack tailored communications to meet the specific needs of the AFN community.

Description: The AFN population must be provided with accommodations to typical text/ visual/ audible notifications and warnings, should successful message and delivery occur. such as translation into a different language or alerts that vibrate/ shake instead of make noise. ***Current Capability:*** Fire services, law enforcement, and emergency managers are able to mass message populations with warnings, but do not always provide the AFN community with the necessary notification accommodations.	***Requirements:*** ▪ R32 – Need effective warnings for vulnerable areas to include AFN populations

Technology Solution Assessment:

Public warnings and notification technologies tailored specifically to all aspects of the AFN populations are not readily available. Future solutions must include multiple methods of mass messaging to ensure critical notifications reach the whole community, especially populations with AFN, and socially or economically vulnerable populations. However, technology solutions will need to be a part of a larger campaign to ensure the whole community receives tailored communications.

Best Assessed Candidate Solution(s)

R32.	Accessible Hazard
Description	The Accessible Hazard Alert System (AHAS), developed and operated by Deaf Link for the City of Fort Worth Office of Emergency Management, is designed to provide a warning system to announce severe weather and disaster events to residents with disabilities and others with access and functional needs such as Deaf, Hard of Hearing, Blind, or Deaf/ Blind populations. The AHAS warnings are delivered in American Sign Language, English verbal, and captioned text on mobile devices such as iPads, cell phones, computers, and wireless Braille readers.

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Developable	Low	Medium	High	1

22	Human Factor Delays Warning

Gap: Human elements of response cause delays in dissemination of warnings (e.g., fear of backlash).

Description: Participants reported delays to information and warning dissemination due to the human factor of hesitating to commit. For example, participants reported delays and system failures due to the lack of pre-established relationships across disciplines. Finally, participants cited the need for a consistent, streamlined process that mitigates delays due to the human factor.

Current Capability: The fire community's reliance on human relationships and the lack of automatic thresholds can sometimes lead to delays in distributing warnings.

Requirements:

- R41 – Need to reduce human-caused delays associated with timely issuing of warnings

Technology Solution Assessment:

Current technologies strive to provide data exchange capabilities between existing platforms, as well as aggregate data in one central location, to increase situational awareness and partnerships between jurisdictions and agencies. Regardless, humans still need to make decisions which inherently causes delays. Technologies that provide clear thresholds may assist humans in decision making.

Best Assessed Candidate Solution(s)

R41.	Intterra
Description	Intterra has built a cloud and analytics platform that provides situational awareness on a moment-by-moment basis. This platform is a foundation for National Interagency Fire Center (NIFC) Enterprise Geospatial Portal (EGP). The EGP is a visualization and analysis tool that organizes and consolidates both spatial wildland fire information and disparate geospatial data. It is used to manage emerging incidents, to develop effective preplans, and to share a common operational picture from the field to the base station.

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Medium	Low	Medium	5

23	Social Media Warning Dissemination

Gap: Insufficient dedicated public information officers to disseminate warnings through social media during a WUI event.

Description: Participants reported that, during major WUI fire incidents, they did not have enough personnel to maintain Public Information Officers (PIO) on full-time social media duty. As a result, emergency responders are often unable to communicate warnings and up-to-date incident information through common channels and incorporate information from survivors into the common operating picture. PIOs must be more than simply social media literate, they need to be able to vet the message, determine reliability, time of origin, source, etc.

Current Capability: The fire community maintains PIOs who know how to effectively use social media, but fire services struggle to ensure this position is filled during incidents and assist emergency responders with warning communications.

Requirements:

- R38 – Need to disseminate information and warnings through social media

Technology Solution Assessment:

Current technologies focus on streamlining the dissemination of information over social media to aid the job of a public information officer. These technologies, however, do not necessarily work at the speed needed to push out information, due to the volatility of a WUI fire. In addition, few tools have been specifically adapted to WUI fires or fire threat in general, and do not possess sufficient analytical capabilities.

Best Assessed Candidate Solution(s)

R38.	Hootsuite
Description	Hootsuite's platform allows for up to ten social profiles to be integrated into one, user-friendly interface streamlining content distribution and account management. Hootsuite has seen great success in the private sector, enabling organizations to better engage with their audience in providing analytics on content and user interaction.

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology
	Available	Low	Low	Medium	1

24	Smoke Monitoring and Warning
Gap: Insufficient systems for monitoring smoke and air quality to warn emergency responders and	
Description: Participants reported they have no system to measure or track the harmful particulate in the air—caused by smoke—that may affect the AFN population and/or be a public health risk. Additionally, smoke desensitizes people; many people do not understand their immediate risk after prolonged smoke exposure. ***Current Capability:*** There exist systems to monitor smoke and air quality, but they are not currently used to detect extremely small and harmful particulates that may affect the AFN population.	***Requirements:*** ▪ R39 – Need to warn about air quality levels (e.g. smog, smoke)
Technology Solution Assessment: Existing technology solutions focus on monitoring smoke plumes and air quality near the fire source but are unable to assess transported and/or dispersed smoke in the atmosphere. Transported smoke worsens air quality and poses serious risk to public health. Potential solutions exist, such as building upon Environmental Protection Agency (EPA) and the National Weather Services' air quality warning efforts to track harmful particulates and issue public alerts. Best Assessed Candidate Solution(s)	
R39.	CALIFORNIA and Nevada Smoke and Air Committee (CANSAC)
Description	CANSAC provides experimental forecast products of fire weather, smoke dispersion/transport, fire danger and fire behavior. Some of the goals and functions of the CANSAC real-time forecasting system are: 1) To provide prognostic and diagnostic meteorological forecast products to be used in assessment of fire, smoke and weather applications. 2) To evaluate and improve the accuracy and capabilities of short term mesoscale meteorological forecast in fire, smoke and weather applications. 3) To evaluate data assimilation techniques and efficiencies in real-time forecasting. 4) To establish a link between air quality and real-time meteorological forecast systems in order to achieve real-time smoke forecasts.

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Medium	Medium	Medium	1

25	Carrier Limitations
Gap: Public information and warning are hindered by telecommunication carrier limitations.	
Description: Participants reported challenges in disseminating public information and warnings due to restrictions created by the telecommunications industry. For example, one participant reported hours of delay in sending out a warning due to the need to limit the warning message to only 90 characters. ***Current Capability:*** The fire community partners with telecommunication carriers, but there are challenges in disseminating public information and warnings due to restrictions created by the industry.	***Requirements:*** ▪ R36 – Need tele-communication carriers to loosen limitations and improve service delivery of emergency messages ▪ R43 – Need multi-platform messaging with a single source capable of national reach

Non-Technology Findings

26	Warning Authorities
Gap: Inconsistent authorities on who orders an evacuation	
Description: Participants across multiple jurisdictions reported a range of authorities that order notification and warnings, occasionally causing confusion during a WUI event, especially for multi-jurisdictional events. While not common, the general lack of clarity on important decisions has a high impact on life-safety. ***Current Capability:*** Fire communities understand the population must be notified and warned, but there are inconsistent authorities such as who orders notification and warnings across multiple jurisdictions.	***Requirements:*** ▪ R33 – Need consistent warning authorities ▪ R42 – Need multi-jurisdictional and interagency integration to warn the public in a consistent manner

27	Warning Thresholds
Gap: Lack of consistently applied thresholds for notification and warning across agencies and jurisdictions	
Description: Participants reported the lack of clear thresholds on when to send out information and warnings delayed or prevented distribution. For example, participants cited numerous issues in distributing wireless emergency alerts (WEA) due to the lack of pre-defined thresholds.	***Requirements:*** ▪ R34 – Need consistent and tiered thresholds for warnings

Current Capability: Fire communities understand the population must be notified and warned, but the lack of clear thresholds on when to send out information and warnings can delay or prevent distribution all together.	

28	Warning Lexicon
Gap: Lack of consistently applied warning terminology across jurisdictions and types of disasters	
Description: Participants reported the need for consistent warning terminology; the lack of consistency leads to confusion among emergency responders and the public. For example, California fire fighters reported requesting a reverse 911—an alert to go out to everyone in the jurisdiction; however, the dispatch used a different term for the same procedure, which delayed the warning ***Current Capability:*** A growing knowledge of WUI fires necessitates a new lexicon, but command staff, the public, and various disciplines do not always understand terms used in fire information and warnings.	***Requirements:*** ▪ R35 – Need commonly understood warning terminology and concepts for response partners and the public

29	Hazardous Condition Warnings
Gap: Hazardous condition warnings (e.g., the red flag system) are not integrated with fire departments and emergency manager's assessment of risk	
Description: Participants noted that WUI hazardous condition warnings do not account for local fire departments and emergency manager's assessment of risk. For example, the National Oceanic and Atmospheric Administration (NOAA) red flag alerts are often helpful, however sometimes conditions are just below the threshold and a warning is not triggered leaving people to believe there is no risk. Conditions prior to Chimney Tops Fire #2 met all the criteria for a red flag warning except for low humidity, which kept it from activation. Participants recommend greater input from fire departments and emergency managers, and a sliding scale which would offer greater granularity into the degree of risk, instead of a binary system. ***Current Capability:*** Fire communities and emergency managers have their own assessment of risk, but WUI hazardous condition warnings often do not account for these risks.	***Requirements:*** ▪ R37 – Need a high-risk fire warning capability with input from key stakeholders with national reach (e.g. improve Red Flag warnings)

30	Warning Tradeoffs
Gap: Tradeoffs between "warning fatigue" and the need for public awareness have not been sufficiently evaluated	
Description: The fire community is cautious of disseminating frequent warnings fearing that the public will become desensitized to their importance. However, the fire community also does not want to avoid informing the public. Participants recommended further study into the tradeoffs of over warning—especially false positives—and under-warning their jurisdictions. ***Current Capability:*** The fire community knows the importance of warning the population and has the tools to do so, but they are sometimes cautious of disseminating frequent warnings fearing that the public will become desensitized.	***Requirements:*** ▪ R40 – Need to find a balance between warning fatigue and the need for public awareness

Evacuation

The WUI Fire Operational Requirements and Technology Capability Analysis Project defines evacuation as Information required to enable survivors to leave or shelter in areas affected by the fire. This section provides a list of gaps and recommended solutions categorized into evacuation mission elements. **Table 14** below provides a summary of evacuation mission element findings.

Table 14: Summary of Evacuation Findings

Gap Title	Specific Gap	Index Number	Identified Solutions?
Technology (May Include Non-Technology Considerations)			
Evacuation Status	Inability to track the status of evacuation routes, safety zones, evacuated buildings and survivors.	G31	Yes
Public-Private Partnerships	Insufficient public-private partnerships to support evacuation efforts.	G32	Yes
Evacuation Modeling	Inadequate modeling of evacuation routes, population behavior, and safety areas.	G33	No
Non-Technology			
Evacuation Routes	Lack of planned, trained, exercised, and education evacuation routes and safety zones.	G34	
AFN Evacuation Routes	Lack of standards and guidelines to evacuate AFN population (e.g., early evacuation warnings and appropriate transportation).	G35	
Evacuation Threshold	Insufficient and inconsistent thresholds to trigger evacuation and/or shelter in place.	G36	
Evacuation Authorities	Inconsistent authorities on who orders an evacuation.	G37	
Evacuation Lexicon	Inconsistent evacuation terminology across jurisdictions, disaster types, and disciplines.	G38	
Evacuation Patterns/Schema	Insufficient study and use of optimal evacuation patterns/schema.	G39	
Animal Evacuation	Lack of warnings, procedures and directions for owners to evacuate their animals.	G40	

Technology Findings

31	Evacuation Status
Gap: Inability to track the status of evacuation routes, safety zones, evacuated buildings and survivors.	
Description: Participants reported the inability to monitor the status of evacuation routes and safety zones in real time. For example, a camera system on a major evacuation route would allow emergency responders to address blockages and reroute the public quickly. Further, participants reported that they lacked a common platform to track inhabitants who have successfully evacuated, not yet evacuated, or refused to evacuate. This	***Requirements:*** ▪ R45 – Need population safety survivor accountability and real-time monitoring of evacuation routes

platform would allow emergency responders to target their operations and reduce duplication of effort. ***Current Capability:*** The fire community strives for clear evacuation routes and procedures but struggle to monitor the status of evacuation routes and safety zones in real-time. Some mass notification systems allow recipients to reply and may allow follow-ups to better assess response to evacuation notices. Some features may be add-ons to basic service, thus increasing cost.	▪ R54 – Need shared real-time situational awareness of evacuation st atus through social media and official channels ▪ R55 – Need an inventory of evacuation capabilities and available resources

Technology Solution Assessment:

A lack of real-time information tracking and monitoring programs exist to view current population evacuation status at the tactical level. The development of a program that is able to map the real-time status of a residence inhabitants evacuation situation through a "stop light" rating system would exponentially increase situational awareness capabilities. Current existing technologies, such as ATAK, can be adapted to achieve this result through a relatively low level of effort.

Best Assessed Candidate Solution(s)

R54.	**Team Connect**
Description	Team Connect is a cloud-native server application that facilitates exchange of situational awareness (SA) data. The Team Connect solution brokers communication and collaboration of information to multiple end user clients. As an information broker, the Team Connect application does not perform Situational Awareness (SA) information processing but does provide bridging adapters to inject and export SA data securely in real time. Team Connect uses a commercially available database to store the SA information that flows through it.

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	2

32	Public-Private Partnerships

Gap: Insufficient public-private partnerships to support evacuation efforts

Description: Participants cited numerous examples of potentially life-saving public-private partnerships to support evacuation efforts. Fire services recommended establishing partnerships so that all popular navigation applications provide up-to-date information on escape routes and refuge areas. ***Current Capability:*** The fire community and the private sector have many potentially life-saving partnerships to support evacuation efforts, but they have yet to be fully realized.	***Requirements:*** ▪ R46 – Need public-private partnerships to support evacuation efforts

Technology Solution Assessment:

Social media platforms (i.e. Facebook) use a check-in feature which allows people to share when they have successfully escaped the danger-area of an incident. These check-ins are typically not real-time. Crowdsourced navigation apps (i.e. WAZE) leverage social media data to inform the response common operating picture during evacuation, but more development is required. Additionally, coordination with the hospitality and advertising industries to ensure transient populations are aware of evacuation procedures and receive all necessary evacuation guidance is necessary.

Best Assessed Candidate Solution(s)

R46.	Waze
Description	Waze has established a partnership with emergency responders to allow users of the app to receive real-time incident information and re-route drivers to avoid incidents (such as fires) and related road closures. This solution helps government officials send information to Waze users in real-time with location-based information about their surroundings and helps emergency responders gather information about emergencies from users.

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	1

33	Evacuation Modeling

Gap: Inadequate modeling of evacuation routes, population behavior, and safety areas

Description: Participants reported current evacuation models have trouble calculating evacuation times, especially for AFN and transient populations. Participants wanted to use evacuation modeling to determine the most effective evacuation route.

Current Capability: Evacuation models exist, but have trouble calculating evacuation timing and are often not used to determine the most effective route.

Requirements:

- R52 – Need reliable modeling of evacuation routes, population behavior, and safety areas

Technology Solution Assessment:

Current evacuation modeling does not typically account for realistic traffic conditions. Potential solutions exist through leveraging crowdsourcing navigation applications, such as Waze and Google Maps, that collect large amounts of traffic pattern information and driver statistics to provide a more accurate picture of the road network landscape. By integrating this data into evacuation models, more reliable routes can be established for all impacted populations.

Best Assessed Candidate Solution(s)					
R52.	**Pathfinder**				
Description	Pathfinder is an emergency egress simulator that includes an integrated user interface and animated 3D results. Pathfinder allows you to evaluate evacuation models more quickly and produce more realistic graphics than with other simulators. Pathfinder provides support for the import of AutoCAD format DXF and DWG files. Pathfinder's floor extraction tool makes it possible to quickly use the imported geometry to define the occupant walking space for the evacuation model.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Medium	Medium	High	1

Non-Technology Findings

34	Evacuation Routes
Gap: Lack of planned, trained, exercised, and education evacuation routes and safety zones	
Description: Participants reported numerous challenges related to evacuation routes and procedures including: overlapping or conflicting evacuation orders, citizens taking longer than expected to evacuate, and ensuring all involved authorities maintain unity of effort on necessary actions (e.g., opening a highway). Participants also reported that it is very difficult to practice an evacuation and current exercises have been too small scale. ***Current Capability:*** The fire community strives for clear evacuation routes and procedures, but faces numerous challenges including overlapping or conflicting evacuation orders, citizens taking longer than expected to evacuate, and ensuring all involved authorities maintain unity of effort on necessary actions.	***Requirements:*** ▪ R44 – Need identification of multiple evacuation routes, safe zones, shelter-in-place facilities and alternatives

35	AFN Evacuation
Gap: Lack of standards and guidelines to evacuate AFN population (e.g., early evacuation warnings and appropriate transportation).	
Description: Participants reported that AFN evacuation is particularly challenging and there is a lack of standards and guidelines to ensure efficacy. For example, participants cited the challenges in evacuating AFN hospitals due to the stress on patients and the difficulty in reopening the facility after the incident. Clear guidelines on evacuation procedures and thresholds would facilitate more deliberate decision-making before and during incidents. ***Current Capability:*** The fire community strives for clear evacuation routes and procedures but struggle to monitor the status of evacuation routes and safety zones in real-time.	***Requirements:*** ▪ R47 – Need standards and guidelines to evacuate individuals with disabilities and others with access and functional needs population

36	Evacuation Threshold
Gap: Insufficient and inconsistent thresholds to trigger evacuation and/or shelter in place.	
Description: Participants reported the lack of clear triggers for evacuation and/or shelter in place orders. In addition, participants recommended creating multiple evacuation thresholds where possible (e.g., lower evacuation threshold for AFN population). Participants recommended the creation of federal evacuation guidelines that could be adapted to each particular incident. ***Current Capability:*** The lack of guidance creates the need for ad hoc decision-making without an established framework.	***Requirements:*** ▪ R48 – Need consistent and tiered thresholds for evacuation warnings

37	Evacuation Authorities
Gap: Inconsistent authorities on who orders an evacuation.	
Description: Participants reported that the responsible entity and the ensuing procedures for ordering evacuations vary across jurisdictions. This creates delays in sending evacuation warnings or causes emergency responders to work around existing processes, instead of using the systems established in policy and doctrine. One participant reported that an evacuation was delayed by two hours during a fast-paced WUI fire incident due to delays caused by tracking down the correct personnel and receiving the proper authorization for an evacuation order. ***Current Capability:*** Authorities understand the importance of issuing timely evacuation orders, however the responsible entity and ensuing procedures for ordering evacuations varies across jurisdictions.	***Requirements:*** ▪ R49 – Need consistent evacuation authorities

38	Evacuation Lexicon
Gap: Inconsistent evacuation terminology across jurisdictions, disaster types, and disciplines.	
Description: Participants reported inconsistent evacuation terminology creating confusion for emergency responders and the public. For example, the terms in one county for a recommended evacuation and a mandatory evacuation are "evacuation warning" and "evacuation order" respectively, but different terms are used in neighboring counties. Participants noted that there is additional confusion because different terms are used for different types of disasters (e.g., "flash flood warning" means evacuate). Finally, participants recommend educating the news media on a unified evacuation lexicon to ensure the public receives evacuation messaging with consistent terminology. ***Current Capability:*** The fire community strives for clear evacuation commands and procedures, but inconsistent terminology leads to confusion for both emergency responders and the public.	***Requirements:*** ▪ R50 – Need commonly understood evacuation terminology and concepts for response partners and the public

39	Evacuation Patterns/ Schema
Gap: Insufficient study and use of optimal evacuation patterns/ schema.	
Description: Participants reported limited insight on whether evacuations should occur from the farthest away to the closest to the hazard, or in a different organizational pattern. In addition, emergency responders highlighted that evacuations have typically resulted in traffic and chaos. Evacuations schema need to account for the vehicles and traffic—for example, one participant cited an instance of an evacuation destination located too close to the incident causing a line of cars still in the hazard zone. ***Current Capability:*** The fire community strives for organized evacuations, but there is limited insight on best practices.	***Requirements:*** ▪ R51 – Need to identify best practices for evacuation patterns and schema

40	Animal Evacuation
Gap: Lack of warnings, procedures and directions for owners to evacuate their animals.	
Description: Participants noted that many citizens care deeply about their animals and risk their lives, and inadvertently the lives of others, when trying to evacuate or save animals. Pet owners may fail to evacuate because of their pets or evacuate without their pets and go back for them, causing road congestion and/ or the potential need for rescue. ***Current Capability:*** Many citizens care deeply about their animals and want to evacuate them during incidents, which may cause additional road congestion and trouble for emergency responders.	***Requirements:*** ▪ R53 – Need to know time to evacuation or shelter-in-place of animals (i.e., farm, exotic, and pets)

Responder Safety

The WUI Fire Operational Requirements and Technology Capability Analysis Project defines responder safety as information required to ensure the protection of the health and safety of emergency responders. This section provides a list of gaps and recommended solutions categorized into responder safety mission elements. **Table 15** below provides a summary of responder safety mission element gaps.

Table 15: Summary of Responder Safety Gaps

Gap Title	Specific Gap	Index Number	Identified Solutions?
Technology (May Include Non-Technology Considerations)			
Positional Awareness for First Responders	Fire services lack precise "blue-force" or GPS-enabled tracking capabilities.	G41	Yes
Connectivity for First Responders	Fire services lack robust systems to ensure a common operating picture and last mile connectivity.	G42	Yes
Cross Discipline Integration	Lack of integration between law enforcement and emergency medical services into fire response.	G43	Yes

Technology Findings

41	Positional Awareness for First Responders
Gap: Fire services lack precise "blue-force" or GPS-enabled tracking capabilities.	
Description: Current tracking capabilities for response assets (i.e., the "blue-force") generally track vehicles but not individual emergency responders. In addition, current systems are often unable to include out-of-area strike teams and emergency responders from other disciplines into the common operating picture Participants reported that improved situational awareness of emergency responder resources would make operations more effective. ***Current Capability:*** Current response resource tracking systems in the fire community track vehicles, but not individual emergency responders.	***Requirements:*** ▪ R56 – Need "blue-force tracking" for emergency responders in a WUI incident —including location with verified time of arrival ▪ R59 – Need continuous hazard assessment that is distributed to emergency responders in the field
Technology Solution Assessment: Current GPS-enabled tracking capabilities are readily available and used in a variety of disciplines but are not sufficiently utilized during WUI fires. In addition, existing tracking systems are not interoperable with other similar systems used by neighboring jurisdictions or other response agencies. Ensuring GPS-enabled tracking technologies are integrated into the common operating picture to increase situational awareness would allow for verified time of arrival of emergency responders, resource tracking, and hazard assessment distributed to those in the field.	

Best Assessed Candidate Solution(s)					
R56.	**Android Team Awareness Kit (ATAK)**				
Description	ATAK is a government-off-the-shelf situational awareness app for Android smartphones. The app uses GPS and maps to give the user a real-time view of the area of operations. The capability includes "Blue-Force Tracking" to see where team members are (which helps with coordinating movements), as well as terrain, weather, and other topographical elements. Additionally, the app enables multiple types of encrypted data communication such as text and file sharing (including photos and video). These communications can be set for user-to-user, user-to-select teams, user-to-command post or user-to-entire force (even if they are from different agencies).				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Low	High	5
R59.	**WIFIRE**				
Description	The WIFIRE Firemap merges a robust array of sensor data with computational techniques like signal processing, data assimilation, modeling, and visualization to monitor environmental conditions and predict where and how fast a wildfire will spread. The Firemap enables analysis of various fire scenarios and the development of real-time forecasts by leveraging the UCSD Supercomputer Center.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Medium	High	7

42	Connectivity for Emergency Responders
Gap: Fire services lack robust systems to ensure a common operating picture and last mile connectivity.	
Description: Participants reported difficulty maintaining situational awareness due to a lack of clear information dissemination. Participants recommended performing briefings to units en route to the disaster so emergency responders can arrive to the incident with a clear understanding of hazards and priorities. ***Current Capability:*** Emergency responders are eager to obtain all the necessary information, but because information is not compiled from the field and disseminated out in a coherent, complete, or expeditious manner they do not always receive a complete picture.	***Requirements:*** ▪ R57 – Need common operating picture capability for WUI Fires that is interoperable

Technology Solution Assessment:

Computer-Aided Dispatch (CAD) systems are widely used in emergency management, but CAD systems are not interoperable across agencies and jurisdictions and do not allow incident command to communicate actionable incident information to all emergency responders. Integrating CAD systems into a common operating picture is required.

Best Assessed Candidate Solution(s)

R57.	Intterra
Description	Intterra has built a cloud and analytics platform that provides situational awareness on a moment-by-moment basis. This platform is a foundation for National Interagency Fire Center (NIFC) Enterprise Geospatial Portal (EGP). The EGP is a visualization and analysis tool that organizes and consolidates both spatial wildland fire information and disparate geospatial data. It is used to manage emerging incidents, to develop effective preplans, and to share a common operational picture from the field to the base station.

Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Medium	Low	Medium	5

43	Cross Discipline Integration

Gap: Lack of integration between law enforcement and emergency medical services into fire response

Description: Participants from other emergency response disciplines reported insufficient awareness of, and integration with fire emergency responders. For example, other emergency responder agencies desire any incident information available, even if fire leadership does not have 100% confidence in its accuracy (e.g., history of previous fires in the area).

Current Capability: Many disciplines respond to WUI fires, but they do not coordinate as effectively as possible.

Requirements:

- R58 – Need timely information to allow for en route incident briefing and planning

Technology Solution Assessment:

Technologies exist to help integrate various disciplines (e.g., Intterra), but they are insufficiently utilized between law enforcement and medical services into fire response. These technologies strive to provide data exchange capabilities between existing platforms, as well as aggregate data in one central location, to increase situational awareness and help partnerships between different jurisdictions and disciplines.

Best Assessed Candidate Solution(s)					
R58.	**WIFIRE**				
Description	The WIFIRE Firemap merges a robust array of sensor data with computational techniques like signal processing, data assimilation, modeling, and visualization to monitor environmental conditions and predict where and how fast a wildfire will spread. The Firemap enables analysis of various fire scenarios and the development of real-time forecasts by leveraging the UCSD Supercomputer Center.				
Preliminary Assessment	Feasibility	Affordability	Usability	Impact	Technology Alignment
	Available	Low	Medium	High	7

Critical Infrastructure

The WUI Fire Operational Requirements and Technology Capability Analysis Project defines critical infrastructure as information required to assess and stabilize human-created elements of the environment (e.g., power, water, chemicals, transportation, healthcare). This section provides a list of gaps and recommended solutions categorized into critical infrastructure mission elements. **Table 16** below provides a summary of critical infrastructure mission element findings.

Table 16: Summary of Critical Infrastructure Findings

Gap Title	Specific Gap	Index Number	Identified Solutions?
Technology (May Include Non-Technology Considerations)			
Resilient Communication	Lack of resilient communication systems (e.g., hardening cell towers).	G44	No
Power Companies/ Utilities	Inability to maintain power connectivity throughout response and access proprietary data (e.g., affected power grid information).	G45	No
Cascading Impacts	Critical infrastructure is insufficiently resilient to prevent cascading impacts	G46	No
Non-Technology			
Sensitive Sites	Protecting sensitive environmental, cultural and national security sites inhibits efficacy of response.	G47	
High Risk Preparations	Insufficient preparation of critical infrastructure during high-risk warnings (e.g., raising municipal water levels and fueling generators) prior to ignition.	G48	

Technology Findings

44	Resilient Communication
Gap: Lack of resilient communication systems (e.g., hardening cell towers).	
Description: Participants reported frequent challenges maintaining telephone and internet connection during WUI incidents. Telecommunication and radio connectivity are essential to maintaining a common operating picture; communicating incident information, warning, and evacuation notices to affected populations; maintaining continuity of operations of affected jurisdictions and maintaining data feeds from operational partners. ***Current Capability:*** The fire community communicates effectively via cell and radio, but should those connections fail during a WUI fire, response is greatly hindered due to few other communication alternatives.	***Requirements:*** ▪ R60 – Need resilient communications infrastructure

45	Power Companies/Utilities
Gap: Inability to maintain power connectivity throughout response and access proprietary data (e.g., affected power grid information)	
Description: Participants stressed the criticality of power connectivity during WUI fire response. Power outages disrupt emergency responder situational awareness and systems, inhibit survivor's ability to evacuate, and make the incident more chaotic (e.g., through increased crime). Moreover, power companies/utilities have access to data using proprietary systems which could include ignition detection and communities without power. Participants noted that they have been unable to access this potentially life-saving data. ***Current Capability:*** The fire community can maintain situational awareness through various systems with power connectivity, but without power, these systems become disrupted and subsequently hinder response.	***Requirements:*** ▪ R61 – Need resilient power infrastructure and better partnerships with utilities

46	Cascading Impacts
Gap: Critical infrastructure is insufficiently resilient to prevent cascading impacts	
Description: Participants reported consistent issues of cascading impacts across critical infrastructure hampering response, particularly power outages causing cell outages. For example, participants cited instances of hazardous materials facilities' cooling systems failing due to power outages. Moreover, participants reported the difficulty in anticipating cascading impacts of critical infrastructure failing during incidents ***Current Capability:*** The fire community relies on several types of critical infrastructure, but when one fails, it often has implications for other critical infrastructures which makes response difficult.	***Requirements:*** ▪ R64 – Need resilient critical infrastructure prepared to avoid cascading impacts ▪ R65 – Need to know status of critical infrastructure necessary to respond

Non-Technology Findings

47	Sensitive Sites
Gap: Protecting sensitive environmental, cultural and national security sites inhibits efficacy of response	
Description: Participants reported that sensitive cultural, historical, environmental, or national security sites can restrict or change how firefighters respond. During response, firefighters report that protecting sensitive sites can become a primary priority (along with life-saving), however participants noted not having access to information on sensitive sites that would help inform their response. Prior to the incident, sensitive sites can hinder preparation and mitigation; for example, endangered birds nesting in trees in WUI areas creates legal challenges for fire mitigation. ***Current Capability:*** The fire community is often aware of sensitive sites that require extra attention or care, but they do not have all the necessary information about these sites to inform a quick response.	***Requirements:*** ▪ R62 – Need to know sensitive site (Environmental and Cultural) locations and specific requirements for first responders during WUI fires

48	High Risk Preparations
Gap: Insufficient preparation of critical infrastructure during high-risk warnings (e.g., raising municipal water levels and fueling generators) prior to ignition.	
Description: Participants reported that critical infrastructure is not sufficiently prepared during high-risk warnings, which hampers response to major incidents. For example, ample water levels are not always maintained in municipal water systems, because they often refill the tanks to only partially full before dawn. Participants reported firefighters depleting the water in multiple municipal water systems during WUI events due to the lack of preparation. ***Current Capability:*** The fire community relies on critical infrastructure (e.g., electricity, water) to fight WUI fires, but, response is hampered because that infrastructure is often not sufficiently prepared during high fire risk periods.	***Requirements:*** ▪ R63 – Need to prepare critical infrastructure during high-risk warnings

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- This study shows how much an individual relies on physical and official cues influences whether or not they will evacuate in a wildfire. The study showed that most people rely on official cues, like evacuation orders from local fire officials, to take action. However, the study also found that a large number of people also rely on a combination of both official and physical cues, such as seeing wildfire flames, before determining whether they will evacuate or stay and defend their property.

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- Although ecosystems, humans, and fire have coexisted for millennia, changes in geology, ecology, hydrology, and climate as well as sociocultural, regulatory, and economic factors have converged to make wildland fire management exceptionally challenging for U.S. federal, state, and local authorities. Given the mounting, unsustainable costs and difficulty translating existing wildland fire science into policy, the National Academies of Sciences, Engineering, and Medicine organized a 1-day workshop to focus on how a century of wildland fire research can contribute to improving wildland fire management. This publication summarizes the presentations and discussions from the workshop.

Nauslar, Nicholas J. et. Al. (2018). The 2017 North Bay and Southern California Fires: A Case Study. Fire 2018, 1, 18, 1-17.

- A study of wildfire events impacting California in 2017, characterizing the meteorological and climatological factors that drove and enabled the wildfires. This study quantifies these conditions across the observational record.

Ronchi, Enrico et.al. (2017). E-Sanctuary: Open Multi-Physics Framework for Modeling Wildfire Urban Evacuation. Fire Protection Research Foundation.

- A proposed framework for modeling wildfire urban evacuations based on multi-physics simulations that can quantify the evacuation performance. The report argues that an integrated approach requires considering and integrating all three important components of WUI evacuation namely: fire spread, pedestrian movement, and traffic movement.

Periodicals

Lakin, Matt. (2017). 'Like Armageddon': How the Gatlinburg fire became unstoppable and swarmed a city. Knox News. November 24, 2017. https://www.knoxnews.com/story/news/2017/11/22/gatlinburg-wildfire-one-year-later-911-calls-evacuation-orders-communications-failures/856270001/

- News article discussing the timeline and efforts that took place to put out the Chimney Tops Fire in the Great Smokey Mountains National Park. This article discusses challenges and issues fire responders and civilians faced.

Graham, Jefferson and Molina, Brett. (2017). Waze sent commuters toward California wildfires, drivers say. USA TODAY. December 7, 2017. https://www.usatoday.com/story/tech/news/2017/12/07/california-fires-navigation-apps-like-waze-sent-commuters-into-flames-drivers/930904001/

- News article on how Waze mapped drivers towards neighborhoods where wildfires created closers and evacuations during the 2017 wildfires in California. This article includes tweets from people who experienced the poor routing and also explains possible reasons why Waze's maps were not updating quick enough.

Rimel, Anthony. (2019). Story Next Door: OSU researcher works to advance wildfire prediction models. Gazette-Times, March 26, 2019. https://www.gazettetimes.com/news/local/story-next-door-osu-researcher-works-to-advance-wildfire-prediction/article_4b487ce1-7e5c-5c34-9b34-25ca0b4aeb92.htm

- News article on Oregon State University's David Blunck who conducted a study on ember propagation. Blunck will be conducting another study on live fuels to enhance a physics-based wildfire model the USFS is developing.

North Valley Animal Disaster Group. https://www.nvadg.org/

- This website provides information on how to evacuate with pets, sheltering or evacuating evacuation of animals during a disaster, volunteer information, and wildfire updates.

Wildermuth, John. (April 23, 2019). As Bay Area Heats Up, Gov. Gavin Newsom warns of coming wildfire danger [Online Article] Retrieved from https://www.sfchronicle.com/california-wildfires/article/As-Bay-Area-heats-up-Gov-Gavin-Newsom-warns-of-13789704.php

- This article discusses California Governor Gavin Newsom's budget for firefighting and ongoing efforts to mitigate and respond to wildland fires.

Wilkins, Alasdair. (December 8, 2017). How do Navigation Apps Handle the Los Angeles Wildfires? We Asked Waze [online article]. Retrieved from https://www.inverse.com/article/39232-california-fires-navigation-app-waze

- This article looks at how navigation apps such as Waze or Maps address deal with challenges of offering real-time directions during a natural disaster, like wildfires.

Appendix A. Acronyms

AAR	After Action Report
AFN	Individuals with Disabilities and Others with Access and Functional Needs
ATAK	Android Tactical Awareness Kit
CA	California
CAL OES	California Governor's Office of Emergency Services
CAL Fire	California Department of Forestry & Fire Protection
CAWFE	Coupled Atmospheric Wildland Fire Environment
COTS	Commercial off-the-shelf
DHS	Department of Homeland Security
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
G	Gaps
GIS	Geographic Information System
GOTS	Government off-the-shelf
GPS	Geographic Positioning System
IC	Incident Command
ICS	Incident Command System
IPAWS	Integrated Public Alert & Warning System
IPT	Integrated Project Team
IRWIN	Integrated Reporting of Wildland-Fire Information
LA	Los Angeles
LANCE	Land, Atmosphere Near Real-time Capability for EOS
MD	Maryland
MODI	Model Data Inventory
NGO	Non-Governmental Organization
NOAA	National Oceanic Atmospheric Administration
PSAP	Public Safety Access Point
R	Requirement
S&T	Science and Technology Directorate
SME	Subject Matter Expert
SOP	Standard Operating Procedure
T	Technology

TN	Tennessee
TRL	Technology Readiness Level
TTX	Tabletop Exercise
USFA	U.S. Fire Administration
WEA	Wireless Emergency Alert
WFRAS	Wildland Fire Risk Assessment System
WUI	Wildland Urban Interface

Appendix B. Glossary

Access and Functional Needs (AFN): Individuals who are or have: physical, developmental, or intellectual disabilities; chronic conditions or injuries; limited English proficiency; older adults; children; low income, homeless, and/or transportation disadvantaged (e.g., dependent on public transit); or, pregnant women.

Affordability: A technology assessment variable that evaluates the resources required to implement the technology solution to address the particular requirement.

Alignment: A technology assessment variable that evaluates the ability for a candidate technology to align to multiple requirements.

Blue-force tracking: A GPS-enabled capability that provides law enforcement and emergency managers with location information of resources.

Critical Infrastructure: Information required to assess and stabilize human-created elements of the environment (e.g., power, water, chemicals, transportation, healthcare).

Defensible Space: An area around a building in which vegetation, debris, and other types of combustible fuels have been treated, cleared, or reduced to slow the spread of fire to and from the building.

Detection: Information required to identify the ignition location and cause of a fire.

Evacuation: Information required to enable survivors to leave or shelter in areas affected by the fire.

Feasibility: A technology assessment variable that evaluates the timeliness of implementing the solution to address the particular requirement.

Fire Community: An all-encompassing term that refers to all components and disciplines which respond to a fire incident including firefighters, emergency management personnel, emergency medical service, and law enforcement.

Forecasting: Information required to model and anticipate the fires future actions including movement, impacts, and spread.

Live Fuel: The amount of living biomass that potentially could burn.

Dead Fuel: The amount of dead biomass that potentially could burn. Dead vegetative fuels burn much more readily than live vegetation.

Ignition: The act or process of something starting to burn.

Impact: A technology assessment variable that evaluates the technology solution's potential to save lives if the solution is implemented to address the particular requirement.

Preparedness: Information required to understand the status and maturity of all pre-ignition measures, such as public education, plans, and pre-staged resources.

Public Information and Warning: Information required to deliver emergency information, alerts, warnings, and notifications to the whole community prior to, and during, a fire incident.

Red Flag Warning: Warnings that alert fire managers on federal lands to conditions that are highly unfavorable for prescribed burns and that may lead to especially dangerous wildfire growth.

Responder Safety: Information required to ensure the protection of the health and safety of responders.

Tracking: Information required to assess the location, direction, and intensity of a fire in real time.

Usability: A technology assessment variable that evaluates the technology solution's degree of difficulty to incorporate the solution into current field operations in order to address the particular requirement

Wildland Urban Interface: The area where houses and wildland vegetation meet or overlap, posing an increased risk for wildfires due to human-caused ignitions and a greater risk posed to lives and property where wildfire problems are most pronounced.

Appendix C. Project Participants

California WUI TTX Participants

Participating Organizations

Cal Fire
California Governor's Office of Emergency Services (Cal OES)
Department of Homeland Security Science and Technology Directorate
FEMA Region IX
Los Angeles (City) Fire Department (LAFD)
Orange County Fire Authority
Sacramento Metropolitan Fire District
San Bernardino County Fire
Santa Rosa Fire Department
Ventura County Fire Department

Tennessee Facilitated Discussion Participants

Participating Organizations

Gatlinburg Fire Department
Oak Ridge Fire Departmen
Pigeon Forge Fire Department
Severe County Emergency Management Agency (EMA)

Command Staff TTX Participants

Participating Organizations

Alameda County Emergency Medical Service (EMS) Agency
Butte County Sherriff's Department
Cal Fire
Cal OES
FEMA
Orange County Sherriff's Department
San Bernardino County Fire Department

SME Technical Review Participants

Participating Organizations

USFA

Gap Prioritization Participants

Participating Organizations

Colorado Fire
Department of Homeland Security (DHS)
Department of Interior (DOI)
FEMA
Johns Hopkins University Applied Physics Laboratory (JHU APL)
Los Angeles Fire Department (LAFD)
National Institute of Standards and Technology (NIST)
National Oceanic and Atmospheric Administration (NOAA)
United States Army Engineer Institute for Water Resources (IWR)
United States Geological Survey (USGS)
University of California San Diego (UCSD)
USFA
USFS (United States Forest Service)

Appendix D. Gaps Index

Gap Number	Topic	Specific Gap	Associated Requirements
G1	Physical Fire Mitigation	Lack of mitigation efforts for WUI fire-specific risks including defensible space, building codes, and fuel mapping/testing	R5, R12
G2	Critical Infrastructure Location Planning	Insufficient location planning for critical infrastructure to account for WUI fire threat (e.g., cell towers and emergency operations centers)	R7
G3	Status of Available Resources	Lack of inventory of available resources from response partners hinders operations	R9
G4	Pre-Incident Modeling	Lack of modeling capability for scenario-based pre-incident planning to understand fire behaviors in localities and assist in planning for major WUI incidents.	R14
G5	Access and Functional Needs Data	Individuals with disabilities and others with access and functional needs (AFN) population data are unreliable and/or dated	R4
G6	Data Standards	Lack of widely-accepted interoperable data standards	R1
G7	Public Education	Public information programs have insufficiently educated the whole community	R2, R10
G8	WUI Fire Doctrine	Doctrine and training have not been sufficiently updated to address extreme WUI fire threat	R3, R11
G9	Coordinated Regional Plans	Current plans are insufficiently integrated with nearby jurisdictions and interagency response partner plans	R6, R13
G10	Common Lexicon	WUI fire terminology and concepts are not sufficiently understood by response partners and the public	R8
G11	Ignition Detection	Detection of WUI fire ignitions is not accurate or fast enough	R15, R17, R18

Gap Number	Topic	Specific Gap	Associated Requirements
G12	Ignition Data Dissemination	Insufficient dissemination of ignition detection data to all response partners	R16, R19, R20
G13	Perimeter Tracking	Real-time perimeter tracking is often unavailable	R21, R26
G14	Fire Characteristics	Lack of tracking data on a fire's parameters to include speed, crowning, spotting, and wind	R22
G15	Crowdsourced Information	Non-traditional, crowdsourced information and communications (e.g., social media) are not frequently incorporated into the WUI fire common operating picture	R24
G16	Common Operating Picture	Insufficient information sharing with all disciplines and jurisdictions to create a common operating picture	R25
G17	Dispatch Centers	Public Safety Answering Point (PSAP) design and methods are not integrated with ICS	R23
G18	Fire Modeling Accuracy	Fire modeling often cannot consistently and accurately predict fire behavior	R27, R30
G19	Fire Modeling Timeliness	Fire modeling and critical information dissemination are not timely enough to support effective decision making for emergency managers	R28, R29
G20	Geographically-Targeted Warnings	Lack of systems and procedures that deliver notifications and warnings to a targeted geographic area	R31
G21	Tailored AFN Warning	Information and warning systems currently lack tailored communications to meet the specific needs of the AFN community	R32
G22	Human Factor Delays Warning	Human elements of response cause delays in dissemination of warnings (e.g., fear of backlash)	R41
G23	Social Media Warning Dissemination	Insufficient dedicated public information officers to disseminate warnings through social media during a WUI event.	R38

Gap Number	Topic	Specific Gap	Associated Requirements
G24	Smoke Monitoring and Warning	Insufficient systems for monitoring smoke and air quality to warn emergency responders and the public	R39
G25	Carrier Limitations	Public information and warning are hindered by telecommunication carrier limitations	R36, R43
G26	Warning Authorities	Inconsistent authorities on who orders an evacuation	R33, R42
G27	Warning Thresholds	Lack of consistently applied thresholds for notification and warning across agencies and jurisdictions	R34
G28	Warning Lexicon	Lack of consistently applied warning terminology across jurisdictions and types of disasters	R35
G29	Hazardous Condition Warnings	Hazardous condition warnings (e.g., the red flag system) are not integrated with fire departments and emergency manager's assessment of risk	R37
G30	Warning Tradeoffs	Tradeoffs between "warning fatigue" and the need for public awareness have not been sufficiently evaluated	R40
G31	Evacuation Status	Inability to track the status of evacuation routes, safety zones, evacuated buildings, and survivors	R45, R54, R55
G32	Public-Private Partnerships	Insufficient public-private partnerships to support evacuation efforts	R46
G33	Evacuation Modeling	Inadequate modeling of evacuation routes, population behavior, and safety areas	R52
G34	Evacuation Routes	Lack of planned, trained, exercised, and educated evacuation routes and safety zones	R44
G35	AFN Evacuation	Lack of standards and guidelines to evacuate AFN population (e.g., early evacuation warnings and appropriate transportation).	R47
G36	Evacuation Threshold	Insufficient and inconsistent thresholds to trigger evacuation and/ or shelter in place	R48

Gap Number	Topic	Specific Gap	Associated Requirements
G37	Evacuation Authorities	Inconsistent authorities on who orders an evacuation	R49
G38	Evacuation Lexicon	Inconsistent evacuation terminology across jurisdictions, disaster types, and disciplines	R50
G39	Evacuation Patterns/ Schema	Insufficient study and use of optimal evacuation patterns/ schema	R51
G40	Animal Evacuation	Lack of warnings, procedures and directions for owners to evacuate their animals	R53
G41	Positional Awareness for First Responders	Fire services lack precise "blue-force" or GPS-enabled tracking capabilities	R56, R59
G42	Connectivity for First Responders	Lack of robust systems to ensure a common operating picture and last mile connectivity	R57
G43	Cross Discipline Integration	Lack of integration between law enforcement and emergency medical services into fire response	R58
G44	Resilient Communication	Lack of resilient communication systems (e.g., hardening cell towers)	R60
G45	Power Companies/ Utilities	Inability to maintain power connectivity throughout response and access proprietary data (e.g., affected power grid information)	R61
G46	Cascading impacts	Critical infrastructure is insufficiently resilient to prevent cascading impacts	R64, R65
G47	Sensitive Sites	Protecting sensitive environmental, cultural and national security sites inhibits efficacy of response	R62
G48	High Risk Preparations	Insufficient preparation of critical infrastructure during high-risk warnings (e.g., raising municipal water levels and fueling generators)	R63, R66

Appendix E. Requirements Index

Requirement Number	Specific Requirement	Classification
R1	Need widely-accepted interoperable data standards	Policy, Standards
R2	Need pre-incident public education, including understanding of actions associated with notifications and warnings	Public Education
R3	Need pre-incident fire community preparedness (e.g. emergency responder knowledge of local risk factors and training and exercising)	Policy, Training
R4	Need the location of at-risk communities (including individuals with disabilities and others with access and functional needs population) in relation to highest risk areas and need planned and resourced procedures for each community	Technology, Standards
R5	Need mitigation measures (status of building and maintenance codes other forms of hardening, and defensible/ green space)	Policy, Technology
R6	Need multi-jurisdictional and interagency integration (i.e. regional planning and pre-identified evacuation routes)	Policy
R7	Need to identify risk to and from critical infrastructure and plan accordingly (e.g. site communications appropriately)	Technology, Standards
R8	Need commonly understood terminology and concepts for response partners and public	Public Education, Standards, Training
R9	Need a catalog of local, state, and federal WUI firefighting resources	Technology, Policy, Standards
R10	Need the public to have more realistic expectations for protection in high-risk areas.	Public Education
R11	Need pre-incident formalized communications between firefighters and the public to ensure public preparedness.	Standards
R12	Need to track highest-risk WUI areas based on fire, weather history, and fuel type (live and dead) and current conditions.	Technology, Policy

Requirement Number	Specific Requirement	Classification
R13	Need pre-established relationships with partners so that information is automatically disseminated during an incident	Policy
R14	Need fire behavior modeling to ensure sufficient scenario-based pre-incident planning	Technology, Policy, Training
R15	Need real-time and continuous identification of heat sources and smoke to detect ignition location	Technology
R16	Need widespread, automatic dissemination of detection data	Technology, Standards, Training
R17	Need integrated data for baseline risk factors (e.g., weather, fuel, topography, fire history) with real-time updates	Technology
R18	Need to exploit all source information (e.g., social media) for ignition detection	Technology
R19	Need to deconflict and process ignition data into actionable information	Technology, Standards, Training
R20	Need standardized format for ignitions that can be easily distributed an understood by emergency responders	Standards
R21	Need real-time and continuously updated tracking of fire perimeter	Technology
R22	Need real-time and continuously updated tracking of fire characteristics (e.g. intensity, spotting, crowning, spread)	Technology
R23	Need public-safety answering points that are integrated with Incident Command (IC)	Policy, Training, Technology
R24	Need to exploit all source information to inform WUI Fire tracking	Technology, Policy, Public Education
R25	Need inter-agency and inter-jurisdictional emergency responder data integration	Technology, Policy
R26	Need tracking capabilities able to penetrate smoke cover and other WUI fire conditions	Technology
R27	Need WUI Fire modeling that generates actionable and reliable data outputs	Technology

Requirement Number	Specific Requirement	Classification
R28	Need timely fire behavior modeling (i.e. updated hourly or less)	Technology
R29	Need to acquire WUI Fire modeling inputs (e.g., fuel, meteorological conditions, wind)	Technology
R30	Need WUI Fire modeling that matches specific WUI conditions	Technology
R31	Need geographically targeted notification and warning to specific areas	Technology, Policy
R32	Need effective warnings for vulnerable areas to include AFN populations	Technology, Policy, Standards
R33	Need consistent warning authorities	Policy, Standards
R34	Need consistent and tiered thresholds for warnings	Standards
R35	Need commonly understood warning terminology and concepts for response partners and the public	Policy, Standards
R36	Need telecommunication carriers to loosen limitations and improve service delivery of emergency messages	Policy, Technology
R37	Need a high-risk fire warning capability with input from key stakeholders with national reach (e.g. improve Red Flag warnings)	Policy
R38	Need to disseminate information and warnings through social media	Technology, Policy
R39	Need to warn about air quality levels (e.g. smog, smoke)	Technology, Policy
R40	Need to find a balance between warning fatigue and the need for public awareness	Policy
R41	Need to reduce human-caused delays associated with timely issuing of warnings	Technology, Standards, Policy
R42	Need multi-jurisdictional and interagency integration to warn the public in a consistent manner	Policy, Standards
R43	Need multi-platform messaging with a single source capable of national reach	Technology

Requirement Number	Specific Requirement	Classification
R44	Need identification of multiple evacuation routes, safe zones, shelter-in-place facilities and alternatives	Policy, Public Education
R45	Need population safety survivor accountability and real-time monitoring of evacuation routes	Policy, Technology
R46	Need public-private partnerships to support evacuation efforts	Policy, Technology
R47	Need standards and guidelines to evacuate individuals with disabilities and others with access and functional needs population	Policy, Standards
R48	Need consistent and tiered thresholds for evacuation warnings	Standards
R49	Need consistent evacuation authorities	Policy
R50	Need commonly understood evacuation terminology and concepts for response partners and the public	Standards, Public Education
R51	Need to identify best practices for evacuation patterns and schema	Standards, Policy
R52	Need reliable modeling of evacuation routes, population behavior, and safety areas	Technology
R53	Need to know time to evacuation or shelter in place of animals (i.e., farm, exotic, and pets)	Policy
R54	Need shared real-time situational awareness of evacuation status through social media and official channels	Technology
R55	Need an inventory of evacuation capabilities and available resources	Policy, Standards
R56	Need "blue-force tracking" for first responders in a WUI incident —including location with verified time of arrival	Technology
R57	Need common operating picture capability for WUI Fires that is interoperable	Technology, Standards
R58	Need timely information to allow for en route incident briefing and planning	Technology, Policy
R59	Need continuous hazard assessment that is distributed to emergency responders in the field	Technology

Requirement Number	Specific Requirement	Classification
R60	Need resilient communications infrastructure	Technology, Policy, Standards
R61	Need resilient power infrastructure and better partnerships with utilities	Policy, Technology
R62	Need to know sensitive site (Environmental and Cultural) locations and specific requirements for emergency responders during WUI Fires	Policy
R63	Need to prepare critical infrastructure during high-risk warnings	Policy, Standards
R64	Need resilient critical infrastructure prepared to avoid cascading impacts	Technology, Policy, Standards
R65	Need to know status of critical infrastructure necessary to respond	Technology, Policy, Standards
R66	Need to know risks posed to and from infrastructure for WUI Fires	Policy, Standards, Public Education

Appendix F. Candidate Technology Solutions Index

Technology Number	Name of Identified Technology Solution	Associated Requirements	Number of Associated Requirements	Associated Gaps
1	WFRAS (Wildland Fire Risk Assessment System)	R7, R12	2	G1A, G2A
2	Dispatchr	R7	1	G2A
3	Wildfire Risk Atlas	R7, R12	2	G1A, G2A
4	FARSITE	R12	1	G1A
5	Geostationary Operational Environmental Satellite Early Fire Detection System (GOES-FED)	R15	1	G11
6	Tanka	R15	1	G11
7	Fire Information for Resource Management System (FIRMS) / Global Fire Information Management System (GFIMS)	R16	1	G12A
8	Intterra	R25, R57, R27, R41, R58	5	G16A, G18, G22A, G42A, G43A
9	GeoMAC	R16, R25	2	G12A, G16A
10	WIFIRE	R17, R21, R27, R28, R30, R58, R59	7	G11, G13, G18, G18, G19, G41, G43A
11	Coupled Atmospheric-Wildland Fire Environment (CAWFE)	R17, R28, R30, R59	4	G11, G18, G19, G41
12	Land, Atmosphere Near Real-time Capability for EOS (LANCE)	R22, R17, R30, R59	4	G11, G14, G18, G41

Technology Number	Name of Identified Technology Solution	Associated Requirements	Number of Associated Requirements	Associated Gaps
13	Dunami	R18, R24, R54	3	G11, G15A, G31A
14	LexisNexis Social Media Monitoring	R18, R24, R54	3	G11, G15A, G31A
15	Integrated Reporting of Wildland-Fire Information (IRWIN)	R19, R41, R25	3	G12A, G16A, G22A
16	Descartes Lab Platform	R26	1	G13
17	LANDFIRE (LF) Data Distribution	R29	1	G19
18	Forest Structure Modeling Quantum Special	R29	1	G19
19	Wide-Area Mass Notification	R31	1	G20A
20	CodeRed	R31	1	G20A
21	Rumbler	R32	1	G21A
22	Accessible Hazard	R32	1	G21A
23	Hootsuite	R38	1	G23A
24	Sprinklr	R38	1	G23A
25	FEMA's Mobile App	R38	1	G23A
26	High-Resolution Rapid Refresh – Smoke (HRRR-Smoke)	R39	1	G24A
27	BlueSky Framework	R39	1	G24A
28	VSmoke-GIS	R39	1	G24A
29	Android Team Awareness Kit (ATAK)	R9, R56, R16, R21, R24	5	G3A, G12A, G13, G15A, G41

Technology Number	Name of Identified Technology Solution	Associated Requirements	Number of Associated Requirements	Associated Gaps
30	FiResponse	R57, R58	2	G42A, G43A
31	Hawkeye	R19, R15, R21	3	G11, G12A, G13
32	Zignal Labs	R18	1	G11
33	High-Altitude UAS	R22	1	G14
34	Team Connect	R54, R25	2	G16A, G31A
35	Commercial, Small UAS	R26	1	G13
36	ALOHA-CAMEO	R26	1	G13
37	FASMEE	R27	1	G18
38	CO-FPS	R28	1	G19
39	Fire Family Plus	R29	1	G19
40	MesoWest	R29	1	G19
41	Everbridge	R31	1	G20A
42	Structure Alarm	R32	1	G21A
43	CANSAC	R39	1	G24A
44	Waze	R46	1	G32A
45	Emergency Evacuation Simulator	R52	1	G33
46	Pathfinder	R52	1	G33
47	Massmotion	R52	1	G33
48	e-Sanctuary	R52	1	G33
49	Team Connect	R54, R25	2	G16A, G31A
50	Firefly	R20	1	G12A

Technology Number	Name of Identified Technology Solution	Associated Requirements	Number of Associated Requirements	Associated Gaps
51	Active911	R57, R58	2	G42A,
52	Situational Awareness for Vulnerable People Needing Evacuation (SAVE)	R32, R47	2	G21A, G35
53	Situation Awareness and Collaboration Tool (SCOUT)	N/A	0	N/A

Appendix G. Technology Scouting Reports

Fire Modeling Research Summary

Overview: Following the December 2018 Technology Scouting Request on fire modeling, the Technology Scouting Team used subject matter experts, commercial datasets, and open-source research to compile a list of relevant technology solutions across government, academia, and the private sector. The full Research Summary is outlined below.

Relevant Background

In recent years, U.S. populations have spread from densely populated cities into the rural fringes of metropolitan areas at an increased rate. These rural fringes are referred to as the Wildland-Urban Interface (WUI), or zones of human development within or adjacent to wildlands such as forests and grasslands. These WUI zones are particularly prone to wildfires. Over time, the lethality of these fires has increased due to rising population density in these areas.

Approaches to managing and fighting fires differ greatly between rural areas and urban/suburban areas. Rather than spreading through only vegetation, WUI fires spread through both vegetative and structural fuels, creating new challenges for firefighters. Additionally, while forest managers previously allowed controlled fires to burn through forests periodically, the increased population of these WUI areas has resulted in the need to extinguish fires quickly to protect nearby communities. As a result, an estimated 98% of fires have been extinguished by firefighters before they grow larger than 300 acres.[8] Because of these new practices, forests have experienced undergrowth, which significantly increases likelihood future fires will spread. This has led to recurring high-intensity fires in the WUI.

Problem Description:

DHS S&T and the Federal Emergency Management Agency (FEMA) are interested in identifying software models and tools that accurately describe the location of WUI fires in real-time and reliably forecast where they are likely to spread. However, the models used today take a considerable amount of time to run and by the time they generate results and are passed onto emergency responders in the field, the fire conditions have already changed, necessitating a new run of the model. The lack of reliable real-time information and accurate forecasting models increases the danger to firefighters and communities.

Use Case:

Technologies identified through this Technology Scouting Report may be used to support WUI fire modeling efforts. Overall, the objective of WUI fire modeling is to help incident commanders make

[8] Plumer, Brad. "There's a Better Way to Tame Large Forest Fires. So Why Don't We Do It?" Vox.com. September 17, 2015. Accessed January 15, 2019. https://www.vox.com/2015/9/17/9347361/wildfire-management-prescribed-burn.

informed and strategic decisions with respect to when/ where they should allocate resources in response to fires. Identified solutions will ideally be able to:

1. Report accurate data associated with the fire including location, size, speed, temperature, wind speed, and other air characterization and atmospheric information in real-time.
2. Forecast the projected path of the fire using a reliable predictive model to identify communities in harm's way and provide actionable intelligence.
3. Process and report real-time and predictive results with enough time for incident commanders and first responders to act.

Previous Efforts at DHS:

FEMA has established the Model Data Inventory (MODI) to identify relevant modeling tools and datasets for natural disasters, including fires.

Solution Option Categories:

Following the initial technology scan, three categories of solutions were identified:

- **Wildfire Modeling Tools:** Software models and tools that assist in decision-making and offer predictions of where wildfires or wildfire smoke will go next.
    - ***Real-time Tactical Fire Modeling***: Tools to help firefighters on the ground predict a wildfire path.
    - ***Smoke Modeling***: Tools to help first responders predict a wildfire's smoke path, which can be used to aid evacuation decisions.
    - ***Preventative Fire Risk Modeling***: Proactive and preventative tools to highlight areas of fire risk.
- **Potential Wildfire Modeling Tool Inputs**: Historical or real-time inputs relevant to a fire area (e.g., foliage, weather) that can supplement the inputs of a model and support informed operational decisions.
- **Early Fire Detection Tools**: Tools that monitor fire-prone areas, detect when fires have started, and subsequently alert authorities before wildfires grow out of control.

Additional Considerations:

As part of this effort, the Technology Scouting Team scanned government, academia, and private sector vendors to gather an inventory of the top approaches and technology solutions for the desired use case.

- **Government:** Government organizations, including federal, state, local, and foreign agencies, that have sought out unique solutions to address the complications of WUI fires.
- **Academic:** Several universities are involved with fire research and are developing various types of datasets and software models, often funded through government grants.

- **Private:** There has been significant private sector interest in modeling, prediction, and real-time fire sensors. Their products and solutions are often sold to the government, as well as other players in private industry (e.g., private fire insurance companies and the associated response teams).

Solution Option Evaluation Criteria:

Identified solutions will be evaluated using the following criteria:

- **Inputs**: Does the tool use robust, high-quality data inputs?
- **Verification**: Has the tool been verified by previous users?
- **Previous/Current Use**: Has the tool been deployed during a fire to assist with response?

The following legend corresponds with the tools found as part of these preliminary findings.

Legend		
Vendor Type		
Government	Private	Academia
Previous/Current Use		
Previously Used	Additional Information Required from Vendor	Not Previously Used

Wildfire Modeling Tools

Category #1 – Real-time Tactical Fire Modeling

#	Solution Vendor	Vendor Type	Description	Previous/ Current Use
1	**WIFIRE** University of California - San Diego (USD), University of Maryland, funded by NSF grant		**Overview:** The WIFIRE Firemap merges a robust array of sensor data with computational techniques like signal processing, data assimilation, modeling, and visualization to monitor environmental conditions and predict where and how fast a wildfire will spread. The Firemap enables analysis of various fire scenarios and the development of real-time forecasts by leveraging the UCSD Supercomputer Center. **Update Frequency:** Real-time **Inputs:** Fire modeling: FARSITE; Weather stations: HPWREN, SDG&E, and MesoWest & SynopticsLabs; Weather forecast: NOAA HRRRX and NWS National Digital Forecast Database; Cameras: HPWREN, SDG&E, UNR Seismological Laboratory, and NVBLM; Historical fire perimeters: CAL FIRE FRAP Program and USGS GeoMAC; Fuels: USGS LANDFIRE Program; Satellite fire detections: NASA FIRMS; Air quality: OpenAQ **Validation:** Researchers working with Los Angeles Fire Department (LAFD)	Thomas Fire Ventura and Santa Barbara Counties, California (2017)
2	**Coupled Atmospheric-Wildland Fire Environment (CAWFE)** National Center for Atmospheric Research (NCAR)		**Overview:** The CAWFE modeling system combines a numerical weather prediction (NWP) model that predicts how weather varies in time and space, even in complex terrain, with wildland fire behavior modules. CAWFE was developed recognizing that fires interact with the atmosphere in its immediate vicinity in unique ways that can affect speed, direction, and intensity. **Update Frequency:** Real-time **Inputs:** The CAWFE model uses data from infrared airborne fire mapping tools and satellite fire detection data to make predictions **Validation:** NCAR	USDA Forest Service
3	**Land, Atmosphere Near Real-time Capability for EOS (LANCE)** National Aeronautics and Space Administration		**Overview:** LANCE supports users interested in monitoring a wide variety of natural and man-made phenomena. Near Real-Time (NRT) data and imagery from the Atmospheric Infrared Sounder (AIRS), Advanced Microwave Scanning Radiometer 2 (AMSR2), Multi-angle Imaging SpectroRadiometer (MISR), Microwave Limb Sounder (MLS), Moderate Resolution Imaging Spectroradiometer (MODIS), (Measurement of Pollution in the Troposphere) MOPITT, Ozone Monitoring Instrument (OMI), (Ozone Mapping Profiler Suite) OMPS, and VIIRS instruments are available much quicker than routine processing allows. Most data products are available within three hours from satellite observation. NRT imagery is generally available three to five hours after observation.	NASA

			Update Frequency: Near real-time (3-5 hours) **Inputs:** AIRS, AMSR2, MISR, MLS, MODIS, MOPITT, OMI, OMPS, and VIIRS instruments **Validation:** NASA	
4	**Enterprise Geospatial Portal** Intterra		**Overview:** Intterra has built a cloud and analytics platform that provides situational awareness on a moment-by-moment basis. This platform is a foundation for National Interagency Fire Center (NIFC) Enterprise Geospatial Portal (EGP). The EGP is a visualization and analysis tool that organizes and consolidates both spatial wildland fire information and disparate geospatial data. It is used to manage emerging incidents, to develop effective preplans, and to share a common operational picture from the field to the base station. **Update Frequency:** Real-time **Inputs:** Infrared aircraft, military resources, telecom equipment for fires, Remote Automated Weather Stations (RAWS) **Validation:** NIFC ***Featured at the Wildfire Technology Summit***	 USFS, State of Colorado, over 6,000 fire fighters
5	**Wildfire Analyst & fiResponse** Technosylva, Inc.		**Overview:** Wildfire Analyst software conducts wildfire behavior and spread simulations for both desktop and web services platforms, delivering real-time modeling capabilities to first responders. Wildfire Analyst was developed to support initial fire attack operations, giving the Fire Chief and Incident Commander the critical intelligence needed to support suppression and resource allocation. fiResponse is an enterprise wide decision support system that provides capabilities for monitoring wildland fire incidents and all associated operational activities related to incident response, dispatch, and resource tracking. The product is designed with multiagency use in mind, enabling data sharing between different users and works over both web and mobile platforms. **Update Frequency:** Real-time **Inputs:** The software can use predefined weather scenarios or current and forecasted weather obtained via web services. Additional vendor outreach required for details **Validation:** USFS, USDA ***Featured at the Wildfire Technology Summit***	 USFS, USDA Fire Lab, Esri, SDGE, Services of Colorado State, and others

6	**Integrated Reporting of Wildland-Fire Information (IRWIN)** USDA and U.S. DOI		**Overview:** IRWIN is a Wildland Fire Information and Technology (WFIT) affiliated investment, intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage wildland fire incident data. IRWIN is focused on reducing redundant data entry, identifying authoritative Inputs, and improving the consistency, accuracy, and availability of operational data. **Update Frequency:** Near real-time (3-5 hours) **Inputs:** Fire location, size, environmental conditions, and resources. **Validation:** Wildland Fire Information and Technology, U.S. DOI	 USDA, U.S. DOI
7	**The Geospatial Multi-Agency Coordination (GeoMAC)** U.S. Department of the Interior		**Overview:** The Geospatial Multi-Agency Coordination (GeoMAC), is an internet-based mapping application originally designed for fire managers to access online maps of current fire locations and perimeters in the United States. Using a standard web browser, fire personnel can view this information to pinpoint the affected areas. **Update Frequency:** Daily **Inputs:** GPS data, infrared (IR) imagery from fixed wing and satellite platforms. **Validation:** USDA, U.S. DOI	 USDA, U.S. DOI
8	**Weather Research and Forecasting (WRF-FIRE)** NCAR and University of Colorado at Denver		**Overview:** WRF-FIRE is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. It features two dynamical cores, a data assimilation system, and a software architecture supporting parallel computation and system extensibility. **Update Frequency:** Real-time **Inputs:** LandFire, topography, atmospheric data, fire perimeters, and ignition. Utilizes physics, numeric, and data assimilation methods developed through scientific research **Validation:** USDA	 National Centers for Environ-mental Predic-tion, Universi-ties, and private compan-ies
9	**Wildland Fire Decision Support System (WFDSS)** Wildland Fire Management Research,		**Overview:** WFDSS is a software that uses geospatial data and fire spread models to inform resource allocation and deployment. The model is used for operational decision-making. As fire incidents escalate in size and complexity, WFDSS provides support through different analytical tools as fire conditions change. Fire spread models generate a predicted footprint of the fire, outlining its likely spread over a specified time. The model	 Wildfire Season 2012 Rocky

	Development and Application		footprint is used to query other spatially registered data including representations of private and public building locations, land ownership, critical infrastructure, and important animal and plant habitats. The resulting values are mapped and displayed to provide strategic situational awareness to incident commanders and agency administrators. **Update Frequency:** Real-time **Inputs:** Wildfire risk, geospatial data, representations of private and public building locations, land ownership, critical infrastructure, and important animal and plant habitats **Validation:** Wildland Fire Management Research has validated this model	Mountains, Colorado
10	**Fire Management** Dispatchr		**Overview:** Dispatchr is a software platform that leverages big data and AI to prevent disasters for the leading utility providers. They specialize in preventing both wildfires and power outages caused by extreme weather or equipment failure. They've worked with utility providers in the past to cover a 70,000 square mile area to prevent over a dozen wildfires and other power outages, that would have left millions without power. Their fire management program includes a database of all utility equipment, easy dispatching to potential fire events and real-time utility crew location tracking. **Update Frequency:** Real-time **Inputs:** Weather Data, real-time crew GPS tracking, utility company data / resource location, **Validation:** Partnered with Hitachi to support a Utility Company ***Featured at the Wildfire Technology Summit****	Utility companies
11	**BehavePlus** USFS, Rocky Mountain Research Station & Systems for Environmental Management		**Overview:** The BehavePlus fire modeling system is a Windows®-based computer program that can be used for any fire management application that needs to calculate fire behavior. It uses specified fuel and moisture conditions to simulate surface and crown fire rates of fire spread and intensity, probability of ignition, fire size, spotting distance, and tree mortality. **Update Frequency:** Daily **Inputs:** Spotting distance, probability of ignition, spot fire growth, and probability of containment **Validation:** Rocky Mountain Research Station; Smoke Science Program	USDA Forest Service
12	**FireFamilyPlus** Fire Research and Management Exchange System (FRAMES)		**Overview:** FireFamilyPlus (FF+) is a software package used to calculate fuel moistures and indices from the U.S. National Fire Danger Rating System (NFDRS) using hourly or daily fire weather observations primarily from Remote Automated Weather Stations (RAWS). NFDRS use is mandated for fire preparedness and response decisions by all Federal and most State agencies and is operationally run with USFS FAM Weather Information Management System (WIMS). FF+ has several subsystems. First, it provides all the necessary model calculations to produce fuel moistures	Additional vendor outreach required

			and fire danger indices for the NFDRS 1978, 1988, and the newly added NFDRS 2016, as well as the Canadian Forest Fire Danger Rating System and the Fosberg Fire Weather Index. Second, the system includes the ability to compare fire danger indices to agency fire reports and establish breakpoints for decision making on local units. **Update Frequency:** Hourly **Inputs:** Hourly or daily fire weather observations primarily from Remote Automated Weather Stations (RAWS) **Validation:** U.S. National Fire Danger Rating at the USFS	
13	**RZAlert** RedZone		**Overview:** RedZone's models predicted which homes in Coffey Park, California, would burn in a major wildfire with more than 90% accuracy. RedZone markets the product to insurance companies; however, the software could have applications for emergency management agencies. They currently monitor first responder network feeds to monitor fire position. **Update Frequency:** Real-time **Inputs:** LAFD helicopter feeds, emergency response paging networks, dispatch alerts. **Validation:** AIG Wildfire Protection Unit	 Camp Fire California 2018

Wildfire Modeling Tools

Category #2 – Smoke Modeling

#	Solution Vendor	Vendor Type	Description	Previous/ Current Use
1	**High-Resolution Rapid Refresh-Smoke (HRRR-Smoke)** NOAA Earth Systems Laboratory (ESRL), Cooperative Institute for Research in Environmental Science		**Overview:** HRRR-Smoke is an experimental model that has accurately predicted the behavior of wildfire smoke. Built on NOAA's High-Resolution Rapid Refresh (HRRR), which forecasts rain, wind and thunderstorms, the HRRR-Smoke produces four forecasts a day and predicts 36 hours into the future, mapping forecasts into a three-dimensional grid that spans 16 miles into the atmosphere. **Update Frequency:** 12 hours **Inputs:** Real-time data from the Joint Polar Satellite System's Suomi-NPP and NOAA-20 polar-orbiting satellites as well as NASA's Terra and Aqua satellites **Validation:** NOAA ESRL has run internal tests on the model	 NOAA, U.S. Depart-ment of Transport-ation
2	**BlueSky Framework** USDA Forest Service Pacific Northwest (PNW) Research Station		**Overview:** BlueSky is a framework that contains and combines models and data about weather, fires and fuels, emissions, and terrain. By integrating these models into a unified framework, BlueSky can predict smoke concentrations and trajectories, and can be used to create forecasts helpful to land and fire managers. **Update Frequency:** Daily **Inputs:** FCCS fuel loading map, Emissions Production Model (EPM), CALPUFF puff-dispersion model **Validation:** USDA Forest Service Pacific Northwest (PNW) Research Station	 National Weather Service
3	**WindNinja** USDA Forest Service		**Overview:** WindNinja is a computer program that computes spatially varying wind fields for wildland fire and other applications requiring high resolution wind prediction in complex terrain. It was developed to be used by emergency responders within their typical operational constraints of fast simulation times (seconds), low central processing unit (CPU) requirements (single processor laptops), and low technical expertise. WindNinja is typically run on domain sizes up to 50 kilometers by 50 kilometers and at resolutions of around 100 meters. **Update Frequency:** Seconds **Inputs:** NWS mesoscale weather model data, surface wind measurements, average surface wind speed and direction, elevation data for the modeling area, date and time, dominant vegetation type	 Further Vendor outreach required

			Validation: USFS	
4	**VSmoke-GIS** USDA Forest Service		**Overview:** The VSmoke-GIS smoke dispersion model is unique when compared to other point source models (i.e., smoke stack models), because it allows the user to control what percentage of the smoke is dispersed at ground level, and how the remaining smoke rises to maximum height in the atmosphere. The VSmoke-GIS model predicts the maximum downwind distance a PM2.5 (fine particle) concentration travels. The model works on hour intervals to produce the "worst case" predictions of what the fine particulate concentrations may have been downwind of the fire. **Update Frequency:** 1 hour **Inputs:** Geostationary Satellite (GOES) **Validation:** National Interagency Fire Center	 National Intera-gency Fire Center
5	**Satellite Smoke Text Product** Satellite Services Division (SSD)		**Overview:** This text product is an analysis of the visible smoke plumes over North America and primarily covers those affecting the United States. If a source of the plume is known, that information may also be included. Areas of smoke are analyzed using GOES-EAST and GOES-WEST Visible satellite imagery and only a general description of areas of smoke or significant smoke plumes will be analyzed. A quantitative assessment of the density/amount of particulate or the vertical distribution is not included. Widespread cloudiness may prevent the detection of smoke even from significant fires. **Update Frequency:** Daily **Inputs:** Satellite **Validation:** NOAA	 NOAA Satellite Services Division (SSD) Further Vendor outreach required

Wildfire Modeling Tools				
Category #3 – Preventative Fire Risk Modeling				
#	**Solution** Vendor	**Vendor Type**	**Description**	**Previous/ Current Use**
1	**FARSITE** USDA's Rocky Mountain Research Station		**Overview:** FARSITE is a fire growth simulation modeling system. It uses spatial information on topography and fuels along with weather and wind files. It incorporates existing models for surface fire, crown fire, spotting, post-frontal combustion, and fire acceleration into a two-dimensional fire growth model. **Inputs:** Spatial and tabular landscape (.LCP), Initial Fuel Moistures (.FMS), Custom Fuel Model (.FMD), Conversion (.CNV), Weather (.WTR), and Wind (.WND) data **Validation:** FARSITE is widely used by the USFS, National Park Service, and other federal and state land management agencies	 Widely used by USFS, National Park Service, and other agencies
2	**WFRAS (**Wildland Fire Risk Assessment System) Sanborn Map Company		**Overview:** WFRAS is a robust suite of wildfire risk assessment methods and software tools. WFRAS has been deployed at regional and local planning departments, providing a repeatable, consistent, and comparable approach for assessing current wildfire risk. WFRAS also includes tools to quantify the risk to areas of concern, such as communities in the WUI. It produces threat assessment maps by combining historical fire ignitions, weather observations, surface fuels, canopy characteristics, and other input data with robust fire science. In addition, by integrating census and assessor data, WFRAS can quantify potential impacts of fires, including estimates for economic and social impacts such as the dollar value of exposed structures, commodity agriculture, plantations, etc. **Inputs:** Aerial photography, datasets for wildfire probability, surface fuel types, historical fire parameters, census data **Validation:** Meets FEMA Hazard Mitigation Plans in support of DMA 2000	 Western Colorado Wildfire Mitigation Task Force, Federal, State Local govern-ment contracts across U.S. for emergen-cy response; Middle East oil and gas company

3	**Wildfire Risk Atlas** Technosylva, Inc.		**Overview:** Wildfire Risk Atlas is a risk-based assessment service. Technosylva works closely with state agencies to develop an interactive web mapping application that provides tools for planners, decision makers, and the public to utilize risk assessment outputs immediately. **Inputs:** The software can use predefined weather scenarios or current and forecasted weather obtained via web services. Vendor outreach required for details. **Validation:** This tool has been used since 1998 to provide predictive capabilities to government and private clients; however, additional vendor outreach is required to validate details. ***Featured at the Wildfire Technology Summit****	 State of Colorado
4	**FOFEM** (First Order Fire Effects Model) USDA Forest Service		**Overview:** FOFEM is a model for predicting tree mortality, fuel consumption, smoke production, and soil heating caused by prescribed fire or wildfire. First order fire effects are those that concern the immediate consequences of fire. First order fire effects form an important basis for predicting secondary effects such as tree regeneration, plant succession, and changes in site productivity. However, these long-term effects generally involve interaction with many variables (e.g., weather, animal use and disease) and are not predicted by this program. FOFEM provides quantitative fire effects information for tree mortality, fuel consumption, mineral soil exposure, smoke, and soil heating. **Inputs:** Tree mortality, fuel consumption mineral soil exposure, smoke and soil heating. **Validation:** USDA, USFS	 USDA, USFS
5	**Wildfire Model for the United States** AIR Worldwide		**Overview:** AIR uses historical fire data to characterize fire behavior in different ecological regions of North America, known as eco-provinces, and uses unique spread models based on recent scientific approaches to create stochastic fires for each of these regions. This wildfire model probabilistically simulates how fires spread into areas based on wind speed and direction, availability of fuels, terrain, and likelihood of suppression. **Inputs:** Historical fire and meteorological data. Additional vendor outreach required for more information. **Validation:** Additional vendor outreach required.	 Insurance companies, Corporate Risk Managers, and Governments. Vendor outreach required

6	**RZExposure** RedZone		**Overview:** RZExposure is a risk-based wildfire modeling platform that allows insurers to underwrite homes with confidence. It accounts for traditional risk scores based on factors such as wildfire frequency and history, as well as incorporates how often wildfires are expected for a specific location. **Inputs:** Information such as immediate hazards near a property and the proximity to areas capable of producing significant ember showers. **Validation:** Additional vendor outreach required	 National under-writers and claim mangers
7	**The National Fire Danger Rating System (NFDRS)** USDA Forest Service		**Overview:** The National Fire Danger Rating System (NFDRS) is a system that allows fire managers to estimate today's or tomorrow's fire danger for a given area. It combines the effects of existing and expected states of selected fire danger factors into one or more qualitative or numeric indices that reflect an area's fire protection needs. It links an organization's readiness level (or pre-planned fire suppression actions) to the potential fire problems of the day. **Inputs:** Fuels, weather, topography, risks, readiness levels **Validation:** USDA, USFS	 USDA, USFS
8	**FlamMap** USFS		**Overview:** The FlamMap fire mapping and analysis system (Finney 2006; Stratton 2006) is a PC-based program that describes potential fire behavior for constant environmental conditions (weather and fuel moisture). The FlamMap software creates maps of potential fire behavior characteristics (e.g., spread rate, flame length, crown fire activity) and environmental conditions (e.g., dead fuel moistures, mid-flame wind speeds, and solar irradiance) over an entire FARSITE landscape. These raster maps can be viewed in FlamMap or exported for use in a GIS, image, or word processor. **Inputs:** Potential fire behavior calculations include surface fire spread crown fire initiation, and crown fire spread. Dead fuel moisture is calculated using the Nelson model and FlamMap permits conditioning of dead fuels in each pixel based on slope, shading, elevation, aspect, and weather **Validation:** USFS, National Park Service	 USFS, National Park Service, and other federal and state land manage-ment agencies
9	**National Significant Wildland Fire Potential Outlooks** National Interagency Fire Center (NIFC)		**Overview:** The main objective of the National Significant Wildland Fire Potential Outlooks is to improve information available to fire management decision makers. These fire outlook assessments are designed to inform decision makers for proactive wildland fire management, thus better protecting lives and property, reducing firefighting costs, and improving firefighting efficiency. **Inputs:** Satellites, Weather forcast **Validation:** National Interagency Fire Center (NIFC), Natural Resources Canada	 National Intera-gency Fire Center (NIFC), Natural Resources Canada

Potential Fire Model Inputs

#	Solution Vendor	Vendor Type	Description	Previous/ Current Use
1	**Visible Infrared Imaging Radiometer Suite (VIIRS)** NCAR, University of Maryland (UMD)		**Increases Accuracy of:** Fire Perimeter **Overview:** VIIRS is a small device placed on NOAA's Suonmi NPP weather satellite which can observe the Earth's surface at a much finer scale than the average satellite sensor. Shifting through the troves of data sent back from VIIRS, University of Maryland identifies signature patterns that denote wildfire activity. By feeding the resulting fire image data into models every 12 hours, scientists can depict the outlines of a fire with a high degree of accuracy, even when fires have lasted for several weeks. **Inputs:** Imagery from the Suomi-NPP satellite and radiometric signals from 4 microns and 11-micron bands **Validation:** UMD scientists, NOAA, and National Firefighting Agencies have validated this model	 Thomas Fire Ventura and Santa Barbara Counties, California (2017)
2	**Descartes Lab Platform** Wildfire Signals		**Increases Accuracy of:** Vegetation **Overview:** Descartes Wildfire Signals system scrapes Inciweb, a government interagency incident management platform, for a list of active fires verified by the USFS. It then sources imagery from GOES-16 – a geostationary satellite that snaps pictures of the entire Western Hemisphere every five minutes – and from two other satellites, Landsat 8 and Sentinel 2. The updates could help evacuees in the path of a wildfire avoid smoky areas. Additionally, because it tweets constantly, even at night when it is harder to see smoke plumes with the naked eye, the system could provide more warning time than other systems for those affected. Alongside the launch of the Twitter bot, Descartes is working to get a version of the system in the hands of first responders. The company has built a dedicated feed for the Santa Fe National Forest and is developing a computer vision platform that can detect fires in satellite imagery before they are flagged by the Forest Service. **Inputs:** Daily satellite imagery from public and commercial sources **Validation:** DARPA ***Featured at the Wildfire Technology Summit****	 DARPA, Santa Fe National Forest

3	**Fire Information for Resource Management System (FIRMS)** University of Maryland funded by NASA & United Nations		**Increases Accuracy of:** Fire Perimeter **Overview:** FIRMS distributes Near Real-Time (NRT) active fire data within 3 hours of satellite overpass from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and NASA's Visible Infrared Imaging Radiometer Suite (VIIRS). The MODIS algorithm examines each pixel of the MODIS swath and ultimately assigns one of the following classes: missing data, cloud, water, non-fire, fire, or unknown. Most locations will receive three to four looks per day by FIRMs, making it especially useful for tracking and modeling ongoing wildfires. **Inputs:** NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and NASA's Visible Infrared Imaging Radiometer Suite (VIIRS) are used in this tool **Validation:** United Nations, NASA, and University of Maryland	 United Nations, NASA Vendor outreach required for specific cases
4	**MQ-9 Predator-B** General Atomics		**Increases Accuracy of:** Fire Perimeter **Overview:** The MQ-9 Predator-B is an unmanned aerial vehicle (UAV) capable of remotely controlled or autonomous flight operations. It was developed by General Atomics Aeronautical Systems (GA-ASI) primarily for the United States Air Force. The UAV captures live video (including thermal imaging) from 20,000 feet and can stay in the air for hours, identifying where fire is spreading. **Inputs:** UAVs can be outfitted with various cameras and sensors, such as thermographic cameras and high definition cameras, to inform incident command about real-time fire progression **Validation:** United States Air Force, California Air National Guard, U.S Customs and Border Protection	 San Diego Fire Rescue and California Air National Guard (2017), Cal Guard (2013), U.S. Customs and Border Protection
5	**Weather Information System (WIMS)** USFS and Rocky Mountain Research Program		**Increases Accuracy of:** Weather **Overview:** WIMS is a mission critical national system managed and maintained by USDA and Forest Service's Fire and Aviation Management (F&AM) branch for interagency use. WIMS serves as the processor for the National Fire Danger Rating System (NFDRS), using weather observations and NWS forecast to generate indices **Inputs:** National Weather Service Telecommunications Gateway (NWSTG); Satellite, RAWS Gateway; Direct observations from field locations **Validation:** National Fire Applications at the USDA National Information Technology Center	 USFS

6	**LANDFIRE (LF) Data Distribution** United States Geological Survey (USGS), Department of the Interior, and the USFS		**Increases Accuracy of:** Vegetation **Overview:** LANDFIRE is a shared wildland fire management program, providing landscape scale geospatial products to support cross-boundary planning, management, and operations. The dataset is fed by a variety of near-real time solutions as well as the Landsat-8 satellite, which was developed by NASA for the USGS and images the entire Earth every 16 days. **Inputs:** Landsat satellite imagery; Burned Area Reflectance Classification (BARC); Rapid Assessment of Vegetation Condition after Wildfire (RAVG); Monitoring Trends in Burn Severity (MTBS); LF Events Geodatabase; User contributed data; Fuel data describe the composition and characteristics of surface and canopy fuel; Vegetation layers; Landsat Data Continuity Mission (LDCM); National Land Cover Database (NLCD) **Validation:** USDA and U.S. DOI	 Currently used by WIFIRE, WRF-Fire, WFDSS, and other models
7	**CruiseBoost** Silvia Terra		**Increases Accuracy of:** Vegetation **Overview**: CruiseBoost uses satellite imagery to analyze forest vegetation and determine characteristics such as average tree size, volume, and quality. For areas that it cannot image, it recommends areas to "cruise" to gather data more efficiently. This data are important because accurate vegetation measurements can greatly affect the accuracy of modeling software. **Inputs:** Landsat, National Agriculture Imagery Program, and Digital Elevation Models **Validation:** NASA	 Vendor outreach required
8	**Forest Structure Modeling** Quantum Spatial		**Increases Accuracy of:** Vegetation **Overview**: The wildfire modeling software uses LiDAR to provide information on land use and management practices, fire suppression planning, and fuel loading calculations. High resolution LiDAR also provides detailed terrain models for the determination of slope and aspect, as well as the identification of access roads. **Inputs:** LiDAR **Validation:** U.S. Bureau of Land Management ***Featured at the Wildfire Technology Summit****	 U.S. Geological Survey, Idaho Army National Guard

9	**Fixed Remote Automated Weather Station** FTS		**Increases Accuracy of:** Weather **Overview**: The FTS fixed Remote Automated Weather Station (RAWS) is the standard for remote automated weather stations used in North America for fire weather monitoring. It is designed specifically for the interests of fire and fuels management agencies – i.e., for use in remote areas and requiring only annual service and maintenance. **Inputs:** Wind speeds, Air temperature / relative humidity, Rain gauge, Barometric pressure, Ultrasonic snow depth **Validation:** U.S. National Fire Rating System ***Featured at the Wildfire Technology Summit****	 Parks Canada
10	**ArcFuels** USDA Forest Service National Forest System		**Increases Accuracy of:** Vegetation **Overview**: ArcFuels is a toolbar implemented in ArcMap which creates a trans-scale (stand to large landscape) interface to apply pre-existing forest growth (e.g., Forest Vegetation Simulator) and fire behavior models (e.g., FlamMap) to aid in vegetation management, fuel treatment planning, wildfire behavior modeling, and wildfire risk assessments. The ArcMap framework helps users incorporate data from a variety of sources to address project-specific issues that typify many fuel treatment projects. ArcFuels was built to accommodate ArcGIS raster data (such as LANDFIRE data) and/or forest inventory data. ArcFuels provides a logical flow from stand to landscape analyses of vegetation, fuel, and fire behavior, using several different models in a simple user interface within ArcMap. **Inputs:** Fire behavior metrics, including fire spread, intensity, likelihood, and ecological risk **Validation:** USDA	 Western Wildland Environ-mental Threat Assess-ment Center
11	**FFE-FVS** USDA Forest Service National Forest System		**Increases Accuracy of:** Vegetation **Overview**: The Fire and Fuels Extension (FFE) to the Forest Vegetation Simulator (FVS) simulates fuel dynamics and potential fire behavior over time in the context of stand development and management. Existing models of fire behavior and fire effects were added to FVS to form the FFE extension. New sub models representing snag and fuel dynamics were created to complete the linkages. Additional outputs available from FFE include estimates of stored carbon and coarse woody debris. **Inputs:** Fire behavior, fire effects, fuel loading, and snag dynamics, live tree, dead tree, down dead wood and forest floor biomass information **Validation:** USDA	 USDA, further Vendor outreach required

12	**FuelCalc** USDA Forest Service		**Increases Accuracy of:** Vegetation **Overview**: FuelCalc is useful for planning fuel treatments, as well as for estimating the effects of wildfire on surface and canopy fuel characteristics. FuelCalc works by simulating changes in ground, surface, piled, and canopy fuel loads. The FOFEM, Burnup, and Nexus simulation models are used for predicting stand structure and fuel loading changes post fire. FuelCalc input files can be created in the FFI ecological monitoring software **Inputs:** Ground, surface, and canopy fuel characteristics **Validation:** USDA and USFS	 USDA, USFS

Early Fire Detection Tools

#	Solution Vendor	Vendor Type	Description	Previous/ Current Use
1	**Geostationary Operational Environmental Satellite Early Fire Detection System (GOES-FED)** University of California Davis, USFS	 	**Overview:** The GOES-FED program optimizes data processing to help detect ignitions as early as 15-30 minutes after fire ignition. Geostationary satellites circle the Earth in geosynchronous orbit, which means they orbit the Earth's equatorial plane at a speed matching the Earth's rotation. This allows them to stay in a fixed position in the sky, remaining stationary with respect to a point on the ground. **Update Frequency:** 15-30 minutes **Inputs:** Heat sensors on satellites, NOAA weather satellites, and fire-detection algorithms **Validation:** UC Davis and the USFS	 USFS
2	**Tanka** (in coordination with: Planet Labs, Inc., and Natural Resources Canada)	,  	**Overview:** Tanka provides machine learning to parse through satellite data (provided by Planet Labs, Inc) and find smoke and flame from forests across Canada's wilderness areas. Tanka then sends the Canadian National Research Council the coordinates of any fires that have started in the last 24 hours, along with information about size, speed, and what kind of fuel is in the area. **Update Frequency:** 5-15 minutes **Inputs:** Planet Labs' 178 "dove" satellites, 5 RapidEye satellites, and Tanka's machine learning software **Validation:** Natural Resources Canada	 Natural Resources Canada
3	**Moderate Resolution Imaging Spectroradiometer (MODIS)** NASA, University of Maryland, USFS	 	**Overview:** The MODIS sensor is on NASA's AQUA and TERRA satellites that view the entire Earth's surface every 12-16 hours, depending on location. The sensors on MODIS show heat sources, which are useful for detecting early wildfires. Machine learning algorithms are used to detect fires from the satellite imagery. **Update Frequency:** 12-16 hours **Inputs:** Heat sensors on satellites **Validation:** NASA	 Noatak, Alaska wildfires (early 2000s), used by FIRMS solution
4	**Hazard Mapping System Fire and Smoke Product**		**Overview:** The Product shows detected hot spots and smoke plumes indicating possible fire locations. This is a blended product using algorithms from the GOES Imager, the POES AVHRR, and MODIS. A quality control procedure is performed on the automated fire detections.	 SSD Fire Team

	NOAA Office of Satellite and Product Operations		**Update Frequency:** Daily **Inputs:** Satellite Data, Automated Fire Detection Algorithms, Ancillary Data Layers **Validation:** NOAA	NOAA, Further Vendor outreach required
5	**High Performance Wireless Research & Education Network (HPWREN)** University of California San Diego, Scripps		**Overview:** HPWREN, a partnership project led by the San Diego Supercomputer Center and the Scripps Institution of Oceanography, supports Internet-data applications in research, education, and public safety. HPWREN can provide live feeds from most of its cameras and couple it with its broad array of sensor data across the United States. to help determine the early start of fires. Inputs do not include satellite heat sensors. **Update Frequency:** Real-time video feeds **Inputs:** Heat sensors on satellites and machine learning algorithms to detect fires on these sensors **Validation:** NASA	 Used in WIFIRE solution, vendor outreach required for more information
6	**Alert Wildfire** The University of Nevada, Reno (UNR), University of California San Diego (UCSD), and the University of Oregon (UO)		**Overview:** ALERTWildfire is a consortium of three universities – The University of Nevada, Reno (UNR), University of California San Diego (UCSD), and the University of Oregon (UO) – providing access to state-of-the-art Pan-Tilt-Zoom (PTZ) fire cameras and associated tools to help firefighters and first responders. The camera system helps identify, locate, and confirm fire ignition, monitor fire behavior through containment. and help inform evacuations through added situational awareness. Its current deployment is focused on the west coast (e.g., Tahoe, Nevada, San Diego). **Update Frequency:** Real-time **Inputs:** Real-time video feeds **Validation:** Bureau of Land Management, USFS	 600 fires, including the Woolsey, Lilac, Wall, Whittier, Thomas, Tule, Wood-chuck, Earth-stone, Truckee, Draw, Snow-storm, Hot Pot, and Emerald fires
7	**Automated Biomass Burning Algorithm**		**Overview:** The Wildfire Automated Biomass Burning Algorithm (WFABBA) processing system uses geostationary satellite data to detect and characterize biomass burning. WFABBA was developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) within the Space Science and Engineering Center (SSEC) at University of Wisconsin (UW-	SSD Fire Team NOAA, Further Vendor

	NOAA / NESDIS / STAR and UW-CIMSS		Madison) as a collaborative effort between NOAA / NESDIS / STAR and UW-CIMSS personnel. **Update Frequency:** Daily **Inputs:** GOES-16 **Validation:** NOAA / NESDIS / STAR and UW-CIMSS personnel	outreach required
8	**Fire Id, Mapping and Monitoring Algorithm (FIMMA)** NOAA/ NESDIS Office of Research and Applications		**Overview:** The FIMMA is an automated algorithm to detect fires from Advanced Very High Resolution Radiometer (AVHRR) data from NOAA polar-orbiting satellites. The FIMMA product was developed by CIRA by modifying an algorithm developed at the University of Maryland. The current version uses geo-corrected High Resolution Picture Transmission (HRPT) AVHRR data over the U.S. (including Alaska and Hawaii). **Update Frequency:** Daily **Inputs:** NOAA polar-orbiting satellites **Validation:** NOAA	SSD Fire Team NOAA, Further Vendor outreach required

Post Fire Modeling / Damage Impact Assessment				
#	**Solution** Vendor	**Vendor Type**	**Description**	**Previous/ Current Use**
1	**Monitoring Trends in Burn Severity (MTBS)** U.S. Geological Survey Center for Earth Resources Observation and Science (EROS) and the USDA Forest Service Geospatial Technology and Applications Center (GTAC)		**Overview:** An interagency program with a goal to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present. This includes all fires 1000 acres or greater in the western United States and 500 acres or greater in the eastern Unites States. The extent of coverage includes the continental US, Alaska, Hawaii, and Puerto Rico. The program is conducted by the U.S. Geological Survey Center for Earth Resources Observation and Science (EROS) and the USDA Forest Service Geospatial Technology and Applications Center (GTAC) **Inputs:** Landsat data **Validation:** USDA, USFS, U.S. DOI, NASA	 USDA Forest Service, NASA
2	**NASA RECOVER** NASA		**Overview:** Rehabilitation Capability Convergence for Ecosystem Recovery (RECOVER) is a GIS-based web map application designed to enable fire managers to develop better informed post-fire recovery plans. For example, RECOVER is compiling an online database of geospatial data (land cover, natural resources, transportation, etc.) for the state of Idaho. **Inputs:** Database of geospatial data (land cover, natural resources, transportation, etc.) **Validation:** Idaho Department of Lands, U.S. DOI, NASA	 NASA, Idaho Depart-ment of Lands

Relevant Agencies | Key Wildfire Resources				
#	Group	Agency Type	Description	Link
1	**Predictive Services Program** National Interagency Fire Center (NIFC)		**Overview:** NIFC was developed to provide decision support information needed to be more proactive in anticipating significant fire activity and determining resource allocation needs. The Predictive Services Program consists of three primary functions: • Fire weather • Fire danger/ fuels • Intelligence/ resource status information Within NIFC is the National Interagency Coordination Center (NICC) and the National Multi-Agency Coordination Group (NMAC). Overviews are listed below respectively: **NICC –** Oversees all interagency coordination activities throughout the United States. When a fire is reported, the local agency and its firefighting partners respond. If the fire continues to grow, the agency can ask for help from its geographic area. When a geographic area has exhausted all its resources, it can turn to NICC at the NIFC for help in locating what is needed, from air tankers to radios to firefighting crews to incident management teams. **NMAC** – Establishes Preparedness Levels throughout the calendar year to help assure that firefighting resources are ready to respond to new incidents. Preparedness Levels are dictated by fuel and weather conditions, fire activity, and resource availability. The five Preparedness Levels range from one to five, with five being the highest level. Each Preparedness Level has specific management directions. As the Preparedness Levels rise, more federal and state employees become available for fire mobilization if needed.	**Website:** NIFC NICC NMAC
2	**U.S. National Park Service (NPS)**		**Overview:** The National Park Service is an agency of the United States federal government that manages all national parks, many national monuments, and other conservation and historical properties with various title designations. The National Park Service's Wildland Fire Program protects the public, communities, and infrastructure; conserves natural and cultural resources; and restores and maintains ecological health. NPS oversees 419 areas covering more than 85 million acres in every state, the District of Columbia, American Samoa, Guam, Puerto Rico, and the Virgin Islands. These areas include national parks, monuments, battlefields, military parks, historical parks, historic sites, lakeshores, seashores, recreation areas, scenic rivers and trails, and the White House	**Website:** NPS

3	**U.S. Forest Service (USFS)**		**Overview:** USFS is an agency of the USDA that administers the nation's 154 national forests and 20 national grasslands, which encompass 193 million acres (780,000 km^2). Major divisions of the agency include the National Forest System, State and Private Forestry, Business Operations, and the Research and Development branch. Managing approximately 25 percent of federal lands, it is the only major national land agency outside the U.S. Department of the Interior. The USFS has managed wildland fire for more than 100 years. As one of the world's premiere firefighting agency, they provide critically needed resources to protect at-risk communities.	**Website**: USFS
4	**Bureau of Land Management (BLM)**		**Overview:** BLM, a leader in the nation's management of wildland fires, carries out a broad range of actions to protect the public, natural landscapes, wildlife habitat, and other values and resources. The agency's national Fire and Aviation Program, which focuses on public safety as its top priority, consists of fire suppression, preparedness, predictive services, vegetative fuels management, prescribed fires, community assistance and protection, and fire prevention through education. To meet its wildland fire-related challenges, the BLM fields highly trained firefighters and managers who are committed to managing fire in the most effective ways.	**Website**: BLM
5	**Northern California Geographic Area Coordination Center (ONCC)**		**Overview:** ONCC is the focal point for coordinating the mobilization of resources for wildland fire and other incidents throughout California. Located in Redding, CA, the Center also provides Intelligence and Predictive Services related-products designed to be used by the internal wildland fire community for purposes of wildland fire and incident management decision-making. The Intelligence Section provides fire management personnel, incident managers, firefighters. This section also provides support staff with access to current intelligence on preparedness levels, fire situation, resources, mapping and satellite imagery climatology data, emergency preparedness levels, resource availability and rotations, and fire potential information. It sources satellite imagery from a host of providers including: MODIS, NOAA Satellite Hazard Mapping System GIS Viewer, and NOAA Current GOES 1km VIS Satellite Imagery.	**Website**: ONCC
6	**U.S. Geological Survey (USGS)**		**Overview:** USGS provides science about the natural hazards that threaten lives and livelihoods, as well as the water, energy, minerals, and other natural resources Americans rely on. Their scientists develop new methods and tools to supply timely, relevant, and useful information about the Earth and its processes. USGS provides maps of current fire locations and perimeters in the conterminous 48 States and Alaska as well as topography information that could influence the spread of fires.	**Website**: USGS

7	**National Weather Service (NWS) Storm Prediction Center (SPC) Fire Weather Program**		**Overview:** Provides national fire weather guidance products intended to delineate areas of the contiguous U.S. where the pre-existing fuel conditions, combined with forecast weather conditions, will result in a significant threat for wildfires	**Website:** NWS SPC
8	**NASA Wildfire Programs**		**Overview:** Wildland fire research and applications spans across multiple NASA programs. NASA Earth observations and models are used to support pre-, active- and post-fire research, as well as the applicable use of these data and products in support of management decisions and strategies, policy planning and in setting rules and regulations. The USFS and NASA work closely to ensure data are quickly available for regional planning, fire identification and model initialization. Furthermore, through the NASA Applied Science Program Wildland Fires, Principle Investigators and their teams have rapidly responded to numerous national and international fire events to provide information critical to disaster mitigation.	**Website:** Wildfire Programs
9	**R-Tech**		**Overview:** The First Responder Technologies Division (R-Tech) works closely with the nation's emergency response community to identify and prioritize mission capability gaps and facilitate rapid development of critical solutions to address responders' everyday technology needs. R-Tech gathers input from local, tribal, territorial, state, and federal first responders, and engages them in all stages of research and development – from building prototypes to operational testing to transitioning the tools that enhance safety and performance in the field.	**Website:** R-Tech

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Emergency Alerting Systems Research Summary

Overview: Following the March 4, 2019 Technology Scouting Request on emergency alerting, subject matter experts, commercial datasets, and open-source research were utilized to compile a list of relevant Solution Options. Please find a Research Summary outlining our findings below:

Relevant Background

In recent years, U.S. populations have spread from densely populated cities into the rural fringes of metropolitan areas at an increased rate. These rural fringes are referred to as the Wildland-Urban Interface (WUI), or zones of human development within or adjacent to wildlands such as forests and grasslands. These WUI zones are particularly prone to wildfires and due to the increased population density in these areas, the lethality of these fires has increased as well.

As WUI fires have increased in size and intensity over the past few years, gaps in existing emergency alert and warning notification systems have emerged. Currently, in states such as California, there is no standardized, statewide system for how the public is notified about looming danger from fires. While the Federal Emergency Management Agency's (FEMA)Wireless Emergency Alerts (WEA) system gives jurisdictions the capability to send notifications to mobile phones in a defined geographical area, gaps remain in the ability to notify all citizens. Some of these gaps include: accessing mobile devices when service is unavailable, alerting citizens with disabilities and others with access and functional needs (AFN), and leveraging social media and other emerging technologies to communicate with citizens more effectively.

Problem Description:

DHS S&T and the WUI Fire Initiative are interested in identifying the most efficient and effective approach to ensure all citizens in potential danger receive the appropriate notifications and warnings. Approaches used in recent wildfires have taken a considerable amount of time to reach individuals and in some cases have failed to reach all individuals in an affected area. These inefficiencies have led to ripple effects, disrupting emergency response units and causing unclear public communications. The lack of reliable, real-time alert and warning capabilities increases the danger to firefighters, residents, and visitors.

Use Case:

Technologies identified through this Technology Scouting Report may be used to support WUI emergency efforts. Overall, the objective of WUI emergency alerting is to help Emergency Management Officials disseminate critical communication messages to residents and visitors in response to a natural disaster/ emergency. Identified solutions will ideally be able to:

4. Leverage state of the art technologies to rapidly and effectively send emergency communications alerting individuals of imminent danger.
5. Ensure individuals with disabilities and others with access and functional needs (AFN) receive communications, as recent emergencies have highlighted capability gaps in the ability to comprehensively reach this community.
6. Identify solutions that leverage social media monitoring to ascertain current fire conditions and improve rescue efforts, incorporating real-time reporting to and from citizens with access to social media.

Previous Efforts at DHS:

FEMA oversees the development and operations of the Integrated Public Alert and Warnings System (IPAWS), a nation-wide system that jurisdictions can adopt to deliver emergency alerts and warnings to the public for

events such as natural disasters. The Wireless Emergency Alert (WEA) system, a component of IPAWS, is a mobile phone alert program designed to send emergency alerts and warnings to mobile phones connected with participating carriers. The alerts are sent through cell towers within the geographic areas affected by the event.

Solution Option Categories:

Following the initial technology scan, three categories of solutions were identified:

- **Warning Systems 2.0:** Next generation software and tools that identify innovative approaches to efficiently and rapidly deliver emergency alerts.
- **Access and Functional Needs (AFN) Compatible:** Delivering solutions to individuals requiring a heightened level of attention considering the limitations in how they may most effectively receive communications.
- **Social Media Tools:** Utilizing integration platforms and social media to build upon current capabilities to further reach communities with access to social media.

Solution Option Evaluation Criteria:

Identified solutions will be evaluated using the following criteria:

- **Previous/Current Use**: Has the tool been previously deployed at scale and for a similar use case?

The following legend corresponds with the tools found as part of this research summary.

Legend

Previous/Current Use

 Previously Used

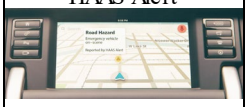
 Additional Information Required from Vendor

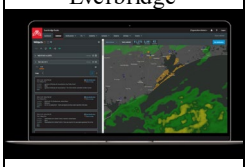
 Not Previously Used

Warning Systems 2.0

Below is a research summary of top technology solutions, specifically highlighting next generation technology solutions and identifying innovative approaches to emergency alerts. These solutions identified in our research summary are sorted by "fit" given the desired use case and relevant evaluation criteria.

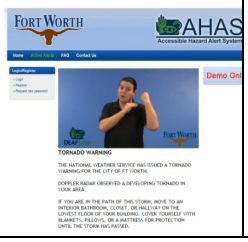
#	Solution Vendor	Description	Previous/ Current Use
1	**Integrated Public Alert & Warning System (IPAWS)** Federal Emergency Management Agency (FEMA) 	**Overview:** The IPAWS is a national system for local alerting and enables authorities at all levels of government to alert and warn people in areas endangered by disasters. It is designed to provide alerts to the majority of the affected population, including nonresident visitors and tourists, individuals with disabilities, people with disabilities and others with access and functional needs, and individuals with limited English proficiency. It also improves the ability of individuals in remote areas to receive alerts. The IPAWS can be used by federal, state, territorial, tribal, and local authorities to send multi-modal emergency alerts (e.g., push-alerts to cell phones, radio, TV etc.). There are more than 1,000 authorized alerting officials in the United States. In short, IPAWS is a federal emergency alerting platform, already in place, that can be leveraged by state, local, and tribal communities to promptly send critical emergency alerting communications to communities at risk. The IPAWS includes two primary components: the IPAWS-Open Platform for Emergency Networks (IPAWS-OPEN) and the National Public Warning System (NPWS). IPAWS-OPEN is the infrastructure that routes authenticated alert messages via Wireless Emergency Alerts (WEA), the Emergency Alert System (EAS), National Oceanic and Atmospheric Association (NOAA) Weather Radio, and the All Hazards Alert and Information Feed. The NPWS is for activation and control of the EAS that provides the President, under all conditions, access to all TV and radio stations for national emergency warnings. The potential success of using IPAWS as an emergency alerting platform is predicated on providing proactive emergency alerting, so recipients of the alert have time to respond. Additionally, several improvements for the IPAWS program are planned for 2019 and include: • Extending the character limit on WEA emergency alerts pushed to cell-phones from 90 characters to 360, allowing emergency responders to include more detailed instructions to recipients of these emergency alerts and warnings • Improving geo-targeting of an IPAWS alert to a 0.1mile accuracy, with the ability to reach 100% of the alert area • Including Spanish language support **Use Case:** IPAWS functionalities: Wireless Emergency Alerts (WEA), Emergency Alert Systems (EAS), and Internet Capabilities are capable of rapidly disseminating critical information across multiple channels. These channels include any WEA-enabled mobile device in a locally targeted area (i.e. broadcast, cable, satellite, wireline radio, television channels); and across internet web services and applications to access, monitor, and retrieve public alerts from an IPAWS Public Alerts Feed that can be monitored over an internet connection.	 First Responders, Federal Government, Military, Nuclear Power Plants, Hospitals, Universities

2	**Wide-Area Mass Notification** Eaton 	**Overview:** Eaton offers a Wide-Area Mass Notification system that can include a combination of audible and visual messages to an impacted area during an emergency in real-time. Their WAVES product broadcasts voice messages, tones, and sirens to large outdoor areas. This e Giant Voice system can be mobile, allowing first responders to spread the message to communities in danger through vehicles or drones. WAVES' visual devices include strobe lights and LED signs for mass alerts. **Use Case:** Eaton's Wide-Area Mass Notification system could be set up in fire-prone areas such as Sonoma County, CA to establish an alternative alerting method to FEMA's wireless emergency alerts. The mobile voice systems and visual devices would provide a method to alert citizens who are unable to receive mobile notifications.	First Responders, Universities
3	**Mass Notification Solutions** American Signal Corporation (ASC) 	**Overview:** ASC provides a suite of robust tools providing end-to-end detection, mass notifications, and emergency alerting. This solution provides not only the hardware, but also a software framework for the most effective ways to rapidly send out communications. This includes detection sensors and a command center, as well as text, email, mobile, social media, sirens, and signage capabilities. **Use Case:** From the onset of an emergency event incident commanders could better detect emerging threats, communicate messaging across multiple channels, including internet of things (IoT) devices, and coordinate strategic responses via a centralized command center.	First Responders, Military, Universities
4	**Siren Warning Systems** High Sierra Electronics 	**Overview:** High Sierra Electronics offers siren warning systems to warn communities of hazardous weather, such as floods. The sirens can be activated remotely by public safety agencies to warn the public of potential danger, or severe weather sensors can be used to automatically activate the sirens. **Use Case:** Although the Siren Warning System is mainly focused on identifying and notifying the public of potential floods, the outdoor sirens could also be used to send emergency warnings to the public in areas under threat from a wildfire.	Federal Government
5	**HAAS Alert Safety Cloud** HAAS Alert 	**Overview:** The HAAS Alert Safety Cloud provides first responders with the capability to send real-time alerts and warnings to nearby connected autonomous vehicles. This technology is currently being used to avoid collisions between motorists and emergency responders. **Use Case:** The HAAS Alert Safety Cloud system could be used to notify connected autonomous vehicles in a specific geographic area of nearby hazards including wildfire and other emergency situations.	First Responders
6	**Precision Location** Skyhook 	**Overview:** Skyhook's Precision Location system uses wi-fi, Global Navigation Satellite System (GNSS), and cell phone signals to locate devices such as wearables, connected and autonomous vehicles, point-of-sale devices, and connected appliances (i.e., smart TVs, refrigerators). This product has the capability to locate devices even when they are offline, such as during a power outage caused by a natural disaster. Currently, Skyhook is primarily sold in the private sector to track asset distribution. **Use Case:** The precise, wide-ranging location data gathered by Skyhook to identify a variety of connected devices could be leveraged by federal, state, and local agencies to push out emergency alerts to cars, mobile phones, and smart appliances in the event of a wildfire or other natural disasters.	

7	**AtHoc** BlackBerry 	**Overview:** AtHoc provides a comprehensive communication and mass notification solution that unifies all channels and devices in a network to communicate during emergency events. AtHoc uses the IP network as a mass notification system. By deploying AtHoc, officials can rapidly alert citizens in geographically dispersed areas during an emergency. **Use Case:** AtHoc's public safety warning system can be used by federal, state, and local agencies to reach citizens through public broadcasts, email, phone, and text messages. Additionally, AtHoc can allow agencies to share information with the public via social media and digital signage.	First Responders
8	**Community Information & Warning System (CIWS)** Mobilaris 	**Overview:** Mobilaris CIWS monitors heatmaps and geofences to determine the location of mobile phones. The system has the capacity to distribute 10,000 geographically controlled text messages per second, and it can change the language and content of the message based on the group of users being notified. **Use Case:** The CIWS system could improve the ability of federal, state, and local agencies to distribute emergency alerts and warnings by monitoring heatmaps and geofences in addition to cell phone tower signals. The CIWS system would augment IPAWS and potentially provide more accurate and timely information to authorities about the locations of people in the areas impacted by the emergency.	First Responders
9	**CodeRED** OnSolve 	**Overview:** CodeRED is used by government agencies across North America to deliver geo-targeted alerts and warnings using voice, email, SMS, and IPAWS. CodeRED is fully integrated with IPAWS and has been used to alert citizens in several emergency events including the Boston Marathon bombings. **Use Case:** The CodeRED system can be expanded to more jurisdictions, including fire-prone areas, to notify residents of impending danger and provide information regarding necessary actions. CodeRED can also push notifications via social media.	First Responders
10	**Mass Notification** Everbridge 	**Overview:** Everbridge's Mass Notification system allows public safety agencies to send emergency alerts to groups and individuals before, during, and after critical events. This system uses geographic information system (GIS)-based message targeting to send SMS alerts to recipients in a specific geographic region and can highlight populations with disabilities and others with access and functional needs, alert type subscribers, and other user groups. **Use Case:** The Mass Notification system has been used by the Ventura County Sherriff's Office during the Thomas Fire in California to send alerts and warnings to residents regarding mandatory and voluntary evacuations, repopulation, boil water orders, and safety advisory messages.	First Responders

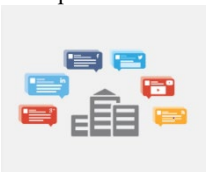
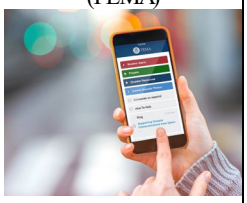
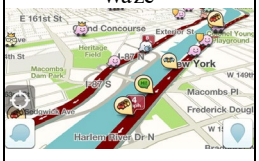
Access and Functional Needs (AFN) Compatible

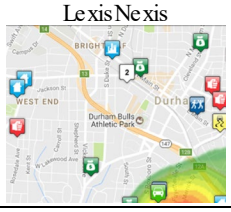
These findings provide tailored solutions for the AFN population providing ample opportunities to receive warnings/alerts, as current approaches have often overlooked AFN individuals. These solutions identified in our research summary are sorted by "fit" given the desired use case and relevant evaluation criteria.

#	Solution Vendor	Description	Previous/ Current Use
1	**Rumbler®** Federal Signal 	**Overview:** The Rumbler® produces low frequency sound waves offering a combination of loud, audible sirens as well as sound waves that can be felt. This attachment is effective in ensuring multiple senses are engaged further intensifying the emergency alert. **Use Case:** As this component can be affixed to a vehicle, potential use cases include attaching to emergency response vehicles driving in affected areas, as well as attaching to an Unmanned Aerial System (UAS) to be flown over affected areas alerting people in danger.	First Responders
2	**Howler™** Whelen Engineering Company 	**Overview:** The Howler™system provides deep, low-frequency tones capable of penetrating barriers (e.g. car walls, buildings) to alert people in the area through sirens and vibrations emitted from the system. This technology was developed in response to the increasing levels of sound density in city streets, as simply raising the volume of speakers is an inefficient and potentially dangerous approach to the problem. **Use Case:** This component is designed to be affixed to vehicles allowing for mobile deployment into target regions where individuals need to be alerted of imminent danger. Remote deployment of this device could lead to safer and more reliable emergency alerting.	First Responders
3	**Accessible Hazard Alert System** Deaf Link 	**Overview:** The Accessible Hazard Alert System (AHAS), developed and operated by Deaf Link for the City of Fort Worth Office of Emergency Management, is designed to provide a warning system to announce severe weather and disaster events to residents with disabilities and others with access and functional needs such as Deaf, Hard of Hearing, Blind, or Deaf/ Blind populations. The AHAS warnings are delivered in American Sign Language, English verbal, and captioned text on mobile devices such as iPads, cell phones, computers, and wireless Braille readers. **Use Case:** This emergency alert system could be used to augment existing emergency alert systems in cities and WUI zones across the United States and address the needs of residents with disabilities and others with access and functional needs.	First Responders

Social Media Tools

Below are solutions that address how social media monitoring can be used to ascertain current fire conditions and improve rescue efforts, incorporating real-time reporting to and from citizens with access to social media. These solutions identified in our research summary are sorted by "fit" given the desired use case and relevant evaluation criteria.

#	Solution Vendor	Description	Previous/ Current Use
1	**Hootsuite®** Hootsuite 	**Overview:** Hootsuite®'s platform allows for up to ten social profiles to be integrated into one, user-friendly interface streamlining content distribution and account management. Hootsuite® has seen great success in the private sector, enabling organizations to better engage with their audience in providing analytics on content and user interaction. **Use Case:** This tool would enable first responders to leverage an array of social media platforms, taking advantage of multiple distribution channels to thoroughly disseminate emergency communications.	Private Sector
2	**Sprinklr** Sprinklr Inc. 	**Overview:** Sprinklr is a platform that offers social media management capable of integrating multiple social media accounts into one platform. This feature enables users to manage their various social media profiles ensuring constant audience engagement and provides valuable data analytics to understand how users are engaging with published content. **Use Case:** This platform could be utilized by emergency response departments to efficiently manage public information that needs to be disseminated. As opposed to manually logging into each unique social media platform, Sprinklr allows owners to outline a message to simultaneously send across all linked platforms.	First Responders, Private Sector
3	**FEMA's Mobile App** Federal Emergency Management Agency (FEMA) 	**Overview:** The FEMA mobile app aggregates weather alerts, safety reminders, preparedness resources (e.g. open shelters), and offers a communication channel for users to submit disaster photos to help guide first responders. The app's team is comprised of dedicated digital communications specialists actively monitoring social media traffic to better guide emergency response strategies. The app also has Spanish language capabilities. **Use Case:** This app could better prepare the public when it comes to emergency response situations. Recent natural disasters have highlighted the negative effects of extreme congestion of 911 phone lines. Using this app could alleviate these stressors, giving 911 responders greater capacity to better facilitate emergency response strategies.	First Responders
4	**Connected Citizens Partners** Waze 	**Overview:** Waze has established a partnership with first responders to allow users of the app to receive real-time incident information and re-route drivers to avoid incidents (such as fires) and related road closures. This solution helps government officials send information to Waze users in real-time with location-based information about their surroundings and helps first responders gather information about emergencies from users. **Use Case:** This tool could allow first responders to notify drivers and passengers of nearby emergencies, including wildfires, and ensure that drivers leave the impacted area as quickly, safely, and efficiently as possible.	First Responders

5	**Social Media Monitoring** Dunami 	**Overview:** Dunami is a social media monitoring company that leverages the power of artificial intelligence and deep neural networks to find signals through all the noise on social media. Dunami has received funding from the CIA's venture capital unit In-Q-Tel and is used by law enforcement throughout the country. The software helps discover interests, activities, demographics, and group affiliations of people through social media scanning. Dunami allows users to know who is (and is not) a meaningful part of a topic of discussion and find the entire network of those who matter. However, Dunami's robust AI platform can also be used to aggregate feeds pertaining to a specific emergency incident or natural disaster and help inform situational awareness. **Use Case:** Dunami could be used to crowdsource information on fire spread or the status of evacuation routes. The tool would aggregate public social media posts and videos to help inform responders' situational awareness.	Chicago PD, Chicago Public Schools, FBI
6	**LexisNexis Social Analytics** LexisNexis 	**Overview:** LexisNexis offers a Social Analytics product that is built for law enforcement to provide situational awareness before, during, and after emergency situations. While the system traditionally uses social media data to locate suspects, discover criminal activity, and prevent crime; it could also be applied to enhance situational awareness. The product monitors feeds from over 10+ social media networks, in 187 languages. **Use Case:** First responders could use social media listening technology to crowdsource critical information from the field, like fire spread or the status of evacuation routes.	Chicago PD

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Appendix H: Other Solution Descriptions

Solution	Description
Hawkeye	This program uses airborne and spaceborne remote sensing assets to rapidly detect and report new fire starts within the continental United States. Detected fire starts are relayed to the **Ignition Point Database** (IgPoint) operated and managed by the Forest Service. The format is simple: Latitude/ Longitude, date/ time, level of confidence (low, moderate and high). Once the alert arrives in the IgPoint Database, anomaly detections are queried and retrieved to the appropriate response authority (e.g., The Enterprise Geospatial Portal or EGP). Local dispatch offices using the EGP view newly reported detections within a few minutes of reporting and allows the local authorities to determine the appropriate response based on local conditions – weather, fuel conditions and proximity to assets at risk
Zignal Labs	Zignal Enterprise is a modern media intelligence platform for communications, marketing and executive teams. Harnessing the power of real-time and predictive analytics, Zignal surfaces insights from news and conversations across the entire media spectrum, allowing teams to make faster decisions with confidence, achieve better outcomes and identify strategic opportunities.
High-Altitude UAS	A high-altitude long-endurance drone is an unmanned aircraft that flies at altitudes higher than about 60,000 ft. and can remain airborne for extremely lengthy periods of time. It is well-suited for carrying out extensive surveillance and image-collection operations.
Team Connect	Team Connect is a cloud-based computing technology that provides Geospatial awareness solutions for organizations. It allows users to communicate, share, and see real-time information that will allow them to better execute the job.
Commercial, Small UAS	A commercially available, small unmanned aircraft or unmanned vehicle weighing less than 55 pounds, including everything that is onboard or otherwise attached to the aircraft, and can be flown without the possibility of direct human intervention from within or on the aircraft.
ALOHA-CAMEO	ALOHA® is the hazard modeling program for the CAMEO® software suite, which is used widely to plan for and respond to chemical emergencies. ALOHA allows you to enter details about a real or potential chemical release, and then it will generate threat zone estimates for various types of hazards. ALOHA can model toxic gas clouds, flammable gas clouds, BLEVEs (Boiling Liquid Expanding Vapor Explosions), jet fires, pool fires, and vapor cloud explosions.
FASMEE	FASMEE is a multi-agency effort to provide advanced measurements necessary to evaluate and advance operationally-used fire and smoke modeling systems and their underlying scientific models. The field campaign will be conducted on large operational prescribed fires targeting heavy fuel loads and burned to produce high-intensity fires with developed plumes in the southeastern and western United States.
CO-FPS	The CO-FPS project is a five-year effort funded by the State of Colorado with the goal of designing, building, and transferring to the state a cutting-edge system for predicting a wildfire's extent and rate of spread; the heat and smoke it generates; the wind, temperature, and humidity in the fire's immediate environment; and aviation hazards around the fire. The core predictive technology in CO-FPS is based on NCAR's Coupled Atmosphere Wildland Fire Environment (CAWFE) model, which uses the Weather Research and Forecasting (WRF) model for simulating weather, and a fire-prediction module for simulating a fire's behavior, fuels, local atmospheric conditions, and the effects those conditions have on fuel moisture. CO-FPS is being integrated with the Colorado Wildfire Information Management System (CO-WIMS), a web-based interface through which users launch CO-FPS, customize simulations, and display output.

Solution	Description
MesoWest	MesoWest depends upon voluntary access to provisional observations from environmental monitoring stations installed and maintained by federal, state, and local agencies and commercial firms. In many cases, collection and transmission of these observations are facilitated by NWS forecast offices, government laboratories, and universities. MesoWest augments the Automated Surface Observing System (ASOS) network maintained by the NWS, Federal Aviation Administration, and Department of Defense. MesoWest increases the coverage of observations in remote locations and helps capture many of the local and mesoscale weather phenomena that impact the public. The primary goal of MesoWest is to improve timely access to automated observations for NWS forecasters at offices throughout the western United States.
Everbridge	Everbridge, Inc. is a global software company that provides enterprise software applications that automate and accelerate organizations' operational response to critical events in order to keep people safe and businesses running faster. Everbridge's Critical Event Management platform can quickly and reliably aggregate and assess threat data, locate people at risk and responders able to assist, automate the execution of pre-defined communications processes, and track progress on executing response plans.
Structure Alarm	An undeveloped technology solution which subject matter experts posed as a possible long-term solution to warning and evacuation challenges. An alarm device, similar to carbon monoxide detectors, in all structures which receives warnings from weather stations. Incorporate into multiple communication networks and use multiple forms of warning (e.g., vibration, strobe lights, etc.) to ensure all members of the community receive and understand warnings.
CANSAC	The California and Nevada Smoke and Air Committee (CANSAC) can oversee the implementation and operation of the CEFA Operations and Forecast Facility (COFF) for Smoke and Fire Management. COFF is managed by the Desert Research Institute (DRI) program for the Climate, Ecosystem and Fire Applications (CEFA) located in Reno, Nevada. It can also facilitate the transfer of MM5 and other mesoscale meteorology research done by the Riverside Fire Lab, California Air Resources Board (CARB), Environmental Protection Agency (EPA), universities, and government agencies to the field for operational applications.
Waze	Waze is a GPS navigation software app owned by Google. It works on smartphones and tablet computers that have GPS support. It provides turn-by-turn navigation information and user-submitted travel times and route details, while downloading location-dependent information over a mobile telephone network.
Emergency Evacuation Simulator (EES)	Emergency Evacuation Simulator is an interactive 3D client-server application. The main purpose of this application is to provide the evacuation training for employees who work in large buildings with complex floor plans and evacuation routes
Pathfinder	Pathfinder is an emergency egress simulator that includes an integrated user interface and animated 3D results. Pathfinder allows you to evaluate evacuation models more quickly and produce more realistic graphics than with other simulators. Pathfinder provides support for the import of AutoCAD format DXF and DWG files. Pathfinder's floor extraction tool makes it possible to quickly use the imported geometry to define the occupant walking space for the evacuation model.
Massmotion	MassMotion is an advanced crowd simulation software that uses crowd modelling technology to provide leading technology to designers, operators and owners with clear information about crowding, usage patterns and occupant safety in a facility. This allows one to simulate the smartest pedestrians within an accurate BIM compatible 3D model.

Solution	Description
e-Sanctuary	An e-Sanctuary is an open multi-physics framework for modelling wildfire urban evacuation or sheltering.
Firefly	An in-development space-based tracking system which relies on the capabilities of Hawkeye.
Wildfire Decision Support System	This system assists fire managers and analysts in making strategic and tactical decisions for fire incidents. It has replaced the WFSA (Wildland Fire Situation Analysis), Wildland Fire Implementation Plan (WFIP), and Long-Term Implementation Plan (LTIP) processes with a single process that is easier to use, more intuitive, linear, scalable, and progressively responsive to changing fire complexity.
Situational Awareness of Vulnerable populations during a crisis or Evacuation	The SAVE application assists medical, emergency and volunteer response agencies in locating and responding to vulnerable populations during extreme and/or disaster situations. It is a web-based solution designed for EOCs to manage ongoing crisis (extended power outage, extreme temperature, etc.) or disaster (hazardous material incident, wild fires, tornado, etc.). It also functions as a mobile application designed for volunteers to communicate with the EOC. The application allows volunteers to be geolocated by the EOC, to receive assigned tasks from the EOC and to update the status of a task to report back to the EOC. Lastly, it functions as an application for clients to register into the SAVE program and identify what restrictions and potential needs they may have in a disaster. SAVE has analytical tools that are able describe the balance between the need and potential resources.
Situation Awareness and Collaboration Tool (SCOUT)	The California deployment of the Next-Generation Incident Command System (NICS) software is called Situation Awareness and Collaboration Tool (SCOUT). SCOUT provides an information sharing environment to facilitate operational and tactical collaboration among California emergency responders and interagency situational awareness for local, tribal, state, and federal partners for small to extreme scale homeland security incidents, such natural disasters, technological hazards, intentional attacks, and human-caused emergencies.