Streamlined Edge Computing for Fire Science and Management using WIFIRE Edge

Ilkay Altintas
San Diego Supercomputer Center
University of California San Diego
La Jolla, CA, USA
ialtintas@ucsd.edu

Shweta Purawat
San Diego Supercomputer Center
University of California San Diego
La Jolla, CA, USA
shpurawat@ucsd.edu

Ismael Perez
San Diego Supercomputer Center
University of California San Diego
La Jolla, CA, USA
i3perez@ucsd.edu

Jenny Lee
San Diego Supercomputer Center
University of California San Diego
La Jolla, CA, USA
jjl053@ucsd.edu

Melissa Floca
San Diego Supercomputer Center
University of California San Diego
La Jolla, CA, USA
mfloca@ucsd.edu

Jessica Block
San Diego Supercomputer Center
University of California San Diego
La Jolla, CA, USA
jlblock@ucsd.edu

Josh Breslow
San Diego Supercomputer Center
University of California San Diego
La Jolla, CA, USA
jbreslow@sdsc.edu

Daniel Crawl
San Diego Supercomputer Center
University of California San Diego
La Jolla, CA, USA
lcrawl@ucsd.edu

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***Abstract*—In recent years, frequent and highly destructive megafires become one of the biggest climate-induced disasters. Fire behavior models using data from many emerging sources can inform decision support tools to respond to and mitigate such megafires. Emerging edge sensing and computing technologies within the fire environment can enhance the speed, reliability, and efficiency of wildland fire management, leading to better prevention, faster response times, and more effective mitigation of fire-related disasters. However, a unified system that streamlines the integration of edge technology advances within fire science and management workflows is needed. This paper presents the design and demonstrated case studies of the WIFIRE Edge Platform that facilitates the integration of sensing and AI capabilities at the edge. The initial attack and prescribed burn concept scenarios are described, highlighting the sensor deployment and utilization at the fire front.**

***Index Terms*—edge computing, fire science, translational computer science, internet of things**

I. Introduction and Motivation

In recent years, frequent and highly destructive megafires become one of the biggest climate induced disasters in the western United States and around the globe. Such megafires can be triggered by lightning, human activity, or pyro-terrorism, causing massive devastation. When they happen, urgent assessment and response is necessary in order to save lives and property, and to inform the public. Fire behavior models using data from many emerging sources can inform decision support tools to respond to and mitigate from megafires.

Next generation fire models can utilize high resolution information including weather forecasting and sensing, fire perimeter detection through satellites, aircraft and drones, and sensing sources that quantify vegetation and landscape. Such remote sensing offers the potential to provide the necessary timely information on emerging wildfires critical to allocating fire fighting resources and making evacuation decisions, but most of these data types are limited in space, time, or both. Accurate wildfire predictions are highly dependent on local weather phenomena, often not resolvable with satellite remote sensing. Ground sensing weather stations do solve some of these issues, but locations for such ground sensing data are often fixed and provide low spatial resolution data. Mobile ground sensors that can be deployed to the scene of an emerging fire are what is needed for such weather observations to advance our response to megafires. While sensor data offers many opportunities to collect and interpret local data, the data quality issues common to physical sensor data require use of data science methods to detect and correct the errors. Fusion of the data obtained by measurements of mobile sensors, ground-based fixed weather stations and satellite remote sensing combined with data science methods can address such sensor data robustness and quality issues.

Edge computing is a form of computing that is done on site or near a particular data source, minimizing the need for data to be processed in a remote data center. Edge computing can provide the necessary capabilities to address the urgent needs of accurate situational awareness data on wildfires and prescribed burn activities via data fusion of mobile wildfire sensors, traditional fixed weather station data and remote sensing data to more accurately identify fire behavior at high resolution. Through such integration of sensing and edge computing into the modeling process, we can improve the quality of wildfire perimeter for locally-informed and more detailed next-generation fire behavior modeling. Emerging edge sensing and computing technologies within the fire environment can enhance the speed, reliability, and efficiency of wildland fire management, leading to better prevention, faster response times, and more effective mitigation of fire-related disasters. However, a unified system that streamlines the integration of edge technology advances within fire science and management workflows is needed. This paper presents the design and demonstrated case studies of the WIFIRE Edge Platform that facilitates the integration of sensing and AI capabilities at the edge.

Based on this problem statement, we developed WIFIRE Edge, an integrated platform to take advantage of advances in edge computing through integrated sensing and AI at the edge. WIFIRE Edge uses ground sensing and in-situ edge computing in the field to improve and optimize situational awareness and forecasting during fire response and risk mitigation. Specifically, we present a concept demonstration for two scenarios (initial attack response; and prescribed burn planning and monitoring) through use of commercially available sensing technology, edge computing and next-generation fire modeling. This demonstration builds on our prior experience with two platforms, Firemap [1] and BurnPro3D [2].

Contributions. WIFIRE Edge builds on critical sensing, data, computing and artificial intelligence capabilities to improve environmental monitoring local to a fire, which not only increase confidence in the use of wildfire models for fire response, but will also make response faster and safer. As a century of suppressing fire in North America has contributed to vegetation accumulation leading to this new era of megafires, requiring prescibed fire to be applied as a way to reduce megafire risk. Our second use case demonstrates use of integrated sensing on proactive prescribed fires as an important tool towards mitigating them. These capabilities are powered by the WIFIRE e-research infrastructure including a Data and Model Commons [3], an AI Gateway, and next-generation fire modeling at scale. WIFIRE simplifies access to all wildfire-related data and provides scalable AI capabilities in ways that turn the data into a utility for fire science and its applications. Specifically, we present:

- A unified architecture for rapid integration of edge computing technologies into fire science and management workflows; and
- Two conceptual use cases, for initial attack and prescribed fire management, that demonstrated use of edge sensing and computing in real-life scenarios.

Outline. The rest of this paper is structured as follows. Section II describes a reference architecture for WIFIRE Edge to unify the interface between edge systems and use-inpired platforms. Section III presents the demonstrated case studies and experimental results, and discusses advantages of using edge computing in these scenarios. In Section IV, we introduce the translational computer science approach we have followed in ensuring the demonstrated case studies lead to realistic results that could be deployed at scale with further development. We review related work in Section V and conclude in Section VI.

II. WIFIRE Edge: A Unified Architecture for Edge Computing in Fire Science

The WIFIRE Edge platform integrates live ground sensing and in-situ edge computing to enhance and optimize situational awareness for fire response and risk mitigation efforts. The platform enables real-time visualization of sensor data and transforms sensor data collected into actionable knowledge for wildland fire scientists and decision-makers who depend on data-driven insights.

A. Sensor Data

The system uses various sensor data (acquired from our industry partner RedLine Safety) for wildfire management, response, and mitigation. Some types of sensor data include:

- ***Weather Sensors:*** These sensors measure critical parameters such as temperature, humidity, wind speed, wind direction, and pressure. This data is vital for understanding and predicting fire behavior.
- ***Air Quality Sensors:*** These sensors monitor particulate matter (PM2.5), carbon monoxide (CO), and carbon dioxide (CO2). Tracking these pollutants is essential for assessing the impacts of wildfire smoke and ensuring air quality.
- ***Geospatial Sensors:*** We are currently using anonymized GPS locations to understand ignition patterns and to visualize fire crew location anonymously.
- ***Advanced systems like Cameras and LiDAR:*** These technologies help in mapping the fire's spread and understanding the terrain and fuel conditions.

Our platform uses these sensors to improve situational awareness, allowing for timely and informed decision-making in wildfire response and mitigation efforts. The real-time sensor data integration ensures that critical data is available in real-time to support effective management strategies.

B. System Architecture

The System Architecture diagram is shown in the Fig. 1. WIFIRE Edge can integrate data from diverse sensor systems. These systems provide real-time data and have edge computing units to process and analyze data on-site, reducing the need to send data to a cloud or a remote server. Some sensors come with built-in edge computing capabilities (e.g., [4]), while others may need to be accompanied by an edge computing device. WIFIRE Edge unifies data from various sensor sources and AI at the edge to provide a complete view for better situational awareness. It provides APIs to connect with fire applications like BurnPro3D [2], Firemap [1], ATAK [5], and others. WIFIRE Edge has several key components that work together to provide reliable, real-time information, helping

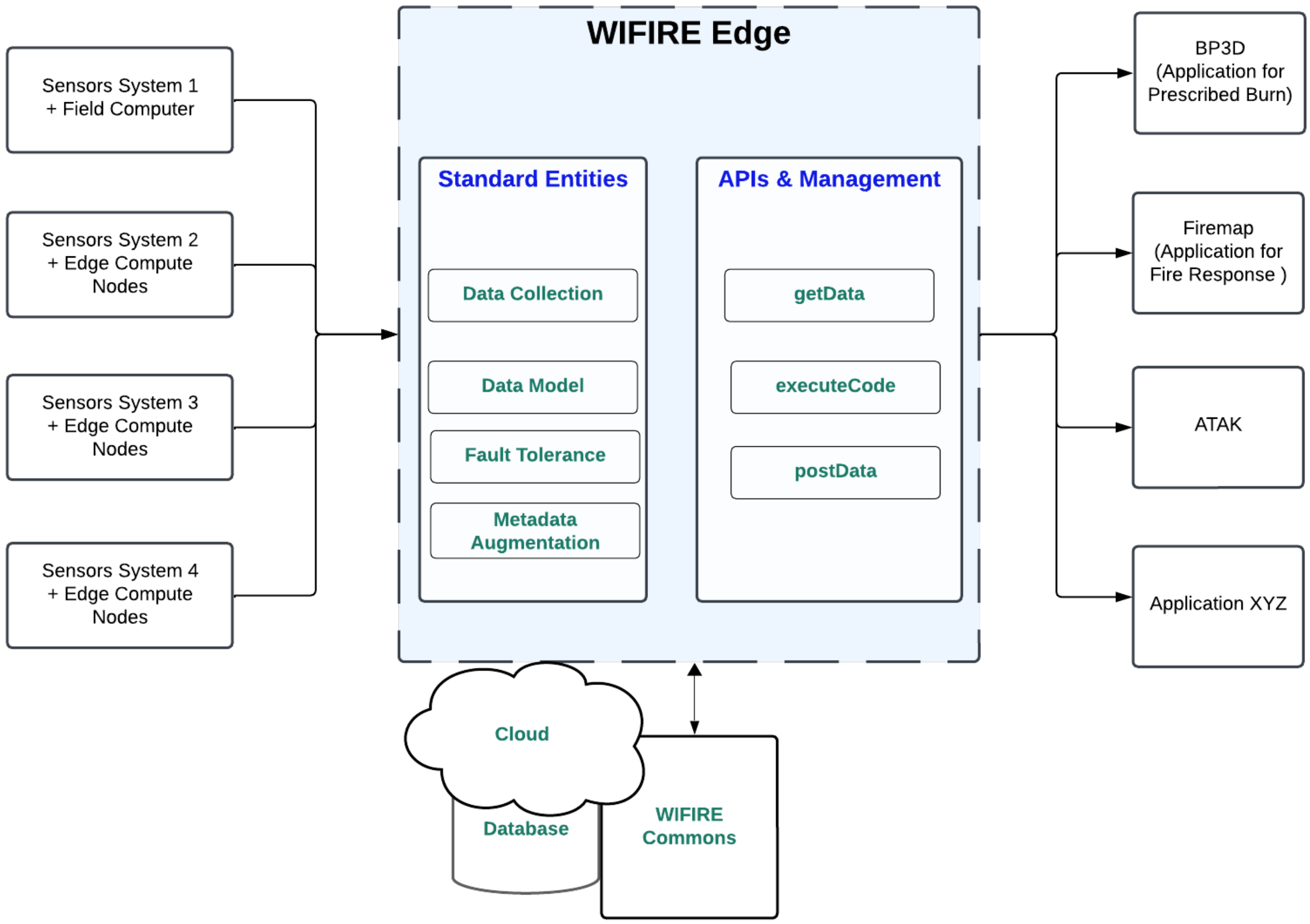

Fig. 1. WIFIRE Edge, the Unified Architecture for Edge Computing in Fire Science

with effective decision-making and response. Some of the key modules are described below:

- ***Data Collection Module:*** This module collects data from various sensor systems, handles different data formats, and ensures smooth data flow into the system. This module cleans, transforms, and processes raw data through normalization, noise reduction, and conversion into a standardized format.
- ***Metadata Augmentation Module:*** This module maintains and, if needed, adds metadata about the data, tracks its origin, and ensures accuracy. This makes the data searchable and reliable for future research use.
- ***API Management Module:*** It offers libraries of RESTful APIs to retrieve data, run code, and provide interfaces for fire modeling applications, visualization platforms, and decision support systems to access integrated data. The executeCode API and associated microservices performs real-time analysis on incoming data. It performs tasks like functional computation, anomaly detection, and trend analysis using scientific algorithms, machine learning models, and statistical tools.
- ***Data Hub and Storage Module:*** This module stores data efficiently and securely and provides scalability, redundancy, and data integrity. It includes relational databases (e.g., PostgreSQL), NoSQL databases (e.g., CouchDB, MongoDB), and cloud storage systems (e.g., Amazon S3, OpenStack, Azure) and WIFIRE Commons, a hub that curates and connects next-generation data and models to enable AI techniques. The data model defines, organizes, and structures the data for storage.
- ***Fault Tolerance Module:*** This module keeps the system reliable, robust, and operational. It detects failures, monitors for issues, and alerts administrators. It also provides backup systems and automatically switches to them if a failure occurs and performs data validation during recovery.

III. Demonstrated Case Studies

The WIFIRE Edge platform supports both reactive and proactive wildfire management approaches. We demonstrated the potential of the platform in operational use in two real-life scenarios: i) Prescribed Burn; and ii) Initial attack fire

Fig. 2. The figure shows Prescribed Burn Quic-Fire Simulation runs for Kern County Burn Units

response. The sensor units developed by Red Line Safety, Inc. were deployed in the two concept demonstrations to acquire sensor data. In the coming subsections, we will elaborate on the concept demonstration in these two scenarios.

A. *Prescribed Burn*

Prescribed burns are an essential fuel treatment approach that can mitigate the future risk of uncontrollable and highly destructive wildfires by reducing dangerous fuel loads. In January 2022, US Forest Service announced a 10-year strategy to confront the nation's wildfire crisis, and prescribed fires are at the heart of the strategy as an important tool for mitigating wildland fires. In this proof of concept, we demonstrated the benefits of edge sensing and computing in enhancing situational awareness by leveraging real-time ground sensing data and edge computing during the planning and execution of prescribed burns.

For this prescribed fire demonstration, WIFIRE Edge integrated live ground sensing data monitoring and edge technology into our BurnPro3D platform. BurnPro3D is designed for burn bosses to plan and execute prescribed burns. It is a science-driven, decision-support platform that helps the fire management community understand risks and tradeoffs when planning and conducting prescribed burns. The next-generation WIFIRE Data and Model Commons power the platform.

We collaborated with the Kern County Fire Department team to participate in their scheduled prescribed burn at CCI Tehachapi, located at 24900 CA HWY 202, Kern County, on July 14, 2023. We used the opportunity to conduct the WIFIRE Edge demonstration for Prescribed Burn. This demonstration enabled us to showcase our ground sensing and edge computing capabilities within the BurnPro3D platform, tailored specifically for the prescribed burn scenario.

This demonstration involved deploying physical sensor units, streaming live sensor data, executing edge computations, and integrating real-time sensor data and edge computation into BurnPro3D, a prescribed burn planning platform. We discuss these activities in details in the text below:

Preparing for the Prescribed Burn: We utilized our BurnPro3D Proactive Fire Management Platform to simulate fire behavior for the Kern County burn units. We simulated complex prescribed fire behavior using our advanced fire modeling and analysis tools. This involved running multiple simulation scenarios (see Fig. 2) using diverse data inputs, including the burn unit map in GeoJSON format, ignition pattern details, and environmental factors like wind speed, wind direction, and fine dead fuel moisture. This comprehensive ensemble was shared with the Kern County fire chief, burn boss, and their team. This proactive strategy enabled us to analyze potential fire scenarios ahead of the actual burn, enhancing our ability to effectively plan and manage the operation.

Setting Up Field Sensors and Deploying Edge Computing: For the prescribed burn scenario, we deployed three types of sensor units and an edge computing device to gather real-time data, as shown in Fig. 3. The Redline Safety team set up a trailer sensor unit equipped with a 3D wind sensor, solar power, a 24-hour battery, and satellite internet. The Kern County prescribed fire team wore body-worn sensors, and gateway sensors were mounted on tripods around the burn unit. The Gateway stationary sensors are lightweight, and the

Fig. 3. The figure shows sensor deployment at the prescribed burn site: the left image displays body-worn sensors, the middle image shows the Gateway sensor unit mounted on a tripod with the UCSD team setting up the edge compute laptop, and the right image features the trailer unit equipped with a 3D wind sensor, solar power, a 24+ hour battery, and satellite internet.

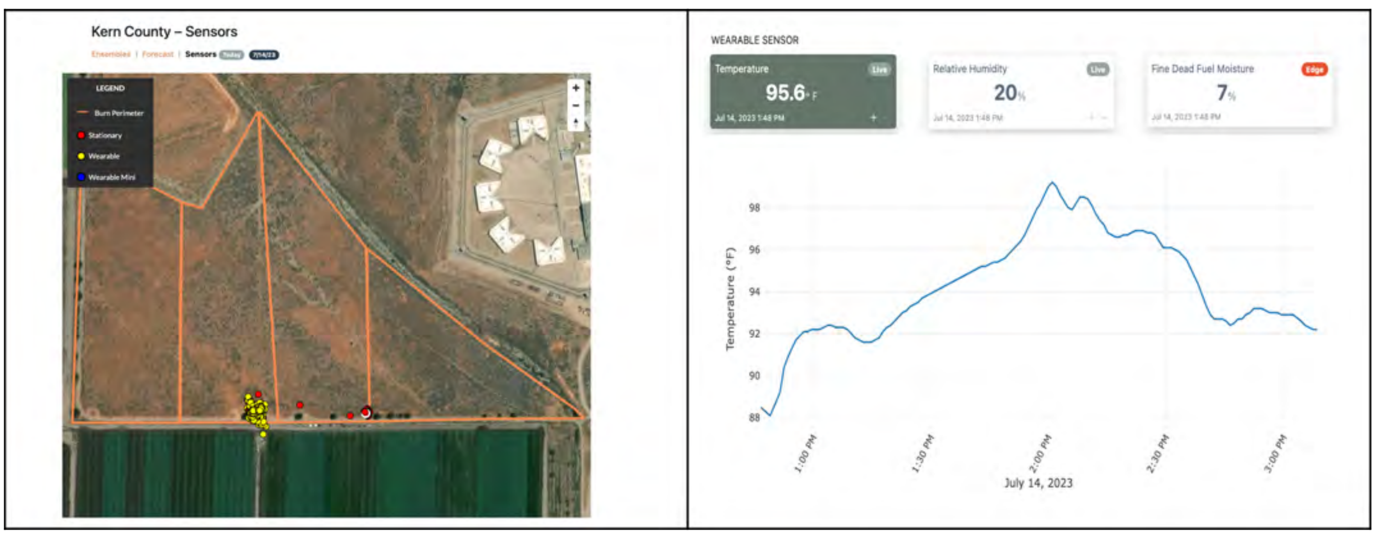

Fig. 4. The figure shows the BurnPro3D Edge UI: the left image presents the burn unit map with live GPS locations of wearable and gateway sensor units, while the right image displays real-time weather sensor data and Fine Dead Fuel Moisture calculated on the edge using real-time sensor data.

Fig. 5. The figure shows the ignitor crew leader briefing the team on weather conditions, ignition techniques, safety protocol, communication protocol, contingency plans.

trailer sensor unit is equipped with wheels, making both easy to move if necessary. The WIFIRE Edge team set up an edge computing laptop to process and analyze data on-site, ensuring immediate access to actionable insights. This setup allowed for efficient data collection and real-time analysis at the edge.

User Interface Extensions within BurnPro3D for Real-time Sensor Data and Edge Computation: The WIFIRE Edge integrates real-time sensor data and edge computation in the BurnPro3D. The BurnPro3D Edge user interface provided three critical pieces of information as shows in Fig. 4. These include the Burn Unit Map featuring sensor deployment location and real-time ignition pattern tracking, live weather data sensing and monitoring at the edge, and FDFM (fine dead fuel moisture), computed using sensor data at the edge, showcasing edge compute capability.

- The Burn Unit Map with Sensor deployment and live Ignition pattern tracking displays the sensor units and ignitor GPS locations on and around the burn unit.

- Live Weather Data Sensing and Monitoring at the Edge integrates real-time sensor data into our Edge Interface to provide real-time monitoring of sensor data such as temperature, humidity, and other critical data on the day of the burn. We flag any anomaly detected in the weather and ignition pattern.
- Edge Computation of FDFM (Fine Dead Fuel Moisture) implements code that calculates Fine Dead Fuel Moisture (FDFM) at the Edge, a critical computation that the Burn boss relies on to assess conditions for conducting a prescribed burn. The data includes forecasted FDFM computation two days in advance and real-time FDFM data using live sensor weather data. The edge computation interface is built to accept any executable service within a deployable container to execute analytical and AI operations on real-time sensor data.

This effort demonstrated the integration of sensor and edge technology into BurnPro3D for planning and monitoring prescribed burns through the WIFIRE Edge Platform.

Fig. 6. The figure shows firefighters attaching the RLS wearable sensor unit to their pack and RLS gateway unit mounted magnetically on the fire truck roof.

B. Initial Attack Fire Response

Initial Attack Fire Response refers to the actions taken by firefighters within the first few hours (3-5 hours) after the start of a fire. The goal is to suppress or control the fire before it grows and becomes more difficult to manage. Our team developed Firemap, an operational tool that provides real-time information on the speed and direction of fire spread, affected structures and population. Firemap uses the FARSITE [6] fire model, which takes into account various factors like weather conditions, fuel type, and topography to predict fire behavior. Firemap has a map interface feature that helps to visualize the fire spread as a function of time. This helps firefighters and emergency responders make informed decisions to control and suppress the fire effectively.

We have found that precise weather data is needed for reliable outputs in this type of use of fire models. Although weather sensors have been deployed densely throughout the State of California over the last 10 years, their spatial resolution is still not precise enough in varied terrain to deliver the needed data. The accuracy of fire modeling depends on the quality of the input data. Therefore, deploying sensor sources on the fire trucks and firefighters will greatly improve location-specific data collection, and Edge computing capabilities on fire trucks for local use of data will provide better situational awareness. The system is designed to adapt in real-time, with sensor data refreshing every minute. Wearable sensors monitor firefighters' live locations, while weather data and edge calculations are continuously collected and updated in the UI every minute. This ensures the system provides accurate and up-to-date information throughout an event. Users can rerun fire behavior models with real-time weather sensor data, latest fire perimeter and personnel location updates.

User Interface Extensions within Firemap and Integration with ATAK: The demonstration activity involved deploying physical RLS sensor units on firefighters and fire trucks as shown in the Fig 6, integrating the streaming data and edge computations to the WIFIRE Firemap to create fire predictions as shown in the Fig. 7, and then displaying them in ATAK to inform fire suppression activities in the field as shown in the Fig. 9.

We established a scenario where the simulated fire began in the drainage to the north of the road where the firefighters arrived. We could track 3 firefighters via GPS from the wearable sensors and the GPS on their ATAK devices. We successfully integrated weather data from the wearable sensors and the gateway device into the Firemap Platform, as shown in Fig.7. Captain at the site then directed those in the field to move west and east of the 30-minute - 1-hour simulation extent, and we then drew containment lines in Firemap to simulate suppression efforts. Subsequent modeling shows the fire contained in Fig. 8.

The ATAK, Android Team Awareness Kit, is an Android application firefighters use for geospatial situational awareness. It helps understand the surrounding terrain, situational awareness, navigation, and data sharing. We integrated sensor data with the ATAK application using a KML network link generated by WIFIRE Edge APIs. The fire simulation outputs are shown in ATAK in Fig. 9.

Importantly, the sensors measured different temperatures and wind directions, as we expected, which gave us very different fire behaviors. In this scenario, the mobile sensors show localized severe conditions not detected in the lower elevation to the south, where the nearest stationary weather sensor is installed. This demonstration successfully shows that mobile sensors, when accessible and accurate, can significantly improve fire behavior models, thus providing greater trust in the outputs and wider adoption by first responders.

IV. TRANSLATIONAL COMPUTER SCIENCE APPROACH

Translational computer science and engineering has been defined as "research that bridges foundational, use-inspired, and applied research with the delivery and deployment of its outcomes to a target community" [7]. Our work in WIFIRE Edge combines foundational advances in computing, fire science and AI to create use-inspired platforms for fire management. As such, we created a translational research methodology from the beginning of this work to ensure the outcomes would be useful when deployed at scale in fire response and mitigation settings and the generated products can be seamlessly integrated in diverse fire management tools

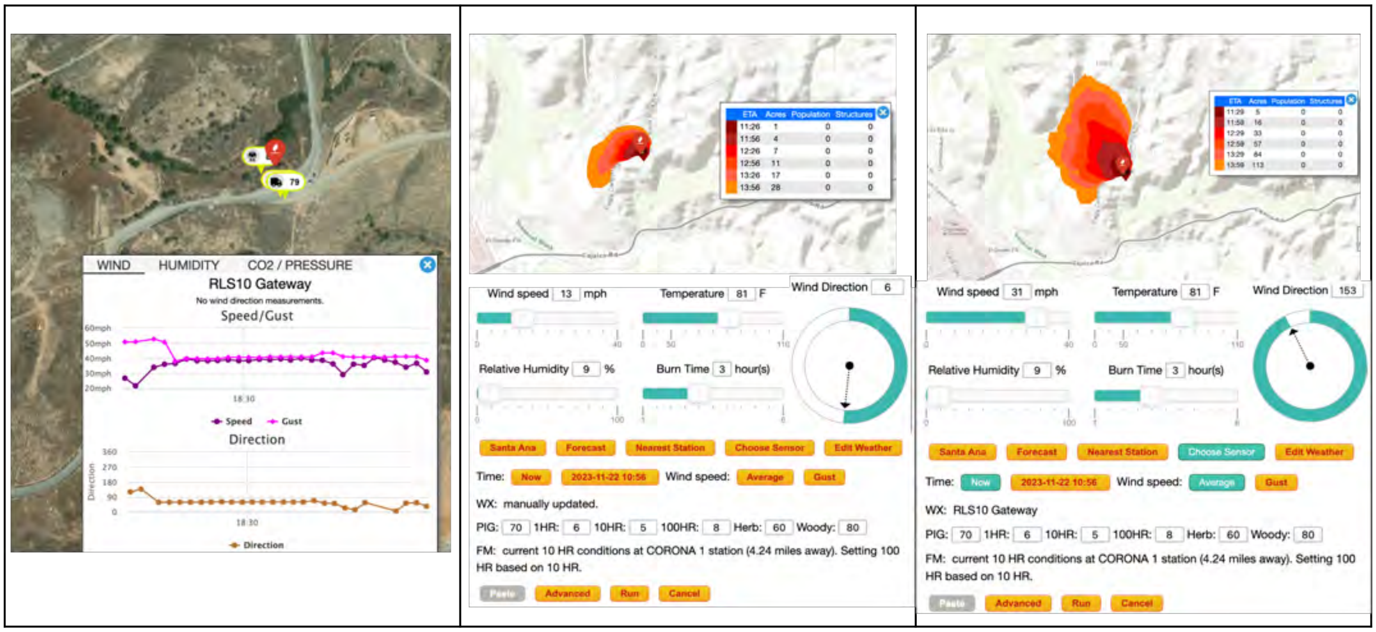

Fig. 7. The figure shows the Firemap User Interface: the left image displays the ignition point set at the location of the responding fire truck, the middle image shows fire behavior modeled using data from the nearest SoCal Edison weather station, and the right image shows fire behavior modeled using sensor weather data.

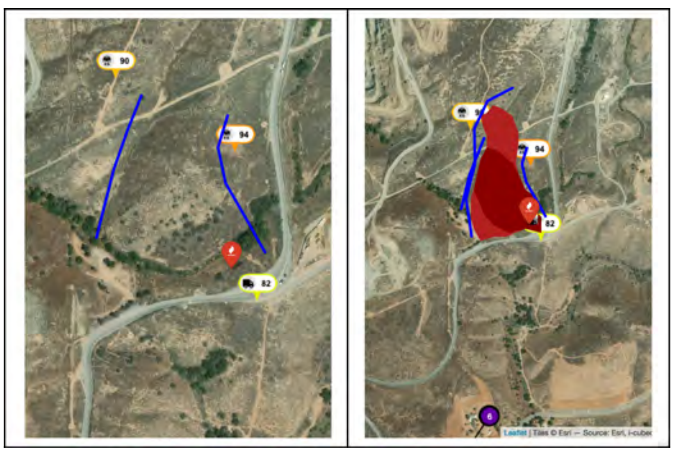

Fig. 8. The left image shows firefighters containing the fire from south to north on either flank of the growing fire, the right image shows simulation re-ran with containment lines and with the weather inputs from the gateway sensor unit to simulate suppression efforts.

and platforms (e.g., for burn planning and common operating picture).

Translation Process. Creating breakthrough technological innovations in the wildfire space requires starting with a clear understanding of use-inspired research problems and a desire to pursue innovation pathways from understanding those problems all the way to implementing solutions in the real world. This entails starting with the needs of conceptual applications, building an architecture around use of technology, deploying in demonstration settings, and scaling use through repeat and learn cycles. Innovation is fueled by integrated workflows that leverage next-generation data and AI, cutting-edge science and engineering, and advanced digital infrastructure. Situating that innovation in partnership models is necessary to enable sustained use at scale.

We worked closely with the end users (Fire Response and Prescribed Burn teams), keeping the translation process in mind during the requirements gathering, design, development, and usability testing stages. This helped us ensure development and continuous improvement based on practical translational user feedback.

Effective communication and knowledge creation across domains and sectors is only part of the approach. A translational project should capture the whole innovation pathway from problem to solution, including learning how to think across the boundaries of expertise as a team. Some of the questions that were focused on during the design and development process are mentioned below:

- How can we build a process that involves all stakeholders in science, technology and government to ensure seamless conduct of research from laboratory to demonstration to operation?
- What is a feasible timeline that can accelerate progress for all stakeholders without challenging operational systems?
- What is the impact of the proposed work at the societal scale and how can we measure the metrics for such impact?
- How can potential roadblocks be identified as risks and mitigated?
- What structures can make translation more effective?

To summarize this process, we have worked with fire management community to understand how edge computing

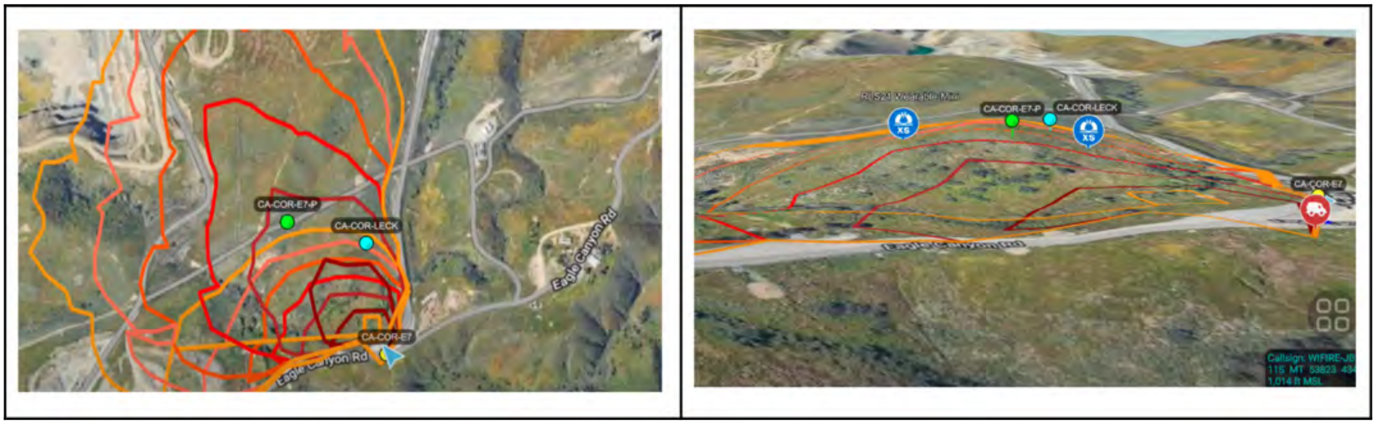

Fig. 9. The figure shows integration with ATAK application. The top left image displays two model outputs—one from a weather station and one from sensor data—overlaid in ATAK via a KML network link created by WIFIRE Edge. The figure also shows the GPS locations of firefighters, tracking their movements using sensors.

could be "useful". We have demonstrated a "usable" system which was used in the collaborative demonstrations and improved with iterative feedback. Currently, we are working on generalizing the architecture to make it "used" at scale by diverse users to deploy different edge technologies within our platforms, ATAK, and other fire application platforms.

Translational Impact. From the beginnig of the effort, our goal was to demonstrate the impacts as quickly as possible. In the short term, we focused on sensing weather variations at a micro scale that will have significant impacts on wildfire response activities for the coming fire season, using existing fire prediction tools. These were demonstrated as part of the initial attack case study. Local weather on emerging fires is currently reported from fire fighters over radio. Streamlining sensed data allowed for automating the ingestion of accurate data to modeling tools, which was transformational to combine measured weather with resource tracking using the ATAK platform. As such, we were able to demonstrate new potential workflows for better situational awareness and decision support. For the prescribed burn project, we leveraged the demonstration activities for BurnPro3D [2] to deploy WIFIRE Edge in a real-life prescribed burn. Opportunities exist for combining the pollution sensor machine learning with other remote sensing to find optimal detection of emerging fires.

To emphasize our long-term scientific impact, fusion of data from multiple sensors will catalyze the development of emerging data-intensive wildfire and prescribed fire simulation models. With the improved data quality obtained by this fusion, fire models will have a much better accuracy and dynamic data-driven ability in predicting and monitoring the fire, and will in turn provide the essential information needed to allocate fire fighting resources, safety procedures, and support decisions on evacuation at the wildland urban interface.

Risk Management. The technical risk for both sensor deployment and edge computing is low because we have used commercially available sensor units developed by Red Line Safety and existing edge computing capabilities. Some risks did arise from the deployment of these sensors in real-life environments that bring challenges related to connectivity and performance. These risks were mitigated by developing a nuanced understanding of the operational conditions when planning the demo scenarios, allowing us to learn while taking on the amount of risk we are ready for. For fire modeling, the technical risks stem from the challenges of integrating real-time monitoring into adaptive management practices for fire mitigation and response. This risk is addressed by the selection of long-time, trusted partners for both the prescribed burn and fire response demonstrations with a vested interest in integrating technology that can increase safety and efficiency into existing workflows. The user experience of partners were thoughtfully connected to our next-generation fire modeling capabilities during the development of user interfaces. We limited the cost risks by the high level of specificity in the planning for the concept demos, which piggybacked on existing funded collaborations that lack edge computing capabilities. The schedule risks were the hardest ones to manage. Both fire response and prescribed burns are largely dependent on weather conditions. We mitigates this schedule risk by planning our fire response demo during fire season alongside an existing collaboration in southern California. We planned our prescribed burn demo for a reliable time frame for prescribed burns carried out by our partners.

In this work, we demonstrated a proof-of-concept for integrating sensor data and performing edge computation for fire response and mitigation scenarios. We executed dockerized edge computations using sensor data, laying the groundwork for future AI model deployment on the edge. We plan to deploy AI models at the edge in real-world operations in the next phase of the project. We recognize several potential risks in using AI with sensor data in wildfire management, including the limited computational resources at the edge, which may necessitate the use of simplified AI models with potentially reduced accuracy. There is also the risk of bias in AI models, especially when trained on specific datasets that may not generalize well to diverse conditions. Additionally, balancing human judgment with AI recommendations is crucial, as there is a risk of over-reliance on AI in critical situations, particularly by new users. Ethical considerations and other challenges will also need to be addressed. We will be able to provide a more comprehensive analysis of issues related to AI model deployment. This will be a key focus of our future work as we scale to more sites and increase the complexity of our deployments.

V. Related Work

Edge computing infrastructure drives real-time data sensing to actionable decision making for personnel on the field. Couple of Edge computing infrastructures have been proposed in the literature. While some are design for one purpose (i.e. fire or smoke detection), the underlying infrastructure is similar in the sense that they combine a cloud and edge computing to deliver data acquired or transformed on the edge to augment their decision making process. In this particular case, determining if the fire has spread. One clear example is the SILVANUS architecture [8]. Their computing architecture is a combination of Cloud, Fog (referred to as Near Edge), and Edge computing to bring focus to three phases of wildfire management services, 1) prevention and awareness, 2) detection and response coordination, and 3) restoration and sustainability.

As a general platform, the Sage Continuum is a collection of multiple edge devices that are deployed on various locations in the USA and also internationally (Scotland) to collect sensor data and run AI applications [4]. The device has two cameras, an optical rain sensor, microphone, relative humidity, barometric pressure, and ambient temperature sensor [9]. Sage is a general platform for developers to create "Edge" applications to run on the devices computing environment (GPU and CPU) while harnessing the various sensor data streams. Furthermore, there are many different applications already provided by Sage for users to explore, query data from, and potentially to develop the application further. Some examples include smoke detection using a deep learning model, solar irradiance estimation through a deep learning model, and monitoring biodiversity using acoustic data, just to name a few. While Sage provides a general platform and is agnostic to any scientific application, the connection to various external data sources has not been developed or provided as an Edge Application in their Model catalog.

On the sensor side, N5 Sensors Inc. sensor is of valuable interest for wildfire science since it is a ultra-small, low-cost hazardous gas and particulate matter detector that can be used by firefighters [10]. This type of sensor provides the ability to detect levels of methane, oxygen, nitrogen oxygen, carbon monoxide and various other gases. In addition, for wildfire science, these sensors act as wildfire detectors by providing 24-hour sensing and alerting capabilities. Recently, they have deployed a sensor network (80 sensors) across the Hawaiian islands for a better alerting mechanism and to prevent other devastating wildfires similar to the 2023 wildfires in Maui [11]. In this deployment, the sensors are the only data part of the data ecosystem in their platform. This is seen as a limitation compared to the current system architecture proposed in this paper.

U. Dampage et al. proposed a wireless sensor network for detecting forest fires [12]. While there's a comprehensive investigation of the sensor placement to cater for harsh weather and environmental conditions, their system architecture does not incorporate any external data sources (from other sensor networks, fire simulation data, or AI derived data) and relies on the data only available through the sensor network. This is in contrast to the the WIFIRE-Edge architecture where a sensor network is only one part of the data ecosystem.

VI. Conclusion and Future Work

Our goal is to expand the WIFIRE Edge platform to effectively serve a wide range of users. We are focused on integrating multiple sensor systems and state-of-the-art edge technologies. By connecting with various fire management tools and platforms, we aim to improve situational awareness. This integration will support more accurate, data-driven decision-making in fire management and response efforts.

We are working on improving the robustness and scalability of the WIFIRE Edge platform to ensure it can be widely deployed in fire response and mitigation settings. We have successfully demonstrated a usable system at one Fire Response site and one Prescribed Burn site. Over the next year, we plan to deploy the platform at three more prescribed fire sites and three Initial Attack Fire Response sites. These real-world deployments will help us gather feedback from users and various scenarios, allowing us to make the system more effective and scalable by using a repeat-and-learn approach and iterative improvements.

Our architecture supports the integration of data from different sensor systems. Another goal in the coming year is to test and validate this through real-life demonstrations, combining data from multiple sensor systems. We plan to incorporate air-quality sensors, remote sensing technologies, and AI at the edge to optimize the detection of emerging fires. We will use sensor systems such as SAGE, N5 Sensor Systems, and RLS.

This work introduced a generalizable architecture for use of edge sensing and computing technologies for fire science and management. Edge computing is a new field, and to our knowledge, is not yet being leveraged in fire response. The more sensors that are being tested and deployed for fire detection, the more efficient computing will need to take place in the field before sending to larger cloud computing. However, our biggest impact will come from being integrated into societal safety systems.

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