Pacific Gas and Electric Company

EPIC Final Report

Program	***Electric Program Investment Charge (EPIC)***
Project	***EPIC 3.45 Automated Fire Detection from Wildfire Alert Cameras***
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Date	August 19, 2024
Version Type	*Final*
Version	1

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Table of Acronyms

PG&E	Pacific Gas & Electric
AI	Artificial Intelligence
API	Application Programming Interfaces
AWS	Amazon Web Services
CEC	California Energy Commission
CPUC	California Public Utility Commission
CSV	Comma Separated Values
EPIC	Electric Program Investment Charge
HAT	Hazard Analysis Tool
HAWC	Hazard Awareness and Warning Center
HFTD	High Fire Threat Districts
IRWIN	Integrated Reporting of Wildland-Fire Information
JSON	JavaScript Object Notation
Lambda	Language Model for Dialog Application
ML	Machine Learning
REST	Representational State Transfer
UDN	Utility Data Network
VPC	Virtual Private Cloud
VPCe	Virtual Private Cloud Endpoint
WSOC	Wildfire Safety Operations Center

1 Executive Summary

This report summarizes the project objectives, technical results and lessons learned for EPIC Project EPIC 3.45 Automated Fire Detection from Wildfire Alert Cameras. The project was authorized on October 25, 2021, and concluded on April 2024.

During extremely dry, hot, and windy weather, the difference between detecting smoke and fog when spotting wildfires is invaluable to analysts in Pacific Gas and Electric Company's (PG&E) Hazard Awareness and Warning Center (HAWC) and fire agencies. There is historic drought and California, along with other western states, continue to experience an increase in wildfire risk and a longer wildfire season. Efforts are in place to explore every new tool and reasonable technology available to improve situational awareness to help mitigate and prevent wildfires. With PG&E's territory of some 70,000 square miles, the HAWC utilizes many different tools, some internal and some publicly sourced. These include first responder dispatch tools and radio feeds, satellite detection, flight trackers, crowdsourcing, and wildfire cameras. The wildfire cameras in particular, over 600 sponsored by PG&E, are key assets. Testing Artificial Intelligence (AI) and Machine Learning (ML) capabilities in PG&E's growing network of high-definition cameras across Northern and Central California might be able to enhance fire-watch and response capabilities. The expert staff in the HAWC, outside agencies and first responders use the fire-watch cameras to monitor, detect, assess for threats, and respond to wildfires. The quicker the data is received, the quicker first responders and PG&E can confirm fires and move the right resources to the right place. As a result, this could help us avoid catastrophic events.

Background.
Pacific Gas & Electric Company (PG&E) opened the Wildfire Safety Operations Center (WSOC) in May 2018 to serve as a physical hub for coordination, facilitation, and communication of PG&E's wildfire response activities. The WSOC was stood up to play a key role in PG&E's efforts to provide customer and community safety while addressing the challenges of climate-driven weather events such as wildfires. In 2021, PG&E expanded the charter of the WSOC to become the Hazard Awareness and Warning Center (HAWC). Additional hazards addressed by the HAWC include debris flow/landslide events, company response to earthquakes, and severe weather events. The center is staffed 24/7 with employees monitoring and reporting on real-time emergency events. The center serves as a centralized hub for emergency and hazard communications and intelligence to internal stakeholders. Since its inception, PG&E has continued to mature the center over the years into where we stand today.
High-definition (HD) wildfire cameras are used by California Department of Forestry and Fire Protection (CAL FIRE), the California Governor's Office of Emergency Services, United States Forest Service (USFS), PG&E, and other local agencies to identify, confirm, and track wildfires and general conditions (based on fire behavior and associated weather risks) in real time. Cameras allow firefighting agencies to quickly confirm fire reports, assess the size and spread of the fire, and inform deployment of fire suppression resources to affected areas. PG&E also utilizes these cameras to assess a fire's potential impact to PG&E assets and provide support to the responding fire agency.

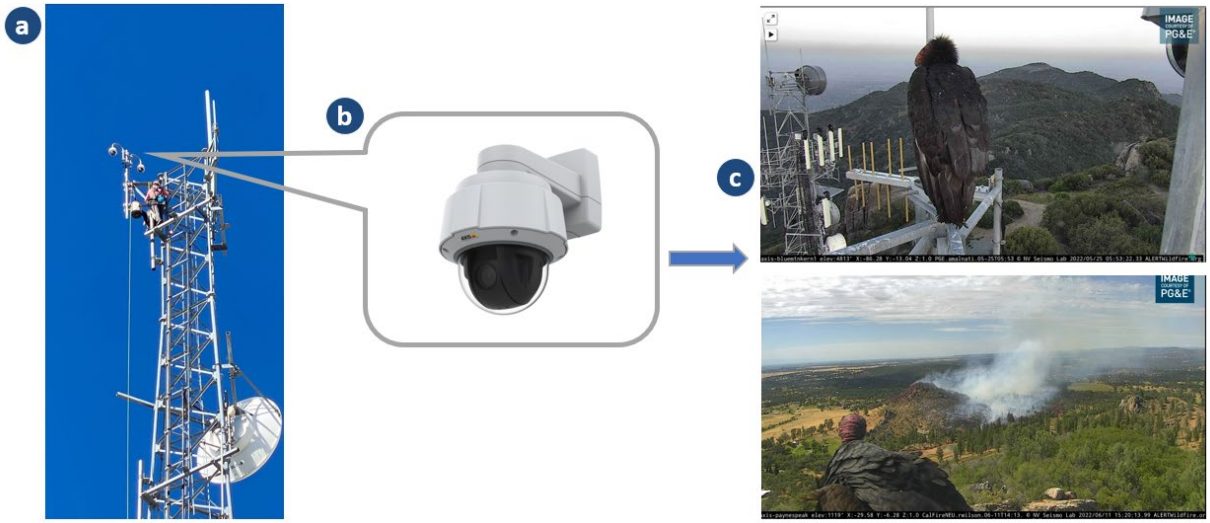


Figure 1 – Illustration of HD Camera Installation infrastructure (a) Cameras are affixed at high elevations that provide excellent viewshed coverage (b) AXIS Q6075-E PTZ Network Camera - one of several types of cameras used for installation (c) Cameras offer valuable views of early fire ignition and potential fire spread, along with wildlife.

PG&E exceeds a long-term goal with lifetime camera installation count of over 600, and viewshed coverage 90.81% vs target 90% across PG&E's service territory within High Fire Threat District (HFTD) areas (Tier 2 and Tier 3) by the end of 2022. Most of the cameras are sited in Tier 2 and Tier 3 HFTD areas. However, some cameras are sited in non-HFTD locations to provide excellent viewsheds into Tier 2 and 3 areas. Finally, there are cameras that are sited in non-HFTD areas that offer valuable views of potential fire spread into Tier 2 and Tier 3 HFTD areas.

By using camera technology, PG&E gains valuable visual intelligence and potential early warning of wildfires that could impact our electric and gas facilities. Wildfire cameras give us the information needed to: (1) issue alerts in the event of a fire and direct employees to seek safety; (2) suspend or reduce services that may be hazardous if damaged (such as lowering pressure in certain gas transmission pipes; or de-energizing power to electrical substations that may be adversely affected); and (3) initiate emergency management and response.

Benefits of wildfire cameras include:

- Heightened awareness of lightning strikes and wildfire; increased ability to take safety precautions prior to a wildfire event, leading to increased employee safety.
- Increased ability to take damage mitigation actions prior to a wildfire event, leading to increased public safety.
- Increased ability to manage crews, assets, and individual personnel through knowledge of geographic areas likely to receive the most damage prior to a wildfire event; and

- Scaled wildfire response based on wildfire intelligence provided by the camera network; and potential for decreased restoration times due to improved situational awareness for senior management directing crew allocation and assignments.

With artificial intelligence attached to each image, the HAWC will essentially have over 600 sentries on fulltime duty hunting ignitions day and night, significantly increasing the HAWC's ability to detect ignitions and potential threats within minutes. AI detections and associated locations are "pushed" directly into the HAWC's situational awareness platform (Hazard Awareness Tool) giving the team critical information at their fingertips in near real-time. The quicker the data is received and interpreted, the more rapidly first responders and PG&E can confirm fires and move the right resources to the right place. As a result, this could further help avoid catastrophic events.

Key Objectives

To help address these barriers, EPIC 3.45 Automated Fire Detection from Wildfire Alert Cameras established the following objectives:

- Demonstrate AI/ML to enable quicker, more accurate fire detection than the existing method. This should be accomplished with low false-positive (when the AI detects smoke or fire when no smoke or fire exists) and false-negative rates (when the AI does not detect smoke or fire, but smoke or fire does exist) and be capable of fully integrating this intelligence into the HAWC capabilities and workflows.
- Improve the response time for confirmation of ignitions compared to the Integrated Reporting of Wildland-Fire Information (IRWIN) alerts followed by visually confirmation.
- Evaluate the ability for full AI solution deployment through system integration and alert notification of smoke and fire detection to the Hazard Analysis Tool (HAT) with minimal operational interruptions. Additionally, evaluate enhanced features such as nighttime detection and triangulation accuracy.

Key Accomplishments

The following summarizes the key accomplishments of the project over the project duration:

Via Request for Proposal, three vendors with experience in fire detection were selected to demonstrate their technology offering through this project. The project demonstrated successful network integration over the course of three milestone phases across 160 HD cameras utilizing a unique ALERTCalifornia Application Programming Interface (API) key to ingest data sets for ML capabilities. Data sets were produced to increase the model training for each of the vendors and improve overall functionality and key metrics. The team was also able to determine which measurable parameters were critical to success. The team used this learning to demonstrate the important features and potential use cases of the AI approach including, but not limited to:

- Day and Night-time detection.
- Median time difference between IRWIN discovery and vendor alerts.
- Redundant alerts.

- Estimated latitude and longitude of the detected ignition events with accuracy analysis to compare against the location of the HAWC's Hazard Analysis Tool (HAT) fire pin drop.
- Integration of automated detection into the HAT dashboard.

Key Takeaways

The following findings are the key takeaways and lessons learned from this project:

- This project's demonstration has identified the use case of AI as a potentially viable solution to expedite initial ignition detection and response. Machine learning and enhanced camera/computer vision technologies can provide an alternative to existing wildfire ignition detection methods with reduced time and integrated response capabilities with fewer errors. Two camera location methods were introduced in this demonstration: Single Camera Location Estimation (finding ignition point of the fire using a single camera) and Triangulation (finding the camera view intersection points with two or more cameras to improve location estimation). A large part of the evaluation was based primarily on the Single Camera Location method to create a baseline coverage across areas highly prone to wildfires, with high number of PG&E assets and varied terrain, to ensure variety of coverage. The project participants continued in their efforts with refining the advancement of the Triangulation method, but it was not available until the last test phase.

- The early assessment of the Single Camera Location Estimation method indicated the basic Day and Night-time ignition detection was successful, however evaluation of increased functionality determined further improvement was needed to decrease the median detection time versus IRWIN discovery and average mile error. The results did not meet the project's established performance requirements.

- The implementation of the Triangulation method showed promise to resolve the limitations of Single Camera Location Estimation. Unfortunately, in order to simplify testing, training, and analysis, only 160 cameras (out of over 600) were made available. The method requires the intersection point with two or more cameras, so if the incident occurred where only one camera was within viewshed distance, technicians had to rely on the Single Camera Location Estimation method instead. Testing across the entire camera network of 600+ cameras would contribute to more robust test results.

Challenges and Resolutions

This project had two major thrusts:

- Determine if the capabilities of AI/ML systems used with a limited set of cameras meet the pre-defined performance standards, and
- Determine if it was feasible to integrate the fire identifications into PG&E's existing HAWC systems.

While the AI/ML fire detection systems were able to consistently identify fires, the indications were not consistently faster than the existing methods used by the HAWC staff. Additionally, the location estimations did not consistently meet the performance standards that had been previously established. The single camera approach was somewhat limiting, but even using the multi-camera triangulation approach did not consistently meet the performance expectations. Consequently, the

team did not select any of the vendors that were tested for subsequent full operational deployment. However, the team recognized the nascent technology was tackling a very difficult problem set and continues to explore the technology and associated improvements.
Regarding the second major thrust, the project was able to demonstrate an integration between the HAWC dashboards and the outputs from the AI/ML vendor.
After the EPIC demonstration established performance criteria, a fourth vendor was identified and taken under contract. While testing of this fourth vendor continues under much more refined criteria, the analytic results are notably improved and are near to performance and integration targets, and in some cases, the resulting predictions exceed the performance metrics.

Recommendations

PG&E, other major California utilities, and local and federal agencies are installing hundreds of wildfire alert cameras through contract work with The Regents of the University of California (specifically University of California San Diego--UCSD). In partnership with UCSD, a third-party vendor who did not participate in the EPIC project was selected as their primary installation vendor for Wildfire Cameras. The vendor also created the new interface/command and control system for the cameras and launched the ALERTCalifornia site (Alertcalifornia.org). This partnership is uniquely positioned to bring AI to the ALERTCalifornia network. The fourth vendor has worked during the recent fire seasons to develop an in-house AI solution that will serve all ALERTCalifornia consumers with a single solution. The metrics and performance standards developed in this project provide a foundation for further testing and assessment of new technology and will be applied to the analysis tasks moving forward. What this means for PG&E, through EPIC 3.45, is that the Company is positioned to be part of this consortium that will provide instantaneous access to all wildfire cameras within the state with no need to work in integrating the camera feeds for control access as noted above.

Data and images from these cameras are publicly available via https://ops.alertcalifornia.org. The training regimen, performance metrics, and operability characteristics that were developed and demonstrated by EPIC 3.45 are foundational for future near real-time fire detection alerts and their dissemination. Wildfire Camera use with Artificial Intelligence is currently operational and being evaluated, along with CAL FIRE, Cal Office of Emergency Services (OES) and other agencies working with the same vendor. Continued sponsorship into this consortium with other major CA utility companies and local and federal agencies will enable all stakeholders to access the AI solution.

This approach is consistent with PG&E's ongoing evaluation of AI/ML for wildfire ignition, and recognizes the promise for greater accuracy and reliability. In 2021 a pilot program was conducted with a vendor related to AI detection on cameras. In 2022 the assessment continued through the program, EPIC 3.45 - Automated Fire Detection from Wildfire Alert Cameras. From the assessment period it was determined that AI detection on camera was currently not meeting our desired performance, but will improve the detection system over time. In 2023, as noted above, PG&E and our partners of ALERTCalifornia have engaged with a fourth vendor to implement AI detection on all cameras and early results are promising.

Conclusion

The EPIC 3.45 Automated Fire Detection from Wildfire Alert Cameras project successfully demonstrated a new set of tools to leverage the value of PG&E's network of over 600 wildfire cameras. As hot, dry, windy conditions become more common with climate change, the importance of

early detection and mitigation increases. At the onset of this project, camera images were evaluated by HAWC staff, and the possibility of increasing the speed and locational capability of fire identification offered additional safety for the public and PG&E's assets. At the conclusion of this project the products tested did not yield sufficient improvements based on the established performance criteria. However, the performance requirements that were defined and the interface requirements that were developed were very beneficial in leading PG&E to adopt another 3rd party solution subsequently identified outside of this project.

2 Introduction

This report documents the EPIC 3.45 Automated Fire Detection from Wildfire Alert Cameras project achievements, highlights key learnings from the project that have industry-wide value, and identifies future opportunities for PG&E to leverage this project.

The California Public Utilities Commission (CPUC) passed several decisions that established the basis for this demonstration program. The CPUC initially issued D. 11-12-035, *Decision Establishing Interim Research, Development and Demonstrations and Renewables Program Funding Level*[1], which established the Electric Program Investment Charge (EPIC) on December 15, 2011. Subsequently, on May 24, 2012, the CPUC issued D. 12-05-037, *Phase 2 Decision Establishing Purposes and Governance for Electric Program Investment Charge and Establishing Funding Collections for 2013-2020*[2], which authorized funding in the areas of applied research and development, technology demonstration and deployment (TD&D), and market facilitation. In this later decision, CPUC defined TD&D as "the installation and operation of pre-commercial technologies or strategies at a scale sufficiently large and in conditions sufficiently reflective of anticipated actual operating environments to enable appraisal of the operational and performance characteristics and the financial risks associated with a given technology."[3]

The decision also required the EPIC Program Administrators[4] to submit Triennial Investment Plans to cover three-year funding cycles for 2012-2014, 2015-2017, and 2018-2020. On November 1, 2012, in A.12-11-003, PG&E filed its first triennial Electric Program Investment Charge (EPIC) Application with the CPUC, requesting $49,328,000 including funding for 26 Technology Demonstration and Deployment Projects. On November 14, 2013, in D.13-11-025, the CPUC approved PG&E's EPIC plan, including $49,328,000 for this program category. On May 1, 2014, PG&E filed its second triennial investment plan for the period of 2015-2017 in the EPIC 2 Application (A.14-05-003). CPUC approved

[1] http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/156050.PDF
[2] http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF
[3] Decision 12-05-037 pg. 37

[4] Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E), Southern California Edison (SCE), and the California Energy Commission (CEC)

this plan in D.15-04-020 on April 15, 2015, including $51,080,200 for 31 TD&D projects.[5] On April 28, 2017, in A.17-04-028, PG&E filed its third triennial EPIC Application at the CPUC, requesting authorization for its for 43 Technology Demonstration and Deployment Projects. CPUC approved this plan through D.18-10-052 on October 25, 2018, and D.20-02-003 on February 10, 2020, and authorized $49,771,845 for the 43 TD&D projects[6].

Pursuant to PG&E's approved 2018-2020 EPIC triennial plan, PG&E initiated, planned and implemented the following project: 3.45 Automated Fire Detection from Wildfire Alert Cameras. Through the annual reporting process, PG&E has kept CPUC staff and stakeholder informed on the progress of the project. The following is PG&E's final report on this project.

3 Project Summary

Pacific Gas and Electric Company's (PG&E) Electric Program Investment Charge (EPIC) Project 3.45, Automated Fire Detection from Wildfire Alert Cameras successfully completed a demonstration program to develop and test the integration of AI ignition predictions with PG&E's situational awareness tool to send fire detection alerts directly to the Hazard Awareness and Warning Center Analyst team. Artificial Intelligence fire detections provide valuable information to PG&E and first responding agencies regarding the presence of new fires. When artificial intelligence (AI) detects new fires, notifications to the utility and first responders can occur more quickly than relying solely on other means of detection.

The project compared the results of these tools across the three vendors chosen to participate. The primary goal of this EPIC project was to demonstrate an automated fire detection model using machine learning, computer vision, or AI techniques that can more accurately detect fires based on visual and infrared camera data streams than can current methodologies such as satellite data. The project leverages an already available HD camera network so the enablement of the AI technology could immediately enhance the capability of the wildfire camera network to accelerate the detection with reduced time and integrated response capabilities with fewer errors and as a result, mitigation of wildfires and limit wildfire spread.

The project intends to speed up identification of wildfire ignitions, including ignitions potentially involving PG&E assets, which would increase the safety of our customers and the system. With extreme dry, hot, and windy weather, in combination with drought, there is an increase in wildfire risk and longer wildfire season.

3.1 Issue Addressed

With over six hundred cameras - spanning across 90.81% of High Fire Threat Districts (HFTD) risk-based viewshed coverage - now deployed in real time for ignitions continuously, HAWC analysts

[5] In the EPIC 2 Plan Application (A.14-05-003), PG&E originally proposed 30 projects. Per CPUC D.15-04-020 to include an assessment of the use and impact of EV energy flow capabilities, Project 2.03 was split into two projects, resulting in a total of 31 projects.

[6] https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M326/K843/326843048.PDF

will not have the capability to manually monitor feeds from each camera. In support of the CPUC approved metric to deliver public safety improvement and hazard exposure reduction, there is continued pursuit of enhancement of situational awareness without having to add additional headcount to perform incident research and reporting. The implementation of Artificial Intelligence technology aims to complement other forms of existing fire detection platforms, such as satellite data, to detect fires as fast as possible. It also potentially delivers improvement in ignition to detection time reduction enabled by AI-generated ignition alerts with alert notifications received before IRWIN or other social media alerts based on current processes. The use of AI technology may provide an ability to identify location with close accuracy, i.e., latitude/longitude coordinates, nearby landmarks, or company assets.

3.2 Project Objectives

To accomplish the objectives for 3.45 Automated Fire Detection from Wildfire Alert Cameras, the following key items were developed:

PG&E is interested to see if a technology solution has the potential to:

- Demonstrate that an AI solution can be used to detect early-stage fires within 3 minutes of ignition through image recognition for a faster response to potentially catastrophic wildfires.
- Demonstrate that an AI solution can be used to detect early-stage fires within 3 minutes of ignition though image recognition in low-light and nighttime environments.
- Demonstrate the ability of AI solution to accurately determine the location of an ignition event to within 0.25 miles.
- Demonstrate the ability to integrate and send alerts about smoke and fire detection to the HAT.
- Demonstrate that AI solution can be used to alert the HAWC about relevant fires without overwhelming the end user with redundant alerts and false positives. Controlled burns are the most dominant source of redundant alerts. The HAWC analysts will be surveyed at the end of the program to gauge where the AI solution ranks in the list of their preferred sources for fire/smoke detections.

This project builds upon two previous internal PG&E demonstrations with enhanced cameras and automated ignition detection systems. In continuation of these efforts, the end-product of this demonstration will potentially integrate the AI technology into the existing HAT through utilization of the HD cameras installed within our service territory with additional feature refinement that have yet to be accomplished from the prior efforts. The enhancements include additional functionality to come from alert management and triangulation accuracy.

a. Detect smoke and/ or fire as soon as visible within the camera frame during day and night.
b. Manage alert notifications for those empowered to direct emergency response.
c. Display real-time fire alerts from the AI, both recent and historical, with time, date, and location of alerts.
d. Enable PG&E to view all connected cameras in real-time.
e. Enable triangulation accuracy of ignition to the degree possible.

<u>Relationship to other efforts</u>:

1. PG&E participated in a pilot through EPRI's Incubatenergy program. The vendor provided access to data feeds from 7 vendor Stations in Lake and Sonoma Counties

which consist of AI cameras with 360° panoramic view. Additionally, the vendor provided access to any new vendor Stations deployed within PG&E territory during the pilot period. This work was focused on technologies daytime detection capabilities, with no systems integration on small scale. EPIC project's scope includes night vision and ignition triangulation refinement.

2. Through a dedicated vendor web dashboard, PG&E will be able to review all alerts and fire detections from the machine vision algorithm, as well as manage the alert notifications which will be sent by SMS or email. This work was focused on technologies daytime detection capabilities, with no systems integration. EPIC project's scope includes night vision and ignition triangulation refinement.

3.3 Scope of Work and Project Tasks

This project focused on the enhancement of the capability of the wildfire camera network to accelerate the detection and mitigation of wildfires and limit wildfire spread. The project's scope was to specify and deliver an integrated automated wildfire detection solution with additional improvements identified during the demonstration, additional integration capabilities identified during the demonstration, and a system that can quickly and reliably detect wildfires automatically with minimal human interference. The participating vendors implemented PG&E requirements for their interactive cloud-based dashboard, and if invited on merit, to participate in the final phase test the integration of automated detection into the HAT.

3.3.1 Tasks and Milestones

The project involved three tasks:

1. Vendor Selection: This task developed a request for proposal package (RFP) including statement of work (SOW) and scoring criteria, which was issued on January 14, 2022.

   PG&E's primary objectives for this RFP were to:
   - Identify and test best-in-class technology solutions that will meet PG&E requirements.
   - Develop mutually beneficial relationships with best-in-class companies.
   - Establish competitive pricing for this technology solution that can scale meet sustainable cost objectives.
   - Establish performance standards, metrics, and reporting processes to generate consistent, efficient, and effective results for PG&E.

   PG&E's overall objective includes identifying a supplier(s) with a technology solution that meets our requirements as identified in this RFP and potentially continue after this project to provide their technology solution in a longer-term operational relationship with reasonable and predictable costs.

2. Develop and Test key metrics of increased functionality and improvement over the course of three (3) milestone phases over the course of eight (8) weeks with each phase. Vendors must demonstrate acceptable performance of current phase to advance to the next.
   a. PHASE 1 FIRE DETECTION (DAY TIME): Deliver a smoke and fire detection for 80 HD cameras utilizing the ALERTCalifornia Wildfire API and made viewable from vendor's

interactive cloud-based dashboard. Ability to demonstrate the features include, but not limited to:

i. Day-time detection
ii. Median time difference between IRWIN discovery and vendor alerts
iii. Monitor percentage of redundant alerts

b. PHASE 2 FIRE DETECTION (ADD NIGHTTIME +LOCATION): Improve upon key metrics outlined during Phase 1 with additional functionality requirements:
    i. Deliver a smoke and fire detection for 160 HD cameras.
    ii. Day and Night-time detections.
    iii. Alerts include estimated latitude and longitude of the detected ignition events with accuracy analysis to compare against the location of the HAT fire pin drop.
c. PHASE 3 INTEGRATION: Continued improvement upon Phase 1 and 2 performance and the final step of the integration of automated detection into the HAT.

3. Final Evaluation: Upon completing the final phase milestone, final evaluations were completed for each vendor that remained, considering achievement of key metric deliverables across all three phases and successful integration of automated detections into the HAT.

4 Project Activities, Results, and Findings

4.1 Technical Results and Findings

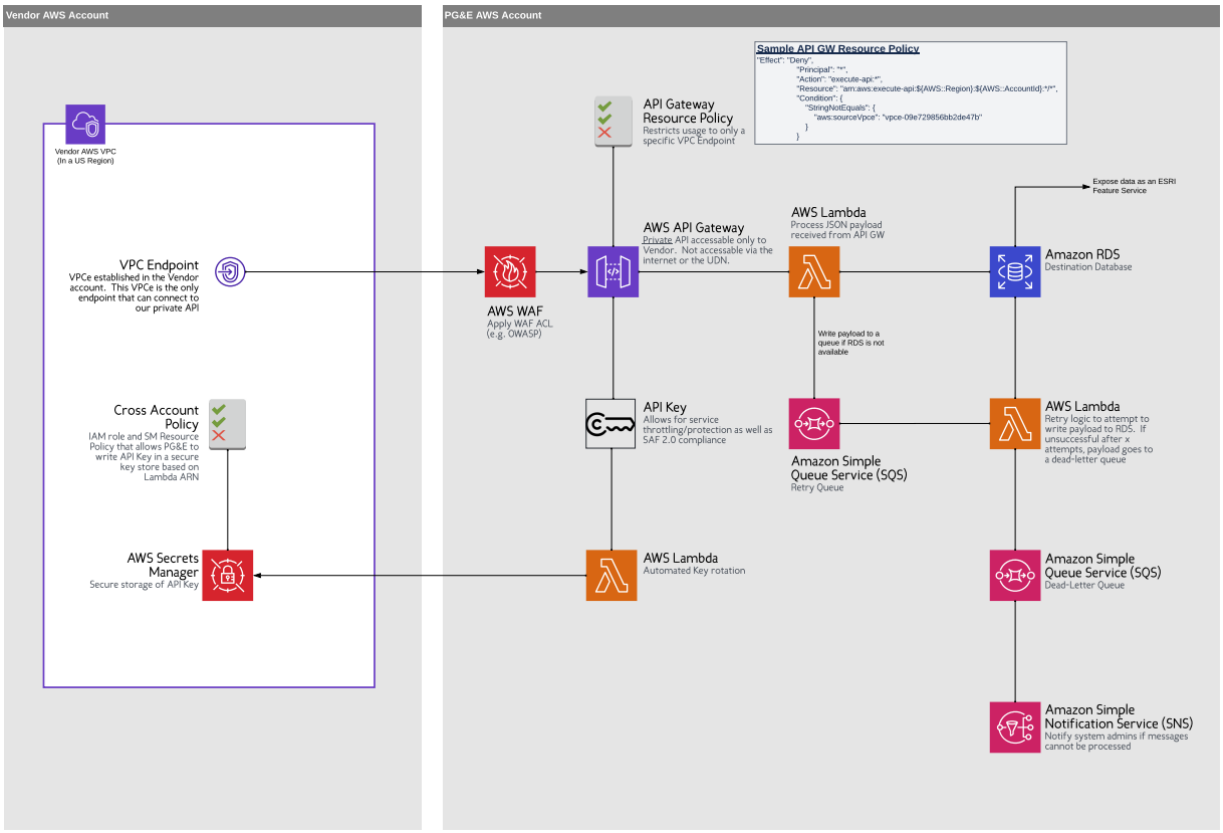
The hypothesis was that employing an AI solution to utilize machine learning algorithms to teach machines to identify patterns and trends from data can provide an alternative to the current process of starting with monitoring IRWIN alerts and visually confirming ignitions with wildfire cameras. The hypothesis further suggest current detection methods can be improved to expedite the initial response time more quickly than human operators.

The project workflow was designed in a similar fashion to the application of training neural networks for self-driving vehicles. First on the vendor side, images of known smoke plumes and infrared signatures from fires will be sourced from existing AlertCalifornia images library to train and optimize the Machine Leaning (ML) Training model. A subset of the image sources will be utilized as a validation dataset to compute precision and recall and other metrics to determine model performance. The model can then be optimized in an iterative process to limit errors of commission and omission. Next, the model will be tested in real-time against AlertCalifornia imagery.

The ML Training Model consumes the fire detections and historical data. The raw historical data extracted from AlertCalifornia are made available in a shared folder in the standalone environment (for example, a laptop) in the form of Comma Separated Values (CSV) files. The raw data files are transformed through a data transformation pre-process to prepare the data for ingestion by the ML Training Model. The transformed data is saved back to the shared folder in the form of CSV files. The ML Training Model then consumes the transformed CSV files and then produces an output JavaScript Object Notation (JSON) file. A JSON file is a file that stores simple data structures and objects in JavaScript Object Notation (JSON) format, which is a standard data interchange format. It is primarily used for transmitting data between a web application and a server. This output JSON data files, also referred to as a “Trained Data” file, represents fire detection identifiers that were “learned” from the historical data. The Trained Data file consists of the fire ignition information for each camera detection image.

Prior to API integration into the HAT during Phase 3, the output of images was monitored through a dedicated vendor web dashboard where PG&E was able to review all alerts and fire detections from the machine vision algorithm, as well as manage the alert notifications which was sent by SMS or email. In Phase 3, a key component of the evaluation was the vendor’s ability to demonstrate a technology solution that meets requirements for successful integration into the HAT. The demonstration explored integration of JSON data files through the AWS Gateway Architectural Design as illustrated in Figure 4 which shows the data flow between a vendor and PG&E’s end applications.

Figure 4 – AWS Gateway Architectural Design



Features of the integration include:

AWS architecture leverages existing Cybersecurity pattern widely used today for exposing private AWS API Gateway resources to the Utility Data Network (UDN) via a Virtual Private Cloud Endpoint (VPCe). In this model, the vendors will be able to simply call Representational State Transfer (REST) endpoints. There will be no need to use the AWS Software Development Kit to call Lambda directly. Lambda is a serverless compute service provided by AWS which enables users to run code without the need to manage infrastructure which respond to events and automatically manage the computing power needed by that code. Vendors would be required to establish a VPC endpoint in their AWS VPC and shared the VPCe ID with the PG&E team. PG&E would establish a resource policy on API Gateway specific to the vendor provided VPCe ID. This would make the API Gateway traffic Private and would only be accessible by a single VPC endpoint. No public internet would be involved as well. All networking would remain in AWS.

A REST API will respond with standard HTTP response codes (e.g., 200, 401, 500, etc.) making error handling easier on the vendor side as opposed to custom error messages required for Lambda integrations.

API Gateway would be SAF2.0 compliant with an API Key (Until a Lambda Authorizer can be established with the emerging AzureAD implementation at PG&E). Documentation for API key established within an internal PG&E Wiki portal, AWS API Gateways without API Keys and Authorization set to NONE - Cloud COE - PGE Wiki, defines this API method as follows:

> "This finding identifies API endpoints that have not been secured. To remediate this finding, you must either require the API to use an API key or you must use a Lambda Authorizer. For the API Key method, API Gateway reads the key and compares it against the keys in the usage plan. If there is a match, API Gateway throttles the requests according to the plan's request limit and quota thereby protecting the service from being overloaded. As for the latter resolution, a Lambda Authorizer is a peculiar type of Lambda function. It accepts an object containing a token and returns a JSON policy to allow or block an API execution. At PG&E the authorizer will take the token and validate access against our IdP (PingFederate) which is also integrated with Active Directory and PG&E's internal electronic access tool, the company's user registration tool. This token validation in the Lambda Authorizer provides both authentication and authorization."

The use of API Gateway will allow protection of the service from over utilization through usage plans that would not be available if Lambda is called directly. Future builds could automate key rotation via Lambda, Secrets Manager, and cross account policies making API key rotation seamless for both PG&E and Vendor.

DEMONSTRATION TEST CAMERA SITES

The HAWC Analyst team identified pilot test sites based on pre-determine criteria:

- Focus on areas highly prone to wildfires anywhere from small (~10 acres) to catastrophic levels.
- Focus on areas with high number of PG&E assets in the area (primarily electric assets but also hydro facilities).
- Cameras with varied terrain: High Fire-Threat District (HFTD) Tier 1 grass/agriculture on the valley floor to rugged forests, steep slopes, ridgelines, or drainages.

Key metrics were developed with which each advancement to subsequent phases were based on corresponding phase evaluation with continued improvement from prior phases. Successful delivery of each milestone metrics resulted in the invitation to continue onto the next phase and so forth until the last milestone of Phase 3.

Table 1 - Key metrics with continued improvement

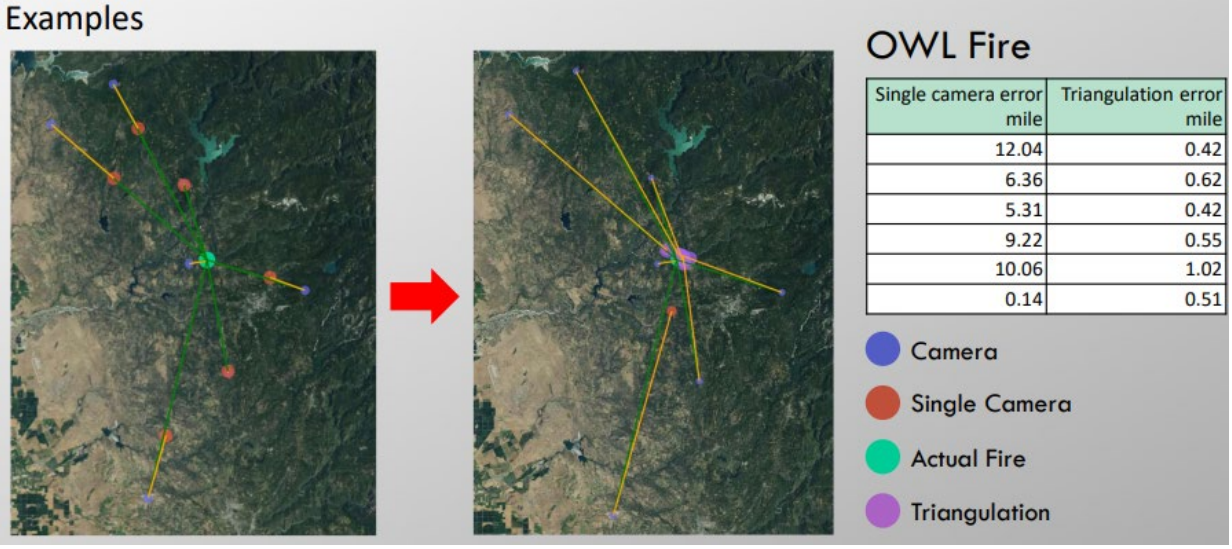
Performance Metrics	Phase 1 Target	Phase 2 Target	Phase 3 Target	Multiplier	Description
Percentage of incidents correctly identified in under 5 minutes - DAYLIGHT	**85%**	**90%**	**95%**	**0.35**	**Detect an ignition and send alert to HAWC within 5 minutes of smoke in frame**
Determination of latitude/longitude within 1 mile of incidents correctly identified	**N/A**	**80%**	**85%**	**0.25**	**Compare vendor lat/long to WIV fire pin drop export**
Median time difference between IRWIN, PulsePoint, CHP and your alert (min) - DAYLIGHT	**+4:00**	**+3:00**	**+2:00**	**0.15**	**Compare vendor notification time against IRWIN, PulsePoint, and CHP alert time.**
Integration into WIV	**N/A**	**N/A**	**Yes**	**0.15**	**Integrate with PG&E's situational awareness tool to send alerts directly to HAWC analysts**
Percentage of incidents correctly identified in under 5 minutes - NIGHT	**N/A**	**80%**	**85%**	**0.1**	**Detect an ignition and send alert to HAWC within 5 minutes of smoke or heat in frame**
Percentage of redundant alerts received	20%	15%	10%		Percentage orf alerts that are received from fires HAWC has already been notified about
Percentage of incidents correctly identified in under 3 minutes - DAYLIGHT	75%	80%	85%		Detect an ignition and send alert to HAWC within 3 minutes of smoke in frame
Percentage of incidents correctly Identified in under 60 seconds - DAYLIGHT	25%	30%	35%		Detect an ignition and send alert to HAWC within 1 minute of smoke in frame
Determination of latitude/longitude within .25 miles of incidents correctly identified	N/A	40%	45%		Compare vendor lat/long to WIV fire pin drop export

4.2 Challenges

Throughout the three phases, a recurring theme across all vendor partners was the low confidence level of AI detection alerts partly contributed by technical constraints behind a nascent technology. For instance, the determination of vendor's latitude and longitude to consistently report within one (1) mile of incident compared to the HAWC HAT fire pin drop was a challenge when utilizing a single-camera location estimation method versus triangulation.

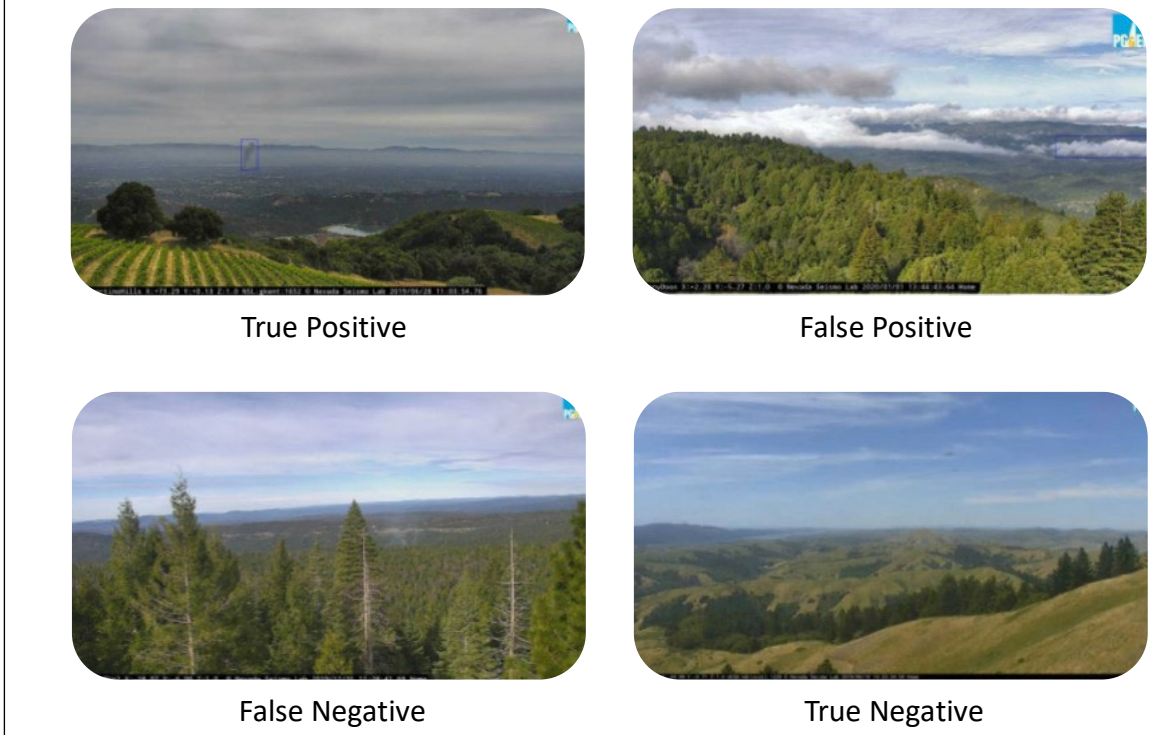
When a vendor reviewed a prior fire detection to test out the triangulation method, they were able to demonstrate an improved location estimation to decrease the error mile.

Figure 5 – Illustration of single-camera location estimation method versus triangulation. The picture on the left shows the location estimation of six cameras, with significant error as shown in the table. The picture on the right shows the improvement by using a second camera to allow triangulation.



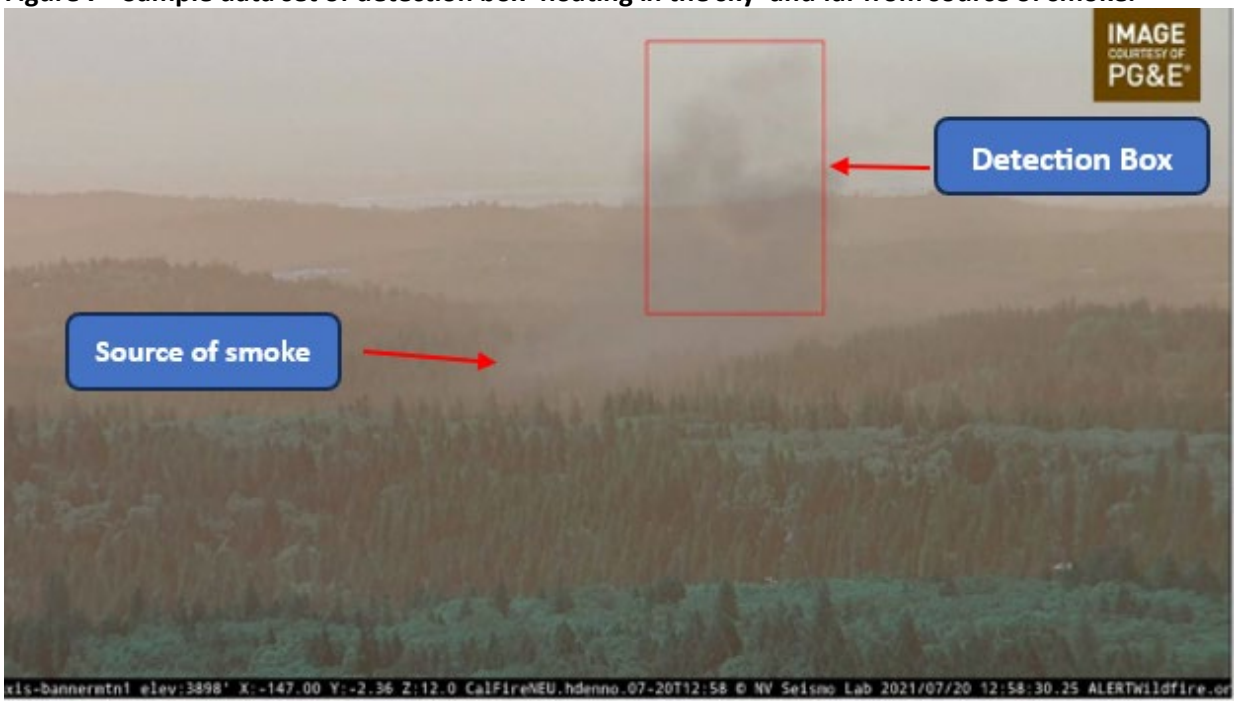
The ability to use triangulation was limited due to the selective number of cameras included during this demonstration. Learning from a previous demonstration with just 46 cameras, large volumes of insignificant detection alerts hindered Analyst productivity so there was a need to put a control of camera count in place. The insignificant detections included repetitive alerts (the AI generated multiple fire detection alerts of the same incident), False Positives and False Negatives. If advanced detection algorithms were implemented with a vendor's machine learning to filter out these detections, there would have been consideration to increase the camera count to further test out the triangulation method.

Figure 6 – Sample data set of useful (True Positive) and insignificant (False Positive/False Negative) fire detection alert algorithm.



Accuracy of distance was impacted when the detection box is 'floating in the sky', so the location is estimated while looking at the sky taking it beyond the location of actual fire. In this same instance, the detection box was fixated on smoke behind tree ridgelines with the smoke column far off from the initial source of smoke.

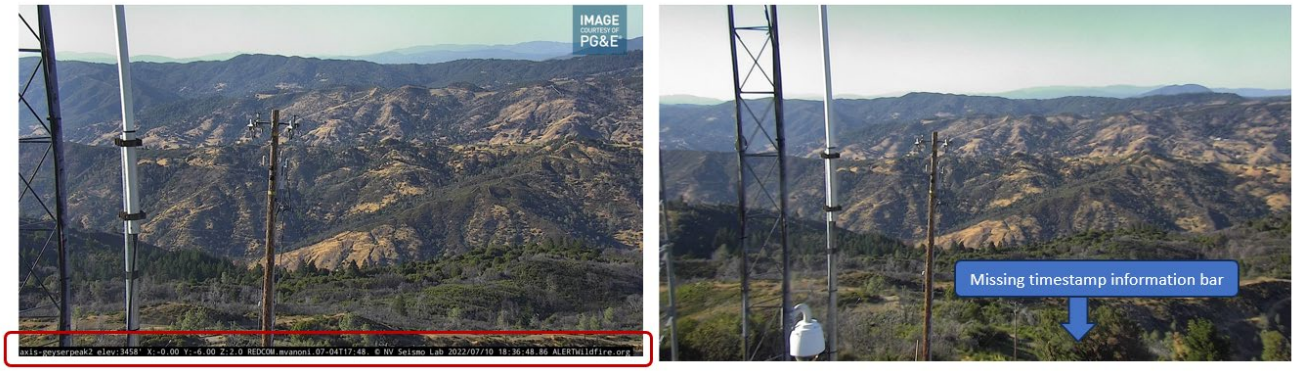
Figure 7 - Sample data set of detection box 'floating in the sky' and far from source of smoke.



In another challenge, the median time difference between the vendor notification against IRWIN discovery time could not meet or exceed the 2-minute threshold because vendors were working against limitations set with API key call rates of 1 frame image per 10 second which impedes on ability to return timely detection for patrol cameras waiting to complete full rotations. In the event AlertWildfire enables faster API key call rates, there may be more favorable results.

The vendors also relied on the timestamp bar on the frame image returned from the HD cameras to reference the X, Y and Z axis to detect camera bearing and assist with location accuracy. When the frame image returned was missing, this resulted in missed or inaccurate alert detections.

Figure 8 - Sample data set of missing timestamp bar on frame image return.



These technical constraints were identified during respective phases and considered as part of each vendor's evaluation to succeed into the next phase.

4.3 Results and Observations

AI Solutions in general have been shown to be lacking in their ability to meet the needs of the PG&E team (HAWC) due to features that need further refinement. There was a significant amount of redundant email alerts that when combined with new camera alerts, created too much "noise" and prevented the ability for Analysts to prioritize the alerts. In testing a small subset of 160 cameras out of 600, the volume was too significant and may have overwhelmed the HAT had we been fully integrated. That is in part as to why this project was broken down into three phases, with the system integration as the final phase. The quality of the data that flowed through illustrated the lack of AI ability to show accurate location under one mile and as a result required additional corroboration with other detection methods. This result suppressed the opportunity to provide accurate and timely information for critical communication channels.

Additional setbacks include immaturity of the technology in general that require continued machine learning to improve False-positive rate (when the AI detects smoke or fire when no smoke or fire exists), False negative rate (when the AI does not detect smoke or fire, but smoke or fire does exist), challenges with night detections, and challenges with properly ingesting the camera data. By Phase 3, there remained only one vendor partner. The IT solution API endpoints between both the vendor and HAT demonstrated successful interface of JSON payload consumed from vendor's production environment into the HAT's QA environment.

Overall, there were cumulative improvements across the three phases with a quicker median time difference between IRWIN discovery time and vendor detection time and reduction of repetitive alerts. Unfortunately, the measurement of distance in miles between latitude and longitude in comparison of AI detection and HAT fire pin entry was still greater than 1 mile. The Operational team shared concern that there a need for more accurate data for this to be a value add to their operational process. As noted in the Executive Summary, after the lesson-filled work of EPIC 3.45, PG&E identified a fourth vendor that has shown great promise and meets or approaches the performance criteria identified earlier in Table 1 of this section.

5 Value proposition

The purpose of EPIC funding is to support investments in technology demonstration and deployment projects that benefit the electricity customers of PG&E, San Diego Gas and Electric (SDG&E), and Southern California Edison (SCE). 3.45 Automated Fire Detection from Wildfire Alert Cameras has demonstrated a novel process of incorporating automated detection to PG&E's systems and operations.

Relevant CPUC-approved metrics:

In support of the CPUC approved metric to deliver public safety improvement and hazard exposure reduction, there is continued pursuit of enhancement of situational awareness.

1) Economic benefits
    a. Maintain / Reduce operations and maintenance costs.
    b. Maintain / Reduce capital costs.
2) Safety, Power Quality, and Reliability (Equipment, Electricity System)
    a. Public safety improvement and hazard exposure reduction

5.1 Primary Principles

The primary principles of EPIC are to invest in technologies and approaches that provide benefits to electric ratepayers by promoting greater reliability, lower costs, and increased safety. This EPIC project contributes to these primary principles in the following ways:

- Increased safety and/or enhanced environmental sustainability: It is critical to identify the location of an ignition in the initial stage of a wildfire to suppress it while the scale is manageable.
- Greater reliability: Improvements in ignition to detection time reduction enabled by AI-generated ignition alerts with alert notifications received before IRWIN or other social media alerts based on current processes may assist with cascading critical communications with timely and accurate information. Further, an ignition detected and managed early results in fewer outages to customers.
- Lower costs: Enhance situational awareness without having to add additional headcount to perform incident research and reporting. With hundreds of cameras now deployed and hundreds more on the way, analysts will not have the capability to manually monitor feeds from each camera.

5.2 Secondary Principles

EPIC also has a set of complementary secondary principles. This EPIC project contributes to the following three secondary principles: societal benefits, greenhouse gas (GHG) emissions reduction, the loading order, low-emission vehicles/transmission, economic development; and efficient use of ratepayer funds.

- Societal benefits: The quicker the data is received, the more quickly PG&E HAWC Analysts can confirm fires and move the right resources to the right place. As a result, this could help us mitigate and prevent catastrophic wildfire events.

- Greenhouse gas (GHG) emissions reduction: Expediting the process of identification of wildfire ignitions in the initial stage of a wildfire to suppress it while the scale is manageable, including ignitions potentially involving PG&E assets, leads to effective fire containment. As a result, this helps with lower CO2 emissions.

5.3 Key Accomplishments

The following summarize some of the key accomplishments of the project over its duration: summarize the key accomplishments of the project over the course of three (3) phases:

- Delivered a smoke and fire detection AI solution for 160 ALERT Wildfire cameras utilizing the ALERT Wildfire API to meet key metrics.
- Displayed AI Detection Alerts on an interactive web-based dashboard provided by the vendor. Alerts contained the following information: UID (Unique ID), Detected camera, camera URLs with AlertCalifornia-detected time and date, and estimated latitude and longitude.
- Opened the door for further investigation within PG&E of this very promising technology stream.

5.4 Key Recommendations

Subsequent to the EPIC 3.45 project completion, PG&E, other major California utilities, and local and federal agencies are installing hundreds of wildfire alert cameras through contract work with The Regents of the University of California San Diego (or UCSD). They've enlisted a third-party as the primary installation vendor for Wildfire Cameras. In partnership with UCSD, they also created the new interface/command and control system for the cameras and launched the ALERTCalifornia site. The new vendor is uniquely positioned to bring AI to the ALERTCalifornia network for all parties. The vendor has worked during the 2022 fire season to develop an in-house AI solution that will serve all ALERTCalifornia consumers with a single solution. What this means for PG&E when we position ourselves to be part of this consortium is that we will have instantaneous access to all wildfire cameras within the state with no need to work in integrating the camera feeds for control access.

PG&E identified potential pain-points and opportunities for improving its fire detection capabilities. In pursuing future initiatives there are recommendations for additional developments:

- Nightly camera calibration using images of star locations throughout the night to calibrate the azimuth and tilt for every camera. This is critical to pinpoint fires with a single camera to improve location accuracy.
- Server upgrades needed to scan more often to further improve detect times vs IRWIN.
- Fully implement Night AI mode and further reduce daytime false positive rates.

- System automatically determines which cameras can see a fire and positions them to automatically view fires through the AI system
- Embellish fire data overlays on high value utility assets to prioritize alerts for resource allocation efficiency.

Smoke detection and alerting by way of AI capabilities among utility companies and first responders remains to be a nascent technology that'll require data collection over time to refine or enhance the dataset used for training the AI. Achieving this involves collecting more diverse and representative data, including different types of wildfires, weather conditions, or other relevant factors. This may improve the accuracy and reliability of the AI system's detection capabilities. The PG&E analysis team is aware that there are emerging automated wildfire detection systems, with currently unproven capabilities. In addition, these systems may work only in their own ecosystem, interdependent of other data resources that HAWC utilizes. System improvement is dependent upon vendor partner's access to external resources with reliable methodologies and through-put.

5.5 Technology transfer plan

5.5.1 IOU's technology transfer plans

A primary benefit of the EPIC program is the technology and knowledge sharing that occurs both internally within PG&E, across the other IOUs, the CEC and the industry. To facilitate this knowledge sharing, PG&E will share the results of this project in industry workshops and through public reports published on the PG&E website. Specifically, below is information sharing forums where the results and lessons learned from this EPIC project were presented or plan to be presented:

Information Sharing Forums Held

- HAWC Tours: Local Gov't officials, International Wildfire Risk Mitigation Consortium, CAL FIRE, Investor-Owned Utilities
- EPIC Symposium, Virtual WebEx, 10/4/2022
- Edison Electric Institute's Transmission, Distribution, Metering and Mutual Assistance Conference (TDM&MA), 10/2/23 through 10/4/2023

PG&E plans on continuing to share the results and lessons learned from this EPIC project in the future as well.

5.5.2 Adaptability to other Utilities and Industry

The following findings of this project are relevant and adaptable to other utilities and the industry:

The AI Detection findings and outcomes from this demonstration was specific to the HAWC business use-case, however, could be leveraged by others within the Utility industry. Other utilities along with local and federal agencies, operate and staff differently in how they develop their staffing matrix and reliance on other social media alerts. Listed below are AI Detection outcomes that are potentially applicable to other utilities:

- Establish baseline time & success criteria to beat by automated systems and develop that into a table of key metrics that need to be achieved each advancement to subsequent phases.

- A web-based dashboard with functionalities that enable decision makers to review and corroborate with other social media platforms.
- Initial Anomaly Review – if internal staffing matrix doesn't support 24/7 assessment, engage with vendor's technicians to review all AI detections so that positive detections are flagged and false detections are dismissed. This may address the large volume of repeated or non-critical alerts. PG&E is uniquely set up for 24/7 monitoring so there would be less reliance on technicians.
- Identify a wide range of camera site locations that not only addresses varying topography but form useful clusters so that the triangulation method may be utilized for accuracy of ignition.

5.6 Data Access

Upon request, PG&E will provide access to data collected that is consistent with the CPUC's data access requirements for EPIC data and results.

6 Metrics

The following metrics were identified for this project and included in PG&E's EPIC Annual Report as potential metrics to measure project benefits at full scale.[7] Given the proof of concept nature of this EPIC project, these metrics are forward looking.

Table 2 – Project Benefit Metrics

D.13-11-025, Attachment 4. List of Proposed Metrics and Potential Areas of Measurement (as applicable to a specific project or investment area)	Reference
3. Economic benefits	
a. Maintain / Reduce operations and maintenance costs	
b. Maintain / Reduce capital costs	
4. Environmental benefits	
g. Wildlife fatality reductions (electrocutions, collisions)	
5. Safety, Power Quality, and Reliability (Equipment, Electricity System)	
d. Public safety improvement and hazard exposure reduction	

[7] 2015 PG&E EPIC Annual Report. Feb 29, 2016.
http://www.pge.com/includes/docs/pdfs/about/environment/epic/EPICAnnualReportAttachmentA.pdf

7 Conclusion

The EPIC 3.45 Automated Fire Detection from Wildfire Alert Cameras project successfully demonstrated a new set of tools to leverage the value of PG&E's network of over 600 wildfire cameras. As hot, dry, windy conditions become more common with climate change, the importance of early detection and mitigation increases. At the onset of this project, camera images were evaluated by HAWC staff, and the possibility of increasing the speed and locational capability of fire identification offered additional safety for the public and PG&E's assets. At the conclusion of this project the products tested did not yield sufficient improvements based on the established performance criteria. However, the performance requirements that were defined and the interface requirements that were developed were very beneficial in leading PG&E to adopt another 3rd party solution subsequently identified outside of this project.