INNOVATION CONCEPT PAPER

RESPONSE TO REQUEST FOR INNOVATIVE IDEAS (RFI²) #12234
WILDFIRE MANAGEMENT

S.M.A.R.T.i.

***S**ystematic **M**onitoring for **A**ctionable **R**eal-**T**ime **i**nformation*

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1. EXECUTIVE SUMMARY

AerialZeus, LLC has pioneered the use of drone technology, artificial intelligence & remote sensing since its foundation in 2013. Our team of engineers and scientists has always prioritized science and technology for practical applications. From mapping Californian endangered plants using multispectral imagery from drones and satellites to inspecting critical infrastructure, we bring best of class practices. We believe that no particular organization, on its own, can entirely solve complex issues effectively; therefore, we have assembled a comprehensive consortium of academics, technologists and scientists to effectively deal with Early Prediction and Early Detection of Wildfires. Thus, we are pleased to lead a wide range of organizations that include UC-San Diego, NASA, Airbus, Worley Parsons, Launch, Direct Technology, Elistair, Timbergrove & DPMG Corp into bringing a situational awareness Geographic Information Systems (GIS) platform for real-time prediction, mitigation & monitoring of Wildfires.

2. THE IDEA

Threats to critical infrastructure and population centers demand fast access to actionable information. Wildfires can wipe out large areas of vegetation and infrastructure in a short amount of time. Such fires are hard to control and manage as they can change directions almost instantly, driven by changing environmental conditions. Effective response to such events requires the ability to monitor and predict the behavior of the fire as fast as they change.

The **SMARTi** innovative idea builds an end-to-end cyberinfrastructure for real-time & data-driven simulation, prediction, and visualization of wildfire behavior.

The ability to provide near real-time information to first responders, decision makers, residents and visitors is critical during any natural disaster, including wildfires. The main objective of **SMARTi** is to provide the tools to predict a more accurate rate of a spreading wildfire. Therefore, AerialZeus and its partners propose the deployment of a comprehensive GIS-platform, cloud-based, capable of ingesting and visualizing heterogenous metadata from stationary cameras, weather-stations, archived data, satellites, tethered-drones, transmission powerlines inspecting-drones, 9-1-1 callers and social media.

It is our intent to provide CAL FIRE, the California first responder community and supporting agencies an end-to-end tactical and operational response platform to assist in early detection and early prediction of wildfires, in order to facilitate communication, coordination, and collaboration prior, during and post-wildfires.

Through apps and/or a web browser, **SMARTi** enables geospatial information visualization and a unified access to geospatial workflows. Using GIS capabilities combined with scalable big data integration and processing, **SMARTi** enables simple execution of the model with options for running ensembles by taking the information uncertainty into account. The results are easily viewable, sharable, repeatable, and can be animated as a time series.

It is important to emphasize that our approach is rooted on proven scientific knowledge & technological experience based on remote sensing technologies, the Internet of Things (IoT), Artificial Intelligence, Visual Computing Algorithms & Deep Learning; enabling Wildfire modeling.

3. THE SOLUTION

SMARTi can be fully integrated into ArcGIS online.

The advantages of cloud-based offerings include scalable computing, storage of large datasets, big data computation, and the ability to surge resources during critical events such as disaster response. The cloud can make nearly infinite computing resources available to scale up queries and tackle operations instantly. Wildfire modeling, early prediction and early detection requires large datasets and inputs from an increasing array of remote sensing technologies, as well as the Internet of Things (IoT).

The combination of advanced spatial analysis and new Artificial Intelligence (AI) tools can help model and visualize complex patters, relationships, and situations. **SMARTi** is designed to be a framework for powering AI algorithms running against data stores to automate processing and reveal insights. **SMARTi** will serve as an architectural gateway to deploy AI services in order to understand and

solve problem sets related to classification, spatial pattern detection, and predictive modeling.

Moreover, users gain portability with access to apps and maps anywhere and anytime. At the same time, office personnel will see in real-time dashboards of field personnel's measurements and monitor safety with real-time people-location. Additionally, we foresee **SMARTi** as a platform enabling app-development to enhance workflows specific to different stakeholders.

The initial stage of **SMARTi** leverages the current architecture of *WIFIRE* designed by UC-San Diego, one of our partners on this offering.

The WIFIRE architecture is shown in Figure 1. An interactive map application called *Firemap* runs in clients' web browsers and communicates with four services: Pylaski, GeoServer, Kepler WebView, and LiveWx.

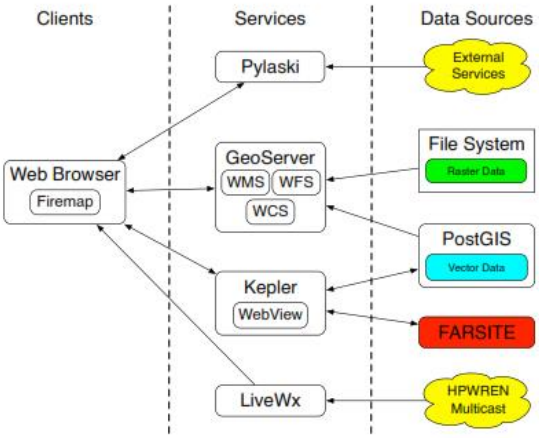


Figure 1: WIFIRE architecture comprised of Firemap user interface, Pylaski, GeoServer, Kepler WebView, and LiveWx services, and local and external data sources.

WIFIRE is a solution that has already been deployed and successfully implemented. Since the fall of 2015, the WIFIRE team has had a partnership with the Los Angeles Fire Department (LAFD) focused on a pilot study to use WIFIRE's new Firemap tool in real-time fire situations. The WIFIRE team and LAFD tested the operational aspects of the developed technology on a drill in July 2016. In addition, in the Sand, Blue Cut, and Soberanes fires, which burned more than 200,000 acres combined in California earlier this summer, the WIFIRE team shadowed the actual fire progression with Firemap. The comparison between the fires' actual daily progression and WIFIRE's real-time prediction model were extremely close.

"For Incident Commanders (IC), the WIFIRE Firemap is one of the most progressive decision-making tools developed in the last decade. Firemap gives the IC accurate and real time data to help make command decisions when prioritizing resource allocation or which communities to evacuate. This has never been available during the initial action phase of brush firefighting, and it has been an honor to work with the WIFIRE team and see their dedication to public safety," as stated by LAFD Fire Chief Ralph Terrazas.

To further illustrate the architecture of WIFIRE's *Pylaski* and its data sources, the following details are provided,

• Weather stations: MesoWest and Synoptics Labs provide observations of over 30,000 weather stations primarily located throughout North America. Additionally, these stations can provide the wildfire model with the current or historical weather conditions at the station nearest the initial fire perimeter.

• Weather forecast: The High-Resolution Rapid Refresh (HRRR) weather forecast has a horizontal spatial resolution of 3km and temporal resolution of 15 minutes. HRRR requires an Environmental Data Exchange (EDEX) server to receive the feed, and the high temporal resolution enhances the accuracy of the wildfire model prediction based on the forecasted weather.

• Camera images: The High-Performance Wireless Research and Education Network (HP-WREN) and San Diego Gas and Electric (SDG&E) operate tower-mounted cameras throughout San Diego County. The cameras are mostly located on mountaintops, which provide ideal viewpoints for locating wildfires in the backcountry. AlertTahoe operates tower-mounted cameras around Lake Tahoe and throughout Nevada. Most of these cameras are pan-tilt-zoom (PTZ), which can be changed to focus on a wildfire. The Camera Layer shows the location and images from these cameras.

• Air Quality Stations: OpenAQ aggregates air quality data from over 40 countries. The Air Quality Layer shows the location and latest measurements from these stations.

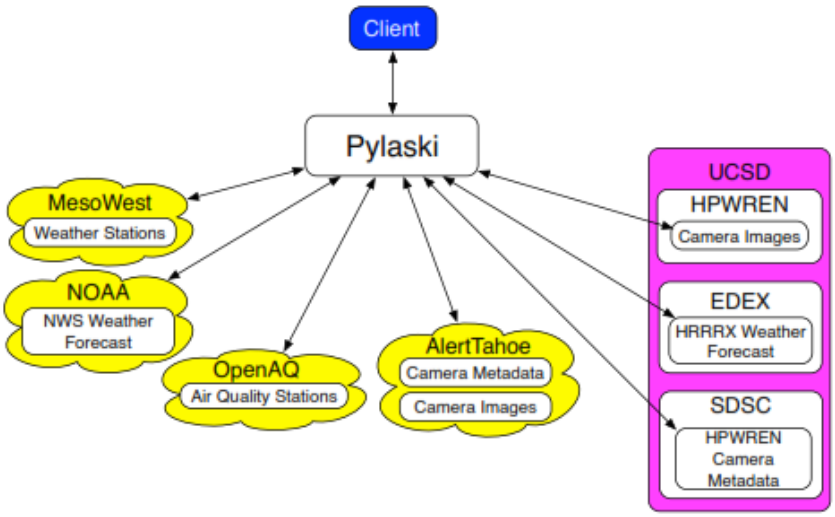


Figure 2: *Pylaski* service and external data sources

WIFIRE's *GeoServer*, an open-source server for accessing geospatial datasets, to display GIS data. *GeoServer* implements a number of open standards from the Open Geospatial Consortium (OGC) such as Web Feature Service (WFS), and Web Map Service (WMS), and Web Coverage Service (WCS). Firemap queries the WMS service to implement several visualization layers. WMS queries return images of the data, which GeoServer reads from a PostGIS database for vector data, and from raster files for raster data as shown in Figure 3.

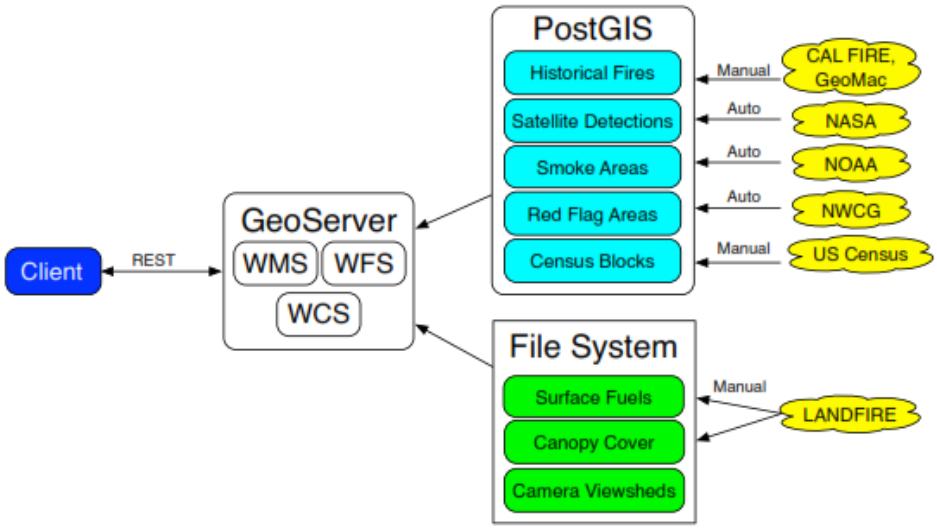


Figure 3: *GeoServer* service and geospatial datasets. Satellite detections, smoke areas, and red flag warnings are automatically added to *PostGIS* every hour.

Further details are provided below,

•Historical Fires: wildfire perimeters in the U.S. during 2000-2015 from GeoMAC and in California during 1878-2014 from CAL FIRE. This layer displays the wildfire perimeters and clicking on a perimeter displays information about the wildfire include the name, start and containment dates, and total area.

• Satellite Detections: thermal imaging wildfire detections from VIIRS and MODIS with 375m and 1km resolution, respectively. Both satellites fly over the same area approximately twice a day. The detections are downloaded from NASA and ingested to the PostGIS database every hour.

• Smoke Areas: smoke plumes indicating possible wildfire locations. The smoke data is retrieved from NOAA's Hazard Mapping System and ingested to the PostGIS database every hour.

• Red Flag Areas: regions currently experiencing weather conditions that "may result in extreme burning conditions" such as high wind speeds and low relative humidity. The Red Flag warnings are downloaded from the National Wildfire Coordinating Group and ingested to the PostGIS database every hour.

• Census Blocks: number of people and housing units from the 2010 U.S. Census. The number of people in a neighborhood threatened by a wildfire is crucial when determining evacuation times. Firemap provides both a graphical layer showing census blocks and the ability to query census information for user-drawn areas.
• Surface Fuels: classification of surface vegetation into thirteen fire behavior fuel models from LANDFIRE. Surface fuels are a critical input parameter for fire modeling and Firemap provides a layer to visualize this data.

• Canopy Cover: percentage of forest floor covered by trees from LANDFIRE. The canopy cover is used to model crown fires, i.e., fires that spread in the top layer of tree foliage.

• Camera Viewsheds: geographical areas with line-of-sight visibility surrounding the HP-WREN and AlertTahoe cameras. The Camera Viewsheds Layers visualizes the regions visible and not visible by the cameras.

Kepler WebView integrates web technologies with the Kepler Scientific Workflow System. A lightweight web server runs inside the Kepler process and provides real-time communication between clients and Kepler workflows. A client can use either REST or WebSockets to execute workflows, and data is exchanged as JSON.

LiveWx provides real-time measurements from HPWREN weather sensors co-located with many of the tower-mounted cameras. These sensors report wind measurements every second, and air temperature, air pressure, and relative humidity every ten seconds. *LiveWx* sends new measurements to clients via a WebSocket as soon as the data appears on the HPWREN multicast network. A WebSocket is used instead of REST since there is a continual stream of measurements from the sensors.

In addition, **SMARTi** will implement the following External Sources into its platform,

a. Multi-task Tethered Drones for various applications

i. Cell on Wings (COW): The ability to provide temporary wireless infrastructure into an existing network and expand cell coverage is critical in the event of a wildfire. Our partnership with Elistair will enable AerialZeus to deploy a Portable Mesh Network Node for high bandwidth for data, voice and video applications. Elistair has deployed more than 200-tethered stations in 60-countries with a total of 15,000+ hours of operations. Compact and tactical Tethered Drones provide and enhance situational awareness. Elistair's Orion requires minimal personnel training, allows easy and fast deployment, and provides multiple square kilometers of coverage at 80m Above Ground Level (AGL) hovering.
This Unmanned Aerial Vehicle (UAV) is capable of providing situational awareness within 15-minutes after receiving the emergency call and remain airborne for up to 12-hours.
The idea is that UAVs can carry various type of payloads from video cameras to telecommunication modules or weather forecast sensors. This variety of assets and the standardization of UAV-systems will provide early detection and tracking of fire outbreaks and allow early stage evacuations, if required, and infrastructure protection.

ii. Realtime Sky Weather Monitoring: Meteorological sensors will be equipped on drones to monitor wind direction, wind speed, temperature, humidity & pressure in order to improve fire modeling.

iii. Live broadcasting of wildfire events: Having the ability to livestream video to multiple mobile devices and Command Centers is key for logistical operations. Moreover, real-time video can be displayed on a map for the right allocation of resources and planning. Our partners in Japan, Soliton,

have successfully deployed its video-encoder during the Tokyo Marathon in 2019, and it will also be used for The Olympic Games in Tokyo 2020.

iv. Wireless LoRa WAN gateways: By combining the use of a near-real time IoT (Internet of Things) platform with Tethered drones retrofitted with LoRa WAN gateways, and LoRa WAN low power long range biometric wearable sensors we intend to provide first responders and CAL FIRE with the information and tools necessary to monitor the developing situation and allocate resources accordingly, while safeguarding life and property. This will give the ability to remotely monitor the environment of the crew members. By integrating micro-bio sensors to monitor, body temperature, skin moisture, heartbeat, and additional sensors to track movement and even position, activity and even light conditions. By combining powerful artificial intelligence and machine learning we can create automated alarms that can tell us if a crew member or an entire crew is found in critical condition and where that crew or crew member is located.

We are proposing using Moonshot IoT platform and Integrating it with IBM Worker Insights, and IBM solution that combines IoT data from wearables, environmental sensors and other data, with advanced analytics. This is an integrated Industrial Internet of Things (IoT) platform that is ready to use and provides an end-to-end solution that brings predictability, visibility and fluency to organizations that manage scarce resources.

By combining Tethered drones retrofitted with LoRa WAN gateways, acting as temporary antennas with 12-mile radius, we can provide a powerful tool for CAL FIRE to monitor, connect and visualize location and vital signs of firefighters when traditional infrastructure is down and to provide temporary means of communications during catastrophic emergencies like wildfires.

b. Emergency Situational Awareness (ESA) from Social Media: ESA is a Twitter social media content analysis tool that in real-time detects the outbreaks of the words and phrases. It is tuned to the local language and trained to tag the disaster-related tweets and tags. It is especially trained to identify "burst-detection" of words and phrases being used in unusually high-frequencies.

In Australia ESA is used in emergency and fire services agencies. They have been able to become aware about earthquakes and wildfires through ESA faster than through other channels. ESA has proven to be reliable in emergency situations detecting people and firefighting personnel in danger. CSIRO have developed techniques to add geolocation to the tweets which are otherwise missing it.

The speed of the ESA exceeds the seismic waves at the distance of around 1000 miles – ESA detected minor earthquake in Brisbane, before seismic waves reached the observation in Canberra.
Fast indexing of tweets and training in local language is the key of ESA efficiency.

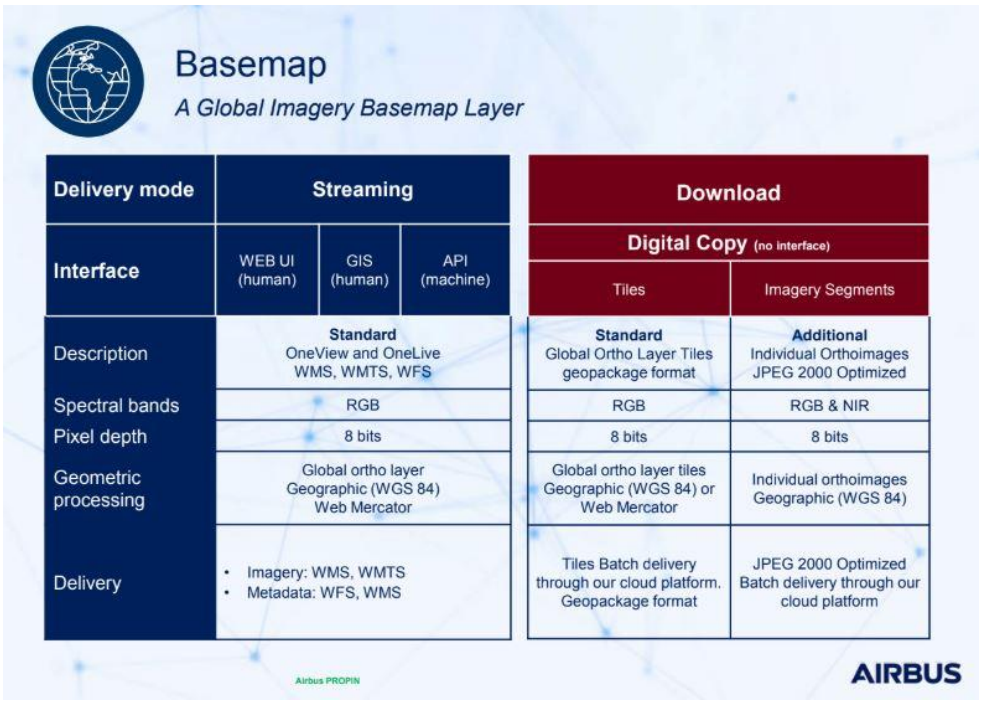
c. Airbus' OneAtlas and Living Library: Incorporating OneAtlas into **SMARTi** will provide easy access to premium, constantly updated, and highly-detailed imagery that allows large-scale image processing and extraction for specific insights, including wildfire prediction and early detection.

   OneAtlas data has 2 kinds of data – Off-the-shelf and On-demand,

   Off-the-shelf offers Basemap (imagery stitched together to create Earth's landmass), Living Library – Pay-per-use access to Airbus cloud library, World DEM – Digital Elevation Model.

   On-Demand offers – Change detection of large areas or targeted sites, One Tasking, tasks Airbus constellation & GEOSTORE, imagery from archives.

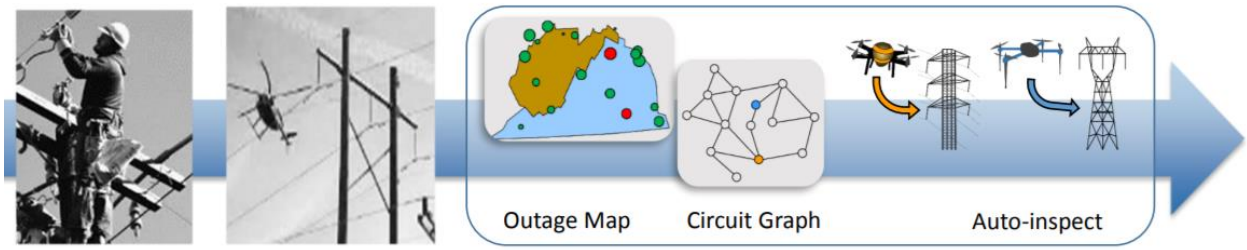
   Basemaps
   Consistent, complete, and nearly cloud-free images. Geolocated 1.5m of the world imagery (SPOT) and 50cm of 3400 cities (Pleiades).
   Updated annually and accessible in multiple formats and protocols.



Living Library
Premium satellite data
Multiresolution, Optical and SAR, constantly updated
Quick and easy access – Streaming, Download and API to be integrated into **SMARTi**

d. NASA's patent for the inspection of Power-Lines: High voltage power transmission efficiency is impaired by electrical faults, such as shorts to the ground. In many circumstances, the faults can be identified by imaging in the ultraviolet (UV) band. While faults can be identified by imaging in the UV band, inspecting high voltage power transmission lines is an expensive, time consuming, labor intensive, and dangerous process that requires lineman to travel the length of the lines, often by helicopter, to collect and analyze images.
Identifying and localizing faults in power systems may be important for many reasons including avoiding dangers in power systems, such as power outages, power system equipment damage, human injury, etc. Faults in power systems are often indicated by corona discharges or electrical arcs. In contrast to coronas, generally all arcs are dangerous due to the arcs ' high heat generation. Therefore, in partnership with NASA, AerialZeus is currently in the process of licensing NASA's patent US2017/0285092 A1, allowing for a comprehensive inspection of power lines, poles, towers and substations using

a corona discharge-sensor mounted on semi-autonomous drones. The ultimate goal is to equip drones with multiple sensors, including thermal, high definition RGB-images & corona sensors in order to get the most accurate condition of the power-grid and its interaction with the surrounding environment.



AerialZeus will jointly collaborate with NASA & Worley Parsons to bring this technology and capabilities to fruition. It is important to mention that Worley Parsons is currently supporting PG&E with inspecting its electric transmission tower and poles to evaluate their strength, durability and quality. Under the direction of PG&E, WorleyParsons has provided analysis and evaluations of drone data from PG&E's flights above and around PG&E electric towers and poles. The incorporation of drone assessments and mapping into **SMARTi** will further enhance wildfire prediction and mitigation.

In addition, AerialZeus is looking to implement the images from small unmanned aerial systems (drones) equipped with high-resolution RGB and Multispectral cameras, alongside images from satellites (RGB, Multispectral, Hyperspectral, Thermal).
Imagery gathered from small UAVs are geotagged, easily stitched to provide maps and 3D models and high levels of details and accuracy.
These images will be processed to provide more information on:

- The health and vigor of vegetation
  By applying near-infrared parts of spectrum we are able to detect, identify and classify stress in vegetation, which further can lead to potential wildfire fuel. Adding this to the vegetation classification layer from WIFIRE will lead to more accurate wildfire predictions.
- 3D vegetation structure
  Vegetation structure affects the fire spread and with high-resolution images we can have – 1-2 cm/pix 3D vegetation structures/models
- Temperature of vegetation and surrounding area.
  Thermal sensors will enable us to identify and classify dry vegetation and use it for asses the risk of wildfires.

- Vegetation species,
  Not all species burn at the same rates, so knowing the spatial distribution of certain species will provide more information for fire growth through the use of AI's visual computing algorithms.
- 3D terrain models,
  Highly detailed terrain models provide us knowledge on fire spread, and the accessibility for personnel.

This additional information in the form of layers will be used in calculations of risk, predictions of occurrence, and simulation of growth of fires, making **SMARTi** most robust on the early prediction and detection of wildfires.

4. THE APPROACH

In order to successfully deploy **SMARTi** and all its components, our consortium requests the full commitment from CAL FIRE, Cal OES, Fire Fighting Departments across California, Power Utilities, Police Departments and decision makers to facilitate all logistics necessary. We are cognizant of the most stressful circumstances in which our ideas might be implemented and anticipate harsh deployment conditions. However, rest assured our unwavering commitment to bringing the best in class personnel, technologies and practices in the pursuit of a safer California.

We hope you give our ideas consideration and look forward to being at your service.