



## What's the Optimal Type of Sensor for Wildfire Detection in Northern California?

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### Abstract

- Wildfires are a huge problem in California. The arid landscape, high temperatures, strong wind, and vast open spaces are ingredients for wildfires. This project investigates different types of sensors that could be used for early detection and prevention of wildfires in California. We will be using optimization to examine existing data provided by researchers to determine the type of sensor best for Northern California early fire detection in theory. The ultimate goal of this project is to provide a recommendation to the state of California of which sensors / sensor technology (including detection algorithms) are best suited for California's unique landscape.

### Introduction

- Wildfire is a recurring threat to human lives and property in California. Table 1 shows the stats of recent years (*Statistics | CAL FIRE*)

INTERVAL	WILDLAND FIRES	ACRES
2023 Combined YTD (CALFIRE & US Forest Service)	5,601	275,058
2022 Combined YTD (CALFIRE & US Forest Service)	5,912	227,897
5-Year Average (same interval)	6,272	1,158,028

California is the state with the most wildfire damage in the US. Thousands of wildfires cause huge damages and economic loss. Over the past five years, 22% of acres destroyed by wildfires are in California, more than 18.7 billion of property was damaged by wildfires, 147 people have been killed, and 318 have been injured by wildfires. (“Wildfire Statistics”)

The frequently occurring wildfires in California makes early fire detection a significant matter, as it could mean earlier containment of the fire and effectively reduces the damages caused by the fires. It could mean saving lives, saving money, and saving lots of work and time. This paper will find the optimal fire sensor for California based on the cost, coverage area, and response time of the sensors.

## Background

There are basically five types of fire detector, Aspirating Smoke Detector, Heat Detector, Linear Heat Detection Cables, Spark/Ember Detector, and Flame Detector. Let's go through each of them.

## Aspirating Smoke Detector (ASD)

### How it works

As its name suggests, it is a type of smoke detection system, which monitors smoke level. It uses a network of pipes with multiple holes to continuously draw air samples. The samples are sent to the Detector Unit to be analyzed. If smoke or airborne particle levels are over a threshold, the alarm can be raised. Aspirating system has high sensitivity. It has been developed to monitor for forest fires in Australia in the early days ("How Does an Aspirating Fire & Smoke Detection System Work?"). The system also requires maintenance to ensure smooth air flow in the network of pipes and sensitivity of the detector unit. Some high-end ASD systems have automatic maintenance capability.

### Response Time

The response time varies depending on sensibility setting, airflow rate, sampling system distribution, air quality, smoke level threshold, and other factors. It can be from a few seconds to a few minutes including the transportation time from sampling holes to the detector unit (*Aspirating Smoke Detection Products*). However, Aspirating Smoke Detectors are considered a rapid response system. They often detect smoke before it is visible to the human eye.

a few seconds: ("Aspirating Smoke Detector")

8-10 seconds, (*Aspirating Smoke Detection System*)

### Area Coverage

Several thousand square feet to several tens of thousands square feet. For example, area coverage of Xtralis VESDA Models is 2690 square feet to 69965 square feet (*VESDA Model Comparison Chart*). Siemens FDA261 and FDA262 can cover up to 72121 square feet (*FDA261, FDA262 ASD Aspirating Smoke Detector Data Sheet • Reader • Smart Information Delivery*). Honeywell FFAST can cover up to 28800 square feet (*Aspirating Smoke Detection Products*).

### Cost

The detector unit price ranges from a few hundred to over then thousand US dollars. The pipes are about \$10 per foot. For example, Xtralis IFT-PT costs about \$3500 per unit. Its coverage is 21500 square feet ("Xtralis IFT-PT"). So, the cost per square feet is about \$0.16/square foot. Siemens FDA261 which has a detection area of 38750 square feet costs about \$3500. This gives approximately \$0.09/square foot.

## Heat Detector

### How it works

Fires cause temperatures to rise. Heat detectors respond to the energy emission from a fire in the form of heat by sensing the changes of temperatures and triggering an alarm or other response systems once the temperature is beyond a threshold. There are several different types of heat detectors.

- Fixed Temperature Heat Detectors  
When the temperature is high enough to exceed the predetermined threshold, an alarm is triggered.
- Rate-of-Rise Heat Detectors  
When the temperature rises fast enough to exceed a predetermined rate threshold, such as 12-15°F (6-8°C) per minute, an alarm is triggered. The temperature may not have reached the threshold of a temperature heat detector yet, but its rapid increase already indicates that a fire might happen.
- Combination Detectors  
Combines both fixed temperature detector and rate-of-rise detector to get more accurate and secure protection.

### Response Time

Anywhere from a few seconds to a few minutes.

Response time of a fixed temperature heat detector depends on how fast the temperature is going up to the threshold. Once they reach the threshold, they should respond within minutes. Rate-of-rise heat detectors usually respond much faster than fixed temperature heat detectors. They can respond within seconds.

Detailed response time is up to the detector's design and the environment conditions.

Smoke detectors usually respond faster than heat detectors. They can respond right away when the smoke particles are noticed before the temperature rises.

### Area Coverage

Heat detectors are generally designed for indoor environments. They are not prepared for outdoor conditions, such as weather, rain, snow, very high or low temperatures. The coverage area of heat detectors is limited to the close area of the detectors, usually within a radius of 30 feet. Small area of coverage is also not suitable for wild, open spaces.

### Cost

- Fixed Temperature Heat Detectors  
Approximately a few tens of dollars. For example, SIMPLEX 4098-9612 costs \$31.44 on Amazon. (*SIMPLEX 4098-9612 - Fixed Temperature Heat Detector - Amazon.Com*)
- Rate-of-Rise Heat Detectors.  
Also, approximately a few tens of dollars. For example, HOCHIKI DSC-EA - Rate of Rise Heat Detector costs only \$10.67 each on Amazon. (*HOCHIKI DSC-EA - Rate of Rise Heat Detector - Amazon.Com*)
- Combination Detectors

About the same price as the other two types of heat detectors.

## **Linear Heat Detection Cables (LHDC)**

### **How it works**

It is a continuous heat detector that can detect and locate heat and fire hazards at any point along its entire length.

The cable is made up of two steel conductors, which are insulated by heat sensitive polymers. The steel conductors and the heat sensitive polymer are wrapped by a protection jacket. When the temperature rises and exceeds a threshold, the polymer melts, then the steel conductors are not insulated any more, their contacting initiates an electrical short, which signals the fire alarm. (*What Is Linear Heat Detection? - Fire Systems, Inc.*)

### **Response Time**

Response time varies depending on cable design, cable length, cable type, and environmental conditions where it is installed. It is usually between a few seconds to a few tens of seconds.

For example, Linear Heat Detection Cable NMS1001 response time is 10 - 20s. (gd-admin)

CDL Linear Heat Sensor Cable response time is less than 8s. (*CDL Linear Heat Sensor Cable*)

### **Area Coverage**

The area coverage of linear heat detection cables varies depending on cable length, cable type, installation, environmental conditions, and other factors. Longer cables would cover more extensive areas. Spacing more apart would cover larger areas, but too much apart would leave uncovered areas.

For example, on a flat surface, linear heat detection cables can space 35 feet apart between runs. (*Digital Linear Heat Detection Cable | Digital LHDC*)

### **Cost**

Depending on the brands, types, models, and others, the price can vary. Basic models are \$1 - \$2 per linear foot. Mid-Range models are \$2 - \$5 per linear foot. High-End models are \$5 - \$10 per linear foot.

For example, PHSC models cost \$1241.19 - \$1617.03 per 500 feet ("Protectowire, Linear Heat Detector Cable, 500 Feet"). If the cables run 35 feet apart, it is about \$0.07 - \$0.09/square foot.

## **Spark/Ember**

### **How it works**

Spark/Ember detectors are focusing on detecting sparks, embers, or hot particles that may not have visible glows, but can potentially cause fires. They use infrared (IR) or ultraviolet (UV) techniques to sense the wavelengths of invisible light emitted by sparks or embers.

Spark/Ember detectors sense a rapid change in infrared (IR) or ultraviolet (UV) from a tiny hot particle in its view. Once a spark is detected, a signal must be sent to the extinguishing system.

### **Response Time**

Response time varies depending on type of detectors, technology applied, spark/ember type, and other factors. In general, they are as fast as within milliseconds or seconds. UV detectors can respond faster than IR detectors to certain types of flames.

For example, the response time of D161 IIR Spark Detector, which uses Infra-Red technology, is 1s. (*D161 IIR Spark Detector*).

The 246-1 of Techfab Systems has a response time of 80ms (“Infra Red Ember Detectors”).

### **Area Coverage**

Detection range of spark/ember detectors typically is within a few feet to 100 feet. Short detection range is 10 - 30 feet, medium detection range is approximately 65 feet, and long detection range is up to 100 feet. For example, D161 IIR Spark Detector’s detection radius is 4.5 feet for n-Heptane fire and 30 feet for IPA fire (*D161 IIR Spark Detector*)

### **Cost**

The cost of Spark/Ember detectors ranges from a few hundred dollars to several thousand dollars per unit. The price varies depending on different types, detection range, sensitivity and features, brands, models, and other factors. Basic models are \$100 - \$300, medium models are \$300 - \$700, and high-end models are \$700 - \$2000.

For example, Grecon 581591 DId1/8A Sensor Infrared Spark Detector is priced at \$500 (“Grecon 581591 DId1/8A Sensor Infrared Spark Detector”), GreCon FM 1/7 Spark Detector 581601 is priced at \$421 (“D161 Spark Detector for Sale”). Since this model’s detection range is approximately 3 to 10 feet, it gives \$1.3 - \$14/square foot.

D161 IIR Spark Detector costs about \$2750 (*Talentum FF732 TALENT. IR Spark Detector*), and its detection radius is 4.5 - 30 feet. This gives \$1 - \$35/square foot.

### **Flame Detector**

#### **How it works**

Flame detectors are designed to detect open flames or fires that include visible light or not visible radiations emitted by flames. They use different technologies including infrared (IR), ultraviolet (UV) or multispectral sensors to detect the radiation emitted by flames.

#### **Response Time**

Typical response time of Infrared (IR) flame detectors is 3 - 5 seconds, while typical response time of Ultraviolet (UV) detectors is 2 - 3 seconds. (Protection)

For example, SharpEye 40/40R Single IR Flame Detector response time is 5s (*40/40R Single IR Flame Detector User Guide*)

#### **Area Coverage**

IR flame detectors can typically detect flames or thermal radiation emitted by flames at longer distances than UV flame detectors. In general, the detection range of flame detectors can be

from several feet to several hundred feet. UV flame detectors' detection range is up to approximately 100 feet, while IR flame detectors have a range of approximately 200 feet.

For examples, Maximum detection radius of Honeywell FSL 100 UVIR is 115 feet (*Technical Handbook Honeywell FSL 100 Series Flame Detectors And Accessories*). Fenwal DETECT-A-FIRE's detection radius is 25 - 50 feet (*40/40R Single IR Flame Detector User Guide*). SharpEye 40/40R Single IR Flame Detector has a detection radius up to 50 feet (*40/40R Single IR Flame Detector User Guide*).

### Cost

Flame detectors' prices range from several hundred to several thousand dollars. For example, For example, Honeywell FSL 100 UVIR costs about \$2200 (*Honeywell Analytics/Vulcain FSL100UVIR UV/IR Flame Detector at Controls Central*). Consider its 115 feet detection radius, it is about \$0.05/square foot.

Fenwal DETECT-A-FIRE costs nearly \$300 ([www.supplyhouse.com](http://www.supplyhouse.com)). Consider its 25 - 50 feet detection radius, it is about \$0.04 - \$0.15/square foot.

SharpEye 40/40R - 111AC Single IR detector costs almost \$1000 ("Spectrex 40/40R -111AC SINGLE IR Detector EN54-10"). Consider its 50 feet detection radius, it is about \$0.13/square foot.

### Methods

- Research fire sensors.
- Find five fire sensors that could potentially be used in an outdoors setting and have enough research data to perform optimization with.
- Find the cost, response time, and coverage distance for all five sensors.
- Input the data into Google Sheet.
- Perform optimization by minimizing cost and response times and maximizing coverage area.
- Used minimization to select optimal sensor(s) In Google Sheets
- Find the sensor with the smallest sum afterwards.

Evaluating Thermal Fire Detection Systems (Stroup et al.)  
Heat Detector. Thermal or Heat Detectors Respond to the Energy Emission from a Fire in the Form of Heat. (*Heat Detector - an Overview | ScienceDirect Topics*)

### Comparison and Conclusion

	Response Time	Area Coverage (sq. ft.)	Cost (\$/sq.ft.)
Aspirating Smoke Detector	few seconds to few minutes	Thousands to tens of thousands	0.09 - 0.16



Heat Detector	few seconds to few minutes	about 2000	0.005 - 0.015
Linear Heat Detection Cable	few seconds to few tens of seconds	35x, x is length in feet	0.07 - 0.09
Spark/Ember Detector	milliseconds to seconds	300 - 30000	1 - 35
Flame Detector	2-3 seconds	3000 - 120000	0.04 - 0.15

The costs are based on detector units only, not including installation, labor, maintenance, accessories, and other equipment that the system needs, such as extinguishers.

- Spark/ember detectors are at high price and only cover a relatively small range.
- Heat detectors are at relatively low price, and cover a small range.
- Flame detectors cover a larger range than spark detectors.
- Aspirating smoke detectors cover the largest area.
- Linear heat detection cables are flexible and provide continuous monitoring along its length.
- Flame detectors, spark detectors, and linear heat detection cables respond faster than aspirating smoke detectors and heat detectors.

Wildfires are vast-scale complex natural events influenced by both nature factors and human activities. Although it is hard to rely on various detectors to prevent wildfires, those detectors can definitely help protect residences by giving warnings and alerting.

## Future Outlook

### Artificial Intelligence (AI) and Machine Learning (ML)

Nowadays Artificial Intelligence (AI) and Machine Learning (ML) are developing fast and have been applied in many fields. They also play a significant role in detection and monitoring wildfires.

Wildfires are closely related to weather. AI and ML can help analyze huge amounts of weather data and find patterns from weather history.

Satellites have been used for wildfire detection for a long time. AI and ML can help process large amounts of images from satellites and recognize important clues.

AI and ML can also help analyze historical fire behavior to predict wildfire risks more accurately.

### Unmanned Aerial Vehicles (UAVs) or Drones

All detectors have limited detection range, and installing and maintaining large amounts of detectors are costly. UAVs greatly increased the range of space that humans can access with very low cost.

Drones can be equipped with cameras and various sensors to monitor wild open spaces and provide real-time images.

Other than observing and getting information, UAVs can also replace humans to access some dangerous areas and fulfill special tasks, such as dropping fireballs to ignite controlled burns.

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