



FireStrike  
industries

# Development and Testing of a Targeting System for Localized Suppression

Presenter: Ian McNamara

CEO

FireStrike Industries LLC.

108 S. Airlite St.

Elgin, IL 60123

1-224-239-5018

[ianmcnamara@firestrikeindustries.com](mailto:ianmcnamara@firestrikeindustries.com)

Co-Presenter: James Andy Lynch

Director of R&D

Fire Risk Alliance

6 Ferndale Road

Seven Valleys PA 17360

1-312-351-5919

[jlynch@fireriskalliance.com](mailto:jlynch@fireriskalliance.com)

# Outline

- Problem
- Objective
- System Design
- Performance Analysis
- Conclusion

# Problem Statement

## Lack of Fire Suppression Systems

- Applications exist where installation of a fixed detection and suppression system would be difficult if not impossible.
  - Cost Prohibitive
  - Dangerous for Installers
  - Room Geometry
- Quick detection and Localized suppression is desired
  - High Value Assets
  - Changes in classification require increased fire protection

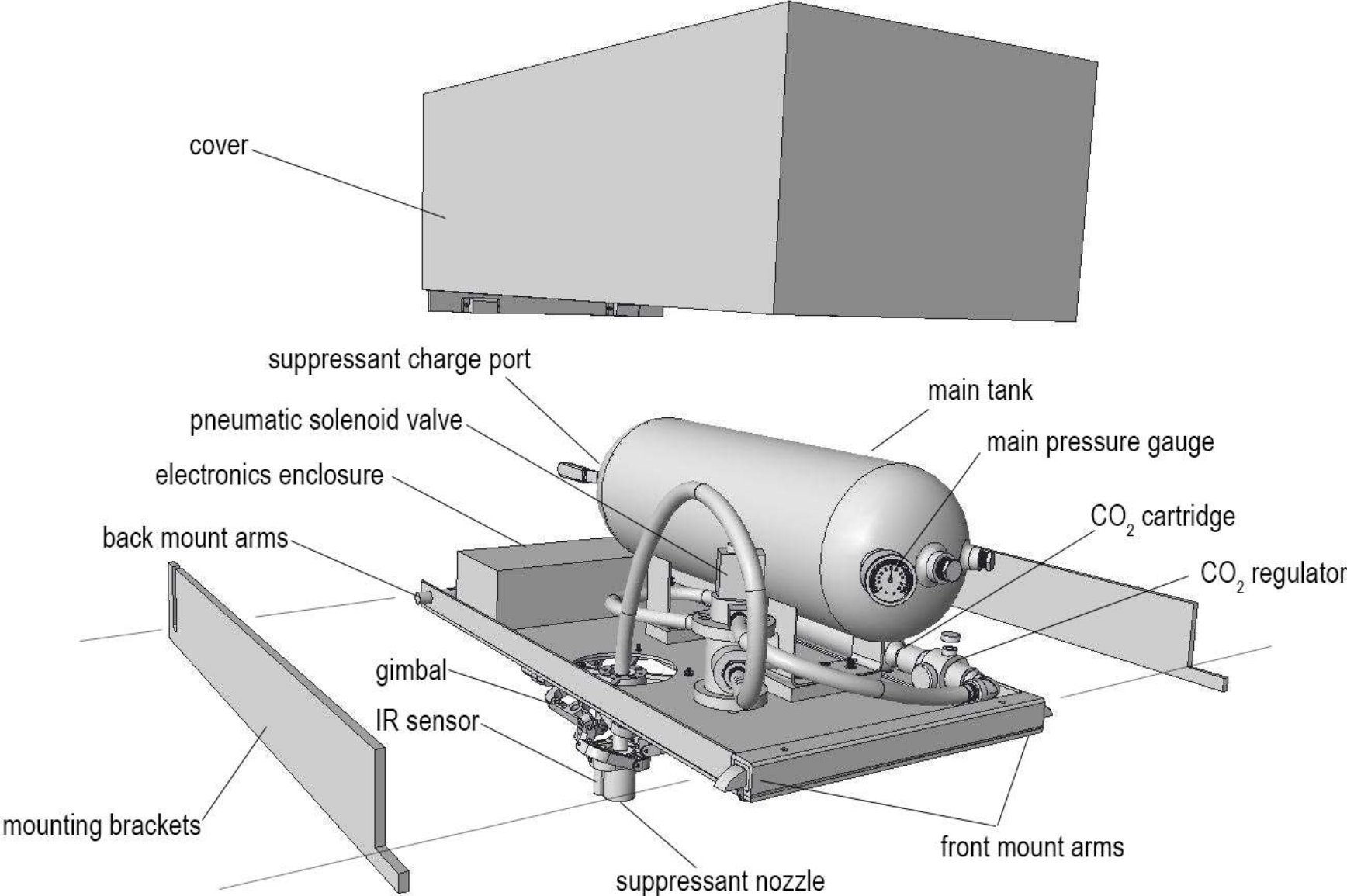
# Our Proposed Solution

- Modular self-contained fire detection and suppression unit
- Localized suppression by directly targeting the suppression agent at the fire location
- Automatically detects and extinguishes a fire(s)
- Responds to multiple fire signatures
- Designed for maximum flexibility

# System Overview

- System is a self-contained and localized fire suppression system
- Self-Contained:
  - Suppression is accomplished by an onboard supply of ABC dry chemical suppressant
  - Entire system is contained in a 24”by 12” by 10” mounting box
  - System only requires 115 VAC 60 Hz or 12 VDC power source
- Localized:
  - Suppressant is targeted only at the fire
  - Infra-red targeting is used to locate the fire
- Entire system is run electrically by an onboard microprocessor
  - Double redundancy with on-board back-up battery and manual failsafe

# System Components

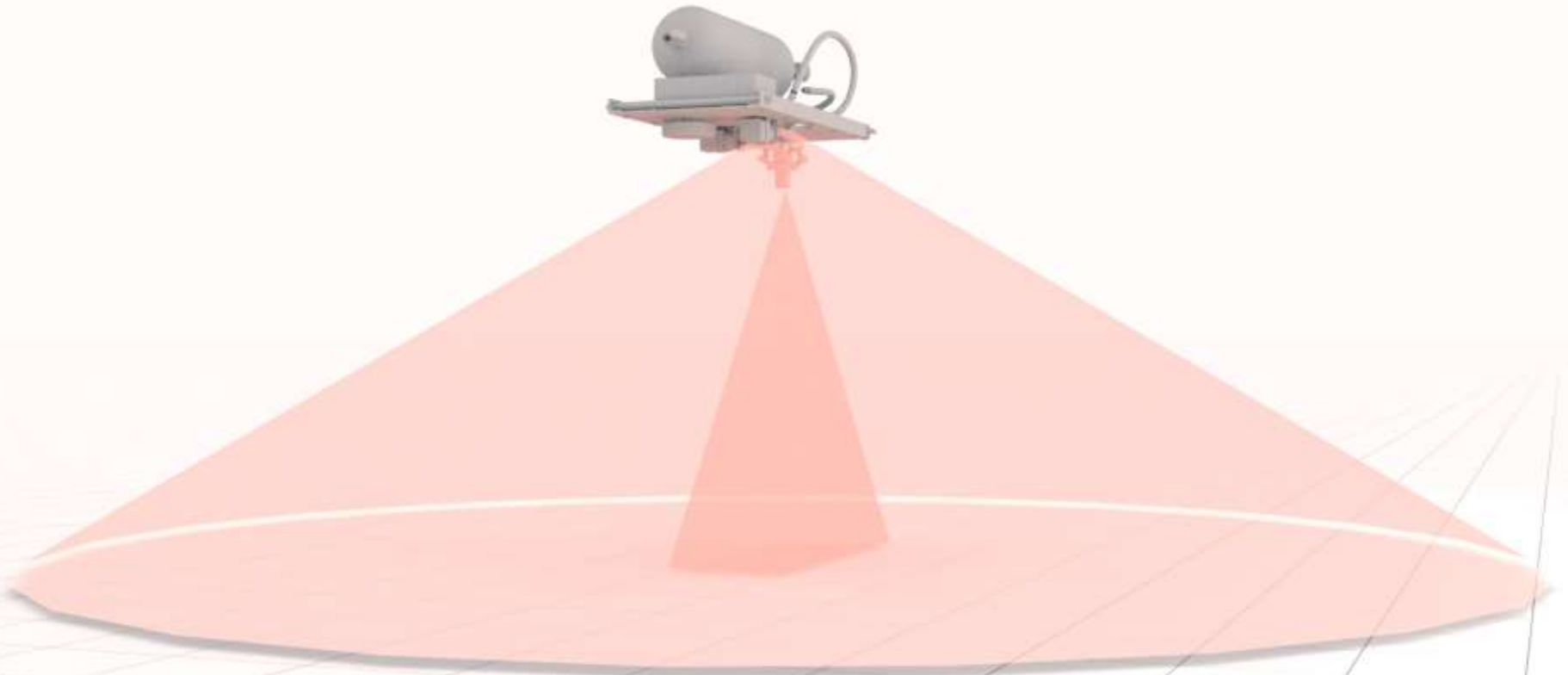


# Monitor Mode

- Monitor mode allows the system to function without continually scanning
  - Reduces power consumption and wear-and-tear on system
- In monitor mode, the system passively monitors for potential fires
- 3 awakening criteria are considered
  - Absolute ceiling temperature
  - Rate of rise
  - Smoke
- System currently switches to active mode if any of the three criteria are met

Awakening criteria are easily adaptable as they are all software based.

# Scanning Mode



Targeting nozzle positions IR Sensor and directs suppressant.

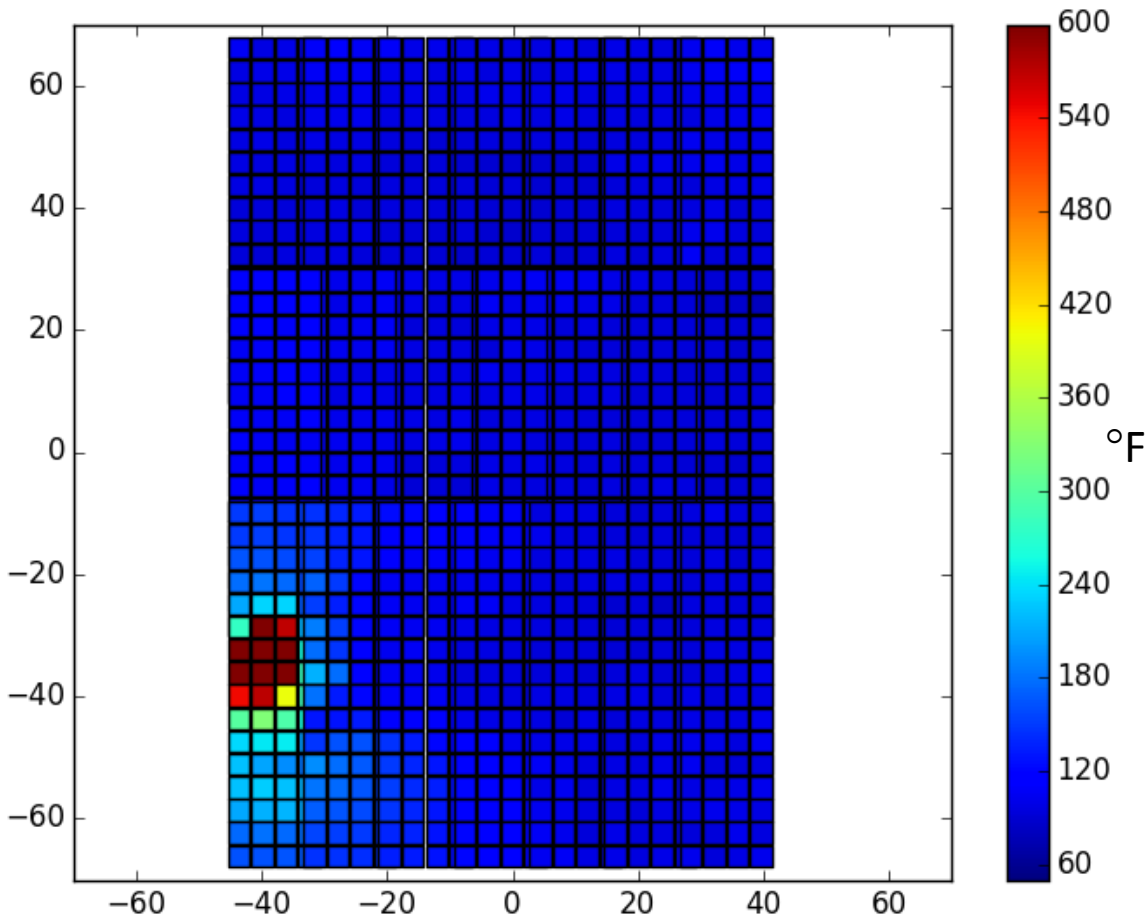


# Scanning Mode continued

- Scanning mode consists of actively searching with the IR Sensor
  - IR Sensor Field of View (FOV) is  $60^\circ$  by  $15^\circ$
  - Nozzle can target anywhere  $38^\circ$  from vertical
  - Coverage area is  $76^\circ$  by  $76^\circ$
  - Multiple images with the IR Sensor required
- Targeting gimbal positions IR Sensor at necessary locations
- System scans entire area upon awakening
  - 21 IR images are required
  - Average time is only 4.4 seconds

Alternative to scanning is a wide-angled IR sensor, which can be prohibitively expensive.

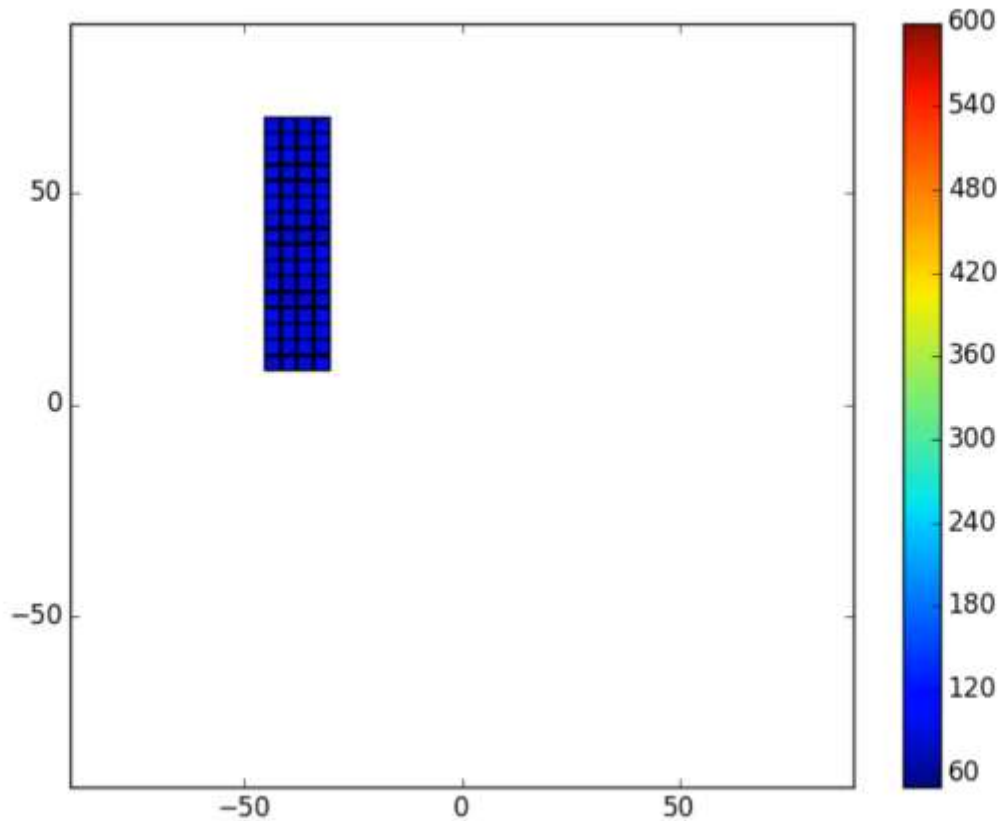
# Scanning Mode continued



IR Data was taken from this fire

Scan took 3.81 seconds and consists of 21 IR images or 1,344 individual readings.

# Infrared Based Fire Locating: Actual Fire



Fire targeting quickly pinpointed actual fire.  
Suppression would occur during single image frame view.

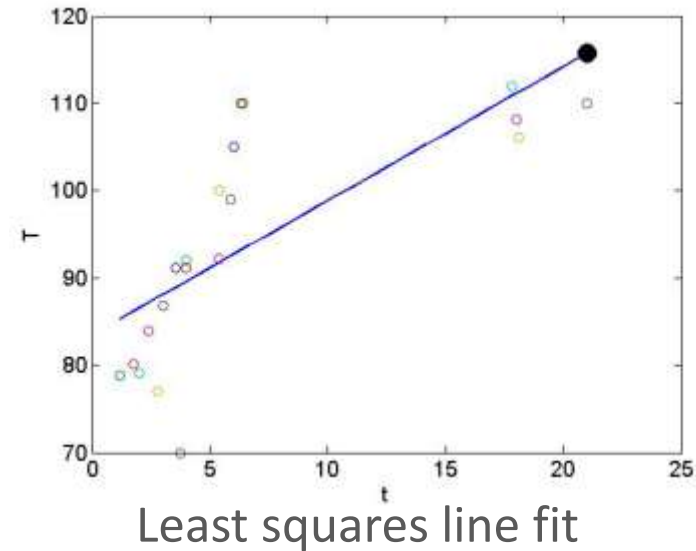
# Activation Mode

- Activation occurs based on two conditions:
  - The targeting algorithm locates the fire
  - The IR and other sensor data fits a fire's profile
- Six different criteria are used to determine if a hot spot is a fire:
  - Absolute Ceiling Temperature
  - Rate of Ceiling Temperature Increase
  - Temperature of Potential Fire
  - Size of Potential Fire
  - Rate of Growth of Temperature of Potential Fire
  - Rate of Growth of Size of Potential Fire

Activation criteria values can be set for almost any application.

# Activation Mode Criteria: Absolute Temperature and Rate of Rise

- Linear least squares (LLS) is used to model ceiling temperature vs time
- LLS is updated at every temperature reading similar to a rolling average
- At every reading, the LLS is used to compute a temperature value
  - If this value is above a preset criteria, the system activates
- The slope gives the rate



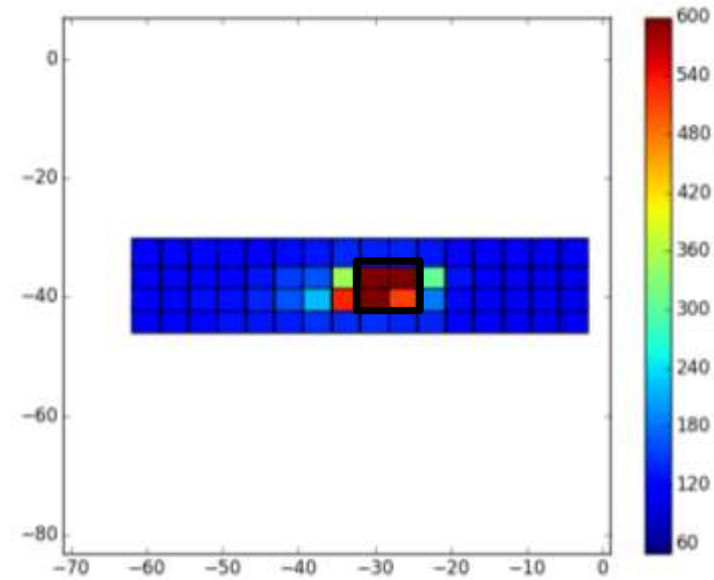
For the mathematicians

$$A = \frac{n(\sum_{i=1}^n t_i T_i) - (\sum_{i=1}^n t_i)(\sum_{i=1}^n T_i)}{n(\sum_{i=1}^n t_i t_i) - (\sum_{i=1}^n t_i)(\sum_{i=1}^n t_i)}$$
$$b = \frac{-(\sum_{i=1}^n t_i)(\sum_{i=1}^n t_i T_i) + (\sum_{i=1}^n t_i t_i)(\sum_{i=1}^n T_i)}{n(\sum_{i=1}^n t_i t_i) - (\sum_{i=1}^n t_i)(\sum_{i=1}^n t_i)}$$

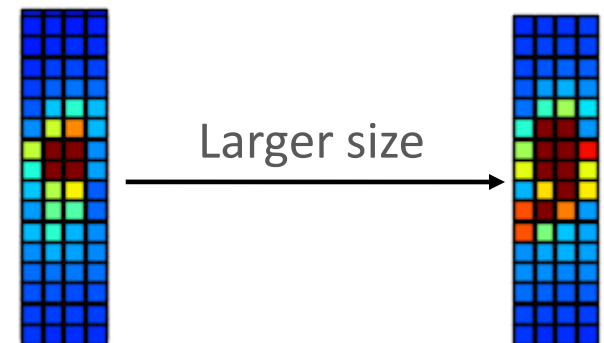
In essence, a time averaged temperature value that includes the effect of temperature increase is used.

# Activation Mode Criteria: Fire Temperature and Size

- IR Sensor is used to calculate the fire's temperature and size
- Fire Temperature
  - Once the fire is located, an IR image centered at the fire is taken
  - The fire's temperature is the average of the four pixels nearest to the hottest location
    - If this value is above a preset limit, the system activates
- Fire Size
  - Using the same IR image, the fire's size is the sum of all pixel values above a preset value

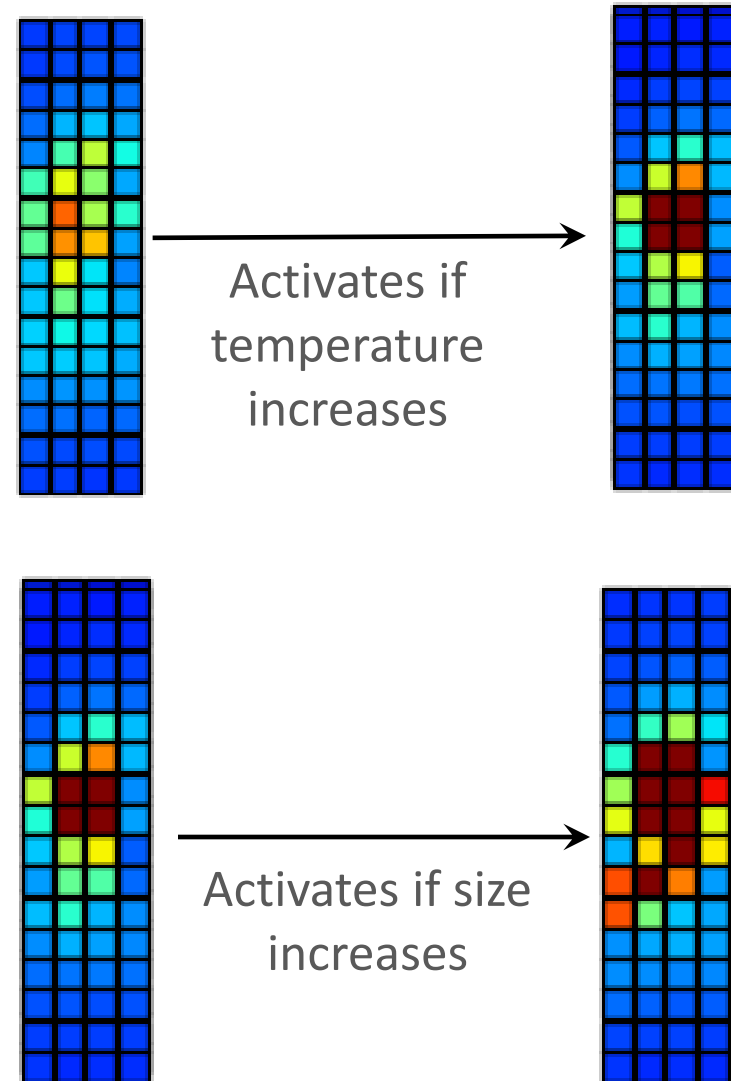


The fire's temperature is the average of the four pixels outlined



# Activation Mode Criteria: Growth in Fire Temperature and Size

- If a potential fire is targeted but the activation criteria are not met
  - System scans the surrounding area
  - Re-targets the location
- Growth in Temperature
  - System activates if the fire's temperature increased since the last check
- Growth in Fire Size
  - System activates if the fire's size increased since the last check



# Activation

- System activates once fire is confirmed and targeted
- During activation, IR images are still recorded
- Discharge time is actively calculated
  - Minimum and maximum times are set
  - In between, activation continues till 10 consecutive IR images are taken without a fire present
- Position is updated while discharging based on IR data
  - System always targets hottest location in the fire
  - This allows the system to handle spreading fires



# Activation in Action



# Awake Parameters

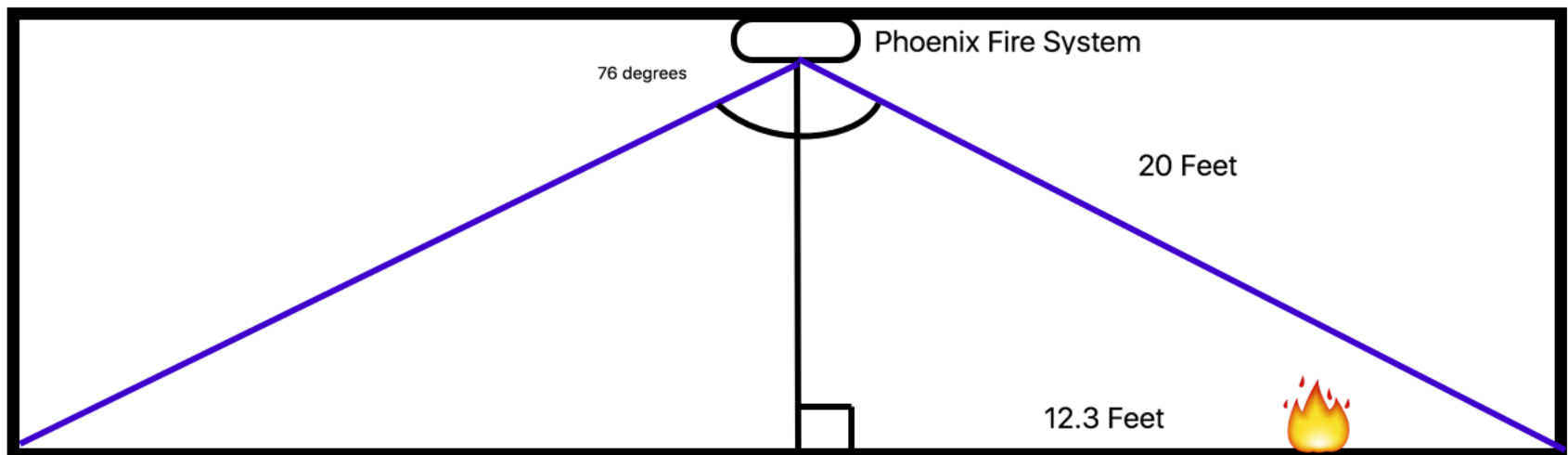
- Temperature = 100 F - This is a time averaged temperature recorded by the thermistors at which the system will switch from sleep mode to awake mode
- Rate of Rise = 3 F/sec - This is a time averaged rate of temperature increase recorded by the thermistors at which the system will switch from sleep mode to awake mode
- Smoke - % Obscuration, The system will switch from sleep mode to awake mode upon the smoke detector reporting the presence of smoke

# Suppression Parameters

- Temperature = 140 F - This is a time averaged temperature recorded by the thermistors at which the system will activate suppression
- Rate of Rise = 5 F/sec - This is a time averaged rate of temperature increase recorded by the thermistors that will activate suppression.
- IR Temperature Limit = 400 F - This is the temperature of the fire seen by the IR at which the system activates suppression
- IR Size Limit = 1000 F/"Area" - This is a measure of the size of the fire seen by the IR at which the system activates suppression
- IR Temp Growth = 100 F – The system will activate suppression upon the IR sensor seeing growth in the fire's temperature even if the temperature of the fire seen by the IR is below the value given previously.
- IR Size Growth = 250 F/"Area" – The system will activate upon the IR sensor seeing this growth in the fire's size even if the size of the fire seen by the IR is below the value given previously

# System Coverage

- Dry Chemical discharge distance is up to 20 feet, dependent of pressure.
- System currently is charged to 100-150 psi
- Discharge duration is >30 seconds.
- System field of view range is 76 degrees allowing for a floor coverage of 24.6 feet.



# Improved Thermal Response

$$t_{operation} = \frac{RTI}{\sqrt{U_m}} \log_e \left( \frac{T_m - T_{\infty}}{T_m - T_{operation}} \right)$$

$t_{operation}$  = Time of activation of Thermal Element

RTI = Response Time Index

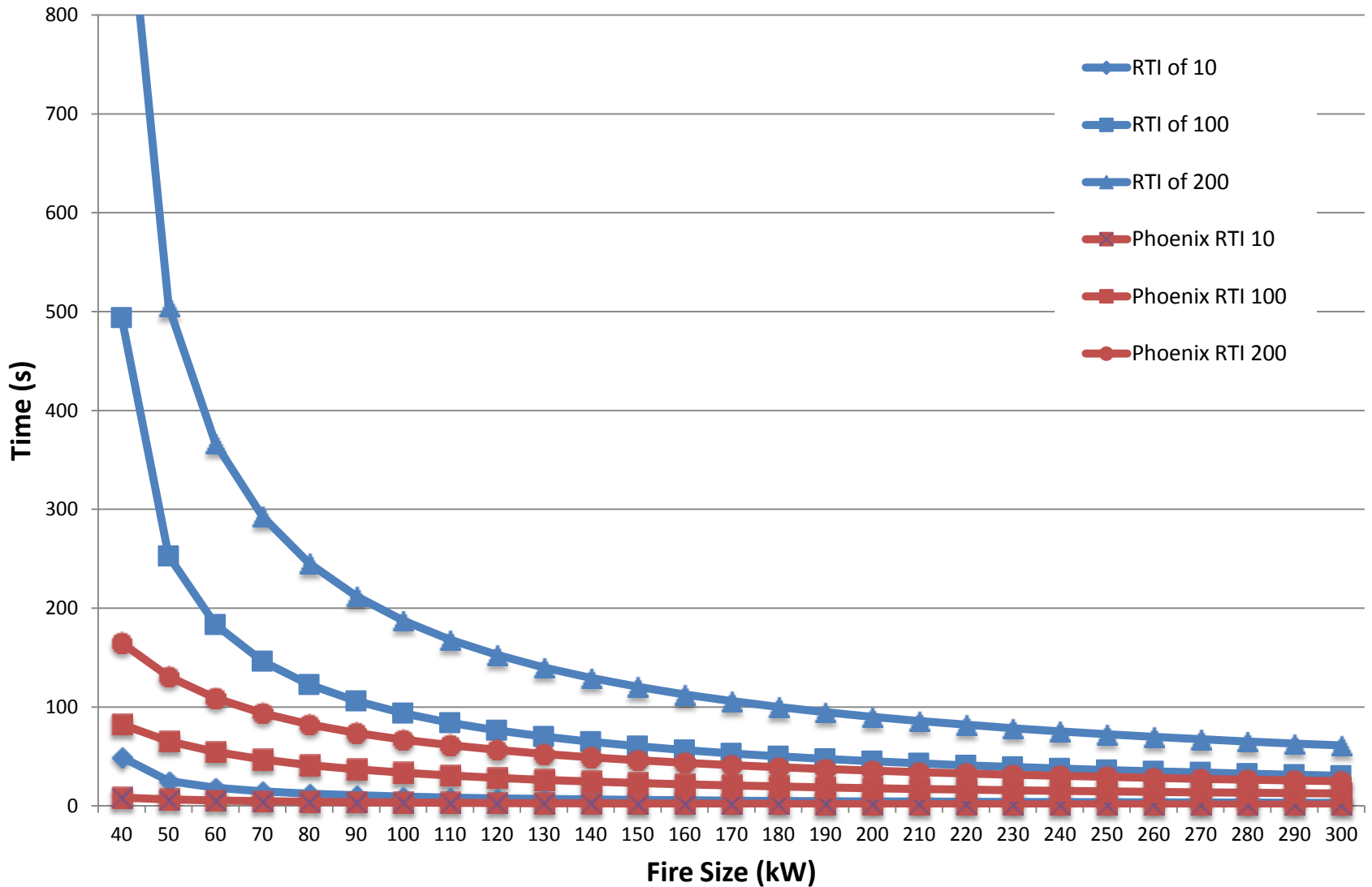
$U_m$  = Gas Velocity

$T_m$  = Gas Temperature

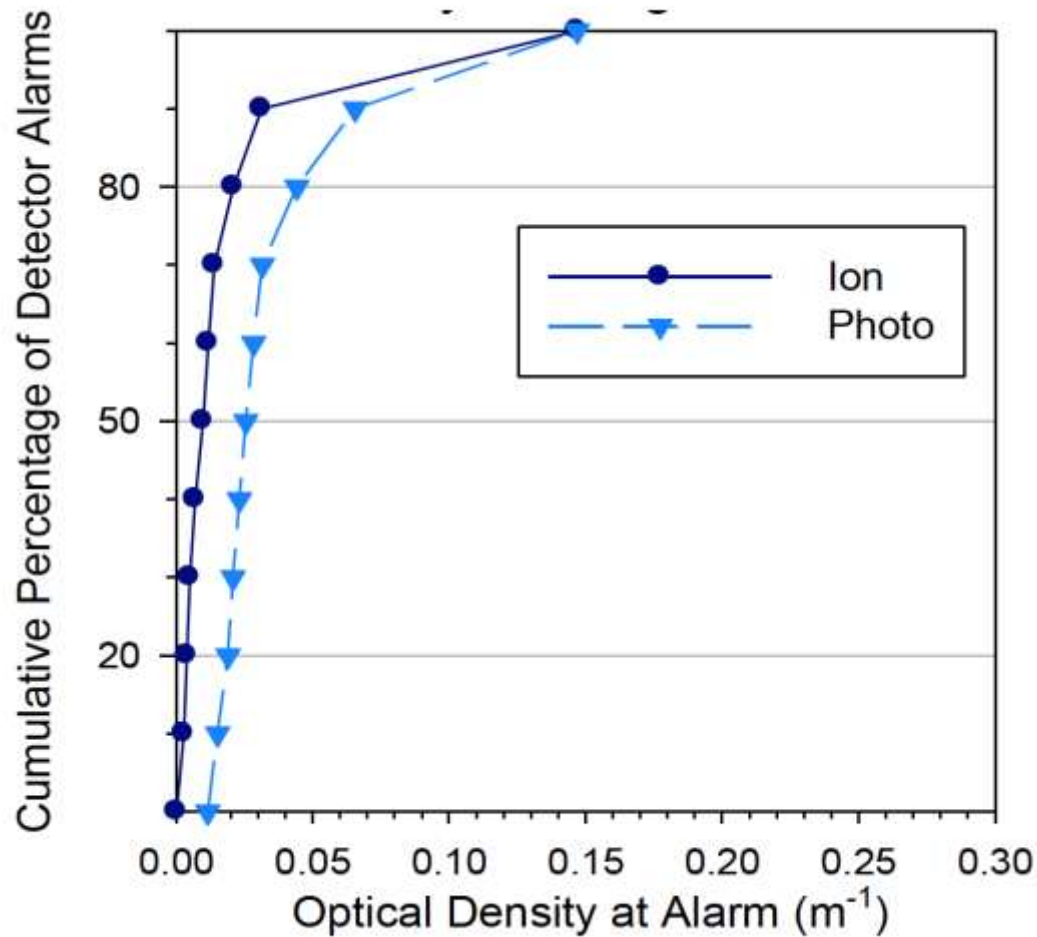
$T_{operation}$  = Thermal element operating Temperatur

- Rate of Rise range from 66 to 330  $m \cdot s^{1/2}$
  - Rate Compensation range from 9 to 64  $m \cdot s^{1/2}$
  - Fixed Temperature range from 3 to 66  $m \cdot s^{1/2}$
- Response Time Index (RTI) or  
Methodology for Heat Detection – Bob  
Elliot FM Global

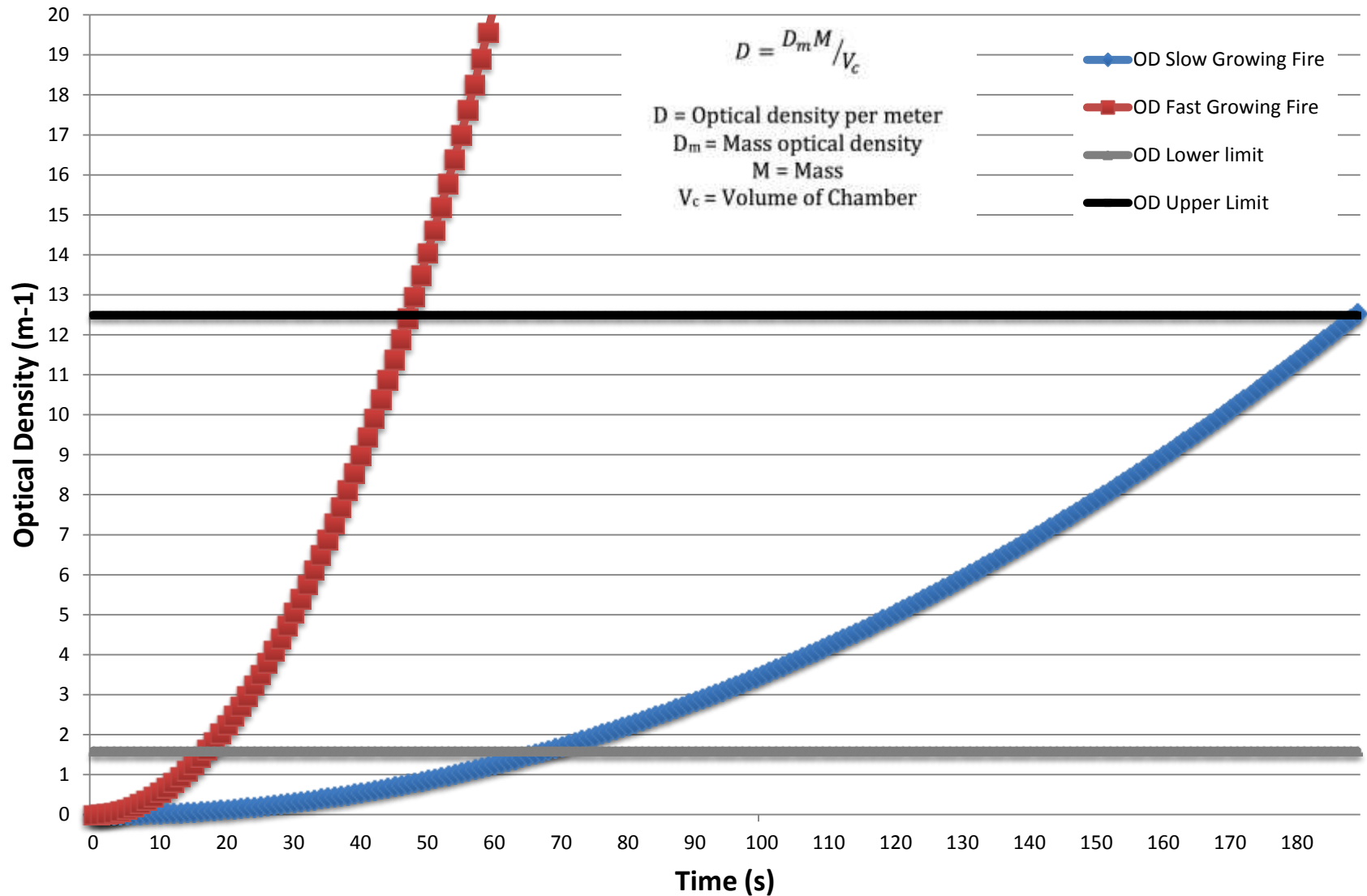
# RTI affect on Response Time



# Improved Smoke Detector response



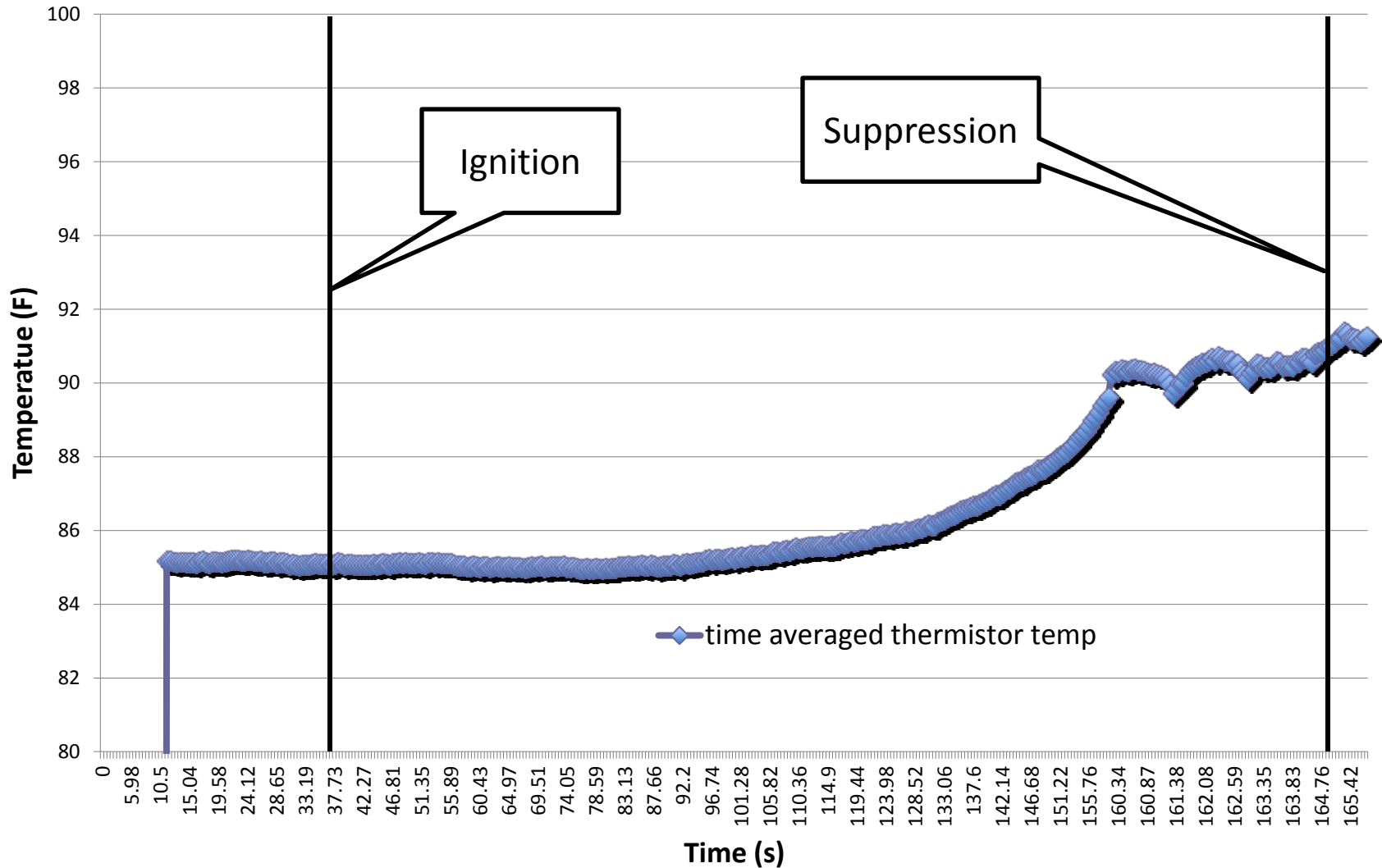
# Optical Density: Based on Slow and Fast Growth Fires





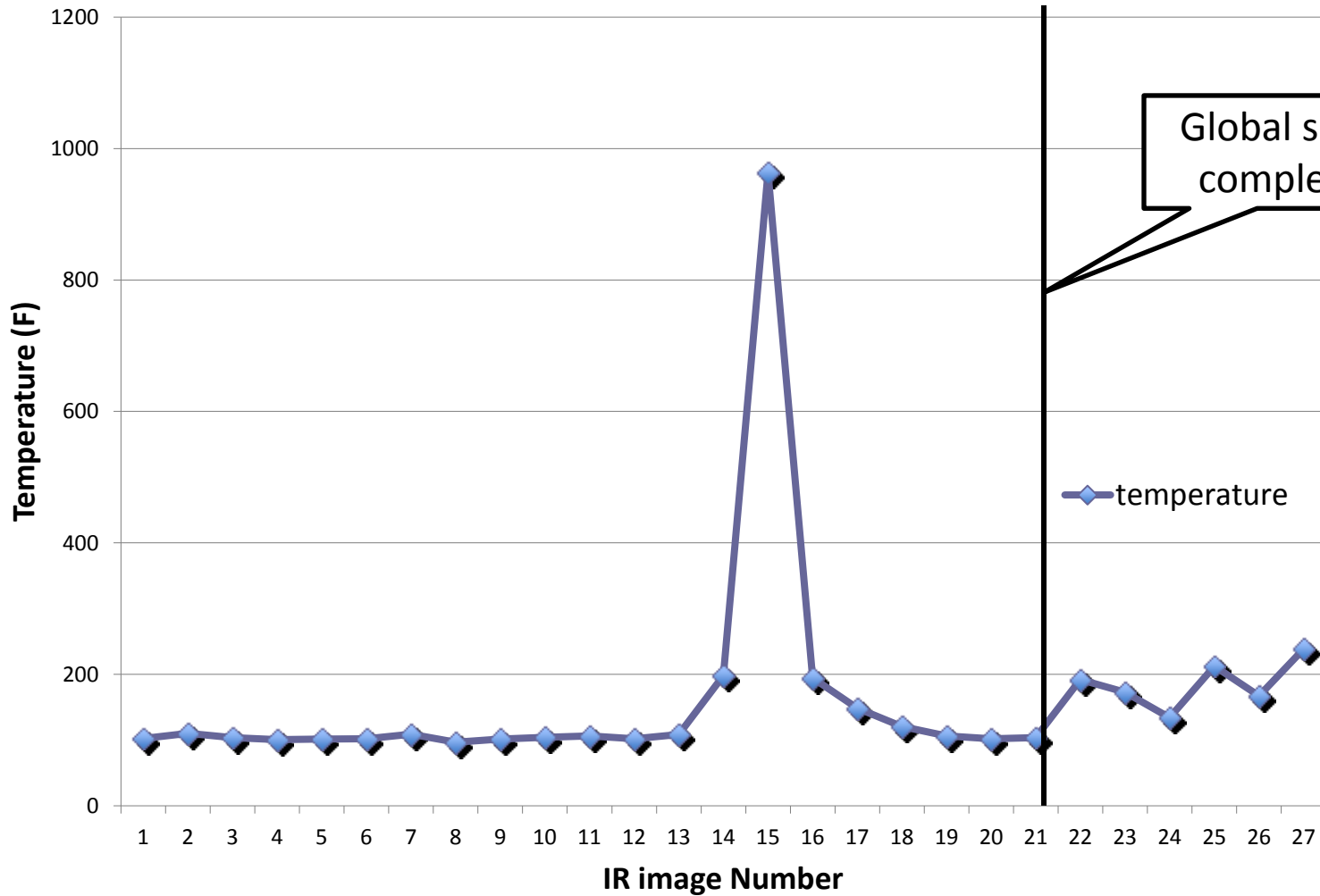
# Example 1

## Thermistor Temperature



# Example 2

## IR Temperature Scan



# Conclusion

- IR targeting can quickly and effectively locate a fire
- Using detection methods in a multi criteria layered approach can improve detection and suppression times.
- System offers maximum flexibility in terms of placement and usages as software is easily adjusted to fit application.
- Additional testing is ongoing

# Questions?

For more information, contact:

Ian McNamara

FireStrike Industries LLC.

[www.FireStrikeIndustries.com](http://www.FireStrikeIndustries.com)

1-224-239-5018

[ianmcnamara@firestrikeindustries.com](mailto:ianmcnamara@firestrikeindustries.com)

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