# IoT-Based Monitoring of Emergent Events For Wildland Fire Resilience

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## SPARx Cal Project: Prescribed Fire for Wildland Fire Resilience

*--Interdisciplinary effort to address the risk of California's megafires*

**Main Topics**

Fire Behavior Modeling | Air Quality Modeling | Fire Ecology | IT support system

**Prescribed fire:** a man-made fire consumes unnecessary fuels – prevent possible future destructive wildfires

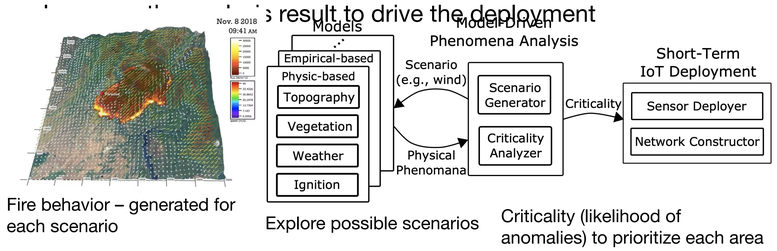
**Escaped fire:** embers fly beyond the controlled perimeter and create unexpected wildfire

**Expectation:** reduce the threat of wildfires via prescribed fires
- Increase the efficiency within a short window of time
- IoT-based monitoring system for improving situational awareness
- Ensure safety – operation staff and neighboring residents

## Model-Driven Static Sensing Platform Deployment

**Goal:** capture abnormal physical phenomena before it occurs
- Sensor deployment: capture physical phenomena and convert it to data
- Network construction: transmit the data to an edge server for analysis

**QuIC-IoT:** a framework for rapid IoT infrastructure deployment
- Integrate physics-inspired models to analyze physical phenomena
- [illegible]s result to drive the deployment




Fire behavior – generated for each scenario

Explore possible scenarios

Criticality (likelihood of anomalies) to prioritize each area

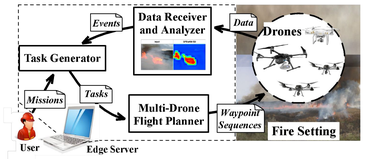
**Benefit** for prescribed fire operations
- Near real-time monitoring rather than weather forecast
- Efficiency – reduce operation time (currently a day for a small burn)
- Safety – quick response to escaped fire

## Drone-assisted Monitoring of Emergent Events

**Goal:** use aerial sensing (drones) to gather real-time data for situational awareness in emergent and evolving events

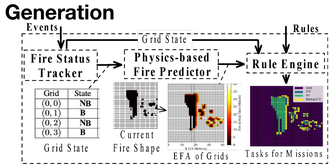
**DOME**: a drone-based monitoring system for aerial sensing in fire settings
- Task Generation: generate tasks (temporal-spatial monitoring needs)
- Multi-drone flight planning: guide motion of drones to fulfill tasks

### System Design & System Semantics



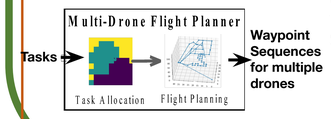

**Mission**: (Monitoring Objective, Period, Significance)
**Event** : (Object Status, Location, Time)
**Task**: (Mission, Location, Start time, End time)

### Physics-inspired Rule-based Task Generation




Event-driven **grid status** transition
**FARSITE** predicts fire arrival time of each grid
**Production rules** are used generate tasks

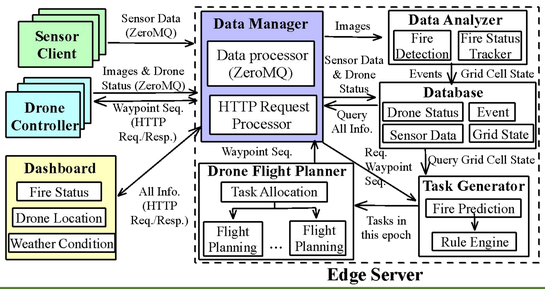
### Multi-Drone Flight Planning




**Task allocation**: assign each task to a specific drone
**Flight Planning:** each drone computes a waypoint sequence to fulfill its assigned tasks
**Special concerns:**
- Drone heterogeneity (sensing and networking capabilities)
- Diverse monitoring and sensing needs
- Coverage vs data quality
- Disconnected network (**store-and-upload data**)

## Demo: Implementation of IoT-based Monitoring System for Monitoring Wildland Fires

### System Overview



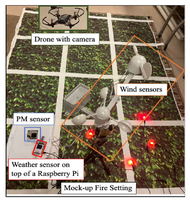

A prototype of IoT-based system developed in a lab-based testbed supports in-situ and mobile sensing for monitoring in fire settings

**In-situ sensor data collection**
- Sensors periodically collect and transmit data to the edge server via Wi-Fi
- Sensors are attached on Raspberry Pis running Scale-Client for processing raw data
- ZeroMQ is used for publishing all sensing data
- A data manager subscribes to all sensing data and stores them in a database

**Drone-based mobile sensing**
- A drone controller guide each drone to fly by following a predefined waypoint sequence
- Images captured at each waypoint are transmitted to the server via Wi-Fi using ZeroMQ
- A data analyzer processes the received images for fire detection
- A drone flight planner generates waypoint sequence based on fire status and rules

**Dashboard**
- HTML-based website retrieves information periodically through HTTP request
- Illustrate weather information and fire status
- Demonstrate Each drone's waypoint sequence, real-time location, captured images
- Interface for user to specify monitoring requirements (missions) for drones

### Demo Overview




**Mock-Up Fire Setting**
- 6 × 8 ft plane with LED lights (mock fires)
- Sensors capturing wind speed, temperature, humidity, and PM 2.5 and 10
- A DJI Tello drone with a top-down RGB camera

**Weather Data Collection**

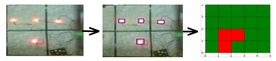
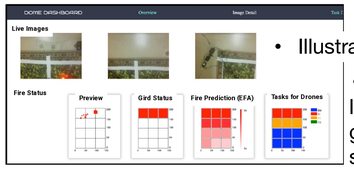




**Image Processing**

**Fire Status Tracking & Task Generation**



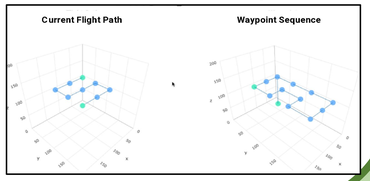

- Illustration of live images
- Fire spot locations and grid-based fire status
- Fire prediction result (EFA)
- Auto-generated tasks based on rules

**Flight Planning Configuration Interface**


- Mission parameters
- Planning time
- Wind speed & direction

- Auto versus manual flight planning mode

**Real-Time Drone location** | **Planned Waypoint Sequence**




## Our Experience in Real Prescribed Fires

- Participate several prescribed burns in the Blodgett Forest Research Station
- Flying diverse type of drones for collecting RGB, thermal, and multispectral imagery data
- Deploying sensor for monitoring weather condition

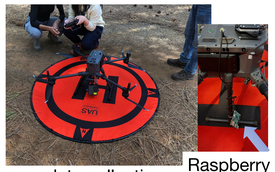
**In-Situ Sensing**

Raspberry Pi – course-grain sensor

QuantAQ – fine-grain sensor

Air quality study – a sensing platform for PM2.5

**Mobile Sensing**



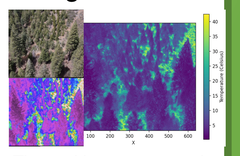
Imagery data collection – RGB, thermal

Raspberry Pi: on-board data proxy handling network disconnection

**Captured Images & Image Processing**

Aerial images for fire tracking

Aerial Images for monitoring human and equipment



Thermal image processing for abstracting fire intensity.


- Fangqi Liu, Janine Ann Baijnath-Rodino, Tung-Chun Chang, Tirtha Banerjee, Nalini Venkatasubramanian, "DOME: Drone-assisted Monitoring of Emergent Events For Wildland Fire Resilience", ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS), 2023.
- Tung-Chun Chang, Tirtha Banerjee, Nalini Venkatasubramanian, Rob York, "QuIC-IoT: Model-Driven Short-Term IoT Deployment for Monitoring Physical Phenomena", ACM/IEEE Conference on Internet of Things Design and Implementation (IoTDI), 2023.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