EGR 314 - Embedded Systems

Team Concept Generation and Design Ideation

Team 315 - Phoenix Force

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Goal of the Project

The goal of our project is to develop a modular wildfire response system that improves the early detection and monitoring of hot spots, which are critical in preventing flare-ups and fire spread. Our system combines mobile sensor modules with a base display module, allowing distributed detection of temperature, smoke, carbon monoxide, and other key indicators of fire activity. By using ESP-Mesh networking, multiple mobile units can cover wide areas, relay information to one another, and transmit data back to a central screen where conditions are clearly visualized. This provides firefighters and fire-watch teams with real-time, field-level situational awareness that is often unavailable in remote or high-risk environments. Ultimately, the project supports wildfire suppression by enabling faster responses, reducing blind spots, and ensuring that hot spots are identified before they reignite into larger, more dangerous fires.

Audience of the Project

Our primary audience is frontline wildfire responders, including firefighters, fire-watch volunteers, and emergency management teams. These groups need rugged, easy-to-use technology that functions reliably in harsh outdoor conditions while providing actionable information at a glance. Secondary audiences include researchers and community stakeholders who can use the collected data for environmental monitoring, long-term fire prevention strategies, and public safety education. By tailoring our design for professionals in the field while also making it understandable for broader audiences, our project bridges the gap between advanced sensor technology and practical wildfire response. The ultimate aim is to create a tool that not only aids trained responders in critical situations but also demonstrates to the public the importance of hot spot detection in protecting lives, property, and ecosystems.

Generating Ideas

1. Temperature sensor
2. Moisture sensor
3. Gas levels sensor
4. Thermal camera
5. Predicting fire escape path + alerting people nearby
6. Soil temperature probes
7. Smoke sensor
8. UV/solar radiation sensor
9. Humidity sensor

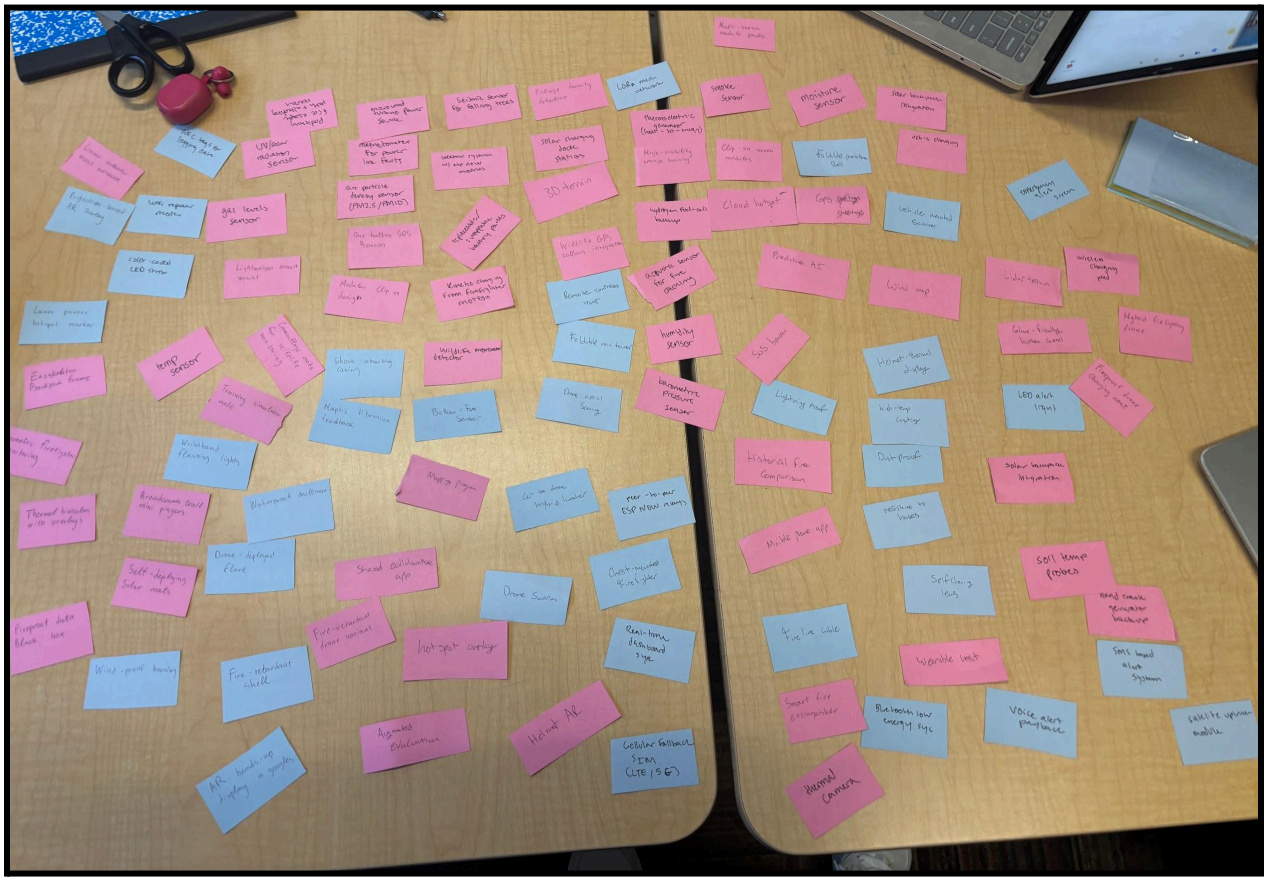
10. Barometric pressure sensor
11. Acoustic sensor for fire crackling
12. Seismic sensor for falling trees
13. Air particle density sensor (PM2.5/PM10)
14. Magnetometer for power line faults
15. Wildlife movement detector
16. Solar charging dock stations
17. Hand-crank generator backup
18. Kinetic charging from firefighter motion
19. Solar backpack integration
20. Replaceable/swappable battery packs
21. USB-C charging
22. Wireless charging pad
23. Micro wind turbine power source
24. Hydrogen fuel-cell backup
25. Thermoelectric generator (heat-to-energy)
26. Weather system with ESP-NOW modules
27. LoRa mesh network
28. Bluetooth Low Energy sync
29. NFC tags for logging data
30. Wi-Fi repeater mode
31. Cellular fallback SIM (LTE/5G)
32. Real-time dashboard sync
33. SMS-based alert system
34. Peer-to-peer ESP-NOW relays
35. Satellite uplink module
36. Emergency alert siren
37. LED alert light
38. Color-coded LED strip

39. Voice alert playback
40. Haptic vibration feedback
41. AR heads-up display in goggles
42. Laser pointer hotspot marker
43. Drone-deployed flare
44. Wristband flashing lights
45. Projection-based AR overlay
46. Shock-absorbing casing
47. Waterproof enclosure
48. Wind-proof housing
49. Fire-retardant shell
50. Lightning-proof surge protection
51. Dustproof/ash-proof sealing
52. Ceramic high-temp casing
53. Submersible resistance to hoses
54. Foldable protective shell
55. Self-cleaning lens cover
56. Drone for aerial scanning
57. Car-to-drone hybrid launcher
58. Drone swarm for mapping
59. Balloon-mounted fire sensors
60. Vehicle-mounted scanner
61. Fireline cable sensor deployment
62. Remote-controlled rover
63. Chest-mounted firefighter module
64. Helmet-integrated thermal display
65. Foldable mini-tower
66. GPS geotagging
67. Lidar terrain scanning

68. Mapping program integration
69. Predictive AI fire spread modeling
70. Cloud hotspot archive
71. 3D terrain + hotspot overlay
72. Wind map overlay
73. Historical fire comparison
74. Augmented evacuation path overlay
75. Shared collaborative map
76. Wearable vest module
77. Helmet AR overlay add-on
78. Mobile phone app companion
79. Glove-friendly button controls
80. One-button SOS beacon
81. Modular clip-on design
82. Lightweight exosuit assist
83. High-visibility orange housing
84. Camouflage mode for wildlife monit
85. Training simulator mode
86. Linear actuator mast antenna
87. Foliage density detection
88. Wildlife GPS collars integration
89. Clip-on screen modules
90. Multi-sensor module packs
91. Fire-retardant drone variant
92. Smart fire extinguisher
93. Hybrid firefighting drone
94. Fireproof drone charging nestling
95. Fireproof data black box
96. Self-deploying solar mats

97. Breadcrumb trail mini pingers
98. Thermal binoculars with overlays
99. Exoskeleton backpack frame
100. Biometric firefighter monitor

Ideas in Sticky Notes



1. What kinds of cues will you provide to make the use of your device easier?

Our brainstorm includes multiple clear, layered cues so users don't rely on just one sense. These include:

- Visual cues such as LED lights (single color alerts and color-coded strips), projection overlays, AR goggles, and thermal displays.
- Auditory cues like sirens, voice alerts ("Hot spot detected, 200m north"), and drone-deployed flares that make noise when dropped.

- Tactile cues such as haptic vibration feedback in a wristband or vest.
  These multimodal cues ensure that even in smoke-filled, noisy, or high-stress conditions, the user still notices alerts.

2. How do you plan on designing your "controls"?

Following the Suggested Guidelines for Designing Interactive Exhibits, we will focus on simplicity and intuitiveness:

- Large, glove-friendly buttons for quick actions (SOS beacon, power toggle).
- One-button activation for emergency features (like broadcasting a hotspot alert).
- Minimal menus on wearable screens, with icons instead of long text.
- Modular clip-on controls so users can configure the system depending on the mission (helmet AR overlay, chest module, handheld).
  The goal is that controls can be understood in seconds and operated without removing gloves or gear.

3. What role will durability, safety, and comfort play in the user experience?

Durability and safety are central in our brainstorm:

- Devices will be fire-retardant, waterproof, dust/ash proof, and shock-absorbing, ensuring they withstand harsh wildfire environments.
- Comfort comes from wearable modules (vests, helmets, exoskeleton frames) designed to be lightweight, balanced, and easy to wear over existing gear.
- Safety extends beyond the device itself - many brainstorm features (predictive fire path AI, evacuation overlays, SOS beacon) actively protect the user's life by improving situational awareness and response speed.

4. What kind of instruction will be needed to use the device?

The device is designed for minimal training:

- Quick-start guide with icons showing button functions.
- Color and sound codes that are intuitive (red = danger, green = safe).
- AR overlays that guide the user step-by-step (e.g., marking safe paths).
- A mobile app companion for settings, logs, and training simulator mode.
  Overall, the goal is that a firefighter could learn core functions in under 10 minutes and practice advanced features in a short training module.

5. Ideas or strategies for avoiding the five common pitfalls (from "Designing Science Museum Exhibits with Multiple Interactive Features"):

- Avoid overwhelming the user → Keep the interface simple (few buttons, color cues, icons).
- Avoid competing feedback → Synchronize alerts (if a vibration alert is active, lights and voice cues reinforce the same message, not different ones).
- Avoid hidden functionality → Ensure that all features are clearly visible on the device or app, not buried in sub-menus.
- Avoid fragile interactions → Design for rugged use: large buttons, fireproof casing, dust/ash resistance.
- Avoid poor guidance → Provide immediate feedback (light flashes, haptic buzz, or voice confirmation) every time a button is pressed or a feature is triggered.

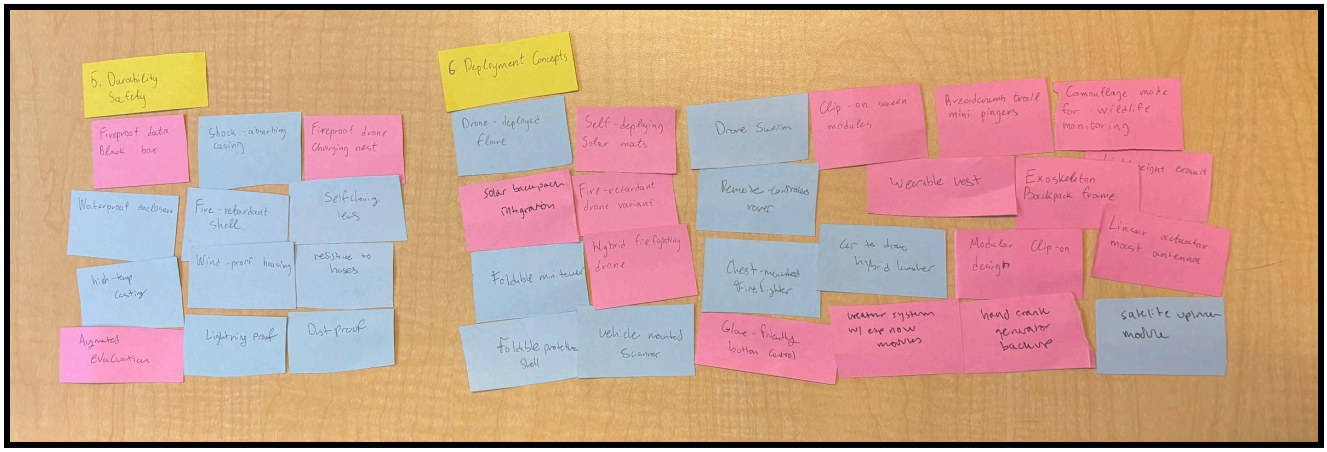
Sort, Rank, and Group

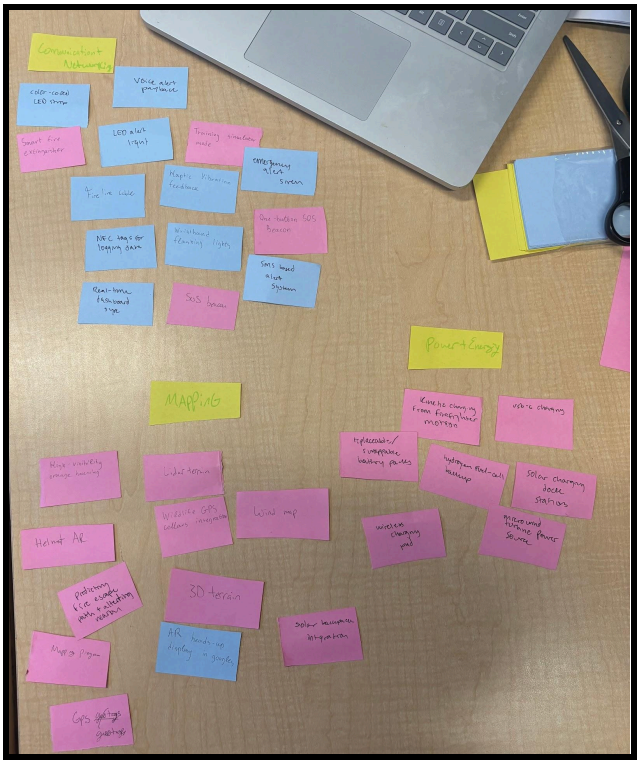
Grouping (Themes from Brainstorm)

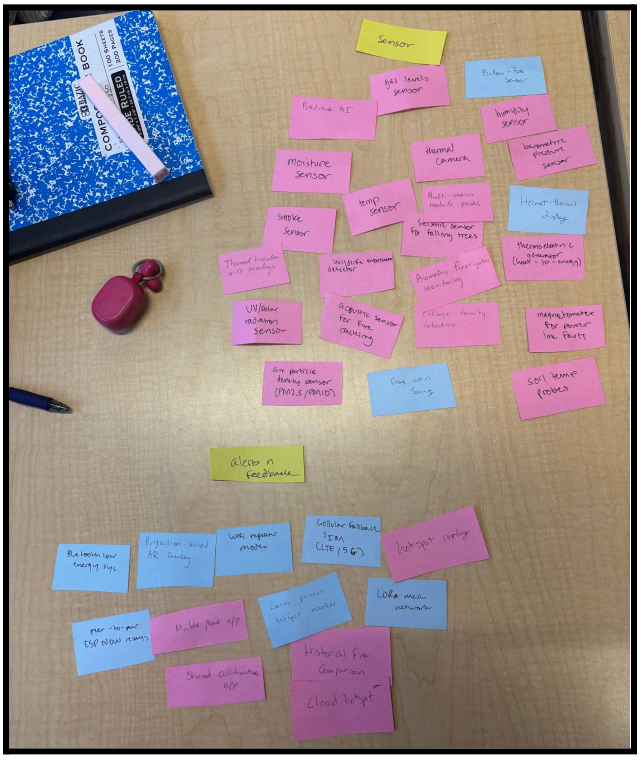
From our brainstorm, we noticed the ideas fell naturally into seven categories:

1. **Sensors & Detection** (e.g., temperature sensor, thermal cameras, wildlife movement detectors)
2. **Power & Energy** (e.g., solar backpack, hydrogen fuel-cell backup, replaceable batteries)
3. **Communication & Networking** (e.g., LoRa mesh, Starlink uplink, SMS alerts)
4. **Alerts & Feedback** (e.g., haptic wristband, voice playback, AR goggles)
5. **Durability & Safety** (e.g., shockproof casing, fire-retardant shell, self-cleaning lens)
6. **Deployment Concepts** (e.g., drones, balloon sensors, rover units, wearable modules)
7. **Mapping & Data Visualization** (e.g., GPS geotagging, AI fire spread modeling, evacuation path overlays)

Different Categories







Ranking (Top Features Selected)

We evaluated each group for usefulness, feasibility, and impact. Our top 15 ranked ideas are:

- Thermal camera (detect hidden hotspots)
- Smoke sensor (detect fire activity early)
- Predictive AI fire spread modeling (anticipate danger zones)
- GPS geotagging + collaborative mapping (situational awareness)
- AR heads-up display in firefighter goggles (hands-free info)
- LoRa mesh network (reliable communication without Wi-Fi/cell)
- Satellite uplink (emergency fallback when no network exists)
- Emergency alert siren + vibration wristband (multi-sensory alerts)
- Fire-retardant, shockproof, waterproof casing (rugged durability)
- Solar backpack integration (portable, renewable power source)
- Replaceable/swappable batteries (field-ready)
- Helmet-integrated thermal display (no need for handhelds)
- Remote-controlled rover for dangerous terrain
- Hybrid firefighting drone (camera + water spray)
- Cloud hotspot archive + real-time dashboard sync (long-term + live analysis)

Concept Sketch

Product Description

Our wildfire response concept is designed to meet the urgent need for early detection and continuous monitoring of fire hot spots. By combining multiple mobile sensor modules with a central base display module, our system provides distributed coverage of dangerous areas while giving responders an intuitive, real-time interface. The mobile modules are equipped with temperature, smoke, and carbon monoxide sensors, along with GPS positioning and a linear actuator mast that raises the sensor package above foliage to capture more reliable readings. These units communicate through an ESP-Mesh network, ensuring that data is relayed even in environments without cellular or Wi-Fi coverage. The base module aggregates the data, visualizes it on a clear screen, and issues alerts through multiple cues. Together, these features satisfy the needs of wildfire response by reducing blind spots, speeding up detection, and helping teams prevent flare-ups that threaten lives, property, and ecosystems.

The functionality of the system will be divided across four teammates to align with the project structure. The internet-based two-way communication role will focus on building the ESP-Mesh backbone, ensuring that multiple mobile units can talk with one another and reliably pass data to the base station. The human–machine interface teammate will design the base module's screen, buttons, and user experience so that responders can quickly see conditions, acknowledge alerts, and issue commands. The sensor and actuator-based controlled response teammate will handle integration of the temperature, smoke, and CO sensors, the GPS, and the linear actuator that raises the mast. Finally, the systems integration teammate will coordinate power management, battery swaps, and the drive mechanism that enables each mobile unit to navigate terrain safely. This division ensures that each student contributes to a core function of the system while maintaining integration across the project.

To make the device easier to use in stressful environments, we will provide multi-sensory cues: LED indicators, audible alarms, voice playback, on-screen alerts, and vibration feedback for wearables. Controls will be designed to be simple and glove-friendly, using large buttons for core actions such as powering on, acknowledging an alert, raising or lowering the mast, and returning a unit to base. Durability is equally important: all enclosures will be fire-retardant, waterproof, dustproof, and shock-absorbing to survive harsh wildfire conditions. Comfort will be addressed by making the base station portable, lightweight, and readable in direct sunlight, while the mobile units will remain compact and self-sufficient. Only minimal instruction will be required to operate the system. A quick-start guide with icons, on-device labels, and a training "demo mode" will help new users understand functions in less than ten minutes. With these features, our design balances technical robustness, safety, and human usability in a way that directly supports wildfire response efforts.