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Post-Fire Risks



Responders exposed to...

- Carbon monoxide
- Carbon dioxide
- Low oxygen
- Air particulate
- Toxins from retardant
- Other carcinogens

Professor David Purser

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Presentation Road Map


- Project Motivation
- Background
- Our Solution
- Subsystem Breakdown
- Requirement Verification



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Problem Statement


Our goal is to design and implement an **unmanned vehicle** that **gathers** and **relays** information on potentially **hazardous environmental conditions** back to its operators.

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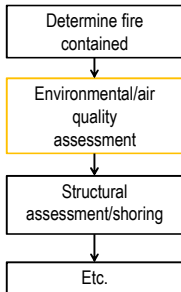
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Post-Fire Investigation Protocol




National Fire Protection Association

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Customer Needs


Results of interviews with two fire fighters

Category	Specific Needs
Sensors	Imaging sensors Multiple gas detectors Air particulate Temperature
Communication	Strong communication link Clear data presentation
Vehicle	Rugged Temperature/weather resistant Travel long distances



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Current Technologies

	<p>Northrop Grummann's Andros F6</p> <ul style="list-style-type: none"> + 5 cameras - No housing for air quality sensors
	<p>Sensefly's UAV EBee</p> <ul style="list-style-type: none"> + Thermal imaging/mapping - No ability to assess air quality on ground

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Legacy Work

- Drive by Wire
- Remote Operator Console
- Analog Override System
- Emergency Stop




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RSL Rover Solution



Information to Mobile Command Center

Air Quality / Hazardous Gas Sensors

Camera Feeds

LIDAR Data

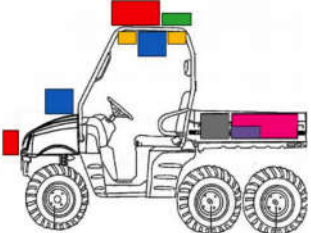
Information to Vehicle Operators

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Five Subsystems

1. Environment Sensing
 - Cameras
 - Payload Sensors
2. Mapping
 - GPS
 - LiDAR Sensors
3. Operation/UI
 - Controllers Electronics
 - Inertial Measurement Unit
4. Communications
 - Network Electronics
5. Power
 - Batteries



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Design Objectives


- Hazardous Environment Evaluation
- LIDAR and GPS Mapping Capabilities
- Dual Purpose Vehicle
- Store Data Streams
- Information Dissemination

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Robot Operating System (ROS)

- All of the rover subsystems are integrated with ROS
- Industry Standard
- This provides pluggable software functionality
- Centralized data collection
- Enables subsystem testing with recorded data

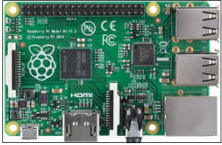


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Cameras

- Dedicated Raspberry Pi 2 Model B
- Four Logitech C615 USB cameras
- OpenCV people detection




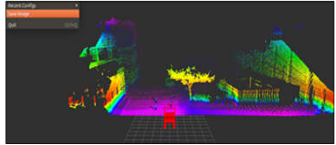


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Localization/Mapping

- Completed Navigation Sensor Integration
 - GPS
 - 2x LIDAR
 - IMU
 - Tachometer
 - Steering Sensor
- 3D LIDAR Visualization
- 2D Environment Mapping
- Complete System Data Acquisition

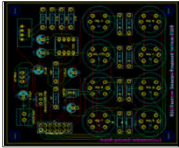



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Air Quality Sensing Unit


- Detects presence of CO, CO2, Natural Gas, LPG, H2, and smoke
- Sensors mounted on a custom printed circuit board

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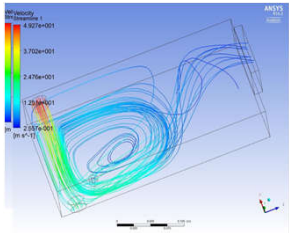
User Interface



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Sensor Housing



- Ensure that sensors receive appropriate airflow
- Multiple Iterations were analyzed
 - Some designs used fan as outlet
 - Single Inlet + Particulate Inlet
- Final Design
 - Fan Used as Inlet for smoothness
 - Double Outlet + Particulate Outlet

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Non-technical Considerations

- Economic
- Health & Safety
- Manufacturability
- Social
- Political
- Ethical



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Testing Results



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Latency Requirement Verification


- Tested latency of cameras and UI


Requirement	Result
Cameras latency < 1s	0.75s
UI camera stream latency < 1s	0.8s
UI vehicle state latency < 1s	2s

Vehicle Forward Camera


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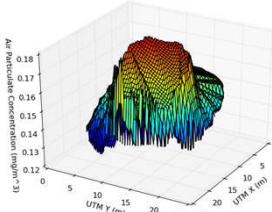
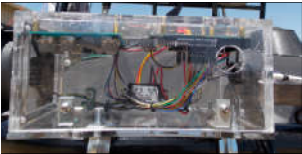




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Environmental Sensor Requirement Verification


- Successfully tested the ability of sensors to detect gases and particulates caused by a fire

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Range Requirement Verification


- Tested maximum distance between rover and driving controls


Requirement	Result
Wifi must reach 150m	250m
Driving control must work at 150m	> 1000m



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Vehicle Blindspot Requirement Verification


- Evaluated the camera coverage and blind-spots


Requirement	Result
360 deg visibility	260 deg



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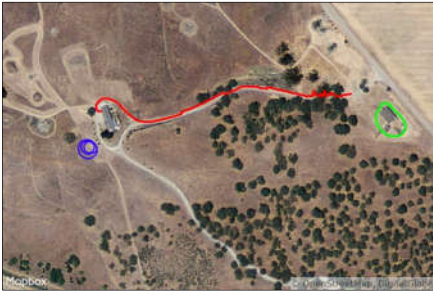
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GPS Requirement Verification



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Localization and Mapping Verification

- 2D maps successfully generated while driving
- 3D point-clouds visualized while driving
- Accumulated 3D point-clouds assembled in post-processing

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Software Architecture

SOFTWARE DIAGRAM OF ONBOARD SYSTEMS

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Conclusion

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System Architecture

ROVER VEHICLE DIAGRAM

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Questions?

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Post Fire Protocol

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Requirements Flowdown

Mission Statement: To create a heterogeneous of terrain vehicle capable of traversing any quality, temperature, and LQAD data to a remote operator to monitor environmental conditions after a wildfire fire.		
		T- Test
		OR- Design Requirement
ID	Description	TYPE
MD-1	Other personnel operate the vehicle and off-road way	OR
MD-1-1	Throttle pedal at a distance of 200m	T
MD-1-2	Provide 360-degree camera view of the vehicle for driving	T
MD-1-3	Video stream of 60s	T
MD-1-4	Real time with information for vehicle health information	OR
MD-1-5	Control response via	T
MD-1-6	Emergency stop system	OR
MD-2	Operate vehicle locally and remotely (disabled)	OR
MD-2-1	Carry 2 dimensions and 200m of area	OR
MD-2-2	Manually operate without vehicle control	T
MD-2-3	Off Road Capable	OR
MD-3	Map the environment in real time	T
MD-3-1	Identify user the environment in 3 dimensions	T
MD-3-2	Provide 360-degree mapping capability	T
MD-3-3	Ability to save data for later analysis	OR
MD-3-4	Generate 3D model in real time	T
MD-4	Evaluate the hazards to humans in an area affected by fire	OR
MD-4-1	Direct smoke concentration	OR
MD-4-2	Detect levels of Natural Gas, CO, CO2, H2	OR
MD-4-3	Compare concentrations to US Forest explosive limit	T
MD-4-4	Sense temperature and humidity	OR
MD-4-5	The weather sensor package	OR
MD-4-6	Stream data in real time to remote operators	OR
MD-4-7	Latency < 5s	T
MD-4-8	Enclosure designed to accurately sample the environment	OR
MD-5	Provide an effective user interface	OR
MD-5-1	Display all information relevant to driving the vehicle and a DA	OR
MD-5-2	Display environmental data correctly	OR
MD-5-3	Third driver data available even in health information	OR
MD-5-4	Latency < 2s non-critical data	T



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References

- = Health Hazards of Smoke: Recommendations of the April 1997 Consensus Conference. Gen. Tech. Rep. [9751-2836](#).
- = [MTC](#). Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center.
- = National Fire Protection Association. Guide for fire and explosion investigations. NASA Technical Standards, 2004
- = Professor David Purser. Toxic hazards to fire fighters, including effects of fire retardants, during fires and post-fire investigation activities. 2009.