PROJECT REPORT:

A UAS NETWORK FOR TRANSPORTATION EMERGENCY RESPONSE

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PROJECT INFO

• Project Title: A UAS Network for Transportation Emergency Response
• Research Team:
  • Danjue Chen (UML)
  • Yuanchang Xie (UML)
• Project Champions:
  • Dr. Jeffrey DeCarlo (MassDOT Aeronautics)
  • Chester Osborne (MassDOT Highway)
• Project Period: Dec 2020- May 2022
OUTLINE

- Introduction
- Analysis of incidents in Massachusetts
- Review of typical UAS types
- Potential application scenarios of UAS
- Pilot flight – tabletop simulation
- UAS network for transportation incident response
- Recommendations
INTRODUCTION

- Objectives: to address three questions below
  
  - Question 1: Which types of highway incidents are most suitable for using UAS?
  
  - Question 2: What are the key UAS operational parameters for successful highway emergency response applications?
  
  - Question 3: How can UAS be effectively integrated into highway emergency response practices?
MASSACHUSETTS INCIDENTS 2013-2019

Filtering Criteria for “targeted incidents”

- Events type:
  - Fire: 10.05%
  - Environmental/Hazmat: 1.45%
  - Roadway/Traffic: 88.5%
- Severity level: 2+
- Time Duration: 30mins-300mins
- Year Duration: 2013-2019
- Records after filtering: 8650
Analysis on the trends (annual, seasonal, day of the week, time of day)

- Traffic incidents dominate (1094 traffic/year vs. 124 fire/year vs. 18 ENVN-HazMat/year).
- Annual trend: increase and then stabilize (or slightly decrease).
- Seasonal trend:
  - Fire: slightly higher in the summer & **winter** (pattern varies across year)
  - ENVN: slightly higher in the fall and summer (pattern varies across year)
  - Traffic: higher in **winter**.
  
  **High incident frequency in winter.**

- Day of the week: higher on **weekdays** than weekends.
- Time of the day: slightly higher in the afternoon than morning; low in the evening.
REVIEW OF TYPICAL DRONES

- Focused on drone-in-a-box and its counterparts.
  - Drone-in-a-box
  - Drone-in-a-box with fixed wings
  - Rotary drones
  - Fixed-wing drones
  - Tethered drones

- Focused on operational features (e.g., takeoff/landing mode, flight speed, range, battery life, sensor compatibility)
REVIEW OF TYPICAL DRONES

Drone-in-a-box

American Robotics
Sensors equipped on drones

- HD Cameras
- LIDAR
- Infrared (thermal)
# UAS TECHNICAL MATRIX

<table>
<thead>
<tr>
<th>Features</th>
<th>Drone-in-a-box</th>
<th>Drone-in-a-box with fixed wing</th>
<th>Rotary</th>
<th>Fixed wing</th>
<th>Tethered Drone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Takeoff/landing</td>
<td>Autonomous</td>
<td>Autonomous</td>
<td>Pilot needed</td>
<td>Autonomous</td>
<td>Autonomous</td>
</tr>
<tr>
<td>Ranges</td>
<td>1.5-13 miles</td>
<td>*Network dependent</td>
<td>1-12 miles</td>
<td>1-100 miles</td>
<td>6 miles / Not provided</td>
</tr>
<tr>
<td>Max speed</td>
<td>30-40 mph</td>
<td>60 mph</td>
<td>35-50 mph</td>
<td>45-90 mph</td>
<td>Not provided</td>
</tr>
<tr>
<td>Flight time</td>
<td>40-50 min</td>
<td>50 min</td>
<td>20-35 min</td>
<td>45 min - 4 h</td>
<td>24 h</td>
</tr>
<tr>
<td>Power charging</td>
<td>battery swap / 30-40 min charge time</td>
<td>Internal Charging</td>
<td>Charging cable and/or battery swap</td>
<td>Not listed</td>
<td>Chargeable during tethered state</td>
</tr>
<tr>
<td>Payload</td>
<td>usually adaptable and interchangeable</td>
<td>Not Provided</td>
<td>about 1 kg</td>
<td>0.7-4.5kg</td>
<td>Not Provided</td>
</tr>
<tr>
<td>Sensors</td>
<td>EO/IR</td>
<td>EO</td>
<td>EO, EO/IR</td>
<td>EO/IR</td>
<td>EO/IR</td>
</tr>
<tr>
<td>Takeoff time</td>
<td>5 min</td>
<td>5 min</td>
<td>10 min</td>
<td>15 min</td>
<td>unknown</td>
</tr>
<tr>
<td>Service ceiling</td>
<td>400' AGL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## APPLICATION SCENARIOS FOR UAS

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Features</th>
<th>Drone Task</th>
<th>Current Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong> Recurring bottlenecks, incident hotspots, scheduled events</td>
<td>Fixed location, recurring</td>
<td>• Regular surveillance to monitor safety and traffic conditions</td>
<td>• CCTV cameras (if exist)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Short mission time (&lt;1h)</td>
<td>• Camera on a pole - needs installation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CCTV cameras (if exist)</td>
<td>• Probe data - not very accurate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Camera on a pole - needs installation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Probe data - not very accurate.</td>
<td></td>
</tr>
<tr>
<td><strong>2</strong> Non-recurring incidents (e.g., fire/hazmat/injury/extreme weather)</td>
<td>Uncertain location; could be risky for personnel</td>
<td>• Preliminary incident assessment</td>
<td>• CCTV cameras (if exist)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Monitor incident for safety</td>
<td>• Rely on human experts on scene to estimate incident severity and clearance time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Record incident for reconstruction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Estimate clearance time</td>
<td></td>
</tr>
<tr>
<td><strong>3</strong> Incidents affecting an extensive area (e.g., flooded roads)</td>
<td>Involve extensive areas</td>
<td>• Damage assessment of incidents</td>
<td>• Satellite Image – resolution may not be sufficient.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## APPLICATION SCENARIOS FOR UAS

- Potentials of UAS for different scenarios
  - Each type of UAS has its pros and cons.
  - Different scenarios favor different types of UAS.

<table>
<thead>
<tr>
<th>Scenario Number</th>
<th>Scenarios</th>
<th>Drone in-a-box/drone-in-a-box-on-truck</th>
<th>Drone in-a-box with fixed wings</th>
<th>Rotary Drone</th>
<th>Tethered Drone</th>
<th>Fixed-wing Drone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Recurring bottleneck, incident hotspot, scheduled events</td>
<td>****</td>
<td>***</td>
<td>****</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>2</td>
<td>Non-recurring incidents (e.g., fire/hazmat/injury/extreme weather)</td>
<td>****</td>
<td>***</td>
<td>***</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>3</td>
<td>Incidents affecting an extensive area (e.g., flooded roads)</td>
<td>*</td>
<td>**</td>
<td>*</td>
<td>*</td>
<td>****</td>
</tr>
</tbody>
</table>
TABLETOP SIMULATIONS

Objectives

➢ To see how the current systems respond to an incident and how a UAS could help with the response of an incident.
➢ To see how to incorporate UAS into the current incident response system.

Procedure

➢ Identified a real (historic) incident for the simulation
➢ Analyzed how the current system responded to the incident
➢ Deployed a drone to collect data for the incident site
➢ Evaluated benefits of drones via tabletop simulation

Participants

➢ MassDOT Aeronautics Division
➢ MassDOT Highway Division
TABLETOP SIMULATIONS

Setup

A multi-day L2 incident caused by a truck striking bridge overpass on I-93.

Images from CCTV camera @ 5pm, 7/19/2021
TABLETOP SIMULATIONS

- Analysis of the existing surveillance system
  - Three systems have provided satisfying traveler information related to this incident.
    - CCTV cameras: incident images
    - INRIX data: traffic delay
    - StreetLight data: changes of trips

INRIX data detected slowdown
TABLETOP SIMULATIONS

Drone flight

- A drone was deployed to the incident site to collect data.
- Data provided good views of bridge/roads and extensive views of traffic

A view of the bridge

View of I-93 SB, looking north

A view of the traffic further away from the bridge

View of I-93 SB, looking south and feeder routes
Potential benefits if UAS is available

- A drone could arrive at the scene 15-20min after a request.
- A drone could provide data to:
  - Help with inspection of the damaged bridge/road before inspection crew enter, improving personnel safety and shortening inspection time.
  - Provide detailed and timely images for the public and the media.
  - Help with traffic management (e.g., more active detour and secondary crash assessment).
Remarks from tabletop discussions

- Per HOC’s main responsibilities (e.g., providing traveler information), the three current systems meet the needs.
- For road segments not covered by CCTV cameras, UAS could be useful, particularly for incidents with severity Level 3+.
- 57% of Level 2+ incidents are not covered by current CCTV cameras.
- UAS have some appealing advantages (e.g., mobile, easy to set-up and maintain, can carry on different sensors to detect HAZMAT or oil spill, and can work in nighttime).
- For extensive deployment of UAS, further research on cost-effectiveness is needed.
Remarks from tabletop discussions

- Per HOC’s main responsibilities (e.g., providing traveler information), the three current systems meet the needs.
- For road segments not covered by CCTV cameras, UAS could be useful, particularly for incidents with severity Level 3+.
- 57% of Level 2+ incidents are not covered by current CCTV cameras.

What if UAS can be used to cover these?
UAS NETWORK

- Needs: 57% incidents are not covered by CCTV cameras.
UAS NETWORK

- Needs: 57% incidents are not covered by CCTV cameras.
- A UAS network can complement current surveillance and provide additional data
  - Set-up: a UAS station can cover a radius of 5 miles.
  - 4 super stations can cover 25% and 10 key stations can cover another 25%.

CCTV Coverage

A UAS Network for Incident Response

4 super stations: 25%
10 key stations: 24%

- not covered by CCTV (4543 incidents, 56.9%)
- covered by CCTV (3441 incidents, 43.1%)

Super stations: 2+ incidents/mo
Key stations: 1-2 incidents/mo
RECOMMENDATIONS FROM STAKEHOLDERS

❑ Interview with three state agencies

➢ Massachusetts Emergency Management Agency (MEMA); The Office of Security and Management; MSP - the Incident Management Assistance Team and specifically the Unmanned Aerial Section.

❑ Feedback from agencies on future development of UAS

 a) Have UAS that can be rapidly deployed from fixed locations and can operate BVLOS to rapidly get sensory and image data from incidents.

 b) Reach out to local agencies and communities to demonstrate the UAS capabilities and make them aware of such resources. Emergency managers of towns would be the priority agencies for such outreach.

 c) MassDOT Aeronautics Division serve as the central point of UAS operations, coordinate the drone purchases and utilization across different entities, help to make the best use of UAS, and provide the service to the agencies needed.
Feedback from agencies on future development of UAS (Cont.)

d. MassDOT enhance the Air Operations Plan: (1) to add a specific drone network to specify the drone operations; (2) to enhance the drone inventory (e.g., a complete and real-time list of the capabilities of the drones, locations of the drones/pilots); and (3) to have an alert layer that can timely alert all the relevant stakeholders about the incidents.

e. Make better use of drones (e.g., pre-event imaging for damage assessment and restoration).

f. Equip drones with proper sensors and software to convert the data into useful information to inform decision making.

g. Consider collaborating with local entities and the private sectors to utilize their drones and/or data they have collected. Consider using pre-qualified private drone operators as a layer of redundancy in emergency response.
INTEGRATING UAS FOR HIGHWAY EMERGENCY RESPONSE

Short-term recommendations

1) MassDOT establish a **small-scale UAS network** (super stations + key stations if possible) to complement current surveillance systems.

2) MassDOT build a few **mobile UAS platforms** (e.g., placing drone-in-a-box on a truck) to serve the on-demand needs (e.g., incidents on roads without CCTV).

3) Reach out to **local communities** to demonstrate UAS capabilities and make them aware of the Air Operations Plan.

4) MassDOT **enhance the Air Operations Plan**: (1) to add a specific drone network to specify the drone operations; (2) to enhance the drone inventory and (3) to have an alert layer that can timely alert all the relevant stakeholders.

5) MassDOT Aeronautics Division further **expand the collaboration** with other state agencies to make better use of drones (e.g., with MEMA for incident assessment and with MBTA for derailment incidents and rail inspection).

6) MassDOT expand the capabilities of the UAS by looking into software and algorithms that can convert the data into useful information to inform decision making.
INTEGRATING UAS FOR HIGHWAY EMERGENCY RESPONSE

Long-term recommendations

1) MassDOT evaluate the cost-effectiveness of building an extensive UAS network to cover the entire state (e.g., cost-effectiveness of UAS to replace CCTV cameras).

2) MassDOT evaluate the effectiveness and feasibility of collaborating with local entities and the private sectors to utilize their drones and/or data they have collected. Particularly, the relevant privacy, liability and security issues should be investigated.

3) MassDOT evaluate the option of incorporating the pre-qualified private drone operators (e.g., contractors, hobbyists) into the Air Operations plan as a layer of redundancy for emergency response.
ACKNOWLEDGEMENT

- Funding support: MassDOT
- Project champions
  - Dr. Jeffrey DeCarlo (MassDOT Aeronautics)
  - Chester Osborne (MassDOT Highway)
- UAS team at MassDOT Aeronautics Division
- Stakeholders interviewed
  - Massachusetts Emergency Management Agency (MEMA)
  - The Office of Security and Management
  - MSP - the Incident Management Assistance Team and specifically the Unmanned Aerial Section
THANK YOU!
QUESTIONS?