Autonomous Aerial Assistance for Search and Rescue

Team F

Team Rescue Rangers

Juncheng Zhang
Karthik Ramachandran
Sumit Saxena
Xiaoyang Liu

Sponsor:

Near Earth Autonomy

Project Description

Motivation

Most of the existing approaches to SAR(Search and Rescue) using aerial vehicles currently rely heavily on teleoperated drones with minimal autonomy, which increases the risk for the rescue team and the cost of SAR operations.

Objective

Our aim is to develop an autonomous aerial system to provide assistance in search and rescue operations. Collecting a variety of perceptual data using multiple sensors, we aim to reliably detect and locate a lost human being in a large area, and conduct rescue operation by accurately dropping a care package at the human location.

http://www.carson.org/government/

http://store.dji.com/product/

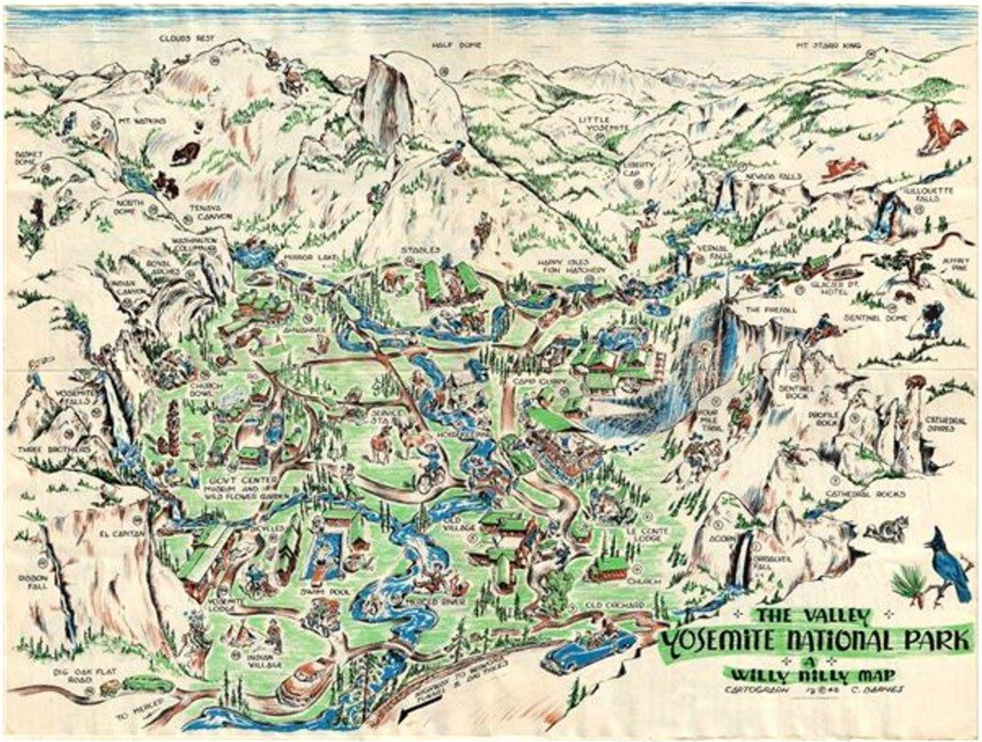
Use Case (Context)

Yosemite National Park (2012)

- Land Mass: 748,036 acres
- Designated Wilderness: 94.45%
- 53,679 overnight hikers
- 800 miles of trail
- 216 Search and Rescue operations

Yosemite Search and Rescue (YOSAR) team

- Well-equipped: 90% of big-wall rescues (~24) require a helicopter
- Rescuers: solid alpine skills required
  - Salary $ 23-34 per hour



http://www.yosemite.ca.us/library/maps/yosemite_valley_map_1946_barnes.jpg

Use Case

Jamie is the Team Coordinator at YOSAR

Use Case

... buys RescueRangers drone

Use Case

1. Aha! Easier than assembling furniture these days
2. Assembles the hardware in 3 hours
3. Installs the mandatory software suite on his laptop in half an hour
4. Goes through the basic tutorials in 2 hours

All done!

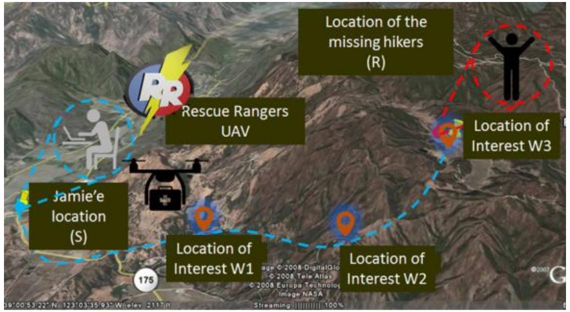
http://store.dji.com/product/

Use Case

5. Emergency SAR SOS at 6 in the morning: 2 hikers missing
6. Sends out alarm to assemble the team
7. Half an hour enough to test the drone?
8. Fires up his laptop
9. Switches the drone on
10. Selects “Search and Map” on the software
11. Inputs the likely locations to search

Use Case

12. Drone takes off, he resumes his preparation
13. 20 minutes later, when the team is almost prepared, the drone comes back
14. Connects the drone to the laptop with a USB cable: data transfer in 5 minutes.
15. In another 3 minutes,the software pops up with some relevant pictures found and their locations on the map. He immediately communicates the location to his team.
16. He attaches a first aid package to the drone and switches ON its power.
17. He selects the option “Drop package” on the software and specifies the chosen location



Humans identified at LOI W3

Use Case

18. The drone takes off and comes back in 10 minutes
19. After another 30 minutes, the team brings the two hikers via a helicopter to the base

! MISSION ACCOMPLISHED !

Functional Requirements

The system shall

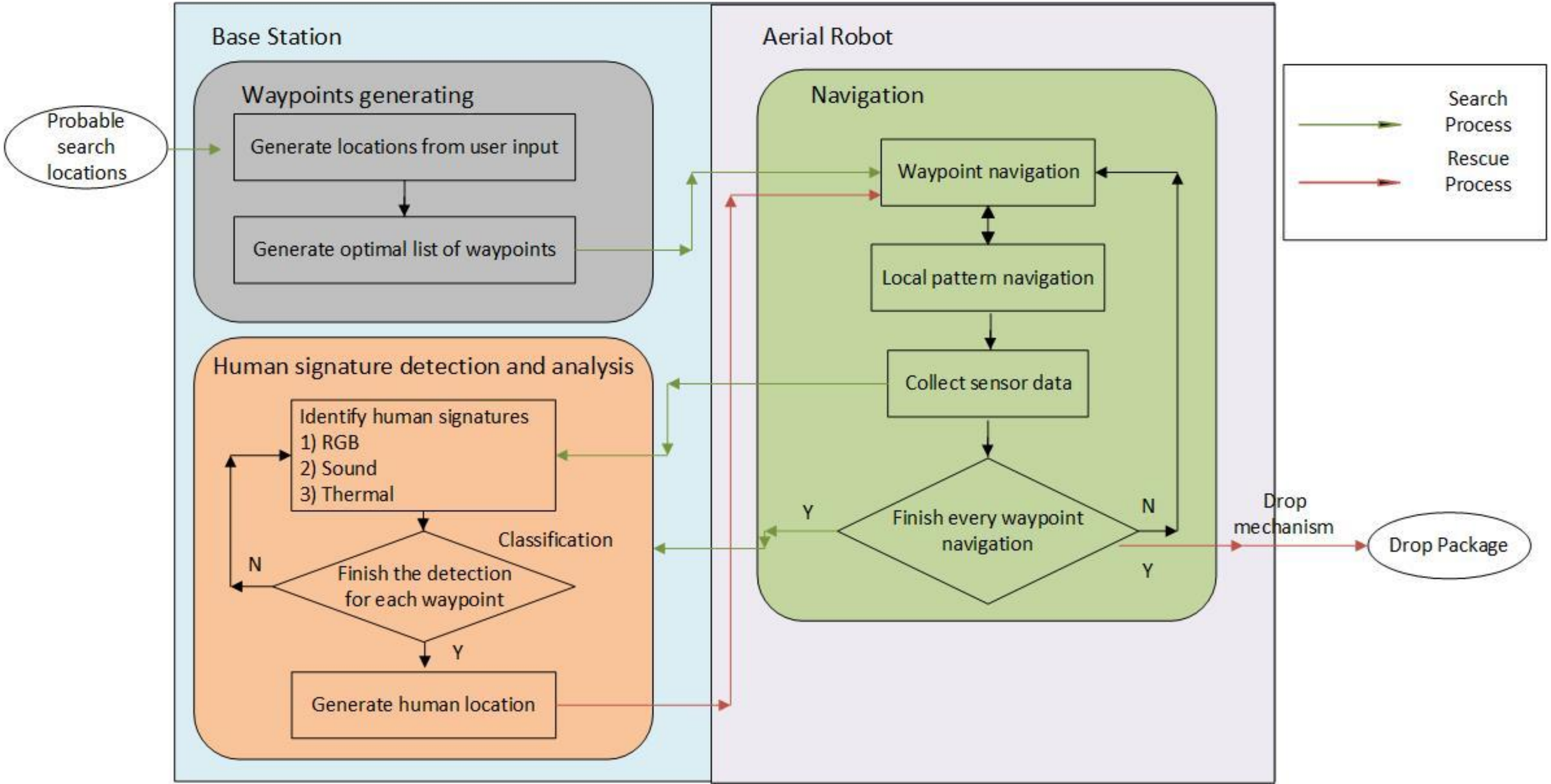
1. Autonomously navigate through a set of provided locations of interest
2. Explore the surroundings around each location of interest
3. Collect perceptual data while navigating
4. Process the data to identify human signatures
5. Analyze the identified signatures to estimate human location
6. Navigate to the rescue location carrying the rescue package
7. Drop the rescue package
8. Complete the search within limited time

Performance Requirements

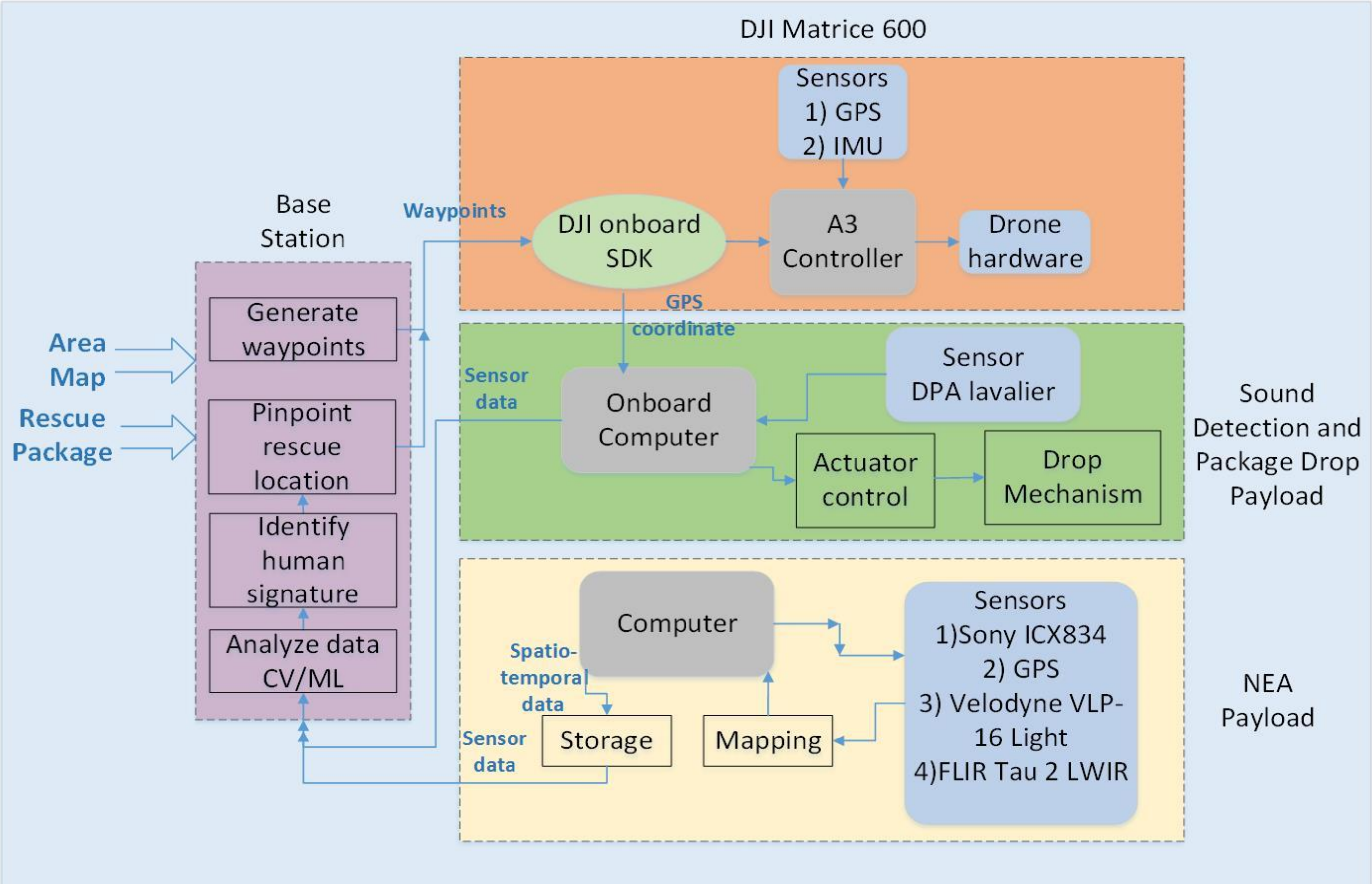
The system will

1. Accurately reach the locations of interest with a tolerance of +-5m
2. Attain up to 80% coverage of the desired local search areas around each location of interest
3. Collect perceptual data limited to 3 types - IR radiation, visual imagery, and sound
4. Identify at least 67% of the locations with human signatures
5. Estimate potential human signature location with +-5m tolerance
6. Carry a rescue package weighing 100g
7. Drop the package at the rescue location with a tolerance of +-5m
8. Complete one iteration of search in an un-occluded operating area of 200m x 200m in <25 minutes

Functional Architecture



Cyberphysical Architecture



Autonomous Flight Subsystem (1/3)

Matrice 100 - Dev

- Test navigation strategies and waypoint following
- Data collection using individual sensors

Matrice 600 - Prod

- Collect sensor data with NEA payload
- Mount sound sensor & Payload Drop mechanism

DJI Matrice 100

DJI Matrice 600

Autonomous Flight Subsystem (2/3)

Generate Locations of Interest

- UI/interface for operator to specify locations of interest.
- Ability to identify potential locations of interest based on terrain/last-known location.

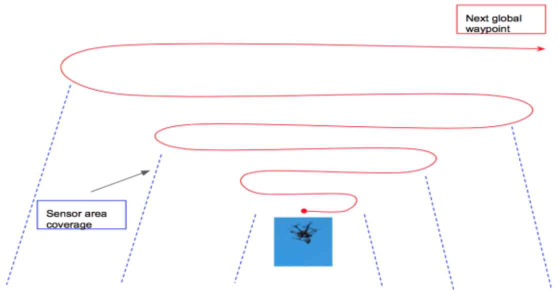
Generate Waypoints for Navigation

- Generate intermediate waypoints for navigation between the locations of interest
- Define strategies for planning search path around locations of interest
- Generate waypoints around each location of interest to define the local search path

Current System Status—Autonomous Flight System

Defining the navigation strategy:

- Terrain considerations
- How can we optimize the search
- Trade-off time, resolution and coverage
- Optimal altitude / speed



First pass at navigation strategy design:

- Reach LOI at altitude of 15 m, speed ~5 m/s
- Spiral up to an altitude of 30 m, complete one circle of radius 6 m, speed ~2m/s
- Move to the next location of interest while reducing the altitude to 15 m

Theoretically, it can achieve:

- >98% overlap between two frames for both thermal and RGB cameras - ***good stitching***
- ***Well detailed imagery***
  - Ground sampling distance: 0.5 cm/pixel for RGB, 2.7 cm/pixel for thermal

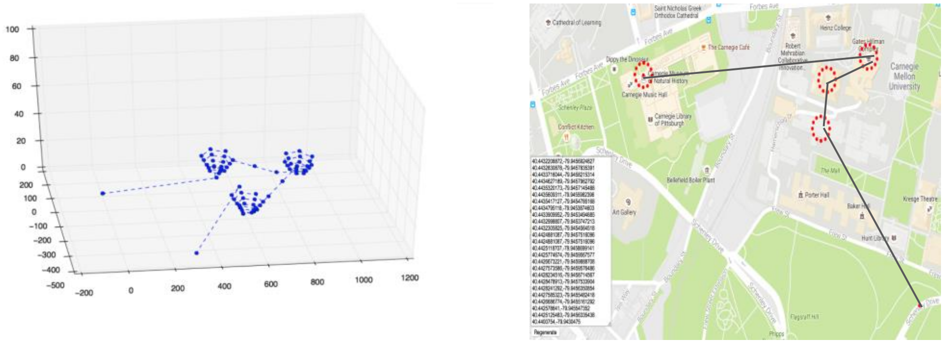
Current System Status—Autonomous Flight System

Generate Location of Interests

- Implemented UI/interface for operator to specify locations of interest and convert to GPS coordinates

Generate Waypoints

- Implemented software to generate intermediate waypoints



Intermediate Waypoint Generation

Sensing Subsystem

Requirements :

- RGB Camera:
  - Cover large area in one image
  - Capture moving objects
- Thermal Camera
  - Differentiate human IR radiations from surroundings
  - Suitable for aerial operation
  - Cover large area in one image
- Microphone
  - Prop noise
  - Capture uni-directional sound

Payload Provided By NEA

Cardioid Unidirectional microphone

Current System Status—Sensing Subsystem

RGB Camera：GRASSHOPPER3 12.0 MP

- Readout Method: Global shutter
- Resolution: 4240 x 2824(12MP)
- 7 Hz frame rate
- Sensor Format: 1"
- Lens Type: TC2016-21MP
- Focal Length(mm): 20
- Field of View: 36.1° x 27.2°

GRASSHOPPER3 12.0 MP COLOR USB3 VISION (SONY ICX834)

Current System Status—Sensing Subsystem

Thermal Imaging camera: FLIR Tau 2 LWIR

LWIR (temp range: -70º C to 250º C)

Resolution: 640 x 512

29.97 Hz frame rate

19 mm lens

Field of View: 32º x 26º

Uncooled VOx Microbolometer

Spectral band: 7.5 - 13.5 μm

FLIR Tau 2 LWIR

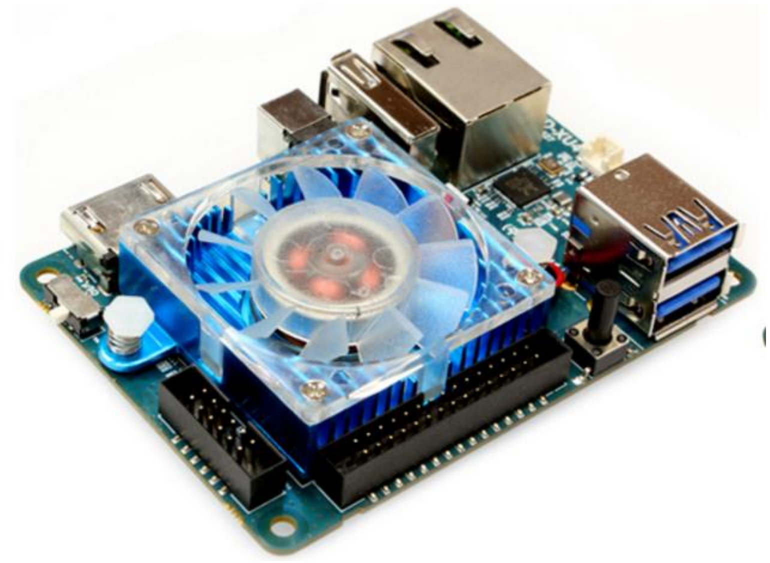
Subsystem—SDPD Payload (1/2)

Human Sound Detection

- Collect sound sensor data
- Process sound sensor data
- Store sound sensor data

Package Drop

- Collect GPS signal from DJI SDK
- Control the actuation of package drop mechanism



ODROID-XU4 based core controlling system

Subsystem—SDPD Payload (2/2)

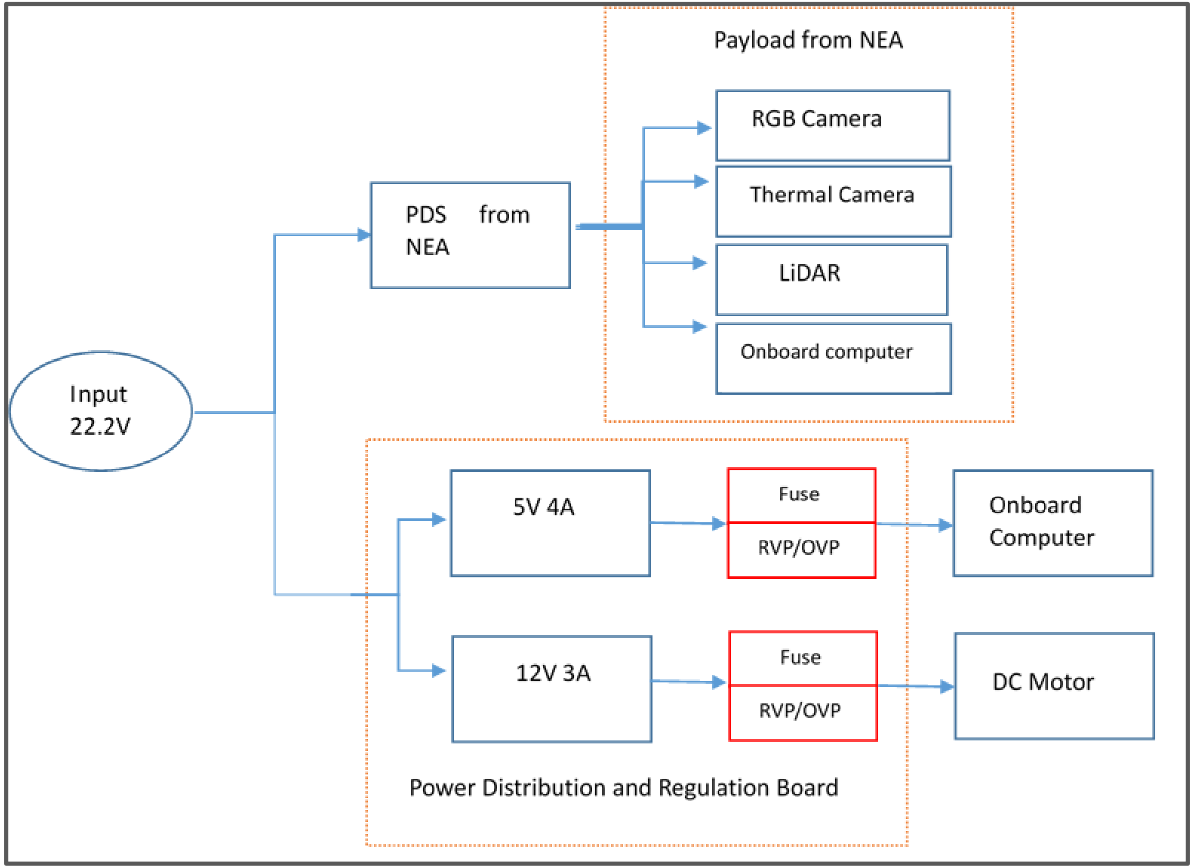
Package drop mechanism

- To carry a 100g package
- Easy to attach the package
- Firm grip to hold the package during the flight
- Self-locking ability after releasing the package
- Easy release without damaging the package

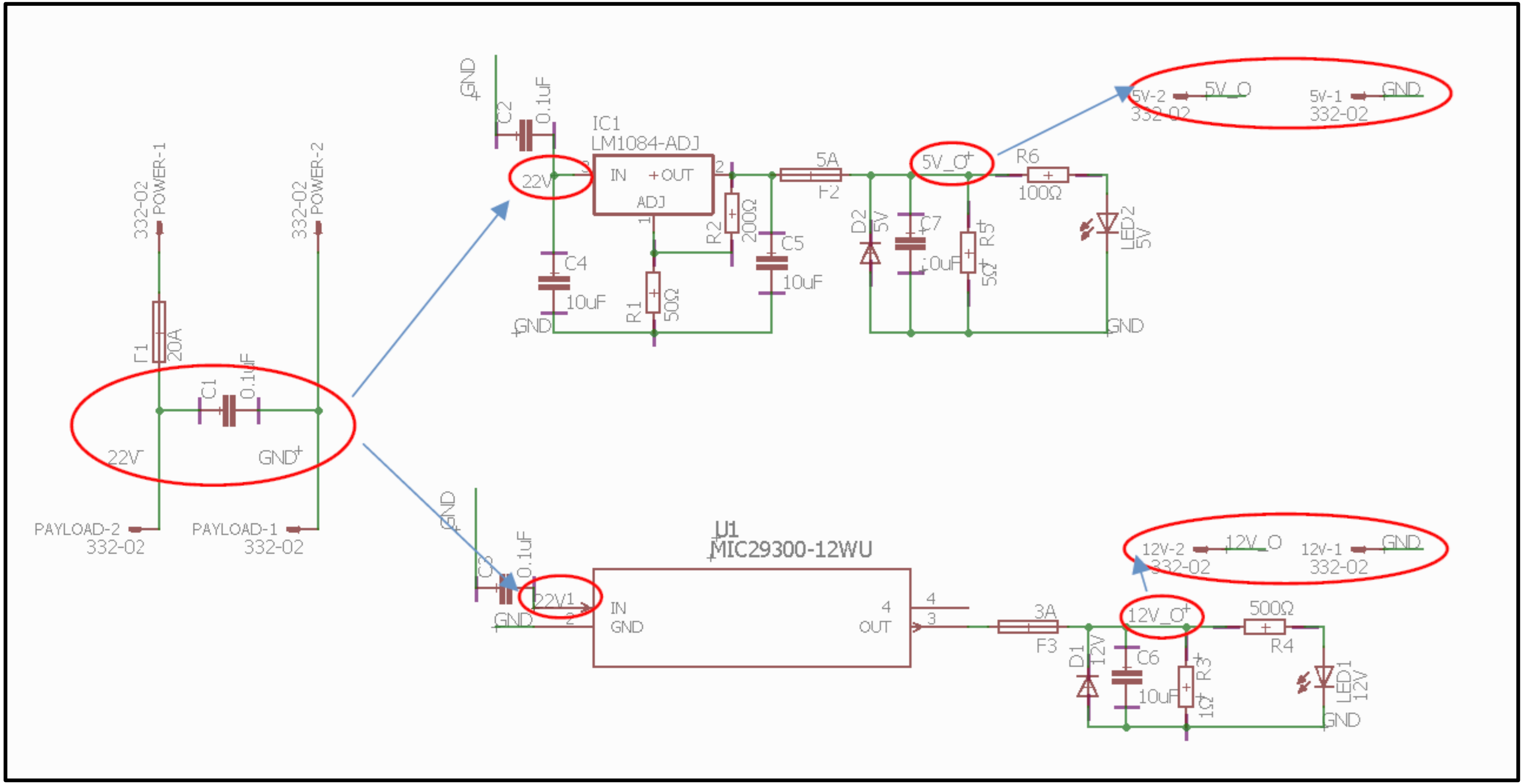
Going over design ideas

This product can carry 2 lbs and is fairly simple

Current System Status—SDPD Payload



Current System Status—SDPD Payload



Subsystem—Signature Detection and Analysis

Identify human signatures
- Visual signature detection
- Thermal signature detection
- Human sound detection

Generate rescue locations
- Sensor fusion
- Probabilistic analysis

RGB image+Thermal Image

Current System Status—Signature Detection

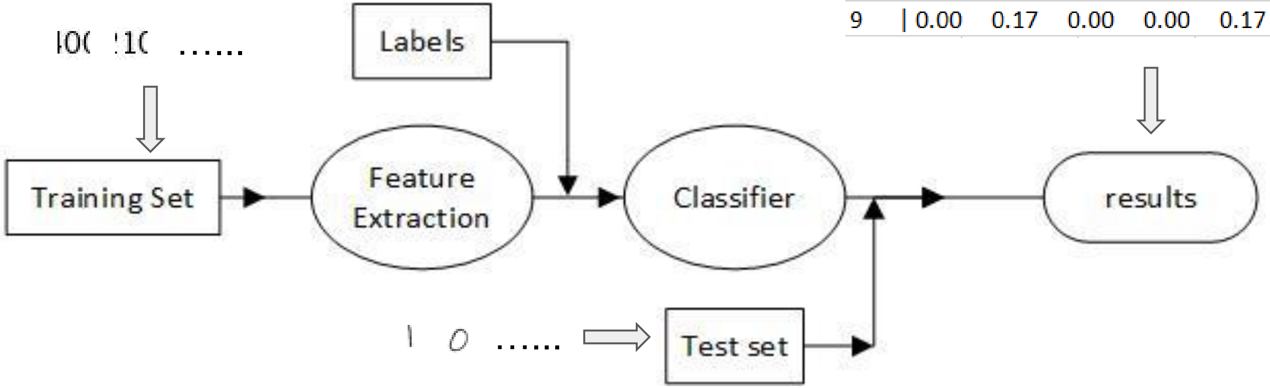
Human feature extraction

- Histogram Oriented Gradient

Classification

- Support Vector Machine

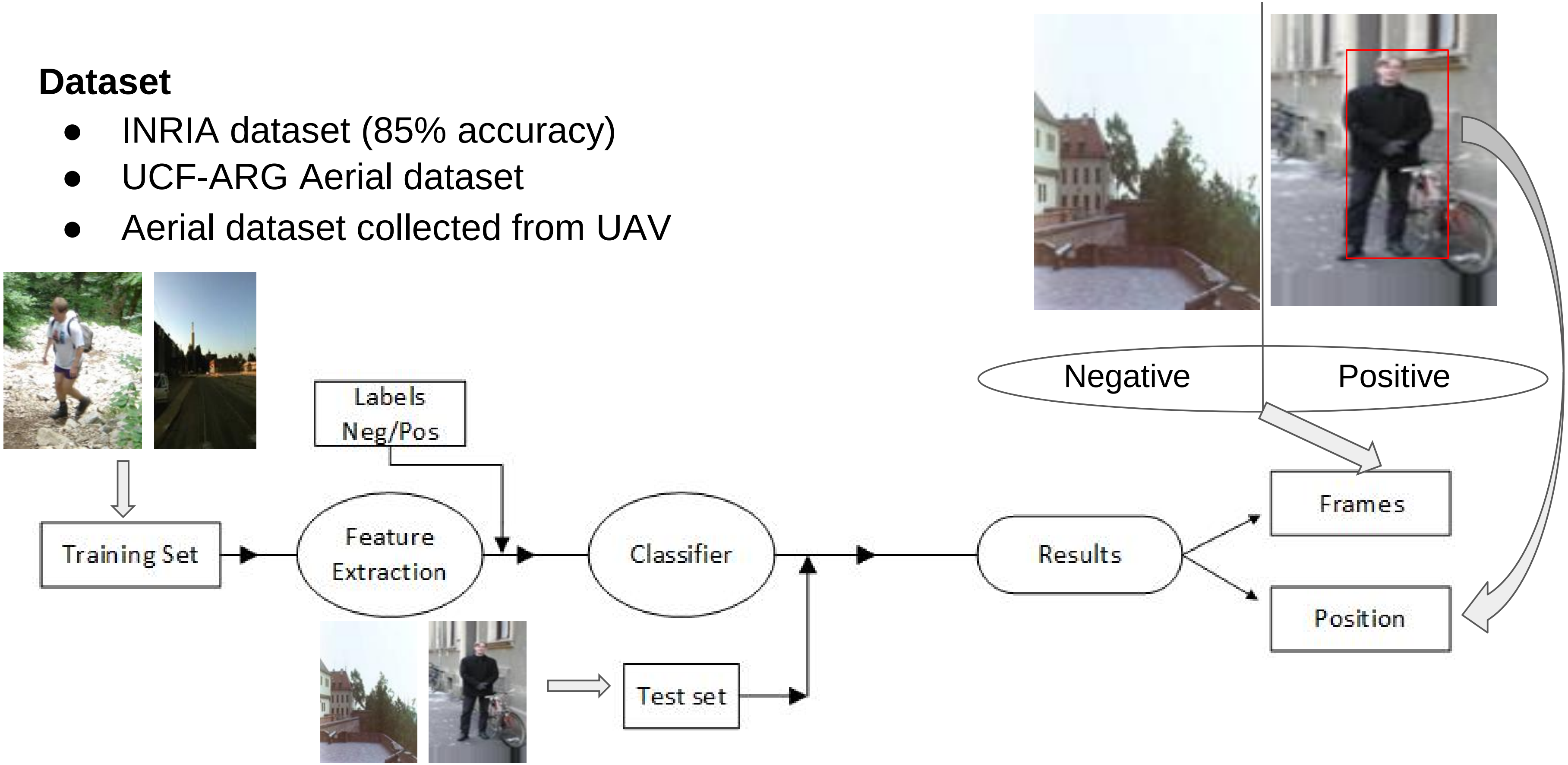
Digit	0	1	2	3	4	5	6	7	8	9
0	0.17	0.00	0.08	0.00	0.00	0.00	0.75	0.00	0.00	0.00
1	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
2	0.08	0.08	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.08
3	0.00	0.00	0.00	0.67	0.00	0.00	0.17	0.08	0.00	0.08
4	0.08	0.00	0.00	0.00	0.83	0.00	0.08	0.00	0.00	0.00
5	0.00	0.00	0.00	0.08	0.00	0.50	0.42	0.00	0.00	0.00
6	0.00	0.08	0.00	0.00	0.00	0.00	0.83	0.08	0.00	0.00
7	0.08	0.08	0.00	0.00	0.08	0.00	0.00	0.67	0.00	0.08
8	0.00	0.00	0.00	0.08	0.08	0.00	0.08	0.17	0.50	0.08
9	0.00	0.17	0.00	0.00	0.17	0.25	0.08	0.00	0.00	0.33



Current System Status—Signature Detection (RGB)

Dataset

- INRIA dataset (85% accuracy)
- UCF-ARG Aerial dataset
- Aerial dataset collected from UAV



Current System Status—Signature Detection (Thermal)

Challenges:

- Significantly low resolution images
- No color or texture information
- Little work exists in literature

"People Detection and Tracking from Aerial Thermal Views" - useful paper[1]

Proposed approach (3-Fold):

Background subtraction using ViBe method: to generate foreground candidate regions

Try out different detectors: HOG /LatentSVM trained on INRIA dataset

Tracker based on a particle filter approach

Evaluation datasets made publically available by the authors

[1] *by Jan Portmann, Simon Lynen, Margarita Chli and Roland Siegwart, Autonomous Systems Lab, ETH Zurich*

Work Breakdown Structure (High-level)

Rescue Rangers
Search and Rescue Assistance System

1. Autonomous Flight System

1.1. Set up Matrice 100

1.2. Set up Matrice 600

1.3. Implement autonomous waypoint navigation

1.4. Implement Local Search strategy

2. Sensing

2.1. Finalize sensors

2.2. Test individual sensor performance

2.3. Software: process NEA payload data

2.4. Software: process specific sensor data

2.5. Design sound sensor mounting

3. Rescue assembly system

3.1. Mechanical structure

3.2. Actuation system

3.3. Integrate mechanical structure & actuation system

4. Signature detection and analysis

4.1. Finalize human signatures to detect

4.2. Basic visual signature detection

4.3. Visual+Thermal signature detection

4.4. Human sound detection

4.5. Optimize/scale Performance

5. System Integration and Testing

5.1. Test flight

5.2. Build SDPD payload; integrate

5.3. Data collection pipeline: UAV to base

5.4. Test end to end system

6. Project Planning

6.1. Initial Planning

6.2. Project Continuity

6.3. Project Delivery

6.4. Risk Management

Work Breakdown Structure (Detailed)

1. Autonomous Flight System

1.1. Set up Matrice 100
- *1.1.1. Assembly*
- *1.1.2. Test simulator*
- *1.1.3. First teleoperated flight*
- *1.1.4. Test basic autonomous flight*

1.2. Set up Matrice 600
- *1.2.1. Assembly*
- *1.2.1. Test simulator*

1.3. Implement autonomous waypoint navigation
- *1.3.1. Software for waypoint navigation*
- *1.3.2. Test on Simulator*
- *1.3.3. Test on external site*
- *1.3.4. Software to autonomously determine likely search locations*
- *1.3.5. Revise software for waypoint navigation*
- *1.3.6. Test on Simulator*
- *1.3.7. Test on external site*

1.4. Implement Local Search strategy
- *1.4.1. Design basic strategy*
- *1.4.2. Software to implement basic strategy*
- *1.4.3. Test on simulator*
- *1.4.4. Test on external site*
- *1.4.5. Software to plan local search with high quality sensor coverage*
- *1.4.6. Software to plan rescue operation*
- *1.4.7. Test on simulator*
- *1.4.8. Test on external site*

2. Sensing

2.1. Finalize sensors
- *2.1.1. RGB camera*
- *2.1.2. Thermal camera*
- *2.1.3. Sound sensor*

2.2. Test individual sensor performance
- *2.2.1. RGB camera*
- *2.2.2. Thermal camera*
- *2.2.3. Sound sensor*

2.3. Software: process NEA payload data

2.4. Software: process specific sensor data
- *2.4.1. RGB camera*
- *2.4.2. Thermal camera*
- *2.4.3. Sound sensor*

2.5. Design sound sensor mounting

3. Rescue assembly system

3.1. Mechanical structure
- *3.1.1. Design*
- *3.1.2. Prototype*
- *3.1.3. Fabricate*

3.2. Actuation system
- *3.2.1. Finalize actuation method*
- *3.2.2. Finalize actuators*
- *3.2.3. Finalize electronic components needed*
- *3.2.4. Develop actuation mechanism*
- *3.2.4. Interface actuator with SDPD computer*
- *3.2.5. Test drop mechanism*

3.3. Integrate mechanical structure & actuation system

4. Signature detection and analysis

4.1. Finalize human signatures to detect

4.2. Basic visual signature detection
- *4.2.1. Literature study/Datasets*
- *4.2.2. Implementation (SVR)*
- *4.2.3. Debugging/Improvements (FVR)*

4.3. Visual+Thermal signature detection
- *4.3.1. Literature study/Dataset (SVR)*
- *4.3.2. Implementation (SVR)*

4.4. Human sound detection
- *4.4.1. Literature study/Dataset (SVR)*
- *4.4.2. Implementation (SVR)*

4.5. Optimize/scale Performance

5. System Integration and Testing

5.1. Test flight
- *5.1.1. Waypoint navigation; NEA payload*
- *5.1.2. Waypoint navigation + basic hover; no payload*

5.2. Build SDPD payload; integrate
- *5.2.1. Schematic for PDS*
- *5.2.2. Layout for PDS*
- *5.2.3. PCB Fabrication for PDS*
- *5.2.4. Interface sound sensor with drone and onboard computer*
- *5.2.5. Form SDPD payload; integrate into the system*

5.3. Data collection pipeline: UAV to base

5.4. Test end to end system
- *5.4.1. Navigation + search; NEA payload*
- *5.4.2. Whole operation*

6. Project Planning

6.1. Initial Planning
- *6.1.1. Define project scope/requirements*
- *6.1.2. Conduct trade studies*
- *6.1.3. Develop functional and cyber-physical architectures*

6.2. Project Continuity
- *6.2.1. Develop and maintain project website*
- *6.2.2. Design Fall and Spring demo*
- *6.2.3. Procure RGB sensor*
- *6.2.4. Procure Thermal sensor*
- *6.2.5. Procure Sound sensor*
- *6.2.6. Procure Matrice 100*
- *6.2.7. Procure material for drop assembly*
- *6.2.8. Fall demo preparation*
- *6.2.9. Field Tests*
- *6.2.10. Spring demo preparation*

6.3. Project Delivery
- *6.3.1. Deliver Conceptual Design Review*
- *6.3.2. Deliver Preliminary Design Review*
- *6.3.3. Deliver Critical Design Review*
- *6.3.4. Fall Demo*
- *6.3.5. Spring Demo*

6.4. Risk Management
- *6.4.1. Risk analysis and mitigation plans*
- *6.4.2. Execute risk mitigation plans*

Fall 2016

Spring 2017

Both

Schedule

Plan	
Not finished	
Finished	

	Tasks	Sems	Hours	Oct,2016			Nov,2016				Break	Jan,2017			Feb,2017				Mar,2017				April,2017				
				10/17/2016	10/24/2016	10/31/2016	11/7/2016	11/14/2016	11/21/2016	11/28/2016		1/16/2017	1/23/2017	1/30/2017	2/6/2017	2/13/2017	2/20/2017	2/27/2017	3/6/2017	3/13/2017	3/20/2017	3/27/2017	4/3/2017	4/10/2017	4/17/2017	4/24/2017	5/1/2017
1	**Autonomous Flight System**		**117**																								
1.1	Matrice 100 setup	FV	17																								
1.2	Matrice 600 setup	FV	5																								
1.3	Implement autonomous waypoint navigation	Both	46																								
1.4	Implement Local Search strategy	SV	49																								
2	**Sensing**		**110**																								
2.1	Finalize sensors	Both	20																								
2.2	Test individual sensor performance	Both	18																								
2.3	Process NEA payload data	SV	16																								
2.4	Process specific sensor data	Both	48																								
2.5	Design sound sensor mounting	FV	8																								
3	**Rescue assembly system**		**70**																								
3.1	Design mechanical system	FV	16																								
3.2	Prototype mechanical system	FV	6																								
3.3	Procure mechanical/electronic components	FV	4																								
3.4	Fabricate mechanical system	SV	24																								
3.5	Develop electronics	SV	12																								
3.6	Integrate mechanical assembly + electronics	SV	8																								

Schedule

Plan	Not finished	Finished

	Tasks	Sems	Hours	Oct,2016			Nov,2016					Jan,2017			Feb,2017				Mar,2017				April,2017				
				10/17/2016	10/24/2016	10/31/2016	11/7/2016	11/14/2016	11/21/2016	11/28/2016	Break	1/16/2017	1/23/2017	1/30/2017	2/6/2017	2/13/2017	2/20/2017	2/27/2017	3/6/2017	3/13/2017	3/20/2017	3/27/2017	4/3/2017	4/10/2017	4/17/2017	4/24/2017	5/1/2017
4	**Signature detection and analysis**		**150**																								
4.1	Finalize human signatures to detect	FV	10																								
4.2	Develop basic visual signatures' detection algorithm	FV	60																								
4.3	Develop visual+thermal signatures' detection algorithm	Both	60																								
4.4	Performance optimizations/scaling (as per SVR)	SV	20																								
5	**System Integration and Testing**		**107**																								
5.1	Test flight: waypoint navigation; NEA payload	FV	10																								
5.2	Test flight: waypoint navigation + basic hover; no payload	FV	10																								
5.3	Build SDPD payload; integrate into the syatem	Both	51																								
5.4	Data collection pipeline from UAV to base	SV	6																								
5.5	Test end to end system: waypoint navigation + search; NEA	SV	10																								
5.6	Test end to end system for the whole operation	SV	20																								
6	**Project Planning**		**143**																								
6.1	Initial Planning	FV	30																								
6.2	Project Continuity	Both	56																								
6.3	Project Delivery	Both	40																								
6.4	Risk Management	Both	17																								

Schedule

Date	Milestone
10/27/2016	- Global waypoint navigation
11/08/2016	- Power distribution System for non-NEA payload
11/18/2016	- Build a rudimentary RGB based signature detection module
11/25/2016	- Test flight with NEA payload sensors
12/01/2016	- Fall Validation Experiment

Schedule

Date	Milestone
01/20/2017	- Software to detect likely search locations in the absence of operator
02/03/2017	- Software for planning localized navigation pattern to drop packet accurately
02/24/2017	- Integrate rescue drop assembly with electronics and onboard processor
03/17/2017	- Mount rescue system assembly on the drone
03/25/2017	- Test end to end system for search and rescue operation

Fall 2016 Test/Validation plan

Date	Test plans

11/10/2016
PR 3
	<u>Autonomous Flight System</u>
	- Test flight of Matrice 100
	    - Input: A set of GPS waypoints in an open area 10m X 10m
	    - Expected Output: Fly the waypoints within tolerance of 2m

11/22/2016
PR 4
	<u>Signature Detection</u>
	- Signature Detection using RGB data
	    - Input: A set of aerial images
	    - Expected Output: Detect humans in at least 60% of the images

12/01/2016 **PR 5**	<u>Rescue Payload</u> - Expected output: Demonstrate model of a rescue payload mechanism without any actuation

Spring 2017 Test/Validation plan

Date	**Test plans**

02/01/2017
PR 1
	Autonomous Flight System
	- Test flight of Matrice 100
	    - Input: Specify locations of interest on a UI map area 200m X 200m
	    - Expected Output:
	        - Generate GPS coordinates for locations of interest
	        - Generate intermediate waypoints for navigation
	        - Actual flight through waypoints within tolerance of 5m

03/01/2017
PR 2
	Sound and Rescue Payload
	- Rescue Payload Drop
	    - Expected Output
	        - Finalized design of actuation for payload drop mechanism
	- Sound sensor control
	    - Expected Output
	        - Finalized design for integrating sound sensor with Payload Mechanism Controls

Spring 2017 Test/Validation plan

Date	Test plans

03/01/2017
PR 2
	<u>Sensor</u>
	- Software to collect and process NEA payload data
	    - Input: Raw NEA payload data
	    - Expected Output: Processed NEA data for use by signature detection
	- Sound sensor
	    - Expected Output: Drone in hover mode at elevation of 15 feet with microphone mounted below and a sound sample on the ground with intermittent human voice. Detect portions of sound clip having human voice.

04/01/2017
PR 3
	<u>Signature Detection</u>
	- Implement Signature Detection using thermal and sound
	    - Input: Map from NEA payload data
	    - Expected Output: GPS coordinates of specific locations with signatures
	<u>Sound and Rescue Payload</u>
	- Fabrication of Payload Drop Assembly and mounting with drone
	    - Expected Output: Test drop functionality (using a first aid kit) actuated at a particular GPS location

Spring 2017 Test/Validation plan

Date	Test plans

04/30/2017
PR 4
	<u>Integration Tasks</u>
	- Test flight of Matrice 100 with NEA and Sound/Rescue payload
	    - Expected Output:
	        - Test conversion of likely search locations on a 200X200 map into GPS coordinates.
	        - Test waypoint generation for optimal path.
	        - Test waypoint navigation within tolerance as defined by SVE
	        - Test signature detection to ensure a single location having test subject is detected.
	        - Test rescue location navigation and package drop within tolerance of SVE

Fall Validation Experiment 2016

Test A: UAV waypoint navigation test

Objective:

To validate the autonomous flight control and waypoint navigation capability of the UAV

Test conditions:

Location	Open 50m x 50m area with GPS access and normal wind conditions
Equipment needed	UAV, Laptop, Nets for safety

Test Sequence:

Step	Description	Performance Measures
A.1.	Place UAV on the ground. Feed GPS locations as waypoints	
A.2.	UAV takes off and goes to the first GPS location and hovers there for 20 seconds	- Accuracy in reaching desired height (+-1m tolerance)
A.3.	UAV navigates from one waypoint to another	- Accuracy in reaching the waypoints (+-5m tolerance)
A.4.	UAV returns to the starting location	- Accuracy in reaching the starting location (+-5m tolerance)

Fall Validation Experiment 2016

Test B: Human detection algorithm test

Objective:
To validate the capability of the algorithm to detect human signatures in RGB images

Test conditions:

Location	Lab
Equipment needed	Software implementing the algorithm, images with relevant human signatures

Test Sequence:

Step	Description	Performance Measures
B.1.	Run the algorithm on the set of images	Ability to detect humans in at least 60% of the images

Fall Validation Experiment 2016

Test C: Package drop mechanism test

Objective:
To validate the working of the mechanism to be used for dropping the rescue package

Test conditions:

Location	Lab
Equipment needed	Prototype for the dropping mechanism

Test Sequence:

Step	Description	Performance Measures
C.1.	Package size and weight	- Should hold package upto a weight of 100g, and size of 10cmx10cm package
C.3.	Hold package while in motion	- Should hold package without failure when moved at x velocity
C.4.	Reliability of actuation mechanism	- Should release package 5 times in a sequence without failure

Spring Validation Experiment 2017

Test D: Full system test (1/3)

Objective:

To validate the system's ability to autonomously search for a human in a search and rescue scenario and also dispatch a rescue package

Test conditions:

Location	Open 200m x 200m area with GPS access and normal wind.
Equipment needed	UAV; Laptop; Rescue package; 3 Mannequins (filled with hot water, wearing red shirt and with a speaker) /other representations of human signatures

Spring Validation Experiment 2017

Test D: Full system test (2/3)

Test Sequence:

LOI = Location of Interest

Step	Description	Performance Measures
D.1.	Place UAV on the ground. Feed GPS locations for 8 LOIs	
D.2.	UAV takes off and reaches the desired altitude for navigation	- Accuracy in reaching desired height (+-1m tolerance)
D.3.	UAV flies to each of the 8 LOI and performs localized search	- Accuracy in reaching the LOI (+-5m tolerance)
D.5.	UAV flies back and lands near the starting point after covering all the waypoints	- Accuracy in reaching the LOIs (+-5m tolerance)
D.6.	Transfer data from the UAV to base station	- Ability to collect the three types of perceptual data with spatial-temporal information

Spring Validation Experiment 2017

Test D: Full system test (3/3)

Test Sequence (contd..):

LOI = Location of Interest

Step	Description	Performance Measures
D.7.	Identify human signatures from sensor data	- Ability to identify at least 67% of the total planted human signatures
D.8.	Based on the identified human signatures, select the best location for rescue	- Accuracy of the human signature location conveyed
D.9.	UAV flies to the selected rescue location	- Accuracy in reaching the rescue location(+-5m tolerance)
D.10.	UAV performs localized search to get as close as possible to the human	- Ability to reach the desired altitude and close to the human (mannequin in our case)
D.11.	UAV releases the rescue package	- Ability to release the package
D.12.	UAV flies back to the base station	- Accuracy in reaching the starting location (+-5m tolerance)

Budget

Part List 1 , Sponsor Provided

Description	Manufacturer	Model	Unit	Weight (g)	Cost
LWIR	FLIR	Tau 2	1	72	$7000
RGB Camera	Pointgrey	Grasshopper	1	520	$2,399
Lidar	Velodyne	VLP-16	1	590	$7,999
Flying platform	DJI	Matrice 600	1	9,600	$4,599

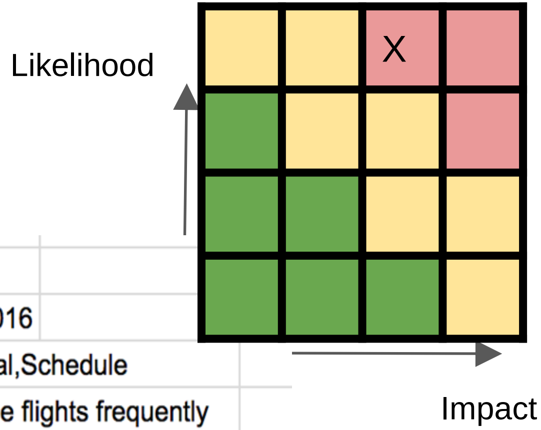
Part List 2, Not provided by Sponsor

Description	Manufacturer	Model	Unit	Weight (g)	Cost
Autonomous Flying System	DJI	Matrice 100	1	680	$3250
Microphone	Rode	NTG2	1	161	$250
Computer	Odroid	XU4	1	50	$87

Key points

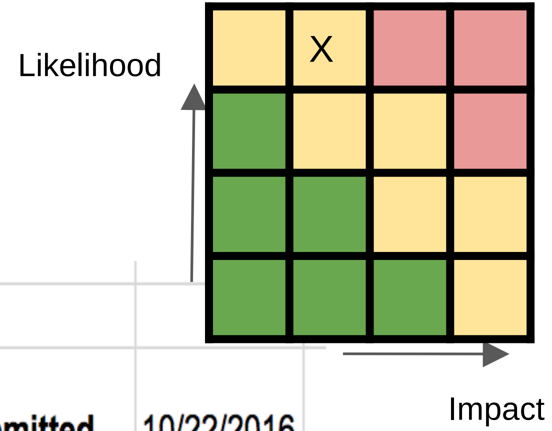
- Total Budget = $5000
- Major items
  - DJI Matrice 100
  - Rode NTG2 Condenser Shotgun Microphone
  - Odroid-XU4
- Percentage spent to date = 65%

Risks and Mitigation



RISK SUMMARY					
Title	Unavailability of drone for frequent testing		**Date Submitted**	10/19/2016	
Owner	Karthik/Sumit		**Risk Type**	Technical,Schedule	
Description	Sponsor requires drone to remain in their premise and may not be able to schedule flights frequently				
Consequence	Will impact ability to iterate quickly on various navigation strategies/sensing evaluation and rescue strategy				
RISK MITIGATION					
Action	**Date**	**Success criteria**		**Risk level**	
Order dev drone	10/25/2016	Ability to test and run navigation strategies iteratively		60	
Validate using sensor payload manually to generate data	11/10/2016	Ability to generate sensor data very similar to aerial flight		50	
Use data from flights scheduled for other projects	11/10/2016	Validate if data matches what we expect		40	
Device sensor mounting strategy for dev drone	11/20/2017	Ability to use rgb and thermal camera for sensing on dev drone		30	

Risks and Mitigation



RISK SUMMARY					
Title	Inability to achieve high accuracy in signature detection			**Date Submitted**	10/22/2016
Owner	Juncheng/Sumit			**Risk Type**	Technical
Description	Sensor data especially sound might be very noisy and could generate inaccurate results				
Consequence	Will impact accuracy with which system can detect signatures				
RISK MITIGATION					
Action	**Date**	**Success criteria**			**Risk level**
Evaluate design for suspended microphone sensor	1/20/2017	Ability to suspend microphone 10 feet below the drone and fly the drone safely			10

Thank you!