Team G: Searching while Modeling the Environment for Time-critical Rescues

Fall Test Plan

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Team Members

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1 Introduction

The Fall Validation Demo (FVD) for the SMoRes project will demonstrate our capabilities in real-time drone autonomy, odometry, and human detection through dense smoke. The progression of the development of these subsystems is further described in Section 3. Our FVD is currently planned at the Alleghany County Fire Academy (ACFA) in Allison Park, PA. All MRSD, AirLab, and external stakeholders will be invited to this demonstration and it is expected to take place on 17 and 24 November at the aforementioned location.

The demonstration will include a walkthrough of the testing environment to explain the problem the project aims to solve and then a drone flight that showcases the technical abilities of the entire system, as described in more detail in Section 4.

2 Logistics

An ideal environment for our drone is a large indoor space that allows drone flight and deployment of smoke. Last semester, we demonstrated the capabilities of the system at ACFA. Being a fire academy, ACFA allowed smoke deployment and had "burn props," or buildings that closely resemble indoor spaces and are regularly set on fire. However, while the rooms are large enough, the small size of doorways connecting adjacent rooms do not allow us to meet the safety margins in which we wish to fly the drone autonomously. Last semester, we circumvented this problem by smoking the building for a few minutes before walking the drone (with propellers removed) through the smoked environment on a cart. This semester, we are currently planning on testing at ACFA but not inside the burn prop to allow for a more representative testing environment while ensuring safety.

The current test plan involves setting up numerous smoke producing equipment (electrical fog machine, smoke pots that are lit on fire, and smoke grenades) around the burn prop such that they produce plumes of dense smoke and areas of areas of semi-dense smoke. Since we showed the quality of reconstruction through dense smoke during SVD next semester, we will concentrate on showcasing drone autonomy through semi-dense smoke.

However, we are in talks with sponsors throughout Pittsburgh to gauge the suitability of using their space to test and demonstrate our capabilities. Some of the options being considered are:

1. **Gather AI** is a Pittsburgh-based startup that operates drones in large warehouses. We are currently in talks with them to either use their warehouse as a test-site or a parking lot adjacent to their office.

2. **CMU Parking** has allowed MRSD teams to use their parking lots in the past for various testing and demonstration purposes. We are reaching out to them to see if any place on campus will allow us to test.

3. **CMU Rec Services** has also allowed drone testing in the CUC in Wegand Gym, Raquetball Courts, and Rangos Ballroom.

4. **Pittsburgh Fire Academy** is another Fire Academy that is closer to campus.

5. **Any outdoor locations that allow smoke deployment and drone flight.**

3 Schedule

Date	PR ID	Capabilities Demonstrated	Test ID	Requirements
September 10th	PR7	Ainstein Radar Integration	T.1 1	FR.M.1
		Revisiting tech stack after Summer	-	-
September 24th	PR8	Integrated Point of Interest(human) detection	T.2 2	FR.M.3
		Integrated thermal-inertial odometry	T.3 3	FR.M.2
October 8th	PR9	Basic autonomy FSM framework	T.4 4	FR.M.X
		Networking demonstration	T.5 5	FR.M.7
		Drone hover in Position-hold	T.6 6	FR.M.4
October 29th	PR10	Obstacle Detection and Avoidance	T.7 7	FR.D.2, FR.D.3
November 12th	PR 11	Reliability Metrics	T.8 8	NR.M.3
November 17th	FVD	Drone takes off, creates a dense 3D reconstruction through smoke and darkness, and lands	T.9 9	all
November 24th	FVD-E	Fine tuning algorithms	T.10 10	all

4 Tests

Test Title	**T.1 Ainstein Radar Integration**
Objective	Validate optimal operation of our new radar altimeter.
Elements	Drone hardware
Location	NSH Basement
Equipment	Drone, Laptop with QGC software
Personnel	Abhishek Iyer
Procedure	
• Run QGroundControl application on laptop • Mount drone on the trolley along with radar. • Move drone around the basement simulating different heights. • Confirm accuracy of altitude readings on QGC software • If possible, test with smoke.	
Requirements Satisfied	**Verification Criteria**
• FR.M.4 • FR.M.1	• Altitude reading error < 20 cm

Table 1: Test T.1

Test Title	**T.2 Integrated Points of Interest(human) detection**
Objective	Detect humans as points of interest on thermal feed.
Elements	POI detection Algorithm
Location	NSH Basement
Equipment	Drone, Laptop with ROS
Personnel	Swastik Mahapatra
Procedure	
• Place humans at different corners of NSH basement. • Run human detection algorithm on drone. • move drone around handheld or using the trolley. • monitor POI detection performance.	
Requirements Satisfied	**Verification Criteria**
• PR.M.4 • PR.M.5 • PR.D.1	• Standing human detection accuracy $\geq$ 80% with $\leq$ 20% occlusion. • $\geq$ 60% detection accuracy for human in other poses.

Table 2: Test T.2

Test Title	T.3 Integrated thermal-inertial odometry
Objective	Validate new inertial odometry algorithm on stereo thermal feed.
Elements	Odometry Algorithm
Location	NSH Basement
Equipment	Drone, Laptop with ROS
Personnel	Aayush Fadia, Amy Jiang, Ranai Srivatsav
Procedure	
• Mount drone on the trolley • Start thermal inertial odometry algorithm. • move drone around the basement and check odometry performance. • simulate high speed motion and vibration to check resilience.	
Requirements Satisfied	**Verification Criteria**
• FR.M.2 • FR.M.4 • PR.M.3	• Odometry Relative Pose Error(RPE) $\leq$ 10cm • Algorithm runs on Orin at $\geq$ 15FPS

Table 3: Test T.3

Test Title	**T.4 Basic autonomy FSM framework**
Objective	Integrate MAVROS with odometry algorithm and pixracer drone control.
Elements	Drone Autonomy
Location	NSH Basement
Equipment	Drone, Laptop with ROS
Personnel	Ranai Srivastav, Abhishek Iyer
Procedure	
• run odometry algorithm and mavROS on Orin. • Confirm communication with drone using Q Ground Control software.	
Requirements Satisfied	**Verification Criteria**
• FR.M.2 • FR.M.4 • FR.D.4 • PR.D.3	• Odometry algorithm communicates with mavROS • mavROS communicated commands and odometry readings to the drone.

Table 4: Test T.4

Test Title	**T.5 Networking demonstration**
Objective	Demonstrate operation of our new Networking and visualization setup
Elements	Drone hardware
Location	NSH Basement
Equipment	Drone, Herelink basestation, Laptop with ROS
Personnel	Swastik Mahapatra, Ranai Srivastav
Procedure	
• Create Local area network between the drone and basestation laptop using herelink radio. • Stream live camera and algorithm output feed from drone using Gstreamer. • visualize streamed data on base station using foxglove.	
Requirements Satisfied	**Verification Criteria**
• FR.M.6 • FR.M.7 • PR.M.6 • PR.M.7	• video transmission latency should be less than $\leq$ 500ms • stable connection with the operater at a distance of 25m from the drone.

Table 5: Test T.5

Test Title	**T.6 Drone hover in Position-hold**
Objective	Test position hold for drone flight with inputs from radar altimeter and odometry.
Elements	Drone Autonomy
Location	RIC Drone Cage
Equipment	Drone, Laptop with ROS
Personnel	Abhishek Iyer, Ranai Srivastav, Amy Jiang
Procedure	
• Fly the drone inside drone cage • initiate position hold mode from controller. • Visually confirm accurate position hold for the drone.	
Requirements Satisfied	**Verification Criteria**
• FR.M.4	• Position drift $\leq$ 0.1cm/s • Altitude drift $\leq$ 0.1cm/s

Table 6: Test T.6

Test Title	**T.7 Obstacle Detection and Avoidance**
Objective	Test performance of obstacle avoidance for drone
Elements	Drone Autonomy
Location	ACFA
Equipment	Drone, Laptop with ROS
Personnel	Abhishek Iyer, Ranai Srivastav, Amy Jiang, Aayush Fadia, Swastik Mahapatra
Procedure	
• Setup obstacles and fly the drone. • Observe drone behavior as it moves close to obstacles.	
Requirements Satisfied	**Verification Criteria**
• FR.M.1 • FR.M.2 • NR.M.3 • PR.M.2 • FR.D.2 • FR.D.3	• drone should stop at $\geq$ 1m from the obstacles • $\geq$ 80% of obstacles hould get detected.

Table 7: Test T.7

Test Title	**T.8 Reliability Metrics**
Objective	Dry run FVD procedure to ensure reliability and repeatability.
Elements	Reliability, repeatability, operational safety
Location	ACFA
Equipment	Drone, Herelink base station, Laptop with ROS
Personnel	Amy Jiang, Ranai Srivastav, Abhishek Iyer, Swastik Mahapatra, Aayush Fadia
Procedure	
• Set up Herelink base station as per test T.5. • Fly the drone inside a perceptually degraded environment, preferably autonomously. • Drone localizes itself and creates a detailed map of the environment. • Drone detects points of interest while in flight and tags them on the global map. • Drone returns to base station and lands.	
	Verification Criteria
• NR.M.2 • FR.D.4 • PR.D.2 • PR.D.3 • PR.D.4	• Drone flies for $\geq$ 3 minutes • Drone localizes itself with Relative Pose Error(RPE) $\leq$ 30 cm. • A dense map of the navigated environment is generated. • Points of Interest are detected with $\geq$ 80% accuracy. • Obstacles are avoided at $\geq$ 1 m distance. • Testing drone reliability with ROVTIO, MAVLINK, Radio, or QGC errors

Table 8: Test T.8

Test Title	**T.9 FVD - Drone takes off, creates a dense 3D reconstruction through smoke and darkness, and lands**
Objective	complete operation demonstration - Drone autonomously flies, creates a dense 3D reconstruction through smoke and darkness, detects POI and lands.
Elements	End-to-end operation
Location	ACFA
Equipment	Drone,Basestation Laptop
Personnel	Aayush Fadia, Abhishek Iyer, Amy Jiang, Ranai Srivastav, Swastik Mahapatra
Procedure	
• Set up Herelink base station as per test T.5. • Fly the drone inside a perceptually degraded environment, preferably autonomously. • Drone localizes itself and creates a detailed map of the environment. • Drone detects points of interest while in flight and tags them on the global map. • Drone returns to base station and lands.	
Requirements Satisfied	**Verification Criteria**
• NR.M.2 • FR.D.4 • PR.D.2 • PR.D.3 • PR.D.4	• Drone flies for $\geq$ 8 minutes • Drone localizes itself with Relative Pose Error(RPE) $\leq$ 10 cm. • A dense map of the navigated environment is generated. • Points of Interest are detected with $\geq$ 80% accuracy. • obstacles are avoided at $\geq$ 1 m distance.

Table 9: Test T.9

Test Title	**T.10 FVD Encore - Fine tuning algorithms**
Objective	Re-demonstrating all functionalities shown in FVD with optimized algorithm performance.
Elements	End-to-end operation
Location	ACFA
Equipment	Drone, Basestation Laptop
Personnel	Aayush Fadia, Abhishek Iyer, Amy Jiang, Ranai Srivastav, Swastik Mahapatra
Procedure	
• Set up Herelink base station as per test T.5. • Fly the drone inside a perceptually degraded environment, preferably autonomously. • Drone localizes itself and creates a detailed map of the environment. • Drone detects points of interest while in flight and tags them on the global map. • Drone returns to base station and lands.	
Requirements Satisfied	**Verification Criteria**
• NR.M.2 • FR.D.4 • PR.D.2 • PR.D.3 • PR.D.4	• Re-create all demonstrations shown during FVD. • improve on algorithm performance.

Table 10: Test T.10

A Associated System Requirements

Table 1. Mandatory Functional Requirements

ID	Requirement	Description	Origin
FR.M.1	Sense the environment	The drone senses the environment through perceptual degradation.	TR
FR.M.2	Localize itself	The drone develops an internal representation of the environment and localizes itself on it.	TR
FR.M.3	Detect Points of Interest (PoI)	The drone helps firefighters detect and locate POIs.	SR
FR.M.4	Autonomously hold position	The drone autonomously takes off, holds position, and lands	TR
FR.M.5	Switch to tele-op upon error	The drone will be autonomous but move to a manually controlled state upon an error	SR
FR.M.6	Visualize the environment	Firefighters will be able to interact with visualizations depicting necessary information	SR
FR.M.7	Communicate with an operator	Firefighters will be able to communicate with the drone, control it, and stop it if necessary	TR

Table 2. Mandatory Non-Functional Requirements

ID	Requirement	Description	Origin
NR.M.1	Weigh less	To ensure ease of transport and sufficient battery life	SR
NR.M.2	Be fast	To ensure timely information	SR
NR.M.3	Be robust	To ensure longevity of the system and less downtime	SR

Table 3. Mandatory Performance Requirements

ID	Requirement	Description	Origin
PR.M.1	Sense the environment farther than 30cm away from itself	Leads to incorrect disparity and depth	TR
PR.M.2	Sense the environment closer than 5m away from itself	Leads to incorrect depth given perceptual degradation	TR
PR.M.3	Localize itself within 2m of true position in perceptual degradation	To provide accurate location estimates for drone, POIs	TR
PR.M.4	Detect humans	Detects and localizes humans on the map	SR
PR.M.5	Detect POI with accuracy greater than 80% when 80% visible	To balance precision vs. recall for detection	DD
PR.M.6	Communicate with an operator with a maximum latency of 500ms	Low latency for teleop and timely information from sensors	TR
PR.M.7	Communicate with an operator within 25m	The system needs to operate through various building materials	TR

Table 4. Desirable Functional Requirements

ID	Requirement	Description	Origin
FR.D.1	Store sensor information	The visualizations will be saved for future retrieval and analysis	SR
FR.D.2	Detect Obstacles	The drone will detect static obstacles through perceptual degradation	TR
FR.D.3	Avoid Obstacles	The drone will avoid detected obstacles through perceptual degradation	TR
FR.D.4	Navigate via Waypoints	The drone will navigate via recieved waypoints	TR

Table 5. Desirable Non-Functional Requirements

ID	Requirement	Description	Origin
NR.D.1	Be easy to use	To provide more natural control for the user and reduce training	SR
NR.D.2	Be modular	To ensure the portability of the system to various environments	DD

Table 6. Desirable Performance Requirements

ID	Requirement	Description	Origin
PR.D.1	Localize POI within 5m of the true position	Crucial information in large spaces	DD
PR.D.2	Navigate the environment at a speed of 10 cm/s	Balances exploration speed with safety	DD
PR.D.3	Autonomously reach the next waypoint within an error bubble of 1m	Autonomously traverse the environment via waypoints	TR
PR.D.4	Navigate to the next waypoint while maintaining 0.1m from any obstacle	Drone will maintain a safe error bubble from obstacles	TR