Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
May 2, 2024
A Regional Conference of the Society for Industrial and Systems Engineering

Project Drop Zone

Mihiri Fernando, Victoria Salvador, James Bowers, and James Walliser

Department of Systems Engineering,
United States Air Force Academy,
Colorado Springs, CO 80841

Corresponding author's Emails: mihiri.fernando@icloud.com, student.victoriasalvador@gmail.com

Author's Note: Mihiri Fernando is a member of the United States Air Force Academy Class of 2024. Upon graduation, she will commission into the United States Air Force as a 2nd Lieutenant and proceed to pursing a Master's in Computational Science and Engineering at Georgia Tech before attending pilot training. Victoria Salvador is also a member of the United States Air Force Academy's Class of 2024. Upon graduation she will also commission into the United States Air Force as a 2nd Lieutenant and proceed to a Master's in Systems Engineering at AFIT before attending pilot training. This team was advised by Lt. Col. James Bowers from USAFA's Physics and Meteorology Department.
The views expressed herein are those of the authors and do not reflect the position of the United States Air Force Academy or the Department of Defense.

Abstract: Project Drop Zone is a revolutionary technological approach to develop a system that discreetly marks the corners of a drop zone to increase the safety of military personnel landing in unfamiliar territory. The system employs four autonomous drones, each landing at a designated corner and utilizing IR beacons for communication. Upon landing, the drones assess wind speed and direction, conveyed to operators through a distinctive blinking pattern of the IR beacons. This approach elevates situational awareness, allowing military members to interpret the drop zone's outline and plan their descent, accordingly, contributing to heightened safety and mission success. In the development of a proof-of-concept demonstration, utilizing commercial-off-the-shelf components, the team is integrating an anemoscope and anemometer with signaling components onto a two-ship drone formation.

Keywords: Systems Engineering, UAS, Windspeed Heading and Direction, Drop Zone

1. Background

1.1 Introduction

Parachuting into unknown territory poses significant risks. In military endeavors, these risks can be reduced by dispatching a solitary parachutist ahead to designate a secure landing zone. This assignment is exceptionally challenging as operations presently send out the first parachutist who must manage navigation devices mounted on their chest, often leading to spatial disorientation and loss of situational awareness (SA). There are currently no devices made or used to mitigate the risk for the first parachutist. Thus, the team's solution is to develop an autonomous unmanned aerial vehicle system that will mark the drop zone (DZ) for the operators, while providing them with a visual location marker and real-time ground wind speed and heading. This solution will eliminate this risk, while also increasing the SA of all operators on the team, by giving them a visual beacon to fly to. By reducing the number of times operators must look down at their navigational devices increases the amount of time that they can spend maneuvering and communicating with each other; thus, increasing the overall safety and improving mission success.

1.2 Literature Review

The US Army Research Institute's report highlights the crucial role of SA in enhancing infantry performance. It stresses the importance of individual and team SA in the complex infantry operational environment, emphasizing soldier capabilities, tactical factors, and environmental dynamics. The report proposes improving SA through advanced training, leader development, and leveraging technology. It introduces an Infantry-centric SA model that integrates perceptual and cognitive abilities, skills, experience, and motivation for effective battlefield navigation. Additionally, it outlines measurement methods for assessing SA performance. The report advocates for ongoing research to refine SA tools and techniques, with potential benefits for doctrine, leadership, training, and technology. These insights are valuable for Army professionals, aiding in the evolution of strategies to boost battlefield SA and mission success.

1.3 Constraints

In order to tackle this problem, the team interviewed a variety of stakeholders and unmanned aerial vehicle civilian companies to gain a better understanding of the scope of this project, the conditions that operators work under, and the stresses that the drones may encounter when deployed. The team posed a variety of questions to each stakeholder to find the most common numbers to determine the constraints. Through 5 interviews with different NSW operators, the team deduced that the aerial system needs to fly between 10 and 30 kilometers from the location it was deployed. Also, it needs to operate between 10,000 and 25,000 feet from ground level. Additionally, the drop zones ranged from an area of 50 square meters to about 900 square meters. This meant at least 4 drones would be needed to mark each corner of the drop zone. Lastly, for operators to land safely, the drones that landed should be within 3 to 5 meters of the drop zone coordinates. These constraints are also summarized in Table 1

Table 1. System Operational Constraints

Constraint	Minimum	Maximum
Deployable Distance	10 km	30 km
Deployable Altitude	10,000 ft	25,000 ft
Drop Zone Size	50 m^2	900 m^2
Marker Accuracy	3 m	5 m

1.4 Requirements

Furthermore, based on the constraints listed above the team developed multiple requirements that the system needs to meet to accomplish the performance. As seen in Table 2, the aerial system needs to operate until the parachutists' land, which could range from 10 to 30 minutes after the operators jump from the aircraft. Additionally, the system needs to be fully autonomous, meaning that once it is deployed it operates without human assistance until it is recovered by the Special Operation Forces (SOF) recovery units. The system also should not leave any noticeable or traceable debris that could be linked to the operations. This is essential to national security and maintaining the safety of the operators. Furthermore, the entire system needs to fit in the pickup vehicles that the operators would use to clear the drop zone once they have landed. Next, the system needs to be able to work both day and night. Thus, IR Beacons are used to indicate the drop zone locations. This allows the operators to see it no matter the visibility, it also provides a level of obscurity so that the location is not being broadcast to everyone in the surrounding area. These requirements were further broken down into sub-requirements that can be found in the Appendix.

Table 2. Top Level System Requirements

Number	Title	Requirement
1	Mark Landing Zone	The system shall mark a drop zone
2	Timeline	The system shall operate until the parachutist's land
3	Autonomous Capability	The system shall have no operator input post deployment
4	Traceability	The system shall leave no debris upon deployment
5	System Size	The system shall fit in delivery and pick-up vehicles
6	Visibility Conditions	The system shall work during the day or night
7	GPS Capabilities	The system shall have access to GPS satellite locations
8	Wind Limits	The system shall operate in winds gusting up to 20 knots
9	Recoverability	The system shall be recoverable by SOF recovery units post marking the drop zone

2. Methodology

2.1 Organization

To solve this complex problem, the team devised a three phased approach, as seen in Figure 1, to lead to mission completion. In Phase I, a primary carrier drone carrying smaller landing drones deploys from the back of a C-130 pre-loaded with the GPS coordinates to the drop zone. In the second phase, the drone flies from its deployment location to the DZ. At this point, the primary carrier drone must stabilize in flight and then navigate to the drop zone. Lastly, once the drone arrives at the drop zone, it must deploy the secondary drones that are attached to it. Then, these smaller quadcopters will land on the ground and use IR beacons to signal to the operators where the drop zone is located. These smaller quadcopters will use an anemoscope and anemometer to measure ground wind speed and direction, using flashing lights to guide operators during landing.

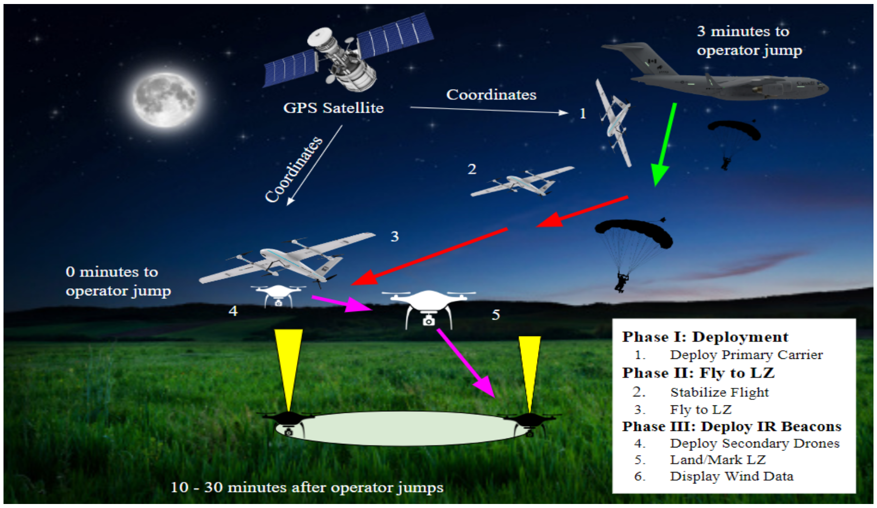

Figure 1. Project Drop Zone OV-1

2.2 Phase I

Phase I focuses on deploying the air asset. There is currently research being conducted on two viable solutions for physically deploying the air asset. The first option is to deploy each of the four drones out of the back of a C-130 which requires the drone to self-stabilize and autonomously navigate to the DZ. An advantage to this option is that the only system being used is the four autonomous drones, making the design simpler. However, the individual drones will require a longer battery life to ensure they can travel the required distance and they may be destroyed in the wind as they are deployed. The second option is to deploy a fixed wing aircraft, the primary system, with the four drones, the secondary system attached to it, out of a C-130. The advantage to the second option is that the individual drones will not need enhanced battery life to support long distance travel, but the primary system that the drones are attached to needs to sustain long distance travel. Furthermore, if the asset is a fixed wing aircraft, it could be stabilized in different and easier ways. However, integrating the drones onto another system will complicate the design process.

Given that the engineering design process is starting with Phase III, the team is working under the assumption that the system will use the second design option. Since the system must be able to cross a far distance, it seems more manageable for the drones to cover the distance if they deploy from a primary system.

2.3 Phase II

Phase II focuses on the air asset stabilizing and flying to the DZ. There is currently research being conducted on the challenging question of how to have the air asset self-stabilize. Working under the same assumption of having the secondary drone system deploy from the primary system, there are possibilities of the air asset utilizing a parachute to help with the descent and stabilization of the air asset. This idea will be researched further to ensure operational practicality. Also, the primary system's ability to fly most of the distance to the DZ and deploy the secondary system which will land on the corners of the DZ is being researched.

2.4 Phase III

Phase III focuses on the deployment of the IR beacons. The drones will deploy from the primary system and have an IR beacon attached to the top of each drone. The drone will fly to a designated corner of the DZ and shut off while the IR beacon illuminates. The IR beacon will illuminate in a specific blinking pattern that the military operators will be able to identify. The blinking pattern signifies the most desirable direction to land-based wind direction at ground level. Additionally, the rate of the blinks will be used to signify wind speed at ground level.

To expand upon the navigational abilities of the drone, the team has conducted research using the program Ardu Pilot Mission Planner. This software is chosen since it has allowed experimentation with waypoint navigation by inputting latitude and longitude coordinates. Additionally, the software Gazebo, Marvos, and QGroundControl have been utilized due to its ability to enable drone swarming with Software in the Loop (SITL). Within these simulations, there are basic object avoidance and detection algorithms implemented. Notably, each software was only used for their specified purposes as that is what the team needed at that time. However, there are many more tools within these software that may be utilized as the research shifts to working Phase II.

Figure 2, depicted below, demonstrates the drone swarming capabilities. It has synced three separate drones to autonomously fly to a specified location. The image on the left pictures that the three drones in a specific formation. The image on the right pictures all three drones functioning at the same time in the same airspace. This function will be used when the secondary system deploys from the primary system and needs to deploy onto the DZ.

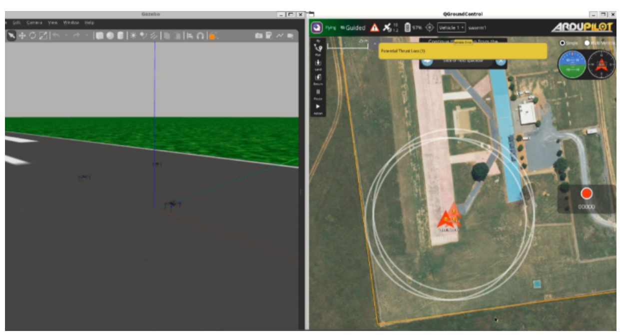

Figure 2: Drone Swarming Demonstration

Figure 3 demonstrates a drone's ability to scan and identify an object. The image on the left is the simulation of what one would see the drone doing while the image on the bottom right displays what the drone is identifying. This function can be helpful to ensure that the drone is landing in the proper locations.

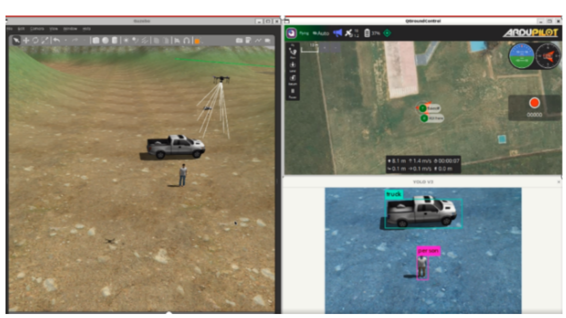

Figure 3: Drone Scanning Demonstration

Figure 4 demonstrates a drone's ability to have basic object detection. The image on the left displays the range of the object detection while detecting a wall. The image on the right displays that the drone will not cross through the intended path because it recognizes that an object is in its way. This will be helpful to ensure that the drone is not going to accidentally break itself by flying into an object.

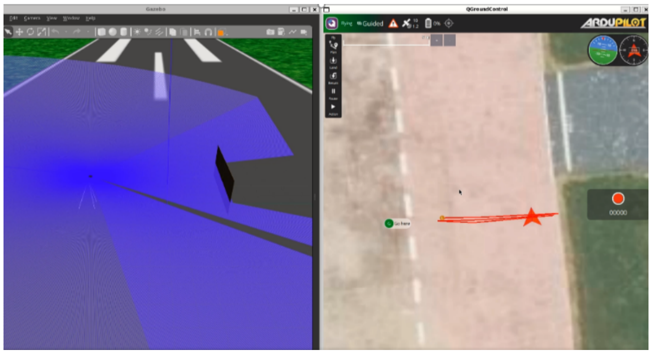

Figure 4: Drone Object Scanning

The IR beacons will be fixed to the top of each drone for four distinct beacons. One drone will be fixed with both an anemoscope and an anemometer to determine wind direction and wind speed, respectively. These exact tools are pictured in Figure 5. This drone, with sensors, will communicate to all IR beacons to display a blinking pattern. Figure 6, pictured below, demonstrates a setup of a marked DZ where the top IR beacons are flashing. This indicates to the military operator that they are advised to land from solid to flashing beacons based on the sensed ground data.

Figure 5: Anemoscope (left) and Anemometer (right) (Weather Meter Kit)

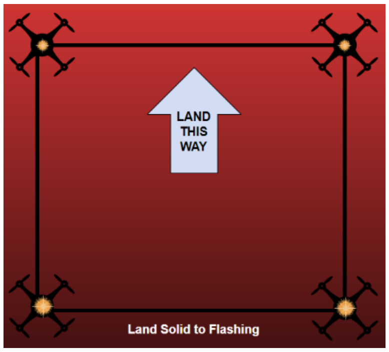

Figure 6: Wind Sensor Concept

With all the simulation techniques learned, they can be applied to the Sentinel Model AI (Artificial Intelligence) drones. The team has two of these drones that will be used in conjunction with the wind sensor hardware to begin experimentation.

ISBN: 97819384962-4-0

3. Future Plans

3.1 Test Plan

Looking into the future, the team will utilize the test plan, as seen in Table 3, to ensure that the system being designed meets all the requirements for this mission. The tests will be verified through demonstration to show proof of concept. The test plan in Table 3, highlights the most important tests and ranges from demonstrating basic point to point navigation, to accurately calculating the wind speed and direction on the ground. In conclusion, the team will use the foundation set up this year to move this project forward.

Table 3. Test Plan

Number	Test	Requirement	Verification Method
1	The test shall mark the landing zone with a quadcopter using ArduPilot and Mission Planner software launched from a field away.	This system shall mark a landing zone. This system shall deploy away from the landing zone. This system shall have no operator input post deployment.	Demonstration
2	The test shall launch the quadcopter using ArduPilot and Mission planner from a field away to determine landing accuracy.	This system shall have the drone mark within 3-5m of accuracy.	Demonstration
3	The test shall use a wind detector aboard the quadcopter to relay accurate wind readings.	The system shall have no operator input post deployment	Demonstration
4	The test shall allow the quadcopter to land and provide a visual marker in grass, swamp, gravel, sand, water, and incline landings.	The system shall land on various terrain determined by given GPS coordinates.	Demonstration
5	The test shall allow an operator to physically pick up the quadcopter.	This system shall be recovered by a SOF recovery unit post marking the landing zone.	Demonstration

4. References

Weather Meter Kit - SEN-15901 - SparkFun Electronics. (n.d.). www.sparkfun.com. https://www.sparkfun.com/products/15901

US Army Research Institute for the Behavioral and Social Sciences, *Modeling and Measuring Situation Awareness in The* ...,citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=168ad9c49ad414a08ac9fedcf262a27bf55e6cca. Accessed 21 Mar. 2024.