Project Name	**Rescue Delivery (RED) System**
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Video Link: https://youtu.be/7E3HIsM8VjE

Problem Statement:

Drones are increasingly being used as innovative tools in the healthcare field. RED (Rescue-Delivery) system is a project that is designed to help others in need by utilizing unmanned aerial systems to deliver medical supplies. By using a combination of a fixed-wing mothership and a multirotor drone, the RED system will be able to conduct fast, accurate and autonomous delivery of a payload from a base to the rescue location and then return to the starting position. This is an aerospace engineering capstone design team that collaborates with other interdisciplinary majors such as mechanical, electrical, software, and computer engineering to achieve this goal.

Figure 1: RED System

Concept of Operation:

The mothership will first be loaded with the payload and the coordinates of the delivery location. Upon reaching the pre-selected area, the multirotor and payload will detach from the mothership. The multirotor will quickly reach the coordinates and deliver the payload. Once the delivery is accomplished, the multirotor will rendezvous and dock with the mothership. Both drones will return to the base with complete autonomy. The communication between mothership and multirotor is accomplished through a high-speed cellular network system. This will give the two drones easy access to the internet regardless of distance between each vehicle. By connecting to the internet, a Raspberry Pi in each UAV will be able to communicate with each other via a Secure Shell (SSH) connection, which will also encrypt the communication between our UAVs and a ground station. One of the hardest parts of the project is to create a reliable docking system and flight procedure for the UAVs. The final docking maneuver is initiated by the image tracking system which captures real-time video and processes it frame by frame. By using an open source python library, each video frame's data can be captured and manipulated to achieve the desired results using OpenCV.

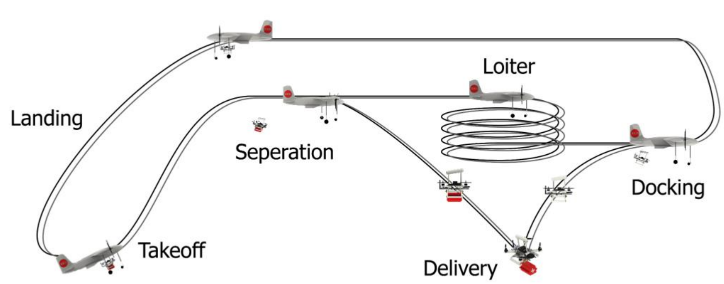

Figure 2: Concept of Operations

Major Challenges:
One major challenge in this project was making a functioning system out of premade parts. While the parts were commercially bought, many components still had to be modified to work with one another. This proved to be a challenge for the many different subsystems; like the aerodynamics subsystem, structures subsystem, and electrical subsystem. Another challenge was that autonomous docking cannot be done with GPS data alone because the margin of error with GPS coordinates is too large for the level of precision needed for docking. The design solution includes a two-phase docking plan that uses GPS location to position the multirotor in close proximity to the mothership, then image tracking based marker detection software that determines the appropriate flight path corrections to center the multirotor into an ideal docking position.

Aerodynamics Subsystem:
Many structural modifications to our commercially bought mothership gave a huge technical challenge to the aerodynamics subsystem. Along with an ANSYS fluent simulations on the mothership, the landing gear, the docking and deployment system along with the package were approximated to be cuboids placed beneath the mothership disturbing the downwash. A lot of traditional hand calculations using empirical methods were performed on MATLAB to compute the flight performance and stability parameters in order to ensure that the system was longitudinally, directionally and laterally stable. These results were eventually passed on to the propulsion subsystem to make important decisions regarding all the electronics on both the UAVs.

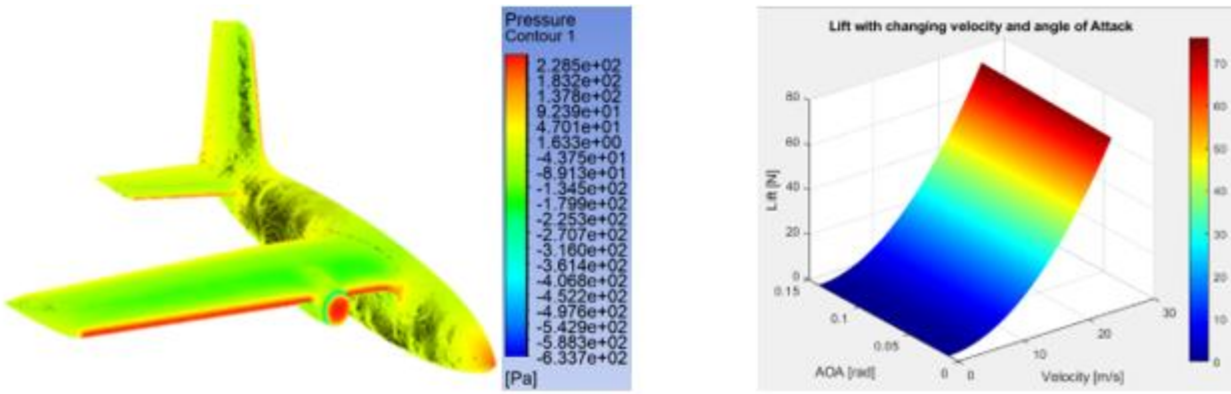

Figure 3: ANSYS Fluent and MATLAB Analysis

Structures Subsystem:
Many components of this project have been commercially bought, but they needed to be integrated together; this required modifications to different parts, such as the mothership. The landing gear needed to be designed to allow the mothership to take off and land while carrying the multirotor beneath it. Additionally, it needs to be able to carry the full weight of the aircraft which is 6.5 kg. To maintain structural integrity, different analysis methods were used such as hand calculations and ANSYS which is a structural analysis software. The landing gear and the wings are both analyzed to make sure they meet the height and strength requirements needed to remain structurally stable during all parts of the mission.

Deployment System Sub-System:
The system consists of a simple claw mechanism, where the package is gripped on either side by two claws, swiveling open to drop the package. Many components for the deployment system were commercially bought, while the main housing and the two claws were 3D printed using PLA plastic. The claws were designed to be actuated by two servos through a set of gears, and they were designed to carry a payload of 400g. The system was designed using CREO Parametric and 3D printed, simple hand calculations and ANSYS Workbench were used for structural analysis.

Docking System Sub-System:
The docking system sub-system was responsible for the drone docking system attached underneath the mothership. The docking system consists of a creased foam board plate under the mothership and a probe attached above the drone. The creased plates guide the probe into a rectangular rail at the end of the plate where a lock mechanism will hold the probe and drone in place. The system was manufactured using commercially bought and 3D printed parts. The rail was 3D printed using PLA plastic, the board was made using commercially bought foam and the attachment hook was made by bending an aluminum plate, the plate was cut using a water jet.

Figure 4: Deployment and Docking Systems

Propulsion Sub-system:

The propulsion subsystem is responsible for selecting the motors, ESCs, batteries and propellers for both the vehicles. Detailed power budgets and energy capacity calculations were also performed. Based on the selection of motors and other propulsion components, the systems have a total mission time of 10 minutes for the mothership and about 5 minutes for the multirotor.

Controls Sub-system:
The controller for the multirotor comes with a powerful control system for most kinds of multirotor configurations and fixed wing aircraft configurations. The controller for the multirotor on the Pixhawk is the standard cascaded position velocity loop. This controller has a feature that allows for the input of other modules to control the loop through the input of a desired velocity. The raspberry pi will house its own control outer controls loop needed for docking. The outer controls loop works similarly to a standard cascaded position velocity loop. The difference is that the distance deviation will be the deviation from the flightpath that is controlled by a docking script.

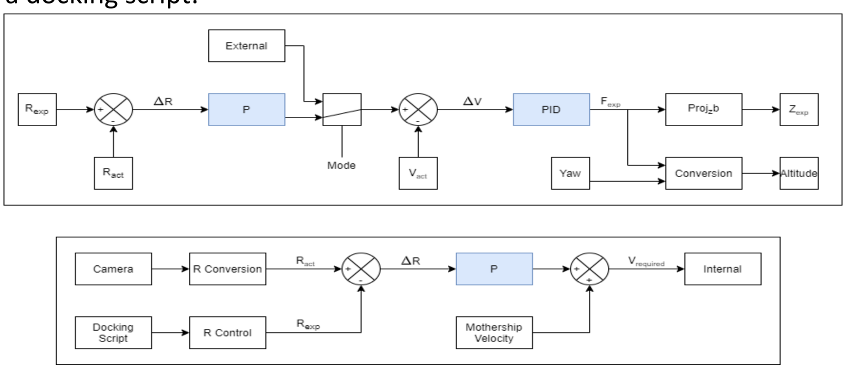

Figure 5: Control Systems

Future Work:
Major parts of the project have been completed, and we are pleased with the progress that we have made. The current status of the project has the majority of the parts either fabricated or manufactured. The mothership has been fully manufactured and the integration of the docking system and deployment system have been completed. Also, the software is ready to be integrated into the system and tested. Due to the complications that has come up in previous weeks, it has caused the team to rescope some aspects of the project. The next stages of the project involve testing of the individual components and a test of the finished product.