

## ECE 4012 Project Summary

<b>Project Title</b>	SkyIsland: Aerial Docking Drone System	
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<b>Semester</b>	2018/Spring	Final (ECE4012)

<b>Project Abstract</b> (250-300 words)	<p>SkyIsland is a drone system comprised of independent quadrotors with the ability to interlock and reconfigure into one collective drone structure. The reconfigured drone structure has the ability to reverse the formation by breaking apart into its constituent drones. The system can reassemble itself based on the characteristics of the assigned task and the required features to execute it.</p> <p>The flexibility of the system makes it versatile and adaptable in applications involving search and rescue in hazardous areas, cargo delivery, military recon, and difficult inspections in inaccessible regions. The ability for the drones to reconfigure and reshape provides flexibility in unnavigable regions, such as narrow canyons and dense forests while minimizing air traffic in open and congested areas.</p> <p>When reassembling into a collective structure, electro-permanent magnets were utilized as a holding force to maintain the connection between coupled drones. Rangefinders and optical detectors were employed to achieve mid-air alignment between approaching drones in preparation for docking. The system uses complex control systems to guide constituent drones when docking mid-air.</p>
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<p>List <b>codes</b> and <b>standards</b> that significantly affect your project. Briefly describe how they influenced your design.</p>	<p><b>Inter-integrated Circuit (I<sup>2</sup>C) Protocol:</b> is employed to allow multiple digital integrated circuits/chips to communicate with one or more master chips.</p> <p><b>SBUS (Futaba) Protocol:</b> for short-range, low-power, low-cost, wireless transmissions between electronic devices.</p> <p><b>TX Protocol:</b> provides communication between TX and FC.</p> <p><b>RX Protocol:</b> provides communication between TX and RX..</p>
<p>List at least two significant <b>realistic design constraints</b> that applied to your project. Briefly describe how they affected your design.'</p>	<p><b>Weight:</b> Payload of the drone cannot exceed the maximum weight limit a drone can support.</p> <p><b>Power consumption:</b> disconnection from power source requires storage battery.</p> <p><b>Size and shape:</b> size of components and physical design of the system limits docking patterns.</p> <p><b>Docking Alignment:</b> Accuracy and range require to use multiple types of sensors, and use of magnet for compensation of errors.</p> <p><b>Cost:</b> limited budget cannot afford drones of very high price, accurate sensors, or high-power motors.</p>
<p>Briefly explain two <b>significant trade-offs</b> considered in your design, <b>including options considered and the solution chosen.</b></p>	<p><b>Electromagnets vs. electro-permanent magnets:</b> electromagnets are widely used and are readily available but they require constant current supply during operation. An electro-permanent magnet, however, only requires a high current impulse to flip its polarity and then it maintains its new state which is more cost effective.</p> <p><b>Crazepony vs SunFounder drone:</b> Crazepony it may not support an increase in the payload. The drone itself weighs 46g. At the time of proposal, the added weight due to onboard sensors, magnets and soft magnetic materials was calculated around 47.95g. This weight does not include the weight of the shell, PCB or vector board and other extra parts. One option to alleviate the payload limitation issue is to find a more powerful battery and compatible motors. The investigated available motors that would fit the geometry of the crazepony drone were not as powerful as the ones on the drone. SunFounder QAV250 drone was chosen as a replacement for the crazepony drones. Despite having more than double the cost of the crazepony drone, the SunFounder drones have more powerful batteries and motors and could support much higher payload without the flight time decreasing drastically. The cost change on the drone</p>

forced the project to have two drones instead of three. Unlike the crazepony, the source code for the flight controller was not available for download online.

**IR LED vs Laser Rangefinders (ToF):** The proposed method for close range positioning and alignment of drones was initially an infrared LED IR333-A and an infrared receiver TSOP38238. IR receiver readings can be impacted significantly depending on the ambient light or outdoor environments. Due to this limitation, laser rangefinders utilizing time-of-flight principles were adopted instead. Two types of laser rangefinders implemented in the project are VL53L0X and VL6180X. Using these time-of-flight sensors over LED system presented a tradeoff, due to the fact that the readings of these time-of-flight sensors are only single point measurements. These time-of-flight sensors are ideal for determining the distance of only the surface directly in front of it. Thus, multiple readings might be needed to determine distance and to ensure accuracy. However, since the close range positioning was aimed at distances below 1 cm, single point measurements didn't interfere with the consistency of the readings. A significant advantage gained by implementing laser rangefinders VL6180x is that compared to IR LED and IR receiver, they weigh considerably less.

**Long range positioning:** Kalman Filter uses background subtraction method to detect moving objects, while machine learning relies on trained dataset. Kalman filter does not require massive amount of training data, and less than 30 frames of the beginning of the video is adequate for background detection. Its disadvantage is that it is only able to detect moving objects, regardless of the identity of the object. The other disadvantage is that the camera has to be stationary, and the process is very slow. On the other hand, machine learning and deep learning are more robust and are able to identify objects, but requires a large set of training data. In the current stage of the project, Kalman filter was used mainly because of the lack of training data. Kalman filter was used based on the assumption that one drone stays stationary while the other drone flies towards it for docking.

<p>Briefly describe the <b>computing aspects</b> of your projects, specifically identifying <b>hardware-software</b> tradeoffs, interfaces, and/or interactions.</p>	<p><b>Low Level control:</b> Position and orientation of drones and docked systems.</p> <p><b>Setting up BeagleBone board:</b> Robot Operating System (ROS) was considered as the software solution for the project. The latest version of ROS, however, does not support the latest BB Blue Debian 9 OS image, and running an outdated OS on the BB Blue introduced driver-level limitations to the BB Blue which is a relatively new and in-development product which are outside the scope of the project to resolve, so an outdated implementation of the Robot Operating System (ROS) was built from the source on a supported version of the Debian 8.7 image on the BB Blue. Unfortunately, the compiled ROS software distribution offered limited tool sets for outdoor drone flight, and developing basic flight control software from scratch using the ROS API is outside the scope of the project.</p> <p><b>Embedded Computing:</b> After all the considerations in software development and choice, a MATLAB &amp; Simulink software solution was ultimately chosen as code blocks and drivers were more readily available for Beaglebone hardware through the Simulink Embedded Coder software suite.</p>
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