OSU Vertical Flight Society (VFS) Design-Build-Vertical-Flight (DBVF) Executive Summary:

Introduction and Design

The Vertical Flight Society (VFS) held its inaugural Design-Build-Vertical Flight (DBVF) student competition. VFS had tasked student teams with designing, manufacturing, and flight testing an urban air mobility (UAM) aircraft with a maximum weight of 20 lbs and the largest dimension of 6.5 ft to compete in their competition. The Oregon State University (OSU) DBVF team comprises 3 engineering disciplines, mechanical engineering , electrical and computer engineering, and computer science. The team is led by Kyle Padgett, senior in Mechanical Engineering (ME). The ME subteam is led by Kyle Padgett and includes Dylan Domingo, senior in ME and Paul Schreiner, Junior in ME. The ME subteam is responsible for design, manufacture, and testing of mechanical components. The Electrical and Computer Engineering (ECE) subteam is led by William Otos and includes Kevin Chau and Chih-Hsuan Su. The ECE subteam is responsible for the implementation and validation of the vehicles power systems, sensors and telemetry. The Computer Science (CS) subteam is led by Andrew Sunderland and includes Gregory Oertli. The CS subteam is responsible for designing, configuring, and testing the components and running the ground control system. The OSU team is advised by Dr. Roberto Albertani, Associate Professor of Mechanical Engineering.

Considerations made for this project were done so with the goal of winning the competition. The team analyzed the framework that would be used to evaluate the competition in the fly-off portion and discovered that maneuverability and endurance were the two most important factors for high scores in the fly-off courses. There was also a bonus autonomous challenge that the team wanted to keep as a possibility. With the maneuverability and endurance categories identified, the mechanical engineers worked on designing an aircraft that fits the competition requirements and will exceed in both maneuverability and endurance. In the final iteration the team's design has a main rotor and an embedded tail rotor that will enable hovering flight while the main rotor coupled with small fixed-wings will provide lift for cruise flight. For ECE and CS, power endurance, time, and autonomous functionality were driving factors for design. The ECE and CS system is based on the flight controller. Due to time constraints the team chose a commercially available flight controller, the Pixhawk 4 Autopilot. This decision meant that the team would have more time configuring the flight controller, instead of building it, and this ensured that the flight controller was capable of autonomous flight. Endurance was a balancing act between the batteries, ESCs, and motors, as those 3 took the most power and the flight controller’s power consumption was negligible compared to those.

For the development and completed phases, the selected flight controller allowed the team to consider flight autonomy with the external sensors: the Holybro 500mW Transceiver Telemetry Radio Set, Neo-M8N GPS, and the Holybro Air Speed Sensor. The basic configuration of the Pixhawk4 includes sensor orientation, compass, gyroscope, accelerometer, and level horizon calibration. The sensor orientation and compass help establish roll, pitch and yaw offsets of the flight controller relative to the aircraft's principal axes. The gyroscope and accelerometer shows the rotation rate in degrees per second. Level horizon calibration compensates for small miss-alignments in controller orientation and levels the horizon in QGroundControl flight view. A Telemetry Radio Set will be implemented for flight data retrieval on a laptop as a ground control station.

For the aircraft's autonomous flight functionality, the team looked at PX4, Ardupilot, and Betaflight autonomous frameworks for use in the flight controller. The subteam decided to use the autopilot framework PX4. PX4 is compatible with the Pixhawk 4 Autopilot flight controller that was used to control the aircraft. In combination with the PX4 Pixhawk, QGroundControl is able to monitor flight and give autonomous directions. By working with components that supported autonomous flight from the start, the CS team would have had more control over achieving autonomous flight and will allow for increased knowledge retention among future OSU DBVF teams giving them a leg up compared to previous years.

A ground control system is needed to achieve autonomous flight to send commands to the aircraft. The ground control system (GCS), a laptop running Windows 10 and QGroundControl served that need. The CS team chose QGroundControl as the ground control software for the aircraft as it is compatible with the PX4 software. QGroundControl provides full flight control and mission planning for both remote and autonomous control. QGroundControl acts as a bridge between the user and the physical flight controller allowing the user to set up the aircraft, upload a custom airframe, set flight modes, and calibrate sensors. The ground control system communicates with the aircraft through telemetry radios attached to both the flight controller and the GCS.

With ongoing evaluation and revision, the team learned of factory bugs that made it difficult to configure the airframe with the provided software QGroundcontrol and PX4. A custom software airframe is needed to circumvent the factory bug in the helicopter airframe. Future teams should consider starting with a custom software airframe to match their aircraft design at the beginning of the project, or the project should transition to be just about making a custom flight controller.

Timeline

VFS DBVF student competition started in September for the students in the competition and ended with a final report on March 29th and a final presentation on April 15th. Below is a simplified Gantt chart showing the 4 main tasks for the project as the rows and shows days as columns. Colored boxes show planned completion dates, actual completion dates, and overlap. As the Gantt chart shows, a problem with this project was always being behind schedule. This has a lot of contributing factors that are further explored in the future recommendations section of this paper. Main issues had to do with the timing of students joining and starting the project and the accelerated deadline for the competition.

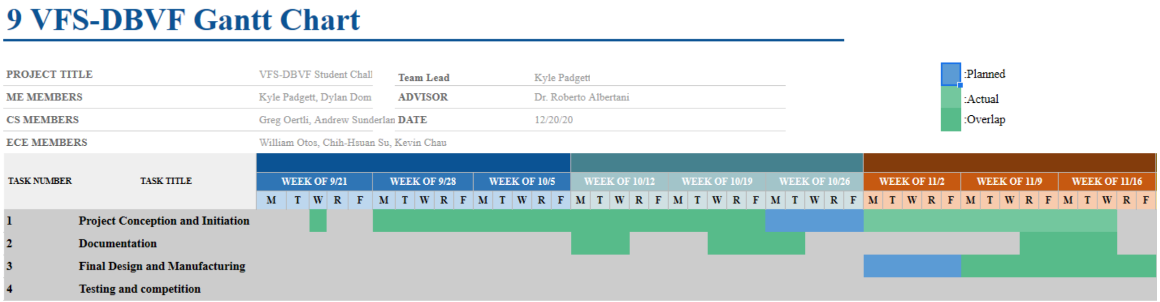

Fig 1: Gantt Chart

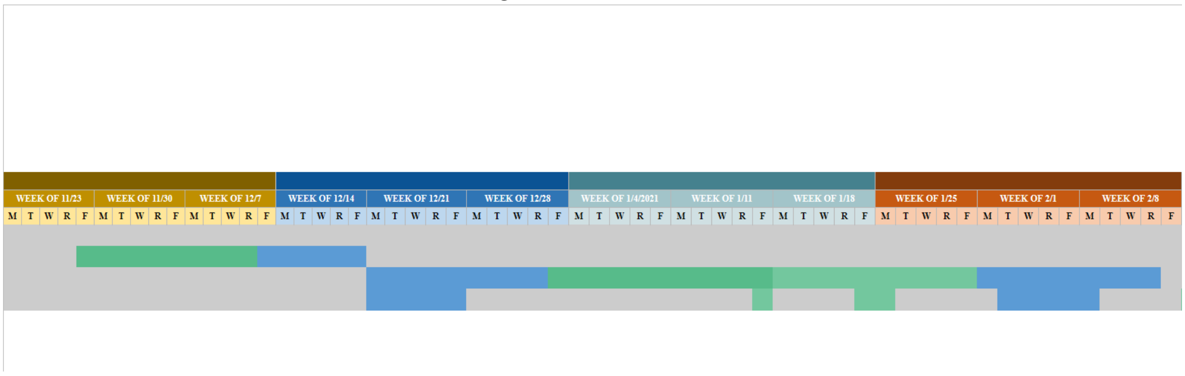

Fig 2: Gantt Chart

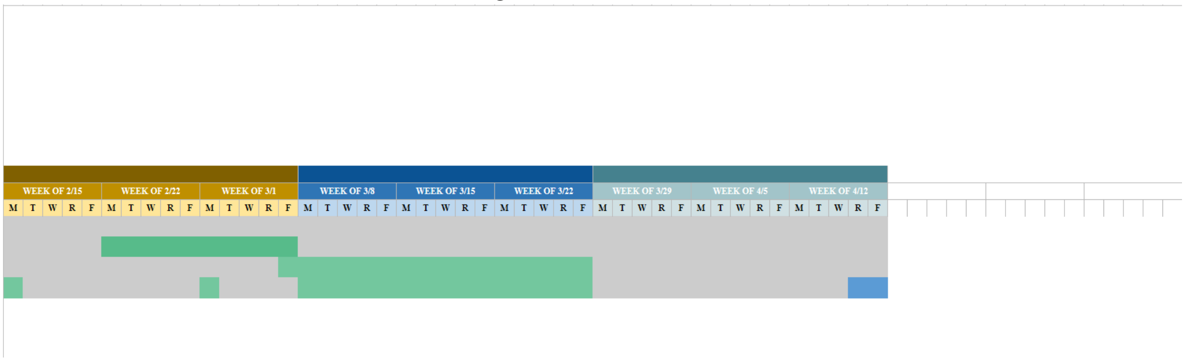

Fig 3: Gantt Chart

Key Lessons

There are two key lessons the team learned from this project. First part is about the technical skill, the team learned how to design, analyze, manufacture, and test an aircraft. The Design-Build-Vertical Flight (DBVF) student competition was a multiple disciplinary projet that required lots of collaboration from the different disciplines to put together an aircraft. The competition also required reports to summerize and document work done. The final report and the final presentation of the competition make each team member learn how to unify and express the project content. Which ties into a second lesson about soft skills. The team learned project management skills such as time management, a project timeline, and how to mitigate the inevitable disasters were essential skills for success. Due to COVID-19 restrictions and not everyone being in Corvallis, managing skills became all that more important, necessary, and difficult to keep the project progressing.