AE 3340 Summative Report

Reflection on System Engineering Concepts with Respect to UAM System

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Fall 2020

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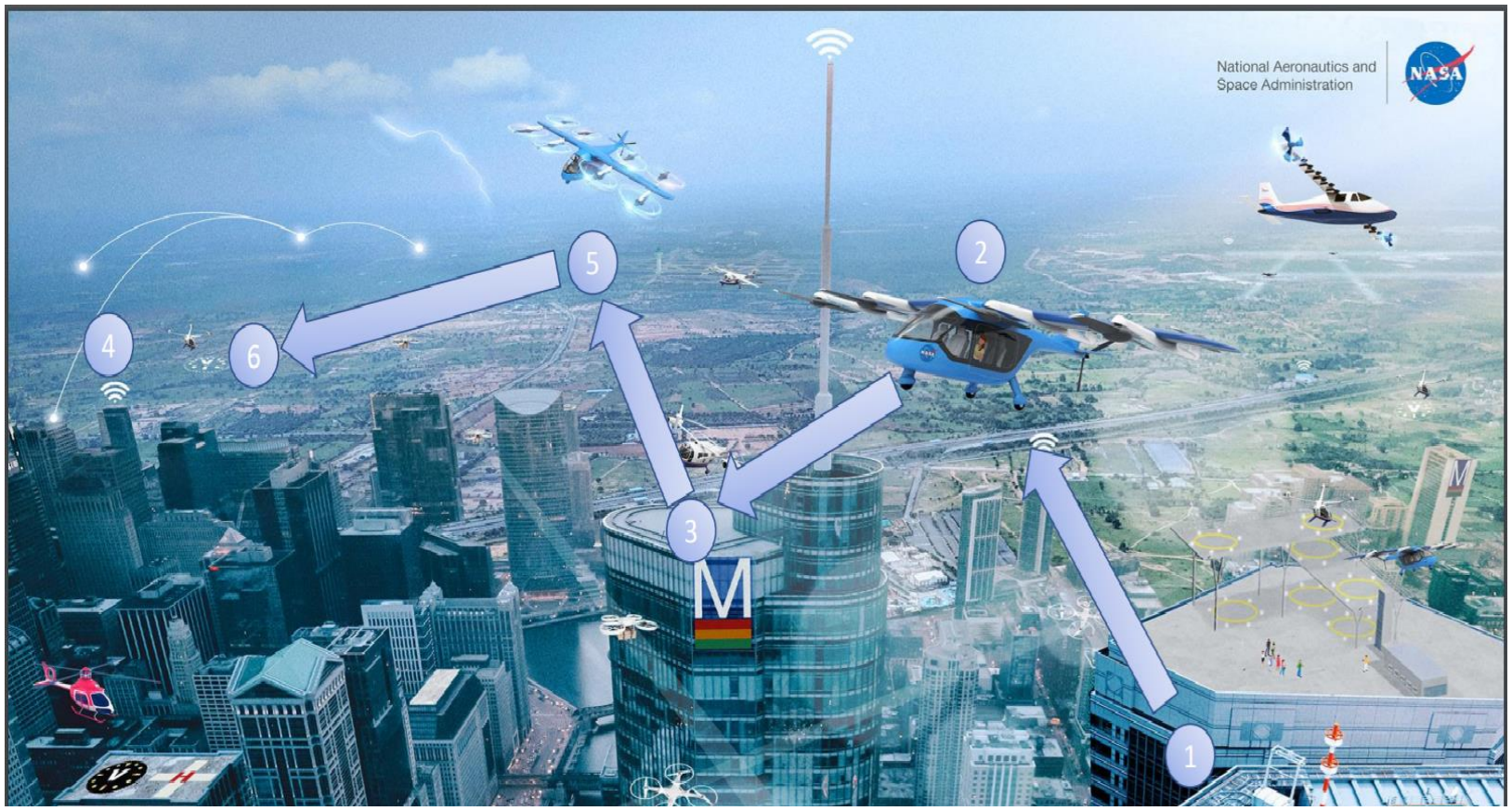
Task 1. Revisiting CONOPS for eVTOL Business



Source: Assignment 1

https://www.nasa.gov/aeroresearch/one-word-change-expands-nasas-vision-for-future-airspace/

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CONOPS For Passenger and Cargo Mission

1

eVTOLs charge overnight at a vertiport while cargo is loaded. In the morning, passengers board the vehicle shortly before takeoff.

2

In flight experience designed to hold up to 6-8 passengers. Flight comfort is a major priority, and flight paths are designed to minimize turning angles and noise.

3

Intermediary stop within the city drops off a few passengers, and some cargo is unloaded. New passengers board the vehicle. The eVTOL then takes off and continues toward the suburbs.

4

Local Air Traffic Control center manages eVTOLs along with helicopters and low-altitude planes within the area.

5

Upon arrival to the nearby suburbs, the eVTOL drops off some of the remaining passengers and cargo at one of the few vertiports up to 50 miles away from downtown.

6

The final scheduled stop is made at another suburban vertiport. After the vehicle is unloaded, it will be charged back up. Once fully charged, the eVTOL will either begin another scheduled flight or wait on an on-demand order.

Edits To CONOPS Description

Source: Assignment 1

- **Step 1**: This step originally did not consider the possibility of on-demand flights that may be requested at any hour of the day. While most eVTOLs would rest at the charging station overnight, a select few vehicles shall always be ready for customer requests at each Vertiport location.
- **Step 2**: Based on requirements regarding speed and timeliness of passenger and cargo trips, turning angles and noise will be minimized to a limited extent while still performing trips in the designated time window.
- **Step 4**: Add the fact that Air Traffic Control may need to direct eVTOLs away from their current flight path depending on other vehicles operating within the local airspace. This could in turn delay flight timings or alter the order of passenger pickups/dropoffs.
- **Step 6**: This step does not take into account the limits on landing space at each Vertiport location. Instead of simply sitting at the landing pad when not in use, eVTOLs will need to move to a storage room near the pad where they will be charged.

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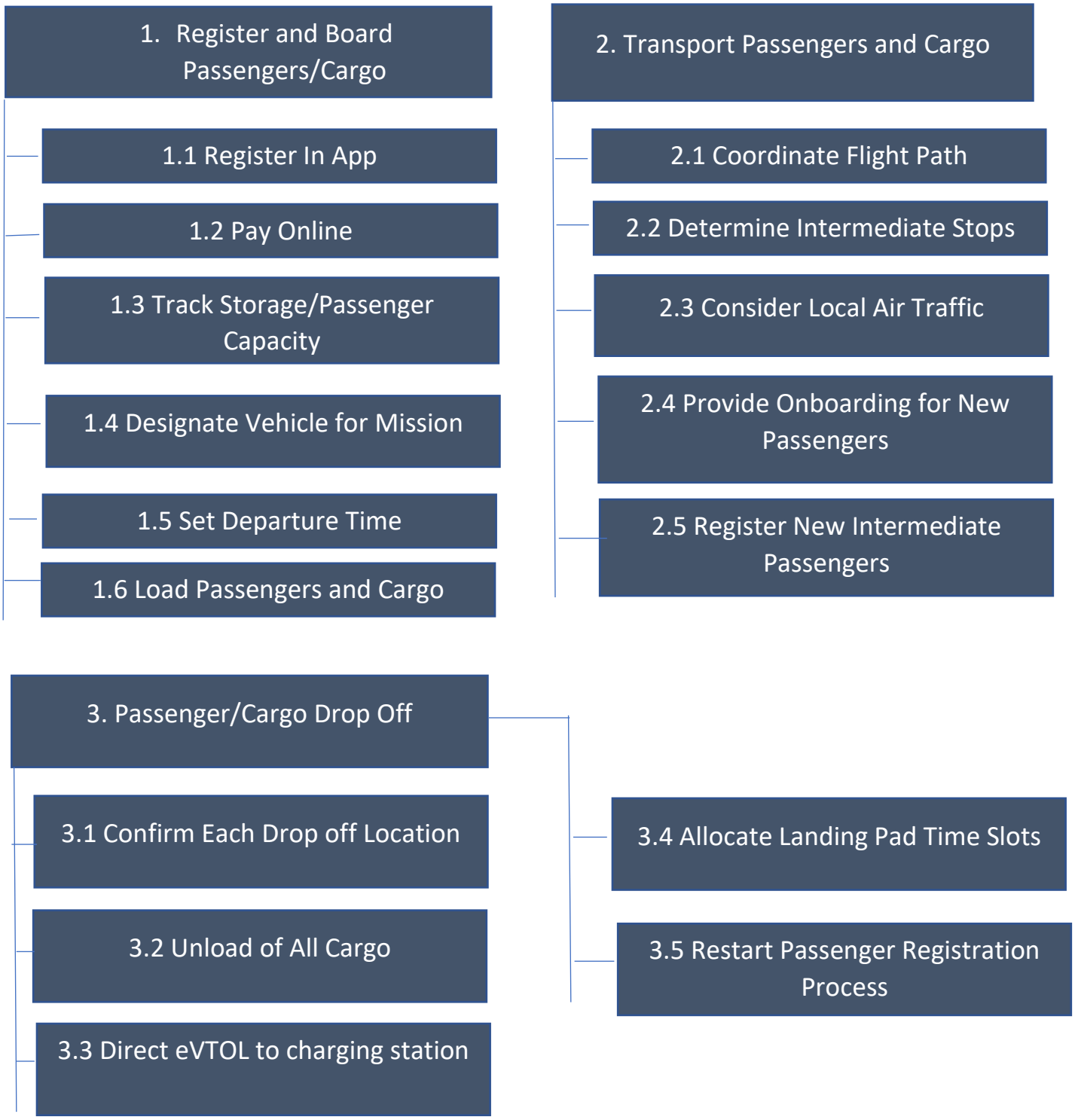
Task 2. UAM Functional Analysis

Functional Architecture Diagram for UAM Passenger/Cargo Transport System



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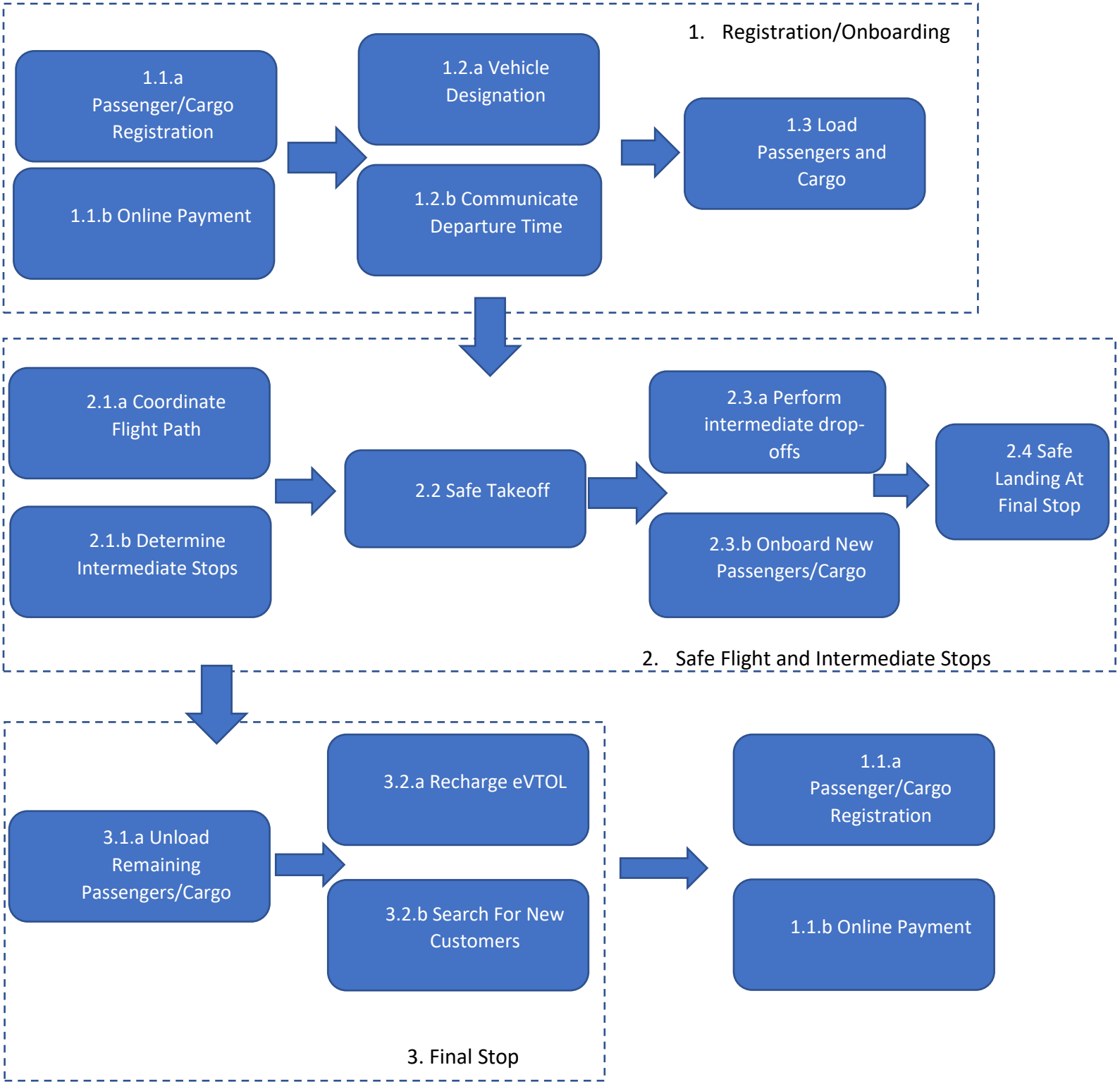
Functional Flow Block Diagram for eVTOL Operation



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Description of Functional Architecture

Primary functions of the eVTOL company can be broken up into three high-level functions. The first involves the general process of registering and boarding passengers/cargo. An online app will carry out the registration of passengers. This allows for all payments and passenger logistics to be processed well before takeoff time. A specific vehicle shall be designated for each mission based on the takeoff location. Crew members will be available to confirm passenger arrival and load up the vehicle with cargo.

The most important high-level function of the mission involves safely transporting passengers and cargo to each stop. Local air traffic control will coordinate flight paths based on nearby air traffic. Intermediate stops will be determined in between the initial and final point based on desired drop-off locations, and onboarding/registration for new passengers will be provided at each intermediate stop.

The third primary function is to efficiently unload passengers and cargo and minimize 'down time' between subsequent missions. Crew members will quickly unload cargo at each stop. Additionally, landing pad spaces and availability shall be coordinated by air traffic control to allow for efficient landing times. After a final stop, the eVTOL will be directed off the landing space and moved to a nearby charging station. While the vehicle is charging, the registration process will reopen within the app, allowing new customers to sign up for a flight.

Description of Functional Flow Block Diagram

The first sequence of events for an eVTOL mission involves registering customers/cargo and receiving payment through an online app. Customers shall be registered well before take-off time in order to ensure a vehicle can be designated for the mission.

Next begins the loading stage of passengers and cargo. By this time, information on all necessary stops will be acquired, and air traffic control will provide a safe and efficient flight path for the mission. The vehicle will briefly take off and head towards each intermediate stop, dropping off and picking up new passengers at specific locations.

When the vehicle reaches the final stop for the mission, passengers and cargo will quickly be unloaded, and the vehicle will move to a charging station to free up the landing pad. While charging, registration for another flight will open up, and the vehicle may be designated for another mission once charging is finished. At this point, the sequence of the FFBD will repeat.

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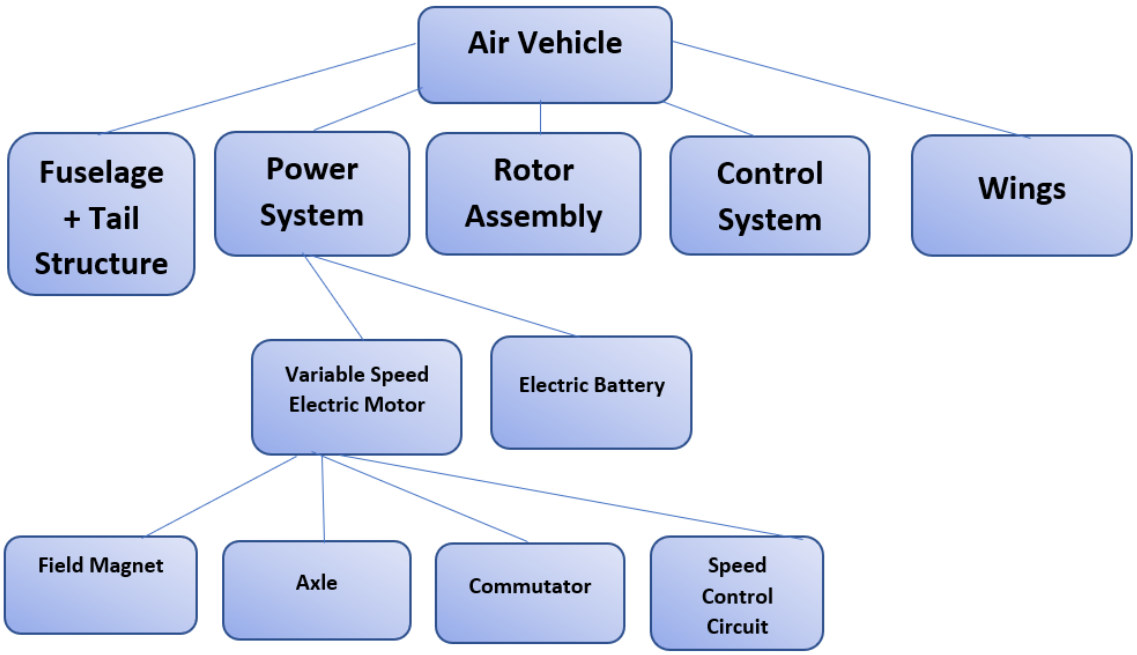
Tasks 3/4 . Product Breakdown Structure Analysis.



Source: Assignment 4

Function 1: The loading of passengers and cargo (1.6) Is satisfied by the Fuselage + Tail Structure Element of the eVTOL. The fuselage is sufficient to contain enough space to store 500 lbs of cargo in addition to up to 8 passengers.

Function 2: Coordinating a flight path for the mission (2.1) is satisfied by the control system of the eVTOL. The vehicle shall autonomously coordinate a flight path based on information provided by air traffic control. The control system will be responsible for converting this predetermined flight path to inputs for the power system and rotors.

Function 3: Performing a safe takeoff (2.2) is satisfied by the simultaneous function of the power system and electric battery. The power system's motor shall provide sufficient power to the rotors to lift off the ground at a steady rate, and the battery will provide sufficient power to generate desired thrust from the rotor assembly.

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Level 1 Requirement: Vehicles shall be able to transport up to 500 lbs of cargo and a maximum of 8 passengers a distance of 40 miles in under 15 minutes.

-This requirement relies on the functionality of both the structure of the vehicle to adequately support the required loads, in addition to an adequate power system to provide the necessary flight speed. Multiple level 2 systems must work simultaneously to achieve this requirement.

Level 2 Requirement: Aircraft propulsion shall be sufficient as to transition to and maintain 175 mph cruise during longer flights to the suburbs from a main metropolitan area.

- This requirement relies on the level 2 'power system' to be able to provide specific thrust during forward flight of the eVTOL. Traveling at a speed of 175 mph would additionally allow the vehicle to satisfy the parent requirement of travelling 40 miles in under 15 minutes when necessary.

Level 3 Requirement: The variable speed electric motor shall be able to perform acceleration and deceleration from max cruise speed of 175 mph to vertical hover and vice versa within a period of 6 seconds as to provide efficient yet comfortable speed changes during flight.

- This level 3 requirement is based on the needed effectiveness of a variable speed electric motor to serve as the main element of the eVTOL's power system. The electric motor must operate within a sufficient range of RPMs as to provide the desired change in thrust within the specified time interval.

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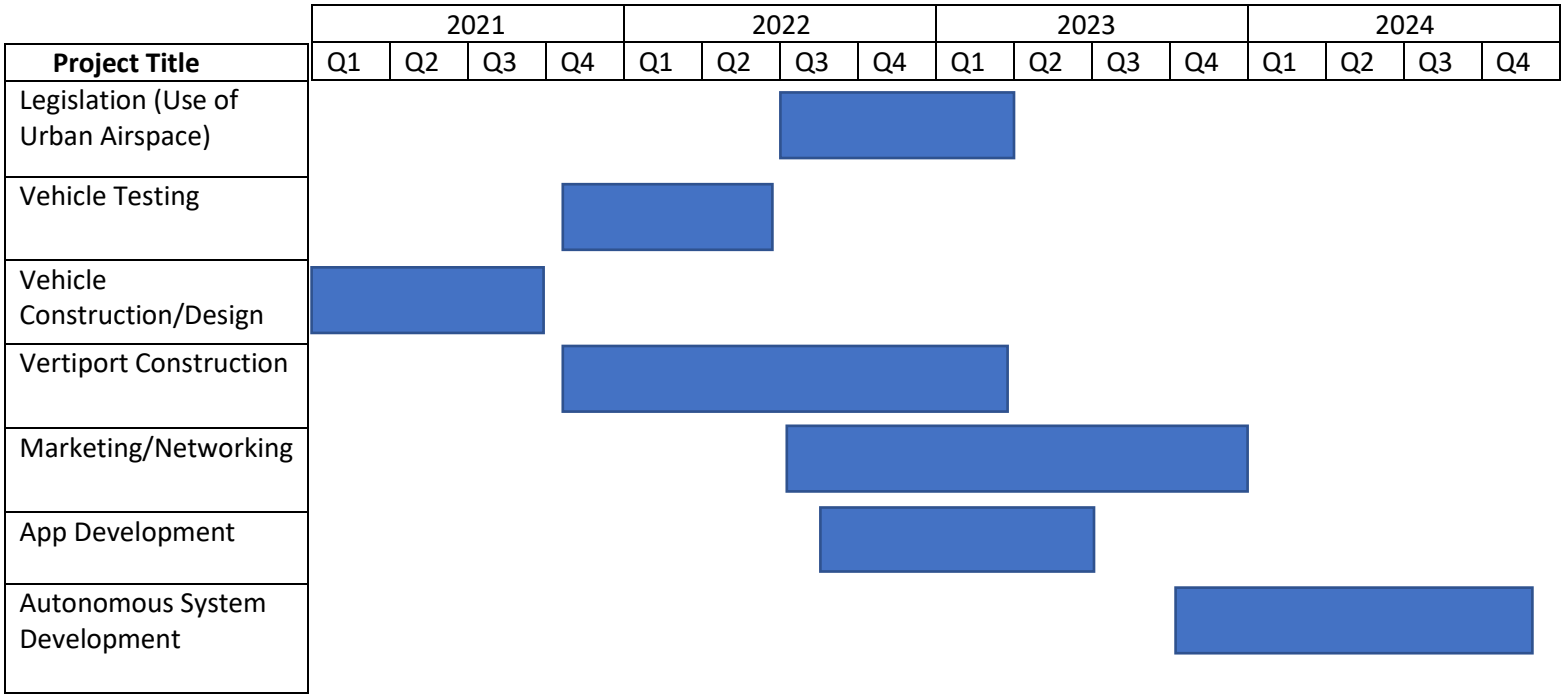
Task 4. Gantt Chart Detailing eVTOL Program Phases



The Gantt chart above depicts key operations that will be implemented within the next four years to ensure timely and complete development of infrastructure and systems that will be required for operation of the eVTOL business. Beginning in 2021, the first 9 months of the year shall be devoted to vehicle design and the construction of enough eVTOLS for testing and operation at at least one Vertiport location in the future.

Testing of the eVTOLs will begin near the end of 2021 and last until halfway through the next year . Vertiport construction in a few select cities will begin around the same time. During the construction of Vertiports, all potential legal issues regarding the use of public airspace within the urban areas we plan to operate within will be cleared. Additionally, physical and digital advertising of the company will begin to see widespread placement. A team will be simultaneously working to develop a phone app, which will serve as the medium for providing all customer services.

Nearing the end of 2023, certain Vertiports will be open for service in a select few cities throughout the country. As soon as vehicles are in the air, flight data will begin to be taken from each flight to work towards eventual autonomous flight. This development is expected to run well into 2024 and beyond, as certain safety requirements shall be met before the widespread implementation of autonomous flights.

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Task 6. Systems Engineering Reflection

Before taking systems engineering and design, I was inclined to believe that every aspect of engineering constated solely of rigorous mathematical formulas and calculations. Learning about systems engineering was a great experience for me, as the topics covered in this class have immediate real-world connections. Concepts such as functional analysis, CONOPS, and requirements writing give insight as to what exactly the goals are with a project, what customer needs need to be met, and what functions must be carried out to achieve the necessary requirements. This class gives concrete details as to why we, as engineers, make certain decisions regarding both physical designs, as well as the design of a business model as a whole. Because I am interested in both the technical and logistic aspects of engineering, I will definitely be considering systems engineering as a career moving forward.

The topic I found the most interesting was Technology Readiness Levels, Risks, and Margins. As engineers who are developing potentially new and groundbreaking technology, there will always be heavy risks when venturing into unknown territories regarding new technologies. However, no progress will ever be made without taking risks at certain times. The concept of risk and margin analysis allows us to take calculated risks based on the possible value of the outcome and the potential consequences of failure. I think the most difficult concept in the class for me was optimization, simply because I had to grasp a strong understanding of the concepts behind why certain optimization techniques are performed. However, once I had a conceptual understanding of mathematical optimization methods, performing the calculations and solving problems proved not to be terribly difficult.

References

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