## 1.3 Functional Decomposition

### Action and Outcome

The expected outcome of the project is to achieve 4 seconds of microgravity for a 3U CubeSat class payload. Our goal is to accomplish this by designing an aerodynamic air vehicle with thrusters, a parachute deployment system, storage for the payload, and a means of recording data. A goal is to store the payload and parachute while allowing access to both, securing the necessary payload, and assuring the weight of both is supported. This allows for access to the data necessary to determine the gravitational quality and prevents damage to the accelerometer. The system also needs actuation by means of a motor or thruster attached in a way that minimizes drag force. This grants the microgravity event enough time to meet the expectation of 4 seconds by counter-acting the effects of drag. The system needs to deploy a parachute for damage minimization and successfully accomplish a microgravity event.

### Explanation of Results

The information used to create our functions originated from the product specification documents and interviewing the sponsor's liaison. From these specifications and needs, we developed our functional decomposition to get a better idea of what our design will need to do. The hierarchy chart was developed to illustrate the functions and relationships between them. The main systems are divided into subsystems and later divided into the specific functions, as seen in Figure 1. A cross-reference table (Table 1) was developed to show the impact the functions have on the various systems involved. The functions that involve more than one system are considered crucial to the design, as focusing on these functions can provide added efficiency to the project.

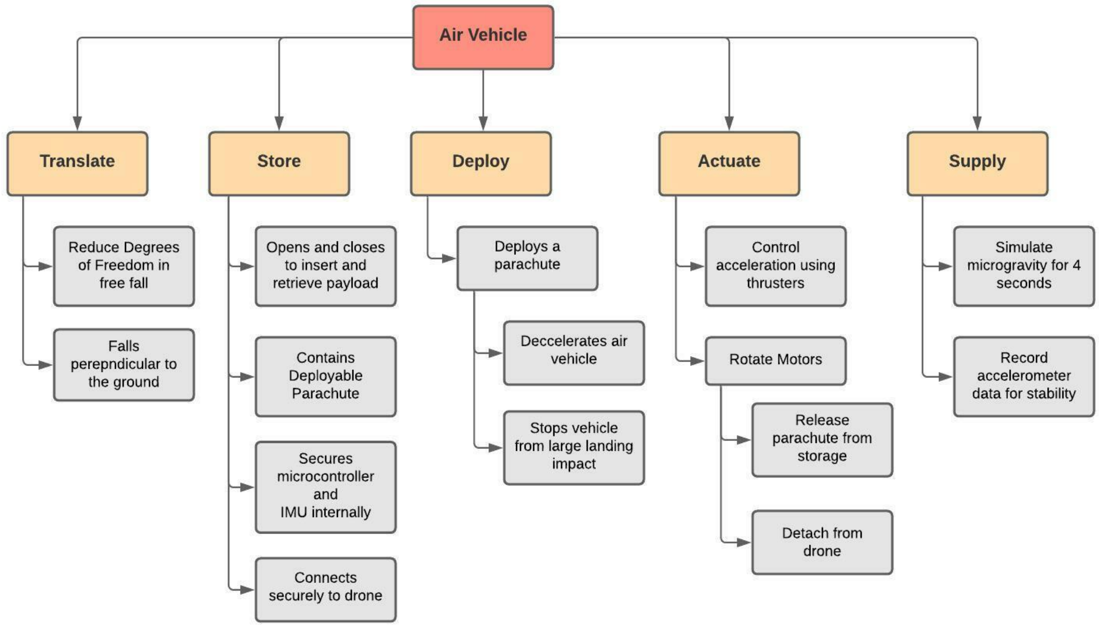


Figure 1. Functional Decomposition Flow Chart.

**Connection to System**

Most of the functions impact at least 2 systems, with only 2 functions affecting 3 systems; the first of which is ensuring the air vehicle can stabilize the payload, which affects the translation system, storage system, and deployment system. The payload must be secured and stabilized through each of these stages of the flight to gather accurate data and ensure high-quality microgravity. Detaching from the drone is also highly important for the deployment system because deployment cannot happen if it does not fulfil this function. The actuation and translation systems are affected by this because the quality of deployment affects the kind of actuation needed, and the translation that is obtained. These two functions must be a central focus during design because failure to accomplish these functions causes three systems to fail.

The air vehicle must be able to support the CubeSat 3U payload. The systems involved in supporting the payload are the storage system, which will include the house for the payload, and the translation system, because the ability to support the payload well impacts the ability to translate the way it will be designed.

Although preventing damage upon impact only affects two different systems, this function needs to be a central focus of the design because this may prove difficult based on the feedback gathered. Failure to prevent damage upon impact could render the entire project unsuccessful. The translation rate must be decreased before touchdown; therefore, the translation system must be involved. The deployment system is also important during this function because the parachute must be deployed to help decrease speed.

The thrusters must initiate at deployment, engaging the deployment system, and they must aid in translation, involving the translation system. This function carries high importance because it involves the deployment system, and it includes the ability to create and maintain microgravity. Deployment of the parachute aids in the function of preventing damage on impact, but it also involves the deployment system and actuation system. The actuation system is involved because the parachute must be deployed with actuators.

Accessing the payload is important because that is how data will be gathered. The storage system is involved in this function because it must include an entrance and exit. To accomplish the microgravity event necessary, the vehicle must be accelerated using the actuation system and affecting the translation system. The function of reducing the degrees of freedom must also be done using the actuation system, thus affecting the way the system translates (translation system).

Another important function that only affects two systems is for the air vehicle to imitate microgravity, this is one of the main criteria to determine success or failure. The actuation system and translation systems are involved in this function. The air vehicle must be able to record data, the data collection device must be stored with the payload, engaging the payload system. The collection system is also involved in this function, as the data collection device must be retrieved. The air vehicle must counteract drag force using the actuation system and the vehicle translation system.

The only function that does not impact multiple systems is the deceleration of the air vehicle. The system involved in this function is the deployment system, since it must deploy the parachute to aid in deceleration.

Looking at the functional decomposition from a systems perspective, the deployment, actuation, and translation systems each contain 7 functions. While the number of functions does not directly correlate to importance, it does mean that the development of these subsystems will take the most time.

Table 1: Functional Decomposition Cross-Reference Table

| | Storage | Deployment | Actuation | Translation | Collection | Frequency |
|---|---|---|---|---|---|---|
| Supports payload | | | | | | 2 |
| Prevents damaging impact | | | | | | 2 |
| Decelerates air vehicle | | | | | | 1 |
| Initiates thrusters | | | | | | 2 |
| Deploys parachute | | | | | | 2 |
| Allows access to payload | | | | | | 2 |
| Accelerates air vehicle | | | | | | 2 |
| Stabilizes payload | | | | | | 3 |
| Reduces DOF | | | | | | 2 |
| Imitates microgravity | | | | | | 2 |
| Detaches from drone | | | | | | 3 |
| Records data | | | | | | 2 |
| Counteracts drag force | | | | | | 2 |
| Frequency | 4 | 7 | 7 | 7 | 2 | 27 |

**Smart Integration**

Most of the functions relate to 2 different subsystems, while a couple are in 3 and only 1 is independent. Instead of a function being specialized for 1 subsystem, it plays a role in multiple. The first function, supports payload, is in both the storage and translation systems because the payload needs to be securely stored in order to read accurate data, and where the CubeSat is stored can affect the translation of the air vehicle. The goal is for the degrees of freedom of the air vehicle to be reduced to one, because we want the air vehicle to travel straight down. If the payload is improperly stored, the center of mass can change and affect the flight path of the air vehicle.

In order to imitate a microgravity event, all acceleration on the payload must be about zero ($10^{-6}$ G). Stabilization of the air vehicle is key to creating a successful microgravity event. That is why this function is part of 3 other subsystems. The payload must be stored in a way where the center of mass remains on the central axis. Any deviation could cause rotation around other axes, creating acceleration disturbances. The parachute deployment system must keep the vehicle stabilized as it decelerates because if the vehicle remains unstable during deceleration, it could cause the parachute to not function properly and damage the air vehicle on impact. The translation of the air vehicle is also integrated within the stabilization sub-system because to get the air vehicle to translate perpendicularly to the ground, it must remain stabilized throughout the entire flight.

The detachment from the drone is also highly important because if the initial detachment causes our air vehicle to be released at an angle, the air vehicle's flight path could stray. This affects the translation of the air vehicle, actuation, and deployment. To ensure a clean detachment, the eyebolt that is used as the attachment/detachment point must be perfectly aligned with the center axis of the air vehicle. Any deviation and it could cause an angled release.

Preventing a damaging impact is important because if the air vehicle is majorly damaged on impact, it could destroy the data for the microgravity event. For the impact to be minimized, deployment of the parachute is paramount. This was demonstrated by past teams whose parachutes did not work, meaning no data was able to be collected. The translation of the air vehicle reduces the damage upon impact because the best chance for survival upon impact is for the nose of the air vehicle to be the first part to hit the ground.

Another important function is the initiation of the thrusters which are needed to overcome air resistance during free-fall. Also, they will play a role in decelerating the air vehicle. That is why it is part of the deployment and actuation subsystems. The initiation of the thrusters is of high importance because to create and maintain a microgravity event for 4 seconds, thrusters are required, and to keep the air vehicle from being destroyed upon impact, deceleration of the air vehicle is necessary.

The air vehicle must give easy access to the payload. Part of the competition is to be able to put in and take out the payload, including an accelerometer for data recording. This must be done within a timeframe, and if that requirement is not met, points will be deducted.

Accelerating the air vehicle is a part of the actuation and translation subsystems because the thrusters must accelerate the air vehicle to the ground in part causing the translation to increase. Accelerating the air vehicle toward the ground is important because that is the best method of overcoming drag.

Stabilizing the payload is a member of 3 different subsystems, making it one of the more important functions. The air vehicle should not allow any involuntary movements to the payload because that is a part of the competition criteria. The payload will be stored using the storage system on the air vehicle and must be stabilized from deployment through translation to successfully complete the function. Reducing degrees of freedom during the flight must be done with actuation. Since the function's goal is to reduce degrees of freedom during the flight, the translation system must be involved as well.

Performing at least 4 seconds of microgravity is highly important to this project making which elevates the importance of the systems involved in this function. Imitating microgravity must be done at deployment using actuation to perform this function, thus including those two systems.

The second 3 system function, detaching from the drone, will be done using the deployment system using a sensor mechanism to release it from the drone. The actuation subsystem must be involved because of the because the release from the drone will be initiated with an actuator. The translation system is involved because at the instant the air vehicle detaches from the drone the translation system must be initiated.

Recording data is a member of the storage system and the collection system, the data collection device will be stored with the payload, therefore, involving the storage system. Once the data has been recorded the data collection device must be obtained post-flight, through the collection system. The final function, counteracts drag force, will be done using the actuation systems thrusters to accomplish the specified microgravity event. The translation system will be involved because that affects the translation speed, the actuation system and the translation system will frequently perform functions simultaneously.

**Function Resolution**

The air vehicle must provide 3-4 seconds of high-quality microgravity by using thrusters to accelerate the vehicle toward the ground, thus counteracting the drag force acting on the vehicle. The microgravity event will be initiated by detaching from the drone and initiating the thrusters. The air vehicle will be able to store the required payload, while allowing reasonable access to the payload before and after flight. During flight, the degrees of freedom must be reduced to one stabilize the payload, ensuring a high-quality microgravity. Once the desired microgravity event has been accomplished, the air vehicle must decelerate using actuation and parachute deployment. Deceleration aids in preventing damage upon impact, guaranteeing that the data collection device stored in the payload can be recovered unharmed.