1.5 Concept Generation

For the generation of concepts, to find a solution fit for our customer's needs, our team found it helpful to ideate surrounding different subsystems of the air vehicle and their required functions. These necessary functions were predetermined by the competition requirements. The subsystems include the air vehicle's body/external aerodynamic factors, the method of storage and monitoring of the payload, the method of deceleration after microgravity event, and the method of combatting air resistance during the microgravity event. We will provide concepts from each of these subsystems to provide a finalized, whole-system concept for each of the medium and high fidelity concepts defined below.

Methods of ideation our team utilized in generating our 100 concepts were brainstorming, biomimicry, and forced analogy. The 100 concept ideas can be found in the appendix. The aim of these concept generation tools was to limit bias and produce creative, original ideas. To brainstorm, the team had a free-flowing conversation where all ideas were accepted and considered, no matter how wild. Each member was included in the conversation and was able to express their ideas. For biomimicry, animals in nature, particularly birds, were used as inspiration for components of our design. Looking at birds, who have the most experience in aerodynamics, helped our group direct and inspire new concepts. Finally, forced analogy was used by writing a random word on a piece of paper and attempting to vocally relate that word back to our project's scope. In this verbalized stream of consciousness, many ideas emerged that would not have been discovered otherwise.

Table 3: Medium Fidelity Concepts

Concept Number	Subsystem	Solution
1	Body/external aerodynamic factors	Pointed nose and long body made with fiberglass.
	Storage & monitoring of the payload	Use suction cups to hold the payload and the camera in place within the interior of the vehicle.
	Deceleration after the microgravity event	Parachute stored in a box on the tail, with a covering that will break off when released by a servo motor.
	Air resistance combatting	Thrusters protrude from the sides of the external body and use compressed CO_2.
2	Body/external aerodynamic factors	Small fins on both ends (nose and tail) of the body, along with the side. Make the exterior body with fiberglass with a bullet-shaped nose and body.
	Storage & monitoring of the payload	The camera will be placed on the side of the pebbles to get a clear shot. Side department on the air vehicle will allow access to the payload.
	Deceleration after the microgravity event	Large parachute made of Kevlar with woven nylon cord and a stabilizing chute at the end. Parachute will be deployed at a predetermined altitude with a gas inflation system and will be stored in the front.
	Air resistance combatting	Thrusters within the body and have exits flush with the tail of the air vehicle. The thruster system will use compressed CO_2 canisters. Servo motors to control the amount of propulsion and the exiting fluid's speed. Teensy will be used as the microcontroller.

3	Body/external aerodynamic factors	Air vehicle body is long and thin. Vehicle has helical features to make it spin for stability.
	Storage & monitoring of the payload	CubeSat stabilized on an internal gyroscope. Teensy used as the microcontroller for the closed-loop feedback system to control the propellers.
	Deceleration after the microgravity event	Ballute used instead of a parachute. Gas inflation system used to fully deploy the ballute.
	Air resistance combatting	Propellers on both the nose and tail of the body.
4	Body/external aerodynamic factors	Exterior geometry mimics a water droplet, with a blunt nose and a thin tail.
	Storage & monitoring of the payload	Magnetic latch on the tail to access the payload, with padded storage compartment.
	Deceleration after the microgravity event	Spring-loaded parachute compartments on each side of the body, and a third remote-activated parachute.
	Air resistance combatting	Electric propulsion system with propellors on the tail of the air vehicle.
5	Body/external aerodynamic factors	External body made of steel and smoothed with sandpaper. Fins on the nose, tail, and sides of the body.
	Storage & monitoring of the payload	GoPro (the heaviest of the payload) in the nose end to account for the parachute weight.
	Deceleration after the microgravity event	Parachute deployed at a predetermined altitude, made of canvas, and attached to the body with copper wires.
	Air resistance combatting	Wide, umbrella-like object attached to the tip of the nose to create a slipstream for the body.

The 5 medium fidelity concepts we have selected are comprised of the four different subsystems. We found it helpful to split the air vehicle's functions into the four categories shown above and place our ideas within them. The medium fidelity concepts listed above are the ideas from our 100 concepts list that are valuable and partially fulfill the necessary functions.

The first medium fidelity concept consists of a long external body with a pointed nose, made of fiberglass. This material is beneficial because it reduces drag, but it is also easily damaged. The internal payload is to be supported by suction cups in this concept. This fulfills the goal of being low cost but only partly ensures the safety of the payload. For the parachute, it will be stored in a box on the tail and deployed by an electrical motor which will release the lid of the box. Finally, the air thrusters will be mounted onto the exterior of the body on the sides and will be fueled with compressed CO_2.

The second medium fidelity concept will use a bullet-shaped geometry made of fiberglass and will also have fins on both the nose and the tail of the vehicle for stability. The payload will be securely fastened in the air vehicle with the GoPro placed horizontally for a clear view of the payload. There will be a side hatch on the air vehicle and will allow for access to the payload. A gas inflation system will be used to make sure the parachute opens fully. The parachute will consist of one large chute and one small stabilizing chute at the end; both chutes will be made of Kevlar while the cord will be made of woven nylon. The parachute will be opened at a predetermined altitude and will be stored in the nose. Thrusters will be held within the air vehicle with exits flush to the end of the body. The thruster system will use compressed CO_2 to accelerate the vehicle. A Teensy will be used as the microcontroller to determine how much CO_2 needs to be released and at what speed. These functions will be controlled by servomotors.

The third medium fidelity concept will have a long, thin external body that will have helical features, causing the vehicle to spin. The spinning of the air vehicle will ensure the body translates towards the ground, rather than veering off to the side. The payload will be on an internal gyroscope to keep it from spinning with the exterior. A ballute will be used instead of a parachute and will use a gas inflation system for deployment. Propellors will be attached to the nose and the tail of the vehicle and will be controlled by a Teensy.

The fourth medium fidelity concept has the external geometry of the air vehicle shaped like a water droplet with a blunt nose. This concept pulls from the aerodynamic way in which rain drops travel through the air. This concept contains a padded storage compartment, to minimize payload damage. The storage compartment contains a magnetic access latch for ease of payload access after the data has been recorded. The air vehicle will have two parachutes on either side of and a third, remotely activated, parachute, for added insurance. This concept contains an electric propulsion system with propellors for actuation, providing a low-cost, reliable actuation option.

The fifth medium fidelity concept consists of an external body made of steel, which is strong but also heavy. The body will be smoothed with sandpaper to reduce air resistance. There will be fins attached to the exterior on the nose, tail, and both sides, which stabilizes the air vehicle. In the internal body, the GoPro will be placed towards the nose with the pebble box right above it; this may skew the data, as the movement of the pebbles will not be as clear. However, this will counteract the weight of the parachute that will be stored within the tail end of the body. The parachute will be made of canvas, which is relatively heavy, and will be attached with copper wires. It will be set to deploy after falling a predetermined distance from the drone. There will be an umbrella-like object attached to the outer portion of the nose that will create a slipstream for the body that reduces air resistance.

Table 4: High Fidelity Concepts

Concept Number	Subsystem	Solution
1	Body/external aerodynamic factors	Four symmetrical wings on the tail with a missile-like geometry. Material will be carbon fiber.
	Storage & monitoring of the payload	Place the payload on an internal track with the GoPro rigidly mounted to the platform that is free to move along the length of the vehicle.
	Deceleration after the microgravity event	Large parachute with its own compartment within the body that deploys based off IMU data.
	Air resistance combatting	Use a Teensy to run feedback control to send compressed air through tubes to 3D printed nozzles, monitored by valves operated by servo motors.
2	Body/external aerodynamic factors	Make the exterior body with nylon and give it a long nose. The body has fins on the tail end.
	Storage & monitoring of the payload	Place the GoPro, accelerometer, and light source horizontally even with the pebble box in the center of the CubeSat.
	Deceleration after the microgravity event	Use a gas inflation system to ensure deployment at the correct time/height.
	Air resistance combatting	Have a bullet-shaped nose on the air vehicle to cut through the air. The body length-to-width ratio is maximized.
3	Body/external aerodynamic factors	Air vehicle body is long and thin. Vehicle has helical features to make it spin for stability. Exterior made from aluminum, with symmetrical fins on the tail and the nose.
	Storage & monitoring of the payload	Make the sides of the pebble box not facing the camera opaque to prevent any internal reflections in the video.

	Deceleration after the microgravity event	Three parachutes with Kevlar cords deployed from the tail of the air vehicle
	Air resistance combatting	Use an electric propulsion system, with propeller actuation to increase descent rate.

The first high fidelity concept has an exterior geometry to mirror a missile and is made of carbon fiber. The process of creating the body will include 3D printing a mold and casting carbon fiber with the mold. The tail will have four fins on the back for stabilization. The payload will be secured to a tray running along an internal track of four metal rods that is free to translate up and down the body of the vehicle. The GoPro will be mounted onto the same translating tray to monitor the payload during freefall. The parachute deployment method will consist of an internal compartment that will be spring-loaded to release the parachute from the tail of the vehicle. The timing of deployment will be based off the IMU data, once a successful microgravity event duration has been reached. To combat air resistance, thrusters will be placed flush with the tail and be controlled through a feedback loop. The feedback loop will run off the acceleration value and drive the error of that value to zero by controlling the amount of compressed air to eject through the nozzle. The microcontroller running this, as well as reading the IMU data, will be a Teensy 3.5 and the method of thrust will be tubes with valves controlled by servo motors.

The second high fidelity concept consists of an exterior body made of nylon, minimizing weight without sacrificing strength. The nose will be long and bullet-shaped to reduce air resistance. There will be fins on the tail of the body to stabilize the air vehicle without creating excessive resistance on it. Within the body, the pebble box will be attached to one side in the center of the CubeSat with the GoPro, accelerometer, and lighting source all attached to the other side. This will grant all three components an unobstructed view of the pebbles being recorded. A gas inflation system will be used to deploy the parachute from within the body. This deployment system will be activated at a predetermined time after it is released from the drone. To reduce the air resistance on the body, it will have a large length-to-width ratio. Drag force is dependent on cross-sectional area, so the smaller the cross-sectional area, or width, the smaller the air resistance.

The third high fidelity concept for the project has an exterior with a long and thin shape to minimize air resistance. The body has helical features that will cause the air vehicle to spin for air stability, as well as having fins on the nose and the tail for added stability. The body will be made of aluminum for the high strength, low-cost option. As for the storage compartment, the sides of the box containing the pebbles that are not facing the camera will be opaque to minimize reflections and improve the quality of data acquisition. This design will use three parachutes, stored near the tail of the air vehicle, for deceleration. These parachutes will have Kevlar chords to ensure reliability. To fight air resistance, the air vehicle will use electric propulsion with propellors as a reliable, inexpensive method of providing thrust actuation.