CargoHopper

by Jozef Baets (user oemlegoem)

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General

The CargoHopper uses 4 vertical lift props/motors arranged on 2 booms placed underneath the main wing. A forward thrust prop/motor is placed in the tail of each boom for forward flight. A cargo box containing the batteries can be loaded/unloaded vertically below the fuselage, or sideways. The CargoHopper has an aerodynamic design with a high aspect ratio wing and a fuselage with low drag.

Safety concept

The CargoHopper has a twin tail design. Each tail has a forward thrust prop/motor. If one motor fails, the CargoHopper can fly with the remaining forward prop/motor and continue the mission or proceed to a safe landing.

The CargoHopper has landing gear and can land like a normal wing plane in case a vertical lift motor fails, using the forward thrust props.

If a vertical motor fails, in order to maintain balance, the vertical motor opposite of the CG, shuts down as well. In such a situation, it becomes a “bicopter”and has no stability control. The forward thrust props/motors can provide balance by yaw, roll and pitch control from the air flow over the horizontal and vertical stabilizers, and differential prop speed.

The CargoHopper has a flight termination parachute attached to the main structural elements near the Center of Gravity CG.

Optionally, but not shown in the drawings, an additional folding prop/motor can be located in the tail of the fuselage and activated in case one or two forward prop/motors fail.

Cargo concept

The cargo concept allows for loading/unloading from below the fuselage and sideways. Below the fuselage loading/unloading assumes an installation below surface level as the clearance between the bottom of the fuselage and ground level is not sufficient. Alternative would be to lift up the aircraft. It should be also possible to load with a mechanism from the bottom, and manually unload sideways.

Battery concept:

A requirement was for easy and fast replacement of the battery pack(s). In the CargoHopper concept, the batteries are attached to the front of the payload box. That way, the batteries are loaded/unloaded together with the payload. This would also allow automatic loading/unloading.

The front towards the nose of the plane was chosen for the battery location, in order to balance the weight in the tail of the CargoHopper, so that the center of gravity CG is a small distance behind the leading edge of the wing and the Static Margin is sufficient. The cargo itself is located at the CG so that flying without cargo does not affect the balance of the CargoHopper.

The payload box is easiest filled when the maximum dimensions 450x350mm are as seen from above, and the height of the payload is then 200mm. The payload box is then positioned this way into the CargoHopper without turning. That way, the payload is least disturbed by not being turned around. The shape of the fuselage is determined by the payload. Because of this, the fuselage has a lower height than width at the maximum section.

The payload box is weatherproof, and the cargo area open to surrounding. The cargo area is separated from the rest of the fuselage by bulkheads. This setup is simpler than cargo doors that have to be weatherproof.

Aerodynamic concept

Length of one detachable wing is 2m. The wing is attached to smaller wing sections attached to the fuselage. Total wing span is 4.76m, total wing area is 1.406m^2 and AR Aspect Ratio is 16. Aspect ratio is high for low induced drag. This gives then a wing load of 17.8kg/m^2. At the cruise speed of 80km/hr, lift coefficient C_L is then 0.74. The wing profile should then have a C_L of approximately 0.8. At the max speed of 194km/hr, wing profile lift coefficient is then 0.14.

In the design the wing profile MH115 is used which has a low drag at the design cruise speed. Max profile lift coefficient at stall is 1.6 which results in a stall speed of 56km/hr. The wings have a dihedral angle of 2.5° for improved stability during forward flight.

Flight control

The CargoHopper design has enhanced flight control and maneuverability in strong, gusty wind conditions during hovering, take-off and landing. In these conditions, the vertical lift props can generate roll and pitch torque by changing prop speed, but the control force change rate is limited by the motor/rotor inertia. The yaw torque provided by the vertical props is very weak.

The improved flight control in the CargoHopper is provided by using a twin tail design. Each tail has a forward thrust prop/motor and a vertical and a horizontal stabilizer. During windy conditions, with the CargoHopper heading into the wind, the forward thrust props direct air flow over the tail stabilizers. By using different prop speeds, rudder and horizontal elevator action, torque can be generated to provide yaw, pitch and roll motion. Optionally –as is shown in the drawing- the vertical lift prop at the trailing edge of the main wing could be positioned at a slight angle backwards, in order to align with the downdraft of the air flow at the trailing edge of the wing, in forward flight. This would reduce drag during forward flight. During hovering conditions, the trailing lift props would then provide a backward force, which has to be counteracted by the forward thrust props, even when there is almost no wind. This would then be able to provide some control force on the vertical and horizontal stabilizers.

In the CargoHopper design, the backward angle of the rear lift prop is 5°. Vertical lift is not affected, it is still 99.6% of the prop force. The backward angle creates a total force of 1.1kg directed backwards. This force is counteracted by the forward thrust props. Even in windless conditions, the force of the rear prop and the flow over the horizontal and vertical stabilizers can provide additional yaw, pitch and roll control.

Structural concept

Two structural beams are mounted transverse to the fuselage (see drawing). The beam connects the main wing to the fuselage. The booms carrying the vertical and forward thrust props are also fixed to the structural beams. Since the payload is also quite heavy, it would be an advantage if it can attach to the structural beams. The beams are 200mm apart. The flight parachute is 120mm wide and fits in between, and is attached to the structural beams.

Ground handling

On the ground, the CargoHopper can be lifted up by 2 persons. One person handling is achieved by wheels in the rudder of the vertical stabilizer, and on the fuselage, so that the CargoHopper can be rolled into a storage location. The wheels on the fuselage have an aerodynamic slim shape and for simplicity, and are non-retractable.

The main elements are the wings, the booms carrying the lift and forward thrust props, and the fuselage. The wings, booms and fuselage have a length of 2m for easy transport. It is assumed –but not necessary- that the propellers are removed for transport in order to protect the propellers.

Support structure for vertical lift props/motors

This was a difficult design tradeoff. Possible was a design with a thin structure as viewed from above. This provides low resistance for the vertical air flow, but it is structurally weak and the air flow would be disturbed in forward flight by the bulkier vertical motors. I opted for a design with constant cross section outer dimensions for low drag. But at the location of the vertical props, the structure is made by 2 flat plates with free vertical air flow in between. See drawings for details.