# Cargo Hopper

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**Update6 May19, 2016**
Dihedral angle:
The dihedral angle is 2.5degree. The wing is curved. Of course a straight wing is cheaper to manufacture, but I thought I get some points from the community for looks, and from Airbus for stability (dihedral).
I also filed a preliminary frame sheet.

**Update5 May19, 2016**
Main structural element:
Two structural beams are mounted transverse to the fuselage (see drawing). The beam connects the main wing to the fuselage. The boom carrying the vertical and forward props is 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 are attached to the structural beams.

**Update4 May19, 2016**
Cargo concept:
The concept was changed so that loading/unloading from below the fuselage and sideways is possible. 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 unload sideways.
Battery concept:
A requirement was for easy and fast replacement of the battery pack(s). In the CargoHopper concept, the batteries could be integrated into the lid of the payload box. That way, the batteries are loaded/unloaded together with the payload. This would also allow automatic loading/unloading.
Wing profile:
The wing profile was changed to MH115, having a higher maximum lift. This would lower the stall speed to 56km/hr and make transitions easier.

**Update3 May17, 2016**
Hovering and vertical lift:
The rear vertical lift prop is angled backward to align the prop with the downdraft airflow coming from the wing in forward flight, with the aim to

reduce drag resistance. In the CargoHopper design, the angle is 5degrees. 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 rear 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.
Cargo handling:
The cargo is contained in a box with handles, and a lid with a seal against rain. The box is positioned underneatch the wing, and then slides sideways into the CargoHopper. For improved handling, the box can be put on a platform trolley. In the present design, the platform trolley including additional spacers should have a height of 140mm above ground level.
Ground handling:
On the ground, the CargoHopper can be lifted up by 2 persons. One person handling is achieved by putting wheels in the rudder of the vertical stabilizer, and on the fuselage. The wheels on the fuselage have an aerodynamic slim shape and for simplicity, and are non-retractable. Although not incorporated in the present design, this can provide a path towards traditional forward flight take-off and landing.

**Update2  May 17, 2016**
Wing airfoil details:
at cruise speed design point 80km/hr, airfoil Lift Coefficient CL=0.8 @Re=500'000, and CL=0.14 @Re=1'200'000. The airfoil Eppler 66 provides a high L/D=129 at the design point. The drag bucket is wide enough so that drag coefficient remains constant up to 194km/hr (source: airfoiltools.com). See details in picture.
Max CL at stall is 1.4. This would then result in a stall speed of 60km/hr. Vertical lift props have to remain engaged at least up to this speed. This could be too high. I will ask Airbus.

**Update1  May 16, 2016:**
Wing details:
Length of one wing half is 2m, total wing area 1.25m2 and AR Aspect Ratio 12.8. Aspect ratio is high for low induced drag. This gives then a wing load of 20kg/m2. At the cruise speed of 80km/hr, lift coefficient CL is then 0.7. The wing profile should then have a CL of approximately 0.8. At the max speed of 194km/hr, wing profile lift coefficient is then 0.14. In a next step, I will look at wing profiles with high CL/CD at CL=0.8, the drag bucket should still have low drag at CL=0.14, and max CL at around 1.5 for sufficient stall margin.
Lift propeller details:
The lift prop has a diameter of 0.56m or a 22"prop. Disc load is then 25kg/m2. In case one lift motor/prop would fail, I would consider that the lift

prop diametrically across from the CG Center of Gravity would shut down as well, in order to have the resulting lift force of the remaining lift props kept at the CG. The resulting disc load would be 50kg/m2. If this is considered too high, and if such an emergency feature is desirable, then lift prop diameter can be increased.

In such an emergency situation, the 2 remaining lift props cannot provide sufficient yaw/pitch/roll control. Possibly the forward thrust props and air flow over the vertical and horizontal stabilizers can provide sufficient additional control.

Payload details:

Considering the size of the payload (450x350x200mm) and its position underneath the wing, easy installation and removal of the payload is tricky. But it is important. I rejected solutions where the front or rear part of the fuselage would lift up, as this would reduce structural integrity and strength of the fuselage.

I consider the center of the payload at the CG Center of Gravity of the CargoHopper, which is approximately at 1/4 to 1/3 of the wing chord behind the wing leading edge.

The payload consist of a box with a lid that can be rainproof sealed. The lid has handles attached. In order to install the payload, the box is positioned in the space between the fuselage and the boom that contains the lift props, underneath the wing. The box slides then sideways into the fuselage, whereby the handles of the box slide into grooves/rails that are fixed into the fuselage. I think the whole operation can be handled by one person in a matter of minutes.

**Original submission:**

The basis of the CargoHopper design is a fairly "traditional" SLT configuration (Separate Lift and Thrust), with 4 props providing vertical lift, arranged on two slim beams mounted underneath the single main wing. In forward flight modus, the vertical lift props are aligned in the direction of motion in order to minimize drag. Such a configuration is well known and used in different commercial designs.

The main aim of the CargoHopper design is to improve 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.

The previous description explains the basic design. Variations are possible. E.g. instead of using a separate vertical and horizontal stabilizer, a V-configuration can be used. In any case, at least one stabilizer extends downwards in order to provide ground protection for the forward thrust prop.

I also think that possibly the vertical lift prop at the trailing side 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 general, the design employs a high aspect ratio main wing in order to reduce drag.

The main elements are two wings, the fuselage and the two beams carrying the lift and forward thrust props. Those elements are at the 2m limit as described in the design brief of component modularity. Including then a cargo dimension of 350 or 200m (still not sure in which direction to mount the cargo), wing span would be slightly below 4.5m. The length of the fuselage could be less than shown on the main drawing, being a matter of aerodynamic shape to minimize drag.

I am not an aeronautical engineer, nor do I have 3D CAD capabilities, although I have a general engineering background. Therefore, I am looking forward to comments from Local Motors and Airbus, if this concept with a twin tail design has potential. And if yes, what details I should work on further.