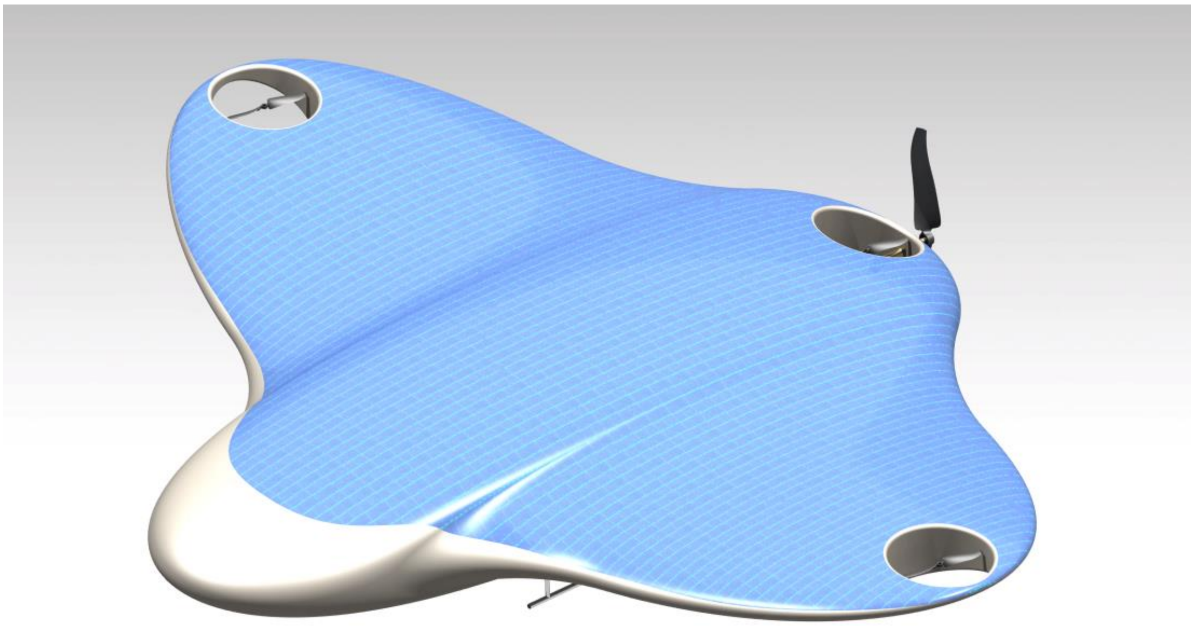
X-Ray Inflatable Cargo Drone



This concept aims to provide an inexpensive, low operating cost, versatile, easy to operate / maintain and safe drone solution for cargo transport and other missions such as surveillance, observation, data transmission, telecommunications, ...

All requirements of the challenge should have been met. A description of the concept is provided here below. An Excel file is also provided in the additional files to support the geometrical sizing, the aerodynamic and mass calculations, for different operating altitudes. These details ensure the coherence of the overall concept between different aspects. A list is included to validate the checks.

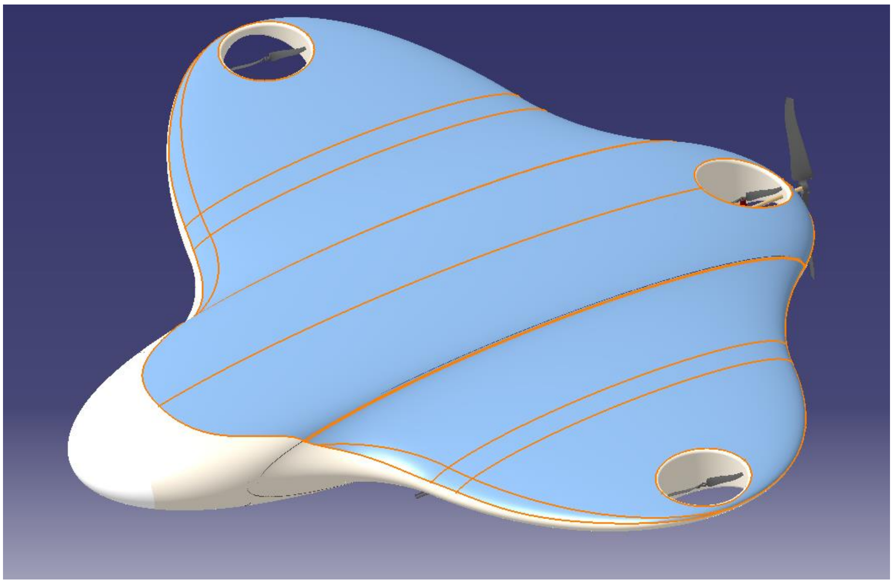
The use of an inflatable structure aims to provide a solution for potential scaling-up, as the air used to pressurize the structure for the low-weight drone considered here could be replaced by helium or hydrogen in larger model and provide buoyancy in addition to the aerodynamic lift. Such hybrid aircraft are interesting to simplify the structure and reduce required engine power, and hence to reduce buying prices, operating costs (through lower fuel consumption) and maintenance costs (less mechanical parts to maintain).

Wires attachment are not fully detailed for the internal structure and are only presented as a sketch.

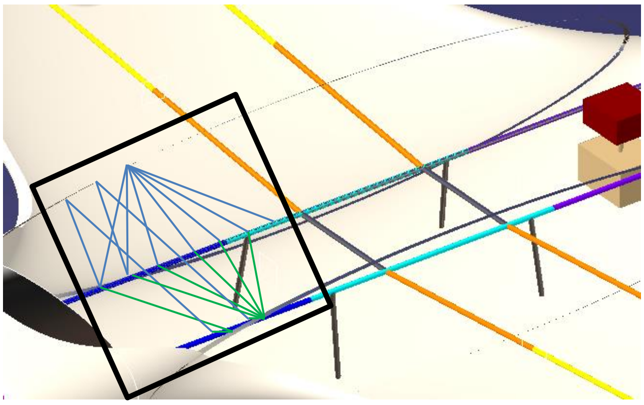
The next sections present the advantages and specificities of the proposed design.

Advantages of inflated structure

- Simple structure compared to traditional metallic designs and assemblies. Hence it could demonstrate easier and faster to build, possibly with lower manufacturing costs.
- Also, the structure does not contain any moveable parts or kinematics and only simple components which can easily be repaired or replaced. Even the envelop can be quickly mended with patches as a last resort in case of local perforation.
- The large exposed planform area can be used for integrating solar film / cells for solar energy absorption (about 90% of the planform area, see figure below), which is particularly interesting for extended endurance missions.

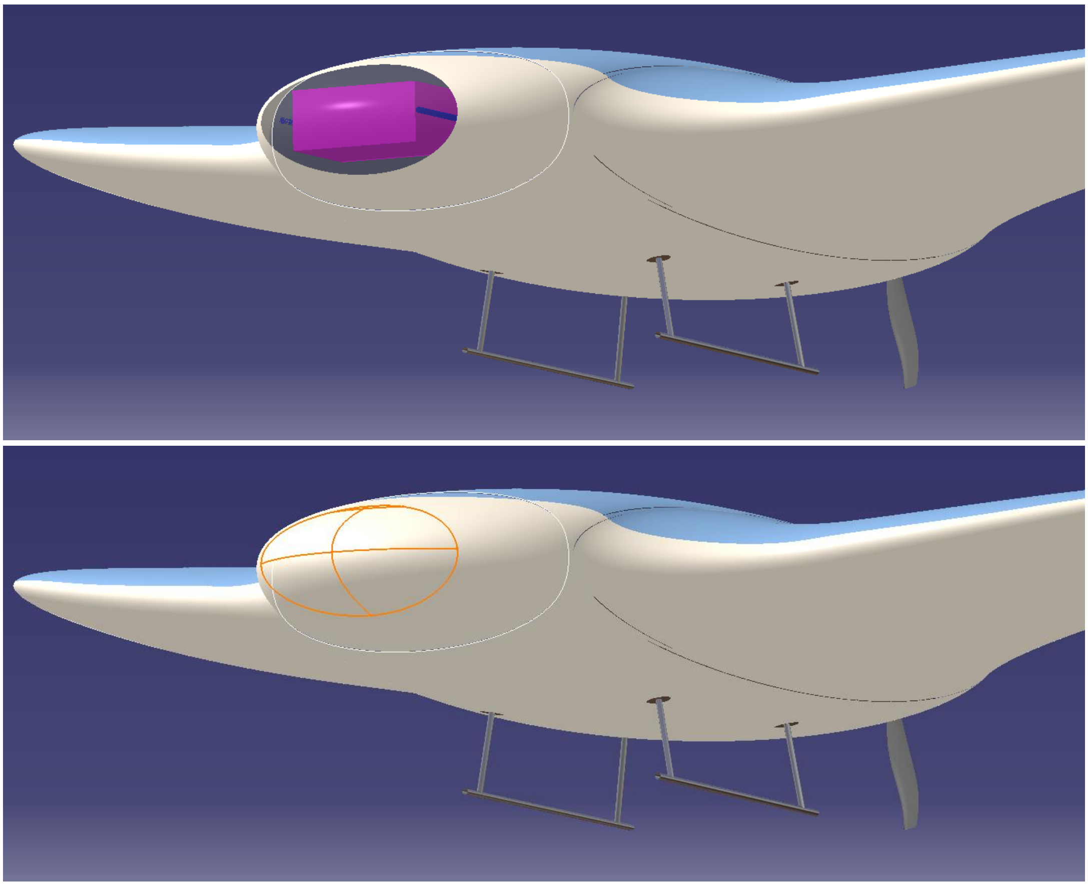


- The sleek blended-wing-body like design associated with thin airfoil provides a smooth aero surface with very low interference, which could lead to better aerodynamic performance. This also allows for lower drag / faster speeds when compared to regular airship or blimp ogive forms.
- As mentioned earlier, it can easily be scaled up and the volume of air can be replaced by helium/hydrogen for buoyancy increased lift. The efficiency of the platform should not be decreased by the scaling operation, which underscores the versatile facet of the concept for carrying out multiple missions.
- The internal structure is harnessed by wires to the envelope (see local example in figure below). This ‘floating’ internal structure offers extra protection to the payload against shocks. N.B. : the wires are not fully detailed here, they are simply sketched as a draft.



<u>Polyvalent concept</u>

- Batteries are stored in easily accessible places for quick change between flights (to be replaced when discharged, after each leg for example). Hence, extra batteries can be easily added or removed depending on the mission, for example by adding 2 kg of batteries when switching from 5kg – 60km legs to 3kg – 100km legs.
- The solar cells / photovoltaic film are optional but would allow for unlimited range if flight speed is reduced to slightly above the stall speed. This is a key advantage if endurance or range becomes a key aspect of the mission. But if this option is not taken, the mass of film is replaced by the equivalent in battery, which still allows for > 100 km range.
- The cargo bay is easily accessed from the front/nose of the drone. The access door can be made either tainted or transparent (see figures below), which can be another advantage if a good visibility is required for specific mission using sensors, antennas, or cameras which also need to be protected from weather conditions (e.g. surveillance, observation, telecom).



- The drone has VTOL capability. In case one or more of the vertical engines fail, it is yet still able to take-off or land on less than 30 meters thanks to the large wing area for such low mass. The landing gear needs to be adapted however.
- The cruise speed has been set to 81 km/h to be able to cover the specified range in all flight cases. Nevertheless, for shorter legs, the speed can be increased. Once again for unlimited range, installed solar cells can provided sufficient power to maintain the drone flying at low speeds (slightly higher to stall speed).

Security aspects:

- Overall, in case of engine failure, mitigation actions are possible such as : gliding away in a desert area in case pusher engine fails ; or combined actions of 2 vertical engines to deviate the drone in case the third fails. A parachute is also included in the system mass calculation.
- In case of crash, the inflatable concept reduces the damages on impact since the deformation of the envelope absorbs part of the energy.
- Moreover, in this specific design the systems, batteries and engines masses can be placed at the rear of the aircraft, with only the payload being at the front to provide the balance, which further reduces the impact energy in case of frontal collision or crash.
- Regarding the psychological acceptance of the drone, this design does not present apparent propellers outside of the airframe, as opposed to conventional quadcopters (N.B. : the pusher propeller can be ducted for protection). This might tend to reassure population and lead to their acceptance of drones flying over their heads, along with the sleek, beautiful, natural like appearance of this drone which could bring a feeling of confidence and security.

Resistance to environmental conditions / rain

- This concept does not use any moveable parts or kinematics. The risk related to possible mechanism jamming due to sand/dust/rocks is avoided.
- The upper surface of the envelope is fully waterproof (as long as not perforated), access only takes place from the nose or front of the underbelly (could also be done by the tail if necessary).
- If the option to include a photovoltaic film is chosen, the envelope could be made transparent at least on the top side to make it possible to install the film on the inside the envelope. This would protect the solar cells without further need of coating.

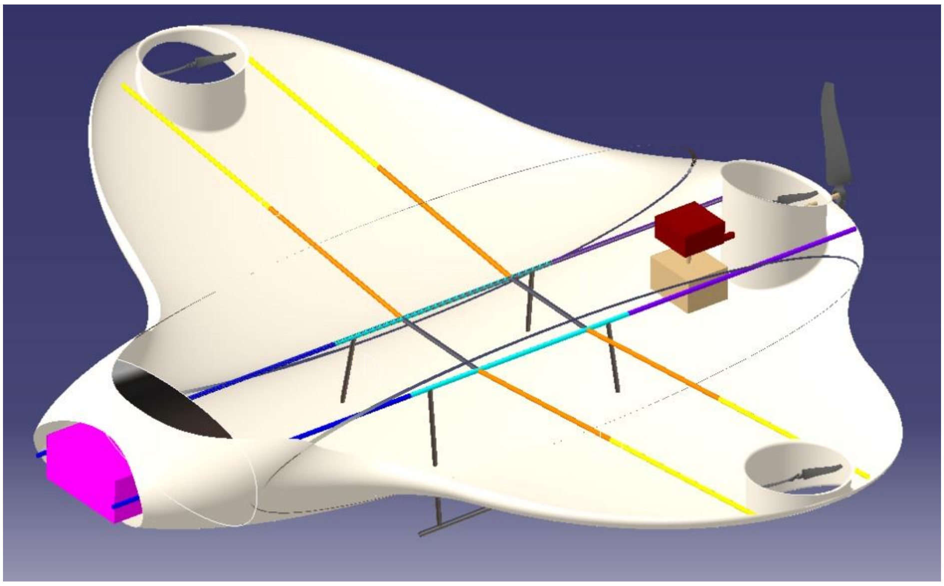
External and internal structure & modularity for transportation:

Overall, the internal structure is not fully representative of the final definition, beams and rods need to be sized and positioned properly and wires attachments need to be further studied.

- A tri-copter layout instead of a quad-copter is a deliberate choice for 3 reasons: it cost less to manufacture / buy, it costs less to operate (i.e. lower mass = lower power consumption = less 'fuel'), and by consuming less power it allows for longer endurance. Hence it is more efficient and the lower parts count also makes it more reliable. Furthermore, there is no need to worry about reverse rotation propellers.
- The envelope is made out of thermoplastic material to give the outside shape when inflated. This solution is well adapted for 'small' size airship, which should preserve their shape.
- The access to the interior of the deflated structure is envisaged through an airtight zip being located right behind the payload bay (represented by the purple box in the figure below). This access would allow to crawl inside the envelope and to disconnect the structural beams

(each independent beam being highlighted in a different color in the figure below) in order to provide a solution for compacting the drone into a box inferior to 2 m long for shipping.

- The landing gears can be easily removed or replaced from the outside, thanks to 4 interface fittings being mounted through the lower skin of the envelope.



- The rear engines distribution shafts are concentric and geared to independently redirect their respective transmission to the lifting propeller and the pusher propeller (see figure below).