X-Wing

Private University of Applied Sciences Hansecampus Stade (PFH Stade)

Team X-Wing (Q11):

Team Captain	**Sven Schrameyer**	Wing	**Jérôme Kaiser-Gärtner**
Pilot	**Christoph Paff**	Empennages	**Viola Jordan**
Fuselage	**Moritz Reiners**	Landing Gear	**Alexander Keck**
Aerodynamics & 3D printing	**Julian Wiemers**		

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1. Design philosophy

As most of the team members participated the Payload Challenge Weight twice, the targets of the design moved from building the lightest possible aircraft to a technically challenging and innovative construction that could be realized within the time span of two months including all design and manufacturing work.

Following the main focus of finding new approaches for common problems and combining them with an attractive and innovative design, all problems were listed and defined to generate proper solutions. The main objectives were to find an attractive plane configuration, a quick payload stowing and release system, an effective brake system and the minimization of assembly complexity to keep the mounting as quick as possible.

2. Team roles and organization

The organization of the team included project management, design and manufacturing of the aircraft and had to be distributed equally to all team members. Due to the already existing knowledge about model aircrafts, the knowledge transfer of experienced and new members was an essential part and had to be integrated into the workflow of the project. This was realized by allocating the design to the experienced members, while the manufacturing was mainly done by new colleagues with support of the experienced.

For a proper structure several milestones and a project plan were set up and controlled, including several test flights at the airfield in Stade.

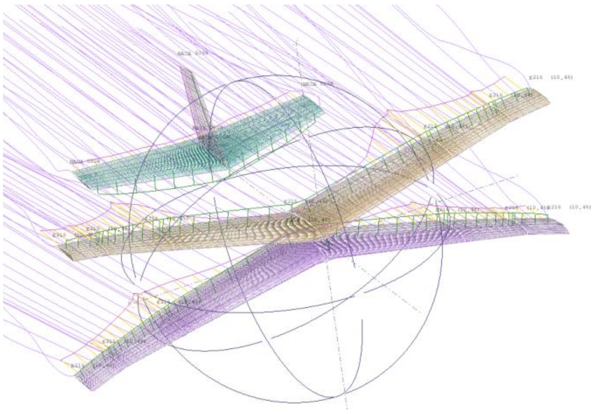
3. Design characterisation

Resulting from the previously defined objectives, the decision for the configuration resulted in an X-wing. This allows an easy distribution of the payload as it provides a vast space within the fuselage, a good tolerance referring to the center of gravity, a relatively low wing span due to its four wings and a robust junction of the main landing gear as it can be mounted to two wings each. Furthermore this configuration generates a huge band width for new design techniques and solutions.

The construction and manufacturing was mainly split into three main aspects, which will be displayed in the following chapters. They consisted of the wings, the fuselage and the empennages. A fourth chapter deals with all additional components like the landing gear, the braking system and the electrical components of the aircraft.

3.1 Aerodynamics

The advantage of a biplane-like airplane is its good short field performance, furthermore the X-form has structural advantages compared to the classis biplane shape. The wing area is twice as big as a normal configuration with same a dimensioned wing, but due to negative aerodynamical effects a biplane is less efficient compared to a standard configuration wing. The ratio of the effectiveness is given as 1,33 times higher than the normal wing shape.



Picture 1: Aerodynamic Analysis

The first step to specify the aerodynamical characteristics of an airplane is the definition of an airfoil. The result was the e216 according a good lift coefficient /drag coefficient ratio. The required lift was set with 45N and with the following formula the wing area of a normally configurated airplane can be calculated:

$$F = \frac{1}{2} * \delta * v^2 * \eta * C_a * S$$

The given lift multiplication factor (1,33) allows a decrease of the bi-plane wing area to 1/1,33=0,75. For better stall behaviour the upper wing has to produce more lift than the lower wing. Therefore the upper wing has a 2° higher angle of attack compared to the lower one.

After the wings were designed the HTP and VTP area was set up, followed by the definition of the centre of gravity.

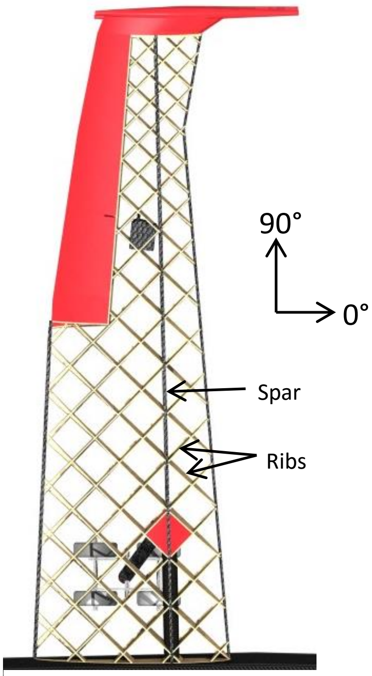
3.2 Wings

Referring to the team targets the wing had to be easy to manufacture as well as robust enough to absorb the forces of the landing gear including the landing shock.

The first design step was to find the best wing architecture for the wing shape. The result were crossed ribs, which are the best compromise between weight as well as a quick manufacturability and stiffness.

Ribs in plus and minus 45 degrees absorb the torsion moments whereas the spars, located at the centre of gravity of the wing absorbs the bending moments. The distance of the ribs varies over the wing span to reinforce the upper wing area as the rudders cause high torsion moments and the wing profile is thinner than directly at the fuselage.

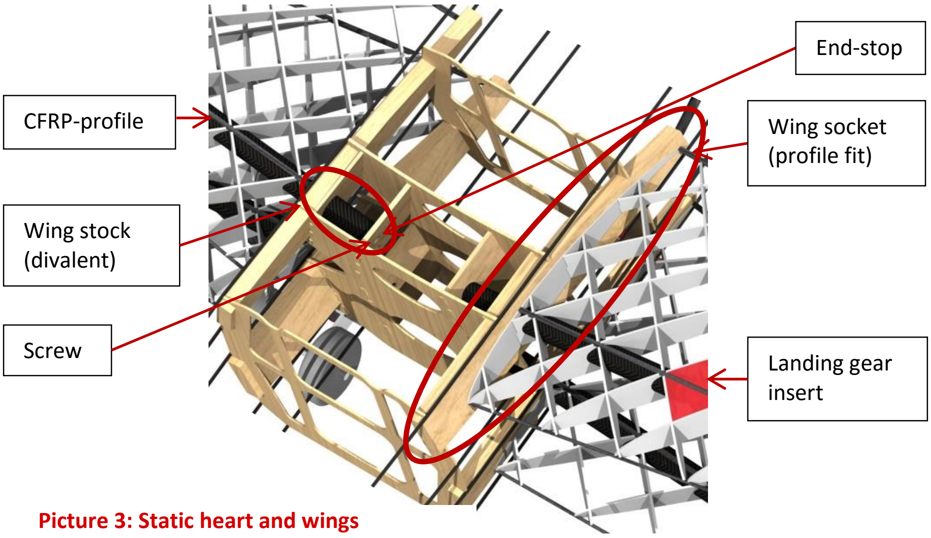
All ribs are laser-cutted which ensures an exact shape of the wing and saves a huge amount of manufacturing time as well as a good force-transmission. Capstrips, small CFRP-profiles, reinforce the ribs to transfer the occurring forces into the "fuselage plug". The structure is covered with a lightweight plastic foil.



Picture 2: Left Upper Wing

The wings can be easily plugged into the "static heart" of the fuselage. A tight profile fit absorbs all occurring torsion moments and a divalent stock absorbs the bending moments.

A divalent stock is realized by a CFRP-profile which is working as a guide when the profile is plugged into the fuselage. Bending forces are absorbed by two ribs with a distance of 35mm. The profile fit is realized as a female plug in which the wing can be plugged into; an end-stop keeps the wing in its final position.



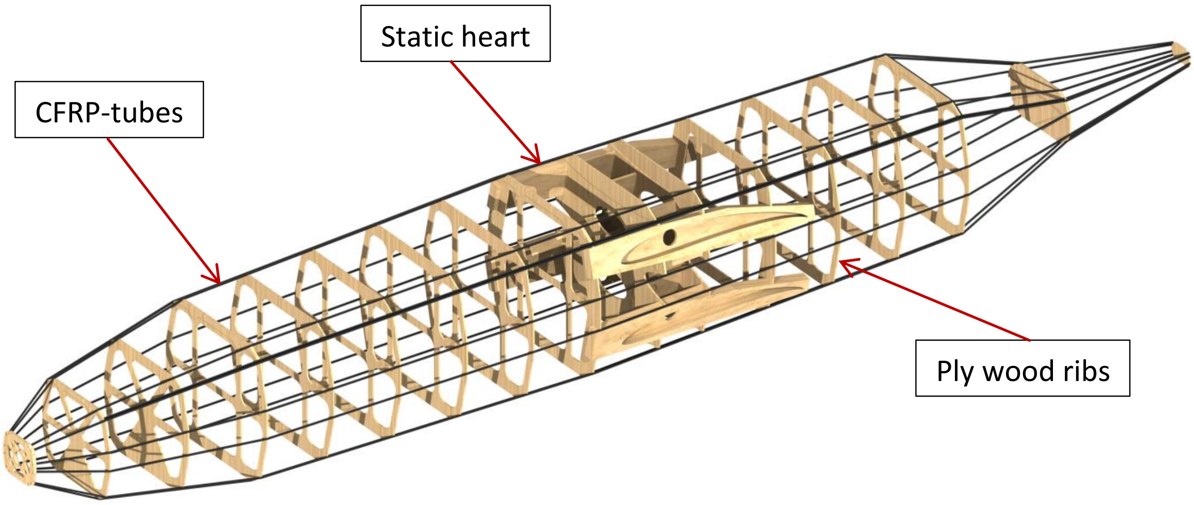
Picture 3: Static heart and wings

Screws are fixing the wing within the static heart. They can be screwed easily into a 3D-printed insert at the end of the CFRP-profile and clamp the wing against the end-stop.

The main landing gears are attached to both wings to increase the stability. The connection to the wing structure is realized by a 3D-printed insert, which is attached to the geodetic ribs, to the upper and the lower spar and to the CFRP-profile which leads the bending moments into the fuselage. This ensures an equal distribution of the landing shock to both wings.

3.3 Fuselage

The concept of the fuselage a structure consisting of a carbon tube frame and 1,5mm ply wood ribs. Bonded with a cover made of one layer of carbon fiber, the structure is able to withstand all appearing bending and torsion moments. As the cover sheets are made of cured CFRP fabric, openings for wings, landing gear or the braking system can be cut out easily, which makes the manufacturing a lot easier and more resistant compared to a foil cover. Furthermore it massively increases the stiffness of the framework.



Picture 4: Fuselage Framework

Another main element is the static heart, which is made of 2mm ply wood and capable of absorbing all forces and loads of the wings and inducing them into the fuselage. It consists of two main ribs and several cross ribs guiding the wing spar and taking over the bending moments. All torsion moments are taken up by a fitting bonded to four ribs on one side and embedding the wing shape on the other side. By simply sticking the wing into the structure, it gets fixed and secured by a screw plugged into a 3D printed insert in the wing spar.

Furthermore it is the most stabile element of the plane, which makes it the best spot for handling the airplane during the loading and unloading process.

The payload is stored in the sections between the wooden ribs in rows of 2x2. All ribs are installed with a distance of 68,5mm, which provides enough space to stow the tennis balls, without allowing too much movement. As the static heart is located at the center of gravity, the tennis balls can be distributed symmetrically to the front and the aft of the aircraft, which allows a maximum of 42 balls carried with one flight. Caused by the use of the foremost sections for the engine and the nose gear not all are filled with tennis balls.

The loading is realized by opening the upper cover electrically with servos linked to a separate circuit. The hatches consist of for four independently working sections, due to the changing geometry of the fuselage. After activating a switch at the outer skin, all sections open and the aircraft can be loaded/ unloaded.

3.4 Empennages

To save building time the VTP and HTP were built in a FDM (Fused Deposition Modelling) 3D printing process. The construction of the CAD model might take more time, but when the design is done the model can be printed completely autonomically within a few hours.

The used 3D-printer had a printing area of 150x220x150mm which made it necessary to build bigger parts like the HTP in more than one part. Therefore the HTP CAD-model was cut into several smaller parts that were connected afterwrds to complete the HTP.

The inner structure are a geodetic ribs with an angle of ~60° to absorb bending and torsion moments. Because of the printed outer skin even the cover is able to absorb forces which results in a very high stiffness.

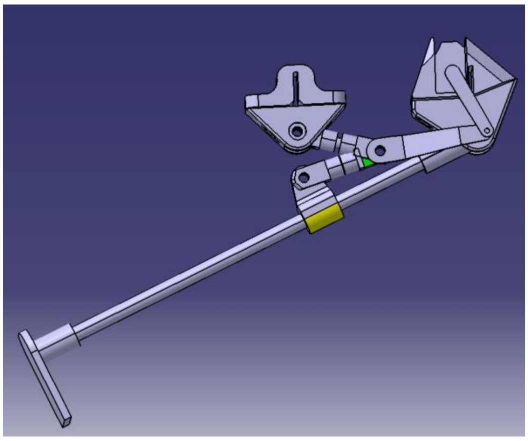
To remove the VTP for transport, inserts with inner nuts are printed into the VTP structure. For a proper connection of the HTP to the fuselage, it has inner beams connected to plywood plates in the fuselage.

4. Additional components

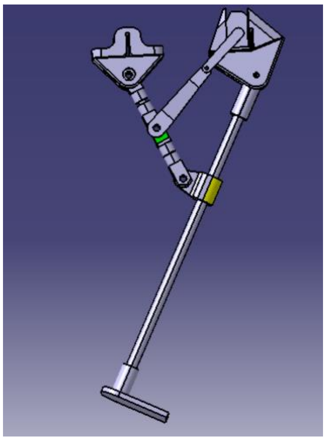
There are two ways to get a plane stop fast after landing. The first one is an airbrake but the decision was to use a mechanical system:

The idea was to use brake pad to stop the airplane after landing as fast as possible. Therefore a CFRP tube with a friction-plate was used with different hinges that were connected with a servo to pull the tube in during flight.

The system draws on the tricycle gear of passenger planes, which allows the use of a smaller servo motor to apply big forces to the brake plate. When the knee-hinge is 180° the servo motor gets no forces from braking at all.



Picture 5: Braking System, Flight Mode

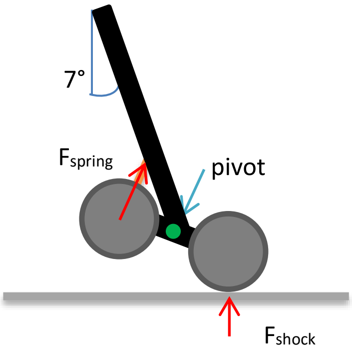


Picture 6: Braking System, Braking Mode

Several flights have to be done in a short period of time to transport as many tennis balls as possible. In order to have the most stable landing gear configuration regarding the structural stability a tricycle gear configuration was chosen as it is less vulnerable to crosswinds, usually occurring on Elvington Airfield. This configuration is also easy to start and to land as the movable nose wheel in the front allows corrections.

In contrast to other concepts the landing gear is not attached to the fuselage but to the wings to enable a wider distance between the left and right landing gear as this increases the stability of the plane during the landing.

The main landing gear is set up in an angle of 7° behind the center of gravity. On each side four small wheels are used to prevent the airplane from canting into a groove of the runway. The landing shock which causes huge forces in the airplane structure is muffled by two springs (see picture).



Picture 7: Main landing gear