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# D3.5 Wing -3 Manufacturing Design for Advanced Wing

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| Dissemination Level | | |
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| PU | Public | X |
| CO | Confidential, only for members of the consortium (including the Commission Services) | |

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# Glossary

| | |
|---|---|
| CAD | Computer Aided Design |
| CAN | Controller Area Network |
| PWM | Pulse-Width Modulation |
| GLA | Gust Load Alleviation |
| MLA | Maneuver Load Alleviation |

# List of Figures

# 1 Executive Summary

In the present deliverable, the plan for the manufacturing of the -3-wing (aimed at showcasing the active MLA, GLA and drag reduction functions) is presented. Since the RCE-design loop, developed within the project, did not reach the level of maturity to be able to deliver a new wing design in time for implementation, this deliverable concentrates on the changes to be implemented on the existing -0-wing to create a -3-wing using pragmatic techniques. For the design considerations, please refer to the deliverables D2.5 and D3.4.
In order to adapt a -0-wing for being suitable to measure the effect of actively shaping the lift distribution for the reduction of induced drag the number of available flaps on each wing has be increased from four to nine. The considerations behind following an approach to increase the number of flaps and distribute them accordingly are described in [4]. To achieve this goal, the following changes are planned:

- Replacing flaps on position 2, 3 and 4 with newly manufactured flaps.
- Outfitting the -3-wing with five additional servos to actuate the flaps.
- Adjusting the wiring to supply the additional servos with power and control signal

The biggest challenge is deemed to be the additional wiring, which already posed a challenge in the design of the -0-wing.
The following sections will describe the required changes and the manufacturing approach in more detail, before the design changes are described in section 3. The manufacturing techniques are described in section 4, before some concluding remarks and an insight into the current stage of implementation is given in section 5.
This deliverable is largely based on the Master's Thesis of Lawan Nuri Sharif *Retrofit Design of an UAV Wing for Active Drag Control* [5].

# 2 Objective and Required Changes

## 2.1 Objective

Since no new design was available for implementation, efforts focused on the implementation of changes to an available -0-wing in order to use this adapted wing, which is named ”-3b-wing”, for the evaluation of a reduction of induced drag by actively adapting the lift distribution according to the considerations explained in deliverable D3.4 and D2.5. In aforementioned deliverables, it was determined that outfitting an -0-wing with 9 flaps, instead of the existing 4, was to be implemented. An extensive trade-off analysis was performed to see the benefits of retrofitting the -0 or -2 wingset, with the main objective to show sufficient improvement from zero flap and aileron deflection vs. the optimum induced drag configuration at various speeds. The objective of the efforts described in the deliverable at hand can be summarized and shown in the following Fig. 1 and Fig. 2.

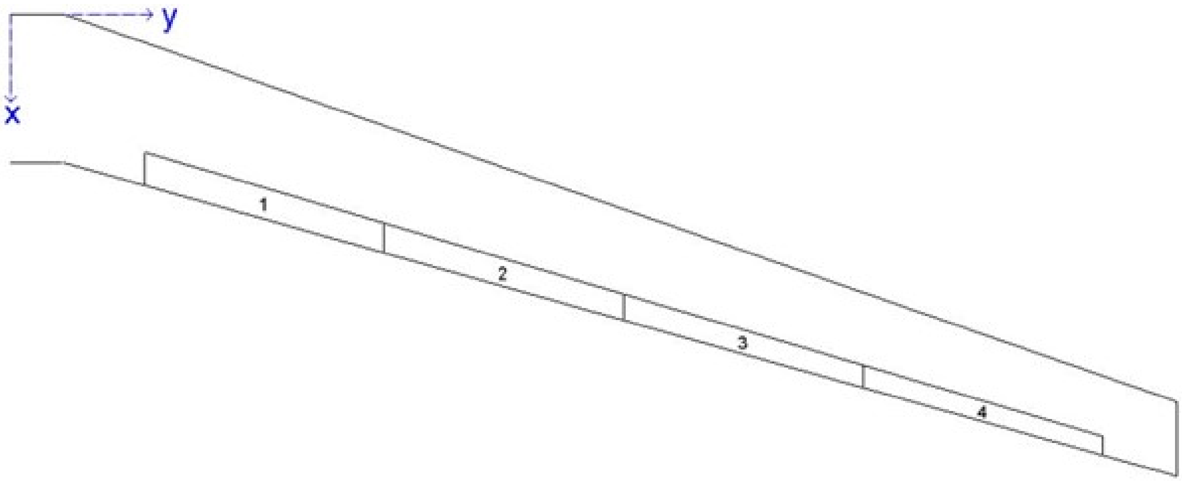


Figure 1: Available -0-wing outfitted with 4 flaps.

As becomes apparent from Figs. 1 and 2, flap 1 of the -0- and -3-wing have the same span, flap 2 of the -0-wing is to be replaced with two flaps and the flaps 3 and 4 of the -0-wing are to be replaced by three flaps on the -3-wing to be designed.
Additionally to the necessary changes to the available -0-wing, this deliverable D3.5 describes the necessary tools to be developed for facilitating the manufacturing and integration of parts of aforementioned changes.

## 2.2 Required Changes

In order to implement the objective described in section 2.1, the following changes need to be implemented in order to go ahead with manufacturing:

- Changes in the mechanical setup:
  - Increase the number of flaps from 4 to 9 flaps per wing, including hard points on the trailing edge to hinge the flaps.
  - Sizing and selection of servos according to the new flap sizes.

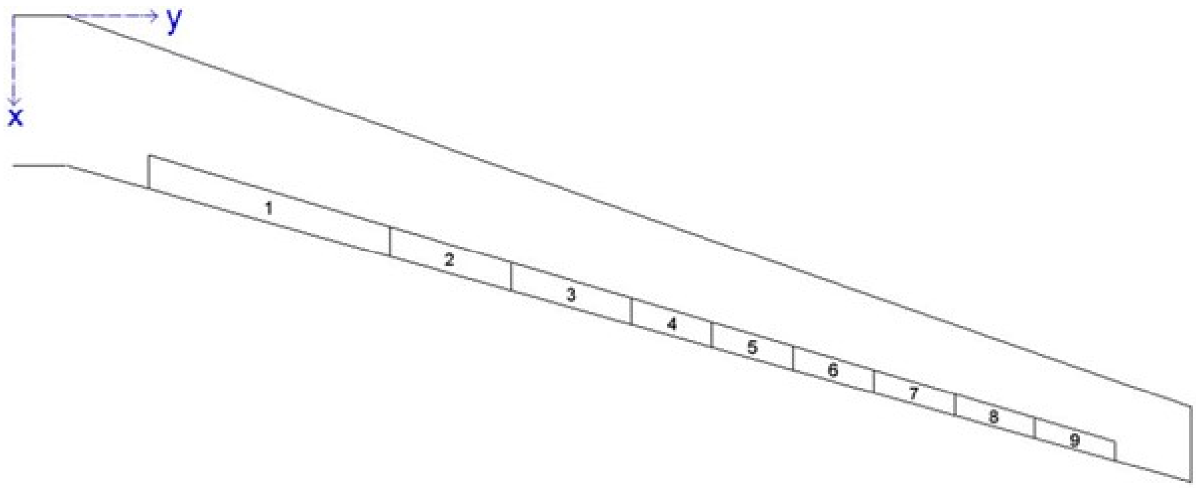


Figure 2: Envisioned -3-wing featuring 9 flaps. Note the identical span of flap 1 and decreasing spans of flaps as the position moves further to the wing-tip.

- Integrate 5 additional servos to actuate the additional flaps, including necessary push-rods and hard-points for fixation.

- Changes in the electrical setup:
  - Integrate a power supply for the additional 5 servos into the existing wing structure.
  - Integrate signal wires for the additional 5 servos.

## 2.3 Design Approach

The required changes are implemented based on the existing CAD-model of the -0-wing in the software *CATIA V5*. The reuse of existing component models whenever appropriate increases the efficiency of design as well as reliability since the experience from the implementation of the -0-wing exists.

# 3 Design Details of the -3-Wing

## 3.1 Flap Design

The design of the flaps follows a standard approach for later manufacturing using a manual lay-up process in a negative mold, based on the CAD-geometry developed during the predecessor project *FLEXOP*.
Each flap consists of a upper and a lower skin, a foam core, flap horns for actuation and a guiding tube for later insertion of hinge wires serving as an axle. An exemplaric flap is shown in the following Fig. 3. The planned manufacturing routine is described in the following section 4.

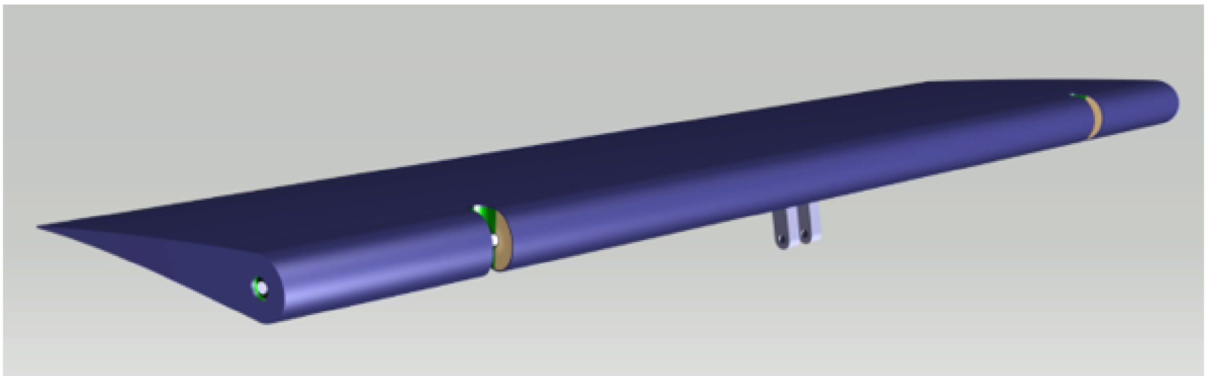

Figure 3: Exemplary design of a designed flap featuring the upper skin (dark blue) and the foam core (green and beige) and flap horns on the lower side for actuation (grey).

## 3.2 Hinge Design, Hinge Moments and Servo Selection

For the fixation of flaps a pragmatic approach is chosen by using nut-plates to locally reinforce the rear spar of the -3-wing and eye-bolts to provide hinges that are adjustable both in depth as well as the axis, thus facilitating the hinge wires serving as an axle. Examples are given in Figs. 4a- 4b.

In order to select appropriate actuators, a study of hinge moments has been conducted using the freely available program *XFLR5* [3] aiming an determining the maximum expected hinge moments. The operating conditions for the simulation are subsequently chosen to the following, rather extreme, values in order to assure a sufficient safety margin:

- Cruise speed 65 $\frac{m}{s}$.
- Maximum limit load factor (5g's).
- Full aileron deflection.

The resulting hinge moments determined in the simulation are presented in the following Table 1.

Table 1: Maximum calculated hinge moments of flap 1 to 9.

| **Flap Number** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Hinge Moment** $\lvert H_m \rvert [Nm]$ | 4.15 | 2.16 | 2.00 | 1.36 | 1.26 | 1.13 | 0.99 | 0.86 | 0.66 |

(a) Exemplary eye-screws planned to provide the hinge-points for the fixation of flaps. Picture: [1]

(b) Examplary nutplates that are planned to be used to locally reinforce the rear spar of the -3-wing and provide threads for the insertion of the eye-screws. Picture: [2]

Figure 4: The components planned to form the fixation of flaps to the rear-spar of the -3-wing.

In preparation of the servo selection a market screening of potentially suitable servos has been conducted. The servos investigated feature the form factor typical for commercially available servos for remote control aircraft but differ in the mode of command signal: The majority of servos uses the widely adopted pulse-width-modulation, a smaller, but not negligible number, are using the CAN-protocol. The reason for the differing numbers is the fact that servos utilizing CAN-protocol are only starting to be marketed, though they feature advantageous functionality such as reduced wiring effort and the provision of telemetry data. The final selection will be taken once the implementable wiring scheme is determined during the manufacturing process (please refer to the feasibility study described in deliverable D3.4). Due to similar form factors an exchange of servos is possible.

Table 2: Selection of Servos potentially suitable for the application in the -3-wing.

| **Manufacturer** | **Model** | **Gear** | **Torque [Ncm]** | **Voltage [V]** | **Speed [s/60°]** |
|---|---|---|---|---|---|
| MKS | HBL599 | Metal | 300/380/420 | 6.0-8.2 | 0.11/0.09/0.08 |
| SAVÖX | SC-1256TG | Metal | 160/200 | 4.8-6 | 0.18/0.15 |
| Traxxas | RCCTRX2255 | Metal | 280 | 6.0-7.4 | 0.15 |
| Amewi | 6221MG Digital | Metal | 150/180/209 | 4.8-7.4 | 0.16/0.14/0.12 |
| SAVÖX | SC-0251MG | Metal | 130/160 | 4.8-6 | 0.2/0.18 |
| Bluebird | BMS-660 DMG | Metal | 126/142 | 4.8-6 | 0.2/0.17 |
| AMewi | DC5821LV WP | Metal | 162/214 | 4.8-6 | 0.18/0.16 |
| SAVÖX | SA-1283SG | Metal | 250/300 | 4.8-6 | 0.16/0.13 |

# 4 Manufacturing Plan

The manufacturing of components and assembly uses standard procedures that will most likely need to be adapted once the actual implementation is conducted. Therefore following sections address the general procedures to clarify the approach and timeline.

## 4.1 Flap Manufacture

The flaps are manufactured by using negative molds that provide the geometric outer surface for the production of the outer skins. After laying in the foam core and guiding tube, the two mold sides are stacked upon each other to form the closed flaps, see Figs. 5 and 6.

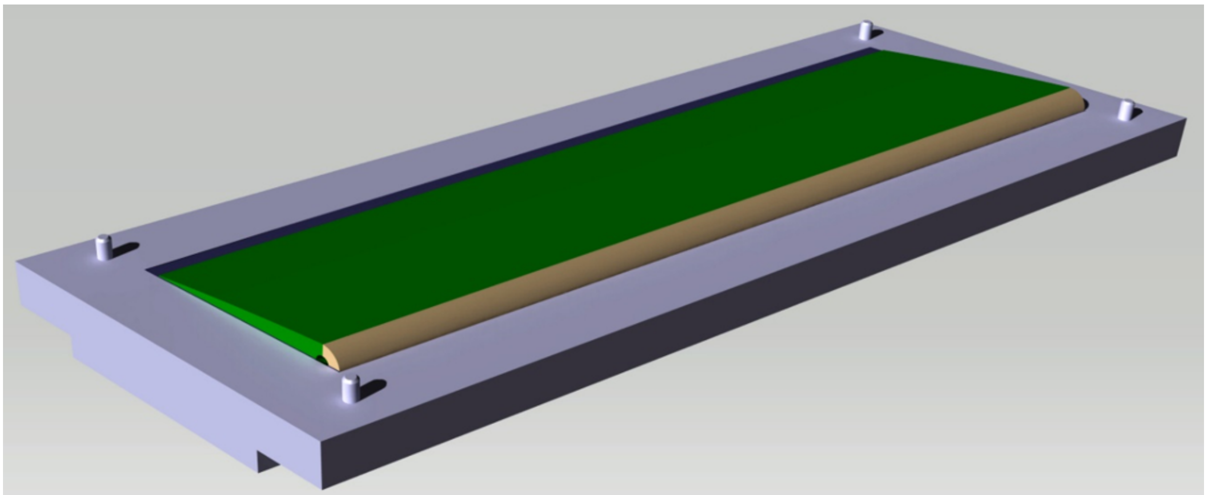

Figure 5: Flap mold with the outer skin laminated and foam core and guide tube inserted, thus prepared for closing the molds.

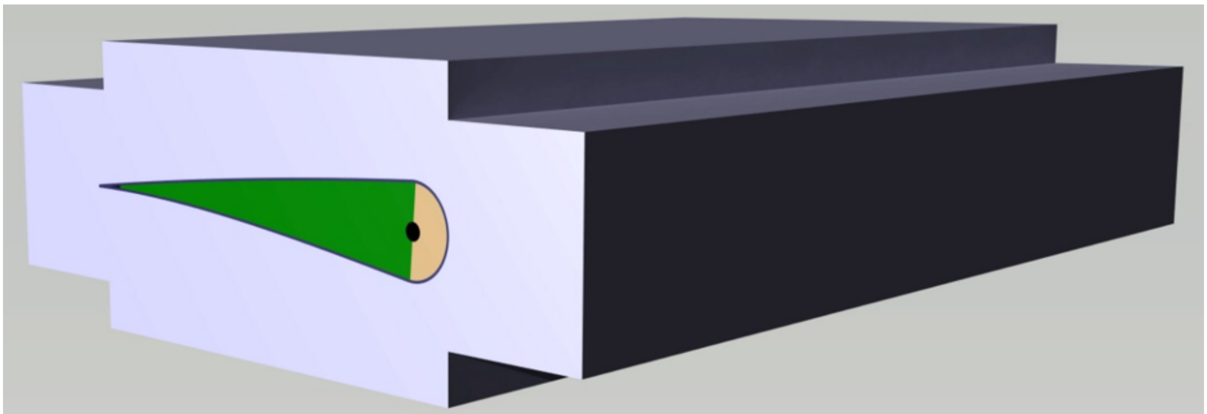

Figure 6: Cut of the closed molds showing the setup for flap production.

As the last manufacturing steps the cutouts for the insertion of the eye-bolts as well as the flap horns are added and the CNC-routed horns glued in using guides to assure the proper servo horn positioning.

## 4.2 Flap Fixation

In preparation of fixing the flaps, holes for the fixation of nut-plates and eye-bolts (see Fig. 4a and 4b) are drilled into the rear spar of the -0-wing to be converted. The position will be determined using the measures from the CAD and guides/templates when necessary. To assure a sufficiently strong and durable connection, it is planned to both glue and bolt the nut-plates to the rear spar. As the next step the eye-bolts for the most inner flap 1 are screwed into their respective places and flap 1 installed by pushing the hinge-wire into the provisioned guide tubing. The eye-bolts will be adjusted if necessary. The flaps will be installed one by one, starting with the most inner one as mentioned.

## 4.3 Wiring

For installing the wires, the possible solutions described in D3.4 are attempted, starting with the routing of new cables as a preferred solution using a pragmatic approach supported by a keyhole camera. The new servo positions, that cannot be reached with new cables due to restrictions in space are supplied using existing cables and routing Y-cables. If no new cables can be routed, the existing CAN-cables in combination of CAN-utilizing servos will be used.

Two CAN buses have been installed earlier in each half wing, which are used by flightHAT for reading IMU and SHM data on the top buses and IMU data on the bottom buses. Bottom IMUs placed as spare sensors and were not used. Therefore, they can be disconnect them from the bus without loss of system funcionality and the bus-cable can be reused for servo control. The top buses can be connected for RX-MUX and flightHAT in the same time and used for sensor reading and servo controlling as well. Figure 7 shows the wiring solution of the -3 wing. For safety reasons, the control surfaces are supplied in a way which resembles the setup of the original -0-wing, thus retaining the redundancy characteristics developed during the design of the *T-FLEX* flight demonstrator, i.e. a controllable aircraft, even if one of the RX-MUXes, batteries or other components such as an individual servo actuator has stopped working.

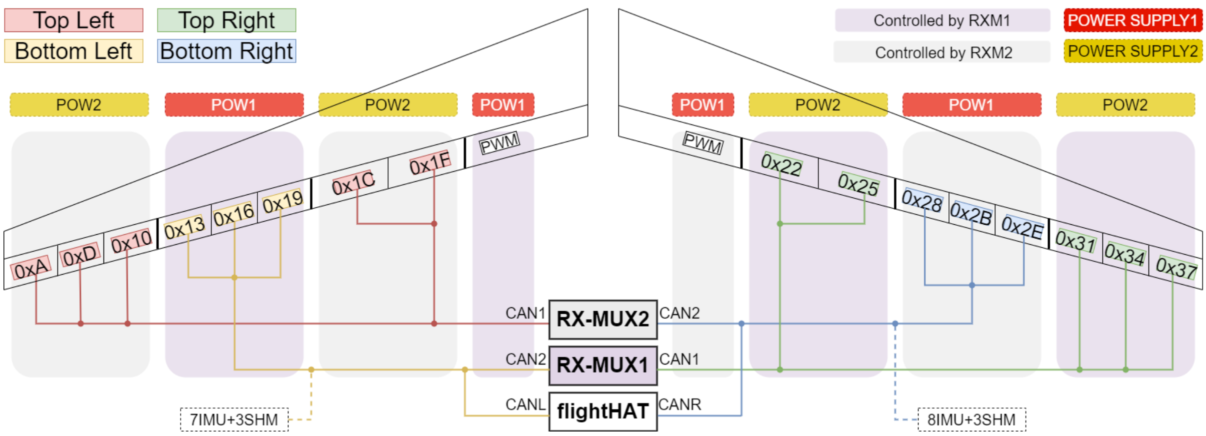


Figure 7: Wiring of -3 wing

# 5 Conclusion and Current State

In conclusion, the implementation of the changes to adapt an existing -0-wing to create a -3-wing has been planned to rely on pragmatic technical approaches and techniques. By and large, the implementation of the changes is deemed technically feasible.
Currently, the described implementation has commenced according to the design described and the state can be described as follows: The molds are produced and the flaps are manufactured to sufficient quality in terms of geometric accuracy. The routing of wires has been investigated, implemented to large extend already and a decision in favour of CAN-utilizing servos has been taken. Required mechanical parts such as flap horns and gluing templates are being manufactured using a CNC-router.
The next steps will include the refinement of the existing CAD-design and testing of technical solutions such as adhesive bonding on mock-up test-stands, setup of sub-assemblies and finally the integration and functional testing of the wing assembly.

# 6 Bibliography


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