D3.7 Manufacturing advanced wing and fuselage finalized

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Glossary

ACMU Actuator Control and Monitoring Unit [6]. 13

CAN Controller Area Network. 10, 12, 13, 15

ECU Electric Control Unit, used to operate the Turbine on the aircraft. 10, 12, 17, 18

EDL Engineering Data Link. 9

FCC Flight Control Computer. 15

FlightHAT Interface card of the FCC-Stack. 9, 12

GCS Ground Control Station. 10

IMU Inertial Measurement Unit, Custom embedded system developed at SZTAKI.. 12

LLS Chair of Aircraft Design, Technical University of Munich. 13

OBC-II Secondary On-Board Computer. 4, 9, 10, 19, 20

OMA Online Mode Analysis, A tool actively developet at DLR. 12

P-FLEX P-FLEX UAV. A slightly redesigned and improoved iteration of the T-FLEX UAV.. 7, 9, 26

RC Remote Control. 9, 10, 13, 15, 17, 18

RX-MUX-II The independent Input-Output module of the FCC-stack. 4, 10, 13, 16, 19

T-FLEX T-FLEX UAV. The technological demonstrator designed, build and flow during the FELXOP project.. 7–9

ZMQ ZeroMQ - An open-source universal messaging library [1].. 21

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1 Executive Summary

Due to an accident with the demonstrator in August 2022, the fuselage had to be rebuilt. This accident also led to a major reorganization of the project flight test objectives and the consortium made a common decision to prioritize the wing-1 flight tests leading to active flutter control experiments, after the demonstrator is rebuilt, rather than proceeding with the wing-3 tests. Hence, the advanced wing manufacturing and integration, aimed at demonstrating active wingshape control via movable trailing edge flaps, was paused and the major focus shifted to fuselage and demonstrator rebuild. To avoid similar events and to improve ground handling and improve ease of operational experience, several design changes were made on the original system. The corresponding changes are described in this deliverable along with notes and decisions on the wing-3b wing manufacturing. The original wing-1 design included no external actuator mounting and flutter stopper, hence the design had to be improved to acomodate these additional features as well.

2 Objective

The main objective of this document is to collect and describe in sufficient detail all the major hardware changes and software updates and improvements which were made on the overall demonstrator during the rebuild process. The secondary objective of the document, is to describe and show the manufacturing state of the wing-3b.

Due to the nature and complexity of the demonstrator, a few subsystems needed to be changed and revised during integration or even during the flight-test campaigns. Typically, the overall functionality of the system can not be tested without a stable software, and a stable software can not be created without adequate testing on a final hardware configuration.

One such system is the telemetry system, which went through a major hardware revision in between the two flight-test campaigns, and software and configuration were still changed during 3 days before the last flight day. All of those changes are explained in details in [4] and in [3] documents.

3 Subsystem changes in the demonstrator

A few key subsystems got drastic change during the rebuild of the P-FLEX compared to the last used version of the T-FLEX and original design showed in [5]. This section describes the major design decisions and implementation results of each subsystem, which deviates from the previous iteration.

3.1 Air brake/

During the early stages of the rebuild process, discussion and investigation were made for the usefulness and the need for the integrated air brake system.

Main reason to have an operational air brake:

- Use it for precise airspeed control
- Increase drag during landing

During the investigation, we found:

- Air brakes are not used for speed control
- During landing, fully opened air breaks are as effective as 10% decrease in throttle command.
- Circles will be flown instead of horse-race for flutter tests, so drastic deceleration and accelerations are not required
- If possible, the additional weigh could be reused for additional fuel, to increase flight-time.

Due to the reasons mentioned above, the air-brakes are not integrated into the fuselage, thus helping to decrees system complexity and increase weight capacity in favour for additional on-board fuel.

3.2 Landing gear

During the early stages of the rebuild process, discussion and investigation were made for the usefulness and the need for the retractable landing gear system.

The main reason to have retractable landing gear:

- Decrease drag during the tight acceleration phase of the flutter tests.

From experience with the previous system, and as well as with additional analysis we found:

- Having the landing gear retractable, increases system complexity and weight.
- It is not possible to make it laterally stiff enough - given our present constraints
- Would be possible to increase 40%-50% fuel capacity, if the internal space would be used for fuel storage instead

In favour for extended fly-time, a fixed landing-gear system is designed and integrated to the fuselage.

3.3 Fuel tank and Fuel Transfer system

Investigation showed, that during a full circle flow, 0.14kg, 0.26kg, 0.41kg and 0.59kg fuel is used if the circle if flow with $30\frac{m}{s}$, $40\frac{m}{s}$, $50\frac{m}{s}$ or $60\frac{m}{s}$, respectively. A possible 40-50% fuel capacity increase will be highly benefitial to maximize the positive outcome a signle flight.

Due to that, as it is already mentioned in 3.1 and in 3.2, an additional design element with the rebuild is to increase the possible fuel capacity. That is achieved mainly designing and manufacturing custom fuel tanks for the space, where the retracted landing gear is located in T-FLEX.

Using the space available, and construction a custom solid tank, it would be possible to increase fuel capacity by ~47%. To aim that goal, a custom solid tank were build. Figure 1 shows one of the auxiliary fuel tank modules. The from the layout two is integrated into the fuselage.

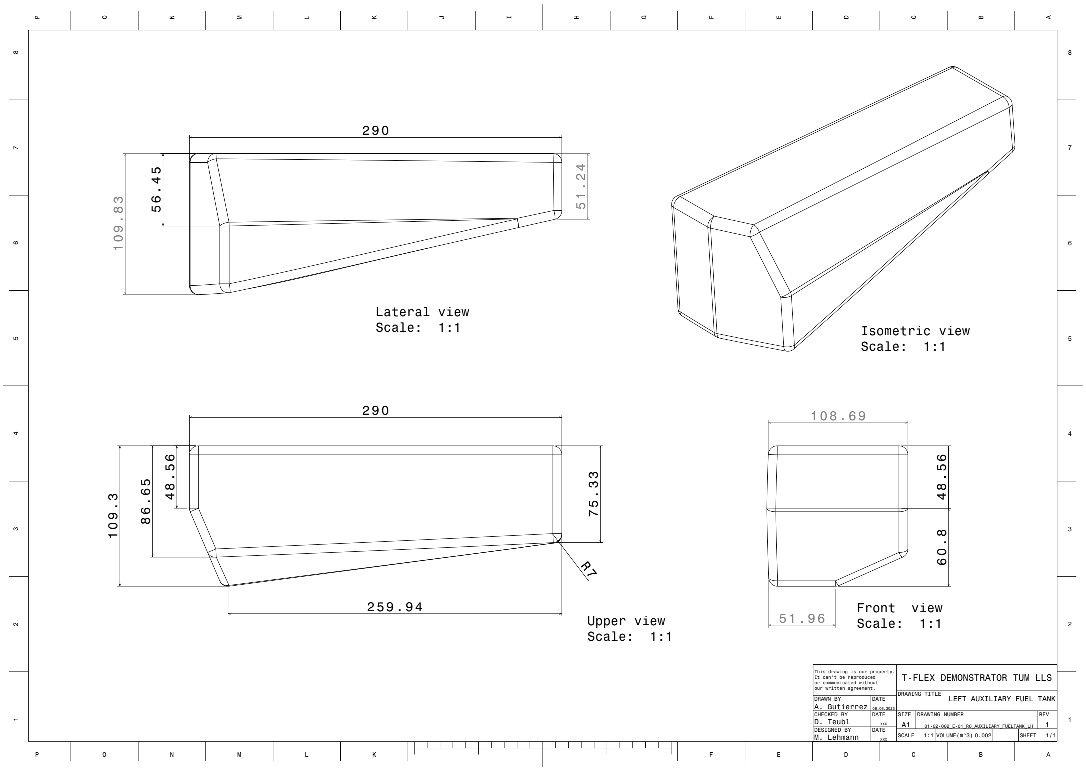


Figure 1: Technical drawing of one of the auxiliary Fuel Tank

Fueling and refueling is made in a way, that auxiliary and the main tanks can be fueled or defueled independently. An additional fuel-pump and on-off control logic is created, to make fuel transfer possible in flight between the auxiliary and the main tanks. The refueling system is controlled via a dedicated PWM channel from the backup transmitter.

3.4 Telemetry System

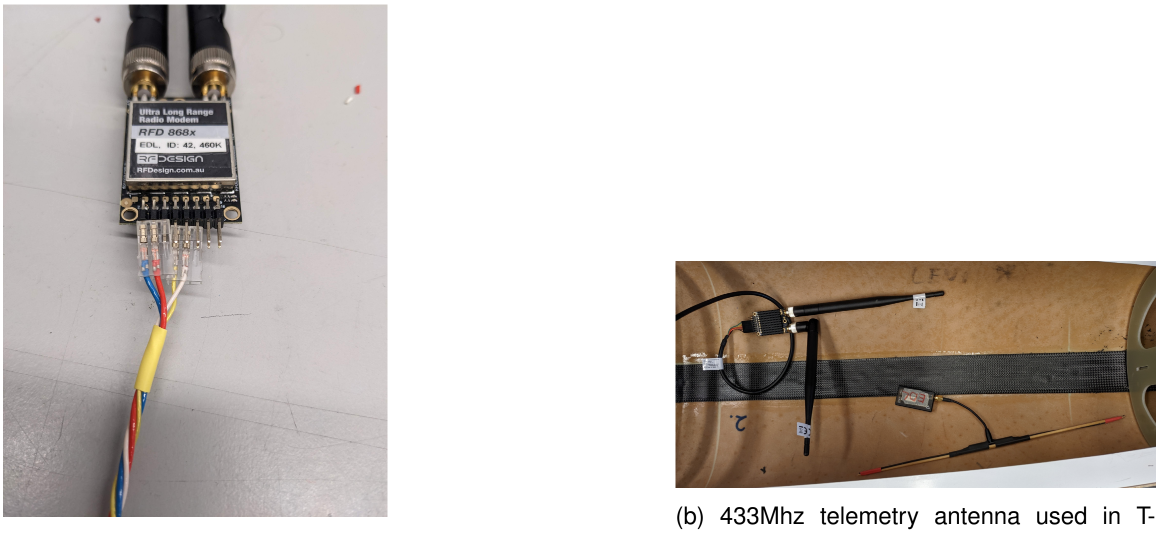
Previously, there were three telemetry module operational in the payload are, with similar physical setup. In each case a 3DR-Sikk 433Mhz telemetry module were used, with a half-wave dipole antenna. Two telemetry module were connected to the FlightHAT, and one additional to the OBC-II module. Frigure 2b shows a similar module before integration into P-FLEX.

The RFD 868x 868Mhz module were chosen, as a plug-in replacement for the EDL telemetry. Due to a software reconfiguration, the EDL is moved to the OBC-II module. That made it also possible to reduce the number of telemetry modules by one. In theory, the increased bandwidth with the 868Mhz telemetry system, both data link can be streamed via the same module.

The chosen telemetry system 2a comes off-the-shelf with two attachable dipole antennas, which can cover the full 3D space around the aircraft, compared to a single dipole antenna, which will have good and bad reception block in the 3D space around the aircraft.

By using only two modules, in the small place in the payload area, the potential interference between each radio link is eliminated - in theory.

To help with the telemetry system reception range, the payload/avionics plate is made of glass-fiber instead of carbon-fiber, like in the previous iteration.



(a) 868Mhz telemetry antenna used in P-FLEX

(b) 433Mhz telemetry antenna used in T-FLEX, located next to the 868Mhz module in the payload area.

Figure 2: Telemetry units planned to be used

3.5 Remote Control System

As one of the cause for the loss of aircraft with T-FLEX, the decision were made to put more effort for testing and upgrade of our remote control system choice for the P-FLEX. The initial testing results are mentioned in [3] in the ”Remote Control System range test” section.

The decision is made to use JETI system for both main and backup RC system, but use a DS-24 transmitter as main, and use a DC-16 with NG capabilities for the backup.

For normal 2.4Ghz antennas, *REX3* modules were chosen with additional ”balloon” antennas for increased range and quality. The backup system got a *DUPLEX Rsat 900 NG* receiver as well.

The main reason to use JETI system as both main and backup system is the similarity in programming and configuration capability. Along with that, JETI support scripting capabilities, which allows us to make custom functionalities on top of the base capabilities of the system, which none of the other systems which we tested are offering at the time.

Along with the increased range and stability a secondary goal were with the RC system update, to allow enough feedback directly to the pilots. They should be able to fully control the aircraft as a normal RC plane, in case there is a major connection loss between either on the communication radio, or between the aircraft and the GCS. For that, additional sensors were introduced, and redundancy were kept for the main and backup system.

Each system got direct airspeed sensors, vario sensor for altitude feedback. On top of that, the backup received a GPS sensors, and fuel-flow sensors, to be able to monitor and control the fuel transfer functionality.

3.6 Power Distribution

Due to lack of time and experience, similar layout were chosen to the power distribution board as we had before.

Main changes compared to the old system:

- The plates are $6mm$ aluminium, instead of $3-4mm$ copper
- a 5V board is introduced
- the two 2S board got separated to 4 board
- the distance between the individual board got doubled

The power inputs and their respective consumers are visible in table 1. With the splitting of the 2S boards, it made possible to have the main system operation as soon as either battery is plugged into the system, but not the power consumers.

6S — 24V	3S —12V	2S — 8.2V #1	P1	2S — 8.2V #2	P2	5V
FCC	Ignition	RX-MUX-II #1	LF_1	RX-MUX-II #1	LF_2	OBC-II
5V	Fuel pump	RX-MUX-II #2	RF_1	RX-MUX-II #2	RF_2	$Telem_1$
		RC #1	LF_3	RC #1	LT_2	$Telem_2$
		RC #2	RF_3	RC #2	RT_2	
		chute	LT_1	chute	brake	
		ECU	LT_2		LFS	
			Tailwheel			
			RFS			

Table 1: Layout of the different power consumers and their connections,

The Direct Drive system is powered directly via dedicated cables from a 12S battery pack, which two 6S in paralell connetion. The 'Flutter-stopper' servo motor power supply is connected via power line of the CAN-bus for the Direct Drive.

Takeaways from the layout and designs:

- Splitting the 2S board made operation easier, and made possible to have longer wait time before takeoff, without discharging the main flight control batteries

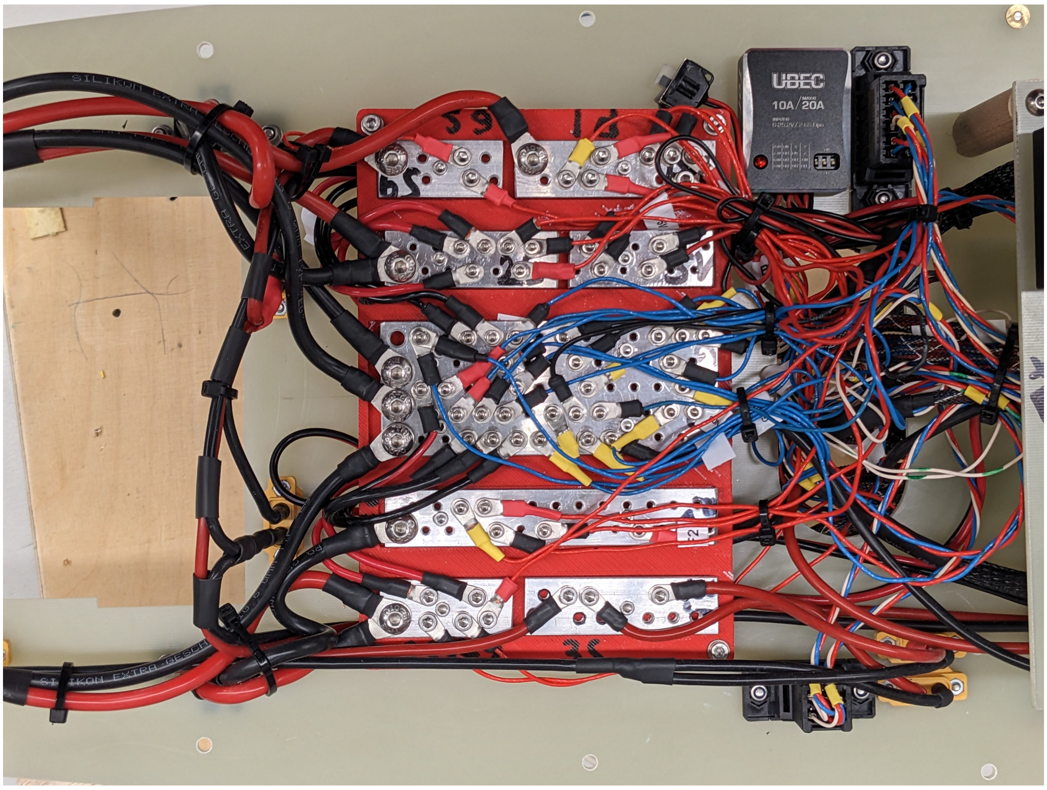


Figure 3: Look of the already integrated design

- Using the regulated $5V$ input for the telemetry modules directly, made the wiring a bit more complex, but allowed the free power input to the telemetry modules. Previously they were powered directly from the FlightHAT module, where the internal $5V$ regulator had way more limited power output.
- Adjusting the spacing between the aluminium plates, made it possible to have a nicer way of wiring than earlier 4
- Having the ECU and the chute directly connected to the battery plates, made possible to confirm ECU communication and chute release checks, without running the overall system.

3.7 IMU sensors

As an expansion for the existing build in IMU's in the wings, four additional IMU is installed. One in the front of the fuselage, one in the empenage, and one next to the V-tial spaar to each side. Since the IMU's are using CAN protokoll for communication, each of the additional IMU is just connected to either of the existing CAN network on the aircraft. Table 2 summary of the IMU location and CAN connection.

The additional IMU's will be used via the OMA during flight.

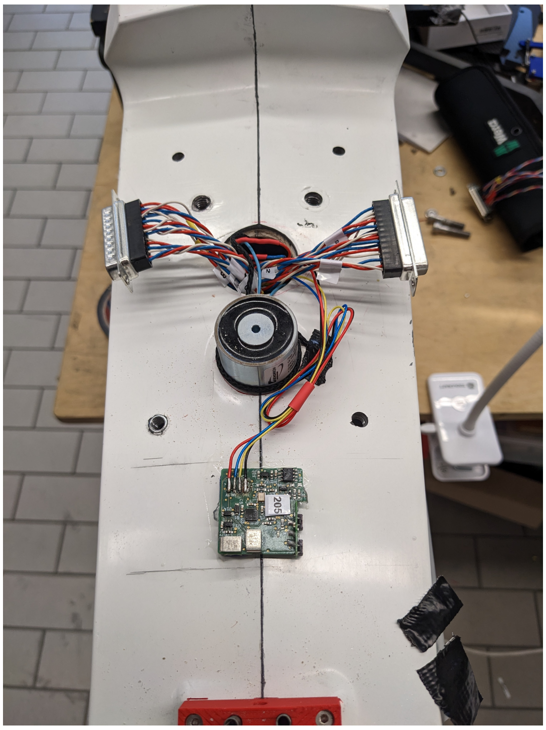


Figure 4: IMU located at the root of the V-Tails

ID	location	CAN bus connection	logID
184	left tail	left	13
191	fuselage nose	left	14
198	right tail	right	15
205	V-tail root	right	16

Table 2: Caption

3.8 Control surface position measurement

During 2022, a set of ACMU's were integrated into the V-tail inner control surfaces by Xiauhuui Chen [2], to show deeper insight of the servo and control surface dynamics during take-off and normal operation. The ACMU system ware designed and developed at LLS [6], and successfully deployed and used in other research UAV's [7].

Each Inner V-tail control surface received one ACMU, with the following configuration.

- Angular position measurement of the servo-shaft
- Angular position measurement of the control surface
- Temperature measurement at the servo housing
- Temperature measurement under the lower skin of the V-tail
- Servo reference signal measurement
- Servo Input voltage measurement

Figure 5 shows the integrated position measurement sensors on the control surface hing-lines.

Due to known limitation of the available hardware design of the ACMU, the servo and the ACMU are connected parallel. With that, no current measurement or any feedback is available to the FCC. However, the operation of the servo is not affected by any known or unknown software or hardware fault in the ACMU.

3.9 Flight Control Computer I/O module — RX-MUX-II

The Flight Control Computer I/O module called RX-MUX has two main task to do. One of them is choosing the source of reference signals between the human pilot radio signals and the autopilot signals. The other main task is creating PWM signals from the incoming data and controlling the actuators. During the project, our team has completely redesigned the RX-MUX unit, both hardware and software. During the redesign we used a microcontroller unit with higher computational capacity and designed more interfaces to handle more actuators on the advanced wing. We also improved the communication with the RC modul using digital communication protocol, called EX Bus. After the complete redesign, we had to redesign the hardware again due to the global chip shortage, the new hardware was able to run the same software with minor modifications. The top side of the second redesign of the hardware shown in the figure 6.

During the rebuild, there was no significant hardware change, but since the {GLSfcc developed at SZTAKI and RC system at TUM it was inevitable to face minor issues during the integration. A slight, on the spot hardware changes needed to be done on the RX-MUX-II units, due to some bad electrical

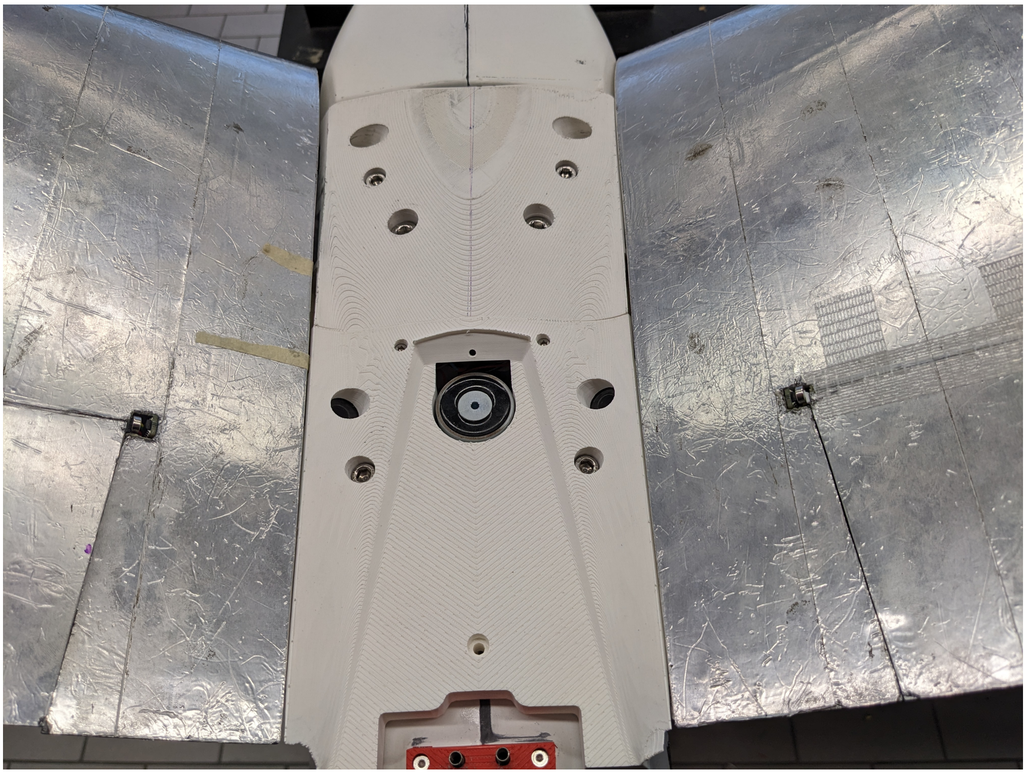


Figure 5: Control Surface Measmurement units visible on the Hinge-line of the Inner V-tail control surfaces

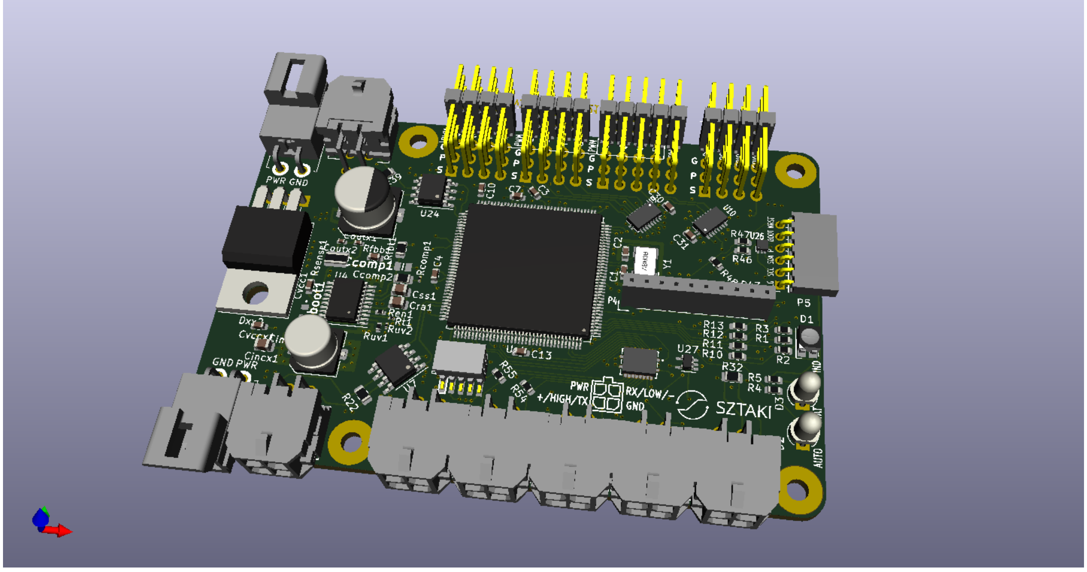


Figure 6: RX-MUX v2.2 top

connection with the RC system. Figure 7 shows the modified pinlayout. For stability reasons, the floating wires were fixed with epoxy.

3.10 Avionics Plate

A major design drive for the avionics plate was, to be able to easily remove it from the fuselage. For that, each cable and subsystem connection needed to be cut and ended in one or many physical, easy to access connectors.

late includes the following subsystems:

- FCC Stack
- Battery holder
- Power distribution board
- RC system
- Fail-Safe system

With the RC system and most of their sub-components directly installed on the avionics plate, the number of connector were minimized. Both part of the Fail-Safe system is connected to the avionics plate via one or more secure connection point. With that, replacement or easy repair of the individual modules are possible.

To keep modularity, the connectors between the avionics plate and the rest of the system were designed based around different subsystems, and their respective location. The 6 main connection point are the following:

- Propulsion system - D-sub
- Sensors and telemetry - D-sub
- Left tail - D-sub
- Right tail - D-sub
- Left wing
- Right wing

For the 4 main connector, replaceable pin D-sub connectors were used. Although, a new tool and technique is needed to be learned for setting the connectors, it turned to be faster and easier to set up all the connections. Moreover, it was possible and easy to fix single wires during integration if it was needed.

The left and right wing connections contains the actuator power and signal cables, CAN cable for the IMU's, CAN and power cable for the direct drive system.

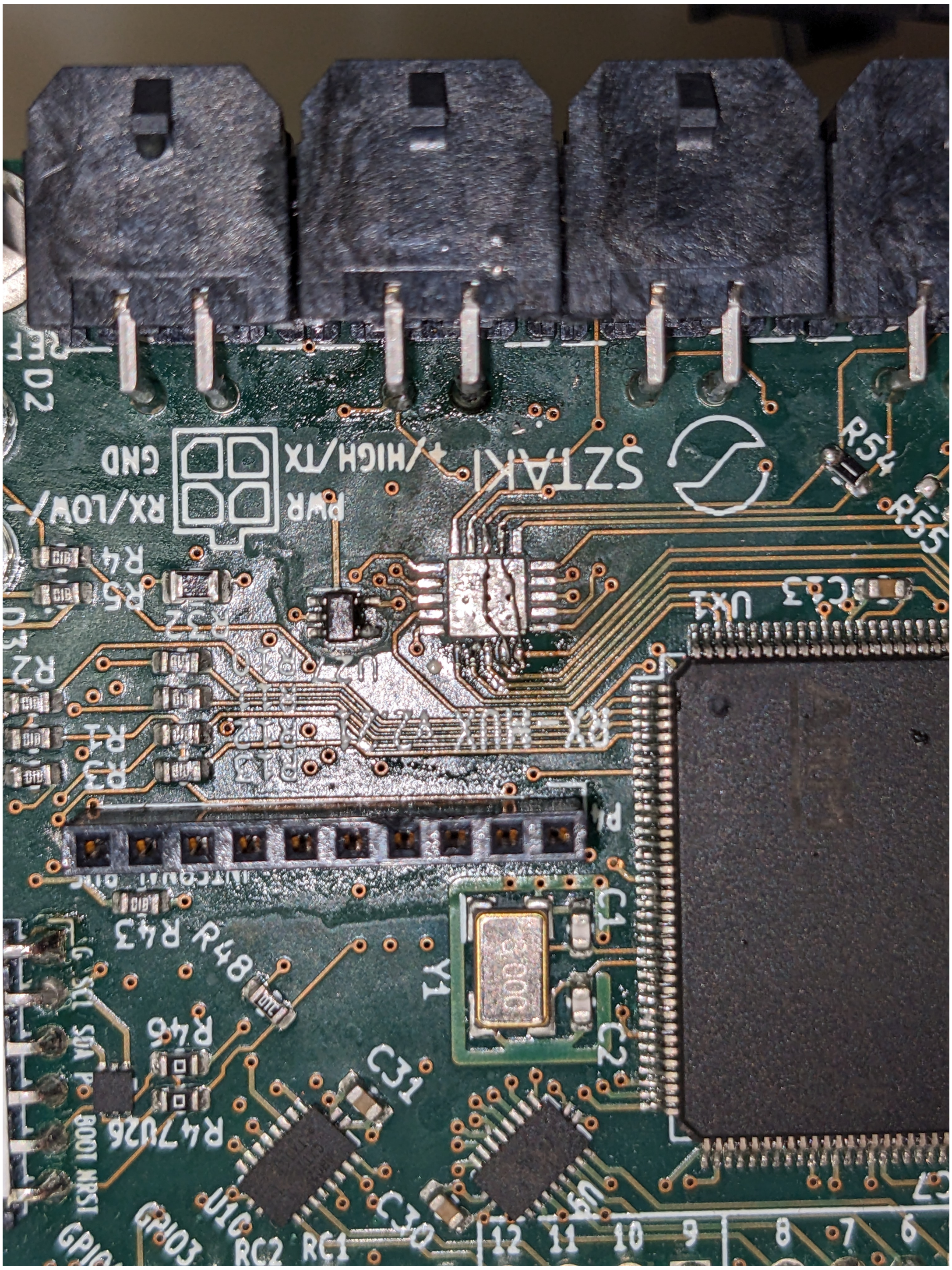
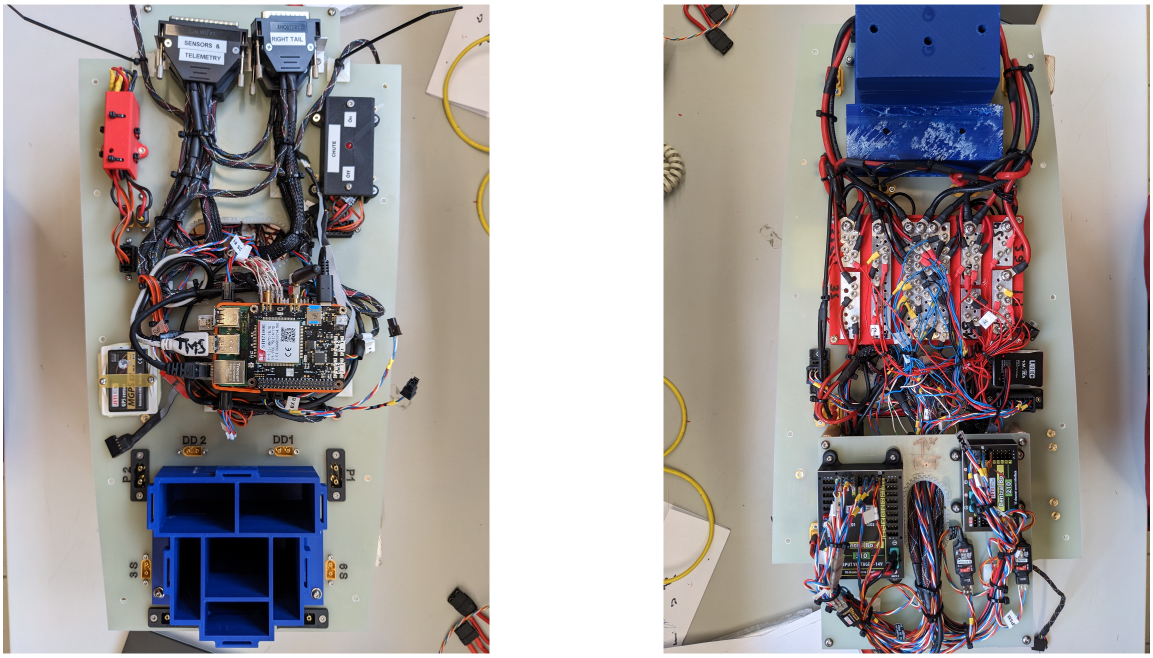


Figure 7: RX-MUX-II modified pin out



(a) Avionics plate top view

(b) Avionics plate bottom view

Figure 8: Fully integrated avionics plate before GVT

3.11 Fail-safe system

During the investigation of the accident, a major cause for the full-loss of aircraft was the unintentional fire. To mitigate that, 2 additional changes were made on the overall system. An additional hardware block were introduced to enable/disable ignition power for the engine, and a software change got introduced to disable engine start command after certain conditions 4.1. The original chute-release mechanism were kept the similar.

3.11.1 Chute release system

The chute release mechanism has two roles. First, release the chute any-time, the right conditions meet. Second, shut down the running engine. The action needs to happen at the same time, to prevent the melting of the parachute itself from the engine exhaust.

For the mechanism itself, 2 opto-switches - JETI SP06, and electric battery switch - EMCOTEC DualBat DPSI Micro - is used. The opto-switches are cutting the power line on the low-side (ground), based on the input signal from the respective transmitter system. The electro-magnet of the parachute is directly connected to the output of the batter switch. The output ground of the battery switch is connected to a safety line of the ECU, which will shut down an operational engine, if the safety line is not on same voltage as the ECU ground.

The system will terminate or release the parachute if:

- Both 2s battery voltage drops too low — battery loss
- Both RC system sends a terminate command
- Both RC system loose reception

- The system stays in terminated/release state after it is released

Because the opto-switches are cutting the ground, the voltage of the safety line will deviate from the ECU ground when the system is terminated.

3.11.2 Ignition switch

The Ignition mechanism uses similar layout as the Chute release, meaning it has one opto switch controlled by each RC subsystem, and a two-input power switch, which can be activated via a magnet. Since the engine requires a dedicated 12V input for ignition, this power-line is enabled/disabled via the Ignition switch.

Similar opto switches are used as with the chute release, but zepsus dual input magnetic switch were used, since that can handle 12V and high current flows.

In practice, this should behave similarly to the chute release mechnizm, expect for staying deactivated, since this module has a built-in memory functionality. Based on manufacturing data, the memory functionality work for some seconds.

3.12 4G-HAT

The purpose of the 4G-HAT was to be able to upload flight data to a remote network and analyzing it online during flight. This would have made it possible to quickly evalutate the results of a flight manouvre and decide if it needs to be repeated or not.

The development was done at SZTAKI throughout the course of the project. Unfortunately, the manual of the 4G-HAT did not provide sufficient information about the product, therefore the integration took much more time than expected. Apart from that, the behaviour of the HAT was not reliable, because it was restarting and losing connection to the SIM card often.

Moreover, the available time available for testing in Germany was very short. In Hungary, it showed promising result regarding upload speeds, but at TUM the performance was much worse. The reason was probably the fact that we only had a Hungarian SIM card to work with so it was roaming outside of Hungary.

Apart from the bad reliability and poor cellular reception, the 4G-HAT interfered with the FCC-OBC2 network communication. The result was unpredictable transmission speed and sometimes packet drops between the two Raspberry Pis. Therefore, the verdict was to omit the 4G-HAT completely from the onboard electronics. It would have been a useful addition but the OBC2's online modal analysis software which relies on the data coming from the FCC is a much more essential part of the system.

4 Major Software Changes

4.1 RX-MUX-II

During the rebuild we redesigned the RC structure of the aircraft and replaced the PPM communication by digital EX Bus protocol between RC receiver and RX-MUX-II. We removed the Sbus implementation from the plan since we chose a Jeti system to primary and backup as well. With the new RC system, we were able to handle more channels and some modifications in the A/C also caused the change of the whole RC structure. These changes necessitated other small changes in other software parts as well. The software changes are shown in figure 9.

The new RC system offers 8 additional channels for a total of 24. Most of the new channels were used to split up functions on the aircraft that were previously combined to one, and the complete channel order was re-assigned, to make it more transparent. The RX-MUX-II was updated to handle the additional channels. Since now we had the ability, we upgraded the RC system selection method. The now implementation allows the pilot monitoring to take control of the aircraft without the other pilot's cooperation. However, the pilot currently controlling the aircraft, cannot give the control to the pilot monitoring. If this is attempted, control is only transferred after the pilot monitoring also flips the correspondig switch on his transmitter.

To control the planned CAN servos in the -3 wing, the software component responsible for handling them was heavily tested, finalized and added to the code. After the plans changed regarding the advanced wing, the CAN servo handling feature had to be slightly modified. This was needed so that we can use a direct drive and a CAN servo, on the same CAN bus.

The direct drive also required additional software changes. To communicate with the drive controller, a new software module was added. This new module consists of a CANopen stack, specifically CANopenNode. CANopen is a high level communication protocol and device profile specification, that is usually used in automation. It uses an ordinary CAN bus for the physical and data link layers. This modification turns the RX-MUX into a CANopen capable device. The CANopen network in our case only consist of 1 RX-MUX and 1 Direct Drive. A simple custom device description was made for the RX-MUX, just enough to be able to control the necessary functions of the drive. RX-MUXs are responsible for one direct drive each. One of the three available CAN ports on the RX-MUX was modified to use CANopen.

On top of this, a state machine was implemented, that establishes communication with the drive, configures the required parameters, and tries to turn on the motor as soon as possible. If the drive detects a problem and stops, the RX-MUX checks the error code, and if the error was declared safe (for example momentary over current), it will attempt a restart. All other maskable fault reactions were disabled in the direct drive, to avoid any unnecessary shutdowns.

4.2 OBC-II

On the old T-Flex aircraft, there were a lot of problems with interference within the telemetry system, because three radio transmitters with the same frequency were used in the payload bay. To cope with this problem, a new 868 MHz radio pair was introduced to the system which handled the EDL and Online Modal Analysis output data streams. This way, one telemetry link was omitted reducing interference. For this, both EDL and OMA had to be run on the same hardware, therefore EDL had to be moved onto the. The resulting data flow of the OBC-II is visible in figure 10.

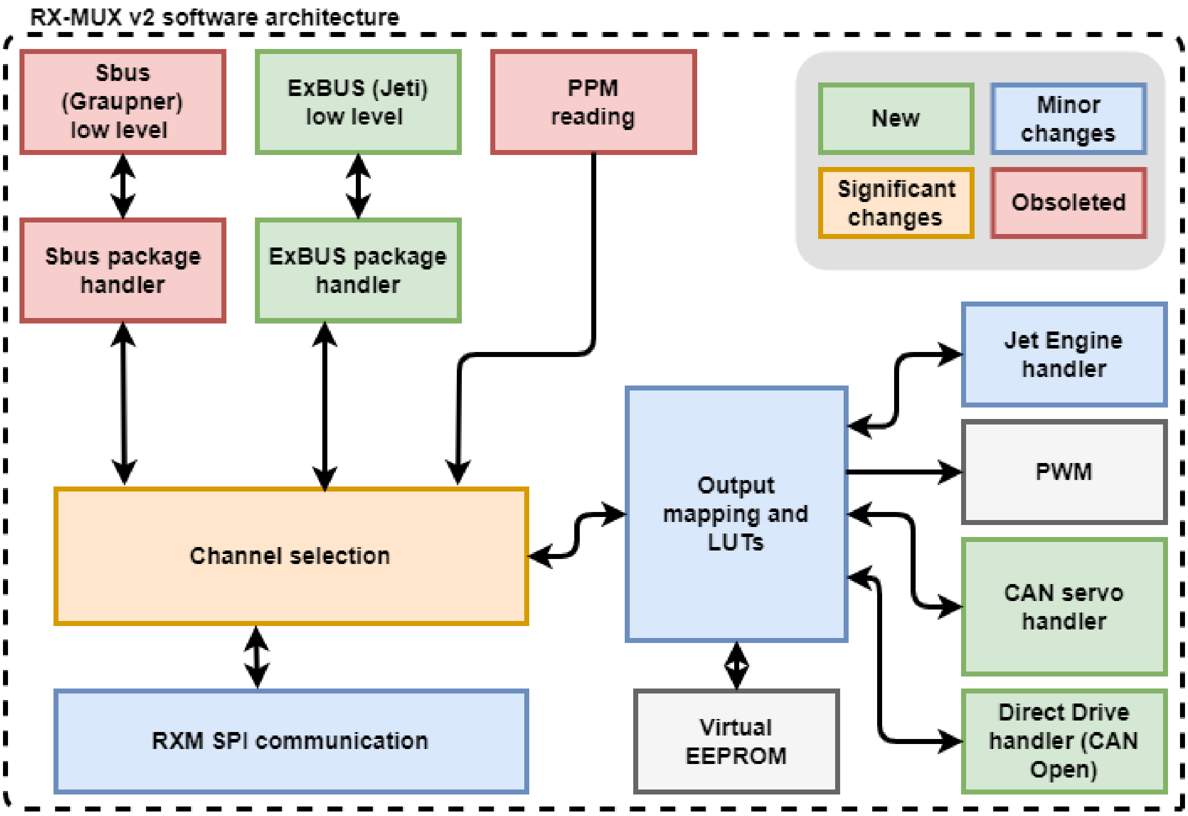


Figure 9: RX-MUX v2.2 software architecture

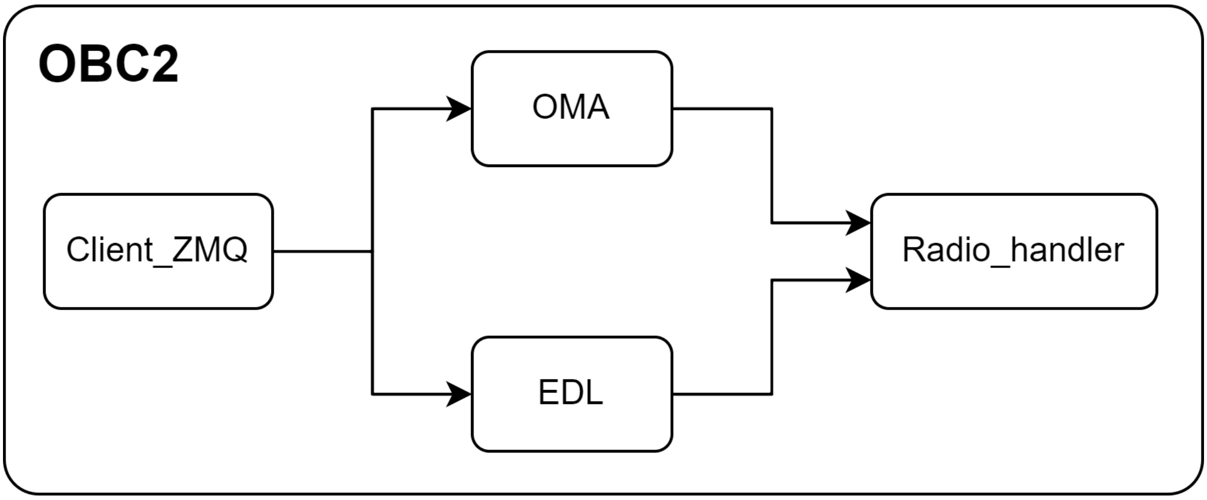


Figure 10: OBC-II datastream

As it is visible in figure 10, the data received by Client ZMQ is further transmitted to both OMA and EDL processes. These then send their output to the Radio handler process which handles the USB connection to the on-board 868 MHz radio module. As it was previously the case, the Client ZMQ - OMA connection is implemented with the ZMQ library. However the rest of the connections are using UNIX sockets as the tool for interprocess communication.

4.3 FCC

Caused by the RC structure change, we had to apply minor changes in the autopilot software as well. We added new flight test pattern, so horse race and cicrle pattern was selectable via the Mission Planner interface. We also implemented new signals for system identification tests. On the advanced wing, IMUs was installed in different orientation, so autopilot had to be able to handle those, it was important for flutter controllers.

The most important changes in the autopilot software was the flutter detector, the flutter controller from DLR and flutter controller from SZTAKI which all implemented in the software.

No major changes were done on the FCCs side of the telemetry system, apart from some additional autopilot tunable parameters which are handled through MavLink messages. Moreover, the output of the newly introduced flutter monitoring system is sent through EDL and MavLink as well. No additional messages were available due to restricted bandwidth, so unused slots of already implemented messages had to be used.

4.4 Telemetry updates on the GCS

The merging of two telemetry channels on the aircraft electronics meant that some changes had to be carried out on the ground as well too. The two data stream handlers had to be merged into one single process which communicates with the 868 MHz module as well. Messages had to be separated based on their headers and the appropriate message handler function had to be used.

The rest of the functionalities in the Ground Control Station remained untouched, apart from some minor updates, like reworked EDL messages containing data about the DirectDrive and ECU. On the MissionPlanner side, most of the changes were made due to the new signal injection options and some new autothrottle reference speeds.

4.5 Remote Control System Interface

Using the integrated programming capabilities of the JETI transmitters, a custom telemetry screen were created for both transmitter, to show the relevant information collected by the on-board sensor for the pilots. Audible and vibrational feedback were also set up to indicate different system states, like low reception quality, low battery voltage and so on.

5 Advanced Wing Manufacturing (Wing-3b) Manufacturing

This chapter summarizes and concludes the manufacturing and integration of the wing-3b. After the flight accident with the demonstrator at the end of august 2022, the consortium decided to use the remaining time and manpower to rebuild the demonstrator and focus on the finalization of the Wing-1, instead of finishing the wing-3b.

5.1 Cabling design

The plan for wing-3b was to divide the existing control surfaces into smaller, independent ones. To control the 5 additional servos in each wing, we've changed the MKS branded PWM controlled servos, to Hitec MD950TW-CAN servos, that can be controlled via CAN bus. This was necessary as there was not enough space inside the wing, to route 5 new PWM signal wires. There were already two CAN bus cables inside, one for the active wing IMUs and SHM units, and one for the backup IMUs. We've decided to use these. On the unused one, the servos would be simply connected as the only (active) nodes. On the other bus, we have conducted experiments to verify that the network usage was acceptable with the 7 IMU + 2 SHM + 5 servos + RX-MUX2 + flightHAT configuration. With the latest firmware on the servos, we had no issues, network traffic was slightly below 70%, with the targeted 200Hz refresh rate.

The batteries were assigned to the servos in a way, that in case we lose voltage from one of them, the other would still keep enough control surfaces operational on both wings, to control the aircraft. The same was considered when choosing the RX-MUX unit to control the servos. This means that we had enough redundancy built on that theoretically we could still control the aircraft in case of a battery and simultaneous RX-MUX failure.

On the innermost flap, we've kept the original PWM servos, as we couldn't find a CAN bus operated replacement with enough torque. Figure 11 shows the cabling layout design.

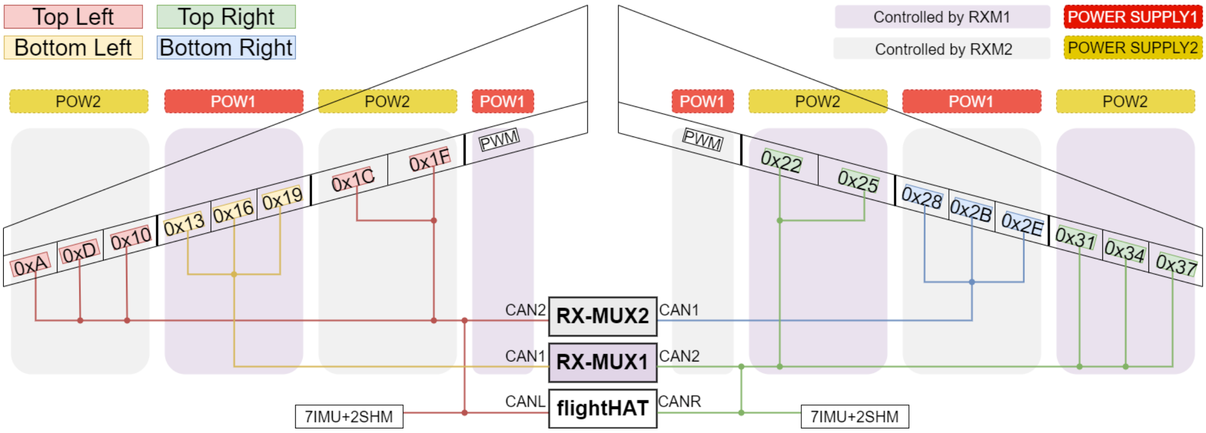


Figure 11: Wing-3b cabling layout with servo CAN ID-s

The CAN servos also have built in diagnostic capabilities. We can monitor the current position of the servo arm, as well as the voltage and temperature via the CAN bus. Because of this, the new servos do not require a SHM unit, making installation and usage easier.

5.2 Cabling implementation

Due to the already tight spaces left in the wing-0, there was no possible way to put in a new cable from the wing root until the wing tip, For that reason, only attachment point at the already existing node were added to support the high number of actuators.

After the servo mounting hole were cut out, all the wires were examined and tested. After a possible routing were found or in some case made, the necessary cabling for all the nodes were integrated. Figure 12 shows the left wing under testing during cable integration.

On both wings, the the cable integration were finished until the point, that all the servo motors were able to connect together. The Cabling were tested against shorts and open cables, were no such problem were found, indicating that the last steps for the integration tests can be started. Figure 13 shows some connected flap actuator.

5.3 Mechanical integration results

The necessary cutouts for the servo motors were made, and the new control surfaces were manufactured. However, due to the shift in focus for the project, the the control surface attachments, the servo motor mountings and final integration and test for the wing were not done.

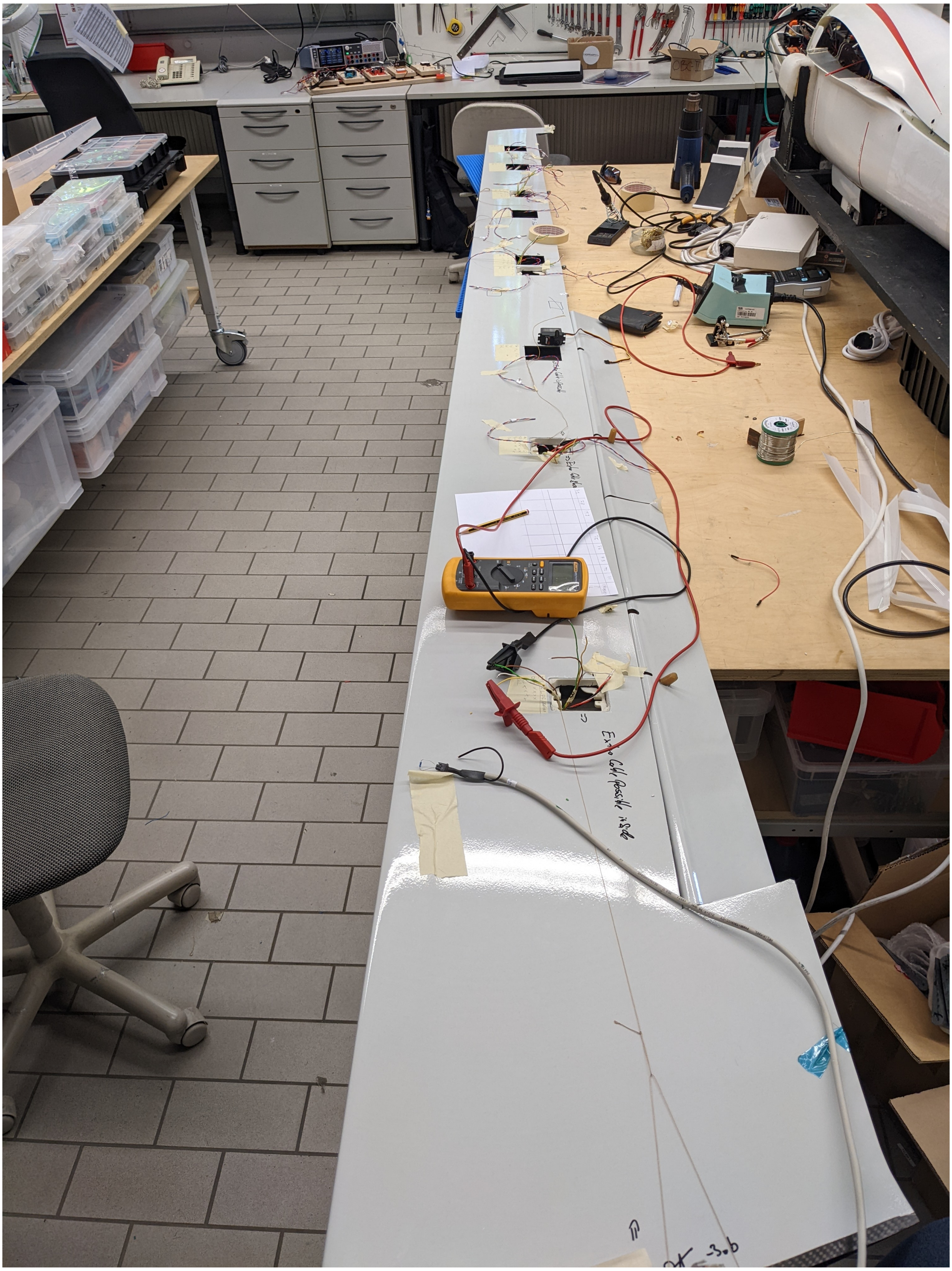


Figure 12: Wing-3b cabling under testing during integration

(a) Flap 2 (b) Flap 3 (c) Flap 8

Figure 13: A few servos in the respective locations in the already cabled wing

6 Conclusion and Current State

The demonstrator were ready in time for the GVT campaign, although some of the subsystem were not fully integrated until that point. Until the first week of the first flight test campaign, all the remaining subsystem were integrated and tested expect for the telemetry system. As expected, the system become operational only after the members of development and operation team spend a couple of days with the fully assembled aircraft at the airport during the first flight test campaign.

Compared to the first iteration of the fuselage, all the design change made on subsystem level and cabling layout proved to be a positive step forward to an easily usable demonstrator. The introduction of programmed interface for the pilots, and the different switches on the payload area allowed a faster and more stable turn-on and turn-off process. The fual tank extension made it possible to make 30-40 minutes flights [**?**], thus allowing to make the most out of each flight. In overall, P-FLEX proved to be a reliable platform for most of our experiments during both flight test campaign.

7 Bibliography

[1] Zmq - an open-source universal messaging library, 13.06.2023.

[2] Xiaohui Chen, Daniel Teubl, and Mirko Hornung. Retrofitting actuators on the t-flex demonstrator with enhanced actuator monitoring system. 2022.

[3] Szabolcs Toth Fanglin Yu, Daniel Teubl. Flipased D3.10 flight readiness review demonstrator with advanced wing. Technical report, TUM, 2023.

[4] Szabolcs Toth Keith Soal, Daniel Teubl. Flipased D3.9 advanced wing integration and ground test completed. Technical report, TUM, 2023.

[5] P. Stahl. Flexop D3.1 report on demonstrator detailed design. Technical report, TUM, 2016.

[6] D. Teubl, T.W. Bitenc, and M. Hornung. Design and development of an actuator control and monitoring unit for small and medium size research uavs. *Deutsche Gesellschaft fr Luft- und Raumfahrt - Lilienthal-Oberth e.V.*, 2021.

[7] Daniel Teubl, Sebastian Oberschwendtner, and Mirko Hornung. Measurement results of the acmu system in various research uavs. In *AIAA SCITECH 2023 Forum*, page 0481, 2023.