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D3.6 Flight Test Report – Flight Test Phase #2, Julius Bartasevicius (TUM), Keith Soal, Thiemo Kier (DLR), Tamas Luspay, Daniel Balogh (SZTAKI)

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Glossary

AGL	Above Ground Level
ATZ	Aerodrome Traffic Zone
BLDC	Brushless Direct Current
CAN	Controller Area Network
CONOPS	Concept of Operations
EDBC	Magdeburg-Cochstedt Airport
EDL	Electronic Dispatch Logging
EDMO	Airport Oberpfaffenhofen
FCC	Flight Control Computer
FT	Flight Test
FTO	Flight Test Operator
GCS	Ground Control Station
GUI	Graphical User Interface
GVT	Ground Vibration Test
HIL	Hardware in the Loop
HW	Hardware
IMU	Inertial Measurement Unit
LBA	National Aviation Authority of Germany
LRZ	Leibniz-Rechenzentrum
LTE	Long Term Evolution
MCT	Mission Control Technologies
MIMO	Multi-Input Multi-Output
PCI	Peripheral Component Interconnect
PID	Proportional–Integral–Derivative
PPM	Pulse-Position Modulation
RC	Remote Controller
SIL	Software in the Loop
SISO	Single-Input Single-Output
SW	Software
TMS	Thrust Measurement Sensor
UAV	Unmanned Aerial Vehicle
VLOS	Visual Line Of Sight
VPN	Virtual Private Network
VV	Verficiation/Validation
RMS	Root Mean Square
TECS	Total Energy Control System
RPM	Revolutions per minute
OMA	Operational modal anaysis
SVD	Singular value decomposition
PCB	Printed circuit board
VLM	Vortex lattice method

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1 Executive Summary

This deliverable describes the flight tests done with the baseline (stiff) -0 wing in 2022. The flights in that year were done in two campaigns - one in May and one in August.

The results of this deliverable build up on results gathered in D3.2 - Flight Test Report Phase 1, where issues with landing gear were being tackled. It includes a summary and description of each flight test, as well as separate chapters for topics stemming from the results of the flight tests like baseline aerodynamic analysis, autopilot mode evaluation, flexible body mode identification, and others.

The second test campaign of 2022 ended with the accident. During the accident, the aircraft lost connection to the pilots, so the parachute was released. Consequently, the engine restarted after landing on the ground, and the plane burnt down. This flight concluded the tests with the baseline wing, and the focus was shifted to rebuilding the fuselage and starting tests with the flexible -1 wing. The results of flight tests with that wing will be described in D3.11 - Flight Test Report Phase 3.

2 Planning and Execution of Flight Test Phase 2

The first two-week flight test campaign within the FLiPASED framework took place between 09-19.05.2022. Many challenges had to be solved before making this campaign happen. Most importantly, the new rules for acquiring flight permits for UAVs have introduced a significant delay in the process.

2.1 Flight Permit Acquisition

The flight permit application required a new edition of Concept of Operations (CONOPS) written explicitly for the Magdeburg-Cochstedt Airport (EDBC). This CONOPS document is available on request.

The application's first version was submitted to the National Aviation Authority of Germany (LBA) on 31st of August, 2021. The second version had to include some significant changes to the application; the second version was submitted on the 30th of September. After this stage, the feedback regarding the application was only received on the 17th of December and was implemented in the third version of the application. The application was submitted on the 13th of January. After receiving the feedback, another version was submitted on 11th of March and the final version on 15th of April. The whole process required significant amount of work on documentation and adjusting the operations that would comply with the new regulations. On top of that, as the requirements were newly introduced during the period of application, it was not clear how to comply with some of the points. For example, the definition of the difference in between the ”sparsely populated area” and ”populated area” is nowhere clearly defined, or the methods to calculate the ground risk buffer was not well described at that point.

Finally, the flight permit was acquired on 25th of April and the detailed planning for the test campaign could take place.

The initial flight permit was issued only from 25th of April till 15th of June. Another update of the permit application had to be done for the permit to be extended from 9th of August till 15th of November. This period was chosen to fit the second and third test campaigns of the year (the third test campaign did not happen due to the accident on flight test 23).

2.2 Goals for the 1st flight test campaign

Due to the problems described in D3.2 Flight Test Report – Flight Test Phase #1, only three test flights were conducted in years 2020 and 2021 (designated FT7, FT8 and FT9). Therefore the first flight of the test campaign in 2022 would be the fourth flight of the project (designated FT10).

The following goals (in decreasing priority) were raised for the campaign:

1. Test all the functionalities of the autopilot so that it is ready for flutter tests. This means testing the following modules:
   (a) Augmented mode,
   (b) Altitude hold,
   (c) Airspeed hold,
   (d) Course angle hold,
   (e) Coordinated turn,
   (f) Waypoint flight (following the race track),

   (g) Signal injection.

2. Gather enough flight data to identify the rigid body modes. Special manoeuvres (pulses, doublets, multisine inputs, pull-ups) were planned for this.

3. Gather enough flight data to identify the flexible body modes. No special manoeuvres were planned for this.

4. Baseline aerodynamic coefficient determination:
   (a) Lift/drag/moment polars for cruise configuration (part of the data from point 2 can be used),
   (b) Gather in-flight data for take-off and landing flap configurations,
   (c) Gather data for drag components (landing gear and different airbrake settings).

5. Flying the -1 wing. Flying it in a flutter-safe configuration would give us confidence for the future flights with it. If it is flown, manoeuvres for rigid body modes, baseline aerodynamics and flexible modes would be done.

6. Training new pilots. Two new pilots have joined the test team at TUM who have never flown the T-FLEX before. With one of the old pilots leaving TUM soon, the new pilots must get confident with the aircraft.

7. Visualization of airflow over the wings:
   (a) Tuft experiments are planned and prepared to look for any unexpected flow separation on -0 wing,
   (b) Oil flow experiments are planned and prepared to investigate transition location on -0 wing. No extra manoeuvres were planned for this.

8. Airspeed calibration in-flight. Manoeuvres to identify the position error of the air data system are prepared.

9. Induced drag experiments. Performing flights with -0 wing with different flap configurations could already give insight if the change of induced drag is measurable. For this reason, three flap configurations would be flown: standard cruise state, maximum induced drag state and minimum induced drag state.

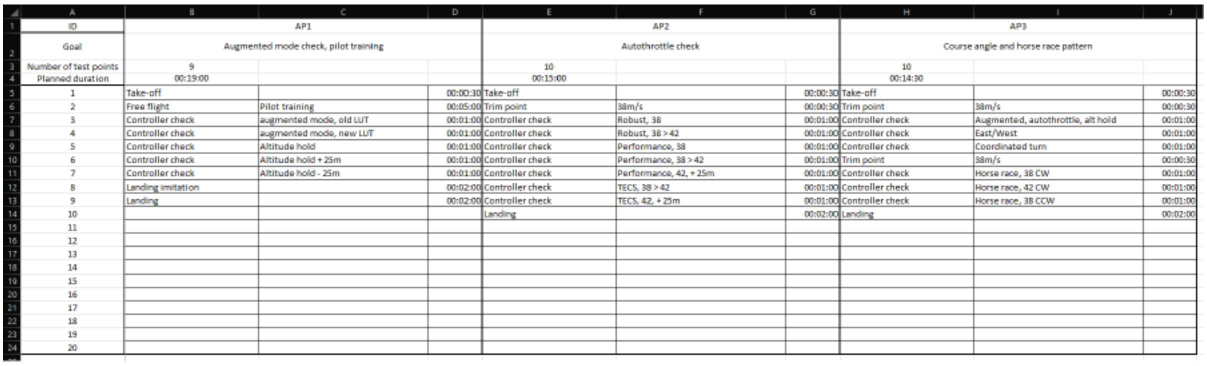
10. Engine model identification. Further throttle injections can be done, if required.

2.3 Planning for the 1st flight test campaign

The goals mentioned above were roughly allocated to specific flight tests for initial planning. Some test points were already assigned to specific flights: 3 Autopilot test flights were estimated (Figure 1), 4 baseline aerodynamic flights (two of them are described in Figure 2) and 6 rigid body mode aerodynamic identification flights (Figures 3 and 4).

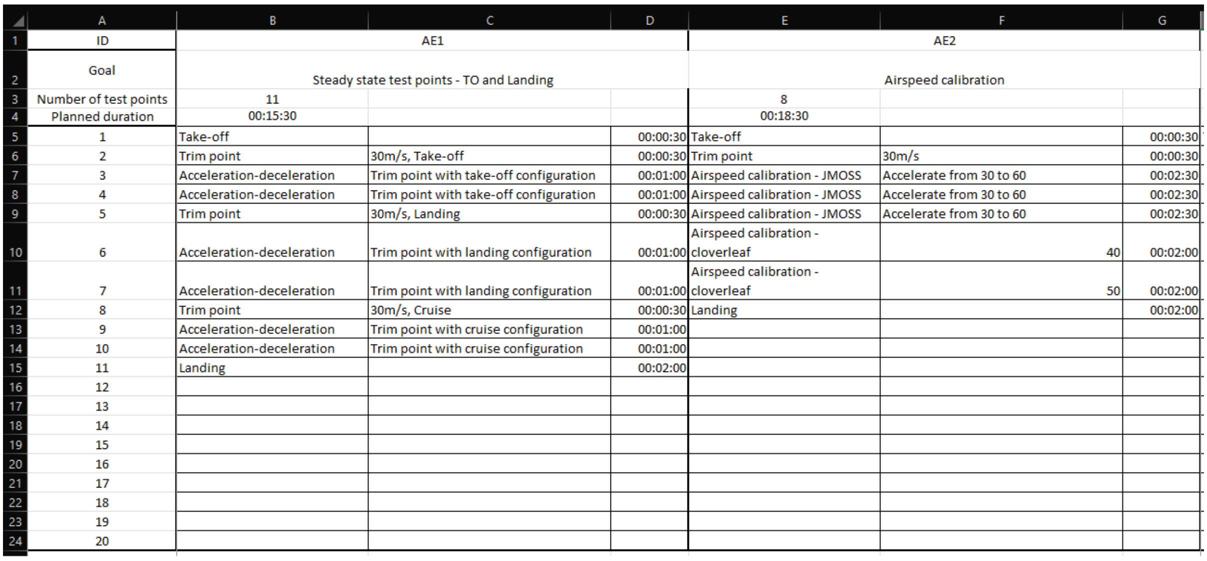
In the end, the test points were discussed before each flight and test plan had to be rewritten due to many unforeseen problems.

Initially it was estimated that at the best case scenario 4 flights could be done per day. Combined with the availability of the crew, a schedule was made (Figure 5). In the schedule the number of flights done is also noted.



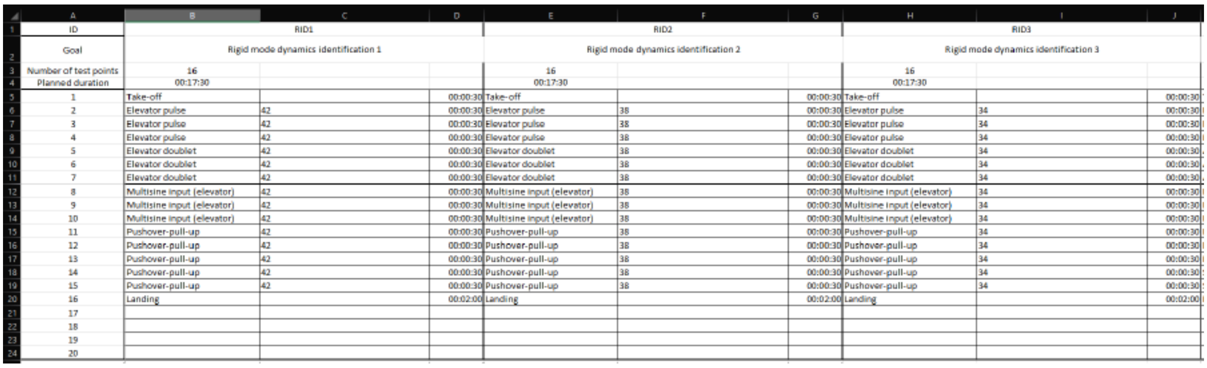
	A	B	C	D	E	F	G	H	I	J
1	ID	AP1			AP2			AP3		
2	Goal	Augmented mode check, pilot training			Autothrottle check			Course angle and horse race pattern		
3	Number of test points	9			10			10		
4	Planned duration	00:19:00			00:15:00			00:14:30		
5	1	Take-off		00:00:30	Take-off		00:00:30	Take-off		00:00:30
6	2	Free flight	Pilot training	00:05:00	Trim point	38m/s	00:00:30	Trim point	38m/s	00:00:30
7	3	Controller check	augmented mode, old LUT	00:01:00	Controller check	Robust, 38	00:01:00	Controller check	Augmented, autothrottle, alt hold	00:01:00
8	4	Controller check	augmented mode, new LUT	00:01:00	Controller check	Robust, 38 > 42	00:01:00	Controller check	East/West	00:01:00
9	5	Controller check	Altitude hold	00:01:00	Controller check	Performance, 38	00:01:00	Controller check	Coordinated turn	00:01:00
10	6	Controller check	Altitude hold + 25m	00:01:00	Controller check	Performance, 38 > 42	00:01:00	Trim point	38m/s	00:00:30
11	7	Controller check	Altitude hold - 25m	00:01:00	Controller check	Performance, 42, + 25m	00:01:00	Controller check	Horse race, 38 CW	00:01:00
12	8	Landing imitation		00:02:00	Controller check	TECS, 38 > 42	00:01:00	Controller check	Horse race, 42 CW	00:01:00
13	9	Landing		00:02:00	Controller check	TECS, 42, + 25m	00:01:00	Controller check	Horse race, 38 CCW	00:01:00
14	10				Landing		00:02:00	Landing		00:02:00
15	11									
16	12									
17	13									
18	14									
19	15									
20	16									
21	17									
22	18									
23	19									
24	20									

Figure 1: Test points planned for autopilot controller tests.



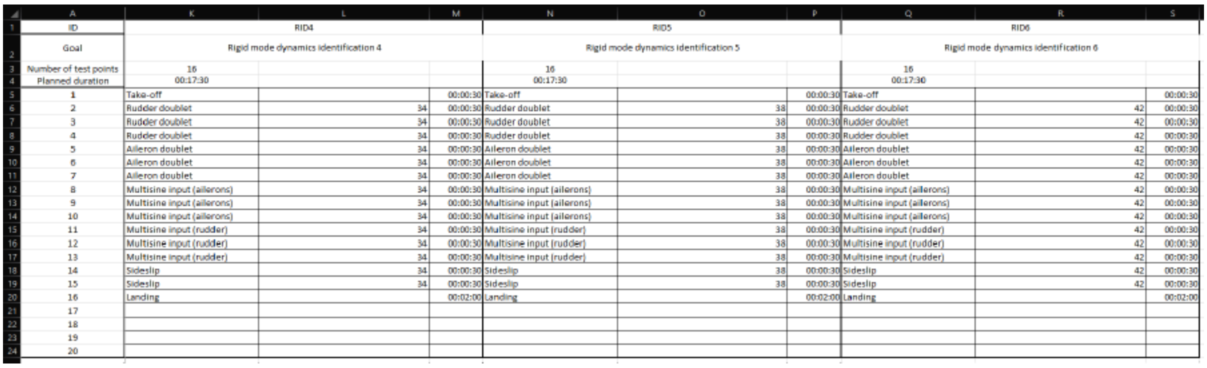
	A	B	C	D	E	F	G
1	ID	AE1			AE2		
2	Goal	Steady state test points - TO and Landing			Airspeed calibration		
3	Number of test points	11			8		
4	Planned duration	00:15:30			00:18:30		
5	1	Take-off		00:00:30	Take-off		00:00:30
6	2	Trim point	30m/s, Take-off	00:00:30	Trim point	30m/s	00:00:30
7	3	Acceleration-deceleration	Trim point with take-off configuration	00:01:00	Airspeed calibration - JMOSS	Accelerate from 30 to 60	00:02:30
8	4	Acceleration-deceleration	Trim point with take-off configuration	00:01:00	Airspeed calibration - JMOSS	Accelerate from 30 to 60	00:02:30
9	5	Trim point	30m/s, Landing	00:00:30	Airspeed calibration - JMOSS	Accelerate from 30 to 60	00:02:30
10	6	Acceleration-deceleration	Trim point with landing configuration	00:01:00	Airspeed calibration - cloverleaf	40	00:02:00
11	7	Acceleration-deceleration	Trim point with landing configuration	00:01:00	Airspeed calibration - cloverleaf	50	00:02:00
12	8	Trim point	30m/s, Cruise	00:00:30	Landing		00:02:00
13	9	Acceleration-deceleration	Trim point with cruise configuration	00:01:00			
14	10	Acceleration-deceleration	Trim point with cruise configuration	00:01:00			
15	11	Landing		00:02:00			
16	12						
17	13						
18	14						
19	15						
20	16						
21	17						
22	18						
23	19						
24	20						

Figure 2: Test points planned for baseline aerodynamic tests.



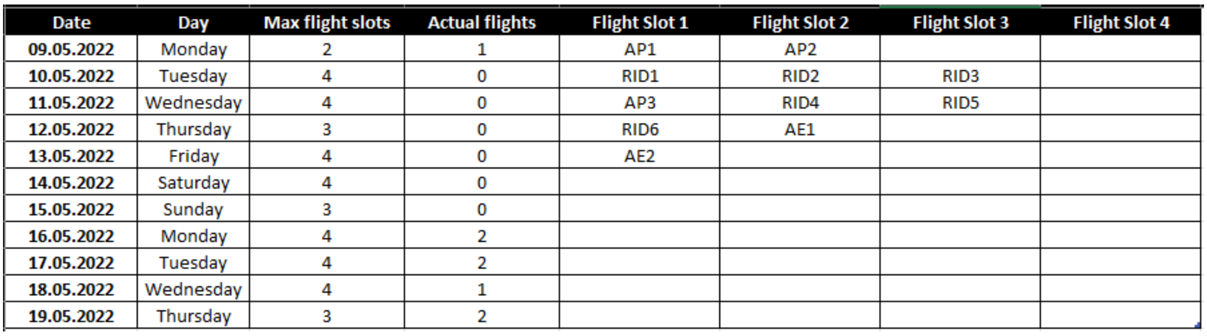
	A	B	C	D	E	F	G	H	I	J
1	ID	RID1			RID2			RID3		
2	Goal	Rigid mode dynamics identification 1			Rigid mode dynamics identification 2			Rigid mode dynamics identification 3		
3	Number of test points	16			16			16		
4	Planned duration	00:17:30			00:17:30			00:17:30		
5	1	Take-off		00:00:30	Take-off		00:00:30	Take-off		00:00:30
6	2	Elevator pulse	42	00:00:30	Elevator pulse	38	00:00:30	Elevator pulse	34	00:00:30
7	3	Elevator pulse	42	00:00:30	Elevator pulse	38	00:00:30	Elevator pulse	34	00:00:30
8	4	Elevator pulse	42	00:00:30	Elevator pulse	38	00:00:30	Elevator pulse	34	00:00:30
9	5	Elevator doublet	42	00:00:30	Elevator doublet	38	00:00:30	Elevator doublet	34	00:00:30
10	6	Elevator doublet	42	00:00:30	Elevator doublet	38	00:00:30	Elevator doublet	34	00:00:30
11	7	Elevator doublet	42	00:00:30	Elevator doublet	38	00:00:30	Elevator doublet	34	00:00:30
12	8	Multisine input (elevator)	42	00:00:30	Multisine input (elevator)	38	00:00:30	Multisine input (elevator)	34	00:00:30
13	9	Multisine input (elevator)	42	00:00:30	Multisine input (elevator)	38	00:00:30	Multisine input (elevator)	34	00:00:30
14	10	Multisine input (elevator)	42	00:00:30	Multisine input (elevator)	38	00:00:30	Multisine input (elevator)	34	00:00:30
15	11	Pushover-pull-up	42	00:00:30	Pushover-pull-up	38	00:00:30	Pushover-pull-up	34	00:00:30
16	12	Pushover-pull-up	42	00:00:30	Pushover-pull-up	38	00:00:30	Pushover-pull-up	34	00:00:30
17	13	Pushover-pull-up	42	00:00:30	Pushover-pull-up	38	00:00:30	Pushover-pull-up	34	00:00:30
18	14	Pushover-pull-up	42	00:00:30	Pushover-pull-up	38	00:00:30	Pushover-pull-up	34	00:00:30
19	15	Pushover-pull-up	42	00:00:30	Pushover-pull-up	38	00:00:30	Pushover-pull-up	34	00:00:30
20	16	Landing		00:02:00	Landing		00:02:00	Landing		00:02:00
21	17									
22	18									
23	19									
24	20									

Figure 3: Test points planned for rigid mode identification tests (flights 1 to 3).



	A	K	L	M	N	O	P	Q	R	S
1	ID	RID4			RID5			RID6		
2	Goal	Rigid mode dynamics identification 4			Rigid mode dynamics identification 5			Rigid mode dynamics identification 6		
3	Number of test points	16			16			16		
4	Planned duration	00:17:30			00:17:30			00:17:30		
5	1	Take-off		00:00:30	Take-off		00:00:30	Take-off		00:00:30
6	2	Rudder doublet	34	00:00:30	Rudder doublet	38	00:00:30	Rudder doublet	42	00:00:30
7	3	Rudder doublet	34	00:00:30	Rudder doublet	38	00:00:30	Rudder doublet	42	00:00:30
8	4	Rudder doublet	34	00:00:30	Rudder doublet	38	00:00:30	Rudder doublet	42	00:00:30
9	5	Aileron doublet	34	00:00:30	Aileron doublet	38	00:00:30	Aileron doublet	42	00:00:30
10	6	Aileron doublet	34	00:00:30	Aileron doublet	38	00:00:30	Aileron doublet	42	00:00:30
11	7	Aileron doublet	34	00:00:30	Aileron doublet	38	00:00:30	Aileron doublet	42	00:00:30
12	8	Multisine input (ailerons)	34	00:00:30	Multisine input (ailerons)	38	00:00:30	Multisine input (ailerons)	42	00:00:30
13	9	Multisine input (ailerons)	34	00:00:30	Multisine input (ailerons)	38	00:00:30	Multisine input (ailerons)	42	00:00:30
14	10	Multisine input (ailerons)	34	00:00:30	Multisine input (ailerons)	38	00:00:30	Multisine input (ailerons)	42	00:00:30
15	11	Multisine input (rudder)	34	00:00:30	Multisine input (rudder)	38	00:00:30	Multisine input (rudder)	42	00:00:30
16	12	Multisine input (rudder)	34	00:00:30	Multisine input (rudder)	38	00:00:30	Multisine input (rudder)	42	00:00:30
17	13	Multisine input (rudder)	34	00:00:30	Multisine input (rudder)	38	00:00:30	Multisine input (rudder)	42	00:00:30
18	14	Sideslip	34	00:00:30	Sideslip	38	00:00:30	Sideslip	42	00:00:30
19	15	Sideslip	34	00:00:30	Sideslip	38	00:00:30	Sideslip	42	00:00:30
20	16	Landing		00:02:00	Landing		00:02:00	Landing		00:02:00
21	17									
22	18									
23	19									
24	20									

Figure 4: Test points planned for rigid mode identification tests (flights 4 to 6).



Date	Day	Max flight slots	Actual flights	Flight Slot 1	Flight Slot 2	Flight Slot 3	Flight Slot 4
09.05.2022	Monday	2	1	AP1	AP2		
10.05.2022	Tuesday	4	0	RID1	RID2	RID3	
11.05.2022	Wednesday	4	0	AP3	RID4	RID5	
12.05.2022	Thursday	3	0	RID6	AE1		
13.05.2022	Friday	4	0	AE2			
14.05.2022	Saturday	4	0				
15.05.2022	Sunday	3	0				
16.05.2022	Monday	4	2				
17.05.2022	Tuesday	4	2				
18.05.2022	Wednesday	4	1				
19.05.2022	Thursday	3	2				

Figure 5: The planned schedule for the flight test campaign.

2.4 Flight Test Description for the 1st Flight Test Campaign, May 2022

In total, 8 flights were done, totalling to around 140min of flight time. The main issue was the windy conditions at the airport with big crosswind components every day. This resulted in three crashes, with one of them being especially severe. The crashes happened the day after the first flight, therefore a few days had to be spent repairing the aircraft (section 2.4.2).

After repairs it was decided to wait for a calmer weather, which did not happen during the first week. The modelled (not recorded) weather history is provided in Figure 6. In between 11-15 of May, $2-8m/s$ wind was estimated. This was also confirmed with the measured wind conditions at the two nearby weather stations (Figure 7), where $8m/s$ wind with gusts up to $16m/s$ was recorded. Note that later on it was established that the safe takeoff crosswind limit for this aircraft is $4m/s$.

2.4.1 FT10

Flight test 10 (FT10) was the first flight of the year and it was conducted in a new environment for the whole flight test crew. During the flight, the new second pilot was trained. The rest of the flight was used to check the augmented mode. At that point it was reported that the aircraft seems to slightly oscillate when the augmented mode was turned on. The flight was concluded after 13min.

2.4.2 FT11

FT11 was planned as another training flight with additional flight segments done for flexible mode identification in-flight (steady coordinated turn points). Also, for this and following flights the left wing was covered in tufts to investigate the airflow separation due to extended flaps (Figure 10). However, due

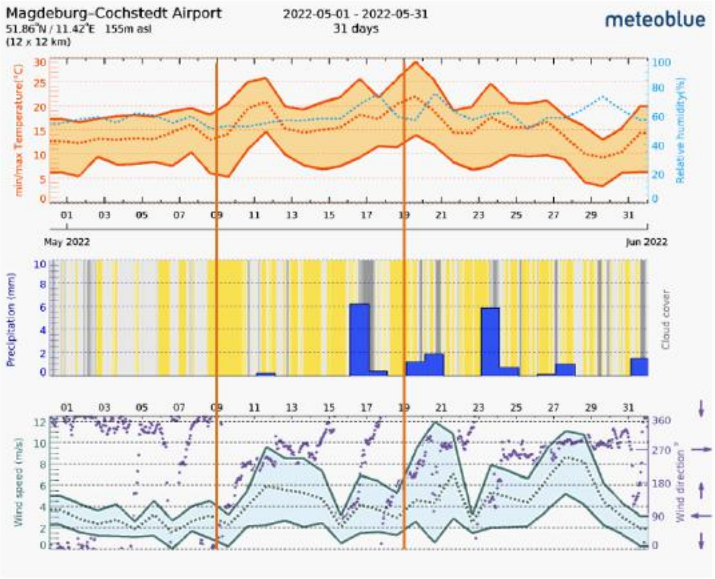


Figure 6: Modelled weather conditions during the test campaign (marked with red lines).

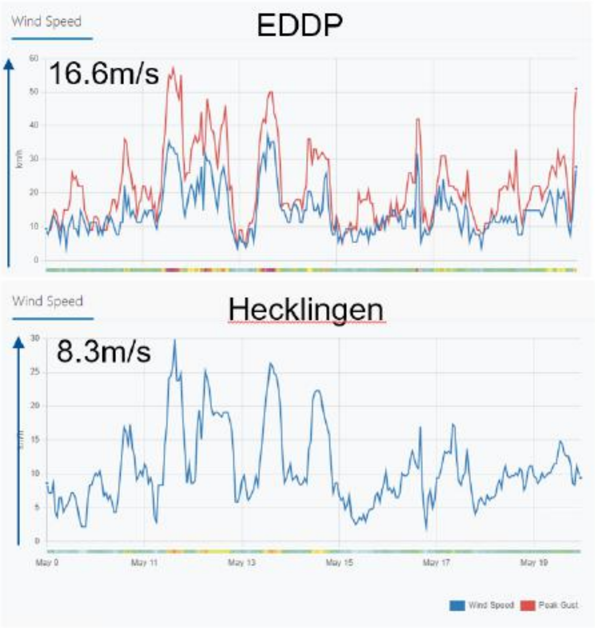


Figure 7: Measured wind conditions at during the test campaign at Hecklingen weather station ($5km$ away from the EDBC airport) and EDDP airport ($74km$ away from the EDBC airport).

to high crosswind components the aircraft veered off to the left into the wind and the wing hit a runway light while moving backwards (Figures 11 and 12). An aileron had to be changed and landing gear had to be repaired.

The repairs were done within 6 hours and another attempt for a flight was made. This time the aircraft again went to the side during the takeoff run. The damage was more serious than during the previous

Table 1: FT10 - Flight information.

Flight number:	10
Flight date:	09-May-2022 15:40:38
Take-off time:	15:45:30
Landing time:	15:58:29
Total flight time:	00:12:59
Total fuel used:	4.26 kg

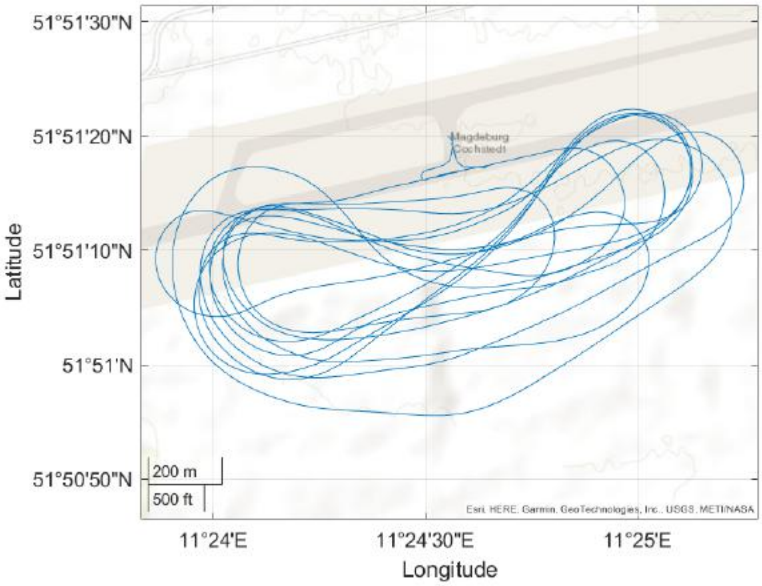


Figure 8: FT10 Trajectory plot.

Figure 9: Team photo after a successful first flight of the year.

attempt. The fuselage was partially ripped open at the front frame, the nose boom was damaged. The parachute was ripped out (Figure 13). All the main frames were ripped out from the fuselage. Main landing gear damper was broken.

Figure 10: Left wing root covered in tufts to investigate the flow separation with extended flaps.

Figure 11: Right wing moving backwards after a ground-loop just before hitting the runway light.

Figure 12: Right wing moving backwards after a ground-loop just after hitting the runway light.

Repairing this damage was a way bigger effort, and it was not clear if it could be done in the hangar at the airfield. In the end it was decided to attempt the repair on the field. The fuselage had to be emptied from components (payload bay, cables, landing gear). The fuselage hull was then repaired

Figure 13: Tail cone flying away from the aircraft after the crash during an unsuccessful takeoff attempt.

(Figure 14) and components were reassembled. Wing alignment had to be done and centre of gravity check performed. The pitot probe had to be exchanged. All this cost another two days of the campaign, but the aircraft was ready for taxi tests within 48h of the crash.

Figure 14: Repairing the fuselage after the crash during an FT11 attempt.

After the crash further investigations were done into the takeoff performance. The flap settings were further discussed, which were increased from 23/16/5/0 for take-off to 25/16/10/5. For landing the settings were 30/16/10/5. Taking into account that full elevator down command is required during the takeoff, it was decided that maybe there is too high nose down pitching moment due to the high flap settings. Deflecting the outboard flaps down also increase the nose down pitching moment a lot due to the wing sweep. Therefore, the outboard flap setting was reduced to 25/16/10/0 for takeoff and 30/16/10/0 for landing.

After the changes another attempt was done on 14.05. But due to crosswind the aircraft went to the side again, without any damages. After this it was also decided to mount the wingtip wheels which could help with directional stability on the ground.

Finally, on 16.05 the FT11 was successfully done. Different augmented mode versions were checked in-flight. Two triangles were flown to check gather data for airspeed probe calibration. Altitude hold mode was checked, but it could not be confirmed to work at that point.

Table 2: FT11 - Flight information.

Flight number:	11
Flight date:	16-May-2022 09:40:06
Take-off time:	09:44:59
Landing time:	10:03:10
Total flight time:	00:18:11
Total fuel used:	5.75 kg

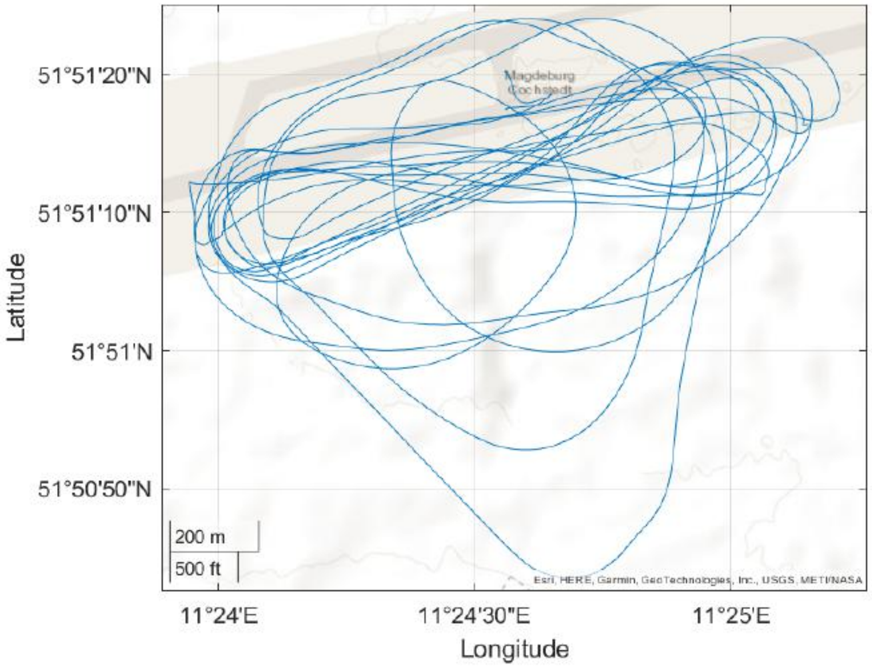


Figure 15: FT11 Trajectory plot.

2.4.3 FT12

On the same day as the previous flight, FT12 took place. The altitude hold mode was tested again, but due to a bug it could not be used. Therefore, only autothrottle tests were done with three different modes - robust, performance and total energy control. Two airspeed commands were issued during the autothrottle tests- 38 and 42m/s. These steps are also visible on the airspeed plot in Figure 16. At the end of the flight pilot training was done together with accelerated turn that would be used for airspeed calibration later on.

Table 3: FT12 - Flight information.

Flight number:	12
Flight date:	16-May-2022 15:42:54
Take-off time:	15:47:44
Landing time:	16:08:36
Total flight time:	00:20:52
Total fuel used:	6.34 kg

2.4.4 FT13

Course angle hold and horse race pattern hold were tested during the FT13. Also, oil was applied on the wing root area to investigate the boundary layer in-flight. More precisely, it was attempted to locate any laminar separation that could drastically reduce lift on the wings.

Due to some problems with the autopilot software, the altitude hold mode did not work again, nor did any other autopilot module. Therefore, another triangle and an accelerated turn were flown for airspeed probe calibration investigation as a backup plan in manual mode.

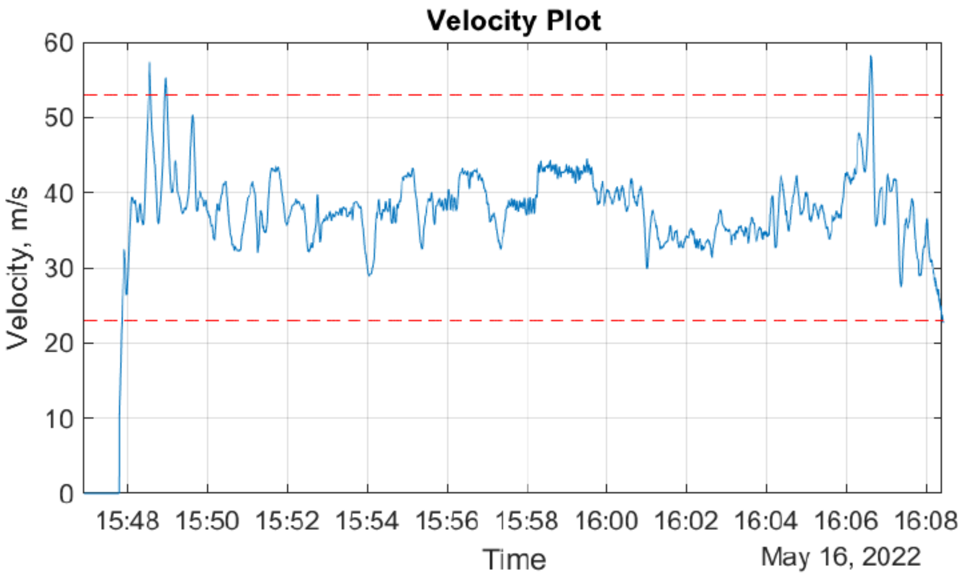


Figure 16: FT12 Airspeed plot.

Table 4: FT13 - Flight information.

Flight number:	13
Flight date:	17-May-2022 15:10:54
Take-off time:	15:15:45
Landing time:	15:36:29
Total flight time:	00:20:44
Total fuel used:	6.4 kg

2.4.5 FT14

One hour after landing, the FT14 was performed to again check the autopilot modes - augmented mode, altitude hold mode, autothrottle mode and course angle hold together with the horse race pattern hold.

This time, all the autopilot modes worked. Good functioning of the altitude hold mode is seen from Figure 17 (note that the wrong altitude limits are plotted). Airspeed was also tracked with reasonable accuracy using the robust autothrottle mode (Figure 18). Finally, automated horse race track pattern was flown by using all the autopilot modes for the first time. The aircraft aligned with the runway and turned around after flying straight for 400m (Figure 19). The airspeed was then decreased from 42m/s to 34m/s and the same pattern was repeated. Everything seemed to work well.

At the end of the flight there was still some fuel remaining, so manoeuvre injections for rigid body modelling was done. Three elevator doublets, an elevator pulse and a rudder multisine input were done.

2.4.6 FT15

Full airspeed envelope with the autothrottle mode was planned for FT15. This meant starting the autothrottle at 30m/s and then gradually increasing the airspeed up to 60m/s (the planned highest speed during flutter tests) while flying in a steady circle. However, multiple problems meant that this flight was not successful.

Firstly, the autopilot modes didn't seem to do what was commanded. While trying to solve this in-

Table 5: FT14 - Flight information.

Flight number:	14
Flight date:	17-May-2022 16:52:27
Take-off time:	16:57:18
Landing time:	17:19:35
Total flight time:	00:22:16
Total fuel used:	6.17 kg

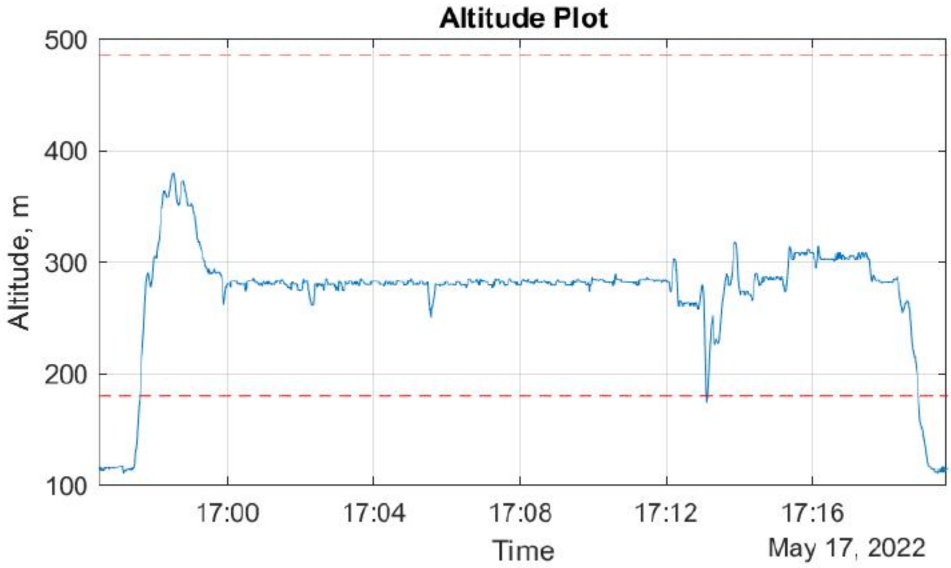


Figure 17: FT14 Altitude plot.

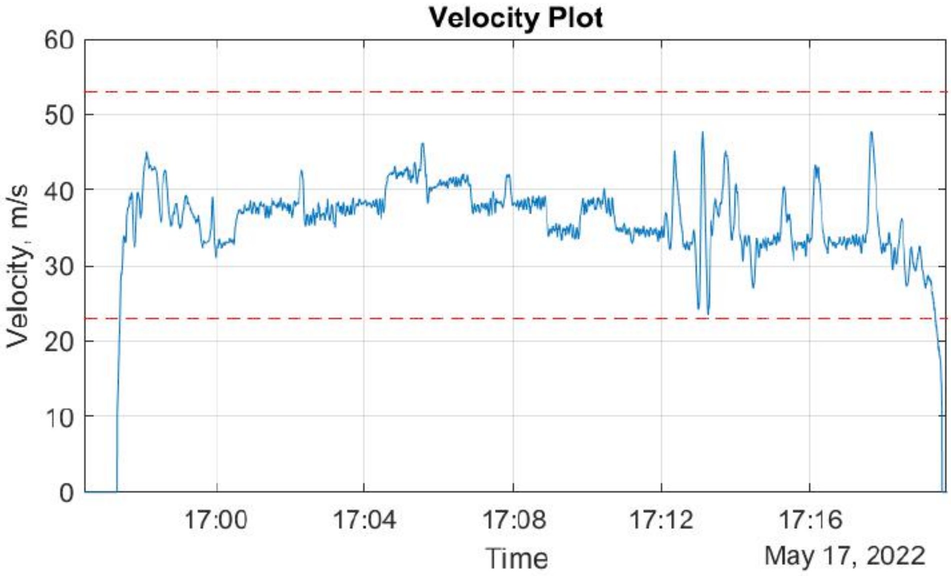


Figure 18: FT14 Airspeed plot.

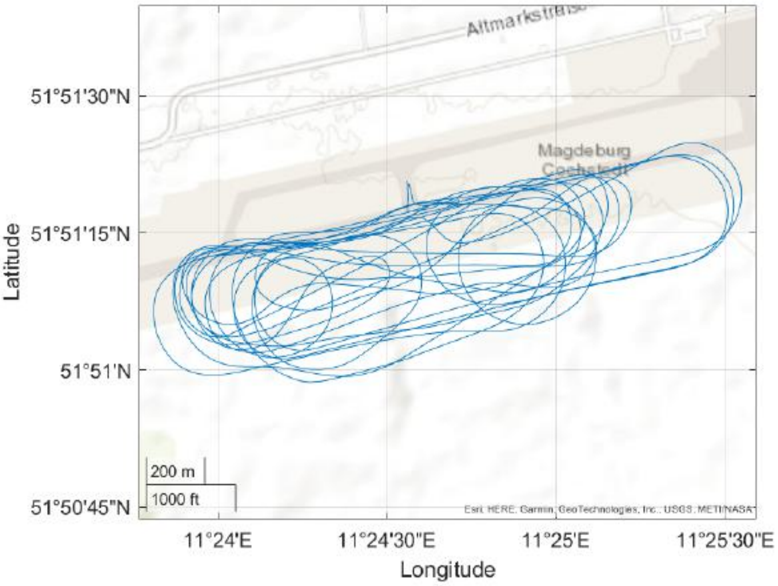


Figure 19: FT14 Trajectory plot.

flight, the pilot switched back to manual control and tried to increase throttle. At that time the engine was spooling up and down. The pilot tried to change the throttle setting, but the aircraft didn't react as commanded. At the same time the telemetry indicated that the aircraft is still in autopilot mode. Consequently, the pilots decided to go for landing.

During the approach the pilots realised that the aircraft was still in autopilot mode even though the command switch on the transmitter was set to manual mode. They then switched once more from manual to autopilot mode and back and aircraft control was regained.

In the end it was discovered that the problems arose due to a defect switch on the main transmitter. Furthermore, it was discovered that the flight log was not created due to changing the setting of the autopilot in-flight.

2.4.7 FT16

The last day of the test campaign was once again windy, so the flights had to wait for the evening. Same goals were assigned for FT16 as for FT15. This time the autopilot modes worked well and the full airspeed envelope of the aircraft was checked. It was also noticed that the airspeed was kept lower than the commanded value. The turns were done automatically up to 50m/s. After that they had to be done manually due to the saturation of the autothrottle command. The complete airspeed graph is plotted in Figure 20.

Finally, for the last part of the flight, two segments were flown with the so called "drag flap" state. This configuration was purposefully designed to increase induced drag. It was hoped that this way it could be established if the drag measurement algorithm can detect an increase of induced drag in-flight.

A description and analysis of the flexible mode identification using data from Flight Test 16 is added in Section 4.2.

Table 6: FT16 - Flight information.

Flight number:	16
Flight date:	19-May-2022 16:09:56
Take-off time:	16:14:46
Landing time:	16:36:31
Total flight time:	00:21:45
Total fuel used:	6.54 kg

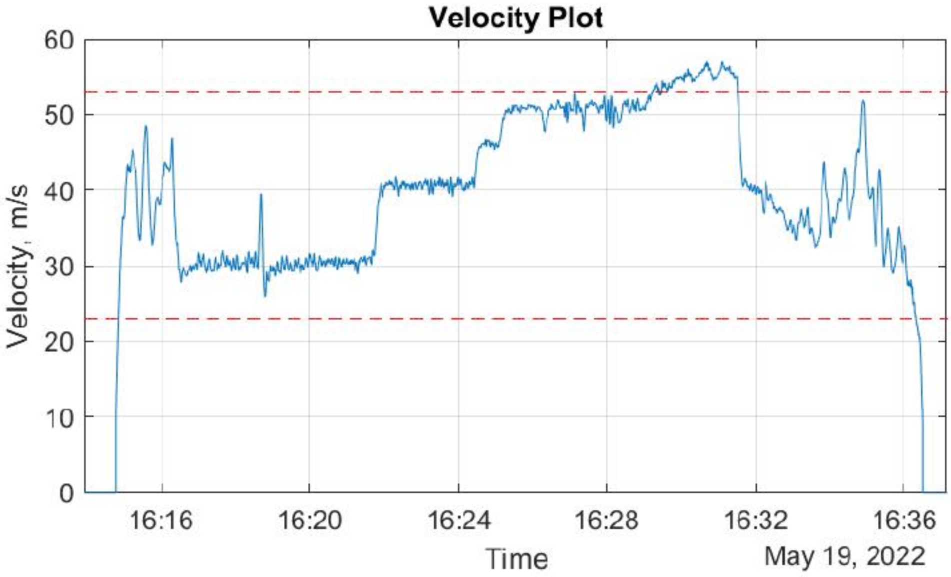


Figure 20: FT16 Airspeed plot.

2.4.8 FT17

Within less than an hour, the second flight of the day, FT17, was done. The flight was targeted at rigid body mode identification manoeuvres - elevator multisine inputs, elevator pulses, aileron multisine inputs and rudder doublets. In total, 14 manoeuvres were done. During these automated inputs it was noticed that the aircraft is highly unstable in roll, and any gust makes it turn to the side. This was the reason why during all of these manoeuvres the aircraft didn't fly completely straight.

During the flight, the second pilot mentioned that the wind is rising. After a second warning it was decided to go for landing, as the wind speed was steadily increasing. This decision was made too late and the aircraft had to be landed in stormy conditions with wind speeds rising from 1 to 7.1m/s and gusts from 1.5 to 15.4m/s. Luckily, the landing went well and the first flight test campaign of the year could be concluded.

Table 7: FT17 - Flight information.

Flight number:	17
Flight date:	19-May-2022 17:15:13
Take-off time:	17:20:05
Landing time:	17:41:42
Total flight time:	00:21:37
Total fuel used:	5.5 kg

2.5 Goals for the 2nd flight test campaign

After completing the 1st flight test campaign in May, planning was done for the next campaign in August. There were changes planned with the main flight control computer of the aircraft (a new RXMUX hardware unit was being assembled at that time), autothrottle controller had to be retuned. It was also planned to test a new, less complex procedure for the upcoming flutter tests. The new procedure suggested that instead of flying horse-race patterns with a short measurement leg (which was a maximum of 15s), a steady coordinated turn at a low bank angle should be flown. Without having to turn, accelerate and decelerate, the measurement leg could be made longer, which was required for online modal analysis method to work properly.

The reviewed goals for the second campaign were as follows:

1. The baseline -0 wing:
    (a) Test the new RXMUXv2 hardware in-flight and confirm that everything is working as before.
    (b) Tune the autothrottle controller.
    (c) Do additional flights for rigid mode identification with injected manoeuvres on -0 wing.
    (d) Test the new suggested flutter procedure (big 800+m radius circles with increasing airspeed).
    (e) Test the new altitude hold mode.
2. The flexible -1 wing:
    (a) Maiden flight with the -1 wing.
    (b) Autopilot tuning for the -1 wing (not expected to differ much).
    (c) Rigid and flexible mode identification with -1, aerodynamic model update.
    (d) Direct drive (flutter suppresion actuator) tests in-flight.
3. Additional goals:
    (a) Pilot training.
    (b) Investigate landing gear drag.
    (c) Investigate the FLAP1 separation effects on the V-Tail.
    (d) Investigate the engine wake effects on the V-Tail.
    (e) Effect of FLAP2 and FLAP3 on the pitching moment.

2.6 Planning for the 2nd flight test campaign

Following the flight campaign goals, the following flight plan was suggested:

1. FT18: Pilot training + pushover-pullup training
2. FT19: RXMUX2 testing + Autothrottle tuning
3. FT20: Rigid body mode manoeuvre injections (calm weather)
4. FT21: Rigid body mode manoeuvre injections (calm weather)
5. FT22: Flutter testing procedure + Envelope expansion (banked turn up to 60m/s)

6. FT23: -1 Wing maiden flight + system check
7. FT24: -1 Wing autopilot mode testing
8. FT25: -1 Wing system identification manoeuvres

2.7 Flight Test Description for the 2nd Flight Test Campaign, August 2022

The flight test crew arrived back at EDBC on 19th of August for the 2nd Flight Test Campaign. But due to the upgrades on the aircraft, the first three days were spent on debugging various issues. It was noticed that the tailwheel steering is coupled to a wrong channel (tail flap deflection instead of a rudder command). Also, the air data system didn't work properly. Only after careful inspection it was realised that the tubes inside the pitot boom are tangled, and the whole system was retubed. Then, during a taxi test the aircraft touched a runway light, which meant that a small repair had to be undertaken. Autopilot modules also ahd to be adjusted based on the ground tests and some further tweaking of the tailwheel steering had to be done after the taxi tests on 22nd of August. Finally, two wing servos had to be replaced due to them burning down during ground tests before continuing with the flight tests the next day.

2.7.1 FT18

Flight test 18 was the first flight test of the second flight test campaign at EDBC. The first test was all focused on pilot training. Three landing imitations were done for the new main pilot to get familiar with the aircraft before landing was done. Only correct functioning of the augmented autopilot mode was checked in-flight. Also the fuel flow meter sensor did not work with the new hardware, so the flight times had to be limited for safe operations.

Note that the take-off and landing flap settings were again changed for this flight based on the takeoff performance investigation made after the 1st flight test campaign. The outboard flaps were deflected upwards to provide more pitch-up moment and help to push the tail down during the ground run, as further described in Section 4.3.1.

Table 8: FT18 - Flight information.

Flight number:	18
Flight date:	23-Aug-2022 09:15:09
Take-off time:	09:20:01
Landing time:	09:37:38
Total flight time:	00:17:36
Total fuel used:	(fuel sensor malfunction)

2.7.2 FT19

Flight test 19 was carried out on the same day as flight test 18. Further tests of the autopilot functionalities were done. This time altitude hold mode was checked. The first try didn't seem to work. The aircraft pitched up a lot when the altitude hold mode was triggered. The next try seemed to work better, but not as good as during the last campaign and it was hard to say what will the aircraft do when the altitude hold will be switched on. Autothrottle mode seemed to work well, smoother than previously. Two steps in commanded airspeed were done for two autothrottle models (robust and performance) and both seemed to work reasonably well.

After the autopilot tests, three pushover-pull-up manoeuvres were done.

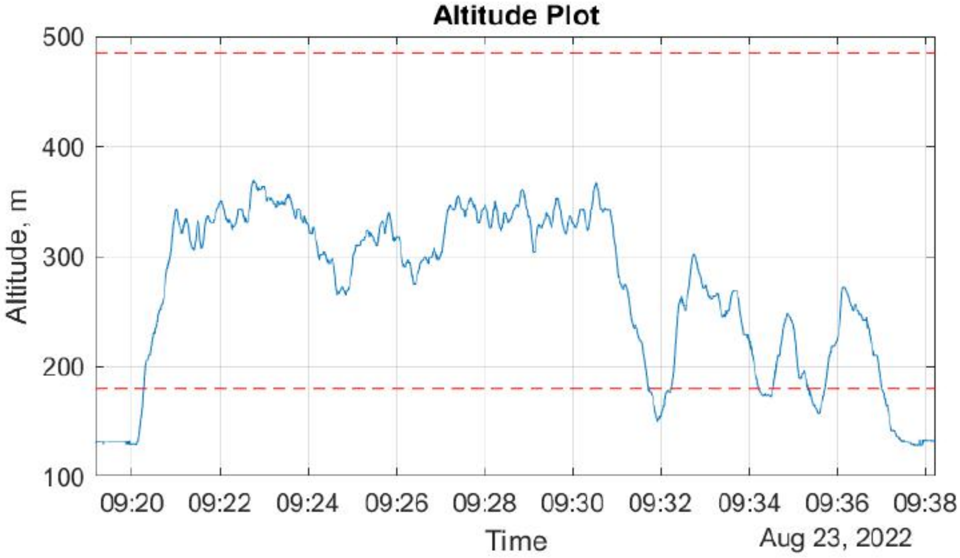


Figure 21: FT18 Altitude plot.

Table 9: FT19 - Flight information.

Flight number:	19
Flight date:	23-Aug-2022 15:36:52
Take-off time:	15:41:30
Landing time:	15:58:13
Total flight time:	00:16:43
Total fuel used:	(fuel sensor malfunction)

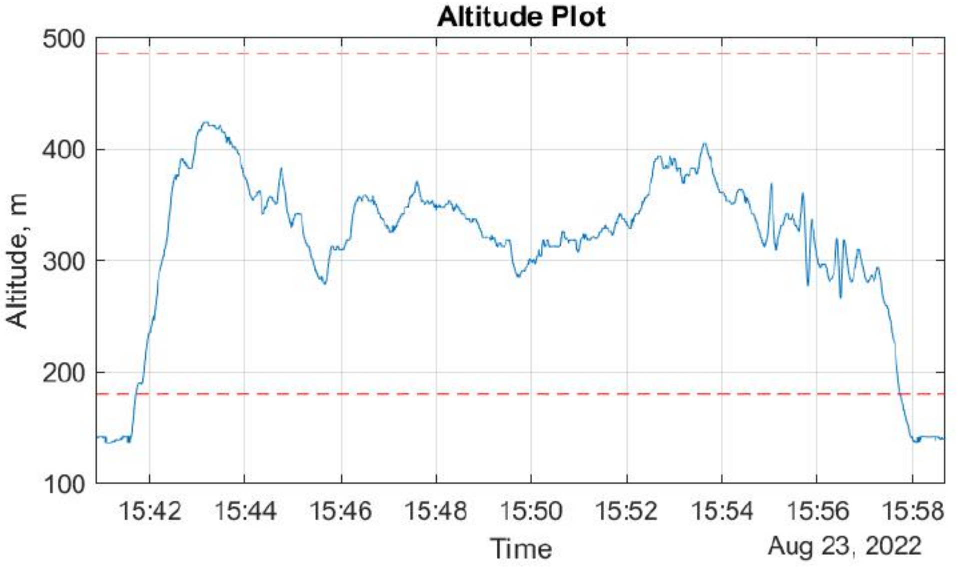


Figure 22: FT19 Altitude plot.

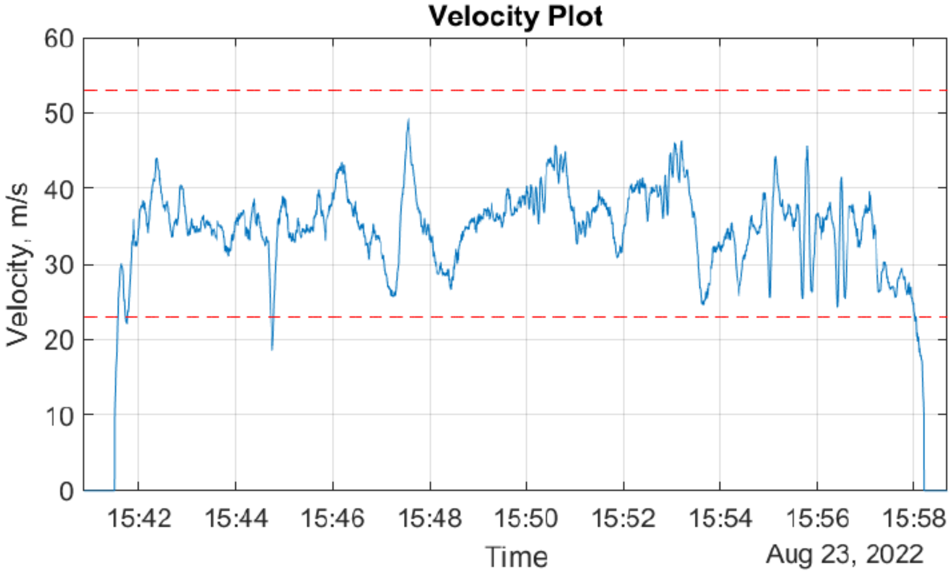


Figure 23: FT19 Airspeed plot.

2.7.3 FT20

Reception problems influenced the flight test 20 a lot. The main telemetry link was barely usable in-flight, so the secondary link had to be used to report airspeeds to the pilots. Five pushover-pull-up manoeuvres were done at load factors from 1.9G to 3.1G. Tailwheel steering servo gear was broken during landing and had to be replaced.

During this flight the fuel flow meter telemetry started working again. Therefore, the consumed fuel could be tracked in-flight and the flight times could be increased again, if not for the incident.

Table 10: FT20 - Flight information.

Flight number:	20
Flight date:	24-Aug-2022 10:10:39
Take-off time:	10:15:30
Landing time:	10:31:30
Total flight time:	00:15:59
Total fuel used:	5.1 kg

2.7.4 FT21

Flight test 21 focused on rigid body mode identification manoeuvres. Six manoeuvres were done. All of them seemed to be unstable and the aircraft rolled sideways during the manoeuvre injection. It was also noticed that the augmented mode commands very big rudder deflections to keep the aircraft at a zero sideslip angle. Later on while reviewing the on-board videos it was recognised that these rudder deflections would result in complete tail twisting. The problem was sent for further investigation.

As the pilot was preparing for another manoeuvre injection the engine flamed out (Figure 26). Luckily this happened at a safe altitude and in a convenient position. Expedited landing checklist was initiated and the secondary pilot helped the main pilot with safely gliding the aircraft down. It was later on discovered that a faulty tube connector allowed air to enter the fuel system and the engine was not getting enough fuel anymore. The problem was realised while investigating the 360 degree camera

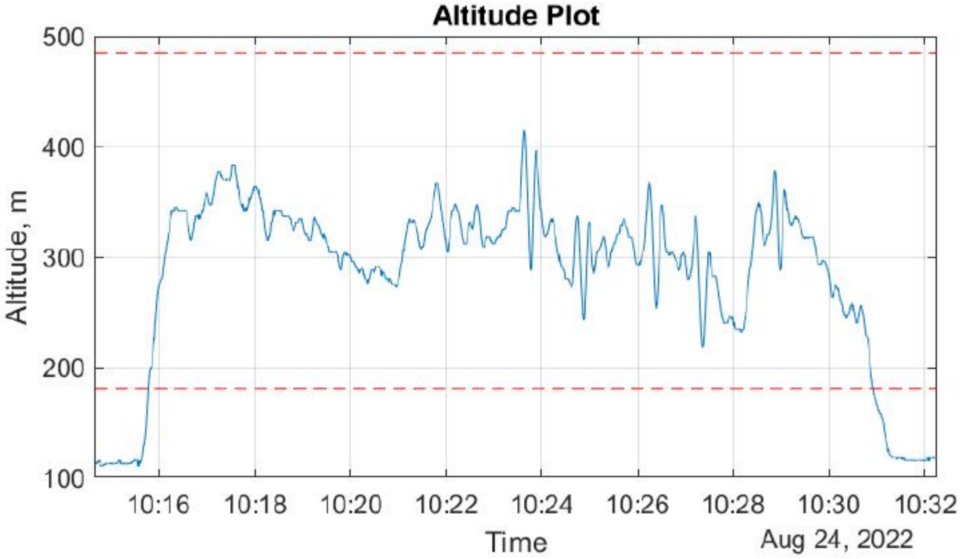


Figure 24: FT20 Altitude plot.

videos where the air bubbles are visible in the fuel line running to the engine. The faulty connector was replaced for the next flight.

After the event, an engine flame-out checklist was prepared.

At this point it was also noticed that pushing the tail down immediately after landing helps with ground controllability.

Table 11: FT21 - Flight information.

Flight number:	21
Flight date:	24-Aug-2022 12:55:38
Take-off time:	13:00:30
Landing time:	13:15:56
Total flight time:	00:15:26
Total fuel used:	4.95 kg

2.7.5 FT22

Flight test 22 was supposed to further focus on rigid body mode identification manoeuvres. However, 4 minutes after take-off the engine has shut down once again. Luckily, the aircraft had enough altitude and speed for the pilot to carry out a landing. Engine flameout checklist was followed and the aircraft was once more brought down safely.

The problem was later on attributed to a bug in the flight control computer which, at a rare instance, could issue a split-second command for the engine to turn off.

2.7.6 FT23

Flight test 23 was once more planned for rigid body mode identification. The flight was going well, with the telemetry looking stable and the weather being comfortable for flying as well. Five manoeuvres were done - three elevator multisines with an increased amplitude and two aileron multisine inputs.

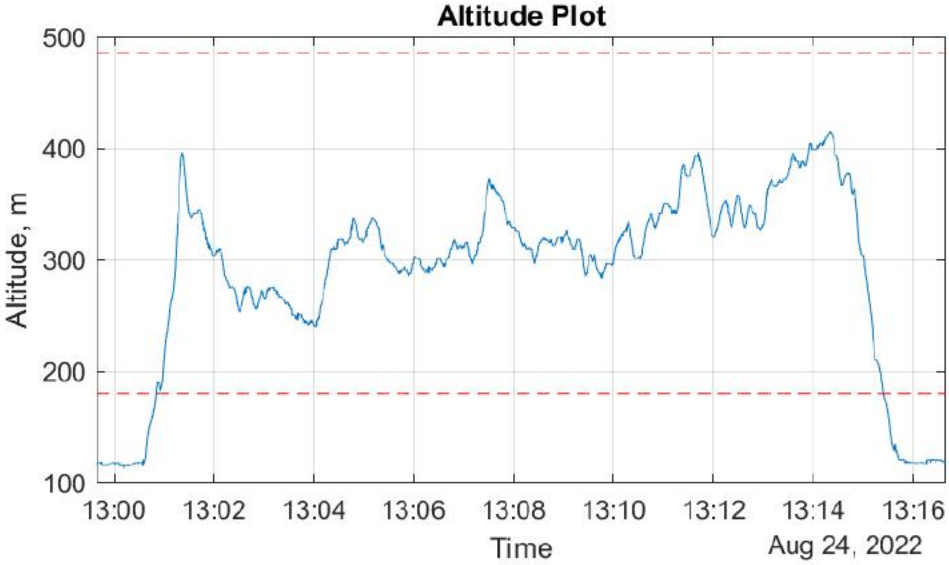


Figure 25: FT21 Altitude plot.

Figure 26: Engine flameout during the FT21.

Table 12: FT22 - Flight information.

Flight number:	22
Flight date:	29-Aug-2022 16:18:03
Take-off time:	16:22:55
Landing time:	16:26:15
Total flight time:	00:03:20
Total fuel used:	1.21 kg

During the flight there were no red flags regarding a bad reception. The distances in between the pilot

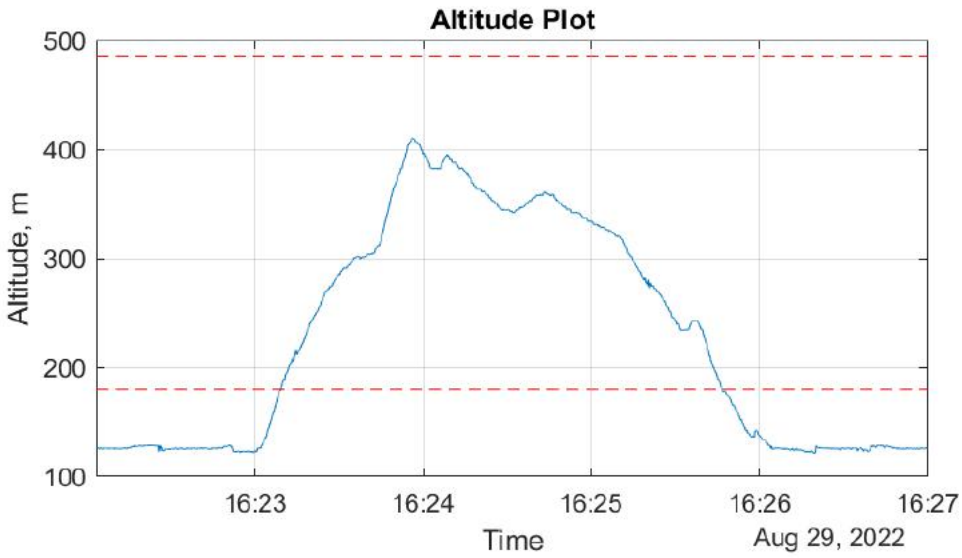


Figure 27: FT22 Altitude plot.

and the aircraft looked good from both optical and telemetry quality perspectives.

Around nine minutes in-flight, the pilot was performing a right turn at the eastern part of the flight box (Figure 28). He saw some white trace following the aircraft and thought that the engine has flamed out once again. Thinking he is still in control, he tried to turn the aircraft back. At that moment the pilot realised that it was the the parachute that was coming out from the aircraft. He announced that via the intercom and the crew followed the ”Terminate” checklist which was prepared in such case. Both pilots were commanded to initiate the TERMINATE command, which then also shuts the engine down.

As the pilots were returning to the ground control station, the Flight Test Manager has informed the tower about the aircraft coming down with a parachute. It was clearly visible to the tower. Within a minute the aircraft hit the ground, outside of the airport zone. After a while the tower has confirmed that a fire has broken out at the impact location. At that point two cars, including the ground control station were driving to the crash site.

Eight minutes after the impact both cars reached the crash site. At that point, only a small fire remained at the front part of the fuselage. The fuselage section from the wing root to the tail was completely burnt down. The wing roots were also burnt. The parachute itself was found laying further back of the aircraft. The remains of the aircraft were extinguished. Extra effort was made to recover as much flight data as possible, including the cameras, to investigate the accident. Luckily, no one got hurt during the crash and the field was mowed down, therefore the fire was not being fueled.

The crash investigation report can be found in Section 4.7.

Table 13: FT23 - Flight information.

Flight number:	23
Flight date:	30-Aug-2022 16:24:55
Take-off time:	16:29:47
Landing time:	16:39:19
Total flight time:	00:09:32
Total fuel used:	2.96 kg

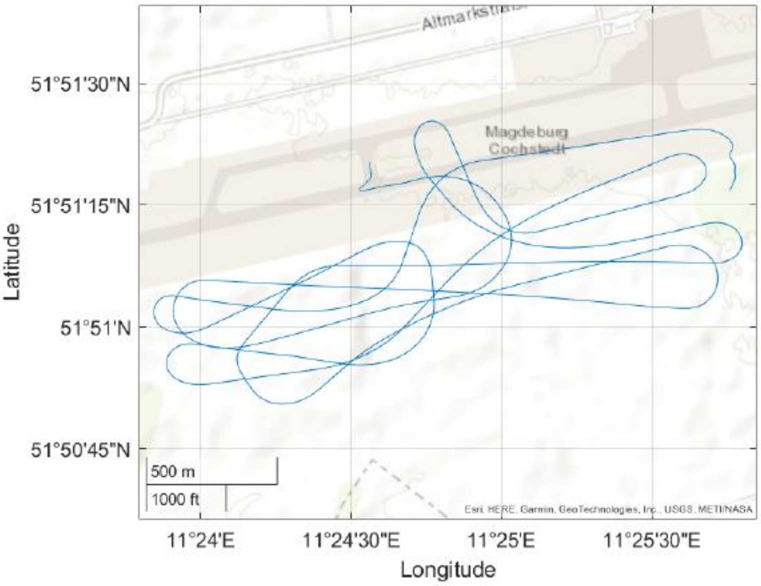


Figure 28: FT23 Trajectory plot. The end of the trajectory in the eastern part of the map is where the aircraft landed with the parachute.

3 Flight Test Data Analysis Tools

The updated data processing workflow is visualized in Figure 29. In comparison to the workflow described in D3.2 Flight Test Report – Flight Test Phase #1, the following upgrades were made:

- To easier extract the segments of interest, a GUI was created;
- An automatic segment extraction for airbrake inputs, autopilot segments, steady-level-flight segments and turns was added;
- Thrust measurement data alignment was updated. As a result, the log delay in between the applied thrust and actual thrust was reduced.

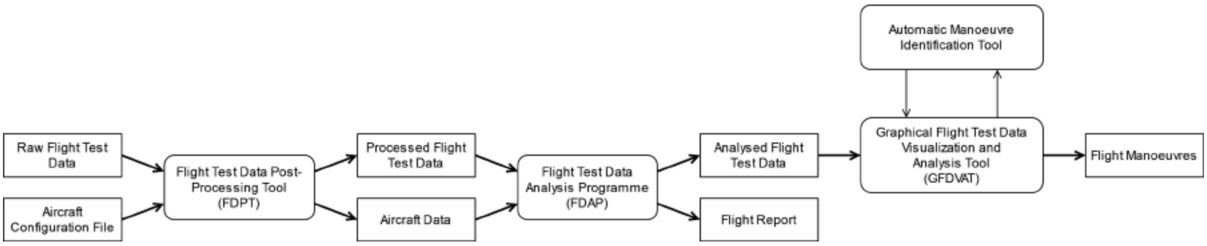


Figure 29: Flight test data processing and analysis workflow.

The created GUI allows the user to import and visualize any flight. The GUI displays the map area and the 3D visualization of the aircraft for the selected flight segment (Figure 30). Below that any data

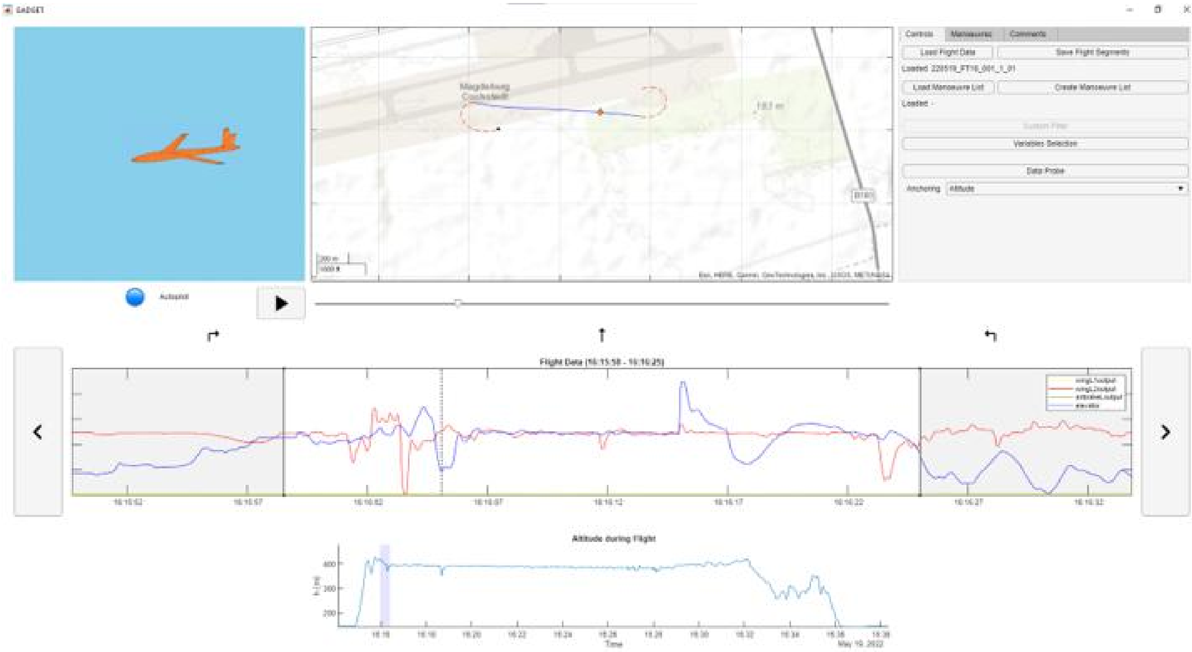


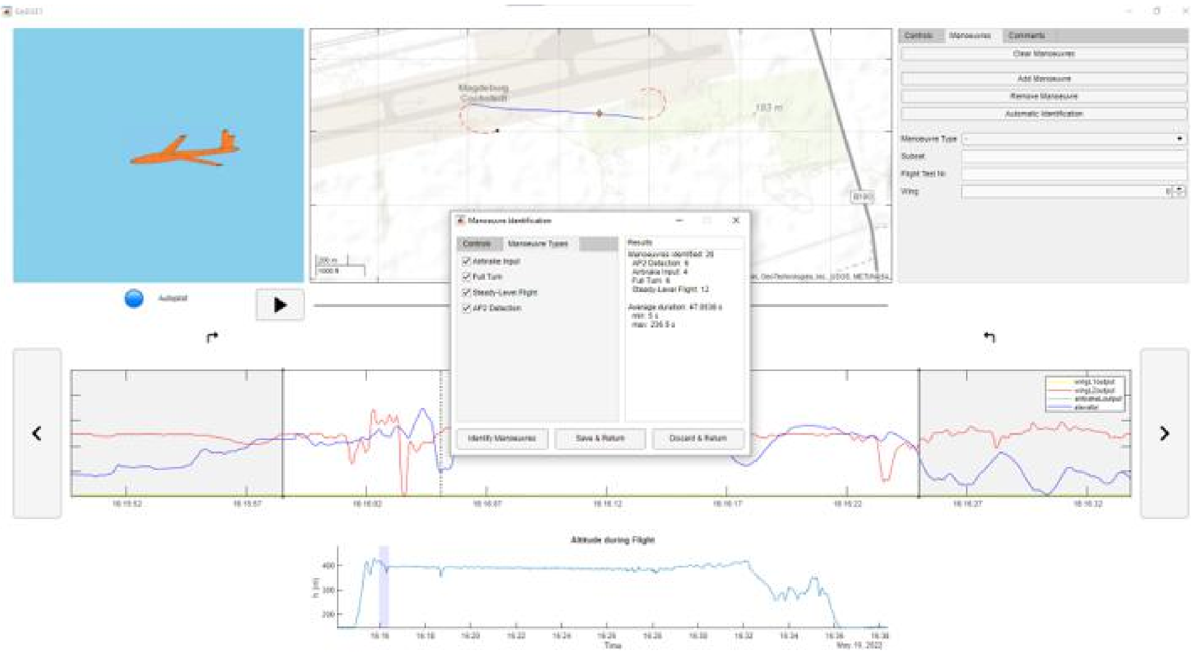
Figure 30: The Graphical User Interface for flight test data analysis.

can be plotted for the selected segment and overall altitude or airspeed graph allows the user to orient better which part of the flight the current segment is from.

A manoeuvre identification module is available (Figure 31). Note that in this case identification means finding the right time period where a specific manoeuvre was performed. Therefore, this module allows the user to automatically locate all the time segments where, for example, steady-level flight was done or where the autopilot mode was changed.

After all the manoeuvres were located in time, titles for the manoeuvres can be changed and comments added (Figure 32). The manoeuvre time segments are also shown in the graph.

Finally the manoeuvres are saved in a separate table with timestamps, titles, comments and additional data. This is then used as a basis of extracting only the required time segments from the overall test data.



Manoeuvres identified: 28
AP2 Detection: 6
Airbrake Input: 4
Full Turn: 6
Steady-Level Flight: 12

Average duration: 47.0536 s
min: 5 s
max: 236.5 s

Figure 31: The manoeuvre identification module for flight test data analysis tool.

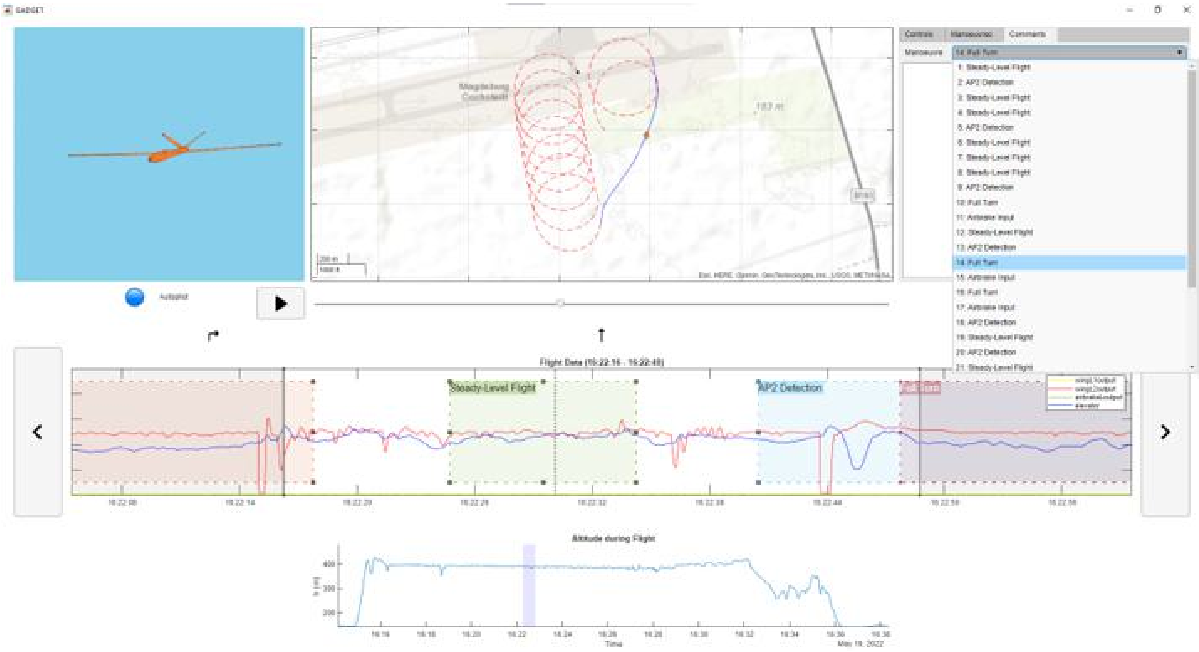


Figure 32: The identified manoeuvre time segments are displayed in the flight test data analysis tool.

4 Flight Test Data Evaluation

4.1 Autopilot mode evaluation (SZTAKI)

Various functionalities of the baseline controller have been tested during the 1st Flight Test Campaign. Among the conducted flight tests FT10, FT12, FT14 and FT16 have been successful in terms of the baseline control testing, other flight tests either focused on different aspects or had technical problems, hindering the testing of the baseline functionalities. The tested functionalities are summarized in Table 14, while each mode is evaluated separately in the forthcoming subsections. Note that in FT10 only 30 seconds of baseline controller tests were performed and hence it is not included in the analysis. Accordingly, FT12, FT14 and FT16 form the basis of the numerical evaluation of the baseline controller's performance.

	FT10	FT12	FT14	FT16
Roll attitude	✓	✓	✓	✓
Pitch attitude	✓	✓	✓	✓
Sideslip control	✓	✓	✓	✓
Altitude control		✓	✓	✓
Lateral directional			✓	
Autothrottle		✓	✓	✓

Table 14: Overview of baseline controller tests during the 1st Flight Test Campaign

4.1.1 Roll attitude

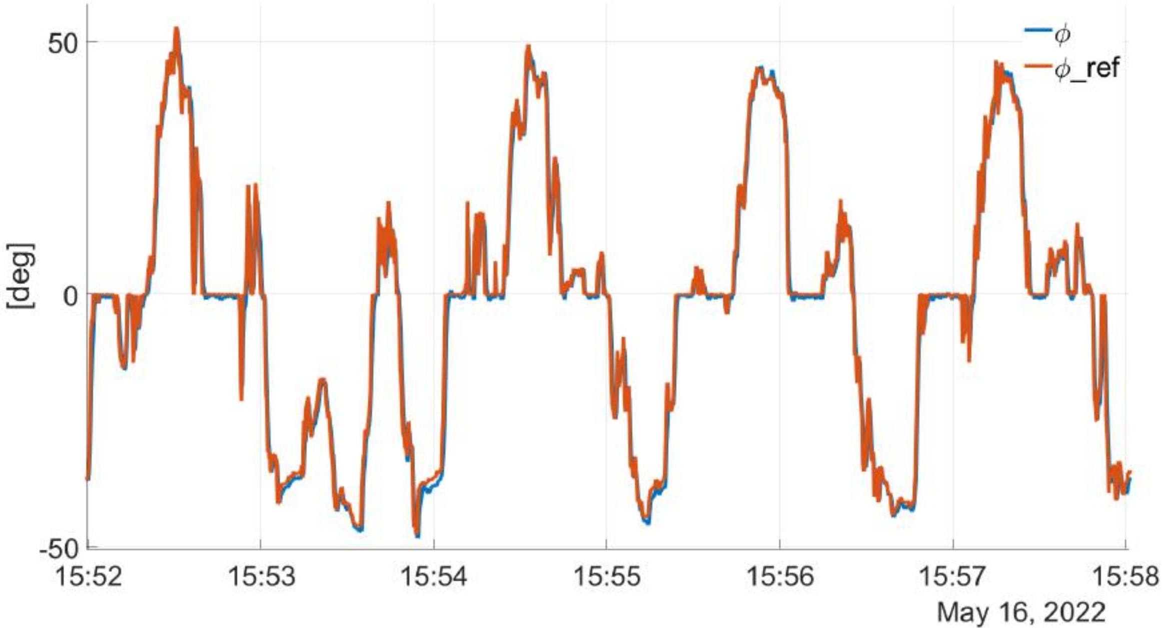


Figure 33: Roll attitude control in augmented mode during FT12

The roll attitude loop is the inner loop controller of the lateral-directional control of the UAV designed for tracking reference bank angle (ϕ_{ref}) coming either directly from the RC, commanded by the pilot, or from the outer loop control for achieving path following through course angle. The augmented mode behavior has been thoroughly tested and verified during the previous Flight Test Campaigns, however in FT12 it has been further tested. Figure 33 shows the typical tracking performance of the roll attitude loop, where the commanded signals were generated by the pilot: fast response time and precise tracking characterize this loop. Similar performance was observed in the previous flight tests as well as in FT16 of the 1st FTC. In FT14, the corresponding lateral outer loop controller was also engaged, i.e. the lateral directional controller provided the reference roll angle, which can be observed on Figure 34.

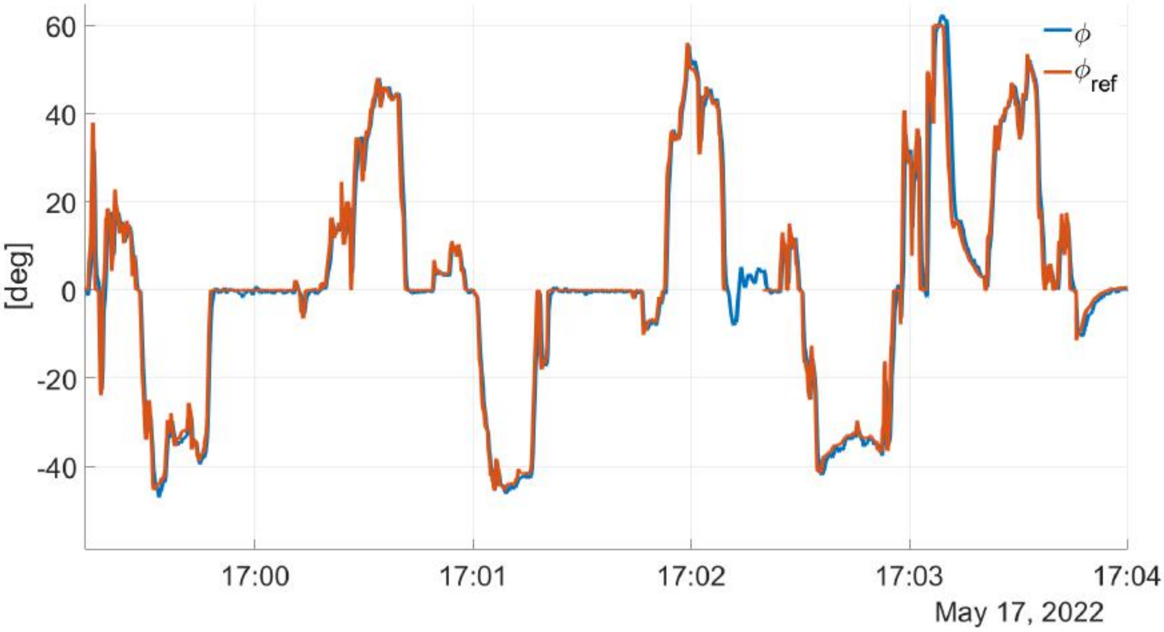


Figure 34: Roll attitude control with lateral-directional outerloop, during FT14

	FT12	FT14	FT16	Σ
Mean error	-0.4263	-0.0649	0.0014	0.1447
RMS error	3.8970	4.5740	3.9373	4.1363

Table 15: Performance of the roll attitude control loop during the 1st Flight Test Campaign

Table 15 summarizes the numerical evaluation of the roll attitude control loop, where the mean error and the root mean square (RMS) error metrics were chosen. The overall tracking performance is characterized by a less than 0.2 degrees error, while the RMS value was 4.16 over the three flight tests. In conclusion: the roll attitude control loop provided a very satisfactory, quick tracking of the reference signal in both augmented and fully automated modes. Accordingly the loop has passed the flight tests and no further modification was necessary.

4.1.2 Pitch attitude

The pitch attitude controller belongs to the longitudinal control architecture and similarly could be operated either in augmented or in fully automated modes. The augmented mode has been tested in the previous Flight Test Campaigns, therefore only the automated functionalities have been tested in the 1st FTC this time. During these flight tests, the outer longitudinal loop, i.e. the altitude control, was

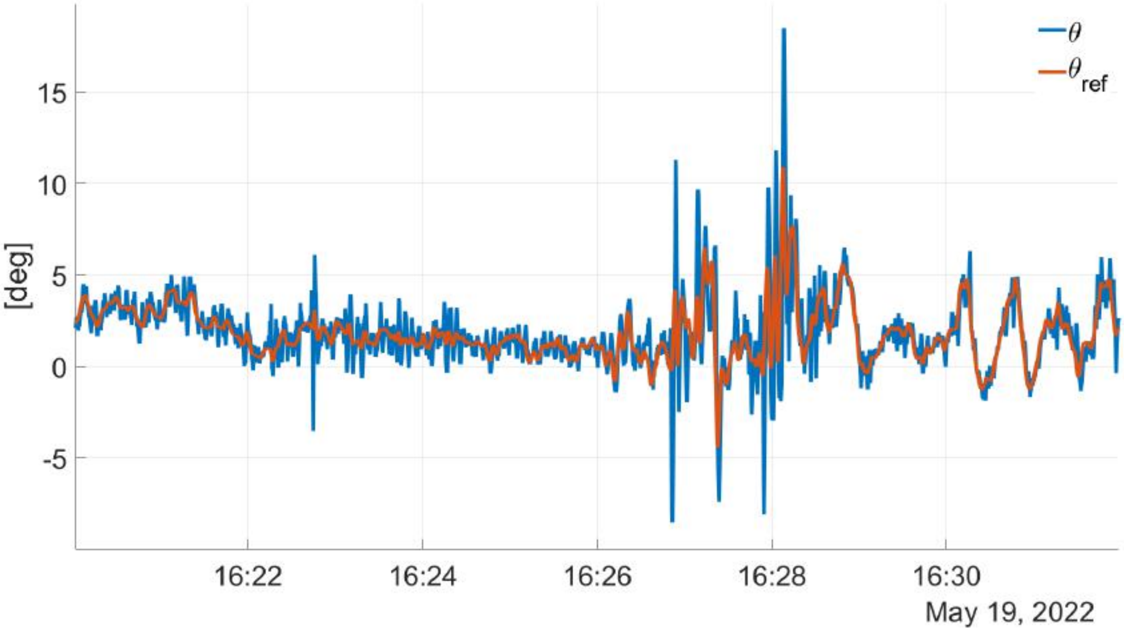


Figure 35: Pitch attitude control with altitude hold outerloop, during FT16

engaged and provided the reference signal for the pitch attitude controller. A typical flight measurement can be seen in Figure 35, while the numerical evaluation in terms of mean and RMS errors is given in Table 16. In Figure 35 a slight oscillation can be observed, this is due to the tuning of the pitch attitude controller, where the design criteria was a slightly under-damped response with damping ratio 0.6, helping the pilots in the augmented mode.

	FT12	FT14	FT16	Σ
Mean error	-0.3687	-0.0226	-0.0940	0.1618
RMS error	4.6637	1.4618	2.0634	2.7296

Table 16: Performance of the pitch attitude control loop during the 1st Flight Test Campaign

For the pitch attitude control a similar performance was achieved as for the roll attitude loop: the mean error was less than 0.2 degrees, while the RMS error was 2.73 for the three flight tests in the 1st FTC. Accordingly, the loop successfully passed the flight tests and no further tuning was required.

4.1.3 Sideslip Control

The sideslip control loop is a single decoupled loop acting on the lateral dynamics of the airplane aiming to ensure zero sideslip angle for the UAV. This functionality of the baseline controller was designed to reject wind disturbances and was always active, when the baseline controller was engaged. Accordingly it has been tested during all flight tests. Figure 36 shows the recorded sideslip values during FT16, where the autopilot was engaged for a longer time period. It can be clearly seen that both the mean and the oscillation of the sideslip angle have been decreased as compared to the uncontrolled case, where no reference command was issued (after 16:32 in Fig 36. Similar behavior was found in the other flight tests as well. The overall numerical evaluation is given in Table 17, where the uncontrolled values are also given for better understanding the effect of the sideslip control. The average tracking error is 0.015 degrees over the three flight tests (compared to the 0.75 degrees in the uncontrolled case) during the 1st Flight Test Campaign, with RMS value of 1.66 (in contrast with the 3.86 for the uncontrolled case). Note also that under specific maneuvers the sideslip angle slightly increased, but within an acceptable region.

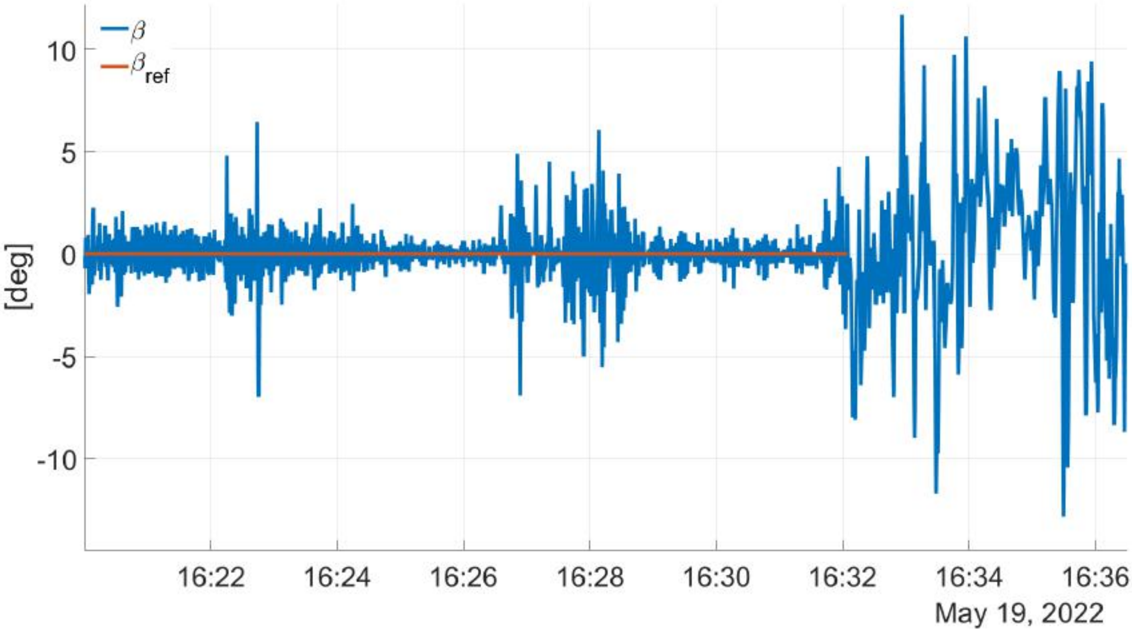


Figure 36: Sideslip control during FT16

	FT12	FT14	FT16	Σ
Error (uncontrolled)	0.0024	-1.8954	0.3534	0.7504
Error (controlled)	-0.0181	-0.0174	0.0085	0.0147
RMS (uncontrolled)	3.3511	4.0527	4.1655	3.8564
RMS (controlled)	1.6704	1.7062	1.5955	1.6574

Table 17: Performance of the sideslip control loop during the 1st Flight Test Campaign

Accordingly, the sideslip loop was considered satisfactory and required no further modificiation for the future flight tests.

4.1.4 Altitude control

The altitude controller is part of the longitudinal control loops and designed for keeping constant barometric altitude of the aircraft. When engaged, the controller provides reference pitch angle for the corresponding longitudinal inner loop (pich attitude controller). The main objective of the control loop is to hold a specific constant altitude during the flight tests. For this, please see Figure 37, where the controller was active for a longer period of time. Here it can be seen that the integral action of the controller was not satisfactory: the error was decreasing slowly. This problem is also clear from the numerical evaluation in Table 18, where the mean error is about 4 meters, paired with a relatively small RMS value. Since this issue was not critical for the flight test campaigns, the performance and the controller was accepted.

Although it was not part of the design requirements, a step tracking test was also performed during FT12, which is depicted in Figure 38.

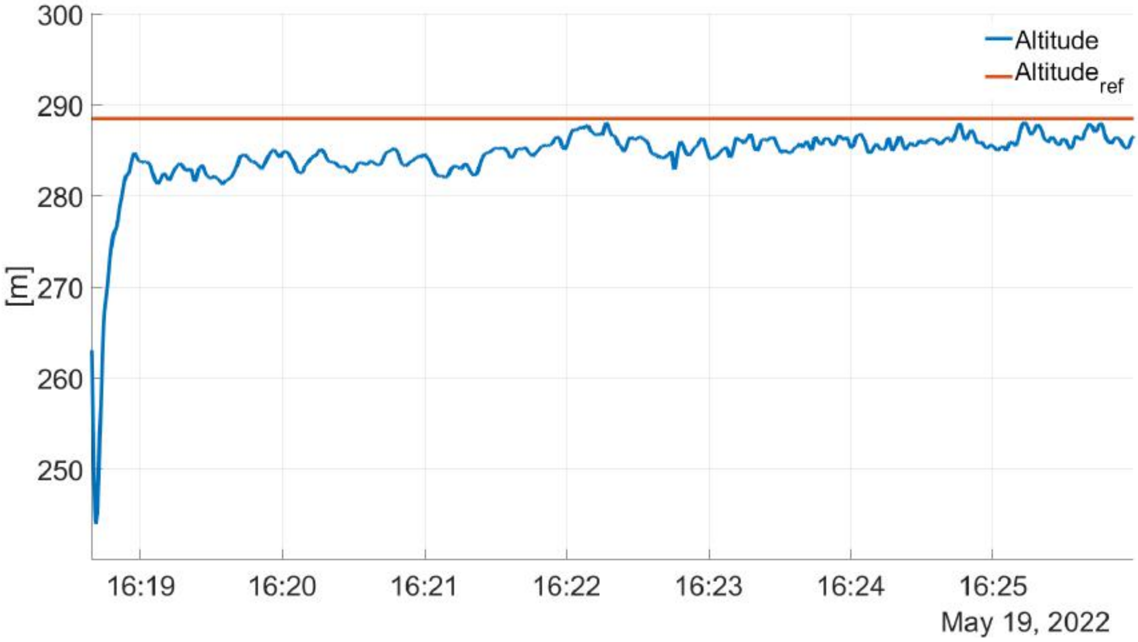


Figure 37: Altitude hold during FT16

	FT12	FT14	FT16	Σ
Mean error	-4.0625	-4.3652	-4.2850	4.2376
RMS error	8.0787	7.0009	5.888	6.9892

Table 18: Performance of the altitude control loop during the 1st Flight Test Campaign

4.1.5 Lateral directional control

The lateral directional control loop was responsible for tracking the course angle (flight path) of the aircraft. Based on the navigation signals a reference χ angle was computed as an input for this controller, which is then forwarded to the roll attitude loop as a bank angle command. This functionality of the baseline controller was only tested in FT14, where the corresponding tracking behavior can be seen in Figure 39. Here, the red reference signals are the ones coming from the navigation logic, which were shaped inside the lateral directional control for smooth turning behavior. This explains the visible gaps in the reference value. During FT 14 all the loops of the baseline controller were working together, i.e. all the functionalities were tested together. This lead to the successful horserace flight test illustrated in the $N-E$ coordinate frame in Figure 40. Note that this horserace pattern corresponds to the course angle reference in Figure 39.

It can be seen that the baseline controller was able to control the aircraft along the flight test pattern. However, due to the technical difficulties, the concept of the horserace flight pattern was discarded. Instead, circular flights were proposed for the flutter tests, where the airplane keeps a constant bank angle. Accordingly, the lateral directional control loop was not used in the future flight tests.

4.1.6 Autothrottle

For the autothrottle loop, responsible for controlling the indicated airspeed of the aircraft initially three different control configurations have been developed. This is due to the inexact knowledge of the engine's dynamics and characteristics, which was later refined by the available in-flight measurements.

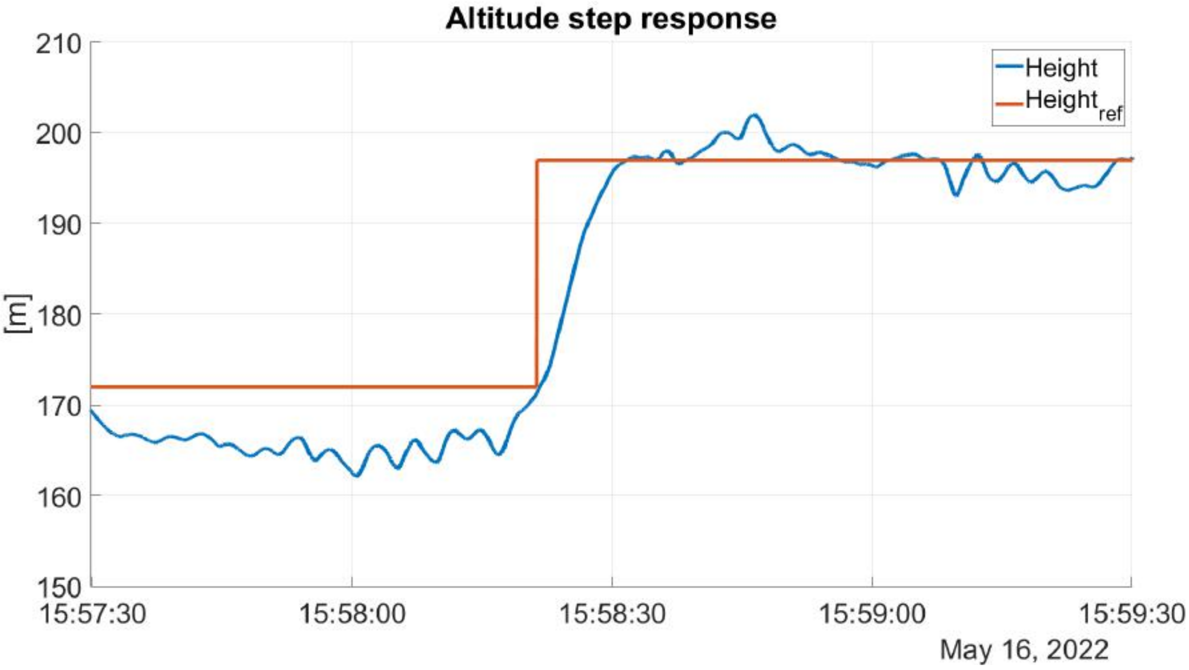


Figure 38: Altitude step reference tracking during FT12

Figure 39: Course angle tracking during FT14

FT12 was the first successful testing of the autothrottle loop, where the three different controllers have been tested subsequently. Two versions of the 2-DOF PID controller have been implemented, where the gains of the 'Robust' version have been decreased, as compared to the 'Performance' version.

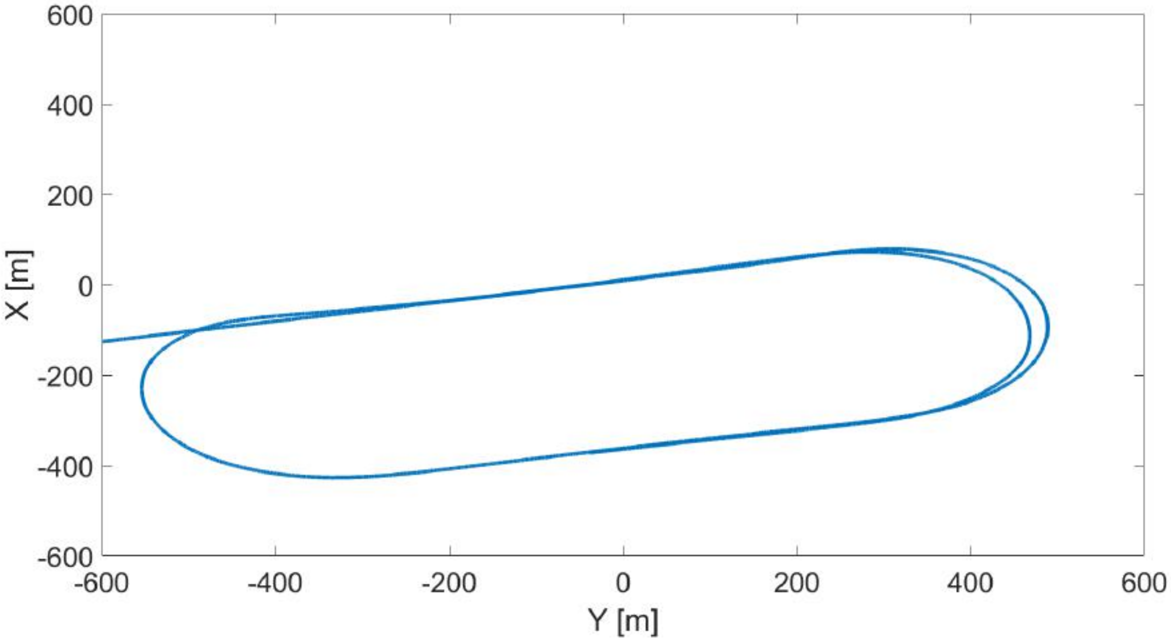


Figure 40: Horserace pattern during FT14

This was necessary for safety reasons: compromising the tracking performance in order to have a less aggressive control behavior. In addition, a coupled altitude-speed control approach, i.e. Total Energy Control System (TECS) was also designed, implemented and tested. The time-domain flight results can be depicted in Figure 41, while the numerical comparison is given in Table 19.

	Robust	Performance	TECS
Mean error	-1.7520	-0.9852	-0.5419
RMS error	2.0620	1.6283	0.9367

Table 19: Performance of the three autothrottle controllers during FT12

Although the TECS controller was slightly outperforming the ’Performance’ and the ’Robust’ versions, this architecture has been discarded due to the high amplitude oscillations in the corresponding RPM values. This phenomena was also present for the ’Robust’ and ’Performance’ controllers, but in a less articulated form, however had to be addressed in the future due to its damaging effect on the engine. Nevertheless, the remaining flight tests were only using the ’Robust’ and the ’Performance’ controllers.

The goal of Flight Test 16 was to further test the authotrottle controller’s performance by increasing the airspeed in multiple steps. The collected flight data can be seen on Figure 42. This flight test revealed an important implementation issue: the upper saturation limit of the controller was set incorrectly and accordingly not all the available control authority was facilitated. This can be clearly seen in Figure 42, where after saturation the aircraft failed to track higher airspeed commands and pilot commands were issued instead.

4.1.7 Summary

In summary, the 1st Flight Test Campaign was sucessful for testing the baseline controller’s functionalities, FT14 was the first flight test were the all the different loops of the controller worked together.

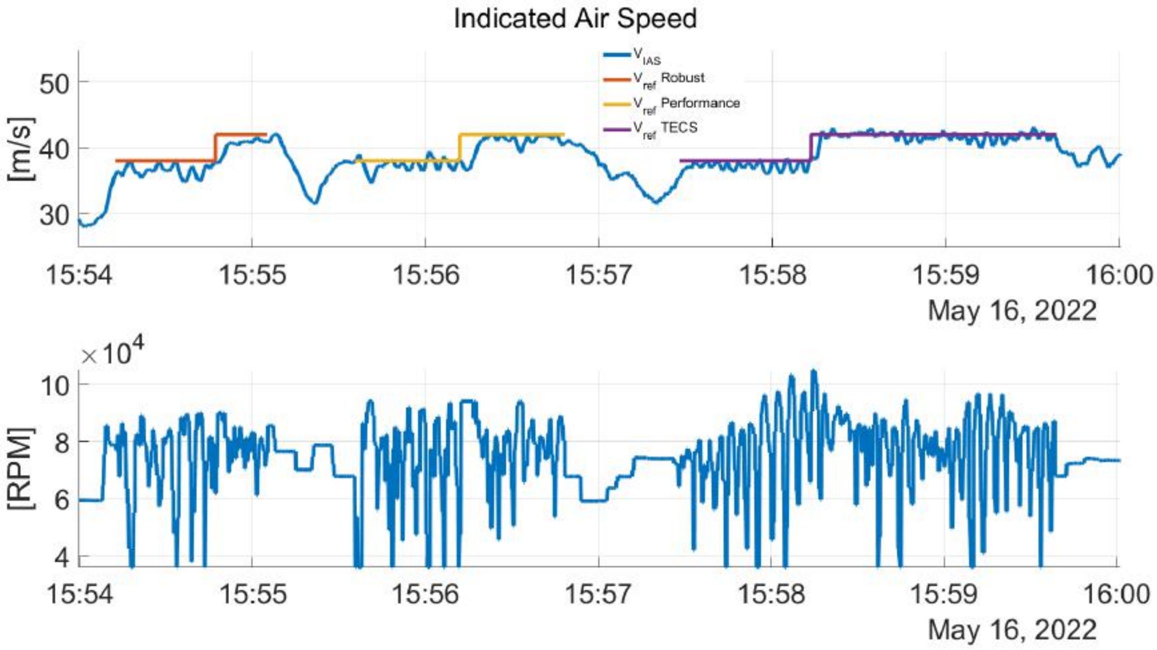


Figure 41: Autothrottle speed tracking and the corresponding control signal during FT12 - Comparison of three controllers

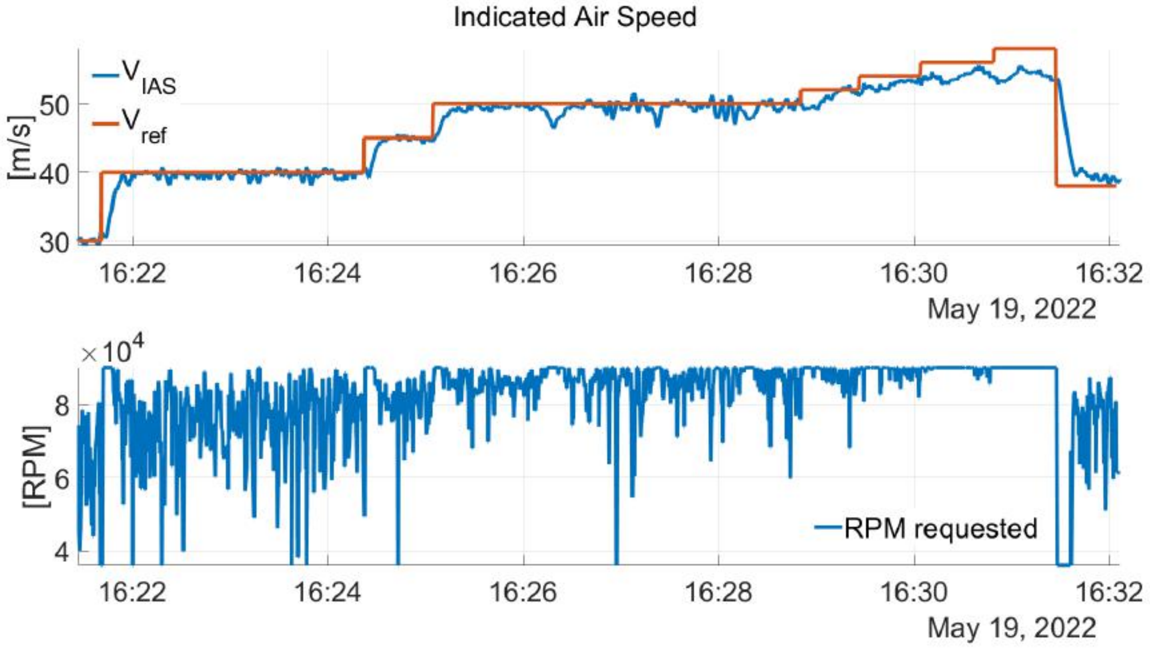


Figure 42: Autothrottle speed tracking and the corresponding control signal during FT16

The most inner loops of the roll and pitch attitude were performing precisely and were also working smooth with the corresponding outer loops of the lateral-directional and altitude controllers. The Flight

Test Campaign also revealed some minor issues related to the baseline controller. These were main related to the implementation of the autothrottle loop: first, the saturation limits had to be fixed, second, the oscillatory nature of the commanded RPM signal had to be eliminated. These issues were fixed in the next flight tests.

4.2 Flexible body mode identification (DLR)

One important aspect of UAV operation is the identification and characterization of their dynamic behavior, particularly in terms of their flexible body modes. Operational Modal Analysis (OMA) is as a powerful tool for extracting dynamic characteristics of structures and mechanical systems. It involves the use of measured output signals to identify the modal parameters, such as natural frequencies, damping ratios and mode shapes without the need for a dedicated external excitation source. In the context of UAVs, OMA can be applied to determine the flexible body modes that significantly influence the flight dynamics.

The flexible body modes of UAVs are associated with the deformations and vibrations that occur due to the interaction of aerodynamic forces with the UAV structure during flight. These modes are typically lower in frequency i.e. under 20 Hz. Understanding and accurately identifying the flexible body modes is important for several reasons. Firstly, flexible body modes can affect the stability, control, and maneuverability of UAVs. Uncontrolled vibrations induced by these modes can lead to reduced flight performance, increased energy consumption, and even catastrophic failure. By characterizing the flexible body modes, engineers can design control systems that mitigate the adverse effects and enhance the UAVs overall performance. Secondly, the identification of flexible body modes enables the development of structural health monitoring (SHM) systems for UAVs. Continuous monitoring of the modal parameters can provide insights into the structural integrity, detect any damage or fatigue, and aid in proactive maintenance, thereby ensuring the long-term reliability and safety of UAV operations.

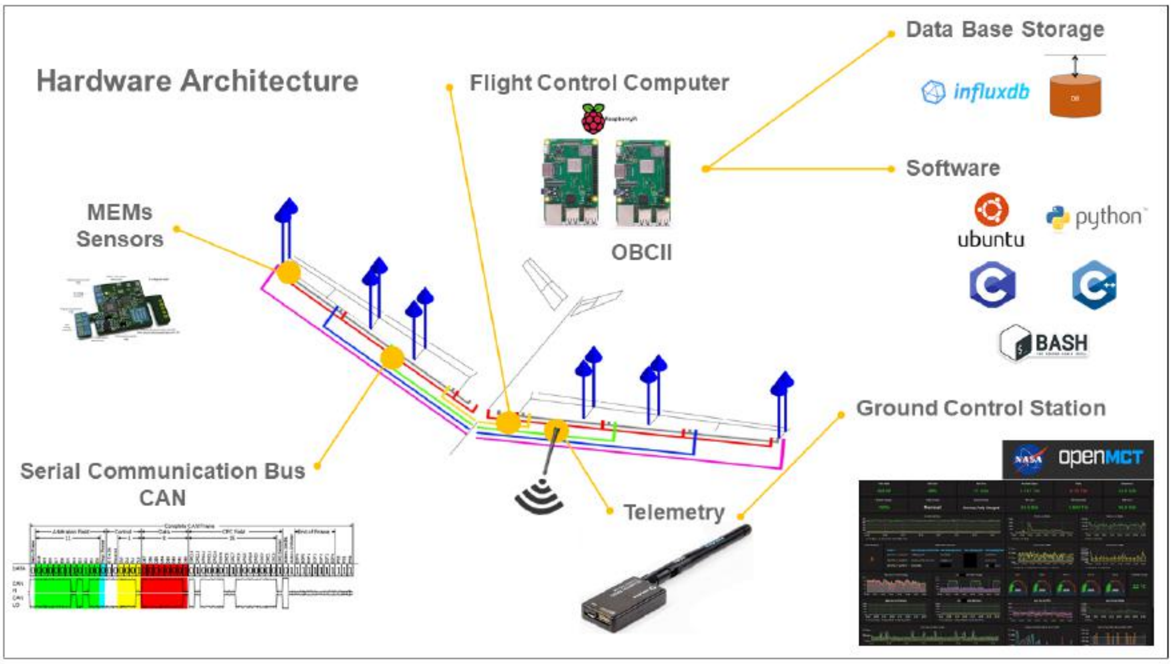


Figure 43: System for online flight vibration monitoring.

To this end a real time capable online monitoring system was developed. The flight testing system for online flutter monitoring is shown in Figure 43. The system architecture was designed to be modular, plug and play with no mandatory user interaction during operation. The system was also designed to be highly configurable for deployment on a large variety of structural layouts of UAVs, from conventional wing-based aircraft to Vertical Take Off and Landing VTOL multicopters. The system is scale-able with different sensor types and communication protocol options to suit different size structures. Furthermore, in order to deploy multiple resource intensive processes such as QR factorisation and Singular Value Decomposition SVD without blocking new data or competing for resources on the miniaturized hardware, the system is setup with multiprocessing. Multiprocessing enables parallelisation by assigning tasks to different CPU cores and threads. In the framework of the FLIPASED project, the system hardware consists of in-house Printed Circuit Board PCB Inertial Measurement Units IMUs which measure acceleration and angular velocity.

Six IMU Printed Circuit Boards PCBs are mounted in each wing at the positions shown in Figure 43. Each IMU PCB consists of a PIC microcontroller, an MPU6000 digital Micro Electro Mechanical Systems MEMs sensor, an AD2286 analog MEMs sensor and a CAN transceiver. Each PCB is mirrored on the top and bottom for full redundancy. The microcontroller requests data from the MEMs sensors at 1 kHz using I2C serial communication, and applies a Finite Impulse Response FIR high pass filter. These sensors are connected via the serial communication CAN bus to the FlightHAT. The data is requested on the CAN bus by the host device FlightHAT at a sample rate of 200 Hz. This sampling and filtering strategy has proven effective to cover the frequency range relevant for flutter of this aircraft and to maintain accurate phase information among the sensor signals.

The flightHAT is a real time embedded controller for collecting data for the Flight Control Computer FCC. A second miniaturized computer was built into the aircraft to enable real time flutter monitoring. A Raspberry pi 4 with quad core cortex-A72 SoC@1.5GHz and 8GB or RAM was integrated into the flight stack with a 3D printed housing. The data is transferred from the FCC to the second Raspberry pi OBCII via ethernet using ZMQ. ZMQ is a lightweight messaging library, which provides standardized messaging over a socket based communication channel. The OBCII receives IMU data in real time, builds a FIFO buffer, performs signal processing, operational modal analysis using Stochastic Subspace Identification SSI and mode tracking using machine learning using state of the art algorithms in Python. Once modal parameters have been identified using SSI, they are tracked using Density Based Spatial Clustering DBSCAN into mode families. Finally, the data is passed to the telemetry system, programmed using Finite State Machine FSM logic to encode and transmit the data over the 433 MHz telemetry module. A ground station running the same Python class then receives and decodes the messages. The data is saved to a time series data base called Influx DB and the frequencies and damping ratios are plotted as a function of time in the NASA OpenMCT GUI in order to observe trends of decreasing damping which would indicate the approach to the flutter boundary.

Flight test FT16 was dedicated to aeroelastic system identification. The aim was to identify and track modal parameters in real time at different points of the flight envelope. In order to identify a consistent Linear Time Invariant LTI system, constant speed circuits were flown. Furthermore, several observations at the same flight test point reduce the uncertainty in the modal parameters. In order to improve the flight speed consistency, loops were flown with constant bank angles. This allowed the time on test point to increase from 16 - 30 seconds for horse race pattern flight to 120 – 240 seconds.

The acceleration time history of the 12 IMUs during FT16 are shown in Figure 44. The sections are colored according to the flight state as follows:

- Cyan: taxi, takeoff, augmented mode and auto-throttle check.
- Magenta: 30 m/s flight speed.
- Yellow: 40 m/s flight speed.
- Green: 50 m/s flight speed.
- Blue: 55 m/s flight speed.
- Red: airbrakes on, landing and taxi.

Acceleration values of up to 150 m/s2 were experienced on the wings during take-off, landing and taxi. In flight values rarely exceeded 20 m/s2 with rms values of 1.3 m/s2 at 30 m/s, 1.9 m/s2 at 40 m/s, 2.6 m/s2 at 50 m/s and 2.2 m/s2 at 55 m/s. Interestingly the rms values increase almost linearly from flight speeds 30 m/s to 40 m/s to 50 m/s but then decrease at the maximum achieved flight speed of 55 m/s. Turbulent conditions were also experienced during each flight state as seen from the spikes in the time history. In general random response as generated by natural turbulence is ideally suited to satisfy the mathematical assumptions of the unmeasured input forces for the OMA algorithms.

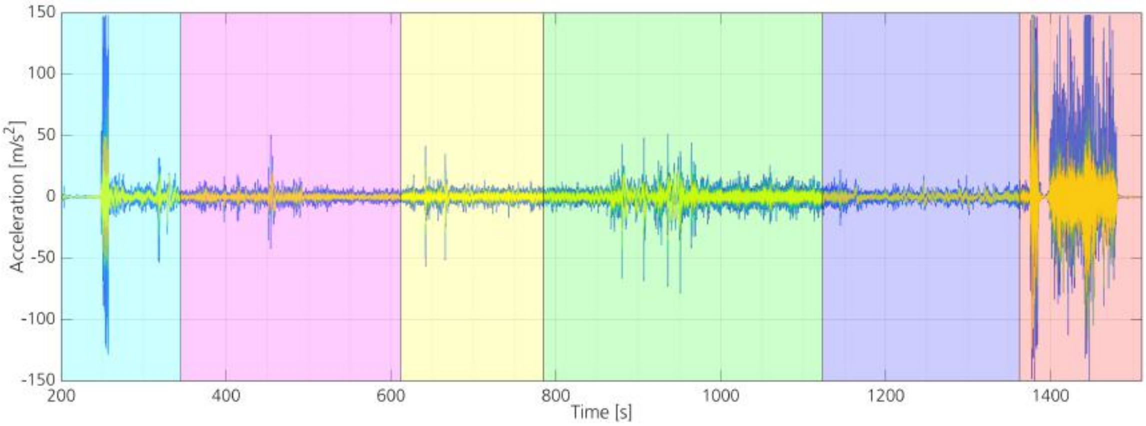


Figure 44: Acceleration time history during flight 16.

Modal analysis was performed in real time on the aircraft on 30 second data buffers with 60 % overlap. The measurement duration of 30 seconds was chosen so as to be short enough to not smear physical changes to the system as well as long enough to contain sufficient observations of the target modes. In theory this data buffer length can be adjusted based on the how well the modes are excited, which is primarily a function of flight speed. However, for this work the buffer length was kept constant. An example of 30 seconds of acceleration data sampled at 200 Hz from the 30 m/s flight speed is shown in Figure 45. Despite a speed variation of less than +- 2 m/s and bank angle variation +- 4 degrees the data is not highly stationary with some gusts (example at 415 seconds) and a slight orientation change in the gravity field (423 seconds). These are challenges which will always be faced with real in-flight data, and should be kept in mind by the engineers when interpreting the results.

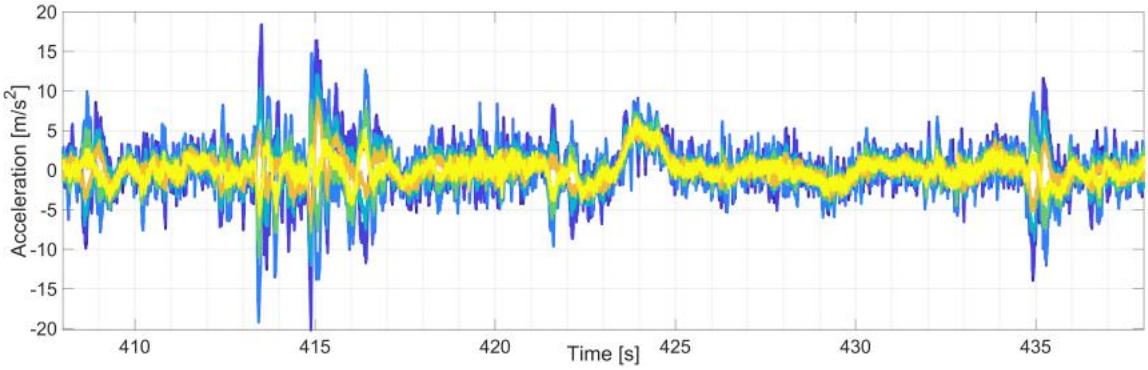


Figure 45: 30 second time buffer.

The cross power spectral densities CPSDs after decimating the data from 200 Hz to 60 Hz are shown in Figure 46. The response spectrum is seen to be relatively flat in the band 0 Hz to 30 Hz, since all modes get additional damping from unsteady aerodynamics, which is more significant than structural damping on ground. This is also an indicator of broadband aerodynamic excitation and supports the use of time domain modal analysis algorithms which are not based on curve fitting in frequency domain. The stabilization diagram is shown in Figure 47. Despite the relatively flat spectrum, lines of consistent poles at increasing model orders can be observed. Six modes are identified using the Stochastic Subspace Identification SSI algorithm from the current data buffer between 0 Hz and 30 Hz. The block size was set to 16 and the maximum model order to 80. The modes which match within a given frequency, damping and eigenvector tolerance belong to a unique mode family and are given a unique color. This mode color will be used consistently throughout this section – i.e. mode 1 will always be red. Finally, the measured average spectra is plotted by the blue curve and the synthesized spectra by the red curve. This shows how well the identified model recreates the measured data in the frequency domain. The fit is seen to be in agreement, but is not perfect. The use of additional sensors on the tail and fuselage as well as measurements in the x direction on the wings are expected to improve the modal model and therefore the synthesis error.

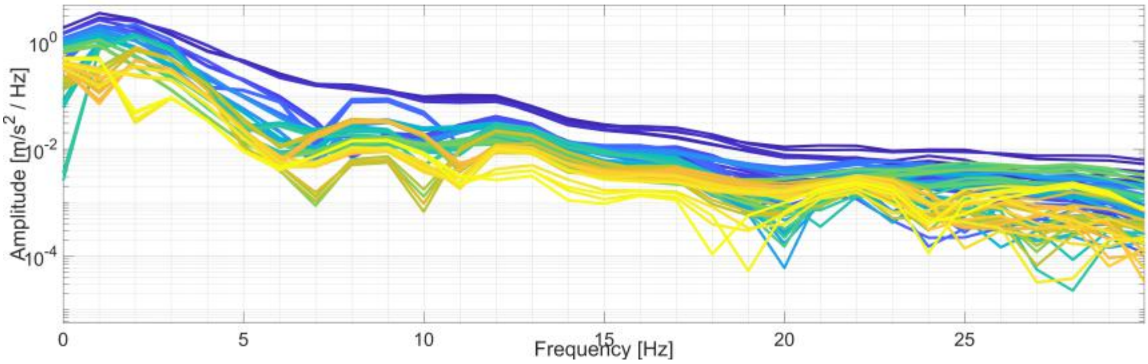


Figure 46: Cross power spectral densities.

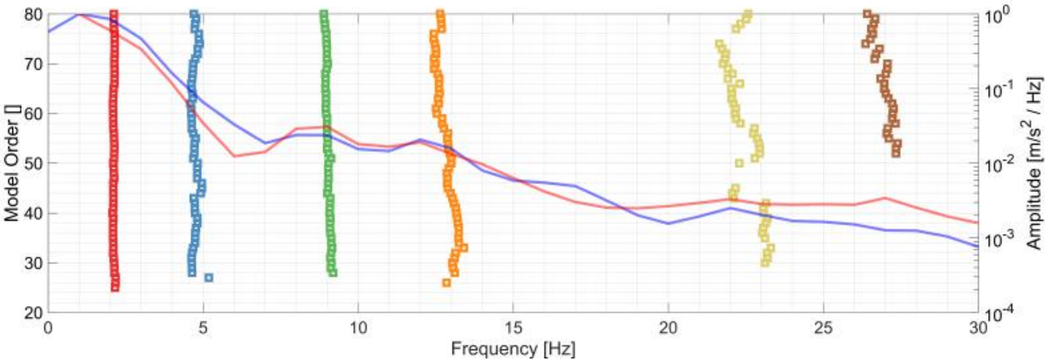


Figure 47: Stabilization diagram from SSI.

The modal assurance criterion MAC shown in Figure 48 is the normalized dot product of the eigenvectors and shows that the six identified modes are linear independent. The eigenvectors or mode shapes of the six modes are shown in Figure 49. The first mode at 2.1 Hz is the rigid body roll mode. The second mode at 4.7 Hz is the 2n wing bending. Next come 3n wing bending at 8.9 Hz, 4n wing bending at 12.6 Hz, 5n wing bending at 22.6 Hz and 6n wing bending at 26.4 Hz. Wing torsion was not identified since it was designed to be above 60 Hz for this baseline wing set. The phase purity of the mode shapes is high and the shapes are clean and symmetric. This is an impressive result considering that the data is measured with MEMS sensors, processed with light weight low cost embedded systems, on short data buffers, in real time during actual flight conditions. Unfortunately due to the lack of sensors on the fuselage or V-tail only wing bending modes could be identified.

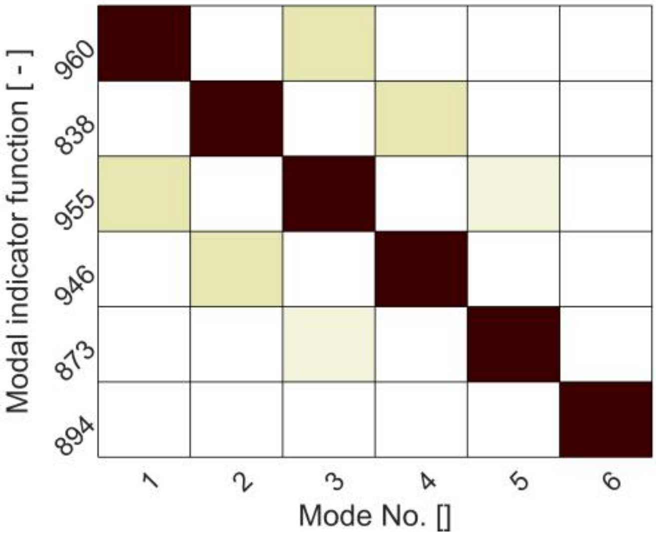
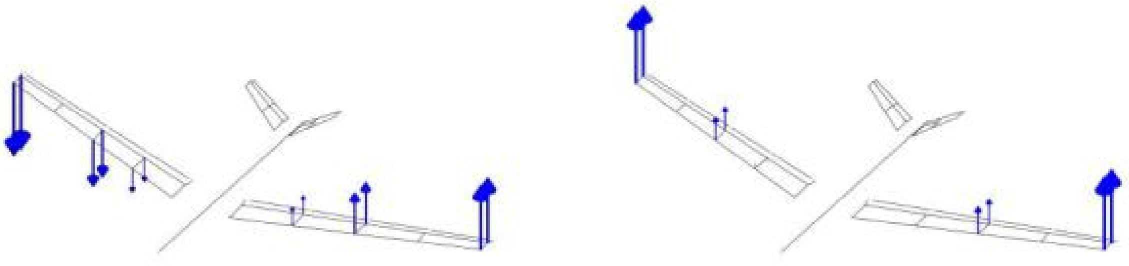


Figure 48: Modal assurance criterion MAC.

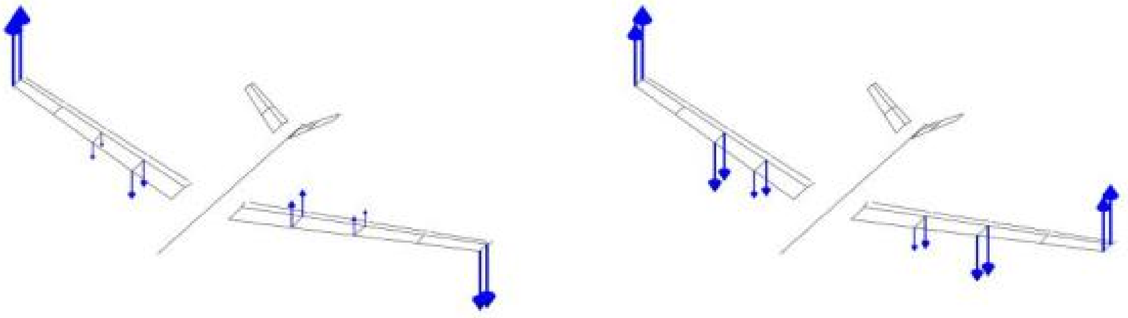
The aim of this system is not simply the real time identification of modal parameters, but also the tracking and quantification of these parameters through the flight envelope. The resulting frequencies and damping ratios of the six mode families are plotted throughout the flight in Figure 50 and Figure 51. The six mode families are represented by uniquely coloured squares as a function of mode set. Each mode set consists of a 30 second data buffer with a 60 % overlap. The flight speed is indicated by the blue line and the flight altitude by the dashed black line. Here the constant speed circuits of 30 m/s, 40 m/s, 50 m/S and 55 m/s can be seen. The flight altitude remained fairly constant at 400 m. In Figure 50 six horizontal lines of uniquely coloured squares representing mode families can be observed. It can be seen that the frequencies vary during the flight and that not all modes are identified in all mode sets. This is expected to be because of the different excitation conditions resulting from flight speeds and wind conditions. The damping ratios show larger variations especially for mode 1 and 2. The identified aeroelastic damping in the range of 10 - 20 for modes 3 - 6 are in the range of expectations from engineering judgement. The question which then arises is whether trends can be seen in the modal parameters as a function of the dominant physical factors.

The frequencies and damping ratio's are therefore plotted as a function of flight speed in Figure 52 and 53. Here the clusters of modal parameters at each flight speed are averaged. Firstly it should be noted that the test was conducted on the baseline wingset (-0 wing). This wingset was designed to be completely stable in the flight envelope, and we therefore do not expect to see flutter. Nevertheles some changes in the modal parameters are expected. The eigenfrequencies show a general increase from 30 m/s to 50 m/s. The damping ratios of modes 2 – 6 also increase from 30 m/S to 55 m/s. The rigid body roll mode shows a reduction in damping ratio from approx. 60 % at 30 m/s to 30 % at 55 m/s.

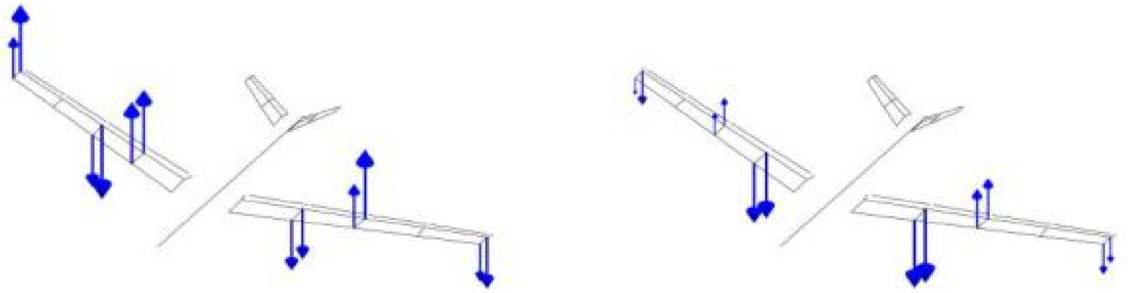
In conclusion, flight testing of the UAV demonstrator T-FLEX in the EU project FLIPASED successfully demonstrated the capabilities of an online modal identification system for flutter monitoring based on miniaturized hardware. The system was deployed in an extensive flight test campaign at the DLR Cochstedt airport. The flight test campaign provided valuable data and thoroughly tested the capabilities of the system. The online monitoring system integration into the flight control system of the aircraft performed well. The on board signal processing, modal analysis and mode tracking produced accurate results and ran in real time. Furthermore, the in-house developed telemetry system proved stable and



(a) Mode 1 - rigid body roll
(b) Mode 2 - 2n wing bending



(c) Mode 3 - 3n wing bending
(d) Mode 4 - 4n wing bending



(e) Mode 5 - 5n wing bending
(f) Mode 6 - 6n wing bending

Figure 49: T-FLEX mode shapes.

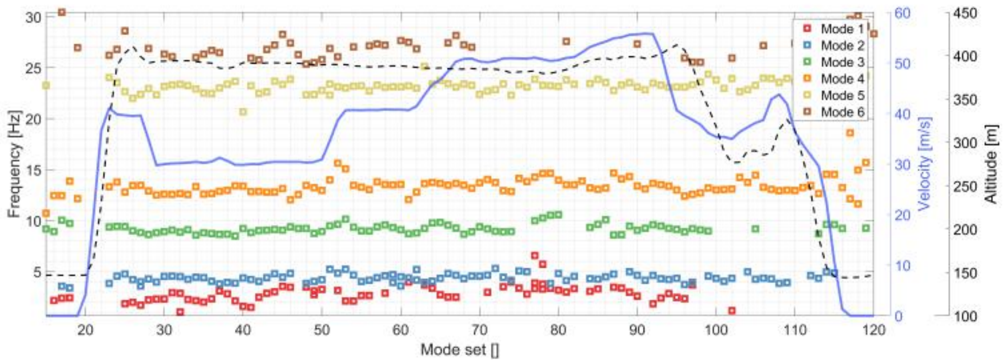


Figure 50: Mode tracking of eigenfrequency during flight 16.

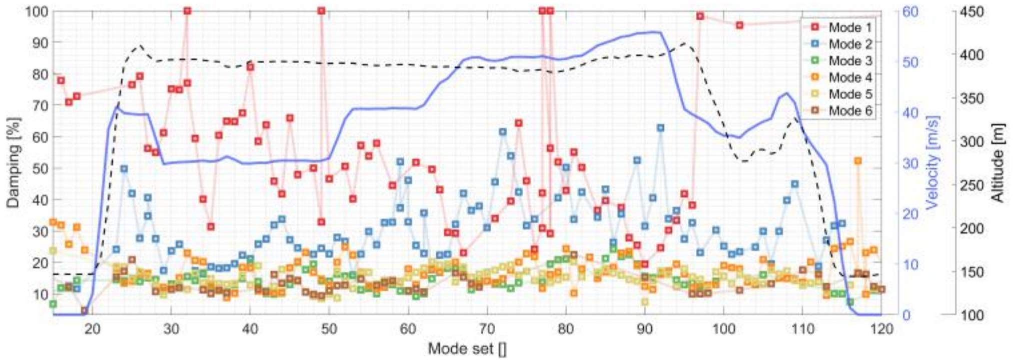


Figure 51: Mode tracking of damping during flight 16.

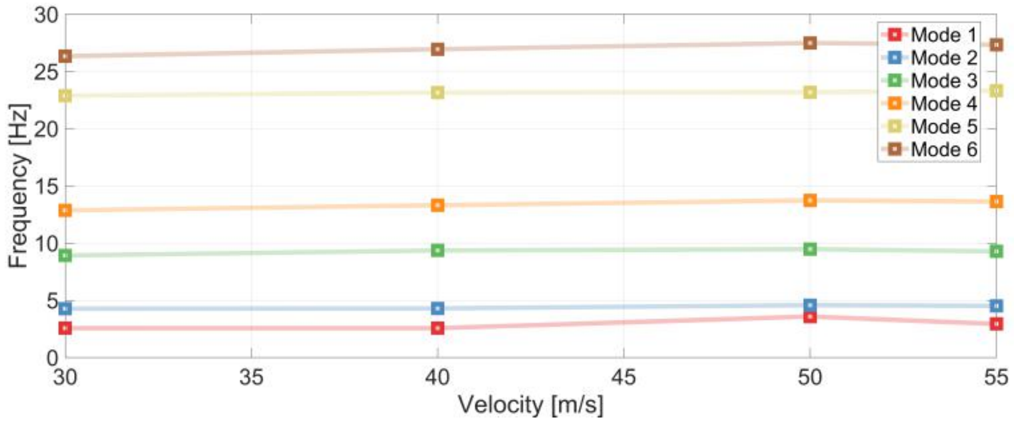


Figure 52: Mode tracking of eigenfrequency as a function of flight velocity.

robust with zero fatal disconnects and no package losses. The system was able to identify and track modal parameters in flight, and flight test engineers were able to visualise the frequencies and damping ratios as a function of time or velocity at the ground control station. Six wing bending modes were identified and tracked during the flight campaign. The six modes showed trends of increasing frequencies and damping ratios for all the elastic modes. This was in agreement with the non-linear aeroservoe-

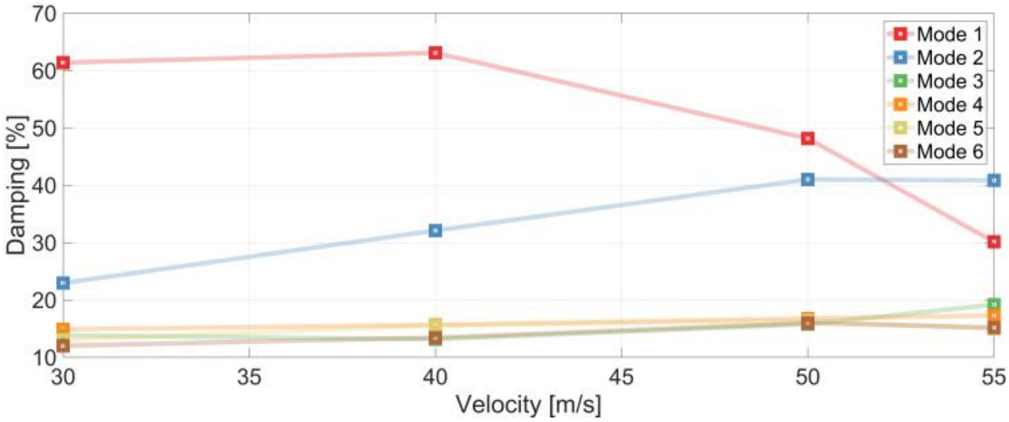


Figure 53: Mode tracking of damping as a function of flight velocity.

lastic model. The system has therefore been demonstrated as a capable and reliable tool for real time flutter monitoring during flight testing. Improvements to the system regarding additional sensors in the V-Tail as well as in-plane measurements in the wings are underway. Furthermore, testing the online monitoring system on the flutter critical wing set will provide the ultimate test of the result accuracy in predicting the flight envelope. Finally, the integration of the online modal analysis system with the onboard flight control system for active flutter control will be the next step in the current research and development.

4.3 Baseline aerodynamic analysis (TUM)

4.3.1 Take-off performance

After analysing all the take-offs performed during the 1st test campaign (Figure 54) it was discovered that even though the elevator is down all the time during the take-off, $2-3s$ before actual take-off point the airplane lifts the tail anyway (note the pitch angle). It is suspected, that this is the point where the ground control is lost. Such a conclusion would also correlate well with the data collected during taxi tests, where it was noted that during the high-speed phase the aircraft becomes very uncontrollable.

This indicates that the tail authority is not enough. As the angle of attack cannot be kept at $4deg$, it could be the reason why the aircraft always lifts-off late with around $30m/s$. Similar pattern can be seen in the previous flight tests as well.

It is suggested to either increase the elevator authority, or use outboard flaps to get more pitch-up moment for the upcoming flights. In such case it could be expected to decrease the TO distance by around $2-3s$ (around 50-70m), and reduce the airspeed by around 6-8m/s.

4.3.2 Lift and drag polars (TUM)

Flight tests 10, 16 and 17 were used as a basis for a publication ”In-flight drag measurement and validation for a medium-sized UAV”[1]. The article presents how the flight test data was used in order to model the lift and drag characteristics of the baseline demonstrator.

You can find the article in the Appendix 7.1.

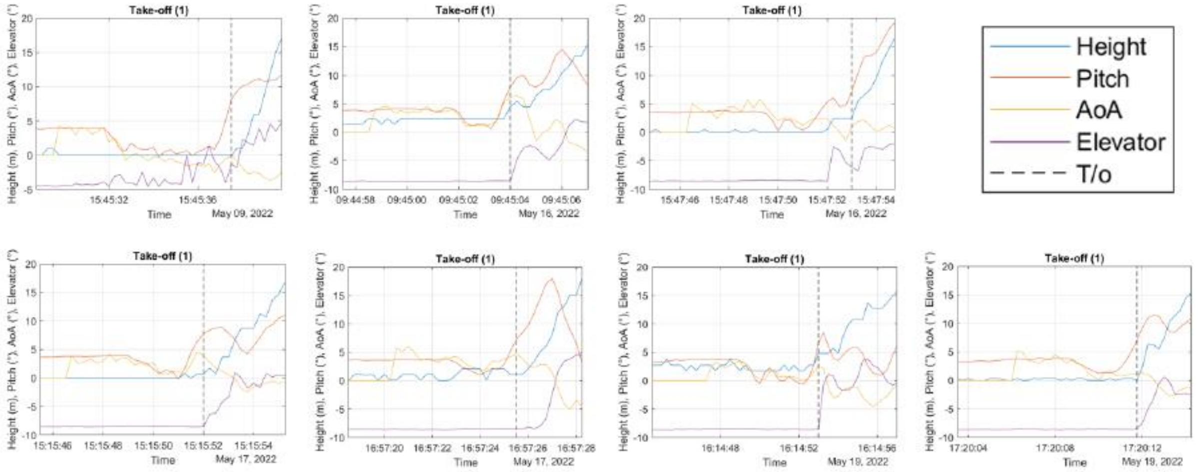


Figure 54: Take-off performance for the 7 test flights. Note the ”pitch bucket” visible for 2-3s before the actual take-off point (marked with the dashed line) and the elevator command (in purple).

4.4 Airflow visualization over the wings (TUM)

Airflow visualization experiments with oil flow were performed to investigate the boundary layer effects in-flight.

A 1:1 mixture of Mobil 1 ESP 5W-30 engine oil and Liqui Moly SAE 75W-90 high performance gear oil was mixed with black pigment [2]. The resulting viscosity of the mixture seemed to fit the airspeeds encountered in flight.

Two flights were done with the mixture applied to the root area of the upper wing - flight tests 13 and 14 (Figure 55a). It was envisioned to be able to record the transition of the oil in-flight, but the resolution of the camera was too low. It was noticed, however, that the pattern stabilizes after around 10min of flight.

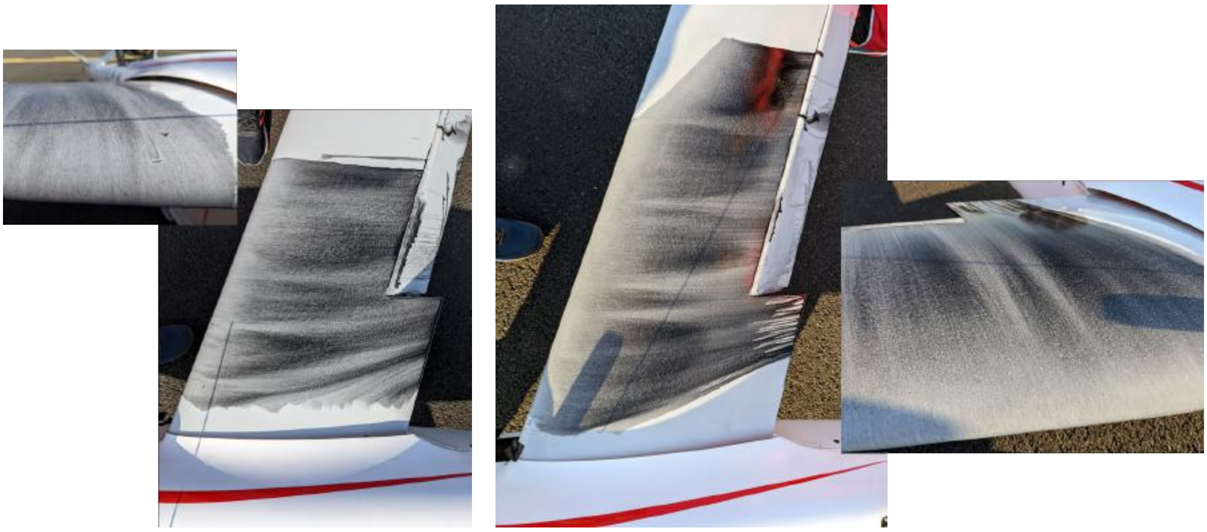
After the first test on FT13 there were clear identifications of boundary layer transition due to particles on the surface after. The cross-flow component inside the boundary layer was also visible towards the trailing edge of the wing.

A bigger area was covered with oil for the second test, and a decreasing chord length was covered on the outboard section to investigate the effects of the oil itself (Figure 55b). Again, clear transition lines were visible after flight. Though it was not completely clear where do all the turbulent wedges come from. It was postulated that maybe it is due to the wing ribs distorting the wing surface (Figure 56, but the hypothesis could not be confirmed.

There was a bigger conglomeration of oil visible on the outboard part of the covered area where the decrease in covered chord length started. Even though a similar pattern would be expected during a laminar separation bubble, it could not be confirmed that that area simply had more oil than the root area.

Even though the experiment seemed to provide visible results, there was not enough time available to prepare the oil for every flight. Therefore, no definite conclusions about the boundary layer effects can be made.

The following lessons can be noted for the future:



(a) Flight test 13.

(b) Flight test 14.

Figure 55: Oil flow patterns after two test flights.

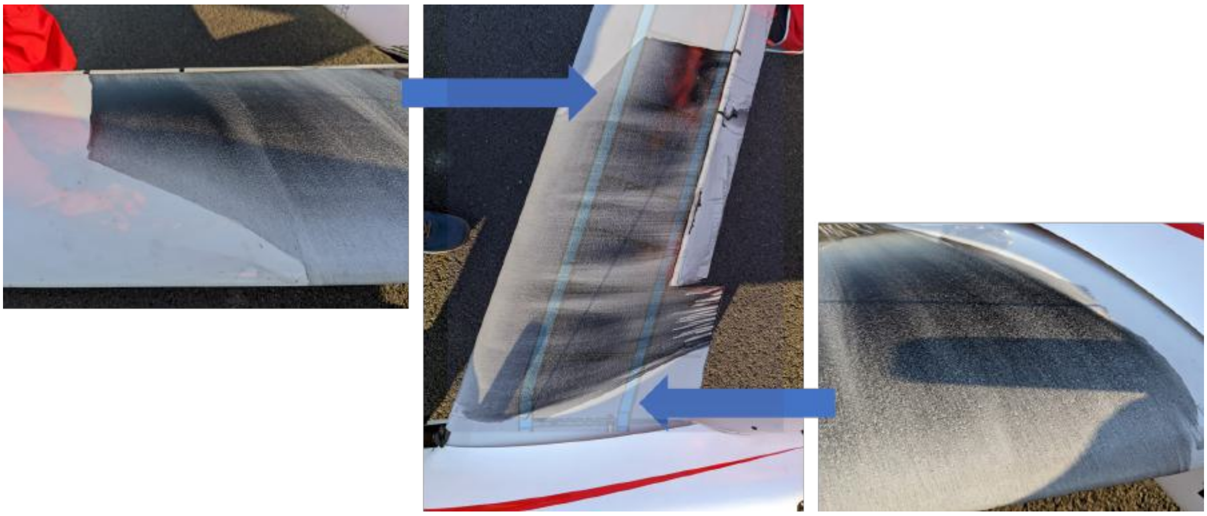


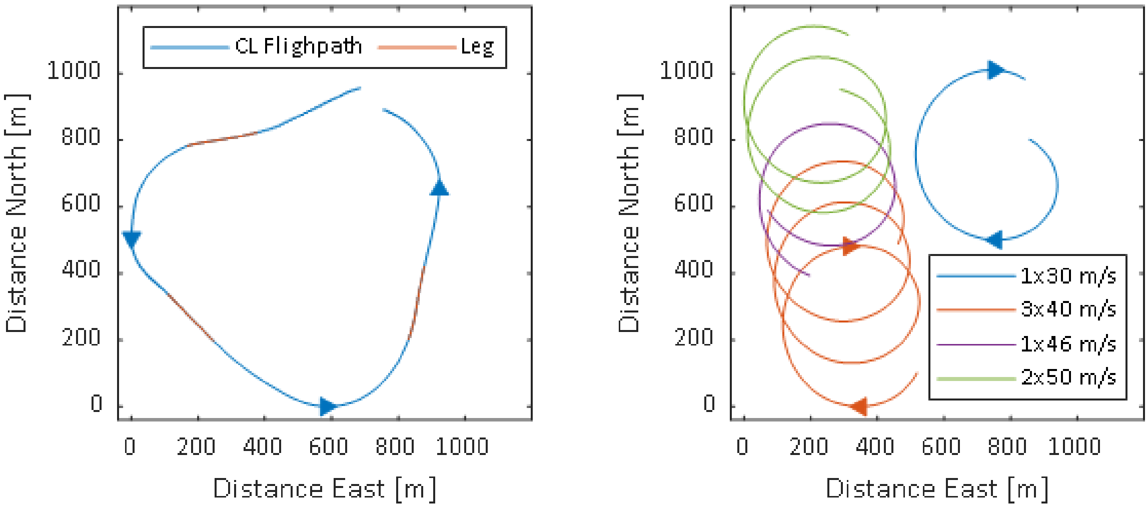
Figure 56: Oil flow pattern after flight test 14 with wing ribs overlayed in the middle.

- The viscosity of the mixture seemed perfect for the Reynolds number regime of the t-FLEX.
- Pattern stabilises after 10min of flight.
- Colour was wrong. Black was too dark during a sunny day which produced too much contrast. The details were not visible on the camera in-flight.
- 360 camera resolution is not good enough to capture the details, only the overall picture at specific sun angles.
- A turbulator should have been glued in the measurement area for comparison.

4.5 Airspeed calibration in-flight (TUM)

Collecting correct data about the aircraft's performance is crucial. However, measurements often contain errors that must be accounted for. The focus of this section is to calibrate the airspeed and altitude measurements of the T-FLEX. By analyzing flight test data, wind speed and direction are determined, as well as position errors caused by the pitot static system. This corrected data can then be used for further development and other performance reviews. Three main airspeed calibration methods are tested and assessed during simulator flights and a flight test campaign. Subsequently these methods are implemented into a flight test data analysis tool in MATLAB. Additionally, the position error is compared to an existing Computational Fluid Dynamics (CFD) simulation to match the results of simulations and test flights.

The airspeed calibration methods that were found applicable for T-FLEX are the cloverleaf method, the level turn and the turning acceleration. The calculations used in the level turn method and the cloverleaf technique are similar and simple regression techniques are applied for both. The trajectories flown for these methods are easy to follow (Figure 57). Subsequently, an external software is used for analysis of the data gathered for accelerated turn (Figure 58).



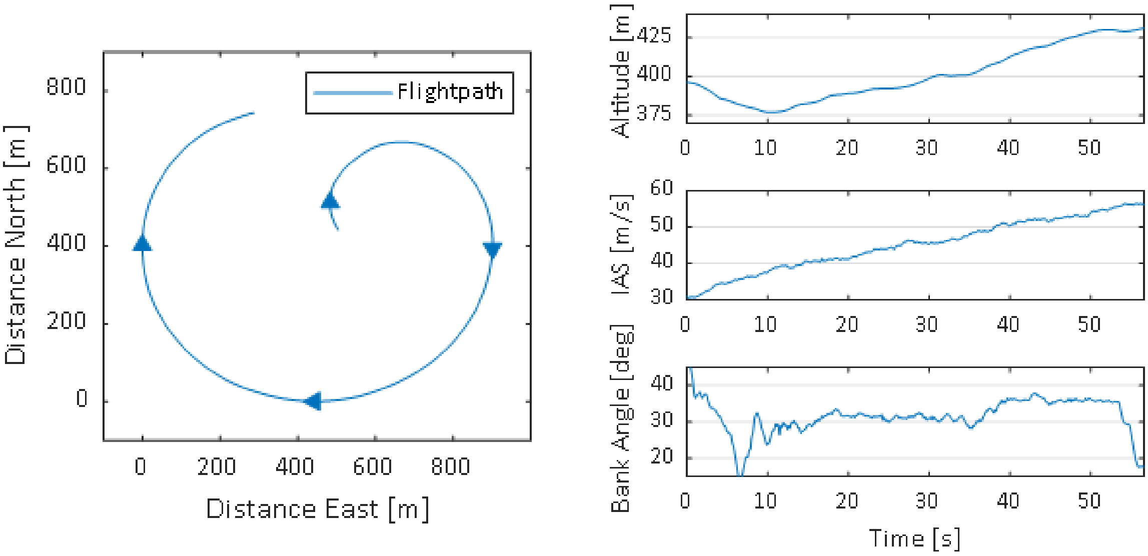
(a) Cloverleaf during flight test 11.

(b) Circles during flight test 16.

Figure 57: Examples of the trajectories used for the cloverleaf and the level turn airspeed calibration techniques.

The resulting airspeed corrections are presented in Figure 59. It is visible that all three methods predict a small, from -0.5 to -2.5m/s correction that should be applied to the indicated airspeed. This means that the air-data system indicates airspeed that is higher than the real one. However, taking into account that the accuracy, claimed by the manufacturer, is either 1 percent or $1m/s$, the errors can be considered small.

For more details about the investigations done in airspeed measurement error, please consult [7].



(a) Accelerated turn during flight test 13.

(b) Altitude, indicated airspeed and bank angle during the accelerated turn.

Figure 58: Data used for the accelerated turn method.

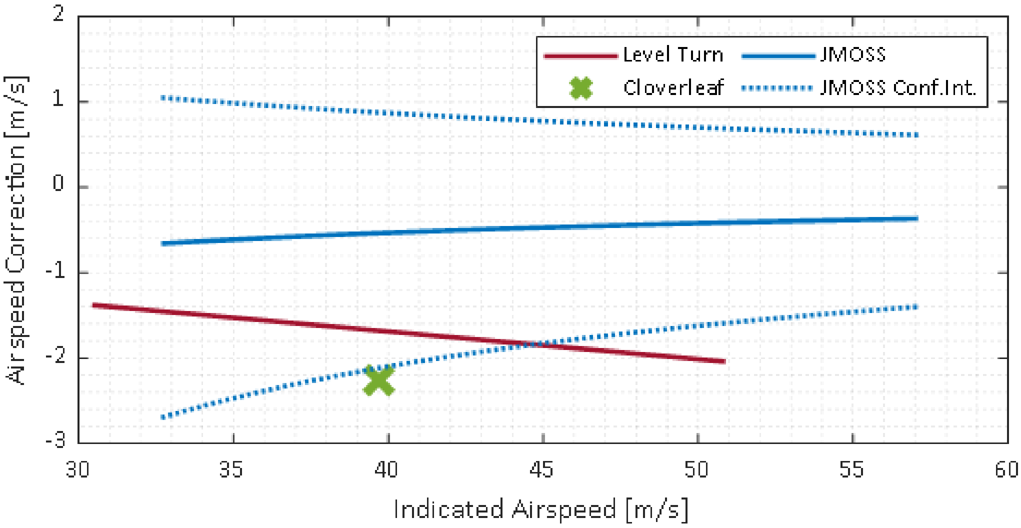


Figure 59: Comparison of airspeed corrections obtained from the level turn method, the cloverleaf method and the accelerated turn method. Note that here JMOSS means the accelerated turn method.

4.6 Induced drag experiments (TUM, DLR)

Purpose of the induced drag experiments is to validate the drag measurement system and the simulation tool for the wing shape control function. The aerodynamic method employed to validate the induced drag is an enhanced version of a Vortex Lattice Method (VLM) [3] as described in detail in [6]. This extended VLM is implemented in the simulation environment VarLoads [4, 5], which is capable of trimming a free flying flexible aircraft using a mean axes based coordinate frame.

The integrated modelling approach of the simulation tool VarLoads accounts for effects on the induced drag due to flexible deflections as well as due to trim settings. This makes a tedious coupling of the aerodynamic code with the structural solver and a trimming routine superfluous. The objective function for minimizing, respectively maximizing the drag is the thrust setting of the engine of the integral model.

The main objective of the flight test was to compare a high drag configuration to a nominal configuration with zero flap deflection. The simulations showed good agreement with intuition, as a crocodile tooth style configuration showed an major increase of the drag coefficient in the simulations. One constraint from a piloting perspective was not to significantly change the pitching moment of the aircraft. Therefore, the deflections of the outermost flaps were adapted to minimize the change in elevator settings, reflecting a minimal change in pitching moment, while substantially increasing the drag values.

The flap setting selected for the high drag configuration was $+10/-10/+10/+5$ degrees (Figure 60).

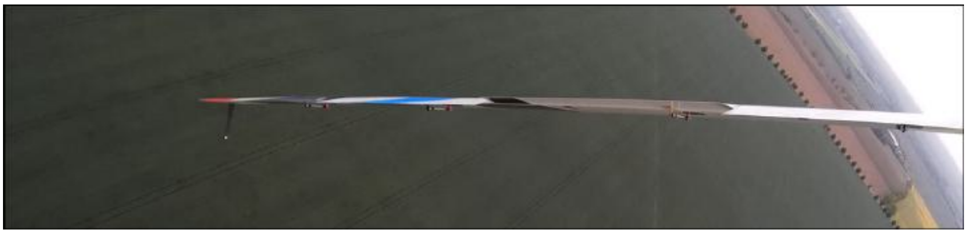


Figure 60: Drag flap configuration during a test point. The flaps here are deflected $+10/-10/+10/+5$ degrees.

The results of the experiment are described in the paper "In-flight drag measurement and validation for a medium-sized UAV", pages 11 and 12 7.1.

4.7 Investigation of the accident during the FT23 (TUM)

On 29th of August an uncommanded parachute release was experienced with the demonstrator. The aircraft landed outside the airport zone and a fire broke out. The bigger part of the aircraft has completely burnt down. Luckily, all the data sources were available - the main flight log, the two transmitter logs, a log from the secondary on-board computer, the videos from the two tail cameras and the video from the 360 camera, which has fortunately fell out of the fuselage right at the moment of impact.

It could be immediately confirmed from the main flight log that the parachute was released as a programmed safety feature when the reception to the pilots is lost for at least 1.5 seconds. During the flight, the reception was lost for 2s. Furthermore, it became clear that the engine did shut down when the parachute was released, just like planned. But it was not clear why did the engine start again when the aircraft hit the ground. Therefore, the following main questions were raised for the investigation:

- Why was the connection to the aircraft lost?
- Why did the engine start again?

The first question is answered in Section 4.7.2.

At the moment of reception loss, at least some of the transmitter antennas had direct line of sight to the transmitter (Figure 61). The transmitter reception quality is logged by the transmitter itself. It is communicated to the pilots via audible warnings. However, the logs of the reception quality was never investigated in connection to the position or orientation of the aircraft. This investigation was done by the Flight Test Manager and communicated to the rest of the Consortium in an email, provided in Section 4.7.3.

Figure 61: The moment of reception loss. Here the antennas are visible at the end of the V-Tail and the pilots stand exactly on the point of the runway where the V-Tail is pointing to.

4.7.1 Timeline of the accident

Below is the timeline of the accident. The start of the timeline is the moment when the engine start command is sent before the flight.

- 00:00 - Engine start command is sent
- 09:54 - Last turn initiated
- 09:56 - Jeti loses reception, aircraft switches to Graupner; aircraft switches to failsafe (landing configuration visible)
- 09:57 - Tail cone flies off, drogue chute is released
- 09:58 - Jeti back in control
- 09:59 - Engine is turned off due to parachute release
- 10:00 - Parachute is completely out
- 10:32 - Aircraft crashes on the ground
- 10:42 - Engine start command is sent again
- 11:10 - Engine starts
- 12:02 - Fire visible behind the airbrakes

- 12:30 - Engine turns off
- 14:32 - Smoke visible from the payload bay
- 15:44 - Fire visible in the payload bay
- 16:08 - Complete fuselage is on fire
- 24:24 - The TUM team arrives at the landing site

Figure 62 display the timeline of the accident as captured by the 360 degree camera.

Figures 63 displays the crash site and the remains of the aircraft.

It took roughly 14 minutes for the TUM team to get to the crash site after the aircraft has hit the ground. This was due to the fact that the crash site was outside of the airport area and the team had to drive around the airport on unpaved roads. It is visible from the timeline, however, that already 5:30min after the crash the complete aircraft is on fire. Therefore, the chance to save any bigger part of the aircraft after a fire broke out would have been very unlikely.

4.7.2 Investigation about the engine restart

As mentioned before, it was not immediately clear why did the engine restart after the crash. It was thought that when the parachute gets released, it also triggers a fuel pump shut-off valve, which prohibits any further fuel being pumped into the engine. It was recognized, however, that the valve is not shut permanently if the trigger command is very short. In this case, the command was lost for mere 1.5s, after which the chute release command was commanded. This triggered the fuel valve as well and turned off the engine. But as the command was regained 0.5s later, the fuel valve was reopened.

Another mistake was found with respect to the fail-safe setting on the secondary transmitter. Due to the architecture of the control system, for the Jeti transmitter to be able to switch to Graupner, the engine command has to be set to positive. This was required due to the lack of separate channels on the transmitter communication line. In this case it was envisioned that if the main transmitter loses reception, it switches to the secondary transmitter. Due to a human error, the same fail-safe setting was programmed on the secondary transmitter. This still meant that in a parachute-release case the engine would turn off due to the fuel valve being shut. This is what happened in the current case.

However, as all the risk analysis trees ended with the moment when the parachute was released, it was not envisioned that the reception could be regained after the fail-safe was initiated. In the current case, the aircraft regained reception with both transmitters while going down with the parachute. In combination with the fuel valve being open (due to the very short period of the fail-safe) this meant that the engine could be restarted. But at this point the pilots did not issue an engine start command. It was the second loss of reception when the aircraft hit the ground and the secondary transmitter went into fail-safe that issued the engine start command ten seconds after the impact.

It is speculated that if not for the unfortunate coincidence described above, the fire would not have started after the aircraft hit the ground.

4.7.3 Email about the T-FLEX Reception investigation, sent on 9th of September by Julius Bartasevicius (edited)

I investigated the reception quality of the Jeti transmitter by looking at the GPS data, at separate and combined receiver (Jeti has two) qualities, at aircraft bank angles, distance from the pilot and altitude. I used data from the last two test campaigns for that (excluding two flights because they had many GPS outages). Note that the antennas are pointing to directions 55deg (RX2, tail) and 150 and 210deg (RX1, fuselage).

I would summarise the findings below:

1. No connection to reception quality and a specific GPS position can be found. Therefore I would not say that there is interference from some antennas around.
2. Reception highly depends on the elevation from the pilot. Elevation angle is the vertical angle from the pilot to the aircraft. When the elevation goes under 13deg, problems can be expected (signal quality of less than 30 percent, Figure 64). Elevation of 13deg means 230m altitude at 1000m distance or 350m altitude at 1500m.
3. It also depends on the lateral angle to the pilot in the aircraft-fixed reference frame. Below is the polar plot showing the quality for each receiver (Figure 65, aircraft nose pointing to the screen; 0 means pilot is above the aircraft, 90 is when pilot is facing directly the right wing). Here I took only flight moments when the aircraft was perpendicular to the pilot (in a top down view the wings were pointing to the pilot, plus minus 20deg) to reduce it to a 2D problem.

   So there is this area of 45-100deg and 270-320deg where reception is worse. If the aircraft is roughly above the pilot (120-240deg), then reception is good. There is no data in the range 330-30 (we don't fly inverted).
4. If the two above are combined, it's visible that the problems with reception are only in right hand turns (Figure 66, angles to the pilot more than 0).
5. I also tried to see the if bearing from the aircraft to the pilot shows some trends (while keeping the bank angle relative to the pilot within some range, Figure 67). The range from 300 to 0deg does seem more problematic for RX2 (meaning the pilot is in front of the aircraft). This might make sense, since the RX2 is in the tail of the aircraft.

Finally, applying this to the terminated flight: At the moment of the loss of reception we flew at elevation angle too low while also doing a right turn, which put us in the very unfavourable reception envelope.

4.7.4 Conclusion of the investigation

Following the email sent on the 9th of September, the investigation of the crash was concluded. In summary, it could be said that:

- For this specific aircraft there was a small reception blind spot when a right turn is done.
- Reception quality was also lower because of the low flight altitude (below 13deg of elevation). This resulted in a short reception loss with the aircraft.
- Risk analysis tree was not investigated further than the moment of parachute release.
- Wrongly programmed fail-safe and the short loss of reception meant that the engine could be restarted after the aircraft lost reception for the second time, when already on the ground.
- The restart of the engine initiated the fire, destroying the bigger part of the fuselage.

5 Conclusion and outlook

During the two flight test campaigns in 2022, 14 flights were made with the baseline demonstrator. Most of the flights averaged around 16 minutes and more than 220 minutes of flight time was collected. The report can be concluded with the following points:

- The aircraft's ground controllability (and, therefore, reliability) was significantly improved. A severe crash was experienced during the take-off in FT11, but upgrading the landing gear once more (with the wingtip wheels) and changing the flap configuration solved the issues that were seen as the biggest challenges for flight testing of this demonstrator.
- New pilot was trained, which increased the flexibility of the flight test team. Furthermore, the flight test team had further optimized flight testing operations, resulting in better preparation for the second test campaign.
- Data was gathered for baseline aerodynamic evaluation of lift and drag, summarised in a publication. Additionally, data was gathered for identifying the flexible body modes in flight.
- All the autopilot modes were tested and proven to work in-flight with only minor updates required before the flutter flights can commence. The autothrottle mode, which appeared to be the most challenging mode to adjust, was tested up to $56m/s$.
- Airspeed calibration was confirmed to be within the required limits using i-flight data.
- The crash during FT23 was investigated in detail, which touched the points that were not investigated before.

Only some of the planned goals were achieved during the campaigns. For example, the flexible -1 wing still needed to be flown. This was planned for the third campaign of the year, but could not be undertaken due to the crash. Additionally, the manoeuvres injected for rigid body mode identification were insufficient to perform proper data analysis.

(a) 09:57 - The drogue chute release.

(b) 10:00 - Full parachute release.

(c) 10:32 - Front part of the fuselage just after impacting the ground.

(d) 10:34 - Fuselage laying down, the main parachute is visible coming down in the background.

(e) 12:02 - Fire breaks out in the rear part of the fuselage.

(f) 15:25 - Fire breaks out in the front part of the fuselage.

(g) 18:24 - The complete fuselage is on fire.

(h) 21:16 - Parts of the fuselage are already burnt down.

Figure 62: The timeline of the crash as recorded by the 360 degree camera.

(a) The crash site right after the fire was extinguished.

(b) The remains of the payload bay. The batteries have already been removed.

(c) The middle section of the fuselage. Burnt engine and landing gear visible.

(d) The tail section of the aircraft.

(e) The middle section of the aircraft.

(f) The crash site after removing the debris.

Figure 63: The crash site after flight test 23.

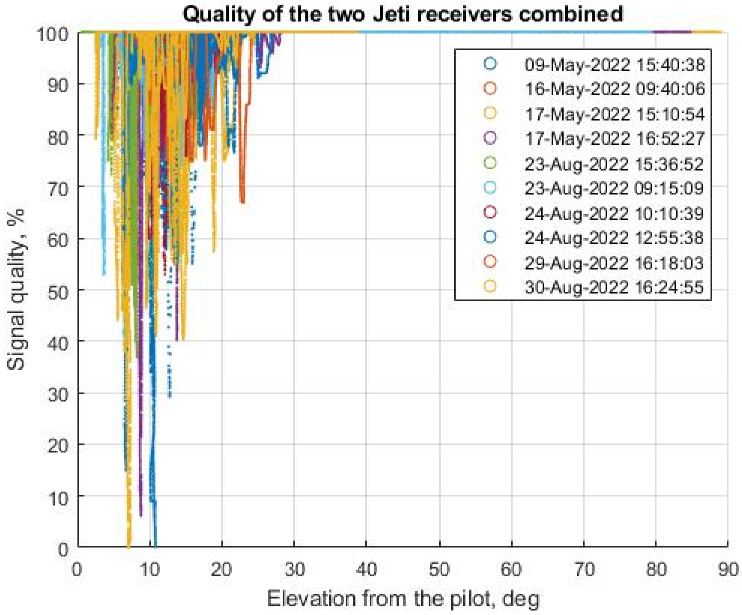


Figure 64: Quality of the two Jeti receivers combined. Note that there is another day when the reception quality went down to zero. At that moment either the reception with the secondary transmitter was still good or the period of no-reception was less than 1.5 seconds.

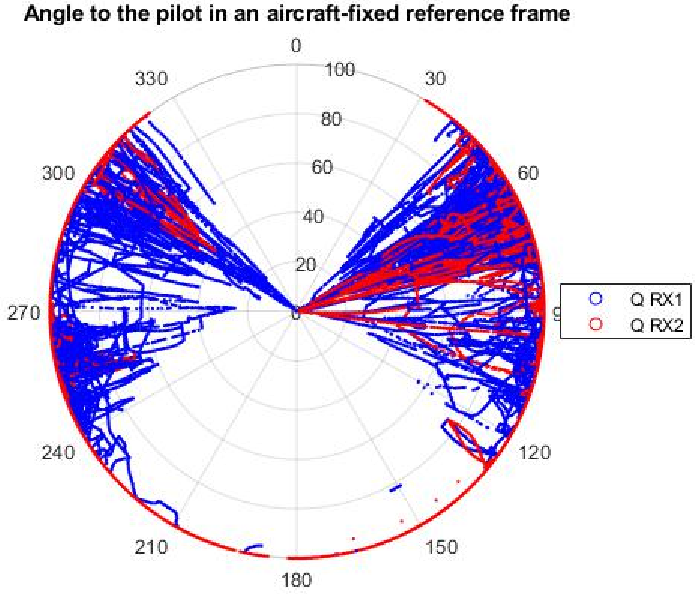


Figure 65: Polar plot of reception quality in relation to the aircraft. Aircraft nose pointing towards the screen.

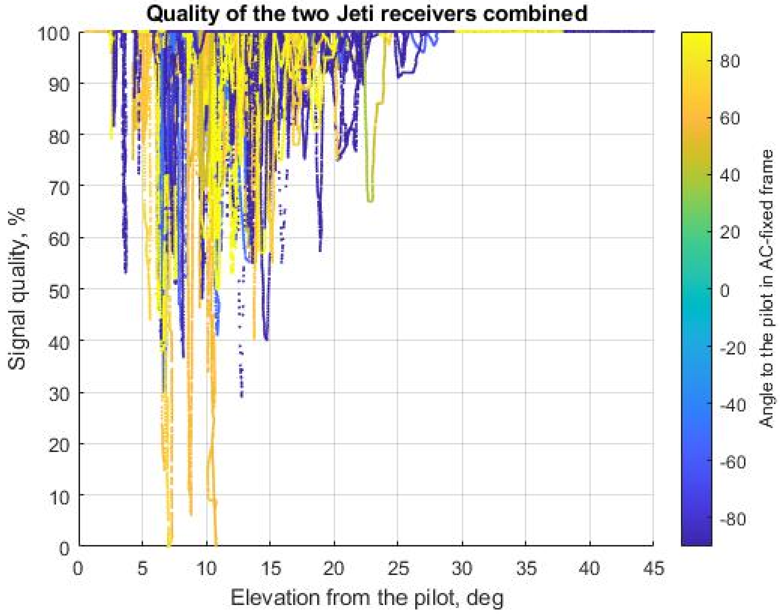


Figure 66: Quality of the two Jeti receivers combined.

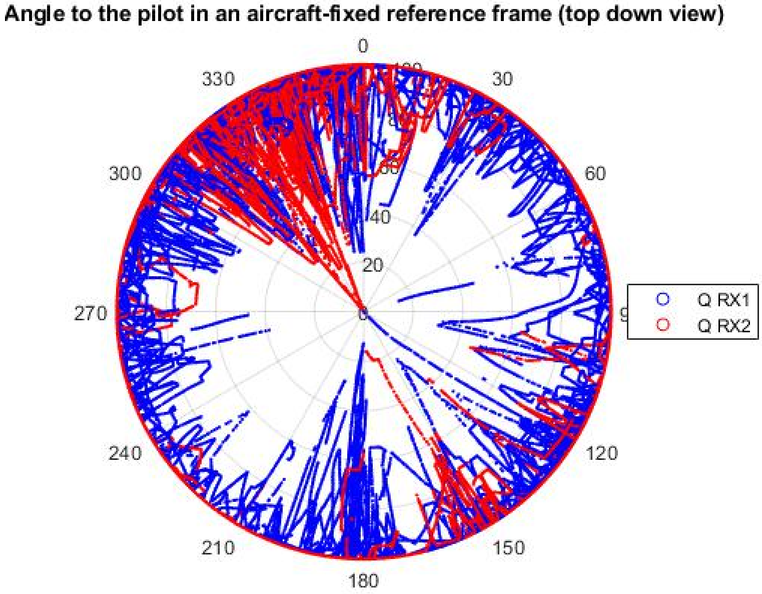


Figure 67: Polar plot of reception quality in relation to the aircraft (top-down view).

6 Bibliography

[1] Julius Bartasevicius and Mirko Hornung. In-flight drag measurement and validation for a medium-sized UAV. In *AIAA SCITECH 2023 Forum*, number January, pages 1–13, Reston, Virginia, jan 2023. American Institute of Aeronautics and Astronautics.

[2] Systems Concepts. Flight Test Measurement Techniques for Laminar Flow (Les techniques de mesure en vol. Technical Report October, 2003.

[3] S. Hedman. Vortex Lattice Method for Calculation of Quasi Steady State Loadings on Thin Elastic Wings. Technical Report Report 105, Aeronautical Research Institute of Sweden, October 1965.

[4] J. Hofstee, T. Kier, C. Cerulli, and G. Looye. A Variable, Fully Flexible Dynamic Response Tool for Special Investigations (VarLoads). In *International Forum on Aeroelasticity and Structural Dynamics*, 2003.

[5] T. M. Kier and J. Hofstee. VarLoads - eine Simulationsumgebung zur Lastenberechnung eines voll flexible, freifliegenden Flugzeugs. In *Deutscher Luft- und Raumfahrtkongress 2004 20.-23. September 2004, Dresden*. DGLR, 2004.

[6] Thiemo Kier. An Integral Flexible Aircraft Model for Optimal Control Surface Scheduling of Manoeuvre Load Alleviation and Wing Shape Control Functions. In *International Forum on Aeroelasticity and Structural Dynamics, 13-17 June 2022, Madrid, Spain*, number IFASD-2022-093, 2022.

[7] Simon Schelle. *Investigation and Implementation of Airspeed Calibration Methods based on UAV Flight Test Data*. Master thesis, Technical University of Munich, 2022.

7 Appendix

7.1 Publication ”In-flight drag measurement and validation for a medium-sized UAV”

In-flight drag measurement and validation for a medium-sized UAV

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In order to maintain low cruise speeds and high efficiency for unmanned aerial vehicles, low wing loading designs are required. Consequently, the influence of atmospheric turbulence on aerodynamic measurements performed on such vehicles increases, especially on drag. The current study evaluates if it is possible to measure the drag of such medium-sized UAVs in-flight. For this reason, a 7m wingspan, 65kg take-off mass conventional configuration UAV is used. Global, induced as well as component drag (airbrakes, landing gear and flaps) is extracted using the data recorded in-flight with high atmospheric turbulence. The measurements are compared to CFD studies as well as empirical data for the airbrakes.

I. Introduction

Correctly estimating or measuring drag is a key factor in quantifying aircraft's performance independent of its size. But while methodologies for investigating drag of manned aircraft are reasonably well understood, not much information can be found on drag investigation for UAVs.

One might note that vehicles of very similar size have already been widely used and tested inside wind tunnels in preparation for manufacturing of their scaled-up versions. However, those wind tunnel tests would usually exhibit only steady flow conditions with close to perfect observation and measurement possibilities. This makes the wind tunnel test result analysis easier than flight tests of similar purpose. In real life conditions the usual methods of steady test data gathering in-flight are challenged by the big influence of turbulence on the UAV. This creates difficulties for an aerodynamicist with no access to wind tunnel when trying to evaluate the actual performance of a UAV. Therefore, investigating the applicability of such in-flight drag measurement methods is necessary.

This work presents the drag measurement method and validation within the framework of the project FLiPASED (Flight Phase Adaptive Aero-Servo-Elastic Aircraft Design Methods, `https://cordis.europa.eu/project/id/815058`). One of the goals of the project FLiPASED is to reduce the induced drag in-flight. This will be done by optimizing control surface deflections, which in turn changes the load shape distribution over the wings. The reduction of induced drag will be shown in-flight with the help of a subscale flight demonstrator (SFD) T-FLEX which has been developed for the predecessor project, FLEXOP (Flutter Free Flight Envelope Expansion for Economical Performance Improvement, `https://flexop.eu/`). Within the FLEXOP project a 65 kg take-off weight, 7 m wingspan swept wing unmanned aircraft was designed and built [1].

Here, a review of existing work on in-flight drag measurement for sub-scale demonstrators will be presented (section II). Design of the SFD used in this work will be described (section III). Methodology for data evaluation and drag extraction will be explained (section IV) and the drag measurement results will be presented (section V).

II. Literature review

Measuring aircraft drag in-flight is a challenge that has caught attention of the community since the early days of aviation. Already in 1925 Betz [2] has described the technique of capturing the wing-section drag by measuring a change in total pressures before and after the wing section. These efforts were further improved and in 1940 integrating total-pressure rake was presented for measuring wing profile drag in-flight [3].

In 1977 Iliff [4] has used the maximum likelihood technique to determine the lift and drag coefficients from dynamic manoeuvres. The presented results of a fighter jet agreed well with the wind-tunnel results, though no comment on the errors fo the technique were made.

In 1985 Bull and Bridges [5] have presented a method to determine propulsive efficiency, parasite and induced drag of an airplane in-flight. The method uses a small power change in a constant altitude flight. The authors emphasizes that

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no single manoeuvre is enough to describe the definite state of the aircraft and that velocity measurement errors of 0.5% already strongly influence the results. In the end the authors do conclude that the “accuracy of the determination of the performance parameters was good, with a standard deviation of about 1% ”also noting that “altitude was maintained to within ½ft in steady flight and to within 1 ft during the transient.”

In 2008 Knaus [6] has presented lift and drag polar measurements of the European combat aircraft Tornado. The author has well described the dynamic manoeuvres used during the flight tests. The presented results have 3 – 4% scatter. He notes that “using test methods currently in existence, it is possible to measure lift and drag polars accurately in-flight.”

Bronz et al. [7] used a thin film force sensor to measure thrust of a flying UAV in 2017 and concluded that “averaged values are usable for the thrust force, drag force, and the drag coefficient.”

Most recently, Bergmann et al. [8] has published an article about estimating lift and drag of an unmanned aircraft in-flight. An integrated thrust measurement sensor was developed for this case, which was mounted in between the electric motor and the airframe. Steady horizontal flights in calm atmospheric conditions were carried out and measurements were averaged over the test leg. Good agreements was found for the measured lift, but, as the authors point out, “the variation of the measured thrust values due to the fluctuating speed controller leads to a high standard deviation (mean 26.56%).”

III. System design

A. Description of the demonstrator

The T-FLEX technology demonstrator is a jet-engine-powered UAV with 65 kg take-off weight and 7 m wingspan (Fig. 1). The UAV is flown manually by pilot via external vision.

Fig. 1 T-FLEX Subscale flight demonstrator with opened airbrakes during the landing phase. Photo by Fabian Vogl.

The geometry of the aircraft is summarized in Table 1.

The aircraft is equipped with integrated measurement equipment. Air data (aerodynamic angles, airspeed and pressures), position (GPS coordinates) and inertial parameters (accelerations, attitude angles) are being logged on

Table 1 Geometry of the T-FLEX UAV.

Wing span, m:	7.07	Tail projected span, m:	1.27
Wing area, m^2:	2.53	Tail area, m^2:	0.39
Wing aspect ratio:	19.74	Tail aspect ratio:	4.2
Wing incidence, deg:	-0.52	Tail incidence, deg:	-4.33
Wing 0.25c sweep, deg:	18.36	Tail 0.25c sweep, deg:	19.83
Wing taper ratio:	0.5	Tail taper ratio:	0.52
Wing twist, deg:	-2	Tail dihedral, deg:	35
Number of wing control surfaces:	8	Number of tail control surfaces:	4
Fuselage length, m:	3.42		
Fuselage maximum height, m:	0.315		
Fuselage maximum width m:	0.3		

the aircraft. In addition, wings are equipped with multiple inertial measurement units spaced along the wingspan for vibration measurement. The measurement frequency is $200Hz$. The logs of separate flight tests are designated as FTX where X is the flight number.

It has been noted that adding a lead of $0.04s$ to the measurements of the air data system reduces the phase difference in between the modelled and the measured lift coefficients. It is suspected that this comes from a delay in the measurement processing of the air data system. The delay was found by trial and error.

For further background on flight test operations of the T-FLEX demonstrator see [9].

B. Jet engine and the thrust measurement system

The main requirements while designing the propulsion system for T-FLEX were high acceleration, low vibration and precise speed tracking [10]. Taking these requirements into account, a jet engine paired with a fast-response airbrake system [11] was selected. The jet engine is a BF B300F turbine with 300 N maximum thrust capability. The engine was mounted on a pylon above the fuselage with the fuel tank located directly below it with the intent to keep the same centre of gravity throughout the flight.

The engine is round in shape and is secured to the aircraft via a steel-cage (Fig. 2). The cage is mounted on four aluminium holders attached to the main propulsion rack structure made out of carbon-fiber-reinforced polymers (CFRP) plates. The components required for the thrust measurement system to function added 0.6 kg of additional mass to the propulsion stack. Logging system is not included in this mass.

A thrust measurement system was developed for the jet engine (Fig. 2). During the static calibration with weights, simulated thrust accuracy of $0.64N$ was achieved. Higher deviations were noted during the calibration check on the static test stand and during an on-site calibration check. However, due to the nature of the two calibration check methods, their accuracy was considered to be lower and the deviations are to be taken with care. Nevertheless, good response of the thrust measurement system was confirmed under operational conditions with the running engine.

A significant challenge was discovered while working with the thrust measurement data. Due to the system architecture, the thrust log had to be recorded on a separate device. Therefore, the main (flight) log and the thrust logs had to be aligned after the flight. This presented a challenge, while the GPS time differences on the two systems were apparent, and none of the flight log variables could be directly correlated to thrust without additional processing. Therefore, it was decided to do a two step alignment procedure, where initial alignment is done by using the engine RPMs and longitudinal acceleration (both proportional to thrust) variables. After that, a manual correction is done by taking a segment on the ground while taxiing and braking. As the thrust measurement system is based on load cell measurements, such braking activities were clearly visible in the thrust log, as well as in the flight log, allowing for a more precise alignment than the automated one.

In some cases the difference between the automated and manual alignment was as much as $0.32s$. After realignment, the drag measurements were significantly improved (Fig. 3).

For more information about the design, calibration and testing of the thrust measurement system, please see [12].

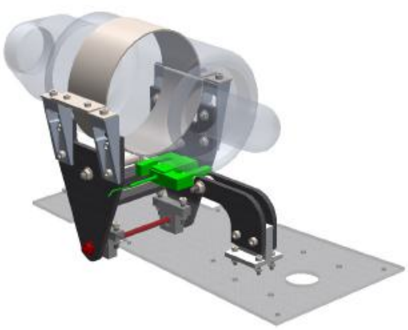

Fig. 2 The thrust measurement system. The load cell is marked in green and the hinge axis in red.

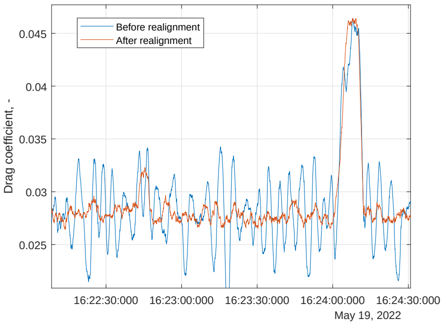

Fig. 3 Comparison of the measured drag before and after the manual alignment of the thrust log. In this case, the log was manually shifted by $0.32s$.

IV. Methodology

To identify the model coefficients described below, stepwise regression based on ordinary least squares was used. Regressors were added one by one until no statistically significant changes were observed. At the same time, attention was paid to keep the model as simple as possible. To read more about the method of stepwise regression, see [13].

Measured drag coefficient for each data point were derived by using the available thrust, accelerometer and air data measurements. The non-dimensional body-axes force components were obtained from:

$$C_T = \frac{F_T}{\bar{q}S} \tag{1}$$

$$C_X = \frac{ma_x - F_T}{\bar{q}S} \tag{2}$$

$$C_Y = \frac{ma_y}{\bar{q}S} \tag{3}$$

$$C_Z = \frac{ma_z}{\bar{q}S} \tag{4}$$

Here C_T, C_X, C_Y and C_Z are the dimensionless thrust and force component coefficients, F_T is the measured thrust, $\bar{q}$ is the dynamic pressure, S is the reference area, m is the aircraft mass and a_z are the acceleration components.

These body-axes force components were converted into stability axis (C_L as lift and C_D as drag coefficients) using the angles of attack α and sideslip β by:

$$C_L = C_X \sin\alpha - C_Z \cos\alpha \tag{5}$$

$$C_D = -C_X \cos\alpha - C_Z \sin\alpha \tag{6}$$

It was postulated that a linear model for drag can be prescribed:

$$C_D = C_{D_0} + C_{D_{C_L}} C_L + C_{D_{C_L^2}} C_L^2 + C_{D_{ab}} \sin\delta_{ab} + C_{D_{lg}} \delta_{lg} + C_{D_{\beta^2}} \beta^2 + C_{D_{\delta_{f1^2}}} \delta_{f1^2} + C_{D_{\delta_{f23^2}}} (\delta_{f2^2} + \delta_{f3^2}) + C_{D_{\delta_{f4^2}}} \delta_{f4^2} \tag{7}$$

Here C_{D_i} are the coefficients for each of the linear term, δ_{ab} and δ_{lg} are the airbrake and landing gear actuation values (for airbrakes this is the average of the left and right airbrake deflection angle, for landing gear this is a binary value). Only quadratic terms of the sum of left and right flap deflections was used in the model in the form $\delta_{fi^2} = \delta_{fiL}^2 + \delta_{fiR}^2$.

Due to the fact that the second and third flap were always controlled together, it was not possible to identify drag coefficients separately. Furthermore, a lack of trimmed test points at different airspeeds meant that the airspeed was correlated with the angle of attack. Therefore, the airspeed was excluded as a regressor. Not to include the drag effects of the flaps twice, the C_L used here is that of the clean configuration, which is the measured C_L corrected for flap deflections.

The drag flap configuration was defined in order to investigate if change in induced drag can be measured. The design goal of this configuration was to keep the overall lift and the trim settings the same as for the clean configuration, but to have a significant increase in the induced drag. A potential flow solver was used for this exercise [14] [15]. The resulting configuration was with the flaps deflected $-10/+10/-10/-5$ degrees from inboard to outboard (Fig. 4).

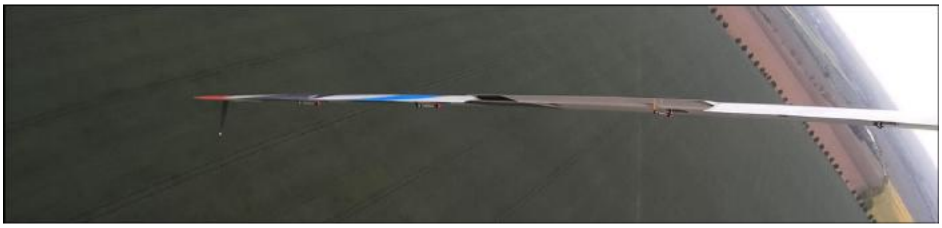

Fig. 4 Drag flap configuration during a test point. The flaps here are deflected $-10/+10/-10/-5$ degrees.

A. Flight tests and data collection

The data presented here has been collected during the flight test campaign carried out in May 2022. 8 Flights were done during the test campaign (FT10 - FT17). The example flight profile from FT16 with altitude, true airspeed and the angle of attack is shown in Fig. 5. The main goal of this flight was to further extend the functionality of the autopilot by testing the altitude hold and the autothrottle modules. Therefore, the gradual airspeed increase during a coordinated turn at a constant altitude is visible (Fig. 6).

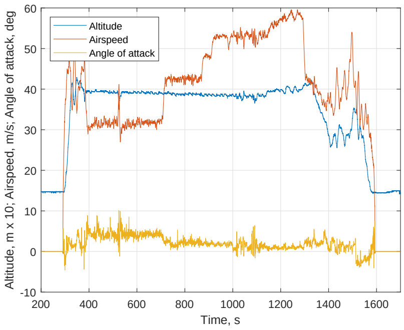

Fig. 5 Altitude, true airspeed and the angle of attack profile for the flight test 16.

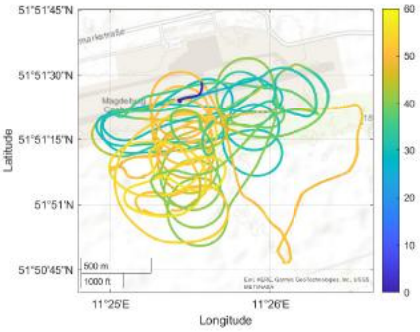

Fig. 6 Trajectory of the flight test 16. The colour represents the indicated airspeed.

For the purpose of this article, only data from flights FT10, FT16 and FT17 is used. An example of the measured drag coefficient and the expected contributions is shown in Fig. 7.

It was not possible to fly in what would be called calm atmospheric conditions. Furthermore, during the FT17 the last calm minutes before the storm were experienced and the landing was conducted already during the storm. The summary of the wind conditions for all three flights are tabulated in Table2.

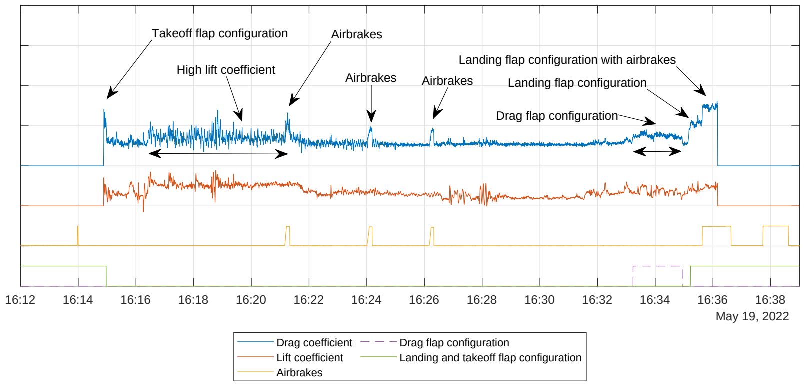

Fig. 7 Measured drag profile for the flight test 16. Drag contribution of separate components are indicated. Note that the measurements are not up to scale.

Table 2 Wind measured at the nearby weather station during the flight tests.

Date	Flight number	10-min average wind	Wind gusts, 10-min window
09.05.2022	FT10	$2.1m/s$	$3.6m/s$
19.05.2022	FT16	$3.6m/s$	$5.1m/s$
19.05.2022	FT17	From 1 to $7.1m/s$	From 1.5 to $15.4m/s$

B. Validation

As the airbrakes can be compared to a flat plate at an angle to the airflow (Fig. 8 and Fig. 9), empirical data of drag of a flat plate corrected for the aspect ratio at an angle was used for validation [11][16]. However, as this does not represent the mounting and the curvature of the airbrake surfaces, wind tunnel tests of the actual geometry are planned in the future.

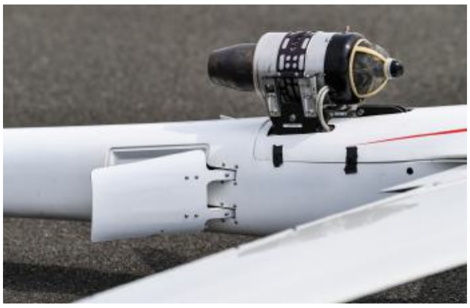

Fig. 8 The opened aibrakes during a taxi. Photo by DLR-Fotomedien SER-FOT KP.

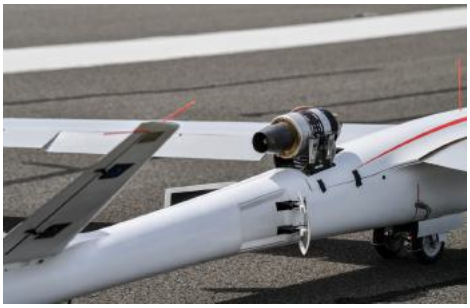

Fig. 9 The opened aibrakes during a taxi. Photo by DLR-Fotomedien SER-FOT KP.

The drag flaps and induced drag curves are compared using the vortex-lattice solver VSPAERO and the computational fluid dynamics solver STAR-CCM+, as described below. No validation is available for the landing gear drag.

1. VSPAERO

VSPAERO [17] is the aerodynamic analysis tool distributed together with the parametric aircraft design package OpenVSP [18]. Two methods are available within the tool - the Vortex Lattice Method and a 3D panel method (not used in this study) [19]. Additionally, parasite drag calculation module based on the component build-up method is available within the OpenVSP.

2. STAR-CCM+

Simcenter STAR-CCM+ is a multiphysics computational fluid dynamics (CFD) software. For the simulation domain, a bullet-shaped was created around the T-FLEX geometry (15 spans in radius and 45 spans in length, Fig. 10). Polyhedral and the prism layer meshers were used. Wake controls for meshing (2 spans in length, 15deg in spread angle) were used on the fuselage, wing and tail (Fig. 11).

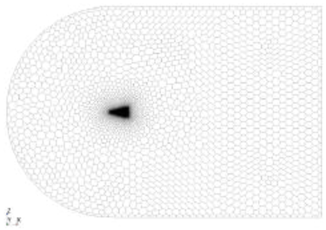

Fig. 10 STAR-CCM+ simulation domain.

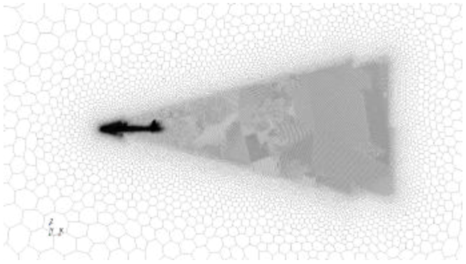

Fig. 11 The wake control for the STAR-CCM+ simulations.

Steady, all-turbulent (Spalart-Allmaras turbulence model) simulations were done where Reynolds-averaged Navier-Stokes (RANS) equations were solved. The total thickness of the prism layer was adjusted to enclose the boundary layer at AoA = 2deg (Fig. 12). Mesh independence study was performed from 0.9 to 22.0 million cells. The final grid consisted of 12.3 million cells.

The lift and drag coefficients from VSPAERO and STAR-CCM+ are presented in Fig. 13. Note that VSPAERO drag results include the parasite and induced drag.

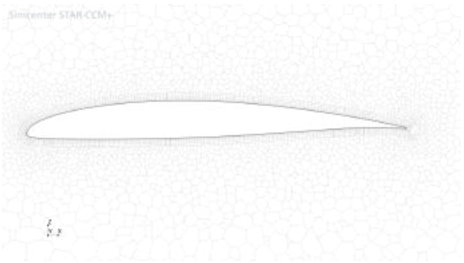

Fig. 12 Prism layer mesh around the wing cross section.

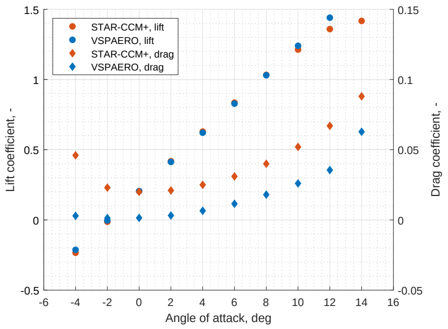

Fig. 13 Lift and drag polars as calculated with VSPAERO and STAR-CCM+.

For more details regarding the aerodynamic tools used on the T-FLEX geometry, please refer to Yu et al.[20]

V. Results

Note that the following results have been obtained by using the data from complete flights.

A. Lift coefficient identification

In order to extract the lift-dependant-drag polar, the measured C_L had to be corrected for separate flap deflections and the sideslip angle. To establish correction coefficients for each of these effects, a linear lift model was used:

$$C_L = C_{L_0} + C_{L_\alpha}\alpha + C_{L_{\beta^2}}\beta^2 + C_{L_{\delta_{f1}}}\delta_{f1} + C_{L_{\delta^2_{f1}}}\delta^2_{f1} + C_{L_{\delta_{f2}}}\delta_{f2} + C_{L_{\delta_{f3}}}\delta_{f3} + C_{L_{\delta_{f4}}}\delta_{f4} \tag{8}$$

where the flap deflection δ_{fi} is the summation of the left and right flap $\delta_{fi} = \delta_{fiL} + \delta_{fiR}$ and positive deflection means trailing edge up for both wings. The comparison of the original measured and the corrected lift curves can be found in Fig. 14 and 15. It is apparent that the unsteady effects (where high positive or negative pitch rates are present) have an impact. However, correcting for these effects appeared to be not as trivial as expected and these effects were ignored. The model coefficients are presented in Table 3.

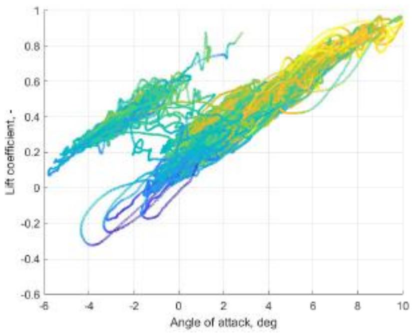

Fig. 14 Measured lift curve. The colours here represent the pitch rate of the aircraft in deg/s.

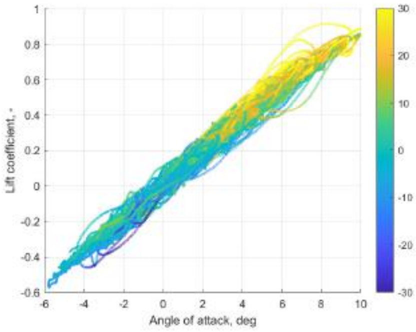

Fig. 15 Lift curve corrected for flap deflections and sideslip. The colours here represent the pitch rate of the aircraft in deg/s.

Table 3 Lift coefficient estimates, their errors and t-statistics of the linear lift model.

Coefficient	Estimate	Standard Error	t-statistic
C_{L_0}	0.14518	5.374e-05	2701.6
C_{L_α}	0.09521	1.986e-05	4795.1
$C_{L_{\beta^2}}$	-0.00019	0.175e-05	-106.26
$C_{L_{\delta_{f1}}}$	-0.01130	1.775e-05	-636.53
$C_{L_{\delta^2_{f1}}}$	-0.00011	0.030e-05	-388.41
$C_{L_{\delta_{f2}}}$	-0.00660	1.026e-05	-643.29
$C_{L_{\delta_{f3}}}$	-0.00195	1.680e-05	-116.05
$C_{L_{\delta_{f4}}}$	-0.00626	4.130e-05	-151.5
	Root Mean Squared Error: 0.021		
	R-squared: 0.973		

The zero angle lift coefficients C_{L_0} and the lift curve slopes C_{L_α} were compared to those acquired computationally in Table 4[20].

Table 4 Comparison of the zero angle lift coefficient C_{L_0} and the lift curve slope C_{L_α} for different aerodynamic modelling tools and test flights[20].

	C_{L_0}	C_{L_α}
STAR-CCM+, fully turbulent	0.206	0.106
STAR-CCM+, inviscid	0.248	0.111
VSPAERO	0.205	0.104
Mean of all flights	0.145	0.095

As data from VSPAERO and the inviscid CFD was available for various flap configurations, it was compared to the lift component coefficients as identified from the flight tests. Fig. 16 shows the increase in the lift coefficient when compared to the baseline (0/0/0/0) case. The flap deflections here are noted from the most inboard to the outboard flap. The difference of lift coefficient at low flap deflection angles (< 20 degrees) shows a good agreement (< 11% difference in between the STAR-CCM+ and the flight test results) apart from the -5/-5/-5/-5 configuration. At higher flap deflections the potential flow methods overpredict the lift coefficient. In addition, aeroelasticity was not included in neither of the simulations and it could expected that the outboard flap deflections influence the shape of the wing the most.

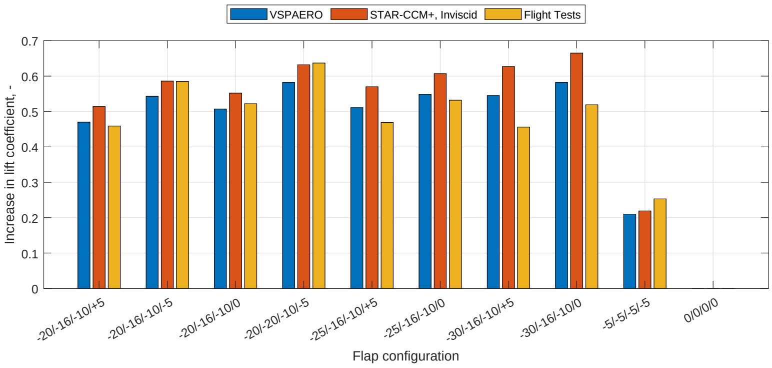

Fig. 16 Computed and measured increase in lift coefficient at $\alpha = 4deg$ for various flap configurations.

B. Drag coefficient identification

The resulting drag component coefficients are tabulated in Table 5. The low R-squared value of $R^2 = 0.76$ indicates that the model does not sufficiently cover all the measured effects. It could be expected that with careful selection of data from flight segments as opposed to full flights, with flight in calm air instead of turbulent weather or different coefficient identification method (for example using frequency domain techniques) could improve the accuracy of the coefficient estimation.

C. Airbrake drag

Two methods were used to identify the airbrake drag. First, a segment from flight test 16 was chosen where three airbrake inputs were performed while flying a coordinated turn with increasing speed. The airbrakes were opened slowly, then held at a fully opened position and closed. Stepwise regression was performed on this segment while keeping only the airbrake coefficient free.

The second method used complete data from the three flights, and all the coefficients were free to estimate.

The first method resulted in airbrake model coefficient $C_{D_{ab}} = 0.0254 \sin \delta_{ab}$ versus $C_{D_{ab}} = 0.0263 \sin \delta_{ab}$ for the

Table 5 Drag coefficient estimates, their errors and t-statistics of the linear drag model.

Coefficient	Estimate	Standard Error	t-statistic
C_{D_0}	0.02123	2.947e-05	720.32
C_{C_L}	-0.00709	13.157e-05	-53.85
$C_{C_L^2}$	0.03077	15.089e-05	203.93
$C_{D_{\beta^2}}$	-0.000007	0.037e-05	19.68
$C_{D_{\delta_{f1}^2}}$	0.000013	0.004e-05	345.09
$C_{D_{\delta_{f23}^2}}$	0.000011	0.006e-05	183.5
$C_{D_{\delta_{f4}^2}}$	0.000022	0.040e-05	54.96
C_{lg}	0.00666	1.357e-05	491.24
$C_{D_{ab}}$	0.02478	6.268e-05	395.31
	Root Mean Squared Error: 0.00445		
	R-squared: 0.76		

second one. Both results were aligned with the experimental data of the flat plate model (Fig. 17). It has to be noted, that the airbrake geometry is not a flat plate, so an exact match is not expected.

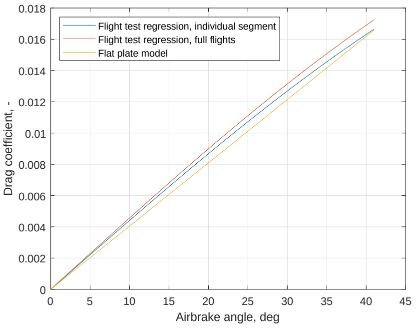

Fig. 17 Identified airbrake drag model compared to the empirical data of a flat plate drag.

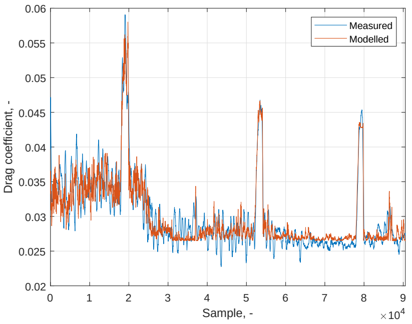

Fig. 18 Drag change during airbrake inputs, measured and modelled.

D. Induced drag

The identified adjusted drag polar $C_D = C_{D_{min}} + k(C_L - C_{LminD})^2$ is noted below:

$$C_D = 0.0208 + 0.0308(C_L - 0.1151)^2 \tag{9}$$

It is compared to the polar as calculated by the STAR-CCM+ and the VSPAERO in Table 6. The identified minimum drag coefficient compares well with the one from STAR-CCM+. Looking at the lift coefficient for minimum drag, a big difference in between the methods can be spotted. The identified wing efficiency is higher than that of the STAR-CCM+. This could be attributed to the fact that the wing fairing which reduces the induced drag is not modelled in the CFD. Additionally, the fully turbulent flow does not represent the reality because laminar flow was observed during the in-flight oil flow experiments (Fig. 19). Finally, many small drag-creating details were not modelled in CFD, like the tailwheel assembly, antennas, gaps in the fuselage hull or servo horns.

Fig. 19 Boundary layer oil flow experiments done during a flight test. Turbulent spots (wedges) and the transition line just in front of the flap hinge line are visible on the root part of the wing.

Finally, taking all of this into account it has to be noted that the residuals from the drag modelling are too high to draw final conclusions (Fig. 20 and 21).

Table 6 Comparison of the adjusted drag polar coefficients.

	$C_{D_{min}}$	k	C_{LminD}	e
STAR-CCM+, fully turbulent	0.0200	0.0344	0.2576	0.460
VSPAERO	0.0117	0.0237	0.0520	0.666
Flight tests	0.0208	0.0308	0.1151	0.513

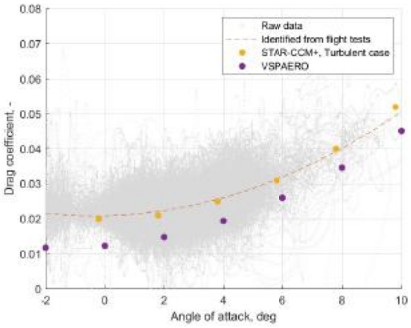

Fig. 20 Calculated and identified baseline drag polar with respect to the angle of attack.

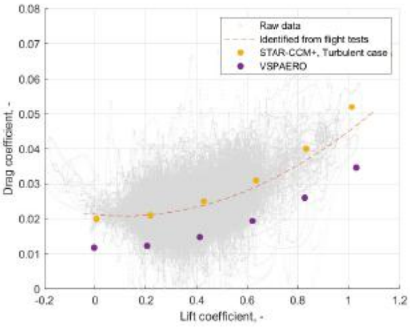

Fig. 21 Calculated and identified baseline drag polar with respect to the lift coefficient.

The induced drag for the clean and drag flap configurations is compared in Fig. 22 and 23. The results from VSPAERO simulations, as well as the average of the flown test point (Fig. 4) are added. Deviation in between the VSPAERO and the flight test polars increases with the increase in angle of attack. However, the actual drag flap flight test point at $C_L = 0.36$ ($\alpha = 1.24deg$) aligns well with the predictions.

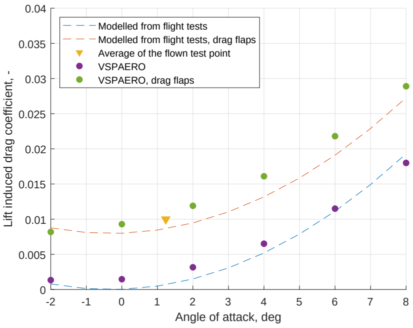

Fig. 22 Calculated and identified induced drag for the clean and drag flap configurations with respect to the angle of attack.

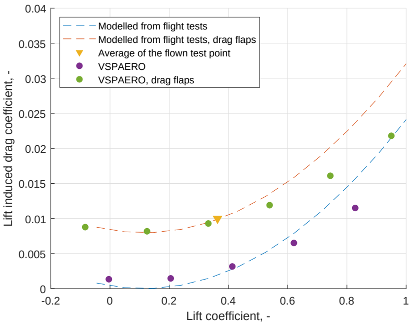

Fig. 23 Calculated and identified induced drag for the clean and drag flap configurations with respect to the lift coefficient.

VI. Conclusion

Global lift and drag polars were identified from flight test data during turbulent weather. Drag of different components has been extracted and compared to available validation data.

Drag model resulted in higher residual values ($RMSE = 0.00445$, $R^2 = 0.760$) than the lift model ($RMSE = 0.021$, $R^2 = 0.973$). It was noted that the residuals were smaller in amplitude when the flight speed was increased. Also, the use of autothrottle seemed to increase the residuals due to the fact that the controller constantly adjusts the engine thrust, creating oscillations of the measured drag. Additionally, known (but uncorrected) actuator position measurement drift (around $0.1deg/20min$) could have influenced both the lift and drag modelling. Finally, as mentioned above, the flights have been conducted in highly turbulent environment (gust speeds from 3.6 to $15.4m/s$). The impact of each of these (and further) effects will be investigated in the upcoming papers.

Complete flight test data was used to create the aforementioned models. It is expected that the results could be improved if only the "measurement leg" flight segments would be used, together with some well-tuned data filtering to filter the turbulence out. Flights in calm atmosphere are planned for the upcoming flight test campaign to prove this hypothesis.

Nevertheless, taking the above mentioned issues into account, the identified drag coefficients agreed with the preliminary drag predictions from the STAR-CCM+ turbulent CFD simulations.

Acknowledgments

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References

[1] Stahl, P., Sendner, F. M., Rößler, C., Hornung, M., and Hermanutz, A., "Mission and aircraft design of FLEXOP unmanned flying demonstrator to test flutter suppression within visual line of sight," *17th AIAA Aviation Technology, Integration, and Operations Conference, 2017*, American Institute of Aeronautics and Astronautics, Reston, Virginia, 2017. https://doi.org/10.2514/6.2017-3766.

[2] Betz, A., "A Method For The Direct Determination Of Wing-Section Drag," *NACA Technical Note 337*, 1925.

[3] Silverstein, A., and Katzoff, S., "A Simplified Method for Determining Wing Profile Drag in Flight," *Journal of the Aeronautical Sciences*, Vol. 7, No. 7, 1940, pp. 295–301. https://doi.org/10.2514/8.1127.

[4] Iliff, K. W., "Maximum likelihood estimation of lift and drag from dynamic aircraft maneuvers," *Journal of Aircraft*, Vol. 14, No. 12, 1977, pp. 1175–1181. https://doi.org/10.2514/3.58911, URL http://arc.aiaa.org.

[5] Bull, G., and Bridges, P. D., "A method for flight-test determination of propulsive efficiency and drag," *Journal of Aircraft*, Vol. 22, No. 3, 1985, pp. 200–207. https://doi.org/10.2514/3.45108, URL http://arc.aiaa.org.

[6] Knaus, A., "A technique to determine lift and drag polars in flight," *Journal of Aircraft*, Vol. 20, No. 7, 2008, pp. 587–593. https://doi.org/10.2514/3.44915, URL http://arc.aiaa.org.

[7] Bronz, M., de Marina, H. G., and Hattenberger, G., "In-flight thrust measurement using on-board force sensor," *AIAA Atmospheric Flight Mechanics Conference, 2017*, 2017. https://doi.org/10.2514/6.2017-0698, URL https://hal-enac.archives-ouvertes.fr/hal-01432789.

[8] Bergmann, D. P., Denzel, J., Pfeifle, O., Notter, S., Fichter, W., and Strohmayer, A., "In-flight lift and drag estimation of an unmanned propeller-driven aircraft," *Aerospace*, Vol. 8, No. 2, 2021, pp. 1–16. https://doi.org/10.3390/aerospace8020043.

[9] Bartasevicius, J., Koeberle, S. J., Teubl, D., Roessler, C., and Hornung, M., "Flight Testing of 65kg T-FLEX Subscale Demonstrator," *32nd Congress of the International Council of the Aeronautical Sciences*, Shanghai, China, 2021, pp. 1–16.

[10] Sendner, F. M., Stahl, P., Rößler, C., and Hornung, M., "Designing an UAV propulsion system for dedicated acceleration and deceleration requirements," *17th AIAA Aviation Technology, Integration, and Operations Conference, 2017*, , No. June, 2017, pp. 1–13. https://doi.org/10.2514/6.2017-4105.

[11] Bauer, P., Anastasopoulos, L., Sendner, F. M., Hornung, M., and Vanek, B., "Identification and Modeling of the Airbrake of an Experimental Unmanned Aircraft," *Journal of Intelligent and Robotic Systems: Theory and Applications*, Vol. 100, No. 1, 2020, pp. 259–287. https://doi.org/10.1007/s10846-020-01204-1.

[12] Bartasevicius, J., Alexandre, P., Fleig, T., Metzner, A., and Hornung, M., "Design and testing of an in-flight thrust measurement system for a pylon-mounted miniature jet engine," 2022, pp. 1–16.

[13] Draper, N. R., and Smith, H., *Selecting the "Best" Regression Equation*, chapter and pages, pp. 327–368. https://doi.org/https://doi.org/10.1002/9781118625590.ch15, URL https://onlinelibrary.wiley.com/doi/abs/10.1002/9781118625590.ch15.

[14] Kier, T., "An Integral Flexible Aircraft Model for Optimal Control Surface Scheduling of Manoeuvre Load Alleviation and Wing Shape Control Functions," *International Forum on Aeroelasticity and Structural Dynamics, 13-17 June 2022, Madrid, Spain*, 2022.

[15] Meddaikar, Y. M., Kier, T., Bartasevicius, J., Yu, F., Vanek, B., Olgyay, A., and Takarics, B., "Aeroservoelastic induced drag modelling and minimization for the T-FLEX demonstrator," *AIAA Scitech 2023 Forum*, 2023, pp. 1–20.

[16] Ortiz, X., Rival, D., and Wood, D., "Forces and moments on flat plates of small aspect ratio with Application to PV wind loads and small wind turbine blades," *Energies*, Vol. 8, No. 4, 2015, pp. 2438–2453. https://doi.org/10.3390/en8042438.

[17] Kinney, D., "Using VSPAERO," , 2015. URL http://openvsp.org/wiki/doku.php?id=vspaerotutorial.

[18] OpenVSP, "Software Package, Version 3.22.0," , 2021. URL http://openvsp.org/.

[19] Kinney, D., "VSPAERO... What's New?" , 2021.

[20] Yu, F., Bartasevicius, J., and Hornung, M., "Comparing Potential Flow Solvers for Aerodynamic Characteristics Estimation of the T-FLEX UAV," *International Council of the Aeronautical Sciences*, 2022.

7.2 Flight Test Cards

FT10 AP1

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Augmented mode check, pilot training
Date	09.05.2022
Engine start/stop time	17:41 - 17:59
METAR (EDMO)	
METAR (EDBC)	
Crew:	
Pilot-in-Command (FLEXOP 1)	Fabian Wiedemann
Back-up Pilot (FLEXOP 2)	Thomas Seren
Flight Test Operator (OPERATOR)	Mateen Javad
Flight Test Engineer (ENGINEER)	Daniel Teubl
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 wing
Zero fuel mass, kg	57.8 + 1.2 ballast
Take-off mass, kg	66.4
Fuel, kg	7.4
Fuel used, kg	4.29
Centre of gravity, mm	606
Limitations	V_min = 25m/s V_max = 55m/s V_flaps = 35m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Flight time limited to 20min.

Debriefing notes:

startup no issues.. Good takeoff. Full elevator during the complete takeoff. Announce airspeeds before takeoff. Trims were good from both transmitters. Maybe a little bit *one step) of aileron for graupner. All states were well trimmed for both TXs.

Nice to fly for Thomas. Announcing by engineer is also good. Maybe having increase altitude would be every third annoucnement? DT will check that. Let's reduce the altitude level to 120.

We could skip the bank angle when distance is close? Or just give warnings that we only exceed bank angle at 60deg. Jeti had low signal. Let's check if we have logs.
MP crashed. We restarted, nothing too serious happened.
Augmented mode. FW: it seemed like it's not level. Otherwise might be fine, but when he did inputs, then it seemed to oscillate more. Did small inputs, but it seemed to do oscillations again. TS: might be a small oscillation when flying level. Mateen: it seemed to be plus minus 5. Let's reduce the gains a bit.
More roll input in AP1 than in manual.
Make a timer for flight time next time.

Landing was a bit rough. Speed announcement more often during the approach. AS off when the in position is.

We need to make a better flight plan for now.
New batteries are better, so no need to change them. No EDL telemetry loss. Fuel burn should be there now.

Test points:

	Take-off	5.41	
FLEXOP 1, FLEXOP 2	Engine **ON**	* ✓	
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
FLEXOP 1	BRAKES **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓ 5 45	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 200	✓	At 30m AGL
FLEXOP 1	TRIM 35m/s		
FLEXOP 1	FLIGHT STATE LANDING	✓	
FLEXOP 1	TRIM 35m/s		
FLEXOP 1	FLIGHT STATE TAKEOFF		
FLEXOP 1	TRIM 35m/s		
	Pilot Training	✓	
FLEXOP 1	FREE FLIGHT		If needed to be familiar with the aircraft
FLEXOP 1	PREPARE FOR LANDING IMITATION	*	
FLEXOP 1	FLIGHT STATE LANDING		At 20m AGL
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
	Augmented mode check	✓	
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1	✓	On MP
ENGINEER	CONFIRM **NEW** LUT SELECTED	✓	
FLEXOP 1	SWITCH AUTOPILOT 1	~	
FLEXOP 1	DO CONTROL INPUTS TO CHECK BEHAVIOUR		
FLEXOP 1	SWITCH MANUAL		If new LUTs OK, then stay with new.
	Altitude hold check		
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2		
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2		Pitch command is limited to 20deg
ENGINEER	CONFIRM **CURRENT ALTITUDE** SELECTED		Under Altitude (AMSL) window
FLEXOP 1	SWITCH AUTOPILOT 1		
FLEXOP 1	SWITCH AUTOPILOT 2		
FLEXOP 1	CIRCLE		
FLEXOP 1	SWITCH AUTOPILOT 1		
	Landing	5 57	
FLEXOP 1	PREPARE FOR LANDING	* ✓	
FLEXOP 1	FLIGHT STATE LANDING	✓	If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	* 5:59	

TMS works
75%

Thomas 5 48

5 49 TO
Cruise
Landing
Cruise

MP Crashed

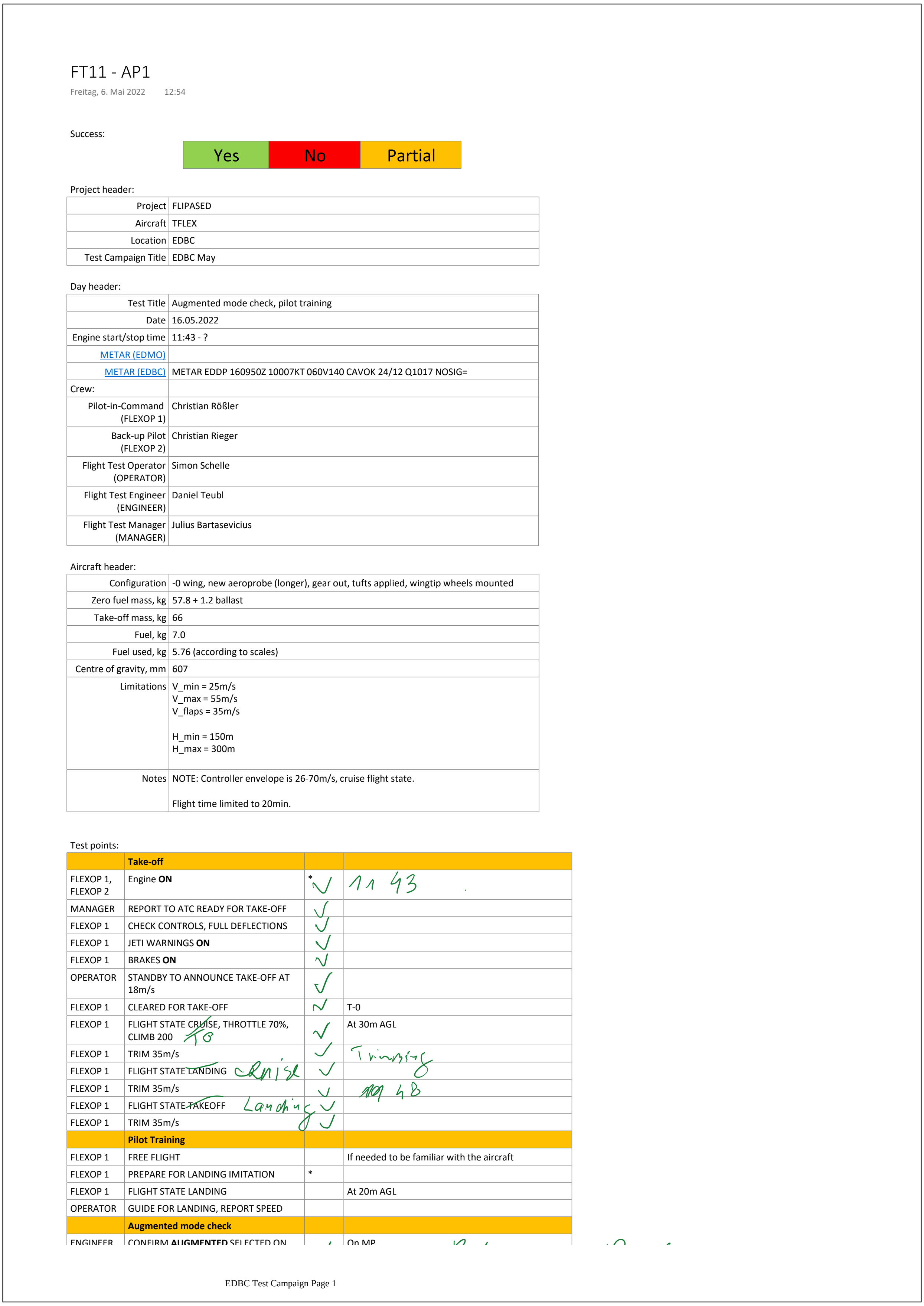
5 52
Oscilations when Aileron inputs made.

	PLAN B - Flap Setting Points		
FLEXOP 1	FLIGHT STATE TAKEOFF		
FLEXOP 1	TRIM 42m/s		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE LANDING		
FLEXOP 1	TRIM 42m/s		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE TAKEOFF		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE LANDING		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	TRIM 34m/s	*	

EDBC Test Campaign Page 2

Emergency checklists:

LAND	TERMINATE	



FT11 - AP1

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Augmented mode check, pilot training
Date	16.05.2022
Engine start/stop time	11:43 - ?
METAR (EDMO)	
METAR (EDBC)	METAR EDDP 160950Z 10007KT 060V140 CAVOK 24/12 Q1017 NOSIG=
Crew:	
Pilot-in-Command (FLEXOP 1)	Christian Rößler
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Simon Schelle
Flight Test Engineer (ENGINEER)	Daniel Teubl
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 wing, new aeroprobe (longer), gear out, tufts applied, wingtip wheels mounted
Zero fuel mass, kg	57.8 + 1.2 ballast
Take-off mass, kg	66
Fuel, kg	7.0
Fuel used, kg	5.76 (according to scales)
Centre of gravity, mm	607
Limitations	V_min = 25m/s V_max = 55m/s V_flaps = 35m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Flight time limited to 20min.

Test points:

	Take-off		
FLEXOP 1, FLEXOP 2	Engine **ON**	* ✓	11 43
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
FLEXOP 1	BRAKES **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0
FLEXOP 1	FLIGHT STATE ~~CRUISE~~, THROTTLE 70%, CLIMB 200 TO	✓	At 30m AGL
FLEXOP 1	TRIM 35m/s	✓	Trimming
FLEXOP 1	FLIGHT STATE ~~LANDING~~ Cruise	✓	
FLEXOP 1	TRIM 35m/s	✓	11 48
FLEXOP 1	FLIGHT STATE ~~TAKEOFF~~ Landing	✓	
FLEXOP 1	TRIM 35m/s	✓	
	Pilot Training		
FLEXOP 1	FREE FLIGHT		If needed to be familiar with the aircraft
FLEXOP 1	PREPARE FOR LANDING IMITATION	*	
FLEXOP 1	FLIGHT STATE LANDING		At 20m AGL
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
	Augmented mode check		
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON		On MP

EDBC Test Campaign Page 1

FLEXOP 1	FLIGHT STATE LANDING		At 20m AGL
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
	Augmented mode check		
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1	✓	On MP RX mux
ENGINEER	CONFIRM **NEW** LUT SELECTED	✓	
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	DO CONTROL INPUTS TO CHECK BEHAVIOUR	✓	
FLEXOP 1	SWITCH MANUAL	✓	If new LUTs OK, then stay with new. If not, then reduce the gains
	Altitude hold check		
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2	✓	Pitch command is limited to 20deg
ENGINEER	CONFIRM **CURRENT ALTITUDE** SELECTED	✓	Under Altitude (AMSL) window
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	~	
FLEXOP 1	CIRCLE	✓	
FLEXOP 1	THROTTLE INPUT	✓	
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
	Landing		
FLEXOP 1	PREPARE FOR LANDING	* ✓	
FLEXOP 1	FLIGHT STATE LANDING	✓	If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED	✓	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

WARNING little

switched lower gain
old LUT

better but

✓

	PLAN B - Flap Setting Points		
	Trim points		
FLEXOP 1	TRIM 30m/s	*	Fly for 2min
FLEXOP 1	TRIM 40m/s	* ✓	Fly for 2min
FLEXOP 1	TRIM 50m/s	*	Fly for 2min
	Accelerated turn		
FLEXOP 1	TRIM 30m/s	*	
FLEXOP 1	CIRCLE	*	Bank angle 30deg
FLEXOP 1	SPEEDUP TO 40m/s	*	
FLEXOP 1	SPEEDUP TO 50m/s	*	

Emergency checklists:

LAND TERMINATE

Debriefing notes:
Take-off: in general it was good, went somewhat into the wind, tried to steer very little. Was a strong headwind. You need to pull very hard to pull. Take-off was announced, but we could not lift off until some 1-2s after that. FY said Takeoff twice, that was very good, was clearer.

There was some basic trimming, not perfect, but flyable.

Anouncer script didn't work initially because the MP was reconnected. It has to be restarted.

There was some EDL data loss. RXMUX had a warning that it does not work. We didn't know if AP would work, but it worked.

AP1.1: new lut, low gain (parameter = 1). the wing was not calm, there were many corrections. It was not oscillating, but shaking. There might have been some gust influence, but according to the pilot it should not have been this much.

AP1.2: new lut, high gain(parameter = 2). It seemed to be a bit better, there still seemed to be oscillations, but not perfect.

AP1.3: old lut, high gain (parameter = 2?). From time to time there was some shaking, it was not constant, maybe due to gusts. That was decided to be OK.

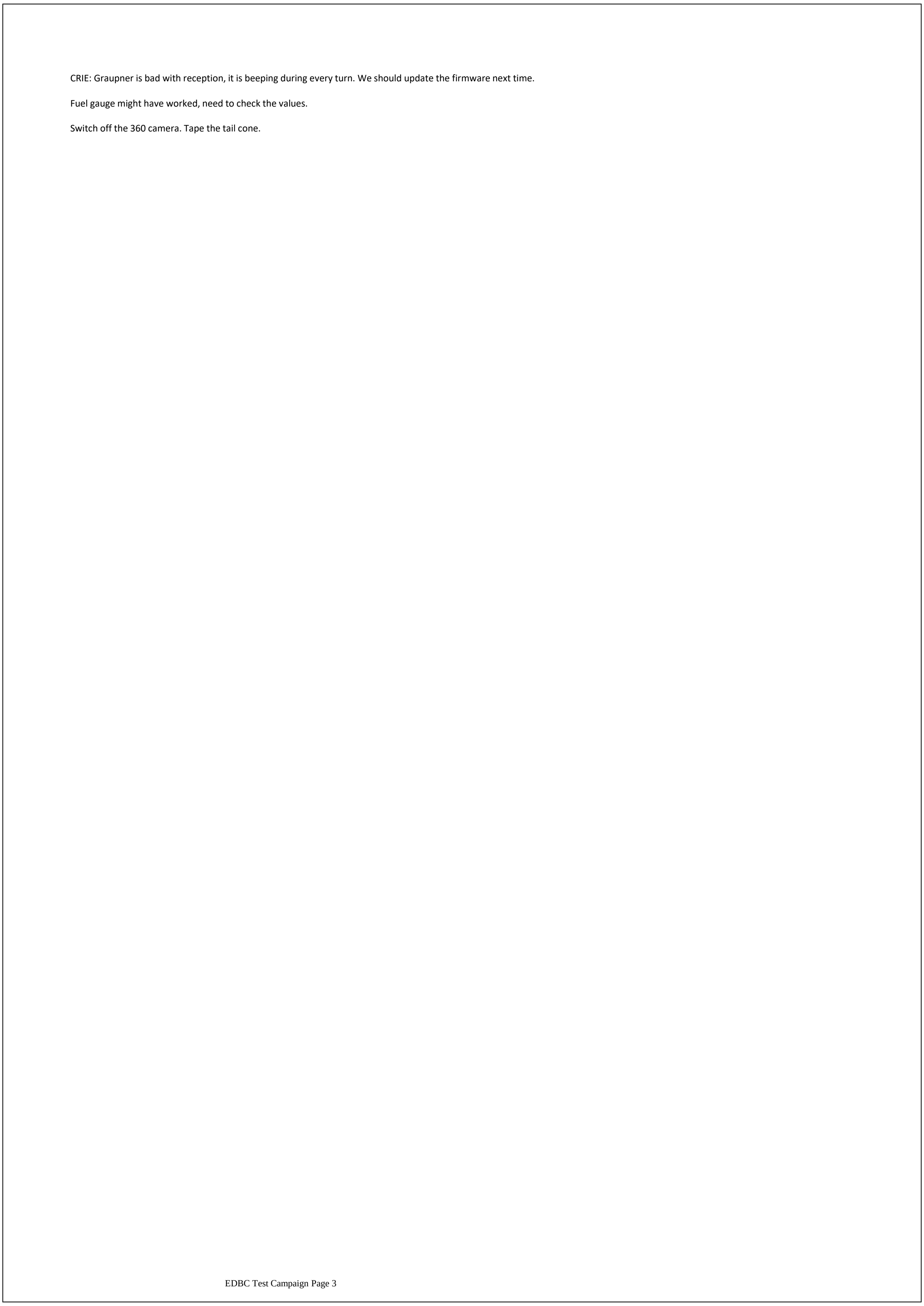
AP2: when it switched to AP2 first time, the nose went down a bit and CR had to correct. Need to check the logs if there was this drop in altitude.

Trim point 40m/s in triangle. For FY: announce a bit earlier. And a bit louder.

For the pilot it was also not clear what to do next at some point.

CR: underestimated the turn rate.

Landing imitation: it was intended. Go around, and then land. You can bring it down with airbrakes. Landing was around 20m/s, and then started going left. After that CR did a hard input to the right and the aircraft turned around. Was not complete full brakes.



CRIE: Graupner is bad with reception, it is beeping during every turn. We should update the firmware next time.

Fuel gauge might have worked, need to check the values.

Switch off the 360 camera. Tape the tail cone.

EDBC Test Campaign Page 3

FT12 - AP2

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Autothrottle check
Date	16.05.2022
Engine start/stop time	17:46 -
METAR (EDMO)	
METAR (EDBC)	METAR EDDP 161550Z 16003KT 090V190 CAVOK 21/14 Q1016 NOSIG=
Crew:	
Pilot-in-Command (FLEXOP 1)	Christian Rößler
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Simon Schelle
Flight Test Engineer (ENGINEER)	Daniel Teubl
Flight Test Manager (MANAGER)	Julius Bartasevicius

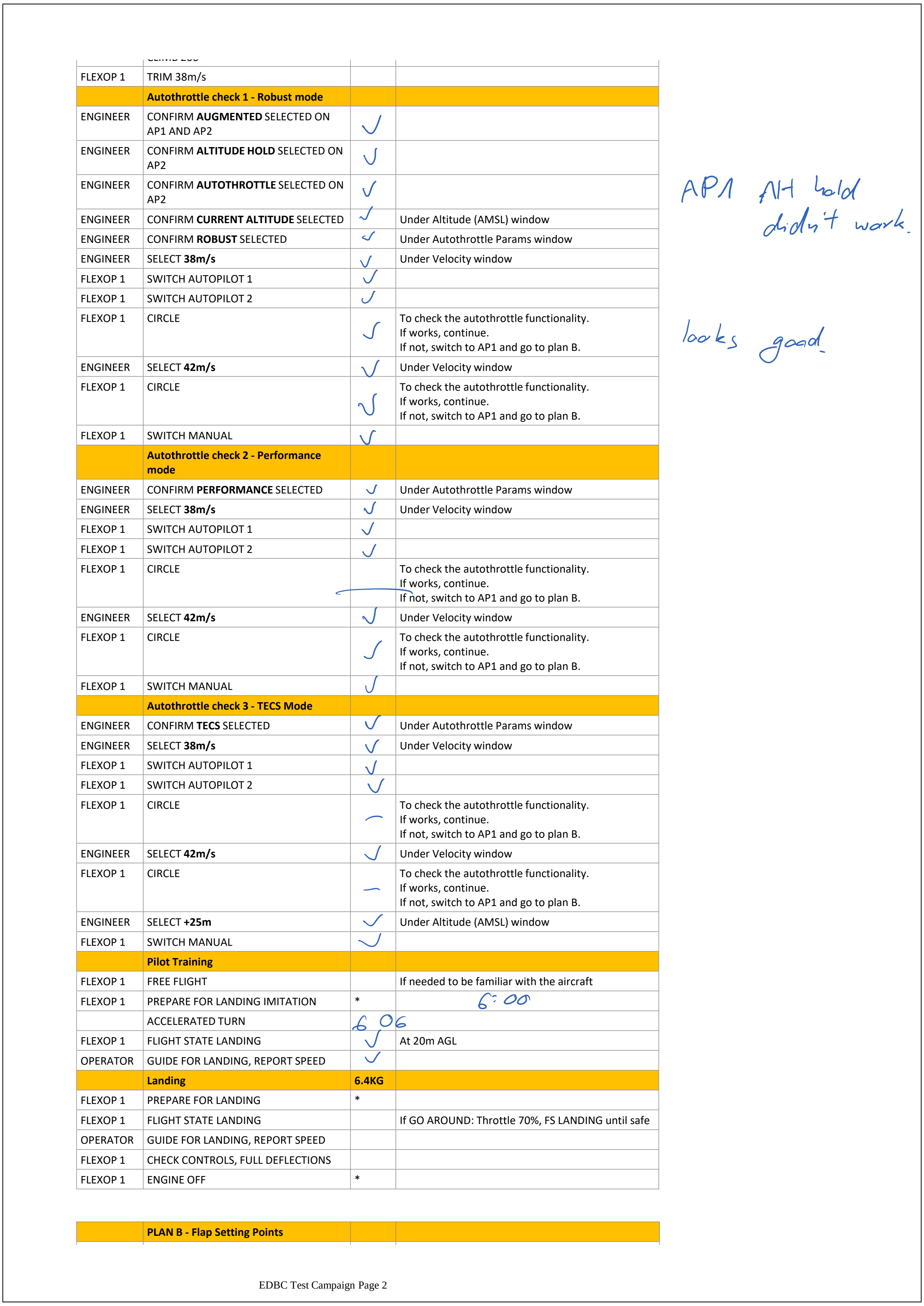
Aircraft header:

Configuration	-0 wing, new aeroprobe (longer), gear out, tufts applied, wingtip wheels mounted
Zero fuel mass, kg	57.8 + 1.2 ballast
Take-off mass, kg	66.2
Fuel, kg	7.15kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	607
Limitations	V_min = 25m/s V_max = 55m/s V_flaps = 35m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Flight time limited to around 25min.

Test points:

	Take-off		
FLEXOP 1, FLEXOP 2	Engine **ON**	*	5:46
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
FLEXOP 1	BRAKES **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 200	✓	At 30m AGL
FLEXOP 1	TRIM 38m/s		
	Autothrottle check 1 - Robust mode		

EDBC Test Campaign Page 1



FLEXOP 1	TRIM 38m/s		
	Autothrottle check 1 - Robust mode		
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2	✓	
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP2	✓	
ENGINEER	CONFIRM **CURRENT ALTITUDE** SELECTED	✓	Under Altitude (AMSL) window
ENGINEER	CONFIRM **ROBUST** SELECTED	✓	Under Autothrottle Params window
ENGINEER	SELECT **38m/s**	✓	Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	✓	
FLEXOP 1	CIRCLE	✓	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
ENGINEER	SELECT **42m/s**	✓	Under Velocity window
FLEXOP 1	CIRCLE	✓	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
FLEXOP 1	SWITCH MANUAL	✓	
	Autothrottle check 2 - Performance mode		
ENGINEER	CONFIRM **PERFORMANCE** SELECTED	✓	Under Autothrottle Params window
ENGINEER	SELECT **38m/s**	✓	Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	✓	
FLEXOP 1	CIRCLE		To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
ENGINEER	SELECT **42m/s**	✓	Under Velocity window
FLEXOP 1	CIRCLE	✓	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
FLEXOP 1	SWITCH MANUAL	✓	
	Autothrottle check 3 - TECS Mode		
ENGINEER	CONFIRM **TECS** SELECTED	✓	Under Autothrottle Params window
ENGINEER	SELECT **38m/s**	✓	Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	✓	
FLEXOP 1	CIRCLE	–	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
ENGINEER	SELECT **42m/s**	✓	Under Velocity window
FLEXOP 1	CIRCLE	–	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
ENGINEER	SELECT **+25m**	✓	Under Altitude (AMSL) window
FLEXOP 1	SWITCH MANUAL	✓	
	Pilot Training		
FLEXOP 1	FREE FLIGHT		If needed to be familiar with the aircraft
FLEXOP 1	PREPARE FOR LANDING IMITATION	*	6:00
	ACCELERATED TURN	6 06	
FLEXOP 1	FLIGHT STATE LANDING	✓	At 20m AGL
OPERATOR	GUIDE FOR LANDING, REPORT SPEED	✓	
	Landing	**6.4KG**	
FLEXOP 1	PREPARE FOR LANDING	*	
FLEXOP 1	FLIGHT STATE LANDING		If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

	PLAN B - Flap Setting Points		

AP1 AH hold didn't work.

looks good.

EDBC Test Campaign Page 2

FLEXOP 1	FLIGHT STATE TAKEOFF		
FLEXOP 1	TRIM 42m/s		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE LANDING		
FLEXOP 1	TRIM 42m/s		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE TAKEOFF		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE LANDING		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	TRIM 34m/s	*	

	PLAN B - Multisine Inputs		
ENGINEER	CONFIRM **MULTISINE** SELECTED ON AP2		
ENGINEER	SELECT AMPLITUDE **X0.5**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		
ENGINEER	SELECT AMPLITUDE **X1**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		
ENGINEER	SELECT AMPLITUDE **X2**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		

Emergency checklists:

LAND	TERMINATE

Debriefing notes:
During start-up all RXMUX got bad data and ignored the AP. That's why we had to restart. Trim settings were transferred to Graupner. We checked that the AP2 did not work on Graupner. Maybe the travel on channel 16 is too low? Now we changed the settings so that you can only get on AP1 with Graupner.

JB skipped some steps during second start-up. This should not be done.

Take-off:
We had quite a calm wind. Went a bit into the wind, CR corrected it with ailerons and rudder. Airspeed differs in between EDL and MP. Also airspeed was jumping a bit. Pilots didn't hear the takeoff command. The flaps make a lot of drag, so after take-off the climb angle needs to be decreased.

We had initially altitude hold on AP1. We tried to fly with that a couple of times, but the aircraft went down always. Maybe the reference altitude is only set when AP2 is initialized?

Autothrottle tests:
When initiated, it always seemed that the engine spools down. This was a bit scary. Maybe RPMs should be initialized at the current setting. It seemed like all the modes worked well.

Crie notes: went well, no trimming required. The connection was better. Maybe less announcement during turns. Was a bit slow during the first circle, went well during the second. We forgot to enter to AP1 during the circle.

We went into the contingency zone. We should relocate ourselves to the west a bit.

Landing: had to lose altitude and airspeed, but went well after that. Landing mode too soon. Did a small hop, but was ok. Descended with airbrakes on, first touchdown without brakes, then brakes partially on and then brakes full. During landing the airspeed can be announced constantly.

We had aroudn 1kg left.

Ask the traffic manager.

FT13 - AP3

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Course angle and horse race pattern
Date	17.05.2022
Engine start/stop time	17:14 -
METAR (EDMO)	
METAR (EDBC)	METAR EDDP 171520Z 08006KT 050V110 9999 FEW030CB 18/14 Q1021 NOSIG=
Crew:	
Pilot-in-Command (FLEXOP 1)	Christian Rößler
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Simon Schelle
Flight Test Engineer (ENGINEER)	Daniel Teubl
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0, aeroprobe (longer), gear out, tufts applied, oil applied, wingtip wheels mounted
Zero fuel mass, kg	57.8 + 1.2 ballast
Take-off mass, kg	66.2
Fuel, kg	7.15kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	607
Limitations	V_min = 25m/s V_max = 55m/s V_flaps = 35m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Flight time limited to around 25min.

Test points:

	Take-off		
FLEXOP 1, FLEXOP 2	Engine **ON**	* ✓	5 14
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
FLEXOP 1	BRAKES **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 150	✓	At 30m AGL
FLEXOP 1	TRIM 38m/s	–	
	Augmented mode check		
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1	✓	On MP

MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
FLEXOP 1	BRAKES **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 150	✓	At 30m AGL
FLEXOP 1	TRIM 38m/s	–	
	Augmented mode check		
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1	✓	On MP
ENGINEER	CONFIRM **OLD** LUT SELECTED	✓	
ENGINEER	CONFIRM LOW GAIN SELECTED	✓	
FLEXOP 1	SWITCH AUTOPILOT 1	✓	5 16
FLEXOP 1	DO CONTROL INPUTS TO CHECK BEHAVIOUR	✓	
FLEXOP 1	SWITCH MANUAL	✓	
	Coordinated turn - preparations		
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2	✓	And on AP1, if confirmed before
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP2	✓	
ENGINEER	CONFIRM **CURRENT ALTITUDE** SELECTED	✓	Under Altitude (AMSL) window
ENGINEER	CONFIRM **ROBUST** SELECTED	✓	Under Autothrottle Params window
ENGINEER	SELECT **38m/s**	✓	Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	–	
FLEXOP 1	CIRCLE	–	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP1		Pitch command is limited to 20deg
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP1		
ENGINEER	SELECT **34m/s**		Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 1		
FLEXOP 1	SWITCH MANUAL		
FLEXOP 1	SWITCH AUTOPILOT 1		Altitude hold might work now
	Coordinated turn		
ENGINEER	CONFIRM **COURSE ANGLE** SELECTED ON AP2		
ENGINEER	CONFIRM **EAST** SELECTED		Depending on intended flight direction
FLEXOP 1	FLY EAST WITH COURSE OFFSET		
FLEXOP 1	SWITCH AUTOPILOT 2		The heading should change to the intended direction
ENGINEER	SELECT **COORDINATED TURN**		AC should start a turn with 200m radius.
ENGINEER	SELECT **42m/s**		Under Velocity window
ENGINEER	CONFIRM **WEST** SELECTED		Depending on intended flight direction
FLEXOP 1	SWITCH AUTOPILOT 1		
	Horse race		
ENGINEER	CONFIRM **HORSE RACE** SELECTED		
ENGINEER	SELECT **CLOCKWISE**		Under Horse race direction
ENGINEER	SELECT **400m**		Under Length of horse track
ENGINEER	SELECT **42m/s**		Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 2		AC Should aim for the WPS and do a track.
ENGINEER	SELECT **34m/s**		Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 1		
ENGINEER	SELECT **700m**		Under Length of horse track
FLEXOP 1	SWITCH AUTOPILOT 2		AC Should aim for the WPS and do a track.
	Landing	**6.4kg**	
FLEXOP 1	PREPARE FOR LANDING	*	

Alt hold doesn't work.

5 24 FX2.

AP1 test.

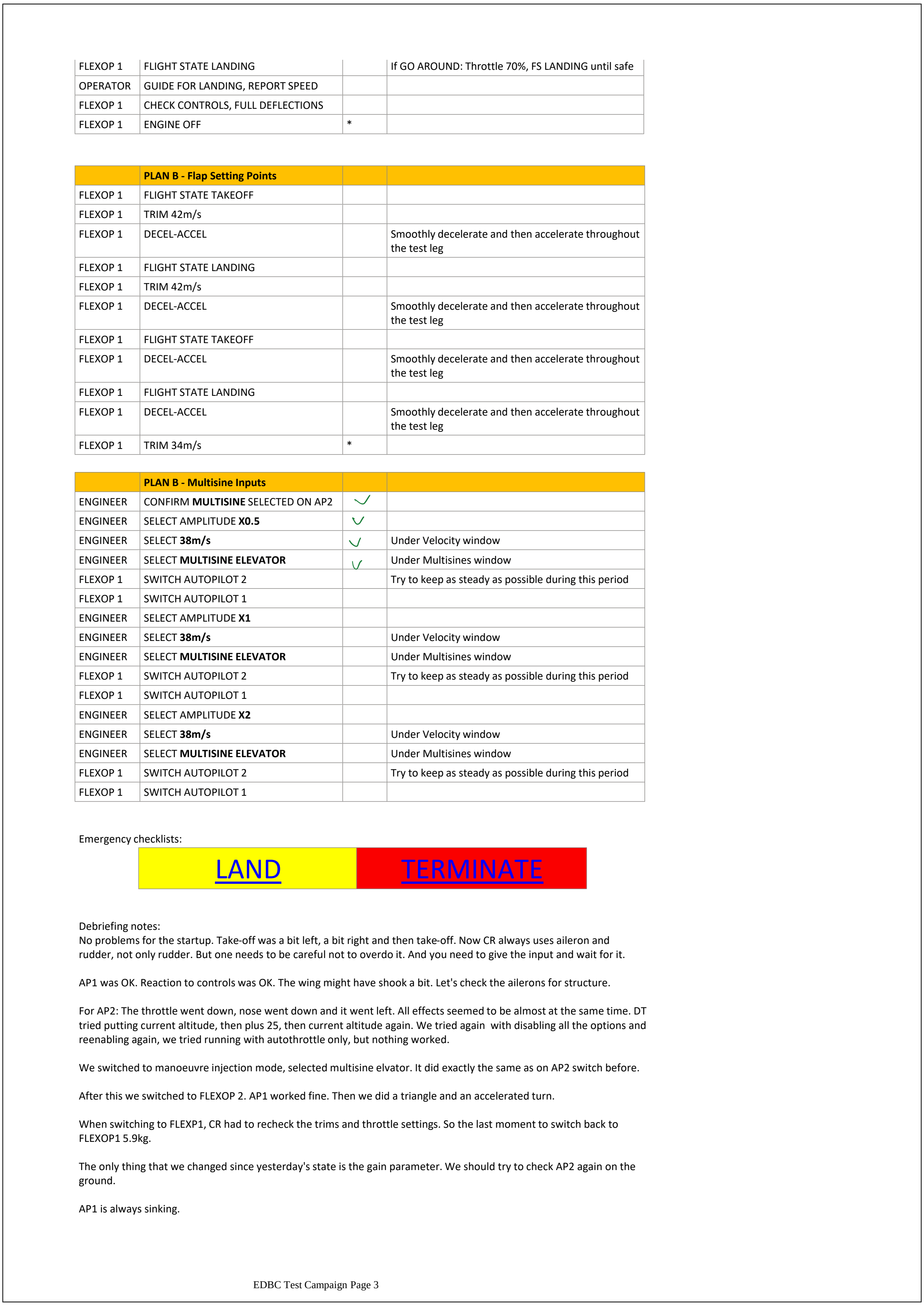
Triangle 5 28

Acc turn

No full throttle

MAN mode.

FLEXOP 1 is weird.



FLEXOP 1	FLIGHT STATE LANDING		If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

	PLAN B - Flap Setting Points		
FLEXOP 1	FLIGHT STATE TAKEOFF		
FLEXOP 1	TRIM 42m/s		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE LANDING		
FLEXOP 1	TRIM 42m/s		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE TAKEOFF		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE LANDING		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	TRIM 34m/s	*	

	PLAN B - Multisine Inputs		
ENGINEER	CONFIRM **MULTISINE** SELECTED ON AP2	✓	
ENGINEER	SELECT AMPLITUDE **X0.5**	✓	
ENGINEER	SELECT **38m/s**	✓	Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**	✓	Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		
ENGINEER	SELECT AMPLITUDE **X1**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		
ENGINEER	SELECT AMPLITUDE **X2**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		

Emergency checklists:

LAND	TERMINATE

Debriefing notes:
No problems for the startup. Take-off was a bit left, a bit right and then take-off. Now CR always uses aileron and rudder, not only rudder. But one needs to be careful not to overdo it. And you need to give the input and wait for it.

AP1 was OK. Reaction to controls was OK. The wing might have shook a bit. Let's check the ailerons for structure.

For AP2: The throttle went down, nose went down and it went left. All effects seemed to be almost at the same time. DT tried putting current altitude, then plus 25, then current altitude again. We tried again with disabling all the options and reenabling again, we tried running with autothrottle only, but nothing worked.

We switched to manoeuvre injection mode, selected multisine elvator. It did exactly the same as on AP2 switch before.

After this we switched to FLEXOP 2. AP1 worked fine. Then we did a triangle and an accelerated turn.

When switching to FLEXP1, CR had to recheck the trims and throttle settings. So the last moment to switch back to FLEXOP1 5.9kg.

The only thing that we changed since yesterday's state is the gain parameter. We should try to check AP2 again on the ground.

AP1 is always sinking.

FT14 - AP3

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

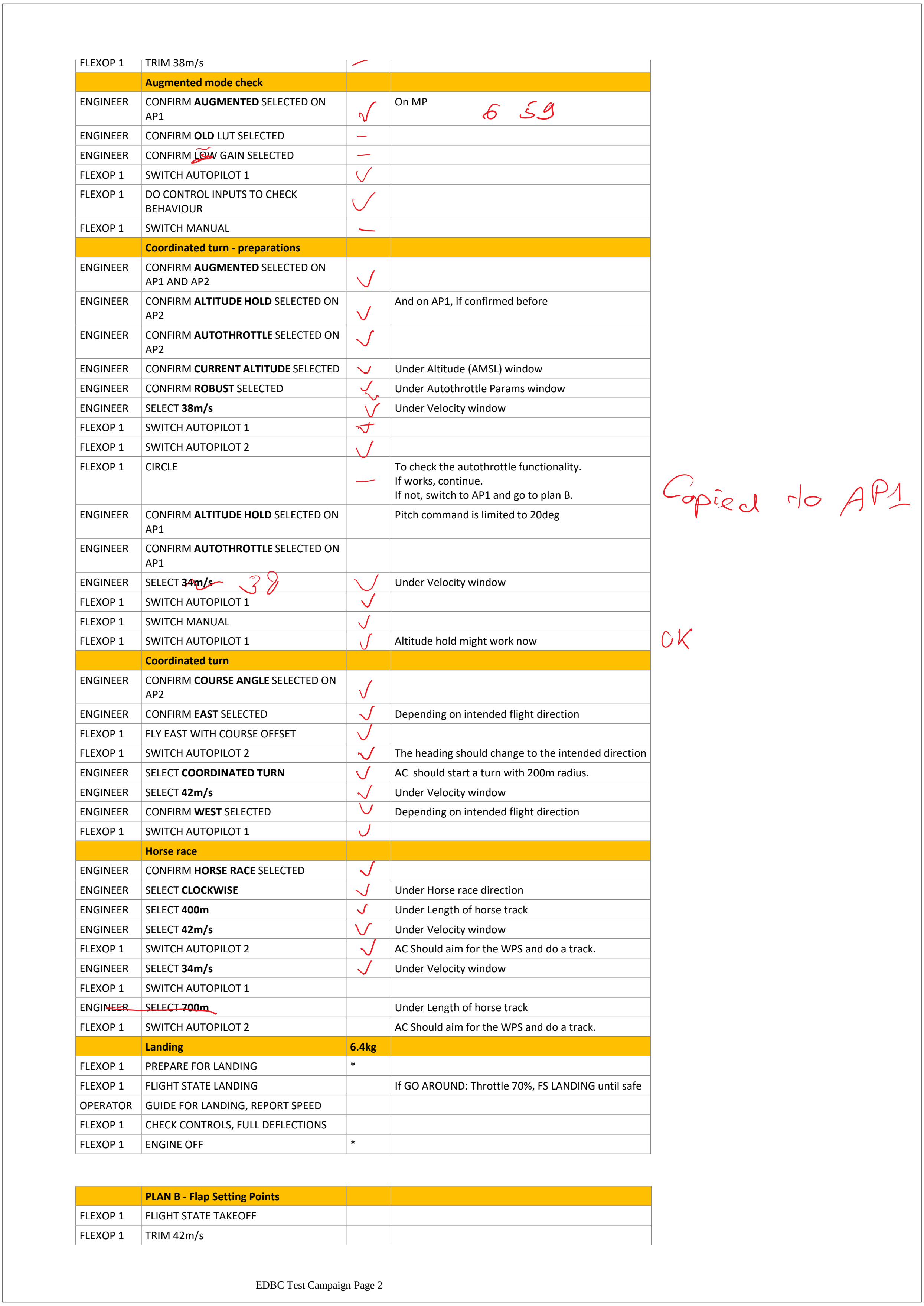
Test Title	Course angle and horse race pattern
Date	17.05.2022
Engine start/stop time	18:55 -
METAR (EDMO)	
METAR (EDBC)	METAR EDDP 171650Z 12004KT CAVOK 19/14 Q1021 NOSIG=
Crew:	
Pilot-in-Command (FLEXOP 1)	Christian Rößler
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Simon Schelle
Flight Test Engineer (ENGINEER)	Daniel Teubl
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 , aeroprobe (longer), gear out, tufts applied, oil applied, wingtip wheels mounted
Zero fuel mass, kg	57.8 + 1.2 ballast
Take-off mass, kg	66.2
Fuel, kg	7.15kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	607
Limitations	V_min = 25m/s V_max = 55m/s V_flaps = 35m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Flight time limited to around 25min.

Test points:

	Take-off		
FLEXOP 1, FLEXOP 2	Engine **ON**	* ✓	655
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
FLEXOP 1	BRAKES **ON** OFF	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 150	✓	At 30m AGL
FLEXOP 1	TRIM 38m/s	–	
	Augmented mode check		
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1	✓	On MP 659



FLEXOP 1	TRIM 38m/s	—		
	Augmented mode check			
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1	✓	On MP 6 59	
ENGINEER	CONFIRM **OLD** LUT SELECTED	—		
ENGINEER	CONFIRM ~~LOW~~ GAIN SELECTED	—		
FLEXOP 1	SWITCH AUTOPILOT 1	✓		
FLEXOP 1	DO CONTROL INPUTS TO CHECK BEHAVIOUR	✓		
FLEXOP 1	SWITCH MANUAL	—		
	Coordinated turn - preparations			
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓		
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2	✓	And on AP1, if confirmed before	
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP2	✓		
ENGINEER	CONFIRM **CURRENT ALTITUDE** SELECTED	✓	Under Altitude (AMSL) window	
ENGINEER	CONFIRM **ROBUST** SELECTED	✓	Under Autothrottle Params window	
ENGINEER	SELECT **38m/s**	✓	Under Velocity window	
FLEXOP 1	SWITCH AUTOPILOT 1	✓		
FLEXOP 1	SWITCH AUTOPILOT 2	✓		
FLEXOP 1	CIRCLE	—	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.	Copied to AP1
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP1		Pitch command is limited to 20deg	
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP1			
ENGINEER	SELECT ~~**34m/s**~~ 38	✓	Under Velocity window	
FLEXOP 1	SWITCH AUTOPILOT 1	✓		
FLEXOP 1	SWITCH MANUAL	✓		
FLEXOP 1	SWITCH AUTOPILOT 1	✓	Altitude hold might work now	OK
	Coordinated turn			
ENGINEER	CONFIRM **COURSE ANGLE** SELECTED ON AP2	✓		
ENGINEER	CONFIRM **EAST** SELECTED	✓	Depending on intended flight direction	
FLEXOP 1	FLY EAST WITH COURSE OFFSET	✓		
FLEXOP 1	SWITCH AUTOPILOT 2	✓	The heading should change to the intended direction	
ENGINEER	SELECT **COORDINATED TURN**	✓	AC should start a turn with 200m radius.	
ENGINEER	SELECT **42m/s**	✓	Under Velocity window	
ENGINEER	CONFIRM **WEST** SELECTED	✓	Depending on intended flight direction	
FLEXOP 1	SWITCH AUTOPILOT 1	✓		
	Horse race			
ENGINEER	CONFIRM **HORSE RACE** SELECTED	✓		
ENGINEER	SELECT **CLOCKWISE**	✓	Under Horse race direction	
ENGINEER	SELECT **400m**	✓	Under Length of horse track	
ENGINEER	SELECT **42m/s**	✓	Under Velocity window	
FLEXOP 1	SWITCH AUTOPILOT 2	✓	AC Should aim for the WPS and do a track.	
ENGINEER	SELECT **34m/s**	✓	Under Velocity window	
FLEXOP 1	SWITCH AUTOPILOT 1			
~~ENGINEER~~	~~SELECT **700m**~~		Under Length of horse track	
FLEXOP 1	SWITCH AUTOPILOT 2		AC Should aim for the WPS and do a track.	
	Landing	**6.4kg**		
FLEXOP 1	PREPARE FOR LANDING	*		
FLEXOP 1	FLIGHT STATE LANDING		If GO AROUND: Throttle 70%, FS LANDING until safe	
OPERATOR	GUIDE FOR LANDING, REPORT SPEED			
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS			
FLEXOP 1	ENGINE OFF	*		

	PLAN B - Flap Setting Points		
FLEXOP 1	FLIGHT STATE TAKEOFF		
FLEXOP 1	TRIM 42m/s		

EDBC Test Campaign Page 2

FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE LANDING		
FLEXOP 1	TRIM 42m/s		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE TAKEOFF		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	FLIGHT STATE LANDING		
FLEXOP 1	DECEL-ACCEL		Smoothly decelerate and then accelerate throughout the test leg
FLEXOP 1	TRIM 34m/s	*	

	PLAN B - Multisine Inputs		
ENGINEER	CONFIRM **MULTISINE** SELECTED ON AP2		
ENGINEER	SELECT AMPLITUDE **X0.5**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		
ENGINEER	SELECT AMPLITUDE **X1**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		
ENGINEER	SELECT AMPLITUDE **X2**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		

doublets

Multisines (later

AC cut.

Emergency checklists:

LAND	TERMINATE

Debriefing notes:
During the start-up we had the same setup as in flight before. We checked the AP2- the tail had differential deflection (like sideslip control?). But Pilot had control still, unlike the flight before. We decided to try again.

Main MP was not reset properly in between the setups. During restart, MP must be restarted completely to make the annoucner work.

Airspeed reading during take-off: if telemetry is not there, anounce it louder.

Delete brakes-on during take-off.

During climb the announcer should be muted, but airspeed must be reported.

When autothrottle was on, it always spools down the engine. If this is turned on at low speed, then it's a problem.

Course angle hold worked well, coordinated turn as well.

We need GPS WPS on the MP. But 400m was quite far away already, so we didn't want to go for 900m.

When we selected it second time, it did something strange, even though we selected it early enough.

Signal injection: we started with multisine elevator, 34m/s, o.5x. It started rolling to the side. Maybe the initial trim points are set wrong? Or initiated wrong? Maybe having augmented mode for bank is better for longitudinal manoeuvres?

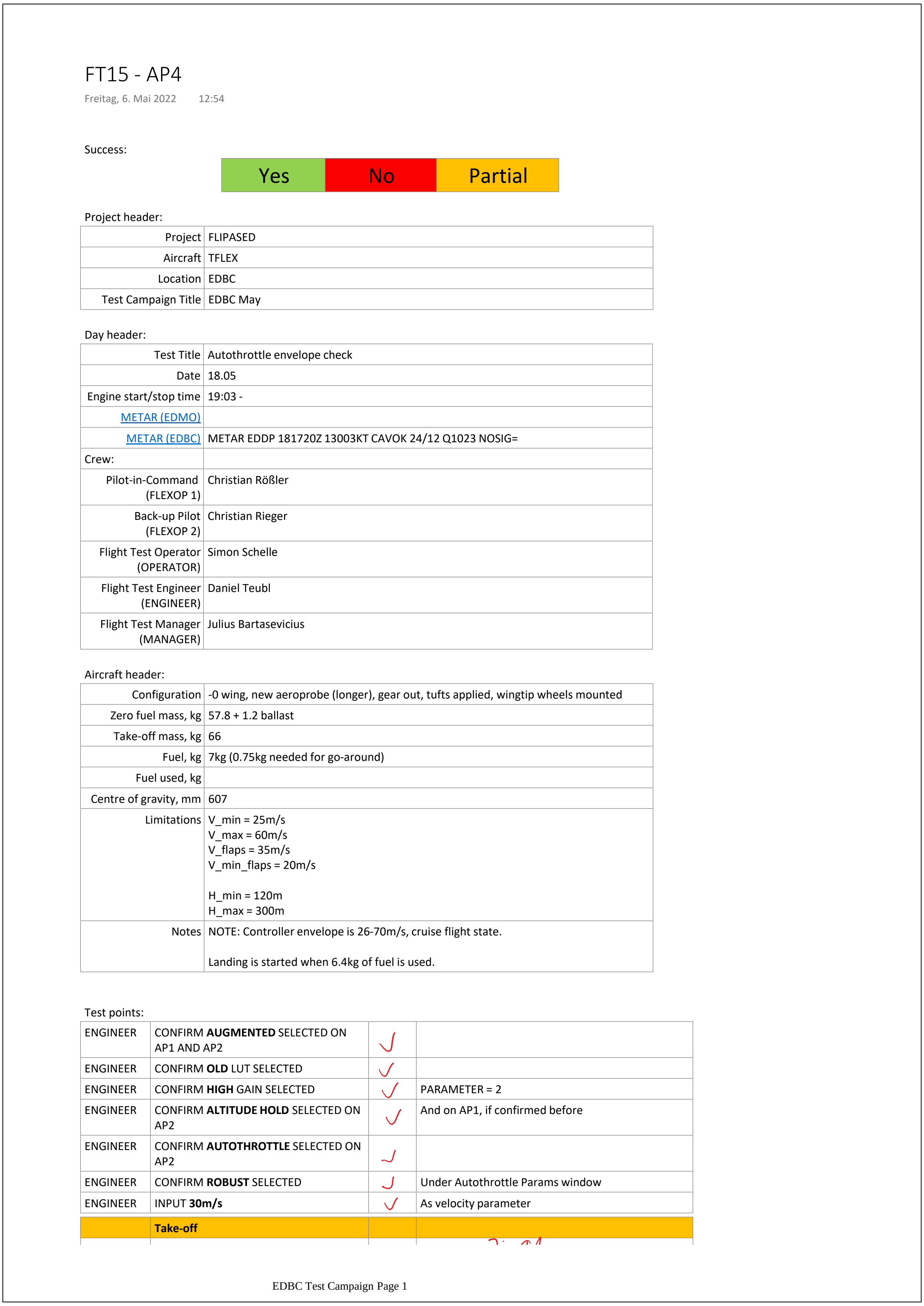
Counting back for manouevres is good.

JB thought that the injections were not good (high bank angle?), for the pilots it seemed like they were kindof OK.

Multisine input: all went to the side slowly, couldn't keep it there.

Was a long flight, we should weight the fuel.

EDBC Test Campaign Page 3



FT15 - AP4

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Autothrottle envelope check
Date	18.05
Engine start/stop time	19:03 -
METAR (EDMO)	
METAR (EDBC)	METAR EDDP 181720Z 13003KT CAVOK 24/12 Q1023 NOSIG=
Crew:	
Pilot-in-Command (FLEXOP 1)	Christian Rößler
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Simon Schelle
Flight Test Engineer (ENGINEER)	Daniel Teubl
Flight Test Manager (MANAGER)	Julius Bartasevicius

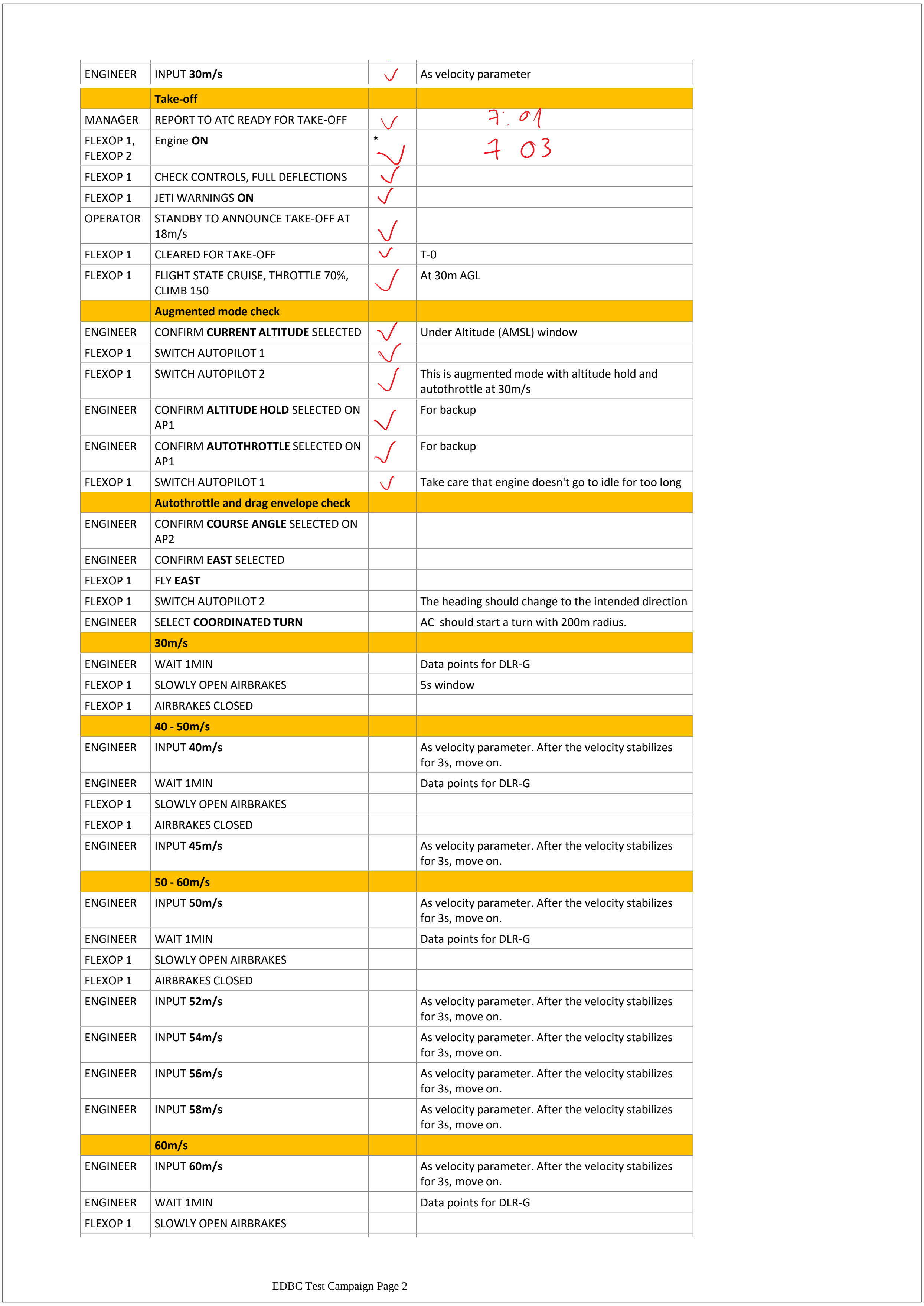
Aircraft header:

Configuration	-0 wing, new aeroprobe (longer), gear out, tufts applied, wingtip wheels mounted
Zero fuel mass, kg	57.8 + 1.2 ballast
Take-off mass, kg	66
Fuel, kg	7kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	607
Limitations	V_min = 25m/s V_max = 60m/s V_flaps = 35m/s V_min_flaps = 20m/s H_min = 120m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Landing is started when 6.4kg of fuel is used.

Test points:

ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **OLD** LUT SELECTED	✓	
ENGINEER	CONFIRM **HIGH** GAIN SELECTED	✓	PARAMETER = 2
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2	✓	And on AP1, if confirmed before
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP2	✓	
ENGINEER	CONFIRM **ROBUST** SELECTED	✓	Under Autothrottle Params window
ENGINEER	INPUT **30m/s**	✓	As velocity parameter
	Take-off		

EDBC Test Campaign Page 1



ENGINEER	INPUT **30m/s**	✓	As velocity parameter
	Take-off		
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	7:01
FLEXOP 1, FLEXOP 2	Engine **ON**	* ✓	7 03
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 150	✓	At 30m AGL
	Augmented mode check		
ENGINEER	CONFIRM **CURRENT ALTITUDE** SELECTED	✓	Under Altitude (AMSL) window
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	✓	This is augmented mode with altitude hold and autothrottle at 30m/s
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP1	✓	For backup
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP1	✓	For backup
FLEXOP 1	SWITCH AUTOPILOT 1	✓	Take care that engine doesn't go to idle for too long
	Autothrottle and drag envelope check		
ENGINEER	CONFIRM **COURSE ANGLE** SELECTED ON AP2		
ENGINEER	CONFIRM **EAST** SELECTED		
FLEXOP 1	FLY **EAST**		
FLEXOP 1	SWITCH AUTOPILOT 2		The heading should change to the intended direction
ENGINEER	SELECT **COORDINATED TURN**		AC should start a turn with 200m radius.
	30m/s		
ENGINEER	WAIT 1MIN		Data points for DLR-G
FLEXOP 1	SLOWLY OPEN AIRBRAKES		5s window
FLEXOP 1	AIRBRAKES CLOSED		
	40 - 50m/s		
ENGINEER	INPUT **40m/s**		As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	WAIT 1MIN		Data points for DLR-G
FLEXOP 1	SLOWLY OPEN AIRBRAKES		
FLEXOP 1	AIRBRAKES CLOSED		
ENGINEER	INPUT **45m/s**		As velocity parameter. After the velocity stabilizes for 3s, move on.
	50 - 60m/s		
ENGINEER	INPUT **50m/s**		As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	WAIT 1MIN		Data points for DLR-G
FLEXOP 1	SLOWLY OPEN AIRBRAKES		
FLEXOP 1	AIRBRAKES CLOSED		
ENGINEER	INPUT **52m/s**		As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	INPUT **54m/s**		As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	INPUT **56m/s**		As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	INPUT **58m/s**		As velocity parameter. After the velocity stabilizes for 3s, move on.
	60m/s		
ENGINEER	INPUT **60m/s**		As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	WAIT 1MIN		Data points for DLR-G
FLEXOP 1	SLOWLY OPEN AIRBRAKES		

EDBC Test Campaign Page 2

FLEXOP 1	AIRBRAKES CLOSED		
ENGINEER	INPUT **38m/s**		As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	CONFIRM **WEST** SELECTED		
FLEXOP 1	SWITCH AUTOPILOT 1		
	ACCELERATED TURN		
FLEXOP 1	MANUAL		
FLEXOP 1	TRIM 32		Check trim, if OK - continue
FLEXOP 1	FLIGHT STATE DRAG		
FLEXOP 1	CIRCLE		Two circles
FLEXOP 1	GRADUALLY INCREASE THRUST		Up to 50m/s
FLEXOP 1	FLIGHT STATE CRUISE		
	Landing	**6.2kg**	
FLEXOP 1	PREPARE FOR LANDING	*	
FLEXOP 1	FLIGHT STATE LANDING		If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

	PLAN B - Pushover-pull-up		
FLEXOP 1	TRIM 35m/s		
ENGINEER	STANDBY TO REPORT LOAD FACTOR		
OPERATOR	STANDBY TO REPORT AIRSPEED		At 35m/s - PUSH DOWN PUSH DOWN At 40m/s - PULL UP PULL UP At 35m/s - LEVEL OUT LEVEL OUT
FLEXOP 1	PUSHOVER-PULLUP		Slightly pull-up to decelerate till 35m/s, then push down -30deg pitch until 45m/s, then pull-up until + 30deg pitch, then level out.
ENGINEER	REPORT LOAD FACTOR		
	REPEAT AS REQUIRED		
1	HIGHEST SPEED:		LOAD FACTOR:
2	HIGHEST SPEED:		LOAD FACTOR:
3	HIGHEST SPEED:		LOAD FACTOR:
4	HIGHEST SPEED:		LOAD FACTOR:
5	HIGHEST SPEED:		LOAD FACTOR:
6	HIGHEST SPEED:		LOAD FACTOR:

Need data for the range 40-55m/s

Emergency checklists:

LAND	TERMINATE

Debriefing notes:

Before take-off we selected the right controllers on AP2. They got updated. Then we accidentally changed the log-on parameter but didn't send it. Then we requested parameters from the aircraft, then it went back to ok. Also openmct was connected to the AC for the first time this week.

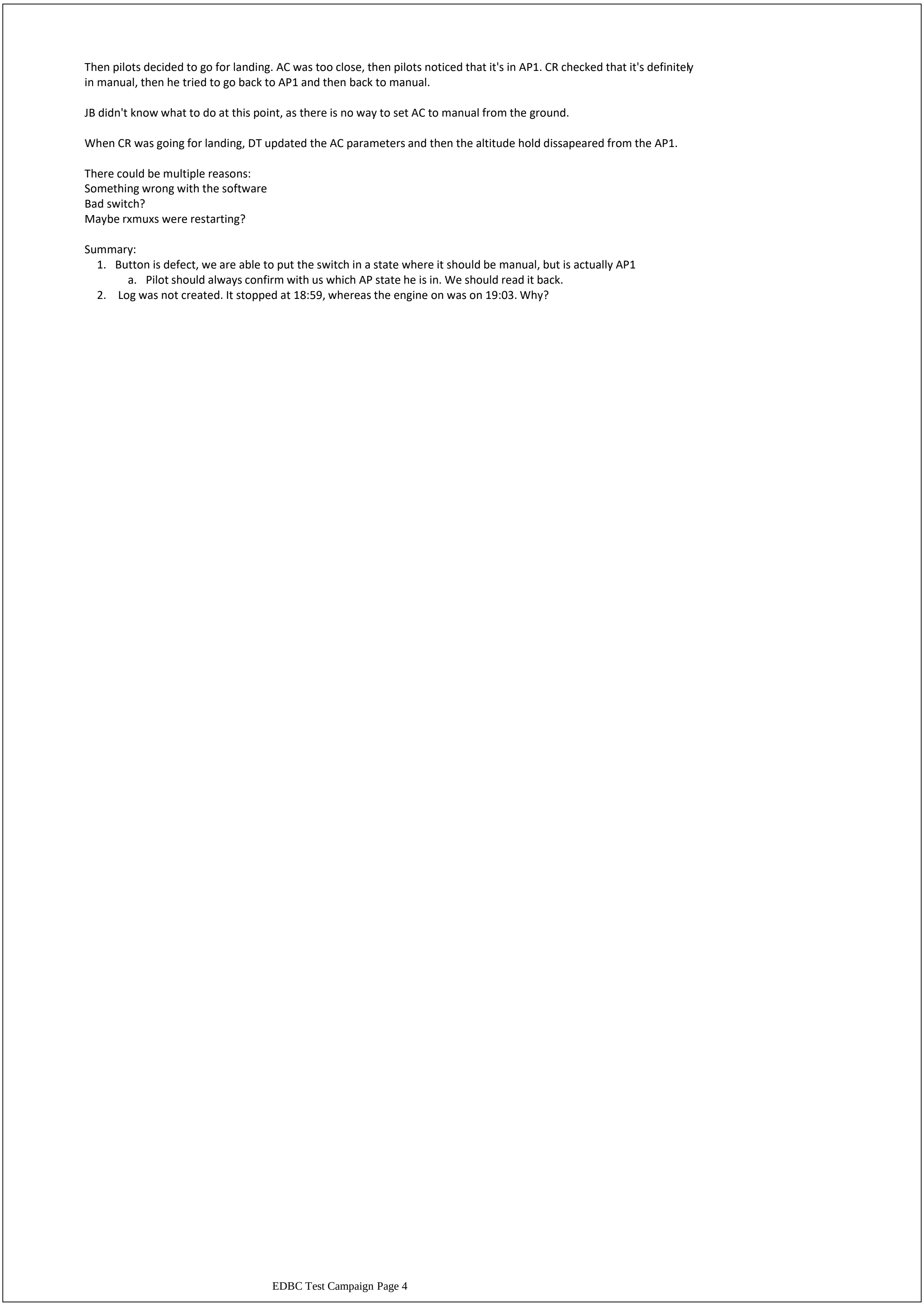
We also tested all the required AP modes before the takeoff.

Takeoff, it went to the wind, CR tried to correct it and it went ot the side quite hard, but it went into the air then.

With AP2, the autothrottle was ok, wthin 28-32. But altitude was dropping. We wanted to copy alt hold and autorhtottle on ap1. DT se;ected alt hold, but nothing happened for a while. Then it said parameter update failed. Then DT clicked it again and then it was OK. Then selected autothrottle as well, it was OK. Then we switched to AP1, it seemed that everything was OK. Maybe the engine went low a bit, but not for long.

After the turn we noticed that we were losing altitude. We switched to manual and CR tried to increase throttle. Engine was going up and down. He was a half throttle, then tried to spool up, nothing happened, then he went to idle, then tried to spool up again, but nothig happened.

In the meantime on the MP2 it seemed to still be on the AP1.



Then pilots decided to go for landing. AC was too close, then pilots noticed that it's in AP1. CR checked that it's definitely in manual, then he tried to go back to AP1 and then back to manual.

JB didn't know what to do at this point, as there is no way to set AC to manual from the ground.

When CR was going for landing, DT updated the AC parameters and then the altitude hold dissapeared from the AP1.

There could be multiple reasons:
Something wrong with the software
Bad switch?
Maybe rxmuxs were restarting?

Summary:

1. Button is defect, we are able to put the switch in a state where it should be manual, but is actually AP1
    a. Pilot should always confirm with us which AP state he is in. We should read it back.
2. Log was not created. It stopped at 18:59, whereas the engine on was on 19:03. Why?

FT16 - AP4

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Autothrottle envelope check
Date	19.05.2022
Engine start/stop time	18:03
METAR (EDMO)	
METAR (EDBC)	METAR EDDP 191620Z 19007KT 170V230 CAVOK 28/13 Q1017 NOSIG=
Crew:	
Pilot-in-Command (FLEXOP 1)	Christian Rößler
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Simon Schelle
Flight Test Engineer (ENGINEER)	Daniel Teubl
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 wing, new aeroprobe (longer), gear out, wingtip wheels mounted
Zero fuel mass, kg	57.8 + 1.2 ballast
Take-off mass, kg	65.9
Fuel, kg	6.9kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	607
Limitations	V_min = 25m/s V_max = 60m/s V_flaps = 35m/s V_min_flaps = 20m/s H_min = 120m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Landing is started when 6.2kg of fuel is used.

Test points:

ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **OLD** LUT SELECTED	✓	
ENGINEER	CONFIRM **HIGH** GAIN SELECTED	✓	PARAMETER = 2
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2	✓	And on AP1, if confirmed before
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP2	✓	
ENGINEER	CONFIRM **ROBUST** SELECTED	✓	Under Autothrottle Params window
ENGINEER	INPUT **30m/s**	✓	As velocity parameter
	Take-off		
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	18 05 200 08KT
FLEXOP 1, FLEXOP 2	Engine **ON**	* ✓	1803
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0 18 14
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 150	✓	At 30m AGL
	Augmented mode check		
ENGINEER	CONFIRM **CURRENT ALTITUDE** SELECTED	✓	Under Altitude (AMSL) window
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	✓	This is augmented mode with altitude hold and autothrottle at 30m/s
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP1	✓	For backup
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP1	✓	For backup
FLEXOP 1	SWITCH AUTOPILOT 1	✓	Take care that engine doesn't go to idle for too long
	Autothrottle and drag envelope check		
ENGINEER	CONFIRM **COURSE ANGLE** SELECTED ON AP2	✓	
ENGINEER	SELECT **COORDINATED TURN**	✓	AC should start a turn with 200m radius.
FLEXOP 1	ALLIGN **EAST WITH OFFSET**	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	✓	If turn not initiated: CONFIRM **EAST** SELECTED and then coordinated

W 170 05KT

+ current ALTITUDE

5:39 checking AP1

Deselect AH + AT

checked AP2 with El doublet

5:42 AT ON
AH ON

170 06
5 45 Secondary disconnect -> connect.

5 49 170 05KT

West left hand.

EDBC Test Campaign Page 1

ENGINEER	SELECT **COORDINATED TURN**	✓	AC should start a turn with 200m radius.
FLEXOP 1	ALLIGN **EAST WITH OFFSET**	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	✓	If turn not initiated: CONFIRM **EAST** SELECTED and then coordinated circle
	30m/s		
ENGINEER	WAIT 1MIN	✓	Data points for DLR-G
FLEXOP 1	SLOWLY OPEN AIRBRAKES	✓	5s window
FLEXOP 1	AIRBRAKES CLOSED	✓	
	40 - 50m/s		
ENGINEER	INPUT **40m/s**	T-11 12	As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	WAIT 1MIN	✓	Data points for DLR-G
FLEXOP 1	SLOWLY OPEN AIRBRAKES	T-11 15	
FLEXOP 1	AIRBRAKES CLOSED	✓	
ENGINEER	INPUT **45m/s**	✓	As velocity parameter. After the velocity stabilizes for 3s, move on.
	50 - 60m/s		
ENGINEER	INPUT **50m/s**	✓	As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	WAIT 1MIN	T- 8:49	Data points for DLR-G
FLEXOP 1	SLOWLY OPEN AIRBRAKES	✓	
FLEXOP 1	AIRBRAKES CLOSED	✓	
ENGINEER	INPUT **52m/s**	✓	As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	INPUT **54m/s**	✓	As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	INPUT **56m/s**	✓	As velocity parameter. After the velocity stabilizes for 3s, move on.
ENGINEER	INPUT **58m/s**	✓	As velocity parameter. After the velocity stabilizes for 3s, move on.
	60m/s		
~~ENGINEER~~	~~INPUT **60m/s**~~		~~As velocity parameter. After the velocity stabilizes for 3s, move on.~~
~~ENGINEER~~	~~WAIT 1MIN~~		~~Data points for DLR-G~~
~~FLEXOP 1~~	~~SLOWLY OPEN AIRBRAKES~~		
~~FLEXOP 1~~	~~AIRBRAKES CLOSED~~		
~~ENGINEER~~	~~INPUT **38m/s**~~		~~As velocity parameter. After the velocity stabilizes for 3s, move on.~~
~~FLEXOP 1~~	~~SWITCH AUTOPILOT 1~~		
	ACCELERATED TURN		
FLEXOP 1	SWITCH MANUAL	✓	
FLEXOP 1	TRIM 32	✓	Check trim, if OK - continue
FLEXOP 1	FLIGHT STATE DRAG	✓	
FLEXOP 1	CIRCLE	✓	Two circles
FLEXOP 1	GRADUALLY INCREASE THRUST	✓	Up to 50m/s
FLEXOP 1	FLIGHT STATE CRUISE	✓	
	Landing	**6.0kg**	
FLEXOP 1	PREPARE FOR LANDING	* ✓	
FLEXOP 1	FLIGHT STATE LANDING	✓	If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED	✓	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	–	
FLEXOP 1	ENGINE OFF	*	

West left hand.
Selected EAST

TKABECT

Too slow

	PLAN B - Pushover-pull-up		
FLEXOP 1	TRIM 35m/s		
ENGINEER	STANDBY TO REPORT LOAD FACTOR		
OPERATOR	STANDBY TO REPORT AIRSPEED		At 35m/s - PUSH DOWN PUSH DOWN At 40m/s - PULL UP PULL UP At 35m/s - LEVEL OUT LEVEL OUT
FLEXOP 1	PUSHOVER-PULLUP		Slightly pull-up to decelerate till 35m/s, then push down -30deg pitch until 45m/s, then pull-up until + 30deg pitch, then level out.
ENGINEER	REPORT LOAD FACTOR		
	REPEAT AS REQUIRED		
1	HIGHEST SPEED:		LOAD FACTOR:
2	HIGHEST SPEED:		LOAD FACTOR:
3	HIGHEST SPEED:		LOAD FACTOR:
4	HIGHEST SPEED:		LOAD FACTOR:
5	HIGHEST SPEED:		LOAD FACTOR:
6	HIGHEST SPEED:		LOAD FACTOR:

Need data for the range 40-55m/s

Emergency checklists:

LAND	TERMINATE

Debriefing notes:
We didn't check the AP modes during startup. Only on the runway.

Secondary MP didn't initialise params once while on the ground, we reconnected.

Little bit of going left, worked well. Quite good take-off, going straight, going up, switching cruise before first turn. Climbing to 250, we switched through all AP modes, worked well.

When we had coordinated turn selected, switching to AP2 did a very strong bank to the wrong side. During this is went to 24m/s. Afterwards it corected, but for the first time we switched to AP1. Then we went for EAST and then

COORDINATED TURN, this worked.

With 30ms it worked, 40ms worked, 50ms worked. But then the connection was really bad.

For 50plus it started to be slower than the input speed, we couldn't not see if the bank angle is saturated. Then we switched to AP1 and did the circles by hand with 45deg.

Drag flight state - was going down, CR had to throttle up quite a bit. We did two accelerated turns then. Elevator was not really constant.

Landing
Applied more brakes than before, the aircraft was hoping. But landing was in the middle.

DT: keep more reserve next time.

EDBC Test Campaign Page 3

FT17 - RID1

Donnerstag, 19. Mai 2022 12:54

Success:

🟩 Yes	🟥 No	🟧 Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Rigid body mode manoeuvres
Date	19.05.2022
Engine start/stop time	19:18 -
METAR (EDMO)	
METAR (EDBC)	METAR EDDP 191720Z 16005KT CAVOK 26/13 Q1017 NOSIG=
Crew:	
Pilot-in-Command (FLEXOP 1)	Christian Rößler
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Simon Schelle
Flight Test Engineer (ENGINEER)	Daniel Teubl
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 wing, new aeroprobe (longer), gear out, wingtip wheels mounted
Zero fuel mass, kg	57.8 + 1.2 ballast
Take-off mass, kg	66
Fuel, kg	7kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	607
Limitations	V_min = 25m/s V_max = 60m/s V_flaps = 35m/s V_min_flaps = 20m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Landing is started when 6.4kg of fuel is used.

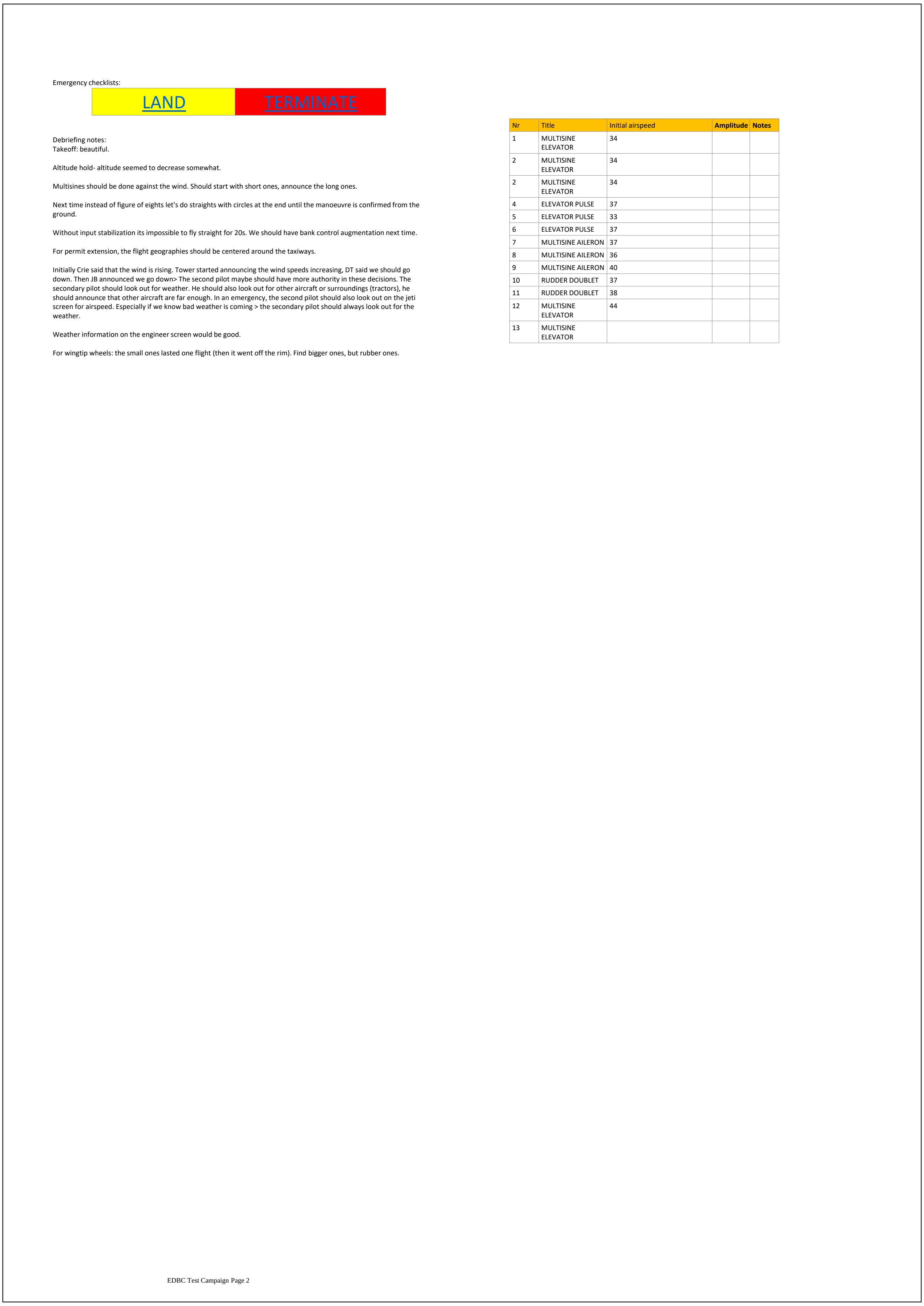
Test points:

ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	Altitude hold as well
ENGINEER	CONFIRM **OLD** LUT SELECTED	✓	
ENGINEER	CONFIRM **HIGH** GAIN SELECTED	✓	PARAMETER = 2 19 17
	Take-off		
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1, FLEXOP 2	Engine **ON**	* ✓	19 18
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 150	✓	At 30m AGL
	Augmented mode check		
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	SWITCH AUTOPILOT 2	✓	This is augmented mode + ALT HOLD
FLEXOP 1	SWITCH AUTOPILOT 1	✓	✓
	Manoeuvre inputs		
See table right			
	Landing	**6.4kg**	
FLEXOP 1	PREPARE FOR LANDING	*	
FLEXOP 1	FLIGHT STATE LANDING		If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

	PLAN B - Pushover-pull-up		
FLEXOP 1	TRIM 35m/s		
ENGINEER	STANDBY TO REPORT LOAD FACTOR		
OPERATOR	STANDBY TO REPORT AIRSPEED		At 35m/s - PUSH DOWN PUSH DOWN At 40m/s - PULL UP PULL UP At 35m/s - LEVEL OUT LEVEL OUT
FLEXOP 1	PUSHOVER-PULLUP		Slightly pull-up to decelerate till 35m/s, then push down -30deg pitch until 45m/s, then pull-up until + 30deg pitch, then level out.
ENGINEER	REPORT LOAD FACTOR		
	REPEAT AS REQUIRED		
1	HIGHEST SPEED:		LOAD FACTOR:
2	HIGHEST SPEED:		LOAD FACTOR:
3	HIGHEST SPEED:		LOAD FACTOR:
4	HIGHEST SPEED:		LOAD FACTOR:
5	HIGHEST SPEED:		LOAD FACTOR:
6	HIGHEST SPEED:		LOAD FACTOR:

	Nr	Title	Initial airspeed	Amplitude	Notes	
1	1	MULTISINE RUDDER	34	0.5	(multisine elevator actually)	✓
2	2	MULTISINE RUDDER	34	0.5	(multisine elevator actually)	TURNS LEFT
3	3	MULTISINE RUDDER	34	0.5	(multisine elevator actually)	
	4					
	5					
4	6	ELEVATOR PULSE	37	0.5		
5	7	ELEVATOR PULSE	33	0.5		✓
6	8	ELEVATOR PULSE	37			
	9					
	10					
7	11	MULTISINE AILERON	37			
8	12	MULTISINE AILERON	36			
9	13	MULTISINE AILERON	40			
	14					
	15					
	16					
10	17	Rudder doublet	37			
11		R Doublet	38			
12		MULTI EL	44			
13		MULTI EL				
14		?				

EDBC Test Campaign Page 1



Emergency checklists:

LAND	TERMINATE

Debriefing notes:
Takeoff: beautiful.

Altitude hold- altitude seemed to decrease somewhat.

Multisines should be done against the wind. Should start with short ones, announce the long ones.

Next time instead of figure of eights let's do straights with circles at the end until the manoeuvre is confirmed from the ground.

Without input stabilization its impossible to fly straight for 20s. We should have bank control augmentation next time.

For permit extension, the flight geographies should be centered around the taxiways.

Initially Crie said that the wind is rising. Tower started announcing the wind speeds increasing, DT said we should go down. Then JB announced we go down> The second pilot maybe should have more authority in these decisions. The secondary pilot should look out for weather. He should also look out for other aircraft or surroundings (tractors), he should announce that other aircraft are far enough. In an emergency, the second pilot should also look out on the jeti screen for airspeed. Especially if we know bad weather is coming > the secondary pilot should always look out for the weather.

Weather information on the engineer screen would be good.

For wingtip wheels: the small ones lasted one flight (then it went off the rim). Find bigger ones, but rubber ones.

Nr	Title	Initial airspeed	**Amplitude**	**Notes**
1	MULTISINE ELEVATOR	34		
2	MULTISINE ELEVATOR	34		
2	MULTISINE ELEVATOR	34		
4	ELEVATOR PULSE	37		
5	ELEVATOR PULSE	33		
6	ELEVATOR PULSE	37		
7	MULTISINE AILERON	37		
8	MULTISINE AILERON	36		
9	MULTISINE AILERON	40		
10	RUDDER DOUBLET	37		
11	RUDDER DOUBLET	38		
12	MULTISINE ELEVATOR	44		
13	MULTISINE ELEVATOR			

EDBC Test Campaign Page 2

PT1

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC August

Day header:

Test Title	Pilot Training 1
Date	
Engine start/stop time	11 18 1137
METAR (EDMO)	
METAR (EDBC)	05 07 kt
Crew:	
Pilot-in-Command (FLEXOP 1)	Thomas Seren
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Mateen Javad
Flight Test Engineer (ENGINEER)	Thando Sissing
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 wing
Zero fuel mass, kg	
Take-off mass, kg	
Fuel, kg	7.23kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	
Limitations	V_min = 25m/s V_max = 60m/s V_flaps = 35m/s V_min_flaps = 20m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is (26)34-70m/s, cruise flight state. Landing is started when 6.2kg of fuel is used.

Test points:

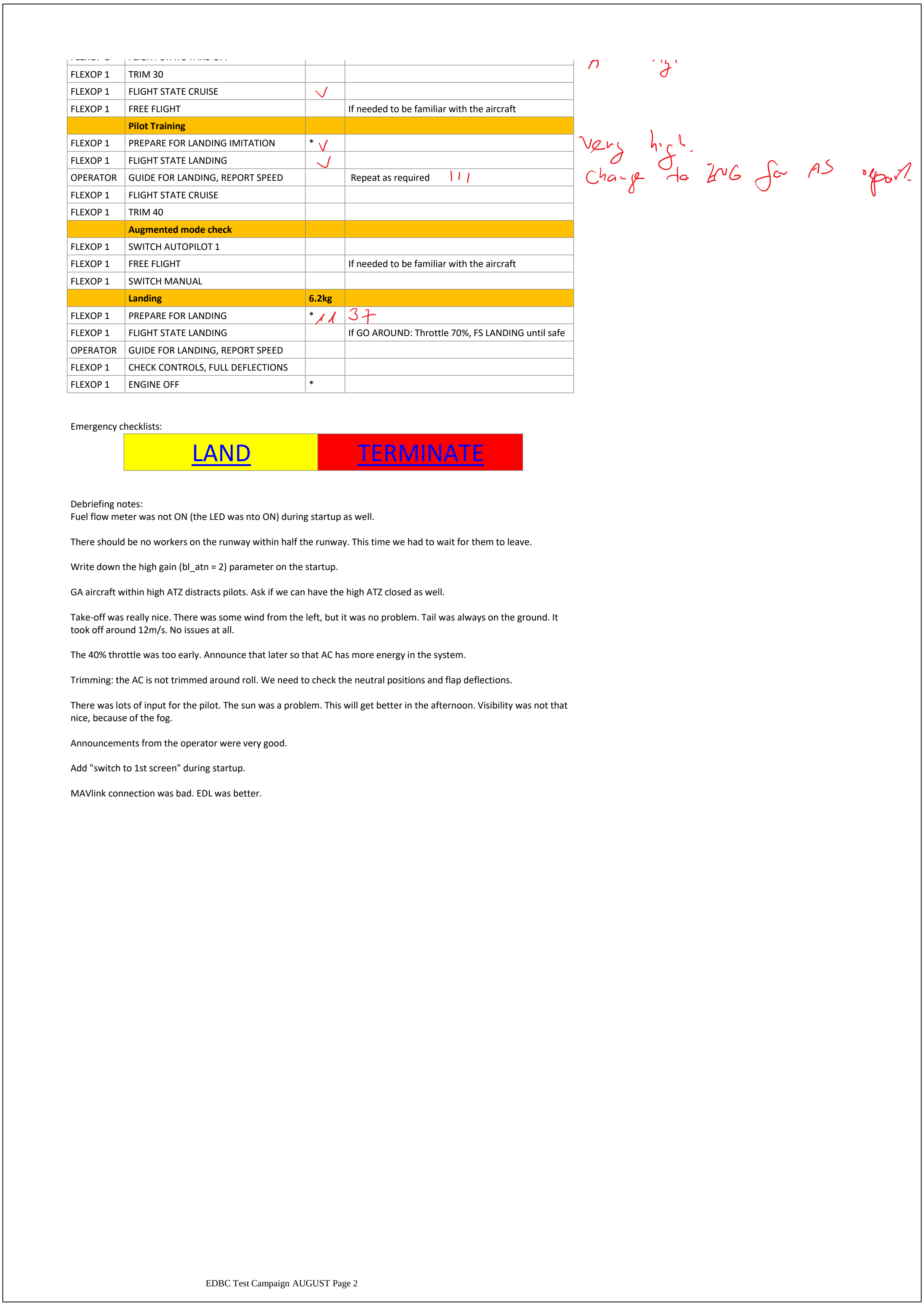
ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **OLD** LUT SELECTED	✓	
ENGINEER	CONFIRM **HIGH** GAIN SELECTED	✓	PARAMETER = 2
	Take-off		
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1, FLEXOP 2	Engine **ON**	*11 18	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
ENGINEER	STANDBY TO ANNOUNCE AIRSPEEDS AND TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 40%, CLIMB 200	✓	At 30m AGL
	Trim check		
FLEXOP 1	TRIM 30	✓	
FLEXOP 1	FLIGHT STATE LANDING	✓	
FLEXOP 1	TRIM 30	✓	
FLEXOP 1	FLIGHT STATE TAKE-OFF		
FLEXOP 1	TRIM 30		
FLEXOP 1	FLIGHT STATE CRUISE	✓	
FLEXOP 1	FREE FLIGHT		If needed to be familiar with the aircraft

Note TO and LA times

06 03

AC turns left.

AC turns right
AC right



FLEXOP 1	TRIM 30		
FLEXOP 1	FLIGHT STATE CRUISE	✓	
FLEXOP 1	FREE FLIGHT		If needed to be familiar with the aircraft
	Pilot Training		
FLEXOP 1	PREPARE FOR LANDING IMITATION	* ✓	
FLEXOP 1	FLIGHT STATE LANDING	✓	
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		Repeat as required III
FLEXOP 1	FLIGHT STATE CRUISE		
FLEXOP 1	TRIM 40		
	Augmented mode check		
FLEXOP 1	SWITCH AUTOPILOT 1		
FLEXOP 1	FREE FLIGHT		If needed to be familiar with the aircraft
FLEXOP 1	SWITCH MANUAL		
	Landing	**6.2kg**	
FLEXOP 1	PREPARE FOR LANDING	* 11	37
FLEXOP 1	FLIGHT STATE LANDING		If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

Very high.
Change to ING for AS report.

Emergency checklists:

🟨 LAND	🟥 TERMINATE

Debriefing notes:
Fuel flow meter was not ON (the LED was nto ON) during startup as well.

There should be no workers on the runway within half the runway. This time we had to wait for them to leave.

Write down the high gain (bl_atn = 2) parameter on the startup.

GA aircraft within high ATZ distracts pilots. Ask if we can have the high ATZ closed as well.

Take-off was really nice. There was some wind from the left, but it was no problem. Tail was always on the ground. It took off around 12m/s. No issues at all.

The 40% throttle was too early. Announce that later so that AC has more energy in the system.

Trimming: the AC is not trimmed around roll. We need to check the neutral positions and flap deflections.

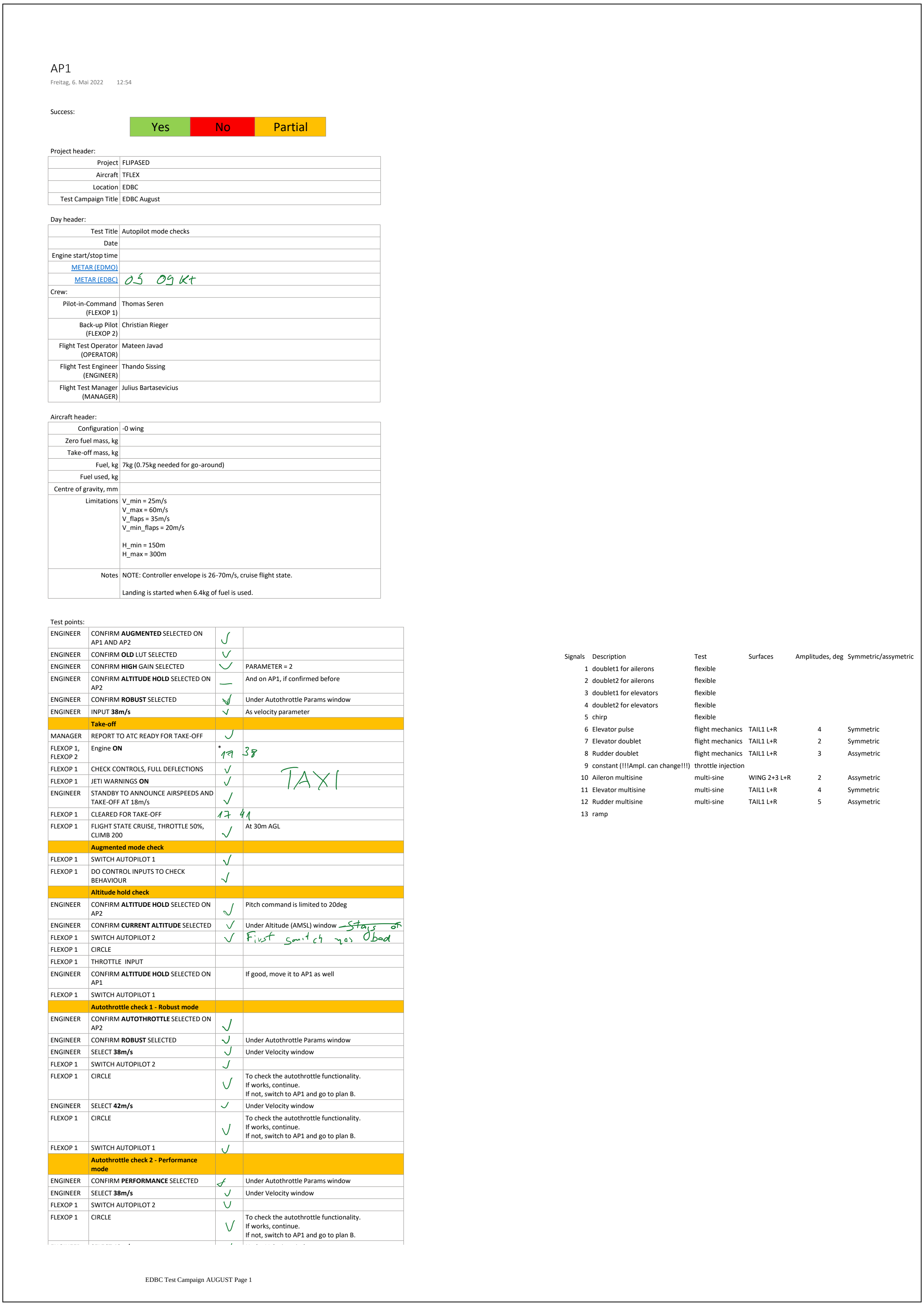
There was lots of input for the pilot. The sun was a problem. This will get better in the afternoon. Visibility was not that nice, because of the fog.

Announcements from the operator were very good.

Add "switch to 1st screen" during startup.

MAVlink connection was bad. EDL was better.

EDBC Test Campaign AUGUST Page 2



AP1

Freitag, 6. Mai 2022 12:54

Success:

Yes No Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC August

Day header:

Test Title	Autopilot mode checks
Date	
Engine start/stop time	
METAR (EDMO)	
METAR (EDBC)	05 09 Kt
Crew:	
Pilot-in-Command (FLEXOP 1)	Thomas Seren
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Mateen Javad
Flight Test Engineer (ENGINEER)	Thando Sissing
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

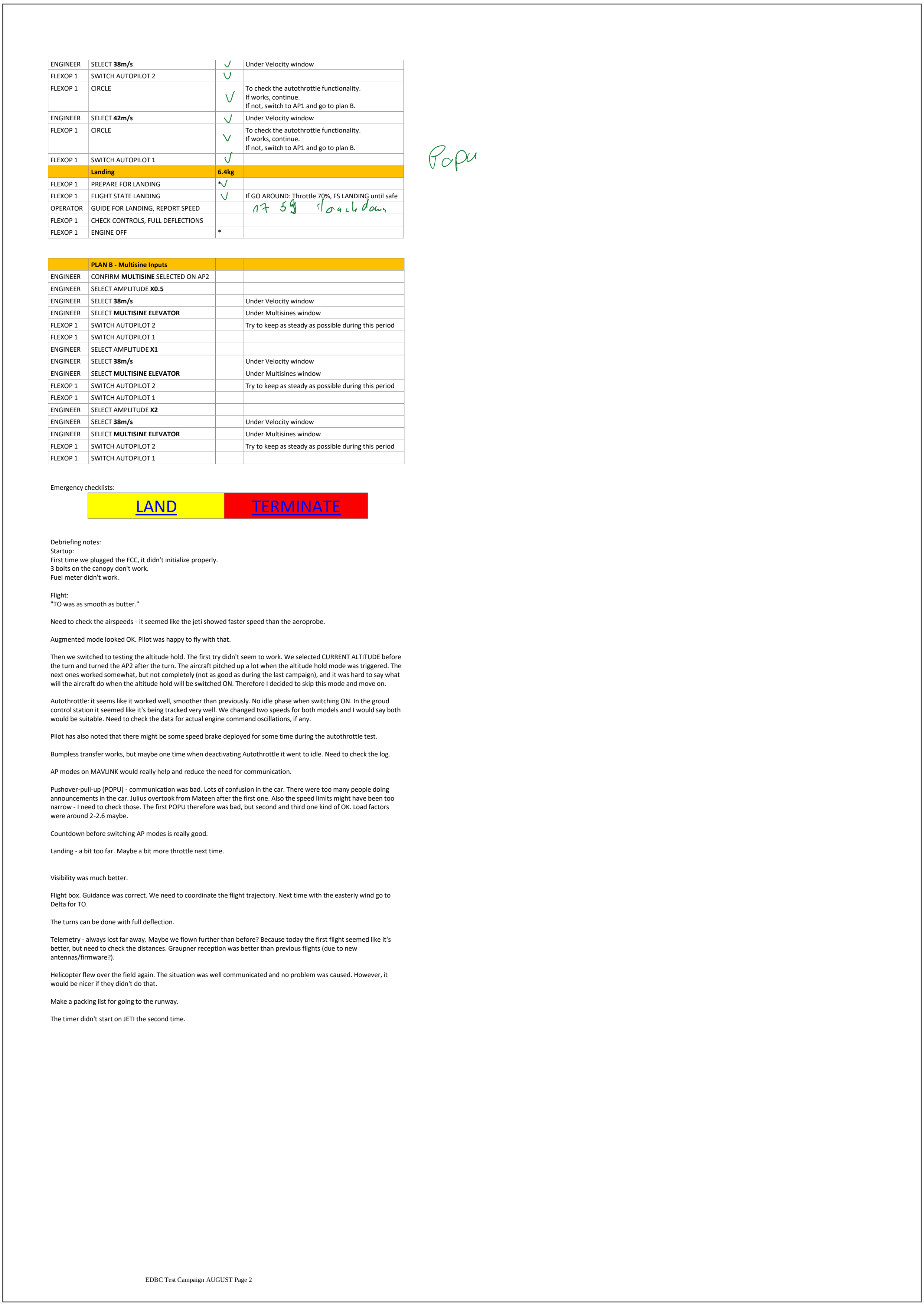
Configuration	-0 wing
Zero fuel mass, kg	
Take-off mass, kg	
Fuel, kg	7kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	
Limitations	V_min = 25m/s V_max = 60m/s V_flaps = 35m/s V_min_flaps = 20m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Landing is started when 6.4kg of fuel is used.

Test points:

ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **OLD** LUT SELECTED	✓	
ENGINEER	CONFIRM **HIGH** GAIN SELECTED	✓	PARAMETER = 2
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2	—	And on AP1, if confirmed before
ENGINEER	CONFIRM **ROBUST** SELECTED	✓	Under Autothrottle Params window
ENGINEER	INPUT **38m/s**	✓	As velocity parameter
	Take-off		
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1, FLEXOP 2	Engine **ON**	*17 38	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	TAXI
FLEXOP 1	JETI WARNINGS **ON**	✓	
ENGINEER	STANDBY TO ANNOUNCE AIRSPEEDS AND TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	17 41	
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 50%, CLIMB 200	✓	At 30m AGL
	Augmented mode check		
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
FLEXOP 1	DO CONTROL INPUTS TO CHECK BEHAVIOUR	✓	
	Altitude hold check		
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2	✓	Pitch command is limited to 20deg
ENGINEER	CONFIRM **CURRENT ALTITUDE** SELECTED	✓	Under Altitude (AMSL) window — Stays on
FLEXOP 1	SWITCH AUTOPILOT 2	✓	First switch was bad
FLEXOP 1	CIRCLE		
FLEXOP 1	THROTTLE INPUT		
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP1		If good, move it to AP1 as well
FLEXOP 1	SWITCH AUTOPILOT 1		
	Autothrottle check 1 - Robust mode		
ENGINEER	CONFIRM **AUTOTHROTTLE** SELECTED ON AP2	✓	
ENGINEER	CONFIRM **ROBUST** SELECTED	✓	Under Autothrottle Params window
ENGINEER	SELECT **38m/s**	✓	Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 2	✓	
FLEXOP 1	CIRCLE	✓	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
ENGINEER	SELECT **42m/s**	✓	Under Velocity window
FLEXOP 1	CIRCLE	✓	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
	Autothrottle check 2 - Performance mode		
ENGINEER	CONFIRM **PERFORMANCE** SELECTED	✓	Under Autothrottle Params window
ENGINEER	SELECT **38m/s**	✓	Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 2	✓	
FLEXOP 1	CIRCLE	✓	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.

Signals	Description	Test	Surfaces	Amplitudes, deg	Symmetric/assymetric
1	doublet1 for ailerons	flexible			
2	doublet2 for ailerons	flexible			
3	doublet1 for elevators	flexible			
4	doublet2 for elevators	flexible			
5	chirp	flexible			
6	Elevator pulse	flight mechanics	TAIL1 L+R	4	Symmetric
7	Elevator doublet	flight mechanics	TAIL1 L+R	2	Symmetric
8	Rudder doublet	flight mechanics	TAIL1 L+R	3	Assymetric
9	constant (!!!Ampl. can change!!!)	throttle injection			
10	Aileron multisine	multi-sine	WING 2+3 L+R	2	Assymetric
11	Elevator multisine	multi-sine	TAIL1 L+R	4	Symmetric
12	Rudder multisine	multi-sine	TAIL1 L+R	5	Assymetric
13	ramp				

EDBC Test Campaign AUGUST Page 1



ENGINEER	SELECT **38m/s**	✓	Under Velocity window
FLEXOP 1	SWITCH AUTOPILOT 2	✓	
FLEXOP 1	CIRCLE	✓	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
ENGINEER	SELECT **42m/s**	✓	Under Velocity window
FLEXOP 1	CIRCLE	✓	To check the autothrottle functionality. If works, continue. If not, switch to AP1 and go to plan B.
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
	Landing	**6.4kg**	
FLEXOP 1	PREPARE FOR LANDING	*✓	
FLEXOP 1	FLIGHT STATE LANDING	✓	If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		17 59 Touchdown
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

Popu

	PLAN B - Multisine Inputs		
ENGINEER	CONFIRM **MULTISINE** SELECTED ON AP2		
ENGINEER	SELECT AMPLITUDE **X0.5**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		
ENGINEER	SELECT AMPLITUDE **X1**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		
ENGINEER	SELECT AMPLITUDE **X2**		
ENGINEER	SELECT **38m/s**		Under Velocity window
ENGINEER	SELECT **MULTISINE ELEVATOR**		Under Multisines window
FLEXOP 1	SWITCH AUTOPILOT 2		Try to keep as steady as possible during this period
FLEXOP 1	SWITCH AUTOPILOT 1		

Emergency checklists:

LAND	TERMINATE

Debriefing notes:
Startup:
First time we plugged the FCC, it didn't initialize properly.
3 bolts on the canopy don't work.
Fuel meter didn't work.

Flight:
"TO was as smooth as butter."

Need to check the airspeeds - it seemed like the jeti showed faster speed than the aeroprobe.

Augmented mode looked OK. Pilot was happy to fly with that.

Then we switched to testing the altitude hold. The first try didn't seem to work. We selected CURRENT ALTITUDE before the turn and turned the AP2 after the turn. The aircraft pitched up a lot when the altitude hold mode was triggered. The next ones worked somewhat, but not completely (not as good as during the last campaign), and it was hard to say what will the aircraft do when the altitude hold will be switched ON. Therefore I decided to skip this mode and move on.

Autothrottle: it seems like it worked well, smoother than previously. No idle phase when switching ON. In the groud control station it seemed like it's being tracked very well. We changed two speeds for both models and I would say both would be suitable. Need to check the data for actual engine command oscillations, if any.

Pilot has also noted that there might be some speed brake deployed for some time during the autothrottle test.

Bumpless transfer works, but maybe one time when deactivating Autothrottle it went to idle. Need to check the log.

AP modes on MAVLINK would really help and reduce the need for communication.

Pushover-pull-up (POPU) - communication was bad. Lots of confusion in the car. There were too many people doing announcements in the car. Julius overtook from Mateen after the first one. Also the speed limits might have been too narrow - I need to check those. The first POPU therefore was bad, but second and third one kind of OK. Load factors were around 2-2.6 maybe.

Countdown before switching AP modes is really good.

Landing - a bit too far. Maybe a bit more throttle next time.

Visibility was much better.

Flight box. Guidance was correct. We need to coordinate the flight trajectory. Next time with the easterly wind go to Delta for TO.

The turns can be done with full deflection.

Telemetry - always lost far away. Maybe we flown further than before? Because today the first flight seemed like it's better, but need to check the distances. Graupner reception was better than previous flights (due to new antennas/firmware?).

Helicopter flew over the field again. The situation was well communicated and no problem was caused. However, it would be nicer if they didn't do that.

Make a packing list for going to the runway.

The timer didn't start on JETI the second time.

MAN1

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC August

Day header:

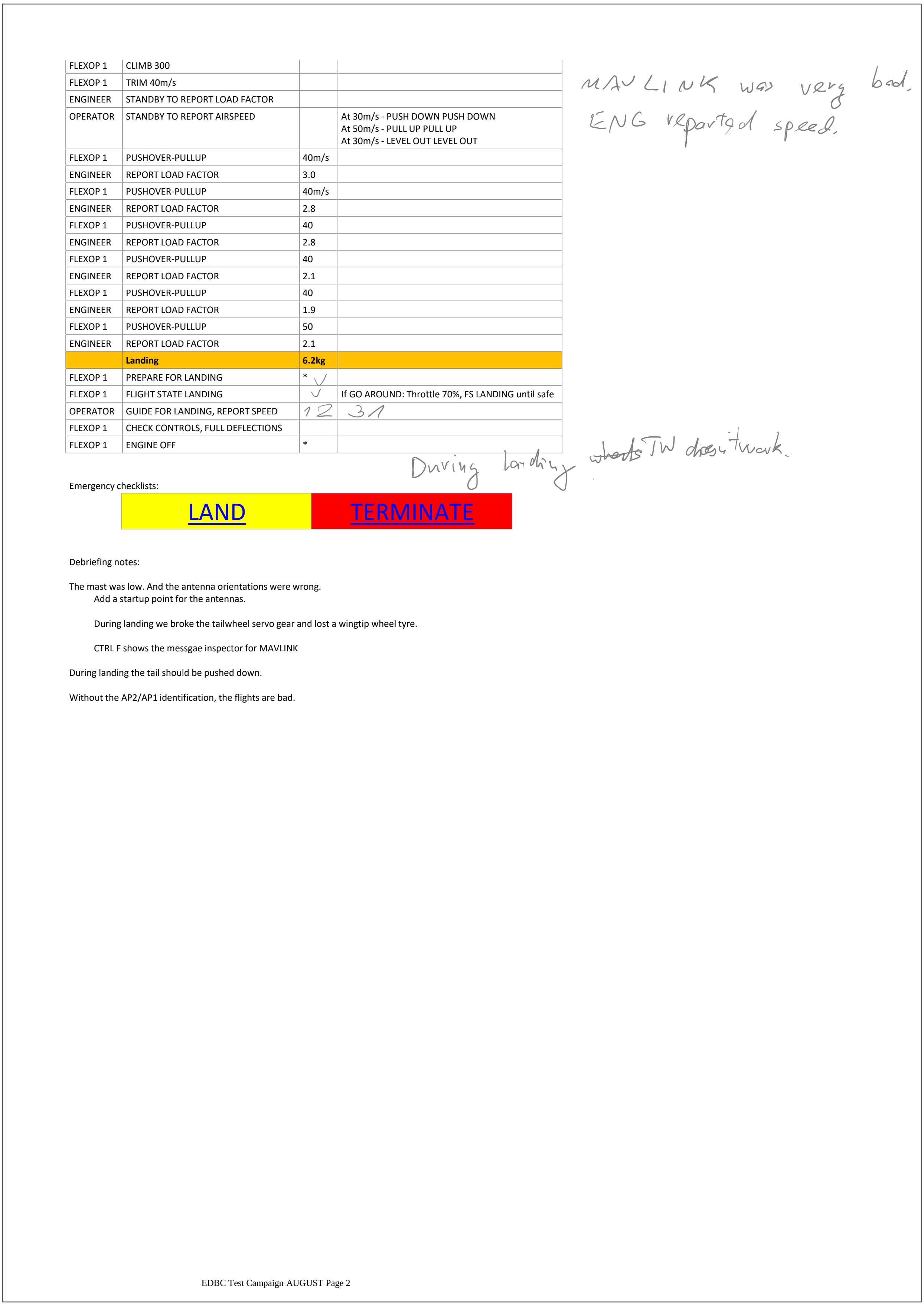
Test Title	Pushover pulllups and engine effects
Date	
Engine start/stop time	
METAR (EDMO)	
METAR (EDBC)	
Crew:	
Pilot-in-Command (FLEXOP 1)	Thomas Seren
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Mateen Javad
Flight Test Engineer (ENGINEER)	Thando Sissing
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 wing
Zero fuel mass, kg	
Take-off mass, kg	
Fuel, kg	7kg (0.75kg needed for go-around)
Fuel used, kg	5131g (EDL) 4819 (refuel weight)
Centre of gravity, mm	
Limitations	V_min = 25m/s V_max = 60m/s V_flaps = 35m/s V_min_flaps = 20m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Landing is started when 6.4kg of fuel is used.

Test points:

~~ENGINEER~~	~~CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2~~		
~~ENGINEER~~	~~CONFIRM **OLD** LUT SELECTED~~		
~~ENGINEER~~	~~CONFIRM **HIGH** GAIN SELECTED~~		~~bl_atn = 2~~
	Take-off		
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1, FLEXOP 2	Engine **ON**	*12	12
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
ENGINEER	STANDBY TO ANNOUNCE AIRSPEEDS AND TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	12 15
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 50%, CLIMB 200	✓	At 30m AGL
	Engine effect check		
~~FLEXOP 1~~	~~Airbrakes ON~~		
~~ENGINEER~~	~~THROTTLE UP 10%~~		~~Hold 5s~~
~~FLEXOP 1~~	~~Airbrakes OFF, Throttle down 10%~~		
~~FLEXOP 1~~	~~TRIM 50~~		
~~FLEXOP 1~~	~~Airbrakes ON~~		
~~ENGINEER~~	~~THROTTLE UP 25%~~		~~Hold 5s~~
~~FLEXOP 1~~	~~Airbrakes OFF, Throttle down 25%~~		
	Pushover pull-ups		



FLEXOP 1	CLIMB 300		
FLEXOP 1	TRIM 40m/s		
ENGINEER	STANDBY TO REPORT LOAD FACTOR		
OPERATOR	STANDBY TO REPORT AIRSPEED		At 30m/s - PUSH DOWN PUSH DOWN At 50m/s - PULL UP PULL UP At 30m/s - LEVEL OUT LEVEL OUT
FLEXOP 1	PUSHOVER-PULLUP	40m/s	
ENGINEER	REPORT LOAD FACTOR	3.0	
FLEXOP 1	PUSHOVER-PULLUP	40m/s	
ENGINEER	REPORT LOAD FACTOR	2.8	
FLEXOP 1	PUSHOVER-PULLUP	40	
ENGINEER	REPORT LOAD FACTOR	2.8	
FLEXOP 1	PUSHOVER-PULLUP	40	
ENGINEER	REPORT LOAD FACTOR	2.1	
FLEXOP 1	PUSHOVER-PULLUP	40	
ENGINEER	REPORT LOAD FACTOR	1.9	
FLEXOP 1	PUSHOVER-PULLUP	50	
ENGINEER	REPORT LOAD FACTOR	2.1	
	Landing	**6.2kg**	
FLEXOP 1	PREPARE FOR LANDING	* ✓	
FLEXOP 1	FLIGHT STATE LANDING	✓	If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED	12	31
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

MAVLINK was very bad.
ENG reported speed.

During landing ~~wheels~~ TW doesn't work.

Emergency checklists:

LAND	TERMINATE

Debriefing notes:

The mast was low. And the antenna orientations were wrong.
Add a startup point for the antennas.

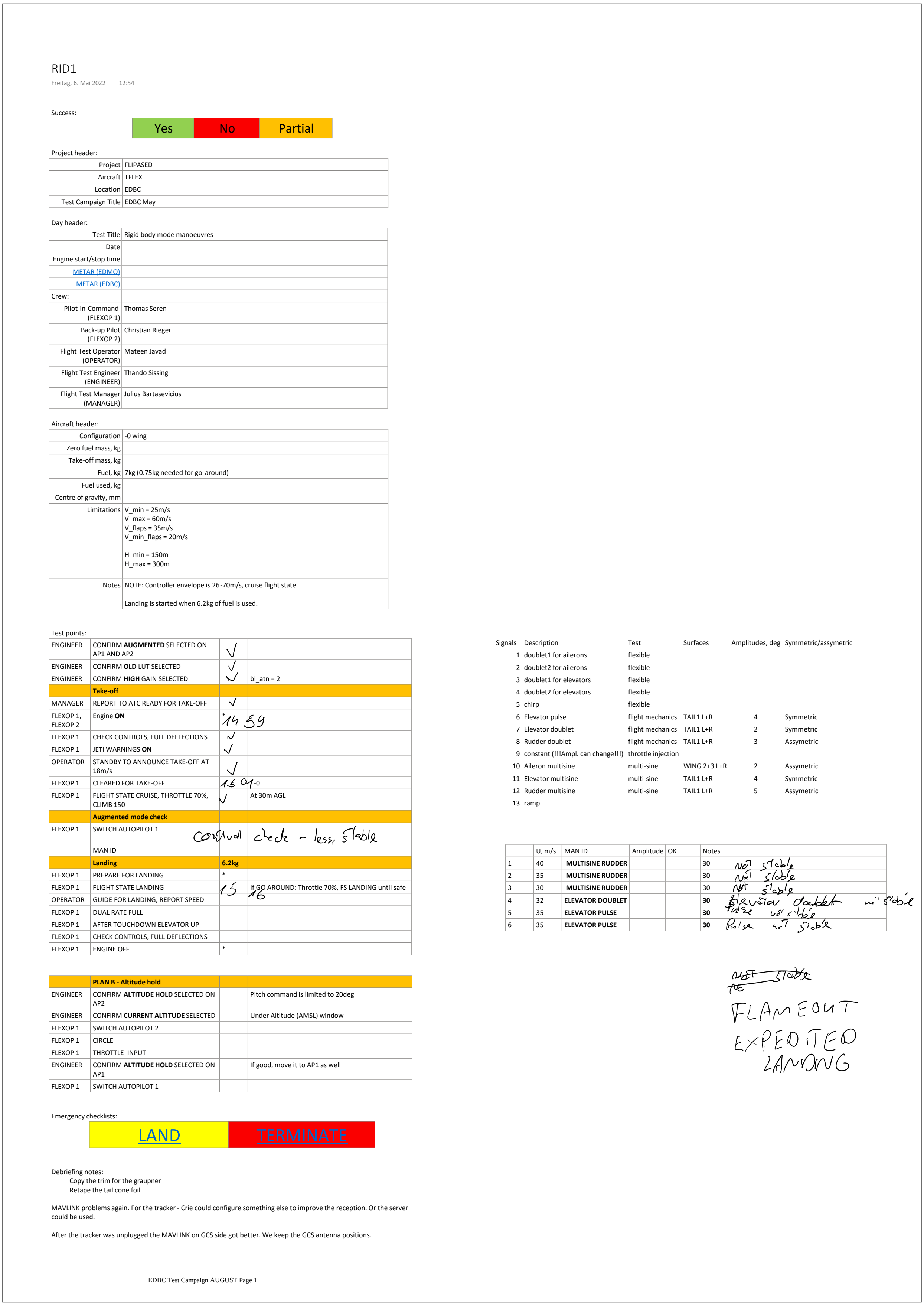
During landing we broke the tailwheel servo gear and lost a wingtip wheel tyre.

CTRL F shows the messgae inspector for MAVLINK

During landing the tail should be pushed down.

Without the AP2/AP1 identification, the flights are bad.

EDBC Test Campaign AUGUST Page 2



RID1

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Rigid body mode manoeuvres
Date	
Engine start/stop time	
METAR (EDMO)	
METAR (EDBC)	
Crew:	
Pilot-in-Command (FLEXOP 1)	Thomas Seren
Back-up Pilot (FLEXOP 2)	Christian Rieger
Flight Test Operator (OPERATOR)	Mateen Javad
Flight Test Engineer (ENGINEER)	Thando Sissing
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 wing
Zero fuel mass, kg	
Take-off mass, kg	
Fuel, kg	7kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	
Limitations	V_min = 25m/s V_max = 60m/s V_flaps = 35m/s V_min_flaps = 20m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Landing is started when 6.2kg of fuel is used.

Test points:

ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **OLD** LUT SELECTED	✓	
ENGINEER	CONFIRM **HIGH** GAIN SELECTED	✓	bl_atn = 2
	Take-off		
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1, FLEXOP 2	Engine **ON**	* 14 59	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	15 01-0	
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 150	✓	At 30m AGL
	Augmented mode check		
FLEXOP 1	SWITCH AUTOPILOT 1	control	check - less stable
	MAN ID		
	Landing	**6.2kg**	
FLEXOP 1	PREPARE FOR LANDING	*	
FLEXOP 1	FLIGHT STATE LANDING	15	If GO AROUND: Throttle 70%, FS LANDING until safe 16
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
FLEXOP 1	DUAL RATE FULL		
FLEXOP 1	AFTER TOUCHDOWN ELEVATOR UP		
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

	PLAN B - Altitude hold		
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP2		Pitch command is limited to 20deg
ENGINEER	CONFIRM **CURRENT ALTITUDE** SELECTED		Under Altitude (AMSL) window
FLEXOP 1	SWITCH AUTOPILOT 2		
FLEXOP 1	CIRCLE		
FLEXOP 1	THROTTLE INPUT		
ENGINEER	CONFIRM **ALTITUDE HOLD** SELECTED ON AP1		If good, move it to AP1 as well
FLEXOP 1	SWITCH AUTOPILOT 1		

Emergency checklists:

LAND	TERMINATE

Signals	Description	Test	Surfaces	Amplitudes, deg	Symmetric/assymetric
1	doublet1 for ailerons	flexible			
2	doublet2 for ailerons	flexible			
3	doublet1 for elevators	flexible			
4	doublet2 for elevators	flexible			
5	chirp	flexible			
6	Elevator pulse	flight mechanics	TAIL1 L+R	4	Symmetric
7	Elevator doublet	flight mechanics	TAIL1 L+R	2	Symmetric
8	Rudder doublet	flight mechanics	TAIL1 L+R	3	Assymetric
9	constant (!!!Ampl. can change!!!)	throttle injection			
10	Aileron multisine	multi-sine	WING 2+3 L+R	2	Assymetric
11	Elevator multisine	multi-sine	TAIL1 L+R	4	Symmetric
12	Rudder multisine	multi-sine	TAIL1 L+R	5	Assymetric
13	ramp				

	U, m/s	MAN ID	Amplitude	OK	Notes
1	40	**MULTISINE RUDDER**			30 Not stable
2	35	**MULTISINE RUDDER**			30 Not stable
3	30	**MULTISINE RUDDER**			30 Not stable
4	32	**ELEVATOR DOUBLET**			**30** Elevator doublet not stable
5	35	**ELEVATOR PULSE**			**30** Pulse not stable
6	35	**ELEVATOR PULSE**			**30** Pulse not stable

~~Not stable~~
~~No~~

FLAMEOUT
EXPEDITED
LANDING

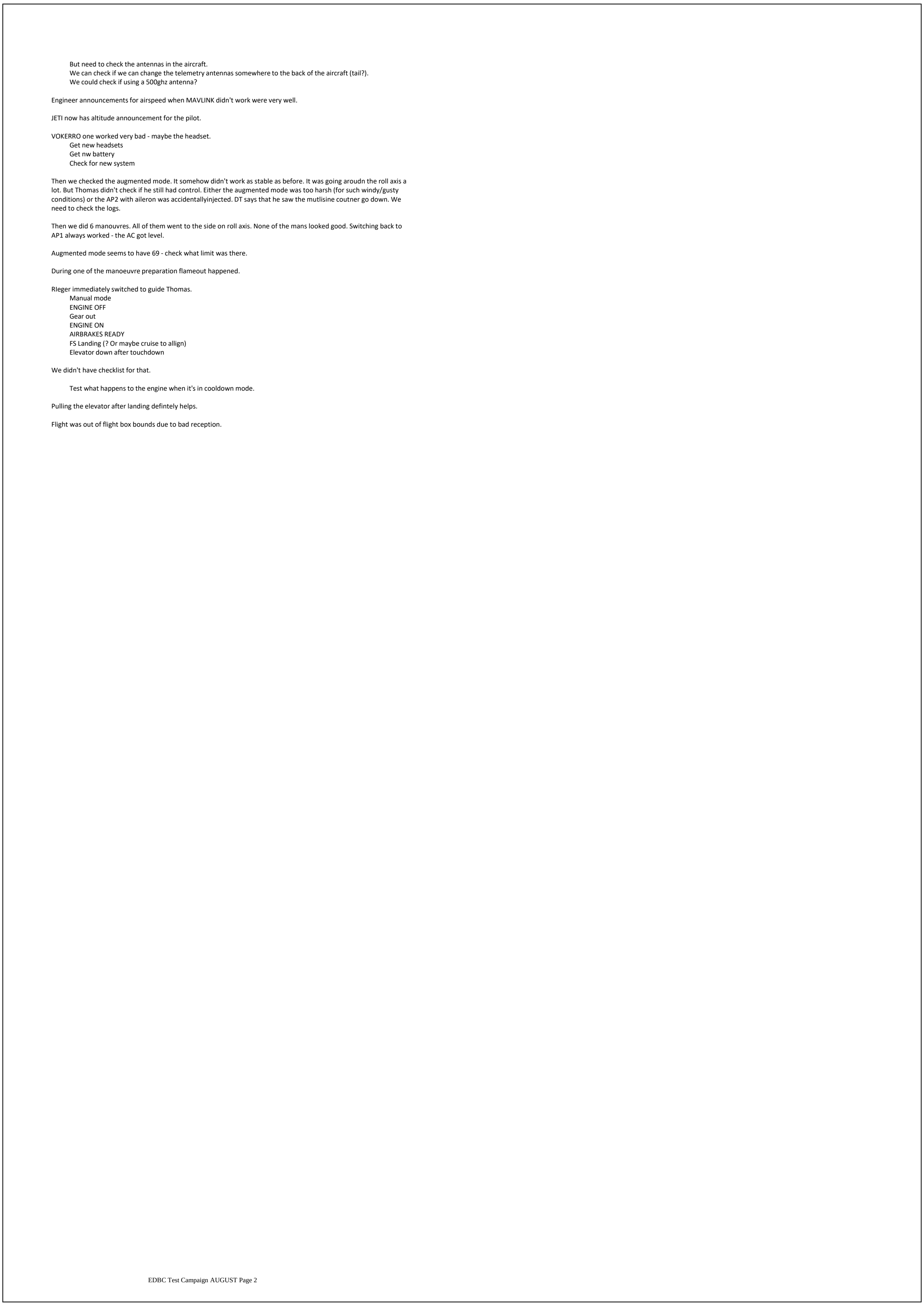
Debriefing notes:

Copy the trim for the graupner
Retape the tail cone foil

MAVLINK problems again. For the tracker - Crie could configure something else to improve the reception. Or the server could be used.

After the tracker was unplugged the MAVLINK on GCS side got better. We keep the GCS antenna positions.

EDBC Test Campaign AUGUST Page 1



But need to check the antennas in the aircraft.
We can check if we can change the telemetry antennas somewhere to the back of the aircraft (tail?).
We could check if using a 500ghz antenna?

Engineer announcements for airspeed when MAVLINK didn't work were very well.

JETI now has altitude announcement for the pilot.

VOKERRO one worked very bad - maybe the headset.
Get new headsets
Get nw battery
Check for new system

Then we checked the augmented mode. It somehow didn't work as stable as before. It was going aroudn the roll axis a lot. But Thomas didn't check if he still had control. Either the augmented mode was too harsh (for such windy/gusty conditions) or the AP2 with aileron was accidentallyinjected. DT says that he saw the mutlisine coutner go down. We need to check the logs.

Then we did 6 manouvres. All of them went to the side on roll axis. None of the mans looked good. Switching back to AP1 always worked - the AC got level.

Augmented mode seems to have 69 - check what limit was there.

During one of the manoeuvre preparation flameout happened.

RIeger immediately switched to guide Thomas.
Manual mode
ENGINE OFF
Gear out
ENGINE ON
AIRBRAKES READY
FS Landing (? Or maybe cruise to allign)
Elevator down after touchdown

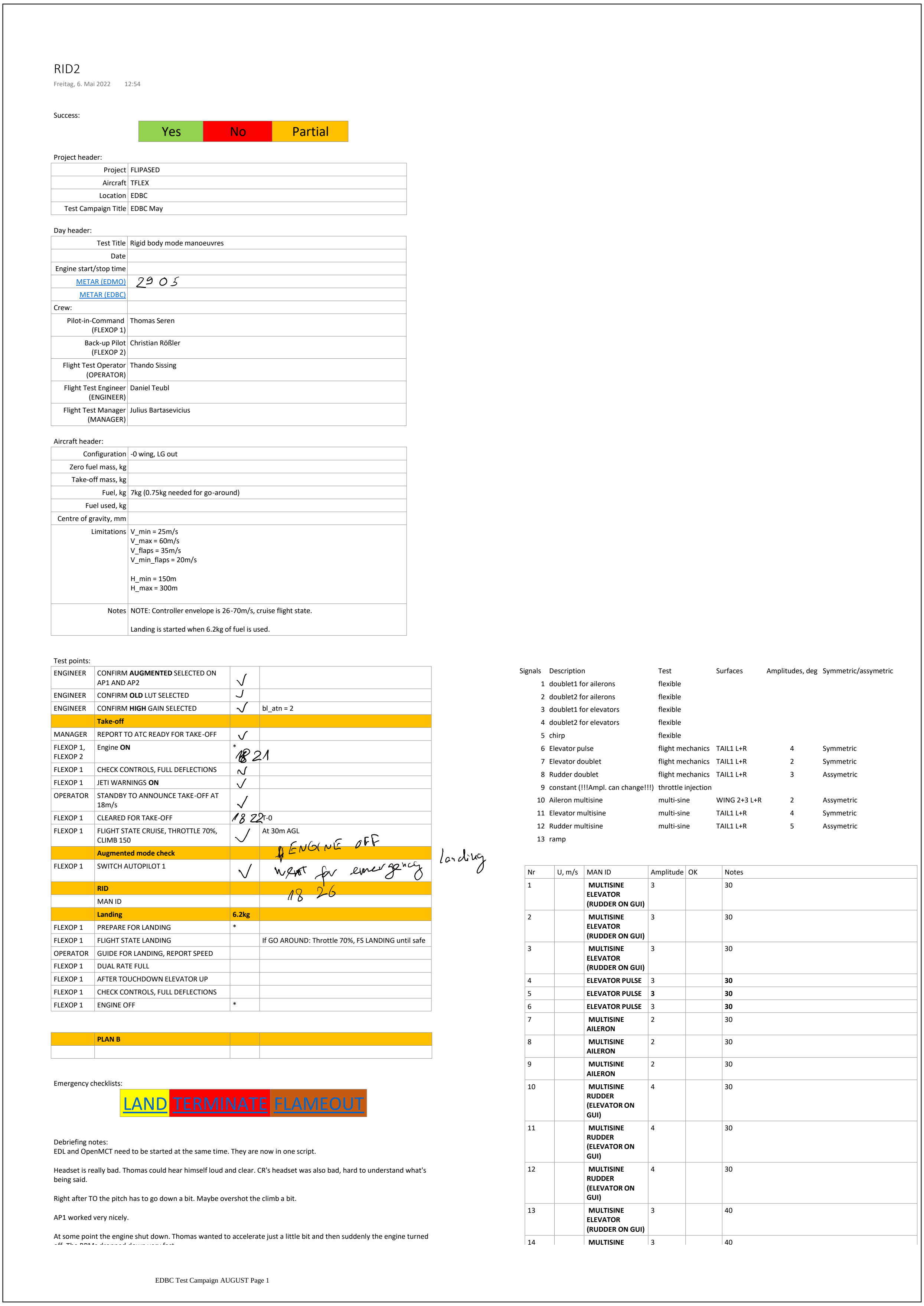
We didn't have checklist for that.

Test what happens to the engine when it's in cooldown mode.

Pulling the elevator after landing defintely helps.

Flight was out of flight box bounds due to bad reception.

EDBC Test Campaign AUGUST Page 2



RID2

Freitag, 6. Mai 2022 12:54

Success:

Yes	No	Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Rigid body mode manoeuvres
Date	
Engine start/stop time	
METAR (EDMO)	29 05
METAR (EDBC)	
Crew:	
Pilot-in-Command (FLEXOP 1)	Thomas Seren
Back-up Pilot (FLEXOP 2)	Christian Rößler
Flight Test Operator (OPERATOR)	Thando Sissing
Flight Test Engineer (ENGINEER)	Daniel Teubl
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 wing, LG out
Zero fuel mass, kg	
Take-off mass, kg	
Fuel, kg	7kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	
Limitations	V_min = 25m/s V_max = 60m/s V_flaps = 35m/s V_min_flaps = 20m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Landing is started when 6.2kg of fuel is used.

Test points:

ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **OLD** LUT SELECTED	✓	
ENGINEER	CONFIRM **HIGH** GAIN SELECTED	✓	bl_atn = 2
	Take-off		
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1, FLEXOP 2	Engine **ON**	* 18 21	
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	18 22	T-0
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB 150	✓	At 30m AGL
	Augmented mode check		ENGINE OFF
FLEXOP 1	SWITCH AUTOPILOT 1	✓	wait for emergency landing
	RID		18 26
	MAN ID		
	Landing	**6.2kg**	
FLEXOP 1	PREPARE FOR LANDING	*	
FLEXOP 1	FLIGHT STATE LANDING		If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
FLEXOP 1	DUAL RATE FULL		
FLEXOP 1	AFTER TOUCHDOWN ELEVATOR UP		
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

	PLAN B		

Emergency checklists:

LAND	TERMINATE	FLAMEOUT

Debriefing notes:
EDL and OpenMCT need to be started at the same time. They are now in one script.

Headset is really bad. Thomas could hear himself loud and clear. CR's headset was also bad, hard to understand what's being said.

Right after TO the pitch has to go down a bit. Maybe overshot the climb a bit.

AP1 worked very nicely.

At some point the engine shut down. Thomas wanted to accelerate just a little bit and then suddenly the engine turned

Signals	Description	Test	Surfaces	Amplitudes, deg	Symmetric/assymetric
1	doublet1 for ailerons	flexible			
2	doublet2 for ailerons	flexible			
3	doublet1 for elevators	flexible			
4	doublet2 for elevators	flexible			
5	chirp	flexible			
6	Elevator pulse	flight mechanics	TAIL1 L+R	4	Symmetric
7	Elevator doublet	flight mechanics	TAIL1 L+R	2	Symmetric
8	Rudder doublet	flight mechanics	TAIL1 L+R	3	Assymetric
9	constant (!!!Ampl. can change!!!)	throttle injection			
10	Aileron multisine	multi-sine	WING 2+3 L+R	2	Assymetric
11	Elevator multisine	multi-sine	TAIL1 L+R	4	Symmetric
12	Rudder multisine	multi-sine	TAIL1 L+R	5	Assymetric
13	ramp				

Nr	U, m/s	MAN ID	Amplitude	OK	Notes
1		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		30
2		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		30
3		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		30
4		**ELEVATOR PULSE**	3		**30**
5		**ELEVATOR PULSE**	**3**		**30**
6		**ELEVATOR PULSE**	3		**30**
7		**MULTISINE AILERON**	2		30
8		**MULTISINE AILERON**	2		30
9		**MULTISINE AILERON**	2		30
10		**MULTISINE RUDDER (ELEVATOR ON GUI)**	4		30
11		**MULTISINE RUDDER (ELEVATOR ON GUI)**	4		30
12		**MULTISINE RUDDER (ELEVATOR ON GUI)**	4		30
13		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		40
14		**MULTISINE**	3		40

EDBC Test Campaign AUGUST Page 1

Right after TO the pitch has to go down a bit. Maybe overshot the climb a bit.

AP1 worked very nicely.

At some point the engine shut down. Thomas wanted to accelerate just a little bit and then suddenly the engine turned off. The RPMs dropped down very fast.

Checking the cabling tomorrow.

OpenMCT worked well. Only fuel flow didn't work.

JB didn't announce the command to restart the engine. Engineer should check for the cooldown phase and announce when it's done.

We should also check what's the best glide ratio.

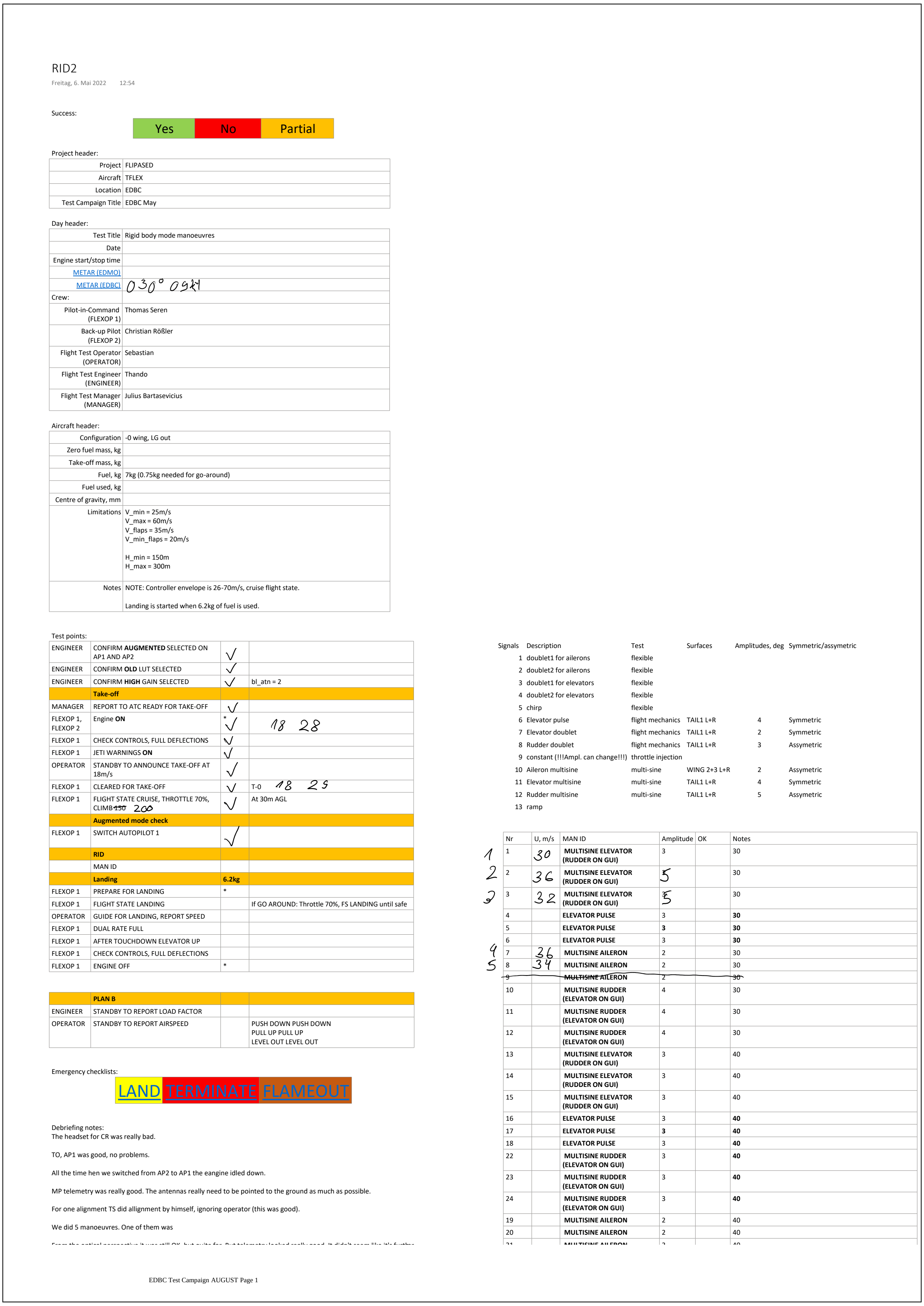
If we are far away, we should definitely try to run the engine again. If we are close and in approach already, then we can skip it.

Tomorrow we should retalk the engine off procedure.

Rudder control was quite nice.

		GUI)			
13		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		40
14		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		40
15		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		40
16		**ELEVATOR PULSE**	3		**40**
17		**ELEVATOR PULSE**	**3**		**40**
18		**ELEVATOR PULSE**	3		**40**
22		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**40**
23		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**40**
24		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**40**
19		**MULTISINE AILERON**	2		40
20		**MULTISINE AILERON**	2		40
21		**MULTISINE AILERON**	2		40
25		**MULTISINE ELEVATOR (RUDDER ON GUI)**	2		50
26		**MULTISINE ELEVATOR (RUDDER ON GUI)**	2		50
27		**MULTISINE ELEVATOR (RUDDER ON GUI)**	2		50
28		**ELEVATOR PULSE**	2		**50**
29		**ELEVATOR PULSE**	**2**		**50**
30		**ELEVATOR PULSE**	2		**50**
31		**MULTISINE AILERON**	2		50
32		**MULTISINE AILERON**	2		50
33		**MULTISINE AILERON**	2		50
34		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**50**
35		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**50**
36		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**50**

EDBC Test Campaign AUGUST Page 2



RID2

Freitag, 6. Mai 2022 12:54

Success:

Yes No Partial

Project header:

Project	FLIPASED
Aircraft	TFLEX
Location	EDBC
Test Campaign Title	EDBC May

Day header:

Test Title	Rigid body mode manoeuvres
Date	
Engine start/stop time	
METAR (EDMO)	
METAR (EDBC)	030° 09kt
Crew:	
Pilot-in-Command (FLEXOP 1)	Thomas Seren
Back-up Pilot (FLEXOP 2)	Christian Rößler
Flight Test Operator (OPERATOR)	Sebastian
Flight Test Engineer (ENGINEER)	Thando
Flight Test Manager (MANAGER)	Julius Bartasevicius

Aircraft header:

Configuration	-0 wing, LG out
Zero fuel mass, kg	
Take-off mass, kg	
Fuel, kg	7kg (0.75kg needed for go-around)
Fuel used, kg	
Centre of gravity, mm	
Limitations	V_min = 25m/s V_max = 60m/s V_flaps = 35m/s V_min_flaps = 20m/s H_min = 150m H_max = 300m
Notes	NOTE: Controller envelope is 26-70m/s, cruise flight state. Landing is started when 6.2kg of fuel is used.

Test points:

ENGINEER	CONFIRM **AUGMENTED** SELECTED ON AP1 AND AP2	✓	
ENGINEER	CONFIRM **OLD** LUT SELECTED	✓	
ENGINEER	CONFIRM **HIGH** GAIN SELECTED	✓	bl_atn = 2
	Take-off		
MANAGER	REPORT TO ATC READY FOR TAKE-OFF	✓	
FLEXOP 1, FLEXOP 2	Engine **ON**	* ✓	18 28
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS	✓	
FLEXOP 1	JETI WARNINGS **ON**	✓	
OPERATOR	STANDBY TO ANNOUNCE TAKE-OFF AT 18m/s	✓	
FLEXOP 1	CLEARED FOR TAKE-OFF	✓	T-0 18 29
FLEXOP 1	FLIGHT STATE CRUISE, THROTTLE 70%, CLIMB ~~150~~ 200	✓	At 30m AGL
	Augmented mode check		
FLEXOP 1	SWITCH AUTOPILOT 1	✓	
	RID		
	MAN ID		
	Landing	**6.2kg**	
FLEXOP 1	PREPARE FOR LANDING	*	
FLEXOP 1	FLIGHT STATE LANDING		If GO AROUND: Throttle 70%, FS LANDING until safe
OPERATOR	GUIDE FOR LANDING, REPORT SPEED		
FLEXOP 1	DUAL RATE FULL		
FLEXOP 1	AFTER TOUCHDOWN ELEVATOR UP		
FLEXOP 1	CHECK CONTROLS, FULL DEFLECTIONS		
FLEXOP 1	ENGINE OFF	*	

	PLAN B		
ENGINEER	STANDBY TO REPORT LOAD FACTOR		
OPERATOR	STANDBY TO REPORT AIRSPEED		PUSH DOWN PUSH DOWN PULL UP PULL UP LEVEL OUT LEVEL OUT

Emergency checklists:

LAND TERMINATE FLAMEOUT

Debriefing notes:
The headset for CR was really bad.

TO, AP1 was good, no problems.

All the time hen we switched from AP2 to AP1 the eangine idled down.

MP telemetry was really good. The antennas really need to be pointed to the ground as much as possible.

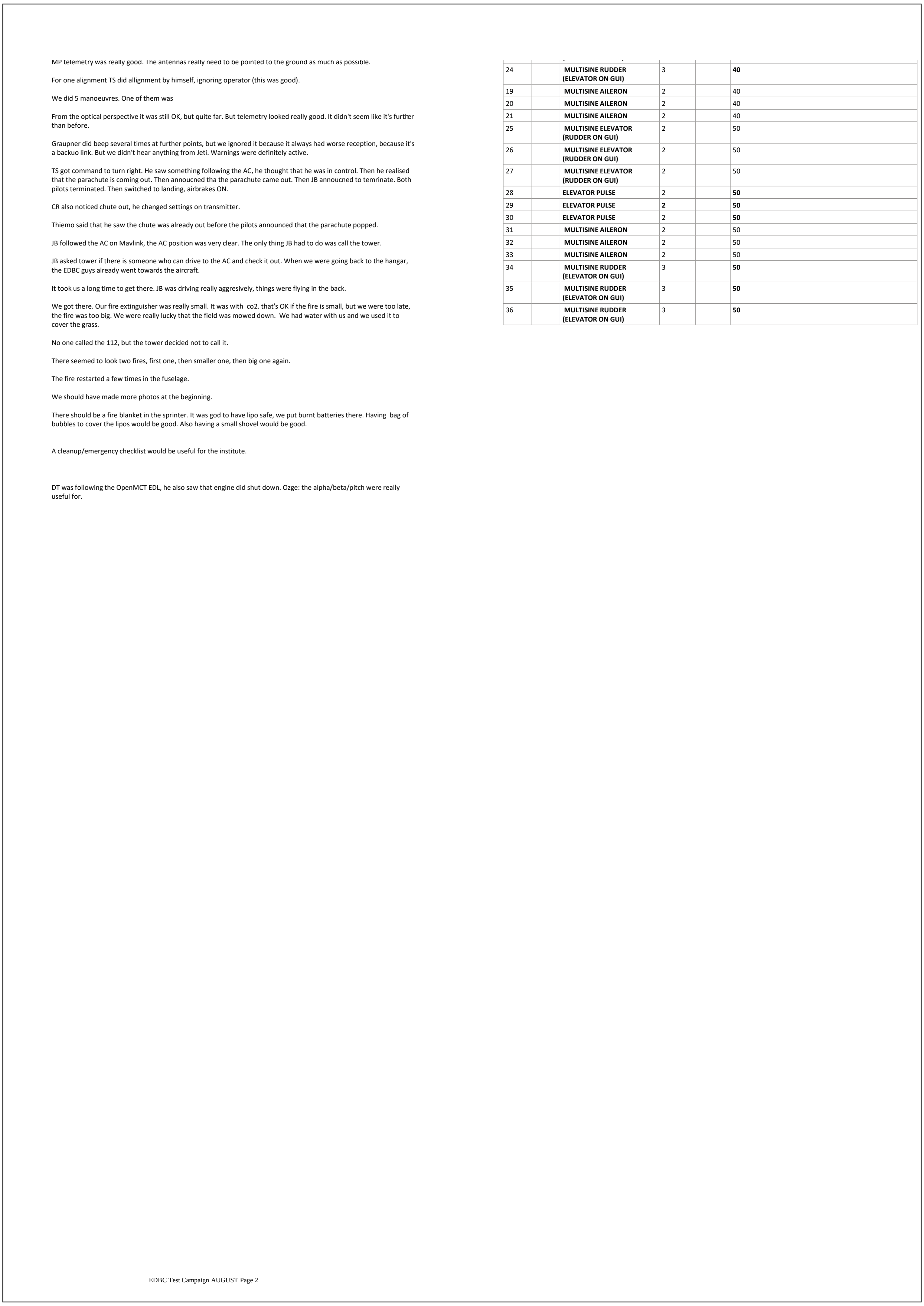
For one alignment TS did allignment by himself, ignoring operator (this was good).

We did 5 manoeuvres. One of them was

Signals	Description	Test	Surfaces	Amplitudes, deg	Symmetric/assymetric
1	doublet1 for ailerons	flexible			
2	doublet2 for ailerons	flexible			
3	doublet1 for elevators	flexible			
4	doublet2 for elevators	flexible			
5	chirp	flexible			
6	Elevator pulse	flight mechanics	TAIL1 L+R	4	Symmetric
7	Elevator doublet	flight mechanics	TAIL1 L+R	2	Symmetric
8	Rudder doublet	flight mechanics	TAIL1 L+R	3	Assymetric
9	constant (!!!Ampl. can change!!!)	throttle injection			
10	Aileron multisine	multi-sine	WING 2+3 L+R	2	Assymetric
11	Elevator multisine	multi-sine	TAIL1 L+R	4	Symmetric
12	Rudder multisine	multi-sine	TAIL1 L+R	5	Assymetric
13	ramp				

	Nr	U, m/s	MAN ID	Amplitude	OK	Notes
1	1	30	**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		30
2	2	36	**MULTISINE ELEVATOR (RUDDER ON GUI)**	~~3~~ 5		30
3	3	32	**MULTISINE ELEVATOR (RUDDER ON GUI)**	~~3~~ 5		30
	4		**ELEVATOR PULSE**	3		**30**
	5		**ELEVATOR PULSE**	**3**		**30**
	6		**ELEVATOR PULSE**	3		**30**
4	7	36	**MULTISINE AILERON**	2		30
5	8	34	**MULTISINE AILERON**	2		30
	~~9~~		~~**MULTISINE AILERON**~~	~~2~~		~~30~~
	10		**MULTISINE RUDDER (ELEVATOR ON GUI)**	4		30
	11		**MULTISINE RUDDER (ELEVATOR ON GUI)**	4		30
	12		**MULTISINE RUDDER (ELEVATOR ON GUI)**	4		30
	13		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		40
	14		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		40
	15		**MULTISINE ELEVATOR (RUDDER ON GUI)**	3		40
	16		**ELEVATOR PULSE**	3		**40**
	17		**ELEVATOR PULSE**	**3**		**40**
	18		**ELEVATOR PULSE**	3		**40**
	22		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**40**
	23		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**40**
	24		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**40**
	19		**MULTISINE AILERON**	2		40
	20		**MULTISINE AILERON**	2		40

EDBC Test Campaign AUGUST Page 1



MP telemetry was really good. The antennas really need to be pointed to the ground as much as possible.

For one alignment TS did allignment by himself, ignoring operator (this was good).

We did 5 manoeuvres. One of them was

From the optical perspective it was still OK, but quite far. But telemetry looked really good. It didn't seem like it's further than before.

Graupner did beep several times at further points, but we ignored it because it always had worse reception, because it's a backuo link. But we didn't hear anything from Jeti. Warnings were definitely active.

TS got command to turn right. He saw something following the AC, he thought that he was in control. Then he realised that the parachute is coming out. Then annoucned tha the parachute came out. Then JB annoucned to temrinate. Both pilots terminated. Then switched to landing, airbrakes ON.

CR also noticed chute out, he changed settings on transmitter.

Thiemo said that he saw the chute was already out before the pilots announced that the parachute popped.

JB followed the AC on Mavlink, the AC position was very clear. The only thing JB had to do was call the tower.

JB asked tower if there is someone who can drive to the AC and check it out. When we were going back to the hangar, the EDBC guys already went towards the aircraft.

It took us a long time to get there. JB was driving really aggresively, things were flying in the back.

We got there. Our fire extinguisher was really small. It was with co2. that's OK if the fire is small, but we were too late, the fire was too big. We were really lucky that the field was mowed down. We had water with us and we used it to cover the grass.

No one called the 112, but the tower decided not to call it.

There seemed to look two fires, first one, then smaller one, then big one again.

The fire restarted a few times in the fuselage.

We should have made more photos at the beginning.

There should be a fire blanket in the sprinter. It was god to have lipo safe, we put burnt batteries there. Having bag of bubbles to cover the lipos would be good. Also having a small shovel would be good.

A cleanup/emergency checklist would be useful for the institute.

DT was following the OpenMCT EDL, he also saw that engine did shut down. Ozge: the alpha/beta/pitch were really useful for.

24		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**40**
19		**MULTISINE AILERON**	2		40
20		**MULTISINE AILERON**	2		40
21		**MULTISINE AILERON**	2		40
25		**MULTISINE ELEVATOR (RUDDER ON GUI)**	2		50
26		**MULTISINE ELEVATOR (RUDDER ON GUI)**	2		50
27		**MULTISINE ELEVATOR (RUDDER ON GUI)**	2		50
28		**ELEVATOR PULSE**	2		**50**
29		**ELEVATOR PULSE**	**2**		**50**
30		**ELEVATOR PULSE**	2		**50**
31		**MULTISINE AILERON**	2		50
32		**MULTISINE AILERON**	2		50
33		**MULTISINE AILERON**	2		50
34		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**50**
35		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**50**
36		**MULTISINE RUDDER (ELEVATOR ON GUI)**	3		**50**

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