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SCALED FLIGHT TESTING FOR EVALUATING DISTRIBUTED ELECTRIC PROPULSION

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Abstract

The potential of Distributed Electric Propulsion (DEP) for future aircraft has been evaluated with Scaled Flight Testing (SFT). Scaled flight testing can contribute to a reduction of risk and cost in the development of a radically new aircraft. The flight dynamics and control of the aircraft have specifically been addressed. The validity of results of scaled flight testing for predicting the full-scale aircraft properties was addressed in a first campaign. A 1:8.5 scaled version of a typical large passenger aircraft was built, tested in the wind tunnel and was subsequently flight tested. During the flight tests an accurate flight test instrumentation system measured the scaled aircraft flight parameters, such as motion, control surface deflections and air data. Results of the scaled flight testing have been compared with full-scale test results which validates the scaled flight testing methodology. In a second campaign the methodology is applied to investigate and demonstrate the benefits of distributed electric propulsion. Aircraft with the same external shape have been used in the two test campaigns, modifying only the propulsion: the twin turbo-jet propulsion of the first campaign was replaced by propulsion with six propellers in the second campaign. This paper presents the highlights and key results of the development, manufacturing, wind tunnel tests, ground tests, taxi tests and flight tests of both campaigns.

Keywords: Flight Test, Scaled, Distributed Electric Propulsion, Sustainable Aviation, Clean Sky 2

1. Introduction

The need for reducing the climate impact of aviation initiated developments of novel aircraft technology to be integrated in new aircraft configurations. To exploit all the benefits of these novel aircraft configurations, a large development effort is currently deployed. In the development process it has been recognized that early flight testing of the novel technology and configurations on scale can reduce risks and costs. This innovative scaled flight testing methodology therefore has been applied, first on a known aircraft configuration and currently the methodology is applied to an aircraft with Distributed Electric Propulsion (DEP). Especially the dynamics and control of the aircraft can be studied with scaled flight testing, see [1], [2] [3] and [4]. Herewith, it adds to the data gathered in the wind tunnel providing clarity on the aerodynamics of the aircraft. The role of scaled flight testing is elaborated on in section 2.

In this paper the design, manufacturing and testing of two versions of scaled Large Passenger Aircraft are described. The first aircraft, the Scaled Flight Demonstrator (SFD) has been developed for the validation of the Scaled Flight Test (SFT) methodology. The validation of the methodology is described in section 3. The second aircraft has the same shape and size, but the two jet engines are replaced by 6 electrically driven propellers. Distributed electric propulsion has potential to offer improved energy consumption, depending on its integration in large passenger aircraft, and offers the ability to produce differential thrust for yaw and roll. Applying differential thrust on the propellers is part of the increase of the efficiency, see [5]. Demonstrating the benefits of distributed propulsion and identifying the risks of the development is the objective of the scaled flight tests and is described in section 4. Conclusions are presented in section 5.

2. SFT in the aircraft development process

In the development process of an aircraft, different phases can be distinguished, see Figure 1. Evaluating the design in the consecutive phases may result in design changes and the evaluation is an iterative process. Changes have a larger impact and cost if a change has to be made in a later phase. Therefore, risk reduction for changes is required during the development process. Generating a good design is the basis, after which a thorough calculation phase is performed, including amongst others aerodynamic verification of the design in Computational Fluid Dynamics (CFD), structural design verification and aeroelasticity. The next phase is normally a phase in which a scale model is tested in the wind tunnel. Aerodynamics is further validated for the aircraft shape and control surfaces. Dynamics and controllability of the aircraft can be tested only to a limited extend in the wind tunnel. Testing a scale model in free-flight adds to the information obtained with the static wind tunnel model and as such to the risk reduction of modifying the design in the more expensive full-scale prototype flight test phase. The dynamics and controllability information is not really needed if a derivative of an already existing configuration is evaluated, but adds valuable information if a radically new aircraft configuration is developed. The risk of developing the wrong or not optimized configuration is reduced in the scale model testing phase instead of the later full-scale prototype flight testing phase or, even worse, the series production.

The scaled flight testing methodology can also be applied for other aspects than dynamics and controllability, such as noise emission assessments, system development, recovery procedures from hazardous flight conditions and aeroelasticity, see [1], [6], which are however not further discussed in this paper.

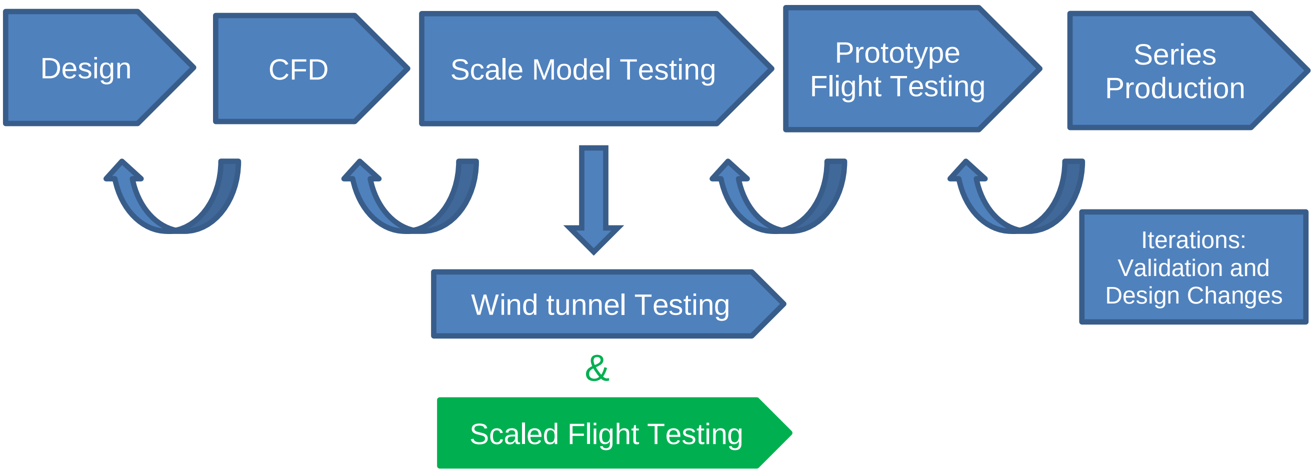

Figure 1 - Illustration of consecutive phases in the development process of a new aircraft. Cost of design changes increases in the subsequent phases. The development risks, the iterations and the design changes should reduce in subsequent phases for a successful development.

3. Validation of the scaled flight test methodology

A scaled version of a Large Passenger Aircraft was developed for the validation of the scaled flight testing methodology. A scale 1:8.5 was chosen for the demonstrator which results in a wingspan of 3.98 m and a fuselage length of 4.42 m. The mass of the aircraft is 142 kg. In this, Froude scaling is applied to obtain a good similarity for the dynamic characteristics. Jet engines, two AMT type Olympus HP engines with a maximum thrust of each 230 N provide the propulsion of the aircraft.

The scaled aircraft was first installed in a large wind tunnel, the Large Low-Speed Facility of DNW in Marknesse in the Netherlands, to acquire aerodynamic data and to test the aircraft and the aircraft systems, see Figure 2. Aerodynamic data was input for the reduction of the risk for the first flight, for developing a simulator to train the pilots and to develop control laws. The jet engines were also operated in the wind tunnel to acquire information on thrust effects.

Figure 2 - SFD for the validation of the scaled flight testing methodology in the wind tunnel and in flight

After the wind tunnel test the same scaled aircraft performed taxi test and flight tests. Lowspeed taxi tests at Breda International Airport, highspeed taxi tests and aircraft qualification flights at Deelen Airbase in the Netherlands and measurement flights at Aeroporti di Puglia in Taranto-Grottaglie, Italy. The aircraft was operated from a ground control station in which pilots and test engineers controlled the aircraft Beyond Visual Line Of Sight (BVLOS).

The test flights were initially attributed to qualify the aircraft for the flight envelope foreseen to achieve the test objectives. In a second phase, dynamic manoeuvres were executed applying a dedicated autopilot, the Guidance, Navigation and Control computer (GNC). The GNC, developed by CIRA, commands the dynamic manoeuvres and flight segments between these manoeuvres. Advantage of this automatic input generation is that the input is better defined and repeatable than a human pilot steering the aircraft. Dynamic inputs were generated with an increasing amplitude during which the pilot monitors the adequate behaviour of the aircraft. In between the steps, the behaviour is analysed and verified on the ground. 6 qualification flights and 19 measurement flights with 69 dynamic manoeuvres were flown successfully with the SFD.

Accurate instrumentation was developed and installed in the aircraft that measures amongst others air data, inertial data, angular position of surfaces and engine parameters. High accuracy was requested in order not to jeopardize the quality of results and as such the validation of the methodology due to measurement errors. Small and accurate instrumentation appeared to be available on the market, which led to measurement uncertainties in the same range as normally applied as for a full-scale prototype aircraft. In this, it was taken into account that the dynamics is different. The velocity of the scaled aircraft is smaller, but the rotations are faster. A description of the major components of the FTI selected is provided in [7]. Table 1 provides an overview of the most important components.

The aircraft, the wind tunnel test, the taxi tests, the flight tests and the results of the tests have been described in more detail in [3] and [4]. The scaled flight test methodology was validated for the aircraft and the operational conditions flown. The results are described in [8].

Table 1 - Main FTI components

Parameter	Manufacturer	Type	Characteristics
Air data	Simtec	ADP55	5-hole probe, sensors integrated in the boom
Inertial and position	iMAR	iNAT-M200/SLN	MEMS accelerometers and gyros and satellite navigation, also for heading inputs
Control surface position	Contelec	Vert-X	Hall sensor
Propulsion	AMT	Olympus HP	Rotation and exhaust gas temperature sensors in the gas turbine

4. Scaled flight testing DEP

4.1 Introduction

A new scaled aircraft was manufactured with the same external fuselage shape, wing shape and tail shape as the SFD, but with propulsion through six electrically driven propellers instead of the two jet engines, see Figure 3 and [9]. The DEP layout was chosen as a subject for scaled flight testing and demonstration, as this configuration was the most promising for commercial transport aircraft in combination with the higher propulsive efficiency of propellers and lower flight speeds [10], [11], [12], [13] and [14]. Another application with ducted distributed propulsion, as demonstrated by the DRAGON concept [15], offers the ability to leverage distributed propulsion at higher flight speeds whilst still offering a significant improvement in the propulsive efficiency. Both these configurations also rely on one of the key benefits of DEP; to produce differential thrust for yaw and roll, leading to the following goals of the scaled flight testing:

- To demonstrate DEP technology in flight;
- To reduce the risk of developing aircraft with distributed propulsion;
- To determine stability and control derivatives under dynamic conditions;
- To determine control and stability in engine-out conditions;
- To assess yaw control capabilities of differential thrust;
- To develop and demonstrate a pilot interface for controlling aircraft with distributed propulsion.

Figure 3 – Computer Aided Design (CAD) model of the DEP-SFD

4.2 Building the DEP-SFD

Many aircraft systems were taken from the SFD and were implemented in the DEP-SFD. The electric propulsion system is completely new and the following components constitute the system, see Figure 4:

- Batteries. 14 LiPo (lithium polymer) pouch battery units are integrated into the fuselage, placed in the centre between the wings, as a power source for the electric propulsion system. The three battery units with LiIon (lithium ion) cylindrical cells powering the avionics system, flight control and flight data system are located here as well.
- Power distribution. The LiPo propulsion batteries are connected to a busbar from which the power is supplied to the distributed electric propulsion system. The cables, sensors and connectors that are part of this power distribution setup.
- Electronic Speed Controllers (ESC). The speed controllers regulate the voltage received by the electric motors and thereby the RPM of the propellers.
- Hexa Engine Controller. This part of the avionics system sends the control signals to the speed controllers.
- Electric motors. The motors convert the electrical power to mechanical power to drive the propellers.
- Propellers. The propellers are fixed pitch propellers designed by NLR and manufactured by the company Mejzlik. The design and specifications of the propellers are based on the analyses performed, the propeller diameters are 0.406 m for the inboard and middle propellers and 0.319 m for the wing tip propeller. The nacelle inclination angle is 3 degree pitch down. Applying a higher rotation on the smaller propeller enables the generation of about equal thrust on all propellers. The smaller tip propeller is selected for aerodynamic, structural integration and tip ground clearance benefits. Integration of the propellers on the aircraft was designed by TU Delft, see [16].

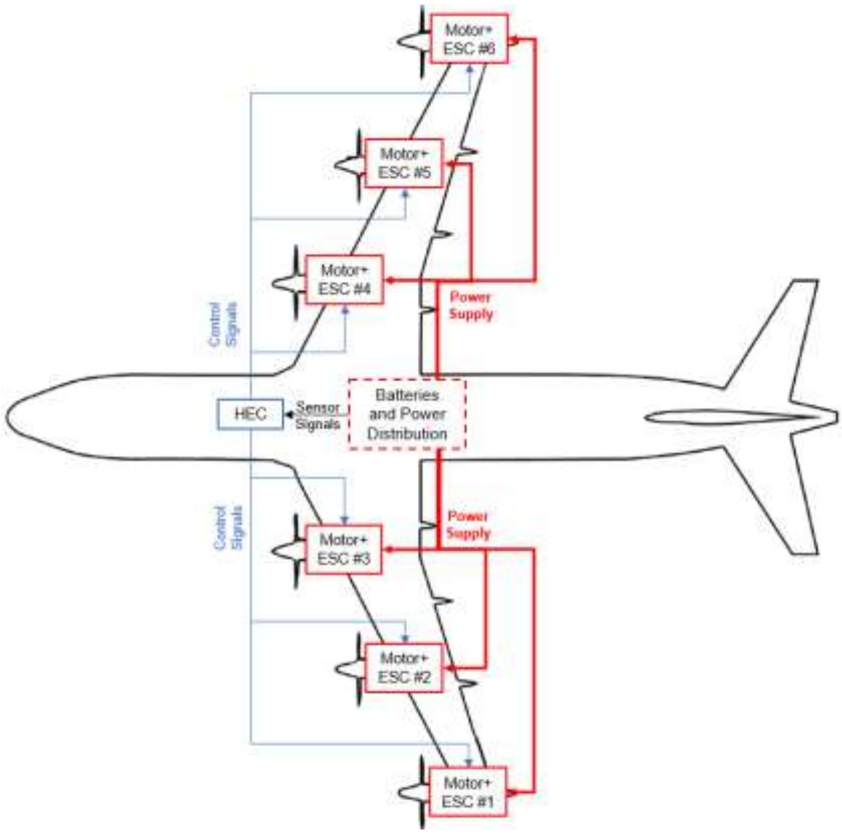

Figure 4 - Power electric propulsion components in the DEP-SFD

The DEP-SFD weight is increased relative to the SFD, especially due to the propulsion batteries, to 162 kg. NLR is the responsible party for the overall design, manufacturing and operation of the DEP-SFD. A part of the design and the manufacturing of the airframe was subcontracted to Orange Aerospace, a company that specializes in the manufacturing of research and prototype UAVs. The airframe of the DEP-SFD is manufactured from carbon fibre-reinforced polymers. The GNC is again provided by CIRA. The flight test instrumentation (FTI) inside the UAV has been developed and installed by NLR. The FTI was taken for the larger part from the SFD, where instrumentation related to the propulsion batteries and electric propulsion is added, replacing instrumentation for monitoring the combustion engines and fuel flow.

4.3 Wind tunnel testing

The DEP-SFD was, like the SFD, tested in the DNW LLF wind tunnel, see Figure 5, with the following objectives:

- Generation of data for the evaluation of the DEP technology
  - Measure installed thrust for the inner, middle and tip propellers individually and combined
  - Measure effectiveness of differential thrust (left, right)
  - Input for performance and / or stability and control as a function of DEP thrust investigations
- Reduction of risk for the first flight by:
  - Supporting flight simulator development
  - Supporting autopilot tuning
  - Supporting flight performance determination
  - Supporting flight envelope determination
  - Verifying structural integrity of the SFD at relevant aerodynamic loads
  - Verifying performance of the Electronic Speed Controller, the motors and the propellers at relevant operating points.

A large test program with 178 measurement conditions was run. The DEP-SFD systems could be controlled remotely (as was the case for the SFD), which allowed for fast operations and in two days the measurements were performed. Runs were performed without the propellers installed and with the propellers installed, both at equal throttle level and with differential throttle settings between the propellers.

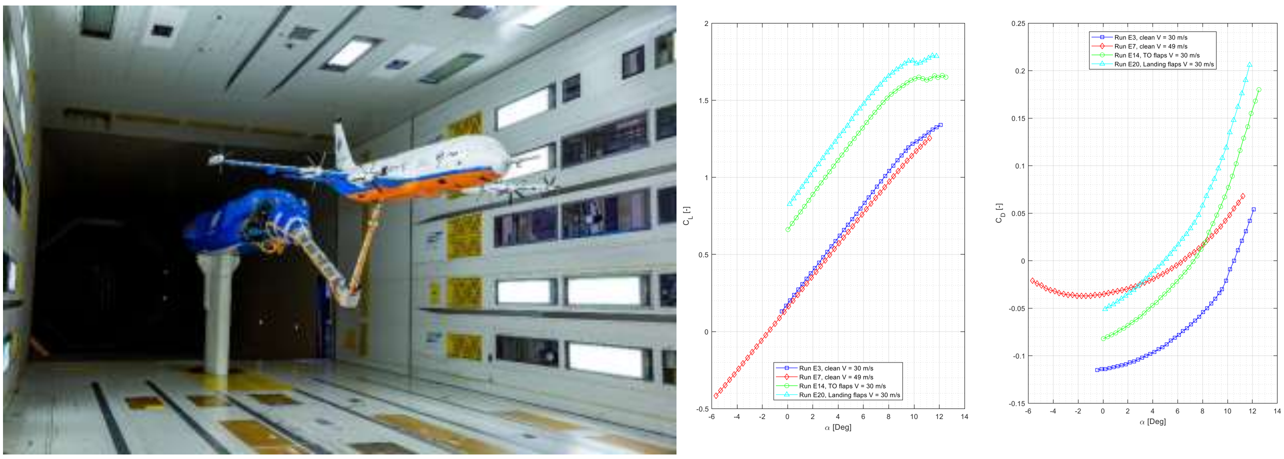

Figure 5 - Scaled aircraft with distributed electric propulsion in the wind tunnel and some results, lift and drag coefficients as a function of flap setting and air speed

4.4 Initial ground testing and a fire incident

Lowspeed taxi tests on Breda International Airport and highspeed taxi tests on Deelen Airbase were performed successfully in the Netherlands in 2023. The aircraft taxied at speeds up to 60 knots in clean configuration.

At the Deelen Airbase also stationary tests were executed parallel to the taxi tests in March 2023. Asking the propulsion power from the aircraft while it is stationary on chocks and brakes was applied to test the propulsion system. A point of attention during the taxi and stationary tests was the observed temperature increase of the batteries that power the propulsion system. The battery temperatures approached the upper operating limit, indicating that the battery temperature may be a limiting factor for conducting the flight test campaign in Italy, which would be conducted at higher ambient temperatures. In response to that, the propulsion battery setup was analysed in detail in April 2023, including bench tests of different battery types.

A new battery type was selected and required additional testing after being installed in de DEP-SFD to confirm that it delivers the anticipated improvements in power and temperature management in the relevant operating environment. During a second ground test with the new Tattu battery setup, see Table 2, installed in the DEP-SFD on Thursday, the 11th May 2023, an abnormality developed, leading to an internal battery fire that resulted in the DEP-SFD being damaged beyond repair. No personal injury or other material damages occurred.

Data measured during the incident has been thoroughly inventoried and analysed in the context of the incident. The possible causes of the incident were investigated and a failure in one of three systems of the aircraft that experienced severe damages during the incident was identified as most likely to constitute the root cause. The systems in question are the propulsion batteries, the electrical propulsion power distribution system and the avionics batteries. Neither the measurement data nor the damage status of the aircraft after the incident provide definite clarity on the root cause.

4.5 Rebuilding the DEP-SFD

The DEP-SFD was rebuilt, where the structure, the avionics, the FTI and the GNC were rebuilt according to the old design. The landing gears were not damaged and were re-used. The designs of the suspected systems, i.e. the propulsion batteries, the power distribution and the avionics batteries, were reiterated and improved. With these improvements the weight of the DEP-SFD increases to 167 kg. The improvements comprise:

- Application of alternative, custom-made propulsion batteries
    - Higher voltage configuration
      The battery configuration was changed from 12 cells in series to 14 cells in series (12S to 14S), leading to a nominal voltage increase from 44.4 VDC to 51.8 VDC, see Table 2. The custom-made batteries have the 14 cells in one unit, whereas the initial configuration had 6-cell units, two units in series. The higher voltage is beneficial for the performance of the electric motors and at the same time reduces the currents in the power distribution when the same power is supplied. The currents govern heat generation for fixed resistance components.
    - Additional monitoring for propulsion battery packs
      Currents individually for each battery pack, voltages of each battery cell, and temperatures per battery pack are monitored during battery tests, system tests, taxi tests and are monitored during the flights, see Figure 11 b). The in-flight monitoring is a sub-set of the ground monitoring and comprises:
        - voltage of each cell (6 batteries x 14 cells = 84 voltages)
        - current & sum of cell voltages of each battery (6 currents and 6 voltages)
        - busbar voltage

    - current, voltage & rpm in each controller and motor (6 currents, 6 voltages and 6 rotation speeds)
    - temperature on top and at side of each batteries (6 batteries x 2 sensor = 12 temperatures)
  - Extensive testing of batteries before installation
    A concern that emerged during the incident analysis is that the propulsion batteries did not have sufficient operating hours before installation in the DEP-SFD to exclude the possibility of a manufacturing fault. Extensively testing of each battery through several discharge at relevant power settings before any application of a battery is introduced after the incident.
- Higher quality components in the power distribution system
  Components in the power distribution are mostly not aerospace quality as these are too heavy and large. Higher quality connectors and many more fuses have been applied in the new design to conduct the large currents.
- Redesign of the fuselage interior
  The interior of the fuselage is reorganized, such that the batteries can be installed with more space between them and that the routing of the cables in the fuselage is better defined. The hatch of the fuselage over the battery compartment is larger, providing easier access to the battery compartment.
- Improve avionics battery setup
  Improvements of the avionics batteries housing and on the monitoring of voltages, currents and temperatures are implemented.

Table 2 - Propulsion battery assembly configuration and specifications for the initial Tattu and eventual Grepow setup

Specification of LiPo Battery Units	Number of Battery Units	Configuration of Assembly	Total Voltage (nominal)	Total Charge Capacity	Total Energy Capacity (nominal)
Tattu 6S1P 30C 22Ah 22.2V	14	12S7P	44.4 V	154 Ah	6838 Wh
Grepow 14S1P 22Ah 51.8 V	6	14S6P	51.8 V	132 Ah	6838 Wh

4.6 Ground testing

Ground testing was performed much more elaborate and in more careful step-by-step approach than for the initial DEP-SFD. Components were tested in the laboratory, the propulsion system first in a dedicated facility, then in the aircraft that is stationary on the ground and then during taxi testing.

4.6.1 Iron bird testing

A ground based “iron bird” test facility was specifically developed for simulating the electrical propulsion system, see Figure 6. The components and the dimensions of the final configuration are identical or equivalent to components and dimensions of the DEP-SFD. The iron bird allowed measurements of temperatures and performances of the components in an easier set-up than the aircraft with its installation and weight constraints. Electric circuits and sensors for monitoring of propulsion battery currents, battery temperatures and battery cell voltages are fixed on the batteries as is shown in Figure 6 d). The boxes installed on top of the batteries with an air gap between the boxes and the batteries contain the electronics and current sensors. The temperature sensors are taped on the batteries on top and on the side. The configuration was to test the final monitoring configuration in the aircraft and to discharge the sets of batteries with the currents requested during flights. The iron bird tests of the DEP-SFD confirmed the design considerations and revealed a few weak aspects in the design that needed improvements:

- nacelles have been modified to improve the cooling of motors and
- limits for operations at higher outside air temperatures have been determined. The

temperature rise in batteries during flights is significant and requires the specification of an upper limit for the temperature of the batteries at the start of the flight.

The iron bird tests gave the opportunity to test the propulsion system beyond limits that will be flown. The extensive monitoring provided a wealth of data to substantiate decisions on the propulsions system design and the operations of the aircraft.

a) b)

c) d)

Figure 6 - a) The iron bird, b) the wing of the iron bird with a cable tray mimicking the cable enclosure in the wing, c) the mimic of the fuselage section around the batteries of the iron bird and d) the propulsion batteries with monitoring installed instrumentation on the batteries.

4.6.2 Stationary testing

For the stationary testing, DEP-SFD was installed on chocks and brakes at NLR, location Marknesse, see Figure 7. From the GCS, the aircraft was controlled by the pilot. Power settings are similar to the settings during a measurement flight in Grottaglie, Italy. The different settings for flying the foreseen trajectory in Grottaglie are for take-off & climb, cruise, approach and 3 go-arounds with circuits of climb, cruise and approach as can be seen in Figure 8. The maximum power settings, applied for take-off and climb, are defined by the maximum RPM of the propellers and the currents through the motors:

- Tip propeller rotations are maximum 7000 rpm
- Middle and inner propeller rotations are maximum 5500 rpm
- Tip motor currents are maximum 100 A
- Middle and inner motor currents are maximum 120 A

The power delivered is sufficient for the trajectory according to flights flown in our simulator. This simulator for training the pilots is based on the aerodynamic and propulsion data from the wind tunnel test. The temperature of the batteries is shown in Figure 9. The temperature rise is just below 30 degree Celsius. Batteries degrade at temperatures higher than 60 degree Celsius, which means that the requirement is to keep the battery temperature during operation below 60 degree Celsius. Therefore, batteries are stored after charging in a refrigerator if ambient temperature is higher than 25 degree Celsius, taking a margin of 5 degree. The capacity used from the batteries during a measurement flight is 123 Ah, well below the nominal capacity of 132 Ah of the batteries.

Figure 7 - DEP-SFD installed for stationary ground tests

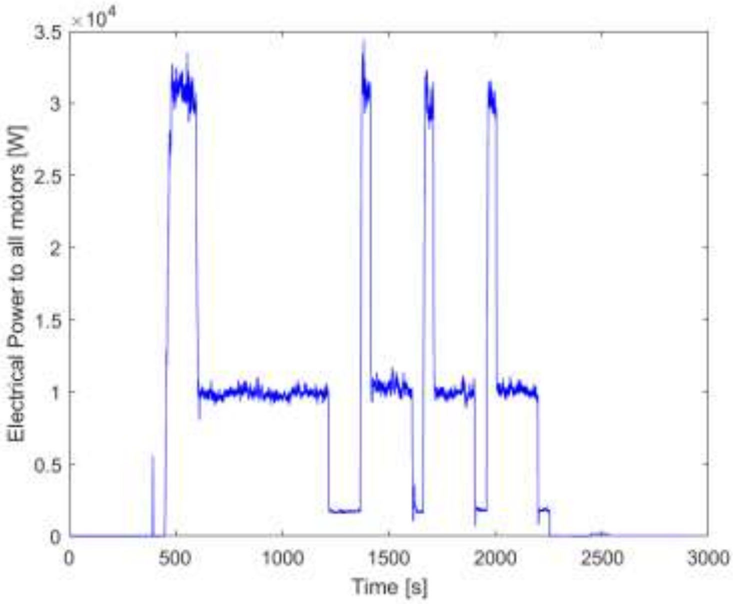

Figure 8 - Electrical power used in a flight. The possibility for three go-arounds has been included.

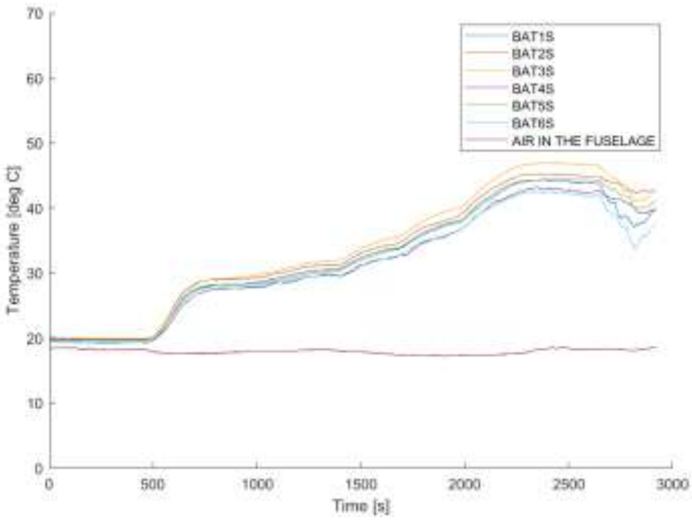

Figure 9 - Temperatures on the side of the batteries and the temperature in the air in the top of the fuselage

4.6.3 Taxi testing

On Deelen Airforce Base (AFB), the ground control station was installed and the DEP-SFD taxied over the runway. Systems were tested, including data links, control, avionics and instrumentation. Deficiencies in the manufacturing of the systems revealed, were solved and were tested before flight tests.

Acceleration tests were performed to ensure safe take-off with the DEP-SFD. The taxi tests were again up to around 80 % of the stall speed, i.e. 60 kts for clean configuration, 55 kts for half flaps and 50 kts for full flaps. The propulsion system operated well and experience and confidence was gained towards flight testing the aircraft.

Figure 10 - Pictures of the DEP-SFD during taxi testing at Deelen AFB

a)

b)

c)

Figure 11 - The Ground Control Station from where the aircraft is BVLOS controlled and systems are monitored. a) overview of the positions for the pilot and system engineers, b) the screen on which the battery parameters (left) and FTI (right) are displayed c) pilot position

4.7 Flight testing

The flight testing of the DEP-SFD has two parts. The first part is dedicated to qualify the aircraft for the foreseen operations. The flight tests comprise:

- A first flight in which the first evaluation of handling is verified. Does the aircraft react as foreseen and implemented in the simulator? Do the different modes, manually or assisted, work properly? Gear retraction and deployment, take-off flaps and clean, one approach and planned go-around and then land. If the approach would not have been comfortable more go-arounds had been available.

And in the next 4 qualification flights were dedicated to:

- Further opening of flight envelope, including evaluation of flying with different flap positions. Gaining further landing practice.
- Evaluation of auto mode and flying to waypoints, leaving the circuit and fly in the whole test area, further opening of flight envelope in altitude, up to 2000 ft.
- Autopilot assisted mode gain tuning.
- Performance evaluation of the aircraft in level flight, gliding flight, climbs and single engine off.

In the second part of the flight test campaign the dynamics of the aircraft is measured. A specific autopilot is in the aircraft to fly the dynamic manoeuvres at one fixed cruise speed of V = 51 m/s indicated airspeed. The manoeuvres comprise:

- Normal, symmetric thrust flight: Inboard, middle and tip motors on left and right wing same thrust. Flight control only by classical control surfaces: rudder, elevator and ailerons:
    - Demonstrate flight characteristics and handling qualities;
    - Standard doublets, step input for stability and control derivatives determination;
- Asymmetric thrust: Based on the optimal combination of all control surfaces and engines for flight control and drag reduction:
    - Normal aircraft mission manoeuvres;
    - Demonstrate flight characteristics and handing qualities using asymmetric thrust;
    - Standard doublets, step input for derivatives determination;
    - Demonstrate flight control by differential thrust
    - Demonstrate flight control could also have been achieved with a reduced vertical tail plane size;
- Failure conditions; One Engine Inoperative (OEI):
    - Demonstrate flight with an inboard, middle or wing tip propeller inoperative.

22 flights were flown in the second part of the campaign to achieve the goals. This adds up to a total of 27 flights with the DEP-SFD, see Figure 11 and Figure 12. Planned manoeuvres for measurements were flown with the GNC. Two control algorithms using asymmetric thrust ran on the GNC and were tested. A description of an algorithm and first results are reported in [17].

Part of the manoeuvres were flow with the remote human pilot in the ground station controlling the aircraft with control surfaces and through differential thrust. The algorithm for controlling the aircraft based on the different pilot and system inputs was implemented as a control mode in the GNC. An assessment was made how the pilot experiences this control. Improvements were suggested and further flights in this mode with a modified algorithm were tested again.

With the scaled flight test results conclusions will be made towards a full scale aircraft with DEP.

Figure 12 - The DEP-SFD just before flight.

5. Conclusion and outlook

Scaled flight testing has a significant potential in reducing the risk of developing new aircraft configurations and novel technologies. The methodology to determine the dynamics and control of aircraft with scaled flight testing has been validated by designing, manufacturing, wind tunnel testing, ground testing and flight testing a scaled model of a typical large passenger aircraft.

After this initial validation of the scaled flight testing approach, the scaled aircraft design was re-used for the demonstration and qualification of the disruptive DEP technology for large passenger aircraft. Again, a scaled version of the aircraft was designed, manufactured, wind tunnel tested, ground tested and flight tested. A fire incident with the first built version of the DEP-SFD aircraft led to a thorough re-design to mitigate fire risks. The re-designed DEP-SFD was subject to thorough ground testing before taking flight in 2024, completing a large number of measurement flights meanwhile.

With the results of the measurement campaign, we shall demonstrate the DEP technology with respect to flight characteristics and handling qualities in normal, symmetric thrust flight, in flight with asymmetric thrust and during failure cases. Alternative yaw and roll control with asymmetric thrust, flight control of the aircraft, reconfigurations strategies for engine failure cases and a pilot interface for aircraft with DEP are demonstrated and investigated. With the knowledge how these features can be implemented successfully, the risks of developing future DEP aircraft will be reduced. The results of the scaled aircraft tests and demonstrations will be input for further studies and designs of full scale large passenger DEP aircraft that are still to be designed.

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