DELIVERABLE 4.3

NOVEL OVERALL AIRCRAFT DESIGN DATABASE

Author(s): DLR, CFSE
WorkPackage N°: WP4
Due date of deliverable: M42
Actual submission date: M42
Document ID: AGILE_D4.3

Grant Agreement number: 636202
Project acronym: AGILE
Project title: Aircraft 3rd Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts
Start date of the project: 01/06/2015
Duration: 42 months
Project coordinator name, title and organisation:
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This project has received funding from the European Union's Horizon 2020 research and innovation framework programme under grant agreement No 636202

DOCUMENT INFORMATION

Document Name			
Document ID	D4.3		
Version	0.3		
Version Date	21.11.2018		
Author	P.D. Ciampa		
Security	PUBLIC		

APPROVALS

	Name	Company	Date	Visa
Coordinator	P. D. Ciampa	DLR	28.11.2018	
WP Leader	G. La Rocca	TU Delft	21.11.2018	

DOCUMENTS HISTORY

Version	Date	Modification	Authors
0.1	05.10.2018	Deliverable Initialized	DLR
0.2	13.11.2018	Deliverable Revised	DLR, CFSE
0.3	21.11.2018	Deliverable Finalized	DLR, CFSE

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DISTRIBUTION LIST

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AGILE Consortium	-
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GLOSSARY

Acronym	Signification
AGILE	Aircraft 3rd Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts
BLI	Boundary Layer Ingestion
BWB	Blended Wing Body
CAD	Computer Aided Design
CPACS	Common Parametric Aircraft Configuration Schema
DC	Design Campaign
DOC	Direct Operating Cost
DOE	Design Of Experiments
MALE	Medium Altitude Long Endurance
MDA	Multidisciplinary Design Analysis
MDAO	Multidisciplinary Design Analysis and Optimization
MDO	Multidisciplinary Design and Optimization
MTOM	Maximum Take-Off Mass
MTOW	Maximum Take Off Weight
OAD	Overall Aircraft Design
UAV	Unmanned Aerial Vehicle
TLAR	Top Level Aircraft Requirement
TOFL	Take Off Field Length

1 Novel Overall Aircraft Design database

1.1 Introduction

The AGILE project has developed the next generation of aircraft Multidisciplinary Design and Optimization (MDO) processes, which target significant reductions in aircraft development costs and time to market, leading to more cost-effective and greener aircraft solutions. In order to accelerate the deployment of large-scale, collaborative aircraft developments, a novel methodology, the so-called AGILE Paradigm, has been developed and proven for the design and the optimization of multiple aircraft.

The measure of the achievable improvements in aircraft performance by MDO techniques is also a function of the aircraft concept maturity, therefore the use cases setup in AGILE target aircraft configurations with diversified technology readiness level and estimated entry into service (EIS) in order to demonstrate the impact of the developed AGILE technologies on medium-term, and long-term aircraft products.

Seven innovative configurations are selected as case studies of the AGILE Paradigm, and the corresponding database, described in the project's deliverable 4.3, represents a major outcome from the AGILE project.

This unique database collects the main data, the digital models, and the results of the 7 novel aircraft configurations, designed and optimized for reduced environmental impacts. The database provides a solid foundation to further research related to novel aircraft.

The novel Overall Aircraft Design (OAD) database is publicly available and accessible online via the AGILE Portal: www.agile-project.eu/novel-overall-aircraft-design-database, shown in Figure 1.

The present document introduces the seven novel configurations and describes the structure of the OAD database.

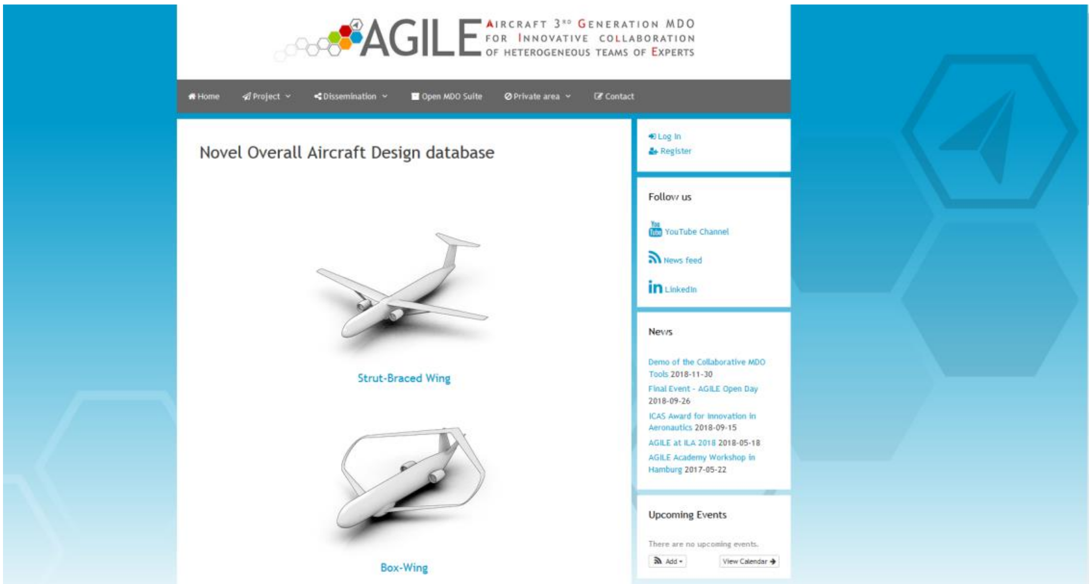

Figure 1 Novel Configurations Database on the AGILE Portal (www.agile-project.eu)

2.1 Innovative aircraft configurations

The seven configurations designed and optimized during the AGILE 3rd Design Campaign are shortly in this Section. The renderings, the CPACS geometry models (represented through TiGL viewer) and the Flight Gear models of the configurations are depicted in

Figure 2.

Strut-braced wing aircraft
A high aspect ratio aircraft with supporting wing struts is designed and optimized, with focus on the hi-fi structural sizing based on aero-elastic tailoring. Additional analyses are included in the MDO process, as stability & control evaluation, on-board systems sizing and nacelle integration (between wing and strut). Several surrogate models are employed in place of high fidelity tools to reduce the high computational cost.

Box-wing aircraft
The study of the box-wing aircraft is mainly focused on the analyses of the flight mechanics and investigation of the stability & control and handling qualities, due to the peculiarity of the closed wing system. In particular, an intermediate fidelity model is derived for the evaluation of control derivatives, exploiting the use case for the investigation of uncertainty propagation. Moreover, a dedicated optimization approach is used for control allocation, due to the large amount of redundant movable surfaces available on the box-wing.

Blended Wing Body (BWB) aircraft
Two alternatives of BWB aircraft are studied. The former is characterized by a conventional propulsion system, i.e. with engines podded on pylons. The latter has semi-buried engines with Boundary Layer Ingestion (BLI) system. Firstly, a large Design Of Experiments (DOE) with more than 500 alternatives is executed employing low-medium fidelity tools, for a first skim among of all the possible solutions. The best ones are then analyzed by means of hi-fi aerodynamic tools. From this study, the wingleted configuration is preferred to the solution characterized by two dorsal fins. A simulator is used for the sizing of winglets and vertical surfaces, determining their dimensions in order to be compliant with stability, control and handling constraints. Afterwards, optimization strategies based on hi-fi aerodynamic tools are applied for both the configurations. It results that the second configuration might be optimal in terms of propulsion efficiency, but the extra secondary (i.e. non-propulsive) power required by the BLI system makes this solution less fuel-efficient than the configuration with podded engines.

Medium Altitude Long Endurance (MALE) Unmanned Aerial Vehicle (UAV)
The core activity of the present design case is the setup of a MDO system for the improvement of the aircraft range under certain constraints. A complex hi-fi aero-structural wing design is adopted. Moreover, particular attention is posed on the preliminary design of the on-board systems, due to their high importance and relevance within this specific design case. In particular, a trade-off analysis among different solutions to de-ice the wing leading edges is conducted, as their masses and power consumption levels might be highly impacted by the long wingspan of the UAV. Eventually, a flight mechanics toolbox is employed to evaluate the flying qualities of the optimized aircraft.

Innovative turboprop aircraft
Two different configurations of innovative turboprop aircraft are investigated. The first configuration is characterized by turboprop engines mounded underneath the wings. In the second configuration, the turboprop engines are placed in the rear part of the aircraft, at the tips of the horizontal tail. Several Multidisciplinary Design Analysis and Optimization (MDAO) problems are studied, as simple converged Multidisciplinary Design Analysis (MDA), DOE and multi-objective optimization (minimization of Direct Operating Costs – DOCs – and environmental impact). In both cases, low and medium fidelity tools are used to design and optimize the aircraft, taking into account the aspects of propulsion integration.

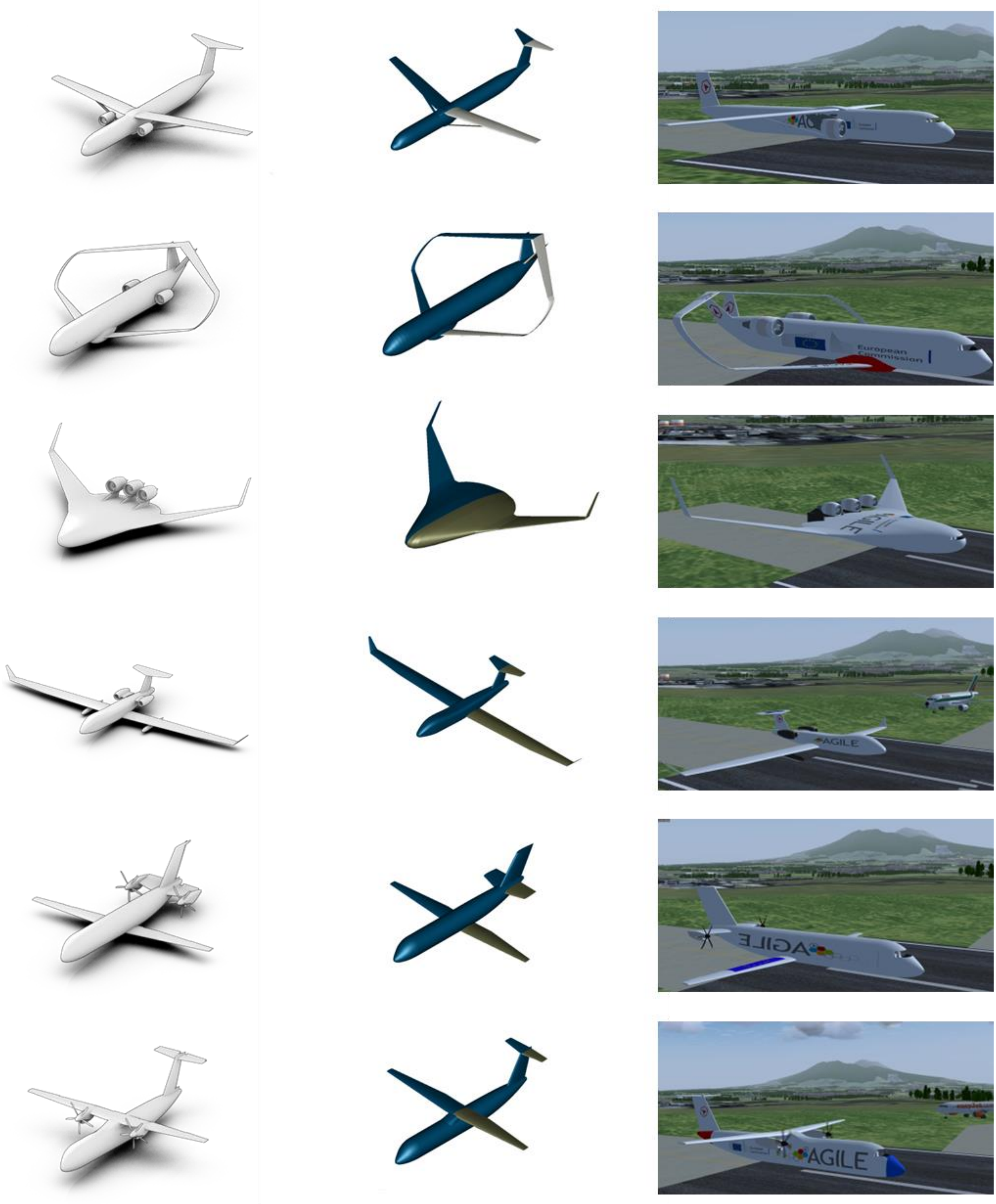

Figure 2 AGILE Novel configurations (left) available in the database and corresponding CPACS models (middle) and FlightGear models (right).

3.1 Structure of the OAD database

The structure of the OAD database, accessible via the AGILE portal, is described in the present Section.

Firstly, the Top Level Aircraft Requirements (TLARs) are collected, such as number of transported passengers, maximum payload, flight mission range and speeds (in cruise and in approach), maximum operating altitude, Take-Off Field Length (TOFL) and fuselage diameter. It is worth noting that some design studies are characterized by the same TLARs, as the case of the BWB concepts with conventional and innovative propulsion systems, and the two alternatives of the innovative turboprop with different engines configuration. The BWB with conventional propulsion system represents also the baseline for further investigations on the BLI system. Regarding the turboprop aircraft instead, one of the aims of the study is the comparison in terms of different results between the two configurations.

In addition, the CPACS files and the Flight Gear models of the seven use cases are collected in the OAD database and can be freely downloaded. These files are relative to the baseline aircraft or to the optimized solutions.

Other information of the MDO processes regards the roles of the different partners for each specific use case. Every innovative concept is indeed managed by an “Architect”, who is required to collect the necessary design competences, to define the design phases and the dimensionality of the design space to be explored. For instance, the industrial partners Bombardier, Airbus DS and Leonardo play this role for respectively the strut-braced aircraft, the MALE UAV and the turboprop. Moreover, other partners are responsible for the deployment and the management of design and optimization processes (“Integrators”). This role is covered by DLR for the development of the strut-braced aircraft, the MALE UAV and the BWB and by ONERA for the box-wing concept. CFSE and University of Naples are the “Integrators” of respectively the BWB with BLI system and the innovative turboprop aircraft. All the other partners – i.e. TU Delft, NLR, Politecnico di Torino, RWTH, TsAGI, CIAM and Airinnova – are involved as “Disciplinary specialists”.

An interactive visualization is also provided, showing the 3D-CAD model of the aircraft and allowing interactions (e.g. zooming, moving) with the users. As an example, Figure 3 shows the 3D model of the MALE UAV.

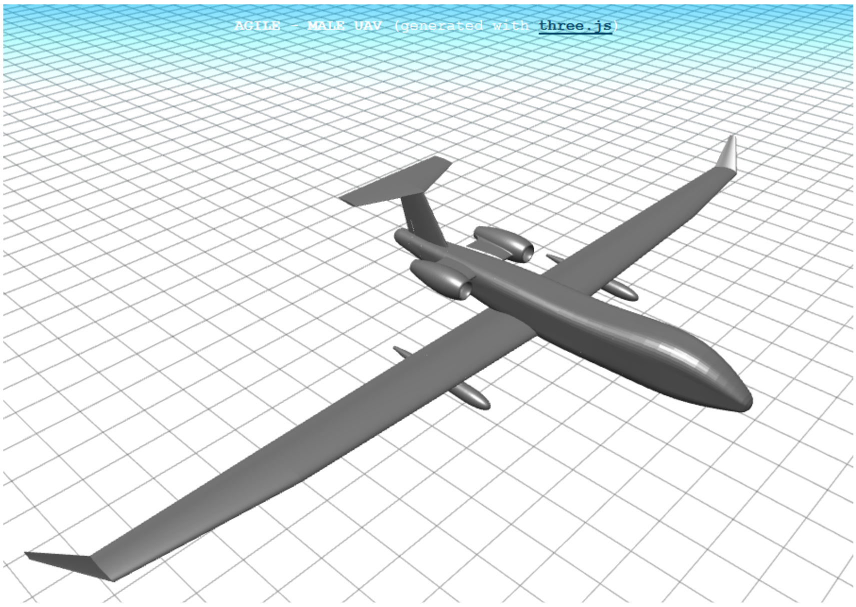

Figure 3 3D-CAD model of the MALE UAV

A significant section of the novel OAD database collects some of the main results of the seven use cases. These results can encompass videos showing disciplinary analyses or MDO processes, optimization results, graphs, charts, outcomes from the Design Of Experiments (DOE) explored.

As an example, Figure 4 and Figure 5 report some of the results of the strut-braced wing aircraft. Some disciplinary results are collected in Figure 4, in particular regarding on-board systems design, structural design and costs estimation.

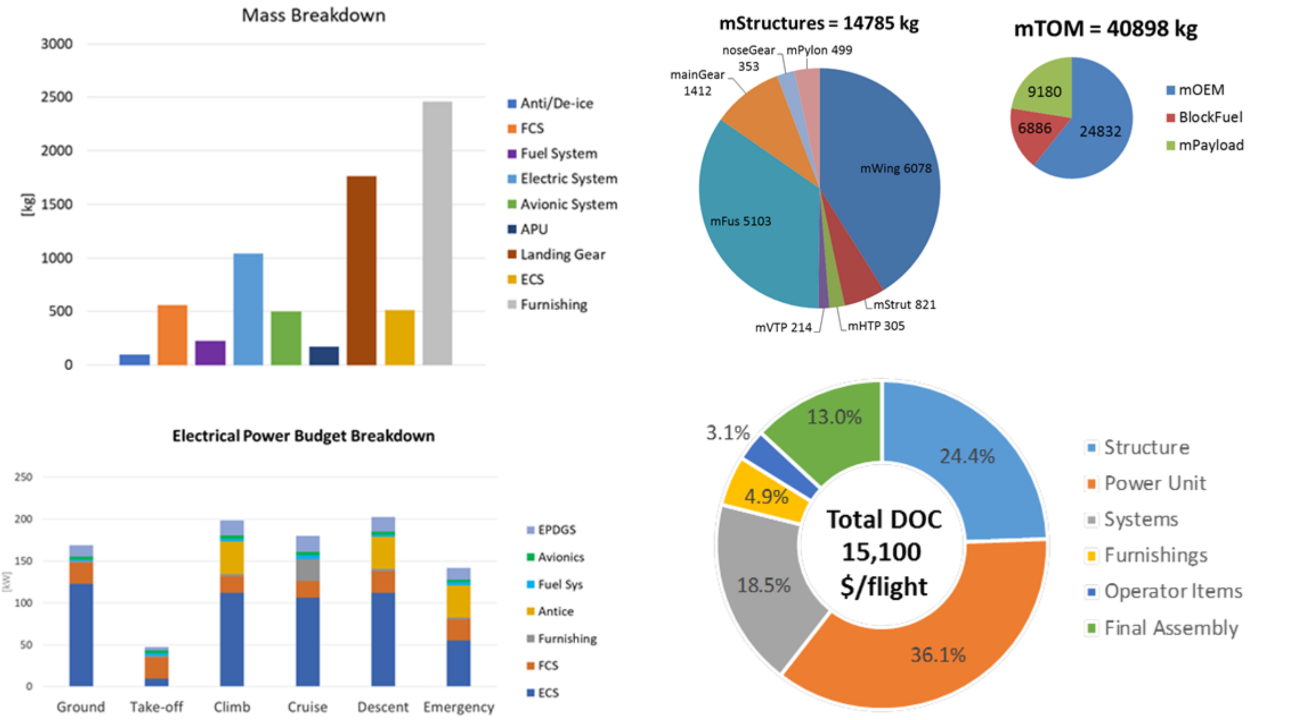

Figure 4 Strut-braced wing use case disciplinary results

The contour plots in Figure 5 represent the investigations on the Design Space for the strut-braced wing aircraft, varying the aircraft Aspect Ratio and the wingspan and visualizing the effects on mission fuel, DOCs and Maximum Take-Off Mass (MTOM). The plots show also the constraints of the Design Space where the solutions are feasible. For instance, in the first figure the area characterized by low values of wingspan or high Aspect Ratios brings to solutions that require more mission fuel than the maximum possible.

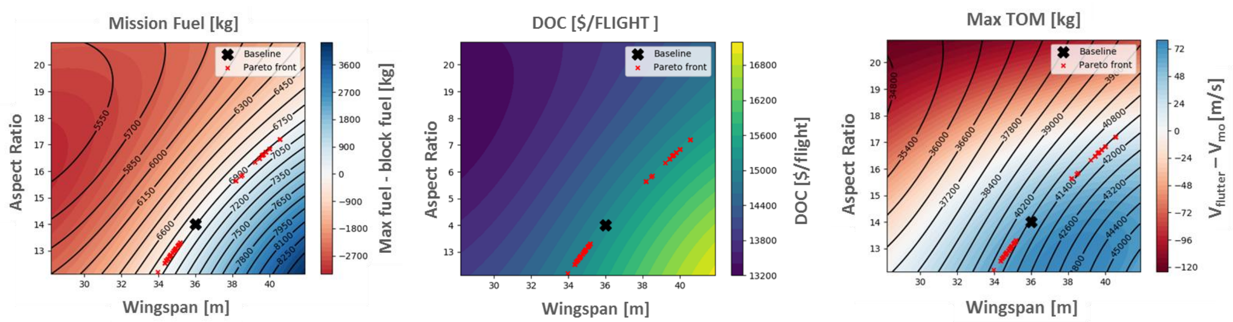

Figure 5 Strut-braced wing use case results from design space investigation

A short bibliography collecting the main publications produced by the AGILE Consortium is provided for each aircraft configuration. The publications provide more details about the novel concepts and their design and optimization processes. Furthermore, the database will be maintained and updated if needed.