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## DISSEMINATION, COMMUNICATION AND EXPLOITATION REPORT

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Project coordinator name & organisation:
Luca Boggero
DLR – System Architectures in Aeronautics | Aircraft Design and System Integration
Tel: +49 40 2489641-338
E-mail: luca.boggero@dlr.de

Project website address: www.agile4.eu



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| | Name | Company | Date | Visa |
|---|---|---|---|---|
| Coordinator | Luca Boggero | DLR | 21.02.2023 | |
| WP Leader | Jan Vos | CFS Engineering | 21.02.2023 | |
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| | | | |

## LIST OF AUTHORS

| Full Name | Organisation |
|---|---|
| Jan Vos with input from all partners | CFS Engineering |
| | |
| | |
| | |

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# 1 EXECUTIVE SUMMARY

## 1.1 Introduction

The high-level objective of the AGILE 4.0 project is to bring **significant reductions in aircraft development costs and time-to-market through the implementation of an integrated cyber-physical aeronautical supply chain**, thereby increasing the competitiveness of the European aircraft industry, from integrators and high-tiers suppliers to SMEs, **leading to innovative and more sustainable aircraft products**.

The AGILE 4.0 project high-level objective is translated into the following **main technical objectives**:

- *To implement a **novel design and optimization paradigm** leading to the development of innovative and constantly evolving aircraft products, in a time and cost-efficient manner*

  The focus is on the digitalization and modelling of **aeronautical systems' architectures**, enabling the effective integration of **virtual products, virtual manufacturing, and virtual testing**.
- *To develop technologies (joint platforms, methods, tools) that permit the integration of computational design environments and the **collaboration of multiple stakeholders** in the aeronautical supply chain, from OEM to SMEs.*

  The focus is placed on the **secure and efficient collaboration** among the multiple actors involved in the development of complex aeronautical products, from OEM to SMEs, and on the deep **common comprehension of product designs** as enabling condition for the decision making of innovative solutions.
- *To develop solutions accelerating the **trade-off and decision-making** processes for complex collaborative development scenarios.*

  The focus is on the development of **user-centric concurrent visualization techniques** and the development of **data analysis and multi-objectives optimization (MOO) methods** supporting large-scale multi-criteria trade-off and decision making.
- *To implement a collaborative computational **design and optimization environment** that has a high (re-) configuration flexibility, enabling the assessment of diverse and complex products.*

  Focus is on the development of efficient **Multidisciplinary Design and Optimization** environments, supporting the efficient and robust optimization of aircraft products during different phases of the development (including **manufacturing and certification**), addressing the **different levels of fidelity**, and associated **uncertainties**.

The **AGILE 4.0** project has provided technology solutions that **answer the following questions** that are rarely answered in industry today:

- Should an investment being made to acquire machines for a novel manufacturing process that will lead to a better performing product (i.e. maintenance, manufacturing costs, design benefit), or should it be allocated to investigate a novel aircraft design? This question is addressed by AGILE 4.0 production driven use case (e.g. composite components).
- Given an available development time for the next aeronautical platform, what is the degree of novelty it can be afforded in terms of costs and certification time, traded with an increase of design performance? This is addressed by the certification driven use-cases (e.g. novel on-board systems architecture)

- How to upgrade constantly evolving systems during its life-cycle? The concurrent design, production, and certification aspects are addressed by AGILE 4.0 upgrade-driven use cases.
- What are the implications due to the uncertainties on the any level of the life cycle of an aircraft, and what is the impact on costs and lead time-to-market? AGILE 4.0 models large scale system of systems scenarios, involving all the stakeholders.

Being able to provide an answer to these questions has an enormous impact on the aircraft-design process, and on aircraft configurations being designed using this process.

Exploitation, Communication and Dissemination of the results of the AGILE4.0 project are fundamental to maximize the impact the project will have on the development of future European aircraft and the competitiveness of the European aircraft industry

## 1.2 Highlights

Exploitation highlights:

- All industrial partners are committed to use the technologies developed in the AGILE4.0 project in their design tools and/or future research projects
- Several national and EU funded projects have started that will use the technologies developed in the AGILE4.0 project
- The AGILE4.0 technologies are (partly) used in 4 ongoing EU funded projects
- All academic partners involved in the AGILE4.0 project have integrated the results of the project in their bachelor and/or master degree courses
- The AGILE4.0 Application cases as well as all publications have been made available in the public domain on zenodo.org

Dissemination highlights:

- Despite the COVID pandemic 49 papers were presented at different conferences, and 5 papers might be presented after the project
- 10 papers were published in peer-reviewed journals, and one paper has been accepted with a revision (and will likely be published after the project)
- 20 Master students and 5 PhD students have been involved in the AGILE4.0 project
- The AGILE4.0 academy attracted the involvement of 35 students from 11 countries distributed over 4 different continents
- Two Open Days were organized, and in total about 130 people outside the AGILE4.0 consortium participated (either virtual as for the first Open Day or on site as for the 2nd Open Day)

Communication highlights:

- The AGILE4.0 LinkedIn group has about 550 followers. This group has been used to announce, among other, the two AGILE4.0 Open Days
- Eight posters, a flyer and a newsletter were prepared.
- The AGILE4.0 project was presented at different occasions for students

# 2 EXPLOITATION OF THE PROJECT RESULTS

## 2.1 Plans of the consortium as a whole

The AGILE4.0 consortium has ensured that information on the technologies developed in the AGILE4.0 project as well as the use of the technologies for the different application challenges are made publicly available through the zenodo.org website, as well as on the AGILE4.0 website.

The consortium as a whole will not further exploit the technologies developed in the AGILE4.0 project, but each individual partner is committed to use the developed technologies either in their company/institute or in follow on research projects.

## 2.2 Individual Partner Exploitable Results

***Exploitable Results Partner DLR***

- **AGILE 4.0 MBSE-MDAO Architectural Framework**: developed by DLR in WP1-2-3, the Architectural Framework includes processes, viewpoints and ontologies for the development of complex aeronautical systems, including activities as stakeholders and needs definition, system architecting, MDAO formulation and execution. The Architectural Framework is published in two (soon: three) conference papers presented at the AIAA Aviation 2021, 2022 (and 2023) and can be exploited by anyone by referencing to the publications.
  In particular, the AGILE 4.0 MBSE-MDAO Architectural Framework includes the following exploitable items:
  - **System Definition (Stakeholders, Needs, Requirements) ontology** (published as a model on ZENODO)
  - **System Definition (Stakeholders, Needs, Requirements) viewpoints** (N.B.: some viewpoints are taken from the literature, others are developed by DLR)
  - **System Definition (Stakeholders, Needs, Requirements) process**
  - **System Architecting ontology**
  - **System Architecting viewpoints** (N.B.: some viewpoints are taken from the literature; others are developed by DLR)
  - **System Architecting process**
  - **System Design ontology** (to be published as a model onto ZENODO)
  - **System Design viewpoints** to be published as a graph in the relative conference paper: 2023 AIAA Aviation
  - **System Design process** to be published as a graph in the relative conference paper: 2023 AIAA Aviation
  - **AGILE4Profile**, new SysML profile developed by DLR. Its representation in Papyrus will be made available (most likely) to externals (e.g. by sharing models of the Applications). Its representation through SysML diagrams has been published (AIAA 2021, AIAA 2022 and ZENODO)
- **Operational Collaborative Environment (OCE)**, is the implementation of the methodology "AGILE 4.0 MBSE-MDAO Architectural Framework". The OCE has been developed and is owned by the WP4 partners (hence including DLR). The exploitation of the OCE needs to be discussed and agreed by the WP4 partners. The OCE includes individual tools developed by partners. Focusing on DLR's tools, these are:

- **MBSElib**: tool developed by DLR in WP4 to automatically create a Papyrus project with SysML diagrams representing stakeholders, needs and requirements. The tool is not open source/access for the moment, but DLR might decide in future to make it open.
- **MultiLinQ**: tool developed by DLR in WP4 to connect system architectures to MDAO formulation by mapping system components and related Quantities of Interest to a central data model used by disciplinary competences. The tool is not open source/access, but it might be exploited in other projects by DLR or other partners.
  - Specifically, MultiLinQ implements an **MBSE-MDAO connection methodology** developed by DLR and published at the INCOSE Symposium in 2022 and can be exploited by anyone by referencing to the associated publication.
- **VALORISE**: interactive dashboard developed by DRL supporting the multi-attribute trade-off and decision-making activity leveraging the value-model methodology (taken from the literature). The tool is not open source/access, but it might be exploited in other projects by DLR or other partners.
- **ADORE**: tool owned by DLR and extended in WP4 to enable system architecture design space modeling and optimization. The tool is not open source/access, but it might be exploited in other projects by DLR or other partners.
  - The *theoretical* background to ADORE, the Architecture Design Space Graph (ADSG), has been published at AIAA Aviation 2020.
  - The *practical* usage of ADORE, together with MultiLinQ, for architecture evaluation has been published at INCOSE Symposium 2022.
- **MDAx:** tool owned by DLR and improved in the AGILE4.0 project. The tool is not open source/access, but it might be exploited in other projects by DLR or other partners.

WP5 tools:

- **AESA**: Aeroelastic stability analysis tool developed and owned by DLR, it is used in AC5; results obtained with it are published in the final AC5 publication (probably a paper in the MDPI Aerospace journal)
- **FAEDO**: Aeroelastic stability framework developed and owned by DLR, it is used in AC5; results obtained with it are published in the final AC5 publication (probably a paper in the MDPI Aerospace journal)
- **PamNG**: Lo-Fi aerodynamic module for aero load and GAF computation, developed and owned by DLR, it is used in AC5; results obtained with it are published in the final AC5 publication (probably a paper in the MDPI Aerospace journal)
- **LIEpp**: postprocessing of LIE results which enable the connection with the cost and mass estimation. It is developed and owned by DLR. Results obtained with it are published in the final AC5 publication (probably a paper in the MDPI Aerospace journal)
- **VMTool**: tool developed by DLR in WP5 to support the multi-attribute trade-off and decision-making activity leveraging the value-model methodology (taken from the literature).

From AC2:

- **AC2 results**, jointly developed by EMBRAER, DLR and FOKKER. Part of these results has been published in journal/conference papers, and can be exploited by anyone by referencing to the publications. For the non-published results, EMBRAER, DLR and

FOKKER need to agree on the exploitation. AC2 results include: requirements, architecture models, XDSM, DOE/Optimization results.

- **AC2 Excel file coupling MfG and SC**, based on equations provided by EMBRAER and FOKKER and implemented by DLR, EMBRAER and FOKKER. To be clarified and agreed between EMBRAER, FOKKER and DLR.
- **Methodology coupling Mfg, SC and OAD through Value-Model theory** is developed by DLR. The methodology couples and includes the following models:
    - **AGILE 4.0 Manufacturing model** and **tool (HTP Manufacturing Concept)**, jointly developed by EMBRAER, FOKKER and DLR. The model is based on equations and attributes provided by EMBRAER and FOKKER.
    - **AGILE 4.0 Supply Chain model** and **tool**, jointly developed by EMBRAER, FOKKER and DLR. The model is based on equations and attributes provided by EMBRAER and FOKKER. Models with different numbers can be exploited by EMBRAER, FOKKER and DLR individually. However, the attributes used to compose the grades of each supplier (3rd level description bringing details of supply chain) in terms of Operation, Logistic, Shop Floor Location, Capacitation, Financial, Planning MUST NOT be shared or disclosed in any hypothesis. The Supply Chain 3rd level attributes is EMBRAER background IP following the Consortium Agreement, and can only be exploited by EMBRAER.
    - **OAD model**, part of literature (e.g. design handbooks) and DLR's background (OpenAD)
    - **Value-model** and **tool (VMtool).** The model is taken from the literature. Its implementation is done and owned by DLR. **The methodology has been published in journal and conference papers, and can be exploited by anyone by referencing to the publications.**

From AC5:

- **AC5 results**, jointly develop by DLR, ONERA, AIRBUS, LEONARDO, POLITO, CFSE, CONCORDIA. Most of the results were already published or will be published in the final AC5 publication.
- **Methodology coupling Structure-OBS-LIE**, jointly developed by DLR, ONERA, AIRBUS, POLITO with some feedbacks from LEONARDO. This will also be part of the final publication on the AC5.
- **LIE analysis database**, entirely developed by LEONARDO. We need to discuss with them if/how we can use the database after the project. The database is currently hosted on the AGILE4.0 cloud
- **LIE Surrogate Model**, developed by ONERA and based on the database by LEONARDO. We need to discuss if/how we can use it after the project. It is currently available as a on-demand service via the ONERA platform WhatsOpt

From AC7:

- **Systems Engineering models** of the business jet family, including stakeholders, needs, and requirements. Jointly developed by DLR and Bombardier.
- **Architecture Design Space Model** of the business jet family, including relevant KPIs and component sharing decisions. Developed and implemented by DLR.
- **Methodology Implementation** of the System Architecting and Optimization Process (AC7)
    - Structure of the analysis workflow (developed by the DLR, published at AIAA Aviation 2022)

    - Component sharing between family members (individual aircraft) by overriding OAD-level input parameters. Developed by the DLR, exploitable only by DLR.
    - Cost estimation tool, developed by RWTH, extended by RWTH to include component sharing effects on costs. Exploitable by RWTH.
- **Surrogate model of PROTEUS tool**, co-developed and owned by DLR and TU Delft
- **Surrogate models of UNINA tools**, co-developed and owned by DLR and UNINA
- **Surrogate model of COST tool**, co-developed and owned by DLR and RWTH
- **Published results** can be exploited by anyone that references the AIAA Aviation 2022 paper. Non-published results need agreement of the following partners for publishing:
    - MBSE models: DLR, Bombardier
    - MDO results: DLR, Bombardier, Polito, TUD, UNINA, RWTH

**Target Markets DLR**

Results can be used in basic research, to generate new knowledge, and industrial research, to increase the TRL of the developments. Results can be exploited in aeronautics, but also in other domains (e.g. space)

***Exploitable Results Partner Airbus Defence and Space***

The following developments and results from AGILE4.0 are exploitable at Airbus Defence and Space:

- New/extended CPACS description of generic on-board systems (to be included in a future release of CPACS, and that will be available through the CPACS license)
- Extended Descartes meshing capabilities for structural attachment and representation of on-board system masses in FEM model.
- New fuselage structure reinforcements CPACS definition (to be included in a future release of CPACS) and Descartes geometry modelling extension.
- Design features in Descartes for fuselage walls, frames and stringers
- Definition and export of Lagrange structural optimization problems in Descartes (sizing design variables, strength and buckling constraints)

The Descartes tool is owned by Airbus Defence and Space, and the Descartes developments will be exploited by Airbus.

**Target Markets Airbus Defence and Space**

The developed results will be introduced into Airbus in-house processes.

### *Exploitable Results Partner Bombardier*

The main exploitable results developed with the help from Bombardier are following:

- The aircraft family design process
- Maintenance and safety assessment methodologies
- MBSE-MDAO architectural framework

**Target Markets Bombardier**

The developed methodologies will be used within Bombardier aircraft design process

### *Exploitable Results Partner CFS Engineering (CFSE)*

The main exploitable result developed by CFSE in the AGILE4.0 project is the open source CEASIOMpy software environment for conceptual aircraft design. Other exploitable results are the knowledge and experience in running complex workflows in a multi-partner environment.
In the AGILE4.0 project the in-house NSMB CFD code was used in two different work packages which led to improvement of the workflow used to generate data to feed a surrogate model. NSMB was used in AC1 to calculate the aerodynamic coefficients for a 2D airfoil. The mesh was generated automatically from extracted sections of a 3D wing with flap. In AC6 NSMB was also used for the generation of a database for a surrogate model. For this case the chimera method was employed to move quickly the engine position. The exploitable results of using NSMB in the AGILE4.0 project are new knowledge and new techniques to generate databases for a surrogate model.

**Target Markets CFSE**

Aircraft design, design of drones and UAVs.

### *Exploitable Results Partner Concordia University (CONU)*

As part of the AGILE4.0 project, CONU developed and improved the following tools and methods:

1) Enhancement of the Thermal Risk Assessment (TRA) tool:
   - Customized it for CPACS integration
   - Allowed analysis of several bays
   - Developed a “single output score” to ease MDAO integration
   - Added Cooling system sizing capability for UAV (vapour cycle system)
2) Development of a maintenance-scoring method: for the moment, only a portion of the score is automated, therefore is needs further development for MDAO integration
3) Development of the ASSESS method and some ASSESS-Modules, for safety analysis
   - This tool is still in the prototype phase, but we plan to transfer the knowledge to Bombardier’s MDAO environment until the end of the project
4) We formalized the process of integrating 3D modelling and subsystem domain analyses (thermal, maintenance, safety) in MDAO workflows
5) We contributed to the following MBSE improvements:

- link between and MBSE specification model in Capella and the link/transition to an MDAO workflow
- Guidelines for scenario modeling in Capella and integration in KE-Chain A4F
- Development of a link between Capella system architecture specification model and the FHA (functional hazard analysis) to enable a model-based FHA
- Development of a reusable framework for system architecture modelling in Capella for aircraft and propulsion system architectures

For all tools and methods, Bombardier was involved to some extent and joint ownership might exist (to be discussed case by case).

**Target Markets**

The results of all three tools and methods target application in aircraft manufacturers or academia in conceptual design frameworks.

### *Exploitable Results Partner Embraer*

The following developments and results from AGILE4.0 are exploitable at Embraer:

- **AC2 results**, jointly developed by EMBRAER, DLR and FOKKER. Part of these results has been published in journal/conference papers, and can be exploited by anyone by referencing to the publications. For the non-published results, EMBRAER, DLR and FOKKER agree on the exploitation as follows: the Parties grant each other full exploitation rights on those jointly owned Results, including, but not limited to, the right to disclose, license or sublicense, use, make, have made, use, sell, and offer to sell the jointly owned Results for any purpose without seeking permission of or accounting to the other Party, and neither Party shall be obligated to share with or pay to the other parties profits, royalties, or fees for future use or commercialization of jointly owned Results. AC2 results include: requirements, architecture models, XDSM, DOE/Optimization results (for these results, ONERA and NLR to be included in the discussion?).
- **AC2 coupling MfG and SC**, based on equations provided by EMBRAER and FOKKER and implemented by DLR, EMBRAER and FOKKER. Part of these equations has been published in journal/conference papers, and can be exploited by anyone by referencing to the publications. For the non-published equations, EMBRAER, DLR and FOKKER agree on the exploitation as follows: the Parties grant each other full exploitation rights on those jointly owned Results, including, but not limited to, the right to disclose, license or sublicense, use, make, have made, use, sell, and offer to sell the jointly owned Results for any purpose without seeking permission of or accounting to the other Party, and neither Party shall be obligated to share with or pay to the other parties profits, royalties, or fees for future use or commercialization of jointly owned Results. It applies to the Excel file provided by Embraer and Fokker or any other implementation based on it. **Methodology coupling Mfg, SC and OAD through Value-Model theory** is developed by DLR. The methodology couples and includes the following models:
    - **AGILE 4.0 Manufacturing model** and **tool (HTP Manufacturing Concept)**, jointly developed by EMBRAER, FOKKER and DLR. The model is based on equations and attributes provided by EMBRAER and FOKKER.

- **AGILE 4.0 Supply Chain model** and **tool**, jointly developed by EMBRAER, FOKKER and DLR. The model is based on equations and attributes provided by EMBRAER and FOKKER. Model with different numbers can be exploited by EMBRAER, FOKKER and DLR individually. However, the attributes used to compose the grades of each supplier (3rd level description bringing details of supply chain) in terms of Operation, Logistic, Shop Floor Location, Capacitation, Financial, Planning MUST NOT be shared or disclosed in any hypothesis.
- **OAD model**, part of literature (e.g. design handbooks) and DLR's background (OpenAD)

**Value-model** and **tool (VMtool).** The model is taken from the literature. Its implementation is done and owned by DLR.

The methodology has been published in journal and conference papers, and can be exploited by anyone by referencing to the publications. Manufacturing, Supply Chain models and Value-Model are co-owned by EMBRAER, FOKKER and DLR, and they agree on the exploitation as follows: the Parties grant each other full exploitation rights on those jointly owned Results, including, but not limited to, the right to disclose, license or sublicense, use, make, have made, use, sell, and offer to sell the jointly owned Results for any purpose without seeking permission of or accounting to the other Party, and neither Party shall be obligated to share with or pay to the other parties profits, royalties, or fees for future use or commercialization of jointly owned Results. However, in AGILE 4.0 Supply Chain model and tool the attributes used to compose the grades of each supplier (3rd level description bringing details of supply chain) in terms of Operation, Logistic, Shop Floor Location, Capacitation, Financial, Planning MUST NOT be shared or disclosed in any hypothesis.

**Target Markets Embraer**

The developed results will be introduced into Embraer in-house processes.

***Exploitable Results Partner GKN-Fokker***

An exploitable result developed by GKN-Fokker is an open-source cost estimation tool for structural parts and this software will be released as open source under the Apache 2.0 license.

Fokker applies and will in future apply the concept of standard communication protocols between tools in an engineering tool chain as developed in AGILE4.0. For some communication parts of the CPACS standard advocated in AGILE4.0 are used, for other communication standard XML formats equivalent to CPACS are defined.

Fokker will incorporate the Requirements Verification Framework developed in AGILE4.0 0 in collaboration with TU Delft and KE-works, or derivatives thereof in the daily engineering practice. This will include the automated verification of requirements as developed in AGILE4.0. Next step for Fokker is to formalize how these tools can be used in daily engineering practice.

Fokker will investigate how to apply the concept of a centralized MDO platform equivalent to the OCE developed in AGILE4.0. Fokker is convinced a centralized MDO like the OCE will be of value in the application of MDO in the everyday engineering practice. Next step is to investigate how to practically set up such a system for internal company use.

Tools developed in AGILE4.0, like Brics, KE Chain, will be used in other projects, such as Defaine (Itea) and Colossus (Horizon Europe).

**Target Markets GKN-Fokker**

The target market for the open-source cost tool are academia and institutions to provide an alternative to commercial packages.

Internally the AGILE4.0 results will be used to improve processes and will be applied throughout the engineering discipline. The focus will hereby lie on the initial design phases such as conceptual and preliminary design.

***Exploitable Results Partner ISAE-Supaero***

WP5 tools:

- **SMT Toolbox:** Enhancements to the open-source toolbox SMT with mixed variables. Part of these developments has been published in journal/conference papers, and can be exploited by anyone by referencing to the publications.
- **SEGOMOE Optimizer:** Enhancements to the Bayesian Optimizer SEGOMOE with mixed variables and multiple objectives. Part of these developments has been published in journal/conference papers, and can be exploited by anyone by referencing to the publications.

**Target Markets ISAE-Supaero**

Results will be exploited in aeronautics especially through other Horizon Europe projects. Researchers, students and any company doing optimization based on surrogate models are also in the market target.

***Exploitable Results Partner KE-works***

The exploitable results for KE-works are two-fold: technical enhancements to the KE-chain platform and exploration of new use-cases.

The KE-chain enhancements aim to provide better services to current and future clients. Example of enhancements developed for the platform in AGILE4.0 are:

- Improvements to the Service Integration Module (SIM) enabling better performance and reduced overhead during service execution.
- Improvements to the security of running services on-platform using Docker technology.
- Implementation of MBSE concepts in KE-chain forms where bi-directional relations are being made between data models.

Exploration of new use-cases during the AGILE4.0 project resulted in a better understanding to provide market fit solutions for target clients. Examples of target clients inside the project are GKN Fokker, NLR and DLR or outside the project such as RWE. KE-chain played a central role as cloud-based collaboration and integration platform for AGILE4.0 technologies. Several of these integrations of these technologies s.a. MDAx, ADORE and MulitLinQ developed by the DLR are currently being used by DLR themselves in other research projects.

Finally, lessons learned and integrated technology together with the TU Delft (s.a. KADMOS and the Requirements Verification Framework) are being exploited in another EU research project DEFAINE (ITEA4)

**Target Markets KE-works**

KE-works is a SME with headquarters in Delft in the Netherlands, providing KE-chain SaaS solution for digital forms and workflows for applications in quality assurance, systems engineering and others, to clients in high-tech manufacturing (aerospace, automotive and energy) and construction industries.

The KE-chain enhancements are exploited for all our clients and markets. The use-cases are expected to be specific for the high-tech manufacturing market.

***Exploitable Results Partner Leonardo***

All the results produced by LEONARDO in AC5 can be exploited being based on representative data.

All results obtained in AC6 can be exploited. The developed methodology gives a cost analysis for a Regional in-service platform modification with new technology components (engine, on board systems). This exploitation could be important also from sustainability point of view.

**Target Markets Leonardo**

The job performed by Leonardo was mainly oriented:

- Towards the integration of the On-Board System architecture during the preliminary design phase of a UAV aircraft configuration (AC5), also including the certification process, focusing on the process to demonstrate compliance with the electrical and electronic system lightning protection regulation. A certification-like simulation campaign was set up in order to estimate the impact of different CFC materials (different levels of electrical conductivity) on the equipment qualification level, according to the regulation constraints with direct implications to the reference market.
- Towards major aircraft configuration modifications, mainly focused to fuel efficiency improvements and to the reduction of environmental impact in terms of Community noise (AC6); these kinds of modifications are currently very important topics due to very stringent environmental targets from relevant Authorities. The choice to include an airplane improvement process in a collaborative Platform can have positive impacts on the Aircraft Design for the next future.

The developed methodologies (in the frame of AC5 and AC6) will be introduced into Leonardo in-house processes.

*Exploitable Results Partner Dutch Aerospace Laboratory - NLR*

Enhancements to AMLoad, Brics, SMR, MASS, MultiFit

**Target Markets NLR**

European industry, European R&D projects, within the aerospace community, but also potentially outside the aerospace community (Brics, SMR, MultiFit).

*Exploitable Results Partner ONERA*

- **Operational Collaborative Environment (OCE)**, is the physical implementation of the A4F, which has been developed and is owned by the WP4 partners (hence including DLR). The exploitation of the OCE needs to be discussed and agreed by the WP4 partners. The OCE includes individual tools developed by partners. Focusing on ONERA's tools, these is:
    - **WhatsOpt:** tool owned by ONERA and improved in the AGILE4.0 project. Within AGILE 4.0, WhatsOpt has been connected to OCE through SMR (from NLR) in order to host parts of surrogate models created by ONERA. In addition, access to ONERA 's optimizer SEGOMOE has also been validated.

WP5 tools:

- **CCM**: Performance Certification tool developed and owned by ONERA, it is used in AC3
- **SMT Toolbox:** Enhancements to the open-source toolbox SMT with mixed variables. Part of these developments has been published in journal/conference papers, and can be exploited by anyone by referencing to the publications.
- **SEGOMOE Optimizer:** Enhancements to the Bayesian Optimizer SEGOMOE with mixed variables and multiple objectives. Part of these developments has been published in journal/conference papers, and can be exploited by anyone by referencing to the publications.

From AC2:

- **Methodology for Mfg, SC and OAD combined optimization** is developed by ONERA with the support of DLR. Part of these results has been published in journal/conference papers, and can be exploited by anyone by referencing to the publications.

From AC3:

- **Aerodynamic Surrogate Model**, developed by ONERA and based on the database by CFSE. We need to discuss if/how we can use it after the project as the data are belonging to CFSE. This Surrogate model is also accessible through WhatsOpt.

From AC4:

- **Methodology components system arrangement optimization** is developed by ONERA with the support of RWTH.

From AC5:

- **LIE Surrogate Model**, developed by ONERA and based on the database by LEONARDO. We need to discuss if/how we can use it after the project as the data are belonging to LEONARDO.

From AC6:

- **Aerodynamic Surrogate Model**, developed by ONERA and based on the database by CFSE. We need to discuss if/how we can use it after the project as the data are belonging to CFSE.
- **Proteus Surrogate Model**, developed by ONERA and based on the database by TUD. We need to discuss if/how we can use it after the project as the data are belonging to TUD.

From AC7:

- Development of the capability to access to ONERA 's optimizer SEGOMOE has also been validated in AC7. Part of these results will be published in journal/conference papers, and can be exploited by anyone by referencing to the publications.

**Target Markets ONERA**

Results will be exploited in aeronautics especially through other Horizon Europe projects. Researchers, students and any company doing optimization based on surrogate models are also in the market target.

***Exploitable Results Partner POLITO***

Enhancement of ASTRID, SFC sensitivity and HEP tools. Regarding new knowledge, we have understood the effect of on-board systems electrification on the other disciplines and the integration of the certification process in the aircraft design workflow.

**Target Markets POLITO**

Researchers, students and aerospace companies

***Exploitable Results Partner RWTH Aachen University***

The primary results obtained by RWTH consist of the software tools developed during the project (e.g. Software: PADME , extensions to Cost&Emission tools.
KNOWLEDGE: MDO, A/C system design, A/C maintainability, improved/enhanced system design process

***Exploitable Results Partner TUDELFT***

- Further developed version of the Proteus tool for aeroelastic sizing of composite structures (WP5)
- Landing Performance tool (WP5) to estimate, based on lifting line theory, the landing distance of an input aircraft in landing conditions (flaps out)
- Further developed version of the Initiator tool (improved module on High lift system selection and sizing) for aircraft conceptual design (WP5)
- Further developed version (new partitioning and sequencing algorithm) of the KADMOS system for automatic formulation and integration of MDAO systems (available open source) (WP4)

- RVF, the MBSE-Based Requirement Verification Framework to support the MDAO Design Process, including its ontology (Stakeholders-needs-requirements-means of compliance-test cases-design competence) and derived implementations, developed in collaboration with GKN Fokker (WP4-5-6). Ontology published at AIAA Aviation 2022
- Operational Collaborative Environment (OCE), developed in collaboration with all WP4 partners (of which KADMOS and RVF is part of)
- A4F (ontology and concepts) developed with all consortium partners (of which the RVF ontology is part)

**Target Markets TUDELFT**

Many elements from the OCE and A4F and the tools from the TU Delft exploitable list will be incorporated in the Design and Engineering Engine, which is the TU Delft in-house MBSE framework to support design space exploration and MDAO of complex systems (latest description submitted to INCOSE 2023), that was already under development before the AGILE4.0 project.
The results achieved in AGILE4.0 will flow into publications and renewed educational material, consolidating the high ranking position of TU Delft in the academic world, and thus keep attracting students, researchers and academic talents, as well as new research funds, from the EC, national agencies and industrial partners.
With the achieved results, TU Delft can actively support the national aerospace industry reaching the digital transformation objectives. The developed knowledge and tools on MBSE and MDAO can be used to develop a multidisciplinary computational framework to monitor and analyze the aviation environmental impact and gauge the impact of new technologies and regulations (see DASAL initiative in exploitation plan)

***Exploitable Results Partner UNINA***

From AGILE4.0:

- The **MBSE-MDAO** methodology has been partially exploited in the definition of IMPACT (funded by the European Union's H2020 research and innovation programme under GA no. 885052) project application case, an innovative fuselage rear end.

- The **MBSE-MDAO** methodology has been partially exploited in the Numerical and Experimental Methods for Aircraft Design (MAD) in the Master's Degree Course in Aerospace Engineering at University of Naples.

WP5 tools:

- **Retrofitting Costs**: tool for retrofitting costs estimation, developed with LEONARDO and owned by UNINA, it is used in AC6; results obtained with it are published in the final AC5 publication (a paper already published in the MDPI Aerospace journal)
- **PerfoMission**: performance, mission profile and emission tool developed and owned by UNINA, it is used in AC3, AC4, AC6, AC7; results obtained with it are published in tool for retrofitting costs estimation, developed with LEONARDO and owned by UNINA, it is used in AC6; results obtained with it are published in several AIAA AVIATION 2022 papers and ICAS 2022 papers

- **Noise**: Lo-Fi certification noise estimation tool, developed and owned by UNINA, it is used in AC3 and AC6; results obtained with it are published in several AIAA AVIATION 2022 papers and ICAS 2022 papers

From AC6:

- **AC6 results**, jointly developed by UNINA, POLITO, LEONARDO, CFSE, TUDELFT and ONERA. Part of these results has been published in journal/conference papers, and can be exploited by anyone by referencing to the publications. For the non-published results, UNINA, POLITO, LEONARDO, CFSE, TUDELFT and ONERA agree on the complete exploitation as a dashboard. AC6 results include: requirements, architecture models, XDSM, DOE/Optimization results.
- **AC6 Excel file of Converged DOA**, based on numbers provided by EMBRAER and FOKKER and implemented by DLR, EMBRAER and FOKKER. To be clarified and agreed between EMBRAER, FOKKER and DLR.
- **Methodology for retrofitting costs** is developed by UNINA with the LEONARDO support and it includes:
  - **Engine model** developed by UNINA: it includes engine deck for performance, emission, noise, weight and costs model.
  - **OBS architecture cost model** developed by LEONARDO and UNINA based on POLITO OBS architecture: it includes the

**Target Markets UNINA**

Results are already used in research projects and academia to increase knowledge, TRL, reducing time and errors in the set-up phase of design process applied to aircraft.
Furthermore, results are useful for OEM, airliners to set-up analysis and business-cases for different scenarios.

## 2.3 Individual Partner Exploitation Plans

***DLR Exploitation Plan***

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | DLR |
| Partner website | www.dlr.de |
| Contact Person(s) | Luca Boggero |
| Department | Institute of System Architectures in Aeronautics |
| Address | Hein-Saß-Weg 22, 21129 Hamburg, Germany |
| Telephone | +49 40 2489641-338 |
| Email | luca.boggero@dlr.de |

DLR aims at exploiting the obtained results in:

- Other research projects, DLR-internal, German- and European-funded. The aim will be to generate new knowledge.
- Exchanges with other research institutes or universities and industrial partners. Aim will be to increase the dissemination and exploitation of what was developed in AGILE 4.0, and find new partners for new potential collaborations (mainly projects, but also co-supervision of students, …)

### *Airbus Defence and Space Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | Airbus Defence and Space GmbH |
| Partner website | https://www.airbus.com |
| Contact Person(s) | Sebastian Deinert |
| Department | Stress Methods and Optimization |
| Address | Rechlinerstr., 85077 Manching, Germany |
| Telephone | +49 8459 81 79008 |
| Email | Sebastian.deinert@airbus.com |

The extensions to the CPACS data format definitions listed above will be included in future releases of the open-source data format allowing a wide exploitation of these results.

Descartes is an Airbus in-house software for parametric modelling and analysis model generation. Therefore, the new features of Descartes developed during this project (on-board system definition, fuselage structure design features, Lagrange optimization model definition) are being introduced in the Airbus internal development processes as part of the Descartes tool to be used in future projects.

### *Bombardier Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | Bombardier Aviation |
| Partner website | Bombardier.com |
| Contact Persons(s) | Jasveer Singh |
| Department | Advanced Design |
| Address | 400 Cote-Vertu 0, Dorval, Québec, H4S 1Y9, Canada |
| Telephone | 1-514-855-5000 |
| Email | jasveer.singh@aero.bombardier.com |

- Follow-up projects with Concordia
- The results obtained in AC3 & AC7 will be considered in conceptual phase of new product development, esp. in exploring viability of aircraft family concepts

### *CFS Engineering Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | CFSE |
| Partner website | www.cfse.ch |
| Contact Person(s) | Aidan Jungo and Jan Vos |
| Department | |
| Address | EPFL Innovation Park, Batiment A, 1015 Lausanne, Switzerland |
| Telephone | +41 21 353 84 71 |
| Email | aidan.jungo@cfse.ch, jan.vos@cfse.ch |

The CEASIOMpy environment developed and maintained by CFS Engineering will be used in the HorizonEurope project Colossus that will start in February 2023.
As CEASIOMpy is open source and based on opensource technologies, it is very suitable for student and master thesis projects. Its modularity permits student to focus on one part of the code, for example by adding a new module which calculate the thrust distribution on an actuator disk.
Initial discussions have been started with the University of Applied Sciences in Wintherthur whether CEASIOMpy could be used in teaching aircraft design courses.
The CEASIOMpy software is also used by Airinnova in Sweden for studies of High-Altitude Drones.

### *Concordia Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | Concordia University |
| Partner website | https://users.encs.concordia.ca/~slhanke/ |
| Contact Person(s) | Susan Liscouet-Hanke |
| Department | Mechanical Industrial and Aerospace Engineering |
| Address | 1455 De Maisonneuve Blvd. West, EV12.183, Montreal, QC, H3G 1M8, Canada |
| Telephone | +1-514-848-2424 ext. 3848 |
| Email | susan.liscouet-hanke@concordia.ca |

We plan two follow-up projects with partners in Canada to enhance or expand the tools and methods developed to new domains or applications:

- The first project is called MDAO-NextGen and funded by the Natural Sciences and Engineering Research Council of Canada (NSERC), Grant Numbers CRDPJ 538897-19 and the Consortium de recherche et d'innovation en aérospatiale au Québec (CRIAQ), and Bombardier.
- The second project is funded by NSERC and CRIAQ as well, called ACI-OPT (Aircraft Component Installation Optimization), 2023-2025, with the partners McGill University, StreamSystems, MTLS Aerostructures and Bombardier

Also, the experience gained in multi-partner MDAO will be used in setting up MDAO frameworks in academics and industry projects in the future.

### *Embraer Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | EMBRAER |
| Partner website | www.embraer.com |
| Contact Person(s) | Ana Paula Curty Coco |
| Department | |
| Address | Avenida Brigadeiro Faria Lima 2170, Sao Jose Dos Campos, 12227 901 Brazil |
| Telephone | |
| Email | ana.cuco@embraer.com.br |

Embraer will exploit the AGILE4.0 project in follow on research projects.

### *GKN-Fokker Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | Fokker Aerostructures B.V. |
| Partner website | https://www.gknaerospace.com/en/about-gkn-aerospace/fokker-technologies |
| Contact Person(s) | Ton van der Laan |
| Department | Centre of Competence design |
| Address | Industrieweg 9, Papendrecht, The Netherlands |
| Telephone | +31786419531 |
| Email | Ton.vanderlaan@fokker.com |

The open-source cost tool developed in AGILE4.0 will be used in cooperation with academia and institutes to investigate how cost analysis can be incorporated in MDO workflows.

All methodologies developed in AGILE4.0 will be used to improve the engineering process at GKN/Fokker. They will also be used in future EU and national research projects such as Defaine (ITEA) and Mobiliteitsfonds (National).

GKN Fokker will collaborate with TU Delft to develop the requirements verification framework. The long-term goal is the incorporate this framework in the engineering processes at GKN Fokker.

### *ISAE-Supaero Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | ISAE-SUPAERO |
| Partner website | https://www.isae-supaero.fr/fr/ |
| Contact Person(s) | Joseph Morlier |
| Department | DMSM |
| Address | 10 avenue Edoaurd Belin, 31400 Toulouse, France |
| Telephone | +33561338131 |
| Email | joseph.morlier@isae-supaero.fr |

The results obtained in the AGILE4.0 project will be used and exploited in Lectures on MDO.

### *KE-Works Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | KE-Works |
| Partner website | https://ke-chain.com/ |
| Contact Person(s) | Bastiaan Beijer, Joost Schut, Jochem Berends |
| Department | |
| Address | Molengraaffsingle 12, 2629 JD Delft, The Netherlands |
| Telephone | +31 15 711 1104 |
| Email | sales@ke-works.com |

The KE-chain enhancements developed in the AGILE4.0 project are exploited for all our clients and markets.

### *Leonardo Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | Leonardo |
| Partner website | https://www.leonardo.com/ |
| Contact Person(s) | Giovanni Cerino |
| Department | Preliminary Design Civil Aircraft |
| Address | Viale dell'Aeronautica snc 80038 Pomigliano D'Arco, Italy |
| Telephone | +390818873096 |
| Email | giovanni.cerino@leonardo.com |

Leonardo will exploit the results of the AGILE4.0 project mainly within new R&D projects.

### *NLR Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | NLR |
| Partner website | www.nlr.org |
| Contact Person(s) | Jos Vankan |
| Department | Collaborative Engineering Systems |
| Address | P.O. Box 90502, 1006 BM Amsterdam, The Netherlands |
| Telephone | + 31 88 511 3059 |
| Email | Jos.Vankan@nlr.nl |

NLR's exploitable results are mainly related to the in-house software tool developments on AMLoad, Brics and SMR/SMG, and to the specific knowledge acquired in their development and application.
NLR will exploit the results of the AGILE4.0 project mainly within new R&D projects and by providing them on demand as licensed products or as-a-service.
The results will be adopted, and further developed and exploited, within various research frameworks, such as the European HE programme Clean Aviation and the Dutch national programme Aviation in Transition (Luchtvaart in Transitie), where NLR will participate in research projects like DASAL (Dutch Aviation Systems Analysis Laboratory) and Flying Vision. Of course, these further initiatives will also proceed with the co-operation of NLR with various partners like GKN Fokker and TU Delft.

### *ONERA Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | ONERA |
| Partner website | www.onera.fr |
| Contact Person(s) | Thierry Lefebvre and Nathalie Bartoli |
| Department | Information Processing and Systems Department |
| Address | 2. av E. Belin, 31055 Toulouse cedex France |
| Telephone | +33 5 62 25 26 44 |
| Email | Thierry.lefebvre@onera.fr and nathalie.bartoli@onera.fr |

ONERA will exploit the results of the AGILE4.0 project mainly within new R&D projects.

### *POLITO Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | Politecnico di Torino |
| Partner website | www.polito.it |
| Contact Person(s) | Marco Fioriti |
| Department | Mechanical and Aerospace Engineering |
| Address | c.so Duca degli Abruzzi 24, 10129 Torino, Italy |
| Telephone | +3901109069816 |
| Email | Marco.fioriti@polito.it |

The Politecnico di Torino will exploit the results of the AGILE4.0 project in new research projects and academic courses.

### *RWTH Aachen University Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | RWTH Aachen University |
| Partner website | www.ilr.rwth-aachen.de |
| Contact Person(s) | M.Sc. Philipp Hansmann, Prof. Dr.-Ing. Eike Stumpf, Dr.-Ing. Ralf Hörnschemeyer |
| Department | Institute of Aerospace Systems (ILR) |
| Address | Wuellnerstr. 7, 52052 Aachen, Germany |
| Telephone | +49 0241 8096818 |
| Email | philipp.hansmann@ilr.rwth-aachen.de, stumpf@ilr.rwth-aachen.de, hoernschemeyer@ilr.rwth-aachen.de |

The Institute of Aerospace Systems (ILR) of RWTH Aachen University will exploit the results and technologies obtained in the AGILE4.0 project mainly within the context of its in-house aircraft design suite MICADO (Multidisciplinary Integrated Conceptual Aircraft Design and Optimization). The developed software within the context of WP5 (e.g. PADME (Preliminary Aircraft Design Maintainability Evaluation)) will be added as a module of MICADO to cover and evaluate maintainability aspects in the context of aircraft design. Subsequently the module will be made public in the context of the parallel research project UNICADO-II.

The knowledge obtained within the context of the development of the AGILE4.0 MBSE Approach will be exploited to develop a similar framework for the MICADO software to:

- facilitate the usability and therefore accelerate the aircraft design process in general
- Easily and flexibly, integrate and evaluate new technologies that are subject of research at the ILR in other projects (e.g. hybrid laminar flow control, hydrogen-powered aircraft…) into the aircraft design process.

Further, the developed procedures and results will be exploited in the institute's lectures (e.g. 'aerospace systems') thus providing students with an insight into modern aircraft system design approaches. The workshop 'aircraft concept studies' will introduce the students to the field of aircraft design optimizations and highlight its specific challenges. Through contributions in the form of Master and Bachelor theses or in the context of a student assistant position, other selected students also benefit.

The PhD student who worked on the project will develop the findings in subsequent research work, which in turn will be published in journal articles and/or conference proceedings within a period of 2 years after the end of the project. The overall results will serve as the basis for a dissertation paper.

### *TU DELFT Exploitation Plan*

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | Delft Univeristy of Technology (TU Delft) |
| Partner website | https://www.tudelft.nl/en/ae |
| Contact Persons(s) | Gianfranco La Rocca |
| Department | Flow Physics & Technology, Flight Performance & Propulsion group |
| Address | Kluyverweg 1, 2629 HS Delft, The Netherlands |
| Telephone | +31152785384 |
| Email | g.larocca@tudelft.nl |

At TU Delft the results from the AGILE 4.0 project are already being used to upgrade the Design and Engineering Engine, which is the TU Delft in-house MBSE framework to support MDAO. This is/will be used for both graduate education (MSc course on MDO) and future research activities. The latter include the running ITEA 3 EC project DEFAINE, the upcoming DASAL initiative to establish the Dutch Aviation Systems Analysis Laboratory (part of the large Dutch national initiative *Luchtvaart in Transitie*) and new EC project proposal(s) to be submitted in the area of design digitalization.
The acquired knowledge and tools have already triggered new research collaborations with GKN Fokker, NLR and KE-works, creating opportunity for several students placements, both for internship and graduation projects.
The KADMOS tools will be maintained as open source. The CMDOWS data exchange format, will be further matured towards formal standardization.

### UNINA Exploitation Plan

| | |
|---|---|
| Grant Agreement Number | 815122 |
| Partner Name | UNINA |
| Partner website | www.unina.it |
| Contact Person(s) | Pierluigi Della Vecchia |
| Department | Industrial Engineering |
| Address | Via Claudio, 21, 80125, Naples, Italy |
| Telephone | +39 081 768 3887 |
| Email | pierluigi.dellavecchia@unina.it |

UNINA will exploit the results obtained in the AGILE4.0 project through:

- Other research projects, UNINA-internal, Italian- and European-funded.
- Bachelor's and Master's Degree courses to increase the students' knowledge about MDO and MBSE.

# 3 Dissemination and Communication Activities

## 3.1 General Overview

| Type | During Project | Confirmed after project | Possible after project |
|---|---|---|---|
| Press releases, flyers, website | 5 | | |
| Workshops/Open Days | 2 | | |
| Master Thesis | 20 | | |
| PhD thesis | | 5 | |
| Conference papers & presentations | 49 | | 5 |
| Journal Publications | 10 | 1 | |
| Other | 13 | | |

## 3.2 Press releases/Flyers/Website

| Date | Type | Audience | Partners involved | Notes |
|---|---|---|---|---|
| 10/2019 | Press release | General public | DLR | 1. |
| 11/2019 | Project web site | General public | CFSE | 2. |
| 11/2019 | Poster | MDO community | DLR/ONERA | 3. |
| 10/2021 | Flyer | Aeronautical Community | DLR/CFSE | 4. |
| 09/2022 | Poster | MDO community | DLR/ONERA | 5. |

Notes

1. A press release in German and English was published on October 15, 2019, on the DLR website:
   https://www.dlr.de/content/de/artikel/news/2019/04/20191015_europaeisches-forschungsprojekt-agile-4-0-gestartet.html
2. The AGILE4.0 website (www.agile4.eu) has become available in November 2019. The website has a public section that includes general information on the projects, its objectives, the partners, status etc.
3. An AGILE/AGILE4.0 poster was prepared for the 2nd MDO Workshop held at IRT Saint Exupery in Toulouse, November 19-20, 2019.
4. A flyer was prepared to announce the AGILE4.0 Open Days in December 2021.
5. A poster showing system architecting and optimization activities done in the context of AGILE 4.0 project was prepared for the workshop on "MDO for Industrial Applications in Aeronautics – Towards Greener Aviation", which took place in IHES - Paris (Bures-sur-Yvette), France, September 20-21, 2022.

## 3.3 Social Media

A LinkedIn group “AGILE4.0 Project” has been created and has been used as a second channel (similar to public website) to communicate and disseminate the project results: https://linkedin.com/company/agile4. This group has about 550 followers.
An AGILE4.0 Twitter account has been created: https://twitter.com/AGILE4project. The M5 meeting organized in Lausanne in February 2020 was announced on Twitter, and about 3000 people have seen this announcement.
The AGILE4.0 Open Days were announced on Twitter and on LinkedIn.

## 3.4 Conferences

The AGILE4.0 partners presented in total 49 papers at the following conferences. These papers can be downloaded from the AGILE4.0 website or from the AGILE4.0 community on zenodo.org.

| Date | Conference | Location | Partner(s) | WP | Title & DOI | Authors |
|---|---|---|---|---|---|---|
| 06 2020 | AIAA Aviation | Virtual | DLR | | MDAx: Agile Generation of Collaborative MDAO Workflows for Complex Systems. AIAA 2020-3133, https://doi.org/10.2514/6.2020-3133 | A.P. Risueño, J.H. Bussemaker, P.D. Ciampa, B. Nagel |
| 06 2020 | AIAA Aviation | Virtual | DLR | | System Architecture Design Space Exploration: An Approach to Modeling and Optimization. AIAA 2020-3172, https://doi.org/10.2514/6.2020-3172 | J.H. Bussemaker, P.D. Ciampa, B. Nagel |
| 06 2020 | AIAA Aviation | Virtual | DLR, POLITO | | Environmental and Flight Control System Architecture Optimization from a Family Concept Design Perspective. AIAA 2020-3113, https://doi.org/10.2514/6.2020-3113 | C. Cabaleiro de la Hoz, J.H. Busse-maker, M. Fioriti, L. Boggero, P.D. Ciampa, B. Nagel |
| 06 2020 | AIAA Aviation | Virtual | DLR, POLITO | | A Model-Based RAMS Estimation Methodology for Innovative Aircraft on-board Systems supporting MDO Applications. AIAA 2020-3151, https://doi.org/10.2514/6.2020-3151 | F. Bruno, M. Fioriti, G. Donelli, L. Boggero, P.D. Ciampa, B. Nagel |
| 06 2020 | AIAA Aviation | Virtual | DLR, TU Delft | | A MBSE Approach to MDAO Systems for the Development of Complex Products, AIAA-2020-3150, https://doi.org/10.2514/6.2020-3150 | P.D. Ciampa, B. Nagel, G. La Rocca |
| 09 2020 | EASN | Virtual | TU Delft | | Aeroelastic optimization of manufacturable tow-steered composite wings with cruise shape constraint and gust loads, In IOP Conf. Series: Materials Science and Engineering, Vol. 1024, No. 1, IOP Publishing, 2021. https://doi.org/10.1088/1757-899X/1024/1/012020 | Z. Wang, D. Peeters, R. De Breuker |
| 10 2020 | READ | Virtual | CFSE | | Using surrogate models to speed-up the creation of aerodynamic databases in CEASIOMpy | A. Jungo, V. Riolo, J.B. Vos |
| 01 2021 | ECCOMAS | Virtual | NLR | | Multidisciplinary Modelling, Analysis and Optimisation for Aircraft and System Level Design and Validation‡ | Jos Vankan, Wim Lammen, Erik Baalbergen |

| Date | Conference | Location | Partner(s) | WP | Title & DOI | Authors |
|---|---|---|---|---|---|---|
| 03 2021 | SIAM Conference on Computational Science and Engineering (CSE21) | Virtual | ONERA – ISAE SUPAERO | | Enhanced Kriging models within a Bayesian optimization framework to handle both continuous and categorical inputs | P. Saves, N. Bartoli, T. Lefebvre, Y. Diouane, J. Morlier |
| 07 2021 | ECCOMAS AEROBEST | Virtual | ONERA – ISAE-SUPAERO | | Constrained Bayesian optimization over mixed categorical variables, with application to aircraft design https://www.eccomas.org/publications/conference-proceedings | P. Saves, N. Bartoli, Y. Diouane, T. Lefebvre, J. Morlier, C. David, E. Nguyen Van, S. Defoort |
| 08 2021 | AIAA Aviation | Virtual | DLR | | Accelerating the Development of Complex Systems in Aeronautics via MBSE and MDAO: a Roadmap to Agility https://doi.org/10.2514/6.2021-3056 | P.D. Ciampa, B. Nagel |
| 08 2021 | AIAA Aviation | Virtual | DLR | | An MBSE Architectural Framework for the Agile Definition of System Stakeholders, Needs and Requirements https://doi.org/10.2514/6.2021-3076 | L. Boggero, P.D. Ciampa, B. Nagel |
| 08 2021 | AIAA Aviation | Virtual | DLR, TU Delft | | System Architecture Optimization: An Open-Source Multidisciplinary Jet Engine Architecting Problem https://doi.org/10.2514/6.2021-3078 | J.H. Bussemaker, G. La Rocca, P.D. Ciampa, B. Nagel |
| 08 2021 | AIAA Aviation | Virtual | DLR, ONERA | | Effectiveness of Surrogate-Based Optimization Algorithms for System Architecture Optimization https://doi.org/10.2514/6.2021-3095 | J.H. Bussemaker, P.D. Ciampa, B. Nagel, N. Bartoli, T. Lefebvre |
| 08 2021 | AIAA Aviation | Virtual | DLR | WP6 | A Model-Based Approach to Trade-Space Evaluation Coupling Design-Manufacturing-Supply Chain in the Early Stages of Aircraft Development https://doi.org/10.2514/6.2021-3057 | G. Donelli, P.D. Ciampa, B. Nagel Gléverson F.C. Lemos, João M.G.D. Mello, Ana P.C. Cuco, Ton van der Laan |
| 08 2021 | AIAA Aviation | Virtual | POLITO, UNINA, DLR, RWTH | | Assessing the Integration of Electrified On-Board Systems in an MDAO framework for a small transport aircraft https://doi.org/10.2514/6.2021-3094 | M. Fioriti, P. Della Vecchia, G. Donelli, P. Hansmann |

| Date | Conference | Location | Partner(s) | WP | Title & DOI | Authors |
|---|---|---|---|---|---|---|
| 08 2021 | AIAA Aviation | Virtual | Concordia University | | Connecting Model-based Systems Engineering and Multidisciplinary Design Analysis and Optimization for Aircraft Systems Architecting https://doi.org/10.2514/6.2021-3077 | A. Jeyaraj, S. Liscouët-Hanke |
| 08 2021 | AIAA Aviation | Virtual | DLR, Airbus-DS, POLITO, CFSE, Leonardo, Concordia | | MBSE Certification-Driven Design of a UAV MALE Configuration in the AGILE 4.0 Design Environment https://doi.org/10.2514/6.2021-3080 | A.F. Torrigiani, P.D. Ciampa, B. Nagel, S. Deinert, M. Fioriti, F. Di Fede, A. Jungo, L. Pisu, A. Jeyaraj |
| 08 2021 | AIAA Aviation | Virtual | GKN-Fokker | | An open source part cost estimation tool for MDO purposes https://doi.org/10.2514/6.2021-3058 | T. van der Laan, A. Johman, T. van Puffelen, S. Nolet, B. van Maanen, E. Daugulis, T. Van den Berg |
| 09 2021 | ICAS | Hybrid | DLR | | The Application of the AGILE4.0 MBSE Architectural Framework for the Modeling of System Stakeholders, Needs and Requirements | L. Boggero, P.D. Ciampa, B. Nagel |
| 09 2021 | ICAS | Hybrid | DLR | | System Architecture Design Space Modelling and Optimization Elements | J.H. Bussemaker, P.D. Ciampa, B. Nagel |
| 09 2021 | ICAS | Hybrid | POLITO, DLR | | Assessment of new Technologies in a Multi-disciplinary design analysis and optimization environment including RAMS and cost disciplines | C. Cabaleiro, M. Fioriti, L. Boggero, S. Corpino, P.D. Ciampa, B. Nagel |
| 09 2021 | ICAS | Hybrid | POLITO, Leonardo | | On-board system architectures for hybrid/all-electric regional aircraft | M. Fioriti, F. Di Fede, S. Corpino, PP. Iodice, G. Cerino |
| 09 2021 | ICAS | Hybrid | CIAM | | The capabilities of automation of MDAO problem statement at collaborative conceptual design of the propulsion system using open source software tools | L.Mirzoyan, A.Mirzoyan, A.Isyanov |
| 09 2021 | EASN | Virtual | UNINA, Leonardo | | Regional jet retro-fitting through multidisciplinary aircraft design. | M. Mandorino, P Della Vecchia, F. Nicolosi, G. Cerino |
| 11 2021 | ECCOMAS CM3 | Barcelona | NLR | | Modelling, optimization and simulation methodologies for low emission aircraft concepts | W.J. Vankan, W.F. Lammen, E.H. Baalbergen |
| 01 2022 | AIAA SCITECH | Hybrid | ONERA, ISAE-SUPAERO | | Bayesian optimization for mixed variables using an adaptive dimension reduction process: applications to aircraft design | P. Saves, N. Bartoli, Y. Diouane, T. Lefebvre, J. Morlier, C. David, E. Nguyen Van, S. Defoort |

| Date | Conference | Location | Partner(s) | WP | Title & DOI | Authors |
|---|---|---|---|---|---|---|
| 06 2022 | ODAS | Hamburg | DLR | | Technologies for Enabling System Architecture Optimization | J.H. Bussemaker, L. Boggero |
| 06 2022 | INCOSE | Detroit | DLR | | From System Architecting to System Design and Optimization: A Link Between MBSE and MDAO | J.H. Bussemaker, L. Boggero, P.D. Ciampa |
| 06 2022 | ILA Berlin Airshow 2022 | Berlin | DLR | | AGILE4.0 : Towards cyber-physical Collaborative Aircraft Development | L. Boggero |
| 06 2022 | AIAA Aviation | Chicago | DLR | | An MBSE architectural framework for the agile definition of complex system architectures https://arc.aiaa.org/doi/10.2514/6.2022-3720 | L. Boggero, P.D. Ciampa, B. Nagel |
| 06 2022 | AIAA Aviation | Chicago | GKN Fokker | | Bringing Manufacturing into the MDO domain using MBSE https://arc.aiaa.org/doi/10.2514/6.2022-3721 | T. van der Laan, A-L. Bruggeman, B. Van Manen, Z. Wang, D. Peeters, J. Sonneveld, H. Timmermans |
| 06 2022 | AIAA Aviation | Chicago | TU Delft, GKN Fokker | | An MBSE-Based Requirement Verification Framework to support the MDAO process https://arc.aiaa.org/doi/10.2514/6.2022-3722 | A-L. Bruggeman, B. Van Manen, T. van der Laan, T. Van den Berg, G. La Rocca |
| 06 2022 | AIAA Aviation | Chicago | DLR, Embraer, GKN-Fokker | | Value-driven model-based optimization coupling design-manufacturing-supply chain in the early stages of aircraft development https://arc.aiaa.org/doi/10.2514/6.2022-3723 | G. Donelli, P.D. Ciampa, T. Lefebvre, N. Bartoli, J. Mello, F. Odagui, T. van der Laan |
| 06 2022 | AIAA Aviation | Chicago | POLITO, ONERA, UNINA, Concordia, DLR, CFSE | | Multidisciplinary design of a more electric regional aircraft including certification constraints https://arc.aiaa.org/doi/10.2514/6.2022-3932 | M. Fioriti, C. Cabaleiro, T. Lefebvre, P. Della Vecchia, M. Mandorino, S. Liscouet-Hanke, A.K. Jeyaraj, G. Donelli, A. Jungo |
| 06 2022 | AIAA Aviation | Chicago | UNINA, Leonardo, POLITO, ONERA, CFSE, TU Delft | | Multidisciplinary Design and Optimization of a Regional Jet Retrofitting Activity https://arc.aiaa.org/doi/10.2514/6.2022-3933 | M. Mandorino P. Della Vecchia, S. Corcione, F. Nicolosi, G. Cerino, M. Fioriti, C. Cabaleiro, T. Lefebvre, D. Charbonnier, Z. Wang, D. Peeters |

| Date | Conference | Location | Partner(s) | WP | Title & DOI | Authors |
|---|---|---|---|---|---|---|
| 06 2022 | AIAA Aviation | Chicago | DLR, Bombardier, POLITO, TU Delft, RWTH, UNINA | | Collaborative Design of a Business Jet Family using the AGILE4.0 MBSE Environment https://arc.aiaa.org/doi/10.2514/6.2022-3934 | J.H. Bussemaker, P.D. Ciampa, J. Singh, M. Fioriti, C.C. De La Hoz, Z. Wang, D. Peeters, P. Hansmann, P. Della Vecchia, M. Mandorino |
| 06 2022 | AIAA Aviation | Chicago | NLR, DLR, ONERA, KE-Works, TU Delft UNINA | | Advancing Cross-Organizational Collaboration in Aircraft Development https://arc.aiaa.org/doi/10.2514/6.2022-4052 | E. Baalbergen, W.J. Vankan, L. Boggero, J.H. Bussemaker, T. Lefebvre, B. Beijer, A. Bruggeman, M. Mandorino |
| 06 2022 | AIAA Aviation | Chicago | ISAE-SUPAERO, ONERA, DLR | | Regularized Infill Criteria for Multi-objective Bayesian Optimization with Application to Aircraft Design https://arc.aiaa.org/doi/10.2514/6.2022-4053 | R. Grapin, Y. Diouane, J. Morlier, N. Bartoli, T. Lefebvre, P. Saves, J.H. Bussemaker |
| 09 2022 | ICAS | Stockholm | DLR, ONERA, NLR, KE-Works, Bombardier | | The AGILE4.0 MBSE-MDAO Development Framework: overview and assessment | L. Boggero, T. Lefebvre, W.J. Vankan, B. Beijer, V. Saluzzi, B. Nagel |
| 09 2022 | ICAS | Stockholm | Concordia, DLR | | Systems architecting: a practical example of design space modeling and safety-based filtering within the AGILE4.0 project | A.K. Jeyaraj, J.H. Bussemaker, S. Liscouet-Hanke, L. Boggero |
| 09 2022 | ICAS | Stockholm | POLITO, DLR | | Methodology for the automated preliminary certification of on-board systems architectures through requirements analysis | C. Cabaleiro, M. Fioriti, L. Boggero |
| 09 2022 | ICAS | Stockholm | UNINA, Leonardo, POLITI, ONERA | | Regional jet retrofitting design from stakeholders need and system requirements to MDAO workflow formulation | M. Mandorino, P. Della Vecchia, F. Nicolosi, S. Corcione, V. Trifari, G. Cerino, M. Fioriti, C. Cabaleiro, T. Lefebvre |
| 09 2022 | ICAS | Stockholm | DLR, Embrear, ONERA, GKN-Fokker | | A Value-driven Quantitative Framework Coupling Aircraft Design, Manufacturing and Supply Chain by Leveraging the AGILE4.0 MBSE-MDO Framework | G. Donelli, J. M.G.D. Mello, F.I.K. Odaguil, T. Lefebvre, N. Bartoli, T. van der Laan, L. Boggero, B. Nagel |

| Date | Conference | Location | Partner(s) | WP | Title & DOI | Authors |
|---|---|---|---|---|---|---|
| 09 2022 | ICAS | Stockholm | POLITO, ONERA, UNINA, Concordia | | Certification driven design from stakeholders needs to MDAO formulation within the AGILE4.0 project | M. Fioriti, C. Cabaleiro, T. Lefebvre, P. Della Vecchia, M. Mandorino, S. Liscouet-Hanke, A.K. Jeyaraj |
| 09 2022 | MDO Workshop | Paris | DLR | | AGILE4.0: Towards cyber-physical Collaborative Aircraft Development | J. Bussemaker |
| 09 2022 | MDO Workshop | Paris | Fokker-GKN | | Bringing Manufacturing into the MDO domain using MBSE | T. van der Laan |
| 09 2022 | Mechanical, Material and Structures Technology Workshop | Virtual | TU Delft, Fokker-GKN | | Toward a front loaded design process: MBSE-based technologies to support KBE and MDAO | G. La Rocca, A.M.R.M. Bruggeman, A.R. Kulkarni, F. Fernandes, T. van den Berg, T. van der Laan, B. van Manen |
| 01 2023 | AIAA Scitech | National Harbor, USA | Concordia | | Integration of the Functional Hazard Assessment within a Model-based System Engineering Framework | N. Tabesh, A. Jeyaraj, S. Liscouet-Hanke |

‡ papers referring to the AGILE project.

At AIAA Aviation 2020 a Technical panel named “MBSE integration with MDO” was organized by AGILE4.0 partners (P.D. Ciampa (DLR) and N. Bartoli (ONERA)).

A special session “MBSE-MDO” was organized by DLR at AIAA AVIATION 2021 with AGILE4.0 contributions from the Consortium.

A special session “Digital Pioneering – Where will MBSE, AI, VR and SoSE bring engineering in 20 years?” was organized by DLR at ICAS 2021. Pier Davide Ciampa gave a presentation entitled “Future perspectives on MDO & MBSE”. Gianfranco La Rocca gave a presentation entitled “Future perspectives on KBE & AI”.

At AIAA Aviation 2022 three special sessions dedicated to the AGILE4.0 project were organized.

## 3.5 Participation in conferences after the end of the project

The following abstracts were submitted for conferences that will take place after the end of the project.

| Date | Conference | Location | Partner(s) | WP | Title & DOI | Authors |
|---|---|---|---|---|---|---|
| 06 2023 | AIAA Aviation | San Diego | DLR | | An MBSE Architectural Framework for the Agile Design and Optimization of Complex System | A.F. Torrigiani, L. Boggero, B. Nagel |
| 06 2023 | AIAA Aviation | San Diego | TU Delft | | From Requirements to Product: Digitization of the Aircraft Design Process using MBSE, MDAO and KBE | A.M.R.M. Bruggeman, G. La Rocca |
| 06 2023 | AIAA Aviation | San Diego | Concordia | | A Scoring Approach to Assess Maintenance Risk for Aircraft Systems in Conceptual Design | S. Sélim, S. Liscouët-Hanke, A. Tfaily, A. Butt, B. Alphonso |
| 07 2023 | INCOSE | Honolulu | DLR | | The AGILE 4.0 Project: MBSE to Support Cyber-Physical Collaborative Aircraft Development | J. Bussemaker, L. Boggero, B. Nagel |
| 07 2023 | INCOSE | Honolulu | DLR | | Function-Based Architecture Optimization: An Application to Hybrid-Electric Propulsion Systems | J. Bussemaker, R. García Sánchez, L. Boggero, B. Nagel |

The TU Delft abstract submitted to the AIAA Aviation Symposium was also submitted to the INCOSE Symposium (to be held in Honolulu in July 2023). If this abstract is accepted then the paper submitted for the AIAA Aviation symposium will be withdrawn.

## 3.6 Journal publications & Book chapters

The Special Issue of Progress in Aerospace Sciences dedicated to the AGILE project became available in November 2020. In this issue reference is made to the AGILE4.0 project.

The following Journal publications were published as Open Access:

| Date | Partner | Journal | Authors | Title | DOI |
|---|---|---|---|---|---|
| June 2020 | ONERA | Structural and Multidisciplinary Optimization | S. Dubreuil, N. Bartoli, C. Gogu, T. Lefebvre | Toward an efficient global multidisciplinary design optimization algorithm | https://doi.org/10.1007/s00158-020-02514-6 |
| March 2022 | POLITO, UNINA, DLR | Aerospace 2022, Vol 9, Issue 3 | M. Fioriti, P. Della Vecchia, G. Donelli | Effect of Progressive Integration of On-Board Systems Design Discipline in an MDA Framework for Aircraft Design with Different Level of Systems Electrification | https://doi.org/10.3390/aerospace9030161 |

| | | | | | |
|---|---|---|---|---|---|
| June 2022 | UNINA | Aerospace 2022, Vol 9, Issue 7 | P. Della Vecchia, M. Mandorino, V. Cusati, F. Nicolosi | Retrofitting Cost Modeling in Aircraft Design | https://doi.org/10.3390/aerospace9070349 |
| September 2022 | TUD | Structural and Multidisciplinary optimization Vol 65 | Z. Wang, D. Peeters, R. De Breuker | An aeroelastic optimization framework for manufacturable variable stiffness composite wings including critical gust loads | https://doi.org/10.1007/s00158-022-03375-x |
| December 2022 | Concordia | Aerospace 2022, Vol 9, Issue 12 | A. K. Jeyaraj, S. Liscouët-Hanke | A safety-focused system architecting framework for the conceptual design of aircraft systems | https://doi.org/10.3390/aerospace9120791 |
| December 2022 | Concordia | Aerospace 2022, Vol 9, Issue 12 | F. Sanchez, S. Liscouët-Hanke, T. Bhise | Influence of ventilation flow rate and gap distance on the radiative heat transfer of aircraft avionics bays | https://doi.org/10.3390/aerospace9120806 |

Unfortunately, the following publications were made without following the requirement to publish it as Open Access:

| Date | Partner | Journal | Authors | Title | DOI |
|---|---|---|---|---|---|
| September 2021 | Concordia | Computers in Industry, Vol. 130, September 2021 | F. Sanchez, S. Liscouet-Hanke, A. Tfaily | Improving Aircraft Conceptual Design through Parametric CAD Modelers – a case study for aircraft systems' thermal analysis | https://doi.org/10.1016/j.compind.2021.103467 |
| March 2021 | DLR | Chapter in Springer book on MBSE | L. Boggero, M. Fioriti, G. Donelli, P. Ciampa | Model-Based Mission Assurance/Model Based Reliability, Availability, Maintainability, and Safety (RAMS) | https://doi.org/10.1007/978-3-030-27486-3_34-1 |
| April 2021 | DLR | Chapter in Springer book on MBSE | J.H. Bussemaker, P. Ciampa | MBSE in Architecture Design Space Exploration | https://doi.org/10.1007/978-3-030-27486-3_36-1 |
| December 2022 | NLR | Chapter in Springer book on "Advances in Computational Methods and Technologies in Aeronautics and Industry. Computational Methods in Applied Sciences" | W.J. Vankan, W.M. Lammen, E.H. Baalbergen | Multidisciplinary Modelling, Analysis and Optimization for Aircraft and System Level Design and Validation | https://doi.org/10.1007/978-3-031-12019-0_11 |

The following publication was submitted and is under review:

| Date | Partner | Journal | Authors | Title | DOI |
|---|---|---|---|---|---|
| 2022 | Concordia | Submitted to AIAA Journal of Aircraft | S. Sélim, S. Liscouët-Hanke, A. Tfaily, A. Butt, B. Alphonso | A Scoring Approach to Assess Maintenance Risk for Aircraft Systems in Conceptual Design | |

## 3.7 Advisory Board

An Advisory Board was created with as members:

- Thierry Chevalier, Head of Digital Design Manufacturing of Airbus France.
- Christopher Jouannet, Principal Engineer Aircraft Conceptual Design at SAAB

The Advisory Board played an active role during the 2nd AGILE4.0 Open Day in February 2023. They gave keynote presentations which were highly interesting, and participated actively in the round-table discussion. Finally, they were invited to join the review meeting with the EU, and they clearly expressed their views and opinions, which was very useful for the EU and for the AGILE4.0 project team.

## 3.8 Master Thesis on AGILE4.0

| Year | Partner | Name | Title |
|---|---|---|---|
| 2020 | UNINA-DLR | Massimo Mandorino | Automatic Aerostructural Analysis and Aerodynamic Optimization for Collaborative Aircraft Design Process |
| 2020 | TU Delft-Fokker | Bas van Dam* | Automated Rudder Design Optimization – Investigating the Effect of Integrating Manufacturability in the Preliminary Design of an Induction Welded Thermoplastic Composite Aircraft Rudder |
| 2020 | TU Delft-Fokker | Jente Sonneveld* | Development and Implementation of a Generative Design and analysis Methodology for Flaps and Deployment Mechanisms |
| 2020 | CFSE-EPFL | Vivien Riolo | Exploration of optimization and machine learning methods in the field of aircraft design |
| 2020 | CFSE-Imperial College | Jean-Philippe Kuntzner | Aero-elastic Tool implemented in a preliminary aircraft design suite |
| 2020 | PoliTo – DLR | Carlos Cabaleiro de la Hoz | Environmental Control System and Flight Control System Architecture Optimization from a Family Concept Design Perspective |
| 2020 | PoliTo - DLR | Francesco Bruno | A Model-Based RAMS Estimation Methodology for Innovative Aircraft on-board Systems developed in a MDO Environment |
| 2020 | ISAE – Supaero - ONERA | Paul Saves | On adapting the Super-Efficient Global Optimization solver to handle mixed-variables, with applications in aircraft design |
| 2020 | NLR-TUD | Huy Tran | Efficient modeling of hybrid-electric aircraft for design and performance optimization studies |

| | | | |
|---|---|---|---|
| 2020 | TU Delft – Fokker | Bas van Manen* | Development and Implementation of an MBSE Requirement Verification Framework in the System Design Process |
| 2020 | UNINA - LDO | Ilaria Sorrentino | Cost modelling in collaborative aircraft design: a retrofitting cost estimation methodology |
| 2021 | RWTH | Jenny Ortmann | A Methodology for the Quantitative Assessment of the Aircraft Systems Accessibility |
| 2021 | TU Delft - DLR | Thibault De Smedt | Aircraft Engine Architecture Modeling<br>Creating a Benchmark Problem using a System Architecting Approach with Mixed-Discrete and Multi-Objective Capabilities |
| 2021 | UNINA | Luca Romano | External noise integration and modelling in collaborative aircraft design |
| 2021 | TU Delft - Fokker | Darpan Bansal* | Manufacturing and Assembly modelling |
| 2022 | TU Delft | Max Rein | Adjustment of the MDAO problem formulation using sensitivity analysis to reduce the computational cost within aircraft design |
| 2022 | DLR | Umberto Merola | Value driven optimization campaign addressing manufacturing, supply chain and overall aircraft design domains in the early development stage |
| 2023 | CFSE-Univ. Genoa | Giacomo Benedetti | Actuator disk modeling in CEASIOMpy (**in progress**) |
| 2023 | Concordia | Nikta Tabesh | MBSE framework to support safety assessment (**in progress**) |
| 2023 | Concordia | Parush Bamrah | Geometric Modelling to support Safety Analyses in conceptual design (**in progress**) |

*These Master thesis are not available in the public domain.

## 3.9 PhD Thesis on AGILE4.0

| Year | Partner | Name | Title |
|---|---|---|---|
| 2023 | TU Delft/DLR | Pier Davide Ciampa | MBSE Approach to Multidisciplinary Design Analysis Optimization |
| 202X | TU Delft | Anne-Liza Bruggeman | MBSE (Model Based Systems Engineering) Framework for Design for Manufacturing in Collaborative MDAO **(in progress)** |
| 202X | TU Delft/DLR | Jasper Bussemaker | Collaborative Architecture Design and Optimization (in progress) |
| 202X | UNINA/DLR | Giuseppa Donelli | A Model-Based Trade-Space Evaluation Coupling Design-Manufacturing-Supply Chain in the Early Stages of Aircraft Development |
| 202X | Concordia | Andrew Jeyaray | Integration of Safety into Systems Architecting for Aircraft conceptual design |

## 3.10 AGILE/AGILE4.0 Academy

The AGILE4.0 Academy was organized from September 2021 until April 2022, and 34 students registered from 11 countries over 4 continents. They were divided into 3 different teams that

applied the AGILE4.0 technologies on the DC2 existing aircraft. Several on-line courses were organized to familiarize the students with the AGILE4.0 technologies:

1. The OCE and KE-CHAIN platform by *Bastiaan Beijer (KE-works)*
2. System Definition Models - Stakeholders, Needs, Scenarios and Requirements by *Jasper Bussemaker (DLR), Bastiaan Beijer (KE-works)*
3. Scenario Modelling with Capella by *Nikta Tabesh, Andrew Jeyaraj, Susan Liscouët-Hanke (Concordia University), Bastiaan Beijer (KE-works), Jasper Bussemaker (DLR)*
4. Architecture Design Space Modelling using ADORE, *Jasper Bussemaker (DLR)*
5. MDAO Problem formalization, KADMOS & MDAx, *Anne-Liza Bruggeman (TU Delft), Pina Donelli (DLR)*

It is planned to make these on-line courses available on zenodo.org.

## 3.11 Links with other H2020 projects

Pier Ciampa was invited to the advisory board of the EU funded project Madeleine that focuses on the development and validation of multidisciplinary design tools for optimization (Grant Agreement 769025), see also https://www.madeleine-project.eu/. Pier Ciampa also gave an invited presentation during the final workshop of this project (November 26, 2021), in which he referred to the AGILE4.0 project.

A teleconference was organized with people from the IMOTHEP project (2020-2023, Grant Agreement 875006), on May 20, 2022, and the idea was to take one of the IMOTHEP concepts, and run the AGILE4.0 technologies on it (DLR/NLR/ONERA). More information on the IMOTHEP project can be found at https://www.imothep-h2020.eu/

The H2020 project "MORE&LESS" (2021-2024, Grant Agreement 101006856), might be interested in using some of the technologies developed in AGILE4.0 in their project. It should be mentioned that P.D. Ciampa is part of the "MORE&LESS" Expert External Advisory Board. See https://www.h2020moreandless.eu/project/ for more information on this project.

TU Delft is using the results of the AGILE4.0 project in the ITEA 3 EC project DEFAINE with partners from the Netherlands and Sweden, see also https://www.defaine.eu/

The AGILE4.0 Framework was partially exploited by the University in Naples in the CleanSky2 project IMPACT (2020-2023, Grant Agreement 885052), where it was used for the innovative fuselage rear end application case.

## 3.12 Links with National Funded Projects

TU Delft will use the results of the AGILE4.0 project in the DASAL initiative to establish the Dutch Aviation Systems Analysis Laboratory (part of the large Dutch national initiative *Luchtvaart in Transitie*).

Concordia participates in the Canadian partner project called MDAO-NextGen and is funded by the Natural Sciences and Engineering Research Council of Canada (NSERC), Grant Numbers CRDPJ 538897-19 and the Consortium de recherche et d'innovation en aérospatiale au Québec (CRIAQ), and Bombardier. A follow-on project will be funded by NSERC and CRIAQ as well,

called ACI-OPT (Aircraft Component Installation Optimization), 2023-2025, with the partners McGill University, StreamSystems, MTLS Aerostructures and Bombardier.

## 3.13 Open Days

The AGILE4.0 project organized 2 Open Days, the first one a virtual meeting on December 16, 2021, and the second Open Day as a physical meeting on February 15, 2023 at DLR Hamburg.

### 3.13.1 Open Day December 16, 2021

Around 80 people external to the AGILE4.0 consortium attended the first Open Day. In the meeting they were informed about the project activities, the different applications studied in the project and the AGILE4.0 academy. The five industrial partners in the project provided feedback on the problems studied and why they did join the AGILE4.0 project. After the meeting the participants received the slides of the presentations as well as of the different recordings made.

### 3.13.2 Open Day February 15, 2023

The second AGILE4.0 Open Day was organized as a hybrid event. About 100 people external to the AGILE4.0 consortium joined physically the meeting at DLR, and about 30 people joined the meeting virtually. Keynote presentations were given by the members of the AGILE4.0 Advisory Board (Thierry Chevalier and Christopher Jouannet) and by Gleverson Lemos from Embraer. The different technologies developed in AGILE4.0 were presented in detail, as well as the 7 application cases on which these technologies were applied. The five industrial partners in the project gave detailed feedback on their experiences using the AGILE4.0 technologies, lessons learned and way forward. The official part of the Open Day was concluded with a Panel Sessions discussion that included the Advisory Board, Embraer and Dassault Systemes.
During the Open Day the AGILE4.0 team presented 6 posters that will be saved on zenodo and the AGILE4.0 website. All registered persons to the Open Day will receive the different presentations.

## 3.14 Zenodo

An AGILE4.0 community was created on zenodo.org. All papers presented during the AGILE4.0 project are saved on zenodo.org, as well as the data of the different application cases. It is planned to add the courses presented during the AGILE4.0 Academy to zenodo as well. Using zenodo.org guarantees preservation of the data and results generated during the AGILE4.0 project.

## 3.15 Other activities

S. Liscouët-Hanke (Concordia) gave a presentation at Rencontre Jacques Cartier (Nov 2019), titled « Relever les défis des avions plus électriques avec des outils de conception avancée » (in french), which refers to the AGILE4.0 project.

M. Fioriti (Polito) mentioned the AGILE and AGILE4.0 activities with special focus on the integration of cost estimation in the MDO workflow during a lecture of the M.Sc. course “Risk, cost and logistic support for aerospace systems” in October 2020 and during a lecture of the Ph.D. course “Parametric cost estimation” in April 2021 both held at Politecnico di Torino.

DLR organized a workshop on “MDAx” for the Energy company RWE in January 2021.

P.D. Ciampa (DLR) gave a Lecture at TU Delft in March 2021 on AGILE4.0 activities for the AWEP students, to promote internships and thesis opportunities.

A. Jungo (CFSE) gave on May 10, 2021 a Lecture at the Swiss University of Applied Sciences in Winterthur on aircraft design, mentioning both the AGILE and AGILE4.0 projects.

Leonardo has organized internal meetings to raise awareness and promote the methodologies developed within the AGILE 4.0 project in order to pave the way for the subsequent exploitation of the project results.

The Requirements ontology developed within the context of the AGILE 4.0 project is published as open access on the Community page of the project on the Zenodo website, from where it can be freely downloaded and re-used by any user inside and outside the project Consortium. (Boggero, Luca, Ciampa, Pier Davide, & Jepsen, Jonas. (2021). AGILE 4.0 MBSE Ontology [Data set]. Zenodo: *http://doi.org/10.5281/zenodo.4671896.)*

EASA and FAA organized a joint workshop on Structures and Materials Safety in November 2021, that included a slide of the AGILE and AGILE4.0 projects.

P.D. Ciampa (DLR) gave an invited presentation at the final meeting of the H2020 Madeleine project in November 2021.

Robin Grapin worked as trainee at ISAE-supaero/ONERA. He presented his work at the AIAA Aviation 2022 conference.

L. Boggero (DLR) presented the main MBSE activities carried out in the AGILE 4.0 project at the “Seminario all’Ordine degli Ingegneri di Torino” (Symposium to the Engineers Association of Turin), December 2022.

Parush Bamrah (Concordia) will present her “thesis in 180 sec” (based on the AGILE4.0 project) at the CRIAQ forum, in Montreal, Feb 15, 2023

A presentation of the AGILE4.0 Framework was added to the public part of the AGILE4.0 website, “AGILE4.0: A Journey from MBSE to MDO”

Details of the AGILE4.0 Application cases were added to the AGILE4.0 website. Several of these application cases include video’s (saved on YouTube) explaining what has been done.

# 4 CONCLUSION AND OUTLOOK

This document gave a summary of the AGILE4.0 project communication, dissemination and exploitation activities.

The AGILE4.0 project high-level objective was to bring significant reductions in aircraft development costs and time-to-market through the implementation of an integrated cyber-physical aeronautical supply chain.

The AGILE4.0 project developed technologies that permit to answer the following questions that are rarely raised in the aeronautical industry:

- Should an investment being made to acquire machines for a novel manufacturing process that will lead to a better performing product, or should it be allocated to investigate a novel aircraft design?
- Given an available development time for the next aeronautical platform, what is the degree of novelty it can be afforded in terms of costs and certification time, traded with an increase of design performance?
- How to upgrade constantly evolving systems during its life-cycle?
- What are the implications due to the uncertainties on any level of the life cycle of an aircraft, and what is the impact on costs and lead time-to-market?

All industrial partners involved in the AGILE4.0 project will use the different technologies in their company, clearly demonstrating the success of the project.

The AGILE4.0 project dissemination targets were 40 papers presented at conferences, and 4 papers published in peer reviewed journals. At the end of the project, we are at 49 papers presented at conferences (with 5 abstracts submitted for presentation after the end of the project), and 10 papers published in peer reviewed journals (with in addition 1 paper that has been accepted with a revision).

The AGILE4.0 project made also a large investment in human capital, 20 Master students as well as 5 PhD students were involved in the project, and the AGILE4.0 Academy attracted 34 students.

The AGILE4.0 project results were presented in 2 Open Days.

An Advisory Board with members of the industry was created, and they joined the AGILE4.0 Open Days.

Finally, the AGILE4.0 technologies will be used in at least 4 on-going EU funded projects, as well as in new National and EU funded projects.