TOICA Final Report – Publishable Summary

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1.1 Final publishable summary report

1.1.1 Executive Summary

The "**T**hermal **O**verall **I**ntegrated **C**oncept **A**ircraft" project (TOICA) started in September 2013 and ended in September 2016. This EU FP7 co-funded project was coordinated by Airbus with a consortium of 32 partners from 8 countries, including aircraft and aero-engine manufacturers & suppliers, Product Lifecycle Management and simulation software solution providers, research centres and academic institutions.

The following High-level Objectives were used to guide and assess the achievable contribution of the results when deployed within the application areas covered during TOICA.

- First, the project aimed at developing customised collaborative and simulation capabilities improving the generation, the management, and the maturity growth along the project life cycle of the Behavioural Digital Aircraft dataset.
- New concepts were then studied for improved thermal load management for aircraft components, systems or equipment, which will integrate innovative cooling technologies and products.
- As a third objective, the developed capabilities and technology concepts had to be assessed in a near-programme design environment and validated against different innovative thermal architectures targeting future commercial aircraft entering into service in 2020 and later.
- The final objective was to seek design optimisation solutions by enabling highly dynamic allocation and association between requirements, functions and product elements (Super-integration) for product innovations.

In order to achieve these goals, the project organised a series of plateaus where the key design actors contributed to specifying, implementing and delivering the needed capabilities to perform the thermal trade-off processes requested by the aircraft architects.

The purpose of these plateaus consisted in identifying and testing through six use cases the capabilities for:

- Improving **the overall multidisciplinary conception** of aircraft during the architecture phases
- Optimising **the overall energy efficiency** of the aircraft through a reduction of energy consumption necessary to thermal load management.
- **Reducing thermal constraints** on systems and structure and thus reducing integration risks.
- **Reducing weight and complexity** through a fully integrated structure and thermal design of systems, enabling optimisation of the aircraft structures and considering thermal constraints as a sizing load.

TOICA has made its results available to the aeronautics supply chain and related scientific community through: dissemination including a dedicated mini-symposium at the ECCOMAS Conference in June 2016, various publications to international events and scientific journals; the creation of a catalogue outlining more than 120 exploitable results grouped in 14 categories; and 85 final deliverable documents. Further information will be found on the TOICA public website: www.toica-fp7.eu/. This report aims at reflecting all the achievements of the project contributing to improve the value of the product and its development plan and the benefits already demonstrated by the whole Consortium.

1.1.2 Summary description of project context and objectives

1.1.2.1 Challenges

The efficient management of thermal sources on board modern commercial aircraft has emerged as a new priority for aircraft manufacturers and their supply chains in order to propose competitive solutions to new market demands whilst continuing to reduce development costs. This priority, which requires the "thermal behaviour" to be managed from an overall aircraft level view point and in detail down to a sub-component level, has become more complex due to the higher electrical power density, to new structural architecture based on composites and more challenging European environmental targets.

Considerable thermal modelling and simulation work is performed today at various levels, and in certain system specific areas, but this typically happens after the architecture phase when crucial design decisions have already been taken.

Therefore TOICA (Thermal Overall Integrated Concept Aircraft), an FP7 project launched in September 2013 with 32 partners for an overall 26.5 M€ budget, aims at assessing and improving the concept of an aircraft architecture environment to support both trade-off and preliminary design phases for the right aircraft architecture selection, taking into account the complex aircraft behaviour and the overall multi-physics and multi-level simulation processes developed through the extended enterprise.

The better definition of the architectures relies on developing new trade-off mechanisms for the challenging integration of more dissipative systems and on the associated pyramids of models, a key output of the project enabling experts to perform earlier and more reliable thermal assessments (for instance, by considering the aircraft operations). The design processes need to be revisited to allow more robust and deeper integration of the aircraft functions. New capabilities are consequently proposed to aircraft architects for a more agile exploration of the overall design space (Super-integration approach) by considering consistently all constraints emerging from both functional and physical representations.

The thermal behavioural dataset encapsulates all thermal requirements, models and simulation results for the evolving aircraft configuration, including all possible variants and trade-offs, as a single coherent dataset enabling full support to the thermal architecture and integration processes. A dedicated Architecture Cockpit has been built to visualize and monitor this dataset from various angles.

1.1.2.2 Integrated Approach

TOICA has taken an integrated approach to managing the thermal architecture. It has defined a set of six use cases (Figure 1) that covers a broad spectrum of thermal aspects that need to be developed and/or improved. The use cases brought various sets of requirements and expected benefits based on concrete studies, input data (context) and key performance indicators. Based on these requirements, the capability teams in the project developed in turn new capabilities to be exploited.

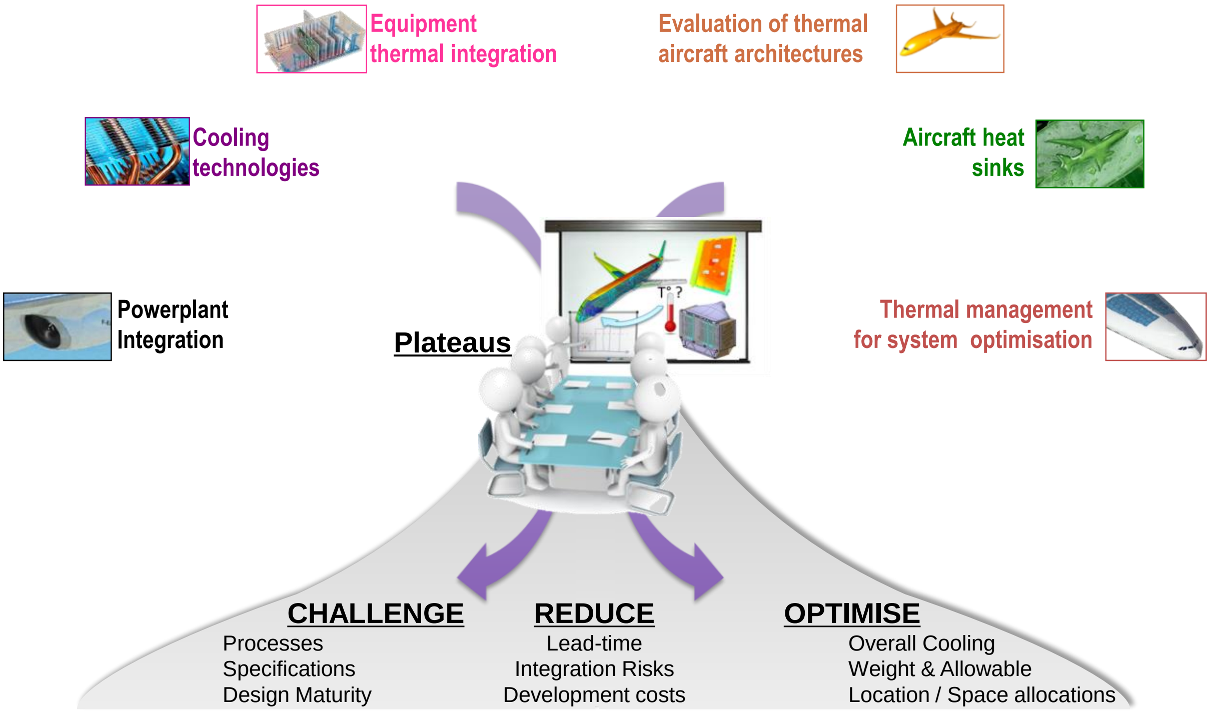


Figure 1 – The six TOICA Use Cases

The use cases provided expertise, evaluations and thermal data for the aircraft alternatives analysed on plateaus and addressed all needed design scales in the architecture (equipment, system, component or the aircraft). The plateaus were animated by the thermal architects to solve specific aircraft concerns driven by the two categories of generic aircraft: the coming configurations of derivative aircraft entering into service in 2020 mainly driven by the integration of new high by-pass ratio engines, and more innovative concepts to be proposed to the market in 2030+ particularly asking for new aircraft cooling strategies.

Resulting from the Consortium knowledge, thermal architects and experts now had new thermal trade-off capabilities to operate in concrete plateaus. The plateau set-up reflects the operational design conditions. The design actors had the opportunity to experiment trade-off methodologies and to challenge the performance of the new thermal concepts, to evaluate the performance of the modelling and simulation methods and to test the overall collaborative network to achieve the final evaluations. During plateaus, architects decided, formalised their priorities, specified the studies and finally instantiated trade-off requests in the collaborative environment. This approach enabled the development, the validation and the maturity convergence of the capabilities.

1.1.2.3 Trade-offs

Today most disciplines are close to their optimal design. Most of the progress margins lie in better transverse integration of the systems and equipment in the aircraft. To address first the thermal architect concerns, the trade-off processes are implemented in collaborative environments enabling data and model exchanges with suppliers.

These platforms host the datasets characterizing aircraft configurations composed by the requirements, the functional descriptions, and obviously the simulation data created from a pyramid of models (Figure 2).

These pyramids represent sets of coupled models used for multi-level and/or multi-disciplinary analyses. These simulation data describe the thermal aircraft behaviour and are delivered to architects within these collaborative platforms for the selection of the best concept.

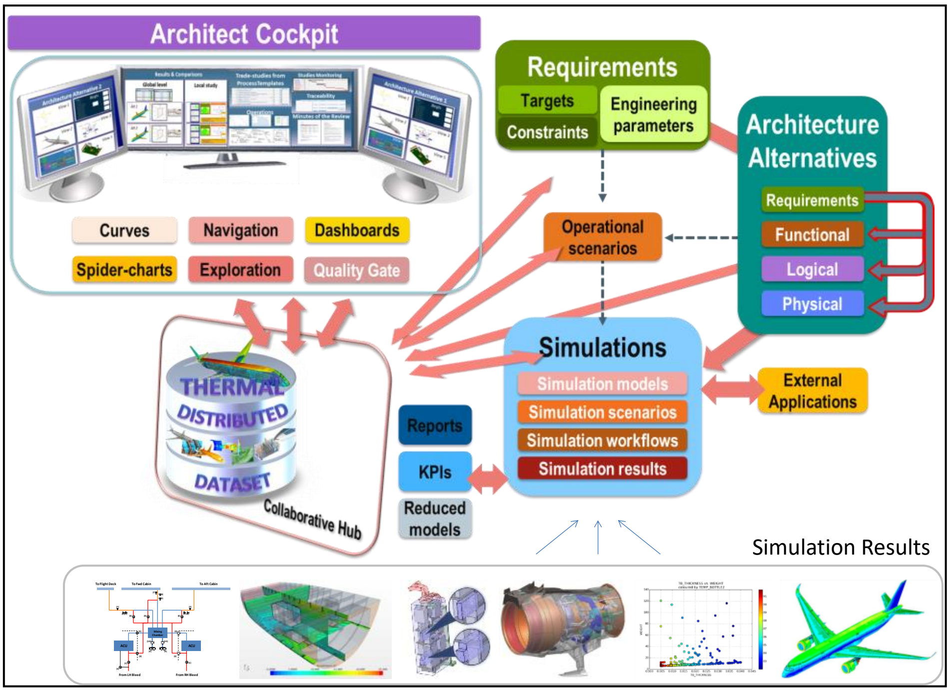


Figure 2 – A new, more efficient set of capabilities to predict and manage thermal behaviour of an aircraft from the early phases of design

To conduct this selection, value creation strategies are defined by architects [1]. The associated design drivers (e.g. weight, development cost, design lead-time, etc.) stress the process setup, the aircraft description (granularity), or the complexity of the modelling approach. The sets of metadata characterising the various design options, the required flexible modelling, and the results and decisions, support the traceability and the dataset consistency that are key enablers for the architect who is accountable for defining and steering the concept definition.

This dataset exists and evolves due to collaboration standards (formalised through the MoSSEC standardisation activity [2], www.mossec.org) in the context of the overall multi-discipline, multi-level and multi-partner Behavioural Digital Aircraft (BDA) dataset alongside all other aircraft behavioural aspects. Collaborative reviews are then easily animated with live access to the key decision data energising debates on the concept thermal behaviours, allowing 3D visualisations, dashboards and the formalisation of the key decisions taken (in the Architecture Cockpit).

1.1.3 Description of main S & T results/foregrounds

1.1.3.1 Overall Results

Airbus now demonstrates for a short range configuration the capability to launch during the trade-off process Super-integration and Value Assessment tools directly from the Architecture Cockpit, giving aircraft architects the opportunity to derive new functional architecture candidates and evaluate them against a Value Creation Strategy. Subsequent thermal study requests are launched illustrating the transfer of the architecture data to thermal experts. Different architectures are compared using more advanced selection criteria (e.g. structural, zonal temperature) for different flight phases. In parallel, important evolutions of the aircraft thermal model that forms the central part of thermal trade-off studies are shown. They are for example based on a standardization of the interfaces between suppliers and internal thermal models for the fast exchange of equipment models and model reconfiguration, on an automatic relocation of equipment models in the aircraft model, or on the co-simulation between system models and the aircraft model. Reductions in the analysis lead time as well as a better visibility on various margins are generally expected from this significant progress [3, 4].

For engine thermal integration studies (Neo configurations), Airbus is now able to seamlessly perform a collaborative multi-disciplinary optimisation process of a pylon [5], based on four working environments across three sites. The approach indicates promising effects on the structural and system weight. The simulation intent concept is also used to support the rapid trade-off of multiple turbine rear structure components by enabling the simulation specialists to propagate interface and analysis information when using geometrical variants [6]. Neo configurations will finally benefit in the future from new transient distributed simulations between airframer, engine manufacturer and component suppliers.

Finmeccanica has developed a complete trade-off focusing on the reduction of direct operating costs associated to engine bleed off-takes through evaluations of alternative thermal and systems architectures. The studies consider the system weight and the development risk management through detailed, model-based, system specifications for system suppliers. They also integrate the development cost reduction through risk mitigation on fuel tank flammability and avionics cooling integration.

The different actors have demonstrated their ability to set up in a collaborative environment the architecture baselines (requirements, functions/systems, drivers, and objectives) at aircraft and system levels, to generate some variants and manage the trade-off up to the choice of architecture [5]. This selection leading to the bleed-off take optimisation is supported by a pyramid of behavioural models assessing airplane conductance and the heat load requirements for the Environmental Control System and bleed system sizing. Live simulations (both steady and unsteady) were performed in ground and flight conditions on the coupled thermal and system models to assess aircraft level and system level parameters (stabilized, pull-up and pull-down temperatures, minimum bleed off-takes from the engines, and system component sizes). The resulting configurations showed a reduction of the direct development and operating costs through risk mitigation on avionics cooling integration. Development cost reduction through risk mitigation on fuel tank flammability will be the next step.

In the frame of Dassault Aviation trade-offs, architects investigated environmental control systems to optimise and reduce the pack size. Both pack performance over the flight envelope and benefits for the aircraft are compared through standardised and automated exchanges with the system supplier of models based on Modelica and Functional Mock-up Unit/Functional Mock-up Interface. In this way, the earlier exchange of design requirements and models with the supplier allows the airframer to develop a more efficient system and a more accurate assessment of its architecture [7]. Through the early use of system models, Dassault Aviation demonstrates the capability to compare different system architectures earlier and reach more robust choices.

Similarly, Airbus Helicopters currently performs some thermal management of an avionic bay with a new collaborative process organised around a complete data model and able to manage automated simulation workflows. With the contribution of suppliers [8], different equipment installation scenarios are evaluated to analyse the equipment obsolescence, the sensitivity of the thermal behaviour to the environmental conditions, etc. Different installation scenarios of a mixed cooling architecture combining air ventilation and heat pipes coupled to a mini-VCS (Vapour Cycle air conditioning System) were evaluated. Thermal architects ran from end-to-end the full trade-off process from the study request to the reception of aero-thermal results and the final acceptance. This final step is materialised by a tree of argumentation [9], ensuring traceability of the decision associated to the specific studies. The execution of this process has shown a significant improvement of the overall lead-time.

For more information, a near-complete presentation of TOICA results was given during the TOICA Mini-symposium 1401 included in the ECCOMAS 2016 Congress [10] and are available on the TOICA website www.toica-fp7.eu/.

1.1.3.2 Foreground

1.1.3.2.1 General considerations

The TOICA project foreground is managed via the Consortium Agreement, available from the very beginning of the project. It has to be noted that all industrial partners were involved in all aspects of the project, in particular:

- **Requirements creation** (about 550 requirements created and traced during the life of the project)
- **Detailed specification of capabilities** (e.g. Architect Cockpit, Super-integration)
- **Utilisation of capabilities** before, during and after the plateaus
- **Assessment of capabilities** (end user validation feedback was provided, Technology Readiness Level (TRL) reviews were performed)

Detailed hereafter are the main areas where foreground was created.

1.1.3.2.2 Architect Capabilities

New architect-level processes and methods were developed:

- Set-based design using surrogate models
- Architect Cockpit to steer and visualize new studies
- Super-integration methods enabling architecture exploration

These new methods help the product architects to evaluate thermal aircraft architectures and Thermal Whole Engine Model. They also improve the collaboration between an integrator (aircraft or engine manufacturer) and its supply chain.

It has to be noted that the capabilities developed here are neither specific to thermal management, nor to aeronautics, and could be used more widely.

1.1.3.2.3 Thermal Capabilities

Many new capabilities were developed including:

- Modelling and simulating air systems
- Fuel as a heat sink
- Fuel pump thermal behaviour
- Heat exchanger thermal behaviour
- Automated geometry simplification exploitation and validation
- Analysis on different models in the Pyramid of Models

1.1.3.2.4 Collaborative Capabilities

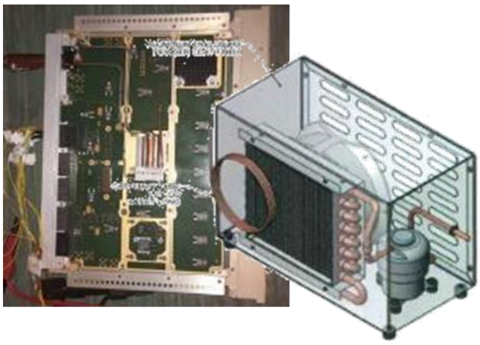
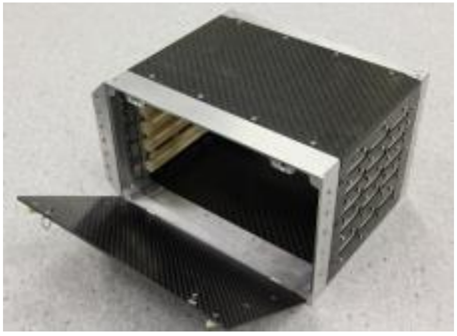
During TOICA, an efficient collaborative design process was developed based on model exchanges between aircraft manufacturers and system suppliers, allowing:

- Definition of a new business process integrating model based analysis enabling the optimization of requirements in early phases of the aircraft development
- Definition of an efficient model exchange process enabling several exchange iterations to support the new business process
- Validation of BDA/MoSSEC concepts to support the new processes
- First approach to integrate the safety point of view in simulation models

Thanks to these collaborative capabilities, the supply chain is more deeply and earlier involved in the early phase of the design. Improvements include standardization of the interfaces between suppliers for the fast exchange of equipment models and model reconfiguration, automatic relocation of equipment models in the aircraft model, co-simulation between system models and the aircraft model, etc.

1.1.3.2.5 Avionics prototypes

Three avionics prototypes were developed to support new concepts of cooling architectures:

A mini Loop heat pipe with thermal plug acting as condenser able to dissipate up to 75 Watts. Associated to a mini-VCS to cool down the evaporator	
A low weight Integrated modular avionics rack for helicopters	
A mini-pumped loop for hot spot cooling	

1.1.3.2.6 Commercial software improvements

Among the Commercial Off-The-Shelf (COTS) software improved thanks to TOICA, we can list:

- LMS Imagine.Lab, LMS Amesim, LMS CAESAM and LMS Samcef Thermal
- MSC.SimManager, MSC.SimXpert & MSC.Apex
- Dassault Systèmes 3DEXPERIENCE platform
- Eurostep ShareAspace Nova
- Siemens Simcenter 3D Thermal & Siemens Teamcenter
- MAYA NX Thermal

New commercial versions of these software will appear on the market shortly after the project termination.

1.1.3.2.7 Software tools developed or improved by research centres

Many tools or models were either developed or improved during the course of the project. In particular:

- Extensions to middleware Brics (NLR) for cross-organisation workflows
  - Technical extensions (including interfaces)
  - MDO workflow application
- Smart surrogate modelling method for transient behaviour

- Coupling of surrogate model and physical model
    - Preparation for integration of surrogate models in Amesim, Dymola
- Coupling solutions for thermal experts to enable multi-physics computations within the model pyramid
    - Thermal Computer Fluid Dynamics (CFD) and Finite Elements Analysis coupling for analysis of hot spots
- Equipment reduced thermal models
- Cooling technologies
    - Mini-pumped loop
- Advanced modelling for two-phase cooling technologies integration support
    - Detailed models for heat sink + mini liquid loop
    - Detailed models for heat sink + multi oriented heat pipes
- Thermal model of the wing compartment adjacent to wing fuel tank
- Fuel Tank 3D structure thermal models

1.1.3.2.8 Software tools developed or improved by Universities

New and improved methods, tools and technologies were developed and integrated. In particular:

- Definition and development of new methods of Super Integration, Value Assessment, Architectural Synthesis, Uncertainty Allocation, 3D to 2D creation, Extraction of Fluid Domain Models from Assembles, Flammability Models, Interactive and Visual technologies for architectures and more
- Implemented and enhanced tool functionality in University tools
    - AirCADia Explorer, AirCADia Architect (CRANFIELD) Configurable Component Modeler (CHALMERS), Cambridge Advanced Modeler (CAMBRIDGE) and plugins for Simulation Intent (QUB)
    - And partner tool environments such as EWB (GKN), Siemens, Dassault and MSC tools.
- Mini Vapour Compression System (mini-VCS) refrigerator/demonstrator (PADOVA)

Several tools are applicable for business exploitation and will be associated to forthcoming industry-led collaborative research projects.

1.1.4 Potential impact and main dissemination activities and exploitation results

1.1.4.1 Impacts and exploitation results

1.1.4.1.1 Main impacts

As a project, TOICA generated several impacts which are analysed and summarised in this section. The purpose of TOICA was clearly to induce positive effects on aircraft development to improve the overall cost efficiency in a European context.

The first contribution from TOICA aimed at improving the trade-off methodologies. The technical management was organised through a series of plateaus, where the key actors gathered to concentrate their efforts in defining the required trade-offs and achievable results to impact the design processes and the product performance.

These plateaus led to collaborative physical reviews of real design concerns expressed by programs, architects and experts. Solutions were studied and developed by the Consortium and evaluated during these plateaus. They were a strong mechanism which, combined with a TRL approach, enabled the project to offer mature solutions to be exploited in the short term by airframers and the supply chain.

By meeting the future process operators and end-users, the other benefit from plateaus was to ensure regular reviews of the data, the capability developments, the implementations, the validation tests and also to enable discussions and agile adaptations of the trade-off studies and solutions.

With good maturity levels (TR4 – TRL5) and a strong involvement of end-users, TOICA guaranteed not only theoretical developments or capability integration but also results confronted by real expectations on both organisations and products which facilitated increasing buy-in from the stakeholders.

In this sense, the project achievements can be judged as excellent. Indeed, the four TOICA high level objectives have been addressed by all plateaus and reached by the whole project through the different demonstrations and validated by key stakeholders.

These achievements logically reflect the TOICA contribution to **Cost efficiency in Air Transport**, with **impacts on**:

- **Aircraft development costs**

  By the implementation of formalised collaborative trade-off processes, faster exchanges, interface contracts and the intensive use of methodologies aiming at automating end-to-end modelling and simulation activities, the project demonstrated opportunities for lead-time reduction of end-to-end processes, as well as risk and rework mitigations.

- **Supply chain**

  The supply chain is involved more deeply and earlier in the early phase of the design as shown through Airbus NSR and Neo, and Dassault Aviation trade-offs. The interactions are more and more model-based compared to the previous document-based or data-based exchanges revealed by the pre-TOICA period. Both architecture and design phases can now be faster with wider exploitation of the means TOICA delivered, since they lead to:
  - Faster design convergence with less iteration in the specification phase. This induces lead-time reduction.
  - Better definitions of the design margins, resulting in better installations, cheaper designs or de-risked integration.

- **Collaborative design**

  The improvement of the collaboration between the key design actors was one of the main drivers and was addressed through various streams in order to provide:
  - A deeper exploitation of the MBSE approach resulting in model-based collaborations and specifications
  - Capabilities offering a more agile exploitation of system models for pyramid of model assembly
  - The enrichment of the BDA approach for delivering a MoSSEC standard to ISO instances,
  - The use of different collaborative platforms being compliant with this MoSSEC standard
  - Designing under uncertainties, allowing some engineering processes to overcome issues coming from asynchronous interactions
  - Capabilities enabling architects to steer reviews, federate the discussions between experts, contributors, process owners, and suppliers, and to trace decisions

  Overall, the efforts TOICA spent on the definition of collaborative processes and associated capabilities highlighted a strong capacity to accelerate the product development plan, either by reducing iterations or by rapidly identifying the best alternatives in regard to trade-off targets and value drivers.

TOICA extended the collaborative multi-partner European aircraft design capacity to the architecture phase and enhanced the simultaneous handling of different levels, the multidisciplinary design and optimisation capacity, in particular for thermal modelling.

These achievements also illustrate several significant **impacts on**:

- **Aircraft operational costs**
  TOICA definitely contributes to reducing the operational cost by introducing methods and capabilities changing the way trade-offs are performed by architects. Today, some new processes revealed promising results on increasing performance while tracing design values for airframer and airlines.
  Examples are given by almost all plateaus with:
  - The reduction of direct operating costs associated to engine bleed off-takes through evaluation of alternative thermal and systems architectures (Finmeccanica)
  - The multi-disciplinary optimisation of the pylon under thermal constraints enabling integration of systems without additional shields or insulation blankets (penalty for maintenance) while keeping an optimum on drag
  - Reduction of engine ‘stop and start’ cycles on the ground coming from a better control of temperature levels in the engine, of stage material dilatations near to tip clearances, and of the casing deformation (Airbus Neo plateau)
  - More efficient integration of systems, associated to weight and development risk management
  - Opportunities to better monitor and control the effects of aircraft operations on local thermal behaviours and on failure cases. This way, further optimisation of the aircraft operations will be enabled (aircraft-system transient co-simulation, Airbus NSR plateau)
  - Reduction of the thermal ambiances and/or better management of design margins resulting in higher Mean Time Between Failures (MTBF) and lower maintainability costs,

The next steps for the Partners will be to secure the full exploitation and implementation of all promising innovations tested and validated in TOICA by actively interacting with their organisations to make the change happen. Internal projects and collaborative projects are planned as spin-offs of the TOICA results.

1.1.4.1.2 Exploitation strategy per sector

1.1.4.1.2.1 Industry exploitation plans

TOICA results are key enablers to ongoing Research & Technology programs. For example:

- Thermal trade-off capabilities will progress internally to **higher TRL** levels
- Thermal cockpit and co-simulation means will be further **tested on more complex** scenarios
- New cooling concepts enabling new trade-offs at system level will be studied from **More Electric Aircraft** (MEA) analyses
- Most of the **use cases** will **continue** (Neo in collaboration with Institut de Recherche Technologique in Toulouse, NSR with extension to electricity & air systems). New ones will come (VA for Airframe, Control Rooms) to explore the use of TOICA results in different contexts.
- **Actual datasets will be upgraded** to support new Architect Cockpit functionalities and cover other disciplines in the frame of these use cases.
- Super-integration, Architect Cockpit, MoSSEC, Uncertainty Quantification & Management (UQ&M) will be used **to accelerate the Product Development Plan** (new project launched

and funded internally). Current capabilities will be linked to emerging **Virtual Reality subjects to support manufacturing use cases.**

Demonstrators used during the course of the project will be maintained for further exploitation.

1.1.4.1.2.2 Software vendor exploitation plans

There will be soon **commercial release** of:

- New versions of **existing COTS** which include TOICA developments
- **New software and tools** based on capabilities developed during TOICA
- Commercial **solutions** better tailored for the **supply chain** based on BDA/MoSSEC environment – improving global competitiveness of the European aeronautical industry

Extension to other industrial sectors will be explored (automotive, shipbuilding, etc.). Some of the results are non-specific to aeronautics, or thermal management, and TOICA helped build a good environment to design complex products in an extended enterprise context.

In addition, **training activities** based on TOICA demonstrations performed during plateaus will be put in place (many videos of live demonstrations are available). This training can be:

- Internal training (**technical and sales force**)
- External training material for **potential users**
- **E-learning material**: Education and training for knowledge
  - Targeting **future engineers** with university programs
  - Competence Centre development outside of Europe to support European OEMs with Offset Credits generation along their international sales
  - Aerospace customer oriented courses

1.1.4.1.2.3 SME exploitation plans

Thanks to TOICA, SMEs participating to the project now have the ability to bring new or enhanced software tools to market:

- Strengthen and extend optimization capabilities of the CENAERO tool Minamo. Industrial partners, such as SAFRAN, can benefit through new releases.
- The model packaging tool will be used to set an improved delivery process for EPSILON activities
- EPSILON will add the dynamic artificial neural network builder prototype and black box model delivery process to their set of tools
- The new tools and prototypes will be proposed in the multi-physics and system modelling EPSILON business offer.
- AZM enables coarse grid CFD within XRG's HumanComfort® Library and will be distributed by Dassault Systèmes (DYMOLA)

They can also market new hardware. For example, ATHERM plans to work on the optimization of the demonstrator designs and adapt them to serial production.

And there are of course opportunities for application and dissemination to other sectors, like automotive, civil engineering, energy, biomedical, etc.

1.1.4.1.2.4 Research and academia exploitation plans

Many methods and tools developed by research partners are exploited through offers of service in research projects or as consultancy and through application in direct projects with customers (aeronautical or other sectors), national programs, European projects, etc.

The standardisation of some of the TOICA results in the ISO MoSSEC project is also ongoing.

1.1.4.2 Dissemination activities

TOICA communicated with the aeronautical community as a whole using means such as conference presentations (including one TOICA mini-symposium organised at the ECCOMAS Conference in June 2016 and two dedicated workshops at EASN Conferences in September 2015 and October 2016), articles, press releases, newsletters (six, the last one being public), and the public website (www.toica-fp7.eu).

Many scientific papers were published during the course of the project (13 publications in conference proceedings and 5 publications in peer-reviewed journals) and more are yet to come. Leaflets and posters were displayed on various occasions and the project had a stand during the AeroDays in October 2015. The project also liaised with other collaborative projects (MoSSEC, for standardization purposes; CAPPADOCIA, for strategic evaluation, etc.).

A film summarizing the project main objectives and results had been created during Period 3. It was shown in various occasions, in particular during public conferences, and is available through the public website. Various technical films taken during demonstrations and plateaus are also available through the public website as are the public deliverables related to Architecture Cockpit specifications and BDA architecture and data exchange.

1.1.4.3 Societal implications

The important difficulties recently met by all the aeronautical industry in developing and producing new aircraft show **the strong economic impact** of:

- A better simulation of the consequences of the customer's expectations on the design requirements, and consequently a better simulation of the impact of these expectations on the development life cycle.

  ➔*This has been specifically addressed within the activities related to the new concept aircraft assessment associated to the value generated for the business. It led to important changes in the thermal trade-off process and to the development of a new Value Assessment methodology*

- A stronger mastering of the complete aircraft development process and of the behavioural aircraft dataset considering the entire supply chain as the basis of a more robust design, risk anticipation and safer aircraft

  ➔*This target was addressed and led to the new BDA environment and associated capabilities.*

- A deeper and earlier integration in the design processes of the technical constraints, which leads to re-thinking the treatment and the cascade of the requirements to the product.

  ➔*TOICA has dealt with these expectations and the results were demonstrated during plateaus*

- Fully integrated technical innovations for more efficient aircraft architecture, and at the same time, for reducing the time to market with a robust Entry Into Service (EIS).

  ➔*This has been the ambition of the whole TOICA project!*

The ultimate objective of TOICA was to deliver the demonstration of an operational solution to contribute to meeting today's challenges and enabling the European aeronautic industry to:

- Be in a position to **fully address the market needs for new aircraft** matching the economic constraints of the airliners
- Enable the aeronautics industry to develop new aircraft within a reduced budget and time frame which – compared to the existing situation – will **significantly reduce development costs thanks to innovations such as these developed in TOICA**

Such demonstrations were successfully performed during the plateaus in front of the project stakeholders.

1.1.5 Conclusion

TOICA strongly impacted the overall thermal design and power consumption by enabling a deeper understanding of the multi-level behaviour of the whole aircraft. As a strong contributor, the supply chain benefits from higher collaboration efficiency thanks to more 'simulation oriented' collaborations with the integrators and more iterations on robust and less-conservative specifications.

More efficient and robust decisions jointly taken by architects with experts comes out from earlier and better assessments, consistent distributed data set, traced and monitored exchanges, or fast and flexible modelling able to support trade-offs or optimisations.

The better integration of the systems and the equipment in the aircraft induce more accurate evaluations of the design margins so that the aircraft performance and development costs will be better controlled. TOICA already demonstrates reductions on the overall process lead-time and on the levels of temperature in certain zones with potential effects on development and operational costs.

Thanks to this European project, the partners have empowered all designers looking for new valuable design opportunities and disruptive changes. They gain competitive advantage by infusing new technologies in trade-off and de-risking their integration on new concepts and certainly initiate the greener next generation of aircraft to be delivered earlier to the market due to a more efficient design process.

1.1.6 Address of project public website and relevant contact details

More information about the project can be found on the project website: www.toica-fp7.eu/

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