FIRST RELEASE OF MDO FRAMEWORK DOCUMENTATION

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LIST OF ACRONYMS

FP6	Sixth Framework Programme
DLR	Deutsches Zentrum für Luft- und Raumfahrt
MDO	Multidisciplinary Design and Optimisation
MTU	MTU Aero Engines GmbH
NLR	Stichting Nationaal Lucht - en Ruimtevaartlaboratorium
RR plc	Rolls-Royce plc (UK)
RRD	Rolls-Royce Deutschland
VIVACE	Value Improvement through a Virtual Aeronautical Collaborative Enterprise

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EXECUTIVE SUMMARY

Current state-of-the-art engines and aircraft are complex products. Their design combines various disciplines like aerodynamics, structures, aero-elasticity, safety, propulsion, noise, emissions, maintenance, etc. Each discipline can optimise the design with respect to its own relevant objectives. However, such single discipline optimisation cannot take into account the interactions between the disciplines involved e.g. optimising on weight might increase production costs or reduce maintenance intervals. Multidisciplinary Design Optimisation (MDO) intends to arrive at an optimal design at aircraft or engine system level, based on a chosen set of measurable design criteria. As some (sub)systems are complex and involve multiple interacting disciplines, similar MDO techniques can also be applied at (sub)system level.

To address such MDO issues, the Value Improvement through a Virtual Aeronautical Collaborative Enterprise (VIVACE) project [1] dedicates a specific work package to MDO. VIVACE is a sixth Framework Programme (FP6) Integrated Project sponsored by the European Union. VIVACE is based on the evolutionary approach [2] to swiftly provide user value, to be able to respond to changing user requirements, and to learn from the experience gained. VIVACE has chosen to use three iterations. This report presents the results from the first iteration. The requirements on a Multidisciplinary Design and Optimisation environment have been expressed in confidential deliverable D.3.2.1_1 [3]. To allow re-use of existing methods and tools, the current state-of-the-art has been analysed in confidential deliverable D3.2.2_1 [4]. This has led to a specification of the services for the first iteration in confidential deliverable D3.2.3_1 [5]. A specification has been provided for MDO for four use cases:

- Preliminary and unconventional design MDO (Prelude);
- Wing MDO;
- Whole engine MDO;
- Complex subsystems MDO (focusing on helicopters).

As the evolutionary approach implies providing early user value, an early prototype is needed to elicit user response. At this stage, three use cases have realised a prototype, the results of which are summarised below. The complex subsystems MDO use case prototype should be available for the first VIVACE forum. Hence, all four MDO work package prototype will be presented at the first VIVACE forum. The use cases are already generic providing similar innovative capabilities for multiple partners at different geographic sites using their different company development environments.

Prelude MDO

For the first VIVACE iteration of MDO for the preliminary and unconventional design (Prelude) use case, effort was concentrated on three areas: a calculation engine, a simulation toolbox and an aerodynamics module. For the calculation engine, the physical programming method has been extended by Cranfield for its potential use in aircraft design. Figure 1.1 shows some results.

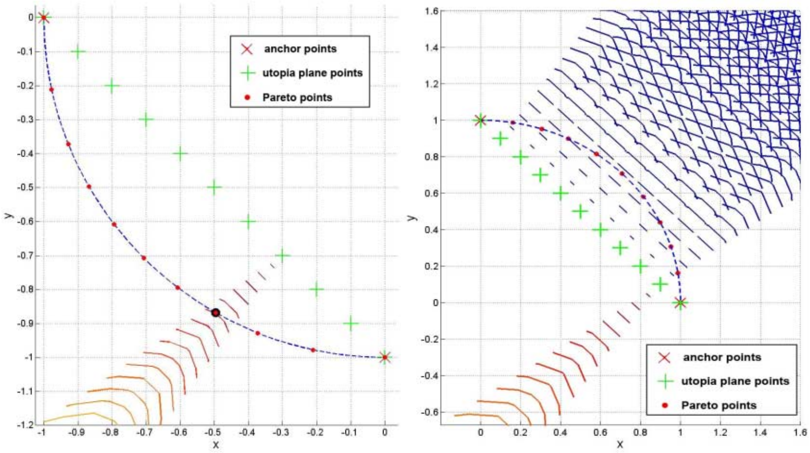

Figure 1.1: Prelude MDO Physical programming results as part of Calculation engine for (a) convex Pareto frontier and (b) concave Pareto frontier.

For the Prelude use case simulation toolbox, the domain specific framework depicted in Figure 1.2 has been proposed by DLR.

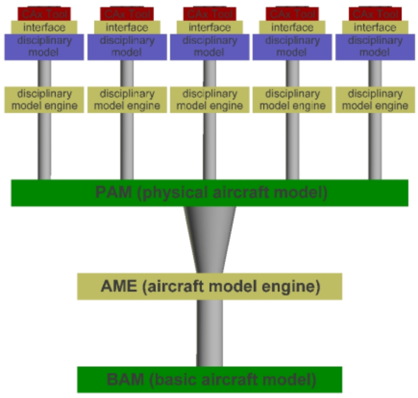

Figure 1.2: Prelude MDO simulation toolbox framework

For the Prelude use case aerodynamics module, a literature review has been performed leading to the selection of a number of promising methods. An initial prototype has been produced by NLR, which provided the results of Figure 1.3.

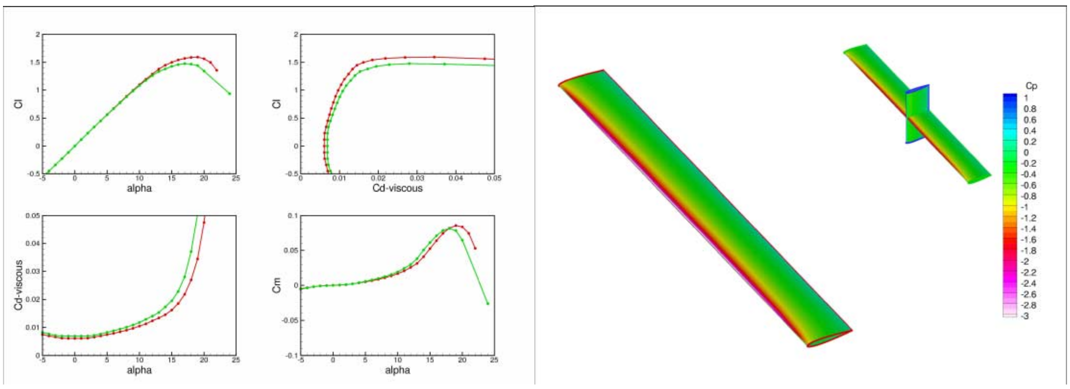

Figure 1.3: Prelude MDO (a) wing (red) and stabilizer (green) aerofoil database and (b) surface pressure coefficient distribution

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Wing MDO

For the wing MDO use case, the effort has been mainly focused towards the domain specific analysis capability. For most relevant disciplines, capabilities have been realised and interconnected. Figure 1.4 illustrates the progress achieved by NLR for the structural optimisation loop together with some initial results.

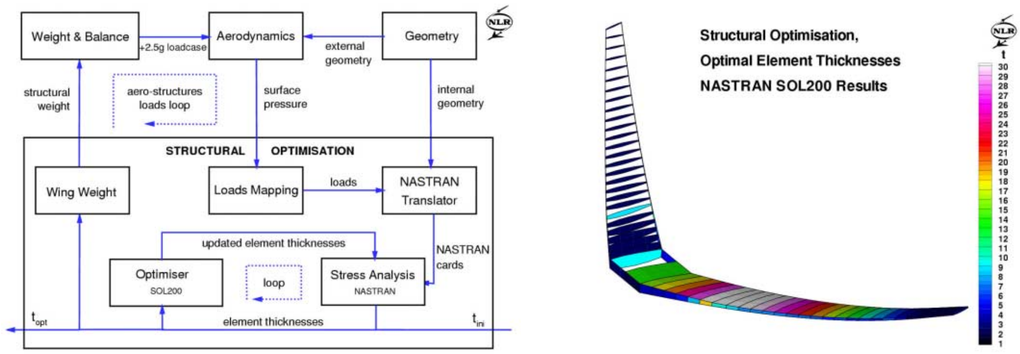

Figure 1.4: Wing MDO
(a) structural optimisation module, (b) first iteration results.

To extend the integrated and multidisciplinary wing engineering capability, other concerns are being taken into account. For the first VIVACE iteration, an interface with manufacturability assessment is being developed by Airbus UK, as shown in Figure 1.5.

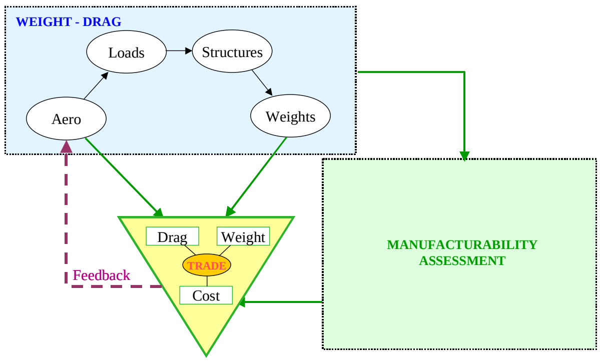

Figure 1.5: Wing MDO incorporating manufacturability assessment

The wing structure description is important information for various modules involved in the optimisation process. CATIA V5 is the industry standard Computer Aided Design package for the aeronautic domain. Consequently an interface has been developed by Cranfield supporting automatic parameterisation of the wing geometry. Figure 1.6 depicts the first results from the VIVACE Geometry Generator.

Finally, the first results towards process integration using a generic Wing MDO workflow (implemented in FIPER) is depicted in Figure 1.7.

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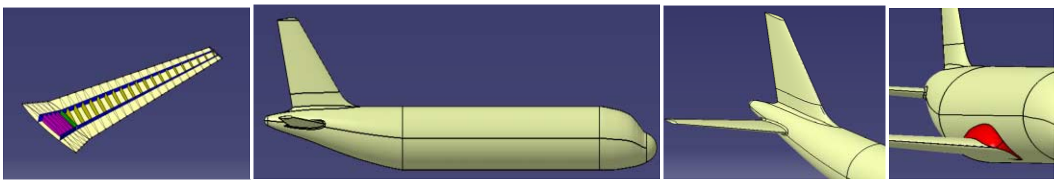

Figure 1.6: Wing MDO parametric geometry generation (a) wing box, (b) fuselage, (c) empennage, (d) onglet (fillet fairing)

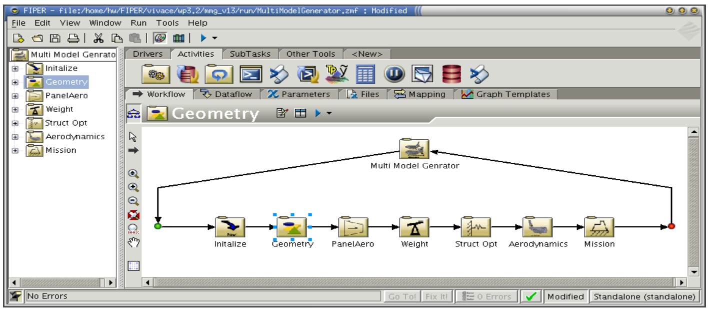

Figure 1.7: Wing MDO workflow

Whole Engine MDO

Based on a long term vision for the whole engine MDO, three independent implementations of a similar simplified single engine component framework have been realised. Figure 1.8 illustrates the results obtained by MTU.

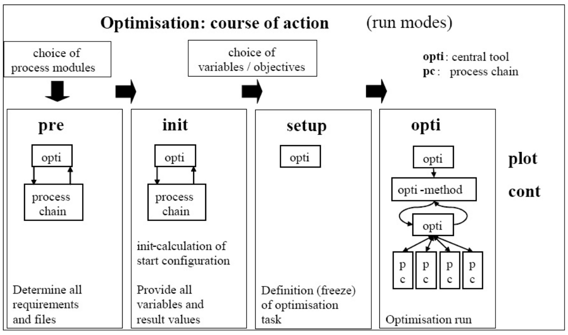

Figure 1.8: Whole engine MDO first single component framework results

The workflow realised by Rolls Royce Deutschland & Rolls Royce plc is provided in Figure 1.9. Its users have already build-up the first experience while deploying such a workflow within the first VIVACE iteration.

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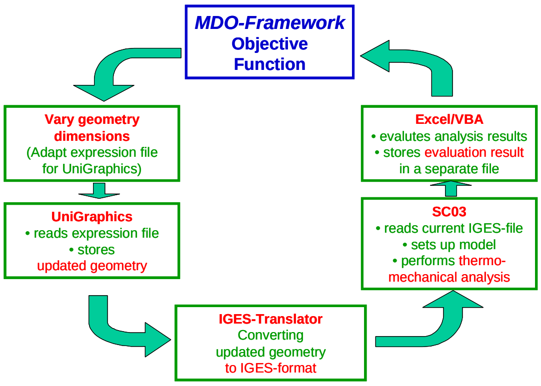

Figure 1.9: Whole engine MDO alternative first single component framework results

The approach taken by NLR is depicted in Figure 1.10, together with the results of the CATIA parametric generated component model.

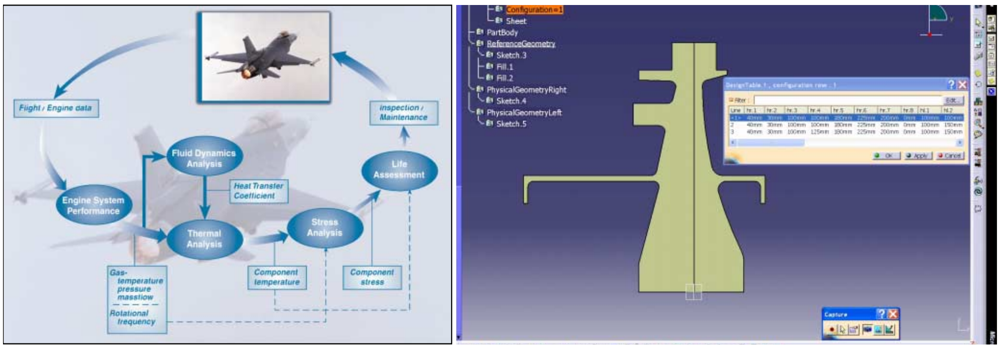

Figure 1.10: Whole engine MDO (a) position of framework in aircraft maintenance and (b) parametric model generation

Dissemination

With respect to training and dissemination, significant results have been achieved. A positioning of the VIVACE MDO approach illustrated with whole engine information is contained in a scientific paper by Kesseler, Kos [6]. For the generic MDO framework, the scientific papers by Guenov, Utyuzhnikov, Fantini [7] and Utyuzhnikov, Fantini, Guenov [8] relate to the physical programming method. To conclude the conference dissemination activities, a scientific paper by Kesseler and Vankan [9] elaborates potential advantages of an object-oriented approach based on the VIVACE objectives combined with an evolutionary approach. Additionally, a journal paper has been completed and submitted for review.

Conclusion

The architecture for each MDO framework discussed above, address generic topics like modelling, analysis, process management, and parametric geometry generation. Each MDO framework is available at multiple geographically distributed sites, making the frameworks generic. Various concepts, like multi-site process integration tools and multiple objective optimisation are generic between use cases allowing, in principle, for generic tools.

The results for the three use cases presented above clearly demonstrate that the first VIVACE iteration produced significant results. These results are useful for the users to (re)assess their requirements. As such, this report achieves its objective to finalise the first VIVACE iteration. The second VIVACE iteration will start with updating of the requirements.

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