ITEA4

Project Results

DEFAINE

Introducing AI to front-loaded design exploration

To better enable a front-loaded design process in the aerospace domain, the ITEA project DEFAINE (Design Exploration Framework based on AI for froNt-loaded Engineering) has developed a design exploration framework to reduce recurring costs and lead times for design updates.

As a multi-tier, cross-organisational process, aircraft design faces numerous challenges. For instance, the design process is iterative and based on the manual exchange of data and models distributed across suppliers and OEMs, but suppliers are not typically involved early in the process. Additionally, single design solutions are generated manually on demand and design risks may be detected late in the development process, wasting time, effort and money.

The aerospace domain has already moved from a sequential to a concurrent design process, but this still relies on assumptions that can generate waste. The next step is a front-loaded design process in which tools are run for many hypothetical projects, providing the necessary information in advance and allowing actions to be performed in parallel when a project begins. Front-loading is uncommon today due to the significant time and money investments needed to develop applications, perform automatic engineering calculations, establish simulation workflows and carry out optimisation. DEFAINE sought to change this by enabling AI-enriched front-loading via a software framework that helps engineers to rapidly develop engineering applications and perform design exploration studies.

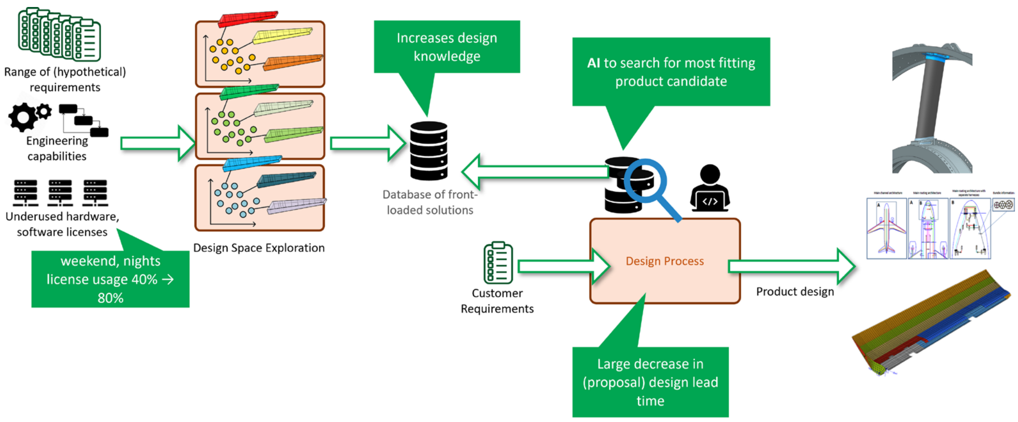
Technology applied

Building on the front-loaded development process prototyped in the ITEA project IDEAaliSM, DEFAINE created a design exploration framework that uses a company's engineering capabilities and range of (hypothetical) requirements to automatically (re)formulate and execute efficient multidisciplinary engineering workflows. This generates a large set of designs that are then used to train surrogate models that identify design space trends, evaluate their accuracy, improve themselves and generate new designs not included in the initial set. In this AI-enriched front-loaded process, simulation workflows proactively sample the design space before a project starts, automatically generating hundreds of designs at any time and thereby maximising the use of software licenses and hardware.

DEFAINE's proposed methodology considers two scenarios:

1. the leveraging of front-loaded design solutions by OEMs for technology assessment at a product level, and
2. the leveraging of front-loaded design solutions by suppliers to rapidly provide component-level design to OEMs.

Use-cases that cover both scenarios show evidence that the DEFAINE framework can be applied to the different elements of multi-tier aircraft design, including moveable design (to automatically size and analyse multiple variants to obtain a more optimal design) and systems architecture design (in which selection, placement, sizing and analysis of systems in an aircraft are automated).



^ DEFAINE framework

Making the difference

Front-loaded design always requires investment. The most significant result of DEFAINE is thus a range of technologies to help engineers create applications that accelerate their engineering work, making front-loading a more cost-effective prospect for companies. Once the investment has been made and the applications are in place, the project has shown that the lead time for design updates can be reduced by >85% as shown in the systems architecture design use-case. Another use-case that demonstrates the benefits of such investments is the moveable design use-case: workflow set-up time has been reduced by >70% and workflow update time by >95%. As shown in the integral use-case, the project ultimately expects OEMs to be able to reduce their recurring costs by >20% by enabling suppliers to become involved in early conceptual design and allowing them to efficiently exchange data with OEMs.

The consortium is now beginning the exploitation of tools and methodologies developed within the framework, offering business impact for companies of all sizes. At the SME level, for example, the ParaPy cloud product has already been incorporated by industrial partners within and outside of the DEFAINE consortium and ParaPy aims to further increase their competitiveness as their tools to speed up the application development process provide more fitting solutions for target clients. At the supplier level, meanwhile, GKN Fokker Aerostructures applies DEFAINE technologies to accelerate the trade-off process in the proposal and preliminary design phases and arrive at more robust, higher-quality designs. In turn, this is an enabler to enter emerging markets like urban air mobility vehicles.

In addition to cost savings, DEFAINE's results free up space for engineers to work on more creative tasks and lead to fewer wasted resources at a time in which sustainability concerns are becoming more integral to the engineering decision-making process. The next step will be to couple large language models, such as ChatGPT, with engineering applications that automate work and enable design studies. This further synthesis of AI and design space exploration can enable digital engineering assistants for even better automatic analysis and design, for which DEFAINE provides an excellent basis.

Major project outcomes

Dissemination

- 19 publications, e.g.:
  - 'Knowledge-based Integration of Aircraft System Simulation within Aircraft Conceptual System Design'.
  - 'Model-Based Approach for the Simultaneous Design of Airframe Components and their Production Process Using Dynamic MDAO Workflows'.
  - 'Design automation strategies for aerospace components during conceptual design phases'.
  - 'An MBSE approach to support Knowledge Based Engineering application development'.
  - 'Dynamic workflow generation applied to aircraft moveable architecture optimization'.
- 14 presentations at conferences/fairs, e.g. CEAS, ICAS, Raytheon, EASN, CEAS, INCOSE, AIAA SciTech, AIAA Aviation, DESIGN.
- 7 workshops, e.g. ModProd, EPIC, Flexible Workflows, DEFAINE Public Demonstrator Day, Innovair DigiDemoDay, SBAW.

Exploitation (so far)

- ParaPy Cloud: dynamic web apps in Python only.
- Club Design: a tool for value/cost assessment of new design alternatives.
- Library of multi-disciplinary geometries and analysis modules.
- New PhD coarse: Engineering Systems Design Analytics and AI.

Standardisation

- Extensions to CMDOWS (Common MDO Workflow Scheme).

DEFAINE

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Partners

Sweden

- GKN Aerospace
- Linköping University
- PE Geometry
- Saab AB
- Chalmers University of Technology

The Netherlands

- Delft University of Technology
- Fokker Aerostructures
- Fokker Elmo
- KE-works BV
- ParaPy BV

Project start

September 2020

Project end

February 2024

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